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River System Hydrology in Texas

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CHAPTER 1
INTRODUCTION

Precipitation, reservoir surface evaporation, reservoir storage, and stream flow in the 15 major river basins and 8 coastal basins of Texas are explored in this report based on information derived from the Water Availability Modeling (WAM) System maintained by the Texas Commission on Environmental Quality (TCEQ) and databases maintained by the Texas Water Development Board (TWDB) and the U.S. Geological Survey (USGS). The research reported here supports updating hydrology, incorporating environmental flow standards, and otherwise expanding the WAM System. However, the characterization of river system hydrology has broad general relevance for water resources planning and management. Analyses of long-term changes in hydrology are a central focus of the report, but the information provided describes river system hydrology in general.

Reservoirs are integral components of river systems that are essential for water resources development and use. The terms *river system* and *river/reservoir system* are used interchangeable in this report. Water resources of streams, rivers, lakes, and reservoirs are investigated with a focus on the major rivers and major reservoirs of the state.

Population and economic growth and accompanying water resources development projects such as dams and reservoirs, diversions to supply agricultural, municipal, and industrial water needs, and return flows from surface and groundwater sources have significantly affected river flows throughout Texas and the world. The impacts of climate change associated with global warming on hydrology and water management have been investigated extensively by the scientific and water management communities. Natural flows in rivers are highly variable with daily, seasonal, and multiple-year fluctuations reflecting extremes of floods and droughts as well as less severe variations. Quantifying long-term changes is difficult due to the great variations in flows that hide long-term trends. The impacts of water development and land use change on low flows are typically very different than on high flows. For example, regulation of rivers by dams reduces flood flows but may increase low flows at downstream locations. Likewise, daily, seasonal, and year-to-year weather fluctuations, multiple-year weather cycles, and long-term climate change can have varying effects on different aspects of river basin water budgets.

Water Management and Use in Texas

Climate, hydrology, economic development, and water management vary dramatically across the 15 major river basins and 8 coastal basins of Texas shown in Figure 1.1, from the arid western desert to humid eastern forests, from sparsely populated rural regions in the western and eastern extremes of the state to the metropolitan areas of Dallas and Fort Worth, Austin, San Antonio, and Houston shown in Figure 1.2. The 2012 State Water Plan (TWDB 2012) and regional plans are presented in reports available at the TWDB website. Annual water demands of 18.0 acre-feet/year in 2010 were distributed among use sectors as follows: agricultural irrigation (56.0%), municipal (26.9%), manufacturing (9.6%), mining (1.6%), consumptive use of stream electric cooling water (4.1%), and livestock (1.8%). The population of the state increased from 5.8 million people in 1930 to 25.4 million in 2010 and is projected to increase to 29.6 million in 2020 and 46.3 million by 2060. Water demands are projected to increase by 22 percent. Municipal and industrial water use is expected to increase dramatically while agricultural use declines. Statewide total surface versus groundwater use are currently about the same, but depleting groundwater supplies are resulting in shifting to a much greater reliance on surface water.

Figure 1.1 Fifteen Major River Basins and Eight Coastal Basins of Texas
as Delineated by the TWDB

Water management in Texas is governed by the need to be prepared for extended droughts. The hydrologically most severe drought on record for most of the state began gradually in 1950 and ended in April 1957 with major flooding throughout the state. Droughts occurring since the 1950's drought have been much more economically costly due to population and economic growth. An intense drought during 1996 motivated the Texas Legislature to enact Senate Bill 1 in 1997, which established the current regional and statewide planning process and authorized creation of the WAM System. In terms of annual precipitation, for more than half of Texas, 2011 was the driest year since the beginning of official precipitation records in 1895. All of Texas suffered severe drought conditions during 2011. Dry conditions have continued since 2011, particularly in the western parts of the state. Droughts have occurred in at least parts of Texas during periods of every decade of the past century. Droughts during the 1910's and 1930's, like the record 1950-1957 drought, were extended multiple-year dry periods over large areas. The infamous Great Plains drought of the early 1930's caused *dust bowl* conditions in Oklahoma and Kansas and extended into West Texas.

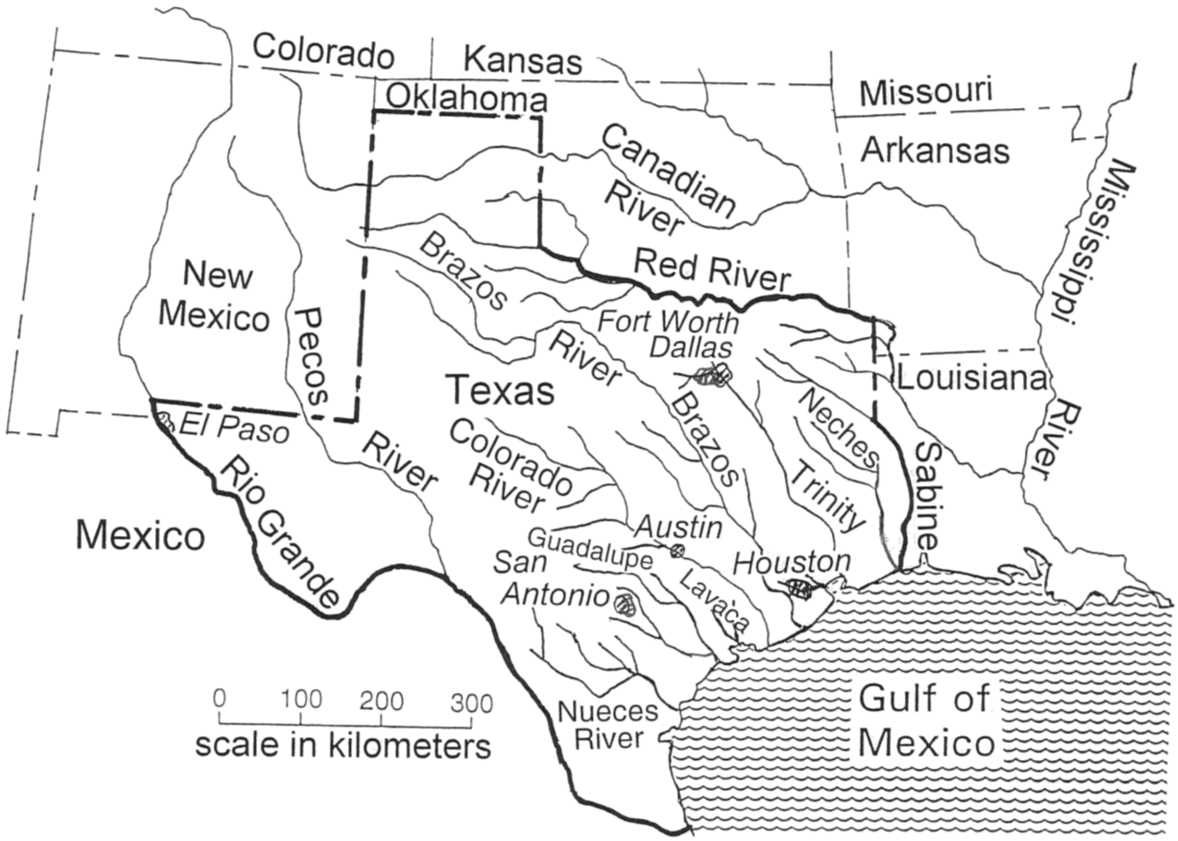

Figure 1.2 Major Rivers and Largest Cities in Texas.

Databases and Computer Programs

Hydrology datasets and computer modeling and analysis tools used in this research are introduced below and discussed in more detail in the chapters to follow.

TWDB Precipitation and Evaporation Databases

Datasets of monthly precipitation depths and reservoir surface evaporation depths in inches along with the map reproduced as Figure 3.1 of Chapter 3 and explanation of methods employed by the TWDB in compiling the data are available at the following website.

http://www.twdb.state.tx.us/surfacewater/conditions/evaporation/index.asp

The precipitation and evaporation datasets are updated each year about May to add data for January through December of the preceding year. The entire state is encompassed by the 92 one-degree quadrangles shown in Figure 3.1. Complete monthly precipitation from 1940 are available for the 92 quadrangles. The methodology used by the TWDB for compiling evaporation data for 1940-1953 was different than for 1954 to the present. The 1940-1953 evaporation data is maintained as a separate dataset.

National Water Information System (NWIS)

The observed daily stream flow data for 35 gaging stations discussed in Chapter 4 was obtained from the National Water Information System (NWIS) maintained by the U.S. Geological Survey (USGS). NWIS data for Texas is available at the following website.

http://waterdata.usgs.gov/tx/nwis/nwis

The NWIS provides daily observations for 936 sites in Texas. However, relatively few of the gaging stations in Texas have periods-of-record as long as the 35 sites selected for the analyses discussed in Chapter 4. The data available at the NWIS website is accessed directly using the HEC-DSSVue computer program.

HEC-DSSVue Visual Utility Engine

The Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE) has developed a suite of generalized hydrologic, hydraulic, and water management simulation models that are applied extensively by various entities. The HEC-DSS (Data Storage System) is used routinely with HEC simulation models and with other non-HEC modeling systems including WRAP. The WRAP programs include options for writing simulation results as HEC-DSS files. Database management and graphics capabilities provided by the HEC-DSS are oriented particularly toward voluminous sets of time series data.

The HEC-DSS Visual Utility Engine (HEC-DSSVue) is a graphical user interface program for viewing, editing, and manipulating data in HEC-DSS files (HEC 2009). The public domain HEC-DSSVue software and documentation may be downloaded from the Hydrologic Engineering Center website: http://www.hec.usace.army.mil/

HEC-DSSVue provides convenient capabilities for plotting data and performing mathematical operations and statistical analyses. Data can be conveniently transported between Microsoft Excel and HEC-DSS files. HEC-DSSVue also accesses the USGS NWIS and other databases. All of the time series plots presented in this report were developed with HEC-DSSVue. HEC-DSSVue was also used to download observed stream flow data from the NWIS.

Texas Water Availability Modeling (WAM) System

The TCEQ WAM System discussed in Chapter 5 consists of the generalized Water Rights Analysis Package (WRAP) modeling system and datasets for all of the river basins of Texas (Wurbs 2005). The Texas WAM System was originally implemented by the TCEQ and its partner agencies and contractors during 1997-2003 pursuant to water management legislation enacted by the Texas Legislature in 1997 as Senate Bill 1. Capabilities provided by WRAP and the WAM System have been expanded over the years since their initial implementation. The original WRAP/WAM modeling system is based on a monthly computational time step. Later development of daily WRAP modeling capabilities and daily versions of the WAM datasets has been motivated largely by environmental flow standards established pursuant to the 2001 Senate Bill 2 and 2007 Senate Bill 3 (Wurbs and Hoffpauir 203).

WRAP is documented by *Reference* and *Users Manuals* (Wurbs 2013), *Fundamentals Manual* (Wurbs 2013), *Hydrology Manual* (Wurbs 2013), *Salinity Manual* (Wurbs 2009), *Programming Manual* (Wurbs and Hoffpauir 2013), and *Daily Manual* (Wurbs and Hoffpauir 2013) which are included in the list of references found at the end of this report. The public domain software and documentation are available at the following website which links to the TCEQ WAM website: http://ceprofs.tamu.edu/rwurbs/wrap.htm

A WRAP/WAM simulation combines historical natural river basin hydrology with a specified scenario of water resources development, allocation, management, and use. River system hydrology is represented by sequences of monthly naturalized stream flows and reservoir surface evaporation less precipitation rates covering a selected hydrologic period-of-analysis. The WAM System WRAP input datasets reflect water management activities that include about 3,400 reservoirs and other constructed infrastructure, a water rights permit system with about 6,000 active permits, five interstate compacts, treaties between the United States and Mexico, federal reservoir storage contracts, and various other institutional arrangements. The simulation model converts input sequences of naturalized stream flows to sequences of regulated and unappropriated flows reflecting a specified scenario of water management and use.

Scope of this Report

The exploration of the characteristics of river system hydrology in this report is designed to support regional and statewide planning, environmental flow studies, administration of the water rights permit system, and other water resources planning and management activities. The information compiled here is pertinent to water availability modeling and other types of studies.

The research applies the TWDB and USGS databases and the TCEQ WAM System to develop a better understanding of river/reservoir system hydrology in Texas. The report focuses on variability characteristics and long-term changes in the quantities of water flowing and stored in the river/reservoir systems of the state. Characteristics of observed river flows change over time. Precipitation and evaporation rates reflect the climatic conditions that govern stream flow. Water resources development and use affect stream flow. Reservoirs regulate river flows and develop reliable water supplies. Differences in WAM naturalized and regulated flows reflect the effects of water resources development and use. The WAM system provides capabilities for comparative assessments of the various components of river/reservoir system water budgets.

Chapters 2, 3, 4, 5, and 6 and the accompanying plots in the five appendices provide the following information. Chapter 7 presents the summary and conclusions.

Chapter 2 – Reservoirs

Chapter 2 provides an inventory of the reservoirs of the state. The WAM System includes about 3,400 reservoirs. Most of the total storage capacity is in a much smaller number of larger reservoirs. Reservoir storage is essential for reducing flooding, developing dependable water supplies, and beneficially using the water resources of river systems.

Chapter 3 and Appendices A and B – Precipitation and Reservoir Evaporation Rates

The TWDB databases of monthly precipitation and reservoir surface evaporation rates in units of inches/month and inches/year are plotted in Appendices A and B. Statistical analyses are presented in Chapter 3. Monthly and annual precipitation exhibit tremendous temporal as well as spatial variability that includes extremes of major floods and multiple-year droughts along with more normal seasonal and year-to-year fluctuations. Though highly variable, precipitation during 1940-2013 appears to be stationary with no trends of long-term changes. Reservoir surface evaporation rates fluctuate greatly seasonally and also vary between years. Reservoir evaporation rates over most of Texas appear to have been steadily increasing since the 1960s.

Chapter 4 and Appendix C – Observed River Flows

Daily flows at 35 selected active USGS gaging stations with long periods-of-record are analyzed in Chapter 4 and Appendix C. All sites exhibit great variability including severe droughts and major floods and continuous fluctuations. Wet and dry periods tend to persist over extended periods of time. Permanent changes due presumably to human activities appear to have occurred at many sites. Long-term trends of decreases in flows are evident at some gages, increases are evident at others, some exhibit both increases and decreases, and some sites exhibit no evident long-term changes. For sites with long-term changes, the characteristics of the changes vary greatly between daily, monthly, and annual flows. Long-term changes also differ greatly between high, median, and low flows.

Chapter 5 and Appendix D – WAM Simulation Results

The river basins of Texas are simulated in this study with the TCEQ WAM System to investigate overall river system water budgets and frequency characteristics of river flows and reservoir storage volumes. Long-term changes in stream flows and other components of river system water budgets attributable to water resources development and use are investigated by comparing regulated and naturalized flows. Naturalized river flows from the WAM system represent natural conditions without human water development and use. Simulated regulated flows represent a specified condition of water resources development and use. The 20 current use scenario WAM datasets are employed in the simulations of Chapter 5. Stream flow and reservoir storage frequency metrics are developed. Plots of simulated reservoir storage in Appendix D are based on combining current water development/use with historical natural river basin hydrology extending back to the 1940s, before most of the reservoirs were constructed, through the 1950s drought and flood and then through continuing hydrologic fluctuations to near the present.

Chapter 6 and Appendix E – Comparison of Observed, Naturalized, and Regulated Flows

Observed flows at selected gages are compared with WAM naturalized and simulated regulated flows in Chapter 6 and Appendix E. The objective is to quantify long-term changes in river flows due to water resources development/use and various other factors. Observed flows are non-stationary reflecting the effects of historical water resources development including construction of reservoirs and other facilities at different times and significant increases in water use. Naturalized and regulated flows from the WAM system are conceptually homogeneous reflecting no water development/use and a specified constant scenario of water development/use.

CHAPTER 2
RESERVOIRS OF TEXAS

Stream flow in Texas is highly variable, subject to devastating floods and severe multiple-year droughts as well as continual lesser fluctuations. Reservoir storage is essential for developing reliable water supplies and reducing flooding. Almost all of the storage capacity in Texas is impounded by constructed dams rather than natural lakes. Most of the reservoir projects were constructed during the period from the 1940s through the 1980s. Though still highly variable, river flows in Texas are significantly regulated by dams and reservoirs.

Reservoirs in the Water Availability Modeling (WAM) System

Information regarding the 20 river basin datasets in the Texas WAM System is provided in Tables 5.1 and 5.2 of Chapter 5. The 15 major river basins and 8 coastal basins of Texas are delineated in Figure 1.1 of Chapter 1. The 20 water availability models (WAMs) listed in Tables 5.1 and 5.2 simulate the 23 basins shown in Figure 1.1. The Guadalupe and San Antonio (GSA) River Basins are combined as a single WAM. The Brazos WAM includes the Brazos San-Jacinto Coastal Basin along with the Brazos River Basin. The Colorado River Basin and Brazos-Colorado Coastal Basin are also combined into a single WAM dataset. The WAM datasets are updated as new and modified water right permits are approved and modeling capabilities are refined. The dates of the latest updates of the datasets used in this study are noted in Table 5.2.

Alternative versions of the 20 WRAP input datasets in the TCEQ WAM system reflect different water use scenarios. The authorized use scenario (called run 3) models the water right permits as written. All water right permit holders are assumed to use the full amounts of water authorized by their permits without return flows. The current use scenario (called run 8) incorporates estimates of recent actual water use and return flows and updated conditions of reservoir sedimentation. The authorized use scenario includes only permanent water rights, but the current use scenario also includes temporary term permits valid for one to several years.

The run 3 datasets include all reservoirs for which permanent water right permits have been approved, which include reservoirs that have not yet been constructed. The run 8 datasets do not include permitted but not yet constructed reservoirs but include additional storage facilities associated with term permits. The authorized use scenario adopts reservoir storage capacities cited in the water right permits which typically have not been adjusted for sedimentation. The reservoir storage capacity in most of the larger reservoirs in the current use scenario WAMs have been adjusted to approximate year 2000 conditions of sedimentation.

The number of model reservoirs in the authorized use scenario (run 3) and current use scenario (run 8) versions of the WAMs are listed in Table 5.2 of Chapter 5. The counts in Table 5.2 are performed automatically by the simulation model. Most of the model reservoirs represent a single actual physical reservoir. However, the counts of model reservoirs in Table 5.2 also include accounting reservoirs that may represent multiple owners having storage in the same reservoir or other water allocation accounting mechanisms. Thus, the counts in Table 5.2 may exceed the actual number of real reservoirs. However, the data in Chapter 2, including Tables 2.1 and 2.2, are for actual reservoirs and do not include the additional computational reservoirs defined in the simulation model for water accounting purposes.

Table 2.1
Number of Reservoirs in the WAM System within Ranges of Conservation Storage Capacity

WAM Dataset	Run	Total Number	200 ac-ft or less	201 to 4,999 ac-ft	5,000 49,999	50,000 99,999	100,000 499,999	500,000 or greater
Brazos	3	673	446	178	30	7	10	2
	8	716	481	190	31	3	9	2
Canadian	3	47	38	6	1	1	0	1
	8	47	38	6	1	1	0	1
Colorado	3	489	395	63	19	1	8	3
	8	489	389	63	25	1	7	4
Cypress	3	86	48	25	9	1	3	0
	8	91	48	30	9	1	3	0
GSA	3	238	189	43	3	1	2	0
	8	241	191	44	3	1	2	0
Lavaca	3	22	16	4	0	1	1	0
	8	21	16	4	0	0	1	0
Neches	3	180	106	61	9	1	2	1
	8	203	129	62	9	1	1	1
Nueces	3	121	88	31	0	0	1	1
	8	125	91	32	0	0	1	1
Red	3	236	150	61	18	1	5	1
	8	237	151	61	18	3	3	1
Rio Grande	3	80	45	28	5	0	1	2
	8	80	45	28	4	0	1	2
Sabine	3	212	134	65	8	2	0	3
	8	213	135	66	8	1	0	3
San Jacinto	3	114	85	25	2	0	2	0
	8	114	85	25	2	0	2	0
Sulphur	3	57	25	26	2	0	2	0
	8	57	25	26	2	0	2	0
Trinity	3	683	499	152	18	3	6	5
	8	686	497	156	21	1	6	5
Colorado-	3	8	3	5	0	0	0	0
Lavaca	8	8	3	5	0	0	0	0
Lavaca-	3	0	0	0	0	0	0	0
Guadalupe	8	0	0	0	0	0	0	0
Neches-	3	31	6	24	1	0	0	0
Trinity	8	31	6	24	1	0	0	0
Nueces-	3	64	19	41	4	0	0	0
Rio Grande	8	65	20	41	4	0	0	0
San Antonio	3	9	6	3	0	0	0	0
-Nueces	8	9	6	3	0	0	0	0
Trinity-	3	13	5	8	0	0	0	0
San Jacinto	8	13	5	8	0	0	0	0
Totals	3	3,361	2,303	849	129	19	43	19
	8	3,444	2,361	874	138	13	38	20

Table 2.2
Capacity of Reservoirs in the WAM System within Ranges of Conservation Storage Capacity

WAM	Run	Total	200 ac-ft or less	201 to 4,999 ac-ft	5,000 to 49,999	50,000 99,999	100,000 499,999	500,000 or greater
Brazos	3	4,698,652	28,133	159,745	557,777	421,066	2,171,092	1,360,839
	8	4,015,865	30,282	177,165	588,547	174,621	1,943,449	1,101,801
Canadian	3	966,248	1,653	3,306	5,500	60,900	894,889	0
	8	879,824	1,653	3,306	5,500	60,900	808,465	0
Colorado	3	4,865,883	20,353	48,070	430,882	71,400	1,577,611	2,717,567
	8	4,649,830	20,250	47,360	382,025	71,300	1,051,422	3,077,473
Cypress	3	901,913	2,307	19,806	177,650	72,800	629,350	0
	8	877,938	2307	19,806	168,937	67,671	619,217	0
GSA	3	806,875	8,019	35,757	75,824	63,200	624,075	0
	8	756,528	8,047	35,261	72,703	60,732	579,785	0
Lavaca	3	265,668	399	1,625	0	93,344	170,300	0
	8	167,716	399	1,625	0	0	165,692	0
Neches	3	3,904,100	6,683	45,257	252,370	94,250	607,340	2,898,200
	8	3,656,259	8,806	45,518	232,938	66,972	403,825	2,898,200
Nueces	3	1,040,446	3,815	36,631	0	0	300,000	700,000
	8	959,827	3,809	37,419	0	0	225,248	693,351
Red	3	4,023,668	9,376	57,943	242,749	59,100	882,500	2,772,000
	8	3,680,342	9,379	57,943	281,595	219,925	670,500	2,441,000
Rio Grande	3	6,009,685	2,234	20,185	62,010	0	300,000	5,625,256
	8	5,963,271	2,234	23,285	38,380	0	274,116	5,625,256
Sabine	3	6,403,211	9,268	50,163	123,502	140,019	0	6,080,259
	8	6,262,314	9,462	54,901	148,831	75,050	0	5,974,070
San Jacinto	3	637,302	5,550	19,147	22,345	0	590,260	0
	8	587,529	5,550	19,255	22,354	0	540,370	0
Sulphur	3	757,158	1,948	33,372	24,938	0	696,900	0
	8	718,699	1,948	33,242	24,639	80,156	658,870	0
Trinity	3	7,596,677	24,862	123,845	414,370	168,800	1,882,900	4,981,900
	8	7,356,202	24,330	132,968	408,362	85,568	1,814,882	4,890,092
Colorado-	3	7,227	299	6,928	0	0	0	0
Lavaca	8	7,227	299	6,928	0	0	0	0
Lavaca-	3	0	0	0	0	0	0	0
Guadalupe	8	0	0	0	0	0	0	0
Neches-	3	57,986	490	25,496	32,000	0	0	0
Trinity	8	57,986	490	25,496	32,000	0	0	0
Nueces-	3	113,084	1,581	45,950	65,553	0	0	0
Rio Grande	8	113,091	1,588	45,950	65,553	0	0	0
San Antonio	3	1,484	484	1,000	0	0	0	0
-Nueces	8	1,484	484	1,000	0	0	0	0
Trinity-	3	4,876	438	4,438	0	0	0	0
San Jacinto	8	4,876	438	4,438	0	0	0	0
Totals	3	43,062,143	127,892	738,664	2,487,470	1,244,879	11,327,217	27,136,021
	8	40,716,808	131,755	772,866	2,472,364	882,739	9,755,841	26,701,243

The number of reservoirs in the authorized use scenario (run 3) and current use scenario (run 8) versions of each of the 20 WAM river basin datasets are tabulated in Table 2.1. The conservation storage capacities of these reservoirs are shown in Table 2.2. The reservoirs are grouped by the following ranges of storage capacity: 200 acre-feet or less; greater than 200 acre-feet but less than 5,000 acre-feet; 5,000 acre-feet or greater but less than 50,000 acre-feet; 50,000 acre-feet or greater but less than 100,000 acre-feet; and 100,000 acre-feet or greater but less than 500,000 acre-feet; and 500,000 acre-feet or greater. The storage capacities in acre-feet shown in Table 2.2 are the totals for the reservoirs falling within the specified ranges.

The storage capacities in Table 2.2 reflect conservation storage capacities from the WAM datasets. The conservation storage is used primarily for water supply but also for recreation and hydroelectric power generation. The data in the WAM datasets and Table 2.2 do not include the storage capacity of designated flood control pools and uncontrolled surcharge storage capacity.

Property owners are not required to obtain permits for reservoirs on non-navigable streams on their land that have storage capacities of 200 acre-feet or less used only for domestic and livestock uses and recreation. Numerous livestock and recreation ponds are not included in the datasets. Water right permits are normally not required for flood control storage. The Natural Resource Conservation Service has constructed about 2,000 flood retarding dams in Texas of which most are not included in the WAMs. Likewise, cities and developers have constructed numerous small flood detention facilities that are not considered. The flood control pools of the U.S. Army Corps of Engineers reservoirs are also not included in the WAM datasets.

The storage capacity data cited in this chapter is complicated by reservoir sedimentation. Storage capacities change over time due to sedimentation. Sediment surveys are periodically performed for many of the reservoirs to update storage capacity information. Sediment accumulation varies greatly between reservoirs and between floods versus periods of normal and low flows. Most but not all of the water right permits and consequently the storage capacities in the authorized use scenario datasets reflect storage capacities at the time of construction prior to accumulation of sediments. However, conservation storage capacities in federal multiple purpose reservoirs have often been cited exclusive of predicted future sedimentation. The current use scenario (run 8) datasets include adjustments of storage capacities in many of the larger reservoirs to reflect estimated year 2000 sediment conditions.

Statewide totals of 3,361 and 3,444 reservoirs are included in the WAM authorized use (run 3) and current use (run 8) datasets with conservation storage capacities totaling 43,062,143 and 40,716,808 acre-feet, respectively. The Trinity River Basin has the largest storage capacity of any river basin in Texas. The Lavaca-Guadalupe coastal basin WAM has no reservoirs.

Texas has numerous storage facilities, but most of the capacity is contained in a relatively small number of the largest reservoirs. The 210 and 209 reservoirs in the authorized and current use scenario WAM datasets with storage capacities of 5,000 acre-feet or more contain 98.0 and 97.8 percent of the total statewide storage capacity included in the WAMs. For the authorized use scenario WAMs, 89.3 percent of the total storage capacity of 43,062,143 acre-feet in 3,361 reservoirs is contained in the 62 reservoirs with individual capacities of 100,000 acre-feet or greater. For the authorized use scenario datasets, the 58 reservoirs with capacities of 100,000 acre-feet or greater contain 89.5 percent of the total storage capacity of the 3,444 reservoirs.

Major Reservoirs

The Texas Water Development Board (TWDB) defines a major reservoir as having a storage capacity of 5,000 acre-feet or larger at its normal operating level. The TWDB counts 188 major water supply reservoirs and 20 other major reservoirs that serve no water supply function. These reservoirs are described at the following TWDB website.

http://www.twdb.state.tx.us/surfacewater/rivers/reservoirs/index.asp

The Texas Water Plan (TWDB 2012) includes discussions of existing and proposed reservoirs and a map showing their locations. The TWDB (1971, 1973, 1974) provides engineering data for dams and appurtenant structures for the larger reservoirs. Wurbs (1985 and 1987) describes the major reservoirs of Texas and their development and management. The major reservoirs with capacities of 5,000 acre-feet or greater are listed with descriptive information in the last section of this chapter.

Eighty reservoirs with conservation storage capacities greater than 50,000 acre-feet and two large flood control reservoirs with no conservation capacity are listed in Table 2.3. These 82 reservoirs contain 91.84% of the total permitted storage capacity of the 3,361 reservoirs in the WAM system and essentially all of the controlled (gated) flood control storage capacity of the state. Addicks and Barker Reservoirs in the City of Houston are large USACE flood control reservoirs with no conservation storage and thus not included in the WAM system. The conservation storage capacities for the other reservoirs are included in Table 2.3 for both the WAM authorized use (run 3) and current use (run 8) scenarios. Three of the reservoirs (Allens Creek, Post, Columbia) have been authorized by water right permits but have not yet been constructed and thus are included in the authorized use scenario but not the current use scenario.

This chapter includes reservoirs located partially as well as entirely in Texas. Several reservoirs on the Rio Grande and interstate rivers are shared by Texas and neighboring states and Mexico. The waters of the Rio Grande are allocated between the United States and Mexico by 1906 and 1944 treaties. Texas participates in six interstate compacts sharing the waters of the Rio Grande, Pecos, Canadian, Red, and Sabine River Basins, and Caddo Lake on Cypress Creek. International Amistad and Falcon Reservoirs on the Rio Grande are operated jointly by the United States and Mexico Sections of the International Boundary and Water Commission under the provisions of the 1944 treaty. Toledo Bend Reservoir on the Sabine River, Caddo Lake on Cypress Creek, and Lake Texoma on the Red River are located on the borders between Texas and Louisiana and Oklahoma and shared by the neighboring states pursuant to interstate compacts. Toledo Bend, Texoma, and Amistad are the three largest reservoirs in Texas and Falcon is the 5th largest. Thus, though few in number, the reservoirs on the state borders contain large storage capacities. About 15 percent of the total conservation storage capacity of major reservoirs located entirely or partially in Texas is controlled by Mexico or neighboring states.

Caddo Lake on the state border between northeast Texas and northwest Louisiana is the only natural lake in Texas with a storage capacity greater than 5,000 acre-feet. All of the major reservoirs, including Caddo Lake now, are impounded by constructed dams. Although originally a natural lake, the Corps of Engineers completed construction of a dam in 1914 to preserve the lake from being drained by erosion. Construction of a new dam was completed in 1971 after the original 1914 dam was found to be no longer safe.

Table 2.3
Reservoirs with Capacities Greater than 50,000 acre-feet

Reservoir	Dam River	Owner	Initial Impound -ment	Run 3 (ac-ft)	Run8 (ac-ft)	Flood Control (ac-ft)
			Brazos River Basin			
Allens Creek	Allens Creek	BRA	proposed	145,533	–	–
Possum Kingdom	Brazos River	BRA	1941	724,739	552,013	–
Granbury	Brazos River	BRA	1969	155,000	132,821	–
Limestone	Navasota	BRA	1978	225,400	208,017	–
Whitney	Brazos River	USACE	1951	636,100	561,074	1,372,400
Waco	Bosque River	USACE	1965	206,562	206,562	553,300
Aquilla	Aquilla Creek	USACE	1983	52,400	41,700	86,700
Proctor	Leon River	USACE	1963	59,400	54,702	310,100
Belton	Leon River	USACE	1954	457,600	432,978	640,000
Stillhouse Hollow	Lampasas River	USACE	1968	235,700	224,279	390,660
Georgetown	San Gabriel R	USACE	1980	37,100	36,980	87,600
Granger	San Gabriel R	USACE	1980	65,500	50,540	162,200
Somerville	Yequa Creek	USACE	1967	160,110	154,254	337,700
Hubbard Creek	Hubbard Creek	WCTMWD	1962	317,750	317,750	–
Post	NF Double Mt	WRMWD	proposed	57,420	–	–
Alan Henry	SF Double Mt	Lubbock	1993	115,937	115,773	–
Fort Phantom Hill	Elm Creek	Abilene	1938	73,960	69,379	–
Stamford	Paint Creek	Stamford	1953	60,000	47,557	–
Graham	Flint Creek	Graham	1929/1958	52,386	44,883	–
Squaw Creek	Squaw Creek	Tex Electric	1977	151,500	151,015	–
			Canadian River Basin			
Meredith	Canadian River	CRMWD	1941	894,889	808,465	543,200
			Colorado River Basin			
Travis	Colorado River	LCRA	1940	1,170,752	1,132,173	779,248
Buchanan	Colorado River	LCRA	1937	992,475	888,864	–
L.B. Johnson	Colorado River	LCRA	1951	138,500	134,353	–
Fayette County	Cedar Creek	LCRA	1977	71,400	71,300	–
O.H. Ivie	Colorado River	CRMWD	1990	554,340	539,164	–
E.V. Spence	Colorado River	CRMWD	1968	488,760	3,077,473	–
J.B. Thomas	Colorado River	CRMWD	1952	204,000	517,272	–
STP Cooling Pond	off-channel	S Tex Proj	1979	202,988	202,988	–
Twin Buttes	South Concho	San Angelo	1962	186,200	177,648	453,800
Brownwood	Pecan Bayou	Brownwood	1933	135,963	131,429	–
O.C. Fisher	Concho River	USACE	1952	119,200	102,400	277,200

Table 2.3 Continued
Reservoirs with Capacities Greater than 50,000 acre-feet

Reservoir	Dam River	Owner	Initial Impound -ment	Run 3 (ac-ft)	Run8 (ac-ft)	Flood Control (ac-ft)
			Cypress River Basin			
Lake O' the Pines	Cypress Creek	USACE	1957	251,000	240,867	587,200
Bob Sandlin	Big Cypress Cr	Titus County	1978	213,350	213,350	–
Caddo	Cypress Bayou	USACE	1914/1971	165,000	165,000	–
			Guadalupe and San Antonio (GSA) River Basins			
Canyon	Guadalupe R	USACE	1964	386,200	371,976	394,900
Medina	Medina River	BMACWCD	1913	237,875	207,809	–
Calavares	Calavares Creek	San Antonio	1969	63,200	60,732	–
			Lavaca River Basin			
Texana	Navidad River	LNRA	1981	170,300	165,692	–
			Neches River Basin			
Sam Rayburn	Angelina River	USACE	1965	2,898,200	2,887,736	1,099,400
B A Steinhagen	Neches River	USACE	1951	94,250	66,972	–
Palestine	Neches River	UNRMWA	1962	411,840	403,825	–
Columbia (Eastex)	Mud Creek		proposed	195,500	–	–
			Nueces River Basin			
Choke Canyon	Frio River	Corpus Chris	1982	700,000	693,351	–
Corpus Christi	Nueces River	LNRWSD	1958	300,000	225,248	–
			Red River Basin			
Texoma	Red River	USACE	1943	2,772,000	2,441,000	2,660,000
Kemp	Wichita River	Wichita Falls	1922	318,000	318,000	248,300
Arrow Head	Little Wichita	Wichita Falls	1966	228,000	228,000	–
Pat Mayse	Sanders Creek	USACE	1967	124,500	124,500	64,600
Truscott	Bluff Creek	USACE	1984	107,000	49,518	–
Kickapoo	Little Wichita	Wichita Falls	1946	105,000	85,825	–
Greenbelt	Salt Fork Red	GM&IWA	1966	59,100	59,100	–
			Rio Grande Basin			
Amistad	Rio Grande	IBWC	1968	2,976,967	2,976,967	1,744,000
Falcon	Rio Grande	IBWC	1953	2,648,289	2,648,289	910,000
Red Bluff	Pecos River	RBWPCD	1936	300,000	274,116	–

Table 2.3 Continued
Reservoirs with Capacities Greater than 50,000 acre-feet

Reservoir	Dam River	Owner	Initial Impound-ment	Run 3 (ac-ft)	Run8 (ac-ft)	Flood Control (ac-ft)
			Sabine River Basin			
Toledo Bend	Sabine River	SRA	1966	4,477,000	4,452,668	–
Lake Tawakoni	Sabine River	SRA	1960	927,440	885,269	–
Lake Fork	Lake Fork Cr	SRA	1979	675,819	636,133	–
Martin Lake	Martin Creek	Tex Utility S	1974	77,619	75,050	–
Lake Cherokee	Cherokee Bayou	Cher Wat Co	1948	62,400	41,157	–
			San Jacinto River Basins			
Conroe	WF San Jacinto	SJRA	1973	430,260	414,143	–
Houston	San Jacinto	Houston	1954	160,000	126,227	–
Addicks	S Mayde Creek	USACE	1948	–	–	204,500
Barker	Buffalo Bayou	USACE	1945	–	–	207,000
			Sulphur River Basin			
Wright Patman	Sulphur River	USACE	1956	386,900	353,870	204,500
Jim Chapman	S Sulphur River	USACE	1991	310,000	305,000	207,000
			Trinity River Basin			
Livingston	Trinity River	TRA	1969	1,750,000	1,739,743	–
Richland-Chambers	Richland Creek	TRWD	1987	1,135,000	1,109,368	–
Ray Roberts	Elm Fork	USACE	1987	799,600	796,474	265,000
Cedar Creek	Cedar Creek	TRWD	1965	678,900	630,550	–
Lewisville	Elm Fork	USACE	1954	618,400	613,957	–
Ray Hubbard	East Fork	Dallas	1968	490,000	484,495	363,363
Lavon	East Fork	USACE	1953	456,500	418,800	–
Bridgeport	West Fork	TRWD	1932	387,000	370,468	291,700
Eagle Mountain	West Fork	TRWD	1934	210,000	195,941	–
Joe Pool	Mountain Crk	USACE	1986	176,900	172,678	127,100
Grapevine	Denton Creek	USACE	1952	162,500	162,500	263,000
Benbrook	Clear Fork	USACE	1952	88,250	85,568	76,550
Navarro Mills	Richland Creek	USACE	1963	63,300	41,335	148,900
Bardwell	Waxahachie Cr	USACE	1965	54,900	44,199	85,100
Fairfield	Big Brown Cr	Ind Gen Co	1969	50,600	43,884	–
Arlington	Village Creek	Arlington	1957	45,710	37,792	–

The non-federal reservoirs are operated primarily to supply water for municipal and industrial uses, agricultural irrigation, and cooling water for steam-electric power plants. Most of the federal reservoirs are operated for both flood control and water supply. Thirty-three of the reservoirs in Table 5.3 have flood control pools with a total capacity of 16,146,221 acre-feet. About 23 hydroelectric power plants are operated in the state, but releases through the turbines are usually limited to water being diverted downstream for water supply. Recreation is popular at most of the major reservoirs. Environmental flows are also important.

Essentially all of the water withdrawn from Texas streams for beneficial use is regulated by reservoirs even though the actual diversion sites may be many miles below the dams. Most reservoirs are operated individually, but major multiple-reservoir system operations are also common. For example, the Brazos River Authority (BRA) operates a system of USACE and BRA reservoirs for water supply with both lakeside diversions and releases from multiple reservoirs supplying diversions at downstream locations. Likewise, the Lower Colorado River Authority operates six reservoirs on the Colorado River as a multiple-reservoir system. Amistad and Falcon Reservoirs and downstream diversion dams are operated by the IWBC as a system to supply water needs along the lower Rio Grande. USACE flood control operations in the Brazos and Trinity Basins involve coordinated releases from multiple system reservoirs.

Storage Capacity Nomenclature

Reservoir storage capacity can be divided between controlled and uncontrolled capacity. The data quoted in this report is limited to controlled capacity. This is the storage below the elevation of an ungated spillway crest or the uncontrolled overflow section of a gated spillway. Releases or withdrawals from controlled storage is regulated by gates, valves, or pumps. Uncontrolled spillways provide a safety valve to allow excessive inflows to pass through a reservoir when the controlled storage capacity is full. Inflows during major floods may greatly exceed outflow through an uncontrolled spillway. Consequently, a relatively large storage capacity above the uncontrolled spillway crest elevation is typically included in a reservoir to insure that the dam is not overtopped. Also, ungated spillways with limited flow capacity are often designed to retard flood flows and thus provide downstream flood protection. Surcharge storage is not included in the storage capacity quantities presented in this report.

Controlled storage capacity is divided between flood control and conservation storage. Flood control storage capacity is empty except during and immediately following a flood event. Outlet works and spillway gates are opened as necessary to keep the flood control space empty, subject to the constraint of not causing downstream flooding. Conservation capacity is used to store water until it is needed. Flood control and conservation capacity in a multiple purpose reservoir is divided by a set top of conservation (bottom of flood control) pool elevation.

"*Conservation storage capacity*" includes all controlled capacity which is not specifically allocated to flood control. Conservation capacity may be further divided into active and inactive capacity. The inactive conservation storage may include dead storage and sediment reserve. Dead storage is reservoir capacity below the lowest outlet level. Water cannot be released from dead storage by gravity flow. Although not normally available for water supply, dead storage may be useful for providing head for hydropower or additional water surface for recreation. The loss of reservoir capacity due to sedimentation is significant in Texas. Rates of sediment deposition vary greatly between reservoirs and over time. A sediment reserve may be allocated to allow for anticipated loss of capacity during the life of the project due to sediment deposition.

Institutional Framework for Reservoir Project Construction and Operation

Storage facilities are constructed, maintained, and operated by federal agencies, state and local government agencies, and private companies. Most of the major reservoirs in Texas are owned and operated by river authorities, water districts, cities, and electric power companies for municipal, industrial, and agricultural water supply and the other conservation storage purposes of recreation and hydroelectric power generation. However, two-thirds of the total conservation plus flood storage capacity is contained in reservoirs constructed by federal agencies. Most of the federal reservoirs are large multiple-purpose projects that include both flood control and conservation storage capacity.

The U.S. Army Corps of Engineers (USACE) is the largest reservoir management agency in Texas, owning and operating 30 of the large reservoirs listed in Table 5.3 and other smaller projects. The USACE Tulsa District constructed and operates Lake Texoma on the Red River which has the largest total storage capacity of any reservoir in Texas and also two other reservoirs included in Table 5.3 located on Texas tributaries of the Red River. The Galveston District constructed and operates Addicks and Barker Reservoirs to provide flood protection along Buffalo Bayou through downtown Houston. The USACE Fort Worth District owns and operates 25 multiple-purpose reservoirs including 24 listed in Table 2.3 and the smaller Hords Creek Reservoir and also maintains Caddo Lake. Non-federal water supply entities contract for the conservation storage capacity in the USACE reservoirs. The nonfederal collaborators control water supply operations and are responsible for all costs allocated to water supply. The USACE maintains the reservoirs and is responsible for flood control operations. Thirty-two USACE reservoirs account for about 30 percent, 75 percent, and 43 percent, respectively, of the conservation, flood control, and total storage capacity of the major reservoirs of Texas.

The U.S. Bureau of Reclamation (USBR) has constructed five reservoir projects in Texas: Lakes Travis, Twin Buttes, Texana, Choke Canyon, and Meredith. These projects were turned over to local sponsors for maintenance and operation. All five reservoirs contain water supply storage, and three have flood control pools.

The International Falcon and Amistad Reservoirs contain about 13% and 16% of the conservation and flood control capacities of the major reservoirs of Texas. These two reservoirs were constructed and are operated by the International Water and Boundary Commission pursuant to a 1944 treaty allocating the waters of the Rio Grande between the two nations.

About 43 water districts and river authorities own and operate about 60 major reservoirs with about 41 percent, 7 percent, and 30 percent of the conservation, flood control, and total storage capacity of the major reservoirs of Texas. Several other reservoirs are owned jointly by cities and either river authorities or water districts. About 39 cities own and operate about 48 other major reservoirs. River authorities, water districts, and cities also contract with the USACE for conservation storage capacity in federal reservoirs. River authorities and water districts control about 60 percent and cities about 15 percent of the total conservation storage in the state.

Reservoirs owned and operated by private companies contain less than three percent of the conservation capacity of the major reservoirs and no flood control. The majority of the privately owned reservoirs are owned and operated by electric utility companies to provide cooling water for steam-electric power plants.

Historical Development of Reservoir Projects

Caddo Lake is the only natural lake in Texas with a storage capacity greater than 5,000 acre-feet. A dam was constructed in 1914 to preserve the existing natural lake. Although a few small dams and reservoirs were constructed in Texas prior to 1900, Eagle Lake with impoundment beginning in 1900 is the oldest of the constructed major reservoirs still in existence. Eagle Lake is a 9,600 acre-feet irrigation reservoir in the Colorado River Basin. Dowell and Breeding (1967) provide a brief history of each of the major reservoirs in existence as of 1966. Wurbs (1985) also reviews the history of reservoir development.

The 35 major reservoirs in operation in 1935 were relatively small projects constructed by local entities primarily for either irrigation or municipal and industrial water supply. Several of these early projects also generated hydroelectric power. Most of the present reservoir capacity in the state was developed during the period from 1935 to 1970. Lake Texoma accounted for over 50 percent and Lake Travis almost 20 percent of the capacity added during the period 1935 to 1950. Numerous projects including most of the larger projects became operational between 1950 and 1970. Reservoir development has progressed at a much slower rate since 1970.

Inventory of Major Reservoirs

Reservoirs in Texas with storage capacities of 5,000 acre-feet or greater are listed in alphabetical order as follows with the following information.

name of reservoir and name of dam which may be the same or different
former or other names for the reservoir and dam
river basin and stream location of the dam
county or counties in which the reservoir is located
reservoir owner or owners and for USACE reservoirs non-federal water supply contractors
primary purposes served by the reservoir
date that construction was completed and/or impoundment of water began
original or early storage capacity in acre-feet usually without adjustments for sedimentation

Lake Abilene and Abilene Dam: Brazos River Basin, Elm Creek; Taylor County; City of Abilene; municipal, industrial, recreation; impoundment began August 1921; 7,900 acre-feet capacity.

Addicks Reservoir and Addicks Dam: San Jacinto River Basin, South Mayde Creek; Harris County; USACE Galveston District; flood control only; completed in 1948; 204,500 acre-feet capacity.

Alcoa Lake and Alcoa Dam: also called Sandow Lake and Sandow Dam; Brazos River Basin, Sandy Creek; Milam County; Aluminum Company of America; industrial and recreation; impoundment began January, 1953; 14,750 acre-feet capacity.

Amarillo City Lake and Amarillo City Lake Dam: see Bivins Lake and Bivins Dam.

Anahuac Lake and Anahuac Dam: also called Turtle Bayou Reservoir; Trinity River Basin, Trinity River; Chambers County; Chambers-Liberty Counties Navigation District; industrial, irrigation and mining including oil production; impoundment began 1914, enlargement 1954; 35,300 acre-feet capacity.

Aquilla Lake and Aquilla Dam: Brazos River Basin, Aquilla Creek; Hill County; operated by USACE Fort Worth District, Brazos River Authority has contracted for conservation storage; municipal, industrial, irrigation, recreation; impoundment began April 1983; 33,600 acre-feet conservation capacity; 86,700 flood control capacity.

Lake Arlington and Arlington Dam: Trinity River Basin, Village Creek; Tarrant County; City of Arlington; municipal, industrial; impoundment began March, 1957; 45,710 acre-feet capacity.

Lake Arrowhead and Lake Arrowhead Dam: Red River Basin, Little Wichita River; Archer and Clay Counties; City of Wichita Falls; municipal; impoundment began October 1966; 262,100 ac-ft capacity.

Lake Athens and Lake Athens Dam: formerly Flat Creek Reservoir and Flat Creek Dam; Neches River Basin, Flat Creek; Henderson County; Athens Municipal Water Authority; municipal, recreation; impoundment began November, 1962; 32,690 acre-feet capacity.

Lake Austin and Tom Miller Dam: Colorado River Basin, Colorado River; Travis County; owned by City of Austin, built and operated by the Lower Colorado River Authority; municipal, industrial, hydropower; impoundment began 1939; 21,000 acre-feet capacity.

Ballinger City Lake and Dam: Colorado River Basin, Valley Creek; Runnels County; City of Ballinger; water supply and recreation; completed in 1947 and enlarged in 1984; 8,215 acre-feet capacity.

Lake Balmorhea and Balmorhea Dam: Rio Grande Basin, Sandia Creek; Reeves County; Reeves County Water Improvement District Number 1; irrigation; impoundment began September, 1917; 6,350 acre-feet capacity.

Bardwell Lake and Bardwell Dam: Trinity River Basin, Waxahachie Creek, Ellis County; owned and operated by USACE Fort Worth District, Trinity River Authority has contracted for conservation storage; flood control, municipal, industrial, recreation; impoundment began November 1965; 42,800 acre-feet conservation capacity; 79,600 flood control capacity.

Barker Reservoir and Barker Dam: San Jacinto River Basin, Buffalo Bayou; Fort Bend and Harris Counties; USACE Galveston District; flood control only; completed in 1945; 207,000 acre-feet capacity.

Lake Bastrop and Bastrop Dam: Colorado River Basin, Spicer Creek; Bastrop County; Lower Colorado River Authority; industrial; impoundment began April 1964; 16,500 acre-feet capacity.

Baylor Creek Reservoir and Baylor Creek Dam: Red River Basin, Baylor Creek; Childress County; City of Childress; municipal and recreation; impoundment began March 1954; 372,700 acre-feet conservation capacity; 640,000 acre-feet flood control capacity.

Benbrook Lake and Benbrook Dam: Trinity River Basin, Clear Fork Trinity River; Tarrant County; owned and operated by USACE Fort Worth District, City of Fort Worth and Benbrook Water and Sewage Authority have contracted for conservation storage; flood control, municipal, industrial, recreation; impoundment September 1952; 72,500 ac-ft conservation capacity; 170,350 ac-ft flood control capacity.

Big Brown Creek Reservoir and Big Brown Creek Dam: see Fairfield Lake and Fairfield Dam.

Bivins Lake and Bivins Dam: also known as Amarillo City Lake, Red River Basin, Palo Duro Creek; Randall County; City of Amarillo; municipal; impoundment began 1926; 5,120 acre-feet capacity.

Blackburn Crossing Lake and Dam: see Lake Palestine and Blackburn Crossing Dam.

Rita Blanca Lake and Rita Blanca Dam: Canadian River Basin, Rita Blanca Creek, Hartley County; City of Dalhart, recreation; impoundment began September 1941; 12,100 acre-feet capacity.

Lake Bonham and Timber Creek Dam: Red River Basin, Timber Creek; Fannin County; Bonham Municipal Water Authority; municipal; impoundment began November 1969; 12,000 acre-feet capacity.

Bowie Lake and Bowie Lake Dam: see Lake Amon G. Carter and Amon G. Carter Dam.

Brandy Branch Cooling Pond and Dam: Sabine River Basin, Brandy Branch; Harrison County; Southwestern Electric Power Company; steam-electric power; impoundment 1983; 29,500 ac-ft capacity.

Victor Braunig Lake and Victor Braunig Plant Dam: also called East Lake; San Antonio River Basin, Arroyo Seco; Bexar County; City Public Service Board of San Antonio; steam-electric power; impoundment began December 1962; 26,500 acre-feet capacity.

Brazoria Reservoir and Brazoria Dam: Brazos River Basin, off-channel on Brazos River; Brazoria County; Dow Chemical Company; industrial; impoundment began April 1954; 21,970 acre-feet capacity.

Bridgeport Reservoir and Bridgeport Dam: Trinity River Basin, West Fork Trinity River; Wise County; Tarrant Regional Water District; municipal, industrial, recreation; impoundment began April 1932; 386,420 acre-feet capacity.

Brownwood Reservoir and Brownwood Dam: Colorado River Basin, Pecan Bayou; Brown County; Brown County Water Improvement District No. 1; municipal, industrial, irrigation; impoundment began July 1933; 143,400 acre-feet capacity.

Brushy Creek Reservoir and Brushy Creek Dam: See Valley Lake and Valley Dam.

Bryan Utilities Lake and Bryan Utilities Lake Dam: Brazos River Basin, un-named creek; Brazos County; City of Bryan; steam-electric power and recreation; impoundment began 1975, 15,230 acre-feet capacity.

Lake Buchanan Dam: Colorado River Basin, Colorado River; Burnet County; Lower Colorado River Authority; municipal, industrial, mining, hydropower; impoundment May 1937; 955,200 ac-ft capacity.

Buffalo Lake and Umbarger Dam: Red River Basin, Tierra Blanca Creek; Randall County; U.S. Department of the Interior, Fish and Wildlife Service; recreation; impoundment began June 1938; 18,150 acre-feet capacity.

Caddo Lake and Caddo Dam: Cypress Creek Basin, Cypress Bayou; Harrison and Marion Counties; maintained by USACE; municipal, industrial and recreation; natural lake, dam constructed in 1914 and reconstructed in 1971; 129,000 acre-feet capacity.

Calaveras Lake and Calaveras Creek Dam: San Antonio River Basin, Calaveras Creek; Bexar County; City Public Service Board of San Antonio; steam-electric power; impoundment began January 1969; 61,800 acre-feet capacity.

Camp Creek Lake and Camp Creek Dam: Brazos River Basin, Camp Creek; Robertson County; Camp Creek Water Company; municipal and recreation; impoundment November 1948; 8,500 ac-ft capacity.

Canyon Reservoir and Canyon Dam: Guadalupe River Basin, Guadalupe River; Comal County; constructed and operated by USACE Fort Worth District, Guadalupe-Blanco River Authority has contracted for the conservation storage; flood control municipal, industrial, recreation; impoundment June 1965; 366,400 ac-ft conservation capacity; 346,400 acre-feet flood control capacity.

Lake Amon G. Carter and Amon G. Carter Dam: also called Bowie Lake and Bowie Lake Dam; Trinity River Basin, Big Sandy Creek; Montague County; City of Bowie; municipal, industrial; impoundment began May 1956; 29,000 acre-feet capacity.

Casa Blanca Lake and Country Club Dam: Rio Grande Basin, Chacon Creek; Webb County; recreation; impoundment began 1949; 20,000 acre-feet capacity.

Cedar Bayou Cooling Reservoir: Trinity-San Jacinto Coastal Basin, Cedar Bayou; Chambers County; Houston Lighting and Power Company; steam-electric power; 20,000 acre-feet capacity.

Cedar Creek Reservoir and Cedar Creek Dam: Colorado River Basin, Cedar Creek; Fayette County; Lower Colorado River Authority; steam-electric power; impoundment 1977; 71,400 acre-feet capacity.

Cedar Creek Reservoir and Joe B. Hoggsett Dam: also called Joe B. Hoggsett Lake; Trinity River Basin, Cedar Creek; Henderson and Kaufman Counties; Tarrant Regional Water District; industrial; impoundment began July 1965; 679,200 acre-feet capacity.

Champion Creek Reservoir and Champion Creek Dam: Colorado River Basin, Champion Creek; Mitchell County; Texas Electric Service Company; municipal, steam-electric power; impoundment began February 1959; 41,600 acre-feet capacity.

Jim Chapman Lake and Dam: also known as Cooper Lake and Dam; Sulphur River Basin, South Sulphur River; Delta and Hopkins Counties; USACE Fort Worth District, water supply for Sulphur Springs, Commerce, North Texas Municipal Water District, and Sulphur River Municipal Water District; completed 1991; 298,930 acre-feet conservation and 131,400 acre-feet flood control capacity.

Lake Cherokee and Cherokee Dam: Sabine River Basin, Cherokee Bayou; Gregg and Rusk Counties; Cherokee Water Company; municipal, industrial, and recreation; impoundment began October 1948; 46,700 acre-feet capacity.

Cherokee Trail Lake and Fort Sherman Dam: see Lake Bob Sandlin and Fort Sherman Dam.

Lake Cisco and Williamson Dam: Brazos River Basin, Sandy Creek; Eastland County; City of Cisco; municipal; impoundment began 1923; 8,800 acre-feet capacity.

Choke Canyon Reservoir and Choke Canyon Dam: Nueces River Basin, Frio River; Live Oak and McMullen Counties; Constructed by U.S. Bureau of Reclamation; operated and maintained by City of Corpus Christi; municipal, industrial, recreation; impoundment began 1982; 700,000 acre-feet capacity.

Lake Pat Cleburne and Cleburne Dam: Brazos River Basin, Nolan River; Johnson County; City of Cleburne; municipal; impoundment began August 1964; 25,300 acre-feet capacity.

Lake Clyde and Upper Pecan Bayou Dam Site 7: Colorado River Basin, North Prong Pecan Bayou; Callahan County; City of Clyde; municipal; impoundment November 1969; 5,748 acre-feet capacity.

Coffee Mill Lake and Coffee Mill Dam: Red River Basin, Coffee Mill Creek; Fannin County; U.S. Forest Service; recreation; impoundment began 1938; 8,000 acre-feet capacity.

Colorado City Lake and Colorado City Dam: Colorado River Basin, Morgan Creek; Mitchell County; Texas Electric Service Company; municipal, industrial and hydropower; impoundment began April 1949; 30,800 acre-feet capacity.

Lake Conroe and Conroe Dam: also called Honea Reservoir and Honea Dam; San Jacinto River Basin, West Fort of the San Jacinto River; San Jacinto River Authority and City of Houston; municipal, industrial and mining including oil production; impoundment January 1973; 429,890 acre-feet capacity.

De Cordova Bend Reservoir and De Cordova Bend Dam: see Lake Granbury.

Lake Corpus Christi and Wesley E. Seale Dam: Nueces River Basin, Nueces River; San Patricio, Live Oak, and Jim Wells Counties; Lower Nueces River Water Supply District; hydropower, municipal, industrial, irrigation, mining and recreation; impoundment began 1923; 9,964 acre-feet capacity.

Lake Crook and Crook Dam: Red River Basin, Pine Creek, Lamar County; City of Paris; municipal; impoundment began 1923; 9,964 acre-feet capacity.

Lake Cypress Springs and Franklin County Dam: formerly Franklin county Lake; Cypress Creek Basin, Big Cypress Creek; Franklin County; Franklin County Water District and Texas Water Development Board; municipal and industrial; impoundment began July 1970; 72,800 acre-feet capacity.

Lake Dallas and Lake Dallas Dan: see Lewisville Lake and Lewisville Dam.

Dam B Reservoir and Dam B: see B.A. Steinhagen Lake.

Lake Daniel and Gonzales Creek Dam: Brazos River Basin, Gonzales Creek; Stephens County; City of Breckenridge; municipal and industrial; 9,515 acre-feet capacity.

Davis Lake and Davis Dam: Brazos River Basin, Double Dutchman Creek; Knox County; League Ranch; irrigation; impoundment began 1959; 5,395 acre-feet.

Barney M. Davis Cooling Reservoir: Nueces-Rio Grande Coastal Basin, off-channel of Laguna Madre; Nueces County; Central Power and Light; steam-electric power; impoundment began 1973; 6,600 acre-feet capacity.

Decker Lake and Decker Creek Dam: see Walter E. Long Lake.

Delta Lake and Delta Dam (Reservoir Unit 1 and Unit 2): formerly Monte Alto Reservoir and Monte Alto Dam; Nueces-Rio Grande Coastal Basin, off-channel from the Rio Grande; Hidalgo County; Hildalgo-Willacy Counties Water Control and Improvement District Number 1; irrigation; impoundment began 1939; 25,000 acre-feet capacity.

Diable Reservoir and Diable Dam: see Amistad Reservoir and Amistad Dam.

Lake Diversion and Lake Diversion Dam: Red River Basin, Wichita River; Acher and Baylor Counties; City of Wichita Falls and Wichita County Water Improvement District No. 2; municipal and industrial; impoundment began 1924; 40,000 acre-feet capacity.

Eagle Lake and Eagle Lake Dam: Colorado River Basin, off channel from Colorado River; Colorado County; Lakeside Irrigation Company; irrigation; impoundment began 1900; 9,600 acre-feet capacity.

Eagle Mountain Reservoir and Eagle Mountain Dam: Trinity River Basin, West Fort Trinity River; Tarrant County; Tarrant Regional Water District; municipal, industrial, irrigation; impoundment began February 1934; 190,300 acre-feet capacity.

East Lake and the Victor Braunig Plant Dam: See Victor Braunig Lake

Eddleman Lake and Eddleman Dam: See Lake Graham and the Eddleman and Graham Dam.

Electra City Lake and Electra City Dam: Red River Basin; Beaver and Camp Creeks; Wilbarger County; City of Electra; municipal and industrial; impoundment began 1950; 8,055 acre-feet capacity.

Ellison Creek Reservoir and Ellison Creek Dam: also called Lone Star Dam; Cypress Creek Basin, Ellison Creek; Ellison county; Lone Star Steel Company; steam-electric power and industrial; impoundment began January 1943; 24,700 acre-feet capacity.

Fairfield Lake and Fairfield Dam: formerly Big Brown Creek Reservoir and Big Brown Creek Dam; Trinity River Basin, Big Brown Creek; Freestone County; Industrial Generating Company; steam-electric power; impoundment began December, 1969, 49,750 acre-feet capacity.

Farmers Creek Reservoir and Farmers Creek Dam: also known as Lake Nocona; Red River Basin, Farmers Creek; Montague County; North Montague County Water Supply District; municipal, industrial, and mining; impoundment began Spring 1961; 25,400 acre-feet capacity.

Ferrells Bridge Dam Reservoir: See Lake O' the Pines and Ferrells Bridge Dam.

O.C. Fisher Lake and Dam: formerly San Angelo Reservoir and Dam; Colorado River Basin, Concho River; Tom Green County; constructed and operated by USACE, Upper Colorado River Authority has contracted for conservation storage; flood control, municipal, industrial, irrigation and recreation; impoundment began February 1952; 80,600 conservation capacity; 277,200 acre-feet flood control capacity.

Flat Creek Reservoir and Flat Creek Dam: See Lake Athens and Lake Athens Dam.

Forest Grove Reservoir and Forest Grove Dam: Trinity River Basin, Caney Creek; Henderson County; Texas Utilities Service Company; steam-electric power; impoundment 1980; 20,040 acre-feet capacity.

Lake Fork Reservoir and Lake Fork Dam: Sabine River Basin, Lake Fork Creek; Rains and Wood Counties; Sabine River Authority; municipal and industrial; impoundment 1980; 635,200 ac-ft capacity.

Forney Reservoir: See Lake Ray Hubbard.

Fort Phantom Hill Reservoir and Fort Phantom Hill Dam: Brazos River Basin, Elm Creek; Jones County; City of Abilene; municipal and recreation; impoundment October 1938; 74,310 ac-ft capacity.

Franklin County Lake and Dam: See Lake Cypress Springs and Franklin County Dam.

Galveston County Industrial Water Reservoir: San Jacinto-Brazos Basin, off channel of Dickinson Bayou; Galveston County; Galveston County Water Authority; impoundment began 1949; municipal and industrial; 7,308 acre-feet capacity.

Garza-Little Elm Lake and Garza-Little Elm Dam: See Lewisville Lake and Lewisville Dam.

Georgetown Lake and Georgetown Dam: formerly North Fork Lake and North Fork Dam; Brazos River Basin, San Gabriel River; Williamson County; owned and operated by USACE Fort Worth District, Brazos River Authority has contracted for conservation storage; flood control, municipal, industrial, and recreation; impoundment began January 1980; 29,200 acre-feet conservation capacity, 87,600 acre-feet flood control capacity.

Gibbons Creek Reservoir and Gibbons Creek Dam: Brazos River Basin, Gibbons Creek; Grimes County; Texas Municipal Power Agency; steam-electric power; impoundment began in 1981; 26,824 acre-feet capacity.

Lake Gladewater and Gladewater Dam: Sabine River Basin, Glade Creek; Upshur County; City of Gladewater, municipal and recreation, impoundment began August 1952; 6,950 acre-feet capacity.

Lake Graham and Eddleman and Graham Dam: also called Eddleman and Salt Creek Lakes; Brazos River Basin, Flint and Salt Creek; Young County; City of Graham; municipal and industrial; impoundment began 1929 (Eddleman Dam) and 1958 (Graham Dam); 45,000 acre-feet capacity.

Lake Granbury and De Cordova Bend Dam: also called De Cordova Bend Reservoir; Brazos River Basin, Brazos River; Hood and Parker Counties; Brazos River Authority; municipal, industrial, irrigation and power; impoundment began September 1970; 153,000 acre-feet capacity.

Granger Lake and Granger Dam: formerly Laneport Lake and Laneport Dam; Brazos River Basin; San Gabriel River; Williamson County; owned and operated by U.S. Army Corps of Engineers, Fort Worth District; Brazos River Authority has contracted for conservation storage; flood control, municipal, and industrial; impoundment began January 1980; 37,900 acre-feet conservation capacity, 162,200 acre-feet flood storage capacity.

Granite Shoals Lake: See Lake Lyndon B. Johnson.

Grapevine Lake and Grapevine Dam: Trinity River Basin, Denton Creek; Tarrant County; owned and operated by USACE Fort Worth District, Cities of Grapevine and Dallas have contracted for conservation storage; municipal, industrial; impoundment began July 1952; 162,250 acre-feet conservation capacity; 243,050 acre-feet flood control capacity.

Greenbelt and Greenbelt Dam: Red River Basin, Salt Fork Red River, Donley County; Greenbelt Municipal and Industrial Water Authority, and Texas Water Development Board, municipal and industrial; impoundment began December 1966; 58,200 acre-feet capacity.

H-4 Reservoir and H-4 Dam: Guadalupe River Basin, Guadalupe River Gonzales County; Guadalupe-Blanco River Authority; hydropower; impoundment began 1931; 5,200 acre-feet capacity.

Lake Halbert and Halbert Dam: Trinity River Basin, Elm Creek; Navarro County; City of Corsicana; municipal, industrial, and recreation; impoundment began 1921; 7,420 acre-feet capacity.

William Harris Reservoir and William Harris Dam: Brazos River Basin, off channel between Brazos River and Oyster Creek; Brazoria County; Dow Chemical Company; industrial; impoundment began 1947; 12,000 acre-feet capacity.

Lake Hawkins and Wood County Dam No. 3: Sabine River Basin, Little Sandy Creek; Wood County; owned by Wood County; recreation and flood control; impoundment August 1962; 11,570 ac-ft capacity.

Lake Allen Henry and John T. Montford Dam: Brazos River Basin, South Fork of Double Mountain Fork of Brazos River; Garza and Kent Counties; City of Lubbock; municipal water supply, irrigation, recreation; impoundment began 1993; 94,808 acre-feet capacity.

Joe B. Hoggsett Lake and Dam: See Cedar Creek Reservoir and Joe B. Hoggsett Dam.

Lake Holbrook and Wood County Dam No. 2: Sabine River Basin, Keys Creek; Wood County; recreation and flood control: impoundment began September 1962; 7,700 acre-feet capacity.

Honea Reservoir and Honea Dam: See Lake Conroe and Conroe Dam.

Hords Creek Reservoir and Hords Creek Dam: Colorado River Basin, Hords Creek; Coleman County; operated by USACE Fort Worth District, Central Colorado River Authority has contracted for conservation storage; flood control, municipal, recreation; impoundment began April 1954;140,520 acre-feet conservation capacity; 16,620 acre-feet flood control capacity.

Lake Houston and Lake Houston Dam: San Jacinto River Basin, San Jacinto River; Harris County, City of Houston; municipal, industrial, irrigation, recreation, and mining, including oil production; impoundment began April 1954; 140,520 acre-feet capacity.

Houston County Lake and Houston County Dam: Trinity River Basin, Little Elkhart Creek; Houston County; Houston County Water Control and Improvement District No. 1; municipal and industrial; impoundment began November 1966; 19,500 acre-feet capacity.

Hubbard Creek Reservoir and Hubbard Creek Dam: Brazos River Basin, Hubbard Creek; Shackleford and Stephens Counties; West Central Municipal Water District; municipal, industrial and mining including oil production; impoundment began December 1962; 314,280 acre-feet capacity.

Lake Ray Hubbard and Rockwall Forney Dam: formerly Forney Reservoir; Trinity River Basin, East Fork Trinity River; Dallas and Kaufman Counties; City of Dallas; municipal; impoundment began December 1968; 490,000 acre-feet capacity.

Imperial Reservoir and Imperial Dam: Rio Grande Basin, Pecos River; Pecos and Reeves Counties; Pecos County Water Control and Improvement District No. 2; irrigation; impoundment began 1915; 6,000 acre-feet conservation capacity.

Inks Lake and Roy Inks Dam: Colorado River Basin, Colorado River; Burnet County; Lower Colorado River Authority; municipal, irrigation, mining and hydropower; impoundment began 1938; 17,540 acre-feet capacity.

International Amistad Reservoir and Dam: also called Diable Reservoir and Diable Dam; Rio Grande Basin, Rio Grande River; Val Verde County; International Boundary and Water Commission; conservation, recreation, irrigation, hydropower and flood control; impoundment began May 1968; 3,497,400 acre-feet conservation capacity; 1,744,000acre-feet flood control capacity.

International Falcon Reservoir and Dam: Rio Grande Basin, Rio Grande; Starr County, Texas and Estado de Tamaulipas, Mexico, International Boundary and Water Commission; municipal, industrial, irrigation, flood control, hydropower conservation capacity, 910,000 flood control capacity.

Iron Bridge Dam Lake: See Lake Tawakoni and Iron Bridge Dam.

O. H. Ivie Lake and S. W. Freese Dam: formerly called Stacey Lake and Dam; Colorado River Basin, Colorado River; Colorado River Municipal Water District; impoundment 1990; 554,340 ac-ft capacity.

Lake Jacksonville and Buckner Dam: Neches River Basin, Gum Creek; Cherokee County; City of Jacksonville; municipal and recreation; impoundment began June 1957; 30,500 acre-feet capacity.

Lake Lyndon B. Johnson and Alvin Wirtz Dam: formerly Granite Shoals Lake, Colorado River Basin, Colorado River, Burnet and Llano Counties, Lower Colorado River Authority, hydroelectric power, impoundment began May 1951, 138,500 acre-feet capacity.

Lake Kemp and Lake Kemp Dam: Red River Basin, Wichita River, Baylor County, City of Wichita Falls and Wichita county Water Improvement District No. 2, municipal, steam-electric power, and irrigation, impoundment began October 1922, reconstruction by U.S. Army Corps of Engineers 1974, 319,600 acre-feet conservation capacity, 248,300 acre-feet flood control capacity.

Lake Kickapoo and Lake Kickapoo Dam: Red River Basin, North Fork Little Wichita River, Archer County, City of Wichita Falls, municipal, impoundment began February 1946, 106,000 acre-feet capacity.

Lake Kiowa and Kiowa Dam: Trinity River Basin, Indian Creek, Cooke County, Lake Kiowa, Inc., recreation, impoundment began 1928, 7,620 acre-feet conservation capacity.

Kirby Lake and Kirby Dam: Brazos River Basin, Cedar Creek, Taylor County, City of Abilene, municipal, impoundment began 1928, 7,620 acre-feet conservation capacity.

Lake Kurth and Kurth Dam: also called Southland Paper Mills Reservoir, Neches River Basin, off channel of Angelina River, Angelina County, Southland Paper Mills, industrial, impoundment began September 1961, 16,200 acre-feet capacity.

Lake Creek Lake and Lake Creek Dam: Brazos River Basin, Manos Creek, McLennan County, Texas Power and Light Company, steam-electric power, impoundment began June 1952, 8,400 ac-ft capacity.

Lake O' the Pines and Ferrells Bridge Dam: also called Ferrells Bridge Dam Reservoir, Cypress Creek Basin, Cypress Creek, Camp, Harrison, Marion, Morris, and Upshur Counties, operated by USACE Fort Worth District, Northeast Texas MWD has contracted for conservation storage, municipal, industrial, recreation, and flood control, impoundment began August 1957, 252,040 acre-feet conservation capacity, 336,100 acre-feet flood control capacity.

Lakeview Lake and Lakeview Dam: See Joe Pool Reservoir and Joe Pool Dam.

Lampasses Reservoir and Lampasses Dam: See Stillhouse Hollow Lake and Stillhouse Hollow Dam.

Laneport Lake and Laneport Dam: See Granger Lake and Granger Dam.

Lavon Lake and Lavon Dam: Trinity River Basin, East Fork Trinity River, Collin County, owned and operated by USACE Fort Worth District, North Texas Municipal Water District has contracted for conservation storage, flood control, municipal, and industrial, impoundment began September 1953, project enlarged 1979, 380,000 acre-feet conservation capacity, 275,600 acre-feet flood control capacity.

Lewis Creek Reservoir and Lewis Creek Dam: San Jacinto River Basin, Lewis Creek, Montgomery County, Gulf States Utilities Company, steam-electric power, impoundment began February 1969, 16,400 acre-feet capacity.

Lewisville Lake and Lewisville Dam: also called Lake Dallas and Lake Dallas Dam and Garza-Little Elm Lake and Garza-Little Elm Dam, Trinity River Basin, Elm Fork Trinity River, Denton County, owned and operated by USACE Fort Worth District, Cities of Dallas and Denton have contracted for conservation storage, flood control, municipal, industrial and recreation, impoundment began November 1954, 436,000 acre-feet conservation capacity, 525,200 acre-feet flood control capacity.

Limestone Lake and Limestone Dam: Brazos River Basin, Navasota River, Leon, Limestone, and Robertson Counties, Brazos River Authority, municipal, industrial, and irrigation, impoundment began 1978, 225,400 acre-feet capacity.

Lake Livingston and Livingston Dam: Trinity River Basin, Trinity River, Polk, San Jacinto, Trinity, and Walker Counties, City of Houston and the Trinity River Authority, municipal, industrial and irrigation, impoundment began October 1968, 1,750,000 acre-feet capacity.

Loma Alta Reservoir and Loma Alta Dam: Nueces-Rio Grande Coastal Basin, off channel from the Rio Grande, Cameron County, Brownsville Navigation District, municipal, industrial, impoundment began 1963, 26,500 acre-feet capacity.

Lone Star Reservoir and Lone Star Dam: See Ellison Creek Reservoir and Ellison Creek Dam.

Walter E. Long Lake and Dam: formerly Decker Lake, Colorado River Basin, Decker Creek, Travis County, City of Austin, municipal, industrial, recreation, impoundment began January 1967, 33,940 acre-feet capacity.

McGee Bend Reservoir and McGee Bend Dam: See Sam Rayburn Reservoir and Sam Rayburn Dam.

Lake McQueeney and Abbott Dam: Guadalupe River Basin, Guadalupe River, Guadalupe county, Guadalupe-Blanco River Authority, hydropower, impoundment began 1928, 5,000 acre-feet capacity.

Mackenzie Reservoir and Mackenzie Dam: Red River Basin, Tele Creek, Swisher and Brisco Counties, Mackenzie Municipal Water Authority, municipal, impoundment April 1974, 46,250 acre-feet capacity.

Marble Falls Lake and Max Starcke Dam: also called Max Starcke Lake, Colorado River Basin, Colorado River, Burnet County, Lower Colorado River Authority, hydropower, impoundment began July 1951, 8,760 acre-feet capacity.

Martin Lake and Martin Dam: Sabine River Basin, Martin Creek, Panola and Rusk Counties, Texas Utilities Services, steam-electric power, impoundment began 1974, 77,619 acre-feet capacity.

Pat Mayse Lake and Pat Mayse Dam: Red River Basin, Sanders Creek, Lamar County, operated by USACE Tulsa District, City of Paris has contracted for conservation storage, municipal, industrial and flood control, impoundment began September 1967, 119,900 acre-feet conservation capacity, 64,600 acre-feet flood control capacity.

Medina Lake and Medina Dam: San Antonio River Basin, Medina River, Medina and Bandera Counties, Bexar-Medina-Atascosa Counties Water Improvement District No. 1, irrigation, impoundment began May 1913, 254,000 acre-feet capacity.

Lake Meredith and Sanford Dam: also called Lake Sanford, Canadian River Basin, Canadian River, Hutchison, Moore, and Potter Counties, constructed by the Bureau of Reclamation, owned and operated by Canadian River Municipal Water Authority, municipal, flood control, and recreation, impoundment began 1965, 864,400 acre-feet conservation capacity, 543,200 acre-feet flood control.

Lake Mexia and Bristone Dam: Brazos River Basin, Navasota River, Limestone County, Bristone Municipal Water Supply District, municipal and industrial, impoundment began June 1961, 10,000 acre-feet capacity.

Millers Creek Reservoir and Millers Creek Dam: Brazos River Basin, Millers Creek, Baylor and Throckmorton Counties, North Central Texas Municipal Water Authority, municipal, impoundment began 1974, 25,520 acre-feet capacity.

Lake Mineral Wells and Mineral Wells Dam: Brazos River Basin, Rock Creek, Parker County, City of Mineral Wells, municipal impoundment began 1920, 16,760 acre-feet capacity.

Monte Alto Reservoir and Monte Alto Dam: See Delta Lake and Delta Dam (Reservoir Units 1 and 2).

Monticello Reservoir and Monticello Dam: Cypress Creek Basin, Blundell Creek, Titus County, Texas Utilities Generating Company, steam-electric power, impoundment August 1972, 40,100 ac-ft capacity.

Hubert H. Moss Lake and Fish Creek Dam: Red River Basin, Fish Creek, Cooke County, City of Gainsville, municipal and industrial, impoundment began April 1966, 23,210 acre-feet capacity.

Mountain Creek Lake and Mountain Creek Dam: Trinity River Basin, Mountain Creek, Dallas County, Dallas Power and Light Company, industrial, impoundment March 1957, 22,840 ac-ft capacity.

Mud Creek Dam Lake: See Lake Tyler and Mud Creek Dam.

Murvaul Lake and Murvaul Dam: also called Panola Lake and Panola Dam, Sabine River Basin, Murvaul Bayou, Panola County, Panola County Fresh Water Supply District No.1, municipal, industrial and recreation, impoundment began 1957, 45,810 acre-feet capacity.

Nacogdoches Lake and Nacogdoches Lake Dam: Neches River Basin, Bayo Loco Creek, Nacogdoches County, City of Nacogdoches, municipal, impoundment began 1957, 45,810 acre-feet capacity.

Lake Nasworthy and Nasworthy Dam: Colorado River Basin, South Concho River, Tom Green County, City of San Angelo, municipal, industrial and irrigation, impoundment began March 1930, 12,390 acre-feet capacity.

Navarro Mills Lake and Navarro Mills Dam: Trinity River Basin, Richland Creek, Navarro and Hill Counties, owned and operated by USACE Fort Worth District, Trinity River Authority has contracted for conservation storage, municipal and flood control, impoundment began March 1963, 53,200 acre-feet conservation capacity, 143,200 acre-feet flood storage capacity.

Lake Nocona and Lake Nocona Dam: see Farmers Creek Reservoir and Farmers Creek Dam.

North Lake and North Lake Dam: Trinity River Basin, South Fork Grapevine Creek, Dallas County, Dallas Power and Light Company, steam-electric power, impoundment began March 1957, 17,000 acre-feet capacity.

North Fork Buffalo Creek Reservoir and North Fork Buffalo Creek Dam: Red River Basin, North Fork Buffalo Creek, Wichita County, Wichita County Water Control and Improvement District No. 3, municipal, impoundment began November 1964, 15,400 acre-feet capacity.

Oak Creek Reservoir and Oak Creek Dam: Colorado River Basin, Oak Creek, Coke and Nolan Counties, City of Sweetwater, municipal, industrial, impoundment May 1953, 39,360 acre-feet capacity.

Olmos Reservoir and Olmos Dam: San Antonio River Basin, Olmos Creek, Bexar County, City of San Antonio, flood control only, impoundment began 1926, 12,600 acre-feet flood control capacity.

Lake Palestine and Blackburn Crossing Dam: also called Blackburn Crossing Lake, Neches River Basin, Neches River, Anderson, Cherokee, Henderson, and Smith counties, Upper Neches River Municipal Water Authority, municipal, industrial, and recreation, impoundment began May 1962, 411,300 acre-feet capacity.

Palmetto Bend Reservoir and Palmetto Bend Dam: See Texana Lake and Texana Dam.

Lake Palo Pinto and Palo Pinto Creek Dam: Brazos River Basin, Palo Pinto Creek, Palo Pinto County, Palo Pinto County Municipal Water District No. 1 and City of Mineral Wells, municipal and industrial, impoundment began April 1964, 42,200 acre-feet capacity.

Panola Lake and Panola Dam: See Murvaul Lake and Murvaul Dam.

Wright Patman Lake and Wright Patman Dam: formerly Texarkana Lake and Dam, Sulphur River Basin, Sulphur River, Bowie and Cass Counties, USACE Fort Worth District, City of Texarkana has contracted for conservation storage, flood control, municipal, industrial and recreation, impoundment began June 1956, 145,300 acre-feet conservation capacity, 2,363,700 acre-feet flood control capacity.

Pinkston Reservoir and Pinkston Dam: formerly Sandy Creek Reservoir, Neches River Basin, Sandy Creek, Shelby County, City of Center, municipal, impoundment began 1974, 7,380 acre-feet capacity.

Joe Pool Reservoir and Joe Pool Dam: formerly called Lakeview Lake and Lakeview Dam, Trinity River Basin, Mountain Creek, Dallas, Ellis and Tarrant Counties, construction and owned by USACE Fort Worth District, Trinity River Authority has contracted for conservation storage, flood control, municipal, and recreation, impoundment began December 1985, 176,900 acre-feet conservation capacity, 123,100 acre-feet flood storage capacity.

Possum Kingdom Lake and Morris Sheppard Dam: Brazos River Basin, Brazos River, Palo Pinto, Stephens and Young Counties, Brazos River Authority, municipal, industrial, irrigation, recreation, power, and mining including oil production, impoundment March 1941, 569,380 acre-feet capacity.

Proctor Lake and Proctor Dam: Brazos River Basin, Leon River, Comanche County, owned and operated by USACE Fort Worth District, Brazos River Authority has contracted for conservation storage, flood control, municipal, industrial, irrigation, and recreation, impoundment September 1963, 31,400 ac-ft conservation capacity, 310,100 ac-ft flood control capacity.

Lake Quitman and Wood County Dam No. 1: Sabine River Basin, Dry Creek, Wood County, Wood County, recreation and flood control, impoundment began May 1962, 7,440 acre-feet capacity.

Lake Randall and Randall Dam: Red River Basin, Shawnee Creek Grayson County, City of Denison, municipal, impoundment began 1909, 6,290 acre-feet capacity.

Sam Rayburn Reservoir and Sam Rayburn Dam: formerly McGee Bend Reservoir and Dam, Neches River Basin, Angelina River, Angelina, Jasper, Nacogdoches, Sabine and San Augustine Counties, operated by USACE Fort Worth District, Lower Neches Valley Authority has contracted for conservation storage, municipal, industrial, irrigation, hydroelectric power, recreation, and flood control, impoundment began March 1965, 1,446,200 acre-feet conservation capacity, 1,099,100 acre-feet flood control capacity.

Red Bluff Reservoir and Red Bluff Dam: Rio Grande Basin, Pecos River, Reeves and Loving Counties, Red Bluff Water Power Control District, irrigation and hydropower, impoundment began September 1936, 307,000 acre-feet capacity.

River Crest Lake and River Crest Levee: Sulphur River Basin, off channel of Sulphur River, Red River county, Texas Power and Light Company, steam-electric power, impoundment began November 1953, 7,000 acre-feet capacity.

Richland-Chambers Reservoir and Dam: Trinity River Basin, Richland and Chambers Creeks, Freestone and Navarro Counties, under construction by Tarrant Regional Water District, municipal, impoundment 1987, 1,112,760 acre-feet capacity.

Ray Roberts Lake and Ray Roberts Dam: formerly Aubrey Lake and Dam, Trinity River Basin, Elm Fork Trinity River, Cooke, Denton, and Grayson Counties, constructed and owned by USACE Fort Worth District, Cities of Dallas and Denton have contracted for conservation storage, flood control, municipal, industrial, recreation, initial impoundment 1987, 788,490 acre-feet conservation capacity, 260,800 acre-feet flood control capacity.

Salt Creek Lake: See Lake Graham and Graham Dam.

Bob Sandlin Lake and Fort Sherman Dam: also called Cherokee Trails Lake; Cypress Creek Basin, Big Cypress Creek; Camp, Franklin, Titus, and Wood Counties; Titus County Fresh Water Supply District No. 1; impoundment began 1978; 202,300 acre-feet capacity.

San Angelo Reservoir and Dam: See O.C. Fisher Lake and Dam.

Sandon Lake and Sandon Dam: See Alcoa Lake and Dam.

Sandy Creek Reservoir and Sandy Creek Dam: See Pinkston Reservoir and Dam.

San Esteban Lake and San Esteban Dam: Rio Grande Basin, Alamito Creek, Presidio County, William B. Blakemore, recreation, impoundment began 1911, 18,770 acre-feet capacity.

Sanford Lake: See Lake Meredith and Sanford Dam.

Santa Rosa Lake and Santa Rosa Dam: Red River Basin, Beaver Creek, Wilbarger County, W.T. Waggoner Estate, mining, impoundment began 1929, 11,570 acre-feet capacity.

Sheldon Reservoir and Sheldon Dam: San Jacinto River Basin, Carpenters Bayou, Harris County, Texas Parks and Wildlife Department, recreation and fish hatchery, impoundment began December 1943, 5,420 acre-feet capacity.

Smithers Lake and Smithers Lake Dam: also called Lake George, Brazos River Basin, Dry Creek, Fort Bend County, Houston Lighting and Power, steam-electric power, impoundment began October 1957, 18,700 acre-feet capacity.

Somerville Lake and Somerville Dam: Brazos River Basin, Yegua Creek, Burleson, Lee, and Washington Counties, owned and operated by USACE Fort Worth District, Brazos River Authority has contracted for impoundment began January, 1967, 143,900 acre-feet conservation capacity, 337,700 acre-feet flood control capacity.

Southland Paper Mills Reservoir: see Lake Kurth and Kurth Dam.

South Texas Project Reservoir: Colorado River Basin, off channel of Colorado River, Matagorda County, Houston Lighting and Power, steam-electric power, 187,000 acre-feet capacity.

E.V. Spence Reservoir and Robert Lee Dam: also called Robert Lee Lake, Colorado River Basin, Colorado River, Coke County, Colorado River Municipal Water District, municipal, industrial, and mining, impoundment began December 1968, 484,800 acre-feet capacity.

Squaw Creek Reservoir and Squaw Creek Dam: Brazos River Basin, Squaw Creek, Hood and Somerville Counties, Texas Utilities Services Company, steam-electric power, impoundment began 1977, 151,047 acre-feet capacity.

Lake Stamford and Stamford Dam: Brazos River Basin, Paint Creek, Haskell County, City of Stamford, municipal and industrial, impoundment began June 1953, 52,700 acre-feet capacity.

B.A. Steinhagen Lake and Town Bluff Dam: also known as Town Bluff Reservoir and Dam B Lake, Neches River Basin, Neches River, Jasper and Tyler Counties, owned and operated by USACE Fort Worth District, Lower Neches Valley Authority has contracted for conservation storage, municipal, industrial, and recreation, impoundment began April 1951, 94,200 acre-feet capacity.

Stillhouse Hollow Lake and Stillhouse Hollow Dam: also called Lampasas Reservoir and Lampasas Dam, Brazos River Basin, Lampasas River, Bell County, owned and operated by USACE Fort Worth District, Brazos River Authority has contracted for conservation storage, flood control, municipal, industrial, irrigation, recreation, impoundment began February 1968, 204,900 acre-feet conservation capacity, 390,600 acre-feet flood control capacity.

Striker Creek Reservoir and Striker Creek Dam: Neches River Basin, Striker Creek, Cherokee and Rusk Counties, Angelina and Nacogdoches Counties Water Control and Improvement District No. 1, municipal and industrial, impoundment began May 1957, 26,960 acre-feet capacity.

Sulphur Springs Lake and Sulphur Springs Lake Dam: formerly White Oak Creek Reservoir and White Oak Creek Dam, Sulphur River Basin, White Oak Creek, Hopkins County, Sulphur Springs Water District, municipal, impoundment began July, 1973, 13,520 acre-feet capacity.

Swauano Creek Reservoir and Swauano Creek Dam: See Welsh Reservoir and Welsh Dam.

Sweetwater Lake and Sweetwater Dam: Brazos River Basin, Bitter and Cottonwood Creeks, Nolan County, City of Sweetwater, municipal and industrial, impoundment 1930, 11,900 acre-feet capacity.

Lake Tawakoni and Iron Bridge Dam: also called Iron Bridge Dam and Lake, Sabine River Basin, Sabine River, Hunt, Rains, and Van Zandt Counties, Sabine River Authority, municipal, industrial, irrigation , and recreation, impoundment began October 1960, 936,200 acre-feet conservation capacity.

New Terrell City Lake and Terrell Dam: Trinity River Basin, Muddy Cedar Creek, Kaufman County, City of Terrell, municipal, recreation, impoundment began November 1955, 8,712 acre-feet capacity.

Texana Lake and Texana Dam: formerly Palmetto Bend Reservoir and Dam, Lavaca River Basin, Navidad River and Sandy Creek, Jackson County, constructed by U.S. Bureau of Reclamation, owned and operated by Lavaca-Navidad River Authority and Texas Water Development Board, municipal and irrigation, impoundment began 1981, 157,900 acre-feet capacity.

Lake Texarkana and Texarkana Dam: See Wright Patman Lake and Wright Dam.

Lake Texoma and Denison Dam: Red River Basin, Red River, Cooke and Grayson Counties, owned and operated by USACE Tulsa District, hydropower, flood control, conservation, and recreation, impoundment began October 1943, 2,722,000 acre-feet conservation capacity, 2,660,000 acre-feet flood control capacity.

J.B. Thomas Lake and Colorado River Dam: Colorado River Basin, Colorado River, Scurry and Borden Counties, Colorado River Municipal Water District, municipal, industrial, and recreation, impoundment began July 1952, 202300 acre-feet capacity.

Toledo Bend Reservoir and Toledo Bend Dam: Sabine River Basin, Sabine River, Newton, Sabine and Shelby Counties, Sabine River Authority of Texas and Louisiana, municipal, industrial, irrigation, hydropower, and recreation, impoundment began October 1966, 4,472,900 acre-feet capacity.

Town Bluff Reservoir and Town Bluff Dam: See B.A. Steinhagen Lake.

Tradinghouse Creek Reservoir and Tradinghouse Creek Dam: Brazos River Basin, Tradinghouse Creek, McLennan County, Texas Power and Light Company, steam-electric power, impoundment began July 1968, 35,124 acre-feet capacity.

Lake Travis and Mansfield Dam: Colorado River Basin, Colorado River, Travis and Burnet Counties, Lower Colorado River Authority, municipal industrial, irrigation, mining, hydropower, flood control, and recreation, impoundment began September 1940, 1,144,100 acre-feet conservation capacity, 781,400 acre-feet flood control capacity.

Trinidad Lake and Trinidad Levee: Trinity River Basin, off-channel of Trinity River, Henderson County, Texas Power and Light Company, hydropower, impoundment 1925, 7,450 acre-feet capacity.

Truscott Brine Lake and Truscott Brine Lake Dam: Red River Basin, Bluff Creek, Knox County, constructed by USACE Tulsa District; permanent impoundment of naturally high salinity flows to improve water salinity downstream; impoundment began 1984, 107,000 acre-feet capacity.

Turtle Bayou Reservoir: See Anahuac Lake and Anahuac Dam.

Twin Buttes Reservoir and Twin Buttes Dam: Colorado River Basin, South Concho River, Spring Creek and Middle Concho River, Tom Green County, constructed by the Bureau of Reclamation, conservation storage maintained and operated by the City of San Angelo, flood control storage operated by USACE municipal, industrial, flood control, irrigation, and recreation, impoundment began December 1962, 177,800 acre-feet conservation capacity, 905,050 acre-feet flood control capacity.

Twin Oaks Reservoir and Twin Oaks Dam: Brazos River Basin, Duck Creek, Robertson County, Texas Power and Light Company, steam-electric power, impoundment 1982, 30,319 acre-feet capacity.

Lake Tyler and Mud Creek Dam and Whitehouse Dam: also called Mud Creek Dam Lake, Neches River Basin, Mud Creek and Prairie Creek, Smith County, City of Tyler, municipal and industrial, impoundment began November 1966 (Mud Creek) and January 1949 (Whitehouse), 73,700 ac-ft capacity.

Upper Nueces Reservoir and Upper Nueces Dam: Nueces River Basin, Nueces River, Zavala County, Zavala and Dimmit Counties Water Improvement District Number 1, irrigation, impoundment began March 1948, 7,590 acre-feet capacity.

Valley Lake and Valley Dam: formerly Brushy Creek Reservoir and Dam, Red River Basin, Brushy Creek, Fannin and Grayson Counties, Texas Power and Light Company, steam-electric power, impoundment December 1960, main water supply is pumped from Red River, 16,400 acre-feet capacity.

Valley Acres Lake and Valley Acres Dam: Nueces-Rio Grande Coastal Basin, off channel from the Rio Grande, Hidalgo County, Valley Acres Water District, irrigation, and municipal, impoundment began 1947, 7,840 acre-feet capacity.

Waco Lake and Waco Dam: Brazos River Basin, Bosque River, McLennan County, owned and operated by USACE Fort Worth District, Brazos River Authority and City of Waco has contracted for conservation storage, flood control, municipal, industrial, and recreation, impoundment February 1965, 104,100 acre-feet conservation capacity, 553,300 acre-feet flood control capacity.

Wallisville Lake and Dam: Trinity River Basin, Trinity River; Chambers County; USACE Galveston District; navigation, salinity control, water supply, fish and wildlife enhancement, and water supply; construction began in 1966 but was halted in 1973. The project has been revaluated and modified.

Lake Waxahachie and South Prong Dam: Trinity river Basin, Clear Fork Trinity River, Parker County, City of Weatherford, municipal and industrial, impoundment March 1957, 19,470 acre-feet capacity.

Weatherford Lake and Weatherford Dam: Trinity River Basin, White River, Crosby County, White River Municipal Water District, municipal, industrial, and mining including oil production, impoundment began October 1963, 37,950 acre-feet capacity.

White River Lake and White River Dam: Brazos River Basin, White River, Crosby County, White River Municipal Water District, municipal, industrial, and mining including oil production, impoundment began October, 1963, 37,950 acre-feet capacity.

White Rock Lake and White Rock Dam: Trinity River Basin, White Rock Creek, Dallas County, City of Dallas, recreation, impoundment began 1910, 10740 acre-feet capacity.

Whitney Lake and Whitney Dam: Brazos River Basin, Brazos River, Bosque, Hill and Johnson Counties, owned and operated by U.S. Army of Engineers, Fort Worth District, Brazos River Authority has contracted for the water supply storage, flood control and hydroelectric power, impoundment began December, 1951, 627,100 acre-feet conservation capacity, 1,372,400 acre-feet flood control capacity.

Lake Wichita and Lake Wichita Dam: Red River Basin, Holiday Creek, Archer and Wichita Counties, City of Wichita Falls, municipal, steam-electric power, and recreation, impoundment began 1901, 14,000 acre-feet capacity.

Lake Winneboro and Wood County Dam No. 4: Sabine River Basin, Big Sandy Creek, Wood County, recreation and flood control, impoundment began July 1962, 8,100 acre-feet conservation capacity.

Winters Lake and Winters Dam: Colorado River Basin, Elm Creek, Runnels County, City of Winters, municipal, 8,370 acre-feet capacity.

Lake Worth and Lake Worth Dam: Trinity River Basin, West Fork Trinity River; Tarrant County; owned and operated by City of Fort Worth; impoundment began March 1957, 17,000 acre-feet capacity.

CHAPTER 3
PRECIPITATION AND RESERVOIR EVAPORATION RATES

Precipitation and reservoir evaporation rates represent climatic conditions that drive river system hydrology. Spatial and temporal variability and long-term trends in precipitation and evaporation rates are analyzed in this chapter using databases maintained by the TWDB. A computer program called HydStats (Hydrology Statistics) was developed specifically for the analyses presented in this chapter and is also used in later chapters. HydStats computes means, standard deviations, and linear regression coefficients, and converts data sequences to DSS files. HydStats is designed primarily for analyzing precipitation and evaporation depths from the TWDB statewide datasets but also reads an input file containing any data sequence such as stream flow or reservoir storage contents and computes the same statistics. The plots presented in this report were developed with HEC-DSSVue which is described in Chapter 1. HEC-DSSVue is also used for arithmetic manipulations and statistical analyses.

TWDB Precipitation and Evaporation Datasets

The TWDB datasets of monthly precipitation depths and reservoir surface evaporation depths in inches along with the map reproduced as Figure 3.1 and explanation of methods employed in compiling the data are available at the following website.

http://www.twdb.state.tx.us/surfacewater/conditions/evaporation/index.asp

These data were used to develop the original net evaporation-precipitation input files for the TCEQ WAM system. A new WRAP feature uses the TWDB datasets to update the naturalized stream flow sequences and net evaporation-precipitation rates in the WAM hydrology datasets.

The monthly precipitation and evaporation depths date back to 1940 and are updated each year about May to add data for January through December of the preceding year. The methodology employed by the TWDB for compiling evaporation data for 1940-1953 was different than for 1954 to the present. The 1940-1953 evaporation data is maintained as a separate dataset, which has missing data in some months for some of the quadrangles.

A total of 168 one-degree quadrangles covering an area extending 12 degrees longitude and 14 degrees latitude encompass adjacent surrounding land area along with Texas. Complete records of monthly precipitation from 1940 and evaporation from 1954 to near the present are available for the 92 quadrangles shown in Figure 3.1 that encompass the state. The datasets include an additional 76 quadrangles located outside of Texas, but there are periods of missing data for these quadrangles. The 168 one-degree quadrangles define a grid with 12 rows and 14 columns. The three or four digit quadrangle identifiers consist of the row and column numbers.

The TWDB databases of monthly precipitation and evaporation rates are based on daily precipitation and pan evaporation rates measured at gages in Texas and neighboring states. The number of gage stations varies from year to year. In 2013, the TWDB compiled data measured at 76 evaporation stations and more than 2,400 precipitation stations. The National Weather Service (NWS) and TWDB administer climatic data collection programs with data being collected by volunteer partners that include various public and private entities such as reservoir operators. The NWS data are available from the National Climatic Data Center.

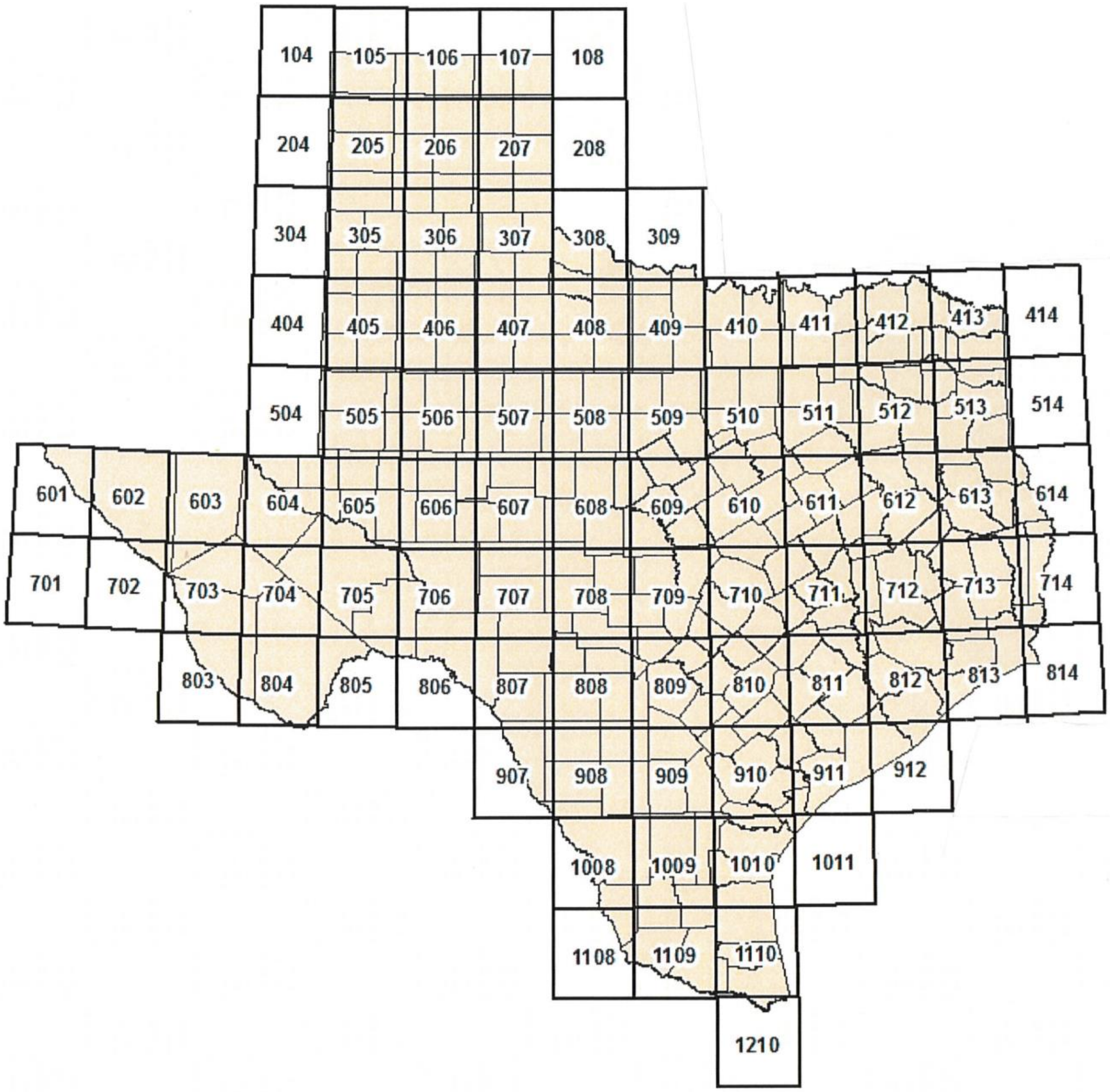

Figure 3.1 Grid of 92 One Degree Quadrangles Encompassing Texas

Daily precipitation and evaporation depths in inches are summed to monthly quantities. The TWDB computer-based data compilation system applies Thiessen polygon networks to spatially average the precipitation and evaporation rates by one-degree quadrangle. Sets of 12 monthly pan coefficients are used to convert pan evaporation measurements to estimates of lake surface evaporation rates.

Areas in square miles of each one-degree longitude by one-degree latitude quadrangle are listed in Table 3.1. The 168 quads in Table 3.1 include the 92 quads in Figure 3.1 that encompass Texas and additional surrounding quads in Mexico, New Mexico, Oklahoma, Arkansas, and Louisiana that cover an area extending 12 degrees longitude and 14 degrees latitude.

