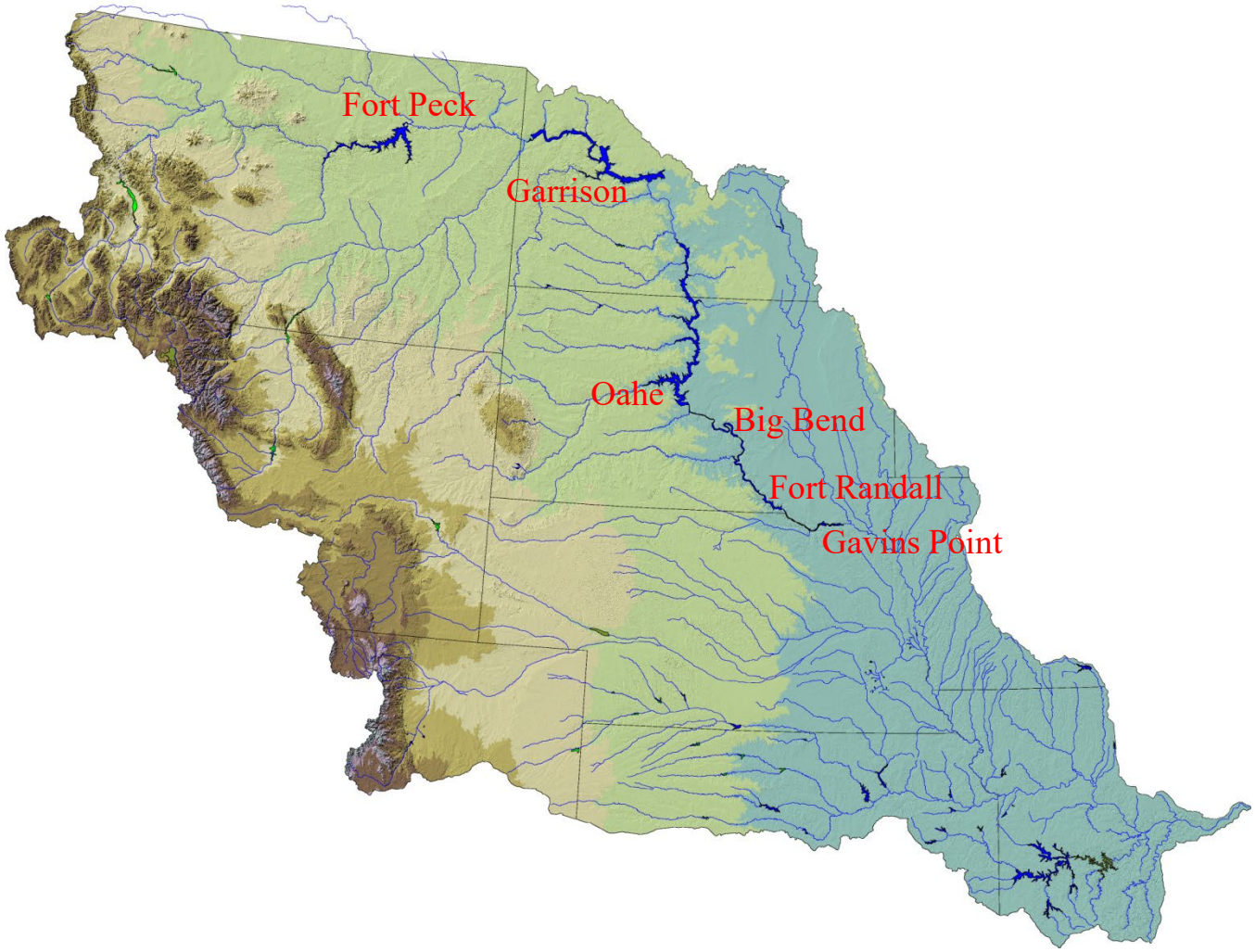
US Army Corps of Engineers ®
Northwestern Division

Missouri River Mainstem Reservoirs
Releases Needed to Support Navigation
Technical Report



Missouri River Basin Water Management Division
Omaha, Nebraska

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I. Introduction

A. Study Purpose

The purpose of this report is to document the methodology, assumptions, data, and results of the analysis of Missouri River Mainstem Reservoir System (System) releases needed to support navigation requirements on the Missouri River. It also provides background information on navigation flow targets, and an analysis of how often each key downstream location serves as the control point for the navigation release.

The previous report "Releases Needed to Support Navigation" was published in August 2000. That report was based on flow data for the period from 1950 to 1996. This updated study presents similar data using a comparable methodology as the previous study with a slightly modified procedure to calculate release requirements. This updated study contains data from 1950 through 2022. This report also expands on the earlier studies with additional analysis of the flow targets and release requirements. This additional analysis will be discussed later in this report.

Missouri River reservoir regulation studies are conducted by the Missouri River Basin Water Management (MRBWM) office to provide support for authorized purposes including flood control, hydroelectric power, navigation, irrigation, water quality control, water supply, recreation, and fish and wildlife including protection of threatened and endangered species.

The regulation of the System considers river flow requirements downstream of the System, river flows within the open river reaches between the reservoirs, and movement of water between the reservoirs (intrasystem regulation). To conduct intrasystem regulation studies, reasonable estimates of the Gavins Point release (often referred to as System release) requirements must be made, considering the interdependent nature of project releases, flows downstream from individual projects, and reservoir storages.

Long-range System regulation studies are updated monthly, or more often if needed. In addition, in the late summer and fall, the Annual Operating Plan (AOP) is developed and displays simulations of the System through the following year and beyond at five different levels of runoff. These long-range studies require assumptions regarding the release requirements for navigation support in future months, which in turn affects the intrasystem regulation.

B. Background Information

Releases to support Missouri River navigation requirements are made from Gavins Point Dam located at river mile 811.1 near Yankton, South Dakota. The Missouri River navigation channel extends for 735 miles from near Sioux City, Iowa (river mile 732.3), to the mouth near St. Louis, Missouri. Construction of the Missouri River Bank Stabilization and Navigation Project (BSNP) was declared complete in September 1981 although maintenance and corrective work will be required as the river continues to form its channel in response to changing flow conditions.

Flow support for navigation has been provided since June 1967, when the System first filled. Flow support for navigation on the Missouri River is limited to the normal ice-free season with a

full-length season extending from April 1 to December 1 at the mouth. To permit a viable navigation industry during the ice-free months, it is desirable to maintain navigable flows throughout this 8-month period. While flow support for navigation is for a defined period each year, navigators can be on the Missouri River all year, if flow and ice conditions permit. Downstream flow support is provided to meet many of the authorized purposes, which includes navigation. Extension of navigation flow support beyond the normal 8-month season length may be scheduled in years with above-normal water supply. Based on experience to date, these season extensions will normally be limited to 10 days beyond the normal closure date, resulting in a flow support season closing on December 11 at the mouth of the Missouri River.

During drought and normal runoff years, navigation support for the 735-river mile navigation channel is dependent upon System releases. During flood periods, System releases are generally geared to evacuating floodwaters at rates that exceed navigation targets although releases may be temporarily reduced to meet downstream flood targets while still meeting specified navigation targets.

System releases are scheduled to provide adequate flows for navigation according to established minimum and full-service flow targets at Sioux City, Omaha, Nebraska City, and Kansas City. The target flows increase in a downstream direction because of the increased flow requirements needed to maintain similar flow depths with naturally increasing channel dimensions.

The assignment of target flows for full service is based upon the water volume necessary to achieve a normal 8-month season, with average downstream tributary flows, combined with winter releases needed to ensure water supply requirements and winter hydropower demand, that approximates the available water supply during a normal year. These target flows may need to be evaluated and adjusted periodically to ensure compatibility between available water supply and current navigation channel conditions.

Operating experience during the 1960's demonstrated that flows of 25,000 cubic feet per second (cfs) at Sioux City and Omaha, 31,000 cfs at Nebraska City, and 35,000 cfs at Kansas City were the minimum flows that permitted navigation. During periods that require minimum flow levels, experience has indicated that it is necessary to reduce drafts by 1 foot and restrict tow boat sizes to reduce the number of lost time events and groundings. With the present level of streamflow depletions, inflows to the reservoir system are sufficient to support the minimum flow levels or higher for the full 8-month navigation season in 69 years of the 93-year period from 1930-2022.

When System storage reserves are adequate, it is desirable to maintain navigation flows above the minimum levels. This allows barge loadings to greater depths than would be possible with minimum flows. In addition, the increased releases which provide the improved service to navigation will reduce the probability of having to release at rates which provide little or no benefit to navigation or to hydropower generation during flood storage evacuation. Based upon numerous operation studies and consideration of the effects the flow levels will have on navigation, target flow levels 6,000 cfs greater than the minimum flows specified above have been selected as the “full service” level for navigation. With the present level of streamflow depletions, inflows to the reservoir system are sufficient to support full-service flows for the 8-month navigation season in

47 years of the 93-year period from 1930-2022.

Operating experience has demonstrated that full-service flow rates of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City, and 41,000 cfs at Kansas City will be adequate to maintain the designed 9-by-300-foot channel with a minimum of groundings and little or no dredging. Slightly greater flows are required at the mouth of the Missouri (approximately 45,000 cfs) but tributary flows below Kansas City are usually adequate to provide the needed incremental flows. Although a 9-foot channel is not provided 100 percent of the time, the problem areas are generally transient and short-term in nature. Increased flows would provide some relief, but experience has shown that regardless of the support provided, some groundings do occur.

Average monthly System releases needed to support navigation target flows were originally studied in 1979. At that time, flow records for the period from 1954 through 1979 were analyzed. This original analysis did not differentiate the release requirements resulting from above or below normal upstream and downstream runoff, and AOP studies at that time used one set of values. The values presented in Table 1 below are reprinted from the "Missouri River Main Stem Reservoir, System Description and Operation," dated Fall 1998. The monthly values represent the average Gavins Point release for the period 1954 through 1979 needed to meet both minimum- and full-service navigation flow targets.

Table 1.
Gavins Point Releases Needed to Meet
Navigation Requirements 1954-1979
(Discharges in 1,000 cfs)

Service Level	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average
Minimum	22.8	22.8	24.8	24.0	26.7	28.2	28.5	27.5	27.5	25.9
Full	28.8	28.8	30.8	30.0	32.7	34.2	34.5	33.5	33.5	31.9

The report published in August 2000 updated the release rates to support navigation and presented an analysis to determine if lower or higher runoff rates upstream from the reservoir system were coincident with above or below average releases needed to meet navigation flow targets. Experience indicated that during years of above normal runoff upstream from the reservoir system, runoff downstream from the System is also generally above normal, thus reducing System release requirements. During years of below normal runoff upstream from the System, release requirements for navigation support have generally been higher than normal.

II. Determination of Releases Needed to Support Navigation

A. Study History

In 1996 and 1997 two analyses were undertaken to estimate the releases required to support navigation requirements. The 1996 study looked at four methods of estimating release requirements. The methods used included the MRBWM's Forecasted Ungaged Inflow (FUI) model, the monthly Long Range Study (LRS) model, and two analyses of observed USGS flow data, with and without lagging to account for travel times. The 1997 study looked at three methods,

including FUI, the monthly LRS model and the Daily Routing Model (DRM). Although both studies were completed and draft reports produced, the results were not implemented at that time. In 1999 both studies were thoroughly reviewed, a technical report was produced, and the new navigation release requirements were used in the development of the 1999-2000 AOP. This previous analysis used the DRM method. Since the August 2000 report, the MRBWM office has replaced the DRM with an HEC-ResSim System model for performing operational studies. This model was developed and used in the alternative analysis for the Missouri River Recovery Management Plan Environmental Impact Statement (MRRMP-EIS). ResSim input data was incorporated into this updated study. Also, since the 2000 report, the MRBWM office has replaced the FUI model with an HEC-ResSim model referred to as the Gavins Release Forecasting Tool (GRFT). Data from GRFT was also used for comparison.

B. Data

Although flow records in the Missouri River basin date as far back as 1898, previous versions of this study used data starting in 1950. It was felt that the flow record since the construction of the mainstem reservoirs was more accurate than the earlier portion of the flow record. Except for Fort Peck, which was built in the 1930's, the System projects were constructed during the 1950's. Input data for the ResSim model was recently updated and was available through 2022, therefore, the 73-year period from 1950 through 2022 was used in this study.

C. Methodology

For this update, preliminary data was produced using three different methods. The first method used data from historic FUI forecasts to calculate the releases needed to meet the full-service navigation targets. This data was available from 1997-2017. The second method used Gavins Point releases from the ResSim planning model for years and months in which full-service navigation releases were required. The third method used the incremental flows from the ResSim model to estimate releases required to meet navigation targets. The incremental flows from ResSim were imported into Excel and were then used to calculate releases needed to meet navigation targets. The three methods were compared for the available years, and in addition, they were compared to the results from the previous study. It was determined that all three methods produced similar results.

The Excel method was chosen since it was more easily reproducible, provided consistent results and eliminated the need to adjust the regulation criteria within the ResSim model in each study year to provide the full-service navigation flows and an 8-month navigation season in all years without conflicting with other purposes. As previously noted, the incremental flows from Gavins Point to Kansas City, which are daily flows between the different nodes in the ResSim model, were imported into Excel. The same routing parameters utilized by ResSim were used to route flows downstream, and the necessary releases from Gavins Point were determined to meet the full-service navigation targets at all four locations. In years with exceptionally high flows downstream of the reservoir system, Gavins Point releases were set to a minimum of 6,000 cfs. (While minimum releases from Gavins Point have ranged from 6,000 cfs to 12,000 cfs to meet water supply at Yankton, 6,000 cfs represented the lowest release in that range.)