Table 3.1
Areas in Square Miles of 168 One-Degree Quadrangles

Quad ID	Area (sq miles)	Quad ID	Area (sq miles)	Quad ID	Area (sq miles)	Quad ID	Area (sq miles)
101	3,855.71	401	3,968.90	701	4,092.19	1001	4,226.81
102	3,855.71	402	3,968.78	702	4,092.19	1002	4,226.80
103	3,855.75	403	3,968.81	703	4,092.20	1003	4,226.81
104	3,855.77	404	3,968.79	704	4,092.17	1004	4,226.82
105	3,855.75	405	3,968.95	705	4,092.18	1005	4,226.83
106	3,855.68	406	3,968.89	706	4,092.14	1006	4,226.83
107	3,855.75	407	3,968.85	707	4,092.17	1007	4,226.83
108	3,855.74	408	3,968.84	708	4,092.14	1008	4,226.83
109	3,855.78	409	3,968.85	709	4,092.13	1009	4,226.81
110	3,855.70	410	3,968.84	710	4,092.16	1010	4,226.77
111	3,855.75	411	3,968.86	711	4,092.17	1011	4,226.82
112	3,855.70	412	3,968.87	712	4,092.16	1012	4,226.87
113	3,855.71	413	3,968.88	713	4,092.20	1013	4,226.87
114	3,855.71	414	3,968.77	714	4,092.22	1014	4,226.86
201	3,892.26	501	4,008.79	801	4,135.74	1101	4,274.40
202	3,892.31	502	4,008.76	802	4,135.72	1102	4,274.39
203	3,892.34	503	4,008.80	803	4,135.72	1103	4,274.40
204	3,892.34	504	4,008.80	804	4,135.74	1104	4,274.40
205	3,892.34	505	4,008.82	805	4,135.81	1105	4,274.40
206	3,892.38	506	4,008.75	806	4,135.74	1106	4,274.40
207	3,892.41	507	4,008.70	807	4,135.75	1107	4,274.39
208	3,892.37	508	4,008.73	808	4,135.77	1108	4,274.36
209	3,892.36	509	4,008.74	809	4,135.74	1109	4,274.39
210	3,892.31	510	4,008.76	810	4,135.70	1110	4,274.44
211	3,892.38	511	4,008.75	811	4,135.73	1111	4,274.46
212	3,892.46	512	4,008.70	812	4,135.77	1112	4,274.49
213	3,892.40	513	4,008.73	813	4,135.77	1113	4,274.48
214	3,892.36	514	4,008.75	814	4,135.71	1114	4,274.47
301	3,930.04	601	4,049.88	901	4,180.60	1201	4,323.42
302	3,929.98	602	4,049.88	902	4,180.60	1202	4,323.41
303	3,930.01	603	4,049.90	903	4,180.60	1203	4,323.41
304	3,930.01	604	4,049.91	904	4,180.62	1204	4,323.41
305	3,930.05	605	4,049.86	905	4,180.64	1205	4,323.41
306	3,930.06	606	4,049.82	906	4,180.62	1206	4,323.41
307	3,930.07	607	4,049.84	907	4,180.62	1207	4,323.41
308	3,930.02	608	4,049.90	908	4,180.60	1208	4,323.43
309	3,930.00	609	4,049.85	909	4,180.55	1209	4,323.46
310	3,930.00	610	4,049.88	910	4,180.53	1210	4,323.52
311	3,930.06	611	4,049.89	911	4,180.59	1211	4,323.55
312	3,930.13	612	4,049.87	912	4,180.64	1212	4,323.54
313	3,930.08	613	4,049.87	913	4,180.66	1213	4,323.53
314	3,930.06	614	4,049.87	914	4,180.65	1214	4,323.51

Annual and Monthly Precipitation and Evaporation Means

The means of 1940-2013 monthly precipitation depths and 1954-2013 evaporation depths in each of the 12 months of the year for each of the 92 quads are tabulated in Tables 3.3 and 3.4 along with annual means. The annual means are in inches/year. The monthly means are expressed as a percentage of the annual means. The next-to-last row shows the arithmetic averages of the 92 quadrangle monthly and annual means without consideration of areas. The last row in Tables 3.3 and 3.4 are area-weighted (Table 3.1) means for the 92 quadrangles.

Delineations of river basin areas within Texas and quadrangle areas were combined to compute the area-weighted means shown in Table 3.2 for each river basin from the data in the TWDB precipitation and evaporation datasets. Annual means of 1940-2013 precipitation depths and 1954-2013 reservoir surface evaporation depths for each of the 15 major river basins and 8 coastal basins delineated in Figure 1.1 are tabulated in Table 3.2. The last row of Table 3.2 contains the area-weighted means for the entire state. The statewide mean annual precipitation and evaporation depths for Texas are 27.9 inches/year and 60.6 inches/year respectively.

Table 3.2
Mean Annual Precipitation and Evaporation by River Basin

River Basin or Coastal Basin	Area in Texas	Mean Precipitation	Mean Evaporation
	(sq miles)	(inches/yr)	(inches/yr)
Canadian River	12,865	19.5	66.2
Red River	24,297	25.6	63.4
Sulphur River	3,580	46.6	50.1
Cypress River	2,929	47.2	48.9
Sabine River	7,570	47.8	50.9
Neches River	9,937	48.7	48.5
Neches-Trinity	769	49.6	45.9
Trinity River	17,913	39.4	55.1
Trinity-San Jacinto	247	48.1	46.5
San Jacinto River	3,936	46.6	49.0
San Jacinto-Brazos	1,440	47.0	46.7
Brazos River	42,865	28.9	60.7
Brazos-Colorado	1,850	44.0	48.6
Colorado River	39,428	23.5	63.7
Colorado-Lavaca	939	40.0	50.6
Lavaca River	2,309	39.7	50.8
Lavaca-Guadalupe	998	39.6	50.8
Guadalupe River	5,953	32.7	54.0
San Antonio River	4,180	31.8	54.3
San Antonio-Nueces	2,652	35.1	53.9
Nueces River	16,700	24.8	59.6
Nueces-Rio Grande	10,442	25.3	62.3
Rio Grande River	49,387	16.1	64.0
Statewide Total	263,186	27.9	60.6

Table 3.3
Mean Monthly Precipitation as a Percentage of 1940-2013 Annual Means

Quad	Annual (inches)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)
104	16.67	2.53	2.72	4.91	6.89	13.21	11.56	18.36	17.47	10.51	5.87	3.39	2.60
105	17.73	3.55	3.52	6.12	7.71	13.08	12.55	14.83	14.70	9.22	6.94	4.05	3.73
106	18.51	2.44	3.03	5.75	7.35	14.69	15.10	15.08	13.46	8.86	7.45	3.77	3.02
107	20.79	2.75	3.92	6.31	7.68	14.49	14.99	12.96	12.48	8.73	7.90	4.23	3.59
108	23.98	2.85	4.57	6.98	8.89	14.86	14.03	10.46	11.39	9.13	8.36	4.72	3.75
204	16.73	2.89	3.23	4.82	6.61	12.00	12.37	16.26	16.40	10.92	7.28	4.03	3.22
205	18.21	3.06	3.33	5.35	6.47	12.05	13.59	15.22	15.73	9.91	7.71	3.87	3.71
206	20.30	2.87	3.54	5.32	7.08	13.63	15.33	13.61	13.87	9.36	8.19	3.84	3.36
207	23.92	3.21	4.24	6.25	8.46	15.23	14.15	10.32	10.80	9.79	8.75	4.64	4.16
208	27.81	4.16	5.11	7.19	8.99	15.32	12.75	8.36	9.63	9.54	8.76	5.43	4.77
304	16.56	2.83	3.10	4.06	5.01	10.80	13.02	16.24	17.03	11.62	9.41	3.38	3.49
305	18.01	3.35	3.47	4.55	5.66	12.04	14.74	13.16	14.66	11.40	9.04	3.92	4.03
306	20.52	3.31	3.79	5.08	7.11	13.76	16.26	11.47	12.28	10.88	8.70	3.78	3.59
307	21.93	3.36	4.17	5.50	8.83	15.15	14.96	9.30	10.33	11.17	9.33	4.22	3.69
308	25.73	3.70	4.51	6.04	8.90	15.72	13.72	8.34	9.16	10.93	10.05	4.81	4.13
309	30.68	3.99	5.01	6.84	9.17	15.45	12.46	7.77	8.18	10.42	9.99	5.80	4.94
404	15.91	3.19	3.30	3.90	4.55	11.01	12.38	15.83	14.93	13.98	9.39	3.95	3.58
405	17.95	3.26	3.67	4.32	5.67	12.69	14.16	13.46	12.88	13.51	9.24	3.64	3.50
406	22.83	4.77	5.21	5.75	7.49	12.86	12.66	10.95	9.70	11.34	9.17	5.22	4.88
407	22.86	4.13	4.95	5.75	7.87	13.58	13.22	9.49	10.62	11.65	9.46	4.78	4.50
408	25.16	4.02	5.44	5.97	8.49	14.35	12.86	8.31	9.00	11.64	10.13	5.27	4.54
409	29.34	4.39	5.70	6.80	9.65	14.13	11.75	7.05	7.50	11.06	10.64	5.99	5.33
410	34.13	4.92	6.27	8.10	10.04	13.57	10.74	6.58	6.47	9.86	10.37	6.80	6.29
411	40.50	5.76	6.96	8.56	10.17	12.96	9.81	6.52	5.76	9.09	9.54	7.68	7.20
412	45.86	6.48	7.36	9.30	9.63	11.65	8.74	7.42	5.61	8.34	8.90	8.43	8.13
413	48.76	6.93	7.79	9.29	9.78	11.07	8.27	7.22	5.56	7.80	8.51	9.01	8.77
414	50.85	7.84	8.01	9.54	9.78	10.17	7.98	7.22	6.09	7.36	7.83	8.98	9.21
504	15.56	4.29	4.27	4.17	4.65	11.25	10.64	14.22	13.88	15.08	8.67	4.52	4.36
505	17.13	4.22	4.26	4.76	5.98	12.92	11.58	12.69	11.07	14.05	9.70	4.45	4.30
506	20.76	4.25	4.57	5.48	7.48	13.57	11.72	10.37	10.20	12.85	9.62	5.02	4.88
507	22.57	4.20	5.22	5.32	8.00	13.97	11.95	9.21	10.06	12.56	10.24	4.68	4.59
508	26.12	4.37	5.47	6.17	8.92	13.61	11.93	8.16	9.47	11.23	10.35	5.50	4.80
509	29.93	5.36	6.37	7.19	9.51	13.90	10.80	7.21	7.58	10.06	10.43	6.10	5.48
510	33.49	5.78	6.95	7.97	10.22	13.06	10.14	6.39	6.74	9.33	9.92	6.97	6.54
511	38.42	6.55	7.66	8.47	10.16	12.41	9.19	5.57	5.72	8.25	10.13	8.02	7.88
512	43.26	7.20	8.05	8.73	9.67	11.38	8.96	5.80	5.40	7.82	9.32	8.87	8.79
513	47.42	8.19	8.22	8.81	9.33	10.24	8.74	6.53	5.80	7.65	8.16	8.97	9.35
514	50.53	9.08	8.71	8.99	9.34	9.72	8.12	7.43	5.73	7.03	7.47	8.79	9.58
601	11.07	6.43	6.12	4.21	4.15	6.02	8.15	15.22	14.38	13.26	8.77	6.19	7.10
602	14.87	5.20	5.61	5.24	5.79	8.68	9.02	12.94	12.94	13.74	9.09	5.85	5.90
603	14.79	4.24	4.15	3.59	4.82	8.48	10.66	14.94	14.50	16.19	9.34	4.48	4.59
604	11.62	4.77	4.12	3.25	4.62	10.39	11.12	14.08	13.19	15.93	10.43	4.01	4.09
605	13.47	4.74	4.71	3.44	5.62	12.82	11.28	11.11	11.99	14.56	11.11	4.22	4.40
606	18.03	4.77	5.07	5.06	7.34	12.75	10.90	9.61	11.24	13.26	10.52	4.77	4.70
607	21.17	4.55	5.51	5.71	8.16	13.65	11.20	7.64	10.39	13.12	10.83	4.95	4.29
608	24.53	4.84	5.86	6.36	8.37	13.76	12.04	7.49	9.13	11.86	10.11	5.47	4.71
609	28.89	5.61	6.72	7.35	9.40	13.45	10.97	6.67	7.50	10.22	9.91	6.47	5.73

Table 3.3 Continued
Mean Monthly Precipitation as a Percentage of 1940-2013 Annual Means

Quad	Annual (inches)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)
610	32.78	6.27	7.19	7.77	9.28	12.60	10.01	6.37	6.62	9.41	9.96	7.58	6.93
611	38.27	7.07	7.61	8.24	9.13	12.12	9.13	5.50	6.17	8.45	9.92	8.52	8.14
612	43.80	7.92	7.76	8.15	8.64	10.51	9.31	6.31	6.33	8.35	8.93	9.20	8.61
613	48.74	8.83	8.34	8.08	8.47	9.92	8.82	6.54	6.29	7.90	8.03	9.28	9.51
614	52.94	9.17	8.76	8.59	8.67	9.60	8.44	7.38	6.24	7.05	7.31	8.89	9.91
701	9.33	5.44	4.78	2.82	3.53	4.95	8.51	17.66	17.27	15.39	9.74	4.41	5.49
702	16.09	4.98	4.90	5.07	5.72	8.23	10.08	13.28	13.25	13.91	9.88	5.14	5.55
703	13.85	4.26	3.13	2.23	2.89	6.50	12.49	17.58	17.61	16.33	9.52	3.68	3.79
704	14.97	4.20	3.16	2.46	4.03	9.45	12.80	15.76	15.91	16.07	9.37	3.34	3.45
705	13.65	4.70	4.21	3.40	6.04	11.98	11.85	10.93	11.81	15.66	11.38	4.41	3.62
706	18.99	5.08	5.12	5.54	8.20	12.14	11.21	8.50	10.20	13.23	11.34	5.25	4.19
707	22.43	4.73	5.57	5.77	8.55	12.34	11.35	8.40	10.65	11.80	10.88	5.62	4.35
708	25.41	4.82	6.04	6.23	8.74	12.93	11.50	7.68	9.42	11.80	10.37	5.74	4.73
709	30.43	5.65	6.72	6.96	8.86	12.83	10.95	6.47	6.96	10.91	10.71	7.07	5.92
710	32.80	6.63	7.27	6.93	8.80	11.99	9.93	6.10	6.47	10.12	10.65	8.02	7.08
711	39.43	7.53	7.58	7.21	8.64	11.06	9.58	5.82	6.39	9.52	9.84	8.69	8.14
712	46.32	7.98	7.42	6.86	8.22	9.98	9.62	7.13	6.94	8.77	9.07	9.44	8.56
713	53.82	8.22	7.62	6.85	8.01	9.24	9.56	8.22	7.16	8.31	8.52	8.99	9.29
714	56.05	8.75	7.56	7.11	7.68	8.87	9.29	9.54	7.87	8.36	7.23	8.38	9.36
803	20.72	5.30	6.80	5.98	7.82	9.58	11.31	11.00	10.98	10.90	8.64	6.60	5.08
804	14.84	4.52	4.27	3.51	5.35	10.01	12.00	14.53	13.79	13.75	9.54	4.81	3.90
805	11.74	4.73	4.23	3.06	5.58	11.94	12.75	12.66	12.65	14.34	10.33	4.24	3.49
806	16.75	4.30	4.95	4.86	7.59	12.93	12.30	9.36	10.03	14.48	11.47	4.36	3.38
807	24.57	4.71	5.67	6.38	8.61	12.59	11.42	8.09	9.28	12.01	10.33	5.89	5.02
808	26.54	5.13	5.83	6.22	8.32	12.58	11.05	8.48	9.59	11.61	10.69	5.79	4.73
809	31.28	5.80	6.48	6.19	8.48	12.08	10.87	7.06	7.72	11.60	10.91	6.97	5.82
810	34.42	6.49	6.59	6.04	8.75	11.63	10.81	6.58	7.15	11.25	10.63	7.72	6.37
811	41.53	7.16	6.82	6.14	7.94	10.71	10.20	7.39	7.50	10.37	10.11	8.46	7.19
812	46.78	7.43	6.61	6.23	7.00	8.90	10.13	8.97	8.66	10.57	9.18	8.63	7.67
813	48.30	7.80	6.17	6.16	6.83	8.59	9.75	9.58	9.38	11.28	8.34	7.92	8.21
814	56.42	8.49	6.43	6.22	6.61	7.86	9.33	11.87	10.15	9.75	7.38	7.81	8.09
907	20.80	4.33	4.90	4.22	8.66	14.70	12.07	8.67	9.94	13.92	10.85	4.17	3.56
908	22.06	4.74	5.56	5.04	8.21	13.39	12.08	7.42	9.40	13.13	11.67	5.07	4.29
909	25.41	5.43	5.90	5.39	8.15	12.45	10.74	8.10	8.65	13.39	10.46	6.10	5.24
910	35.26	6.27	6.43	6.11	7.68	10.93	9.90	8.38	8.41	12.89	10.10	6.71	6.19
911	39.60	7.02	6.42	5.55	6.08	9.86	9.54	8.67	8.89	13.35	10.80	7.35	6.47
912	43.71	7.45	6.42	5.87	7.00	9.23	9.94	8.88	8.49	11.60	9.44	8.16	7.53
1008	20.40	4.46	5.14	4.08	7.29	12.86	12.01	8.11	9.87	15.62	10.88	5.21	4.48
1009	23.86	5.05	5.57	4.36	6.85	12.31	11.48	8.16	9.25	16.56	10.63	5.21	4.54
1010	29.25	5.66	6.20	4.66	6.17	10.53	9.84	7.43	9.72	17.43	11.47	5.82	5.06
1011	34.55	6.54	6.53	4.95	5.68	9.64	8.93	7.66	9.41	16.66	11.58	6.48	5.92
1108	17.93	4.43	4.74	3.78	7.21	10.52	10.51	9.66	10.18	19.22	9.67	5.44	4.64
1109	21.74	5.12	5.31	3.92	6.08	11.09	11.32	7.88	9.31	18.93	11.44	4.81	4.79
1110	25.89	5.59	5.80	4.04	5.90	10.58	10.11	6.95	8.46	19.46	11.48	6.40	5.23
1210	26.12	5.26	5.17	3.46	5.74	9.41	10.40	6.90	9.40	20.64	12.50	6.04	5.09
Mean	27.90	5.90	6.14	6.40	7.94	11.55	10.71	8.86	8.99	11.09	9.47	6.67	6.28
Total	27.93	5.91	6.15	6.39	7.93	11.52	10.69	8.85	8.98	11.13	9.49	6.68	6.29

Table 3.4
Mean Monthly Evaporation as a Percentage of 1954-2013 Annual Means

Quad	Annual (inches)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)
104	59.59	3.71	4.85	8.03	9.76	9.92	12.42	12.61	11.19	9.62	7.88	5.74	4.27
105	67.05	3.12	4.13	7.06	9.22	9.47	12.79	14.49	12.48	10.15	7.96	5.30	3.82
106	67.08	3.06	4.05	7.04	9.03	9.34	12.80	14.79	12.77	10.24	7.98	5.19	3.71
107	64.10	3.32	4.11	7.23	8.92	9.09	12.43	14.54	13.05	10.25	7.97	5.28	3.81
108	57.49	3.61	4.44	7.23	8.53	8.70	11.94	14.34	13.31	10.15	8.34	5.38	4.03
204	63.37	3.62	4.68	7.61	9.57	10.29	12.80	12.92	11.52	9.61	7.72	5.56	4.09
205	66.57	3.35	4.35	7.09	9.43	9.77	12.65	13.89	12.17	9.79	8.21	5.44	3.86
206	66.29	3.19	4.16	7.07	9.41	9.74	12.64	14.18	12.38	9.91	8.14	5.38	3.79
207	63.55	3.30	4.14	7.34	9.27	9.30	12.32	14.18	12.64	9.95	8.16	5.45	3.94
208	56.84	3.72	4.61	7.16	8.50	8.64	11.81	14.45	13.17	9.93	8.18	5.55	4.28
304	63.24	3.84	4.96	8.10	9.69	10.33	12.66	12.76	11.25	8.96	7.60	5.65	4.19
305	64.39	3.69	4.76	7.56	9.69	10.13	12.50	13.16	11.48	9.17	8.01	5.70	4.16
306	66.53	3.54	4.45	7.28	9.58	9.93	12.37	13.46	11.94	9.59	8.22	5.65	3.97
307	66.12	3.52	4.31	7.22	9.01	9.19	12.16	14.15	12.68	9.78	8.11	5.76	4.09
308	64.57	3.54	4.36	6.79	8.66	8.87	12.28	14.62	13.20	9.92	8.08	5.62	4.07
309	58.82	3.57	4.26	7.05	8.78	8.94	12.12	14.35	13.10	9.97	8.06	5.64	4.17
404	64.51	3.89	4.97	8.09	10.03	10.49	12.95	12.61	11.29	9.01	7.39	5.29	3.99
405	66.57	3.93	4.89	7.87	10.01	10.33	12.51	12.81	11.00	9.03	7.81	5.61	4.21
406	68.35	3.91	4.75	7.68	9.67	10.01	12.12	13.12	11.55	9.31	7.87	5.75	4.27
407	69.71	3.68	4.50	7.47	9.19	9.34	11.98	13.62	12.52	9.60	8.03	5.80	4.27
408	64.51	3.73	4.40	7.07	8.83	8.92	11.95	14.15	13.19	9.64	8.18	5.74	4.19
409	60.67	3.58	4.12	6.97	8.63	9.04	12.05	14.39	13.43	10.07	8.20	5.48	4.04
410	55.14	3.69	4.34	7.09	8.50	8.86	12.02	13.82	13.51	10.20	8.22	5.65	4.10
411	53.45	3.84	4.52	7.15	8.56	8.78	11.78	13.89	13.30	10.16	8.14	5.69	4.20
412	52.93	3.84	4.60	7.17	8.44	8.86	11.67	13.36	13.18	10.26	8.15	6.10	4.36
413	43.88	3.86	4.54	7.21	8.68	9.55	12.02	13.37	13.23	10.08	7.72	5.40	4.34
414	38.78	3.99	4.74	7.10	9.06	9.87	12.04	13.44	12.97	10.01	7.53	4.96	4.28
504	67.66	3.74	4.63	7.84	10.38	11.07	13.03	12.74	11.50	9.09	7.07	4.97	3.93
505	71.03	3.75	4.57	7.66	10.02	10.39	12.61	13.08	11.76	9.28	7.53	5.30	4.04
506	69.71	3.94	4.67	7.76	9.68	9.81	12.24	13.32	12.04	9.33	7.59	5.48	4.13
507	64.86	3.86	4.67	7.65	9.31	9.47	12.17	13.42	12.28	9.65	7.79	5.59	4.13
508	63.11	3.84	4.53	7.39	9.24	9.28	12.03	13.42	12.59	9.69	8.08	5.71	4.19
509	59.35	3.93	4.50	7.23	8.80	8.83	11.97	13.92	12.95	9.96	8.08	5.69	4.13
510	57.87	3.69	4.35	7.01	8.39	8.74	11.89	14.29	13.54	10.30	8.15	5.61	4.03
511	57.13	3.80	4.41	7.07	8.40	8.71	11.67	13.85	13.45	10.50	8.36	5.68	4.10
512	55.02	3.71	4.58	7.21	8.39	9.05	11.64	13.41	13.32	10.39	8.40	5.71	4.19
513	49.28	3.65	4.51	7.28	8.79	9.75	11.98	13.26	13.04	10.25	8.00	5.34	4.14
514	45.57	3.85	4.62	7.21	9.03	10.16	12.17	13.23	12.77	10.02	7.68	5.10	4.16
601	70.40	3.77	4.81	7.89	10.51	11.66	13.67	12.57	10.56	8.88	7.14	4.88	3.66
602	71.19	3.81	4.97	8.10	10.57	11.70	13.47	12.33	10.40	8.73	7.24	4.97	3.73
603	65.53	3.97	4.86	8.21	10.48	11.29	12.75	12.36	11.08	8.77	7.17	5.04	4.02
604	69.11	4.07	4.85	7.93	10.35	11.07	12.53	12.51	11.42	8.90	7.12	5.21	4.03
605	71.47	3.78	4.67	7.81	10.06	10.50	12.55	12.98	11.72	9.14	7.28	5.40	4.12
606	68.12	3.85	4.59	7.83	9.79	9.97	12.37	13.27	12.11	9.30	7.57	5.27	4.07
607	65.66	3.81	4.45	7.60	9.68	9.96	12.44	13.70	12.47	9.30	7.43	5.19	3.97
608	65.10	3.85	4.51	7.44	9.46	9.52	12.02	13.43	12.60	9.74	7.85	5.50	4.08
609	56.72	3.89	4.51	7.32	8.84	8.77	11.95	13.79	13.04	9.96	8.00	5.73	4.19

Table 3.4 Continued
Mean Monthly Evaporation as a Percentage of 1954-2013 Annual Means

Quad	Annual (inches)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)
610	56.39	3.77	4.42	6.95	8.26	8.62	11.76	14.21	13.59	10.40	8.23	5.74	4.05
611	59.00	4.07	4.62	7.10	8.35	8.93	11.48	13.55	13.24	10.43	8.29	5.71	4.22
612	52.70	4.20	4.81	7.28	8.61	9.42	11.65	13.11	12.63	10.09	8.13	5.69	4.37
613	47.01	4.02	4.76	7.42	8.89	9.97	12.04	12.75	12.51	9.99	7.97	5.54	4.15
614	49.84	4.14	4.87	7.56	8.88	10.08	11.97	12.55	12.03	9.74	8.07	5.69	4.42
701	68.27	3.86	4.96	8.02	10.59	11.72	13.60	12.40	10.20	8.83	7.12	4.94	3.75
702	63.09	4.23	5.30	8.41	10.63	11.45	13.02	11.72	9.88	8.60	7.29	5.30	4.15
703	56.08	4.66	5.68	8.86	10.63	10.95	12.19	11.24	9.79	8.26	7.36	5.68	4.71
704	58.55	4.51	5.34	8.52	10.43	10.96	12.37	11.71	10.19	8.31	7.37	5.65	4.63
705	63.79	4.21	4.98	7.91	9.79	10.32	12.29	12.74	11.61	9.03	7.42	5.46	4.23
706	63.05	4.02	4.72	7.58	9.20	9.60	12.15	13.57	12.71	9.59	7.61	5.22	4.03
707	61.88	3.99	4.62	7.51	9.35	9.70	12.11	13.70	12.79	9.46	7.53	5.19	4.04
708	57.82	4.02	4.70	7.32	9.01	9.32	11.98	13.45	12.83	9.84	7.85	5.52	4.15
709	54.48	3.97	4.56	6.95	8.43	9.05	11.91	13.74	13.32	10.01	8.12	5.80	4.13
710	52.31	4.03	4.65	7.04	8.36	8.83	11.74	13.65	13.28	10.24	8.28	5.70	4.20
711	53.27	4.06	4.55	6.92	8.45	9.36	11.85	13.38	12.87	10.20	8.49	5.73	4.15
712	49.85	4.34	4.74	7.17	8.83	10.01	11.86	12.54	12.13	9.75	8.32	5.79	4.53
713	44.99	3.98	4.73	7.32	8.96	10.30	11.99	12.66	12.13	9.79	8.38	5.55	4.21
714	46.80	4.01	4.81	7.45	8.88	10.18	12.00	12.52	12.09	9.77	8.37	5.66	4.26
803	56.21	4.66	5.59	8.61	10.42	10.96	12.41	11.46	9.90	8.13	7.38	5.71	4.76
804	55.89	4.62	5.46	8.40	10.12	10.57	12.20	11.73	10.45	8.35	7.58	5.77	4.76
805	65.15	3.97	4.75	7.57	9.33	9.59	12.15	13.26	12.71	9.57	7.69	5.34	4.06
806	68.25	3.77	4.53	7.38	9.10	9.33	12.19	13.70	13.23	9.96	7.74	5.24	3.84
807	66.35	3.82	4.56	7.34	9.04	9.37	12.12	13.69	13.20	9.92	7.80	5.25	3.89
808	57.43	3.92	4.78	7.28	8.75	9.39	11.94	13.53	13.12	9.97	7.99	5.33	3.99
809	53.70	4.00	4.68	7.05	8.43	9.30	12.02	13.55	13.13	10.06	8.23	5.50	4.06
810	52.82	4.26	4.79	7.08	8.34	9.19	11.71	13.23	12.72	10.05	8.41	5.81	4.39
811	49.78	4.20	4.77	7.16	8.67	9.69	11.69	12.63	12.31	9.89	8.56	5.98	4.46
812	46.71	4.37	4.88	7.32	9.05	10.20	11.63	12.06	11.78	9.60	8.51	5.90	4.70
813	45.99	4.40	4.91	7.33	8.90	10.16	11.72	12.09	11.54	9.61	8.65	5.96	4.72
814	45.63	4.14	4.77	7.35	9.01	10.15	11.82	12.35	11.73	9.80	8.62	5.87	4.39
907	66.47	3.80	4.59	7.32	8.98	9.38	12.07	13.68	13.23	9.89	7.82	5.30	3.94
908	59.45	3.84	4.63	7.35	8.72	9.46	11.98	13.69	13.33	9.94	7.86	5.29	3.90
909	56.60	3.79	4.63	7.28	8.67	9.56	12.05	13.64	13.01	9.98	8.06	5.34	4.00
910	53.02	4.16	4.75	7.22	8.44	9.59	11.78	13.16	12.41	9.85	8.33	5.77	4.54
911	50.61	4.09	4.71	7.04	8.38	9.58	11.92	13.14	12.37	9.81	8.55	5.85	4.58
912	48.66	4.30	4.75	7.22	8.46	9.78	11.92	12.71	12.10	9.71	8.60	5.90	4.56
1008	66.26	3.87	4.91	7.53	8.94	9.63	12.20	13.74	13.05	9.34	7.53	5.33	3.93
1009	63.76	4.03	4.94	7.60	8.83	9.57	11.71	13.26	12.60	9.54	7.96	5.66	4.30
1010	59.57	4.28	4.94	7.41	8.60	9.69	11.44	12.62	12.22	9.67	8.48	5.92	4.75
1011	54.57	4.28	4.80	7.15	8.36	9.65	11.48	12.59	12.23	9.83	8.77	6.07	4.79
1108	65.96	3.85	4.97	7.64	9.27	10.11	12.18	13.42	12.78	9.14	7.38	5.35	3.92
1109	62.64	4.14	5.12	7.86	9.15	9.70	11.57	12.98	12.45	9.35	7.68	5.67	4.32
1110	62.56	4.38	5.18	7.73	9.06	9.64	11.24	12.67	12.02	9.26	8.23	5.94	4.65
1210	61.31	4.34	5.17	7.68	9.12	9.69	11.36	12.58	12.03	9.15	8.26	5.91	4.72
Mean	59.48	3.89	4.69	7.48	9.21	9.77	12.18	13.27	12.30	9.62	7.91	5.53	4.17
Total	59.45	3.90	4.69	7.48	9.21	9.77	12.17	13.26	12.30	9.61	7.91	5.53	4.17

The statewide 1940-2013 mean annual precipitation of 27.9 inches/year shown in Table 3.2 is for the entire state of Texas which covers an area of about 268,800 square miles of which about 263,200 square miles contribute drainage to the rivers. The 92 quads cover a total area of 373,028 square miles which includes all of Texas plus additional adjacent areas. The last two rows in Table 3.3 show an area-weighted mean of 27.93 inches/year for the 92 quadrangles recognizing that the different quads have different areas as shown in Table 3.1 and an arithmetic mean of 27.90 inches/year for the 92 quadrangles. Thus, the following means are all 27.9 inches:

- area-weighted mean of the 1940-2013 annual precipitation for the 92 quadrangles based on the areas listed in Table 3.1
- arithmetic mean of the 1940-2013 annual precipitation for the 92 quadrangles without consideration of the different areas of each quadrangle
- area-weighted mean of the 1940-2013 annual precipitation for the quadrangles considering only the area within Texas

The statewide mean reservoir evaporation rate of 60.6 inches/year in Table 3.2, which considers only area within Texas, differs a little from the area-weighted mean of 59.45 and arithmetic mean of 59.48 inches/year for the 92 quads shown in Table 3.4.

Tables 3.3 and 3.4 provide an indication of the seasonality of precipitation and evaporation. The monthly distribution of monthly means of precipitation and evaporation as a percentage of annual means varies between the 92 quads located in different regions of the states. From a statewide perspective, May is the wettest month with a 92-quad mean precipitation of 3.42 inches (11.52% of 29.73 inches) and January is the driest month with a 92-quad mean precipitation of 1.65 inches (5.91% of 29.73 inches). Mean evaporation over the 92 quads range from 2.48 and 2.32 inches for December and January to 7.88 and 7.31 inches in July and August.

Precipitation and evaporation metrics for each of the 92 quadrangles are presented in Tables 3.5 and 3.6, respectively. Each grid cell represents a quadrangle. The quadrangle identifiers from the map of Figure 3.1 are shown in the vertical and horizontal margins of Tables 3.5 and 3.6. Each grid cell (quad) in Tables 3.5 and 3.6 contains two numbers. The top number in each quad in Table 3.5 is the mean annual precipitation for the quad expressed as a percentage of the 92-quad mean of 27.93 inches/year. The top number for each quad in Table 3.6 is the mean annual evaporation for the quad expressed as a percentage of the 92-quad mean of 59.45 inches/year. The annual means are tabulated in inches in Tables 3.3 and 3.4 and as percentages of the total 92-quad means in Tables 3.5 and 3.6.

The second number in each quad in Tables 3.5 and 3.6 is the slope of the linear trend line expressed as a percentage of the mean for the particular quad. These quantities are from Tables 3.10 and 3.14 which are explained in the next section of this chapter.

As illustrated by Table 3.5, mean annual precipitation varies greatly while increasing fairly uniformly from west (dry) to east (wet) across the state. Quadrangle 601 at the dry western extreme of the state, which includes the city of El Paso, has a 1940-2013 mean annual precipitation of 11.1 inches/year which is 39.7 percent of the statewide mean of 27.9 inches/year. Since 11.1 inches/year is the average for the entire 4,050 square mile quadrangle, some sites within the quad will have an even lower mean annual precipitation. Quadrangle 713 in east

Texas has a mean annual precipitation of 53.8 inches/year which is 193 percent of the statewide mean. Quadrangle 714 which crosses the border, including areas in both Louisiana and Texas, has an even higher mean annual precipitation.

Table 3.5
Mean Annual Precipitation and Annual Trend Slopes

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
100				59.7 -0.116	63.5 -0.285	66.3 -0.255	74.4 0.0111	85.8 0.0423						
200				59.9 -0.388	65.2 -0.142	72.7 -0.085	85.6 0.0239	99.6 -0.105						
300				59.3 0.0503	64.5 0.0048	73.5 -0.0051	78.5 0.0954	92.1 0.0283	109.8 0.0170					
400				57.0 -0.0629	64.3 0.0488	81.7 -0.206	81.8 0.2055	90.1 0.0429	105.1 0.0378	122.2 0.0834	145.0 0.0668	164.2 -0.169	174.6 0.0111	182.1 -0.0228
500				55.7 -0.1322	61.3 -0.1734	74.3 -0.1167	80.8 -0.0035	93.5 0.0060	107.2 0.1213	119.9 0.0738	137.6 0.0651	154.9 -0.0692	169.8 0.0198	180.9 0.0540
600	39.6 0.0011	53.3 0.1139	53.0 -0.0737	41.6 0.1136	48.2 -0.0248	64.6 -0.2121	75.8 0.05032	87.8 0.2080	103.4 0.1323	117.3 0.2461	137.0 0.0894	156.8 0.0096	174.5 0.0164	189.5 0.0286
700	33.4 0.0939	57.6 -0.0515	49.6 0.0616	53.6 -0.0677	48.8 0.1222	68.0 -0.249	80.3 0.0824	91.0 0.0813	108.9 0.0773	117.4 0.1482	141.1 -0.0722	165.9 -0.0618	192.7 0.0631	200.6 0.1167
800			74.2 -2.8068	53.1 -1.1957	42.0 -0.1045	60.0 -0.0073	88.0 0.1006	95.0 0.2036	112.0 0.1065	123.2 0.1108	148.7 0.0518	167.5 0.1735	172.9 0.3287	202.0 0.0262
900							74.4 -0.1062	79.0 -0.0533	91.0 0.0321	126.2 -0.0471	141.8 0.0007	156.5 0.1002		
1000								73.0 0.0343	85.4 0.0556	104.7 0.0999	123.7 -0.0893			
1100								64.2 0.419	77.8 0.0559	92.7 0.0063				
1200										93.5 0.1219				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**

Fluctuations and Long-Term Trends

All of the precipitation statistics and plots presented in this chapter are for January 1940 through December 2013. Metrics presented in this chapter for reservoir surface evaporation rates are from a dataset that extends from January 1954 through December 2013. Plots of monthly precipitation for January 1940 through December 2012 and reservoir surface evaporation rates for January 1954 through December 2012 for each of the 92 quads are presented in Appendices

A and B. The plots in Appendices A and B were prepared prior to data for 2013 becoming available during 2014 and have not been updated. Annual precipitation and evaporation during 2013 were close to long-term means.

Table 3.6
Mean Annual Reservoir Surface Evaporation Rates and Annual Trend Slopes

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
100				100.24 0.2263	112.79 0.3436	112.84 0.2976	107.83 0.2760	100.04 0.3634						
200				106.59 0.4333	111.99 0.5165	111.51 0.4269	106.90 0.3208	98.91 0.3269						
300				106.38 0.3369	108.32 0.4934	111.92 0.5597	111.22 0.2577	108.62 0.1553	98.95 0.2547					
400				108.51 0.4010	111.97 0.5501	114.97 0.5751	117.26 0.4717	108.52 0.3135	102.06 0.4187	92.76 0.4215	89.91 -0.0080	89.04 0.0199	73.82 -0.0559	66.33 0.2451
500				113.81 0.1232	119.48 0.2144	117.26 0.2727	109.10 0.2191	106.15 0.0017	99.83 -0.0943	97.34 -0.1269	96.06 -0.0428	92.55 0.1313	82.89 0.1295	76.66 0.1695
600	118.42 -0.0876	199.75 0.0307	110.22 0.0392	116.25 0.0731	120.23 0.1315	114.58 -0.0493	110.45 -0.1589	109.51 0.0322	95.42 -0.0821	94.86 0.0605	99.25 0.1610	88.65 0.2490	79.08 0.2899	83.84 0.4612
700	118.79 -0.0481	106.12 -0.2279	94.33 -0.2306	98.50 -0.2291	107.30 0.0351	106.06 0.0276	104.09 -0.1661	97.25 0.1047	91.64 0.1539	88.00 -0.0741	89.61 0.1623	83.85 0.2943	75.67 0.2243	78.72 0.2998
800			94.54 -0.3136	94.01 -0.2133	109.59 0.2391	114.80 0.2385	111.61 0.1212	96.61 0.0587	90.32 -0.0066	88.86 -0.1314	83.74 0.1184	78.58 0.3282	77.35 0.3246	76.75 0.2984
900							111.81 0.2976	100.00 0.1829	95.20 0.1452	89.18 -0.0637	85.14 0.1020	81.84 0.3542		
1000								111.45 0.0976	107.24 -0.2544	100.21 -0.0429	91.79 0.0658			
1100								110.96 -0.2408	105.37 -0.2173	105.23 0.1971				
1200										103.13 0.1928				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**

Plots of monthly area-weighted total average precipitation over the 92 quads for January 1940 through December 2013 are presented in this chapter as Figures 3.2 and 3.3. Plots for 1954-2013 evaporation are presented as Figures 3.4 and 3.5. The sequences of monthly precipitation and evaporation depths in inches/month plotted in Figures 3.2 and 3.4 are the statewide area-weighted means for the 92 quads. Calendar year annual totals in inches/year of the monthly depths are plotted as the top line in Figures 3.3 and 3.5. The maximum and minimum depths in any two consecutive months of each year are also plotted in Figures 3.3 and 3.5. These are annual maxima and minima of two-month forward moving totals. Plots in this same format are provided in Appendices A and B for each of the 92 individual quadrangles. The 92-quad area-weight annual means of the 1940-2013 precipitation and 1954-2013 evaporation are tabulated in Table 3.7.

Table 3.7
Annual Precipitation and Evaporation

Year	Precip (inches)	Evap (inches)	Year	Precip (inches)	Evap (inches)	Year	Precip (inches)	Evap (inches)
1940	30.2		1965	26.6	59.9	1990	31.6	55.3
1941	40.6		1966	27.0	57.8	1991	37.1	65.7
1942	29.3		1967	26.4	62.3	1992	33.0	56.2
1943	22.4		1968	33.2	53.3	1993	27.8	67.6
1944	31.2		1969	29.3	54.4	1994	28.6	65.8
1945	28.4		1970	25.0	53.4	1995	30.7	59.8
1946	32.6		1971	28.7	59.3	1996	26.1	64.6
1947	24.2		1972	28.2	56.5	1997	34.4	58.6
1948	21.9		1973	36.3	53.7	1998	27.3	64.4
1949	33.8		1974	33.0	59.3	1999	21.9	59.8
1950	25.6		1975	28.5	54.1	2000	26.0	65.2
1951	22.8		1976	30.2	55.2	2001	27.2	58.7
1952	22.2		1977	24.1	61.1	2002	28.9	60.4
1953	24.2		1978	26.5	59.2	2003	24.5	60.6
1954	19.1	65.0	1979	32.4	56.0	2004	39.1	55.2
1955	23.3	60.6	1980	24.9	63.1	2005	22.3	58.7
1956	16.7	68.6	1981	32.1	55.5	2006	26.1	66.2
1957	35.8	55.7	1982	27.9	57.9	2007	35.4	53.6
1958	31.6	50.6	1983	27.1	58.5	2008	24.4	63.3
1959	29.9	55.0	1984	27.6	62.3	2009	28.4	63.2
1960	31.2	54.0	1985	30.9	56.1	2000	27.5	61.0
1961	29.2	53.7	1986	33.5	56.5	2011	13.6	73.0
1962	24.4	59.6	1987	30.8	53.8	2012	24.6	62.1
1963	19.9	62.9	1988	22.6	58.8	2013	27.0	60.6
1964	24.1	64.1	1989	26.4	59.6	mean	27.9	59.5

Figure 3.2 and the corresponding monthly precipitation plots in Appendix A show the tremendous variability of rainfall in Texas. Fluctuating wet and dry periods are also indicated by Table 3.7 and the annual plots of Figure 3.3 and Appendix A. The longest period of consecutive years with statewide annual precipitation each year being below the 1940-2013 mean of 27.9 inches/year is the 7-year period 1950-1956 with a 7-year mean of 22.0 inches/year. This most meteorological severe drought of record began gradually in 1950 and ended with one of the largest floods on record in April-May 1957. Two six-year periods with each year having below average annual precipitation, 1962-1967 and 2008-2013, have six-year means of 24.7 and 24.25 inches/year. The three driest years in Table 3.7 are 2011 with a statewide mean precipitation of 13.6 inches and 1954 and 1956 with 19.1 and 16.7 inches. The six wettest years are 1941 (40.6 inches), 1957 (35.8 inches), 1973 (36.3), 1991 (37.1), 2004 (39.1), and 2007 (35.4 inches).

Linear Regression Analyses to Detect Trends Reflecting Long-Term Changes

Long-term changes in hydrology due to global warming is of great interest to the science and water management communities and have been extensively addressed in the published literature. Long-term trends in precipitation, evaporation, and other hydrologic variables are very difficult to detect due to tremendous normal variability. Long-term trends are not evident in the precipitation plots of Appendix A. The plots of Appendix B suggest trends of increasing evaporation rates.

Linear regression analysis was applied to further explore the possibility of long-term changes in precipitation over the 74-year period 1940-2013 and changes in evaporation rates over the 60-year period 1954-2013 for the 92 quads. Standard least-squares linear regression computations were performed using the computer program HydStats. The purpose of the analyses was to detect any long-term trends in the precipitation and evaporation sequences that may have occurred. Regression analyses were performed for the following variables: monthly depths, annual depths, minimum depth occurring during any two consecutive months in each year, and maximum depth occurring during any two consecutive months in each year. These are the same variables that are plotted in Figures 3.2-3.5 and Appendices A and B. The results of the trend analyses are presented in the remaining tables of this chapter which are listed as follows.

Table 3.8 Summary of Means and Regression Slopes
Table 3.9 Monthly Precipitation Regression Results
Table 3.10 Annual Precipitation Regression Results
Table 3.11 Annual 2-Month Maximum Precipitation Regression Results
Table 3.12 Annual 2-Month Minimum Precipitation Regression Results
Table 3.13 Monthly Evaporation Regression Results
Table 3.14 Annual Evaporation Regression Results
Table 3.15 Annual 2-Month Maximum Evaporation Regression Results
Table 3.16 Annual 2-Month Minimum Evaporation Regression Results

Tables 3.9 through 3.16 are all in the same format. Table 3.8 summarizes information from Tables 3.9-3.16. Regression coefficients for each of the 92 quads are presented as a row in Tables 3.9-3.16. The next-to-last row is the arithmetic averages of the coefficients for the 92 quads. The last row in each table is the coefficients determined by applying the regression analysis to the area-weighted 92-quad means of the precipitation and evaporation data sequences.

Linear regression fits a straight line through data in the form of the following equation:

$$Y = aX + b$$

where the coefficients a and b are the slope and y-intercept. In this chapter, X is either months or years and Y is either precipitation or evaporation depth in inches. For an annual analysis, the slope (a) is in inches/year and for a monthly analysis is in inches/month. The intercept (b) is the precipitation depth at the beginning of 1940 or evaporation depth at the beginning of 1954 as computed by the regression equation (Y= aX+b). Least-squares regression equations are applied to the precipitation or evaporation sequences to compute the coefficients a and b. A slope (a) of zero and y-intercept (b) equal to the mean, or values very close thereto, indicate that there is no long term trend. A negative slope indicates a long-term decrease in the expected value or mean of precipitation or evaporation. A positive slope indicates an increase.

The quadrangle identifiers are listed in the first column of Tables 3.9 through 3.16. Means are tabulated in the 2nd column. The regression coefficients slope (a) and intercept (b) are in the 3rd and 4th columns. The 5th and 6th columns express the slope and intercept (3rd and 4th columns) as percentages of the mean (2nd column). The last column is the mean (2nd column) expressed as a percentage of the 92-quad area-weighted annual mean. For precipitation, the last column is the mean (2nd column) expressed as a percentage of 29.93 inches. For evaporation, the last column is the mean (2nd column) expressed as a percentage of 59.45 inches.

As previously discussed, the 92 quadrangles are delineated in Tables 3.5 and 3.6. The top number in each quad in Tables 3.5 and 3.6 is from the last column of Tables 3.10 and 3.14 and is the mean annual precipitation for the quad expressed as a percentage of the 92-quad mean of 27.93 inches/year or mean annual evaporation for the quad expressed as a percentage of the 92-quad mean of 59.45 inches/year. The second number in each quad in Tables 3.5 and 3.6 is the slope of the linear trend line expressed as a percentage of the mean for the particular quad. These quantities are from the 6th column of Tables 3.10 and 3.14.

The slopes for annual regressions of precipitation in Tables 3.10, 3.11, and 3.12 and evaporation in Tables 3.14, 3.15, and 3.16 are summarized in Table 3.8. The linear trend line fitted to 92-quad mean annual precipitation has a decreasing slope of 0.0389 inch per 100 years. Annual precipitation slopes are positive for 59 quads and negative for 33 quads. The trend metrics for two-month maxima and minima in each year provide an indication of long-term changes during the drier and wetter seasons. The minimum precipitation depth during any two consecutive months in each of the 74 years average 2.12 inches and has a decreasing trend slope of 0.50 inch in 100 years. Long-term trends are small relative to the tremendous rainfall variability that includes intense floods and multiple-year droughts as well as continuous less severe fluctuations. There are no evident long-term trends in participation.

Table 3.8
Means and Regression Slopes

	Trends for Annual Precipitation			Trends for Annual Evaporation		
	Annual Total	2-month Maximum	2-month Minimum	Annual Total	2-month Maximum	2-month Minimum
Mean depth (inches/year)	27.93	7.69	2.122	59.45	15.49	4.497
Slopes (inches/year)	-0.000389	0.01038	-0.005006	0.08137	0.003055	0.01868
Number of positive slopes	59	65	26	68	52	85
Number of negative slopes	33	27	66	24	40	7

Reservoir evaporation rates appear to be gradually increasing. The linear trend line fitted to 92-quad mean annual reservoir surface evaporation during the years 1954-2013 has an increasing slope of 8.14 inches in 100 years, with 68 quads having positive slopes and 24 negative slopes. A steady increase of evaporation rates since the 1960s at most of the quadrangles is also evident in the plots of Appendix B. Plots are presented in Appendix B for either 1940-2102 or 1954-2012 depending on data availability. The TWDB compiled evaporation rates for 1940-1953 using a different methodology than for 1954 and later data.

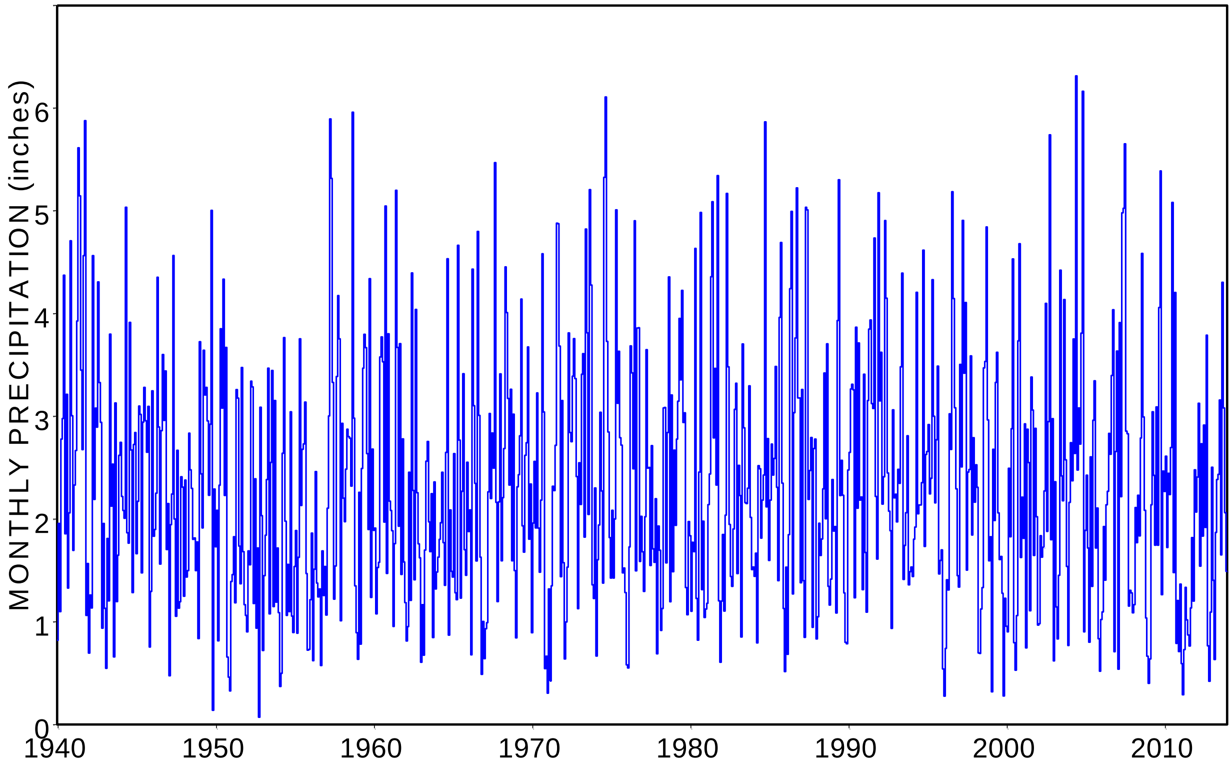

Figure 3.2 Monthly Precipitation during 1940-2013 for the 92 Quadrangles

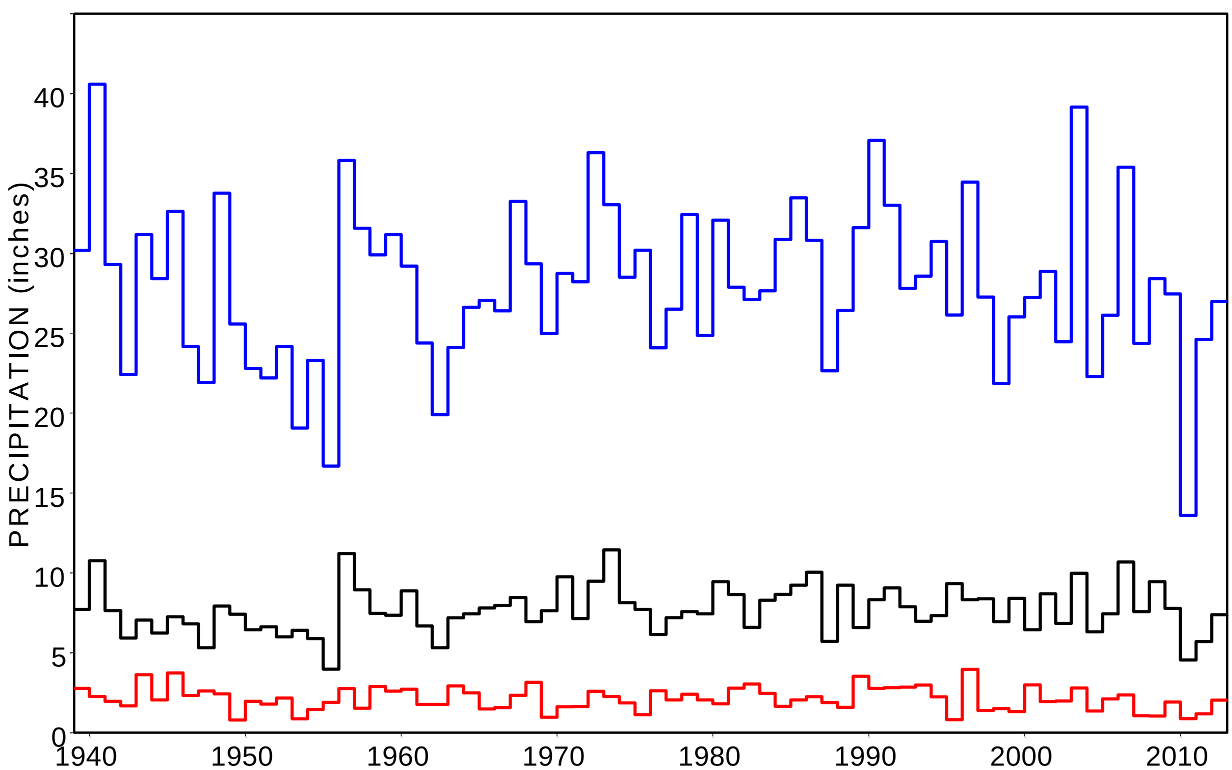

Figure 3.3 Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation During Each Year of 1940-2013 for the 92 Quadrangles

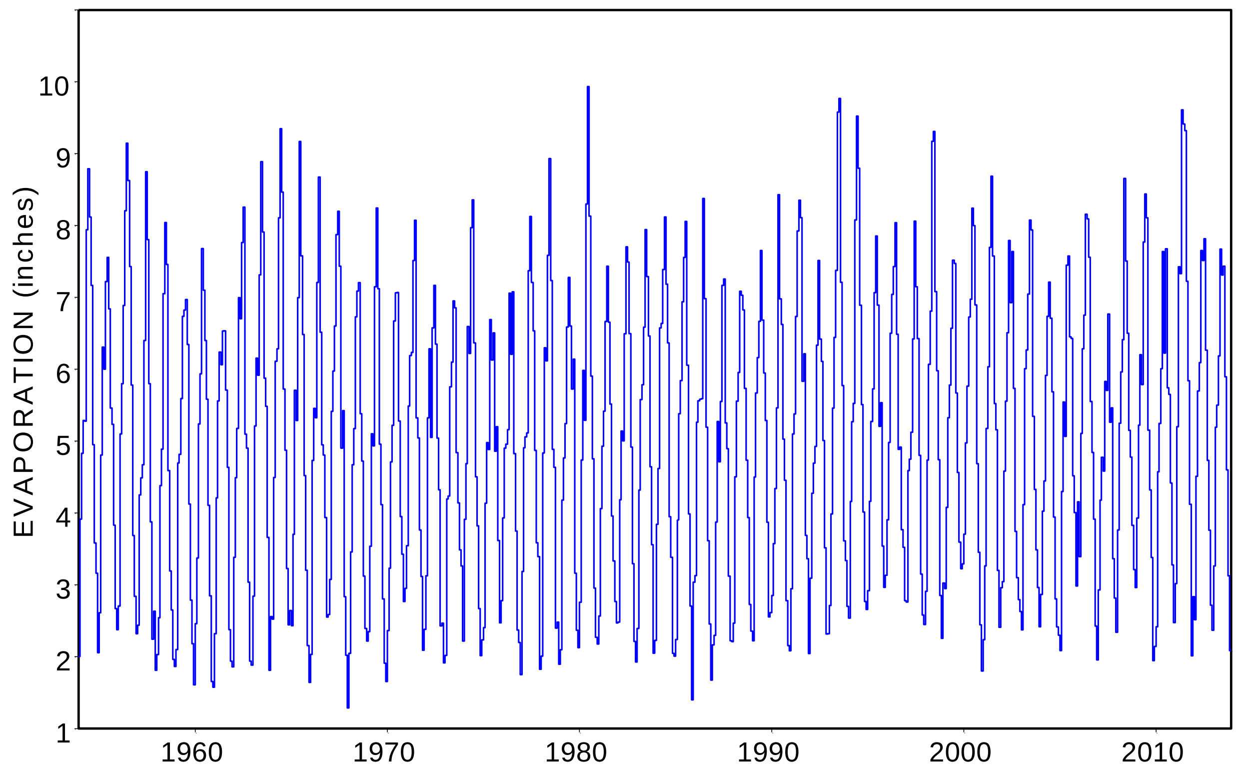

Figure 3.4 Monthly Reservoir Evaporation During 1954-2013 for the 92 Quadrangles

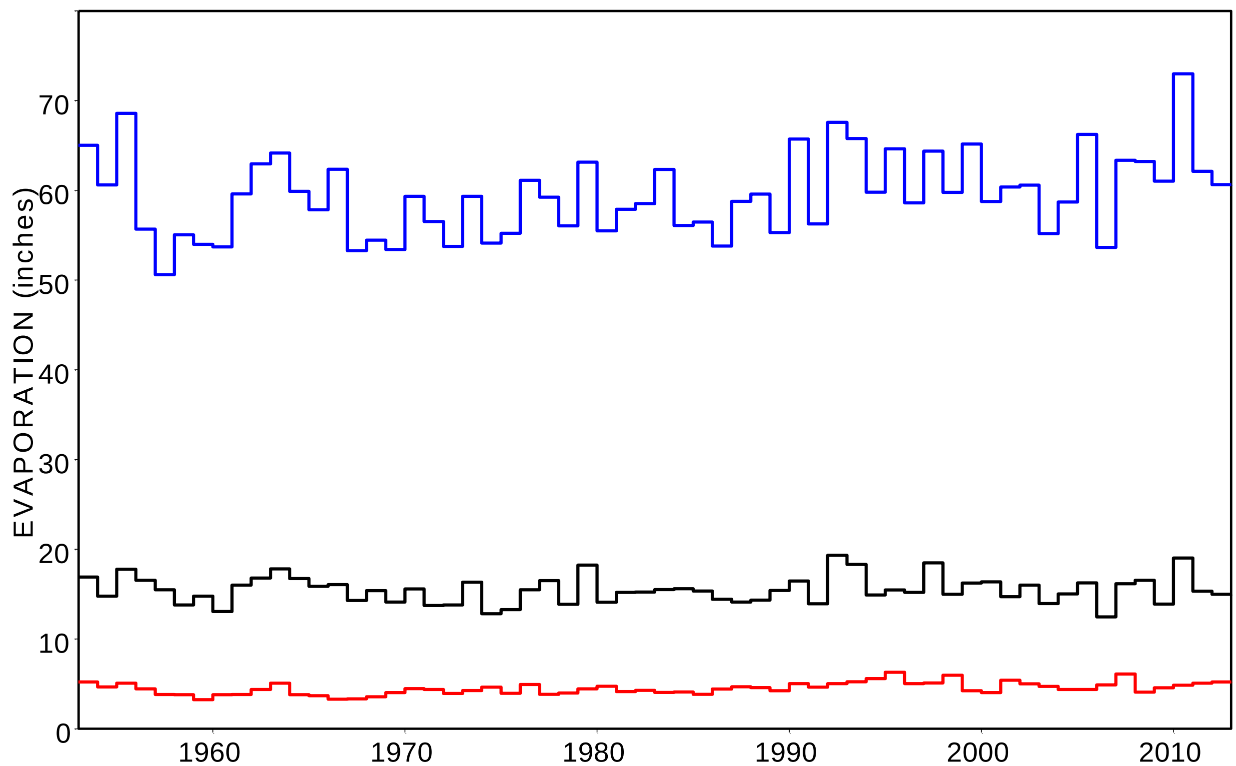

Figure 3.5 1954-2013 Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation During Each Year of 1954-2013 for the 92 Quadrangles

Table 3.9
Linear Regression Analysis of 1940-2013 Monthly Precipitation

Quad	Mean (inches)	Intercept (inches)	Slope (inch/month)	Intercept % Mean	Slope % Mean	Mean % Mean
104	1.3889	1.4461	-0.000129	104.117	-0.00926	4.9729
105	1.4778	1.6325	-0.000348	110.468	-0.02355	5.2909
106	1.5422	1.6865	-0.000325	109.359	-0.02105	5.5216
107	1.7327	1.7244	0.000019	99.519	0.00108	6.2039
108	1.9981	1.9658	0.000073	98.382	0.00364	7.1540
204	1.3942	1.5913	-0.000443	114.134	-0.03180	4.9918
205	1.5177	1.5944	-0.000173	105.055	-0.01137	5.4339
206	1.6914	1.7425	-0.000115	103.021	-0.00680	6.0558
207	1.9933	1.9742	0.000043	99.044	0.00215	7.1366
208	2.3171	2.4069	-0.000202	103.876	-0.00872	8.2962
304	1.3801	1.3497	0.000069	97.794	0.00496	4.9414
305	1.5006	1.4940	0.000015	99.557	0.00100	5.3727
306	1.7102	1.7113	-0.000002	100.062	-0.00014	6.1231
307	1.8271	1.7611	0.000148	96.389	0.00812	6.5416
308	2.1444	2.1205	0.000054	98.883	0.00251	7.6779
309	2.5567	2.5389	0.000040	99.305	0.00156	9.1539
404	1.3258	1.3517	-0.000058	101.955	-0.00440	4.7468
405	1.4955	1.4647	0.000069	97.938	0.00464	5.3544
406	1.9025	2.0458	-0.000322	107.534	-0.01695	6.8115
407	1.9048	1.7576	0.000331	92.274	0.01738	6.8199
408	2.0964	2.0611	0.000079	98.317	0.00379	7.5058
409	2.4451	2.4090	0.000081	98.524	0.00332	8.7545
410	2.8444	2.7557	0.000200	96.879	0.00702	10.1842
411	3.3753	3.2919	0.000188	97.530	0.00556	12.0847
412	3.8220	4.0608	-0.000537	106.247	-0.01405	13.6843
413	4.0634	4.0469	0.000037	99.594	0.00091	14.5484
414	4.2373	4.2749	-0.000085	100.889	-0.00200	15.1710
504	1.2966	1.3558	-0.000133	104.564	-0.01027	4.6423
505	1.4272	1.5154	-0.000198	106.175	-0.01389	5.1100
506	1.7301	1.8017	-0.000161	104.135	-0.00930	6.1945
507	1.8812	1.8810	0.000001	99.987	0.00003	6.7354
508	2.1768	2.1698	0.000016	99.677	0.00073	7.7938
509	2.4945	2.3823	0.000252	95.501	0.01012	8.9313
510	2.7911	2.7152	0.000171	97.281	0.00612	9.9932
511	3.2017	3.1249	0.000173	97.601	0.00540	11.4631
512	3.6046	3.6971	-0.000208	102.568	-0.00578	12.9057
513	3.9519	3.9242	0.000062	99.298	0.00158	14.1493
514	4.2110	4.1308	0.000180	98.096	0.00428	15.0769
601	0.9225	0.9185	0.000009	99.563	0.00098	3.3031
602	1.2394	1.1833	0.000126	95.467	0.01020	4.4376
603	1.2326	1.2610	-0.000064	102.302	-0.00518	4.4133
604	0.9680	0.9237	0.000100	95.421	0.01030	3.4657
605	1.1226	1.1296	-0.000016	100.623	-0.00140	4.0194
606	1.5028	1.6178	-0.000259	107.657	-0.01723	5.3805
607	1.7642	1.7289	0.000079	98.003	0.00449	6.3164

608	2.0442	1.8853	0.000357	92.227	0.01749	7.3189
609	2.4078	2.2899	0.000265	95.104	0.01102	8.6207
610	2.7313	2.4818	0.000561	90.867	0.02055	9.7790
611	3.1888	3.0825	0.000239	96.666	0.00750	11.4171
612	3.6502	3.6361	0.000032	99.613	0.00087	13.0692
613	4.0617	4.0371	0.000055	99.394	0.00136	14.5425
614	4.4113	4.3674	0.000099	99.005	0.00224	15.7942
701	0.7776	0.7466	0.000070	96.009	0.00898	2.7843
702	1.3411	1.3621	-0.000047	101.565	-0.00352	4.8018
703	1.1540	1.1215	0.000073	97.190	0.00632	4.1317
704	1.2475	1.2736	-0.000059	102.089	-0.00470	4.4666
705	1.1372	1.0822	0.000124	95.162	0.01088	4.0715
706	1.5824	1.7257	-0.000322	109.059	-0.02038	5.6654
707	1.8691	1.8095	0.000134	96.810	0.00718	6.6922
708	2.1175	2.0519	0.000148	96.902	0.00697	7.5816
709	2.5357	2.4614	0.000167	97.070	0.00659	9.0789
710	2.7336	2.5814	0.000343	94.430	0.01253	9.7874
711	3.2856	3.3710	-0.000192	102.602	-0.00585	11.7635
712	3.8603	3.9447	-0.000190	102.186	-0.00492	13.8214
713	4.4847	4.3754	0.000246	97.564	0.00548	16.0569
714	4.6710	4.4667	0.000460	95.627	0.00984	16.7239
803	1.7269	3.5212	-0.004037	203.906	-0.23376	6.1829
804	1.2362	1.7796	-0.001223	143.958	-0.09889	4.4261
805	0.9784	1.0135	-0.000079	103.591	-0.00808	3.5029
806	1.3962	1.3975	-0.000003	100.091	-0.00021	4.9989
807	2.0478	1.9690	0.000177	96.151	0.00866	7.3320
808	2.2114	2.0422	0.000380	92.352	0.01721	7.9175
809	2.6069	2.5008	0.000239	95.932	0.00915	9.3336
810	2.8686	2.7474	0.000273	95.775	0.00950	10.2707
811	3.4607	3.3894	0.000160	97.939	0.00464	12.3907
812	3.8982	3.6401	0.000581	93.380	0.01489	13.9571
813	4.0248	3.5267	0.001121	87.623	0.02784	14.4103
814	4.7015	4.6494	0.000117	98.892	0.00249	16.8331
907	1.7330	1.7988	-0.000148	103.796	-0.00854	6.2049
908	1.8385	1.8720	-0.000075	101.822	-0.00410	6.5824
909	2.1177	2.0892	0.000064	98.654	0.00303	7.5823
910	2.9381	2.9847	-0.000105	101.586	-0.00357	10.5195
911	3.2999	3.2910	0.000020	99.731	0.00061	11.8147
912	3.6425	3.4998	0.000321	96.083	0.00881	13.0414
1008	1.6999	1.6739	0.000059	98.469	0.00344	6.0863
1009	1.9882	1.9425	0.000103	97.700	0.00517	7.1185
1010	2.4377	2.3401	0.000219	95.998	0.00900	8.7278
1011	2.8792	2.9655	-0.000194	102.995	-0.00674	10.3087
1108	1.4941	1.2570	0.000534	84.127	0.03571	5.3495
1109	1.8114	1.7677	0.000098	97.591	0.00542	6.4854
1110	2.1574	2.1442	0.000030	99.388	0.00138	7.7243
1210	2.1766	2.0681	0.000244	95.013	0.01122	7.7931
Mean	2.3247	2.3233	0.000003	100.872	-0.00196	8.3231
Total	2.3275	2.3258	0.000004	99.926	0.00017	8.3333

Table 3.10
Linear Trend Regression Analysis of 1940-2013 Annual Precipitation

Quad	Mean (in/yr)	Intercept (inches)	Slope (inches/yr)	Intercept % Mean	Slope % Mean	Mean % Mean
104	16.67	17.3912	-0.019308	104.344	-0.11584	59.6747
105	17.73	19.6292	-0.050563	110.692	-0.28513	63.4911
106	18.51	20.2783	-0.047251	109.575	-0.25532	66.2597
107	20.79	20.7061	0.002316	99.582	0.01114	74.4466
108	23.98	23.5912	0.010297	98.390	0.04295	85.8477
204	16.73	19.1630	-0.064869	114.540	-0.38773	59.9011
205	18.21	19.1807	-0.025828	105.318	-0.14182	65.2063
206	20.30	20.9443	-0.017269	103.191	-0.08508	72.6699
207	23.92	23.7049	0.005710	99.105	0.02387	85.6391
208	27.81	28.8985	-0.029146	103.931	-0.10482	99.5542
304	16.56	16.2495	0.008322	98.116	0.05025	59.2968
305	18.01	17.9746	0.000871	99.819	0.00484	64.4728
306	20.52	20.5617	-0.001052	100.192	-0.00513	73.4775
307	21.92	21.1400	0.020925	96.421	0.09544	78.4987
308	25.73	25.4605	0.007278	98.940	0.02828	92.1351
309	30.68	30.4846	0.005215	99.363	0.01700	109.8463
404	15.91	16.2848	-0.010012	102.360	-0.06293	56.9613
405	17.95	17.6179	0.008749	98.172	0.04875	64.2532
406	22.83	24.5970	-0.047131	107.742	-0.20645	81.7385
407	22.86	21.0964	0.046963	92.295	0.20546	81.8386
408	25.16	24.7522	0.010782	98.393	0.04286	90.0696
409	29.34	28.9254	0.011096	98.582	0.03782	105.0535
410	34.13	33.0655	0.028477	96.871	0.08343	122.2102
411	40.50	39.4885	0.027059	97.495	0.06681	145.0167
412	45.86	48.7641	-0.077325	106.322	-0.16859	164.2119
413	48.76	48.5569	0.005429	99.583	0.01113	174.5809
414	50.85	51.2818	-0.011589	100.855	-0.02279	182.0518
504	15.56	16.3303	-0.020567	104.957	-0.13218	55.7072
505	17.13	18.2405	-0.029700	106.503	-0.17341	61.3202
506	20.76	21.6700	-0.024228	104.376	-0.11670	74.3339
507	22.57	22.6042	-0.000792	100.132	-0.00351	80.8250
508	26.12	26.0626	0.001574	99.774	0.00602	93.5251
509	29.93	28.5725	0.036316	95.451	0.12132	107.1760
510	33.49	32.5651	0.024749	97.229	0.07389	119.9183
511	38.42	37.4820	0.025011	97.559	0.06510	137.5574
512	43.25	44.3775	-0.029938	102.596	-0.06921	154.8685
513	47.42	47.0711	0.009383	99.258	0.01979	169.7919
514	50.53	49.5080	0.027299	97.974	0.05402	180.9225
601	11.07	11.0662	0.000117	99.960	0.00105	39.6367
602	14.87	14.2380	0.016939	95.729	0.11389	53.2518
603	14.79	15.2002	-0.010900	102.763	-0.07369	52.9590
604	11.62	11.1209	0.013197	95.740	0.11361	41.5889
605	13.47	13.5968	-0.003346	100.931	-0.02483	48.2325
606	18.03	19.4675	-0.038248	107.954	-0.21209	64.5657
607	21.17	20.7705	0.010654	98.113	0.05032	75.7965

608	24.53	22.6164	0.051029	92.199	0.20803	87.8265
609	28.89	27.4595	0.038229	95.038	0.13231	103.4481
610	32.78	29.7502	0.080671	90.770	0.24613	117.3482
611	38.27	36.9828	0.034206	96.648	0.08939	137.0049
612	43.80	43.6450	0.004213	99.639	0.00962	156.8310
613	48.74	48.4409	0.007999	99.385	0.01641	174.5103
614	52.94	52.3684	0.015138	98.928	0.02860	189.5309
701	9.33	9.0029	0.008769	96.476	0.09397	33.4112
702	16.09	16.4046	-0.008288	101.931	-0.05150	57.6217
703	13.85	13.5278	0.008531	97.690	0.06160	49.5799
704	14.97	15.3507	-0.010145	102.541	-0.06777	53.5991
705	13.65	13.0210	0.016673	95.418	0.12218	48.8585
706	18.99	20.7616	-0.047288	109.339	-0.24904	67.9850
707	22.43	21.7360	0.018492	96.908	0.08244	80.3058
708	25.41	24.6363	0.020648	96.953	0.08126	90.9792
709	30.43	29.5473	0.023507	97.103	0.07725	108.9464
710	32.80	30.9804	0.048620	94.442	0.14822	117.4492
711	39.43	40.4947	-0.028483	102.709	-0.07224	141.1620
712	46.32	47.3987	-0.028656	102.320	-0.06186	165.8574
713	53.82	52.5435	0.033946	97.635	0.06308	192.6831
714	56.05	53.5997	0.065388	95.625	0.11666	200.6862
803	20.72	42.5490	-0.582034	205.326	-2.80868	74.1950
804	14.83	21.4863	-0.177378	144.839	-1.19571	53.1134
805	11.74	12.2007	-0.012278	103.922	-0.10458	42.0345
806	16.75	16.8006	-0.001235	100.277	-0.00737	59.9867
807	24.57	23.6470	0.024717	96.228	0.10058	87.9838
808	26.54	24.5098	0.054037	92.364	0.20363	95.0095
809	31.28	30.0331	0.033322	96.006	0.10652	112.0037
810	34.42	32.9930	0.038146	95.845	0.11081	123.2490
811	41.53	40.7226	0.021495	98.059	0.05176	148.6880
812	46.78	43.7347	0.081172	93.493	0.17352	167.4850
813	48.30	42.3441	0.158759	87.673	0.32871	172.9233
814	56.42	55.8644	0.014763	99.019	0.02617	201.9974
907	20.80	21.6242	-0.022076	103.981	-0.10615	74.4587
908	22.06	22.5027	-0.011758	101.999	-0.05330	78.9893
909	25.41	25.1073	0.008147	98.798	0.03206	90.9874
910	35.26	35.8798	-0.016601	101.766	-0.04708	126.2343
911	39.60	39.5876	0.000287	99.973	0.00073	141.7770
912	43.71	42.0674	0.043788	96.243	0.10018	156.4962
1008	20.40	20.1364	0.006996	98.714	0.03430	73.0352
1009	23.86	23.3609	0.013267	97.915	0.05561	85.4219
1010	29.25	28.1561	0.029225	96.253	0.09991	104.7332
1011	34.55	35.7076	-0.030851	103.348	-0.08929	123.7043
1108	17.93	15.1141	0.075077	84.298	0.41873	64.1942
1109	21.74	21.2808	0.012156	97.903	0.05592	77.8252
1110	25.89	25.8277	0.001633	99.764	0.00631	92.6920
1210	26.12	24.9257	0.031830	95.430	0.12187	93.5169
Mean	27.90	27.9148	-0.000506	101.047	-0.02792	99.8776
Total	27.93	27.9447	-0.000389	100.052	-0.00139	100.0000

Table 3.11
Linear Trend Regression Analysis of Annual 2-Month Maximum Precipitation

Quad	Mean (inches)	Intercept (inches)	Slope (inch/year)	Intercept % Mean	Slope % Mean	Mean % Mean
104	6.6732	6.8923	-0.005842	103.283	-0.08755	23.8927
105	6.4147	6.4649	-0.001338	100.782	-0.02086	22.9671
106	7.3054	8.1654	-0.022934	111.773	-0.31394	26.1561
107	7.7177	8.0851	-0.009798	104.761	-0.12695	27.6323
108	8.6595	8.9941	-0.008924	103.865	-0.10306	31.0041
204	6.4773	6.9786	-0.013367	107.739	-0.20637	23.1911
205	6.7285	7.1639	-0.011609	106.470	-0.17254	24.0906
206	7.7268	8.5475	-0.021886	110.622	-0.28325	27.6647
207	8.6059	8.9881	-0.010190	104.440	-0.11841	30.8125
208	9.3396	9.4030	-0.001690	100.679	-0.01810	33.4392
304	6.6628	6.7830	-0.003204	101.803	-0.04809	23.8554
305	6.8400	6.6474	0.005137	97.184	0.07510	24.4898
306	7.7647	8.0847	-0.008534	104.121	-0.10990	27.8006
307	8.2008	8.5030	-0.008059	103.685	-0.09827	29.3620
308	9.4455	9.9549	-0.013584	105.393	-0.14381	33.8186
309	10.5300	10.4095	0.003214	98.856	0.03052	37.7013
404	6.4872	6.3592	0.003414	98.027	0.05262	23.2265
405	7.1914	7.3380	-0.003911	102.039	-0.05438	25.7477
406	7.7405	7.7161	0.000652	99.684	0.00843	27.7140
407	8.0336	7.3001	0.019560	90.870	0.24348	28.7635
408	8.9793	8.7170	0.006995	97.079	0.07790	32.1493
409	9.8839	9.8581	0.000689	99.739	0.00697	35.3881
410	11.0112	10.8541	0.004190	98.573	0.03805	39.4242
411	12.5746	12.1542	0.011211	96.657	0.08916	45.0217
412	13.2481	13.6159	-0.009807	102.776	-0.07402	47.4332
413	14.0596	13.9993	0.001607	99.571	0.01143	50.3386
414	14.3604	14.0675	0.007810	97.961	0.05439	51.4156
504	6.0308	5.9313	0.002655	98.349	0.04402	21.5926
505	6.4793	6.4487	0.000816	99.528	0.01259	23.1984
506	7.2569	7.2656	-0.000231	100.120	-0.00319	25.9824
507	7.9568	7.8822	0.001990	99.062	0.02500	28.4882
508	8.8087	8.9047	-0.002561	101.090	-0.02907	31.5383
509	9.7730	9.4116	0.009636	96.303	0.09860	34.9909
510	10.6635	10.3340	0.008788	96.910	0.08241	38.1794
511	11.8524	11.7385	0.003039	99.038	0.02564	42.4361
512	12.9215	13.2563	-0.008928	102.591	-0.06909	46.2637
513	13.6142	12.9757	0.017027	95.310	0.12507	48.7439
514	14.3368	13.2543	0.028866	92.450	0.20135	51.3309
601	4.1904	3.8678	0.008603	92.301	0.20531	15.0032
602	5.2278	4.9764	0.006704	95.191	0.12823	18.7176
603	5.7004	5.5748	0.003350	97.796	0.05877	20.4096
604	4.8251	4.3933	0.011515	91.051	0.23864	17.2758
605	5.2193	4.9856	0.006232	95.522	0.11941	18.6871
606	6.3853	6.5113	-0.003361	101.974	-0.05264	22.8616
607	7.3753	7.3505	0.000660	99.664	0.00895	26.4062

608	8.2746	7.7958	0.012768	94.213	0.15431	29.6261
609	9.1019	8.6650	0.011651	95.200	0.12801	32.5882
610	10.1774	8.7442	0.038219	85.918	0.37552	36.4390
611	11.3301	10.3597	0.025879	91.435	0.22841	40.5661
612	12.5268	12.2070	0.008528	97.447	0.06808	44.8504
613	13.9196	13.6763	0.006488	98.252	0.04661	49.8373
614	15.2186	14.8185	0.010671	97.371	0.07012	54.4884
701	4.3053	4.0569	0.006622	94.232	0.15382	15.4145
702	5.7592	5.6422	0.003121	97.968	0.05419	20.6200
703	5.9766	5.7059	0.007219	95.471	0.12078	21.3985
704	6.2080	6.0397	0.004487	97.290	0.07228	22.2269
705	5.3984	4.8836	0.013729	90.464	0.25431	19.3282
706	6.8986	6.8882	0.000280	99.848	0.00405	24.6997
707	7.7481	7.5788	0.004515	97.815	0.05828	27.7411
708	8.5111	8.0997	0.010971	95.166	0.12890	30.4728
709	9.7414	8.4128	0.035428	86.362	0.36368	34.8777
710	10.2457	8.4495	0.047898	82.469	0.46749	36.6833
711	11.8423	11.1648	0.018066	94.279	0.15256	42.3998
712	13.4742	12.6352	0.022373	93.774	0.16604	48.2426
713	15.3268	14.3420	0.026260	93.575	0.17134	54.8755
714	15.7280	14.9409	0.020988	94.996	0.13344	56.3120
803	7.5301	13.2822	-0.153389	176.387	-2.03700	26.9607
804	5.6945	7.2177	-0.040620	126.749	-0.71332	20.3883
805	4.6816	4.4652	0.005770	95.378	0.12325	16.7620
806	6.9358	7.0810	-0.003870	102.093	-0.05580	24.8328
807	8.3272	8.2911	0.000961	99.567	0.01154	29.8143
808	9.1766	8.0224	0.030780	87.422	0.33541	32.8557
809	10.5189	8.8198	0.045310	83.847	0.43074	37.6616
810	11.2323	9.9340	0.034622	88.441	0.30823	40.2158
811	12.6943	11.5264	0.031144	90.800	0.24534	45.4504
812	13.9774	12.7012	0.034034	90.869	0.24349	50.0444
813	14.5962	12.6168	0.052784	86.439	0.36163	52.2599
814	16.7015	16.0400	0.017639	96.039	0.10562	59.7976
907	8.3426	8.9200	-0.015398	106.922	-0.18458	29.8695
908	8.2416	8.6713	-0.011458	105.214	-0.13903	29.5081
909	8.8216	8.4846	0.008987	96.180	0.10187	31.5847
910	11.1824	10.7713	0.010964	96.323	0.09804	40.0373
911	13.2688	13.1536	0.003071	99.132	0.02314	47.5072
912	13.2234	11.5210	0.045396	87.126	0.34330	47.3446
1008	7.8177	8.2592	-0.011774	105.648	-0.15061	27.9903
1009	9.0316	9.1461	-0.003053	101.268	-0.03380	32.3366
1010	11.1920	10.7074	0.012924	95.670	0.11548	40.0716
1011	12.7849	12.5898	0.005203	98.474	0.04069	45.7746
1108	7.0078	5.7656	0.033126	82.274	0.47270	25.0907
1109	8.7128	8.2713	0.011775	94.932	0.13515	31.1952
1110	9.9342	9.6893	0.006530	97.535	0.06573	35.5681
1210	10.6489	10.2517	0.010593	96.270	0.09947	38.1271
Mean	9.3181	9.1132	0.005465	98.513	0.03965	33.3624
Total	7.6870	7.2976	0.010383	94.935	0.13508	27.5224

Table 3.12
Linear Trend Regression Analysis of Annual 2-Month Minimum Precipitation

Quad	Mean (inches)	Intercept (inches)	Slope (inch/year)	Intercept % Mean	Slope % Mean	Mean % Mean
104	0.3888	0.4040	-0.000405	103.907	-0.10418	1.3920
105	0.6196	0.9419	-0.008595	152.018	-1.38713	2.2184
106	0.4268	0.4840	-0.001526	113.409	-0.35757	1.5279
107	0.5792	0.5820	-0.000074	100.479	-0.01278	2.0737
108	0.7782	0.9126	-0.003584	117.268	-0.46049	2.7864
204	0.4403	0.6425	-0.005394	145.942	-1.22512	1.5763
205	0.5870	0.7305	-0.003825	124.432	-0.65153	2.1018
206	0.5778	0.5666	0.000299	98.057	0.05182	2.0689
207	0.8900	0.9024	-0.000330	101.389	-0.03704	3.1865
208	1.3309	1.7666	-0.011618	132.735	-0.87292	4.7653
304	0.3859	0.4033	-0.000464	104.504	-0.12010	1.3818
305	0.5500	0.6768	-0.003381	123.054	-0.61477	1.9692
306	0.5915	0.5556	0.000957	93.932	0.16182	2.1177
307	0.6304	0.5756	0.001462	91.304	0.23189	2.2571
308	0.8973	0.8504	0.001250	94.775	0.13933	3.2127
309	1.3619	1.2019	0.004267	88.250	0.31333	4.8761
404	0.3500	0.4164	-0.001771	118.971	-0.50589	1.2531
405	0.4069	0.3417	0.001740	83.967	0.42755	1.4568
406	0.9955	1.3795	-0.010239	138.569	-1.02852	3.5644
407	0.8781	0.7936	0.002252	90.381	0.25652	3.1440
408	0.9468	0.8689	0.002077	91.775	0.21934	3.3897
409	1.3549	1.1485	0.005504	84.766	0.40624	4.8509
410	1.8822	1.5018	0.010142	79.793	0.53885	6.7388
411	2.4966	2.2894	0.005526	91.699	0.22136	8.9388
412	3.1786	3.4012	-0.005936	107.003	-0.18674	11.3807
413	3.4768	3.2323	0.006520	92.968	0.18752	12.4481
414	3.8549	3.7999	0.001466	98.574	0.03804	13.8019
504	0.5354	0.7141	-0.004764	133.366	-0.88977	1.9170
505	0.5366	0.6358	-0.002644	118.476	-0.49270	1.9213
506	0.8195	1.0699	-0.006680	130.567	-0.81512	2.9340
507	0.8343	0.9172	-0.002210	109.931	-0.26483	2.9872
508	1.1055	1.0888	0.000446	98.489	0.04031	3.9582
509	1.4254	1.3087	0.003112	91.814	0.21831	5.1035
510	1.9130	1.6316	0.007502	85.294	0.39217	6.8492
511	2.4805	2.3567	0.003303	95.006	0.13317	8.8813
512	3.0080	2.9478	0.001605	97.999	0.05335	10.7697
513	3.4676	3.1597	0.008209	91.122	0.23675	12.4152
514	3.7912	3.4445	0.009246	90.855	0.24387	13.5740
601	0.4720	0.5447	-0.001938	115.400	-0.41065	1.6900
602	0.7192	0.7134	0.000153	99.202	0.02129	2.5750
603	0.4559	0.5217	-0.001753	114.417	-0.38444	1.6325
604	0.2107	0.1743	0.000970	82.726	0.46064	0.7543
605	0.3243	0.3903	-0.001759	120.343	-0.54247	1.1612
606	0.6055	1.0928	-0.012993	180.465	-2.14573	2.1681
607	0.7031	0.8003	-0.002591	113.817	-0.36845	2.5174

608	0.9912	0.9643	0.000718	97.286	0.07239	3.5489
609	1.4330	1.4592	-0.000698	101.828	-0.04874	5.1306
610	1.8693	1.8626	0.000180	99.640	0.00961	6.6929
611	2.5346	2.7082	-0.004629	106.848	-0.18262	9.0748
612	3.3005	3.5384	-0.006342	107.206	-0.19216	11.8172
613	3.7747	3.8618	-0.002322	102.307	-0.06152	13.5149
614	4.0680	4.1356	-0.001803	101.662	-0.04432	14.5649
701	0.1743	0.1863	-0.000320	106.881	-0.18350	0.6241
702	0.7341	0.7986	-0.001720	108.787	-0.23431	2.6282
703	0.2480	0.2203	0.000739	88.822	0.29807	0.8878
704	0.2834	0.3396	-0.001499	119.843	-0.52913	1.0146
705	0.3196	0.3610	-0.001104	112.951	-0.34536	1.1443
706	0.7186	1.2844	-0.015087	178.728	-2.09942	2.5730
707	0.8789	0.9504	-0.001907	108.136	-0.21695	3.1469
708	1.0239	1.2037	-0.004794	117.557	-0.46819	3.6660
709	1.4600	1.7092	-0.006645	117.068	-0.45515	5.2273
710	1.9234	2.0868	-0.004359	108.499	-0.22664	6.8864
711	2.6030	2.8280	-0.006001	108.645	-0.23054	9.3196
712	3.6566	4.0138	-0.009525	109.768	-0.26048	13.0921
713	4.1647	4.4436	-0.007436	106.695	-0.17854	14.9113
714	4.4473	4.4757	-0.000758	100.639	-0.01705	15.9230
803	0.9227	2.7112	-0.047693	293.831	-5.16882	3.3036
804	0.4685	1.1088	-0.017075	236.669	-3.64451	1.6775
805	0.2753	0.3900	-0.003059	141.679	-1.11144	0.9856
806	0.4476	0.5394	-0.002448	120.508	-0.54688	1.6025
807	1.1977	1.2779	-0.002138	106.695	-0.17854	4.2882
808	1.1649	1.5509	-0.010293	133.136	-0.88363	4.1707
809	1.4523	2.0341	-0.015516	140.064	-1.06837	5.1998
810	1.9115	2.2395	-0.008747	117.160	-0.45761	6.8438
811	2.7714	3.0974	-0.008694	111.764	-0.31371	9.9225
812	3.2065	3.4291	-0.005937	106.944	-0.18517	11.4804
813	3.2458	3.3829	-0.003655	104.223	-0.11261	11.6212
814	4.0146	4.2678	-0.006753	106.308	-0.16822	14.3737
907	0.5234	0.7458	-0.005931	142.496	-1.13321	1.8739
908	0.7242	0.9094	-0.004938	125.573	-0.68193	2.5929
909	1.1268	1.3332	-0.005506	118.324	-0.48865	4.0342
910	2.1118	2.7497	-0.017013	130.211	-0.80564	7.5609
911	2.1007	2.3633	-0.007004	112.504	-0.33343	7.5212
912	2.9774	3.7446	-0.020459	125.767	-0.68713	10.6603
1008	0.5632	0.6426	-0.002115	114.084	-0.37557	2.0166
1009	0.7628	0.9058	-0.003812	118.738	-0.49968	2.7312
1010	1.0916	1.1593	-0.001805	106.202	-0.16537	3.9084
1011	1.4370	1.8692	-0.011523	130.071	-0.80190	5.1451
1108	0.5343	0.5350	-0.000017	100.123	-0.00327	1.9131
1109	0.6855	0.6704	0.000404	97.791	0.05891	2.4545
1110	0.9600	1.1375	-0.004733	118.490	-0.49306	3.4372
1210	0.7982	0.9081	-0.002931	113.768	-0.36713	2.8580
Mean	1.4386	1.5654	-0.003382	114.306	-0.38148	5.1506
Total	2.1220	2.3098	-0.005006	108.846	-0.23590	7.5977

Table 3.13
Linear Regression Analysis of 1954-2013 Monthly Evaporation

Quad	Mean (inches)	Intercept (inches)	Slope (inch/month)	Intercept % Mean	Slope % Mean	Mean % Mean
104	4.9661	4.6253	0.000945	93.1375	0.01904	8.3536
105	5.5877	5.0018	0.001625	89.5149	0.02908	9.3992
106	5.5903	5.0809	0.001413	90.8876	0.02528	9.4036
107	5.3420	4.8899	0.001254	91.5354	0.02348	8.9860
108	4.9558	4.4233	0.001528	89.2541	0.03083	8.3363
204	5.2805	4.5894	0.001917	86.9117	0.03631	8.8825
205	5.5478	4.6795	0.002409	84.3476	0.04342	9.3321
206	5.5245	4.8077	0.001988	87.0248	0.03599	9.2928
207	5.2957	4.7768	0.001440	90.1997	0.02719	8.9081
208	4.8999	4.4253	0.001362	90.3137	0.02779	8.2422
304	5.2702	4.7356	0.001483	89.8568	0.02814	8.8651
305	5.3661	4.5666	0.002218	85.1013	0.04133	9.0264
306	5.5445	4.6057	0.002604	83.0688	0.04697	9.3265
307	5.5101	5.0741	0.001210	92.0867	0.02195	9.2687
308	5.3809	5.1193	0.000726	95.1376	0.01349	9.0514
309	4.9018	4.5172	0.001067	92.1540	0.02176	8.2455
404	5.3754	4.7298	0.001791	87.9887	0.03332	9.0421
405	5.5471	4.6291	0.002546	83.4508	0.04591	9.3309
406	5.6957	4.7076	0.002741	82.6512	0.04812	9.5809
407	5.8093	4.9775	0.002307	85.6830	0.03971	9.7719
408	5.3759	4.8599	0.001432	90.4003	0.02663	9.0430
409	5.0559	4.4099	0.001792	87.2224	0.03544	8.5047
410	4.5952	4.0042	0.001639	87.1396	0.03567	7.7296
411	4.4540	4.4563	-0.000007	100.0528	-0.00015	7.4921
412	4.4108	4.3754	0.000098	99.1952	0.00223	7.4196
413	3.6569	3.7128	-0.000155	101.5298	-0.00424	6.1513
414	3.2862	3.0450	0.000680	92.6616	0.02070	5.5277
504	5.6381	5.4309	0.000575	96.3241	0.01020	9.4840
505	5.9189	5.5353	0.001064	93.5193	0.01798	9.9564
506	5.8093	5.3300	0.001329	91.7498	0.02289	9.7720
507	5.4050	5.0440	0.001001	93.3204	0.01853	9.0919
508	5.2587	5.2488	0.000027	99.8120	0.00052	8.8458
509	4.9457	4.9517	-0.000016	100.1202	-0.00033	8.3193
510	4.8222	4.9961	-0.000482	103.6052	-0.01000	8.1116
511	4.7605	4.8116	-0.000142	101.0722	-0.00297	8.0078
512	4.5851	4.3950	0.000527	95.8544	0.01150	7.7127
513	4.1062	3.9403	0.000460	95.9589	0.01121	6.9072
514	3.7978	3.6005	0.000547	94.8068	0.01441	6.3883
601	5.8665	6.0252	-0.000440	102.7063	-0.00751	9.8681
602	5.9325	5.8832	0.000137	99.1675	0.00231	9.9793
603	5.4605	5.3996	0.000169	98.8842	0.00310	9.1852
604	5.7590	5.6348	0.000345	97.8418	0.00599	9.6874
605	5.9561	5.7194	0.000657	96.0256	0.01102	10.0189
606	5.6764	5.7577	-0.000226	101.4322	-0.00397	9.5484
607	5.4719	5.7299	-0.000716	104.7142	-0.01308	9.2045

608	5.4253	5.3669	0.000162	98.9238	0.00299	9.1260
609	4.7270	4.8358	-0.000302	102.3025	-0.00639	7.9514
610	4.6992	4.6037	0.000265	97.9662	0.00564	7.9047
611	4.9167	4.6697	0.000685	94.9753	0.01394	8.2706
612	4.3919	4.0571	0.000929	92.3778	0.02114	7.3877
613	3.9178	3.5724	0.000958	91.1837	0.02446	6.5903
614	4.1537	3.5740	0.001608	86.0444	0.03871	6.9870
701	5.8849	5.9728	-0.000252	101.4931	-0.00428	9.8991
702	5.2574	5.6227	-0.001013	106.9490	-0.01928	8.8436
703	4.6733	5.0021	-0.000912	107.0346	-0.01951	7.8611
704	4.8795	5.2188	-0.000941	106.9528	-0.01929	8.2080
705	5.3159	5.2595	0.000156	98.9395	0.00294	8.9419
706	5.2543	5.2069	0.000131	99.0978	0.00250	8.8384
707	5.1566	5.4101	-0.000703	104.9157	-0.01364	8.6740
708	4.8179	4.6607	0.000436	96.7361	0.00905	8.1044
709	4.5399	4.3218	0.000605	95.1947	0.01333	7.6367
710	4.3595	4.4484	-0.000246	102.0376	-0.00565	7.3333
711	4.4392	4.2148	0.000623	94.9444	0.01402	7.4673
712	4.1539	3.7814	0.001033	91.0322	0.02488	6.9873
713	3.7488	3.4920	0.000712	93.1493	0.01900	6.3060
714	3.9000	3.5442	0.000987	90.8779	0.02530	6.5602
803	4.6837	5.1291	-0.001235	109.5089	-0.02638	7.8787
804	4.6575	4.9580	-0.000834	106.4536	-0.01790	7.8344
805	5.4293	5.0352	0.001093	92.7413	0.02014	9.1328
806	5.6871	5.2733	0.001148	92.7225	0.02019	9.5665
807	5.5290	5.3213	0.000576	96.2434	0.01042	9.3005
808	4.7859	4.6955	0.000251	98.1116	0.00524	8.0504
809	4.4746	4.4765	-0.000005	100.0419	-0.00012	7.5268
810	4.4020	4.5683	-0.000461	103.7774	-0.01048	7.4048
811	4.1486	3.9943	0.000428	96.2827	0.01031	6.9784
812	3.8927	3.5042	0.001078	90.0210	0.02768	6.5479
813	3.8321	3.4537	0.001050	90.1250	0.02739	6.4461
814	3.8024	3.4568	0.000959	90.9107	0.02521	6.3960
907	5.5392	5.0372	0.001392	90.9385	0.02514	9.3175
908	4.9538	4.6756	0.000772	94.3823	0.01558	8.3330
909	4.7163	4.5043	0.000588	95.5037	0.01247	7.9335
910	4.4182	4.4958	-0.000215	101.7549	-0.00487	7.4320
911	4.2178	4.0810	0.000379	96.7573	0.00899	7.0948
912	4.0545	3.6170	0.001214	89.2079	0.02994	6.8202
1008	5.5213	5.3553	0.000461	96.9929	0.00834	9.2875
1009	5.3129	5.7130	-0.001110	107.5302	-0.02089	8.9370
1010	4.9645	5.0211	-0.000157	101.1417	-0.00317	8.3508
1011	4.5475	4.4491	0.000273	97.8367	0.00600	7.6494
1108	5.4969	5.8920	-0.001096	107.1876	-0.01994	9.2466
1109	5.2200	5.5571	-0.000935	106.4588	-0.01792	8.7806
1110	5.2133	4.8997	0.000870	93.9849	0.01669	8.7695
1210	5.1093	4.8085	0.000834	94.1129	0.01633	8.5945
Mean	4.9633	4.7399	0.000621	95.5357	0.01241	8.3488
Total	4.9541	4.7454	0.000579	95.7883	0.01168	8.3333

Table 3.14
Linear Trend Regression Analysis of 1954-2013 Annual Evaporation

Quad	Mean (in/yr)	Intercept (inches)	Slope (inches/yr)	Intercept % Mean	Slope % Mean	Mean % Mean
104	59.5930	55.4812	0.134815	93.100	0.22623	100.24
105	67.0523	60.0258	0.230377	89.521	0.34358	112.79
106	67.0837	60.9956	0.199608	90.925	0.29755	112.84
107	64.1045	58.7077	0.176943	91.581	0.27602	107.83
108	59.4697	53.0944	0.216109	89.280	0.36339	100.04
204	63.3663	54.9922	0.274561	86.785	0.43329	106.59
205	66.5740	56.0864	0.343856	84.247	0.51650	111.99
206	66.2937	57.6624	0.282994	86.980	0.42688	111.51
207	63.5490	57.3321	0.203834	90.217	0.32075	106.90
208	58.7988	53.1281	0.192226	90.356	0.32692	98.91
304	63.2423	56.7434	0.213079	89.724	0.33692	106.38
305	64.3932	54.7022	0.317737	84.950	0.49343	108.32
306	66.5340	55.1768	0.372368	82.930	0.55967	111.92
307	66.1213	60.9251	0.170369	92.141	0.25766	111.22
308	64.5712	61.5135	0.100252	95.265	0.15526	108.62
309	58.8218	54.2517	0.149840	92.231	0.25474	98.95
404	64.5050	56.6258	0.258334	87.785	0.40049	108.51
405	66.5650	55.3966	0.366179	83.222	0.55011	111.97
406	68.3488	56.3593	0.393100	82.458	0.57514	114.97
407	69.7112	59.6801	0.328886	85.611	0.47178	117.26
408	64.5112	58.3428	0.202242	90.438	0.31350	108.52
409	60.6712	52.9236	0.254018	87.230	0.41868	102.06
410	55.1420	48.0537	0.232403	87.145	0.42146	92.76
411	53.4477	53.5784	-0.004288	100.245	-0.00802	89.91
412	52.9302	52.6092	0.010525	99.394	0.01988	89.04
413	43.8823	44.6311	-0.024548	101.706	-0.05594	73.82
414	39.4339	36.5345	0.096646	92.648	0.24508	66.33
504	67.6573	65.1155	0.083338	96.243	0.12318	113.81
505	71.0270	66.3821	0.152292	93.460	0.21441	119.48
506	69.7117	63.9131	0.190116	91.682	0.27272	117.26
507	64.8598	60.5255	0.142110	93.317	0.21910	109.10
508	63.1045	63.0719	0.001070	99.948	0.00170	106.15
509	59.3487	59.5193	-0.005595	100.288	-0.00943	99.83
510	57.8670	60.1067	-0.073434	103.871	-0.12690	97.34
511	57.1263	57.8711	-0.024419	101.304	-0.04275	96.09
512	55.0210	52.8177	0.072240	95.996	0.13129	92.55
513	49.2748	47.3285	0.063814	96.050	0.12951	82.89
514	45.5732	43.2176	0.077231	94.831	0.16947	76.66
601	70.3975	72.2778	-0.061649	102.671	-0.08757	118.42
602	71.1905	70.5251	0.021818	99.065	0.03065	119.75
603	65.5260	64.7421	0.025703	98.804	0.03923	110.22
604	69.1085	67.5674	0.050527	97.770	0.07311	116.25
605	71.4733	68.6067	0.093987	95.989	0.13150	120.23
606	68.1167	69.1409	-0.033582	101.504	-0.04930	114.58
607	65.6630	68.8459	-0.104357	104.847	-0.15893	110.45

608	65.1035	64.4650	0.020933	99.019	0.03215	109.51
609	56.7240	58.1448	-0.046582	102.505	-0.08212	95.42
610	56.3908	55.3501	0.034124	98.154	0.06051	94.86
611	59.0008	56.1031	0.095009	95.089	0.16103	99.25
612	52.7023	48.6996	0.131237	92.405	0.24902	88.65
613	47.0142	42.8570	0.136300	91.158	0.28991	79.08
614	49.8438	42.8322	0.229888	85.933	0.46122	83.84
701	70.6186	71.6215	-0.033996	101.420	-0.04814	118.79
702	63.0888	67.4746	-0.143796	106.952	-0.22793	106.12
703	56.0798	60.0241	-0.129321	107.033	-0.23060	94.33
704	58.5542	62.6449	-0.134123	106.986	-0.22906	98.50
705	63.7903	63.1076	0.022384	98.930	0.03509	107.30
706	63.0514	62.5206	0.017401	99.158	0.02760	106.06
707	61.8790	65.0130	-0.102755	105.065	-0.16606	104.09
708	57.8153	55.9691	0.060533	96.807	0.10470	97.25
709	54.4792	51.9216	0.083855	95.305	0.15392	91.64
710	52.3145	53.4960	-0.038737	102.258	-0.07405	88.00
711	53.2705	50.6333	0.086464	95.050	0.16231	89.61
712	49.8463	45.3727	0.146676	91.025	0.29426	83.85
713	44.9858	41.9086	0.100891	93.160	0.22427	75.67
714	46.7997	42.5192	0.140345	90.854	0.29988	78.72
803	56.2050	61.5801	-0.176231	109.563	-0.31355	94.54
804	55.8895	59.5261	-0.119234	106.507	-0.21334	94.01
805	65.1522	60.4013	0.155765	92.708	0.23908	109.59
806	68.2457	63.2811	0.162774	92.725	0.23851	114.80
807	66.3482	63.8949	0.080435	96.302	0.12123	111.61
808	57.4305	56.4013	0.033745	98.208	0.05876	96.61
809	53.6950	53.8028	-0.003535	100.201	-0.00658	90.32
810	52.8243	54.9420	-0.069430	104.009	-0.13144	88.86
811	49.7827	47.9844	0.058958	96.388	0.11843	83.74
812	46.7118	42.0358	0.153312	89.990	0.32821	78.58
813	45.9857	41.4330	0.149267	90.100	0.32459	77.35
814	45.6283	41.4762	0.136134	90.900	0.29835	76.75
907	66.4698	60.4354	0.197851	90.922	0.29766	111.81
908	59.4462	56.1292	0.108753	94.420	0.18294	100.00
909	56.5962	54.0902	0.082162	95.572	0.14517	95.20
910	53.0188	54.0493	-0.033786	101.944	-0.06372	89.18
911	50.6132	49.0386	0.051625	96.889	0.10200	85.14
912	48.6545	43.3982	0.172337	89.197	0.35421	81.84
1008	66.2555	64.2837	0.064650	97.024	0.09758	111.45
1009	63.7550	68.7013	-0.162174	107.758	-0.25437	107.24
1010	59.5735	60.3541	-0.025594	101.310	-0.04296	100.21
1011	54.5695	53.4739	0.035920	97.992	0.06582	91.79
1108	65.9633	70.8085	-0.158859	107.345	-0.24083	110.96
1109	62.6397	66.7916	-0.136128	106.628	-0.21732	105.37
1110	62.5600	58.7995	0.123296	93.989	0.19708	105.23
1210	61.3118	57.7065	0.118209	94.120	0.19280	103.13
Mean	59.5592	56.8981	0.087398	95.573	0.14542	100.19
Total	59.4486	56.9669	0.081367	95.826	0.13687	100.00

Table 3.15
Linear Trend Regression Analysis of Annual 2-Month Maximum Evaporation

Quad	Mean (inches)	Intercept (inches)	Slope (inch/year)	Intercept % Mean	Slope % Mean	Mean % Mean
104	15.2085	15.21	-0.000081	100.016	-0.000530	25.5826
105	18.8712	17.88	0.032411	94.762	0.171750	31.7437
106	19.2330	18.60	0.020771	96.706	0.108000	32.3523
107	18.2333	17.81	0.013731	97.703	0.075310	30.6707
108	16.7317	15.89	0.028491	94.977	0.170280	28.1449
204	16.5743	14.68	0.062120	88.569	0.374790	27.8801
205	18.1080	15.45	0.087062	85.336	0.480790	30.4599
206	18.2235	15.94	0.074998	87.448	0.411550	30.6542
207	17.4775	16.45	0.033715	94.116	0.192900	29.3993
208	16.4264	15.63	0.027049	95.142	0.164670	27.6312
304	16.5945	15.36	0.040412	92.573	0.243520	27.9140
305	17.0355	14.84	0.072075	87.096	0.423090	28.6558
306	17.6642	15.10	0.084142	85.472	0.476340	29.7133
307	18.1370	17.70	0.014445	97.571	0.079650	30.5087
308	18.3162	18.37	-0.001915	100.319	-0.010450	30.8101
309	16.5222	15.91	0.020007	96.307	0.121090	27.7923
404	16.9047	15.67	0.040329	92.724	0.238570	28.4358
405	17.2467	14.61	0.086435	84.714	0.501170	29.0111
406	17.8960	15.46	0.079744	86.409	0.445600	30.1033
407	18.8545	16.85	0.065749	89.364	0.348720	31.7156
408	17.9722	16.84	0.037015	93.718	0.205960	30.2314
409	17.1460	15.29	0.060793	89.186	0.354560	28.8417
410	15.3175	13.75	0.051274	89.790	0.334740	25.7660
411	14.7108	15.60	-0.029280	106.071	-0.199030	24.7455
412	14.2835	14.92	-0.020824	104.447	-0.145790	24.0266
413	11.8710	12.33	-0.015113	103.883	-0.127310	19.9685
414	10.5975	9.82	0.026060	92.623	0.245910	17.8262
504	17.9710	17.58	0.012973	97.798	0.072190	30.2295
505	18.6910	17.64	0.034612	94.352	0.185180	31.4406
506	18.4617	17.31	0.037868	93.744	0.205120	31.0548
507	17.2335	16.71	0.017017	96.988	0.098740	28.9889
508	16.8217	17.56	-0.024267	104.400	-0.144260	28.2961
509	16.2870	16.67	-0.012702	102.379	-0.077990	27.3968
510	16.2790	17.39	-0.036578	106.853	-0.224700	27.3833
511	15.7362	16.58	-0.027570	105.344	-0.175200	26.4702
512	14.8588	14.67	0.006056	98.757	0.040760	24.9944
513	13.1503	12.70	0.014912	96.541	0.113400	22.1205
514	12.1142	11.54	0.018842	95.256	0.155540	20.3775
601	18.7058	19.15	-0.014542	102.371	-0.077740	31.4655
602	18.7007	18.61	0.002939	99.521	0.015720	31.4569
603	16.9843	17.24	-0.008396	101.508	-0.049440	28.5698
604	17.9358	18.09	-0.005137	100.874	-0.028640	30.1703
605	18.7313	18.27	0.015068	97.547	0.080440	31.5084
606	18.1098	18.88	-0.025293	104.260	-0.139670	30.4630
607	17.8748	19.43	-0.050991	108.701	-0.285270	30.0677

608	17.4612	18.20	-0.024340	104.252	-0.139400	29.3719
609	15.5255	16.55	-0.033594	106.600	-0.216380	26.1158
610	15.8272	16.24	-0.013619	102.625	-0.086050	26.6233
611	15.9520	16.18	-0.007450	101.424	-0.046700	26.8333
612	13.8125	13.56	0.008421	98.141	0.060960	23.2344
613	12.2820	11.39	0.029370	92.706	0.239130	20.6599
614	12.6692	11.52	0.037693	90.926	0.297520	21.3111
701	18.7698	18.99	-0.007388	101.161	-0.039360	31.5732
702	16.1415	17.57	-0.046973	108.876	-0.291000	27.1520
703	13.9940	15.83	-0.060106	113.100	-0.429510	23.5397
704	14.8527	16.66	-0.059411	112.200	-0.400000	24.9840
705	16.5805	16.84	-0.008509	101.565	-0.051320	27.8905
706	17.2252	17.46	-0.007670	101.358	-0.044530	28.9749
707	16.8930	18.45	-0.051041	109.215	-0.302140	28.4161
708	15.6007	15.98	-0.012492	102.442	-0.080070	26.2423
709	14.9758	14.83	0.004658	99.051	0.031110	25.1912
710	14.2308	14.84	-0.019997	104.286	-0.140520	23.9380
711	14.2275	13.77	0.015062	96.771	0.105860	23.9324
712	12.5735	11.76	0.026781	93.504	0.212990	21.1502
713	11.4615	11.24	0.007254	98.070	0.063290	19.2797
714	11.8548	11.48	0.012353	96.822	0.104200	19.9413
803	14.2213	16.43	-0.072307	115.507	-0.508440	23.9221
804	14.2563	16.32	-0.067533	114.448	-0.473710	23.9809
805	17.4317	16.95	0.015743	97.246	0.090310	29.3222
806	18.9050	18.31	0.019387	96.872	0.102550	31.8006
807	18.2782	18.44	-0.005142	100.858	-0.028130	30.7462
808	15.5883	16.24	-0.021491	104.205	-0.137860	26.2215
809	14.5822	15.20	-0.020299	104.246	-0.139200	24.5290
810	13.9255	15.05	-0.036990	108.102	-0.265630	23.4244
811	12.7027	12.43	0.008901	97.863	0.070070	21.3675
812	11.4810	10.40	0.035585	90.547	0.309950	19.3125
813	11.2768	10.56	0.023417	93.667	0.207650	18.9690
814	11.4003	11.04	0.011822	96.837	0.103700	19.1768
907	18.3198	17.53	0.025754	95.712	0.140580	30.8162
908	16.4383	16.38	0.001910	99.646	0.011620	27.6513
909	15.4682	15.46	0.000232	99.954	0.001500	26.0194
910	13.9720	15.06	-0.035699	107.793	-0.255510	23.5026
911	13.2962	12.81	0.015812	96.373	0.118930	22.3658
912	12.4997	10.89	0.052901	87.092	0.423220	21.0260
1008	18.1745	18.20	-0.000975	100.164	-0.005370	30.5718
1009	16.7430	18.72	-0.064770	111.799	-0.386850	28.1638
1010	15.1173	16.13	-0.033268	106.712	-0.220060	25.4292
1011	13.8778	14.57	-0.022782	105.007	-0.164160	23.3442
1108	17.7598	19.57	-0.059269	110.179	-0.333720	29.8743
1109	16.2917	17.52	-0.040328	107.550	-0.247540	27.4046
1110	15.7410	14.99	0.024629	95.228	0.156470	26.4783
1210	15.5515	14.80	0.024613	95.173	0.158270	26.1596
Mean	15.9023	15.73	0.005601	99.001	0.032900	26.7497
Total	15.4869	15.39	0.003055	99.398	0.019730	26.0508

Table 3.16
Linear Trend Regression Analysis of Annual 2-Month Minimum Evaporation

Quad	Mean (inches)	Intercept (inches)	Slope (inch/year)	Intercept % Mean	Slope % Mean	Mean % Mean
104	4.0983	2.6920	0.046108	65.6859	1.12505	6.8939
105	4.0248	2.6847	0.043940	66.7023	1.09173	6.7703
106	3.9190	2.7288	0.039023	69.6303	0.99573	6.5922
107	3.9335	2.5933	0.043941	65.9282	1.11711	6.6166
108	3.9016	2.6371	0.042863	67.5910	1.09861	6.5629
204	4.2583	3.1017	0.037922	72.8389	0.89053	7.1630
205	4.1345	2.7158	0.046513	65.6874	1.12500	6.9547
206	4.0058	2.6884	0.043195	67.1117	1.07830	6.7383
207	3.9402	2.7959	0.037518	70.9582	0.95219	6.6279
208	4.0564	2.9479	0.037574	72.6744	0.92629	6.8233
304	4.4067	3.6232	0.025689	82.2199	0.58295	7.4126
305	4.4248	3.1102	0.043102	70.2903	0.97409	7.4431
306	4.3418	2.7514	0.052145	63.3700	1.20098	7.3035
307	4.4160	3.2862	0.037044	74.4151	0.83885	7.4283
308	4.2537	3.1980	0.034611	75.1827	0.81368	7.1552
309	3.8453	2.8112	0.033906	73.1068	0.88174	6.4683
404	4.4703	3.5926	0.028778	80.3655	0.64376	7.5197
405	4.7478	3.6666	0.035451	77.2265	0.74667	7.9864
406	4.8928	3.5521	0.043958	72.5983	0.89842	8.2304
407	4.8890	3.7664	0.036807	77.0380	0.75285	8.2239
408	4.5043	3.5987	0.029693	79.8944	0.65920	7.5769
409	3.9468	3.3371	0.019991	84.5517	0.50650	6.6391
410	3.8565	2.9928	0.028317	77.6048	0.73427	6.4871
411	3.8458	3.0812	0.025071	80.1169	0.65190	6.4692
412	3.9220	3.2745	0.021230	83.4904	0.54130	6.5973
413	3.2492	2.9696	0.009165	91.3968	0.28207	5.4655
414	2.9490	2.5820	0.012233	87.5558	0.41481	4.9606
504	4.5290	4.3313	0.006483	95.6338	0.14315	7.6183
505	4.9123	4.4655	0.014650	90.9043	0.29822	8.2632
506	4.9333	4.2583	0.022133	86.3165	0.44864	8.2985
507	4.5927	3.8814	0.023320	84.5133	0.50776	7.7254
508	4.4975	4.1520	0.011327	92.3184	0.25186	7.5654
509	4.3228	4.1770	0.004782	96.6260	0.11062	7.2715
510	4.0367	3.8219	0.007040	94.6805	0.17441	6.7902
511	4.1227	3.5340	0.019301	85.7209	0.46817	6.9348
512	4.0482	3.4904	0.018288	86.2211	0.45177	6.8095
513	3.5763	3.2224	0.011605	90.1030	0.32449	6.0158
514	3.3528	3.1540	0.006520	94.0691	0.19446	5.6399
601	4.9545	5.0650	-0.003624	102.2310	-0.07315	8.3341
602	5.0588	4.9157	0.004693	97.1707	0.09276	8.5096
603	4.7453	4.2943	0.014786	90.4962	0.31160	7.9822
604	4.9098	4.4269	0.015834	90.1641	0.32249	8.2590
605	5.0040	4.6849	0.010461	93.6237	0.20906	8.4174
606	4.8215	4.7083	0.003712	97.6519	0.07699	8.1104
607	4.5843	4.4717	0.003692	97.5436	0.08054	7.7114

608	4.6770	4.2048	0.015481	89.9041	0.33101	7.8673
609	4.1660	4.0387	0.004174	96.9442	0.10019	7.0077
610	3.9962	3.3860	0.020005	84.7314	0.50061	6.7221
611	4.4967	3.4368	0.034749	76.4303	0.77278	7.5640
612	4.2108	3.2146	0.032665	76.3400	0.77574	7.0831
613	3.6168	3.1590	0.015010	87.3424	0.41500	6.0840
614	4.0185	3.0067	0.033173	74.8218	0.82552	6.7596
701	5.0326	5.0805	-0.001623	100.9515	-0.03225	8.4654
702	4.9432	4.8979	0.001486	99.0833	0.03006	8.3150
703	4.7528	4.4074	0.011325	92.7327	0.23827	7.9949
704	4.8182	4.6303	0.006159	96.1014	0.12782	8.1048
705	4.8870	4.5744	0.010250	93.6030	0.20974	8.2205
706	4.5933	4.4136	0.005894	96.0865	0.12831	7.7266
707	4.4838	4.5059	-0.000724	100.4923	-0.01614	7.5424
708	4.3938	4.0648	0.010787	92.5125	0.24549	7.3910
709	4.0372	3.8032	0.007671	94.2045	0.19002	6.7910
710	3.9705	3.9554	0.000496	99.6189	0.01249	6.6789
711	4.0988	3.8066	0.009583	92.8692	0.23380	6.8947
712	4.0523	3.4566	0.019531	85.3000	0.48197	6.8165
713	3.5012	3.0367	0.015227	86.7349	0.43492	5.8894
714	3.6885	2.9472	0.024304	79.9034	0.65891	6.2045
803	4.7825	4.5512	0.007585	95.1629	0.15859	8.0448
804	4.6903	4.3363	0.011608	92.4515	0.24749	7.8897
805	4.7668	4.1640	0.019766	87.3528	0.41466	8.0184
806	4.7568	4.1494	0.019916	87.2303	0.41868	8.0016
807	4.7023	4.1871	0.016891	89.0440	0.35921	7.9099
808	4.3163	3.9388	0.012378	91.2535	0.28677	7.2606
809	4.1027	3.9146	0.006167	95.4151	0.15032	6.9012
810	4.2232	4.2621	-0.001277	100.9225	-0.03024	7.1039
811	4.0003	3.9443	0.001838	98.5984	0.04596	6.7291
812	3.9053	3.6777	0.007464	94.1709	0.19112	6.5693
813	3.9043	3.5935	0.010191	92.0392	0.26101	6.5676
814	3.6757	3.1650	0.016743	86.1066	0.45552	6.1829
907	4.6890	3.7730	0.030034	80.4643	0.64052	7.8875
908	4.2423	3.6524	0.019343	86.0938	0.45594	7.1361
909	4.0832	3.6672	0.013638	89.8128	0.33401	6.8684
910	4.2278	3.9182	0.010153	92.6755	0.24015	7.1117
911	4.0012	3.8810	0.003939	96.9977	0.09844	6.7305
912	3.9590	3.9028	0.001842	98.5811	0.04652	6.6595
1008	4.6960	4.4272	0.008814	94.2754	0.18769	7.8993
1009	4.9270	5.0421	-0.003772	102.3352	-0.07656	8.2878
1010	4.8810	4.6804	0.006577	95.8899	0.13476	8.2105
1011	4.4492	3.9621	0.015969	89.0531	0.35891	7.4841
1108	4.7420	4.8977	-0.005105	103.2834	-0.10765	7.9766
1109	4.9340	5.0881	-0.005051	103.1226	-0.10238	8.2996
1110	5.1862	4.8652	0.010525	93.8104	0.20294	8.7238
1210	5.0840	4.7986	0.009358	94.3859	0.18407	8.5519
Mean	4.3326	3.7859	0.017956	87.0485	0.42543	7.2880
Total	4.4971	3.9275	0.018676	87.3336	0.41529	7.5647

CHAPTER 4
OBSERVED STREAM FLOW

Characteristics of observed flows at 35 USGS gaging stations are investigated in Chapter 4 and Appendix C. Flow rates at all of the sites exhibit tremendous variability with floods, droughts, and continual daily, seasonal, and year-to-year fluctuations. Long-term changes in flow characteristics are significant at many of the sites but vary greatly between sites.

River Systems of Texas

Texas has 11,247 named streams that have been identified by the U.S. Geological Survey (USGS). These streams have a combined length of 80,000 miles and drainage areas totaling 263,000 square miles. The Rio Grande, Nueces, Guadalupe, San Antonio, Lavaca, Colorado, Brazos, Red, Canadian, San Jacinto, Trinity, Neches, Sabine, Sulphur, and Cypress Rivers are considered the major rivers of Texas. These rivers have numerous tributaries and the tributaries have numerous tributaries. There are also eight coastal basins draining into the Gulf of Mexico between the major river basins. Texas is divided into the 15 major river basins and eight coastal basins delineated in Figure 1.1 which cover the entire state. Their drainage areas are listed in Table 3.2. The 15 major river basins are also shown below in Figure 4.1. The major rivers are shown in the map of Figure 1.2. The lengths of the six longest rivers are as follows: Rio Grande (1,900 miles), Red (1,290 miles), Brazos (1,280 miles), Pecos (926 miles), Canadian (906 miles), and Colorado (865 miles).

Figure 4.1 Fifteen Major River Basins of Texas

Selected Gaging Stations

Flows at the 35 gaging stations listed in Table 4.1 are examined in this chapter and Appendix C. The locations of the 35 gages are shown in Figure 4.2. Information describing each gage site is provided in Appendix C along with plots of flows. The National Water Information System (NWIS) maintained by the USGS includes daily flow data for over 900 stream gages on numerous streams in Texas. However, the period-of-record is relatively short for most of the gages. The 35 selected gages are located on major rivers and have records of at least 70 years. These sites were selected as being representative of flows on the major rivers of the state.

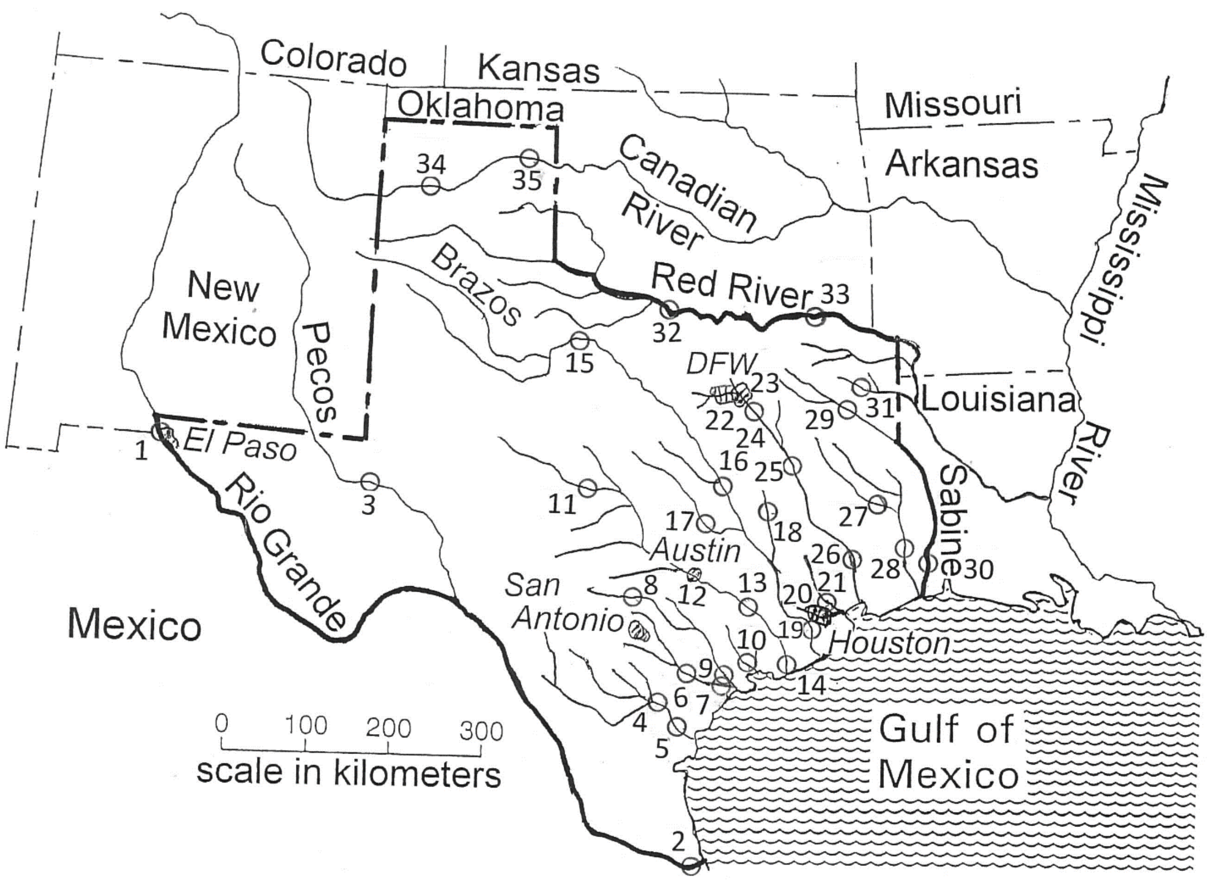

Figure 4.2 Selected Stream Flow Gaging Stations

The selected gaging stations are listed in Tables 4.1 and 4.2 with descriptive information. The two gages on the Rio Grande are maintained by the International Boundary and Water Commission (IBWC). Daily flow data for these two sites were downloaded from the IBWC website. The other gages are maintained by the USGS. Daily flows for these sites were downloaded from the NWIS using HEC-DSSVue. The map identifier in the first column of Table 4.1 refers to the locations in Figure 4.2. The total and contributing watershed areas for the USGS gages are included in the information provided by the NWIS. Portions of river basins in dry flat West Texas and New Mexico contribute essential no runoff to stream flow, and thus the contributing drainage area may be significantly less than the total area of the river basin. Unless indicated otherwise in Table 4.1, the contributing area is the same as the total drainage area.

Table 4.1
Selected Stream Flow Gaging Stations

Map ID	Gage ID	Location River and Nearest City	Record Begins	Watershed Area Total	Watershed Area Contributing	Mean Flow
			–	(square miles)		(inches/year)
1	08-3640.00	Rio Grande at El Paso	5/1899		29,270	0.0093
2	08-4750.00	Rio Grande at Brownsville	1/1934	356,000	176,000	0.0034
3	08412500	Pecos River at Orla	6/1937	25,070	21,229	0.083
4	08210000	Nueces River at Three Rivers	7/1915	15,427	same	0.662
5	08211000	Nueces River at Mathis	8/1939	16,503	same	0.574
6	08183500	San Antonio River Falls City	5/1925	2,113	same	3.173
7	08188500	San Antonio River at Goliad	7/1939	3,921	same	2.795
8	08167500	Guadalupe River at Spring Branch	6/1922	1,315	same	3.781
9	08176500	Guadalupe River at Victoria	11/1934	5,198	same	5.079
10	08164000	Lavaca River near Edna	8/1938	817	same	6.172
11	08147000	Colorado River near San Saba	11/1915	31,217	19,819	0.686
12	08158000	Colorado River at Austin	3/1898	39,009	27,606	1.055
13	08161000	Colorado River at Columbus	5/1916	41,640	30,237	1.344
14	08162500	Colorado River near Bay City	5/1948	42,240	30,837	1.085
15	08082500	Brazos River at Seymour	12/1923	15,538	5,972	0.760
16	08096500	Brazos River at Waco	10/1898	29,559	19,993	1.596
17	08106500	Little River at Cameron	11/1916	7,065	same	3.352
18	08110500	Navasota River at Easterly	3/1924	968	same	5.857
19	08114000	Brazos River at Richmond	1/1903	45,107	35,541	2.807
20	08074000	Buffalo Bayou in Houston	6/1936	336	same	19.56
21	08068000	West Fork San Jacinto, Conroe	5/1924	828	same	8.137
22	08048000	West Fork Trinity at Fort Worth	10/1920	2,615	same	2.050
23	08057000	Trinity River at Dallas	10/1903	6,106	same	3.803
24	08062500	Trinity River near Rosser	8/1924	8,146	same	5.220
25	08065000	Trinity River near Oakwood	10/1923	12,833	same	5.531
26	08066500	Trinity River at Romayor	5/1924	17,186	same	6.126
27	08033500	Neches River near Rockland	7/1904	3,636	same	8.782
28	08041000	Neches River near Evansdale	8/1922	7,951	same	10.46
29	80220400	Sabine River near Beckville	10/1938	3,589	same	9.442
30	80305000	Sabine River near Ruliff	10/1924	9,329	same	11.81
31	07346000	Big Cypress Bayou at Jefferson	8/1924	850	same	10.04
32	07315500	Red River near Terrel, OK	4/1938	28,723	22,784	1.106
33	07335500	Red River at Arthur City, Texas	10/1905	44,445	36,517	2.684
34	07227500	Canadian River near Amarillo	4/1938	19,445	15,376	0.218
35	07228000	Canadian River near Canadian	4/1938	22,866	18,178	0.189

The observed flows date back to before at least 1940 at all but one of the gages and to before 1925 at 22 of the gages. The oldest gages are on the Brazos River at Waco (1898), Rio Grande at El Paso (1899), Brazos River at Richmond (1903), Trinity River at Dallas (1903), Neches River at Rockland (1904), and Red River at Arthur City (1905). All of the 35 gages are still active as of 2014. Seven of the gages have gaps in their periods-of-record which are evident in the plots of Appendix C.

Analysis of Flows

Mean river flows expressed as watershed depth equivalents in the last column of Table 4.1 illustrate the dramatic differences between the characteristics of the different watersheds. The mean flow as an equivalent watershed depth is computed by dividing the mean flow of the river in cubic feet per second (cfs) by the contributing watershed area in square miles and multiplying by the unit conversion factor of 13.57438. Mean flows in cfs are included in Table 4.2.

Table 4.2
Summary Statistics for Observed Daily Flows

		Period-of-Record			Standard	Skew
	River, Nearest City	from	through	Mean	Deviation	Coefficient
				(cfs)	(cfs)	(cfs)
1	Rio Grande, El Paso	10May1889	31Dec2011	20.1	32.9	6.79
2	Rio Grande, Brownsville	31Dec1933	30Dec2011	43.6	94.7	4.09
3	Pecos River, Orla	01Jun1937	01Jun2013	130.4	533	26.3
4	Nueces, Three Rivers	01Jul1915	31Dec2012	752	2,822	14.4
5	Nueces, Mathis	05Aug1939	31Dec2012	698	2,862	16.2
6	San Antonio, Falls City	01May1925	01Jun2013	494	1,220	17.6
7	San Antonio, Goliad	01Jul1939	01Jun2013	807	2,128	16.9
8	Guadalupe, Spring Branch	28Jun1922	01Jun2013	366	1,454	26.8
9	Guadalupe, Victoria	04Nov1934	01Jun2013	1,945	4,393	23.5
10	Lavaca, Edna	13Aug1938	01Jun2013	371	1,853	20.7
11	Colorado, San Saba	01Nov1915	01Jun2013	1,002	4,258	17.1
12	Colorado, Austin	01Nov1898	01Jun2013	2,146	5,719	16.5
13	Colorado, Columbus	22May1916	01Jun2013	2,995	6,228	8.51
14	Colorado, Bay City	01May1948	01Jun2013	2,464	5,295	5.90
15	Brazos, Seymour	01Dec1923	01Jun 2013	334	1,609	15.1
16	Brazos, Waco	01 Oct 1898	01Jun 2013	2,350	5,852	8.05
17	Little River, Cameron	01Nov1916	01Jun 2013	1,744	4,589	30.4
18	Navasota, Easterly	27Mar1924	01Jun 2013	418	1,787	11.2
19	Brazos, Richmond	31Dec1902	08Mar2014	7,350	11,779	3.5
20	Buffalo Bayou, Houston	01Jun1936	19May2013	484	820	3.1
21	WF San Jacinto, Conroe	01May1924	01Jun 2013	496	1,822	18.6
22	WF Trinity, Fort Worth	01 Oct1920	01Jun 2013	395	1,230	10.5
23	Trinity, Dallas	01 Oct1903	01Jun 2013	1,711	4,058	8.57
24	Trinity, Rosser	01Aug1924	01Jun 2013	3,133	5,686	5.62
25	Trinity, Oakwood	01 Oct1923	01Jun 2013	5,229	9,095	4.25
26	Trinity, Romayor	01May1924	01Jun 2013	7,755	11,453	2.73
27	Neches, Rockland	01Jul1904	01Jun 2013	2,352	3,681	3.52
28	Neches, Evansdale	01Aug1922	01Jun 2013	6,126	7,460	2.78
29	Sabine, Beckville	01 Oct1938	01Jun 2013	2,496	4,227	5.96
30	Sabine, Ruliff	01 Oct1924	01Jun 2013	8,118	9,709	2.70
31	Big Cypress, Jefferson	01 Aug1924	01Jun 2013	629	1,292	10.38
32	Red, Terrel	31Mar1938	09Mar2014	2,340	6,927	10.4
33	Red, Arthur City	30Sep1905	10Mar2014	8,788	14,063	5.65
34	Canadian, Amarillo	01Apr1938	01Jun 2013	247	1,292	19.74
35	Canadian, Canadian	01Apr1938	01Jun 2013	253	1,488	15.8

The observed data consists of daily flows for the period-of-record shown in Table 4.2. The mean, standard deviation, and skew coefficient for the flows at each of the 35 gages are tabulated in the last three columns of Table 4.2. HEC-DSSVue was used to compute forward moving averages and identify the periods at each gage site that experienced the lowest mean flow for durations of 30 days, 60 days, 365 days, and 1,095 days. The minimum 30-, 90-, 365-, and 1,095-day mean flows are show in Table 4.3. The first day of the period with the smallest flow for the specified duration is shown with the mean flow for the period. The 1950s drought is reflected in the dates found in Table 4.3 more than any other dry period. Minimum period-of-record low flows occurred in 2011 at many sites. However, minimum low flows are shown to have occurred at many different dates at the 35 sites scattered throughout Texas.

Table 4.3
Minimum Mean Flows (cfs) for Durations of 30, 90, 365, and 1,095 Days

	River, Nearest City	30 days		90 days		365 days		1,095 days	
		Mean (cfs)	Date	Mean (cfs)	Date	Mean (cfs)	Date	Mean (cfs)	Date
1	Rio Grande, El Paso	0.00	27Aug1889	0.00	26Oct1889	0.00	30Jun1894	0.00	29Jun1896
2	Rio Grande, Brownsville	0.00	03Apr1952	0.00	23Aug1953	0.24	26Aug1953	2.14	06Sep1958
3	Pecos River, Orla	0.00	25Oct2011	0.00	31Jan2012	0.18	31Jan2012	24.9	31Jan2012
4	Nueces, Three Rivers	0.00	28Jun1917	0.730	07Dec1931	20.1	17Nov1917	122	08Aug1964
5	Nueces, Mathis	24.3	25Feb1942	27.5	01Mar1940	94.6	13Jul2011	108	02Oct1964
6	San Antonio, Falls City	33.0	19Jun1956	49.5	02Oct1954	78.0	20Aug1956	101	14Oct1956
7	San Antonio, Goliad	20.9	22Aug1956	37.3	23Aug1956	91.3	03Sep1956	136	16Oct1956
8	Guadalupe, Spring Br	0.00	12Aug1954	0.00	27Jul1956	9.03	22Feb1957	28.0	22Feb1957
9	Guadalupe, Victoria	31.0	17Oct1956	41.5	17Oct1956	126	18Dec1956	259	24Feb1957
10	Lavaca, Edna	0.00	05Dec1956	0.13	17Dec1956	5.38	17Dec1956	37.1	08Jan1991
11	Colorado, San Saba	0.04	14Aug1964	4.22	02Oct2011	45.1	08Oct2011	113	01Jun2013
12	Colorado, Austin	31.2	17Dec1989	44.9	13Jan1964	240	11May2013	622	01Jun2013
13	Colorado, Columbus	125	29Aug1917	180.0	29Jan1964	430	27May2013	997	01Jun2013
14	Colorado, Bay City	0.91	18Aug1967	97.2	09Oct2011	286	10Dec2011	328	05Oct2000
15	Brazos, Seymour	0.00	21Dec1924	0.00	05Feb1924	3.95	05May2012	105	05Jun2004
16	Brazos, Waco	1.67	04Sep1918	23.3	26Apr1909	179	31Oct1999	636	14Jul1911
17	Little River, Cameron	0.56	10Nov1952	1.73	16Nov1952	87.9	03Feb1955	252	12Mar1957
18	Navasota, Easterly	0.00	22Aug1924	0.318	14Nov1931	8.93	03Mar1964	54.9	08Jan1965
19	Brazos, Richmond	113	03Sep1934	234	08Sep1934	688	10Dec2011	731	06Oct1922
20	Buffalo Bayou, Houston	2.56	14Dec1938	5.48	01Jun1939	29.1	17Feb1957	35.0	02Jan1962
21	WF San Jacinto, Conroe	6.23	01Oct1965	8.02	02Nov1956	17.5	09Nov1939	17.5	09Nov1939
22	WF Trinity, Fort Worth	0.00	11Sep1930	0.048	09Oct1956	10.39	02Feb1955	16.0	17Dec1956
23	Trinity, Dallas	0.00	30Oct1910	0.00	29Dec1910	8.22	31Oct1918	132	27Jul1913
24	Trinity, Rosser	32.3	05Nov1924	42.5	23Dec1924	58.3	11Jul1926	58.3	10Jul1928
25	Trinity, Oakwood	45.8	13Sep1925	77.1	13Sep1925	613	29Apr1956	884	01Feb1957
26	Trinity, Romayor	127	29Aug1956	150	25Oct1956	704	31Oct1971	1766	05Feb1957
27	Neches, Rockland	2.43	20Oct1956	5.23	11Nov1956	217	04Dec2011	690	16Jul1972
28	Neches, Evansdale	84.9	20Dec1956	128	21Jan1957	763	19Dec2011	1,984	01Oct1972
29	Sabine, Beckville	10.6	14Oct1939	15.5	21Oct1956	251	22Nov2011	580	17May2013
30	Sabine, Ruliff	281	23Oct1956	310.2	08Dec1967	1031	23Nov2011	2,991	11Apr2013
31	Big Cypress, Jefferson	0.00	23Oct1939	0.170	10Nov1939	42.0	18Jun1996	83.1	01Jun2013
32	Red, Terrel	14.4	20Aug2012	29.2	29Sep2012	118	18Apr2013	169	09Mar2014
33	Red, Arthur City	170	16Dec1956	338	06Feb1940	1027	15May2013	2,518	26Sep2013
34	Canadian, Amarillo	0.00	16Sep2000	0.031	13Sep2011	6.16	16Sep2011	12.7	01Jun2013
35	Canadian, Canadian	0.00	28Sep1983	0.038	12Sep1970	22.3	09May2013	35.0	01Jun2013

The following four observed flow variables in units of cfs are plotted in Appendix C for each of the 35 gaging stations. The plots were developed using HEC-DSSVue.

1. daily flows obtained from the USGS NWIS
2. monthly flows computed by averaging the daily flows in each month
3. annual flows computed by averaging the daily flows in each year
4. the minimum monthly mean flow occurring in each year

Low flow fluctuations in the daily plots are hidden due to the scale required to plot high flows. Daily fluctuations are averaged out and thus hidden in the monthly and annual plots. Daily, monthly, and annual flows exhibit tremendous continuous variability with large fluctuations at all of the 35 sites. River flows throughout Texas are characterized by great variability.

The plots in Appendix C provide a means to explore long-term flow changes over time that have resulted from reservoir storage, water supply diversions and return flows, land use changes, and other factors. Long-term trends or permanent changes resulting from human activities are largely hidden by the tremendous natural variability of river flows. However, significant changes in flow characteristics are evident in some of the plots. Changes differ greatly between the different sites. Each of the 35 sites can be assigned to one of the following alternative categories. The gage sites are referenced by the integer identifiers in Figure 4.2.

- Both high flows and low flows have decreased at sites 1, 2, 3, 11, 34, and 35.
- Both high flows and low flows have increased at sites 6, 7, 8, and 20.
- High flows have decreased and low flows have increased at sites 23, 24, 25, and 28.
- High flows have decreased but low flow changes are not clearly evident at sites 4, 12, 13, 16, 17, 19, 29, and 31.
- Low flows have increased but high flow changes are not evident at sites 26 and 30.
- Long-term trends or permanent changes are not clearly evident at sites 5, 9, 10, 14, 15, 18, 21, 22, 27, 32, and 33.

Decreases in observed stream flows over the past 100 years are most dramatic on the Rio Grande (sites 1, 2) and the Canadian River (sites 34, 35). The flows of the Rio Grande are regulated by the very large Elephant Butte, Amistad, and Falcon Reservoirs on the Rio Grande and smaller reservoirs on tributaries. Large diversions from the river are made for agricultural irrigation in New Mexico and Texas and to a lesser extent for municipal and industrial use. The decreases in river flows are evident in the plots of Appendix C. The dramatic decrease in flows of the Canadian River may have resulted largely from irrigation from groundwater.

The San Antonio River illustrates increases in flow that may result presumably from return flows from municipal groundwater use and increased runoff from urbanization. The Trinity River illustrates increases in low flows combined with decreases in high flows.

The flows of the Brazos River at Waco (site 16) illustrate situations in which daily flows are affected by development very differently than monthly or annual flows. Daily flows have deceased greatly but changes in monthly and annual flows are not evident. Three large flood control reservoirs located upstream have attenuated flood flows which are reflected in the plot of daily flows but not in the monthly and annual flows. Flows at this site have also been reduced by upstream water supply operations but the effects are small enough to be hidden in the plots.

CHAPTER 5
WATER AVAILABILITY MODELING SYSTEM ANALYSES

Results of executing WRAP with the current use scenario versions of the 20 WAM datasets are presented in Chapter 5. This study deals with aggregate totals for each river basin rather than results for individual water rights. Water budgets are developed for each of the 20 water availability models (WAMs) that show the relative magnitude of the long-term means of pertinent quantities. The 20 river basin volume budgets are aggregated into a statewide water budget. Chapter 5 also includes frequency analyses for the total reservoir storage contents in each river basin and the naturalized and regulated flows at the basin outlets. Plots of simulated reservoir storage volumes are presented in Appendix D.

A comparative evaluation is provided in Chapter 6 of naturalized and regulated flows generated by the WAMs described in Chapter 5 and the observed flows presented in Chapter 4. Chapter 6 includes linear trend analyses of the observed flows of Chapter 4 and WAM synthesized naturalized and regulated flows at the gage sites of Chapter 4.

Water Availability Modeling (WAM) System

The TCEQ WAM system consists of the generalized Water Rights Analysis Package (WRAP) modeling system and WRAP input datasets for each of the river basins of Texas. WRAP is described by the reference, users, fundamentals, hydrology, daily, and salinity manuals cited in Chapter 1. The WAM system is described by Wurbs (2005). Although capabilities for performing daily simulations have recently been added, the simulation results presented in this report are based on a conventional monthly computational time step.

A WRAP/WAM simulation combines historical natural river basin hydrology with a specified scenario of water resources development, allocation, management, and use. River system hydrology is represented by sequences of monthly naturalized stream flows and reservoir surface evaporation less precipitation rates covering a selected hydrologic period-of-analysis. The WAM datasets represent water management activities that include about 3,400 reservoirs and other constructed infrastructure, a water rights permit system with about 6,000 active permits, five interstate compacts, treaties between the United States and Mexico, federal reservoir storage contracts, and various other institutional arrangements.

The 15 major river basins and 8 coastal basins of Texas are delineated in Figure 1.1. The 20 water availability models (WAMs) listed in Tables 5.1 and 5.2 simulate the 23 basins shown in Figure 1.1. The San Antonio River flows into the Guadalupe River. The Guadalupe and San Antonio (GSA) River Basins are combined as a single WAM. The Brazos River Basin and Brazos San-Jacinto Coastal Basin are combined into one WAM. The Colorado River Basin and Brazos-Colorado Coastal Basin are also combined. The WAM datasets are updated as new and modified water right permits are approved and modeling capabilities are refined. The dates of the latest updates of the datasets used in this study are noted in Table 5.2.

Alternative versions of the 20 WAMs simulate different water use scenarios. The authorized use and current use scenarios (called runs 3 and 8) are the main scenarios applied in the water rights permitting process. The current use scenario datasets are used in this study.

Table 5.1
Water Availability Models (WAMs)

Major River Basin and/or Coastal Basin (filename root of datasets)	Basin Area (TWDB) in Texas ($mile^2$)	Basin Area (TWDB) outside Texas ($mile^2$)	Original Simulation Period	Updated Simulation Period
Brazos and San Jacinto-Brazos Coastal (bwam8)	44,305	2,708	1940-1997	1940-2012
Canadian River Basin (CRUN8)	12,865	34,840	1948-1998	−
Colorado and Brazos-Colorado Coastal (C8)	41,278	201	1940-1998	1940-2012
Cypress Bayou Basin (cyp08)	2,929	623	1948-1998	−
Guadalupe and San Antonio Basins (gsarun8)	10,133	0	1934-1989	1934-2012
Lavaca River Basin (lav8)	2,309	0	1940-1996	−
Neches River Basin (neches8)	9,937	0	1940-1996	1940-2012
Nueces River Basin (N_Run8)	16,700	0	1934-1996	−
Red River Basin (red8)	24,297	69,153	1948-1998	−
Rio Grande Basin (RG8)	49,387	132,828	1940-2000	−
Sabine River Basin (sabine8)	7,570	2,186	1940-1998	1940-2012
San Jacinto River Basin (sjarun8)	3,936	0	1940-1996	−
Sulphur River Basin (sulphur8)	3,580	187	1940-1996	−
Trinity River Basin (trin8)	17,913	0	1940-1996	1940-2012
Coastal Basins				
Colorado-Lavaca (col-lav8)	939	0	1940-1996	−
Lavaca-Guadalupe (lavguad8)	998	0	1940-1996	−
Neches-Trinity (NT8)	769	0	1940-1996	−
Nueces-Rio Grande (Nrg8)	10,442	0	1948-1998	−
San Antonio-Nueces (SANueces8)	2,652	0	1948-1998	−
Trinity-San Jacinto (TSJ8)	247	0	1940-1996	−

The authorized use scenario WRAP input datasets in the TCEQ WAM system model the water right permits as written. All water right permit holders are assumed to use the full amounts of water authorized by their permits. No return flows are included in the model since return flows are not required in the permits. Reservoir storage capacities cited in the permits typically have not been adjusted for sedimentation. However, many water rights permit holders use less water than authorized and return flows are significant. The current use scenario adopted in this study incorporates estimates of current actual water use and return flows, updated conditions of reservoir sedimentation, and temporary term perms.

The number of control points, water right (WR) records, instream flow (IF) records, and model reservoirs in the authorized use scenario (run 3) and current use scenario (run 8) versions of the WAMs are listed in Table 5.2. Although both the authorized and current use scenarios are included in Table 5.2 for comparison, only the current use scenario datasets are used in the simulations presented in this report. The reservoirs in the WAMs are described in Chapter 2.

Table 5.2
Number of Control Points, Water Rights, and Reservoirs in the WAMs

WAM	Latest Update	Run	Number of Control Points				WR Records	IF Records	Reser- voirs
			Total	Primary	Evap	FA			
Brazos	Sep 2008	3	3,842	77	67	0	1,643	122	678
		8	3,852	77	67	0	1,734	145	719
Canadian	Jan 2013	3	85	12	9	0	56	0	47
		8	85	12	9	0	56	0	47
Colorado	Mar 2010	3	2,422	45	48	20	2,006	99	518
	Aug 2007	8	2,396	45	47	20	1,928	93	510
Cypress	Jan 2010	3	147	10	11	0	163	1	91
		8	147	10	10	0	159	1	91
GSA	Oct 2008	3	1,338	46	11	5	848	200	238
		8	1,340	46	13	5	872	214	241
Lavaca	Nov 2010	3	185	8	7	0	70	30	22
		8	184	8	7	0	65	30	21
Neches	Oct 2012	3	378	20	12	0	399	75	180
	Sep 2012	8	395	20	12	0	385	78	203
Nueces	Jan 2013	3	543	41	10	0	374	30	121
		8	546	41	10	0	393	32	125
Red	Jan 2013	3	448	47	40	5	507	102	247
		8	451	47	40	12	508	111	248
Rio Grande	Jun 2007	3	957	55	25	1	2,584	4	113
		8	957	55	25	1	2,597	4	113
Sabine	Aug 2007	3	387	27	20	0	321	22	212
		8	387	27	20	0	328	23	213
San Jacinto	Nov 2009	3	412	17	4	0	150	15	114
		8	414	17	4	0	158	17	114
Sulphur	Nov 2012	3	84	8	4	0	83	10	57
		8	89	8	4	0	85	10	57
Trinity	Oct 2012	3	1,398	40	50	0	1,061	71	697
		8	1,418	40	50	0	1,067	89	700
Colorado-	Jul 2007	3	111	1	1	0	27	4	8
Lavaca		8	111	1	1	0	27	4	8
Lavaca-	Oct 2001	3	68	2	2	0	10	0	0
Guadalupe		8	68	2	2	0	12	0	0
Neches-	Jan 2013	3	249	4	4	0	139	11	31
Trinity		8	249	4	4	0	139	11	31
Nueces-	Jan 2013	3	200	29	5	0	104	7	64
Rio Grande		8	200	29	5	0	109	7	65
San Antonio-	Jan 2013	3	53	9	3	0	12	2	9
Nueces		8	53	9	3	0	12	2	9
Trinity-	Jan 2013	3	94	2	3	0	24	0	13
San Jacinto		8	94	2	3	0	26	1	13
Totals		3	13,401	500	336	31	10,581	805	3,460
		8	13,436	500	336	38	10,660	872	3,528

Each WRAP input dataset consists of a DAT file containing information regarding water resources development, management, allocation, and use for a specified scenario of interest and FLO, DIS, and EVA files representing river system hydrology. Naturalized stream flows are provided in a FLO file for all primary control points and distributed to secondary control points within the simulation computations based on watershed parameters provided in a DIS input file. Each period-of-analysis sequence of monthly net evaporation-precipitation rates in an EVA file is applied for one or more reservoirs in the simulation. Channel losses representing seepage and evapotranspiration along stream channels are modeled using channel loss factors included in the DAT input files. As indicated in Table 5.2, the Guadalupe and San Antonio (GSA), Colorado, and Rio Grande WAMs also have a flow adjustment FAD file containing *FA* records with adjustments to naturalized flows dealing with the effects of spring flows from groundwater.

The 20 current use scenario datasets listed in Table 5.2 have a total of 13,436 control points for which naturalized monthly stream flows are either provided in an input file or computed by the simulation model. Naturalized flows are provided in input files for 500 primary control points and naturalized flows at the other 12,936 secondary control points are synthesized based on flows at the 500 primary control points. The models provide 336 sets of monthly reservoir evaporation rates used to simulate evaporation from 3,528 reservoirs. The 20 current use scenario datasets have a total of 10,660 water right (*WR*) records used to model water use associated with the approximately 6,000 water right permits. Multiple *WR* records are used to model a single water right permit. A total of 872 *IF* records specify instream flow requirements.

The simulation model converts input sequences of naturalized stream flows to sequences of regulated and unappropriated flows reflecting the specified scenario of water management and use. Naturalized flows represent natural river basin hydrology without human development, management, and use of water. Regulated flows are computed in the simulation reflecting the effects on flows of the water resources development/management/use activities being modeled. Regulated flows at a site may be greater than unappropriated flows due to instream flow requirements at the site and pass-through flows committed for downstream water users. This report focuses on naturalized and regulated flows. Unappropriated flows are not discussed.

River system hydrology in the WRAP/WAM system consists of sequences of monthly naturalized stream flows and reservoir evaporation-precipitation rates covering the hydrologic period-of-analysis. Naturalized flows at primary control points have been developed by adjusting observed monthly flows at gaging stations to remove the effects of reservoirs and water users located upstream. Reservoir surface evaporation less precipitation rates have been developed using the TWDB datasets described in Chapter 3, supplemented in some cases with pan evaporation and rainfall measurements recorded at reservoir sites by reservoir operating agencies. The net evaporation-precipitation rates include adjustments for precipitation falling on the land at the reservoir site that contributes to natural stream flow in the absence of the constructed reservoir project.

The original and updated hydrologic periods-of-analysis are listed in the last two columns of Table 5.1. Six of the WAMs have updated hydrology which was used in the simulations reported here. Naturalized flows are synthesized by a hydrologic model described in the *WRAP Hydrology Manual* (Wurbs 2013) that relates WAM naturalized flows to precipitation and evaporation sequences from the TWDB database discussed in Chapter 3.

River System Water Budgets

The water budgets presented in Table 5.3 were developed from the simulation results obtained by executing WRAP with the 20 current use scenario WAMs. The top portion of Table 5.3 provides descriptive information about each of the 20 WAM river basins. The middle section of Table 5.3 presents the river system volume budgets derived from the simulation results. The bottom of the table provides more concise summaries of the volume budgets.

Each of the WAM river system volume budgets of Table 5.3 account for the inflows into and outflows from the river system. The simulations are performed with a WRAP feature that matches beginning-of-simulation reservoir storage contents with end-of-simulation storage contents. Thus, total inflows equal total outflows. The terms in the volume budgets of Table 5.3 are defined as follows.

Naturalized flows at outlet – For the Canadian, Red, Sulphur, and Cypress Basins, naturalized flow outflows are the naturalized flows leaving Texas at the state border. For the other WAMs, naturalized stream flows at one or more outlet control points represent flows into the Gulf of Mexico. Most of the major river basins have a single outlet. The coastal basins have multiple outlets representing multiple small streams flowing into the Gulf of Mexico.

Regulated flows at outlet – Regulated flows are tabulated in Table 5.3 for the same outlet control points adopted for the naturalized flows.

Water supply diversions – The total of all water right diversions in the WAM.

Return flows – Return flows in the WAM associated with the water right diversions.

CI record constant inflows – Flows entered on constant inflow CI records usually represent return flows from groundwater use but may also represent interbasin transfers or other inflows.

Net reservoir evaporation – Reservoir surface evaporation less precipitation falling on the reservoir surface adjusted for the portion of the precipitation that contributes to stream flow without the reservoir as reflected in the naturalized flows. The net reservoir evaporation is computed in the WRAP/WAM simulation. The split between evaporation and precipitation is estimated using results from a previous study (Wurbs and Ayala 2014).

Channel losses – Channel losses computed in the simulation are associated with return flows and reservoir releases.

Channel loss credit deductions – Channel loss credits computed in the simulation are associated with stream flow depletions for water supply diversions and filling reservoir storage. These credits represent a reduction in channel losses.

Other gains and losses – This quantity that completes the following volume balance represents inaccuracies as well as other physical gains and losses not otherwise addressed.

naturalized flows – regulated flows – water supply diversions + return flows
+ CI record constant inflows – net reservoir evaporation – net reservoir storage change
+ channel loss credits – channel losses + other gains or losses = zero

Table 5.3
Descriptive Information and Volume Budgets for River Basins

Descriptive Informative for Each WAM River Basin					
WAM river basin	Colorado	Brazos	San Jacinto	Trinity	Neches
simulation period for WAM	1940-2012	1940-2012	1940-1996	1940-2012	1940-2012
watershed area (square miles)	41,278	44,305	3,936	17,797	9,937
mean precipitation (inches/year)	24.5	29.4	46.6	39.4	48.7
mean precipitation (ac-ft/year)	53,864,400	69,573,637	9,789,535	37,624,284	25,790,700
mean evaporation (inches/year)	63.05	60.20	49.0	55.13	48.5
number of reservoirs	489	719	114	700	180
storage capacity (acre-feet)	4,709,829	4,015,865	587,529	7,356,200	3,656,259
mean storage (acre-feet)	3,274,978	3,332,800	535,814	5,819,605	3,590,176
mean storage (% of capacity)	69.53%	82.99%	91.20%	79.11%	98.19%
diversion target (acre-feet/year)	2,235,420	1,519,141	520,360	6,617,851	621,609
volume reliability (percent)	82.52%	93.29%	83.18%	86.92%	81.15%
naturalized flow (% of precip)	5.79%	10.42%	23.19%	17.62%	24.13%
regulated flow (% precipitation)	3.54%	8.77%	11.43%	12.83%	21.60%
WAM River System Volume Budget (acre-feet/year)					
naturalized flows at outlet	3,118,790	7,246,374	2,270,089	6,630,282	6,223,550
regulated flows at outlet	1,907,890	6,100,112	1,119,168	4,828,743	5,571,735
water supply diversions	1,844,678	1,417,246	432,840	5,752,039	504,452
return flows	808,709	307,849	70,451	3,696,714	310,406
CI record constant inflows	14,420	63,750	544,970	635,934	36,158
net reservoir evaporation	284,690	425,646	34,026	538,291	137,618
(reservoir evaporation)	(628,767)	(1,026,529)	2,197,590	(2,546,026)	(648,870)
(reservoir precipitation)	(344,077)	(600,883)	2,163,547	(2,007,735)	(511,252)
net change in reservoir storage	0	-37.9	0	-731.8	-25.8
(beginning storage)	(2,741,179)	(3,014,288)	(532,785)	(5,292,818)	3,615,774
(ending storage)	(2,741,179)	(3,011,520)	(532,785)	(5,239,394)	3,613,887
channel loss credits	6,903	223,806	0	257,862	0.0
channel loss credit deductions	1,818	26,320	0	87,074	0.9
other gains and losses	90,254	127,545	-1,299,476	-15,377	356,334
Volume Budget Summary (acre-feet/year)					
naturalized flows at outlet	3,118,790	7,246,374	2,270,089	6,630,282	6,223,550
return flows and other inflows	823,129	371,599	615,421	4,332,648	346,564
water supply diversions	1,844,678	1,417,246	432,840	5,752,039	504,452
net reservoir evaporation-precip	284,690	425,646	34,026	538,291	137,618
other gains and losses	95,339	325,031	-1,299,476	156,143	-356,309
regulated flows at outlet	1,907,890	6,100,112	1,119,168	4,828,743	5,571,735

The volume budget summaries at the bottom of Table 5.3 are developed from the quantities in the preceding more detailed volume budgets as follows.

Naturalized and regulated flows, water supply diversions, and net reservoir evaporation-precipitation volumes in the summaries are the same as in the preceding tabulations.

return flows and other inflows = return flows + CI record constant inflows
other gains and losses = other gains and losses + channel losses credits – loss credit deductions

Table 5.3 Continued
Descriptive Information and Volume Budgets for River Basins

WAM river basin	Rio Grande	Nueces Rio-Grande	Nueces	Guadalupe & San Antonio	Lavaca
Descriptive Informative for Each WAM River Basin					
simulation period for WAM	1940-2000	1948-1998	1934-1996	1936-2012	1940-1996
watershed area (square miles)	49,387	10,442	16,700	10,133	2,309
mean precipitation (inches/year)	16.1	25.3	24.8	32.3	39.7
mean precipitation (ac-ft/year)	42,316,084	14,084,821	22,097,548	17,453,349	4,891,348
mean evaporation (inches/year)	64.0	62.3	59.6	54.1	50.8
number of reservoirs	113	65	125	241	21
storage capacity (acre-feet)	3,499,068	113,092	959,827	756,527	167,716
mean storage (acre-feet)	1,713,859	39,059	508,744	603,433	155,253
mean storage (% of capacity)	48.98%	34.54%	53.00%	79.76%	92.57%
diversion target (acre-feet/year)	2,228,867	12,146	637,039	420,776	61,620
volume reliability (percent)	81.71%	38.04%	87.37%	90.92%	82.44%
naturalized flow (% of precip)	2.60%	2.13%	2.93%	12.72%	17.59%
regulated flow (% precipitation)	0.18%	2.26%	1.99%	11.82%	16.48%
WAM River System Volume Budget (acre-feet/year)					
naturalized flows at outlet	1,099,597	300,314	647,932	2,220,137	860,402
regulated flows at outlet	75,163	318,006	440,410	2,063,020	806,335
water supply diversions	1,821,216	4,620	556,610	382,559	50,798
return flows	34,651	443	423,900	110,698	1,758
CI record constant inflows	0	53,208	11,241	172,962	16,050
net reservoir evaporation	217,632	12,808	93,002	65,288	21,078
(reservoir evaporation)	(304,111)	(23,982)	(201,597)	(158,119)	(106,652)
(reservoir precipitation)	(86,479)	(11,174)	(108,595)	(92,831)	(85,574)
net change in reservoir storage	0	0	0	871	0
(beginning storage)	(444,488)	(44,967)	(20,268)	572,268	(167,675)
(ending storage)	(444,488)	(44,967)	(20,268)	573,139	(167,675)
channel loss credits	0	1,117	91,984	740,722	0
channel loss credit deductions	0	4,620	21,085	305,638	0
other gains or losses	979,763	-15,028	-63,950	7,070	1
Volume Budget Summary (acre-feet/year)					
naturalized flows at outlet	1,099,597	300,314	647,932	2,220,137	860,402
return flows and other inflows	34,651	53,651	435,141	283,660	17,808
water supply diversions	1,821,216	4,620	556,610	382,559	50,798
net reservoir evaporation-precip	217,632	12,808	93,002	65,288	21,078
other gains and losses	979,763	-18,531	6,949	7,070	1
regulated flows at outlet	75,163	318,006	440,410	2,063,020	806,335

The quantities sum to zero in the following volume balance equation.

naturalized flows at outlet + return flows and other inflows + other gains or losses
– water supply diversions – net reservoir evaporation – regulated flows = zero

Table 5.3 Continued
Descriptive Information and Volume Budgets for River Basins

Descriptive Informative for Each WAM River Basin					
WAM river basin	Canadian	Red	Sulphur	Cypress	Sabine
simulation period for WAM	1948-1998	1948-1998	1948-1996	1948-1998	1948-1998
watershed area (square miles)	12,865	24,297	3,580	2,929	7,570
mean precipitation (inches/year)	19.5	25.6	46.6	47.2	47.8
mean precipitation (ac-ft/year)	13,372,409	33,128,908	8,899,780	7,377,989	19,282,844
mean evaporation (inches/year)	66.2	63.4	50.1	48.9	50.9
number of reservoirs	47	248	57	91	213
storage capacity (acre-feet)	879,824	3,780,342	718,699	877,938	6,262,314
mean storage (acre-feet)	610,254	3,369,963	624,481	753,868	6,114,799
mean storage (% of capacity)	69.36%	89.14%	86.89%	85.87%	97.64%
diversion target (acre-feet/year)	94,164	860,601	242,065	496,232	550,276
volume reliability (percent)	95.38%	97.25%	99.21%	77.96%	98.74%
naturalized flow (% of precip)	–	–	29.11%	22.71%	34.40%
regulated flow (% precipitation)	–	–	25.29%	19.96%	32.11%
WAM River System Volume Budget (acre-feet/year)					
naturalized flows at outlet	217,548	10,093,274	2,590,678	1,675,698	6,633,087
regulated flows at outlet	128,393	9,116,350	2,250,450	1,472,695	6,191,736
water supply diversions	89,809	836,901	240,152	386,843	543,324
return flows	88,682	243,357	1,222	248,388	190,691
CI record constant inflows	1,715	7,900	217,250	1,754	107,644
net reservoir evaporation	62,269	328,422	55,808	42,312	216,206
(reservoir evaporation)	(90,564)	(948,381)	(224,763)	(170,409)	(1,056,656)
(reservoir precipitation)	(28,295)	(619,959)	(168,955)	(128,097)	(840,450)
net change in reservoir storage	0	1,948	0	-2.9	0
(beginning storage)	(429,055)	(3,200,513)	(628,635)	(783,458)	(6,013,477)
(ending storage)	(429,055)	(3,299,854)	(628,635)	(783,309)	(6,013,476)
channel loss credits	62,576	26,372	0	0	0
channel loss credit deductions	693	1,832	0	0	0
other gains or losses	-89,357	-85,450	-262,740	-23,993	19,844
Volume Budget Summary (acre-feet/year)					
naturalized flows at outlet	217,548	10,093,274	2,590,678	1,675,698	6,633,087
return flows and other inflows	90,397	251,257	218,472	250,142	298,335
water supply diversions	89,809	836,901	240,152	386,843	543,324
net reservoir evaporation-precip	62,269	328,422	55,808	42,312	216,206
other gains and losses	-27,474	-62,858	-262,740	-23,990	19,844
regulated flows at outlet	128,393	9,116,350	2,250,450	1,472,695	6,191,736

The WAM system is designed for assessing water availability in Texas. WAMs for the international and interstate river basins consider the entire river basin to the extent necessary to assess water availability in Texas. The volume budget computations for the Rio Grande, Red, and Sabine River Basins are adjusted in this study to limit the volume budget quantities to reflect the portion of the river basins contained within the state of Texas using quantities shown in Tables 5.4 and 5.5 and discussed in the following paragraphs.

Table 5.3 Continued
Descriptive Information and Volume Budgets for River Basins

Descriptive Informative for Each WAM Coastal Basin					
WAM coastal basin	San Antonio-Nueces	Lavaca-Guadalupe	Colorado-Lavaca	Trinity-San Jacinto	Neches-Trinity
simulation period for WAM	1940-1998	1940-1996	1940-1996	1940-1996	1940-1996
watershed area (square miles)	2,652	998	939	247	769
mean precipitation (inches/year)	35.1	39.6	40.0	48.1	49.6
mean precipitation (ac-ft/year)	4,958,103	2,108,064	2,005,438	633,847	2,032,559
mean evaporation (inches/year)	53.9	50.8	50.6	46.5	45.9
number of reservoirs	9	0	8	13	31
storage capacity (acre-feet)	1,481	0	7,227	4,876	57,986
mean storage (acre-feet)	1,139	0	5,967	3,194	19,827
mean storage (% of capacity)	76.91%	–	82.57%	65.50%	34.19%
diversion target (acre-feet/year)	481	230	36,103	10,094	208,845
volume reliability (percent)	89.40%	69.13%	65.13%	78.43%	67.39%
naturalized flow (% of precip)	11.40%	19.28%	19.76%	28.54%	56.72%
regulated flow (% precipitation)	11.40%	19.78%	19.19%	30.00%	51.82%
WAM River System Volume Budget (acre-feet/year)					
naturalized flows at outlet	565,201	406,539	396,183	180,904	1,152,769
regulated flows at outlet	565,236	416,945	384,800	190,137	1,053,371
water supply diversions	430	159	23,514	7,917	140,746
return flows	209	24	3,263	338	0
CI record constant inflows	851	11,247	9,621	17,625	47,183
net reservoir evaporation	529	0	753	475	3,234
(reservoir evaporation)	(1,758)	(0)	(4,869)	(1,975)	(33,634)
(reservoir precipitation)	(1,229)	(0)	(4,116)	1,500	(30,400)
net change in reservoir storage	0	0	0	0	0
(beginning storage)	(1,365)	(0)	(6,635)	(3,016)	(19,357)
(ending storage)	(1,365)	(0)	(6,635)	(3,016)	(19,357)
channel loss credits	31	0	0	0	0
channel loss credit deductions	111	0	0	0	0
other gains or losses	14	-706	0	-338	-2,601
Volume Budget Summary (acre-feet/year)					
naturalized flows at outlet	565,201	406,539	396,183	180,904	1,152,769
return flows and other inflows	1,060	11,271	12,884	17,963	47,183
water supply diversions	430	159	23,514	7,917	140,746
net reservoir evaporation-precip	529	0	753	475	3,234
other gains and losses	-66	-706	0	-338	-2,601
regulated flows at outlet	565,236	416,945	384,800	190,137	1,053,371

Rio Grande simulation results in Table 5.3 include only water allocated to the United States. The WAM simulation results for the Red and Sabine Basins presented in Table 5.3 are further adjusted for later incorporation in the statewide water budget of Table 5.6 to approximately remove stream flow and reservoir storage that is not available to Texas.

Table 5.4
Simulation Results for Rio Grande WAM

	United States	Mexico	Total
storage capacity (acre-feet)	3,499,068	2,400,304	5,899,372
Amistad	(1,673,055)	(1,303,912)	(2,976,967)
Falcon	(1,551,897)	(1,096,392)	(2,648,289)
Red Bluff	(274,116)	–	274,116
mean storage (acre-feet)	1,713,859	1,933,102	3,646,962
Amistad	(1,102,287)	(1,196,322)	(2,298,609)
Falcon	(570,458)	(736,780)	(1,307,238)
Red Bluff	(41,114)	–	(41,114)
net reservoir evaporation (acre-feet/year)	217,632	239,217	456,849
Amistad	(107,690)	(118,254)	(225,944)
Falcon	(100,945)	(120,963)	(221,908)
Red Bluff	(8,997)	–	(8,997)
net change reservoir storage (ac-ft/year)	0	0	0
(beginning storage Amistad)	(342,459)	(232,876)	(575,355)
(beginning storage Falcon)	(80,834)	(76,204)	(157,038)
(beginning storage Red Bluff)	(21,195)	–	(21,195)
(ending storage Amistad)	(342,459)	(232,876)	(575,355)
(ending storage Falcon)	(80,834)	(76,204)	(157,038)
(ending storage Red Bluff)	(21,195)	–	(21,195)
Rio Grande			
water supply diversions targets (ac-ft/year)	2,228,867	3,086,086	5,314,953
water supply diversions (acre-feet/year)	1,821,216	2,840,024	4,661,240
return flows (acre-feet/year)	34,651	57,097	91,748
Red Bluff Reservoir on Pecos River			
water supply diversions targets (ac-ft/year)	66,625	–	66,625
water supply diversions (acre-feet/year)	39,628	–	39,628
return flows (acre-feet/year)	0	–	0
naturalized flows at outlet (acre-feet/year)	1,099,597	3,206,243	4,305,840
regulated flows at outlet (acre-feet/year)	75,163	899,476	974,639

The Rio Grande WAM is complicated by the allocation of water between the United States and Mexico in accordance with 1906 and 1944 treaties. Most use of the water resources of the Rio Grande in Texas is from water stored in the International Amistad and Falcon Reservoirs. The water budget in Table 5.3 for the Rio Grande WAM includes only the United States allocation of the flows of the Rio Grande and water stored in International Amistad and Falcon Reservoirs on the Rio Grande and Red Bluff Reservoir on the Pecos River. Quantities from the Rio Grande WAM are summarized in Table 5.4. Only the quantities in Table 5.4 allocated to the Rio Grande are included in the Table 5.3.

Table 5.5
International and Interstate Rivers

	Rio Grande	Red River		Sabine River	
	Texas	WAM	Texas	WAM	Texas
number of reservoirs	3	248	248	213	213
(reservoirs on border)	(2)	(1)	(1)	(1)	(1)
storage capacity (ac-ft)	3,499,068	3,780,342	2,647,342	6,262,314	4,035,980
(reservoirs on border)		(2,266,000)	(1,133,000)	(4,452,668)	(2,226,334)
mean storage (ac-ft)	1,713,859	3,369,963	2,249,585	6,114,799	3,899,396
(reservoirs on border)		(2,240,757)	(1,120,379)	(4,430,807)	(2,215,404)
net evap-precip (ac-ft/yr)	217,632	328,422	272,171	216,206	174,079
(reservoirs on border)		(112,502)	(56,251)	(84,255)	(42,128)
diversion target (ac-ft/yr)	2,228,867	860,601	860,601	550,276	550,276
diversions (ac-ft/yr)	1,821,216	836,901	836,901	543,324	543,324
naturalized flows (ac-ft/yr)	1,099,597	10,093,274	5,046,637	6,633,087	837,849
regulated flow (ac-ft/yr)	75,163	9,116,350	4,558,175	6,191,736	736,348

The Red River serves as the border between Texas and Oklahoma. The Sabine River is the border between Texas and Louisiana. Lake Texoma on the Red River in Texas and Oklahoma has the largest total storage capacity, including combined flood control and conservation capacity, of any reservoir in Texas. Toledo Bend Reservoir on the Sabine River in Texas and Louisiana has the largest conservation storage capacity of any reservoir in Texas and the southern United States.

The Red WAM and Sabine WAM model the interstate basins to the extent required to simulate water availability in Texas. The WAMs include only water supply diversions in Texas. The water budgets in Table 5.3 are based on quantities obtained directly from the WAMs. However, the present study allocates to Texas for inclusion in the Table 5.6 statewide volume budgets only 50.0 percent of the storage and evaporation in Lakes Texoma and Toledo Bend and 50.0 percent of the naturalized and regulated flows. The quantities incorporated in the Table 5.6 statewide volume budgets are shown in the Texas columns of Table 5.5.

Statewide Water Budget

The water budget for the entire state of Texas presented in Table 5.6 was developed by aggregating the river basin water budgets of Table 5.3. The next-to-last column of Table 5.6 shows the totals resulting from summing the quantities from Table 5.3. The statewide volume budget in the last column of Table 5.6 reflects adjustments consisting removal of 50 percent of the stream flow and reservoir storage and evaporation of Texoma and Toledo Bend Reservoirs for the interstate Red and Sabine River Basin WAM simulation results to approximate the allocation of the shared water resources to neighboring states under the interstate compacts.

Texas has a mean annual precipitation of 27.93 inches/year, which is equivalent to 391,286,000 acre-feet/year. The long-term mean naturalized and regulated stream flows leaving the state as inflows to the Gulf of Mexico or flows at the state border are an estimated 11.80 and 9.54 percent of the long-term mean precipitation based on the premises reflected in the WAMs.

Table 5.6
Descriptive Information and Volume Budgets for Entire State of Texas

	WAM Total	Texas
Descriptive Information		
watershed area (square miles)	259,181	259,181
mean precipitation (inches/year)	–	27.93
mean precipitation (ac-ft/year)	391,285,647	391,285,647
mean evaporation (inches/year)	–	59.61
number of reservoirs	3,484	3,484
storage capacity (acre-feet)	38,412,599	35,053,265
mean storage (acre-feet)	31,300,013	27,964,230
mean storage (% of capacity)	81.48%	79.78%
diversion target (acre-feet/year)	17,373,920	17,373,920
volume reliability (percent)	86.55%	86.55%
naturalized flow (% of precip)	–	11.80%
regulated flow (% precipitation)	–	9.54%
Volume Budget Summary (acre-feet/year)		
naturalized flows at outlets	54,529,348	46,166,168
return flows and other inflows	8,513,236	8,513,236
water supply diversions	15,036,853	15,036,853
net reservoir evaporation-precip	2,540,087	2,441,708
evaporation	(10,375,252)	(10,006,928)
precipitation	(7,835,148)	(7,565,200)
other gains and losses	-464,949	145,809
regulated flows at outlets	45,000,695	37,346,652

Descriptive information is provided in the top portion of Table 5.6. The volume budget summary provided in the bottom portion of Table 5.6 represents current conditions of water resources development, allocation, management, and use. The corresponding water budget for natural conditions, without human water development/use, consists of only the naturalized flows shown in the table. All of the other quantities reflect human activities that convert naturalized flows to regulated flows. Essentially all of the reservoir storage in Texas is water impounded by constructed dams. As noted in Chapter 2, Caddo Lake is the only natural lake in the state.

The quantities in the volume budget summary sum to zero in the following volume balance equation.

naturalized flows at outlet + return flows and other inflows + other gains or losses
– water supply diversions – net reservoir evaporation – regulated flows = zero

The term *other gains or losses* is computed simply as the quantity that forces the volume balance equation to sum to zero. *Other gains or losses* include approximations and inaccuracies in the simulation as well as the net of gains and losses not otherwise explicitly included in the accounting summary such channel losses due to seepage and evapotranspiration and inflows from neighboring states.

Reservoir Surface Evaporation and Precipitation

The long-term mean simulated reservoir evaporation volume of 10,006,928 acre-feet/year in Table 5.6 is notable, being 66.5 percent as large as the mean total water supply diversions. Likewise, the precipitation volume of 7,565,200 acre-feet/year is a large reservoir inflow. The precipitation volume of 7,565,200 acre-feet/year represents precipitation falling on reservoir water surfaces less estimated precipitation from the reservoir sites included in naturalized flows

Precipitation falling on the water surface is an inflow to a reservoir. Evaporation from the reservoir water surface is a loss. The WAM input datasets include a file of net evaporation less precipitation rates in feet for each month of the hydrologic period-of-analysis for each of the reservoirs. Net evaporation-precipitation volumes are computed in the simulation by multiplying net evaporation-precipitation depths by water surface areas determined as a function of storage volume. For most reservoirs, the net evaporation-precipitation depths in the WAM input datasets are based on the TWDB databases described in Chapter 3. In some cases, data from evaporation pans and rain gages maintained by reservoir operators are used for particular reservoirs.

All of the precipitation falling on the water surface is inflow to the reservoir. Without the reservoir, only a portion of the precipitation contributes to stream flow with the remainder lost to infiltration and evapotranspiration. The WAMs adjust precipitation falling on reservoir water surfaces to prevent double-counting precipitation at the reservoir site that is reflected in the naturalized stream flows. The net evaporation-precipitation volumes cited in this chapter are evaporation less precipitation falling on the water surface adjusted to exclude the precipitation runoff from the reservoir site that is already included in the naturalized stream flows.

The WRAP/WAM modeling system deals with net evaporation less precipitation without separating the two components. The separate evaporation and precipitation volumes shown in Tables 5.5 and 5.6 were approximated by multiplying the simulated net evaporation-precipitation volumes by factors derived from simulation results from a previous WRAP/WAM simulation study focused on estimating reservoir evaporation volumes. Wurbs and Ayala (2014) describe this earlier study conducted with a modified version of the WRAP/WAM system that separated reservoir surface precipitation and evaporation. However, simulations were performed with the authorized use scenario WAM datasets which are significantly different than the current use scenario datasets adopted for the present study.

Current use scenario water supply demands are smaller, in many cases much smaller, than the amounts authorized in the water right permits. Also, the authorized use scenario assumes zero return flows. Thus, storage draw-downs are much greater in the authorized use scenario than in the current use scenario datasets, resulting is smaller evaporation volumes. The authorized use scenario reflects reservoir storage capacities in the water right permits, and the current use scenario includes adjustments for sedimentation.

Net evaporation-precipitation volumes were computed by the simulation model in the conventional manner in the present study. After completion of the simulations, evaporation volumes and precipitation volumes were estimated for each of the 20 individual WAMs based on multiplying the net evaporation-precipitation volumes by factors determined from the previous reservoir evaporation study reported by Wurbs and Ayala (2014). Although storage draw-downs are much less and net evaporation-precipitation volumes are much larger in the current use scenario than in the authorized use scenario, the relative proportions of precipitation and evaporation in the net evaporation-precipitation volumes are assumed to be about the same.

The statewide totals from Table 5.6 are compared to the earlier reservoir evaporation study as follows.

	Current Use Scenario	Authorized Use Scenario
net evap-precip (acre-feet/year)	2,441,708	1,434,800
evaporation (acre-feet/year)	10,006,928	6,102,100
adjusted precipitation (ac-ft/yr)	7,565,200	4,667,300

In East Texas, reservoir surface precipitation is greater than evaporation. In West Texas, reservoir surface precipitation is much less than evaporation. For most of the reservoirs in Texas, evaporation exceeds the adjusted water surface precipitation. Precipitation falling on reservoir water surfaces and evaporation from reservoir water surfaces are major components of river/reservoir system water budgets throughout Texas.

Reservoir Storage

The 20 current use scenario WAMs contain a total of 3,484 reservoirs that contain a total permitted conservation storage capacity, adjusted to reflect sedimentation, of 38,412,599 acre-feet. The 3,528 reservoirs included in Table 5.2 include additional computational reservoirs that are used in water allocation accounting computations but are not actual reservoirs.

For each of the 20 WAMs, the total storage contents of all reservoirs were computed in each month of the hydrologic period-of-analysis. Plots of these total end-of-month storage contents for each WAM are presented in Appendix D. Linear regression analysis was applied to the sequences of simulated storage volumes yielding the results presented in Table 5.8. Storage frequency metrics are presented in Table 5.9.

Means of the total simulated storage contents for each WAM are included in Table 5.3 and summed to obtain the totals in Tables 5.6, 5.7, 5.8, and 5.9. The long-term mean storage contents of 31,077,179 acre-feet is the summation of the means for the 20 individual WAMs. The total of the simulation storage contents is 90.48% of the total conservation storage capacity.

The beginning-of-simulation storage contents of each reservoir is set equal to its end-of-simulation contents. An initial preliminary simulation serves the sole purpose of determining end-of-simulation storage volumes. This approach is different than the more typical WAM applications for which all reservoirs are assumed to be full at the beginning of the simulation. The linear trend analysis results of Table 5.8 are significantly affected by setting the beginning-of-simulation storage contents equal to end-of-simulation contents rather than full to capacity.

Table 5.7
Simulated Monthly Reservoir Storage Volume

Water Availability Model	Capacity	Mean	Stand Dev	Minimum	Maximum
	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
Brazos and San Jacinto-Brazos	4,015,865	3,332,798	366,301	1,941,981	3,861,882
Canadian River Basin	879,824	610,254	171,942	332,058	878,597
Colorado and Brazos-Colorado	4,709,829	3,274,978	291,605	2,356,907	4,330,434
Cypress Bayou Basin	877,938	753,868	44,350	605,165	812,735
Guadalupe and San Antonio	756,527	603,433	81,690	325,510	756,055
Lavaca River Basin	167,716	155,253	15,389	88,291	167,716
Neches River Basin	3,656,259	3,590,175	77,428	3,061,236	3,645,493
Nueces River Basin	959,827	508,744	264,848	4,813	952,669
Red River Basin	3,780,342	3,369,963	164,352	2,846,774	3,668,677
Rio Grande Basin	3,449,068	1,713,859	3,536,295	1,872,593	14,852,787
Sabine River Basin	6,262,314	6,114,800	171,985	5,138,603	6,258,565
San Jacinto River Basin	587,529	535,814	56,969	253,077	580,467
Sulphur River Basin	718,699	624,451	65,620	379,281	718,681
Trinity River Basin	7,356,200	5,819,605	854,458	2,527,518	7,295,806
Coastal Basins					
Colorado-Lavaca	7,227	5,967	755	4,112	7,072
Lavaca-Guadalupe	0	0	0	0	0
Neches-Trinity	57,986	19,826	2,544	13,231	28,996
Nueces-Rio Grande	113,092	39,059	4,772	27,470	52,188
San Antonio-Nueces	1,481	1,138	229	413	1,385
Trinity-San Jacinto	4,876	3,194	681	1,051	3,886
Total	34,346,734	31,077,179			

Table 5.8
Regression Coefficients for Simulated Monthly Reservoir Storage Contents

Water Availability Model	Mean (ac-ft)	Intercept (ac-ft)	Slope (ac-ft)	Intercept (% Mean)	Slope (% Mean)
Brazos and San Jacinto-Brazos	3,332,800	3,063,283	615	91.9	0.0184
Canadian River Basin	610,254	830,128	-717	136	-0.118
Colorado and Brazos-Colorado	3,274,977	3,243,269	72.31	99.0	0.00221
Cypress Bayou Basin	753,868	748,098	18.8	99.2	0.00250
Guadalupe and San Antonio	756,527	602,442	2.09	99.8	0.00035
Lavaca River Basin	155,253	150,693	13.3	97.1	0.00857
Neches River Basin	3,590,175	3,599,930	-22.2	100	-0.00062
Nueces River Basin	508,744	596,049	-231	117	-0.0453
Red River Basin	3,369,965	3,282,500	285	97.4	0.00847
Rio Grande Basin	1,713,859	1,794,619	-220	105	-0.01286
Sabine River Basin	6,114,800	6,126,140	-25.9	100	-0.00042
San Jacinto River Basin	535,814	519,028	49.0	96.9	0.00915
Sulphur River Basin	624,451	625,488	-3.03	100	-0.00049
Trinity River Basin	5,819,603	5,200,339	1,412	89.4	0.02427
Coastal Basins					
Colorado-Lavaca	5,967	5,896	0.205	98.8	0.00344
Lavaca-Guadalupe	0	0	0	0	0
Neches-Trinity	19,827	19,840	-0.0383	100	-0.00019
Nueces-Rio Grande	39,059	37,880	3.85	97.0	0.00985
San Antonio-Nueces	1,139	1060	0.26	93.1	0.0226
Trinity-San Jacinto	3,194	3,133	0.177	98.1	0.00555

Table 5.9
Reservoir Storage Frequency Metrics in acre-feet

	Colorado	Brazos	San Jacinto	Trinity	Neches
Mean	3,274,978	3,332,798	535,814	5,819,604	3,590,175
SD	434,369	366,301	56,969	854,458	77,428
Min	1,703,109	1,941,981	253,077	2,527,518	3,061,236
99.5%	1,943,192	2,101,658	279,338	2,642,273	3,243,630
99%	2,065,189	2,146,023	327,304	3,045,641	3,308,954
98%	2,263,165	2,297,065	386,944	3,364,477	3,371,322
95%	2,454,602	2,599,524	415,450	4,246,650	3,423,859
90%	2,673,102	2,844,695	452,510	4,785,074	3,484,408
85%	2,813,601	3,012,033	485,580	5,133,439	3,524,542
80%	2,922,046	3,080,316	501,486	5,315,968	3,552,808
75%	3,026,422	3,133,384	512,108	5,417,545	3,570,501
70%	3,108,938	3,203,081	523,719	5,512,516	3,589,987
60%	3,241,059	3,288,125	544,291	5,715,956	3,612,185
50%	3,330,371	3,428,300	561,332	5,931,644	3,623,266
40%	3,402,275	3,514,518	570,123	6,094,204	3,631,042
30%	3,488,144	3,576,961	574,893	6,248,728	3,636,754
25%	3,555,350	3,618,770	577,042	6,380,957	3,638,729
20%	3,672,154	3,652,525	578,193	6,519,455	3,640,652
15%	3,744,935	3,685,262	578,956	6,628,969	3,641,926
10%	3,818,686	3,706,213	579,430	6,804,933	3,643,083
5%	3,902,309	3,758,571	580,110	7,100,001	3,644,772
2%	4,003,559	3,800,552	580,354	7,261,623	3,645,230
1%	4,059,010	3,828,657	580,409	7,273,592	3,645,328
0.5%	4,109,053	3,840,319	580,438	7,291,789	3,645,384
Max	4,133,082	3,861,882	580,467	7,295,806	3,645,493

	Canadian	Red	Sulphur	Cypress	Sabine
Mean	610,254	3,369,963	624,451	753,868	6,114,800
SD	171,942	164,352	65,620	44,350	171,985
Min	332,058	2,846,774	379,281	605,165	5,138,603
99.5%	340,403	2,890,551	397,378	614,070	5,249,399
99%	341,913	2,907,920	433,698	618,828	5,395,487
98%	344,855	2,972,759	466,342	635,168	5,646,705
95%	353,143	3,042,846	503,895	662,179	5,780,343
90%	367,195	3,111,638	538,457	689,688	5,903,030
85%	398,887	3,197,816	557,207	707,454	5,965,109
80%	422,412	3,239,806	573,477	717,662	6,014,913
75%	439,231	3,274,452	588,893	731,344	6,044,374
70%	477,418	3,302,715	602,561	738,954	6,077,161
60%	549,521	3,361,189	619,924	755,031	6,127,765
50%	639,546	3,403,304	629,973	767,632	6,169,118
40%	685,745	3,438,492	636,538	775,246	6,206,933
30%	738,107	3,471,458	662,211	783,933	6,235,053
25%	754,551	3,486,422	676,156	788,447	6,245,369
20%	777,207	3,509,374	689,848	792,865	6,248,876
15%	812,676	3,531,653	696,756	796,167	6,252,497
10%	845,210	3,554,812	714,741	799,302	6,254,827
5%	870,696	3,604,061	718,336	803,050	6,256,493
2%	876,792	3,616,589	718,650	807,254	6,258,001
1%	878,289	3,633,843	718,679	810,218	6,258,422
0.5%	878,452	3,649,513	718,680	811,850	6,258,516
Max	878,597	3,668,677	718,681	812,735	6,258,565

Table 5.9 Continued
Reservoir Storage Frequency Metrics in acre-feet

	San Ant-Nueces	Lavaca-Guadalupe	Colorado-Lavaca	Trinity-San Jacinto	Neches-Trinity
Mean	1,139	0	5,967	3,194	19,827
SD	229	0	755	681	2,544
Min	413	0	4,112	1,051	13,231
99.5%	488	0	4,174	1,143	14,394
99%	526	0	4,236	1,293	14,924
98%	611	0	4,367	1,537	15,252
95%	693	0	4,578	1,875	15,990
90%	752	0	4,817	2,202	17,081
85%	854	0	4,966	2,518	17,845
80%	938	0	5,149	2,584	18,156
75%	990	0	5,408	2,614	18,404
70%	1,046	0	5,660	2,775	18,585
60%	1,147	0	6,014	3,207	19,021
50%	1,214	0	6,062	3,379	19,354
40%	1,272	0	6,251	3,641	19,815
30%	1,315	0	6,411	3,802	20,366
25%	1,330	0	6,569	3,816	20,695
20%	1,344	0	6,680	3,825	21,342
15%	1,365	0	6,807	3,833	22,318
10%	1,368	0	6,947	3,843	23,614
5%	1,378	0	6,962	3,852	25,394
2%	1,382	0	6,976	3,867	26,623
1%	1,383	0	6,994	3,878	27,255
0.5%	1,384	0	7,031	3,884	27,679
Max	1,385	0	7,072	3,886	28,996

	Rio Grande	Nueces-Rio Grande	Nueces	GSA	Lavaca
Mean	1,713,860	39,059	508,744	603,433	155,253
SD	999,347	4,772	264,848	81,691	15,389
Min	222,827	27,470	4,814	325,501	88,291
99.5%	287,636	28,363	5,208	333,810	93,687
99%	303,787	28,668	5,885	375,109	100,808
98%	327,357	29,277	7,389	425,032	112,764
95%	352,302	30,740	39,477	473,224	126,293
90%	387,840	32,348	125,603	501,422	132,784
85%	438,122	33,667	176,153	513,571	138,093
80%	539,589	34,661	247,620	528,311	143,682
75%	666,864	35,456	304,904	542,790	147,560
70%	903,770	36,508	356,647	558,889	150,925
60%	1,375,231	37,968	450,449	585,752	156,660
50%	1,715,720	39,308	546,301	612,419	160,837
40%	2,096,475	40,877	611,164	636,834	165,037
30%	2,425,137	41,984	677,416	650,708	167,684
25%	2,564,534	42,904	716,155	662,066	167,714
20%	2,764,003	43,401	760,545	678,031	167,714
15%	2,939,645	43,956	814,263	688,781	167,716
10%	3,116,707	44,927	856,561	706,997	167,716
5%	3,233,823	46,041	911,147	725,313	167,716
2%	3,319,648	47,720	944,674	749,527	167,716
1%	3,405,030	49,698	949,561	754,474	167,716
0.5%	3,495,433	50,824	951,819	755,521	167,716
Max	3,498,063	52,188	952,669	756,055	167,716

Frequency Metrics for Naturalized and Regulated Flows

Sequences of monthly naturalized and regulated flows at the river basin outlets at the Gulf of Mexico or state borders for the hydrologic periods-of-analysis listed in Table 5.1 are provided by the WAM simulations. Frequency analysis results are presented in Tables 5.10, 5.11, and 5.12. A comparison of regulated versus naturalized flows provides an indication of the effects of water resources development, management, and use on river flows.

Frequency metrics in acre-feet/month are presented in Table 5.10. This same information is repeated in Tables 5.11 and 5.12 in formats designed to facilitate comparison of regulated and naturalized flows. Table 5.11 shows flow metrics for naturalized flows in acre-feet/month followed by the corresponding metrics for regulated flows as a percent of the naturalized flow metrics. For each basin WAM, the quantities in the first line are naturalized flows in acre-feet/month at the basin outlets, and the metrics in the second line are regulated flows expressed as percentages of the naturalized flow quantities. Table 5.12 shows only the regulated flows expressed as a percent of the corresponding naturalized flow metrics.

The mean and standard deviation of the monthly flow volumes in acre-feet/month are provided as the first two rows of Table 5.10. The remainder of the table consists of monthly flow volumes in acre-feet/month that are equaled or exceeded during the percentages of the months of the simulation listed in the first column.

The quantities in Table 5.10 are repeated in Table 5.11 in a format designed for convenient comparison of regulated flows with naturalized flows. Naturalized flow quantities in acre-feet/month are followed by the corresponding metrics for regulated flows expressed as a percentage of naturalized flows. Table 12 is condensed to show only the regulated flow metrics expressed as a percentage of the corresponding naturalized flow metrics. There is no percentage for regulated flow in Tables 5.10 and 5.11 if the naturalized flow quantity is zero.

The naturalized (Nat) and regulated (Reg) flows represent the stream flows flowing out of each of the 20 basins under natural undeveloped conditions and current conditions of water development and use. For the Rio Grande the flows include only the portion allocated to the United States. The flows for the Canadian, Red, Sulphur, and Cypress WAMs are the total outflows crossing the state border. The flows for the other WAMs are total flows flowing into the Gulf of Mexico.

The effects of water resources development, management, and use vary greatly between the different river basins. The means of the regulated flows for the San Jacinto River Basin is 106.4% and for the Nueces-Rio Grande, San Antonio-Nueces, Lavaca-Guadalupe, and Trinity-San Jacinto Coastal Basins are 105.9%, 100.0%, 102.6%, and 105.1% of the means of their naturalized flows. The means of the regulated flows for the other WAMs and less than their naturalized flow means. For example, mean regulated flows for the Colorado, Brazos, and Trinity WAMs are 61.2%, 84.2%, and 72.8% of the means of their naturalized flows.

Regulated flows associated with specified exceedance frequencies are presented as percentages of the corresponding naturalized flows in Table 5.12. Regulated flows are less than naturalized flows for the full range of exceedance frequencies for the Colorado, Brazos, Neches, Rio Grande, Nueces-Rio Grande, Guadalupe and San Antonio (GSA), Red, Cypress, and Sabine WAMs. The 11 other WAMs each have regulated flow percentages that vary between less than 100% and greater than 100% over the range of frequencies shown in Table 5.12. Regulated flows tend to be a smaller percentage of naturalized flows for low flows than for high flows.

Table 5.10
Frequency Metrics in acre-feet/month
for Naturalized and Regulated Flows at Basin Outlets

	Colorado		Brazos		San Jacinto		Trinity		Neches	
	Nat	Reg	Nat	Reg	Nat	Reg	Nat	Reg	Nat	Reg
Mean	259,899	158,991	603,864	508,343	189,174	201,247	552,523	402,395	518,629	464,311
SD	325,784	280,161	786,811	765,166	254,331	244,428	679,163	598,593	584,119	591,800
Min	7,909	0	4	6,981	2,791	40,591	749	407	4,994	0
99.5%	10,553	0	13,372	7,869	5,428	41,213	2,232	1,505	10,923	0
99%	14,479	0	17,611	8,646	6,196	41,773	3,408	5,725	12,712	0
98%	20,898	0	25,190	9,391	7,717	42,710	5,993	9,530	15,567	0
95%	34,149	1,223	38,338	11,121	10,905	45,860	11,908	10,611	24,953	0
90%	45,931	3,188	59,028	14,528	14,583	48,451	30,487	14,099	43,258	1,691
85%	54,576	9,417	82,255	24,918	19,987	51,014	48,113	17,199	59,447	4,060
80%	66,073	16,651	108,003	42,557	25,461	55,809	68,064	19,766	79,925	14,592
75%	75,635	20,685	131,538	62,325	32,393	59,495	100,678	22,783	98,825	29,465
70%	84,755	22,468	161,341	82,164	40,138	62,802	141,863	27,232	125,075	54,883
60%	109,193	33,784	226,102	131,086	60,857	76,668	211,016	71,463	205,239	130,108
50%	142,149	48,514	306,959	196,625	86,984	99,991	285,135	136,368	287,667	223,969
40%	191,547	76,896	409,074	295,867	126,001	135,882	422,850	248,579	426,012	366,105
30%	265,618	145,931	600,253	470,179	203,779	191,444	607,035	395,816	630,880	553,972
25%	322,934	186,456	735,958	628,899	248,301	237,967	750,025	540,770	761,127	701,327
20%	377,934	237,732	940,576	821,493	314,771	305,465	942,151	702,955	908,150	846,565
15%	461,371	315,901	1,254,435	1,124,451	388,272	384,418	1,153,102	887,741	1,068,342	1,036,418
10%	602,881	413,935	1,559,164	1,432,321	524,462	517,392	1,436,856	1,180,682	1,326,510	1,278,601
5%	843,832	643,383	2,261,526	2,026,017	701,710	710,395	2,007,756	1,653,765	1,744,840	1,704,955
2%	1,368,840	1,094,956	3,033,807	2,917,662	942,826	930,232	2,741,290	2,423,908	2,236,289	2,213,305
1%	1,724,149	1,503,652	3,769,842	3,730,842	1,126,219	1,142,190	3,149,243	2,805,262	2,564,708	2,572,751
0.5%	2,043,951	1,695,060	4,183,200	4,040,264	1,472,855	1,479,899	3,765,780	3,371,059	2,854,361	2,854,859
Max	2,947,059	2,867,877	7,573,162	7,375,430	2,264,852	2,238,260	4,629,959	3,847,882	3,942,327	3,865,810

Table 5.10 Continued
Frequency Metrics in acre-feet/month
for Naturalized and Regulated Flows at Basin Outlets

	Rio Grande		Nueces-Rio Grande		Nueces		Guadalupe and San Antonio		Lavaca	
	Nat	Reg	Nat	Reg	Nat	Reg	Nat	Reg	Nat	Reg
Mean	91,633	6,264	25,026	26,500	53,994	36,701	185,011	171,918	71,700	67,195
SD	84,373	35,923	82,274	81,514	126,476	90,170	236,167	233,266	123,746	121,105
Min	12,898	4.94	0	1,506	92	534	1,352	0	0	178
99.5%	23,714	9.58	0	1,539	175	1,206	3,530	838	0.38	413
99%	25,440	13.3	0	1,557	280	1,785	4,607	1,074	66	468
98%	27,651	28.3	0	1,569	377	8,697	6,868	1,597	389	610
95%	34,019	68.2	0	1,633	698	8,819	11,794	6,367	1,700	1,256
90%	40,058	131	0	1,776	1,445	9,520	26,744	20,058	2,798	2,785
85%	44,204	193	0	1,820	2,031	9,724	38,598	26,996	4,997	4,383
80%	47,540	256	0	1,909	3,170	9,880	48,135	38,255	6,631	5,954
75%	50,846	337	0	2,032	4,085	10,432	57,883	45,776	8,184	7,438
70%	53,592	392	0	2,088	5,355	10,694	66,784	55,611	10,391	9,323
60%	60,018	545	0	2,145	8,193	11,479	85,253	70,586	15,550	12,328
50%	67,964	690	8.69	2,194	12,400	13,226	104,962	91,999	22,239	18,120
40%	76,965	895	663	2,557	21,930	14,126	133,967	121,790	35,268	29,065
30%	91,964	1,224	3,824	5,326	35,215	21,980	187,250	170,597	61,205	50,636
25%	103,636	1,460	7,959	9,264	47,780	24,554	222,115	206,069	75,036	68,999
20%	112,705	1,993	15,658	16,761	69,568	33,497	275,412	257,721	107,172	98,702
15%	136,980	2,925	28,410	28,854	100,619	45,990	332,823	316,342	139,881	134,821
10%	158,731	4,789	66,134	65,598	142,052	69,213	435,713	424,763	208,550	202,336
5%	212,498	14,546	152,482	151,985	229,647	135,572	558,313	540,738	310,262	302,682
2%	321,721	72,700	263,741	262,910	416,438	295,849	991,366	959,690	476,902	470,762
1%	562,280	147,053	432,098	431,541	593,797	419,235	1,226,298	1,195,312	639,956	613,460
0.5%	683,349	236,509	632,501	627,111	798,457	736,631	1,419,013	1,418,177	818,156	805,978
Max	938,629	663,763	884,553	886,800	1,775,739	1,300,862	2,485,789	2,462,770	1,147,303	1,123,271

Table 5.10 Continued

	Canadian		Red		Sulphur		Cypress		Sabine	
	Nat	Reg	Nat	Reg	Nat	Reg	Nat	Reg	Nat	Reg
Mean	18,129	10,699	841,106	759,696	215,890	209,162	139,642	122,725	552,757	515,978
SD	39,454	29,604	909,792	884,994	295,309	281,126	178,930	174,578	564,470	572,702
Min	0	18.5	10,988	8,249	1	9,907	0	0	4,190	3,303
99.5%	0	22	35,594	22,725	41.7	9,907	0	0	13,298	9,027
99%	11.5	28	43,374	29,140	69	9,907	0	0	16,947	11,185
98%	98.7	81.8	59,408	45,270	118	9,907	1.48	0.69	22,188	13,360
95%	417	203	93,625	65,017	808	13,229	297	10.7	37,220	19,270
90%	664	315	126,644	88,958	2,048	15,094	1,519	107	58,792	31,391
85%	850	407	159,415	111,335	5,223	16,184	3,566	119	78,191	45,446
80%	1,122	544	189,766	132,373	9,547	17,256	8,892	128	99,199	60,087

75%	1,596	735	239,388	172,435	12,997	20,978	14,315	140	130,133	80,585
70%	2,073	944	289,111	210,174	20,088	27,811	20,331	140	162,333	114,812
60%	3,136	1,535	382,079	306,647	42,253	44,741	37,312	14,875	235,498	184,482
50%	5,201	2,894	527,208	448,777	91,751	87,935	64,737	41,501	349,501	297,513
40%	8,838	5,049	723,617	614,502	162,359	147,491	108,998	91,111	505,222	454,203
30%	14,433	7,016	963,235	883,137	255,347	241,061	167,690	147,014	684,841	647,757
25%	17,631	8,615	1,158,713	1,094,913	307,025	284,912	203,078	185,087	823,795	797,532
20%	23,560	11,011	1,342,618	1,238,228	380,647	356,242	243,178	226,921	990,837	957,570
15%	30,780	15,097	1,607,078	1,507,619	457,778	440,138	299,747	279,812	1,139,717	1,108,683
10%	42,627	21,345	1,875,588	1,752,718	608,303	585,394	388,209	373,940	1,336,891	1,321,293
5%	75,848	42,152	2,657,580	2,570,737	864,124	834,620	515,721	500,022	1,628,330	1,634,512
2%	145,050	102,467	3,678,647	3,459,597	1,138,103	1,072,663	695,768	647,140	2,055,026	2,046,774
1%	228,077	142,093	4,350,456	3,973,142	1,341,679	1,316,299	831,095	801,007	2,446,408	2,375,020
0.5%	289,275	218,011	5,205,627	5,131,623	1,586,838	1,506,763	904,173	873,950	3,021,878	3,053,333
Max	431,251	388,692	7,930,258	7,674,306	1,925,586	1,813,977	1,166,637	1,055,123	4,224,389	4,239,640

Table 5.10 Continued
Frequency Metrics in acre-feet/month
for Naturalized and Regulated Flows at Basin Outlets

	San Antonio-Nueces		Lavaca-Guadalupe		Colorado-Lavaca		Trinity-San Jacinto		Neches-Trinity	
	Nat	Reg	Nat	Reg	Nat	Reg	Nat	Reg	Nat	Reg
Mean	47,100	47,103	33,878	34,745	32,700	31,752	15,075	15,845	96,064	87,781
SD	155,369	155,391	70,436	70,426	53,668	53,094	23,482	23,370	117,721	113,379
Min	1	69.7	0	520	0	31	0	1,393	129	1,482
99.5%	50.2	104	0	546	0	102	0	1,486	150	1,687
99%	96.4	140	0	562	0	178	131	1,515	165	2,212
98%	187	207	0	605	0	389	369	1,634	550	2,479
95%	350	382	43.6	747	174	856	558	1,775	1,089	3,584
90%	556	565	403	1,219	858	1,443	829	1,941	4,561	5,136
85%	834	838	748	1,636	1,556	2,209	1,058	2,175	9,571	7,482
80%	1,042	1,030	1,159	2,100	2,049	2,694	1,426	2,439	15,232	11,441
75%	1,193	1,195	1,595	2,551	3,261	3,498	1,915	2,848	20,275	16,055
70%	1,469	1,474	2,227	3,130	4,208	4,226	2,588	3,481	25,693	20,106
60%	2,252	2,238	4,097	4,959	6,352	6,292	4,006	4,580	39,031	32,713
50%	3,808	3,816	7,446	8,403	12,636	10,448	5,643	6,241	57,302	49,486
40%	7,743	7,761	12,401	13,334	19,600	18,004	8,441	8,861	81,833	71,434
30%	17,423	17,367	20,966	21,890	30,226	28,222	14,346	14,931	113,585	100,631
25%	24,313	24,151	30,978	31,695	36,554	34,355	18,420	18,606	131,646	117,388
20%	36,626	36,704	43,429	44,122	46,621	44,890	23,955	24,456	151,466	138,726
15%	65,028	65,129	65,110	65,960	68,635	67,754	32,049	32,205	179,679	165,768
10%	103,882	103,922	99,668	100,488	93,810	92,359	41,302	42,197	219,223	204,249
5%	251,606	251,735	163,155	163,987	131,978	129,152	59,345	60,324	319,685	306,101
2%	536,597	536,771	277,267	277,987	189,995	189,058	85,577	86,418	465,176	442,608
1%	597,850	598,025	383,610	384,299	290,822	290,312	133,641	132,868	620,661	601,403
0.5%	666,612	666,607	464,636	465,237	378,539	378,787	159,854	160,366	739,043	716,614
Max	2,591,183	2,591,572	619,624	620,274	431,306	429,875	197,802	198,678	1,006,057	986,885

Table 5.11
Comparison of Regulated Flows with Naturalized Flows

Basin WAM	Mean	Standard Deviation	99%	90%	75%	50%	25%	10%	1%
			Exceedance Frequency						
Colorado	259,899	325,784	14,479	45,931	75,635	142,149	322,934	602,881	1,724,149
	61.2%	86.0%	0.0%	6.9%	27.3%	34.1%	57.7%	68.7%	87.2%
Brazos	603,864	786,811	17,611	59,028	131,538	306,959	735,958	1,559,164	3,769,842
	84.2%	97.2%	49.1%	24.6%	47.4%	64.1%	85.5%	91.9%	99.0%
San Jacinto	189,174	254,331	6,196	14,583	32,393	86,984	248,301	524,462	1,126,219
	106.4%	96.1%	674.2%	332.2%	183.7%	115.0%	95.8%	98.7%	101.4%
Trinity	552,523	679,163	3,408	30,487	100,678	285,135	750,025	1,436,856	3,149,243
	72.8%	88.1%	168.0%	46.2%	22.6%	47.8%	72.1%	82.2%	89.1%
Neches	518,629	584,119	12,712	43,258	98,825	287,667	761,127	1,326,510	2,564,708
	89.5%	101.3%	0.0%	3.9%	29.8%	77.9%	92.1%	96.4%	100.3%
Rio Grande	91,633	84,373	25,440	40,058	50,846	67,964	103,636	158,731	562,280
	6.84%	42.58%	0.05%	0.33%	0.66%	1.02%	1.41%	3.02%	26.15%
Nueces-	25,026	82,274	0	0	0	8.69	7,959	66,134	432,098
Rio Grande	105.9%	99.1%	–	–	–	–	116.4%	99.2%	99.9%
Nueces	53,994	126,476	280	1,445	4,085	12,400	47,780	142,052	593,797
	68.0%	71.3%	637.5%	658.8%	255.4%	106.7%	51.4%	48.7%	70.6%
GSA	185,011	236,167	4,607	26,744	57,883	104,962	222,115	435,713	1,226,298
	92.9%	98.8%	23.3%	75.0%	79.1%	87.6%	92.8%	97.5%	97.5%
Lavaca	71,700	123,746	66	2,798	8,184	22,239	75,036	208,550	639,956
	93.7%	97.9%	709.1%	99.5%	90.9%	81.5%	92.0%	97.0%	95.9%
Canadian	18,129	39,454	11.5	664	1,596	5,201	17,631	42,627	228,077
	59.0%	75.0%	243.5%	47.4%	46.1%	55.6%	48.9%	50.1%	62.3%
Red	841,106	909,792	43,374	126,644	239,388	527,208	1,158,713	1,875,588	4,350,456
	90.3%	97.3%	67.2%	70.2%	72.0%	85.1%	94.5%	93.4%	91.3%
Sulphur	215,890	295,309	69	2,048	12,997	91,751	307,025	608,303	1,341,679
	96.9%	95.2%	14358.0%	737.0%	161.4%	95.8%	92.8%	96.2%	98.1%
Cypress	139,642	178,930	0	1,519	14,315	64,737	203,078	388,209	831,095
	87.9%	97.6%	0.0%	7.0%	1.0%	64.1%	91.1%	96.3%	96.4%
Sabine	552,757	564,470	16,947	58,792	130,133	349,501	823,795	1,336,891	2,446,408
	93.3%	101.5%	66.0%	53.4%	61.9%	85.1%	96.8%	98.8%	97.1%
San Antonio-	47,100	155,369	96.4	556	1,193	3,808	24,313	103,882	597,850
Nueces	100.0%	100.0%	145.2%	101.6%	100.2%	100.2%	99.3%	100.0%	100.0%
Lavaca-	33,878	70,436	0	403	1,595	7,446	30,978	99,668	383,610
Guadalupe	102.6%	100.0%	–	302.5%	159.9%	112.9%	102.3%	100.8%	100.2%
Colorado-	32,700	53,668	0	858	3,261	12,636	36,554	93,810	290,822
Lavaca	97.1%	98.9%	–	168.2%	107.3%	82.7%	94.0%	98.5%	99.8%
Trinity-	15,075	23,482	131	829	1,915	5,643	18,420	41,302	133,641
San Jacinto	105.1%	99.5%	1156.5%	234.1%	148.7%	110.6%	101.0%	102.2%	99.4%
Neches-	96,064	117,721	165	4,561	20,275	57,302	131,646	219,223	620,661
Trinity	91.4%	96.3%	1340.6%	112.6%	79.2%	86.4%	89.2%	93.2%	96.9%

The first row for each WAM in Table 5.11 shows naturalized flows in acre-feet/month.
The second row for each WAM in Table 5.11 shows regulated flow amounts expressed as a percentage of the naturalized flow quantities in the preceding row.