The releases from the Excel method were also compared to actual releases in periods of full or near full service, and where there were minimal effects from flood control, threatened and endangered species regulation, or missed flow targets (due to not supporting a target). While the number of comparison periods was not large, it was generally found that the actual releases were slightly higher than the calculated Excel releases, likely due to this method functioning as a less conservative or better forecast. The modeled ResSim releases were also slightly higher than the Excel method in comparable periods. The actual and modeled ResSim releases averaged about 3 percent higher than the Excel method. Therefore, the calculated monthly average releases from the Excel method were increased by 3 percent to better match actual releases.

Regarding navigation flow support, flow targets may not be met in upstream reaches without commercial navigation. For example, in some drought years, there was no commercial navigation in the reaches above Nebraska City, and the target at Sioux City was not always met. With that in mind, the study for this report was expanded to determine what releases from Gavins Point would be necessary to meet only the Nebraska City and Kansas City full-service flow targets. To keep releases reasonable with respect to flows in the upper reaches, Gavins Point releases were determined that at least met minimum service targets at Sioux City and Omaha, while meeting the specified full-service targets at Nebraska City and Kansas City.

For this study, the correlation between runoff and System releases was also re-examined, as was the percentage of time that each target location controlled the releases.

III. Study Results

A. Navigation Release Requirements Compared to Annual Runoff

The original 1979 analysis, as seen in Table 1, did not differentiate the navigation release requirements based on whether the upper basin was experiencing a wet, dry or normal year. As noted in the 1999 report, experience operating the System appeared to indicate that the release requirement for navigation support was less in years of high runoff in the upper basin, and more in years of below normal upper basin runoff, i.e. a correlation exists between upper and lower basin runoff. The updated 1999 report included an analysis of upper basin runoff and downstream requirements.

To re-verify this correlation, the average Gavins Point release for the navigation season was compared graphically with the total runoff upstream from Sioux City. Although there is a great deal of scatter, Figure 1 indicates that generally during years of below normal upstream runoff, the release requirements for navigation support are increased and vice versa. Sufficient correlation exists to conclude that regulation studies prepared for the Annual Operating Plan for differing levels of runoff should acknowledge the changed navigation release needs. For AOP study purposes this is most significant during low runoff years because flood control evacuation becomes the driving factor in determining Gavins Point releases during high runoff years. Therefore, for the purposes of the AOP studies, two navigation release requirement levels were determined, the first for Median (and above) runoff, and the second for the two lower runoff conditions (Lower Quartile and Lower Decile).

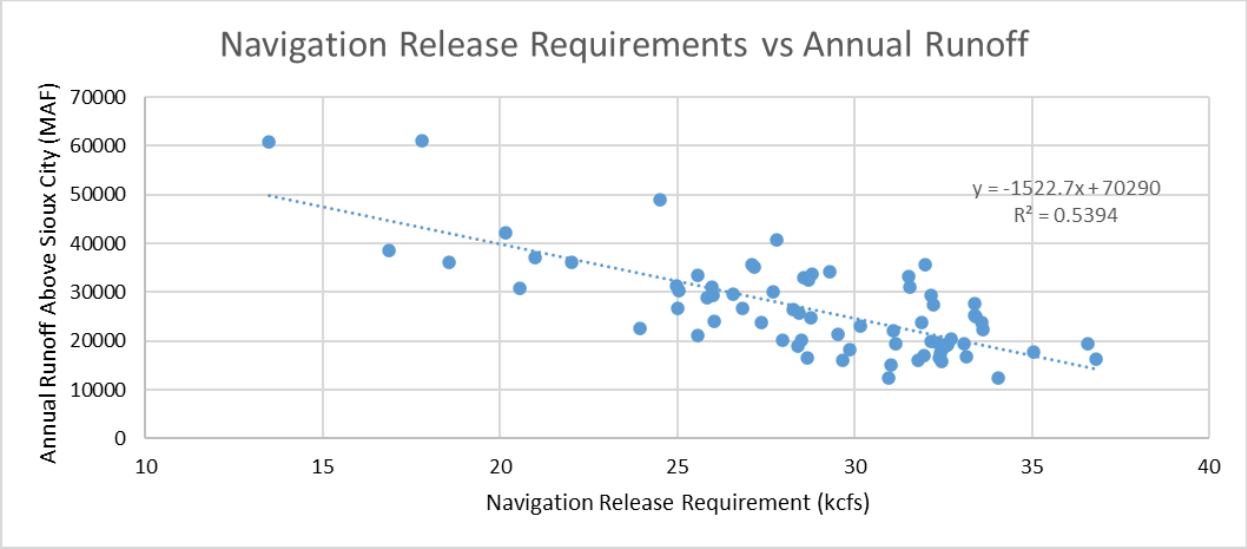

Figure 1. Navigation Release Requirements vs Annual Runoff

B. Releases Needed to Meet All Navigation Targets

Plate 1 presents the release requirements to support navigation at all target locations determined using the methodology described previously. Monthly values in 1000 cfs are tabulated for the years 1950 through 2022 for each month April through November, as well as the average release for the April-November period. Also shown is the total annual runoff upstream from Sioux City, Iowa for each year in million acre-feet (MAF).

Plate 2 presents the monthly and annual release requirements sorted based upon total annual runoff upstream from Sioux City. The sorted table was divided into three parts representing the 25 years when the total runoff compared with Lower Decile and Lower Quartile runoffs, the 24 years when runoff approached Median runoff, and the 24 years when total runoff resembles Upper Quartile and Upper Decile runoff conditions.

The average monthly release requirement was computed for the Median and Lower Decile/Lower Quartile runoff conditions and the results for full-service navigation are summarized in Table 2 below. Minimum service flow requirements are 6,000 cfs less than the full-service flows presented in the table. Median release requirements are appropriate for use during high runoff years when flood evacuation is not controlling Gavins Point releases. The greatest difference between the Median and lower runoff conditions is during the high spring and early summer runoff months, while the differences are smaller during the late summer and fall months.

Table 2.
Gavins Point Releases Needed to Meet Navigation Requirements at All Target Locations 1950-2022
(Discharges in 1,000 cfs)

Runoff Scenario	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average
Median, Upper Quartile, Upper Decile	26.1	26.7	26.6	29.8	31.6	32.2	31.5	30.9	29.4
Lower Quartile, Lower Decile	29.2	29.9	29.9	32.5	34.0	34.3	33.3	32.2	31.9

The values shown in Table 2, which result in an average seasonal release of 29,400 cfs to support full-service navigation requirements for the Median runoff scenario and 31,900 cfs for the Lower Quartile/Lower Decile scenario, are recommended for use in future AOP regulation studies. The values are about 3 percent lower than the August 2000 study for Median runoff and about 1 percent lower for Lower Quartile/Lower Decile runoff. A comparison of the updated study values to the August 2000 study values is shown in Table 3.

Table 3.
Updated Navigation Release Requirements (1950-2022)
Compared to August 2000 Study (1950-1996)
(Discharges in 1,000 cfs)

Runoff Scenario	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average
Median, Upper Quartile, Upper Decile	-0.6	-1.3	-1.3	-1.8	-1.6	-0.4	-0.5	-0.2	-1.0
Lower Quartile, Lower Decile	-0.6	-1.4	-1.3	-1.8	0.0	0.8	0.2	1.0	-0.4

Negative number indicates the new value is lower than the August 2000 study.

C. Releases Needed to Meet Only Nebraska City and Kansas City Targets

As noted previously, in some situations flow targets may not be met in upstream reaches without commercial navigation. During some previously experienced drought years there was no commercial navigation in the reaches above Nebraska City. The study for this report was expanded to determine what releases from Gavins Point would be necessary to meet only the Nebraska City and Kansas City full-service flow targets. Plate 3 presents the release requirements to support navigation at the two downstream locations. Monthly values in 1000 cfs are tabulated for the years 1950 through 2022 for each month April through November, as well as the average release for the navigation year. Also shown is the total annual runoff upstream from Sioux City, Iowa for each year in MAF. Plate 4 presents the monthly and annual release requirements sorted based upon total annual runoff upstream from Sioux City. The sorted table was divided into three parts representing the 25 years when the total runoff compared with Lower Decile and Lower Quartile

runoffs, the 24 years when runoff approached Median runoff, and the 24 years when total runoff resembles Upper Quartile and Upper Decile runoff conditions. A summary is shown in Table 4. Median release requirements are appropriate for use during high runoff years when flood evacuation is not controlling Gavins Point releases.

Minimum service flow requirements are 6,000 cfs less than the full-service flows presented in Table 4. It should be noted where minimum service release rates would be used with this table, flows may be less than the minimum service targets at Sioux City and Omaha. For long-term regulation studies in those situations, consideration would have to be given to some minimum flow level at Sioux City and Omaha to support other authorized purposes such as recreation.

Table 4.
Gavins Point Releases Needed to Meet Navigation
Requirements at Nebraska City and Kansas City 1950-2022
(Discharges in 1,000 cfs)

Runoff Scenario	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average
Median, Upper Quartile, Upper Decile	21.9	22.2	22.2	27.0	29.7	30.7	29.3	28.3	26.4
Lower Quartile, Lower Decile	26.8	27.0	27.0	31.2	33.3	33.6	32.7	31.4	30.4

D. Navigation Target Location

Using the release requirements to meet all four downstream targets, an additional analysis was completed to compute the percent of time each downstream location becomes the control point for the navigation target. Figure 2 shows the percentage of time that each target location is the controlling point from April through November.

As shown on Figure 2, Sioux City is the primary control point for navigation releases, controlling more than 70 percent of the time during the spring and early summer. That percentage drops to about 40 percent of the time during the late summer months as the control point shifts downstream to Nebraska City and to Kansas City.

The Omaha target rarely controls the navigation releases but can during dry periods when reach losses between Sioux City and Omaha exceed tributary inflows for that reach and Platte River and other tributary flows meet the additional increments at Nebraska City and Kansas City.

Nebraska City controls the navigation target about 7 percent of the time in the early spring to 31 percent of the time during the late summer.

Kansas City is the second most frequent navigation target control point ranging from about 8 percent of the time in the early spring to more than 30 percent of the time in the late summer and

fall months.

Although not typical, incremental tributary flows would be sufficient to meet all navigation targets without supplemental releases about 6 percent of the time in the early spring and about 1 to 2 percent of the time in the early summer months.

For the average 8-month navigation season, Sioux City controls the navigation target 59 percent of the time, Omaha controls 2 percent of the time, Nebraska City 18 percent, Kansas City 19 percent, and incremental flows are sufficient to meet all targets nearly 2 percent of the time resulting in a minimum release from Gavins Point of 6,000 cfs. These values are based on the navigation target only, and do not consider the effects of flood control targets and system releases to evacuate flood control storage from the reservoir system.

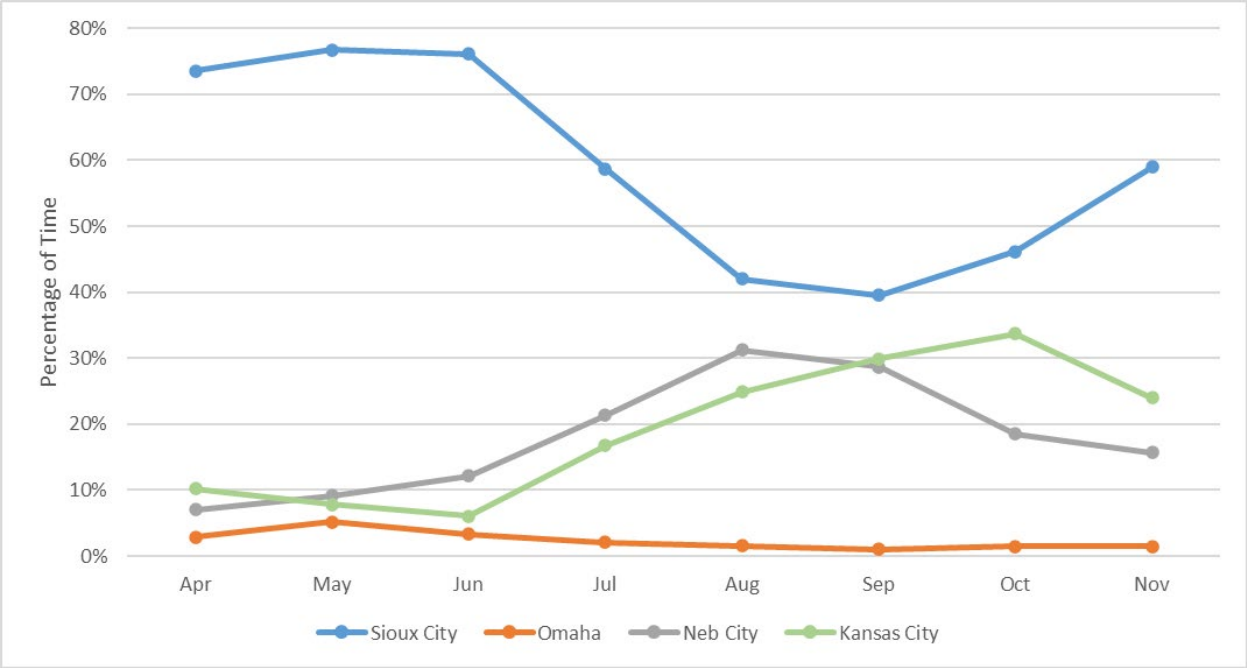

Figure 2. Location of Controlling Navigation Target

IV. Additional Analysis

While the information in Table 2 is typically sufficient for use in AOP studies, widely varying conditions throughout the year often require adjustments to the releases used in long-term monthly studies. The additional information described in the following paragraphs may be useful in these situations.