Table 5.12
Simulated Regulated Flow as a Percent of Naturalized Flow

Basin	Exceedance Frequency						
WAM	99%	90%	75%	50%	25%	10%	1%
	Regulated Flow as Percent of Naturalized Flow						
Colorado	0.0%	6.9%	27.3%	34.1%	57.7%	68.7%	87.2%
Brazos	49.1%	24.6%	47.4%	64.1%	85.5%	91.9%	99.0%
San Jacinto	674.2%	332.2%	183.7%	115.0%	95.8%	98.7%	101.4%
Trinity	168.0%	46.2%	22.6%	47.8%	72.1%	82.2%	89.1%
Neches	0.0%	3.9%	29.8%	77.9%	92.1%	96.4%	100.3%
Rio Grande	0.05%	0.33%	0.66%	1.02%	1.41%	3.02%	26.15%
Nueces-Rio Grande	–	–	–	–	116.4%	99.2%	99.9%
Nueces	637.5%	658.8%	255.4%	106.7%	51.4%	48.7%	70.6%
GSA	23.3%	75.0%	79.1%	87.6%	92.8%	97.5%	97.5%
Lavaca	709.1%	99.5%	90.9%	81.5%	92.0%	97.0%	95.9%
Canadian	243.5%	47.4%	46.1%	55.6%	48.9%	50.1%	62.3%
Red	67.2%	70.2%	72.0%	85.1%	94.5%	93.4%	91.3%
Sulphur	14358%	737.0%	161.4%	95.8%	92.8%	96.2%	98.1%
Cypress	0.0%	7.0%	1.0%	64.1%	91.1%	96.3%	96.4%
Sabine	66.0%	53.4%	61.9%	85.1%	96.8%	98.8%	97.1%
San Antonio- Nueces	145.2%	101.6%	100.2%	100.2%	99.3%	100.0%	100.0%
Lavaca- Guadalupe	–	302.5%	159.9%	112.9%	102.3%	100.8%	100.2%
Colorado-Lavaca	–	168.2%	107.3%	82.7%	94.0%	98.5%	99.8%
Trinity-San Jacinto	1156%	234.1%	148.7%	110.6%	101.0%	102.2%	99.4%
Neches- Trinity	1341%	112.6%	79.2%	86.4%	89.2%	93.2%	96.9%

CHAPTER 6
COMPARATIVE ANALYSES OF
OBSERVED, NATURALIZED, AND REGULATED FLOWS

Chapter 6 compares the observed stream flows at the USGS gaging stations discussed in Chapter 4 and naturalized and regulated flows at the sites of these gaging stations obtained from the WRAP/WAM modeling system described in Chapter 5. The expected value (mean) and other characteristics of observed flows at many sites vary significantly over time as a result of water development and use. Naturalized flows are derived by adjusting observed flows to remove the effects of water development and use. The objective is for naturalized flows to be homogeneous with no permanent long-term trends. The simulated regulated flows represent current conditions of water development and use and should reflect no permanent long-term changes over time.

Sets of plots comparing observed, naturalized, and regulated flows at the selected sites are provided in Appendix E. Linear trend analysis results are presented in this chapter. The plots and computed metrics provide insight regarding

- the differences between observed flows versus naturalized and regulated flows and
- the homogeneity or stationarity of the observed and computed flows.

Observed flows at the 35 gaging stations listed in Table 4.1 are plotted in Appendix C and discussed in Chapter 4. These sites are adopted again in Chapter 6 except for the two sites on the Rio Grande and two sites on the Red River. The 31 USGS gaging stations adopted in Chapter 6 are listed in Table 6.1. The locations of these sites are shown in Figure 4.2. Each of the sites of the USGS gages are represented by control points in the WAMs. The WAM control point identifiers are listed in the 4th column of Table 6.1.

Comparison of River Flows

The analyses of observed flows in Chapter 4 use the complete periods-of-record of the gages. However, the WAM hydrologic periods-of-analysis shown in the 5th column of Table 6.1 are adopted for observed flows in the Chapter 6 analyses to be consistent with the naturalized and regulated flows. The gage on the Colorado River at Bay City (map identifier 14), with a record beginning in May 1948, is the only gage that does not completely cover its corresponding WAM period-of-analysis.

The observed flows obtained from the USGS NWIS are daily flows in cfs as noted in Chapter 4. The naturalized and regulated flows from the WAMs are monthly flows in acre-feet/month. The analyses presented in the present Chapter 6 are based on converting the flows to sequences of the following variables.

- annual flow volumes in acre-feet
- flow volumes in acre-feet for the two consecutive months in each year that have the minimum 2-month volumes for the year
- flow volumes in acre-feet for the two consecutive months in each year that have the maximum 2-month volumes for the year

Means of observed, naturalized, and regulated flows are shown in Table 6.2. Period-of-analysis means of 2-month minimum and maximum flows in each year are compared in Table 6.3.

Table 6.1
Selected Control Points at Stream Flow Gaging Stations

Fig. 4.3 ID	Gage ID	Location River and Nearest City	WAM CP ID	Analysis Period	Watershed Area Total	Watershed Area Contributing
					(square miles)	
3	08412500	Pecos River at Orla	GT3000	1940-2000	25,070	21,229
4	08210000	Nueces River at Three Rivers	CP29	1934-1996	15,427	–
5	08211000	Nueces River at Mathis	CP30	1934-1996	16,503	–
6	08183500	San Antonio River Falls City	CP32	1940-2012	2,113	–
7	08188500	San Antonio River at Goliad	CP37	1940-2012	3,921	–
8	08167500	Guadalupe River at Spring Branch	CP02	1940-2012	1,315	–
9	08176500	Guadalupe River at Victoria	CP15	1940-2012	5,198	–
10	08164000	Lavaca River near Edna	GS300	1940-1996	817	–
11	08147000	Colorado River near San Saba	F10000	1940-2012	31,217	19,819
12	08158000	Colorado River at Austin	I10000	1940-2012	39,009	27,606
13	08161000	Colorado River at Columbus	J10000	1940-2012	41,640	30,237
14	08162500	Colorado River near Bay City	K10000	1940-2012	42,240	30,837
15	08082500	Brazos River at Seymour	BRSE11	1940-2012	15,538	5,972
16	08096500	Brazos River at Waco	BRWA41	1940-2012	29,559	19,993
17	08106500	Little River at Cameron	LRCA58	1940-2012	7,065	–
18	08110500	Navasota River at Easterly	NAEA66	1940-2012	968	–
19	08114000	Brazos River at Richmond	BRRI70	1940-2012	45,107	35,541
20	08074000	Buffalo Bayou in Houston	BBHO	1940-1996	336	–
21	08068000	West Fork San Jacinto near Conroe	WSCN	1940-1996	828	–
22	08048000	West Fork Trinity at Fort Worth	8WTFW	1940-2012	2,615	–
23	08057000	Trinity River at Dallas	8TRDA	1940-2012	6,106	–
24	08062500	Trinity River near Rosser	8TRRS	1940-2012	8,146	–
25	08065000	Trinity River near Oakwood	8TROA	1940-2012	12,833	–
26	08066500	Trinity River at Romayor	8TRRO	1940-2012	17,186	–
27	08033500	Neches River near Rockland	NERO	1940-2012	3,636	–
28	08041000	Neches River near Evansdale	NEEV	1940-2012	7,951	–
29	8022040	Sabine River near Beckville	SRBE	1940-2012	3,589	–
30	8030500	Sabine River near Ruliff	SRRL	1940-2012	9,329	–
31	07346000	Big Cypress Bayou at Jefferson	B10000	1940-1998	850	–
34	07227500	Canadian River near Amarillo	A10000	1948-1998	19,445	15,376
35	07228000	Canadian River near Canadian	B10000	1948-1998	22,866	18,178

Appendix E consists of a set of the following four graphs for each of the 31 sites.

1. The first graph is a plot of naturalized monthly flows.
2. The second graph has three plots comparing annual observed, naturalized, and regulated flows.
3. The third graph has three plots comparing annual two-month minimum observed, naturalized, and regulated flows.
4. The fourth graph has three plots comparing annual two-month maximum observed, naturalized, and regulated flows.

Table 6.2
Mean Annual Flows

Fig. 4.3	Location River, Nearest City	Mean Annual Flow (acre-feet/year) Observed	Naturalized	Regulated	Nat (Percent of Observed)	Reg
3	Pecos River, Orla	99,293	124,378	77,003	125.3	61.9
4	Nueces, Three Rivers	544,744	575,466	598,812	105.6	104.1
5	Nueces, Mathis	533,083	585,993	492,724	109.9	84.1
6	San Antonio, Falls City	388,601	328,547	357,568	84.5	108.8
7	San Antonio, Goliad	589,033	528,485	556,432	89.7	105.3
8	Guadalupe, Spring Branch	284,370	257,372	250,323	90.5	97.3
9	Guadalupe, Victoria	1,412,554	1,329,654	1,267,790	94.1	95.3
10	Lavaca, Edna	249,702	250,968	250,591	100.5	99.8
11	Colorado, San Saba	575,496	819,503	525,213	142.4	64.1
12	Colorado, Austin	1,320,592	1,749,807	1,024,126	132.5	58.5
13	Colorado, Columbus	2,002,189	2,459,684	1,764,293	122.8	71.7
14	Colorado, Bay City	1,486,548	2,767,169	1,516,501	186.1	54.8
15	Brazos, Seymour	223,943	238,820	230,604	106.6	96.6
16	Brazos, Waco	1,622,980	1,882,353	1,520,040	116.0	80.8
17	Little River, Cameron	1,268,964	1,351,437	1,129,312	106.5	83.6
18	Navasota, Easterly	303,359	325,370	259,276	107.3	79.7
19	Brazos, Richmond	13,094,677	5,822,300	5,103,043	44.5	87.6
20	Buffalo Bayou, Houston	331,338	224,032	248,821	67.6	111.1
21	WF San Jacinto, Conroe	362,369	379,319	318,392	104.7	83.9
22	WF Trinity, Fort Worth	291,285	440,922	224,582	151.4	50.9
23	Trinity, Dallas	1,383,755	1,612,520	1,062,185	116.5	65.9
24	Trinity, Rosser	2,334,780	2,487,750	1,843,320	106.6	74.1
25	Trinity, Oakwood	3,949,702	4,149,320	3,146,506	105.1	75.8
26	Trinity, Romayor	5,824,135	6,077,828	4,983,771	104.4	82.0
27	Neches, Rockland	1,752,373	1,746,876	1,693,894	99.7	97.0
28	Neches, Evansdale	4,468,493	4,532,595	4,158,388	101.4	91.7
29	Sabine, Beckville	1,837,156	2,007,905	1,694,619	109.3	84.4
30	Sabine, Ruliff	5,979,583	6,271,324	5,854,440	104.9	93.4
31	Big Cypress, Jefferson	297,780	500,164	373,063	168.0	74.6
34	Canadian, Amarillo	152,878	153,760	153,547	100.6	99.9
35	Canadian, Canadian	130,457	189,221	97,582	145.0	51.6

Table 6.2 provides a comparison of the long-term period-of-analysis averages of annual observed, naturalized, and regulated river flows. The last two columns of Table 6.2 are the mean naturalized flow and mean regulated flows expressed as a percentage of the mean observed flow. The percentages vary greatly between the different sites. As discussed in the preceding Chapters 4 and 5, the impacts of water resources development and use vary significantly between the different sites. The differences between the impacts on low flows versus high flows are demonstrated by the two-month minimum and maximum flow means in Table 6.3.

Table 6.3
Means of Annual 2-Month Minimum and 2-Month Maximum Flows

	Location	2-Month Minimum (acre-feet)			2-Month Maximum (acre-feet)		
	River, Nearest City	Observed	Natural	Regulated	Observed	Natural	Regulated
3	Pecos River, Orla	2,002	5,782	857	40,829	54,217	33,153
4	Nueces, Three Rivers	6,352	7,227	20,430	318,014	337,537	303,623
5	Nueces, Mathis	10,560	6,413	32,771	312,841	345,454	223,278
6	San Antonio, Falls City	26,455	14,745	22,817	143,749	139,626	139,044
7	San Antonio, Goliad	33,333	20,113	28,171	241,730	237,673	236,481
8	Guadalupe, SpringBranch	11,785	9,834	9,008	125,221	111,918	110,370
9	Guadalupe, Victoria	79,335	62,429	56,001	543,697	551,387	539,552
10	Lavaca, Edna	4,524	4,300	4,267	130,623	131,702	131,612
11	Colorado, San Saba	13,589	29,415	16,749	308,926	410,542	278,642
12	Colorado, Austin	51,957	83,449	26,833	521,552	769,199	478,627
13	Colorado, Columbus	100,181	113,973	71,375	759,916	1,027,331	747,226
14	Colorado, Bay City	57,747	129,424	17,170	634,909	1,126,143	740,021
15	Brazos, Seymour	2,318	2,564	2,506	131,872	142,277	137,808
16	Brazos, Waco	50,357	35,893	16,828	813,948	941,290	842,464
17	Little River, Cameron	25,597	25,631	18,177	555,770	664,722	583,781
18	Navasota, Easterly	1,853	1,374	500	170,591	178,897	155,139
19	Brazos, Richmond	329,852	170,782	129,274	5,357,842	2,520,559	2,326,046
20	Buffalo Bayou, Houston	7,591	7,127	11,327	121,665	92,445	96,544
21	WF San Jacinto, Conroe	5,297	4,539	4,288	172,780	179,495	155,782
22	WF Trinity, Fort Worth	5,573	4,537	927	182,127	264,162	160,861
23	Trinity, Dallas	47,796	20,957	43,978	660,926	879,891	565,301
24	Trinity, Rosser	86,396	34,983	78,834	1,069,880	1,309,667	941,155
25	Trinity, Oakwood	110,312	61,313	88,441	1,878,444	2,075,970	1,625,333
26	Trinity, Romayor	161,127	116,710	142,659	2,571,135	2,708,987	2,283,471
27	Neches, Rockland	34,153	27,962	24,334	771,425	774,980	769,180
28	Neches, Evansdale	211,669	87,610	50,544	1,683,207	1,923,570	1,872,013
29	Sabine, Beckville	30,582	35,037	23,993	856,086	912,283	830,215
30	Sabine, Ruliff	241,493	174,384	129,298	2,298,889	2,499,285	2,447,682
31	Big Cypress, Jefferson	3,793	4,622	840	135,109	234,779	197,117
34	Canadian, Amarillo	1,752	1,757	1,817	84,429	84,745	84,579
35	Canadian, Canadian	1,913	2,275	1,015	74,185	102,188	55,618

Conceptually, naturalized flows should be close to the observed flows during the 1940s prior to most of the dam construction and growth in water use. The regulated flows simulated with the current use scenario WAMs should approximately reproduce the observed flows during recent years. The plots in Appendix E provide comparisons of the differences in mean annual flows, low flows (annual 2-month minima), and high flows (annual 2-month maxima) for observed, naturalized, and regulated flows.

Flows at all of the sites exhibit great variability with a significant tendency for flow decreases or increases to persist over significant periods of time. However, differences between observed, naturalized, and regulated flows vary greatly between the 31 sites.

Linear Regression Analyses

The plots in Appendix E can be viewed to detect long-term trends or permanent changes in flows. Trend analysis computations also help provide insight regarding possible flow changes.

Standard linear least-squares regression analysis was performed using the computer program HydStats introduced in Chapters 1 and 3. The results for annual flows and the 2-month minimum flows and 2-month maximum flows in each year are presented in Tables 6.4, 6.5, and 6.6. The computed slopes and y-intercepts are expressed as a percentage of the mean flows tabulated in Tables 6.2 and 6.3.

Table 6.4
Linear Trend Regression Coefficients for Mean Annual Flow

	Slope (percent of mean)			Intercept (percent of mean)		
River, Nearest City	Observed	Natural	Regulated	Observed	Natural	Regulated
3 Pecos River, Orla	-3.455	-2.825	-3.348	207.1	187.6	203.8
4 Nueces, Three Rivers	-1.086	-0.770	-0.582	131.5	122.3	116.9
5 Nueces, Mathis	-1.400	-0.948	-0.880	140.6	127.5	125.5
6 San Antonio, Falls City	1.253	0.619	0.643	53.6	75.2	74.3
7 San Antonio, Goliad	0.892	0.430	0.451	67.0	82.8	81.9
8 Guadalupe,Spring Branch	1.021	0.462	0.471	62.2	81.5	81.2
9 Guadalupe, Victoria	0.561	0.160	0.175	79.2	93.6	93.0
10 Lavaca, Edna	0.823	0.852	0.853	76.1	75.3	75.3
11 Colorado, San Saba	-1.364	-0.534	-0.615	150.5	119.8	122.8
12 Colorado, Austin	-0.474	-0.0234	0.212	117.5	100.9	92.1
13 Colorado, Columbus	-0.327	-0.0490	0.0776	112.1	101.8	97.1
14 Colorado, Bay City	0.818	0.0953	0.345	69.7	96.5	87.2
15 Brazos, Seymour	-1.108	-0.701	-0.714	141.0	125.9	126.4
16 Brazos, Waco	-0.345	-0.073	-0.038	112.8	102.7	101.4
17 Little River, Cameron	0.057	0.238	0.306	97.9	91.2	88.7
18 Navasota, Easterly	0.013	0.235	0.271	99.5	91.3	90.0
19 Brazos, Richmond	-0.362	0.070	0.099	113.4	97.4	96.3
20 Buffalo Bayou, Houston	3.246	0.568	0.510	5.9	83.5	85.2
21 WF San Jacinto, Conroe	-0.087	0.109	0.073	102.5	96.8	97.9
22 WF Trinity, Fort Worth	-0.288	0.038	0.215	110.6	98.6	92.1
23 Trinity, Dallas	0.529	0.360	0.555	80.4	86.7	79.5
24 Trinity, Rosser	0.626	0.422	0.597	76.8	84.4	77.9
25 Trinity, Oakwood	0.248	0.110	0.190	90.8	95.9	93.0
26 Trinity, Romayor	0.143	0.073	0.105	94.7	97.3	96.1
27 Neches, Rockland	-0.059	-0.112	-0.144	102.2	104.1	105.3
28 Neches, Evansdale	-0.083	-0.072	-0.102	103.1	102.7	103.8
29 Sabine, Beckville	-0.231	-0.074	-0.095	108.5	102.7	103.5
30 Sabine, Ruliff	-0.439	-0.294	-0.372	116.3	110.9	113.8
31 Big Cypress, Jefferson	0.802	0.416	0.525	79.2	89.2	86.3
34 Canadian, Amarillo	-1.696	-1.700	-1.698	144.1	144.2	144.1
35 Canadian, Canadian	-4.496	-2.104	-2.973	216.9	154.7	177.3

Table 6.5
Linear Trend Regression Coefficients for Annual 2-Month Minimum Flow

		Slope (% mean)			Intercept (% mean)		
	River, Nearest City	Observed	Natural	Regulated	Observed	Natural	Regulated
3	Pecos River, Orla	-3.611	-1.883	-4.458	211.9	158.4	238.2
4	Nueces, Three Rivers	1.666	0.508	0.409	51.7	85.3	88.1
5	Nueces, Mathis	1.935	2.013	-0.109	43.9	41.6	103.1
6	San Antonio, Falls City	0.637	-0.776	-0.232	76.4	131.0	109.3
7	San Antonio, Goliad	0.763	-1.078	-0.612	71.8	143.1	124.5
8	Guadalupe, SpringBranch	0.551	-0.358	-0.310	79.6	114.3	112.4
9	Guadalupe, Victoria	0.238	-1.301	-1.275	91.2	152.1	151.0
10	Lavaca, Edna	-0.684	-0.769	-0.773	119.8	122.3	122.4
11	Colorado, San Saba	-1.598	-0.107	-0.248	159.1	103.9	109.2
12	Colorado, Austin	-2.318	0.0405	0.577	185.8	98.5	78.6
13	Colorado, Columbus	-1.304	-0.137	0.0830	148.3	105.1	96.9
14	Colorado, Bay City	0.483	-0.178	-0.0898	82.1	106.6	103.3
15	Brazos, Seymour	0.845	0.797	0.762	68.7	70.5	71.8
16	Brazos, Waco	-0.308	-0.438	0.546	111.4	116.2	79.8
17	Little River, Cameron	-0.148	-0.605	-0.276	105.5	122.4	110.2
18	Navasota, Easterly	-0.208	-2.465	-3.154	107.7	191.2	216.7
19	Brazos, Richmond	-0.358	0.797	-0.433	113.3	121.0	116.0
20	Buffalo Bayou, Houston	2.782	1.749	1.075	19.3	49.3	68.8
21	WF San Jacinto, Conroe	0.078	-1.080	-0.751	97.7	131.3	121.8
22	WF Trinity, Fort Worth	-2.356	-1.713	0.179	187.2	163.4	93.4
23	Trinity, Dallas	1.581	0.371	0.072	41.5	86.3	97.3
24	Trinity, Rosser	1.736	-0.255	-0.117	35.8	109.4	104.3
25	Trinity, Oakwood	1.131	-0.460	0.022	58.2	117.0	99.2
26	Trinity, Romayor	0.473	-0.815	-0.216	82.5	130.1	108.0
27	Neches, Rockland	0.041	-0.829	-0.756	98.5	130.7	128.0
28	Neches, Evansdale	1.565	-1.364	-1.295	42.1	150.5	147.9
29	Sabine, Beckville	-0.629	-0.533	-0.569	123.3	119.7	121.1
30	Sabine, Ruliff	0.471	-0.862	-1.067	82.6	131.9	139.5
31	Big Cypress, Jefferson	0.343	-2.431	-0.696	91.1	163.2	118.1
34	Canadian, Amarillo	0.140	-0.015	0.000	96.4	100.4	100.0
35	Canadian, Canadian	1.154	0.947	1.111	70.0	75.4	71.1

The plots in Appendix E show the tremendous temporal variation of river flows that make detection of long-term trends difficult. Large fluctuations occur with a significant degree of persistence. The appearance of trends can change significantly with a several-year lengthening or shortening of the period-of-analysis. Long-term changes in flow characteristics cannot be accurately measured with least-squares linear regression analysis. However, the analysis does help in detecting the occurrence of changes or lack thereof. Linear regression slopes are used here to approximate permanent long-term change or to serve as an indication of possible change.

The slope determined in the regression computations represents the change in the expected value or mean of the variable being analyzed. A slope of zero percent and intercept of one hundred percent in Tables 6.4, 6.5, and 6.6 would be an indication of no long-term linear trend which approximates no permanent long-term change. A positive or negative slope indicates that the mean (expected value) is increasing or decreasing, respectively. The intercept represents the expected value of flow at the beginning of the analysis period according to the regression. An intercept greater than 100 percent corresponds to a negative slope. The slopes and intercepts in Tables 6.4, 6.5, and 6.6 are expressed as percentages of the means in Tables 6.2 and 6.3 to facilitate comparisons of the regression results at the different sites.

Table 6.6
Linear Trend Regression Coefficients for Annual 2-Month Maximum Flow

		Slope (% mean)			Intercept (% mean)		
	River, Nearest City	Observed	Natural	Regulated	Observed	Natural	Regulated
3	Pecos River, Orla	-3.650	-2.446	-3.837	213.1	175.8	219.0
4	Nueces, Three Rivers	-1.159	-0.697	-0.569	133.6	120.2	116.5
5	Nueces, Mathis	-1.643	-0.960	-1.208	147.7	127.8	135.0
6	San Antonio, Falls City	1.456	1.024	1.041	46.1	59.1	58.3
7	San Antonio, Goliad	0.865	0.634	0.626	68.0	74.6	75.0
8	Guadalupe,SpringBranch	1.262	0.573	0.584	53.3	77.1	76.7
9	Guadalupe, Victoria	0.844	0.615	0.634	68.8	75.4	74.7
10	Lavaca, Edna	1.250	1.274	1.275	63.8	63.1	63.0
11	Colorado, San Saba	-1.258	-0.537	-0.664	146.5	119.9	124.6
12	Colorado, Austin	0.063	-0.047	0.290	97.7	101.7	89.3
13	Colorado, Columbus	0.109	0.067	0.277	96.0	97.5	89.7
14	Colorado, Bay City	1.201	0.232	0.589	55.5	91.4	78.2
15	Brazos, Seymour	-1.275	-0.743	-0.750	147.2	127.5	127.7
16	Brazos, Waco	-0.221	-0.066	-0.083	108.2	102.4	103.1
17	Little River, Cameron	0.009	0.527	0.645	99.7	80.5	76.1
18	Navasota, Easterly	0.061	0.258	0.304	97.7	90.5	88.8
19	Brazos, Richmond	-0.209	0.157	0.178	107.7	94.2	93.4
20	Buffalo Bayou, Houston	2.509	0.299	0.287	27.2	91.3	91.7
21	WF San Jacinto, Conroe	-0.216	-0.021	0.009	106.3	100.6	99.7
22	WF Trinity, Fort Worth	0.102	0.280	0.332	96.2	89.6	87.7
23	Trinity, Dallas	0.266	0.370	0.525	90.1	86.3	80.6
24	Trinity, Rosser	0.332	0.499	0.721	87.7	81.5	73.3
25	Trinity, Oakwood	0.113	0.125	0.107	95.8	95.4	96.0
26	Trinity, Romayor	0.080	0.073	0.012	97.0	97.3	99.6
27	Neches, Rockland	-0.015	0.014	-0.008	100.6	99.5	100.3
28	Neches, Evansdale	-0.441	0.085	0.080	116.3	96.9	97.0
29	Sabine, Beckville	-0.303	-0.167	-0.206	111.2	106.2	107.6
30	Sabine, Ruliff	-0.566	-0.177	-0.226	120.9	106.5	108.4
31	Big Cypress, Jefferson	0.753	0.019	0.132	80.4	99.5	96.6
34	Canadian, Amarillo	-2.029	-2.030	-2.028	152.8	152.8	152.7
35	Canadian, Canadian	-5.480	-2.867	-3.896	242.5	174.5	201.3

Conceptually, observed flows can be expected to exhibit significant non-zero regression slopes as a result of reservoir construction and increasing degrees of water development, regulation, and use over time. The objective of the flow naturalization process is to remove the effects of human water development and use from the observed flows. Thus, the slopes for the naturalized flows should be flatter than for the observed flows, preferably perfectly flat as indicated by a slope of zero and intercept of 100 percent. Since a specified constant condition of water development and use is simulated, the slopes for the regulated flows should be about the same as for the naturalized flows, preferably zero or very close thereto.

The slopes for the three flow variables at the 31 sites in Tables 6.4, 6.5, and 6.6 are a mixture of positive and negative values indicating both increases and decreases. The annual means of naturalized flows (Table 6.4) have 17 positive and 14 negative slopes. Two-month minima of naturalized flows (Table 6.5) have 8 positive and 23 negative slopes. Two-month maxima of naturalized flows (Table 6.6) have 19 positive and 12 negative slopes. Observed flows change more than naturalized and regulated flows. Naturalized and regulated flows have about the same slopes. Naturalized flows appear to be reasonably homogeneous with no long-term changes over time at most of the sites. The Canadian River is the most evident exception.

Observed, naturalized, and regulated flows decrease significantly over several decades at the two-sites on the Canadian River. Agricultural irrigation from groundwater is the dominant water use in the Canadian River Basin. One possible explanation for the decreasing naturalized flows could be that the naturalized flows perhaps do not accurately reflect the effects of groundwater pumping on the flow of the Canadian River.

The negative slopes for the Pecos River gage site near Orla are due to extremely high flows in 1941 and 1942. Flows after 1942 have a flat regression slope similar to the other sites.

In terms of statewide mean precipitation, 1941 is the wettest year and 2011 is the driest year on record for Texas. The WAM hydrologic periods-of-analysis are listed in Table 5.1. Twenty-two of the 31 sites are in the GSA, Colorado, Brazos, Trinity, Neches, and Sabine River Basins which have WAM hydrologic periods-of-analysis of 1940-2012. The other sites have shorter periods-of-analysis that exclude the very wet 1940-1942 and/or very dry 2010-2012.

With the exception of the Canadian River, the information compiled for this report indicates that the WAM naturalized flows at the sites investigated are reasonably homogeneous. The naturalized flows appear to be representative of constant natural conditions without human water development and use as required by the modeling system.

Differences between naturalized and observed flows are significant at many sites as to be expected in a state with many reservoirs and water users. The differences between naturalized and observed flows vary greatly with location and over time. The differences also vary between high flows, low flows, and average flows and between daily, monthly, and annual flows.

CHAPTER 7
SUMMARY AND CONCLUSIONS

The TCEQ Water Availability Modeling (WAM) System consists of the generalized Water Rights Analysis Package (WRAP) modeling system and 20 sets of WRAP input files covering the 15 major river basins and eight coastal basins of Texas. Alternative versions of the 20 water availability models (WAMs) for the individual river basins simulate different scenarios of water resources development and use. The WAMs combine a specified scenario of water resources development and use with historical natural hydrology represented by sequences of naturalized stream flows and net reservoir surface evaporation-precipitation rates. The routinely applied WAM System is based on a monthly computational time step. Recent development of the new daily version of the modeling system was motivated by needs for expanded capabilities for incorporating environmental instream flow standards in water availability modeling.

River system hydrology is fundamental to water availability modeling. Developing and updating hydrology input data is a major aspect of maintaining and expanding the WAM System. Conversely, the WAM system provides unique opportunities to explore river system hydrology. This report focuses on the WAM System. However, the information compiled in this report has general applicability in developing an enhanced understanding of river system hydrology.

The WAM system and water resources management and modeling in general have been based on the premise that historical natural river basin hydrology is representative of the statistical characteristics of future stream flow, evaporation, and other relevant hydrologic variables. However, stationarity or lack thereof is an issue of significant concern in the hydrologic science and water management communities. From the perspective of this report long-term permanent changes or trends can be viewed as follows.

- Changes in long-term characteristics of precipitation and evaporation rates, if they occur, may be associated with global warming or other aspects of long-term climate change.
- Differences between WAM simulated regulated and naturalized stream flows represent the effects of water resources development, allocation, management, and use.
- Long-term trends or non-homogeneities in naturalized flows conceptually represent the effects of factors other than the water development, allocation, management, and use activities considered in developing the naturalized flows. Such factors could include climate change, land use changes, or water management activities not included in the flow naturalization process.
- Changes in the long-term characteristics of actual observed stream flow may result from combinations of any or all of the factors noted above.

The five appendices consist of simulation period or period-of-record time series plots of precipitation, reservoir evaporation rates, observed river flows, naturalized river flows, simulated regulated river flows, and simulated reservoir storage contents. These plots provide a visual presentation of the characteristics of river system hydrology in Texas. The preceding chapters present frequency analyses and trend analyses of the data plotted in the appendices. Chapter 5 also develops long-term river basin and statewide water volume budgets. Information compiled in this report is summarized and conclusions therefrom are discussed in this final chapter.

Precipitation

Precipitation is the source of watershed runoff that results in stream flow. Precipitation in Texas is extremely variable both spatially and temporally.

The Texas Water Development Board (TWDB) maintains a database of monthly precipitation averaged over each of 92 one-degree quadrangles that encompass Texas. Monthly, annual total, annual 2-month minimum, and annual 2-month maximum precipitation depths for each of the 92 quadrangles are plotted in Appendix A. These precipitation data for the 92 quadrangles are analyzed in Chapter 3. Statewide means of the monthly, annual, 2-month minimum, and 2-month maximum depths are also plotted and analyzed in Chapter 3.

The 1940-2013 mean annual precipitation in Texas is 27.9 inches/year. Precipitation ranges from less than 10 inches/year in far west Texas to greater than 56 inches/year on the eastern border. Precipitation increases at a fairly uniform rate from west to east. The 1940-2013 means for the Texas portions of the Rio Grande and Sabine River Basins are 16.1 and 47.8 inches/year, respectively. The Neches Basin has a mean precipitation of 48.7 inches/year.

The seasonal variation of precipitation for each of the 92 individual quadrangles is illustrated in Chapter 3 with a table of 1940-2013 means for each of the 12 months of the year. Monthly means of the statewide 92-quadrangle totals range from 1.65 inches for January and 1.72 inches in February to 3.22 inches for May. The second highest statewide monthly mean is 3.11 inches in September and the third wettest month is June.

The three driest years since 1940 in terms of statewide mean precipitation are 2011 with 13.6 inches and 1954 and 1956 with 19.1 and 16.7 inches. The six wettest years are 1941 (40.6 inches), 1957 (35.8 inches), 1973 (36.3 inches), 1991 (37.1 inches), 2004 (39.1 inches), and 2007 (35.4 inches). The longest period of consecutive years with statewide annual precipitation each year being below the 1940-2013 mean of 27.9 inches/year is the 7-year period 1950-1956 with a 7-year mean of 22.0 inches/year. This most meteorological severe drought of record began gradually in 1950 and ended with one of the largest floods on record in April-May 1957. Two six-year periods with each year having below average annual precipitation, 1962-1967 and 2008-2013, have six-year means of 24.7 and 24.25 inches/year.

Linear trend analyses were applied to the 1940-2013 sequences of monthly, annual, 2-month minimum, and 2-month maximum precipitation depths for each of the 92 individual quadrangles and the 92-quadrangle means. The resulting slopes are consistently close to zero indicating no long-term trends. Long-term trends or permanent changes in precipitation characteristics are not evident from the plots in Appendix A. Trends or long-term changes, if they exist, are hidden by the extreme variability inherent in precipitation.

Reservoir Surface Evaporation Rates

Reservoir evaporation is a major component of river system water budgets. Variations in evaporation rates are dependent on weather conditions. Evaporation rates vary greatly seasonally but annual means for evaporation do not vary as much as precipitation. Spatial variations across Texas are significantly less for annual evaporation rates than annual precipitation rates.

The TWDB maintains databases of both monthly reservoir evaporation depths and monthly precipitation depths for 92 one-degree quadrangles that encompass Texas. Monthly, annual, 2-month minimum, and 2-month maximum evaporation depths for each of the 92 quadrangles are plotted in Appendix B. The evaporation rate data for the 92 quadrangles and statewide means are analyzed in Chapter 3. The same types of statistical analyses and plots are presented in Chapter 3 for both evaporation and precipitation depths.

The 1954-2013 statewide annual mean reservoir evaporation is 60.6 inches/year. Evaporation rates in individual quadrangles range from 43.9 inches/year in northeast Texas to 71.5 inches/year in west Texas. The mean annual evaporation for the aggregate total of the 92 quadrangles ranges from 50.6 inches in 1958 to 73.0 inches in 2011.

The seasonal variation of evaporation rates for each of the 92 individual quadrangles is illustrated in Chapter 3 with a table of 1954-2013 means for each of the 12 months of the year. Monthly means of the statewide 92-quadrangle totals range from 2.3 inches for January to 7.9 inches for July. Reservoir evaporation rates exhibit a pronounced seasonal pattern that is repeated each year. Seasonal fluctuations are much greater than year-to-year fluctuations.

Linear trend analyses were applied to the 1954-2013 sequences of monthly, annual, and annual 2-month minimum and maximum evaporation depths for each of the 92 quadrangles and the 92-quadrangle means. Time series sequences of these variables are plotted in Appendix B. The reservoir evaporation rates appear to have been increasing since the 1960s in the majority of the quadrangles. The statewide mean is also increasing. Evapotranspiration from land is not addressed in this study. However, increases in reservoir evaporation rates could imply increases in watershed evapotranspiration which could affect river flows.

<u>Reservoirs</u>

The terms *river system* and *river/reservoir system* are used interchangeable in this report. Dams and reservoirs are integral components of the river systems. Flows in the rivers of Texas are regulated by thousands of reservoirs. However, most of the storage capacity is contained in a much smaller number of the largest reservoirs. For example, the 80 reservoirs with conservation storage capacities of 50,000 acre-feet or greater contain 91.84 percent of the total permitted storage capacity of 43,062,000 acre-feet in the 3,361 reservoirs in the WAM System. Of the 3,361 reservoirs with regular water right permits, 210 have conservation storage capacities of 5,000 acre-feet or greater. The total authorized storage capacity of 43,062,000 acre-feet in the 20 WAMs is about 80 percent of the total mean annual naturalized river flow at the basin outlets flowing into the Gulf of Mexico or across state borders under natural undeveloped conditions.

Flood control pools are not included in the water right permits and WAM datasets. Twenty-eight U.S. Army Corps of Engineers, three U.S. Bureau of Reclamation, and two International Boundary and Water Commission reservoirs contain flood control pools with capacities totaling 16,146,000 acre-feet, which is almost all of the controlled (gated) flood control storage capacity in Texas.

The three largest reservoirs and the 5th largest reservoir in Texas are located on borders with Louisiana, Oklahoma, and Mexico and operated pursuant to interstate compacts and an international treaty. With a permitted conservation storage capacity of 4,477,000 acre-feet, Toledo Bend Reservoir on the Sabine River has the largest conservation storage in Texas and the southern United States. With conservation pool and flood control pool capacities of 2,772,000 and 2,660,000 acre-feet, respectively, Lake Texoma on the Red River has the largest total storage capacity of any reservoir in Texas. International Amistad and Falcon on the Rio Grande and Sam Rayburn on the Angelina are the 3rd, 5th, and 4th largest reservoirs in the state.

Numerous smaller reservoirs not included in the data presented in this report may also affect inflows into the river systems. The Natural Resource Conservation Service has constructed almost 2,000 flood retarding dams in Texas that are empty except during and following floods. Numerous stormwater detention facilities have been constructed in cities throughout the state. Land-owners have constructed many ponds with storage capacities of 200 acre-feet or less that are exempt from water right permit requirements and not included in the WAM system.

Reservoir storage capacities are reduced over time by sedimentation. Sedimentation rates vary greatly with location and between periods of low flow and high flow. Some of the capacities cited in this report reflect pre-sedimentation conditions. Other capacity data cited in this report reflect updates by sediment surveys.

Stream flow in Texas is extremely variable. Reservoir storage is essential for developing reliable supplies for municipal, industrial, agricultural irrigation, and other beneficial purposes. Surface water supplies with reasonable levels of reliability cannot be developed without reservoir storage to deal with flow fluctuations. About half the volume of water withdrawn for beneficial use in Texas currently is from river/reservoir systems and the other half is from groundwater aquifers. Depletion of aquifer storage has resulted in a shift from groundwater to surface water sources over the past several decades and this shift is expected to continue in the future.

Reservoirs facilitate water supply diversions which have the effect of diminishing the volume of stream flow. Releases from dams to supply diversions at downstream sites may increase low flows in the reach between the dams and downstream diversion sites though long-term mean flows are decreased. Flow peaks are decreased. Reservoir operations change the timing of downstream flows in various ways as well as long-term mean flow volumes.

As further noted in the last section of this chapter, evaporation from and rain falling on reservoirs are important components of river/reservoir system volume budgets. All of the precipitation falling on the water surface is inflow to the reservoir. Without the reservoir only a portion of the precipitation contributes to stream flow with the remainder lost to infiltration and evapotranspiration. Thus, reservoir storage increases the amount of rainfall that contributes to surface water availability. Evaporation from reservoir water surfaces represents a significant water loss that reduces stream flow and water availability. Reservoir evaporation is a function of water surface area which fluctuates with storage volume and evaporation rates which vary with weather.

The WRAP/WAM modeling system computes long-term means and frequency statistics for reservoir storage contents, evaporation, diversions, releases, and other variables for current conditions of water development and use combined with historical hydrology extending back to 1934, 1940, or 1948 for the different WAMs before most of the reservoirs were constructed.

Reservoir Storage Contents

The total storage volume at the end of each month of the simulation for all of the reservoirs in each of 19 WAMs from the current use scenario simulations of Chapter 5 are plotted in Appendix D. One of the 20 WAMs has no reservoirs. The 20 current use scenario WAMs contain a total of 3,444 reservoirs, though most of the storage capacity is contained in 209 major reservoirs. Storage in individual reservoirs fluctuate much more than aggregated total storage in all of the reservoirs in each WAM.

The simulation period for the Brazos, Colorado, Neches, Sabine, and Trinity River Basin WAMs is January 1940 through December 2012 and for Guadalupe and San Antonio (GSA) is January 1934 through December 2012. The other WAMs have shorter simulation periods that do not include the current drought which began in late 2010. The hydrologic periods-of-analysis extend back to 1948 for the Canadian, Red, and Cypress WAMs and to 1940 for the other WAMs. Thus the 1950s drought is included in all of the WAMs.

The beginning-of-simulation storage content of each reservoir is set equal to its end-of-simulation contents in this study. An initial preliminary simulation serves the sole purpose of determining end-of-simulation storage volumes. This is different than the typical WAM approach of assuming all reservoirs are full at the beginning of the simulation.

The basin-wide storage plots in Appendix D can be used as drought indices. The WAM simulations combine current conditions of water development and use with historical hydrology. Drought severity is measured by reservoir storage drawdown. One of the eight coastal basins has no reservoirs, and the other seven have relatively small amounts of storage capacity with continual storage content fluctuations but no well-defined single periods of maximum drawdown. The 15 major river basins are categorized as follows based on observing the severity of reservoir storage depletions in the plots of Appendix D.

The 1950-1957 drought was the most severe drought since 1940 for the Brazos, Colorado, Red, Lavaca, San Jacinto, Trinity, and Guadalupe and San Antonio (GSA) River Basins. Other information (Wurbs 1985) indicates that the 1950s drought was more hydrologically severe than the 1909-1910, 1916-1917, and 1933-1934 droughts. Thus, for these eight river basins, the 1950-1957 drought appears to be the worst since before 1900.

The current use scenario WAM storage plots for the Rio Grande and Nueces River Basins exhibit dramatic drawdowns during several multiple-year periods. The simulations show severe storage depletions during the 1950s, 1960s, 1980s, and late 1990s. The latest drawdowns in the simulation are in the real-world continuing through the present. Fluctuations are dramatic, but there is no single well-defined most severe period of drought for the Rio Grande and Nueces Basins in West Texas.

The Neches and Sabine River Basins in East Texas exhibit the opposite extreme. The WAM reservoir storage fluctuations are so minimal that no severe drought period is defined. Storage drawdowns are a little greater during the 1950s and 2010s than during the remainder of the 1940-2012 hydrologic period-of-analysis.

The Canadian River Basin and Lake Meredith on the Canadian River are unique. Lake Meredith contains almost all of the storage capacity in the Texas portion of the Canadian River Basin. Simulated storage drawdowns during 1950-1957 are significant. The reservoir refills during 1957-1962 and then lowers and refills again during the 1960s. However, the simulated reservoir storage behavior since about 1973 is unusual. Severe storage depletions during the 1970s are not refilled during the remainder of the 1948-1998 simulation. In actuality, Lake Meredith has been very low during the past several years. Storage contents dropped from about 50 percent of capacity in early 1999 to below 2.0 percent of capacity in January 2012 and has stayed below 2.0 percent of capacity through the present (July 2014).

River Flows

Observed flows at 35 selected gaging stations with long periods of record and locations on major rivers across Texas are plotted in Appendix C and discussed in Chapter 4. Period-of-record sequences of the following observed flow variables are plotted in Appendix C and analyzed in Chapter 4: daily means, monthly means, annual means, and the minimum monthly mean in each year.

Current use scenario WAM simulations are presented in Chapter 5. Reservoir storage contents and volume budgets derived from the Chapter 5 simulation study are discussed in the following two sections of the present Chapter 7. Chapter 5 also provides frequency metrics for naturalized and regulated flows at the basin outlets.

WAM system naturalized and regulated flows at the sites of 31 of the 35 gages of Appendix C are compared with the observed flows in Chapter 6 and Appendix E. The flow sequences plotted in Appendix E cover the WAM periods-of-analysis. The first graph for each site in Appendix E is monthly naturalized flows. The second graph consists of plots of annual means of naturalized, regulated and observed flows. The 3rd and 4th graph in each set compares 2-month minima and 2-month maxima for annual naturalized, regulated and observed flows.

The expected value (mean) and other characteristics of observed flows at many sites vary significantly over time as a result of water resources development and use. Naturalized flows are derived by adjusting observed flows to remove the effects of water development and use. These adjustments are necessarily approximate and cannot include absolutely all effects of human activity. However, the naturalized flows should conceptually be homogeneous with no permanent long-term trends. The simulated regulated flows represent current conditions of water development and use and should conceptually reflect no permanent long-term changes over time.

Stream flow in Texas is characterized by tremendous variability with the extremes of intense floods and severe multiple-year droughts along with continual lesser fluctuations. There is a degree of persistence with dry or wet conditions extending over significant periods of time. Long-term trends or permanent changes in observed flows are largely hidden by the great natural variability. However, significant changes in the characteristics of the observed flows at the 35 gages are evident in some of the plots of Appendix C. Changes differ greatly between the different sites. Both high and low flows have decreased at four sites. Both high and low flows have increased at four other sites. High flows have decreased and low flows have increased at another four sites. High flows have decreased but low flow changes are not clearly evident at eight of the sites. Low flows have increased but high flow changes are not evident at two sites. Long-term trends or permanent changes are not clearly evident at eleven of the 35 sites.

Differences between naturalized flows and observed flows are significant at many sites but the differences vary with location and over time and between low and high flows. Comparisons of frequency metrics for naturalized versus regulated flows in Chapter 5 also illustrate the different effects of reservoirs and water use on low flows, high flows, and median flows. These relationships vary with location. The naturalized flows on the major rivers appear to be reasonably homogeneous as required by the WAM modeling system. The Canadian River is the only river with naturalized flows displaying evident trends long-term change.

River System Water Volume Budgets

The WAM simulation study reported in Chapter 5 provided the river storage sequences discussed in the preceding section, naturalized and regulated flows also discussed earlier in this summary chapter, and the volume budgets discussed below. The current use scenario versions of the 20 WAMs were adopted for the study. Thus, the simulation results describe a hypothetical situation in which current conditions of water development and use occur during a repetition of historical hydrology dating back to 1934 for one WAM, 1940 for 17 of the WAMs, and 1948 for the other two. The models are based on a monthly computation time interval.

Simulation studies for each of the 20 individual river basins are presented in Chapter 5. River system water volume budgets and flow and storage frequency metrics are presented for each of the 20 basin WAMs. The results from the 20 WAM simulations are aggregated as described in Chapter 5 to develop the statewide river system volume budget discussed here. The information presented in Tables 7.1 and 7.2 and the following discussion includes only the estimated Texas share of the flow and storage of the international and interstate river basins. Pertinent information describing Texas is provided in Table 7.1. The long-term means of the naturalized and regulated flows flowing out of Texas either into the Gulf of Mexico or across state borders is 11.8% and 9.54% of the long-term mean of the precipitation falling on the state.

Table 7.1
Descriptive Information for Entire State of Texas

watershed area (square miles)	259,200
mean precipitation (inches/year)	27.9
mean precipitation (ac-ft/year)	391,286,000
mean evaporation (inches/year)	60.6
number of reservoirs	3,444
storage capacity (Texas, ac-ft)	35,053,000
mean storage (acre-feet)	27,964,000
mean storage (% of capacity)	79.8%
diversion target (acre-feet/year)	17,374,000
volume reliability (percent)	86.6%
naturalized flow (% of precip)	11.8%
regulated flow (% precipitation)	9.54%

A river system volume budget for natural conditions without human water development is viewed as consisting of the long-term mean precipitation and naturalized flows presented in Table 7.1. Precipitation falling on the river basin is the input. Naturalized flows at the basin outlets is a component of the output. The naturalized flows include both surface runoff and flow into streams from subsurface water with both ultimately supplied from participation. The long-term mean of the naturalized flow is 11.8 percent of the precipitation. The other 88.2 percent of the precipitation replenishes soil moisture and groundwater and is lost to evapotranspiration. An unknown amount of the groundwater may flow into the ocean or across state borders.

The river system volume budget in Table 7.2 reflects the effects of current conditions of water resources development, allocation, management, and use as defined by the WAMs. All terms are long-term means in acre-feet/year. The quantities in the volume budget summary sum to zero in the following volume balance equation.

naturalized flows at outlet + return flows and other inflows + other gains or losses
– water supply diversions – net reservoir evaporation – regulated flows = zero

Table 7.2
River System Volume Budget for Texas

	(acre-feet/year)
naturalized flows at outlets	46,166,200
return flows and other inflows	8,513,200
water supply diversions	15,036,900
net reservoir evaporation-precipitation	2,441,700
evaporation	(10,006,900)
precipitation	(7,565.200)
net of other gains and losses	145,800
regulated flows at outlets	37,346,700

Inflows to the state equal the summation of the naturalized flows at the outlets, return flows from groundwater supplies, and inflows across state borders. Return flows are from water users supplied by groundwater as well as from the river system diversions shown in the table. Other gains and losses reflect changes in channel losses due to water management activities along with any other factors required to balance the volume budget.

The volume budget in Table 7.2 includes estimated long-term mean annual reservoir evaporation, precipitation, and evaporation-precipitation volumes totaling 10,006,900 ac-ft/yr, 7,565,200 ac-ft/yr, and 2,441,700 ac-ft/yr, respectively, for all of the reservoirs in the current use scenario WAMs, with the quantities for the international and interstate reservoirs reflecting only the portions allocated to Texas. The precipitation volumes from the WAMs exclude the portion of the precipitation that is already included in the naturalized flow.

Reservoir evaporation volumes are large. To provide perspective, the statewide long-term mean simulated reservoir evaporation volume of 10.0 million acre-feet/year is equivalent to 206 percent of the estimated 2010 total statewide municipal water use of 4.85 million acre-feet or

99.3 percent of the total 2010 agricultural water use of 10.1 million acre-feet/year from all surface and groundwater sources.

The long-term statewide means of evaporation and precipitation are 60.6 and 27.9 inches/year. However, the relative volumes of evaporation and precipitation in Table 7.2 reflect the greater reservoir surface area in the wet eastern regions of the state than in the dry western regions. Much of the reservoir precipitation volume occurs at Toledo Bend, Sam Rayburn, and the other large reservoirs in the wet Neches, Sabine, Sulphur, Cypress, and Trinity River Basins.

Long-term mean regulated flow is 80.9 percent of mean naturalized flow. Flow frequency tables in Chapter 5 comparing naturalized and regulated flows illustrate the significant differences between river basins and between low, median, and high flows. Regulated flows are expressed as a percentage of naturalized flows in the final summary frequency table (Table 5.12) of Chapter 5. For different exceedance frequencies at different locations, regulated flows range from a small fraction of naturalized flows to being much greater than naturalized flows.

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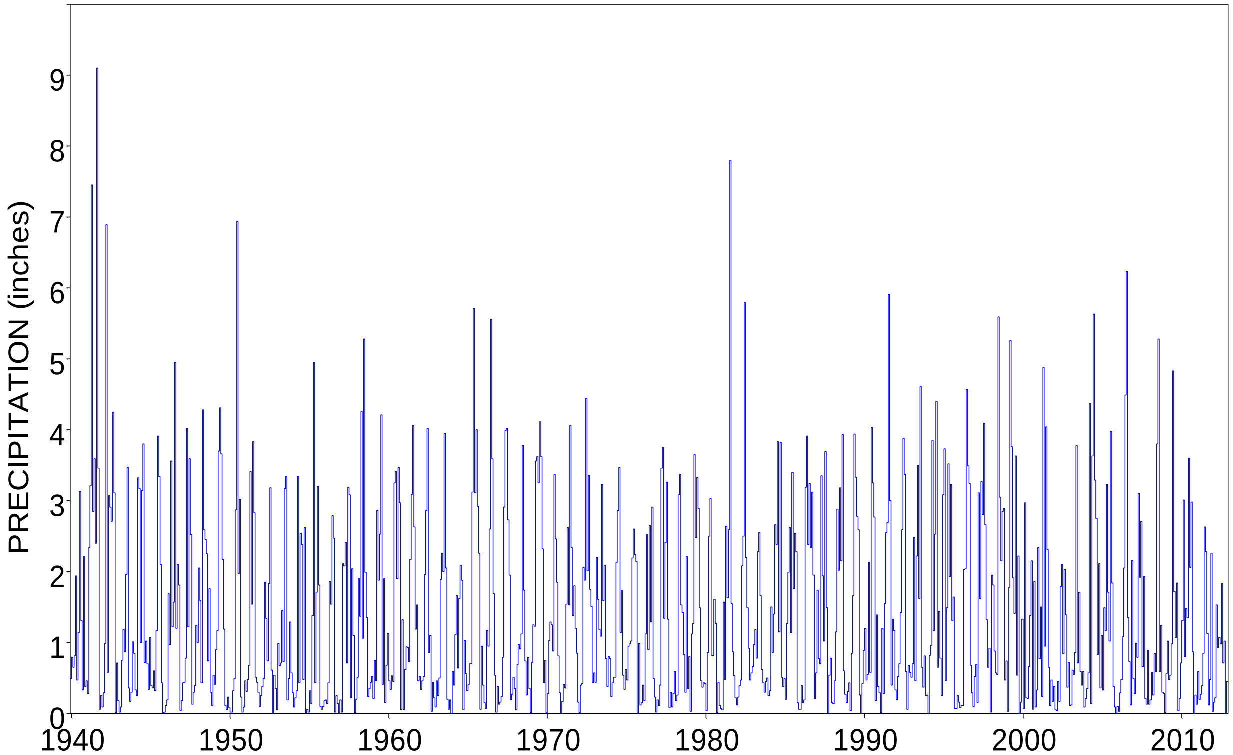
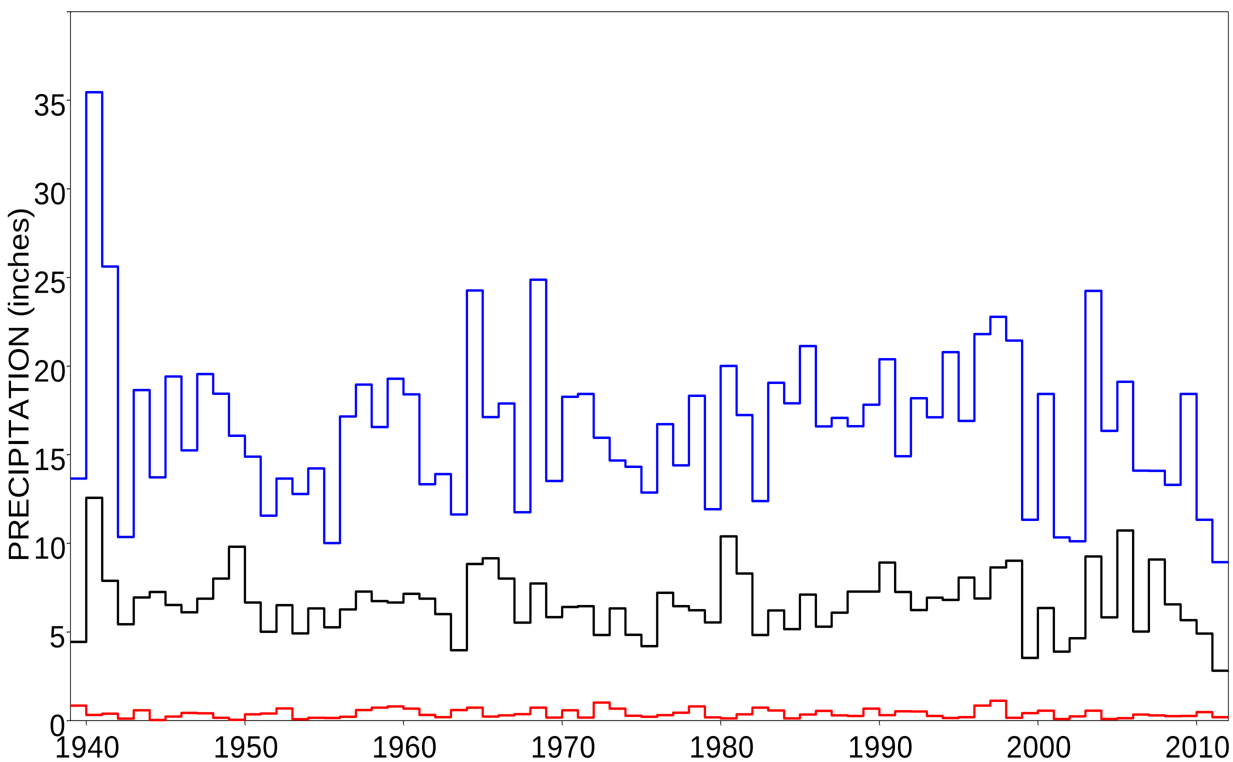
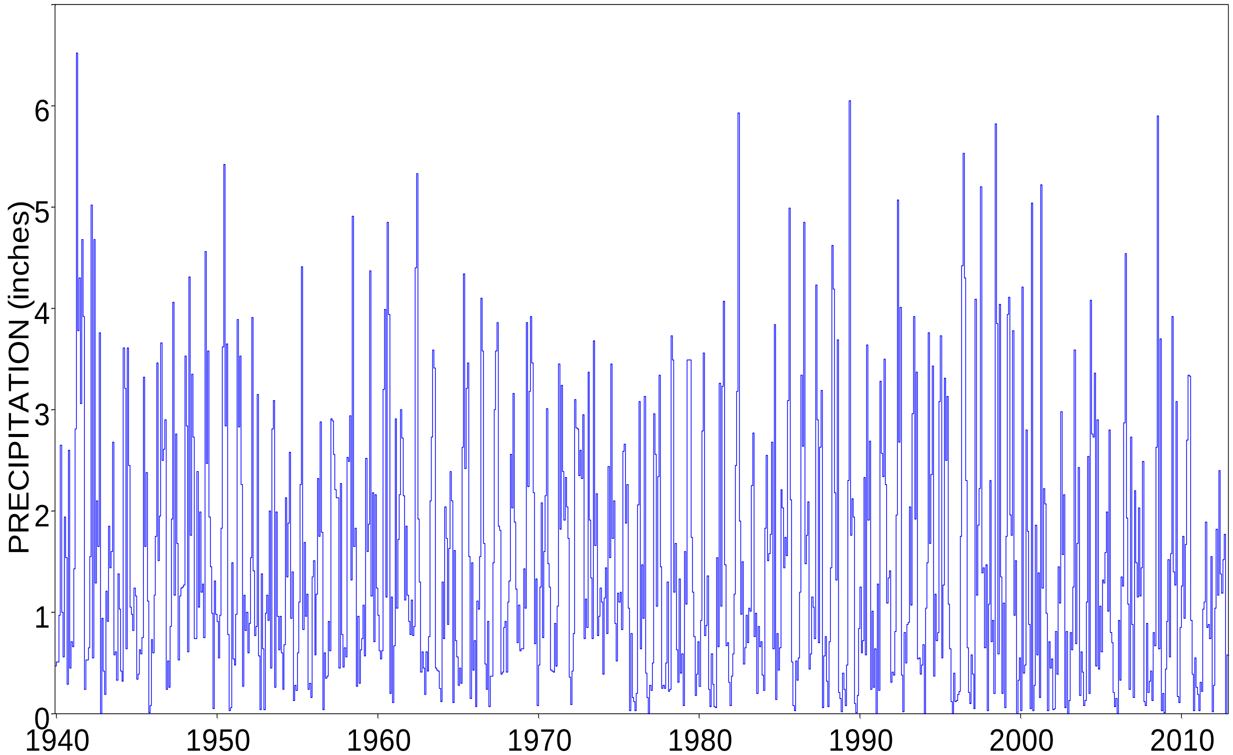


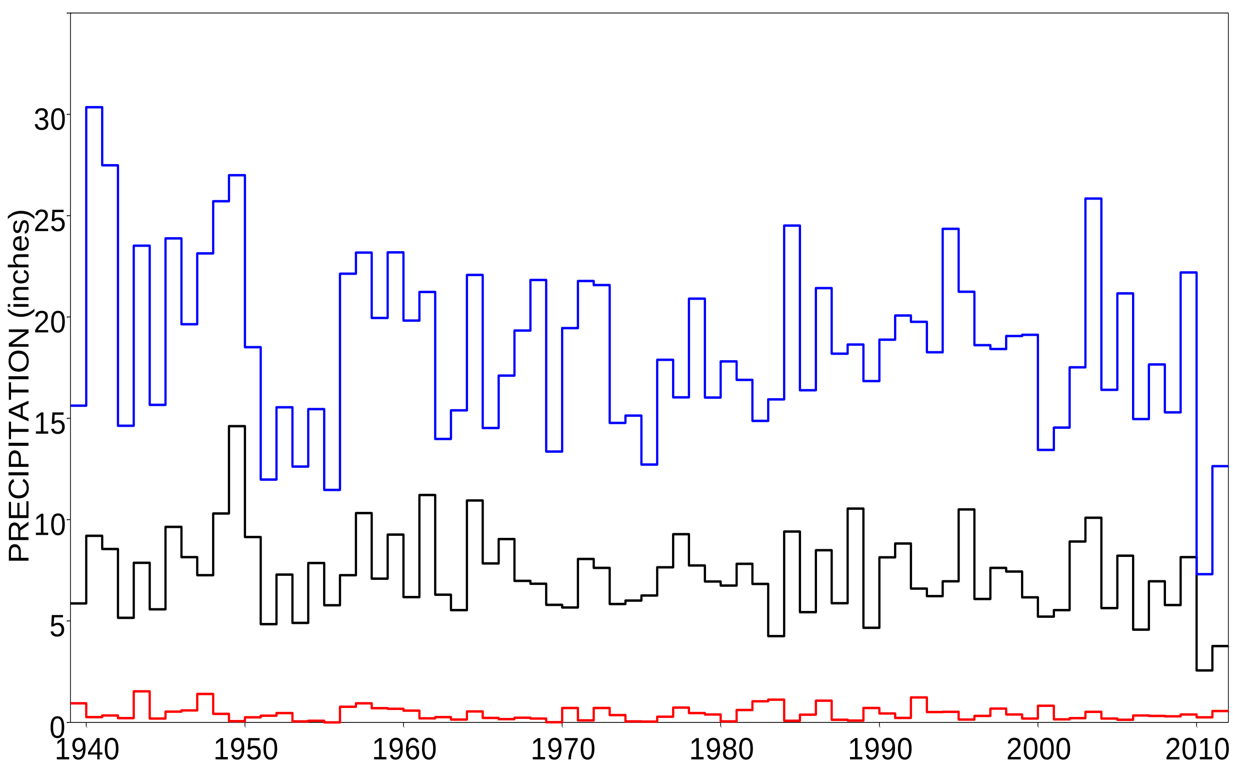
Monthly Precipitation for Quadrangle 104



Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 104



Monthly Precipitation for Quadrangle 105



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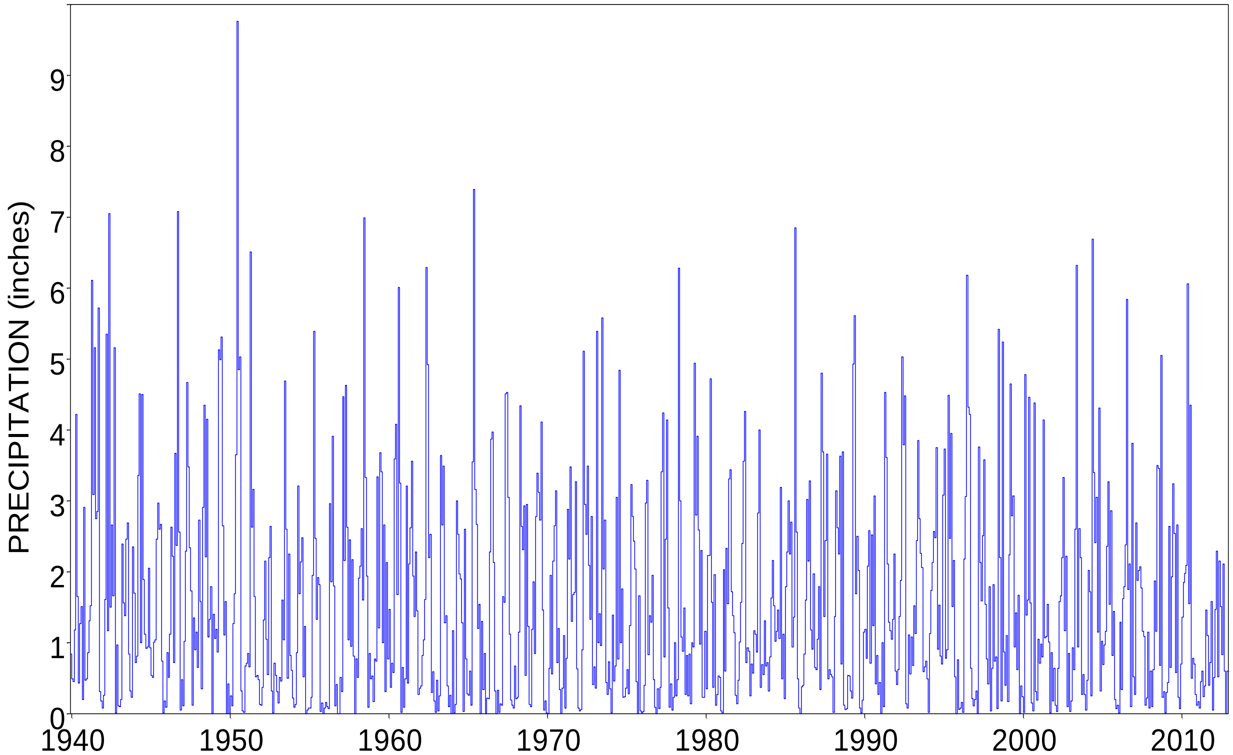

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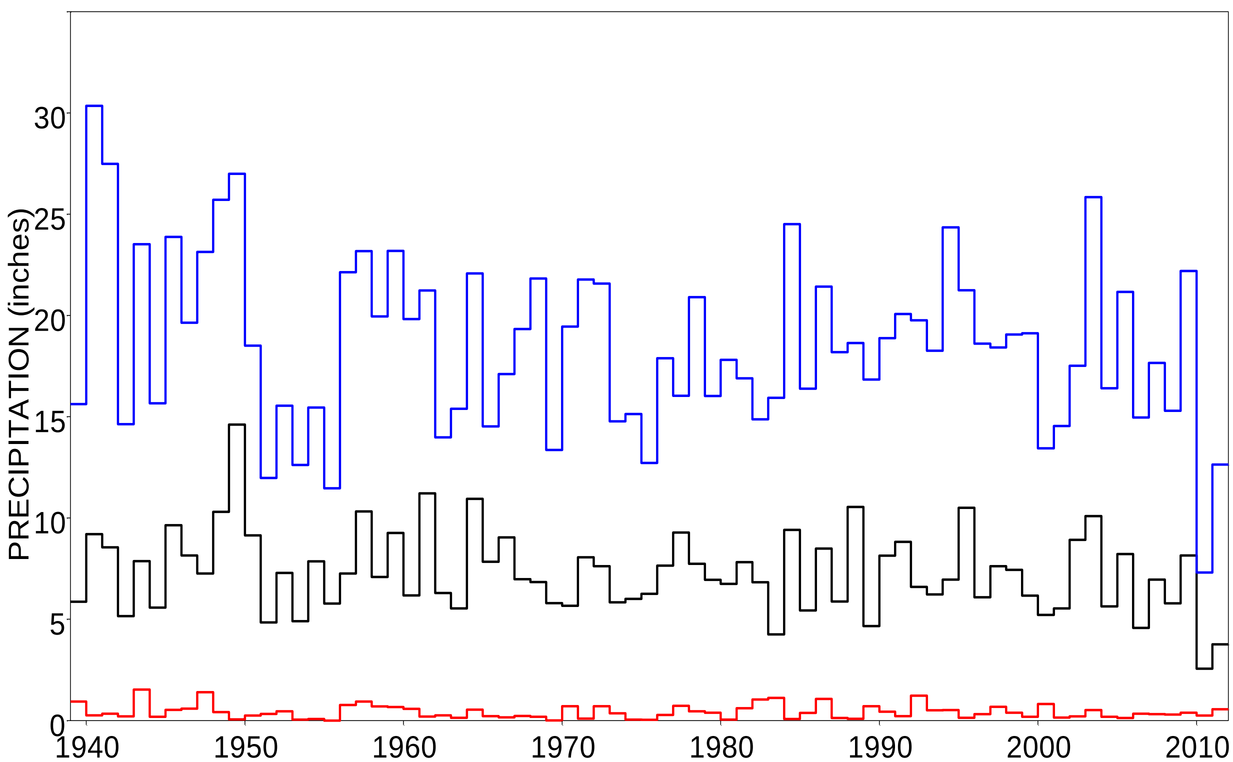

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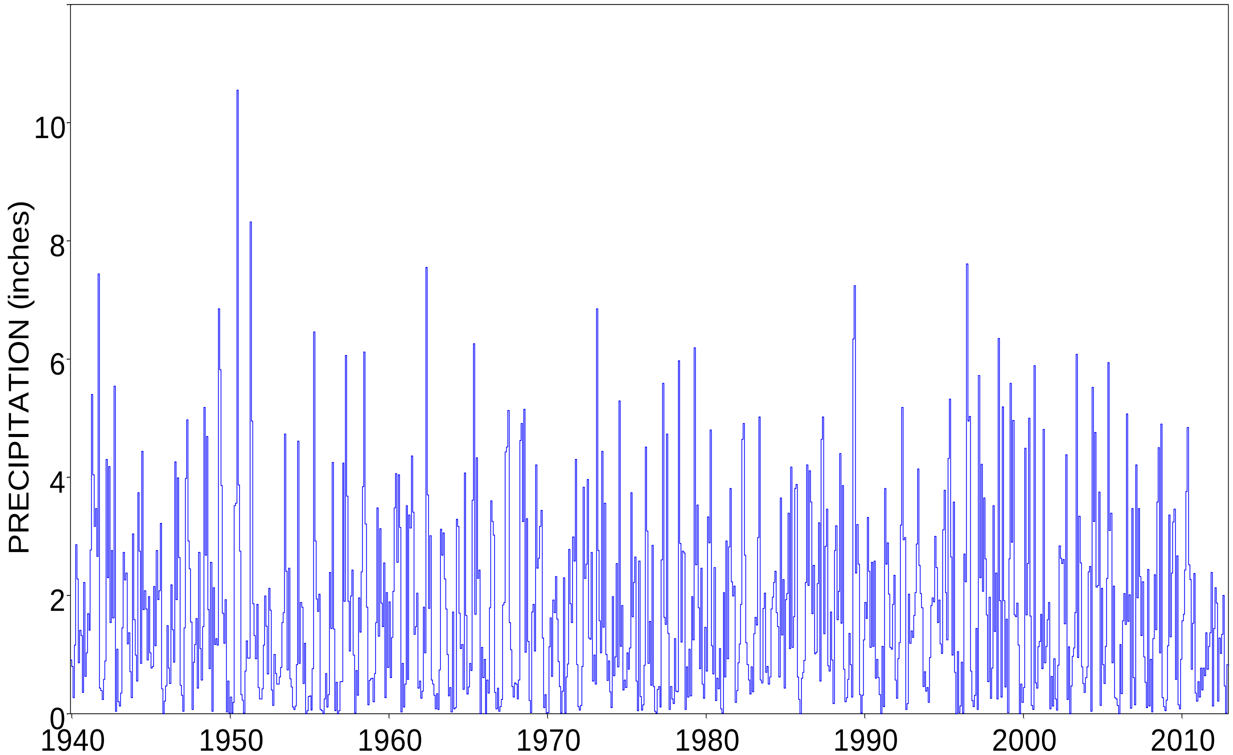

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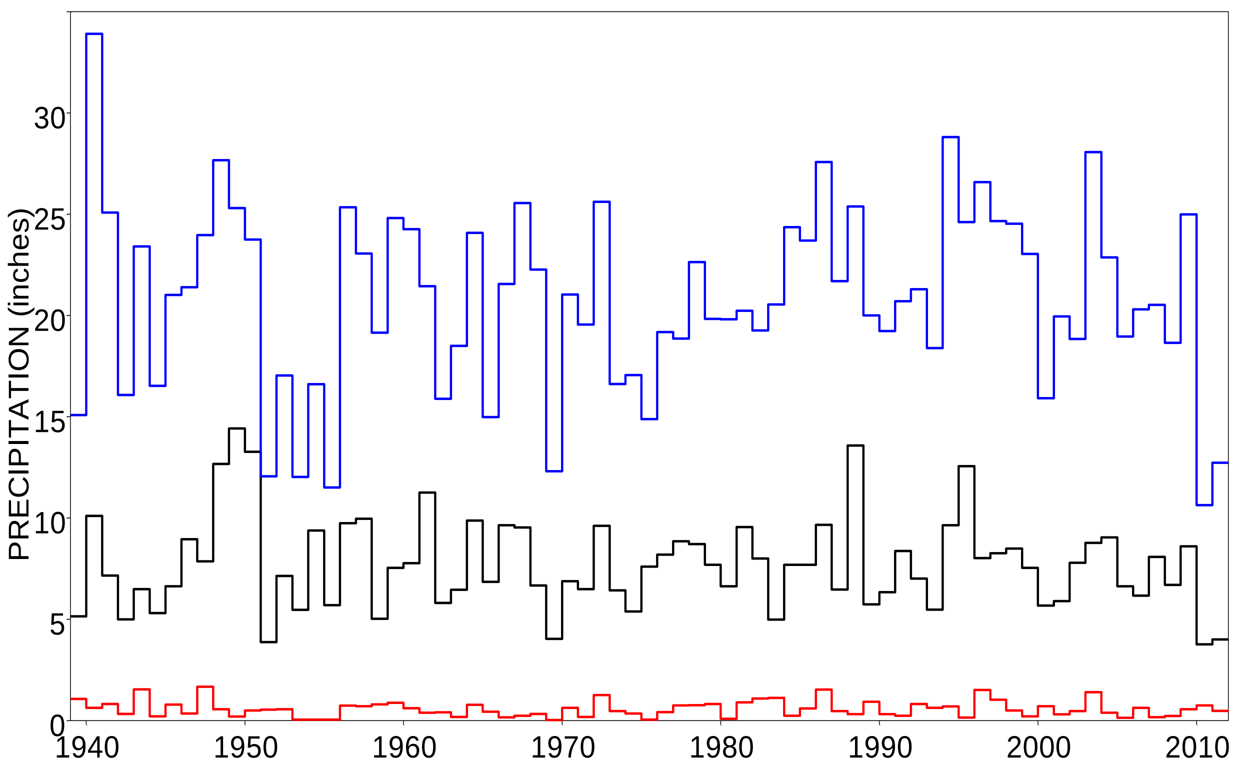

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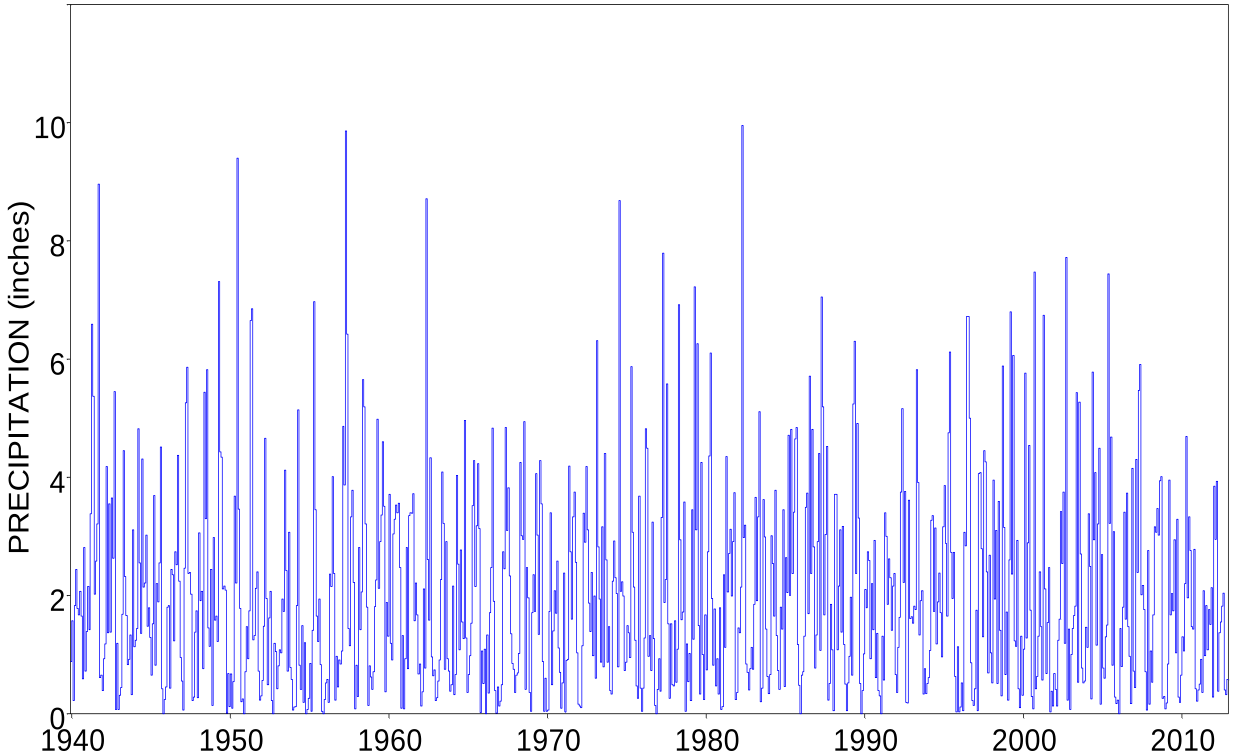

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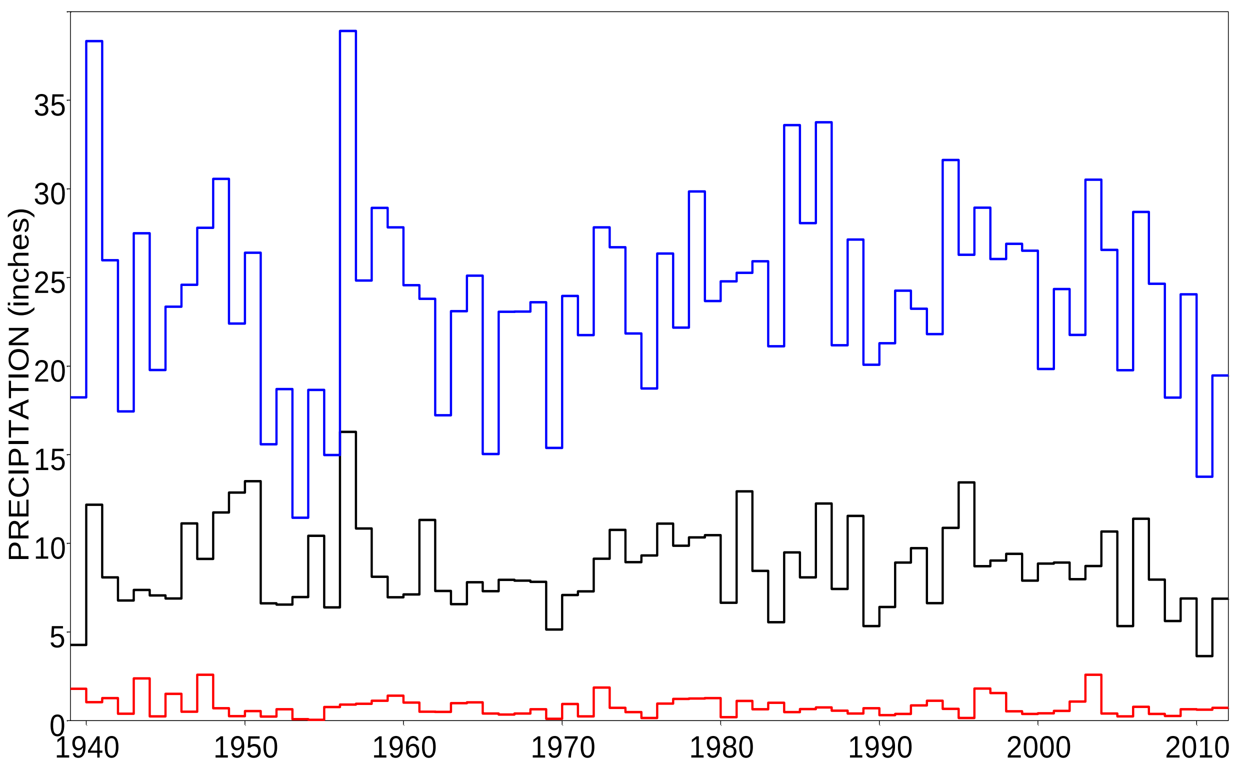

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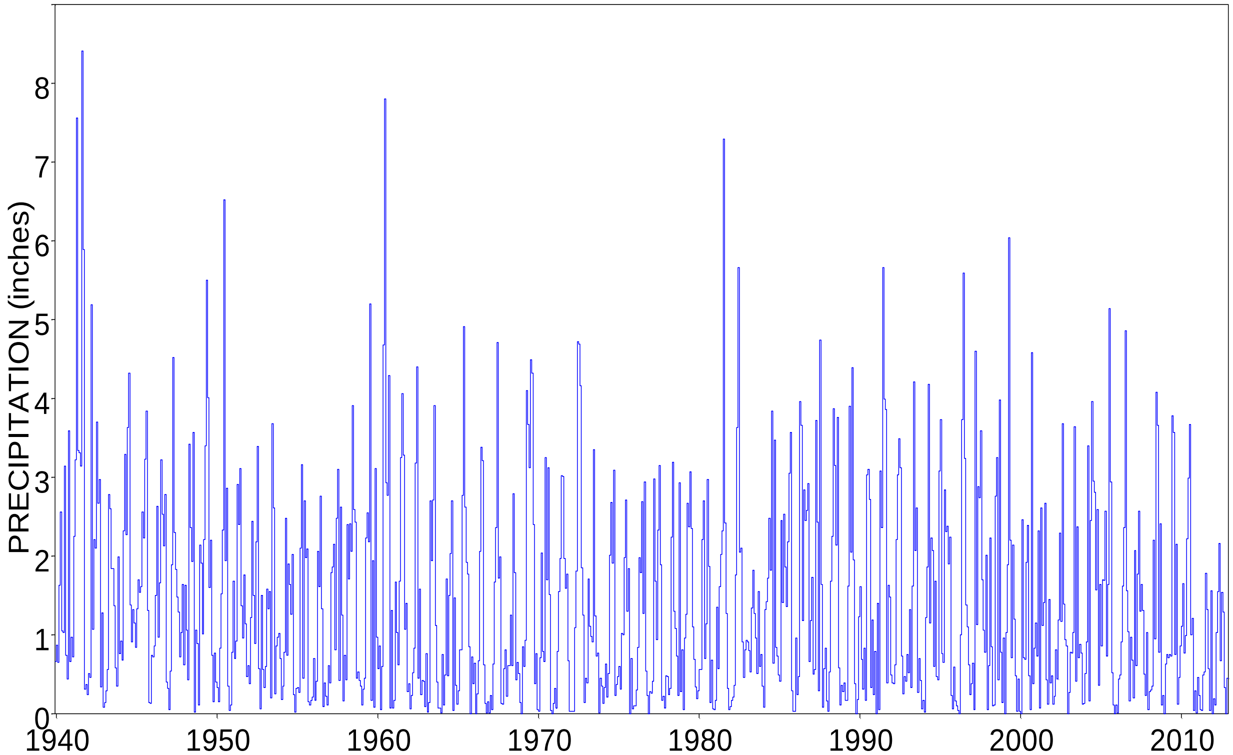

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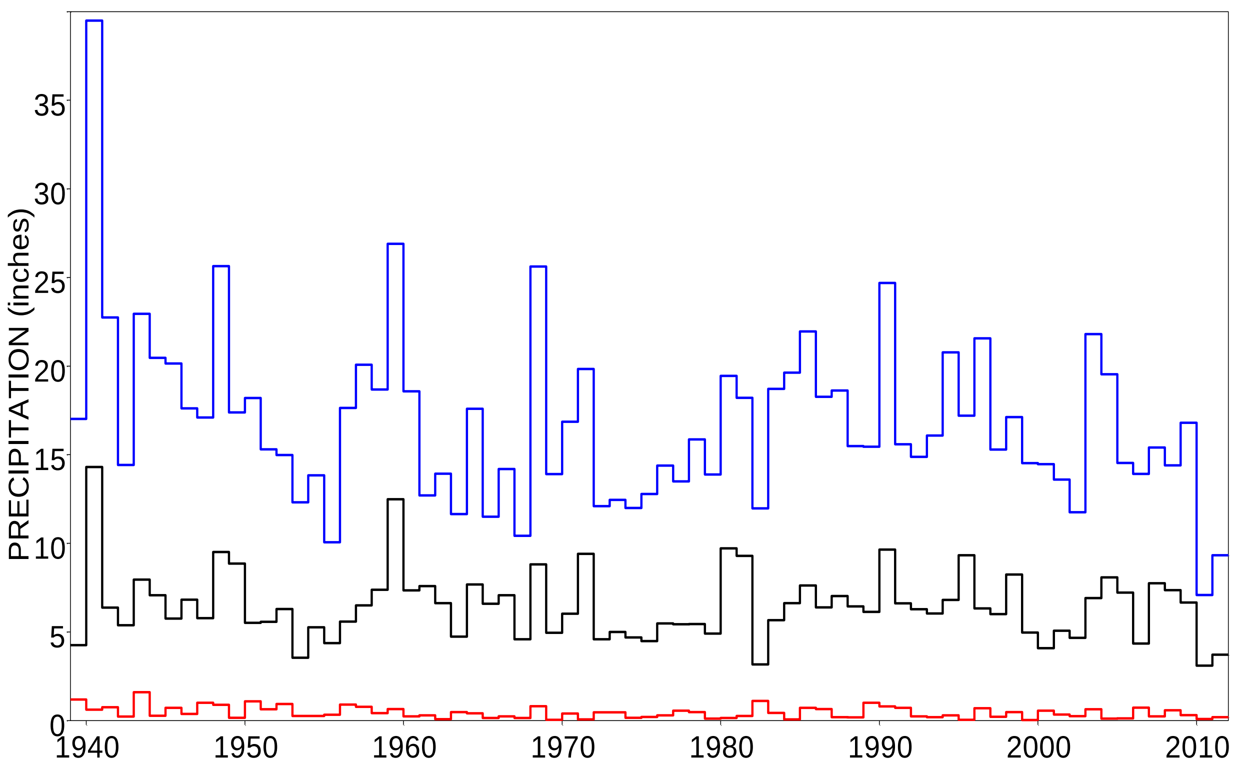

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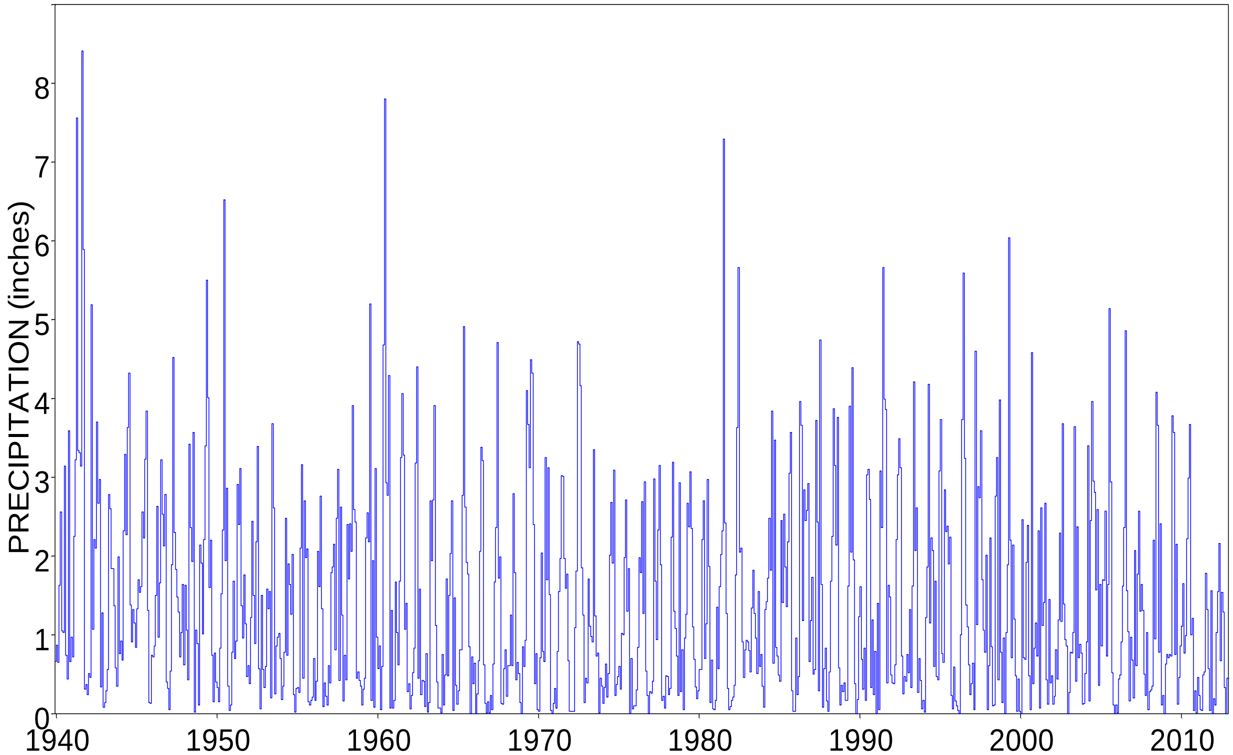

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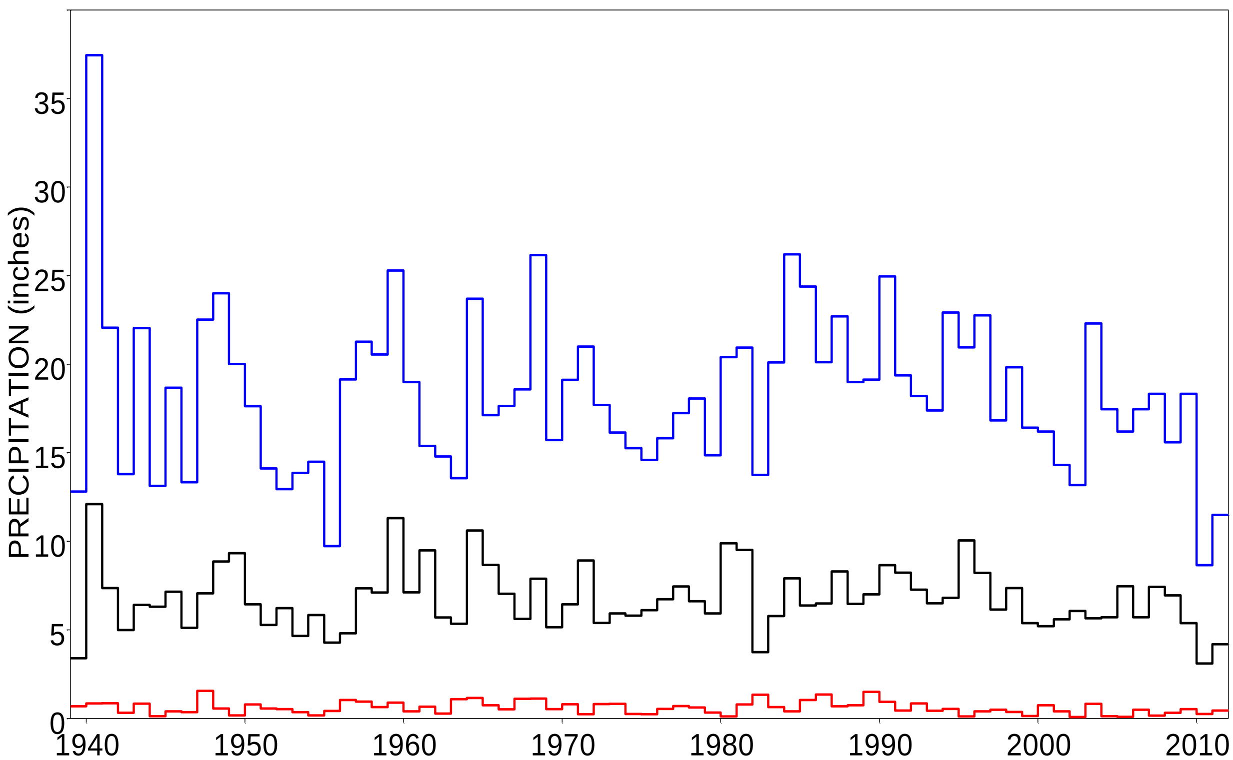

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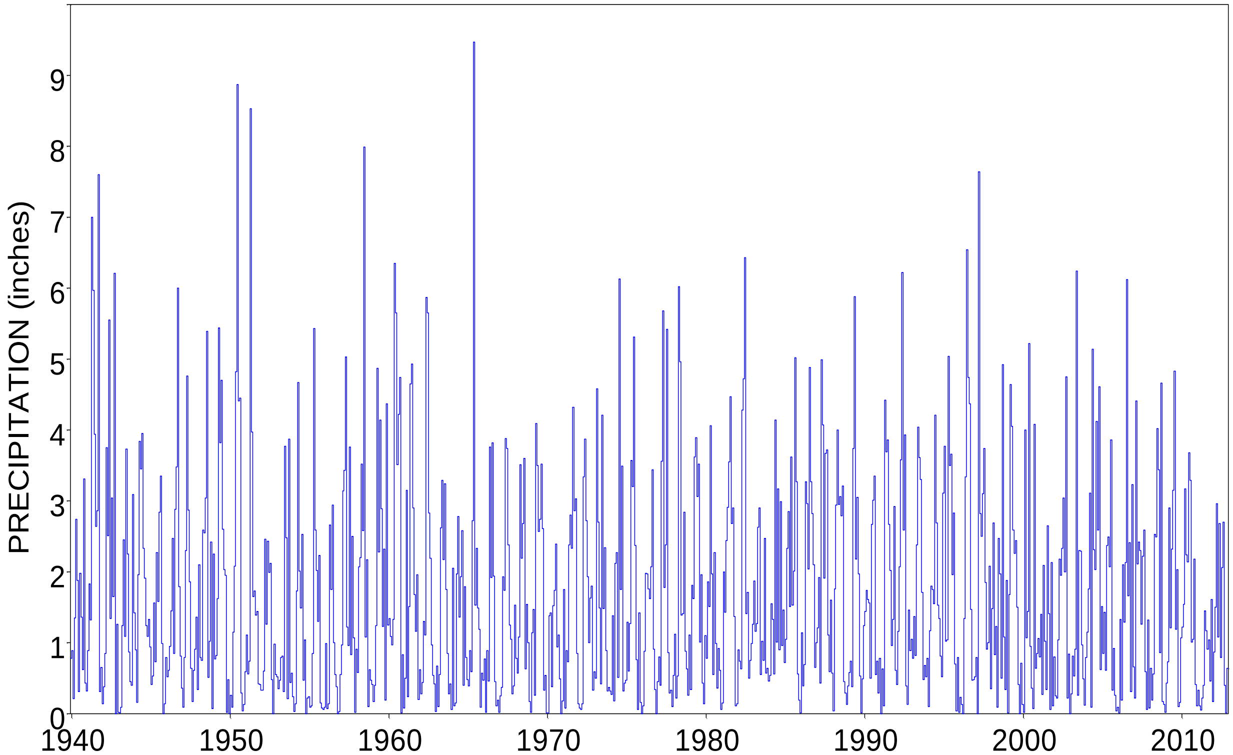

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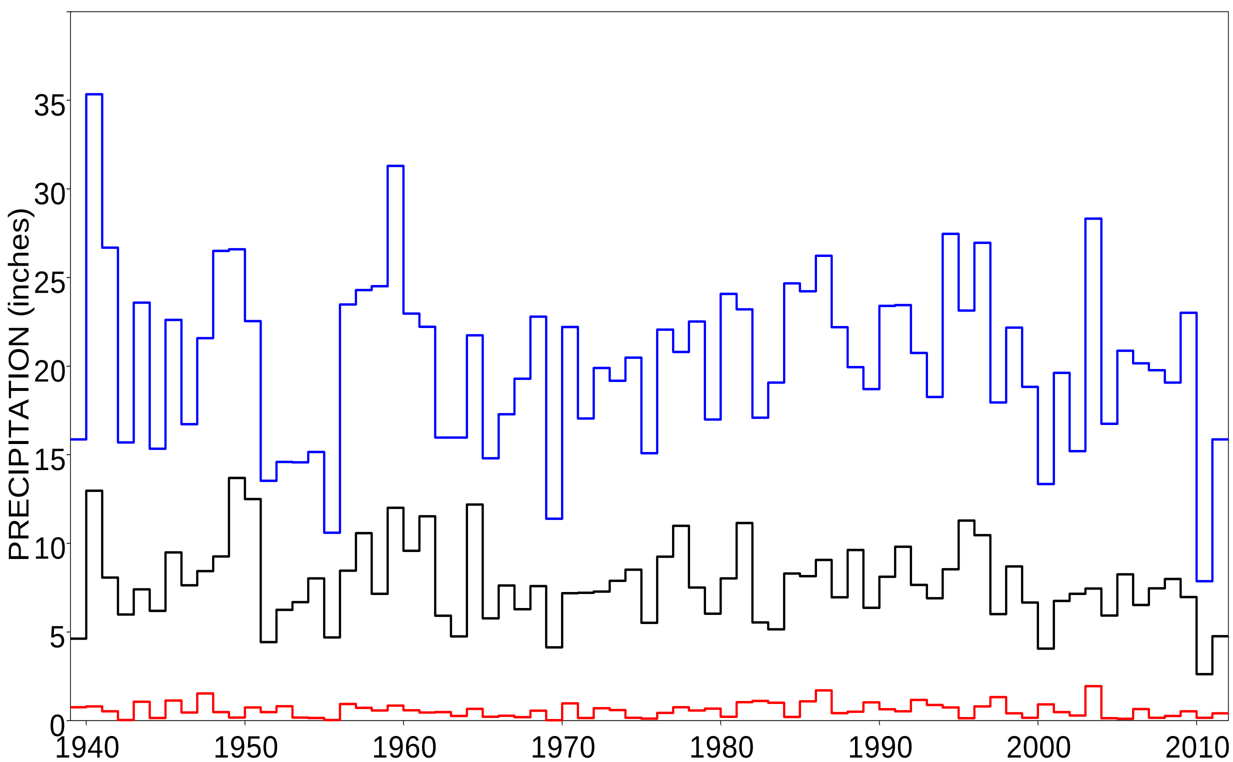

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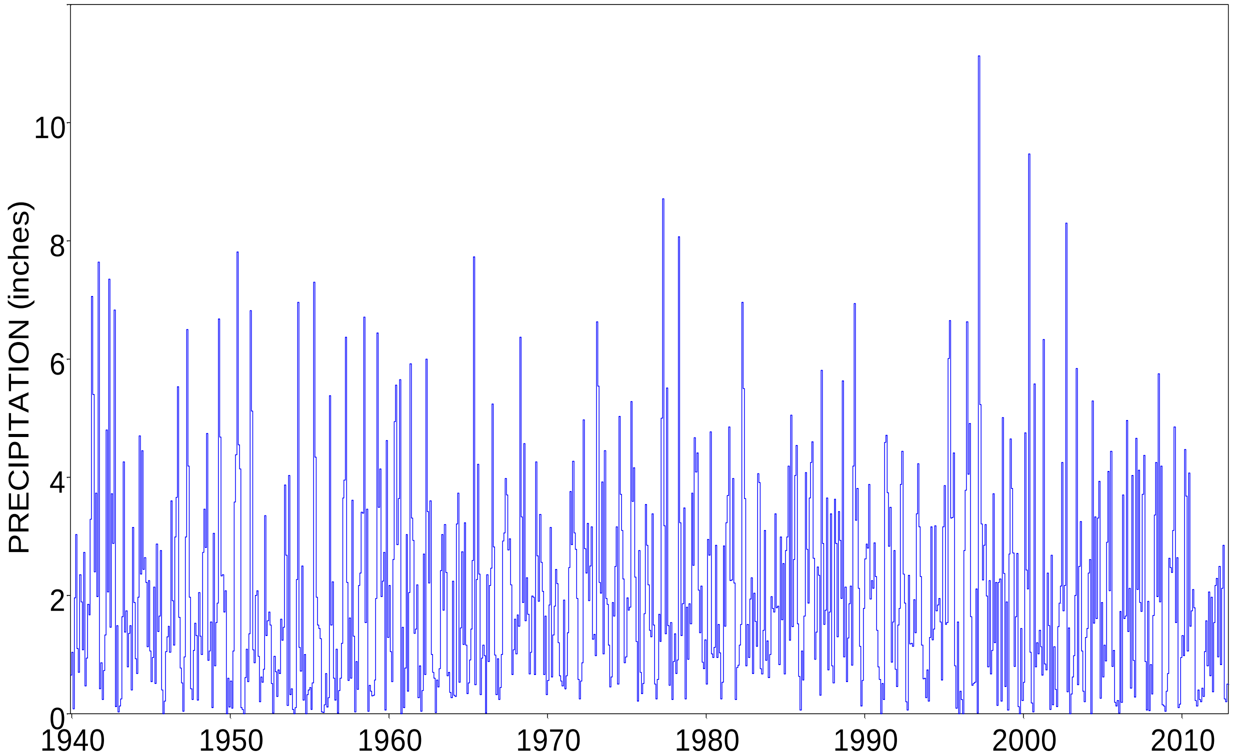

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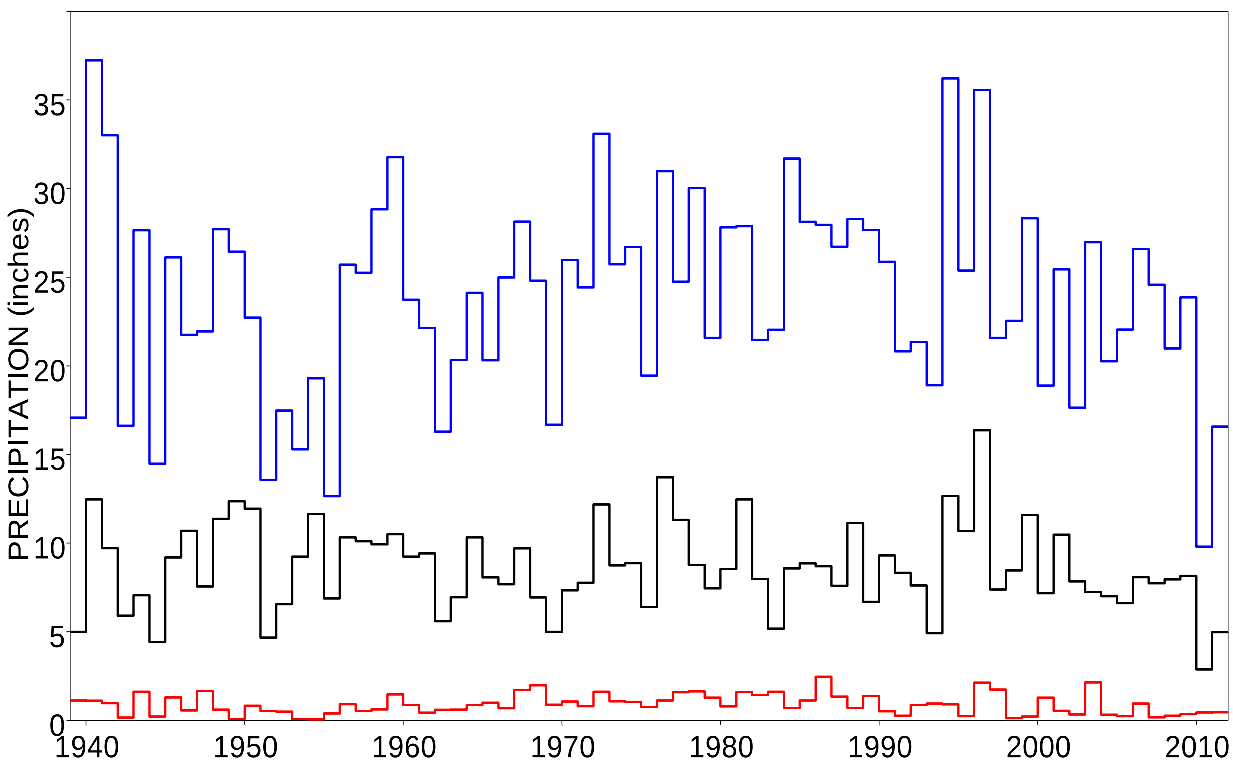

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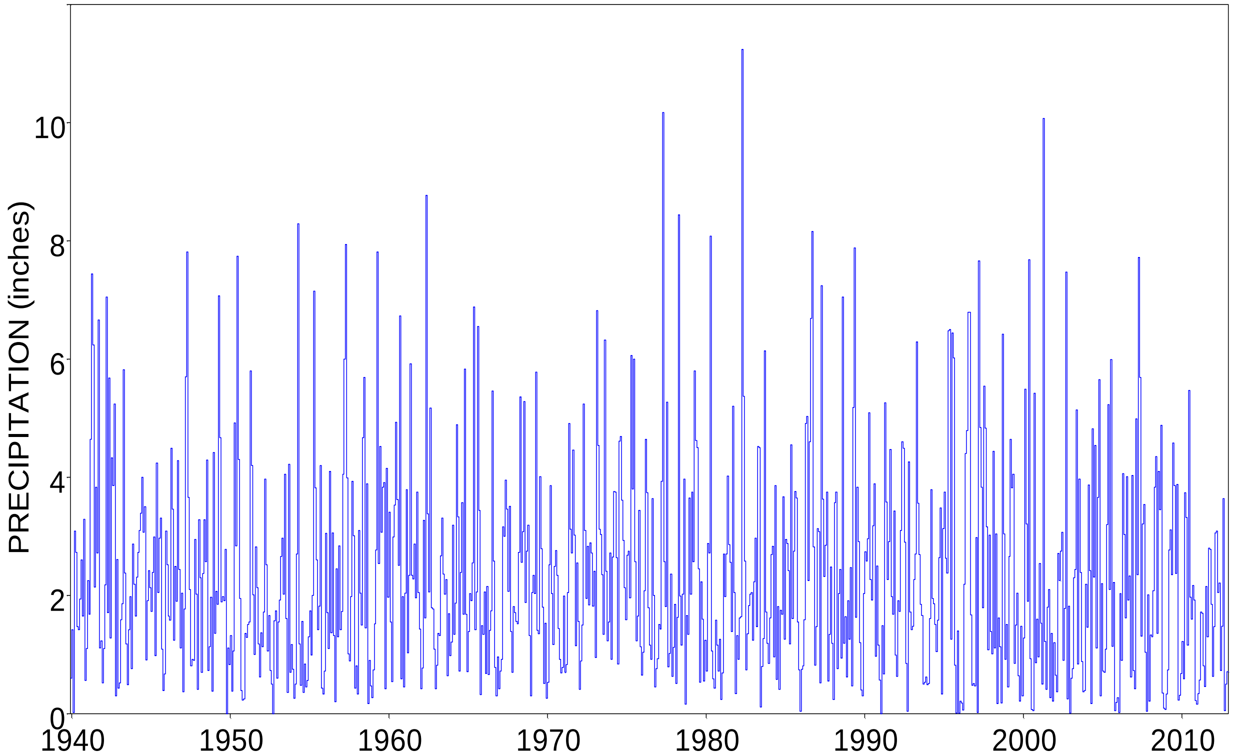
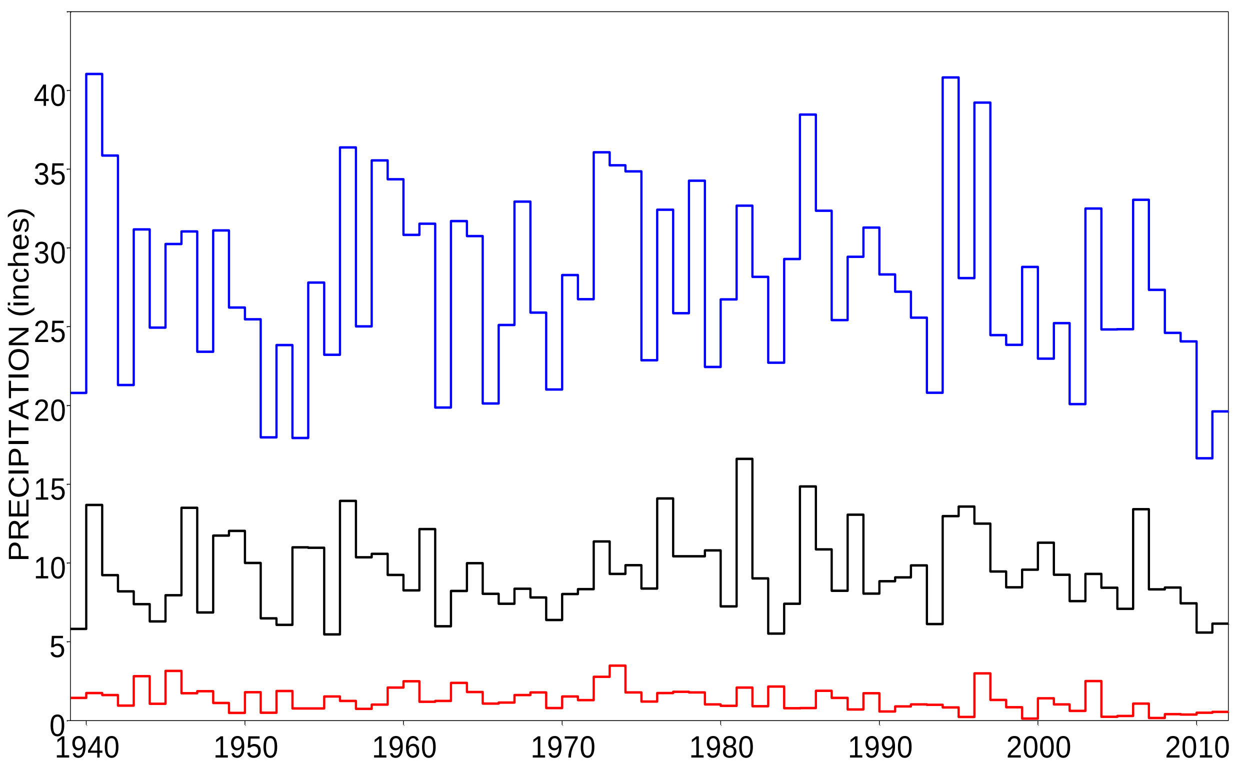


Monthly Precipitation for Quadrangle 207



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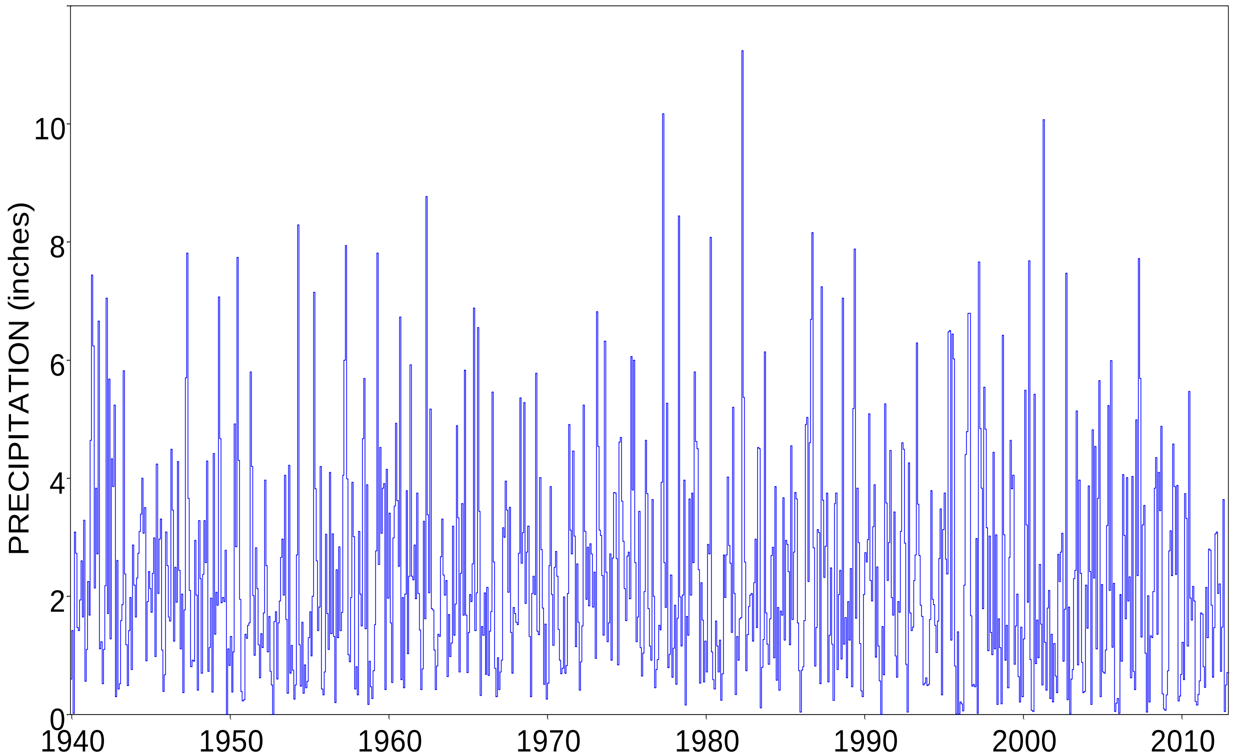
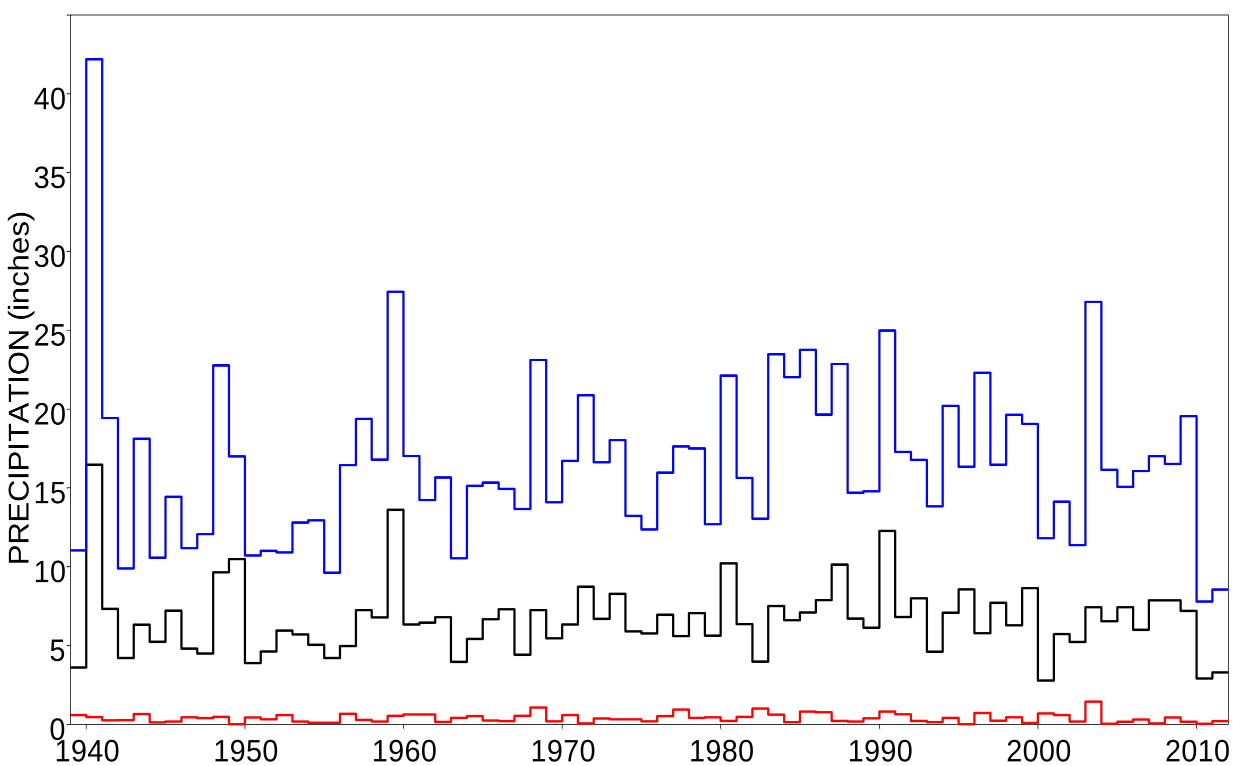


Monthly Precipitation for Quadrangle 304



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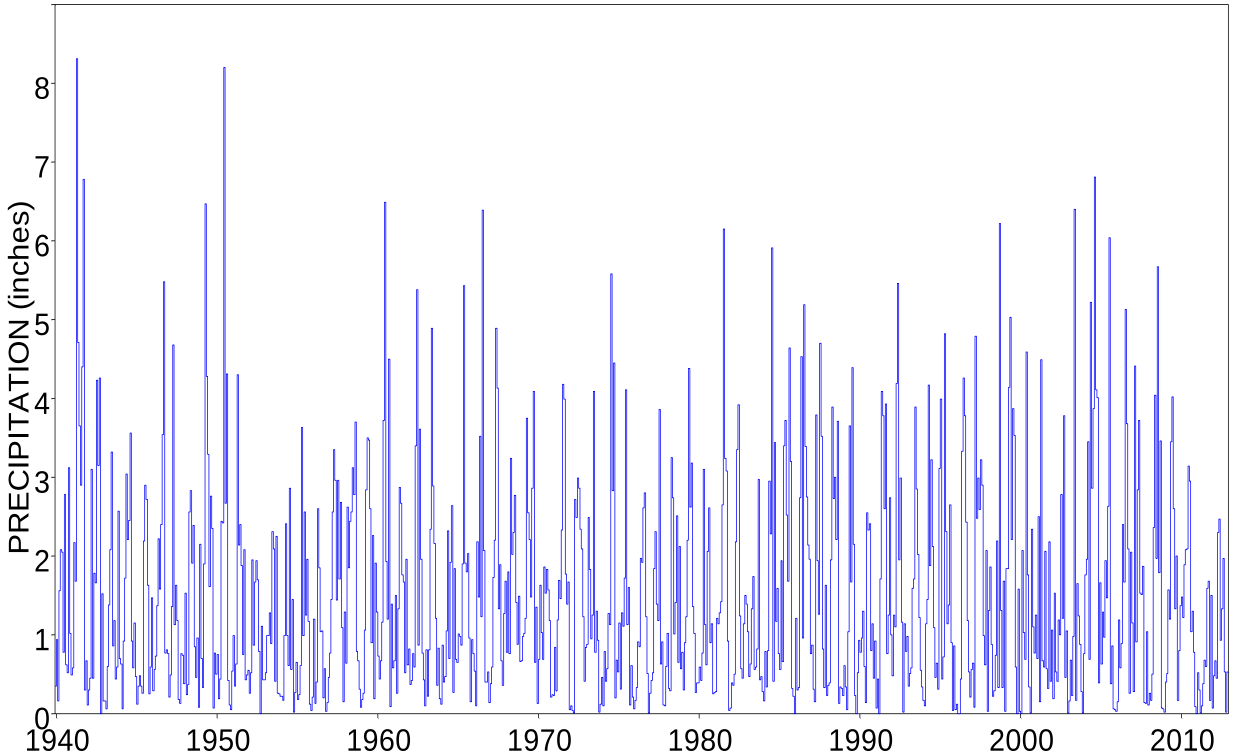
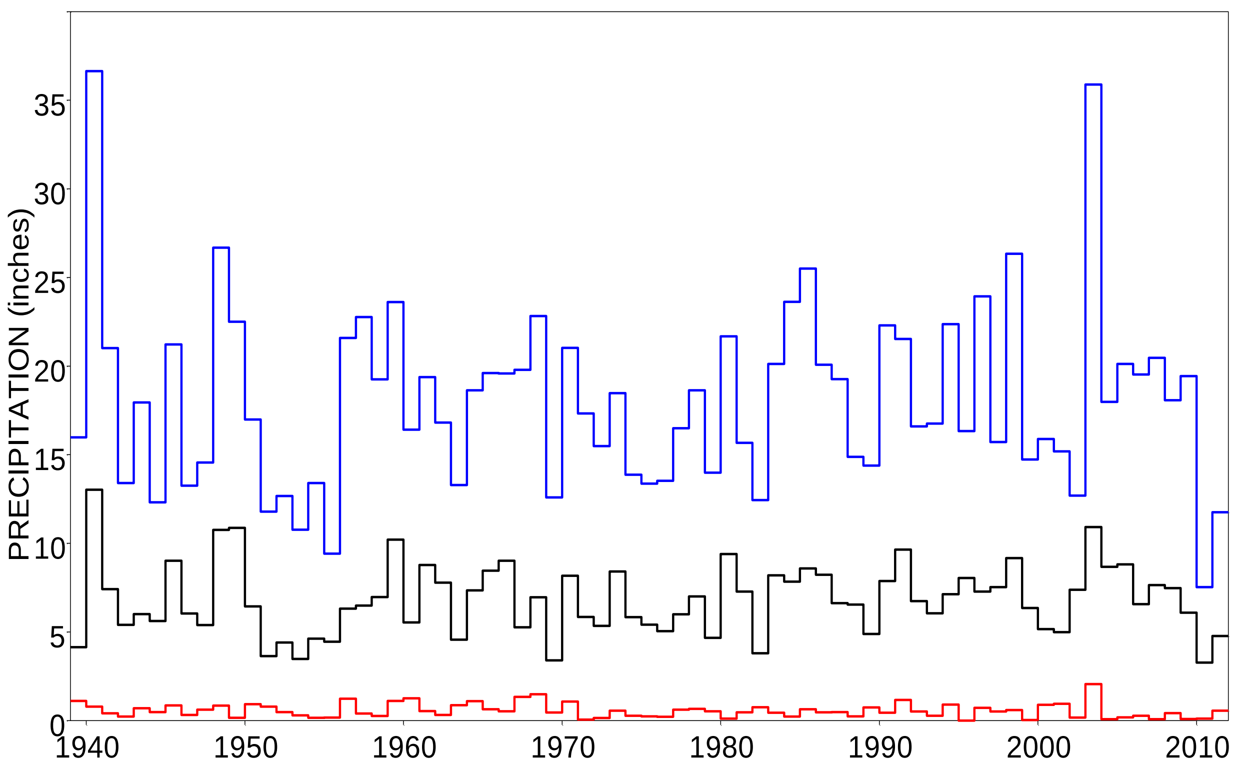


Monthly Precipitation for Quadrangle 305



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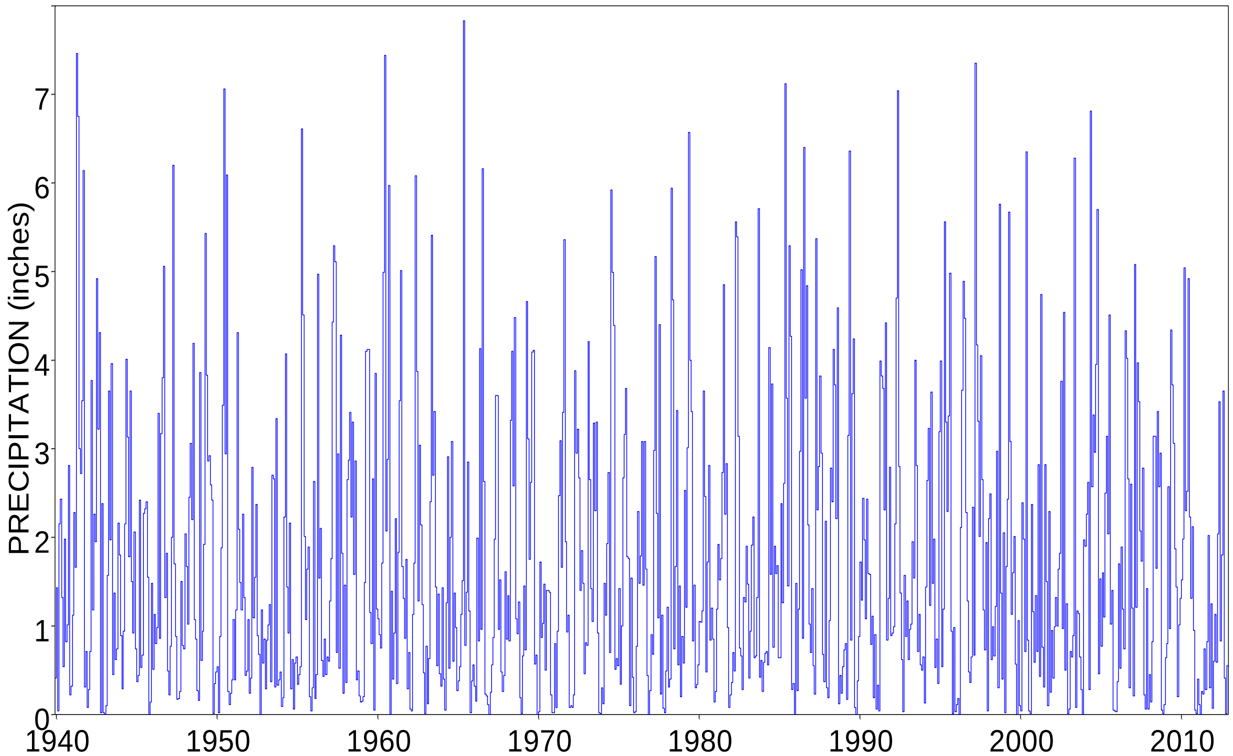

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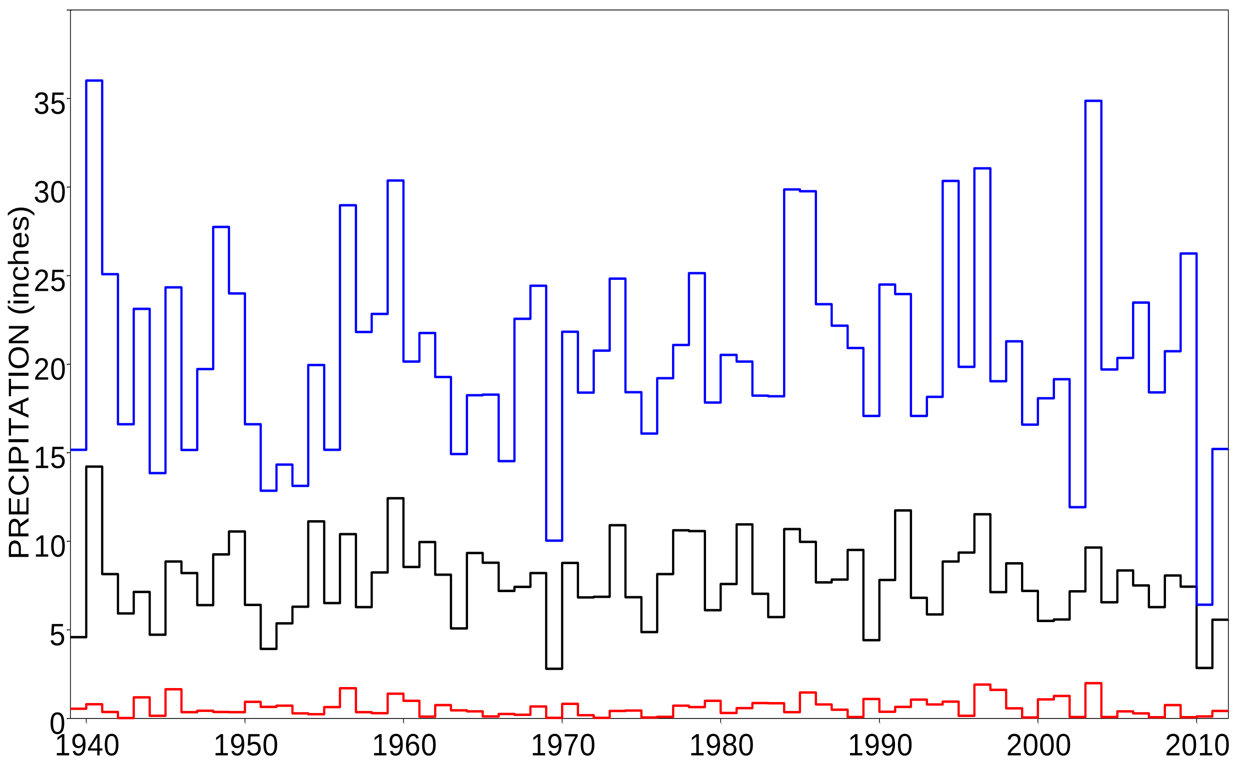

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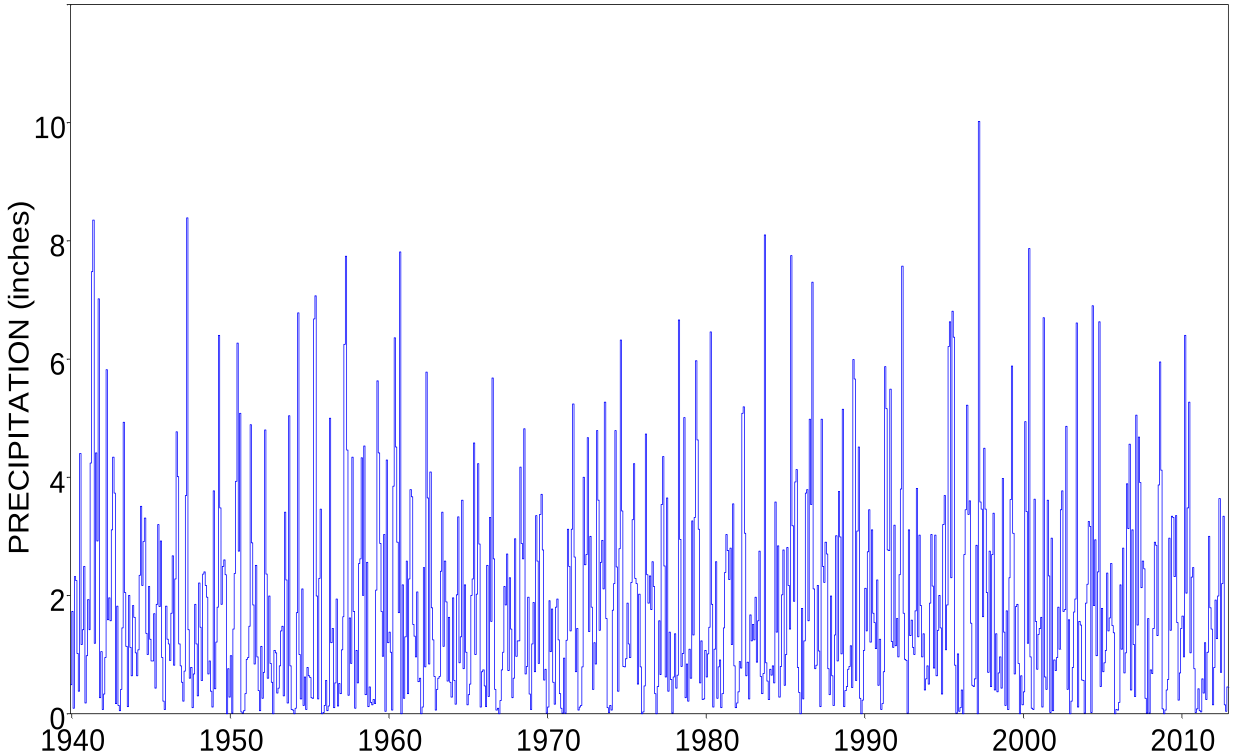
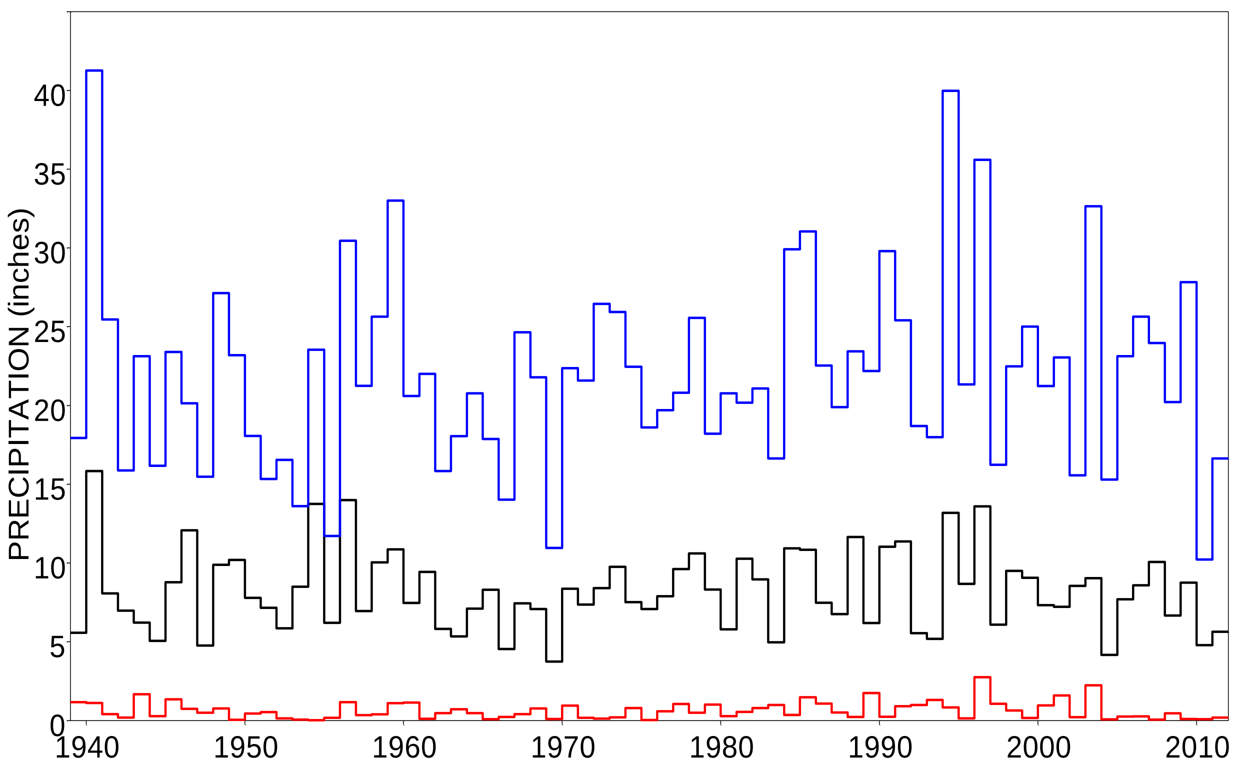
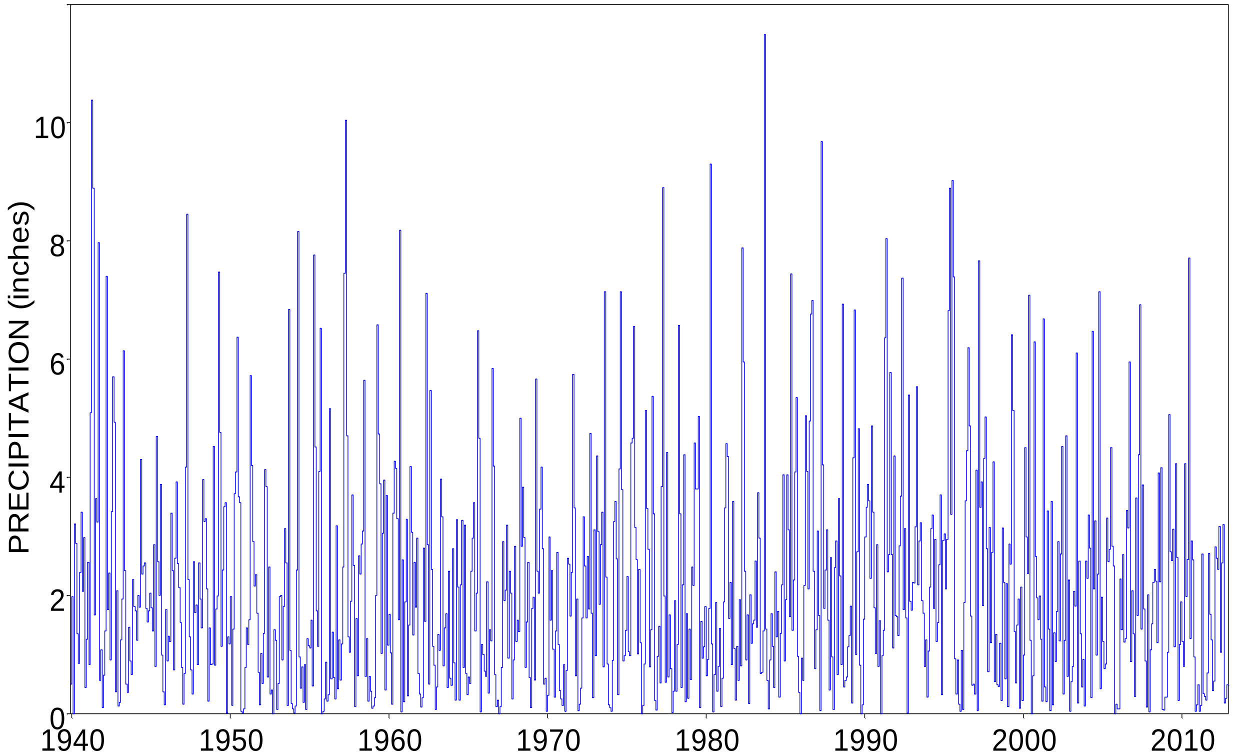


Monthly Precipitation for Quadrangle 307



Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 307



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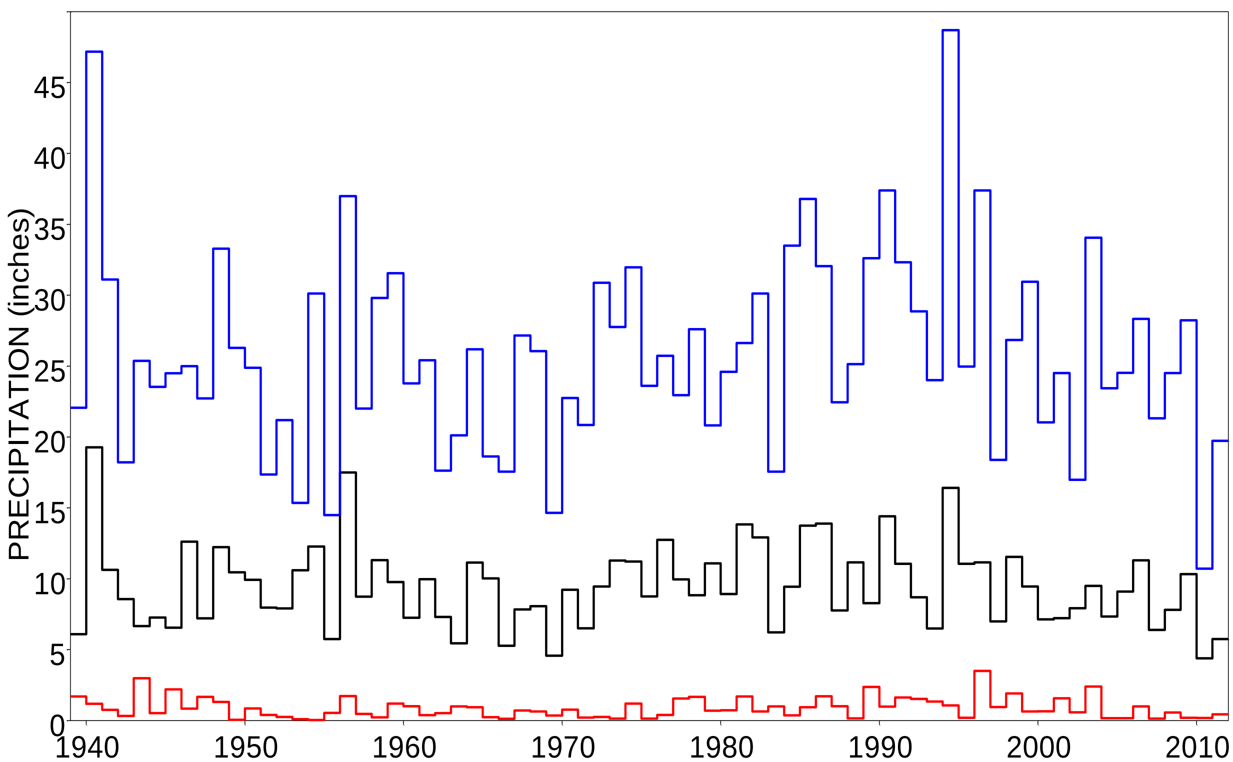

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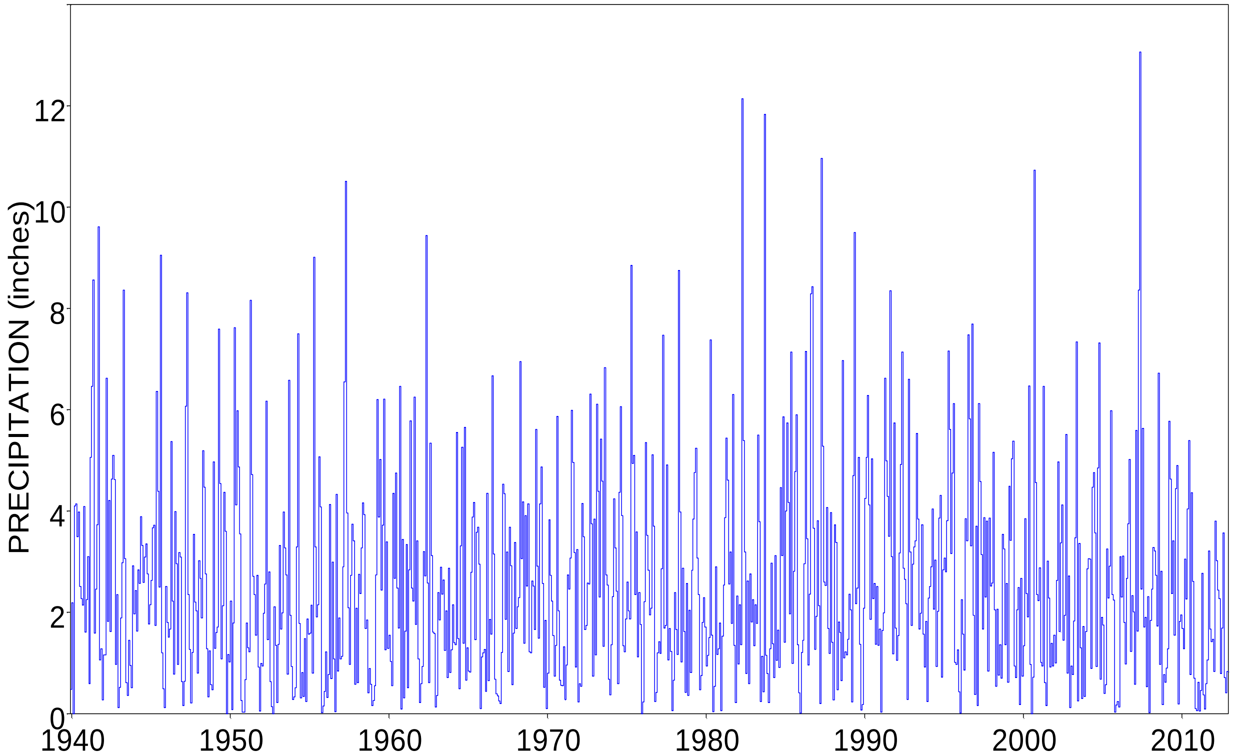

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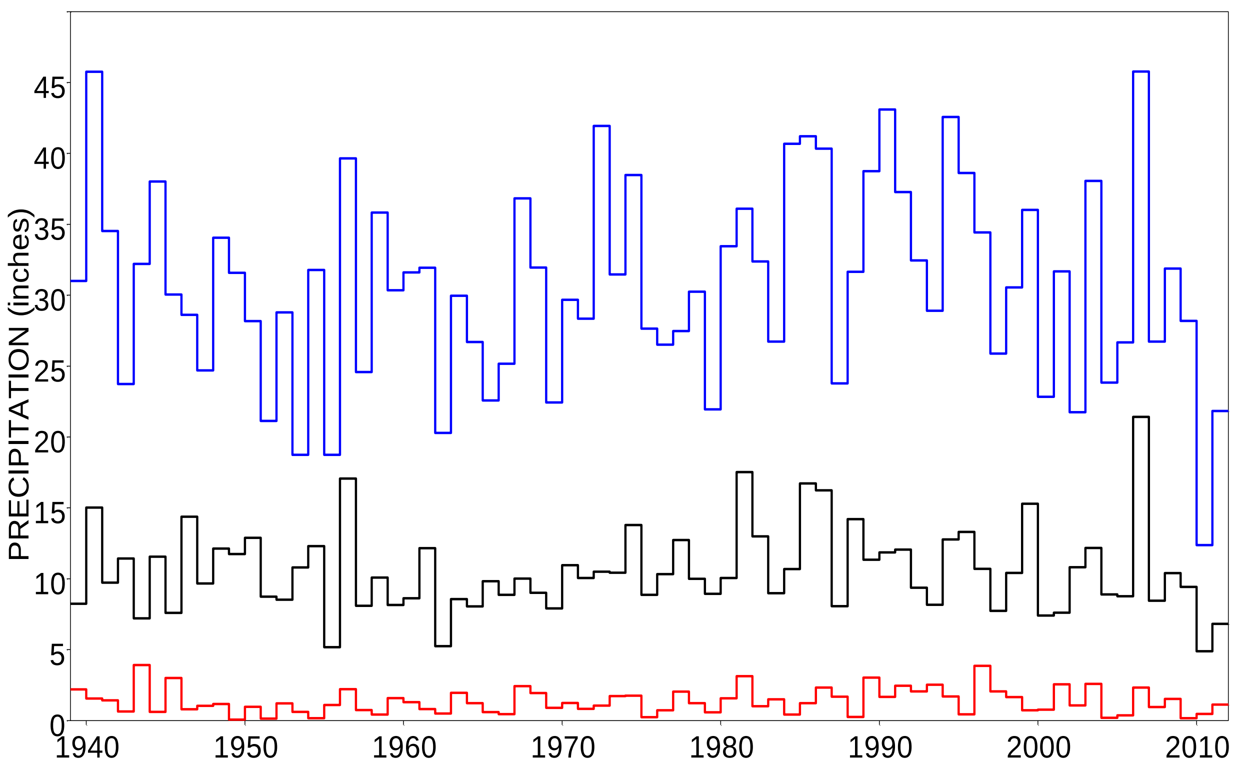

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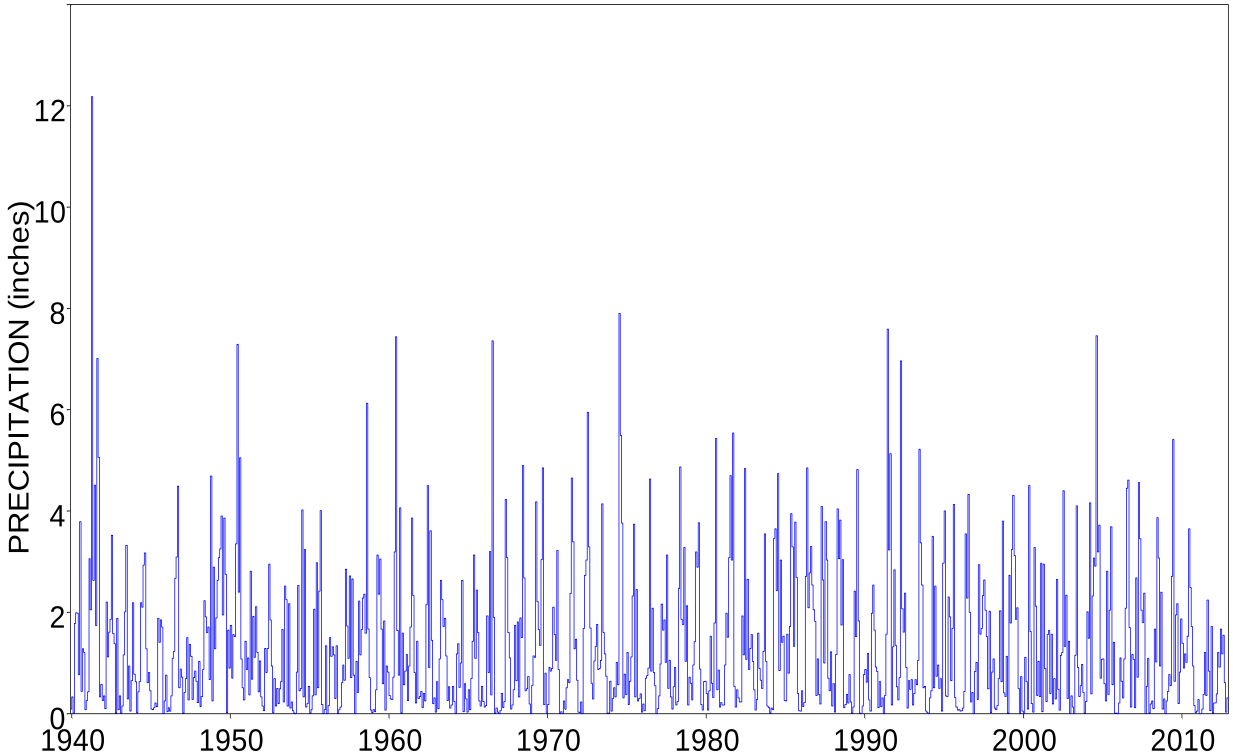
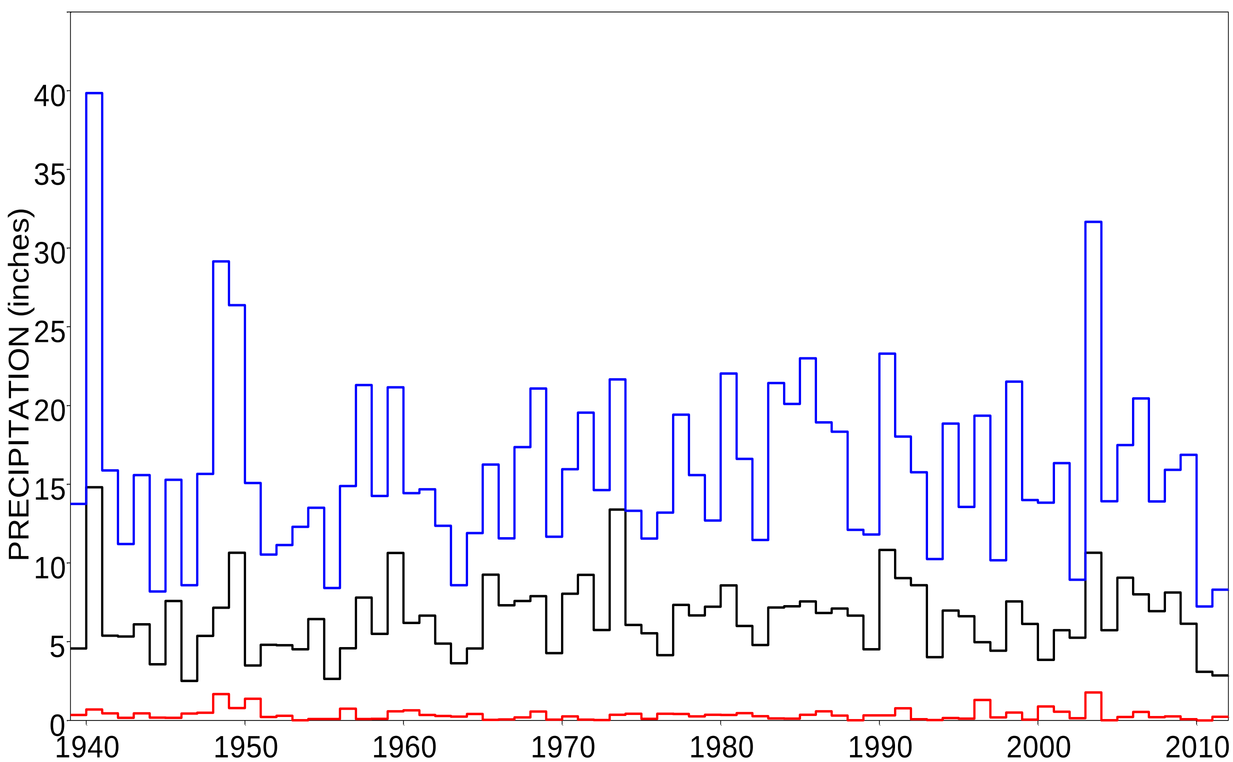


Monthly Precipitation for Quadrangle 404



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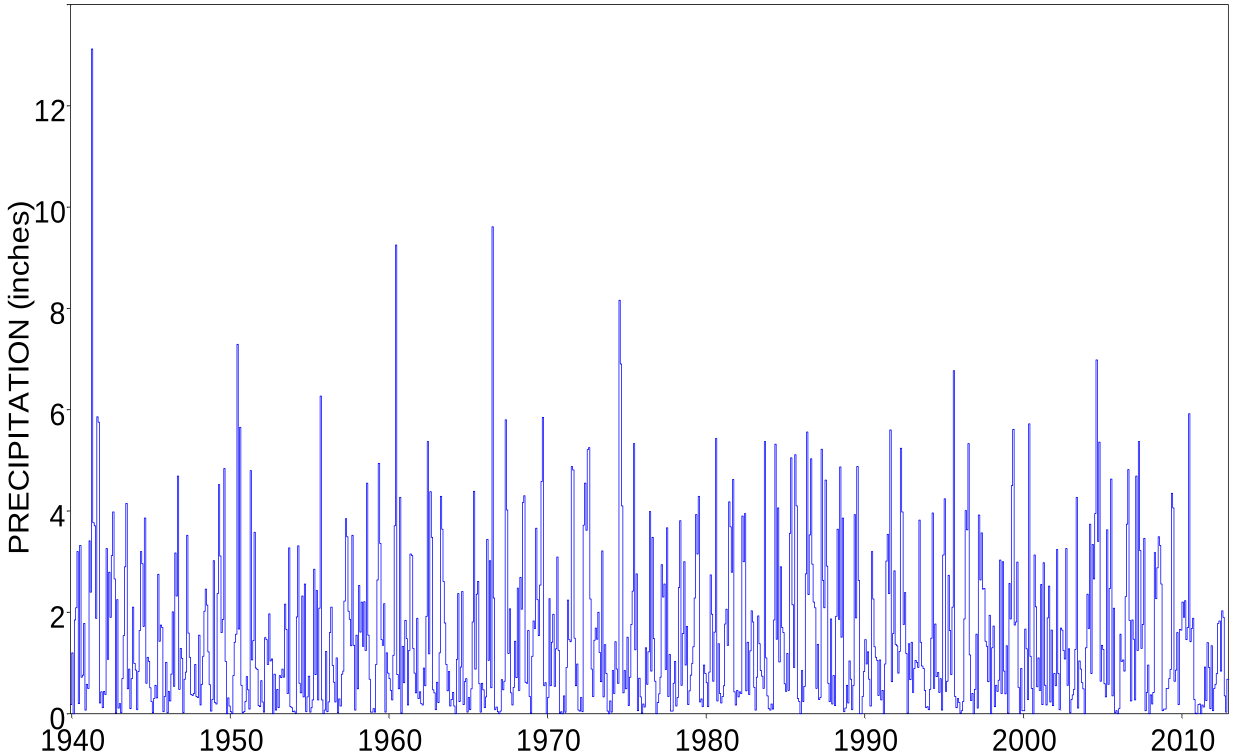
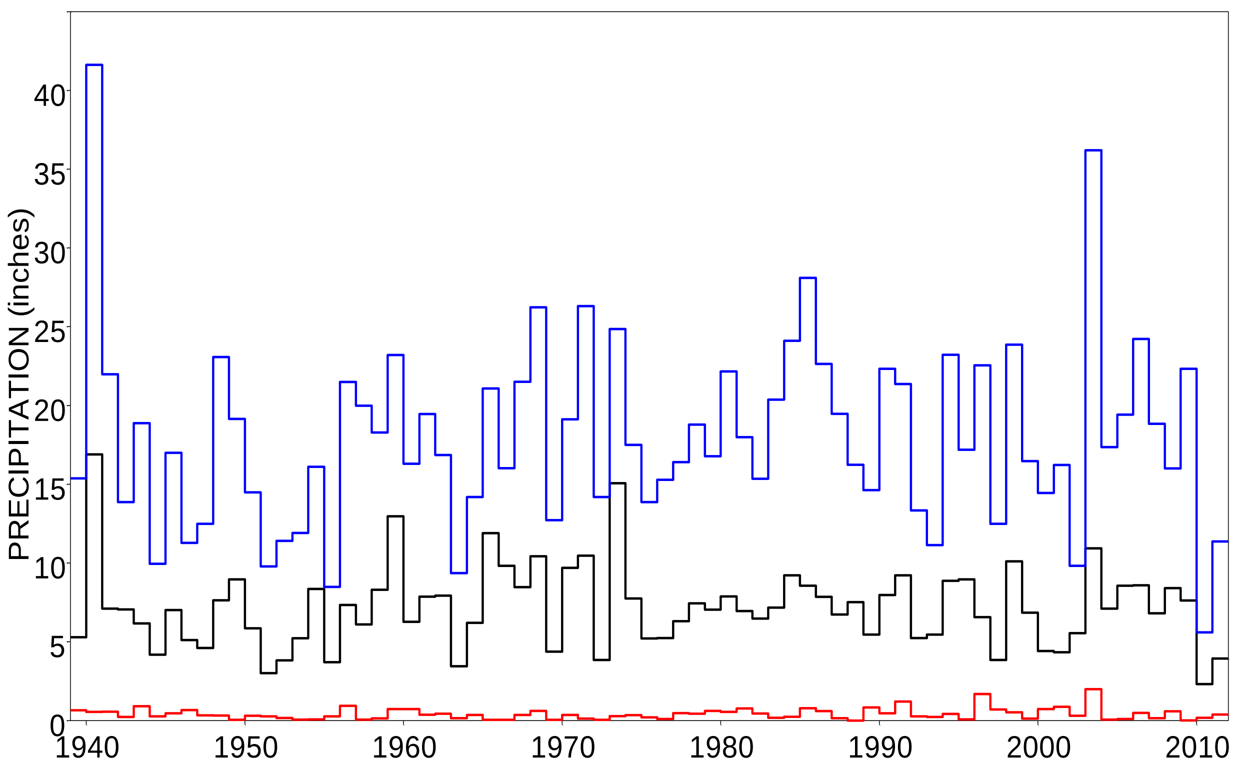


Monthly Precipitation for Quadrangle 405



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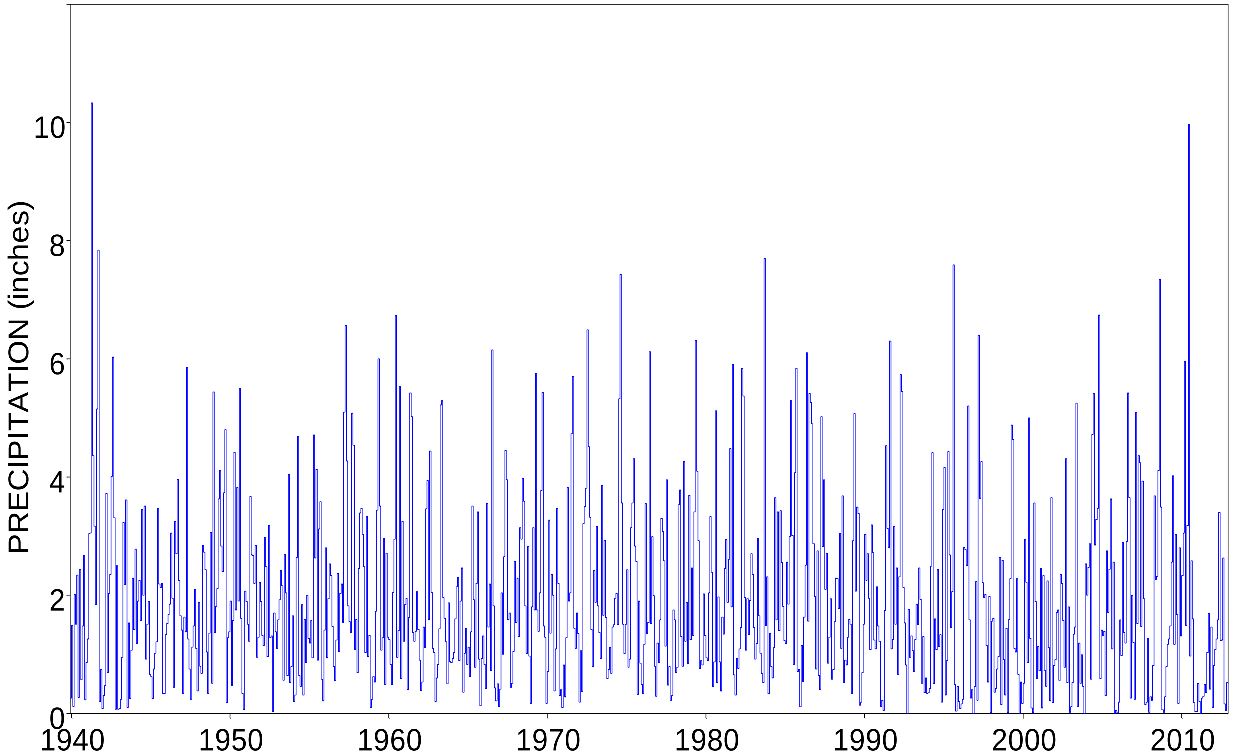
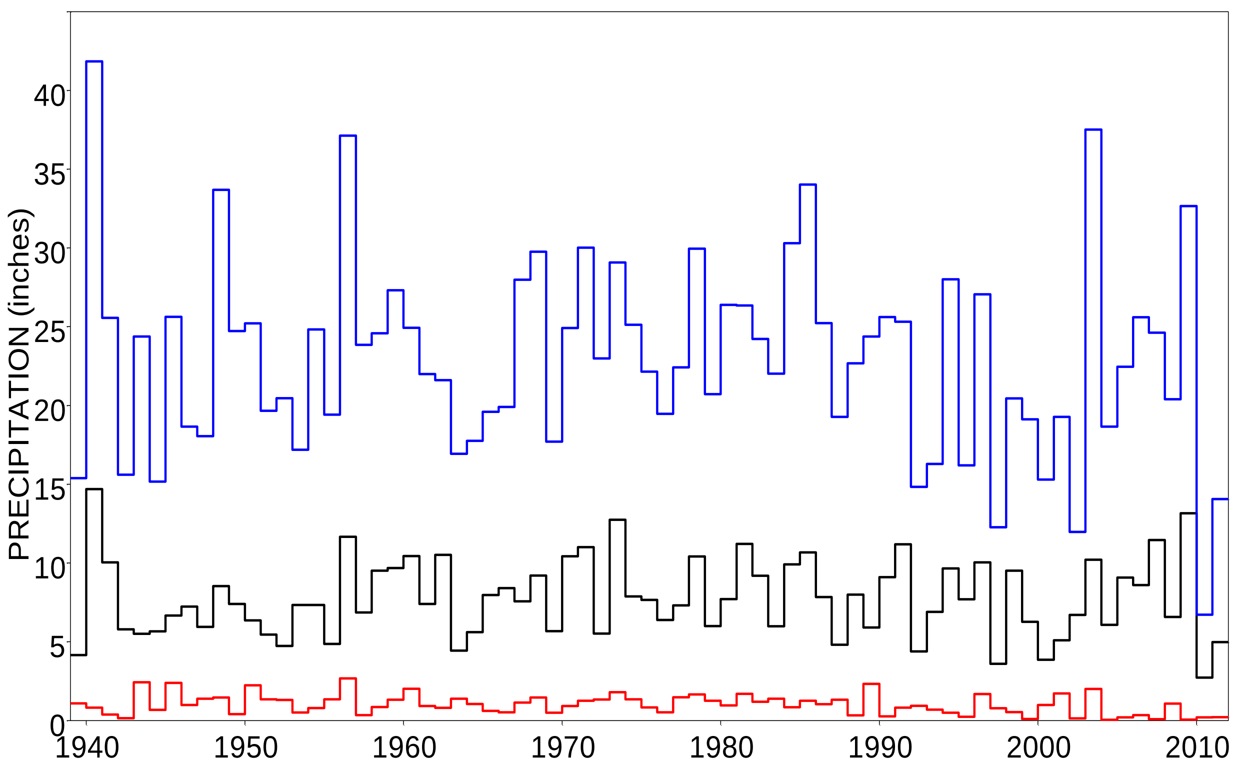


Monthly Precipitation for Quadrangle 406



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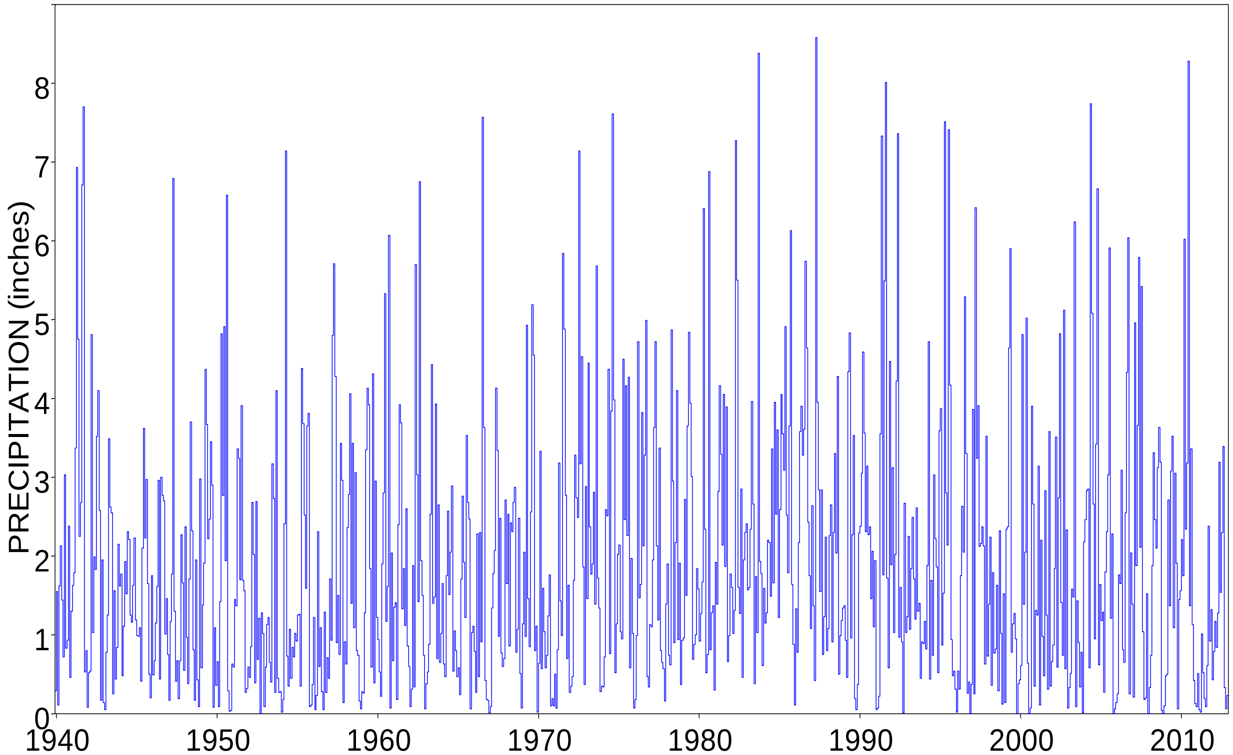
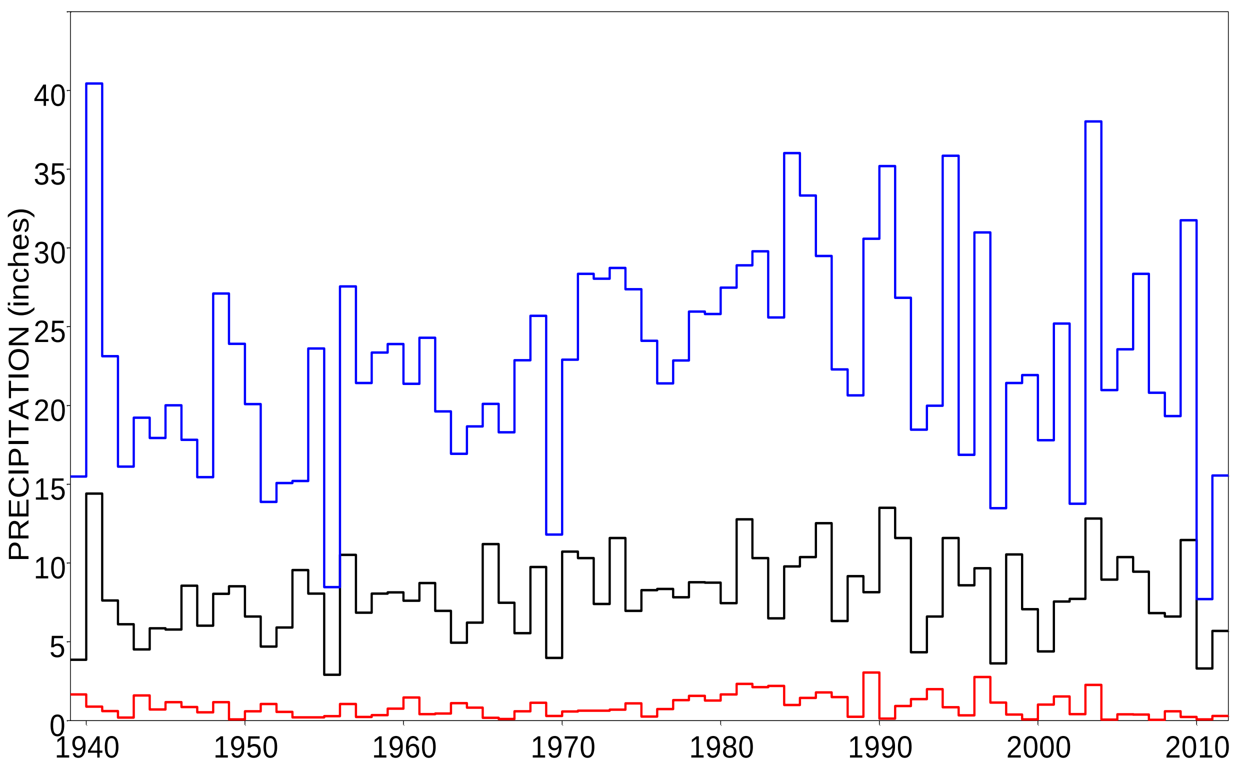
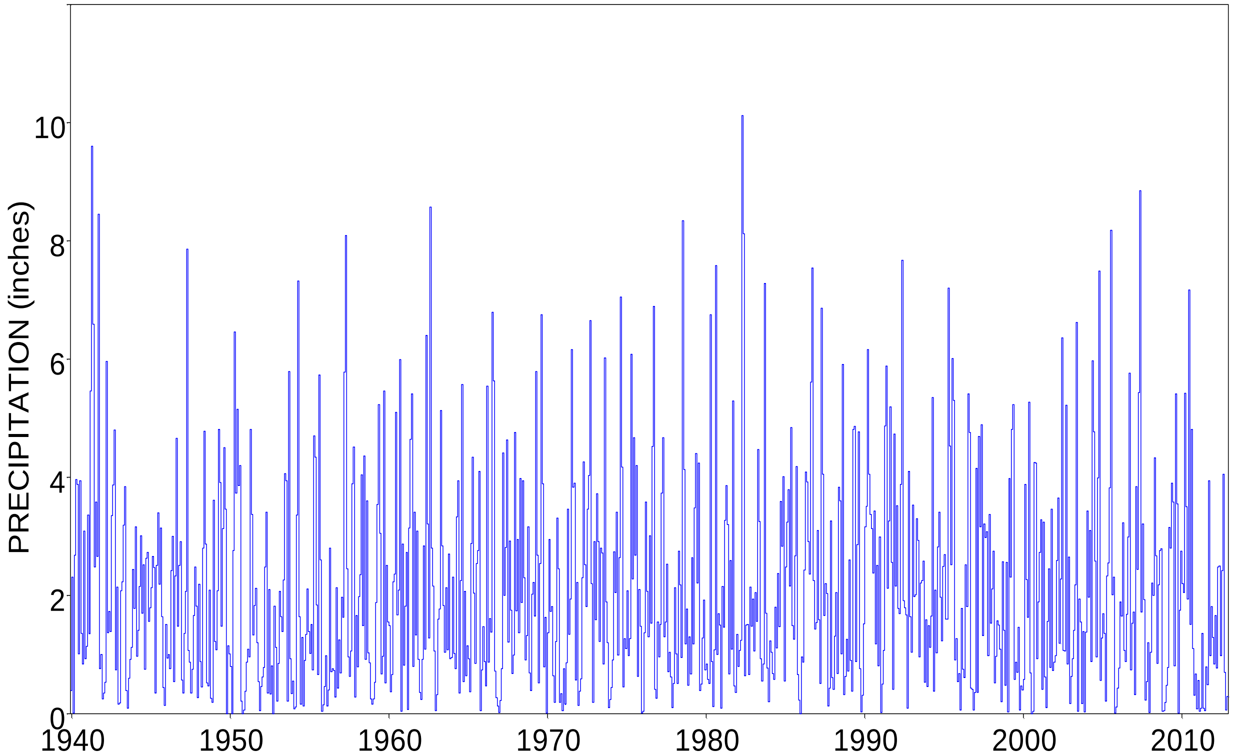


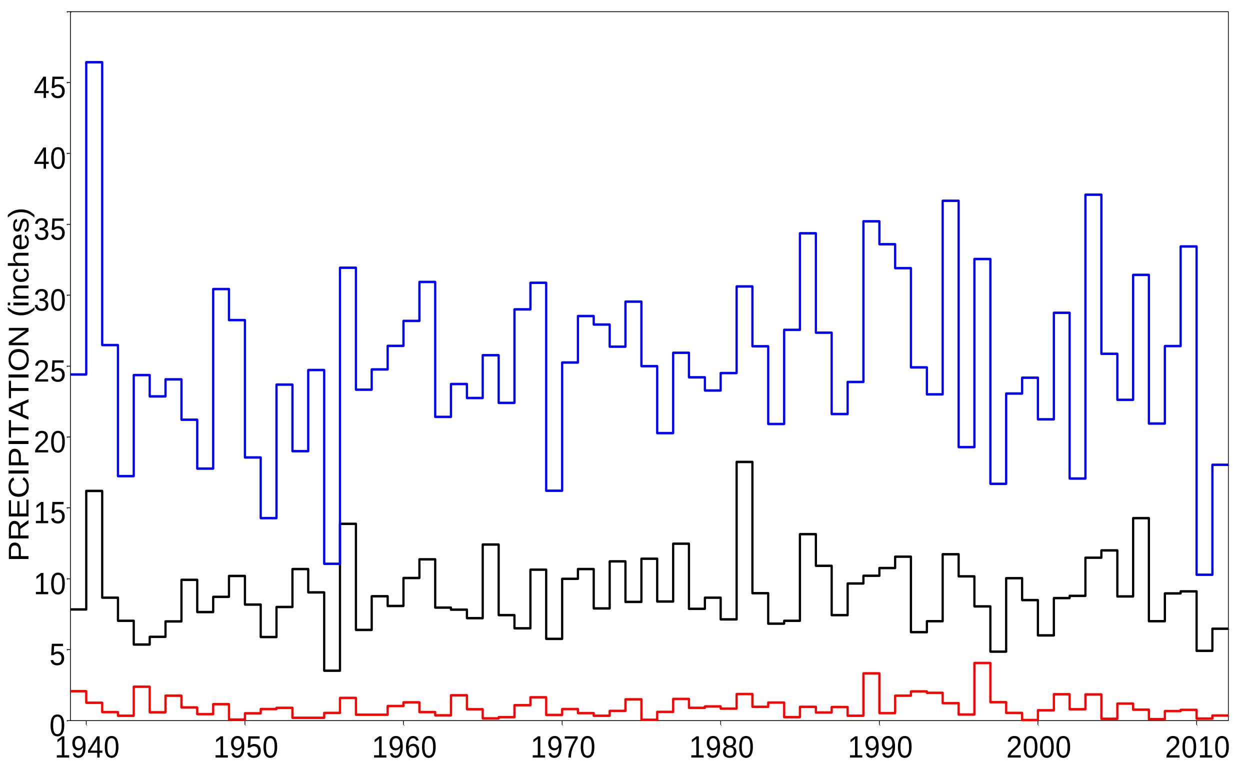
Monthly Precipitation for Quadrangle 407



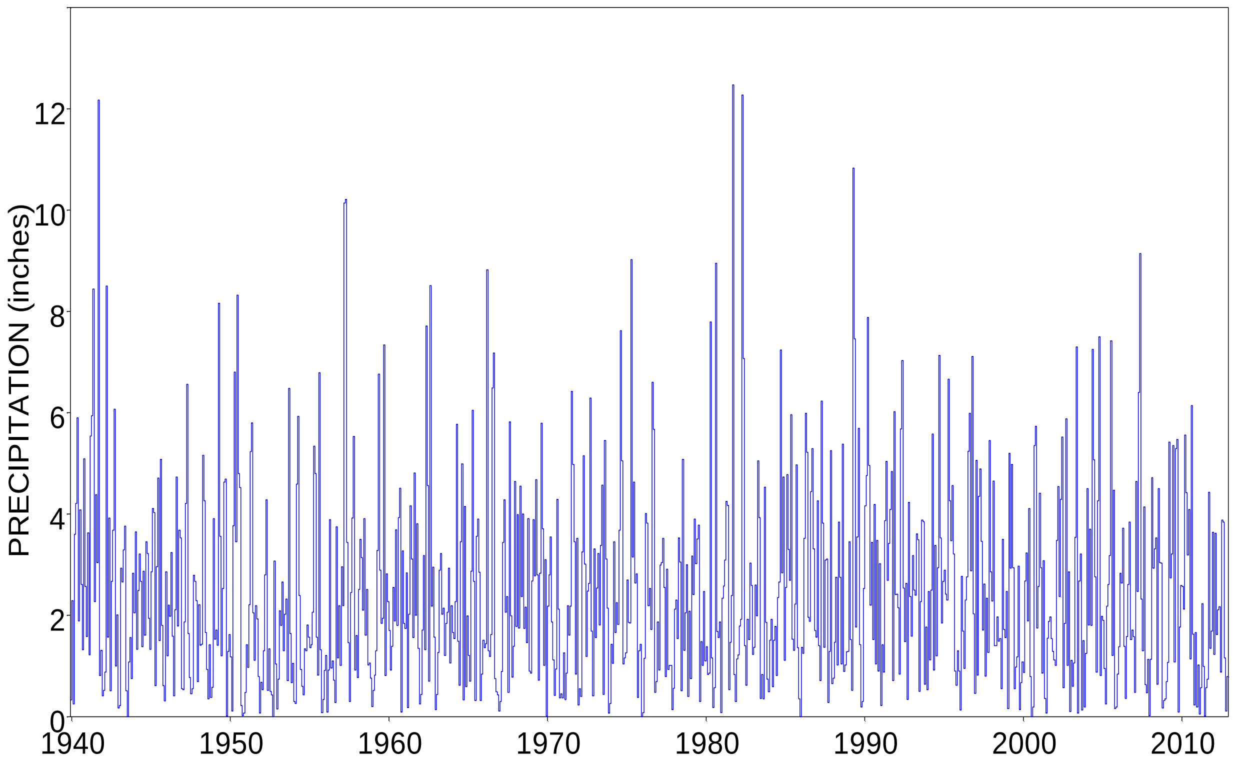
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 407



Monthly Precipitation for Quadrangle 408



Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 408



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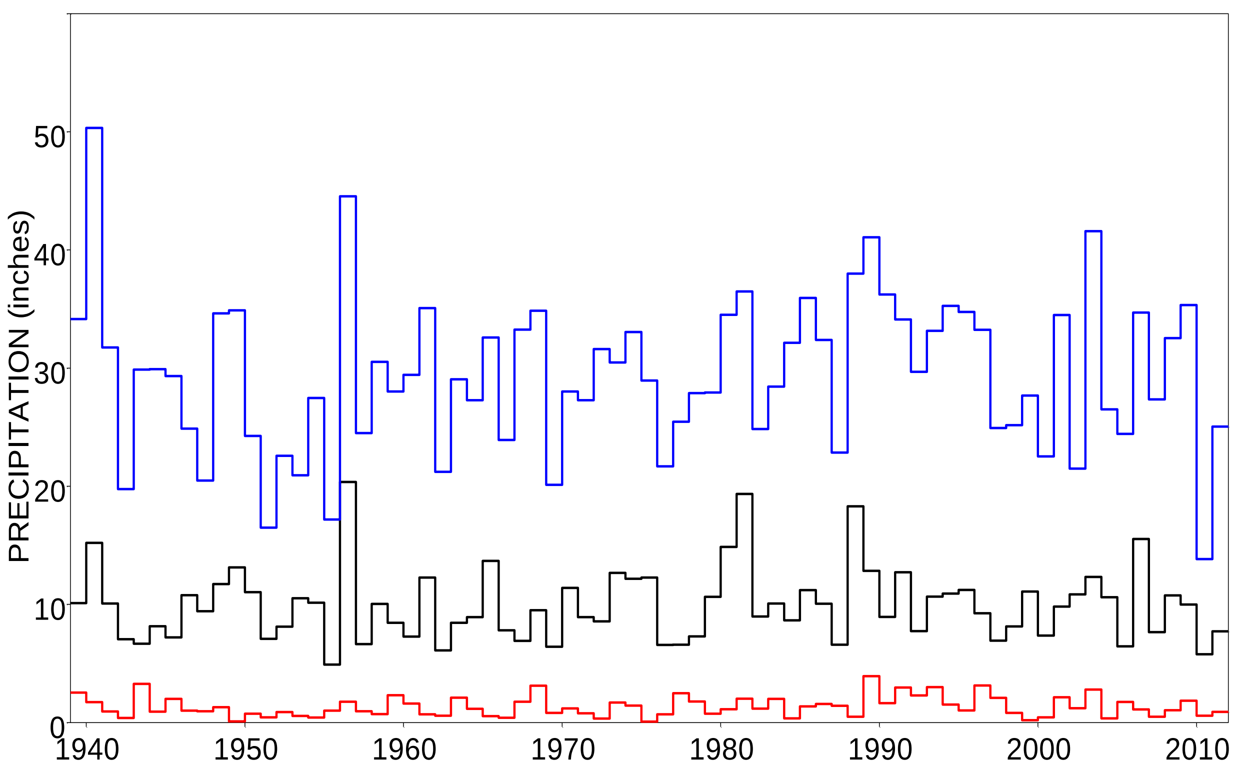

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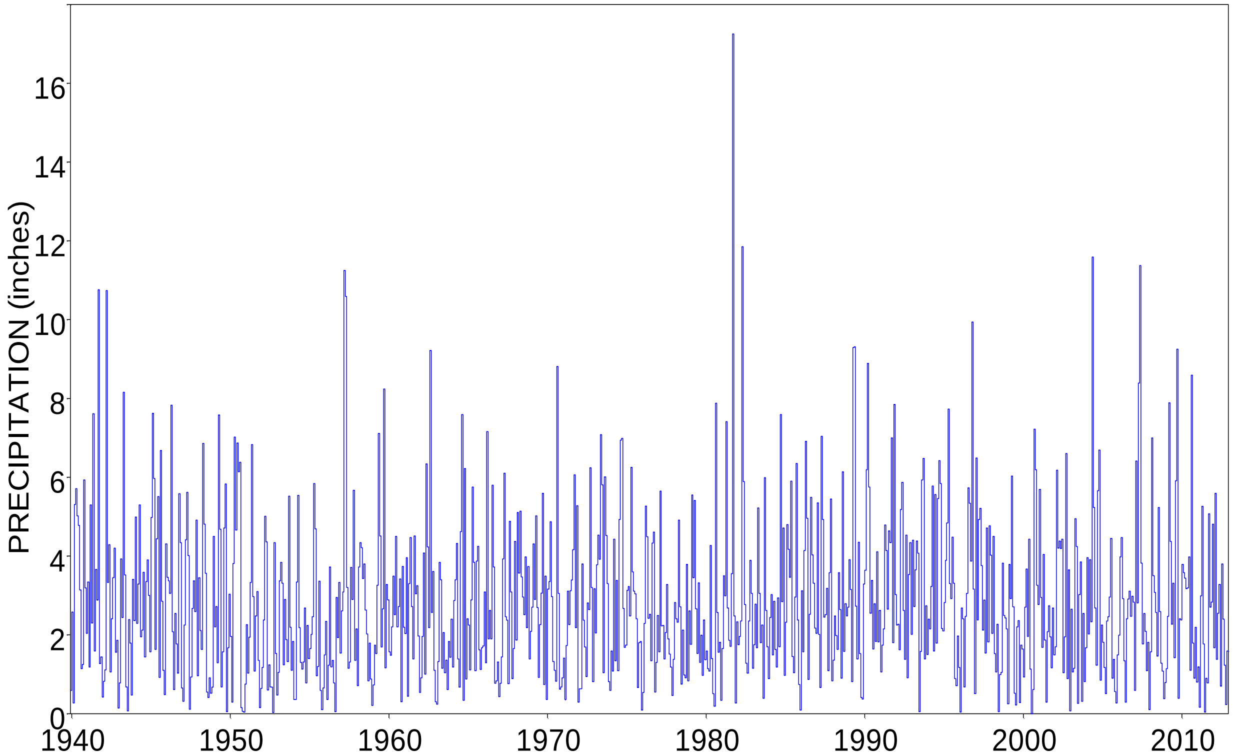

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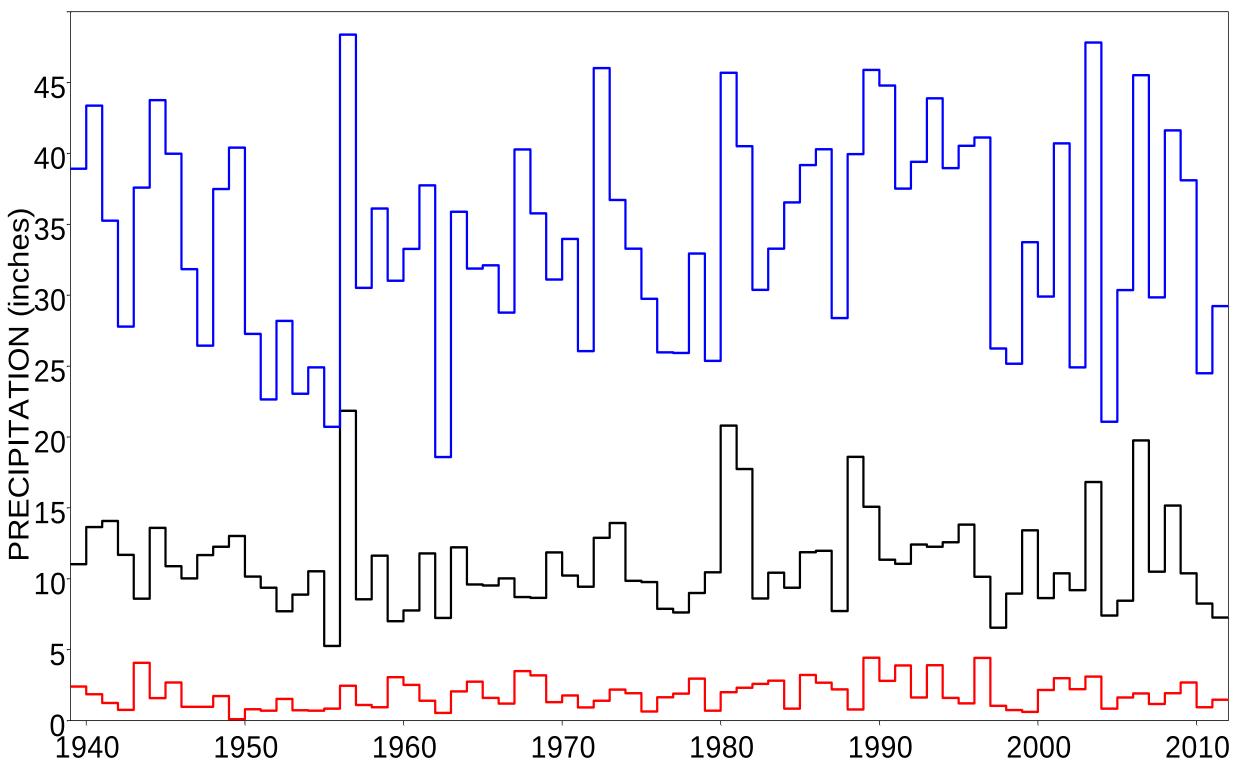
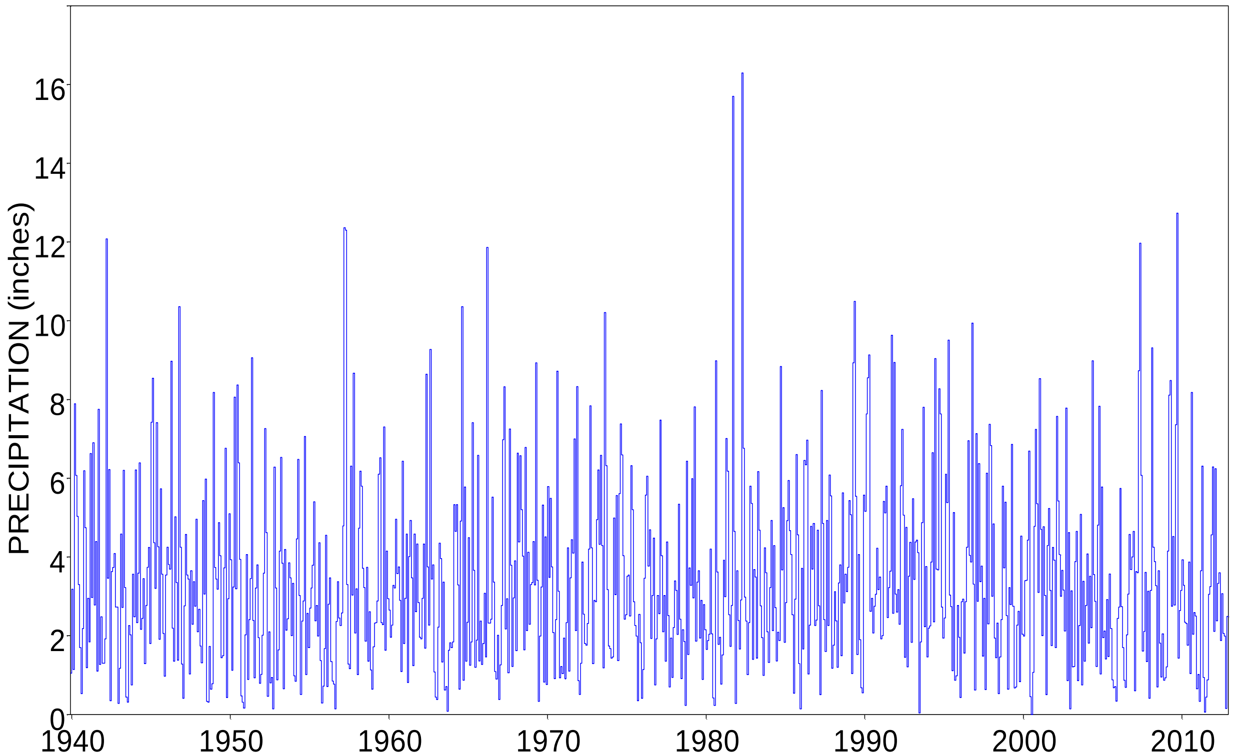
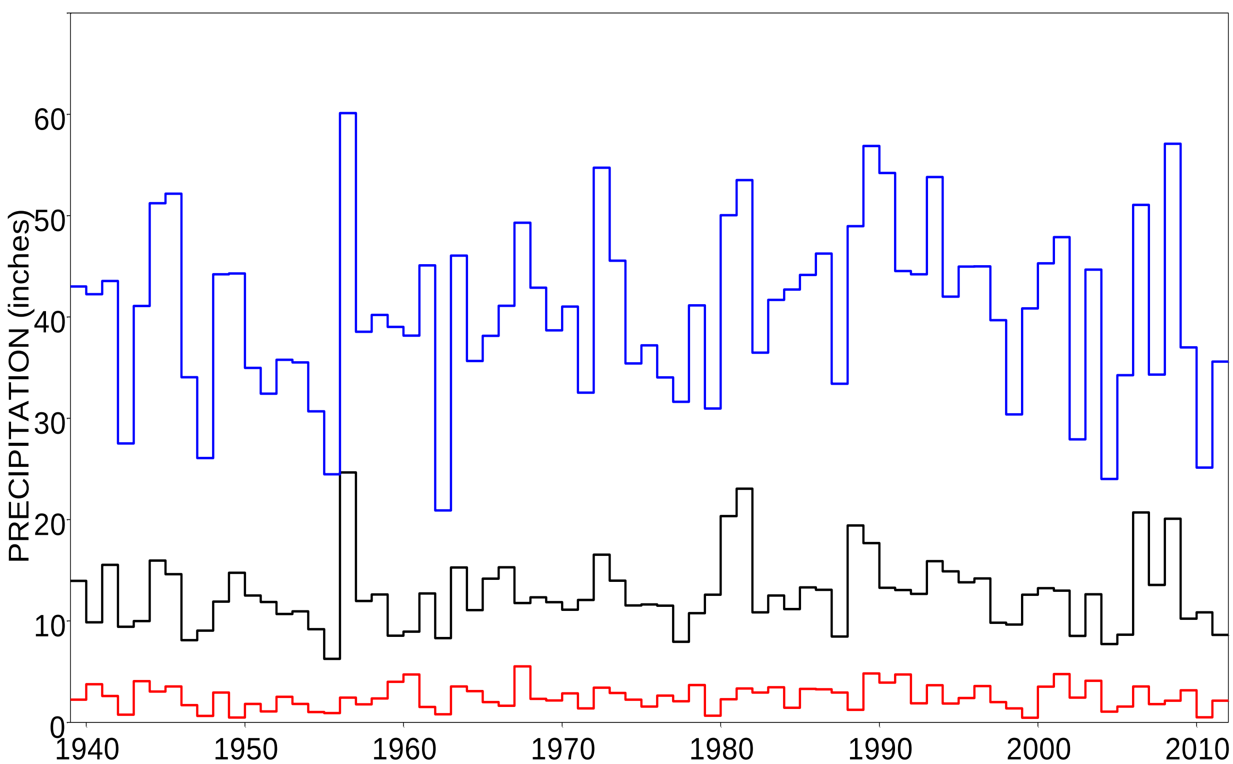


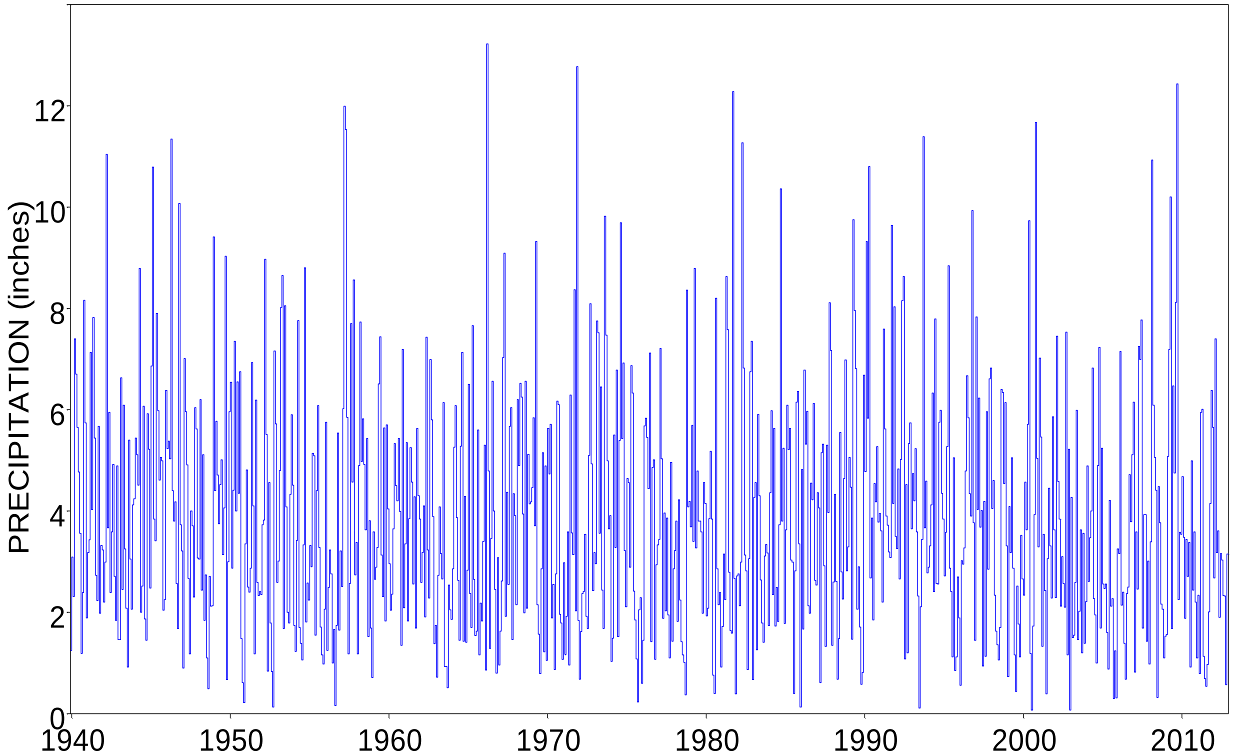
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 410



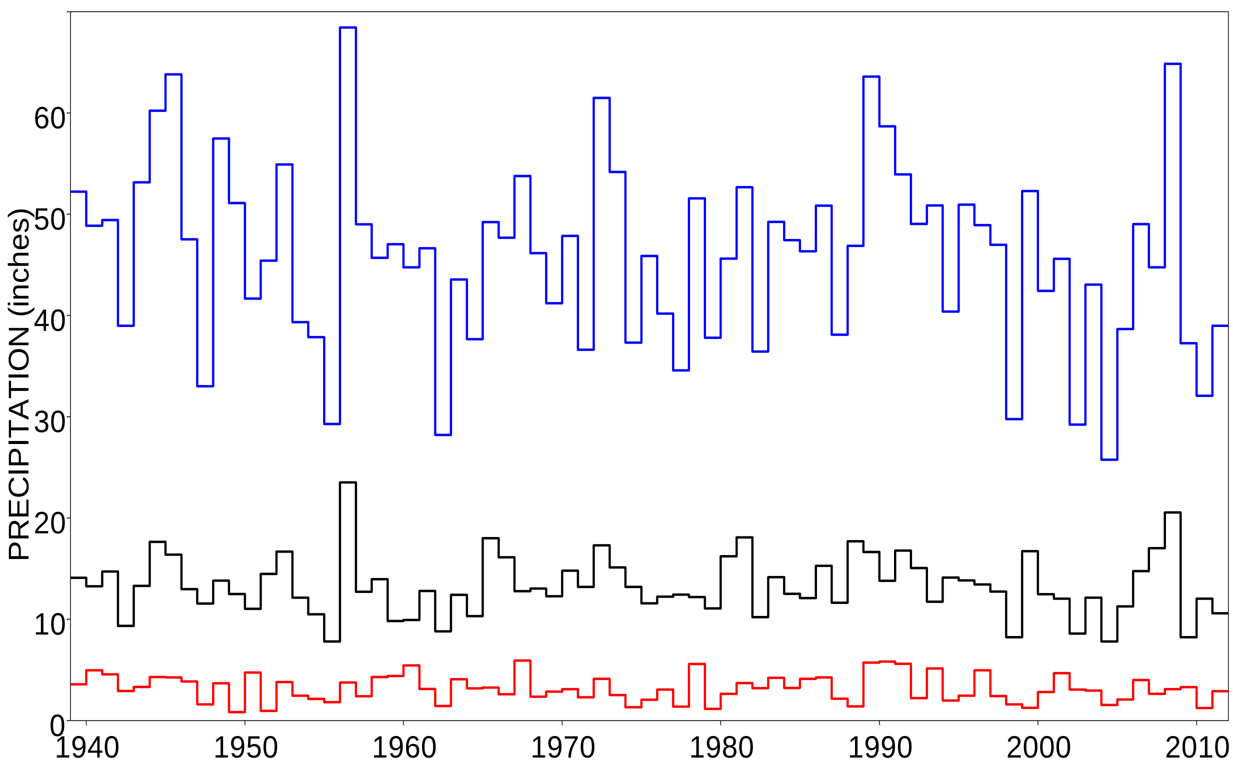
Monthly Precipitation for Quadrangle 411