A. Required Releases Sorted by Month

As an additional step using the data from this study, average monthly Gavins Point releases to meet full-service navigation were sorted from lowest to highest for each month from April through November. Sorted releases are shown on Plate 5. The Median, Lower Quartile, Lower Decile, Upper Quartile, and Upper Decile releases are also displayed for each month.

B. Releases to Meet Minimum Service

Studies conducted for the Endangered Species Act consultation in 2003 concluded that 30,000 cfs would be needed to provide a 90 percent assurance of meeting minimum service flow targets in July and August. A similar analysis was performed for this updated report. More information can be found in Appendix A.

C. Correlation of Releases Based on Previous Month

Releases were correlated from month to month to see if the current month's release could be used to predict the following month's release. This could help inform releases used in long-range monthly studies. For example, if the May release is much lower than the value in Table 3 (due to wet downstream conditions), could it be used to predict the average June release for the monthly simulation. More information and sample correlation plots are shown in Appendix B. This preliminary data may be useful in choosing releases from month to month, but likely needs additional evaluation, and could be compared to future investigations using the HEC Watershed Analysis Tool (HEC-WAT).

Appendix A. Releases Required to Meet Minimum Service Targets

As stated in the 2018 Missouri River Mainstem Reservoir System Master Manual, studies conducted for the Endangered Species Act consultation in 2003 concluded that a Gavins Point release of 30,000 cfs would be needed to provide a 90 percent assurance of meeting minimum service flow targets in July and August. That study used data from the DRM for 1898-1997, for mid-April to mid-August. For the consultation analysis, a range of releases were added to the unrouted incremental flows at the target locations, and the resulting flows were compared to the minimum service targets at each location. For each release rate, the number of days in each month where the target was met or not met were computed. A follow-up to that study produced duration curves for the Gavins Point releases needed to meet minimum service at Kansas City for various summer periods.

A similar analysis was repeated for this report using ResSim incremental data from 1950-2022. Rather than using mid-month to mid-month computations, this analysis used data for May 1 through August 20. In this case, the routed incremental flows were added to the releases and compared to the minimum service targets at each location. Plots showing the percent of years that a Gavins Point release would need to be increased to meet the minimum service target in each month a certain percent of the time are shown in Figures A-1 through A-4 for each of the four target locations of Sioux City, Omaha, Nebraska City, and Kansas City. Figure A-5 shows data for the combined requirement of all four target locations.

This analysis also produced duration curves for Gavins Point releases needed to meet minimum service targets for the May 10 to August 20 period and the July 1 to August 20 period. The duration curve indicates that a release slightly over 29,000 cfs would meet the targets about 90 percent of the time for the late summer period. A duration curve was also developed using data from only the drought years (1954-1961, 1987-1992, and 2000-2007). Duration curves are shown in Figure A-6.

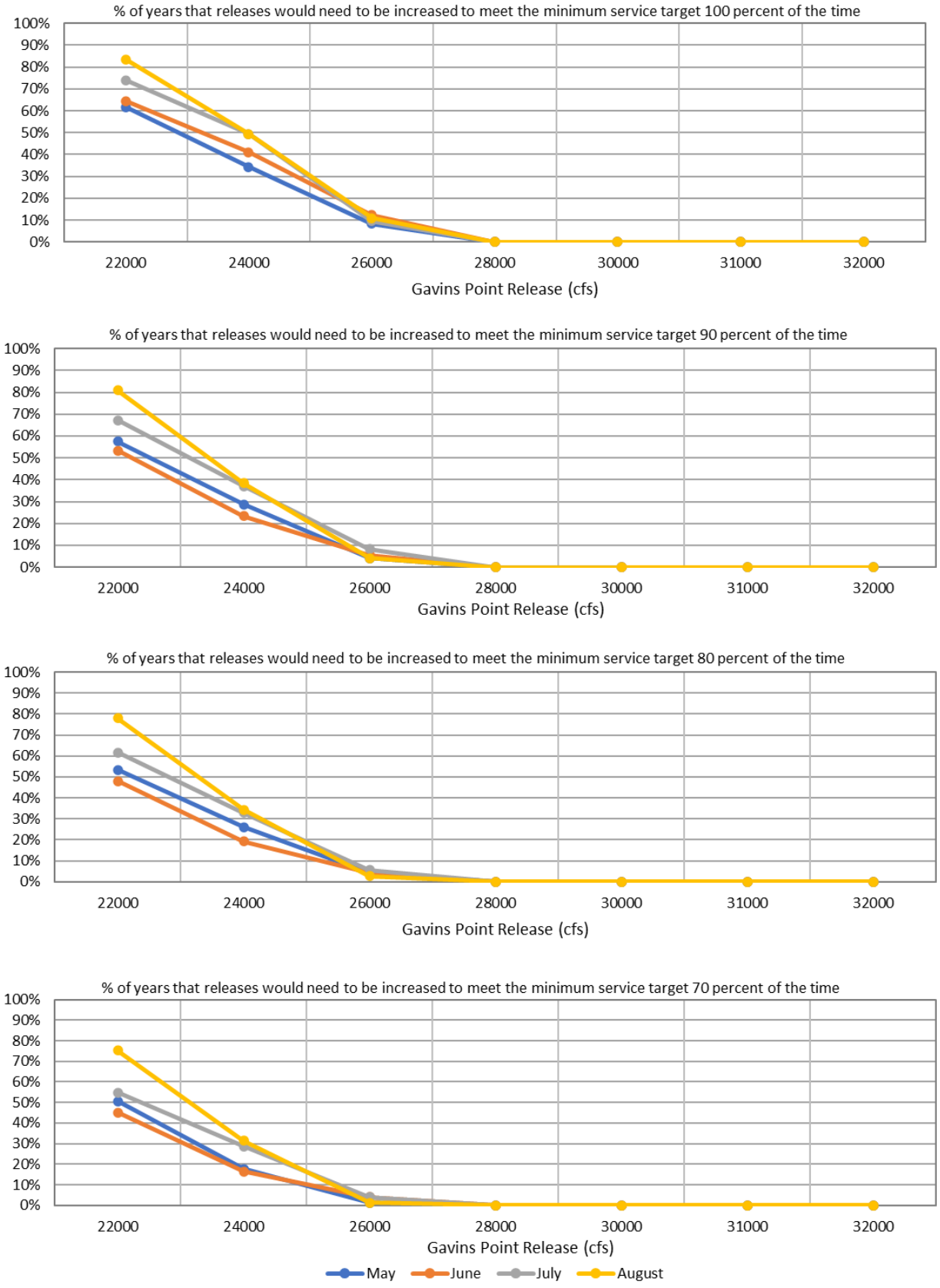

Figure A-1. Percent of Years Requiring Higher Release to Meet Minimum Service at Sioux City (1950-2022)

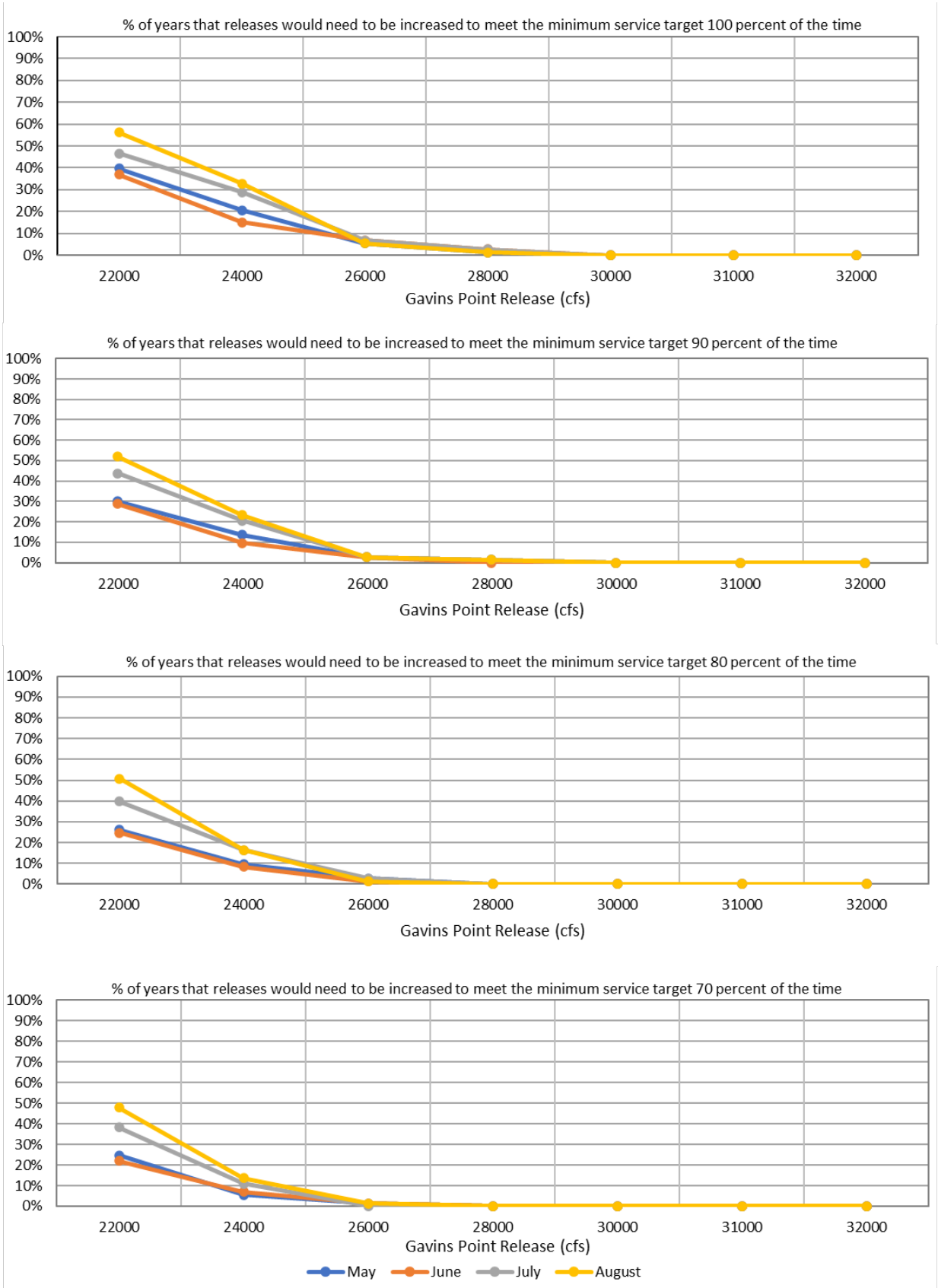

Figure A-2. Percent of Years Requiring Higher Release to Meet Minimum Service at Omaha (1950-2022)

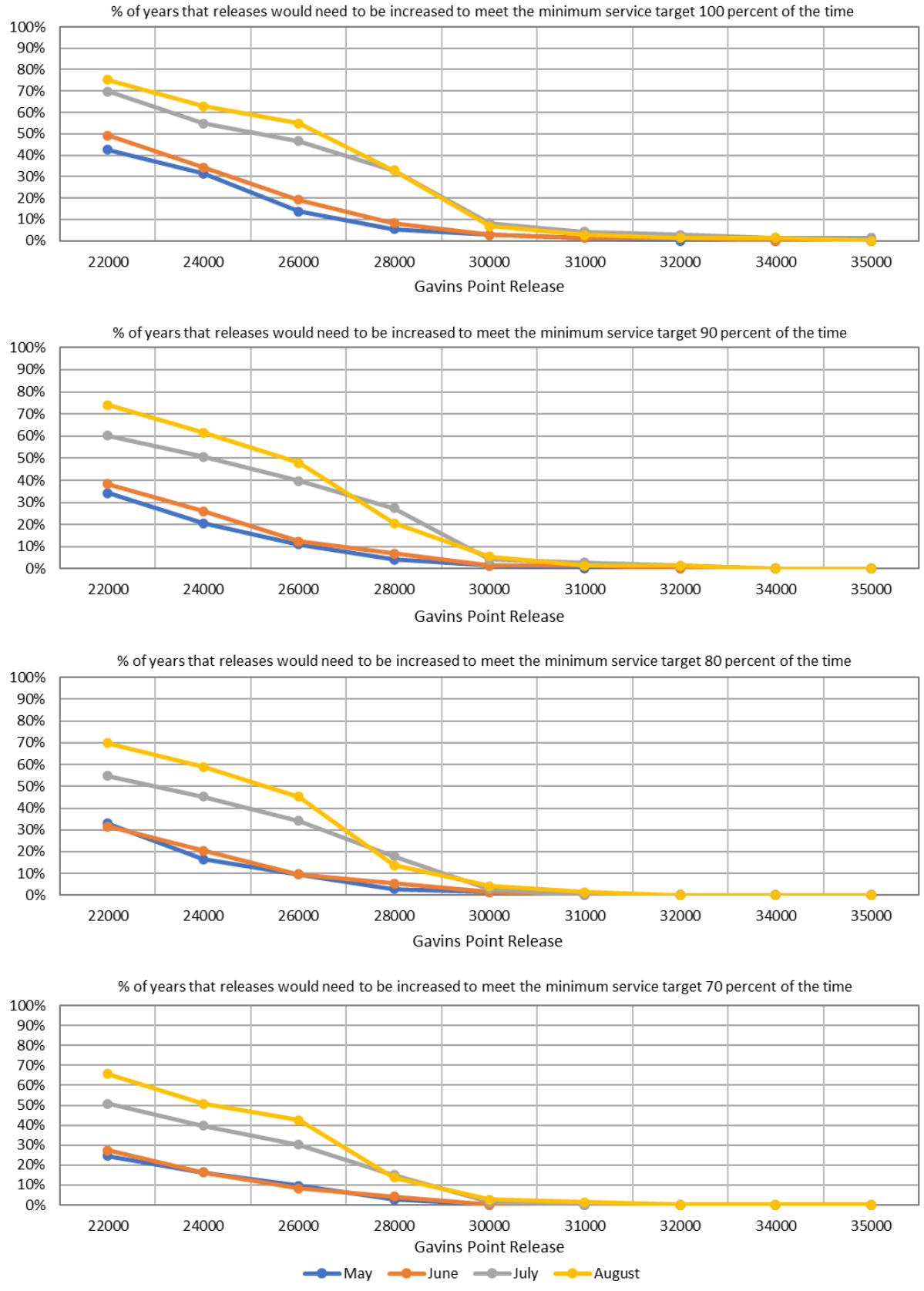

Figure A-3. Percent of Years Requiring Higher Release to Meet Minimum Service at Nebraska City(1950-2022)

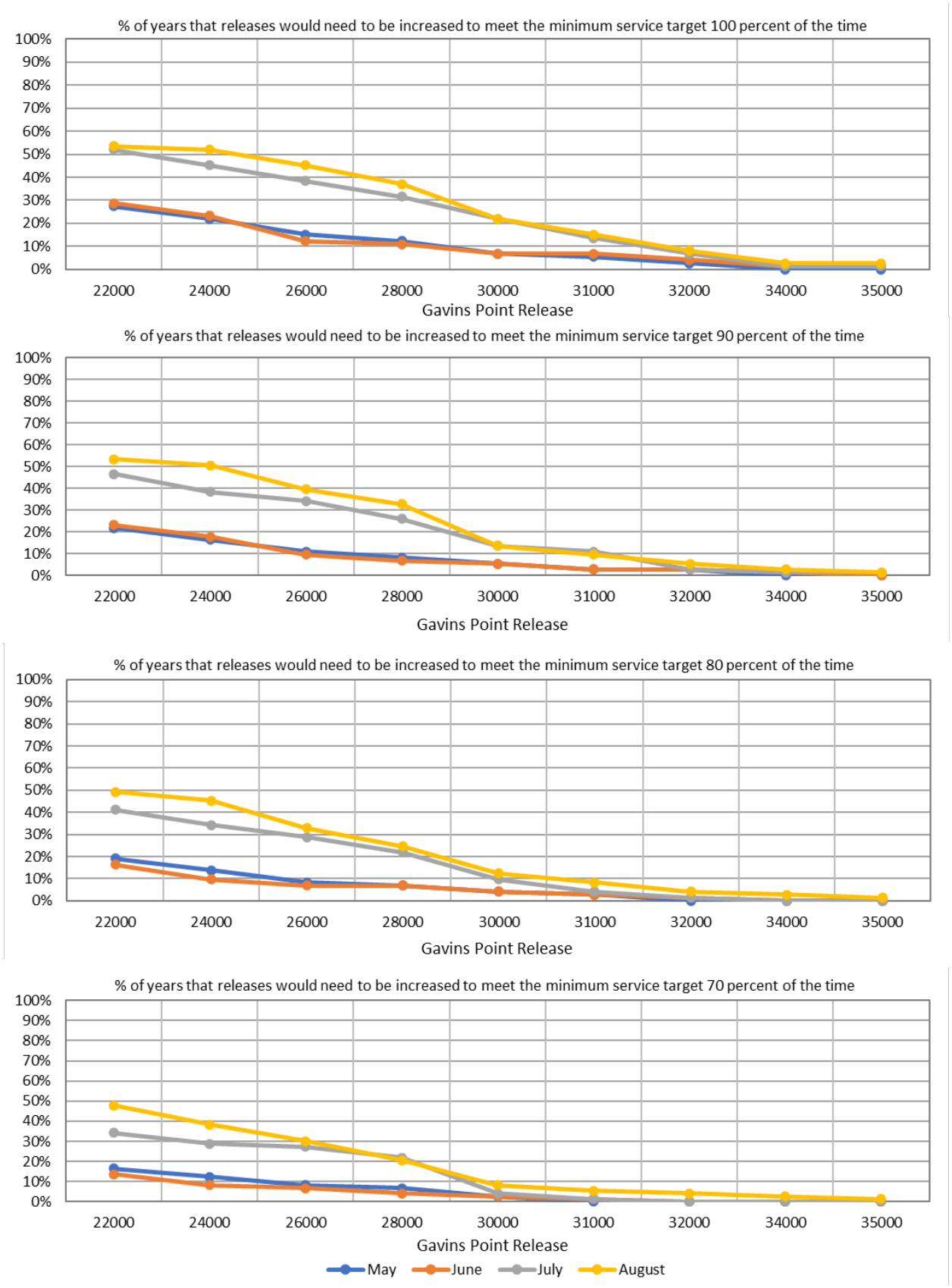

Figure A-4. Percent of Years Requiring Higher Release to Meet Minimum Service at Kansas City (1950-2022)

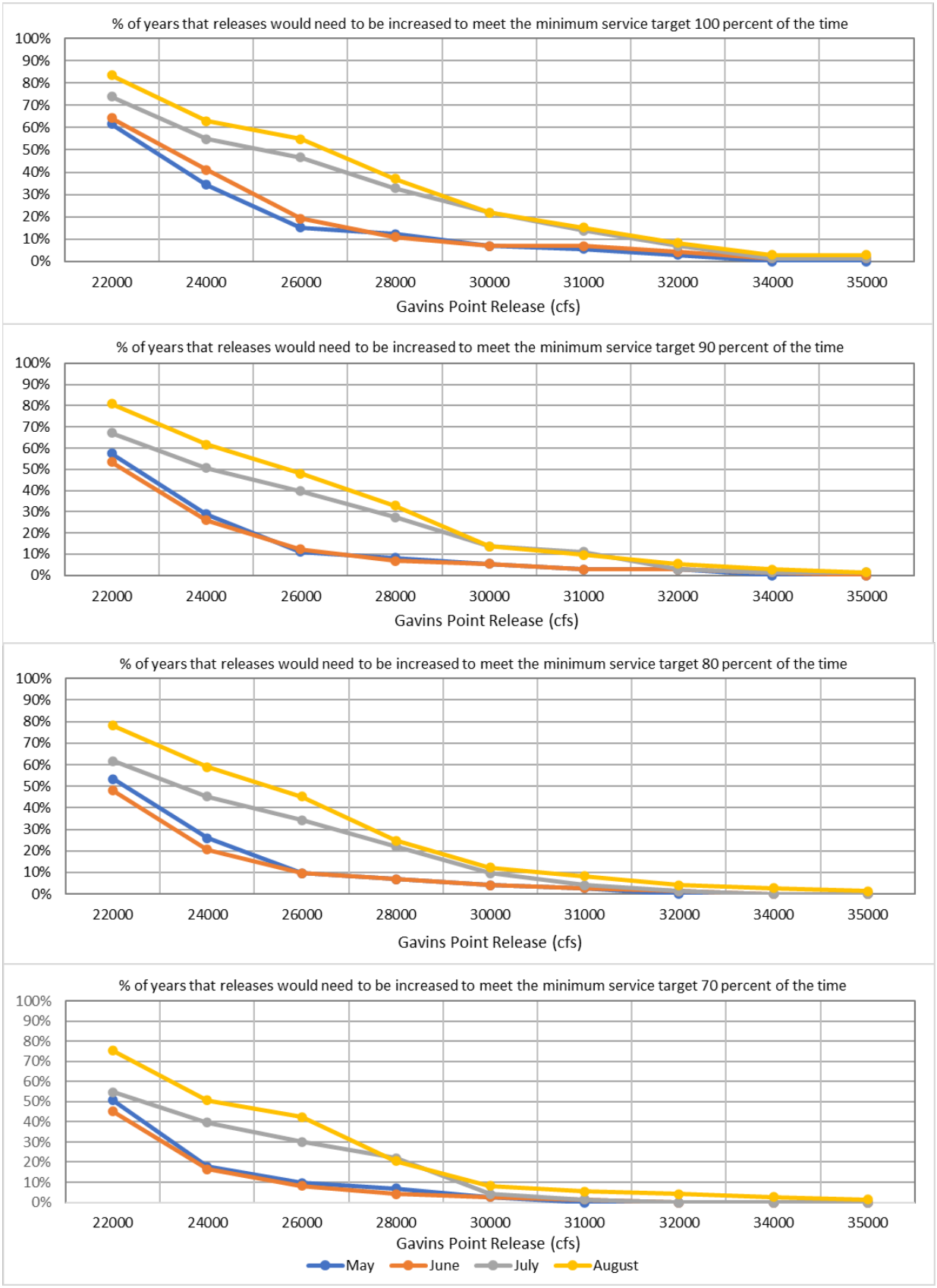

Figure A-5. Percent of Years Requiring Higher Release to Meet Minimum Service All Targets (1950-2022)

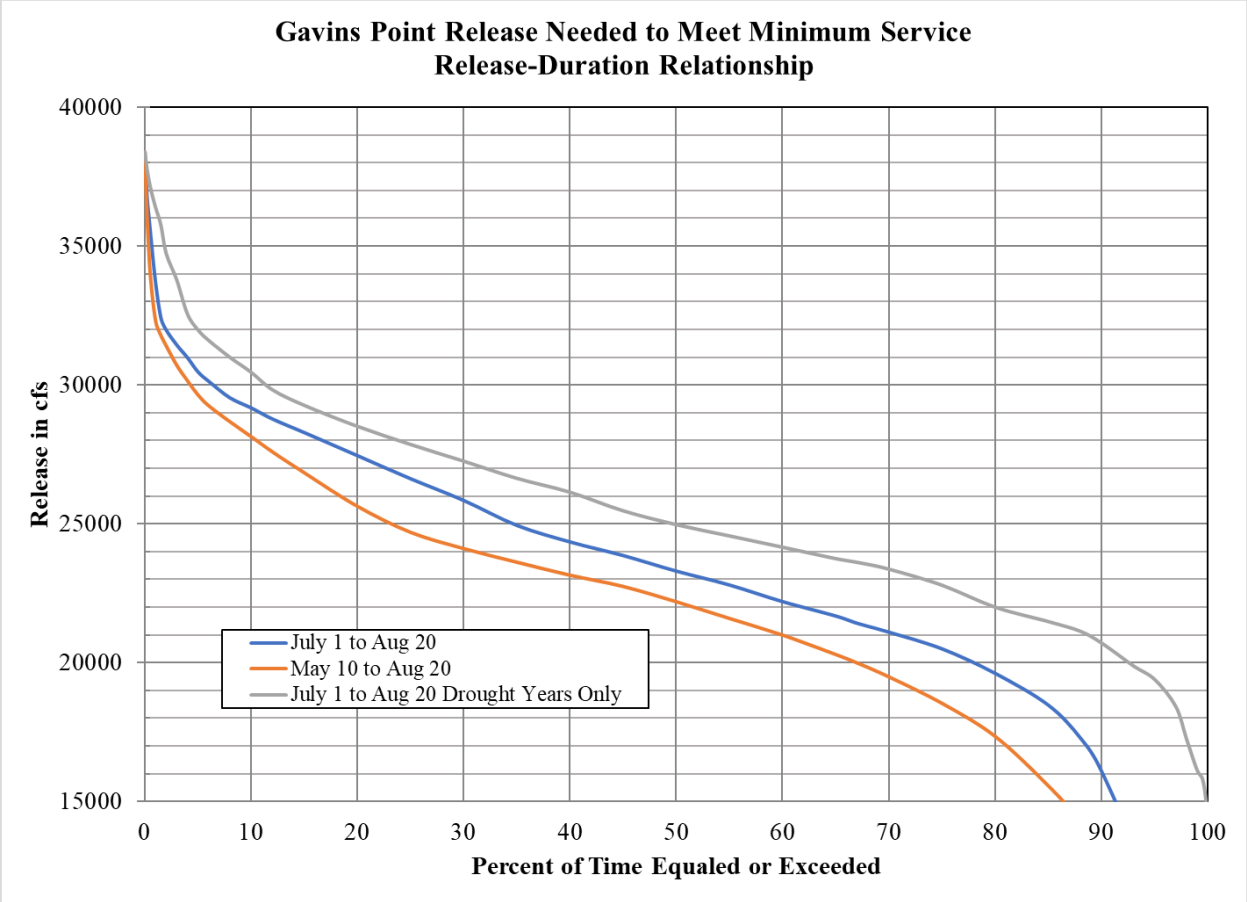

Figure A-6. Gavins Point Releases Needed to Meet Minimum Service Navigation Targets Release-Duration Relationship (1950-2022)

Appendix B. Correlation of Monthly Releases

Monthly average releases required to meet full-service targets for the four target locations were correlated from month to month in the same year to see if the current month's Gavins Point release could be used to predict the following month's Gavins Point release. Strong correlations could help inform releases used in long-range monthly studies. Results varied, but stronger correlations are observed in the late summer and fall months. Sample correlation plots are included in Figure B-1 in this appendix. Additional analysis could be performed including computing correlations of future non-adjacent months. For example, comparing the May release with the August release.