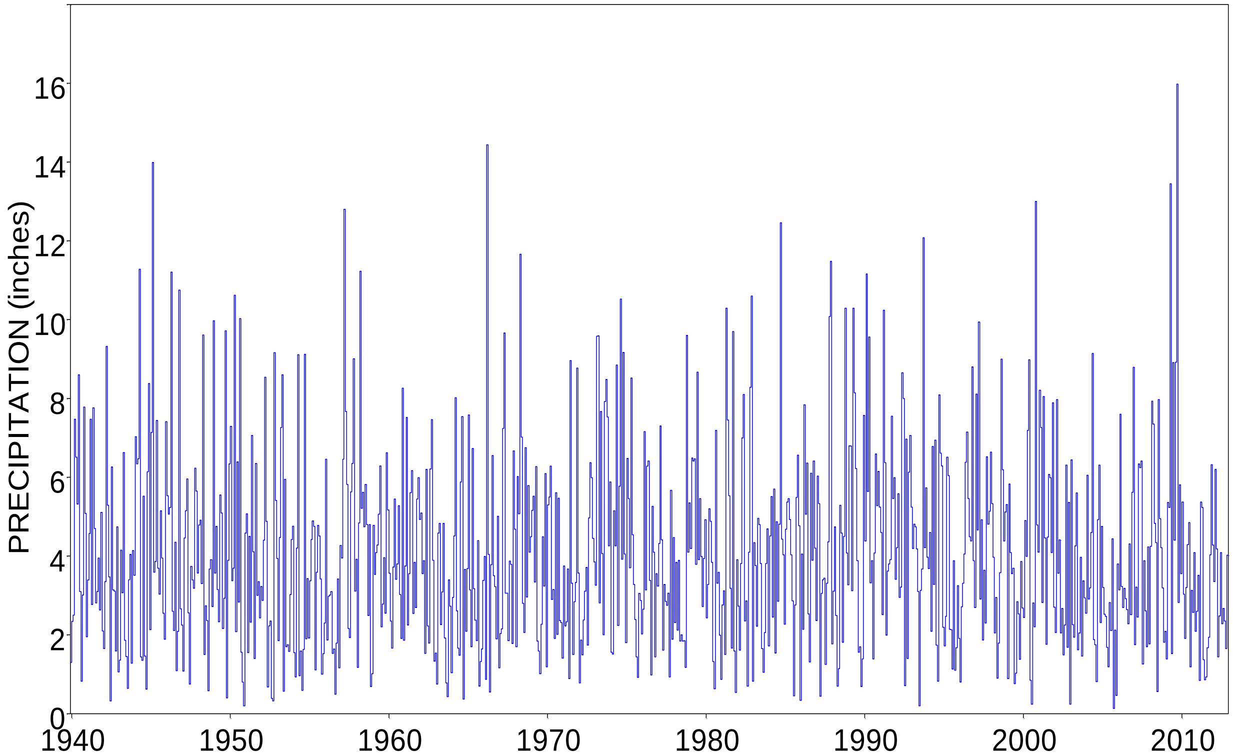
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 411



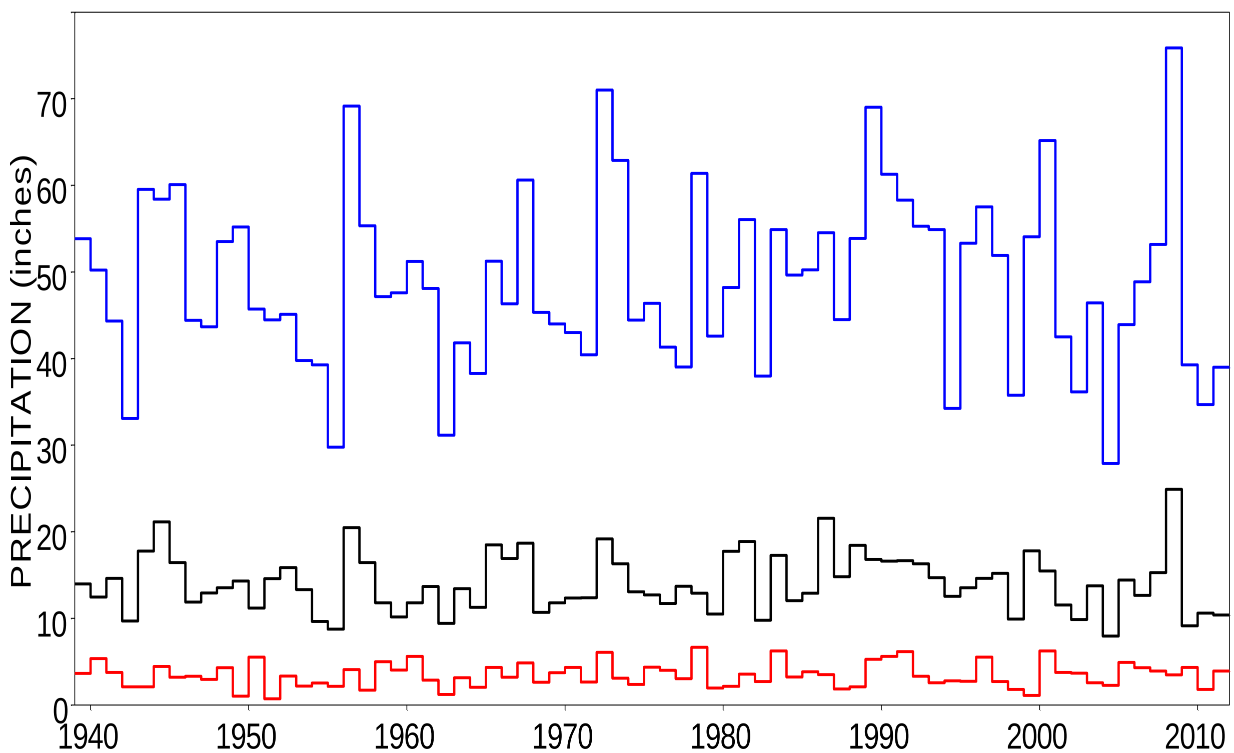
Monthly Precipitation for Quadrangle 412



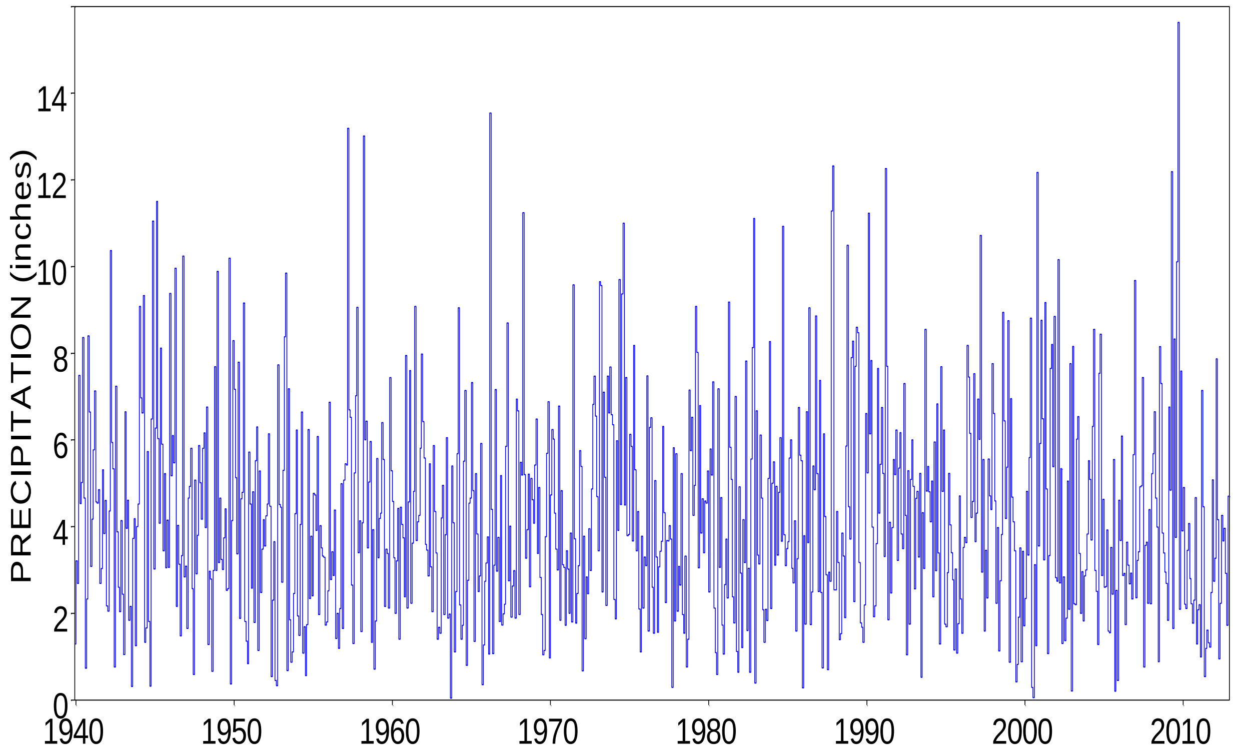
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 412



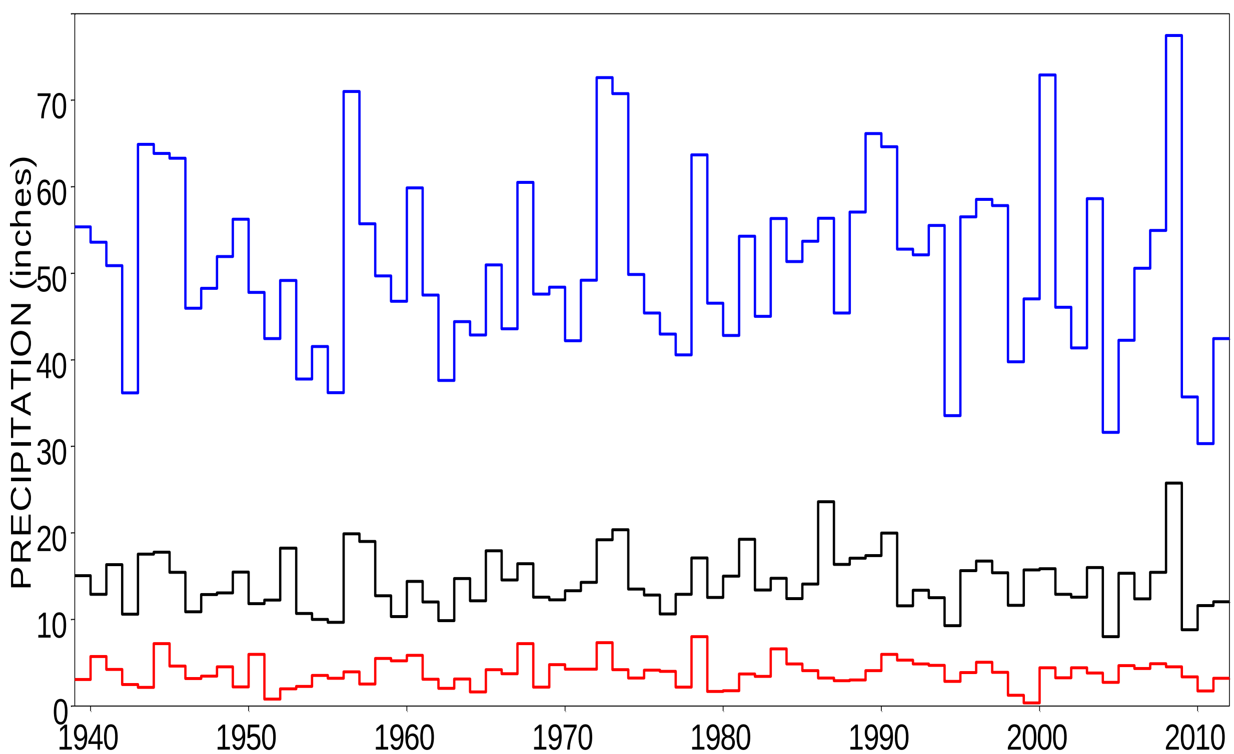
Monthly Precipitation for Quadrangle 413



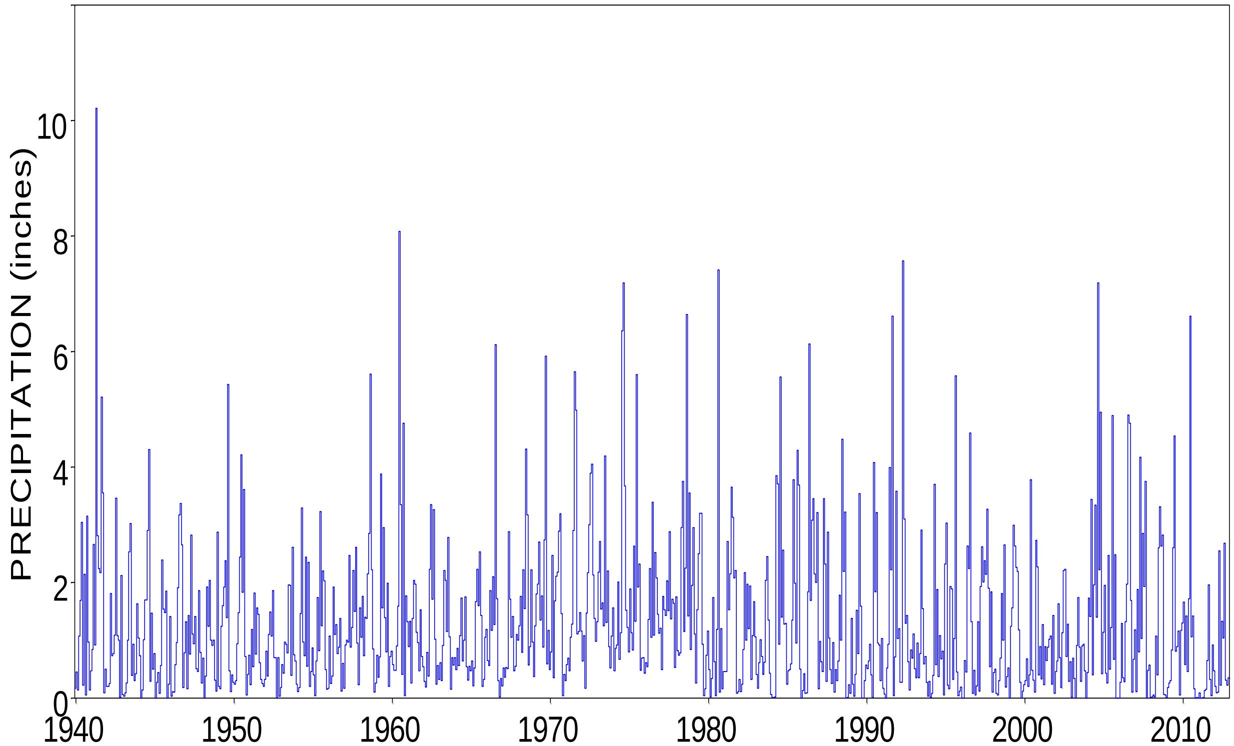
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 413



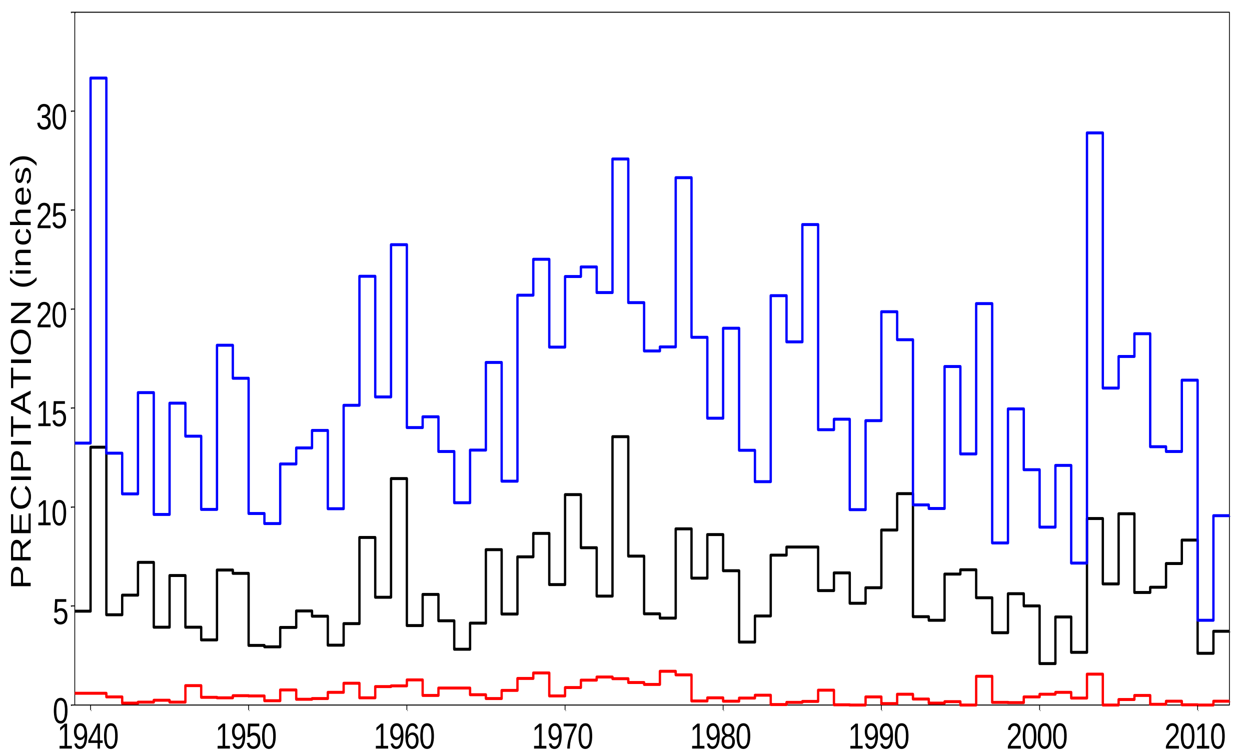
Monthly Precipitation for Quadrangle 414



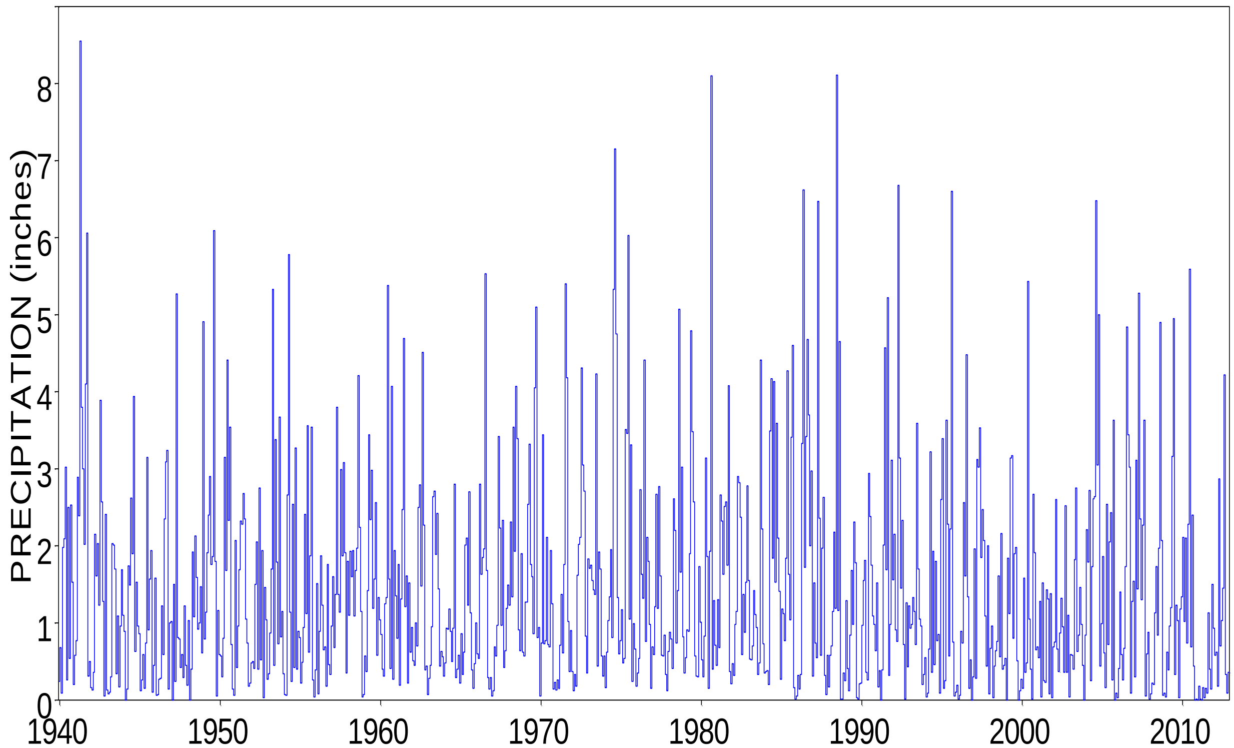
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 414



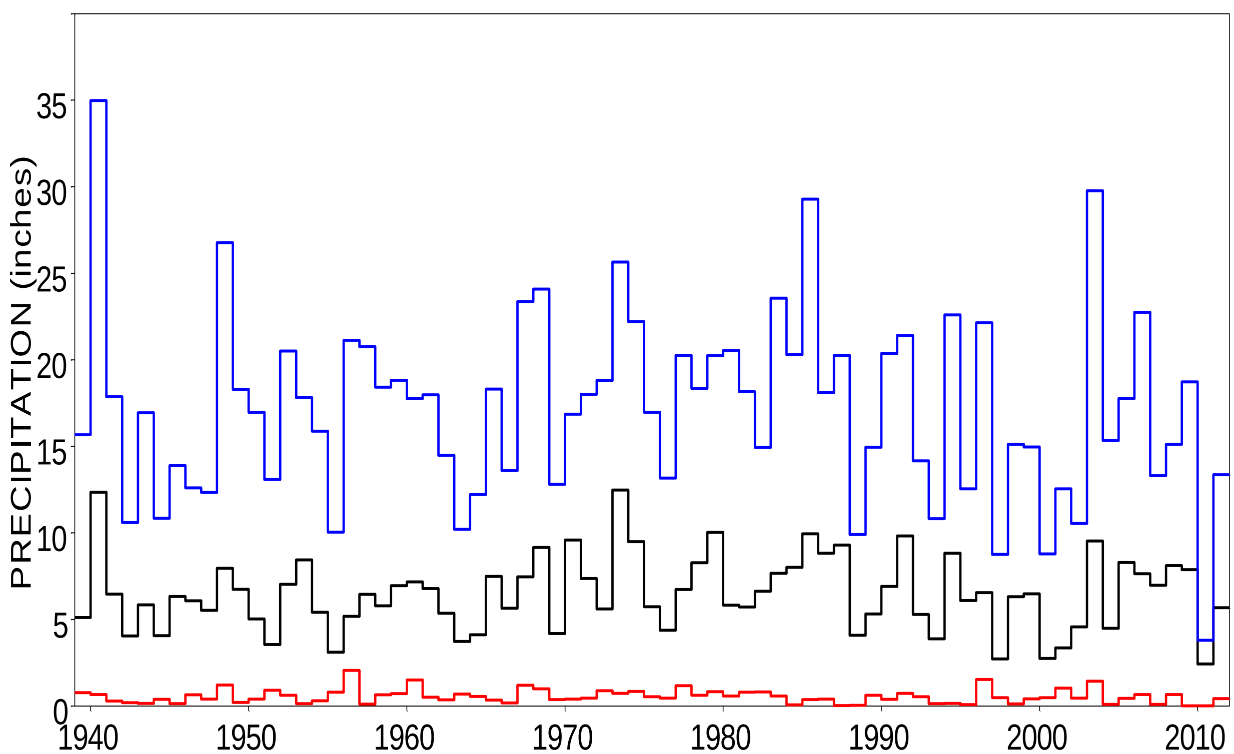
Monthly Precipitation for Quadrangle 504



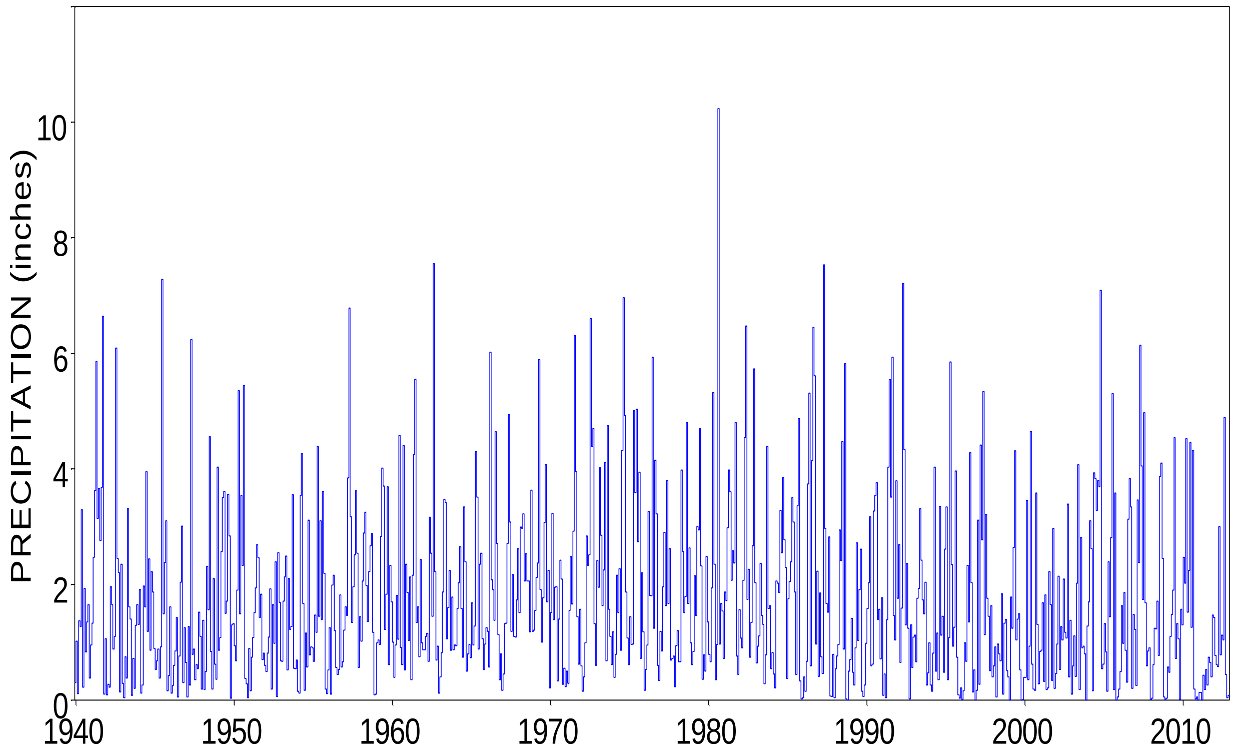
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 504



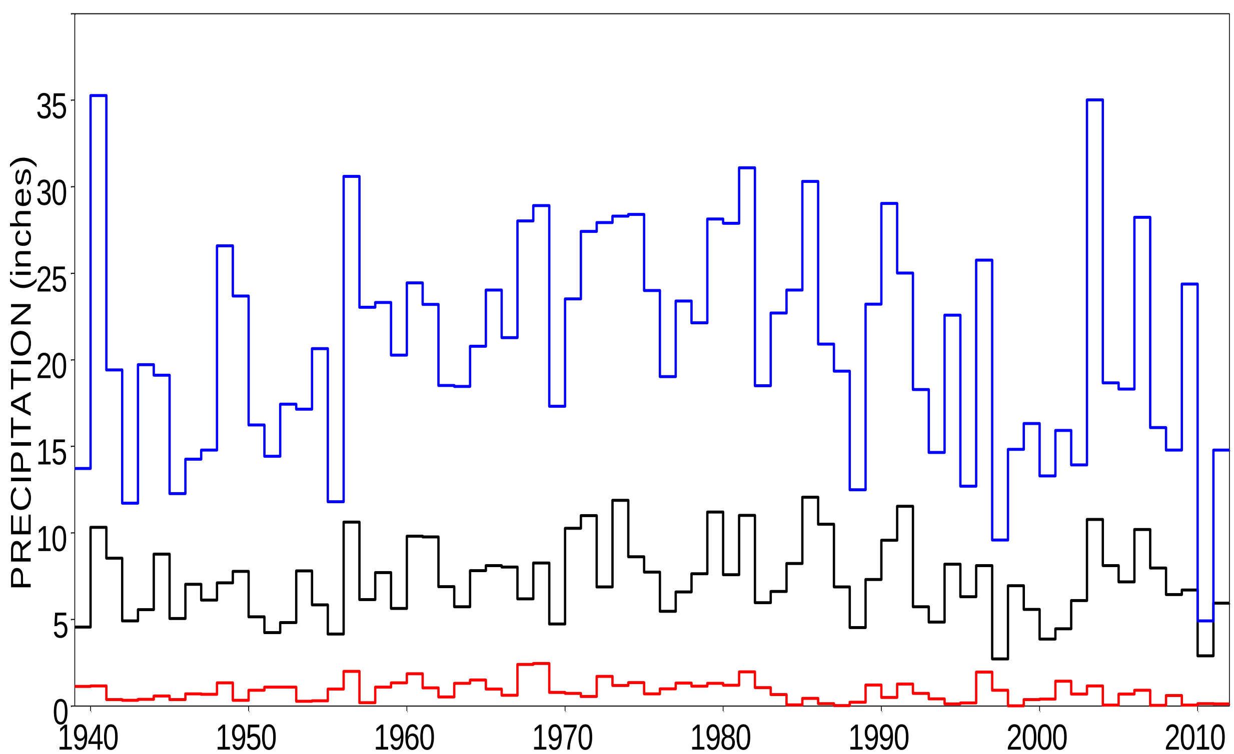
Monthly Precipitation for Quadrangle 505



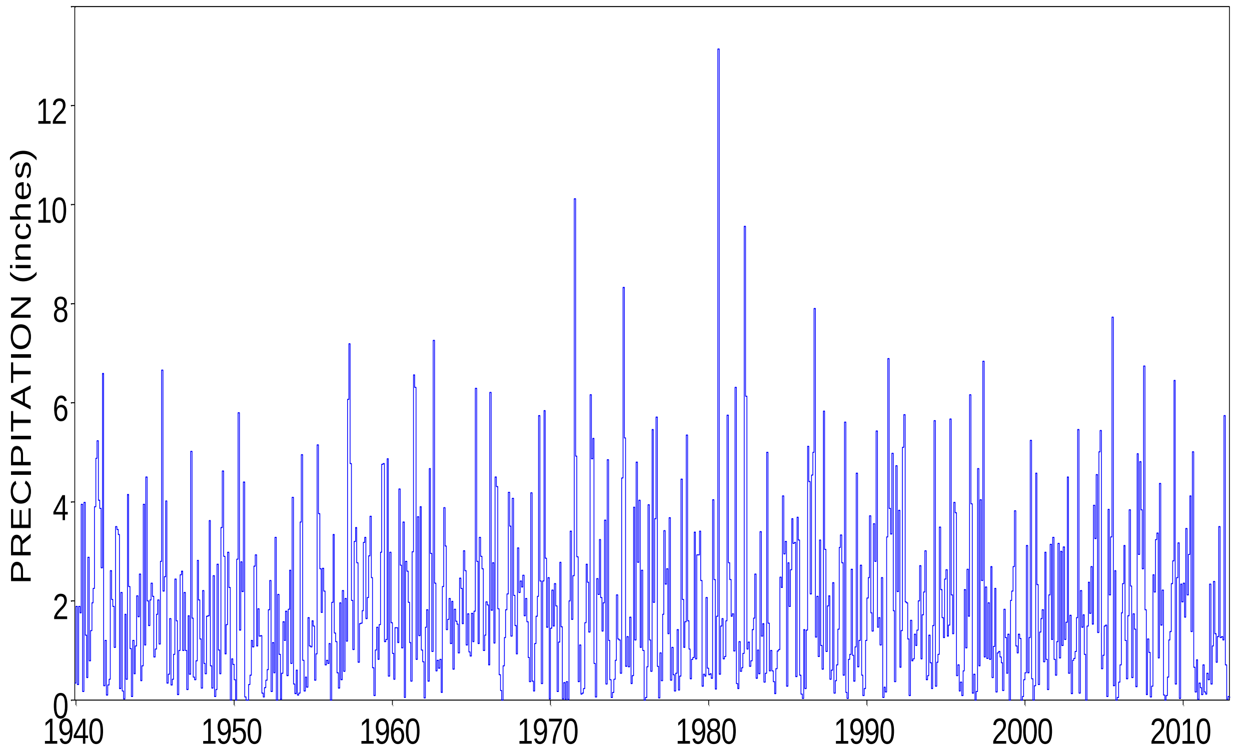
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 505



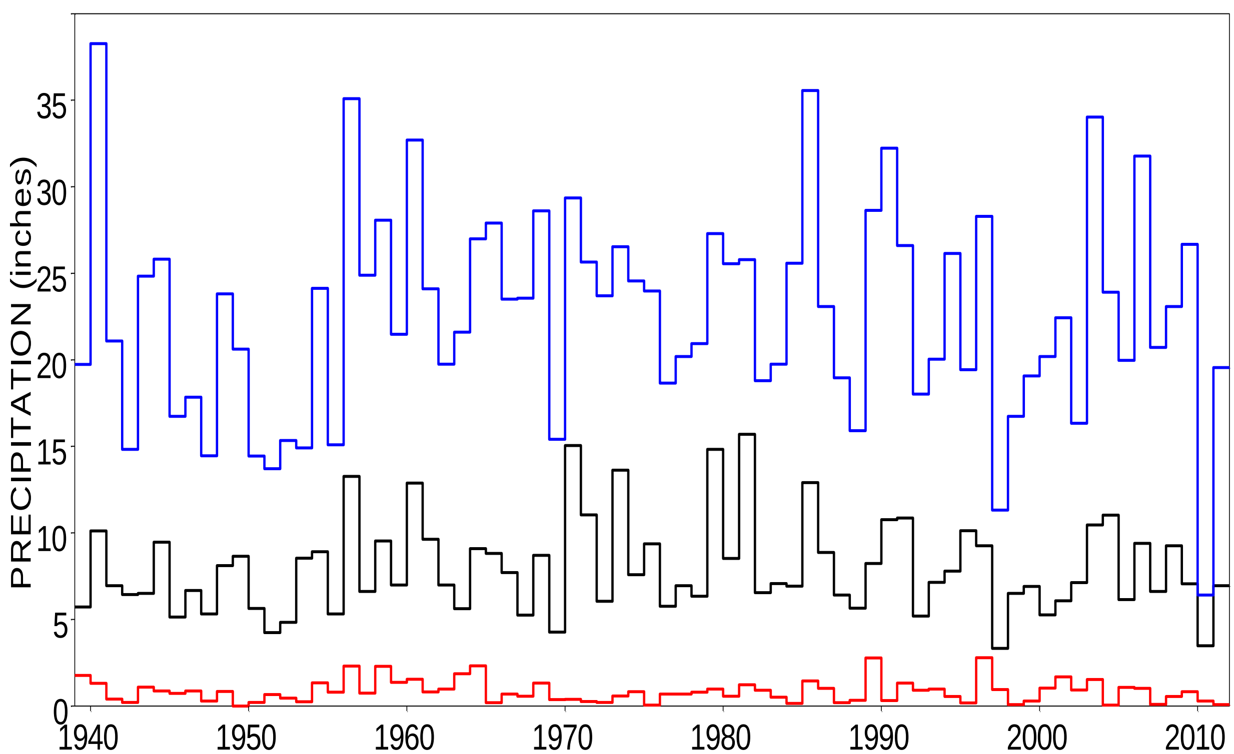
Monthly Precipitation for Quadrangle 506



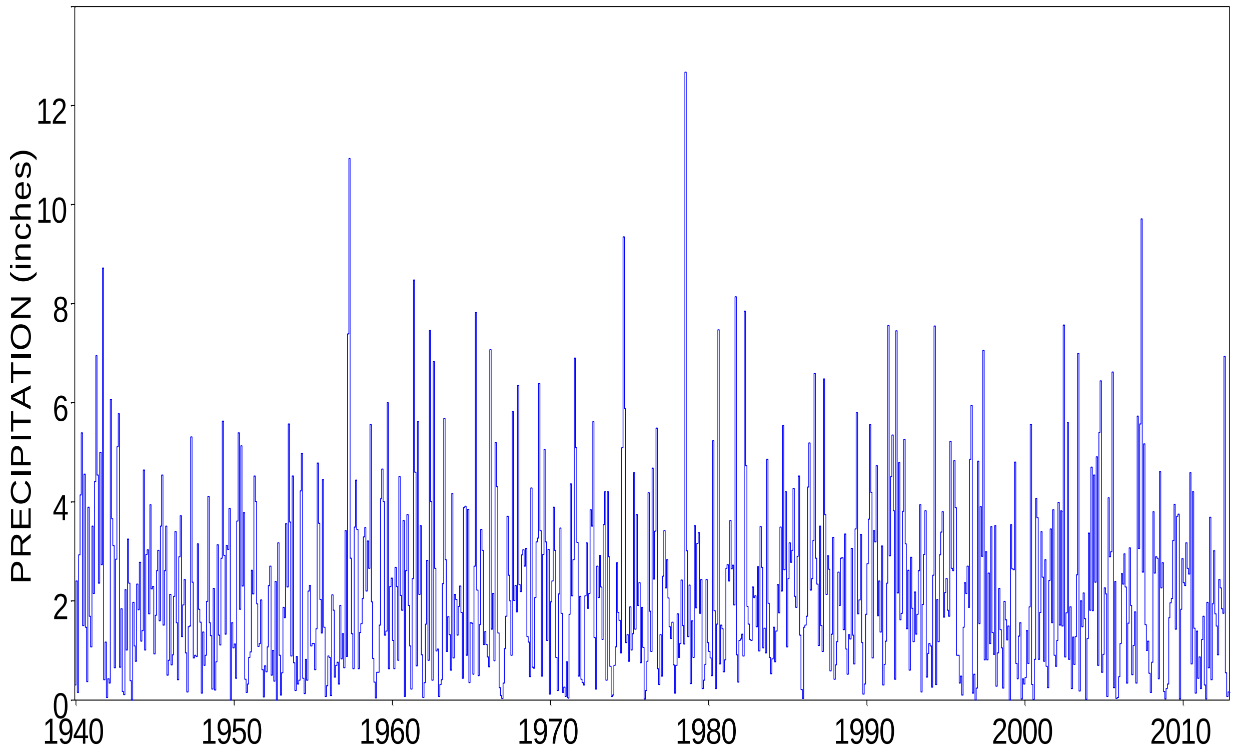
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 506



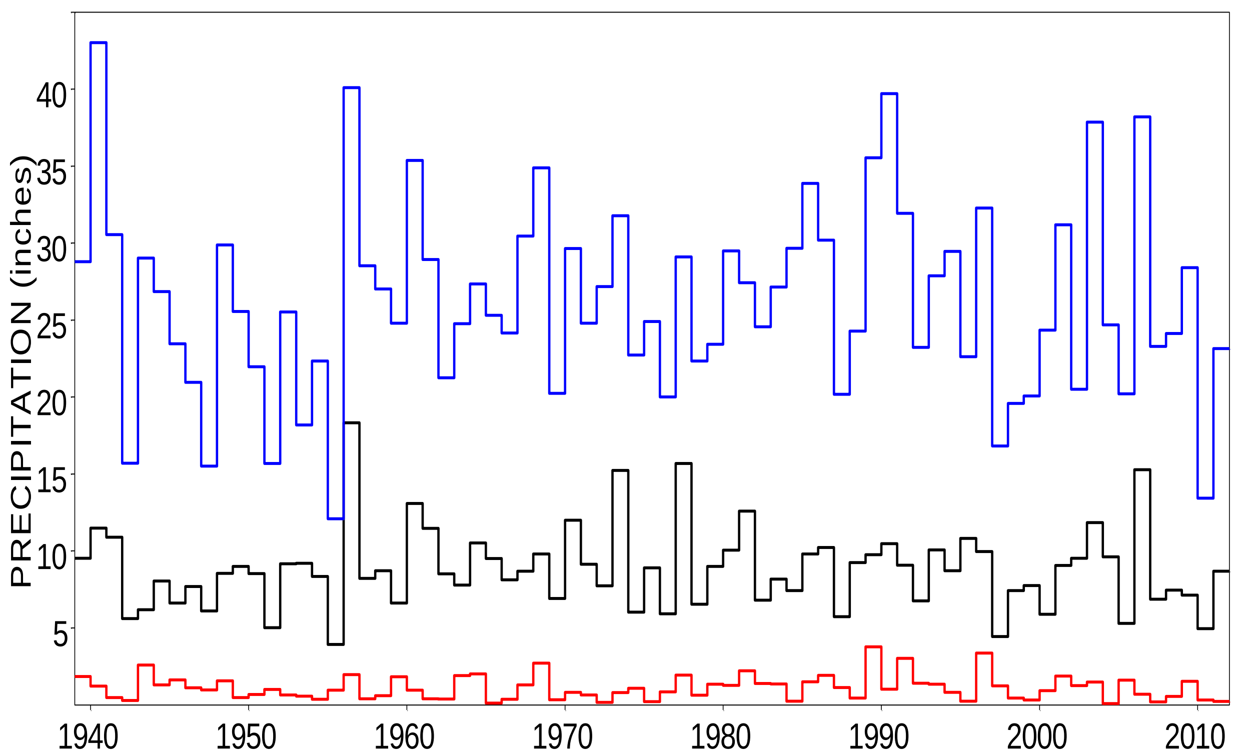
Monthly Precipitation for Quadrangle 507



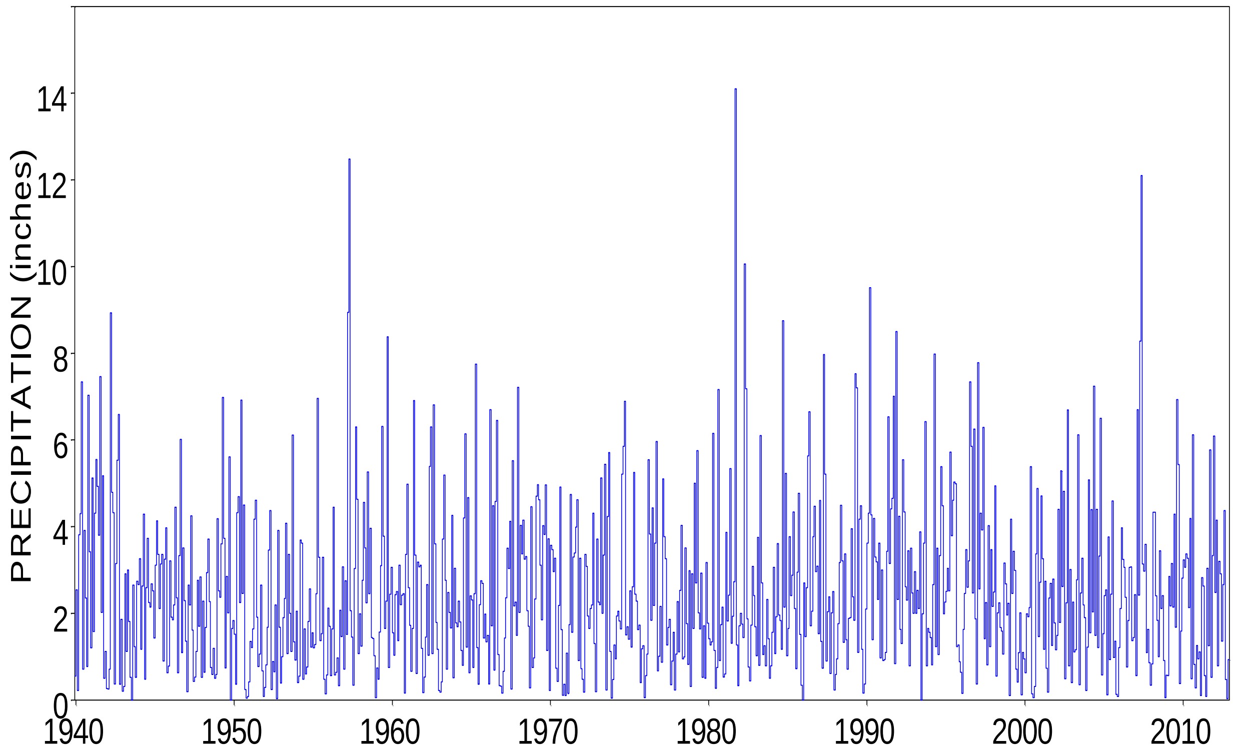
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 507



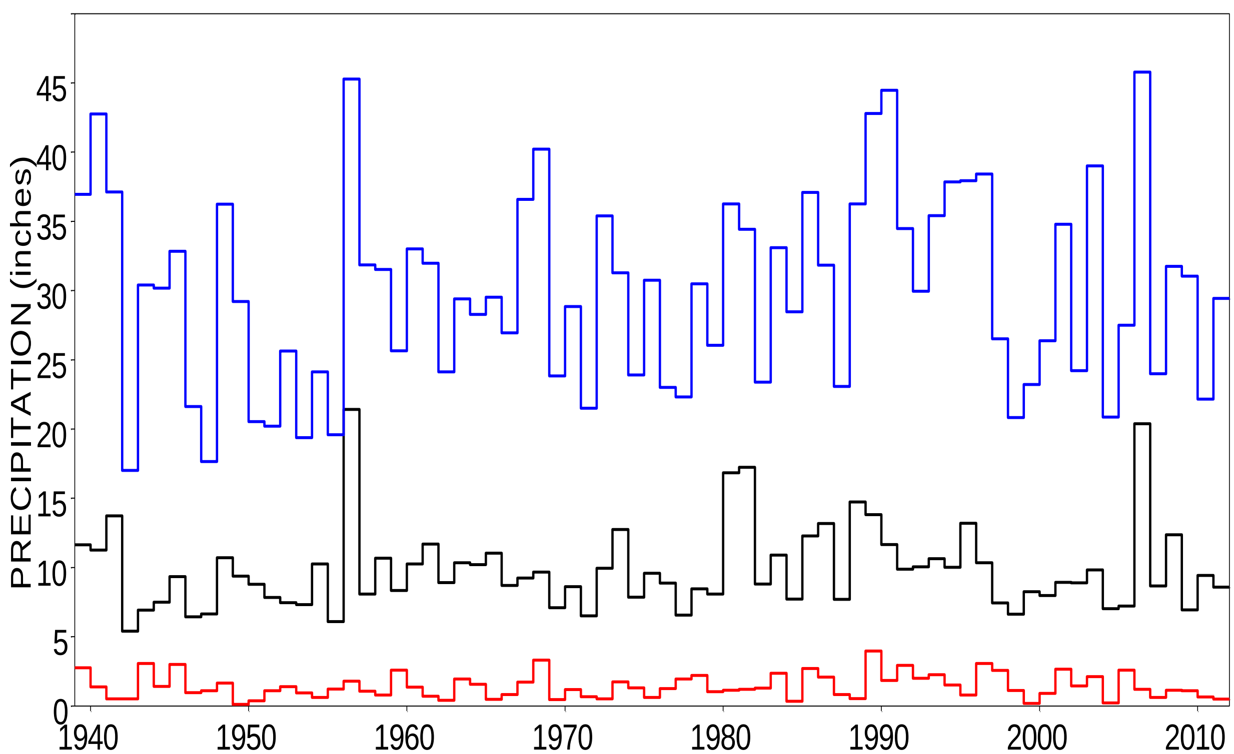
Monthly Precipitation for Quadrangle 508



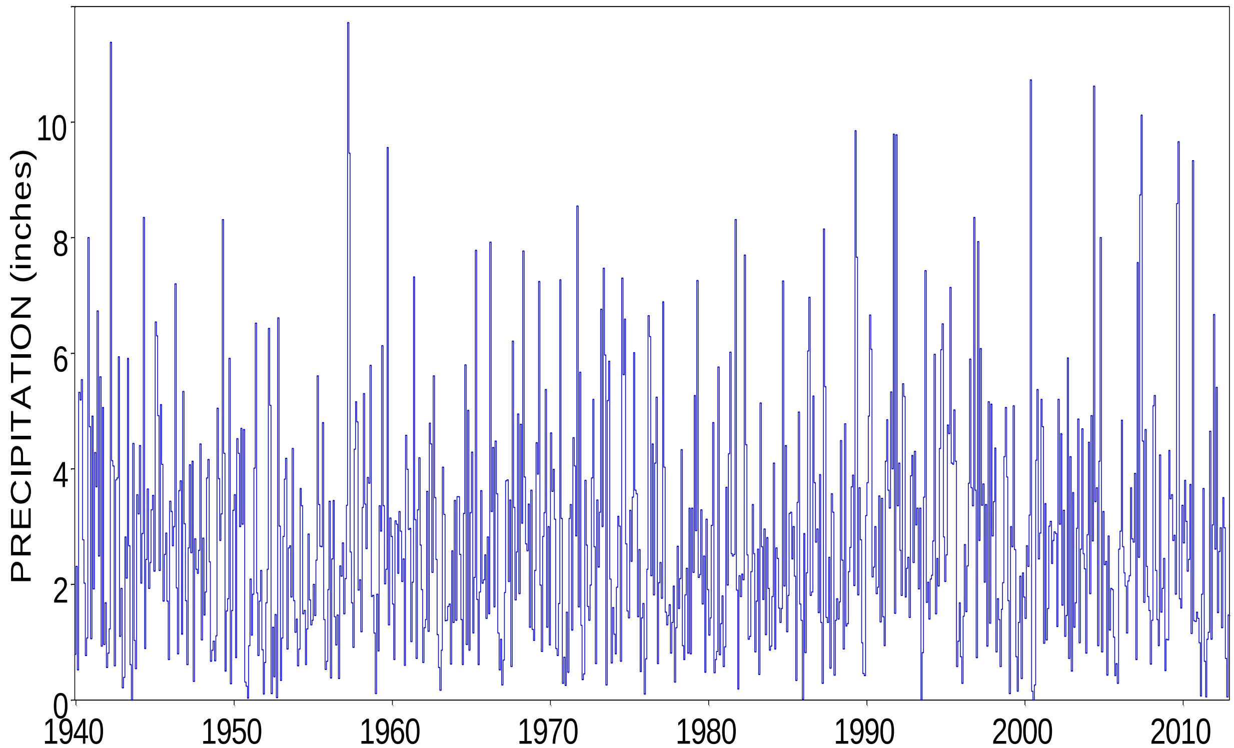
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 508



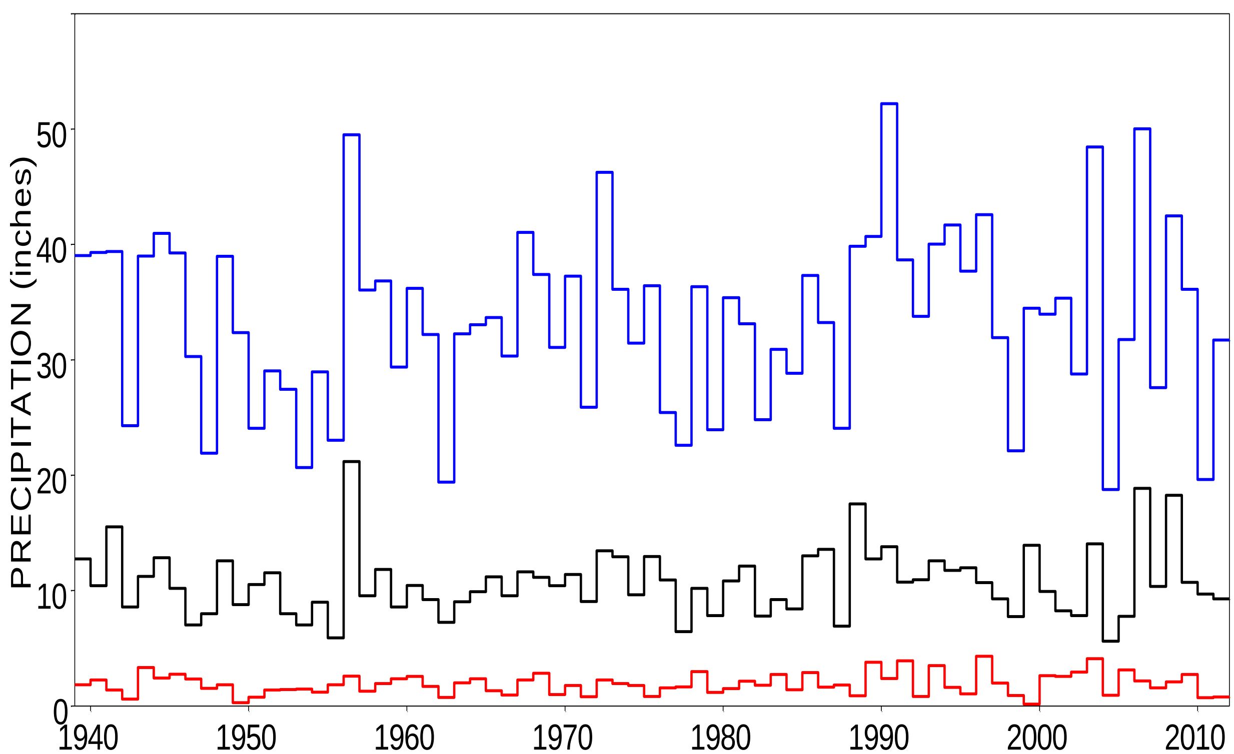
Monthly Precipitation for Quadrangle 509



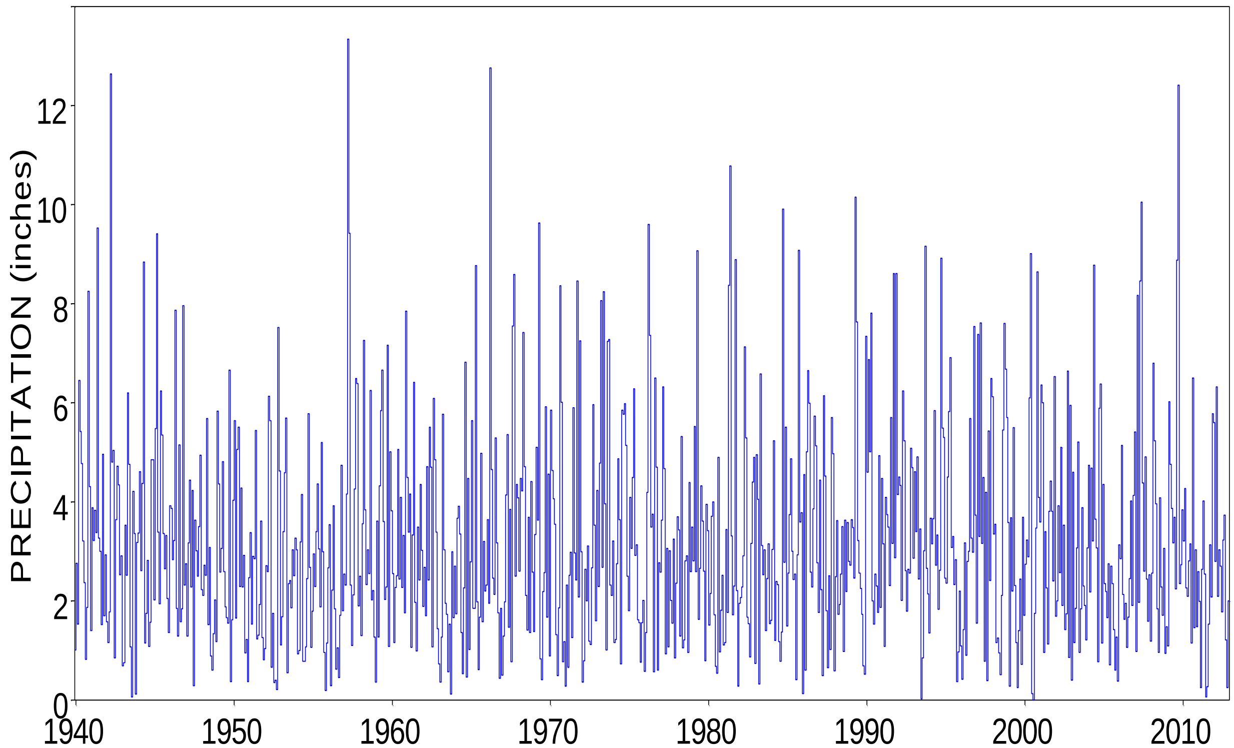
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 509



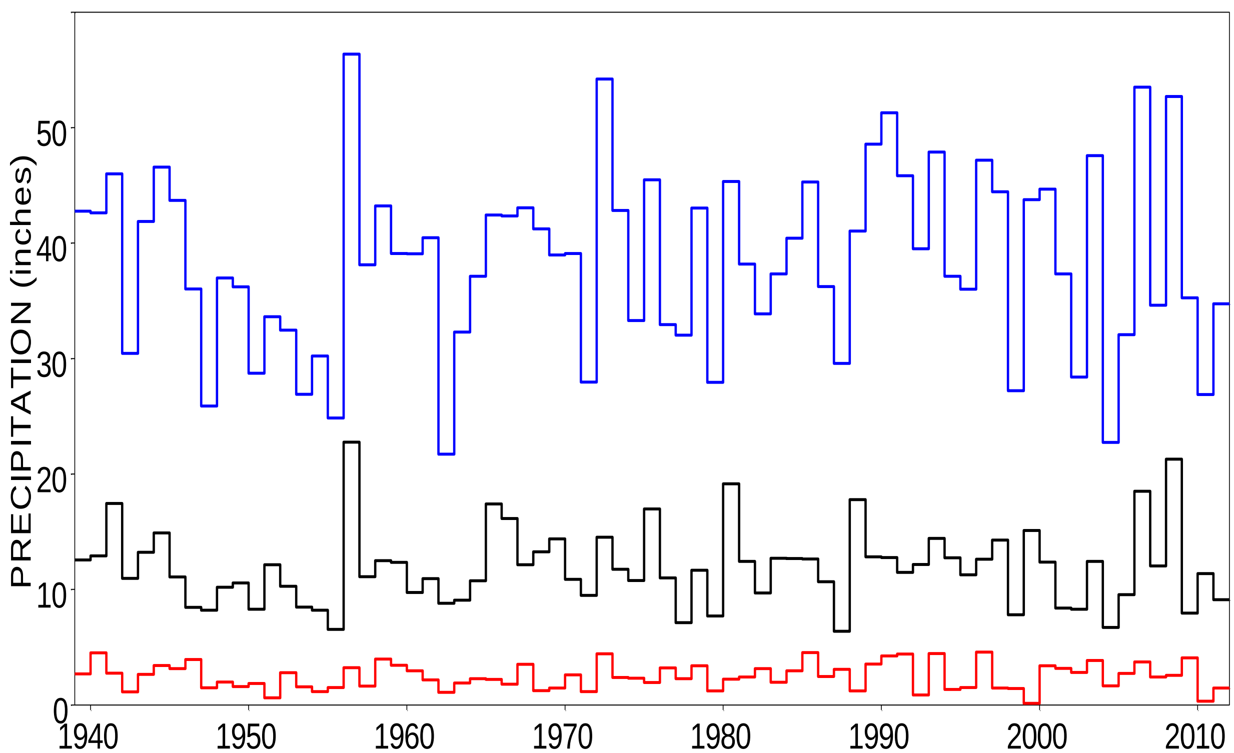
Monthly Precipitation for Quadrangle 510



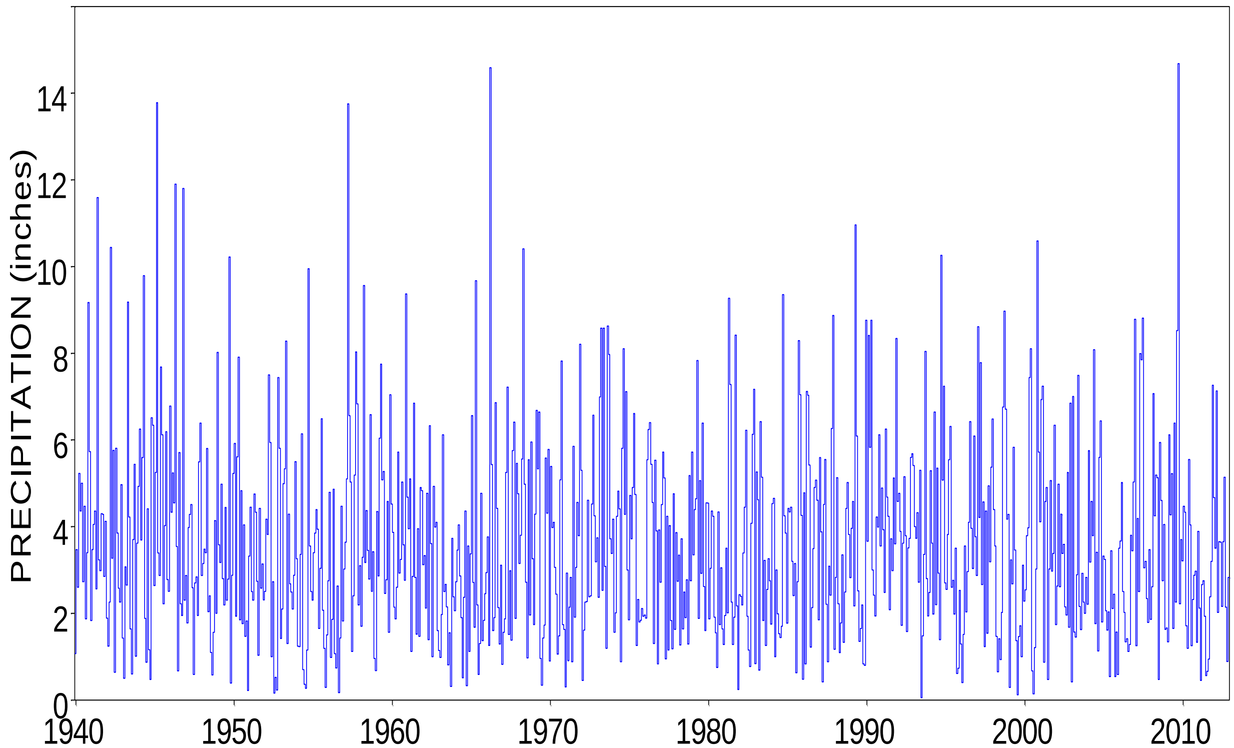
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 510



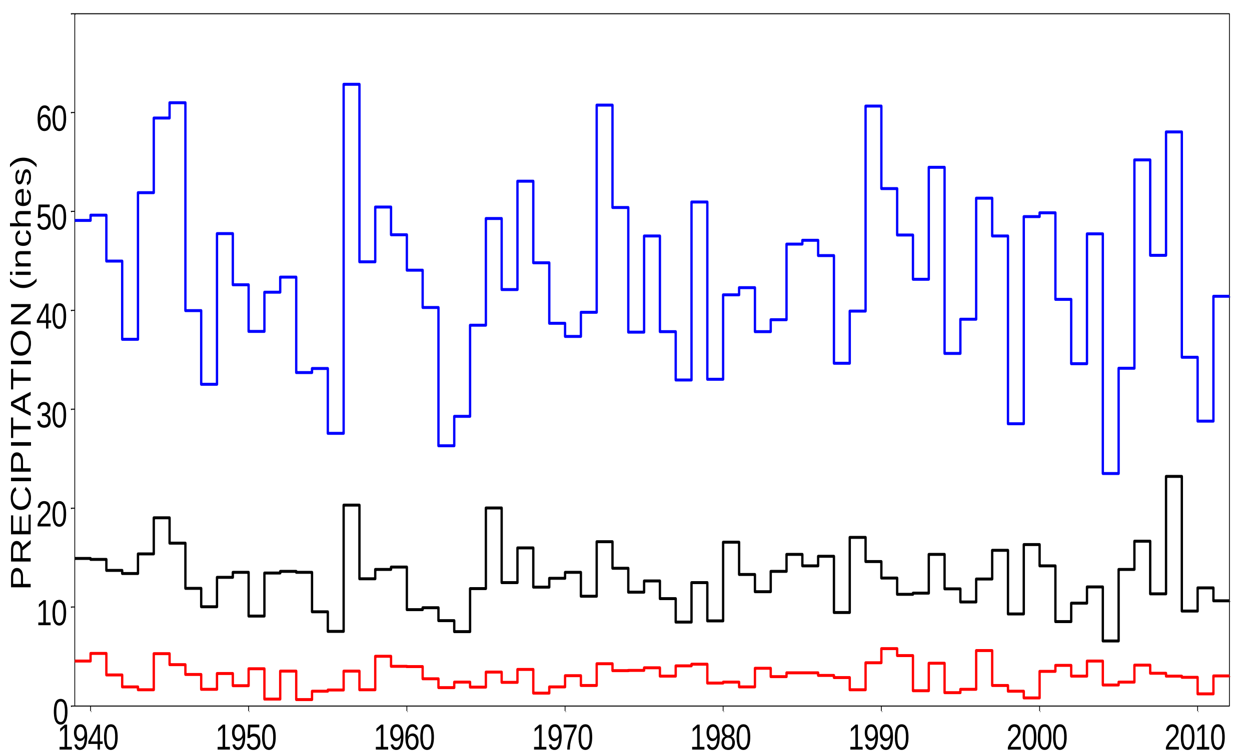
Monthly Precipitation for Quadrangle 511



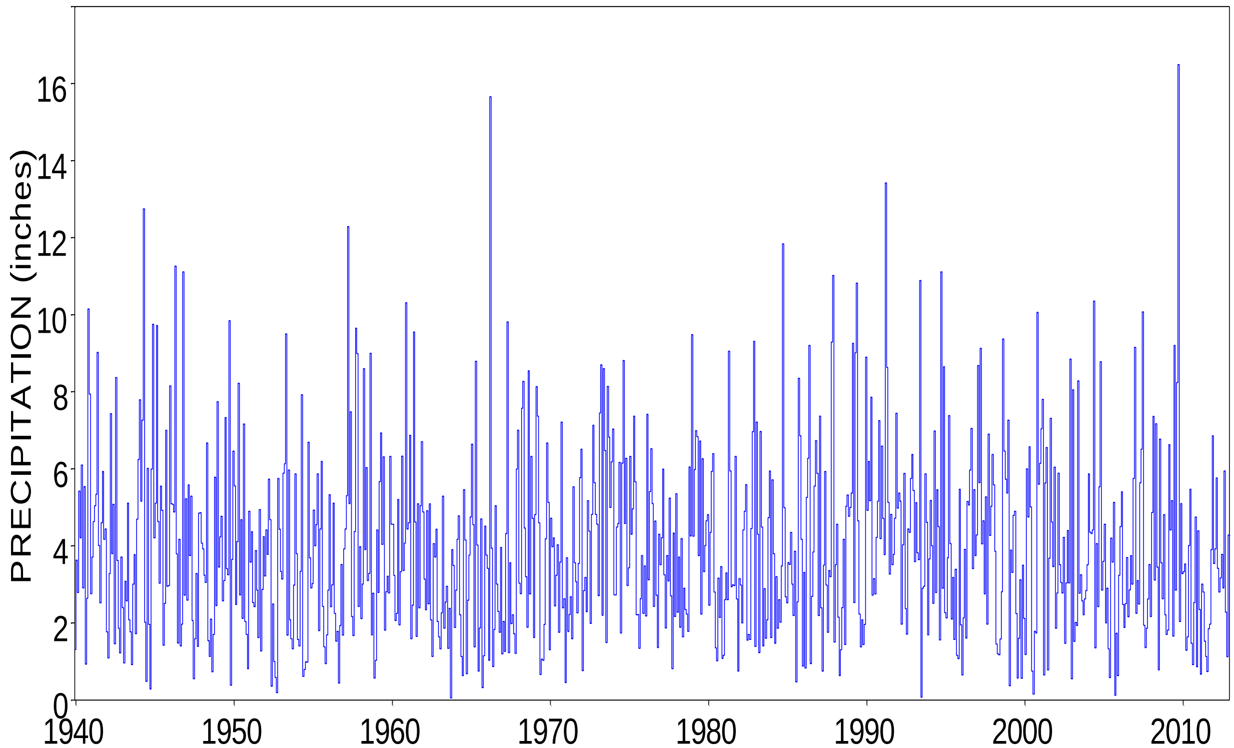
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 511



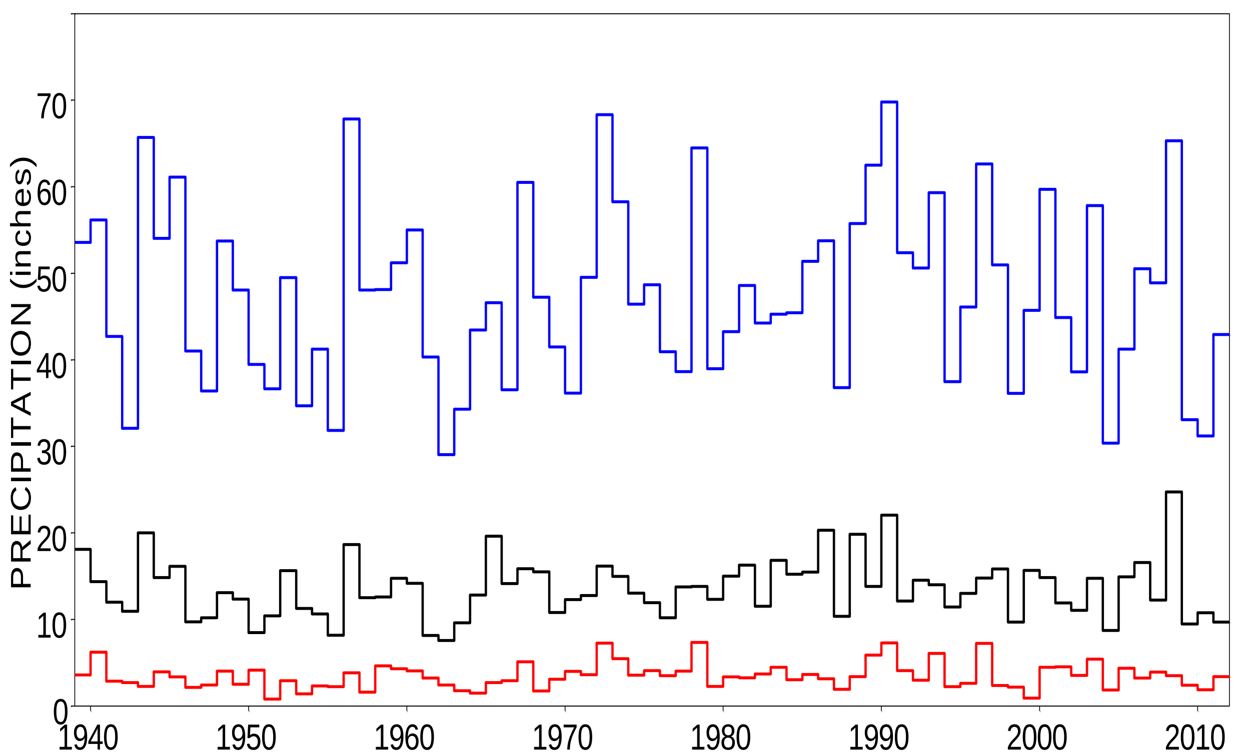
Monthly Precipitation for Quadrangle 512



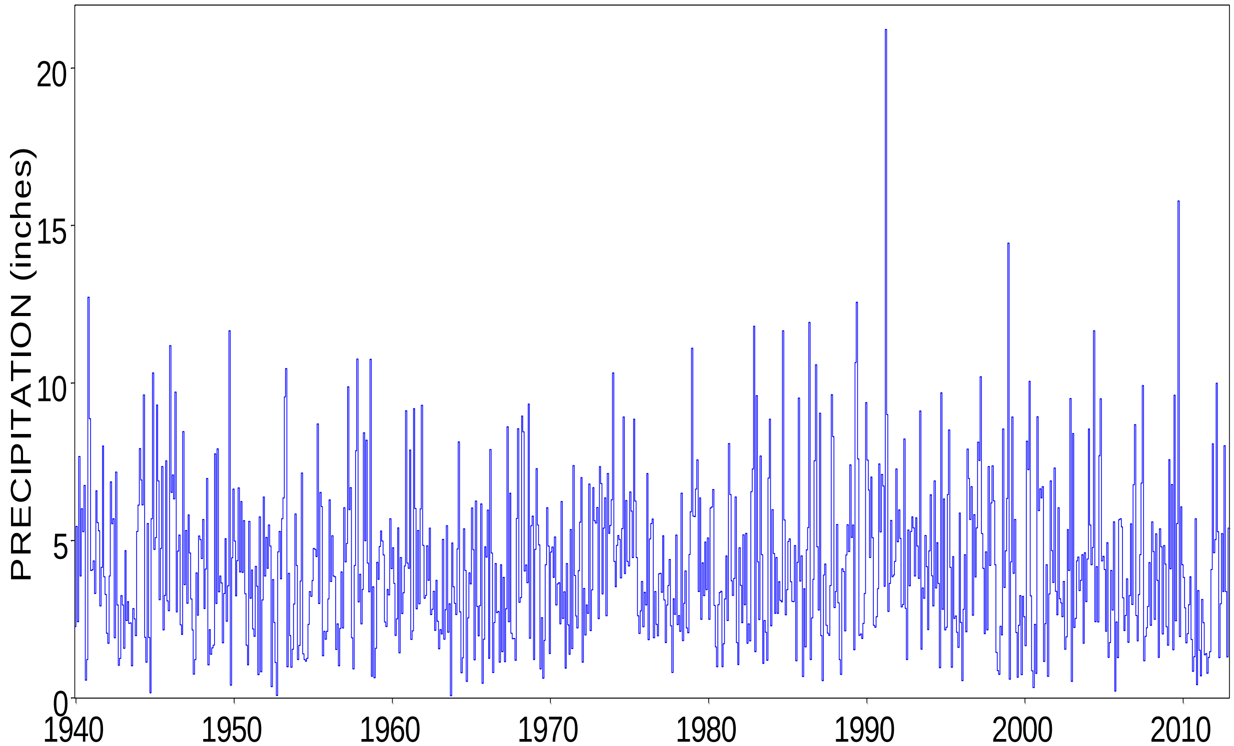
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 512



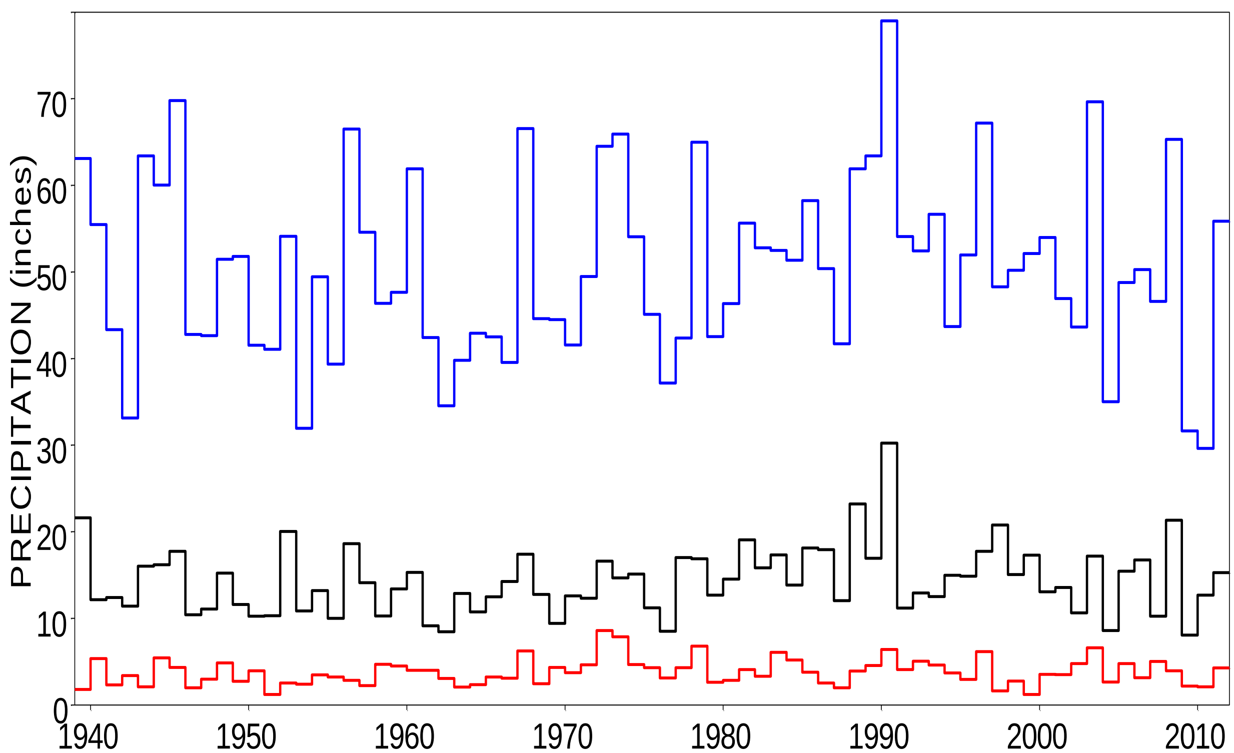
Monthly Precipitation for Quadrangle 513



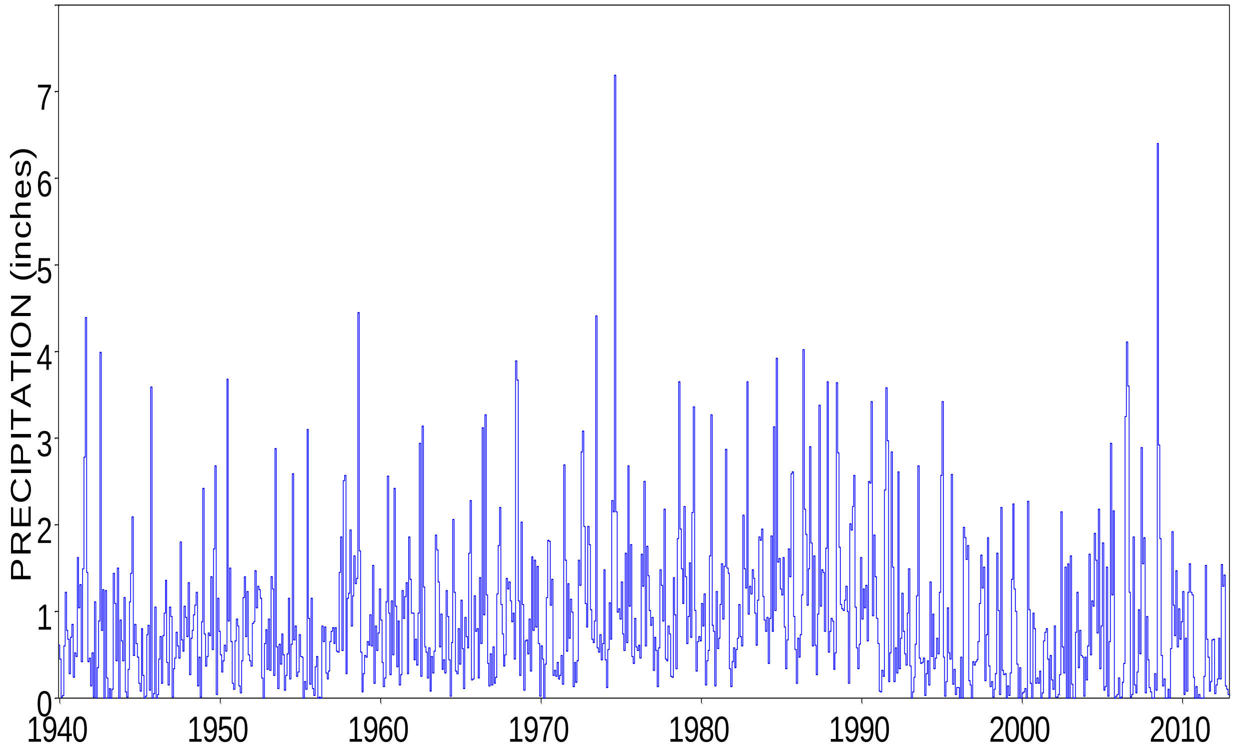
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 513



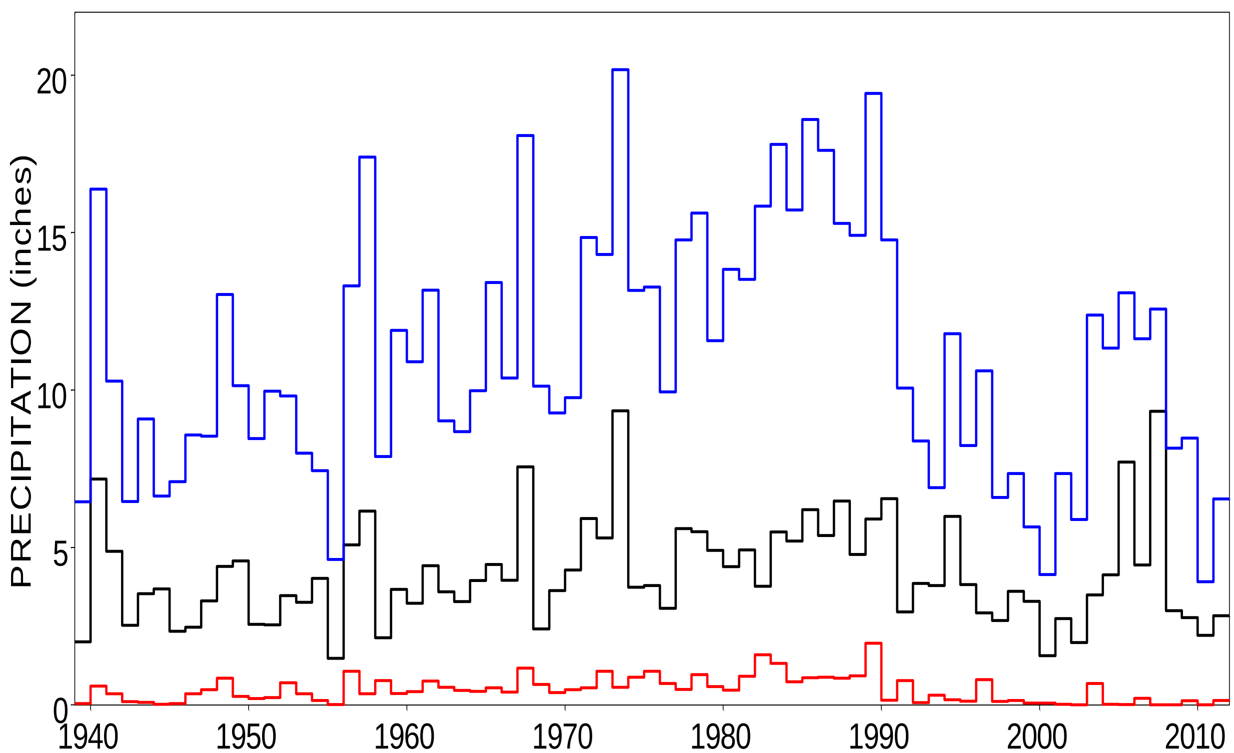
Monthly Precipitation for Quadrangle 514



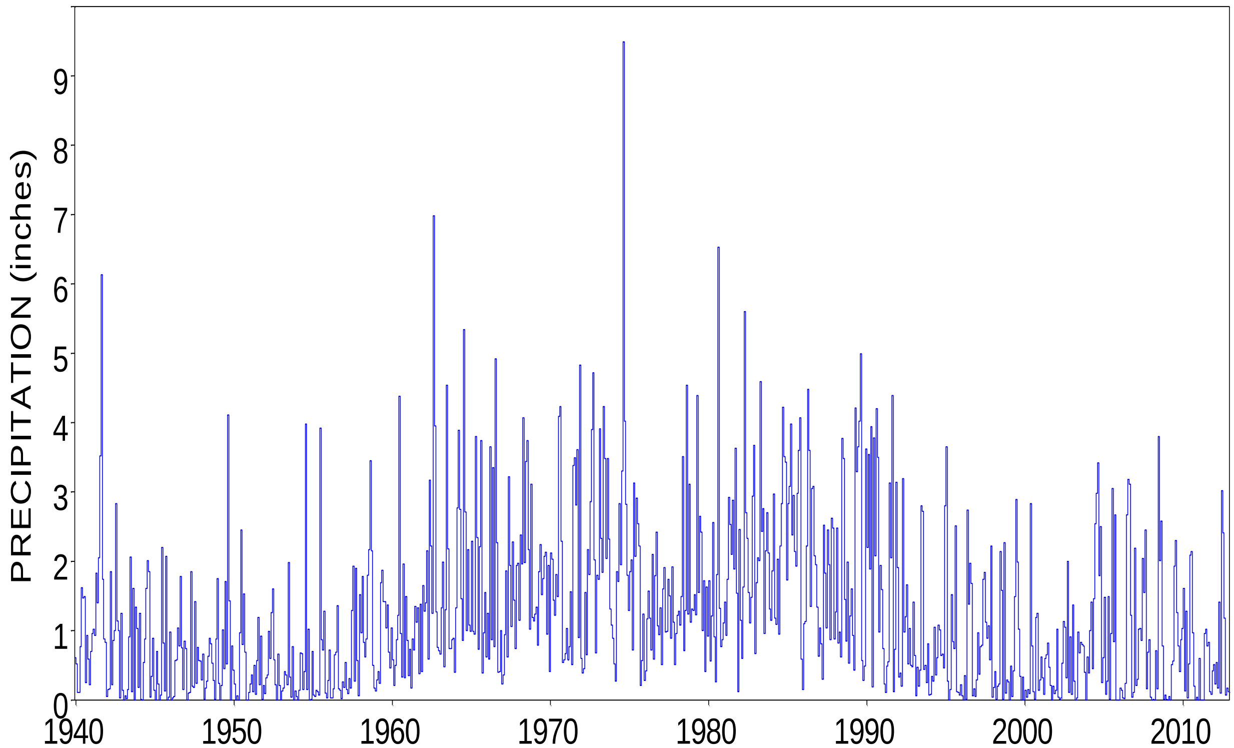
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 514



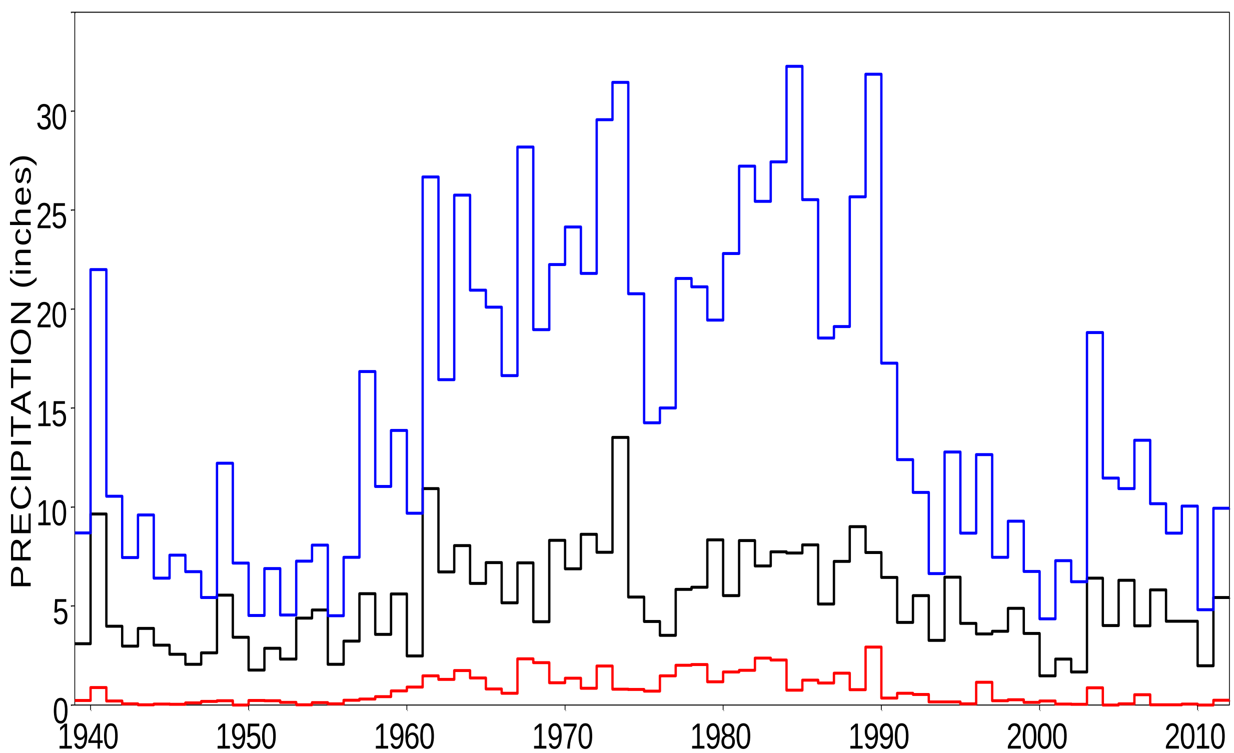
Monthly Precipitation for Quadrangle 601



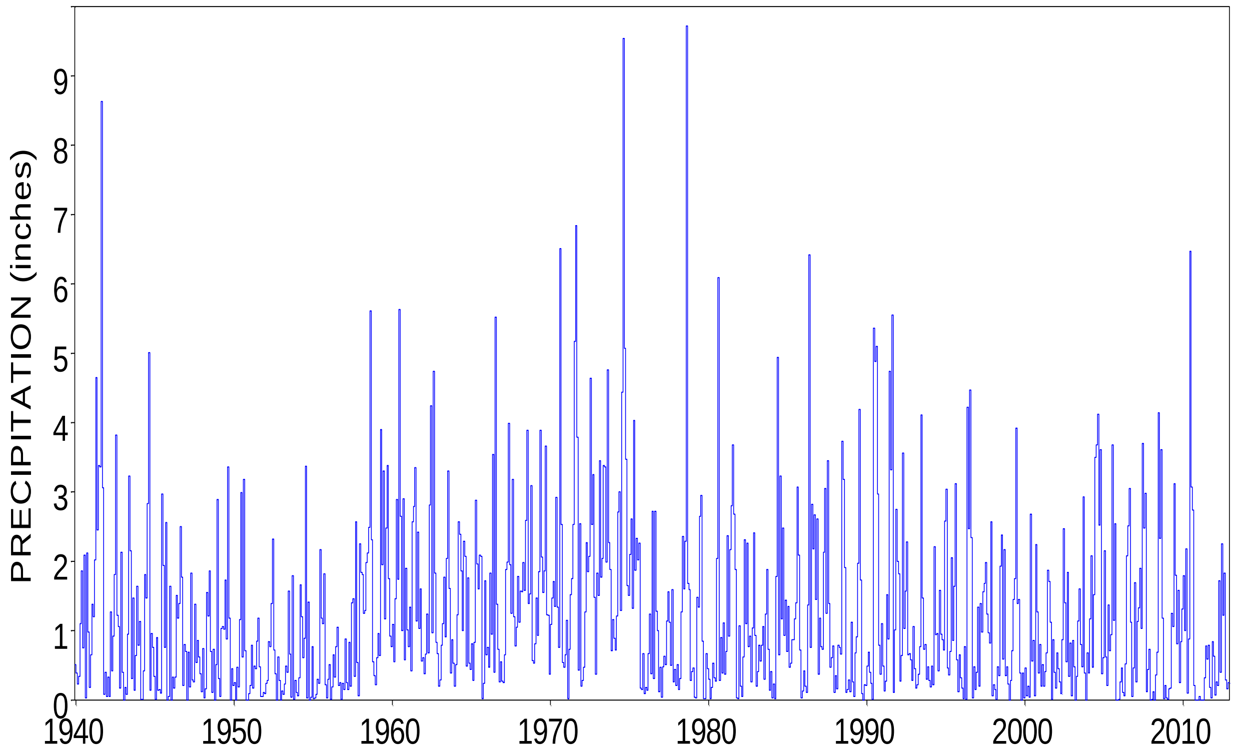
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 601



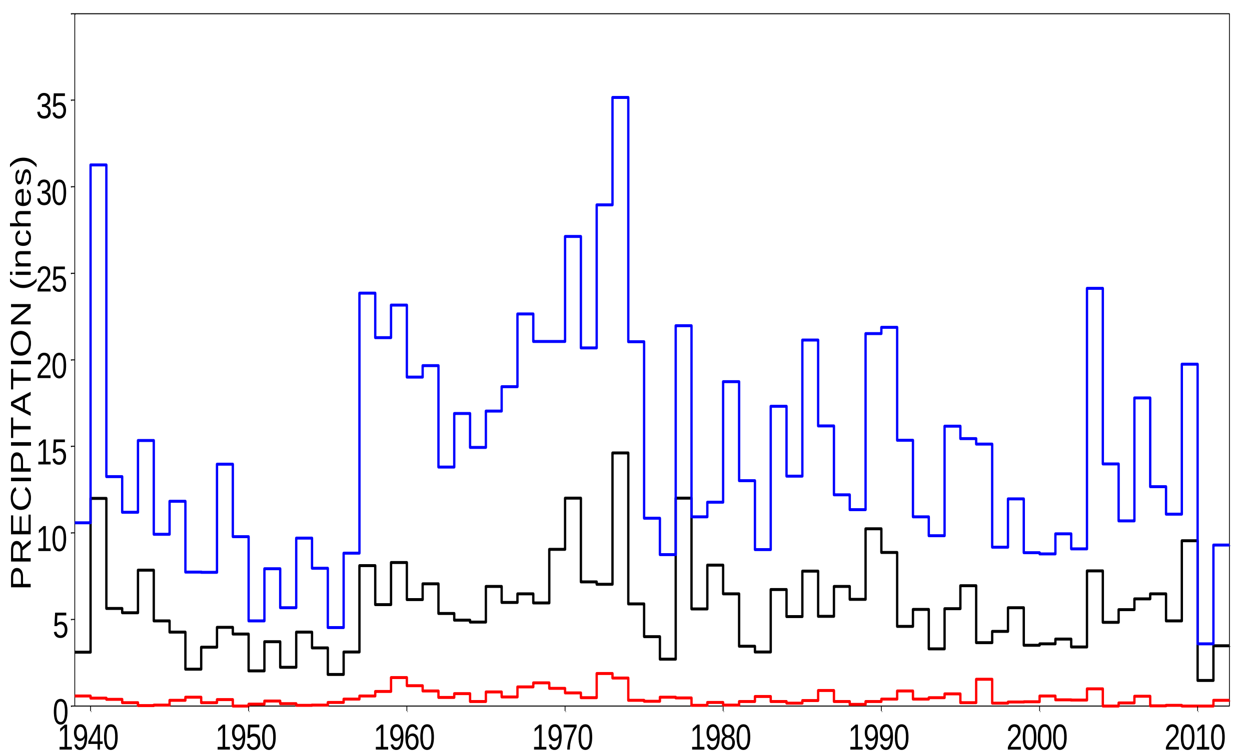
Monthly Precipitation for Quadrangle 602



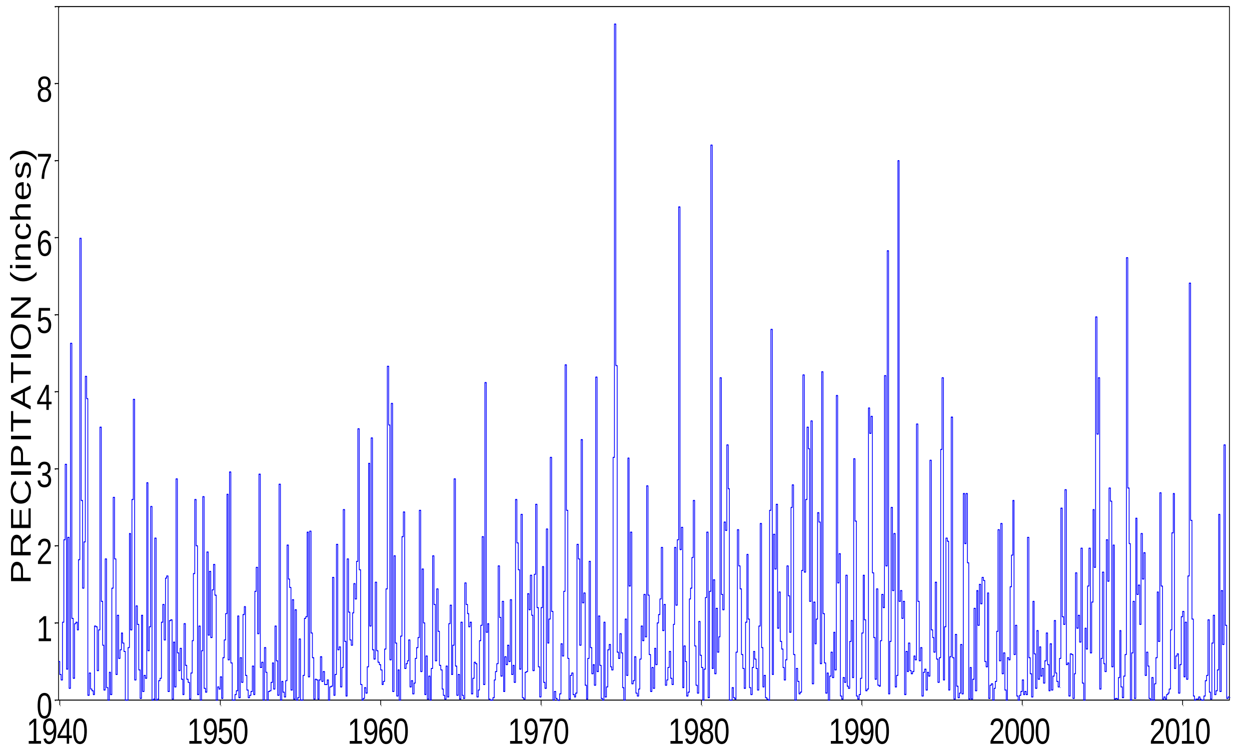
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 602



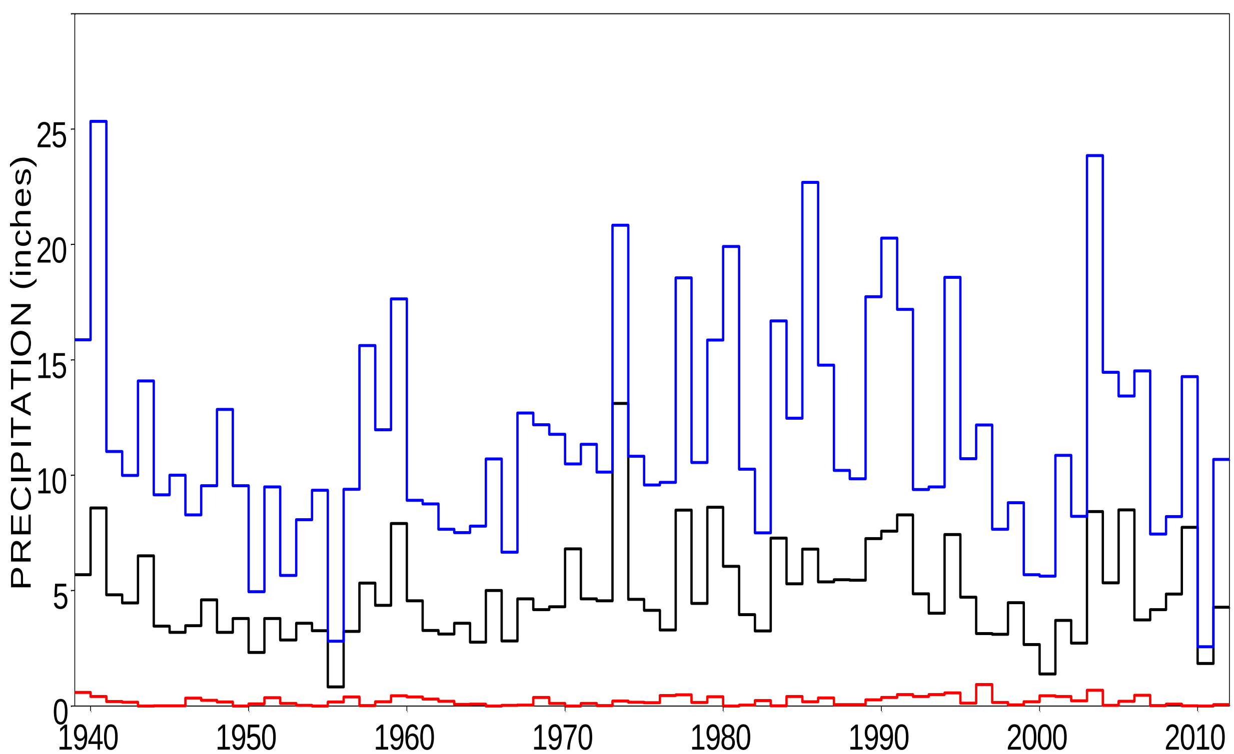
Monthly Precipitation for Quadrangle 603