To further illustrate example data, the computed required May release was used to predict the June release using the correlation formula. The June release from the formula was compared to the June table value and the computed required release for June. When compared to the computed required June release, the correlated June release value and the table value vary, some positive and some negative, and neither appears to be a consistently better predicter of the June release. An example plot is shown in Figure B-2. Based on the limited data, it appears that in years where the current month's release varies considerably from the table value, the release computed from the correlation release might be a better predicter of the next month's value, but this would need more analysis, including comparisons of additional months.

The preliminary data in Figure B-1 may be useful in choosing releases from month to month, but likely needs additional evaluation, and could be compared to future investigations using HEC-WAT.

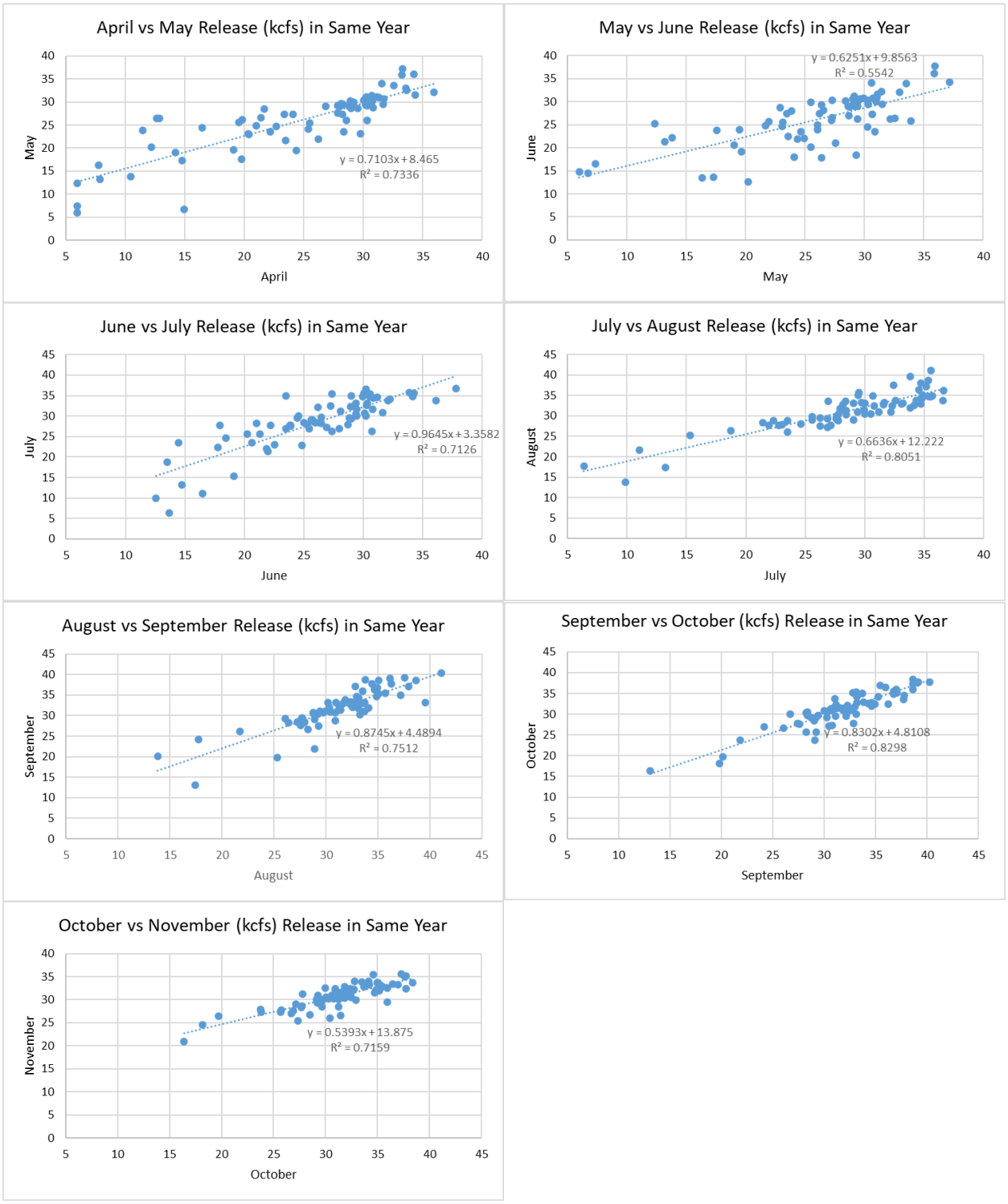

Figure B-1. Example Month to Month Required Release Correlation Plots

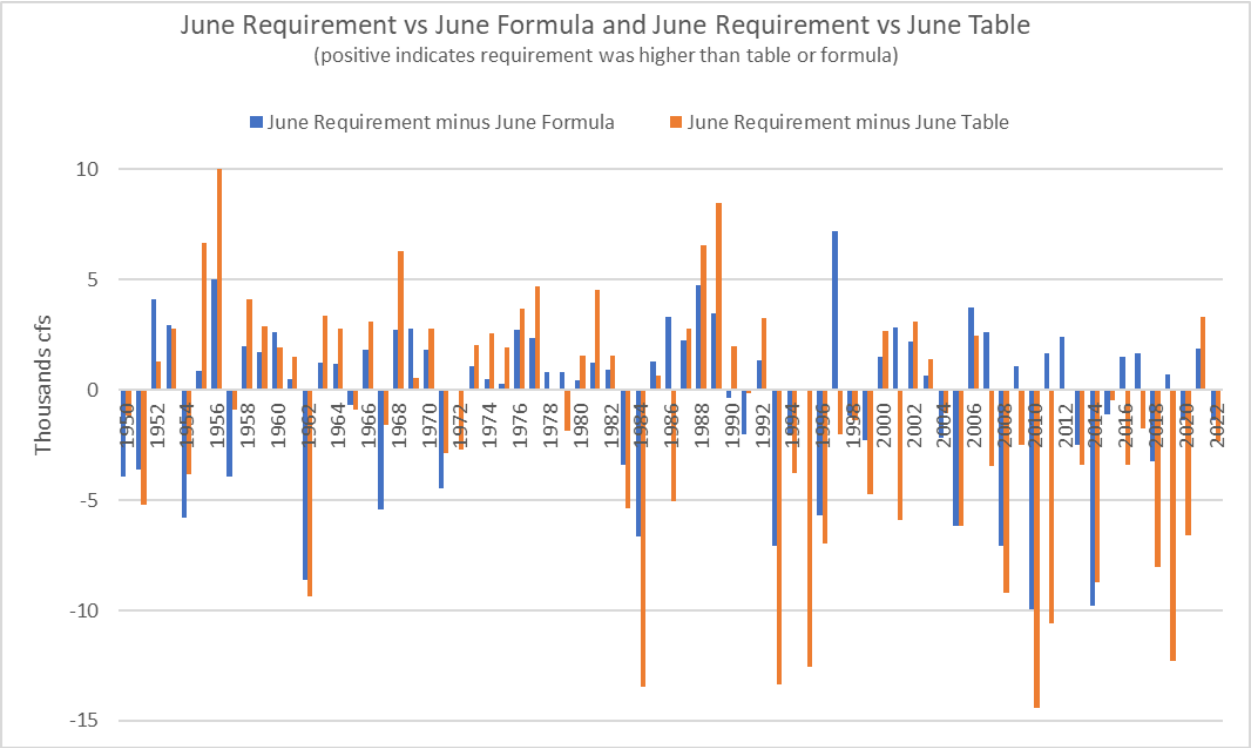

Figure B-2. Difference Between June Requirement and June Formula, and Difference Between June Requirement and June Table

Average Gavins Point Release to Meet Full-Service Navigation at Sioux City, Omaha, Nebraska City, and Kansas City (1000 cfs)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average	Runoff (MAF)
1950	35.9	32.2	26.2	32.2	31.0	33.2	32.8	33.9	32.2	29.4
1951	21.0	24.9	22.0	21.4	28.3	26.7	30.0	32.5	25.9	28.9
1952	20.4	22.9	28.7	28.0	31.8	33.7	35.0	33.8	29.3	34.2
1953	28.3	27.3	30.3	36.6	33.8	38.6	38.4	33.8	33.4	25.4
1954	31.3	30.9	23.5	34.9	34.4	37.7	33.5	33.8	32.5	19.2
1955	33.3	37.2	34.3	35.6	42.3	40.3	37.8	35.1	37.0	16.4
1956	34.3	36.0	37.8	36.7	36.2	39.1	37.6	35.1	36.6	19.4
1957	33.7	32.6	26.5	28.1	32.7	32.3	32.2	30.9	31.1	22.1
1958	30.3	31.1	31.6	30.8	32.3	33.2	34.7	31.5	32.0	17.0
1959	31.7	29.5	30.4	33.1	33.0	34.6	32.7	32.3	32.2	20.0
1960	12.7	26.4	29.4	30.5	30.4	31.1	32.2	31.1	28.0	20.1
1961	30.3	29.2	29.0	32.3	32.4	32.7	30.9	31.0	31.0	12.4
1962	12.9	26.4	17.8	22.3	28.8	30.6	30.7	30.9	25.0	30.3
1963	31.2	31.1	30.9	34.4	33.7	33.2	34.2	33.2	32.7	20.3
1964	30.8	30.3	30.3	32.6	33.7	31.0	33.7	32.8	31.9	23.7
1965	23.4	27.3	26.5	29.7	33.3	30.3	29.2	30.0	28.7	32.5
1966	28.1	29.7	30.6	34.7	32.9	33.7	35.1	33.7	32.3	19.7
1967	31.6	33.9	25.8	29.1	33.1	34.3	32.6	31.9	31.5	31.0
1968	32.6	33.5	33.9	35.7	34.9	34.6	31.9	31.6	33.6	23.7
1969	11.5	23.9	28.0	26.9	33.6	33.0	31.8	32.8	27.7	30.1
1970	27.9	29.2	30.3	35.2	37.2	34.9	32.4	30.6	32.2	27.3
1971	28.9	30.3	24.5	29.5	35.1	38.6	35.9	29.5	31.5	33.1
1972	29.8	23.1	24.6	30.0	30.4	30.9	31.2	28.5	28.6	33.0
1973	26.9	29.1	29.5	30.0	33.0	32.1	30.1	30.5	30.2	23.1
1974	30.9	31.0	30.1	35.6	34.7	36.8	35.5	32.8	33.4	25.0
1975	30.1	30.3	29.4	33.2	33.1	32.8	35.2	32.0	32.0	35.5
1976	28.2	29.2	31.2	34.6	36.3	37.8	34.6	35.4	33.4	27.7
1977	30.7	31.4	32.2	34.2	32.5	32.0	31.2	30.1	31.8	16.1
1978	19.9	26.2	27.4	26.2	29.4	31.0	31.8	30.4	27.8	40.6
1979	20.3	23.1	25.5	26.9	27.3	28.4	30.4	26.1	26.0	29.5
1980	28.3	29.4	29.0	34.9	35.0	35.3	34.1	33.9	32.5	18.7
1981	33.6	33.0	32.1	33.8	31.9	33.8	32.9	30.0	32.6	19.3
1982	29.0	28.6	29.0	29.4	30.9	30.8	27.4	25.4	28.8	33.6
1983	16.5	24.4	21.9	21.9	27.7	29.2	29.2	29.4	25.0	26.8
1984	7.8	16.3	13.5	18.7	26.4	28.2	25.7	27.8	20.6	30.8
1985	21.4	26.6	28.1	31.2	30.9	28.7	29.3	31.0	28.4	18.8
1986	10.4	13.8	22.2	27.7	28.9	21.9	23.8	27.3	22.0	36.2
1987	21.7	28.4	30.2	29.9	31.4	31.3	31.6	31.6	29.5	21.3
1988	30.2	30.6	34.2	34.7	38.0	37.0	35.1	32.6	34.1	12.4
1989	33.3	35.9	36.2	33.9	39.6	33.1	35.3	33.2	35.0	17.7
1990	34.4	31.5	29.5	31.6	32.8	37.0	35.9	32.5	33.1	16.7
1991	31.7	30.7	27.3	32.5	37.5	39.2	37.8	32.3	33.6	22.3
1992	30.4	30.7	30.7	26.2	27.5	27.6	27.7	28.4	28.7	16.4
1993	14.8	17.3	13.6	6.4	17.7	24.1	26.9	27.6	18.6	36.2
1994	22.7	24.7	23.5	26.9	29.2	30.3	30.6	30.9	27.4	23.9
1995	15.0	6.8	14.5	23.5	26.1	29.2	25.7	27.3	21.0	37.2
1996	25.5	25.5	20.2	25.6	29.0	30.0	30.8	30.3	27.1	35.6
1997	6.0	12.4	25.3	27.9	31.3	31.3	31.4	30.4	24.5	49.0