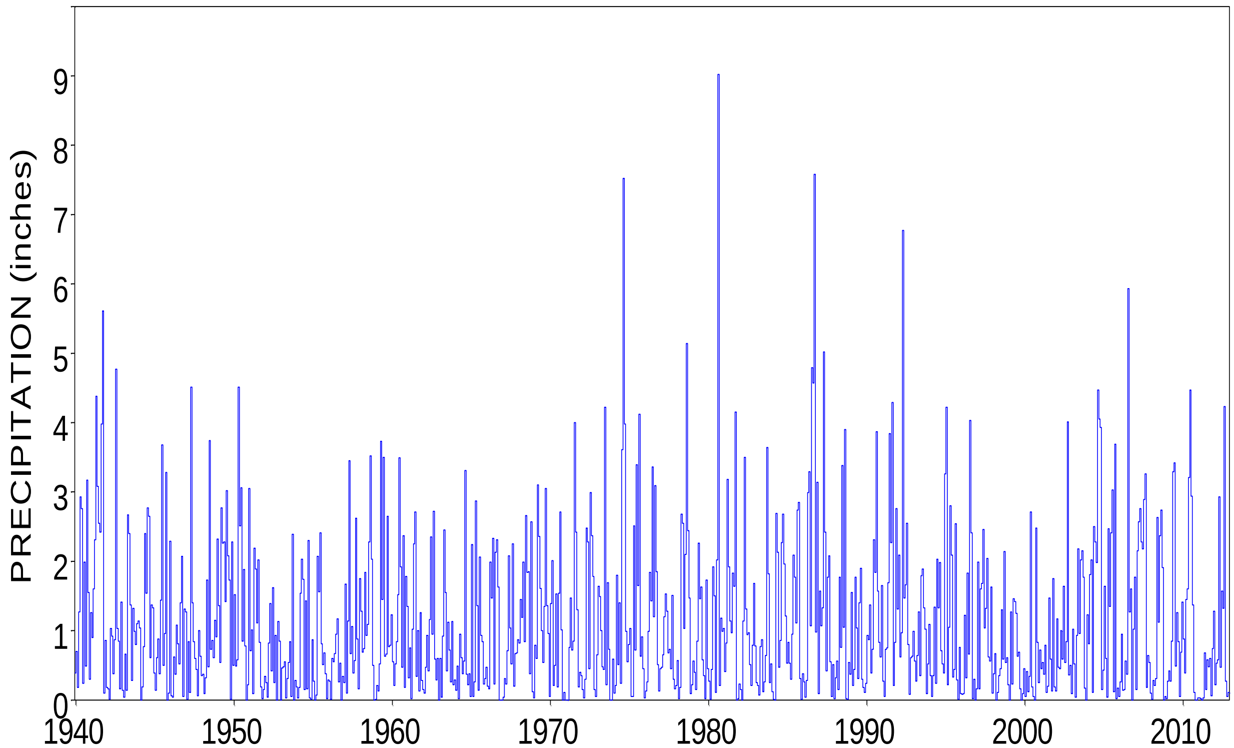
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 603



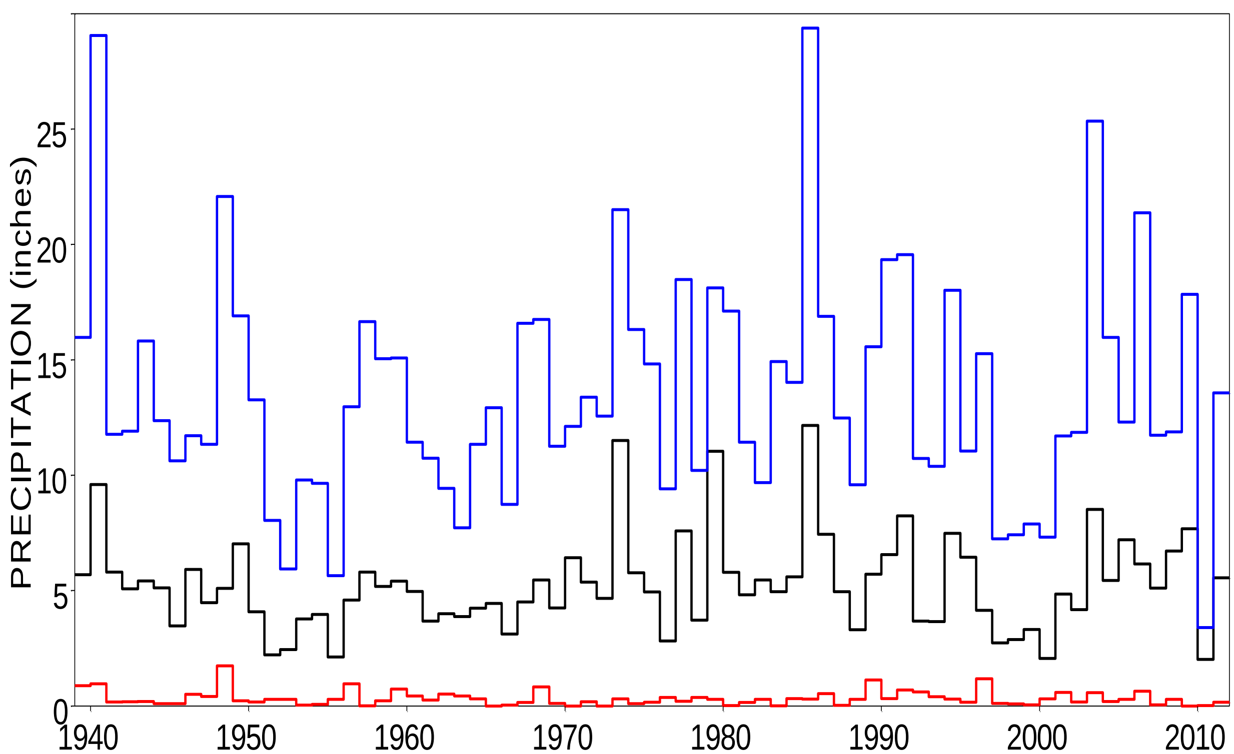
Monthly Precipitation for Quadrangle 604



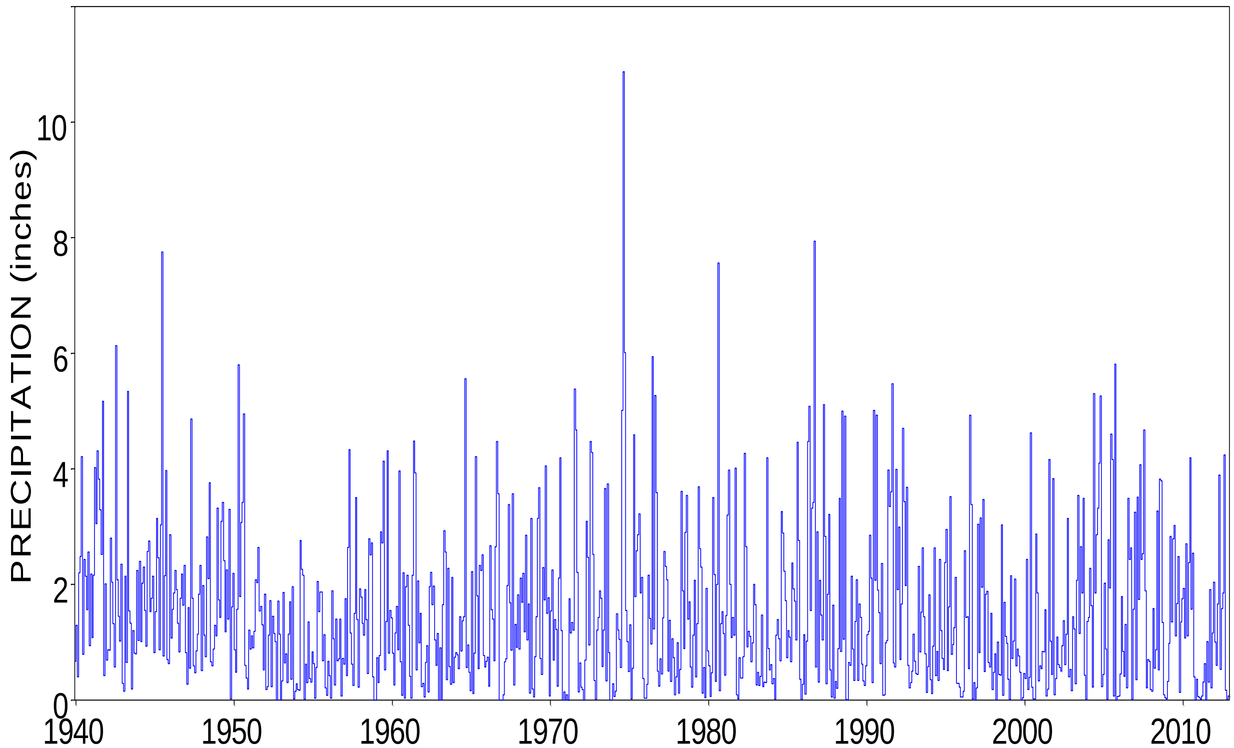
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 604



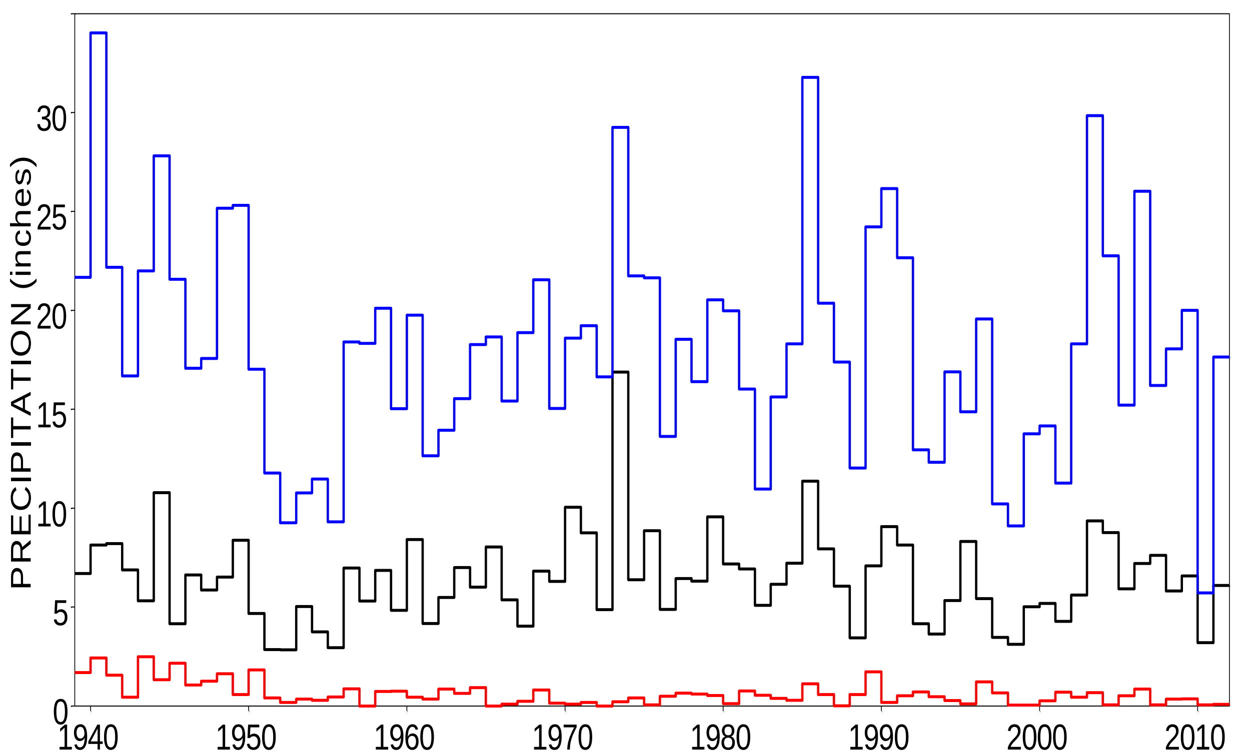
Monthly Precipitation for Quadrangle 605



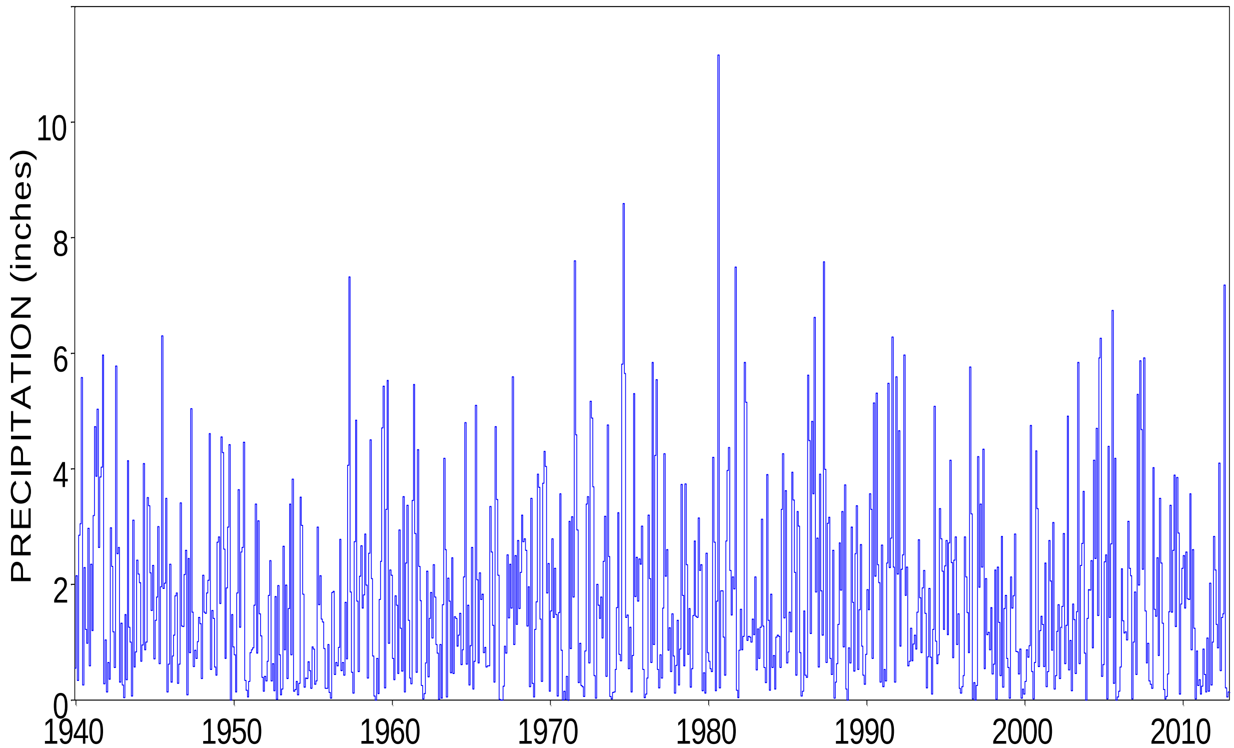
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 605



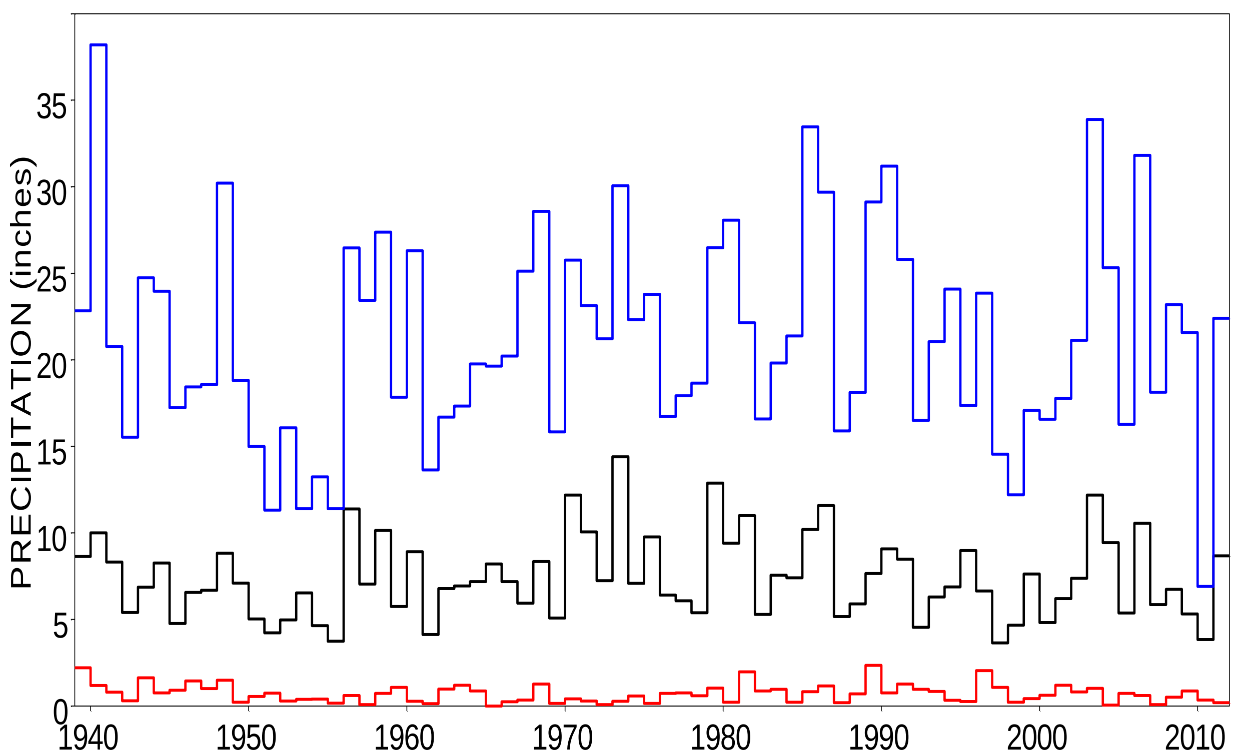
Monthly Precipitation for Quadrangle 606



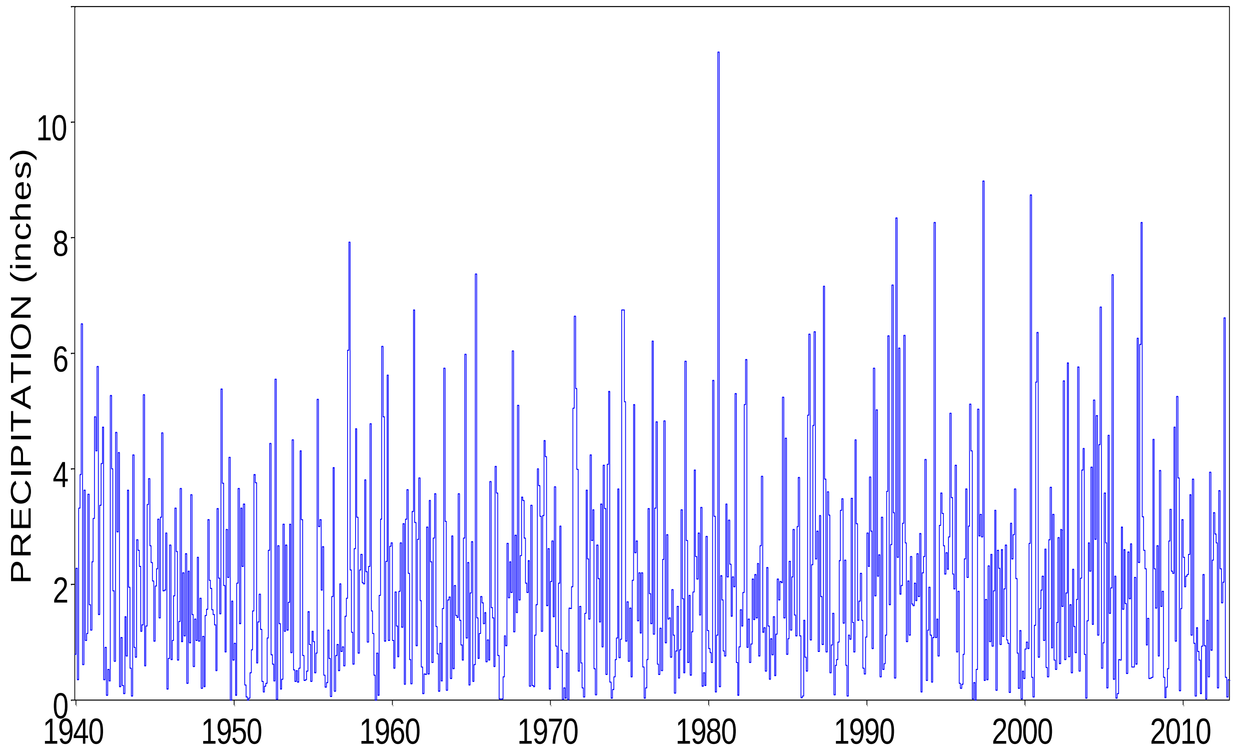
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 606



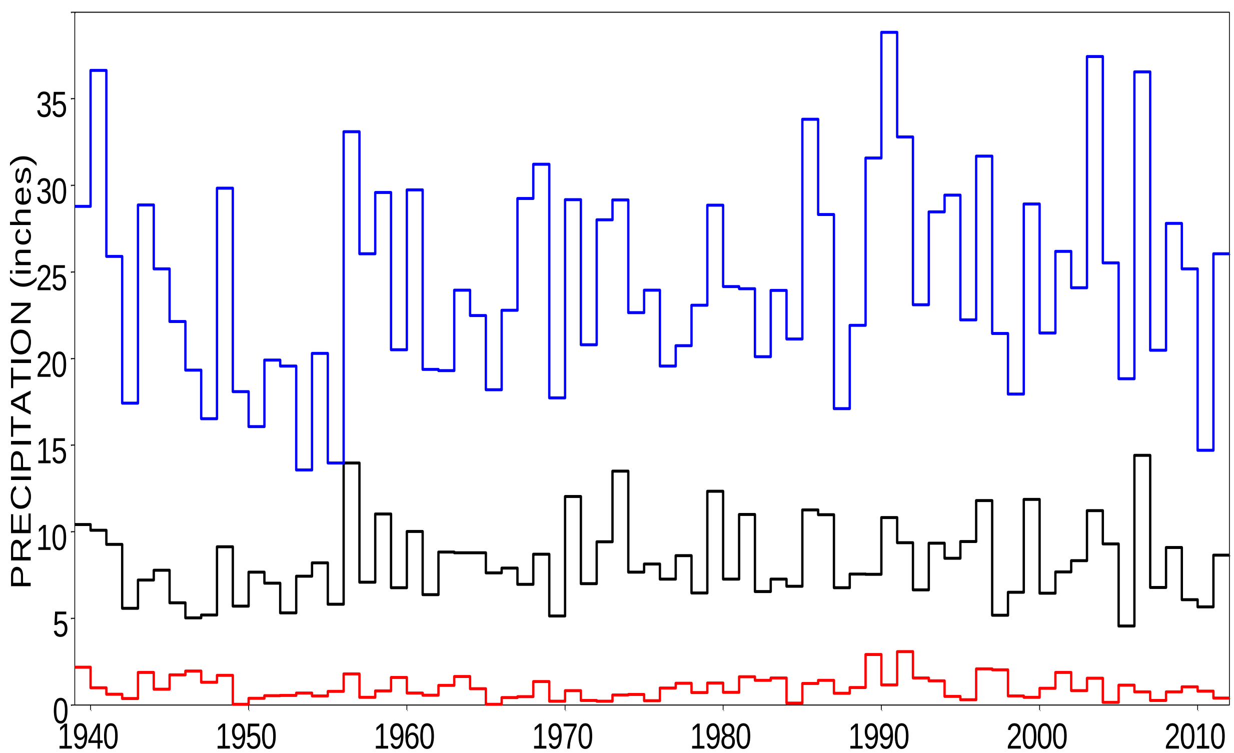
Monthly Precipitation for Quadrangle 607



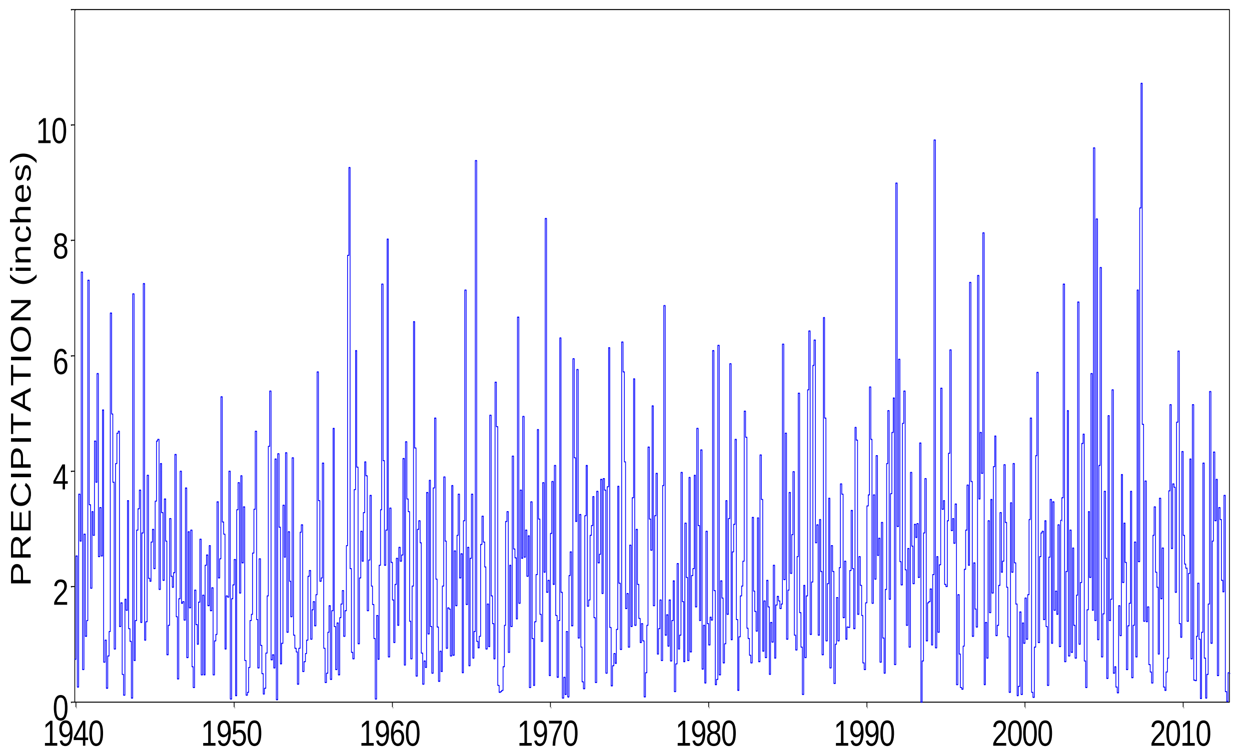
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 607



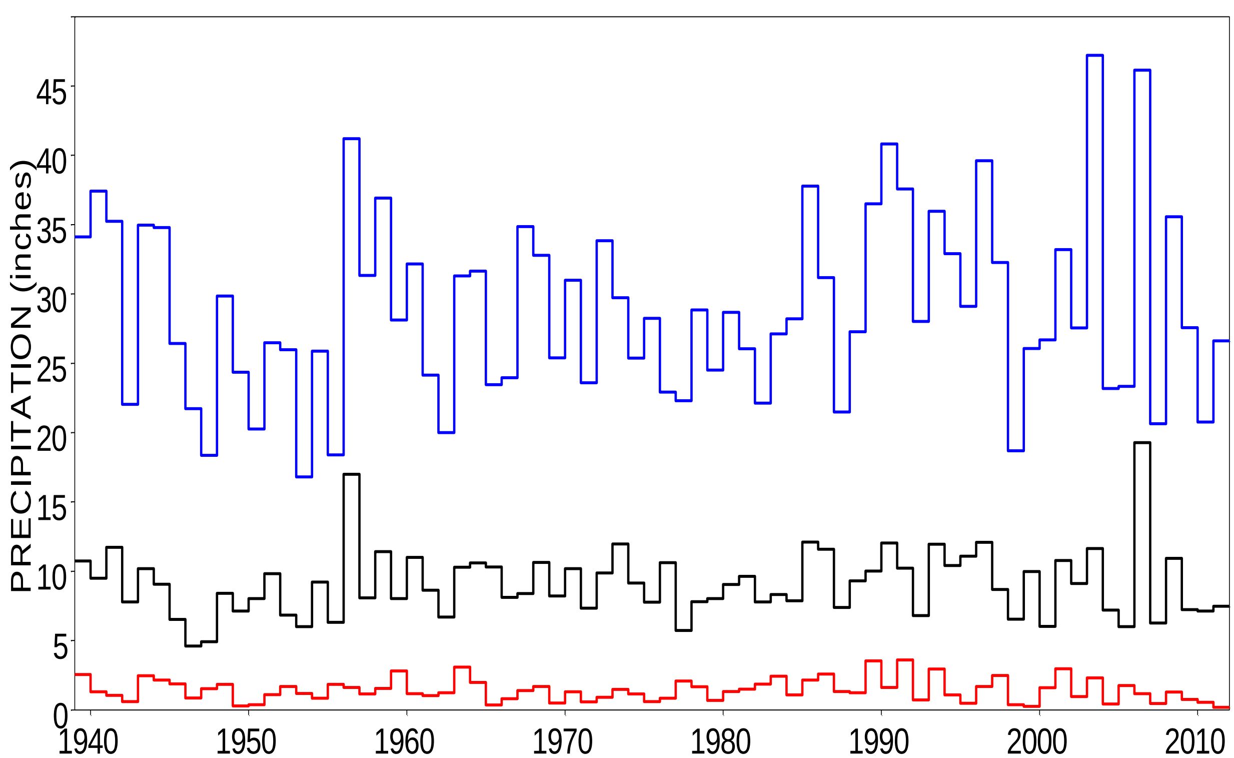
Monthly Precipitation for Quadrangle 608



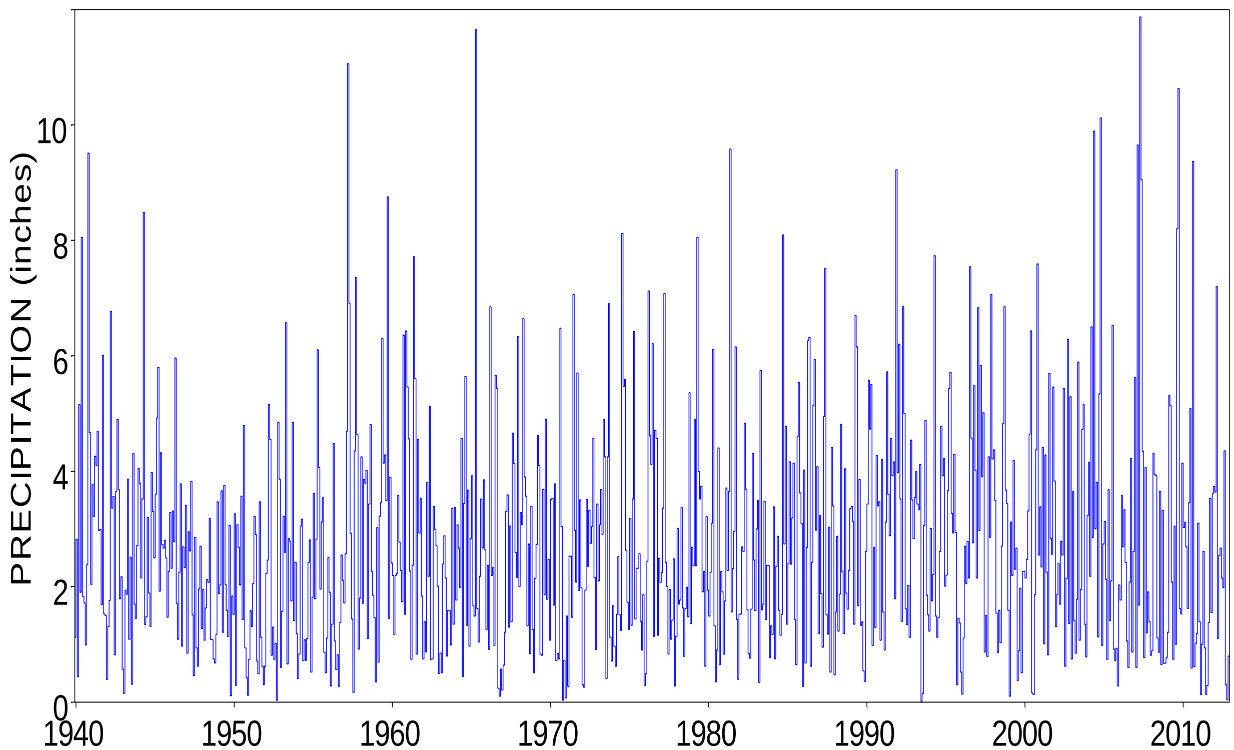
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 608



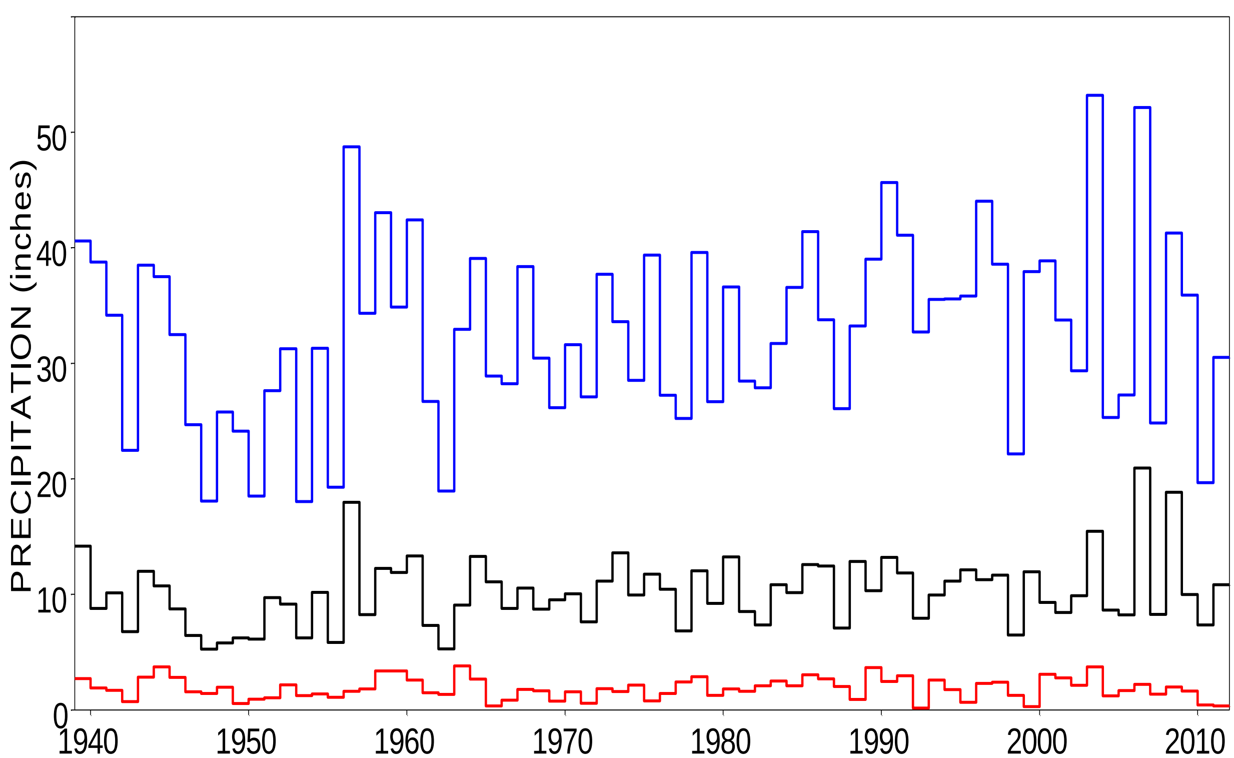
Monthly Precipitation for Quadrangle 609



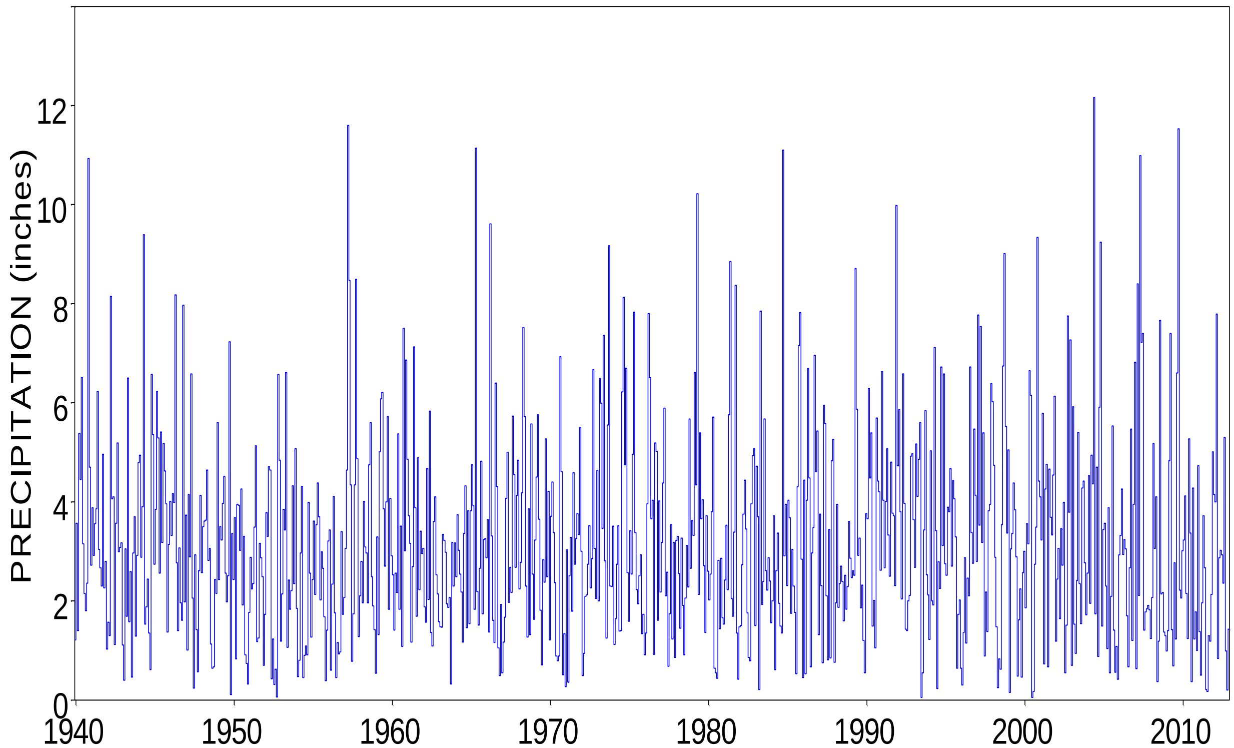
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 609



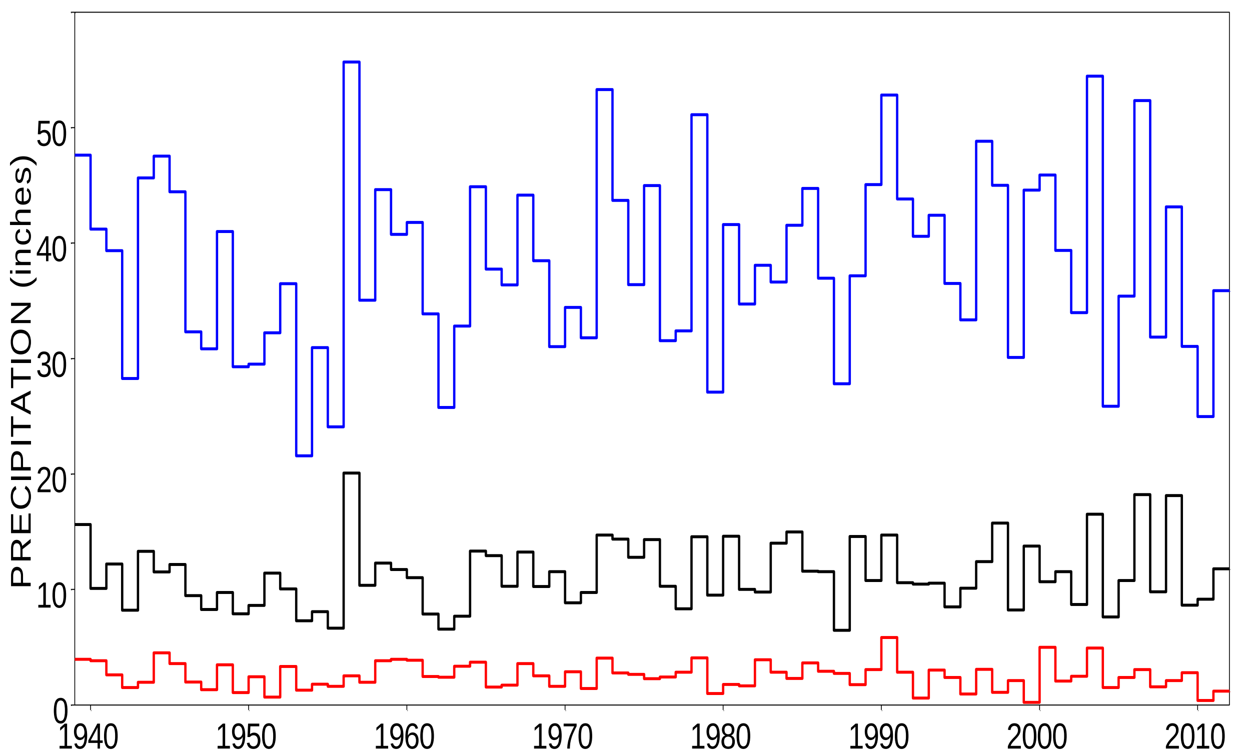
Monthly Precipitation for Quadrangle 610



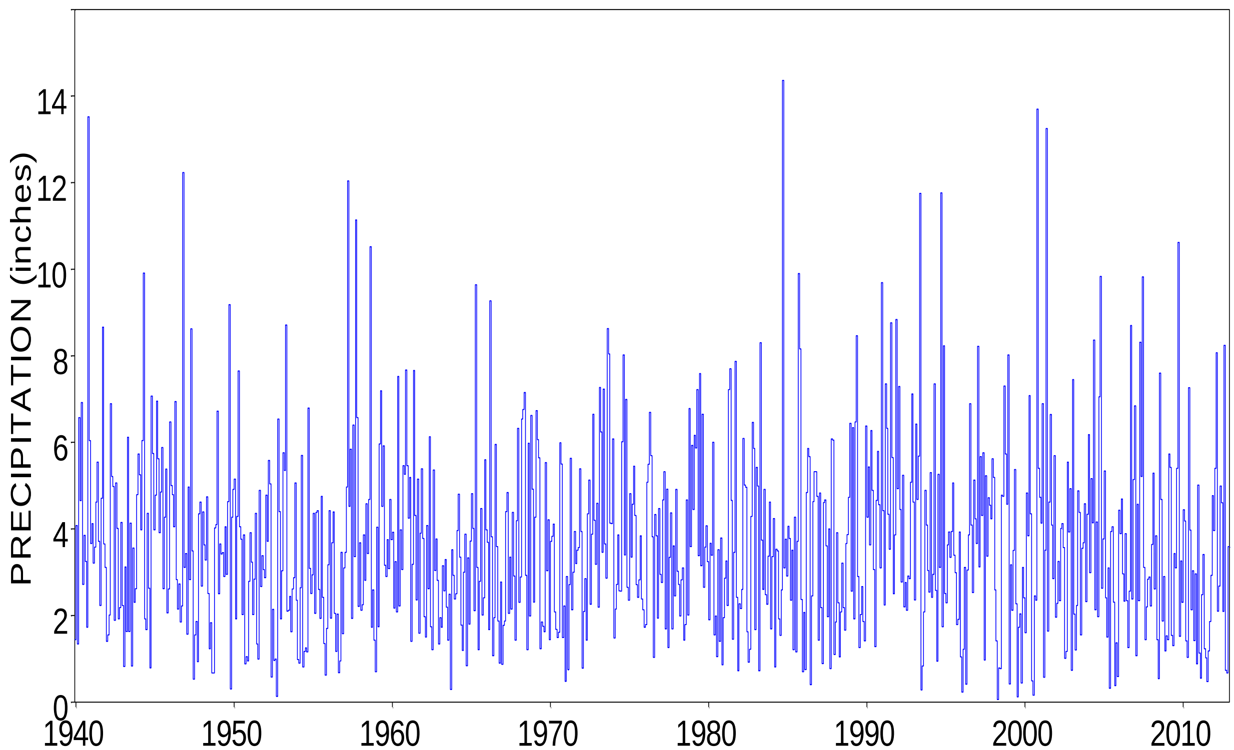
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 610



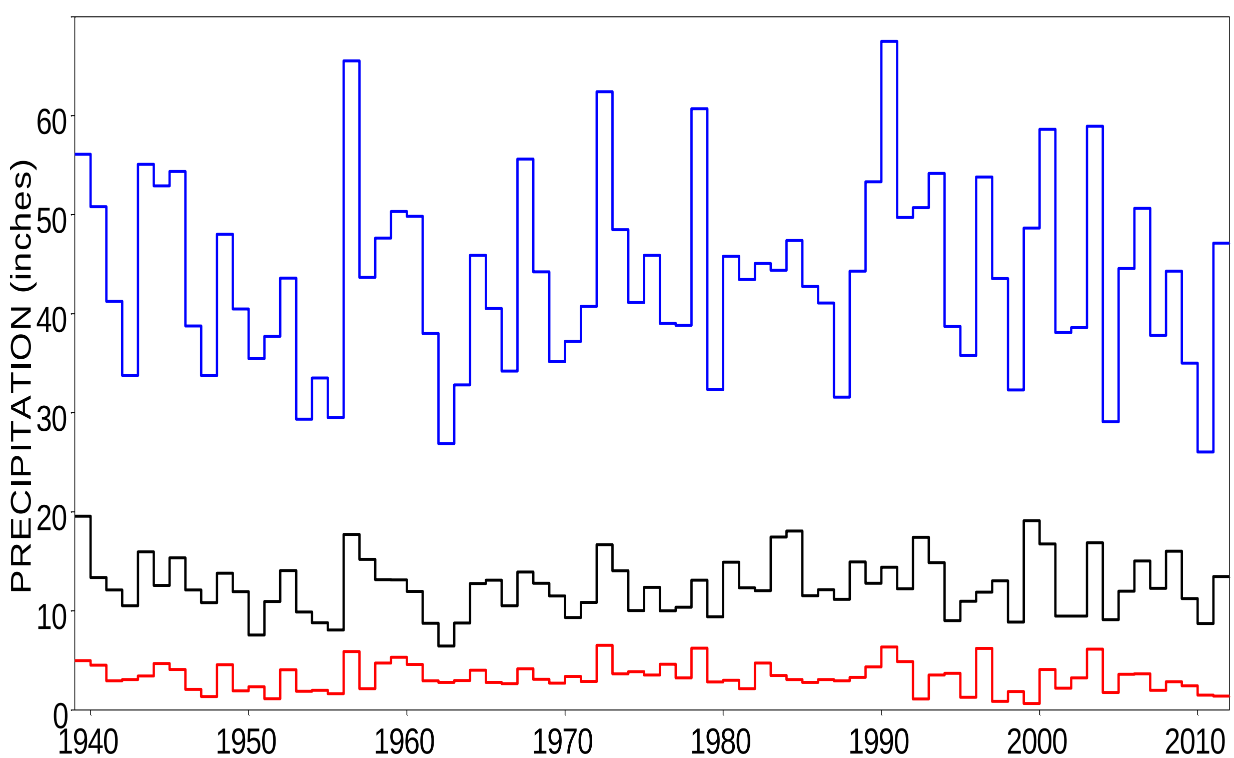
Monthly Precipitation for Quadrangle 611



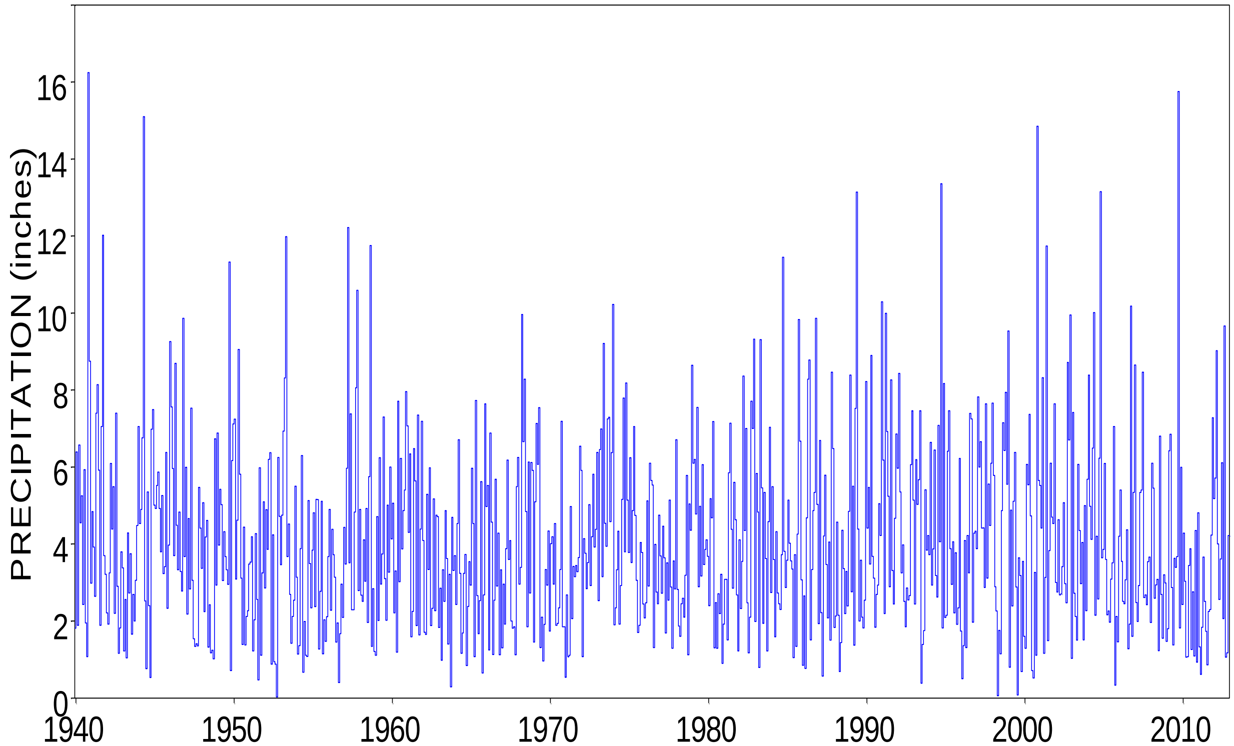
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 611



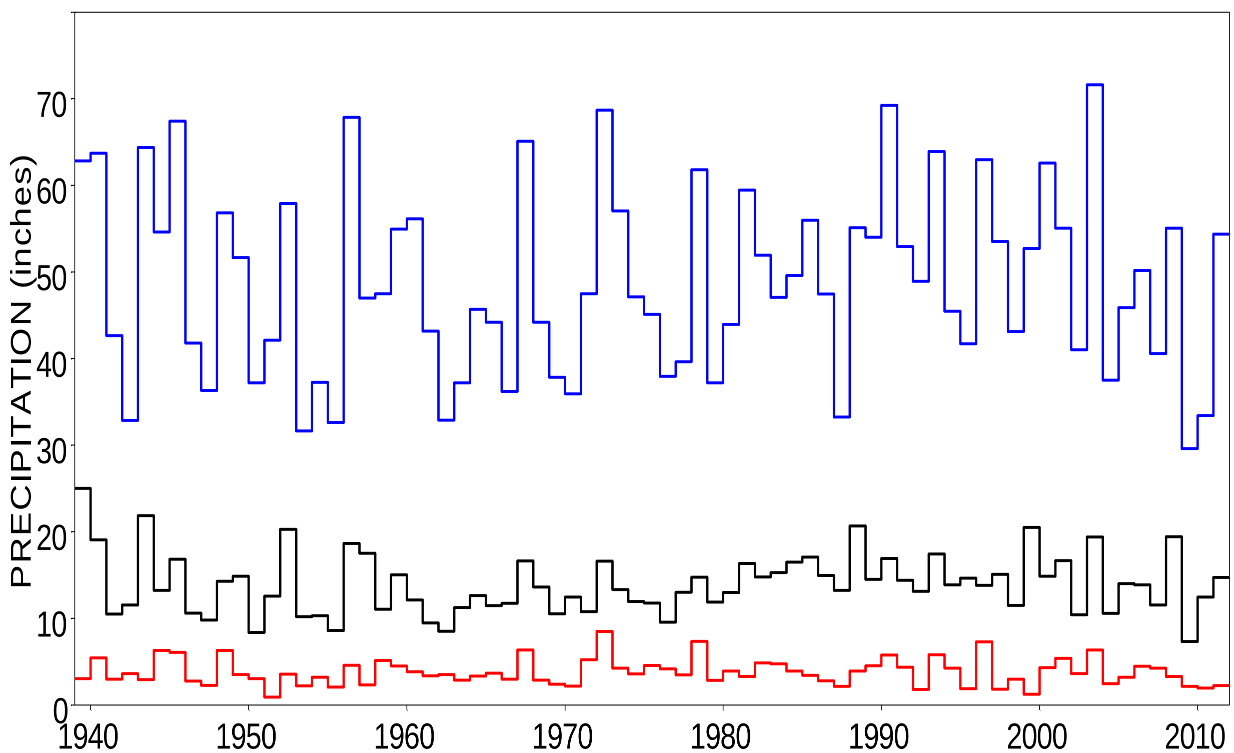
Monthly Precipitation for Quadrangle 612



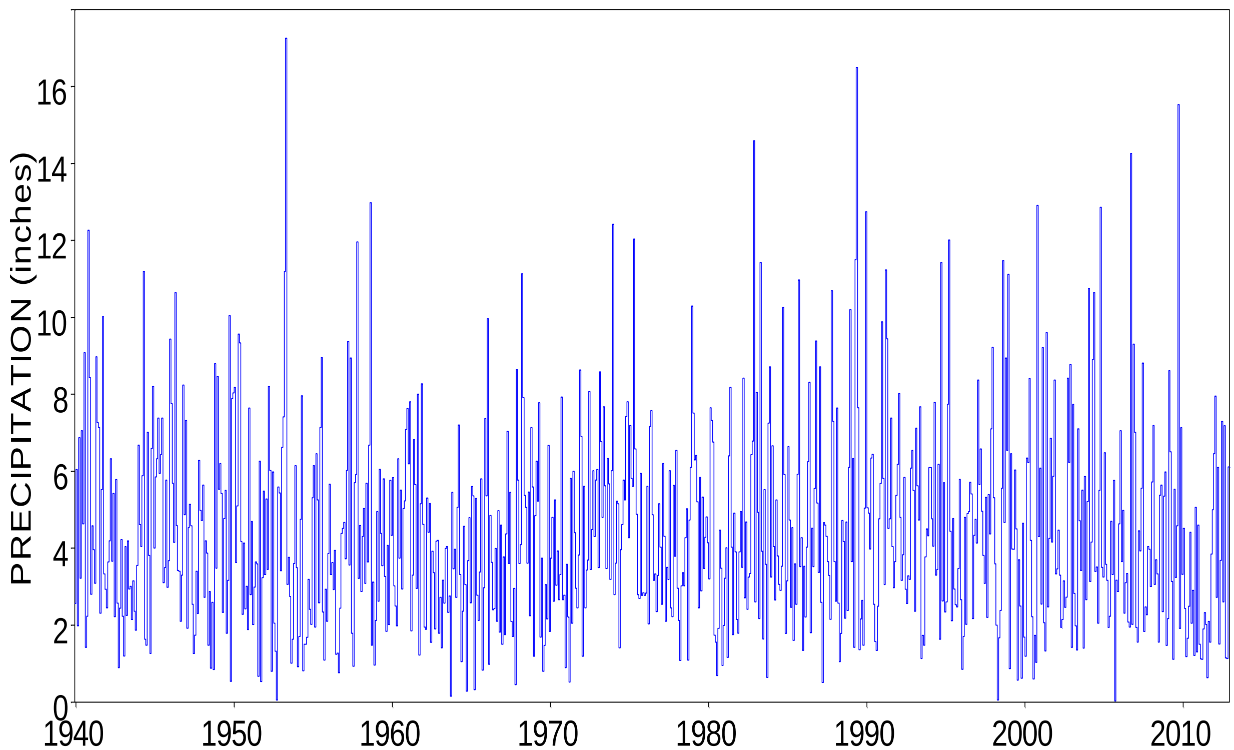
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 612



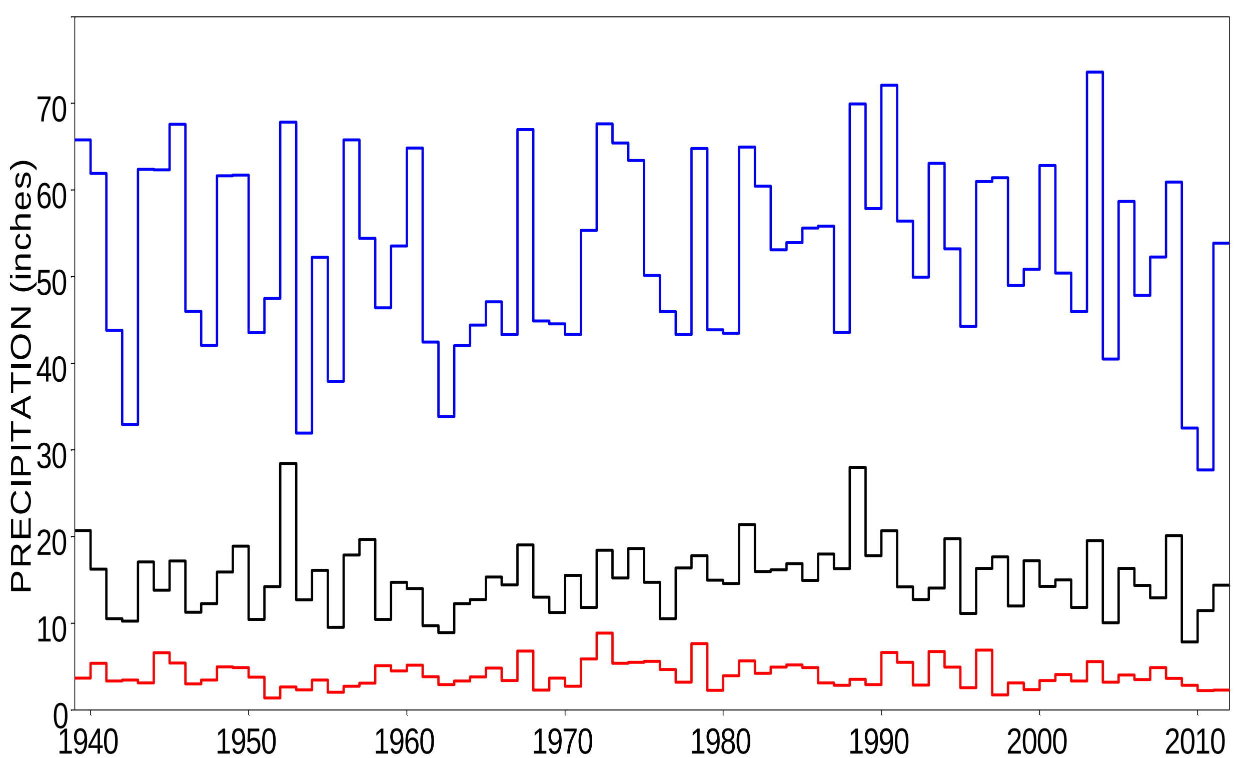
Monthly Precipitation for Quadrangle 613



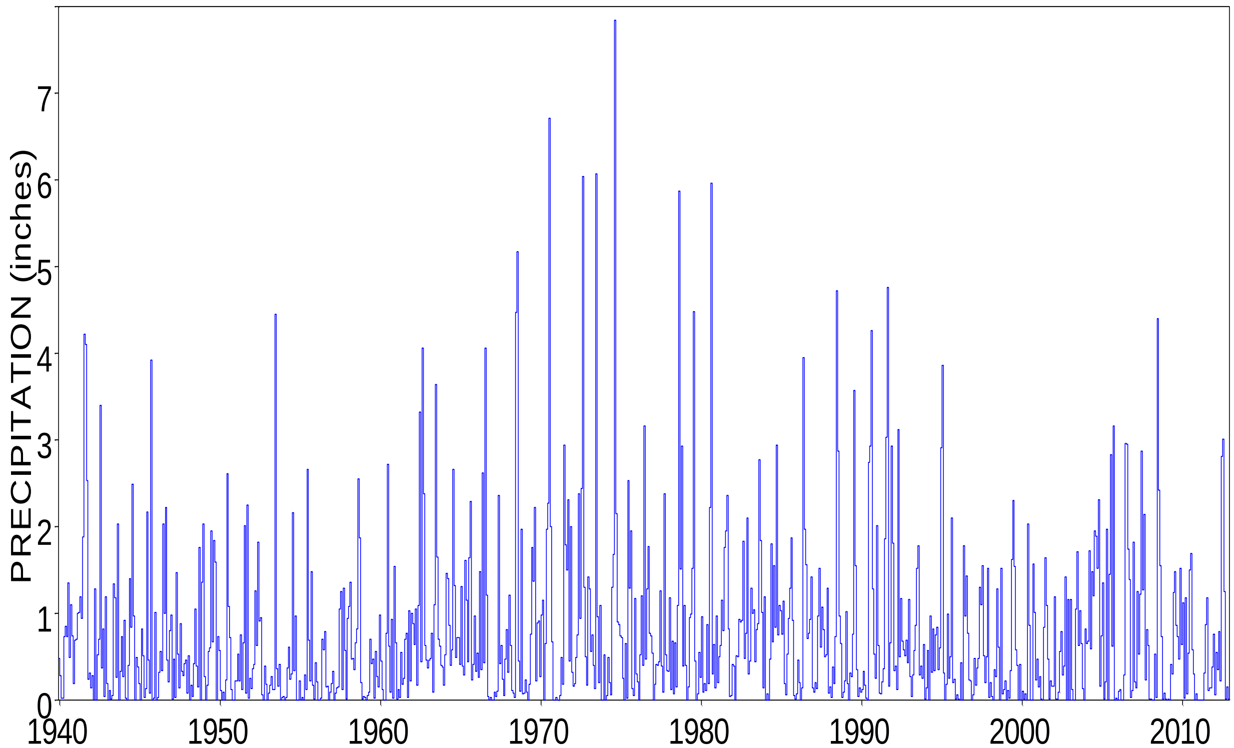
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 613



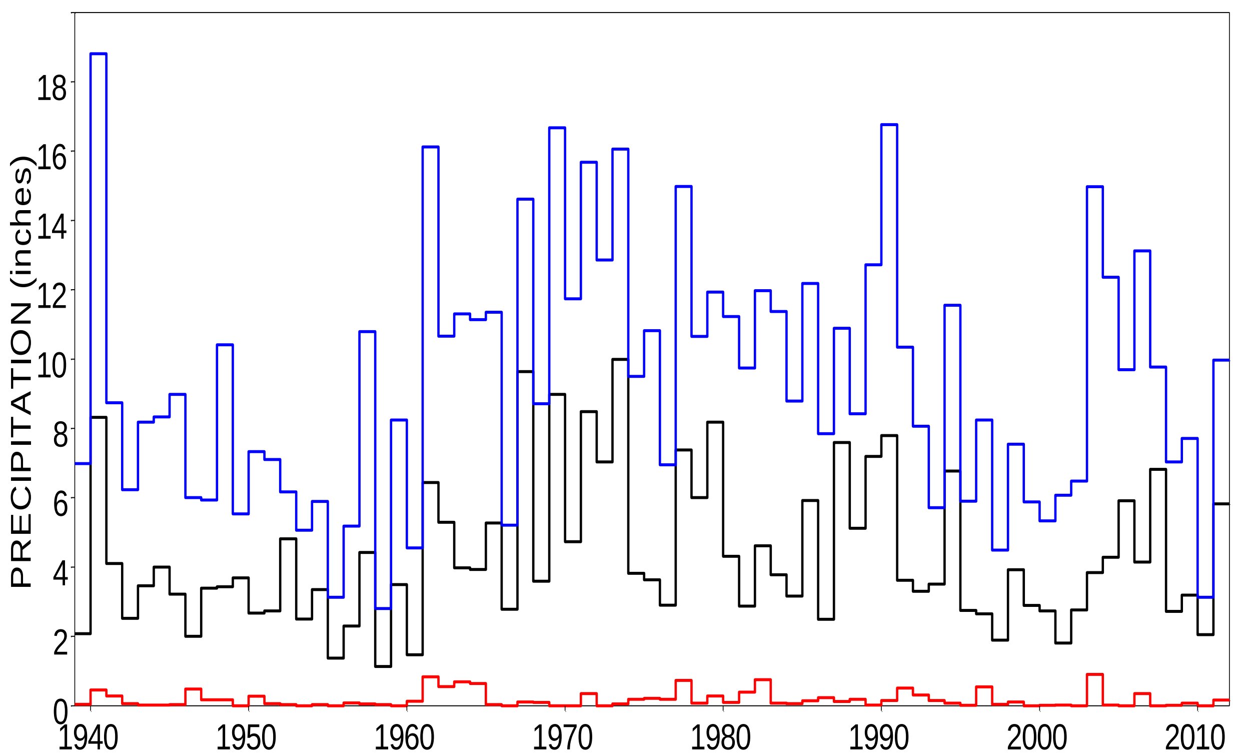
Monthly Precipitation for Quadrangle 614



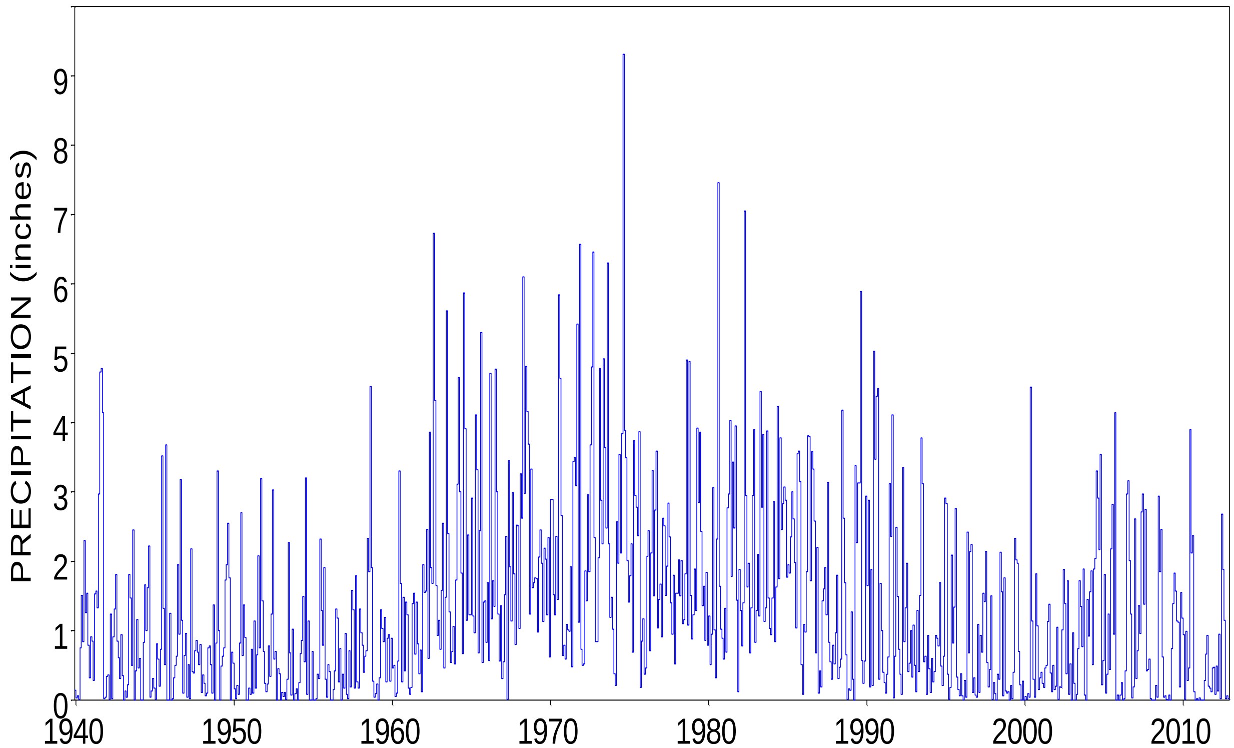
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 614



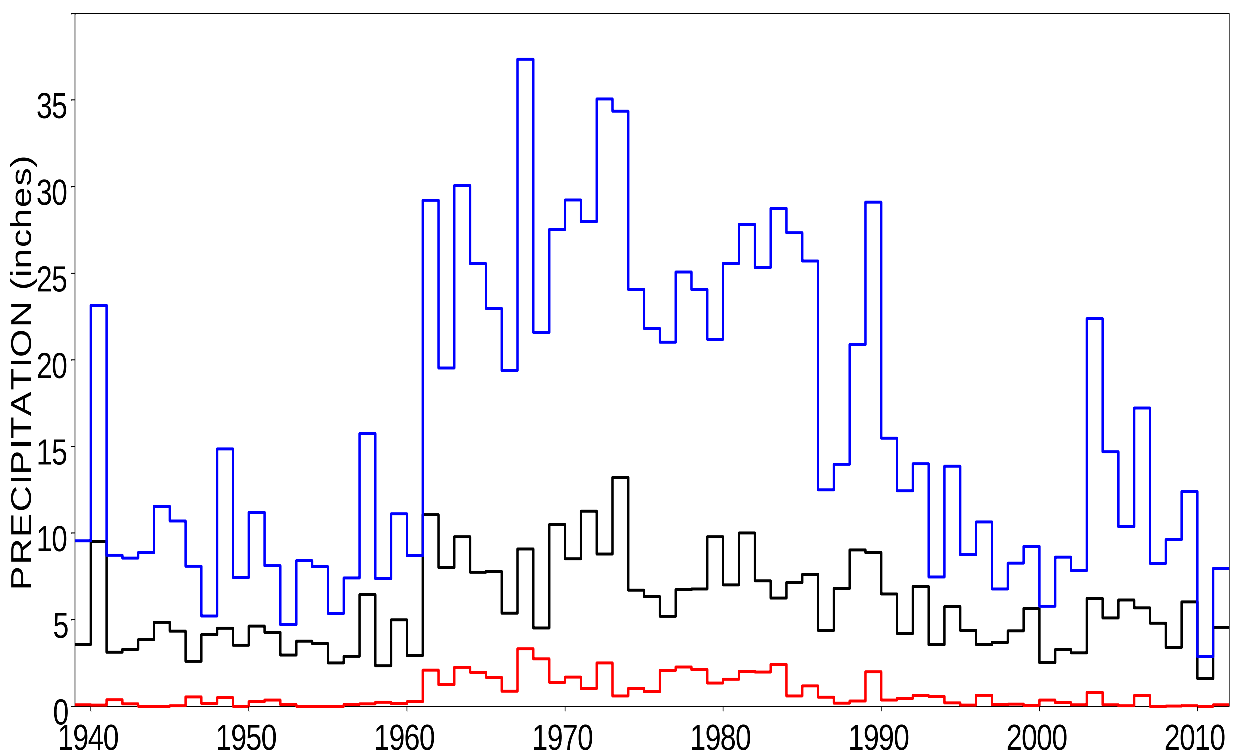
Monthly Precipitation for Quadrangle 701



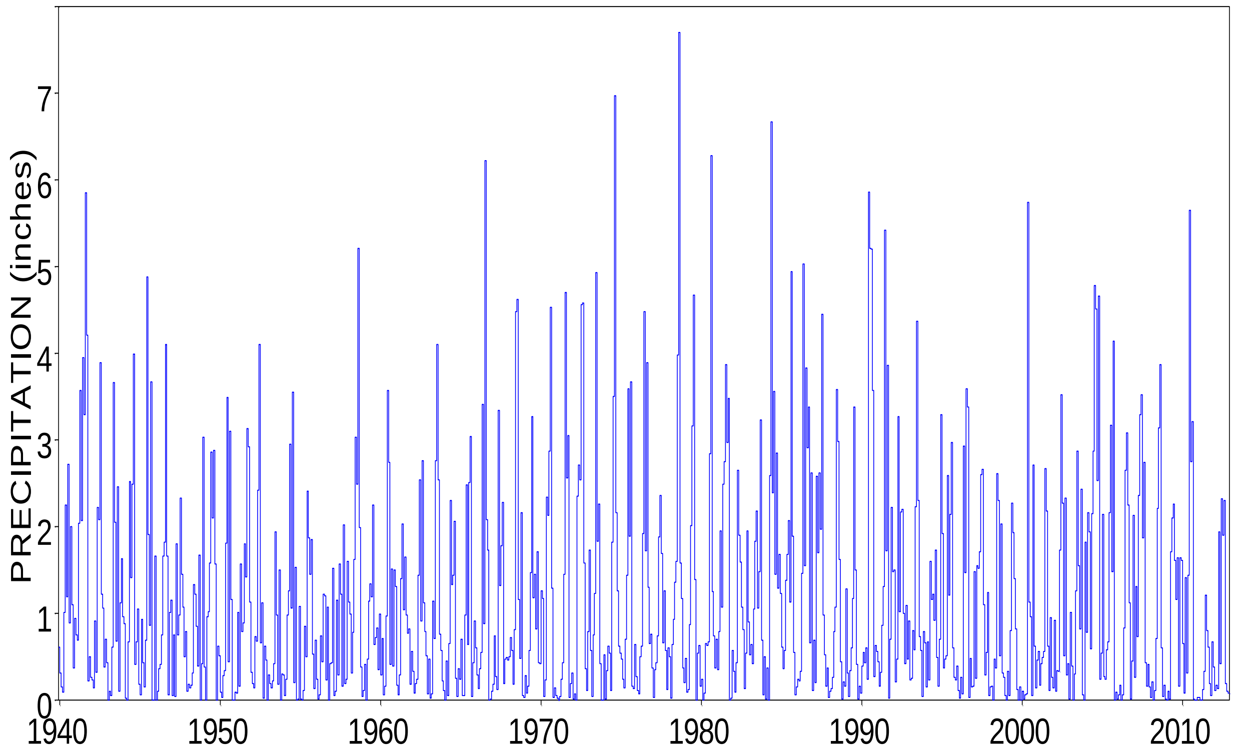
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 701



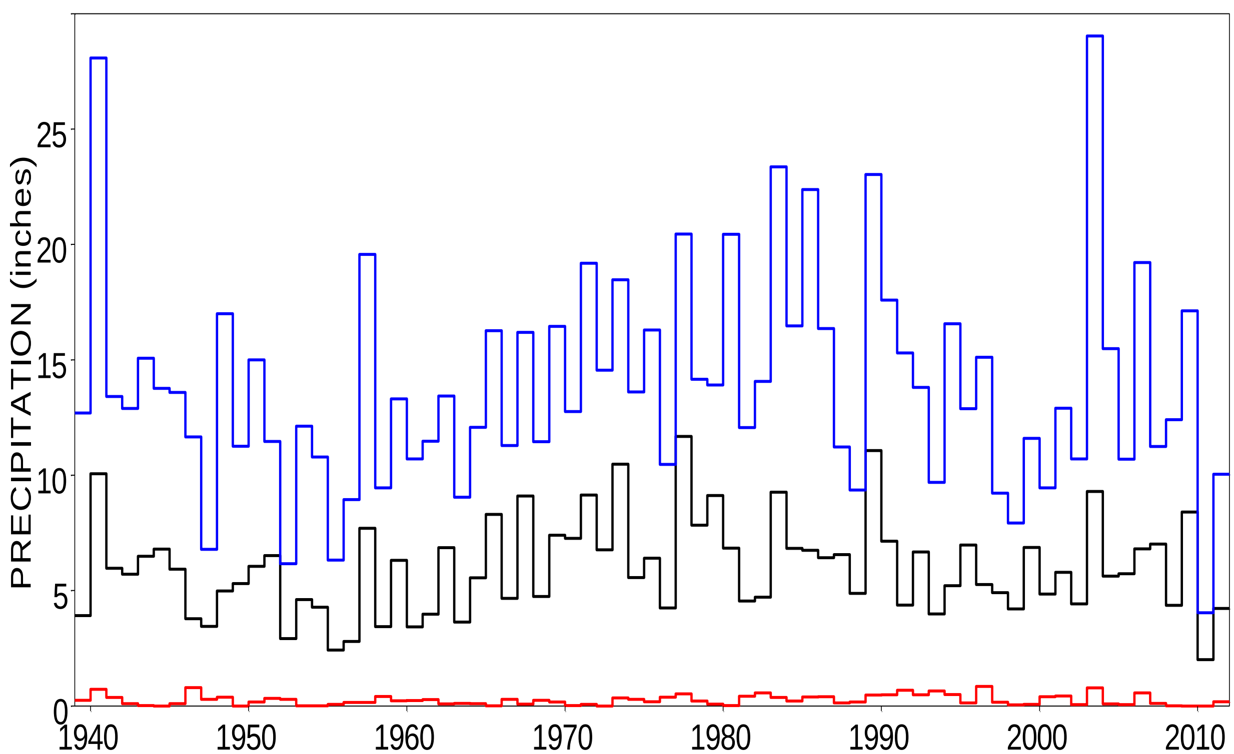
Monthly Precipitation for Quadrangle 702



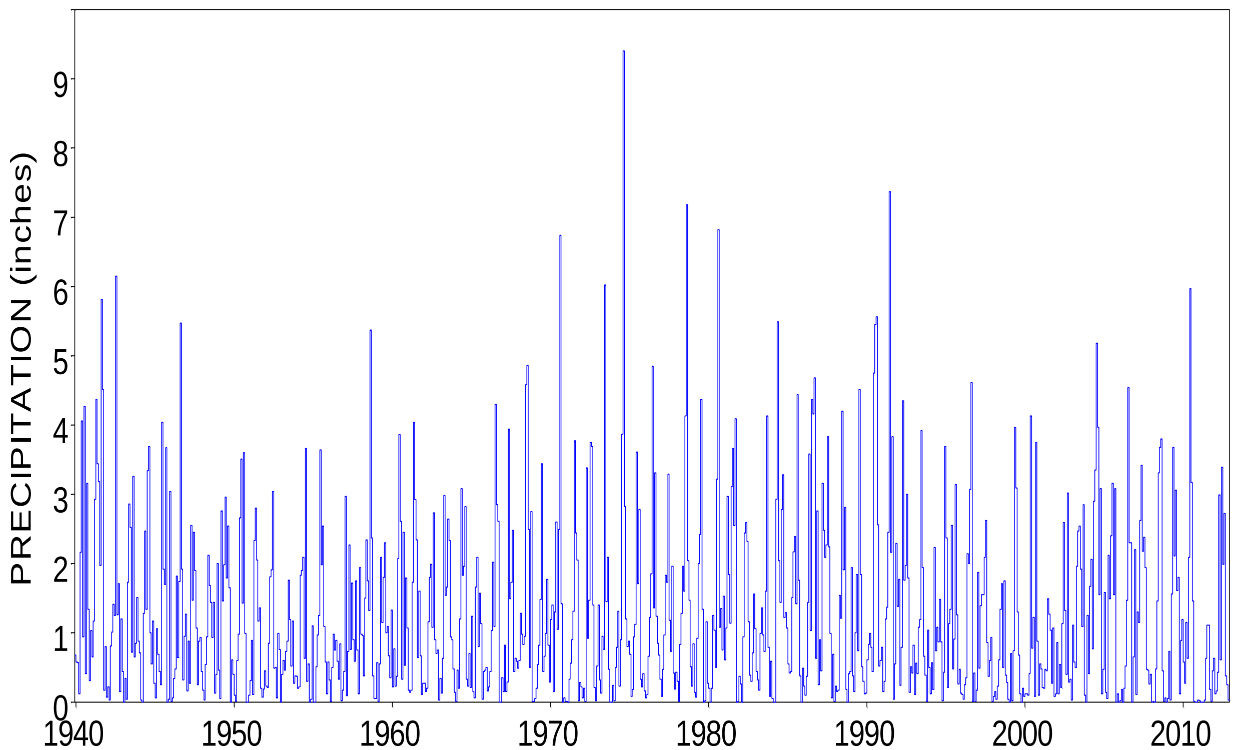
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 702



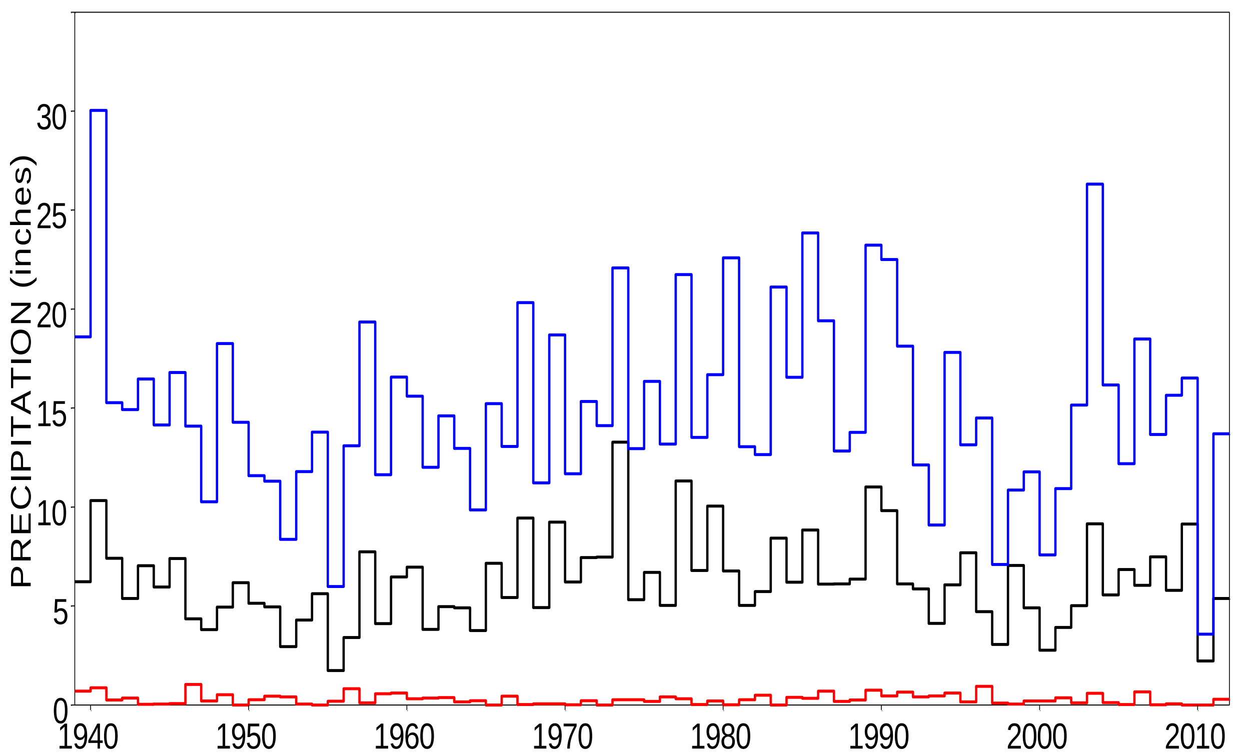
Monthly Precipitation for Quadrangle 703



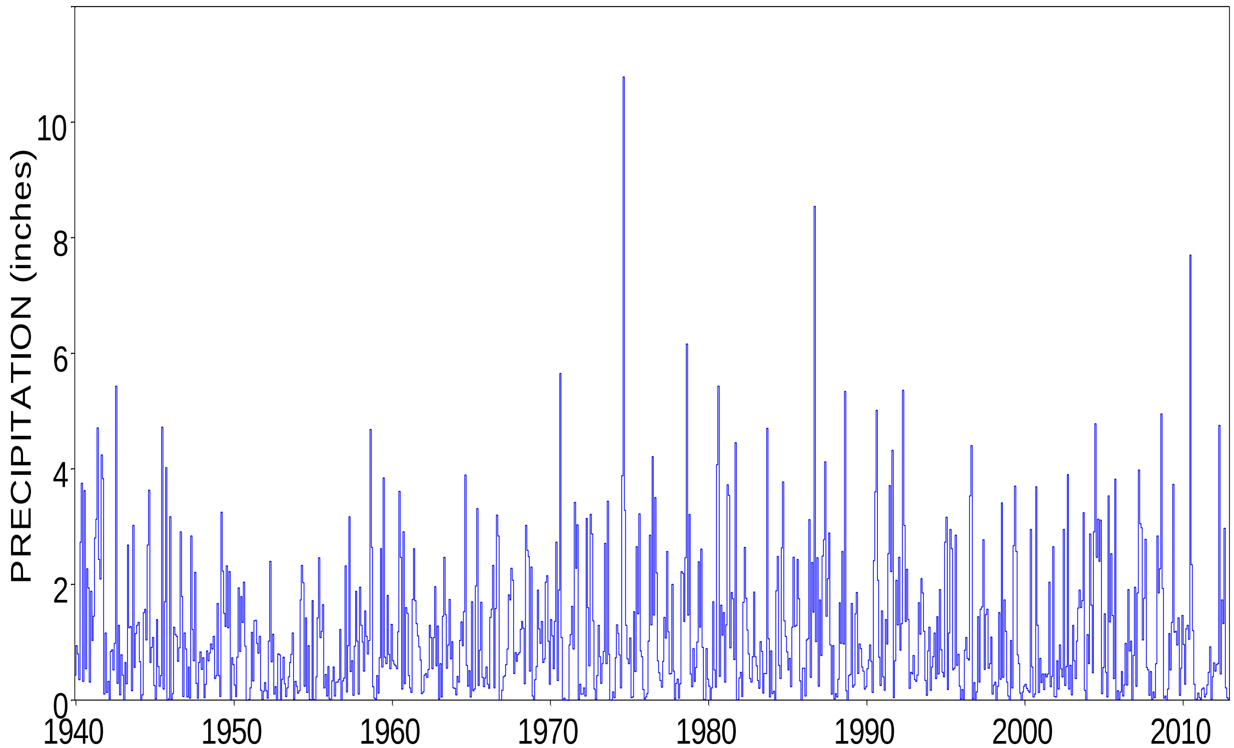
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 703



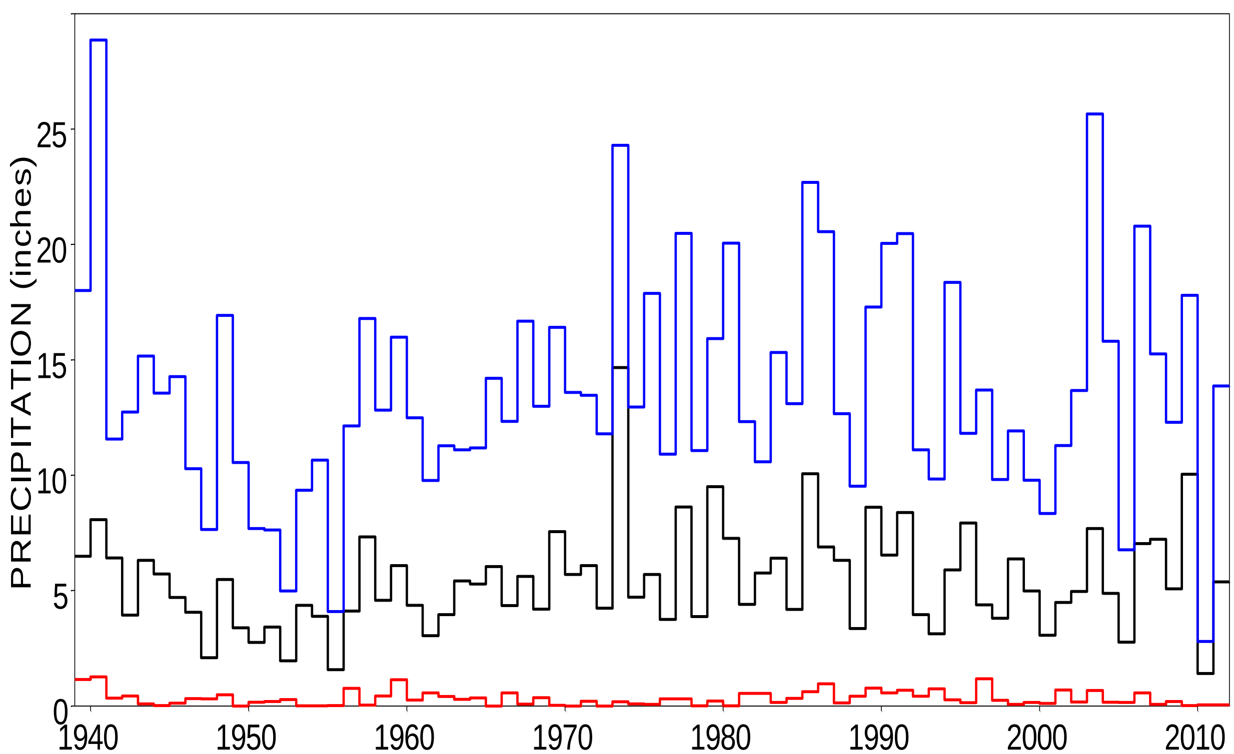
Monthly Precipitation for Quadrangle 704



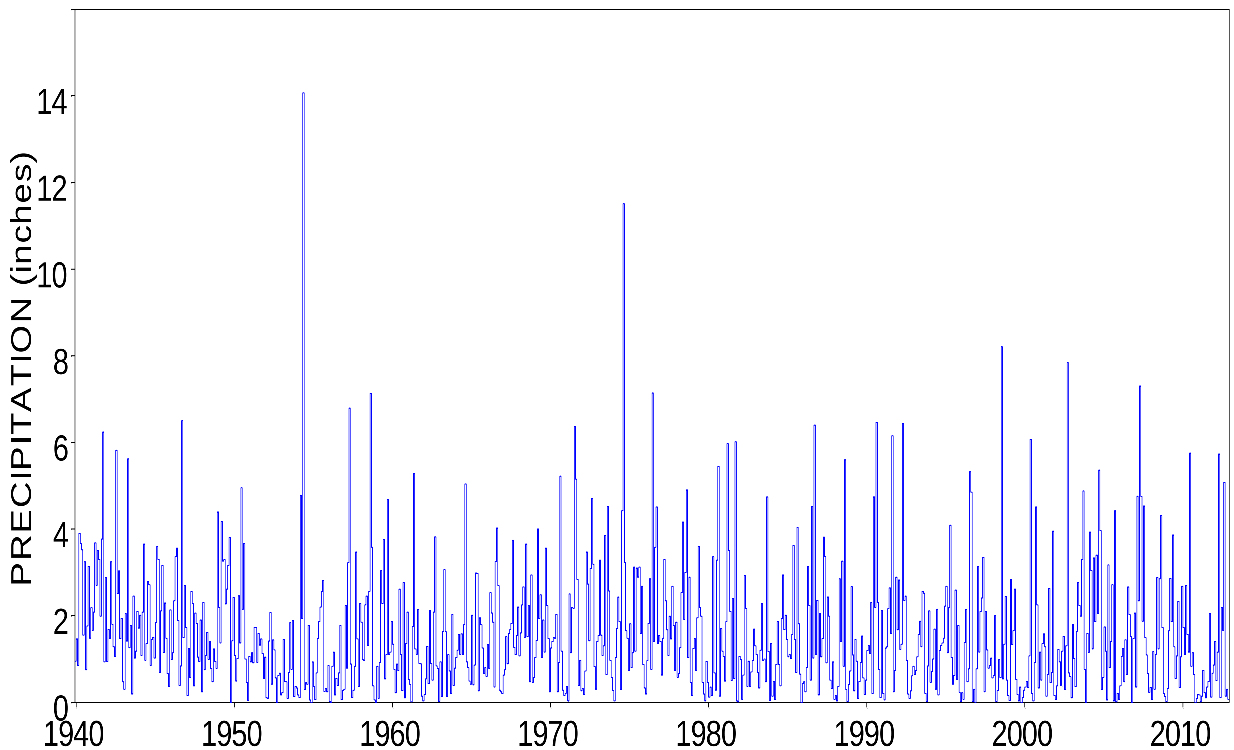
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 704



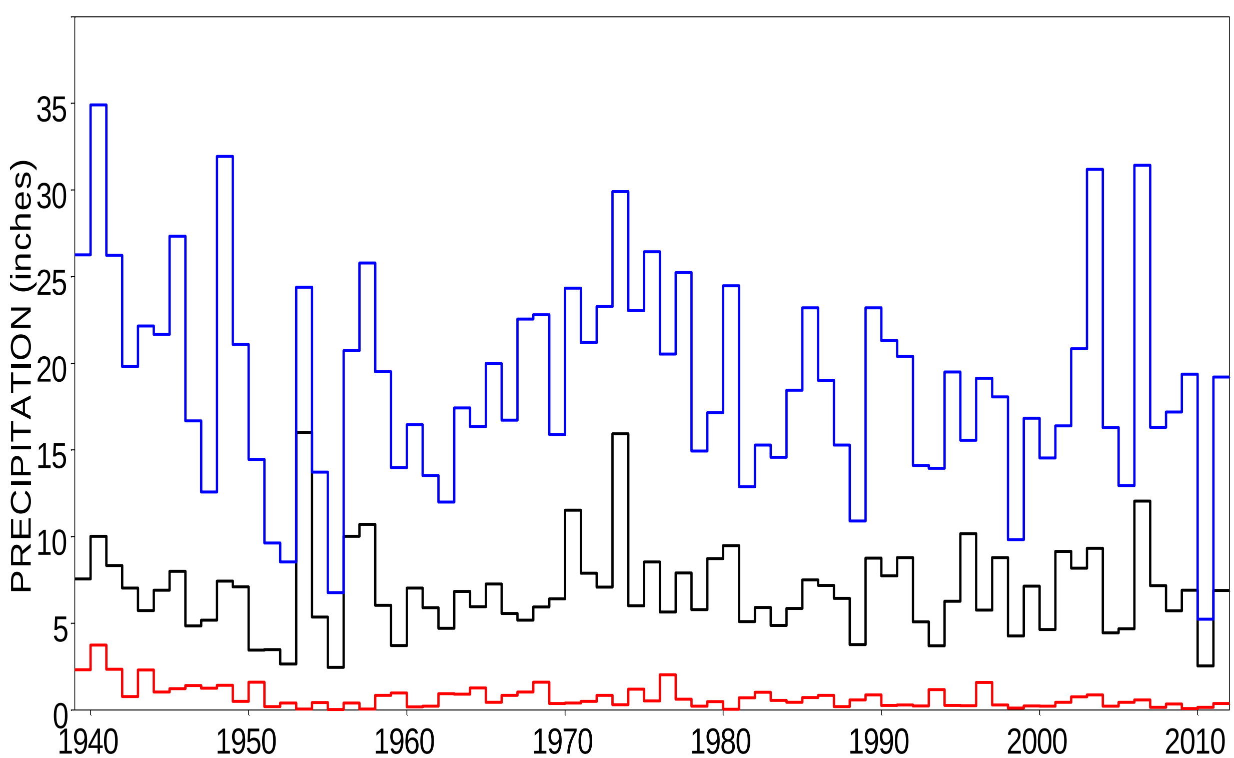
Monthly Precipitation for Quadrangle 705



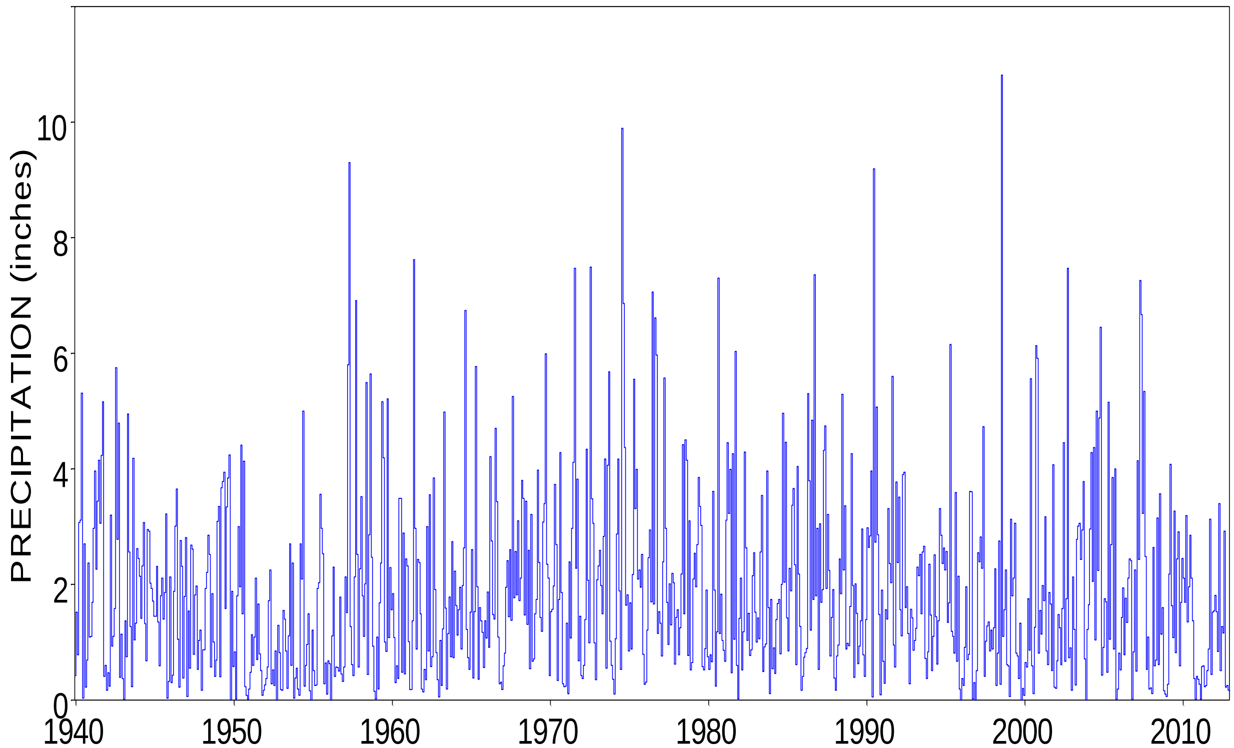
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 705



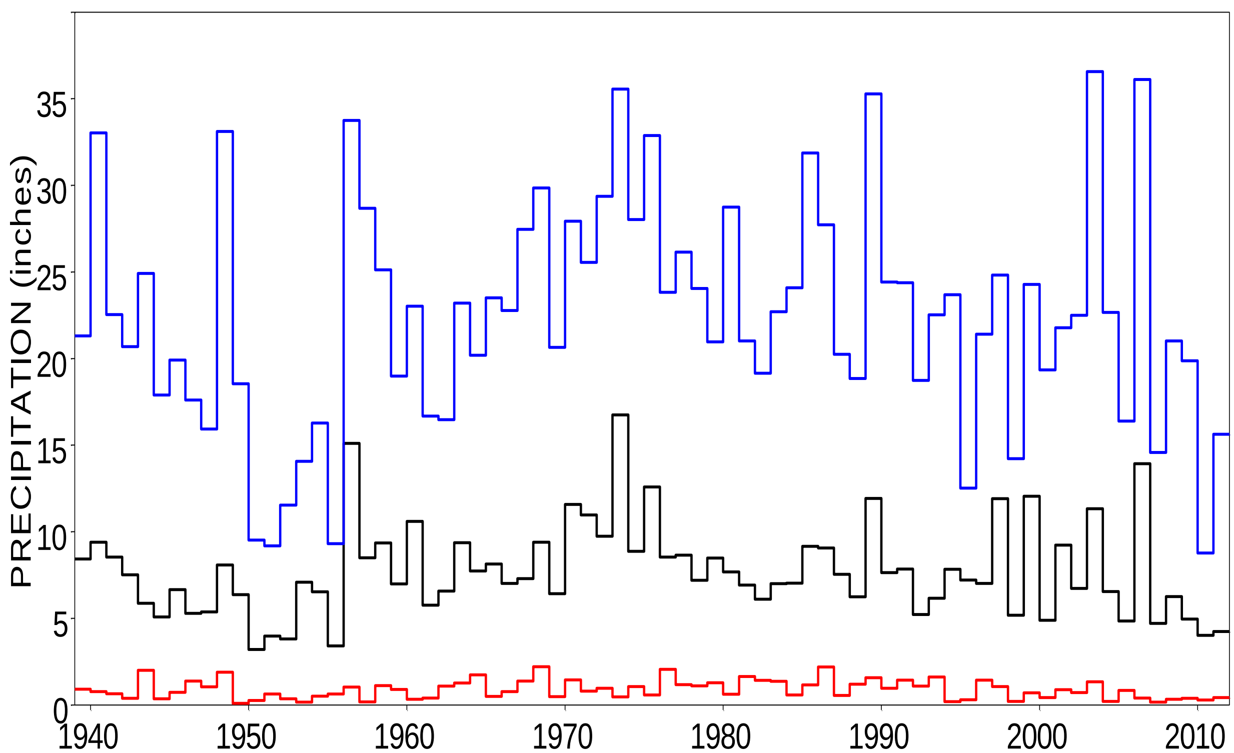
Monthly Precipitation for Quadrangle 706



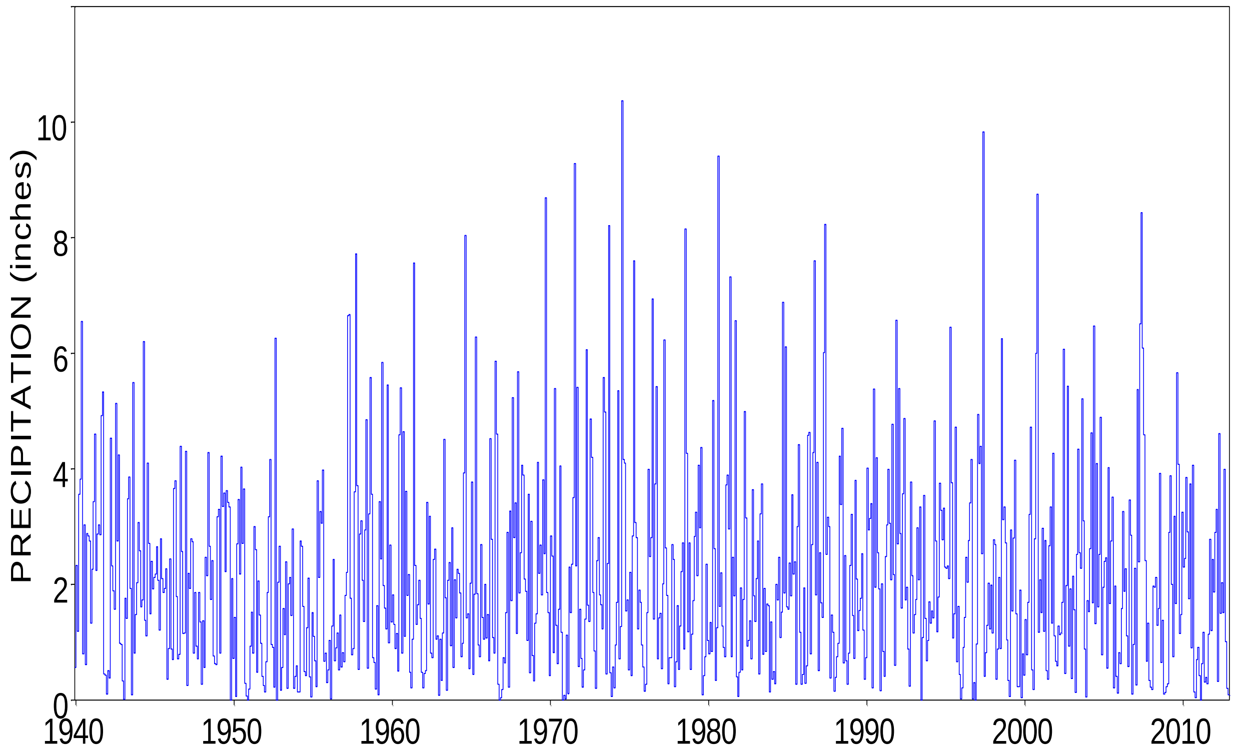
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 706