Average Gavins Point Release to Meet Full-Service Navigation at Sioux City, Omaha, Nebraska City, and Kansas City (1000 cfs)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average	Runoff (MAF)
1998	24.1	27.2	26.0	28.4	30.3	32.0	31.4	26.6	28.3	26.4
1999	22.2	23.6	22.5	23.1	27.9	28.2	30.3	30.2	26.0	31.2
2000	30.3	29.5	30.1	30.7	34.9	36.7	34.8	32.1	32.4	16.5
2001	7.9	13.2	21.3	25.6	29.8	30.8	30.9	32.1	23.9	22.5
2002	28.8	29.1	30.6	35.4	34.7	36.3	32.4	32.5	32.5	15.7
2003	30.8	28.8	28.8	29.5	35.7	35.5	36.9	33.3	32.4	17.4
2004	30.2	29.4	26.3	28.4	31.3	32.2	29.6	29.9	29.7	16.2
2005	27.9	27.6	21.0	28.2	31.6	32.9	27.8	31.2	28.5	20.1
2006	19.6	25.5	30.0	34.7	34.1	31.8	31.0	32.3	29.9	18.2
2007	19.8	17.6	23.9	27.8	28.8	30.5	27.1	29.1	25.6	21.1
2008	25.4	24.1	17.9	27.7	29.9	31.1	29.5	29.0	26.8	26.6
2009	23.5	21.7	24.8	22.8	27.6	29.0	28.5	26.7	25.6	33.4
2010	12.2	20.2	12.6	9.9	13.8	20.2	19.7	26.5	16.9	38.7
2011	6.0	7.4	16.5	11.0	21.7	26.1	26.7	27.0	17.8	61.0
2012	28.4	23.5	27.3	35.3	38.7	38.6	37.3	35.6	33.1	19.5
2013	28.6	26.1	23.9	27.8	30.2	33.1	30.1	30.4	28.8	24.7
2014	28.9	29.3	18.4	24.6	28.0	28.4	29.7	29.9	27.2	35.3
2015	29.5	28.7	26.9	27.2	27.7	29.4	29.6	28.5	28.4	25.8
2016	24.4	19.5	23.9	27.6	29.3	27.4	27.7	28.6	26.0	24.1
2017	26.2	22.0	25.6	29.1	28.9	29.1	23.7	27.9	26.6	29.6
2018	19.1	19.7	19.1	15.3	25.3	19.8	18.2	24.6	20.1	42.1
2019	6.0	6.0	14.7	13.3	17.5	13.1	16.4	20.9	13.5	60.9
2020	14.2	19.0	20.6	23.5	28.8	30.7	31.4	31.6	25.0	31.2
2021	29.2	29.9	30.8	31.6	33.2	31.7	31.4	30.5	31.0	15.2
2022	30.3	26.0	25.0	28.4	33.5	35.9	36.4	33.5	31.1	19.3
Average	24.7	26.0	26.1	28.6	31.2	31.8	31.2	30.7	28.8	

Average Gavins Point Release to Meet Full-Service Navigation at Sioux City, Omaha, Nebraska City, and Kansas City Sorted by Upstream Runoff (1000 cfs)

Lower Runoff Years (Lower Quartile and Lower Decile)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average	Runoff
1988	30.2	30.6	34.2	34.7	38.0	37.0	35.1	32.6	34.1	12.4
1961	30.3	29.2	29.0	32.3	32.4	32.7	30.9	31.0	31.0	12.4
2021	29.2	29.9	30.8	31.6	33.2	31.7	31.4	30.5	31.0	15.2
2002	28.8	29.1	30.6	35.4	34.7	36.3	32.4	32.5	32.5	15.7
1977	30.7	31.4	32.2	34.2	32.5	32.0	31.2	30.1	31.8	16.1
2004	30.2	29.4	26.3	28.4	31.3	32.2	29.6	29.9	29.7	16.2
1955	33.3	37.2	34.3	35.6	42.3	40.3	37.8	35.1	37.0	16.4
1992	30.4	30.7	30.7	26.2	27.5	27.6	27.7	28.4	28.7	16.4
2000	30.3	29.5	30.1	30.7	34.9	36.7	34.8	32.1	32.4	16.5
1990	34.4	31.5	29.5	31.6	32.8	37.0	35.9	32.5	33.1	16.7
1958	30.3	31.1	31.6	30.8	32.3	33.2	34.7	31.5	32.0	17.0
2003	30.8	28.8	28.8	29.5	35.7	35.5	36.9	33.3	32.4	17.4
1989	33.3	35.9	36.2	33.9	39.6	33.1	35.3	33.2	35.0	17.7
2006	19.6	25.5	30.0	34.7	34.1	31.8	31.0	32.3	29.9	18.2
1980	28.3	29.4	29.0	34.9	35.0	35.3	34.1	33.9	32.5	18.7
1985	21.4	26.6	28.1	31.2	30.9	28.7	29.3	31.0	28.4	18.8
1954	31.3	30.9	23.5	34.9	34.4	37.7	33.5	33.8	32.5	19.2
1981	33.6	33.0	32.1	33.8	31.9	33.8	32.9	30.0	32.6	19.3
2022	30.3	26.0	25.0	28.4	33.5	35.9	36.4	33.5	31.1	19.3
1956	34.3	36.0	37.8	36.7	36.2	39.1	37.6	35.1	36.6	19.4
2012	28.4	23.5	27.3	35.3	38.7	38.6	37.3	35.6	33.1	19.5
1966	28.1	29.7	30.6	34.7	32.9	33.7	35.1	33.7	32.3	19.7
1959	31.7	29.5	30.4	33.1	33.0	34.6	32.7	32.3	32.2	20.0
2005	27.9	27.6	21.0	28.2	31.6	32.9	27.8	31.2	28.5	20.1
1960	12.7	26.4	29.4	30.5	30.4	31.1	32.2	31.1	28.0	20.1
Average	29.2	29.9	29.9	32.5	34.0	34.3	33.3	32.2	31.9	
Maximum	34.4	37.2	37.8	36.7	42.3	40.3	37.8	35.6		
Minimum	12.7	23.5	21.0	26.2	27.5	27.6	27.7	28.4		

Middle Runoff Years (Median)

1963	31.2	31.1	30.9	34.4	33.7	33.2	34.2	33.2	32.7	20.3
2007	19.8	17.6	23.9	27.8	28.8	30.5	27.1	29.1	25.6	21.1
1987	21.7	28.4	30.2	29.9	31.4	31.3	31.6	31.6	29.5	21.3
1957	33.7	32.6	26.5	28.1	32.7	32.3	32.2	30.9	31.1	22.1
1991	31.7	30.7	27.3	32.5	37.5	39.2	37.8	32.3	33.6	22.3
2001	7.9	13.2	21.3	25.6	29.8	30.8	30.9	32.1	23.9	22.5
1973	26.9	29.1	29.5	30.0	33.0	32.1	30.1	30.5	30.2	23.1
1964	30.8	30.3	30.3	32.6	33.7	31.0	33.7	32.8	31.9	23.7
1968	32.6	33.5	33.9	35.7	34.9	34.6	31.9	31.6	33.6	23.7
1994	22.7	24.7	23.5	26.9	29.2	30.3	30.6	30.9	27.4	23.9
2016	24.4	19.5	23.9	27.6	29.3	27.4	27.7	28.6	26.0	24.1
2013	28.6	26.1	23.9	27.8	30.2	33.1	30.1	30.4	28.8	24.7
1974	30.9	31.0	30.1	35.6	34.7	36.8	35.5	32.8	33.4	25.0
1953	28.3	27.3	30.3	36.6	33.8	38.6	38.4	33.8	33.4	25.4

Average Gavins Point Release to Meet Full-Service Navigation at Sioux City, Omaha, Nebraska City, and Kansas City Sorted by Upstream Runoff (1000 cfs)

Lower Runoff Years (Lower Quartile and Lower Decile)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average	Runoff
2015	29.5	28.7	26.9	27.2	27.7	29.4	29.6	28.5	28.4	25.8
1998	24.1	27.2	26.0	28.4	30.3	32.0	31.4	26.6	28.3	26.4
2008	25.4	24.1	17.9	27.7	29.9	31.1	29.5	29.0	26.8	26.6
1983	16.5	24.4	21.9	21.9	27.7	29.2	29.2	29.4	25.0	26.8
1970	27.9	29.2	30.3	35.2	37.2	34.9	32.4	30.6	32.2	27.3
1976	28.2	29.2	31.2	34.6	36.3	37.8	34.6	35.4	33.4	27.7
1951	21.0	24.9	22.0	21.4	28.3	26.7	30.0	32.5	25.9	28.9
1950	35.9	32.2	26.2	32.2	31.0	33.2	32.8	33.9	32.2	29.4
1979	20.3	23.1	25.5	26.9	27.3	28.4	30.4	26.1	26.0	29.5
2017	26.2	22.0	25.6	29.1	28.9	29.1	23.7	27.9	26.6	29.6
Average	26.1	26.7	26.6	29.8	31.6	32.2	31.5	30.9	29.4	
Maximum	35.9	33.5	33.9	36.6	37.5	39.2	38.4	35.4		
Minimum	7.9	13.2	17.9	21.4	27.3	26.7	23.7	26.1		

Higher Runoff Years (Upper Quartile and Upper Decile)

1969	11.5	23.9	28.0	26.9	33.6	33.0	31.8	32.8	27.7	30.1
1962	12.9	26.4	17.8	22.3	28.8	30.6	30.7	30.9	25.0	30.3
1984	7.8	16.3	13.5	18.7	26.4	28.2	25.7	27.8	20.6	30.8
1967	31.6	33.9	25.8	29.1	33.1	34.3	32.6	31.9	31.5	31.0
1999	22.2	23.6	22.5	23.1	27.9	28.2	30.3	30.2	26.0	31.2
2020	14.2	19.0	20.6	23.5	28.8	30.7	31.4	31.6	25.0	31.2
1965	23.4	27.3	26.5	29.7	33.3	30.3	29.2	30.0	28.7	32.5
1972	29.8	23.1	24.6	30.0	30.4	30.9	31.2	28.5	28.6	33.0
1971	28.9	30.3	24.5	29.5	35.1	38.6	35.9	29.5	31.5	33.1
2009	23.5	21.7	24.8	22.8	27.6	29.0	28.5	26.7	25.6	33.4
1982	29.0	28.6	29.0	29.4	30.9	30.8	27.4	25.4	28.8	33.6
1952	20.4	22.9	28.7	28.0	31.8	33.7	35.0	33.8	29.3	34.2
2014	28.9	29.3	18.4	24.6	28.0	28.4	29.7	29.9	27.2	35.3
1975	30.1	30.3	29.4	33.2	33.1	32.8	35.2	32.0	32.0	35.5
1996	25.5	25.5	20.2	25.6	29.0	30.0	30.8	30.3	27.1	35.6
1993	14.8	17.3	13.6	6.4	17.7	24.1	26.9	27.6	18.6	36.2
1986	10.4	13.8	22.2	27.7	28.9	21.9	23.8	27.3	22.0	36.2
1995	15.0	6.8	14.5	23.5	26.1	29.2	25.7	27.3	21.0	37.2
2010	12.2	20.2	12.6	9.9	13.8	20.2	19.7	26.5	16.9	38.7
1978	19.9	26.2	27.4	26.2	29.4	31.0	31.8	30.4	27.8	40.6
2018	19.1	19.7	19.1	15.3	25.3	19.8	18.2	24.6	20.1	42.1
1997	6.0	12.4	25.3	27.9	31.3	31.3	31.4	30.4	24.5	49.0
2019	6.0	6.0	14.7	13.3	17.5	13.1	16.4	20.9	13.5	60.9
2011	6.0	7.4	16.5	11.0	21.7	26.1	26.7	27.0	17.8	61.0
Average	18.7	21.3	21.7	23.2	27.9	28.6	28.6	28.9	24.9	
Maximum	31.6	33.9	29.4	33.2	35.1	38.6	35.9	33.8		
Minimum	6.0	6.0	12.6	6.4	13.8	13.1	16.4	20.9		

Average Gavins Point Release to Meet Full-Service Navigation at Nebraska City and Kansas City (1000 cfs)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average	Runoff (MAF)
1950	33.3	27.7	23.6	28.5	28.2	33.2	31.8	33.9	30.0	29.4
1951	16.8	18.8	16.2	16.3	24.8	22.6	26.8	30.0	21.5	28.9
1952	16.7	19.0	24.4	26.3	31.1	33.7	35.0	33.6	27.5	34.2
1953	24.9	22.5	26.5	36.4	33.4	38.6	38.4	33.6	31.8	25.4
1954	30.7	28.9	18.9	34.3	33.4	37.7	33.5	33.6	31.4	19.2
1955	32.5	37.2	33.1	35.1	42.3	40.3	37.8	35.1	36.7	16.4
1956	34.3	36.0	37.7	36.4	36.0	39.0	37.6	35.1	36.5	19.4
1957	33.3	29.8	22.2	26.1	32.5	31.6	31.7	30.2	29.7	22.1
1958	25.6	30.1	30.5	26.4	29.9	32.7	34.7	31.3	30.1	17.0
1959	28.9	23.9	27.2	32.0	31.7	34.5	32.5	30.5	30.2	20.0
1960	10.1	20.4	24.0	28.3	29.0	30.5	32.0	30.4	25.6	20.1
1961	26.9	27.1	24.7	32.1	31.7	32.4	29.4	29.7	29.2	12.4
1962	10.2	22.6	11.9	17.1	26.1	28.2	29.9	30.5	22.1	30.3
1963	29.4	30.0	28.3	34.2	33.7	33.1	34.2	33.2	32.0	20.3
1964	28.9	27.1	26.6	31.0	33.3	30.2	33.7	32.7	30.4	23.7
1965	18.1	24.0	21.3	26.4	33.2	25.4	24.8	27.9	25.2	32.5
1966	25.2	28.9	29.0	34.7	31.6	33.7	35.1	33.7	31.5	19.7
1967	31.4	33.9	20.3	25.3	33.1	34.3	32.6	31.9	30.4	31.0
1968	32.4	33.5	33.0	35.7	34.9	34.6	30.2	31.1	33.2	23.7
1969	8.8	19.7	25.9	21.9	33.4	33.0	31.3	32.6	25.8	30.1
1970	24.4	27.7	29.6	35.1	37.2	34.9	31.2	29.5	31.2	27.3
1971	25.7	24.8	18.4	26.7	35.1	38.6	35.8	28.9	29.2	33.1
1972	28.8	17.3	23.7	28.1	30.1	29.6	31.0	24.5	26.6	33.0
1973	20.8	23.0	23.3	27.5	33.0	30.3	24.0	26.0	26.0	23.1
1974	24.9	25.8	27.4	35.6	34.7	36.8	35.5	32.8	31.7	25.0
1975	24.6	26.8	26.0	32.4	33.1	32.8	35.2	31.2	30.3	35.5
1976	26.7	27.5	31.1	34.6	36.3	37.8	34.6	35.4	33.0	27.7
1977	29.0	29.6	31.0	34.1	31.2	30.2	30.6	27.6	30.4	16.1
1978	13.7	22.1	25.1	23.6	29.3	29.8	31.8	30.4	25.7	40.6
1979	14.2	17.9	22.9	24.9	25.5	27.3	30.1	20.8	22.9	29.5
1980	23.3	24.5	23.7	34.9	34.9	35.3	34.1	33.9	30.6	18.7
1981	33.5	32.3	31.1	33.6	30.0	33.8	32.9	29.4	32.1	19.3
1982	27.3	24.1	22.8	24.6	27.8	27.9	21.7	20.3	24.6	33.6
1983	10.4	18.2	16.9	16.5	22.8	25.4	24.5	25.3	20.0	26.8
1984	6.2	11.6	10.5	13.7	24.1	25.3	21.5	21.6	16.8	30.8
1985	16.1	20.4	22.9	29.2	30.3	25.7	24.8	28.7	24.8	18.8
1986	7.0	8.9	16.1	22.4	24.4	18.7	17.7	21.2	17.1	36.2
1987	15.5	22.2	24.4	25.6	28.6	27.4	30.5	29.6	25.5	21.3
1988	26.9	27.8	33.3	34.6	38.0	36.8	35.0	32.1	33.1	12.4
1989	33.3	35.8	35.7	33.2	39.6	31.0	35.2	32.7	34.6	17.7
1990	34.4	29.6	25.3	29.6	32.2	37.0	35.9	32.2	32.0	16.7
1991	27.9	24.8	21.4	31.4	37.5	39.2	37.6	31.5	31.4	22.3
1992	26.4	26.7	28.0	22.1	23.2	23.8	23.0	23.0	24.5	16.4
1993	10.0	12.0	9.1	6.0	11.6	18.0	20.8	22.4	13.7	36.2
1994	18.1	21.6	18.6	21.1	26.7	29.3	29.7	28.9	24.2	23.9
1995	11.2	6.0	10.3	18.7	25.1	28.5	24.4	25.4	18.7	37.2
1996	21.9	20.1	14.5	20.7	23.9	27.5	28.9	27.4	23.1	35.6
1997	6.0	9.6	19.4	25.5	31.0	30.0	29.6	28.6	22.5	49.0

Average Gavins Point Release to Meet Full-Service Navigation at Nebraska City and Kansas City (1000 cfs)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average	Runoff (MAF)
1998	17.9	21.1	19.8	22.6	25.4	31.8	28.2	20.5	23.4	26.4
1999	16.1	17.4	16.4	17.7	23.2	28.0	30.3	29.0	22.3	31.2
2000	29.1	29.1	28.7	28.9	34.9	36.7	34.8	31.1	31.7	16.5
2001	6.8	9.4	15.4	22.9	29.6	30.2	30.9	31.4	22.1	22.5
2002	28.2	25.3	28.9	35.4	34.4	36.3	32.3	32.1	31.6	15.7
2003	30.6	23.4	25.6	25.8	35.7	35.4	36.9	33.1	30.8	17.4
2004	28.9	27.3	20.8	24.2	30.9	29.9	28.4	28.5	27.4	16.2
2005	24.4	23.0	14.9	26.4	31.6	32.9	27.5	31.2	26.5	20.1
2006	14.2	22.0	29.9	34.7	34.1	30.8	30.5	32.3	28.6	18.2
2007	13.6	12.2	17.7	26.3	24.6	26.2	21.3	23.4	20.7	21.1
2008	19.3	17.9	12.6	21.5	28.1	30.2	26.0	22.9	22.3	26.6
2009	18.2	17.9	19.7	17.6	24.2	28.1	25.4	20.6	21.5	33.4
2010	8.1	14.0	9.8	7.1	10.3	15.3	14.8	20.5	12.5	38.7
2011	6.0	6.0	11.6	7.1	15.5	20.4	21.9	24.0	14.1	61.0
2012	24.6	18.9	23.3	35.3	38.7	38.6	37.3	35.6	31.5	19.5
2013	24.6	21.9	17.8	26.6	30.1	33.1	27.9	29.5	26.4	24.7
2014	28.3	27.1	14.7	19.6	25.2	23.1	24.9	28.3	23.9	35.3
2015	24.5	22.6	20.8	21.1	22.0	23.7	24.2	22.8	22.7	25.8
2016	18.2	13.5	17.7	21.5	24.1	22.1	21.5	22.6	20.2	24.1
2017	20.0	15.8	19.5	25.6	25.8	26.9	18.0	23.0	21.8	29.6
2018	13.0	13.5	14.7	10.6	20.7	15.6	12.3	18.4	14.8	42.1
2019	6.0	6.0	10.4	8.2	11.3	10.2	10.5	14.7	9.7	60.9
2020	9.3	12.9	14.5	18.1	26.9	30.5	31.1	31.0	21.8	31.2
2021	23.7	25.7	27.4	29.8	33.1	30.2	30.3	28.0	28.5	15.2
2022	29.7	21.4	20.8	27.9	33.5	35.9	36.4	33.3	29.9	19.3
Average	21.5	22.3	22.2	25.9	29.5	30.3	29.4	28.6	26.2	

Average Gavins Point Release to Meet Full-Service Navigation at Nebraska City and Kansas City Sorted by Upstream Runoff (1000 cfs)

Lower Runoff Years (Lower Quartile and Lower Decile)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Average	Runoff (MAF)
1988	26.9	27.8	33.3	34.6	38.0	36.8	35.0	32.1	33.1	12.4
1961	26.9	27.1	24.7	32.1	31.7	32.4	29.4	29.7	29.2	12.4
2021	23.7	25.7	27.4	29.8	33.1	30.2	30.3	28.0	28.5	15.2
2002	28.2	25.3	28.9	35.4	34.4	36.3	32.3	32.1	31.6	15.7
1977	29.0	29.6	31.0	34.1	31.2	30.2	30.6	27.6	30.4	16.1
2004	28.9	27.3	20.8	24.2	30.9	29.9	28.4	28.5	27.4	16.2
1955	32.5	37.2	33.1	35.1	42.3	40.3	37.8	35.1	36.7	16.4
1992	26.4	26.7	28.0	22.1	23.2	23.8	23.0	23.0	24.5	16.4
2000	29.1	29.1	28.7	28.9	34.9	36.7	34.8	31.1	31.7	16.5
1990	34.4	29.6	25.3	29.6	32.2	37.0	35.9	32.2	32.0	16.7
1958	25.6	30.1	30.5	26.4	29.9	32.7	34.7	31.3	30.1	17.0
2003	30.6	23.4	25.6	25.8	35.7	35.4	36.9	33.1	30.8	17.4
1989	33.3	35.8	35.7	33.2	39.6	31.0	35.2	32.7	34.6	17.7
2006	14.2	22.0	29.9	34.7	34.1	30.8	30.5	32.3	28.6	18.2
1980	23.3	24.5	23.7	34.9	34.9	35.3	34.1	33.9	30.6	18.7
1985	16.1	20.4	22.9	29.2	30.3	25.7	24.8	28.7	24.8	18.8
1954	30.7	28.9	18.9	34.3	33.4	37.7	33.5	33.6	31.4	19.2
1981	33.5	32.3	31.1	33.6	30.0	33.8	32.9	29.4	32.1	19.3
2022	29.7	21.4	20.8	27.9	33.5	35.9	36.4	33.3	29.9	19.3
1956	34.3	36.0	37.7	36.4	36.0	39.0	37.6	35.1	36.5	19.4
2012	24.6	18.9	23.3	35.3	38.7	38.6	37.3	35.6	31.5	19.5
1966	25.2	28.9	29.0	34.7	31.6	33.7	35.1	33.7	31.5	19.7
1959	28.9	23.9	27.2	32.0	31.7	34.5	32.5	30.5	30.2	20.0
2005	24.4	23.0	14.9	26.4	31.6	32.9	27.5	31.2	26.5	20.1
1960	10.1	20.4	24.0	28.3	29.0	30.5	32.0	30.4	25.6	20.1
Average	26.8	27.0	27.0	31.2	33.3	33.6	32.7	31.4	30.4	
Maximum	34.4	37.2	37.7	36.4	42.3	40.3	37.8	35.6		
Minimum	10.1	18.9	14.9	22.1	23.2	23.8	23.0	23.0		

Middle Runoff Years (Median)

1963	29.4	30.0	28.3	34.2	33.7	33.1	34.2	33.2	32.0	20.3
2007	13.6	12.2	17.7	26.3	24.6	26.2	21.3	23.4	20.7	21.1
1987	15.5	22.2	24.4	25.6	28.6	27.4	30.5	29.6	25.5	21.3
1957	33.3	29.8	22.2	26.1	32.5	31.6	31.7	30.2	29.7	22.1
1991	27.9	24.8	21.4	31.4	37.5	39.2	37.6	31.5	31.4	22.3
2001	6.8	9.4	15.4	22.9	29.6	30.2	30.9	31.4	22.1	22.5
1973	20.8	23.0	23.3	27.5	33.0	30.3	24.0	26.0	26.0	23.1
1964	28.9	27.1	26.6	31.0	33.3	30.2	33.7	32.7	30.4	23.7
1968	32.4	33.5	33.0	35.7	34.9	34.6	30.2	31.1	33.2	23.7
1994	18.1	21.6	18.6	21.1	26.7	29.3	29.7	28.9	24.2	23.9
2016	18.2	13.5	17.7	21.5	24.1	22.1	21.5	22.6	20.2	24.1
2013	24.6	21.9	17.8	26.6	30.1	33.1	27.9	29.5	26.4	24.7
1974	24.9	25.8	27.4	35.6	34.7	36.8	35.5	32.8	31.7	25.0
1953	24.9	22.5	26.5	36.4	33.4	38.6	38.4	33.6	31.8	25.4

Average Gavins Point Release to Meet Full-Service Navigation at Nebraska City and Kansas City Sorted by Upstream Runoff (1000 cfs)

Lower Runoff Years (Lower Quartile and Lower Decile)

2015	24.5	22.6	20.8	21.1	22.0	23.7	24.2	22.8	22.7	25.8
1998	17.9	21.1	19.8	22.6	25.4	31.8	28.2	20.5	23.4	26.4
2008	19.3	17.9	12.6	21.5	28.1	30.2	26.0	22.9	22.3	26.6
1983	10.4	18.2	16.9	16.5	22.8	25.4	24.5	25.3	20.0	26.8
1970	24.4	27.7	29.6	35.1	37.2	34.9	31.2	29.5	31.2	27.3
1976	26.7	27.5	31.1	34.6	36.3	37.8	34.6	35.4	33.0	27.7
1951	16.8	18.8	16.2	16.3	24.8	22.6	26.8	30.0	21.5	28.9
1950	33.3	27.7	23.6	28.5	28.2	33.2	31.8	33.9	30.0	29.4
1979	14.2	17.9	22.9	24.9	25.5	27.3	30.1	20.8	22.9	29.5
2017	20.0	15.8	19.5	25.6	25.8	26.9	18.0	23.0	21.8	29.6
Average	21.9	22.2	22.2	27.0	29.7	30.7	29.3	28.3	26.4	
Maximum	33.3	33.5	33.0	36.4	37.5	39.2	38.4	35.4		
Minimum	6.8	9.4	12.6	16.3	22.0	22.1	18.0	20.5		

Higher Runoff Years (Upper Quartile and Upper Decile)

1969	8.8	19.7	25.9	21.9	33.4	33.0	31.3	32.6	25.8	30.1
1962	10.2	22.6	11.9	17.1	26.1	28.2	29.9	30.5	22.1	30.3
1984	6.2	11.6	10.5	13.7	24.1	25.3	21.5	21.6	16.8	30.8
1967	31.4	33.9	20.3	25.3	33.1	34.3	32.6	31.9	30.4	31.0
1999	16.1	17.4	16.4	17.7	23.2	28.0	30.3	29.0	22.3	31.2
2020	9.3	12.9	14.5	18.1	26.9	30.5	31.1	31.0	21.8	31.2
1965	18.1	24.0	21.3	26.4	33.2	25.4	24.8	27.9	25.2	32.5
1972	28.8	17.3	23.7	28.1	30.1	29.6	31.0	24.5	26.6	33.0
1971	25.7	24.8	18.4	26.7	35.1	38.6	35.8	28.9	29.2	33.1
2009	18.2	17.9	19.7	17.6	24.2	28.1	25.4	20.6	21.5	33.4
1982	27.3	24.1	22.8	24.6	27.8	27.9	21.7	20.3	24.6	33.6
1952	16.7	19.0	24.4	26.3	31.1	33.7	35.0	33.6	27.5	34.2
2014	28.3	27.1	14.7	19.6	25.2	23.1	24.9	28.3	23.9	35.3
1975	24.6	26.8	26.0	32.4	33.1	32.8	35.2	31.2	30.3	35.5
1996	21.9	20.1	14.5	20.7	23.9	27.5	28.9	27.4	23.1	35.6
1993	10.0	12.0	9.1	6.0	11.6	18.0	20.8	22.4	13.7	36.2
1986	7.0	8.9	16.1	22.4	24.4	18.7	17.7	21.2	17.1	36.2
1995	11.2	6.0	10.3	18.7	25.1	28.5	24.4	25.4	18.7	37.2
2010	8.1	14.0	9.8	7.1	10.3	15.3	14.8	20.5	12.5	38.7
1978	13.7	22.1	25.1	23.6	29.3	29.8	31.8	30.4	25.7	40.6
2018	13.0	13.5	14.7	10.6	20.7	15.6	12.3	18.4	14.8	42.1
1997	6.0	9.6	19.4	25.5	31.0	30.0	29.6	28.6	22.5	49.0
2019	6.0	6.0	10.4	8.2	11.3	10.2	10.5	14.7	9.7	60.9
2011	6.0	6.0	11.6	7.1	15.5	20.4	21.9	24.0	14.1	61.0
Average	15.5	17.4	17.1	19.4	25.4	26.4	26.0	26.0	21.7	
Maximum	31.4	33.9	26.0	32.4	35.1	38.6	35.8	33.6		
Minimum	6.0	6.0	9.1	6.0	10.3	10.2	10.5	14.7		

Average Gavins Point Release to Meet Full-Service Navigation
at Sioux City, Omaha, Nebraska City, and Kansas City
Sorted by Monthly Average Release
(1000 cfs)

Apr		May		Jun		Jul		Aug		Sep		Oct		Nov	
1997	6.0	2019	6.0	2010	12.6	1993	6.4	2010	13.8	2019	13.1	2019	16.4	2019	20.9
2011	6.0	1995	6.8	1984	13.5	2010	9.9	2019	17.5	2018	19.8	2018	18.2	2018	24.6
2019	6.0	2011	7.4	1993	13.6	2011	11.0	1993	17.7	2010	20.2	2010	19.7	1982	25.4
1984	7.8	1997	12.4	1995	14.5	2019	13.3	2011	21.7	1986	21.9	2017	23.7	1979	26.1
2001	7.9	2001	13.2	2019	14.7	2018	15.3	2018	25.3	1993	24.1	1986	23.8	2010	26.5
1986	10.4	1986	13.8	2011	16.5	1984	18.7	1995	26.1	2011	26.1	1995	25.7	1998	26.6
1969	11.5	1984	16.3	1962	17.8	1951	21.4	1984	26.4	1951	26.7	1984	25.7	2009	26.7
2010	12.2	1993	17.3	2008	17.9	1983	21.9	1979	27.3	2016	27.4	2011	26.7	2011	27.0
1960	12.7	2007	17.6	2014	18.4	1962	22.3	1992	27.5	1992	27.6	1993	26.9	1986	27.3
1962	12.9	2020	19.0	2018	19.1	2009	22.8	2009	27.6	1999	28.2	2007	27.1	1995	27.3
2020	14.2	2016	19.5	1996	20.2	1999	23.1	2015	27.7	1984	28.2	1982	27.4	1993	27.6
1993	14.8	2018	19.7	2020	20.6	2020	23.5	1983	27.7	2014	28.4	1992	27.7	1984	27.8
1995	15.0	2010	20.2	2005	21.0	1995	23.5	1999	27.9	1979	28.4	2016	27.7	2017	27.9
1983	16.5	2009	21.7	2001	21.3	2014	24.6	2014	28.0	1985	28.7	2005	27.8	1992	28.4
2018	19.1	2017	22.0	1983	21.9	2001	25.6	1951	28.3	2009	29.0	2009	28.5	1972	28.5
2006	19.6	1952	22.9	1951	22.0	1996	25.6	1962	28.8	2017	29.1	1965	29.2	2015	28.5
2007	19.8	1972	23.1	1986	22.2	1978	26.2	2020	28.8	1995	29.2	1983	29.2	2016	28.6
1978	19.9	1979	23.1	1999	22.5	1992	26.2	2007	28.8	1983	29.2	1985	29.3	2008	29.0
1979	20.3	2012	23.5	1954	23.5	1979	26.9	2017	28.9	2015	29.4	2008	29.5	2007	29.1
1952	20.4	1999	23.6	1994	23.5	1994	26.9	1986	28.9	1996	30.0	2004	29.6	1983	29.4
1951	21.0	1969	23.9	2007	23.9	1969	26.9	1996	29.0	1965	30.3	2015	29.6	1971	29.5
1985	21.4	2008	24.1	2016	23.9	2015	27.2	1994	29.2	1994	30.3	2014	29.7	2004	29.9
1987	21.7	1983	24.4	2013	23.9	2016	27.6	2016	29.3	2007	30.5	1951	30.0	2014	29.9
1999	22.2	1994	24.7	1971	24.5	2008	27.7	1978	29.4	1962	30.6	2013	30.1	1981	30.0
1994	22.7	1951	24.9	1972	24.6	1986	27.7	2001	29.8	2020	30.7	1973	30.1	1965	30.0
1965	23.4	1996	25.5	2009	24.8	2013	27.8	2008	29.9	1982	30.8	1999	30.3	1977	30.1
2009	23.5	2006	25.5	2022	25.0	2007	27.8	2013	30.2	2001	30.8	1979	30.4	1999	30.2
1998	24.1	2022	26.0	1997	25.3	1997	27.9	1998	30.3	1972	30.9	1994	30.6	1996	30.3
2016	24.4	2013	26.1	1979	25.5	1952	28.0	1960	30.4	1978	31.0	1962	30.7	1997	30.4
2008	25.4	1978	26.2	2017	25.6	1957	28.1	1972	30.4	1964	31.0	1996	30.8	1978	30.4
1996	25.5	1962	26.4	1967	25.8	2005	28.2	1982	30.9	2008	31.1	1961	30.9	2013	30.4
2017	26.2	1960	26.4	1998	26.0	2022	28.4	1985	30.9	1960	31.1	2001	30.9	2021	30.5
1973	26.9	1985	26.6	1950	26.2	1998	28.4	1950	31.0	1987	31.3	2006	31.0	1973	30.5
2005	27.9	1998	27.2	2004	26.3	2004	28.4	1997	31.3	1997	31.3	1972	31.2	1970	30.6
1970	27.9	1965	27.3	1957	26.5	1967	29.1	2004	31.3	2021	31.7	1977	31.2	1957	30.9
1966	28.1	1953	27.3	1965	26.5	2017	29.1	1987	31.4	2006	31.8	2020	31.4	1962	30.9
1976	28.2	2005	27.6	2015	26.9	1982	29.4	2005	31.6	1977	32.0	1997	31.4	1994	30.9
1953	28.3	1987	28.4	1991	27.3	1971	29.5	1952	31.8	1998	32.0	2021	31.4	1985	31.0
1980	28.3	1982	28.6	2012	27.3	2003	29.5	1981	31.9	1973	32.1	1998	31.4	1961	31.0
2012	28.4	2015	28.7	1978	27.4	1965	29.7	1958	32.3	2004	32.2	1987	31.6	1960	31.1
2013	28.6	2003	28.8	1969	28.0	1987	29.9	1961	32.4	1957	32.3	1978	31.8	2005	31.2
2002	28.8	2002	29.1	1985	28.1	1973	30.0	1977	32.5	1961	32.7	1969	31.8	1958	31.5
2014	28.9	1973	29.1	1952	28.7	1972	30.0	1957	32.7	1975	32.8	1968	31.9	1968	31.6
1971	28.9	1976	29.2	2003	28.8	1960	30.5	1990	32.8	2005	32.9	1957	32.2	2020	31.6
1982	29.0	1970	29.2	1961	29.0	2000	30.7	1966	32.9	1969	33.0	1960	32.2	1987	31.6
2021	29.2	1961	29.2	1982	29.0	1958	30.8	1959	33.0	2013	33.1	2002	32.4	1967	31.9
2015	29.5	2014	29.3	1980	29.0	1985	31.2	1973	33.0	1989	33.1	1970	32.4	1975	32.0
1972	29.8	2004	29.4	1960	29.4	1990	31.6	1975	33.1	1963	33.2	1967	32.6	2001	32.1
1975	30.1	1980	29.4	1975	29.4	2021	31.6	1967	33.1	1950	33.2	1959	32.7	2000	32.1
1988	30.2	1959	29.5	1990	29.5	1950	32.2	2021	33.2	1958	33.2	1950	32.8	1959	32.3
2004	30.2	2000	29.5	1973	29.5	1961	32.3	1965	33.3	1952	33.7	1981	32.9	1991	32.3
2000	30.3	1966	29.7	2006	30.0	1991	32.5	2022	33.5	1966	33.7	1954	33.5	2006	32.3
1958	30.3	2021	29.9	1974	30.1	1964	32.6	1969	33.6	1981	33.8	1964	33.7	2002	32.5
1961	30.3	1964	30.3	2000	30.1	1959	33.1	1963	33.7	1967	34.3	1980	34.1	1990	32.5
2022	30.3	1971	30.3	1987	30.2	1975	33.2	1964	33.7	1959	34.6	1963	34.2	1951	32.5
1992	30.4	1975	30.3	1953	30.3	1981	33.8	1953	33.8	1968	34.6	1976	34.6	1988	32.6

Apr		May		Jun		Jul		Aug		Sep		Oct		Nov	
1977	30.7	1988	30.6	1970	30.3	1989	33.9	2006	34.1	1970	34.9	1958	34.7	1974	32.8
1964	30.8	1991	30.7	1964	30.3	1977	34.2	1954	34.4	1980	35.3	2000	34.8	1964	32.8
2003	30.8	1992	30.7	1959	30.4	1963	34.4	1974	34.7	2003	35.5	1952	35.0	1969	32.8
1974	30.9	1954	30.9	2002	30.6	1976	34.6	2002	34.7	2022	35.9	1966	35.1	1989	33.2
1963	31.2	1974	31.0	1966	30.6	2006	34.7	1968	34.9	2002	36.3	1988	35.1	1963	33.2
1954	31.3	1963	31.1	1992	30.7	1988	34.7	2000	34.9	2000	36.7	1975	35.2	2003	33.3
1967	31.6	1958	31.1	2021	30.8	1966	34.7	1980	35.0	1974	36.8	1989	35.3	2022	33.5
1959	31.7	1977	31.4	1963	30.9	1954	34.9	1971	35.1	1990	37.0	1974	35.5	1966	33.7
1991	31.7	1990	31.5	1976	31.2	1980	34.9	2003	35.7	1988	37.0	1990	35.9	1953	33.8
1968	32.6	1950	32.2	1958	31.6	1970	35.2	1956	36.2	1954	37.7	1971	35.9	1952	33.8
1989	33.3	1957	32.6	1981	32.1	2012	35.3	1976	36.3	1976	37.8	2022	36.4	1954	33.8
1955	33.3	1981	33.0	1977	32.2	2002	35.4	1970	37.2	1971	38.6	2003	36.9	1950	33.9
1981	33.6	1968	33.5	1968	33.9	1955	35.6	1991	37.5	2012	38.6	2012	37.3	1980	33.9
1957	33.7	1967	33.9	1988	34.2	1974	35.6	1988	38.0	1953	38.6	1956	37.6	1956	35.1
1956	34.3	1989	35.9	1955	34.3	1968	35.7	2012	38.7	1956	39.1	1955	37.8	1955	35.1
1990	34.4	1956	36.0	1989	36.2	1953	36.6	1989	39.6	1991	39.2	1991	37.8	1976	35.4
1950	35.9	1955	37.2	1956	37.8	1956	36.7	1955	41.1	1955	40.3	1953	38.4	2012	35.6
Lower Decile	11.7		16.6		17.8		21.6		26.7		26.9		26.0		26.8
Lower Quartile	20.0		23.2		22.8		26.4		28.9		29.3		29.3		29.0
Median	28.1		27.4		26.7		29.2		31.5		31.9		31.4		30.9
Upper Quartile	30.3		30.3		30.2		33.2		33.7		34.5		34.2		32.5
Upper Decile	32.3		32.0		31.5		35.1		36.0		37.5		35.9		33.8