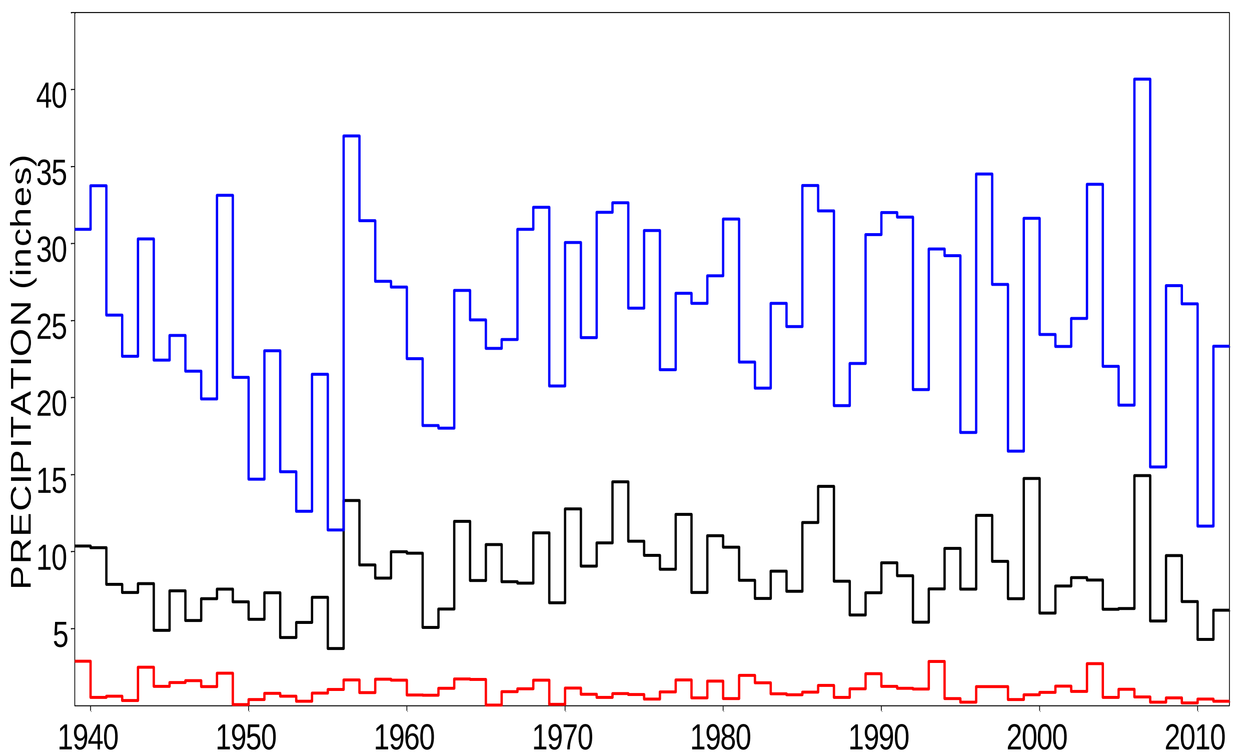
Monthly Precipitation for Quadrangle 707



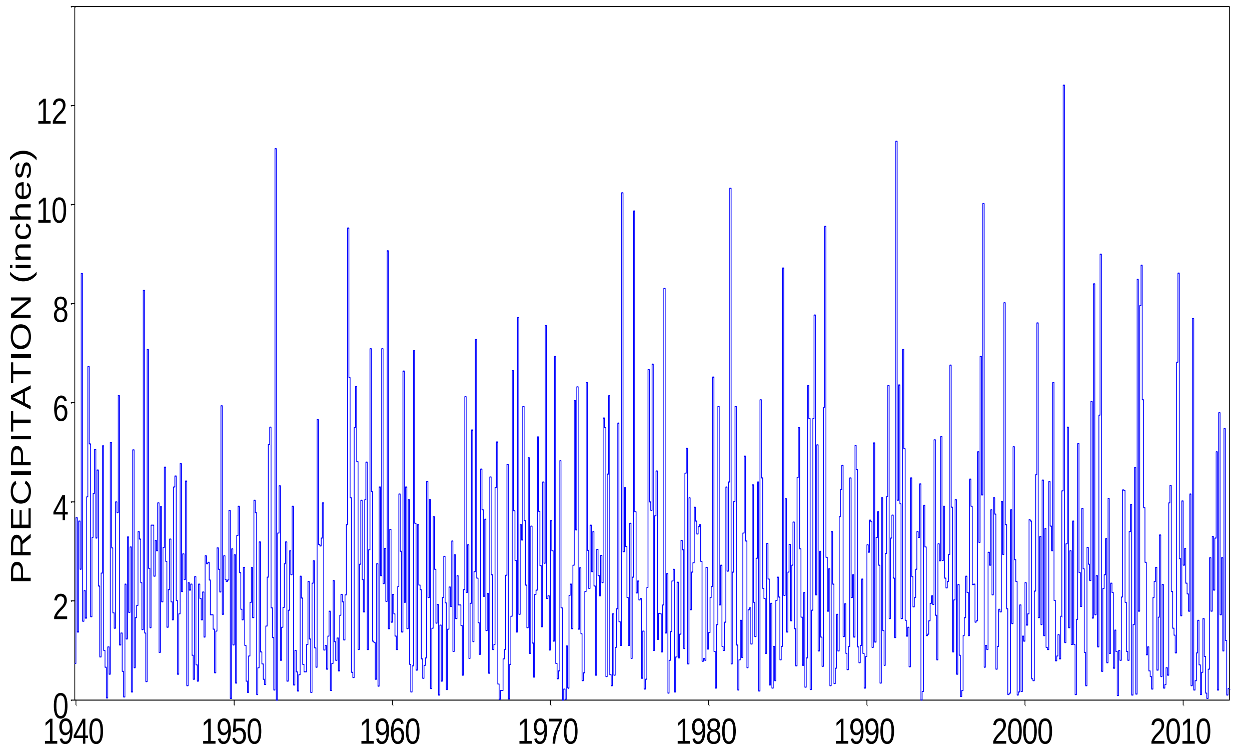
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 707



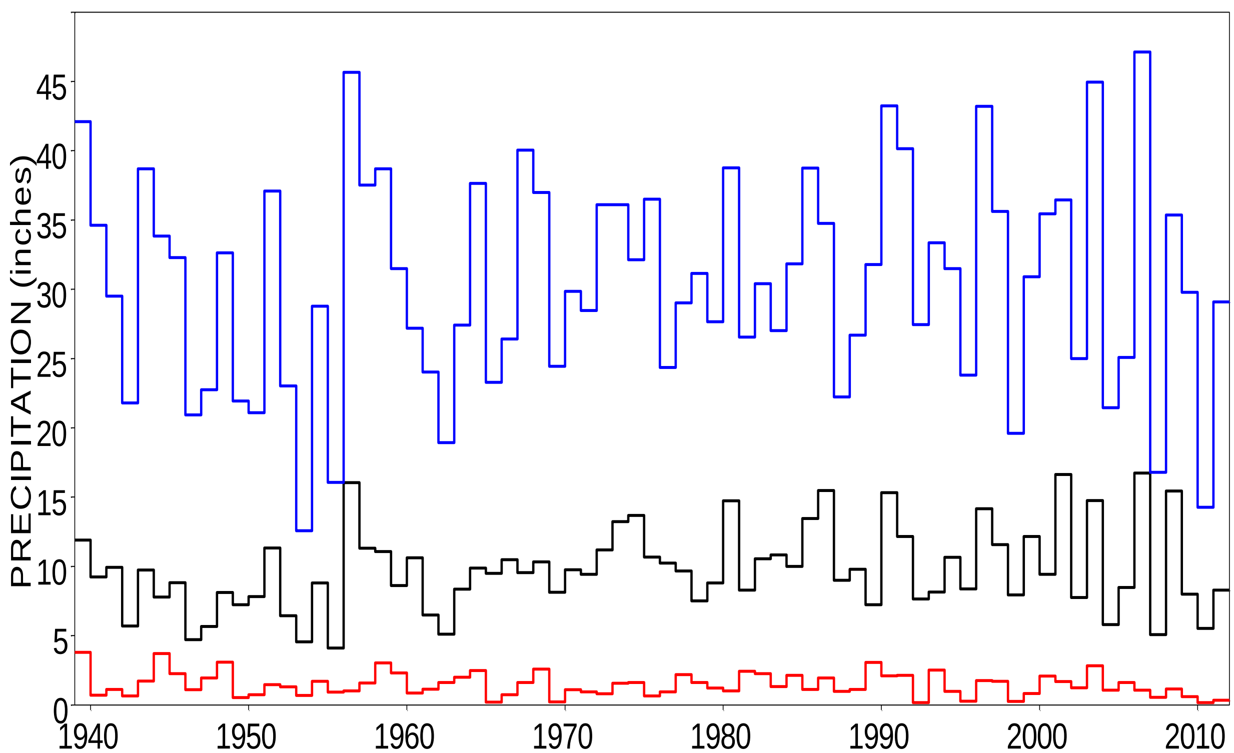
Monthly Precipitation for Quadrangle 708



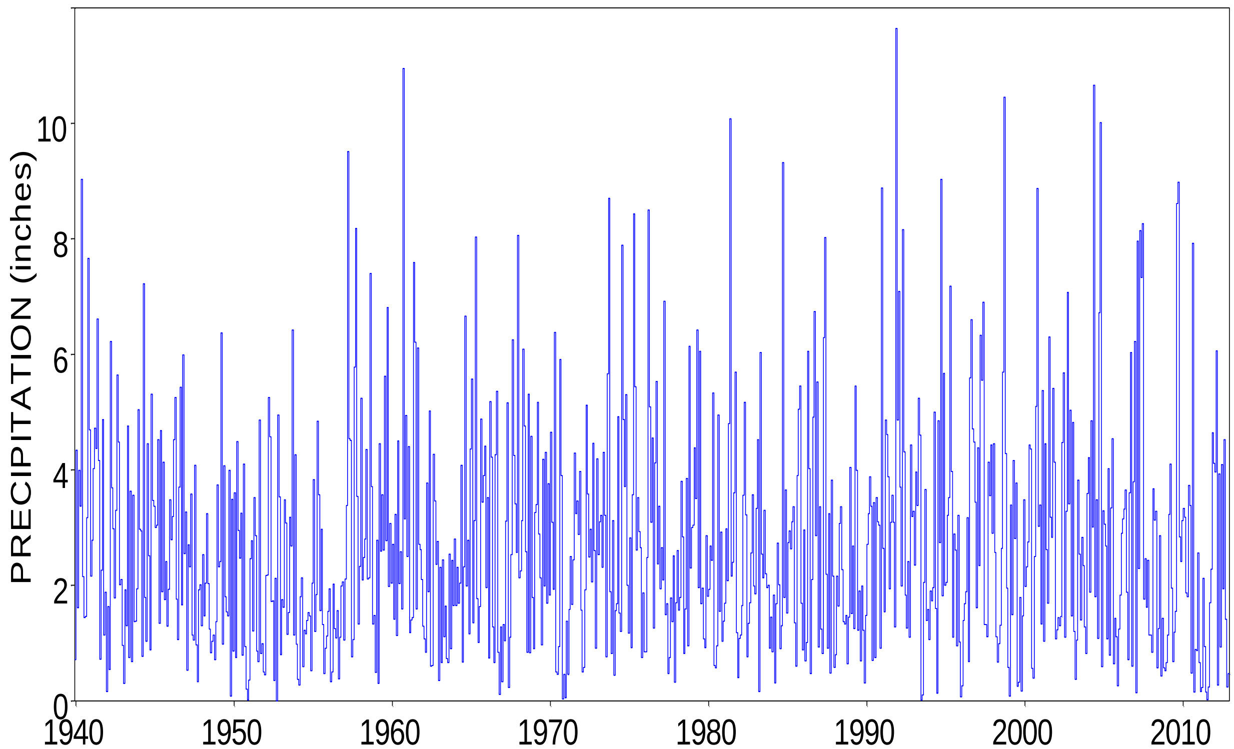
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 708



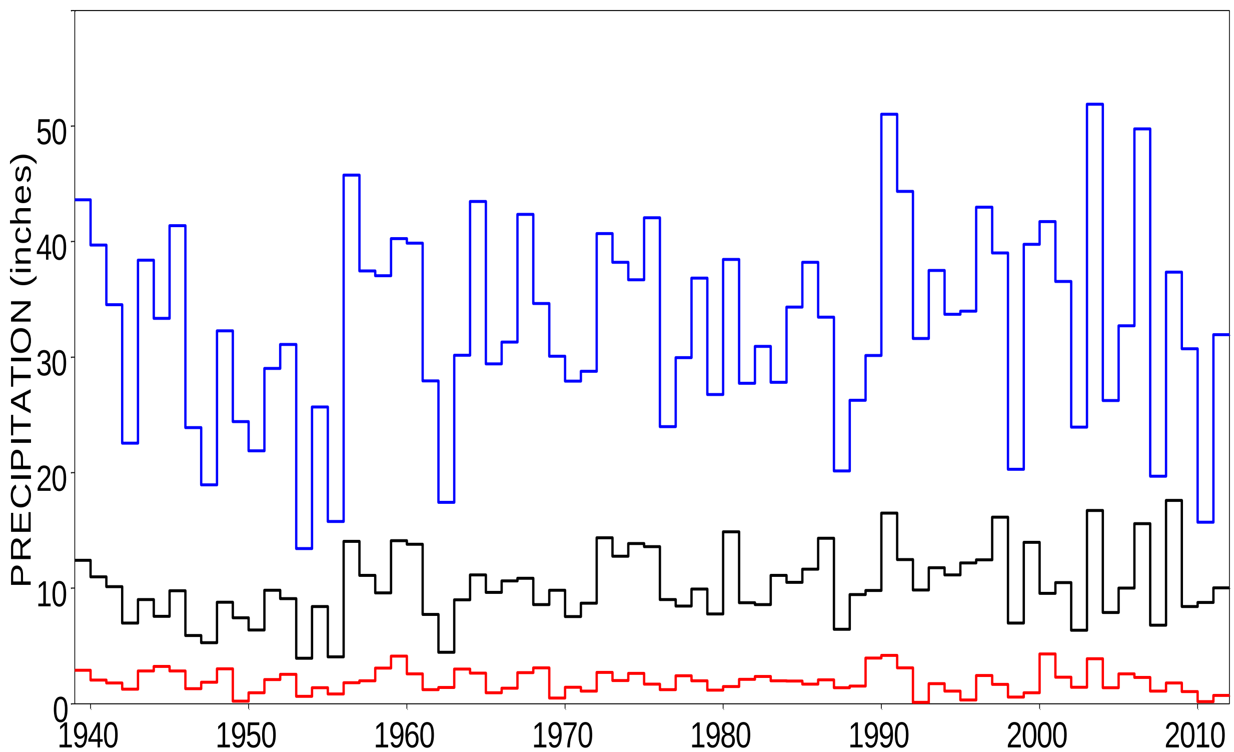
Monthly Precipitation for Quadrangle 709



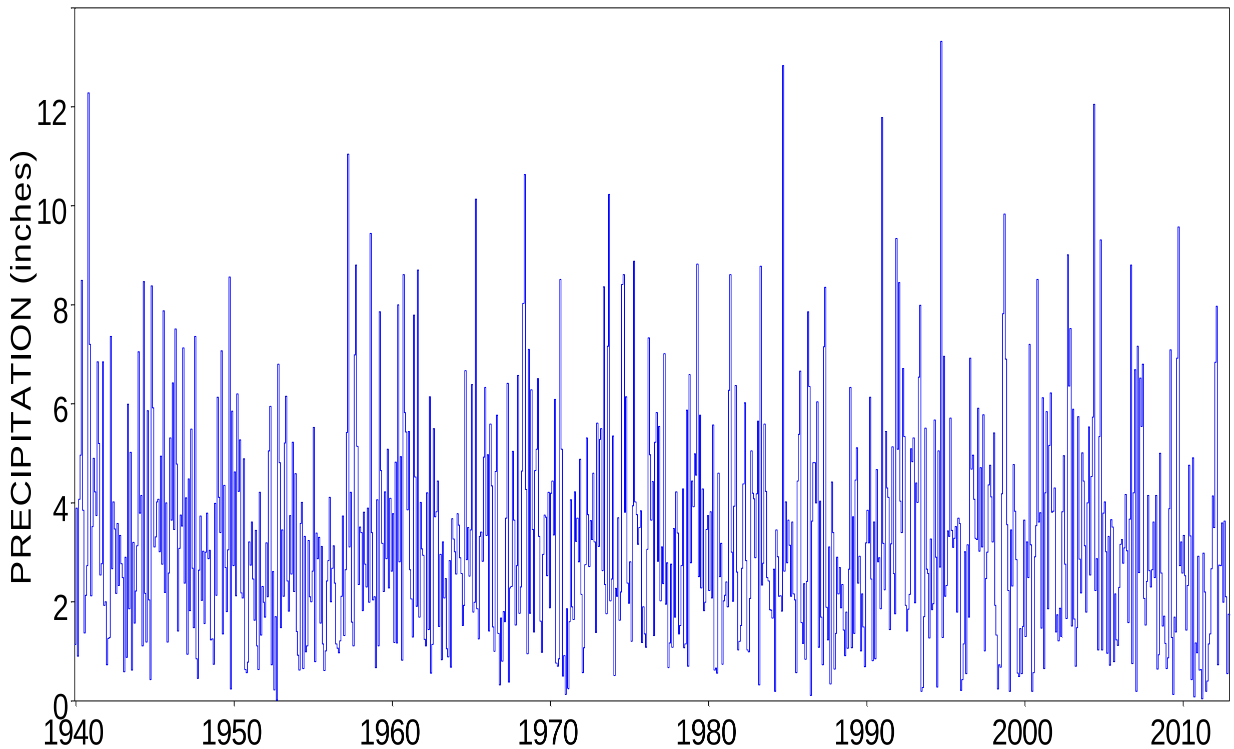
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 709



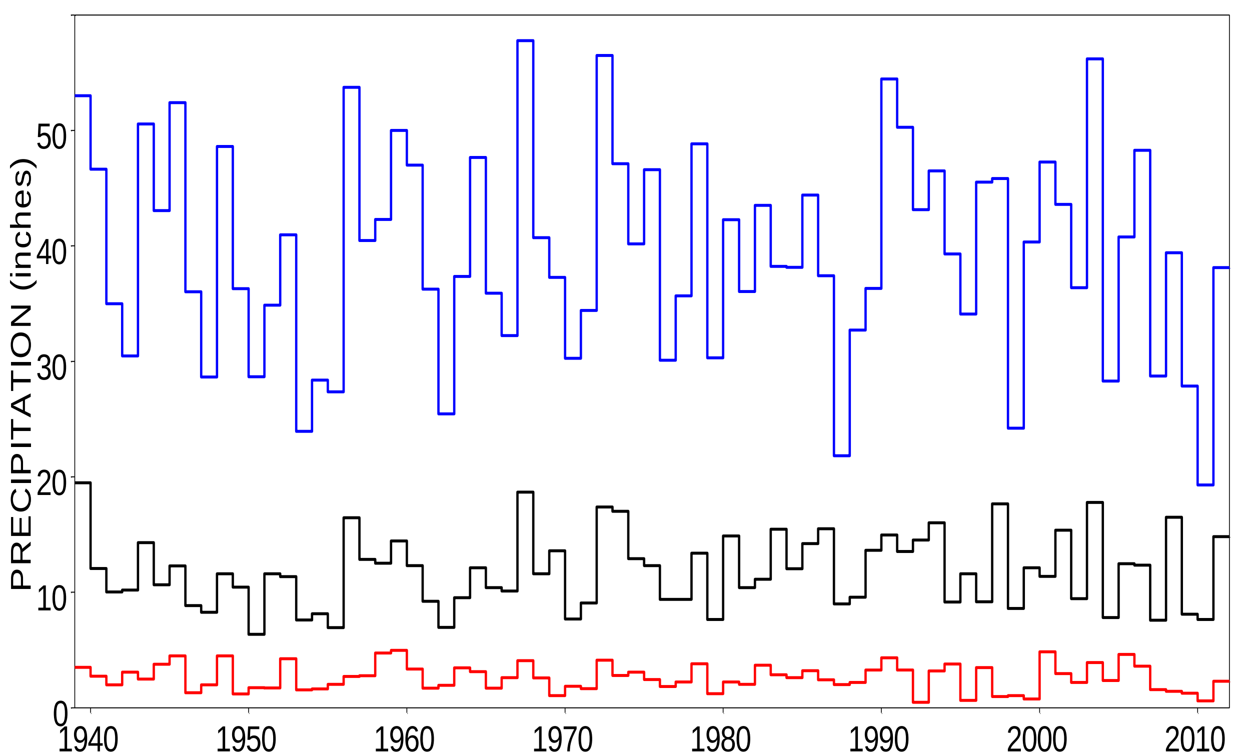
Monthly Precipitation for Quadrangle 710



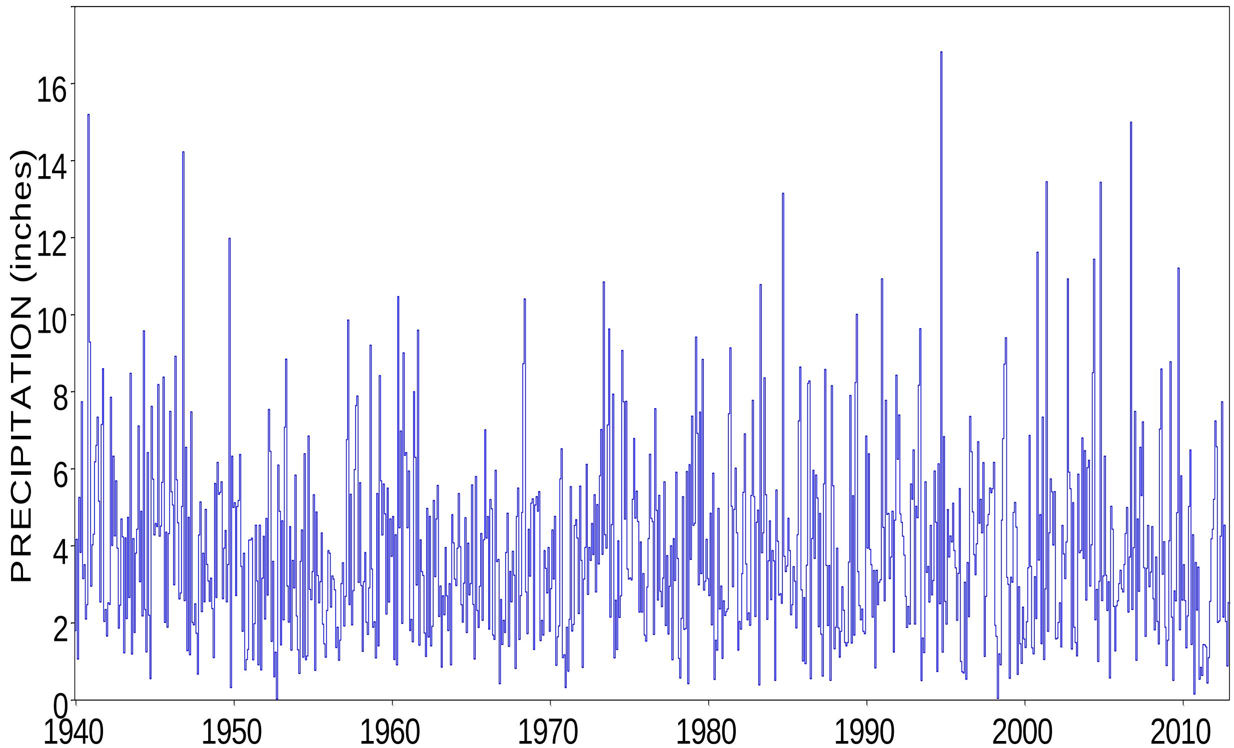
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 710



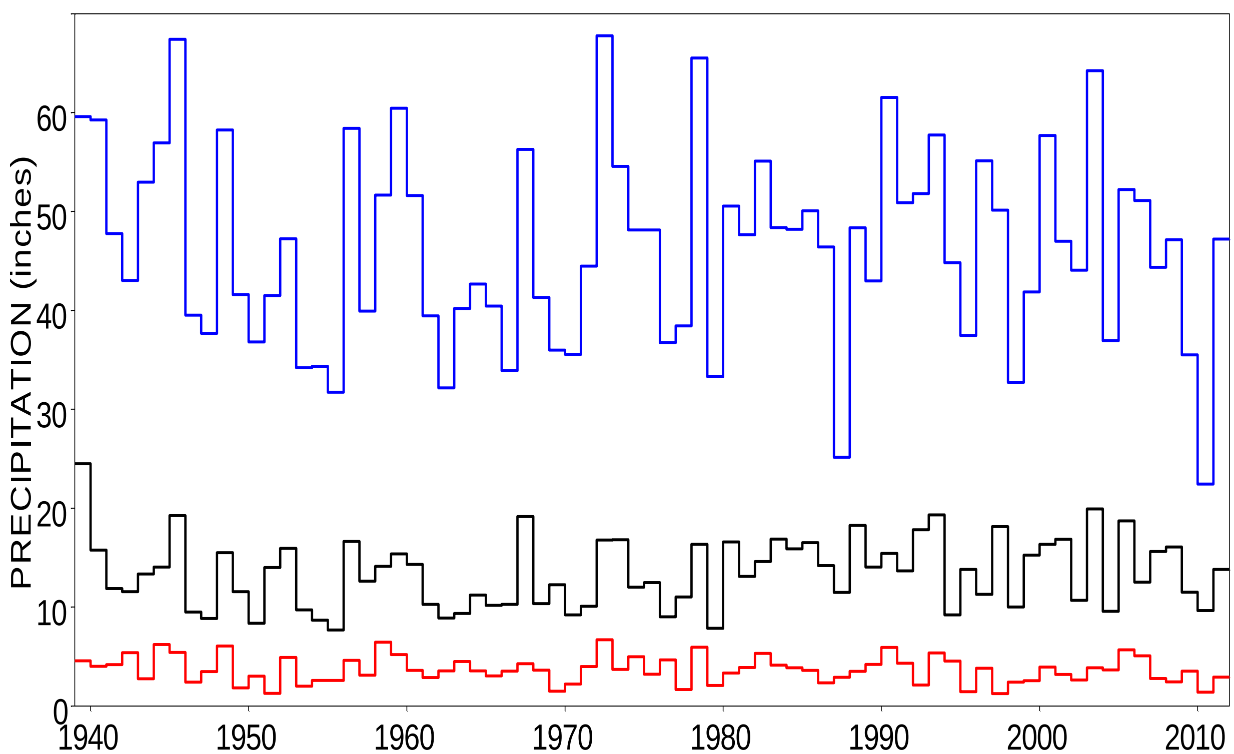
Monthly Precipitation for Quadrangle 711



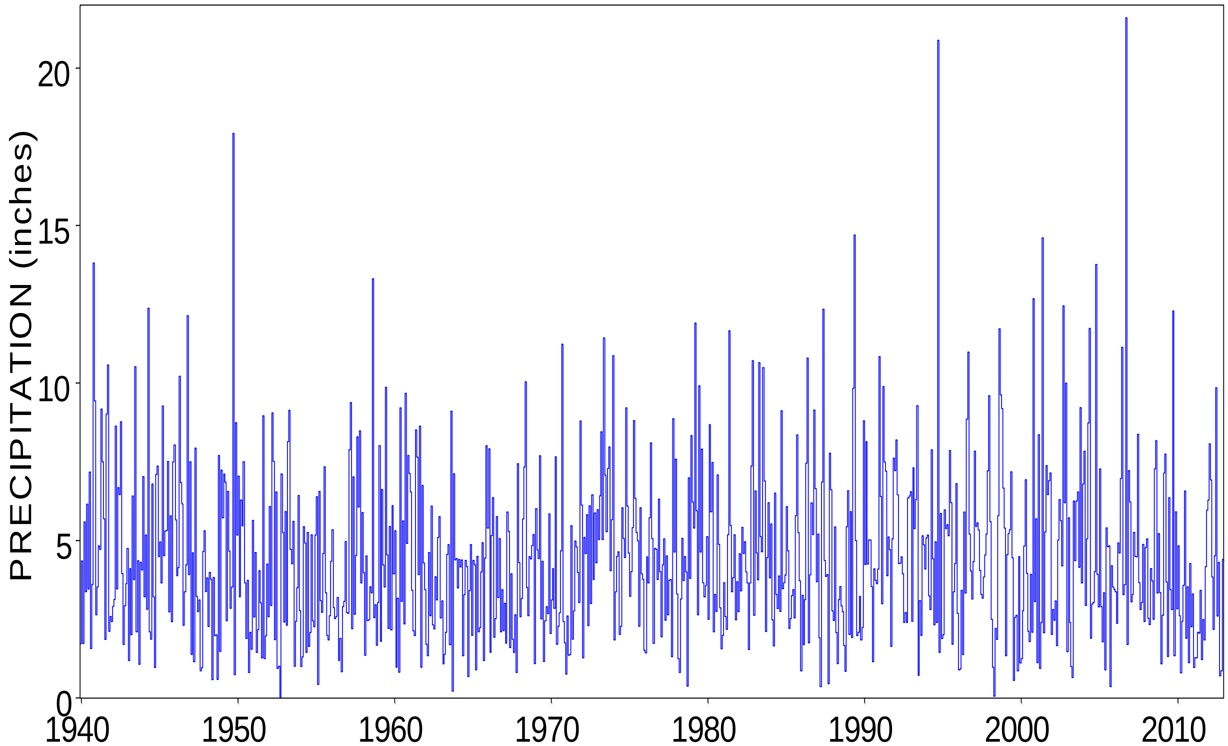
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 711



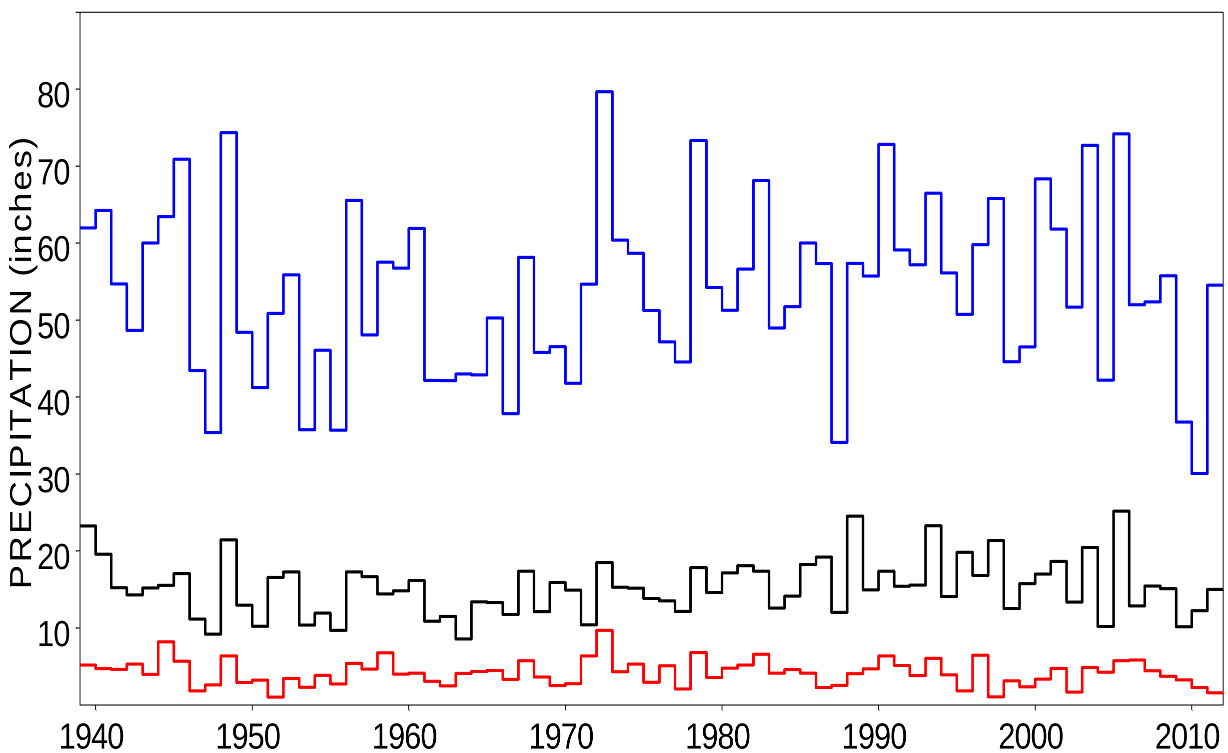
Monthly Precipitation for Quadrangle 712



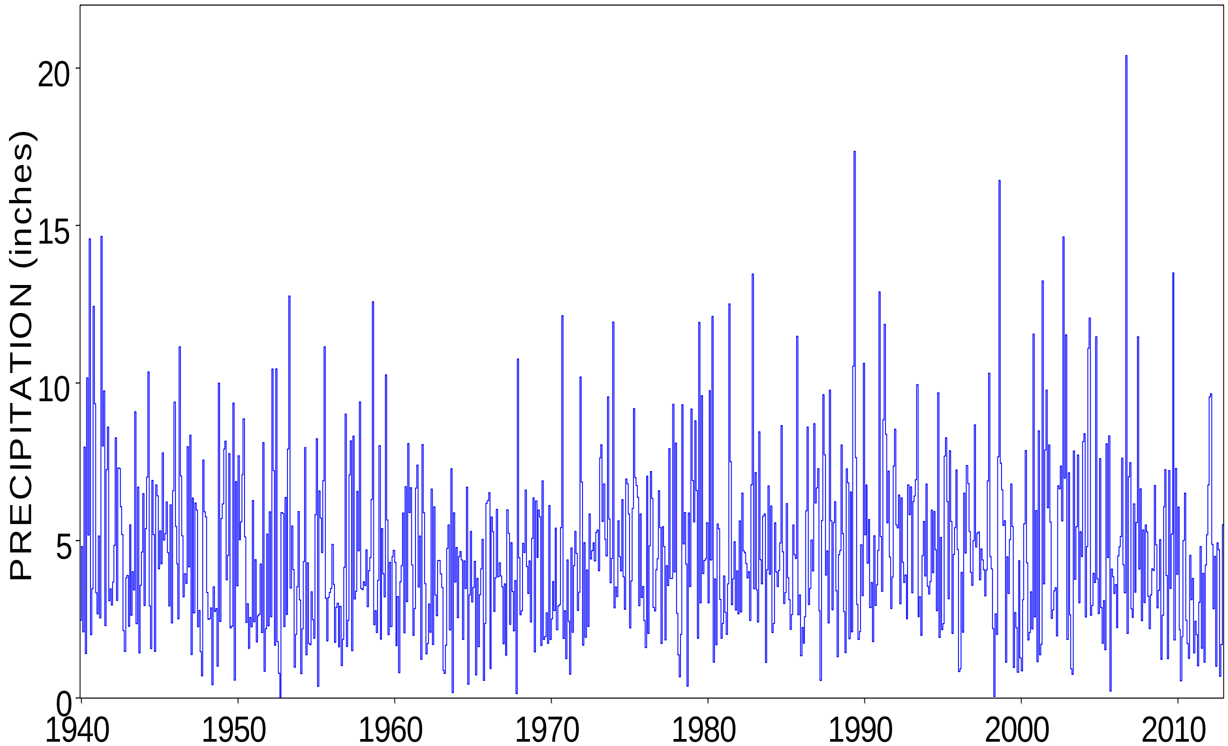
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 712



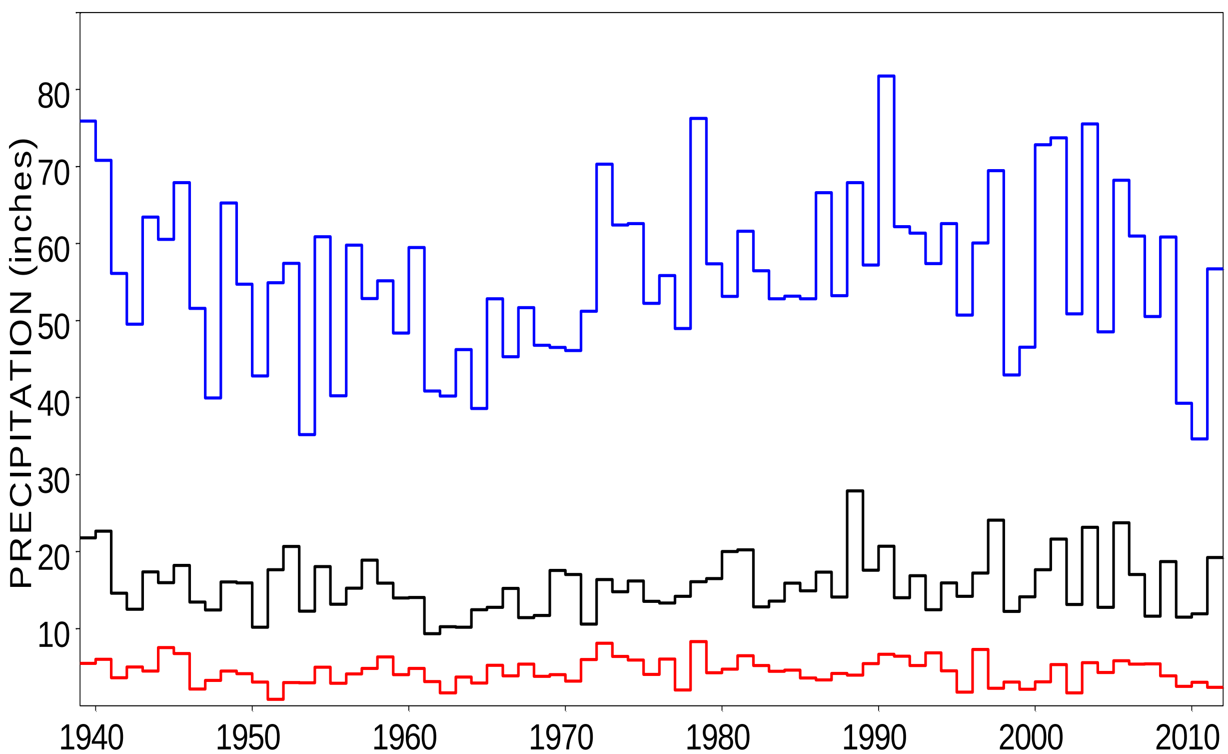
Monthly Precipitation for Quadrangle 713



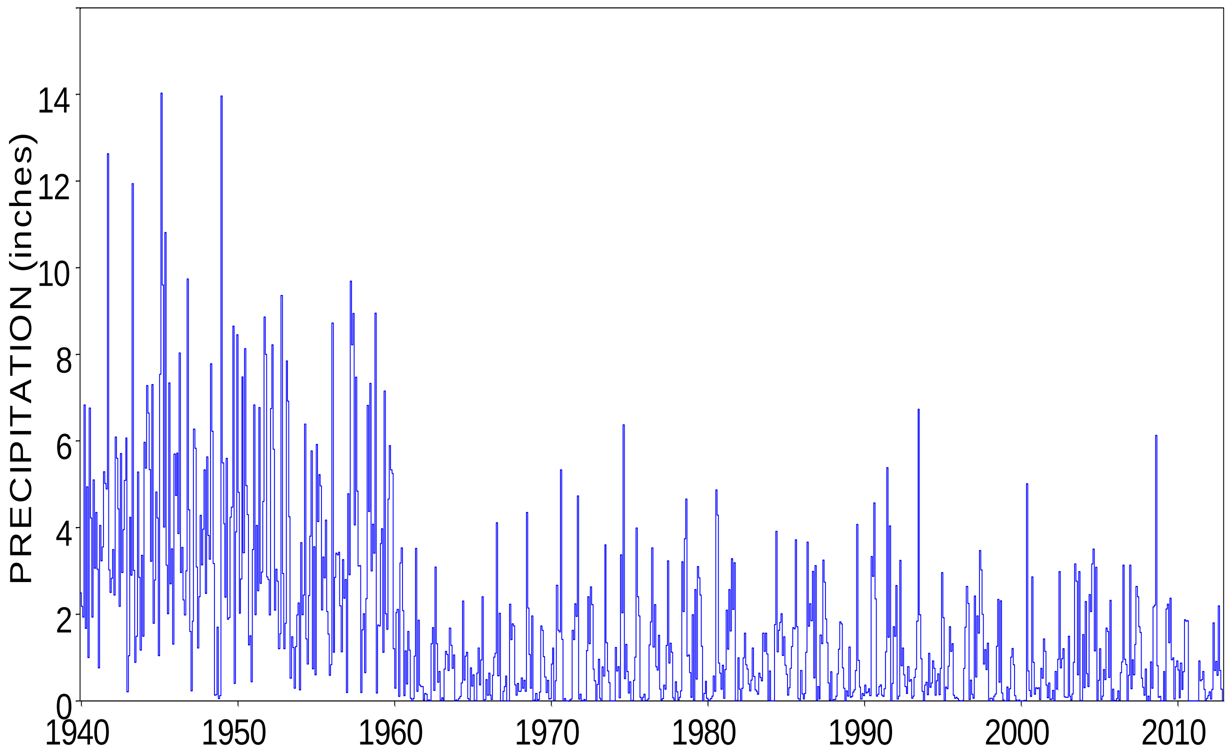
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 713



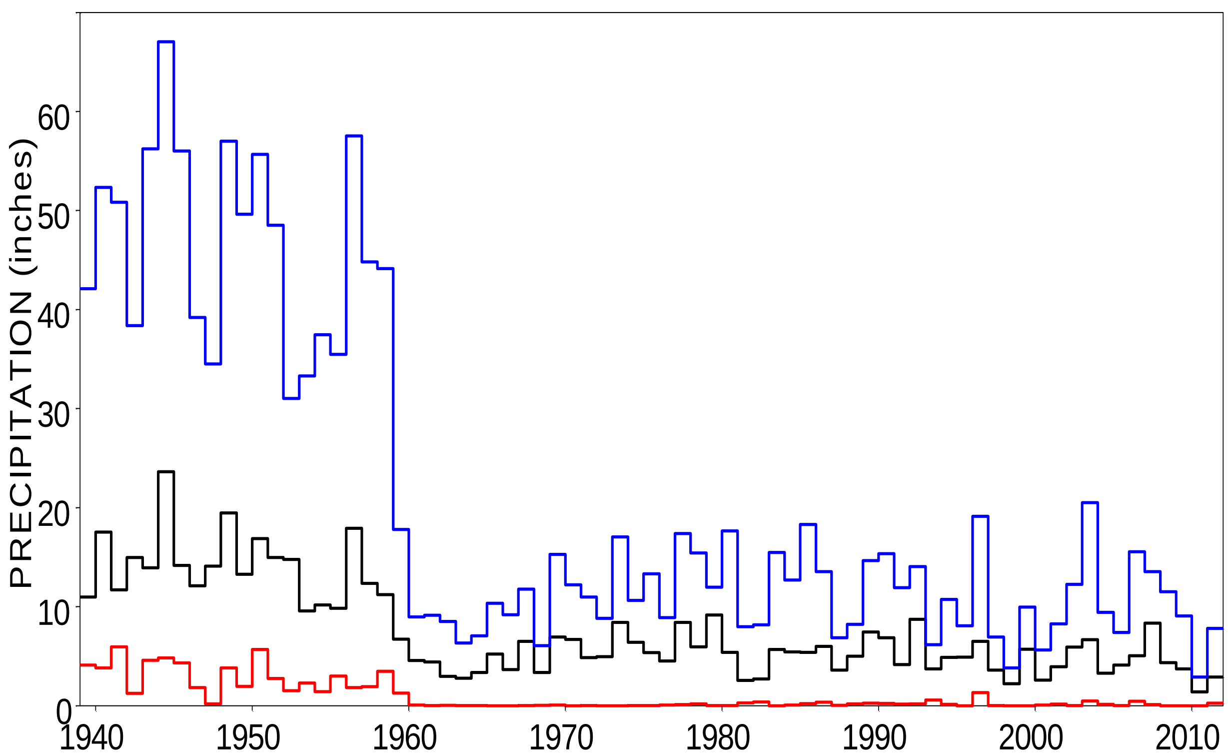
Monthly Precipitation for Quadrangle 714



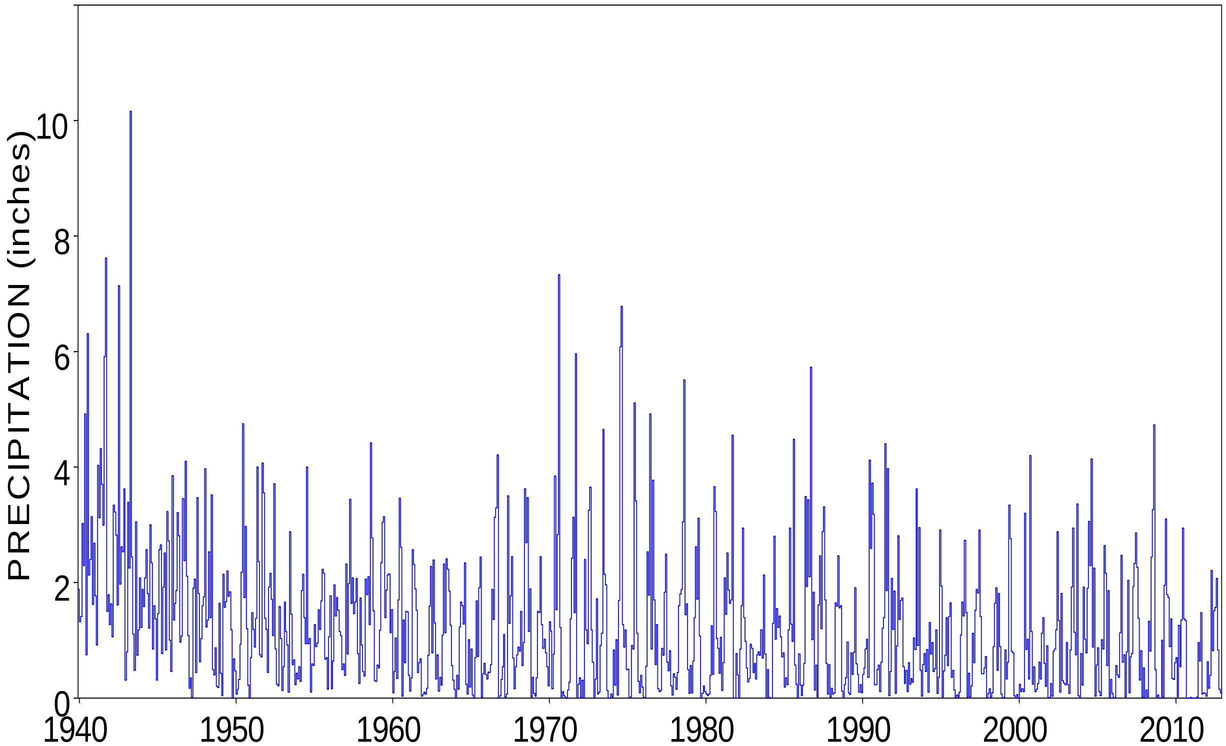
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 714



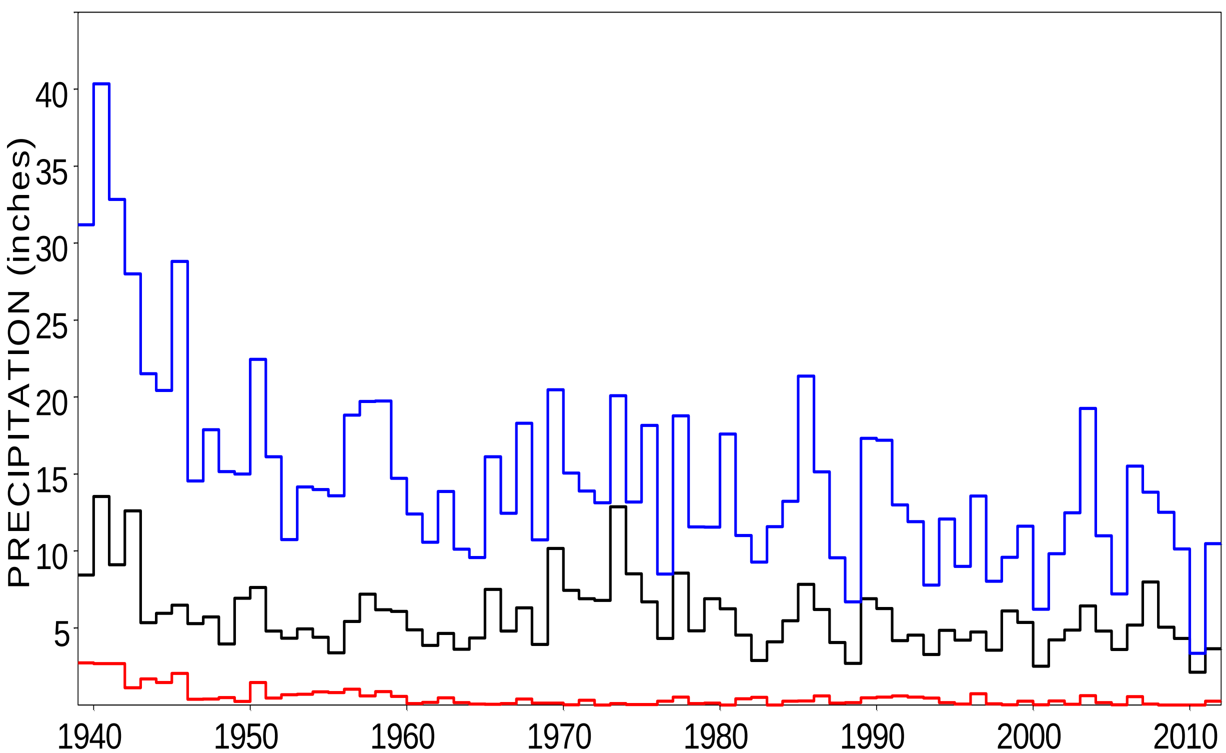
Monthly Precipitation for Quadrangle 803



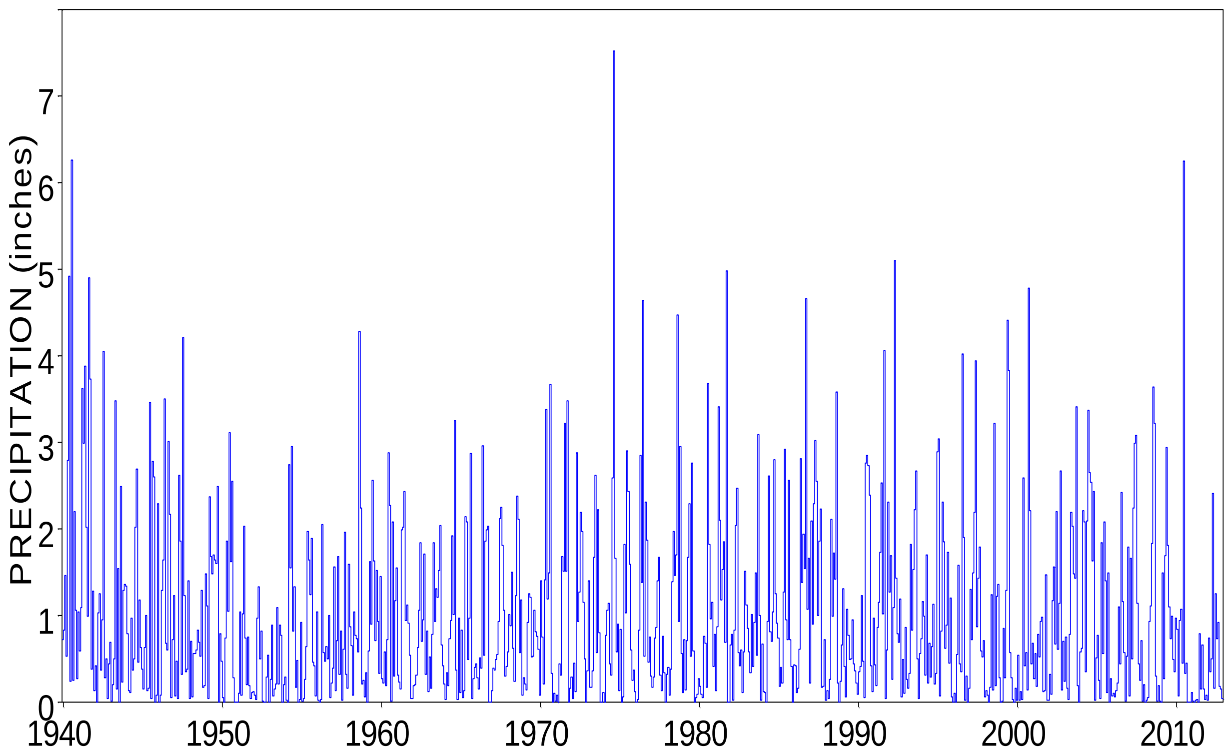
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 803



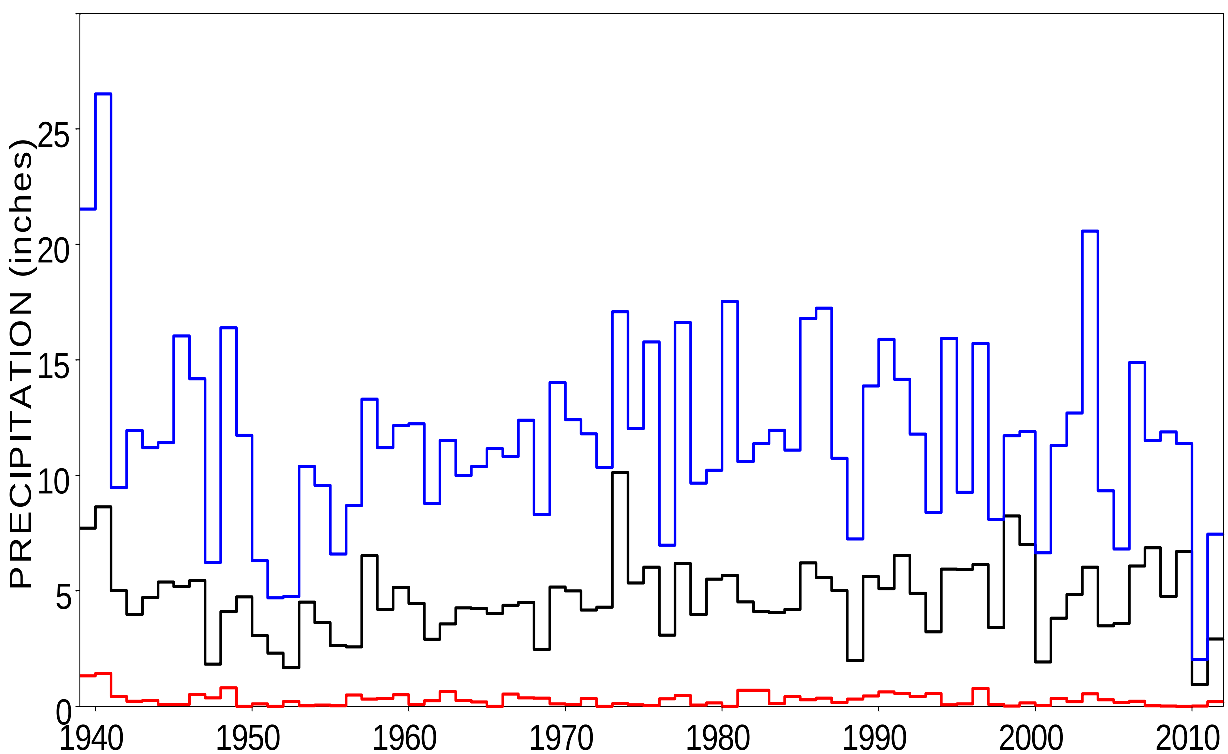
Monthly Precipitation for Quadrangle 804



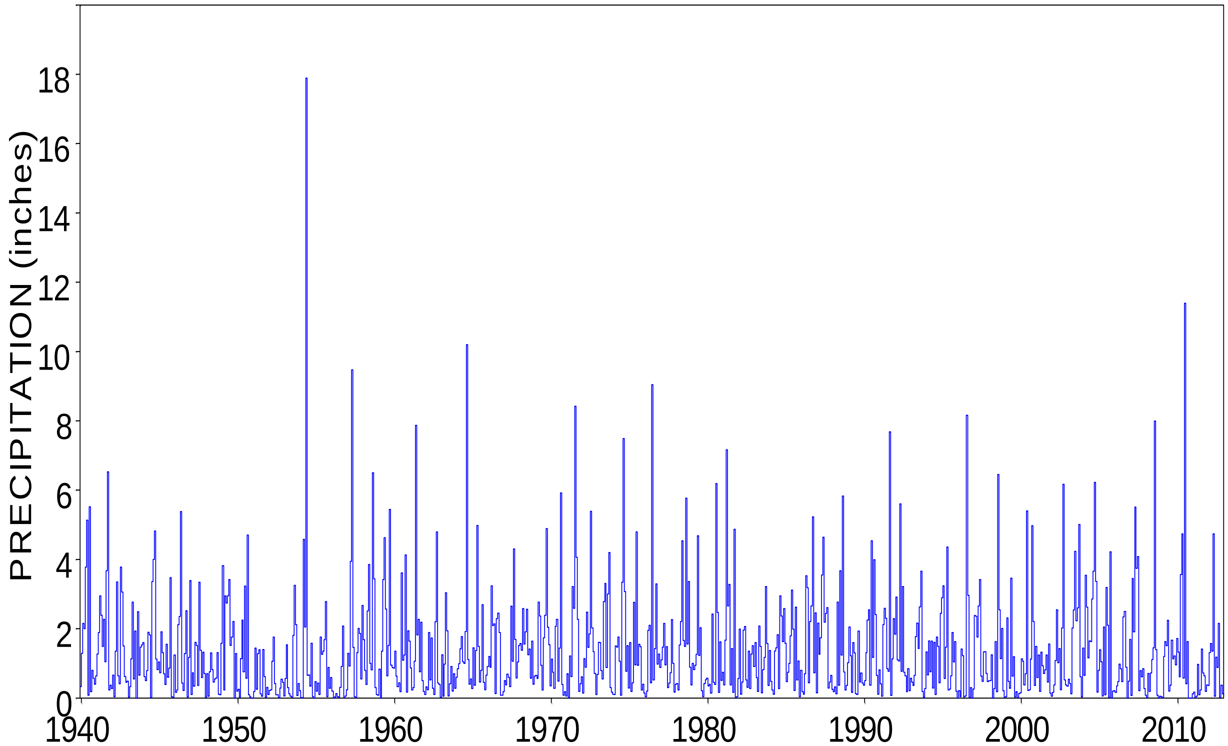
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 804



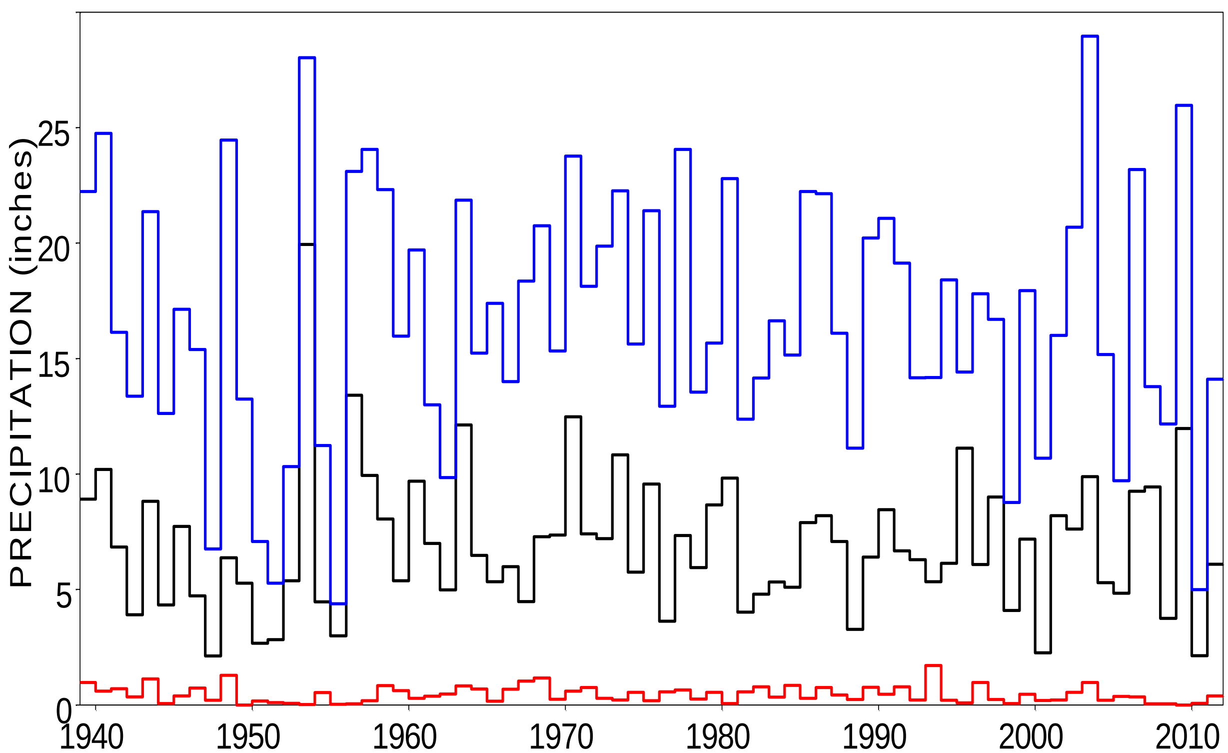
Monthly Precipitation for Quadrangle 805



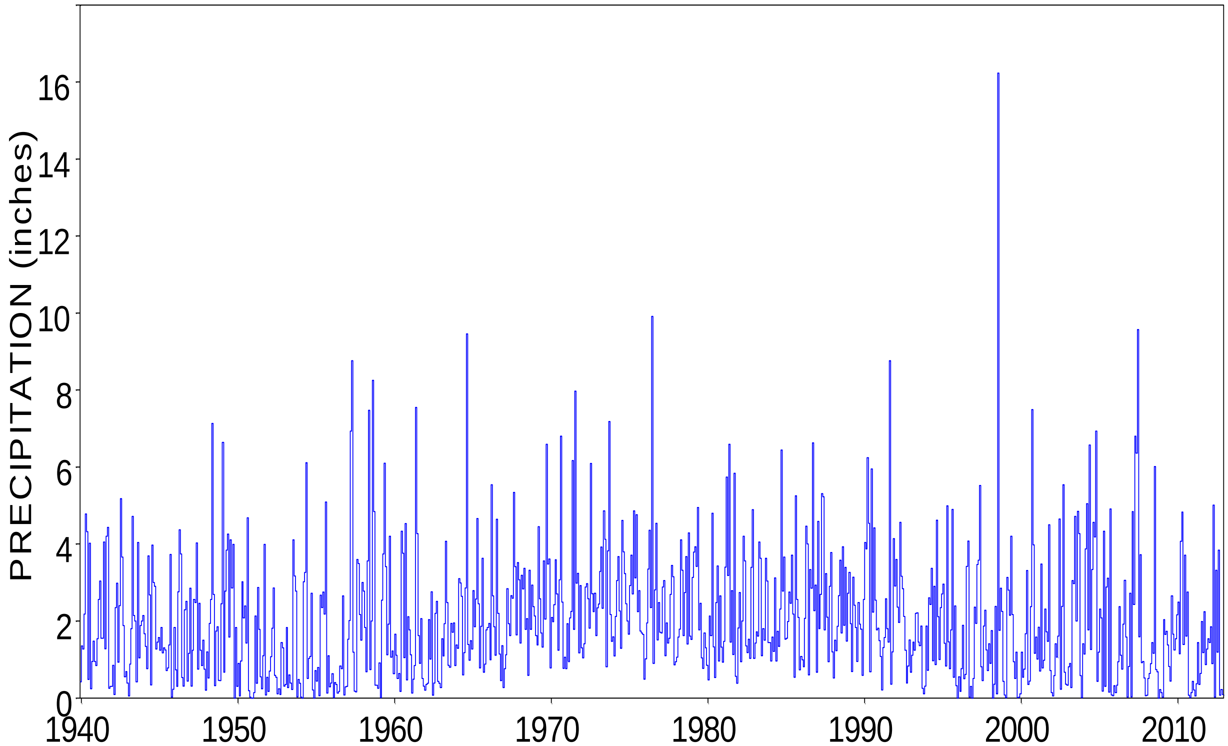
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 805



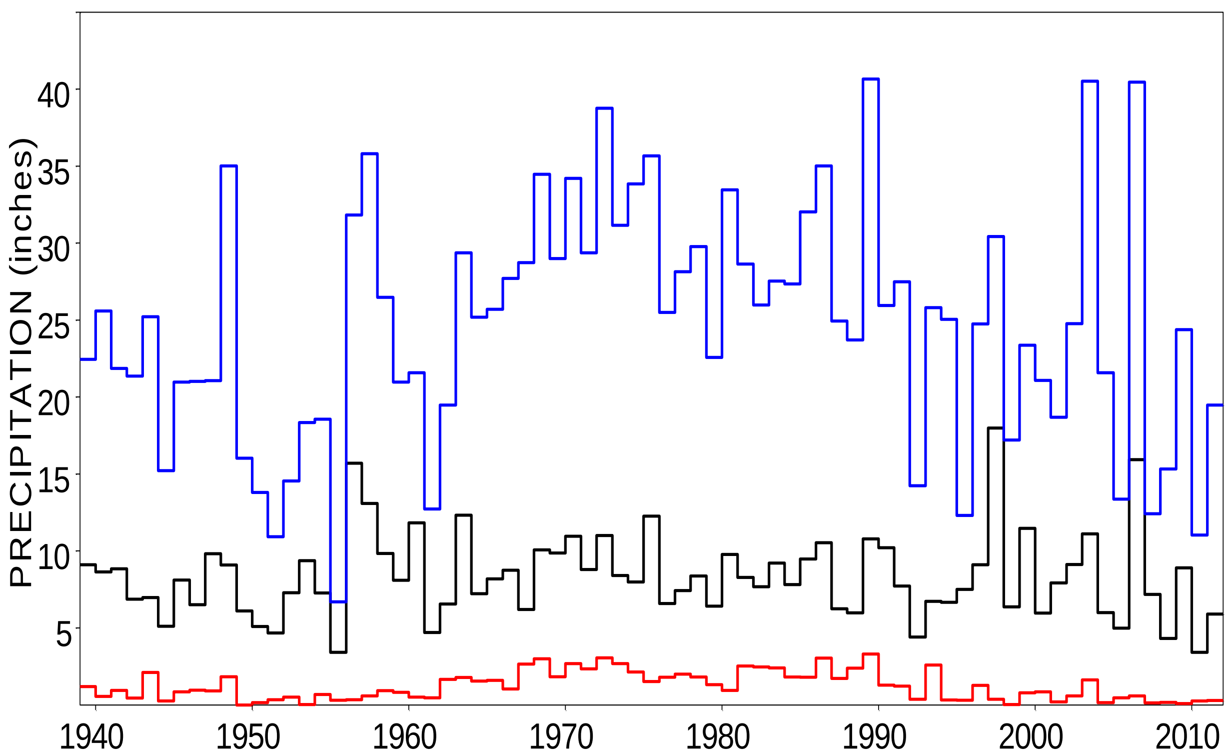
Monthly Precipitation for Quadrangle 806



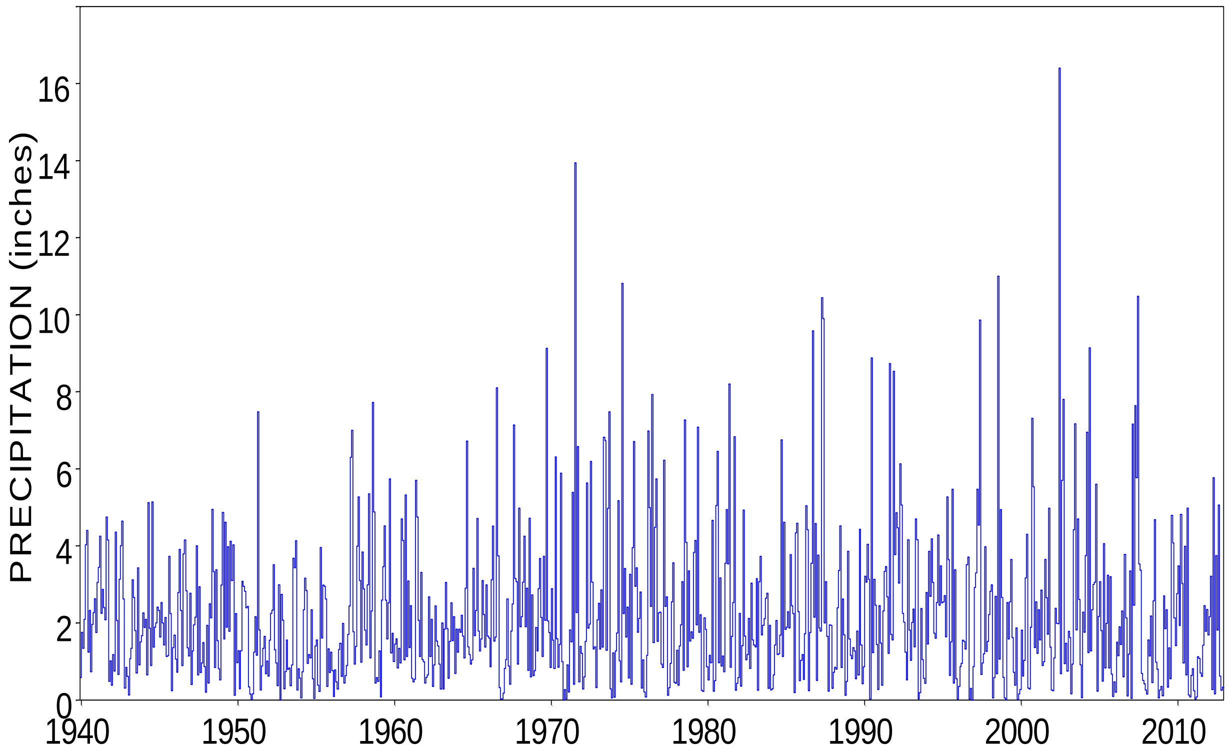
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 806



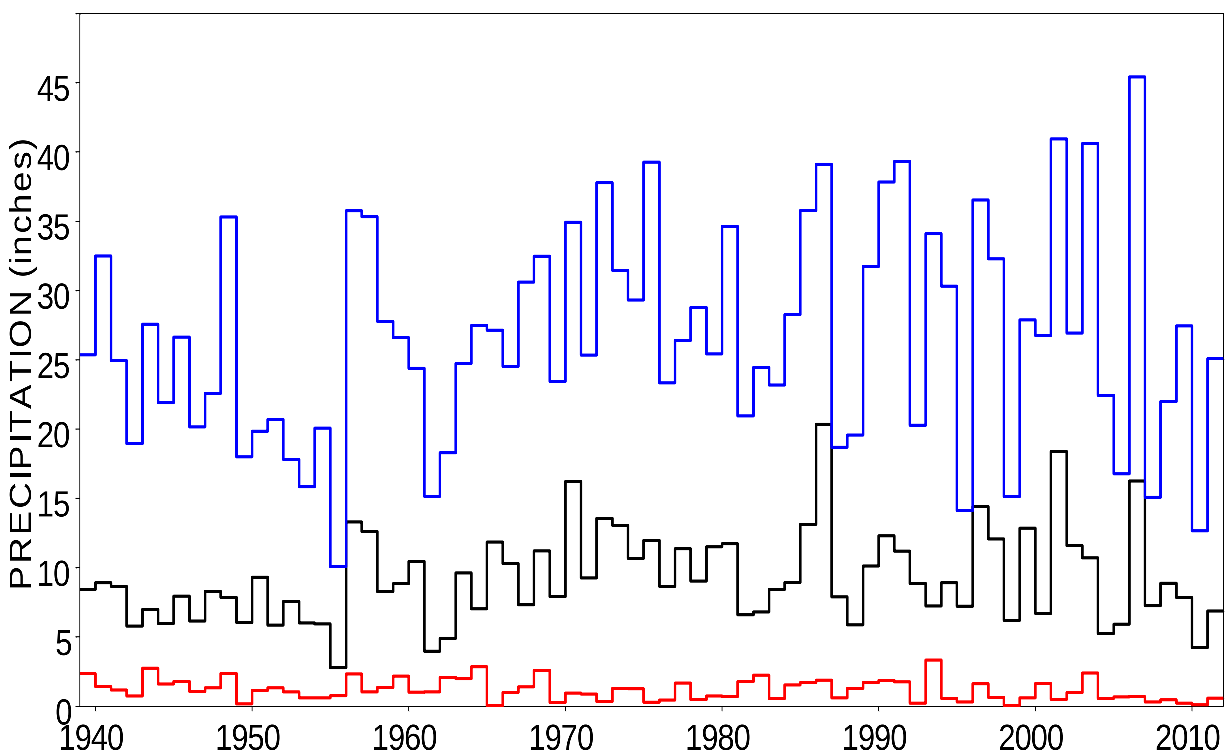
Monthly Precipitation for Quadrangle 807



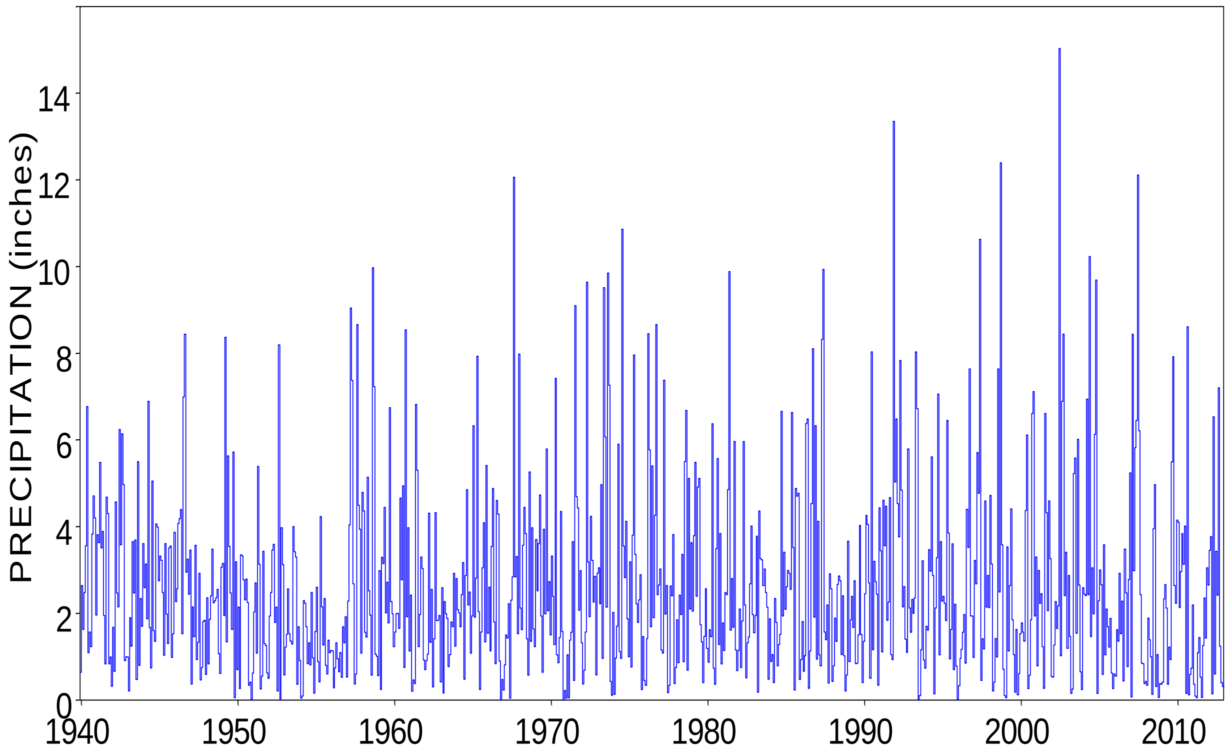
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 807



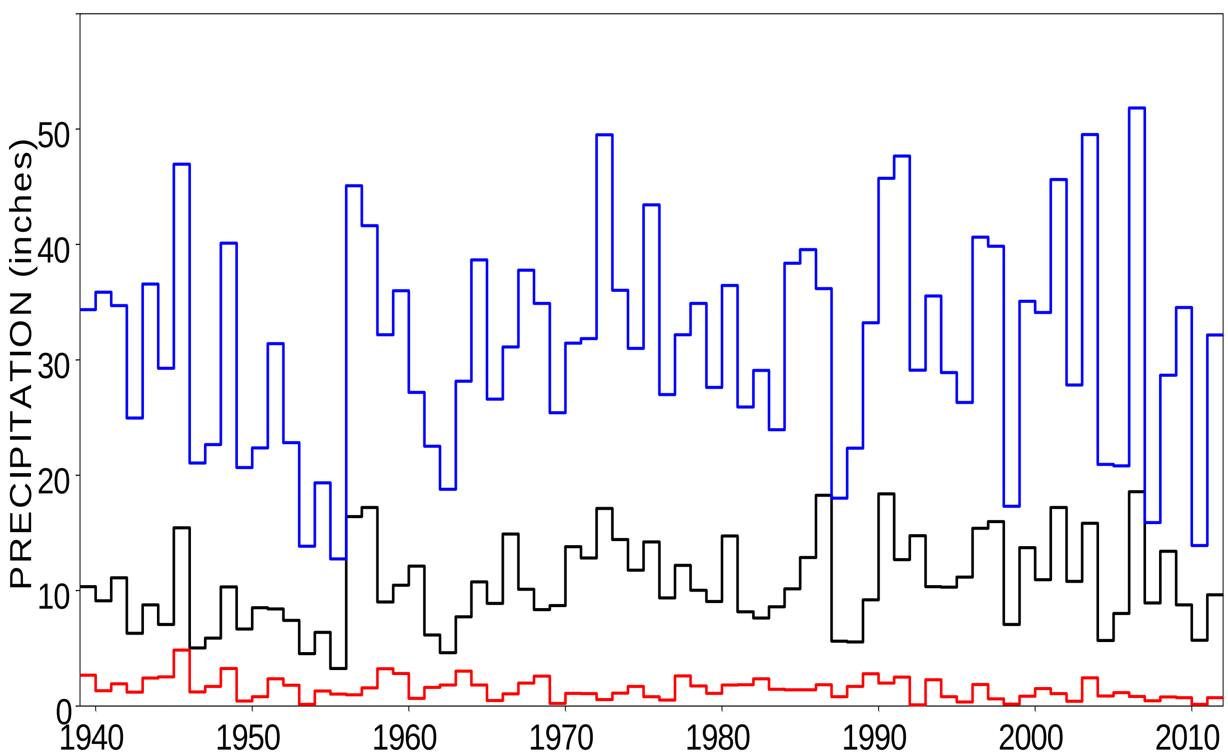
Monthly Precipitation for Quadrangle 808



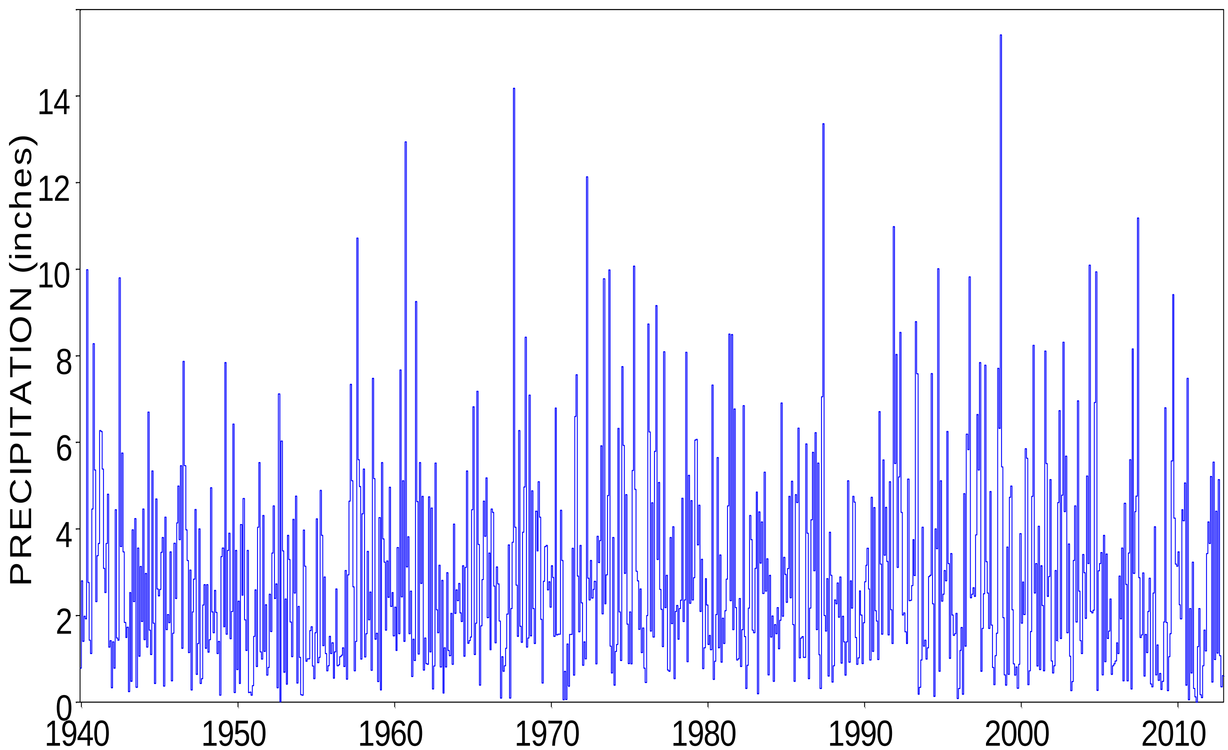
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 808



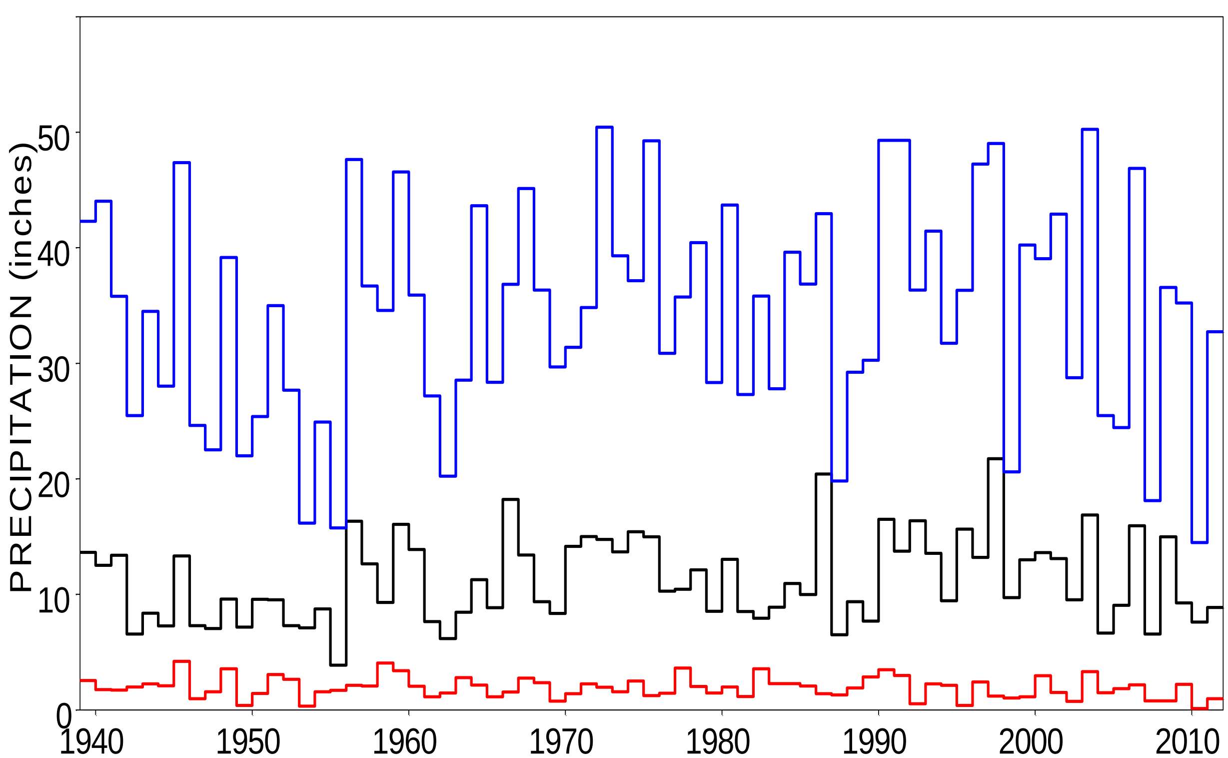
Monthly Precipitation for Quadrangle 809



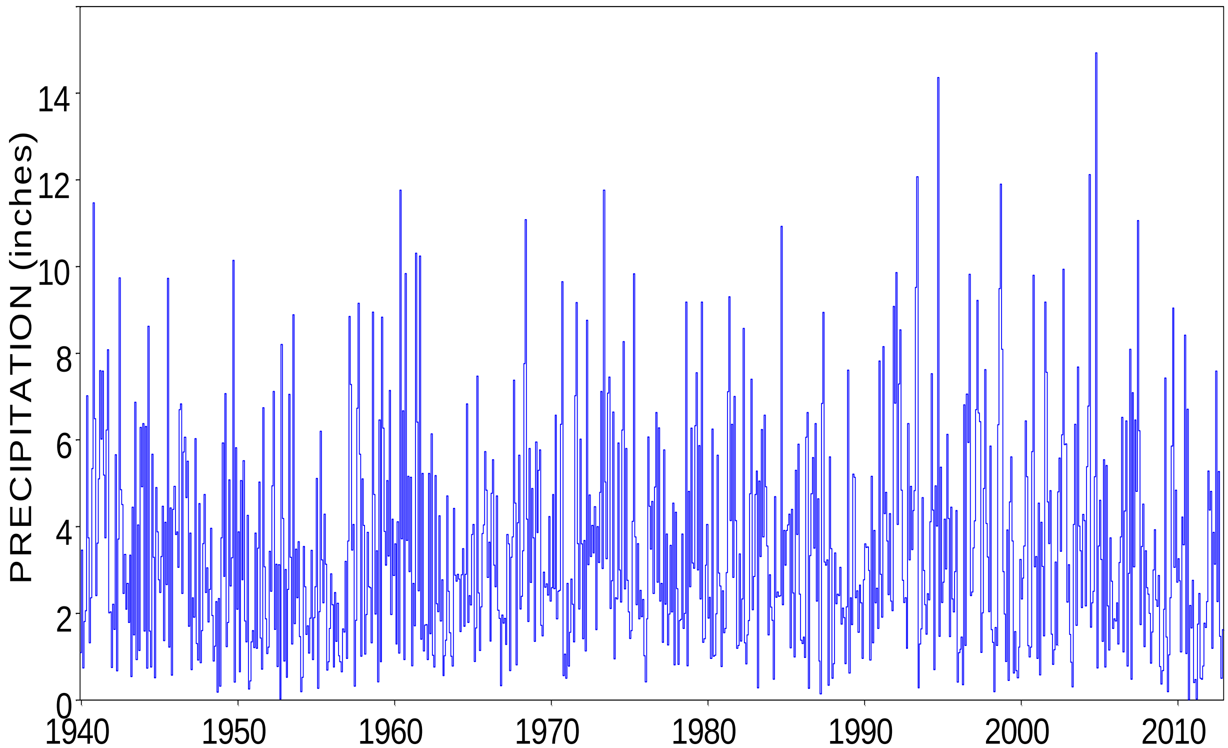
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 809



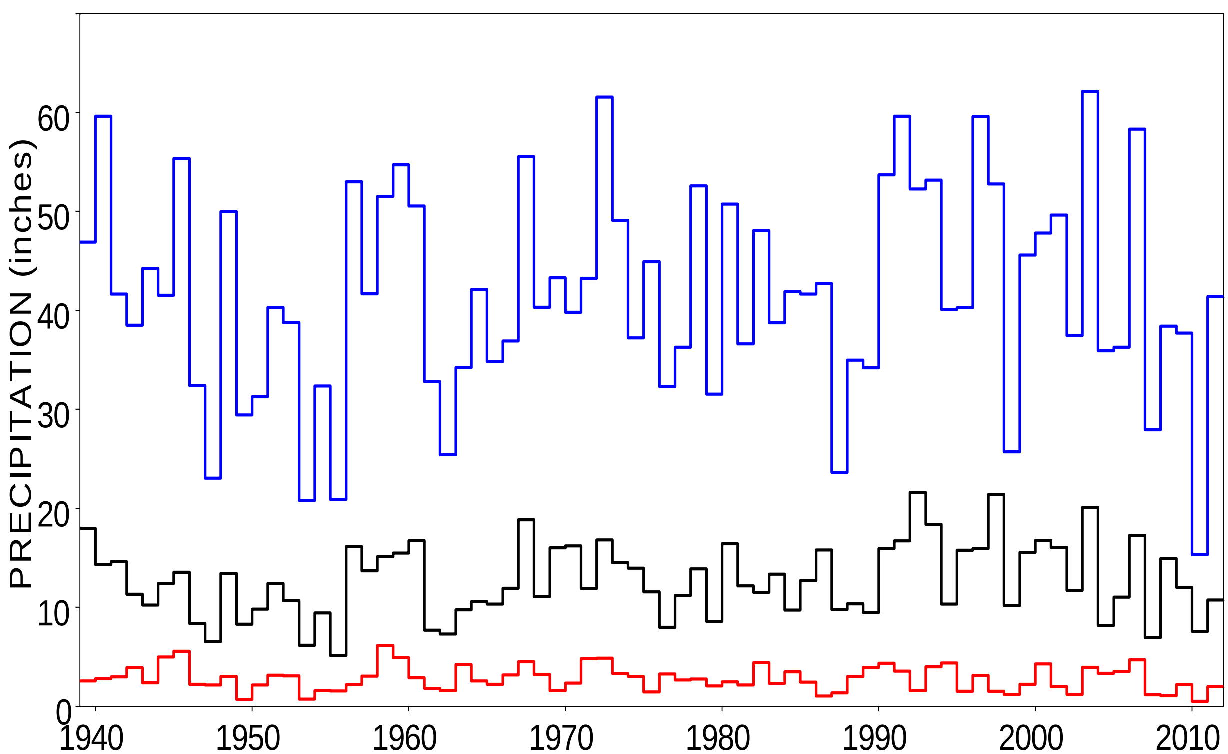
Monthly Precipitation for Quadrangle 810



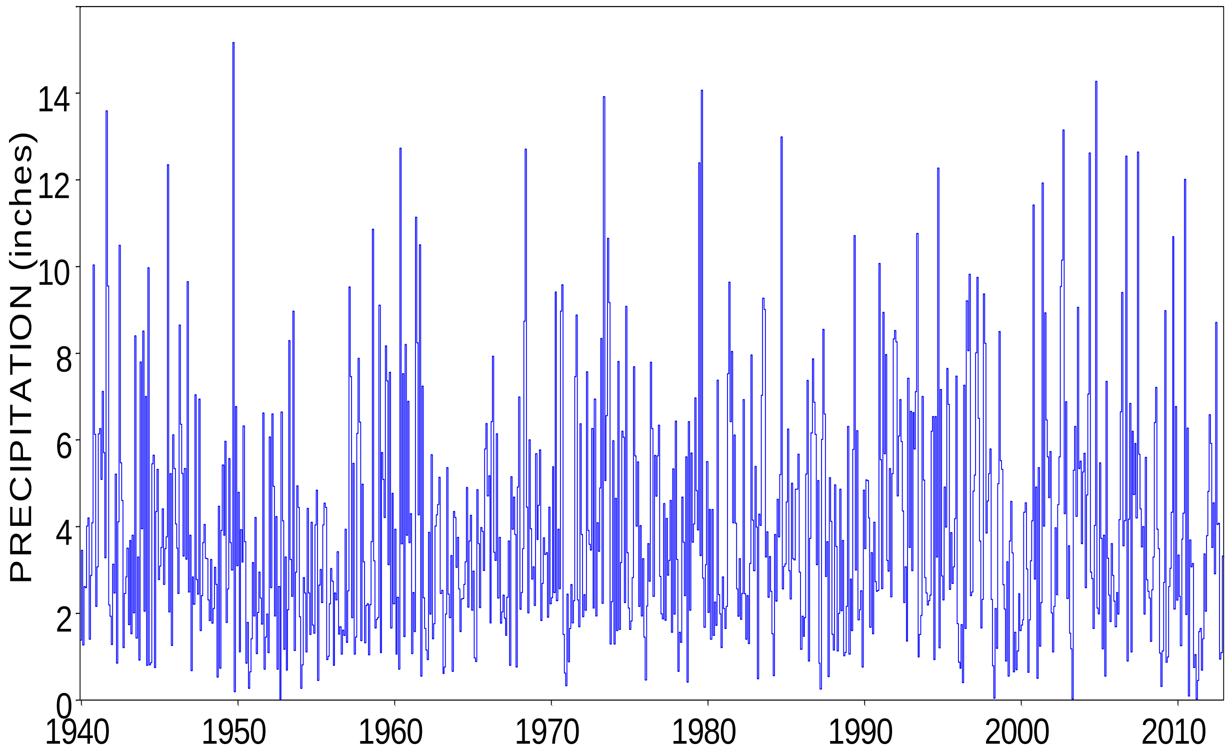
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 810



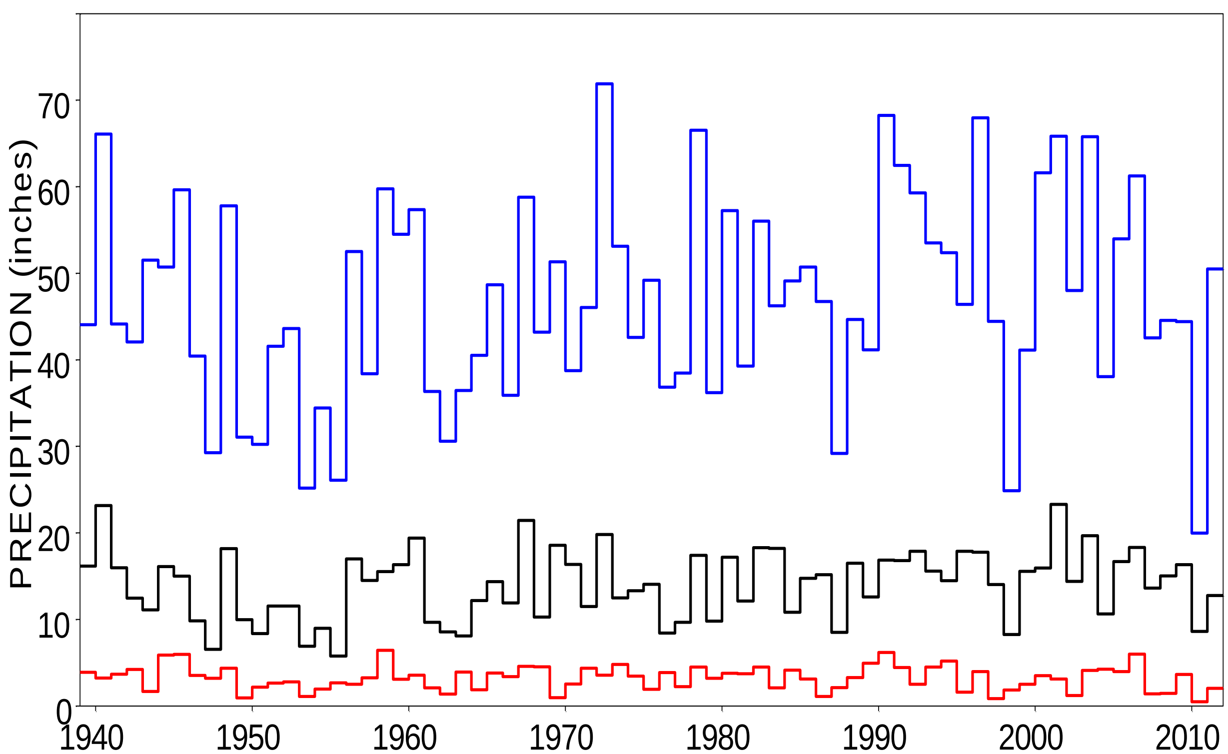
Monthly Precipitation for Quadrangle 811



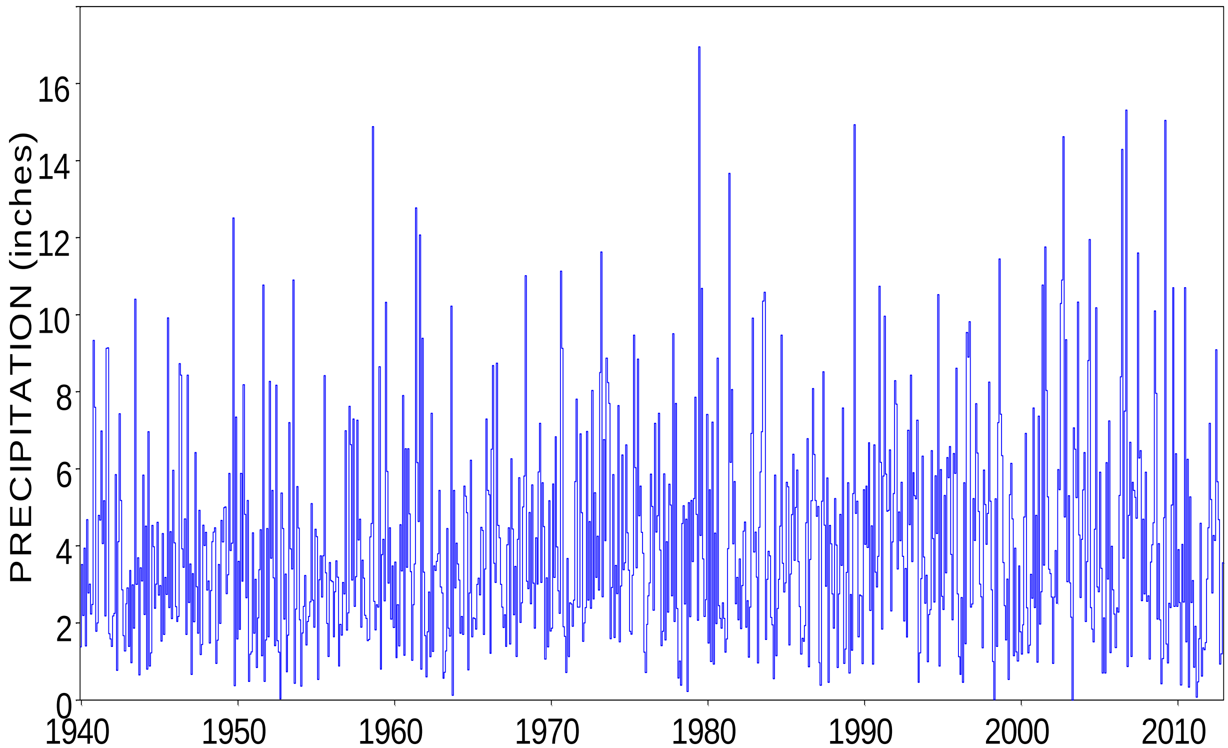
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 811



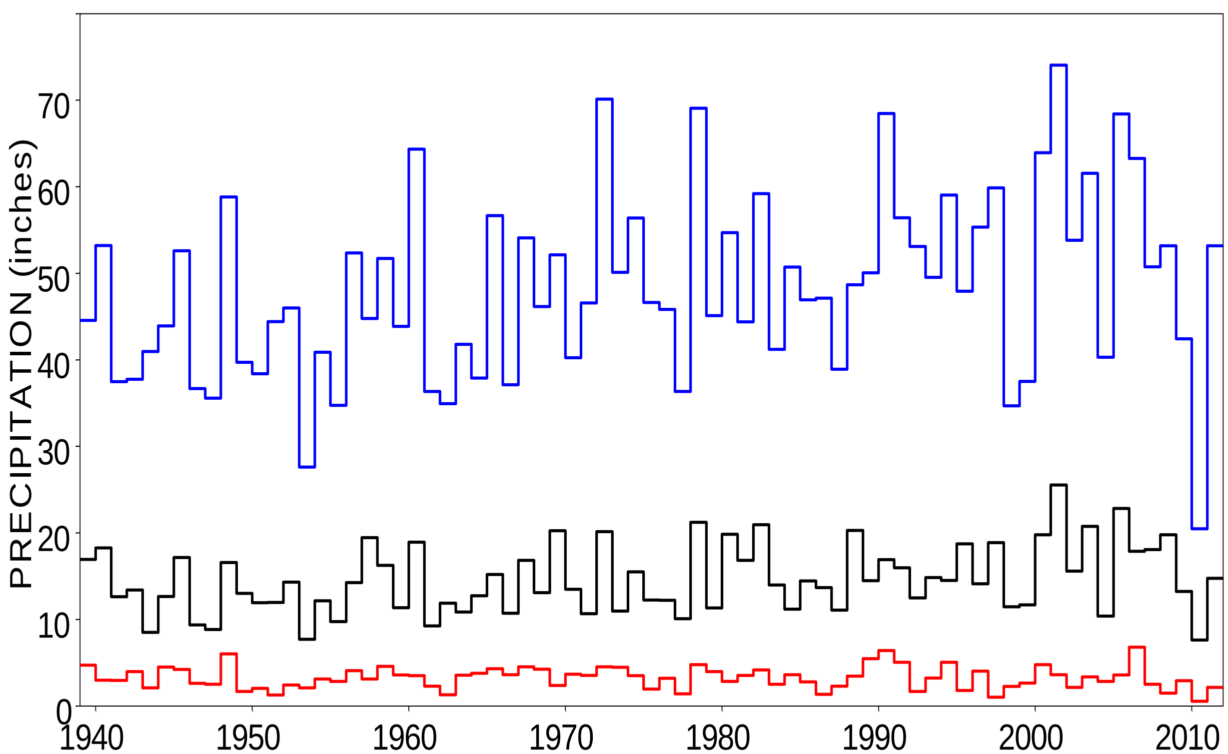
Monthly Precipitation for Quadrangle 812



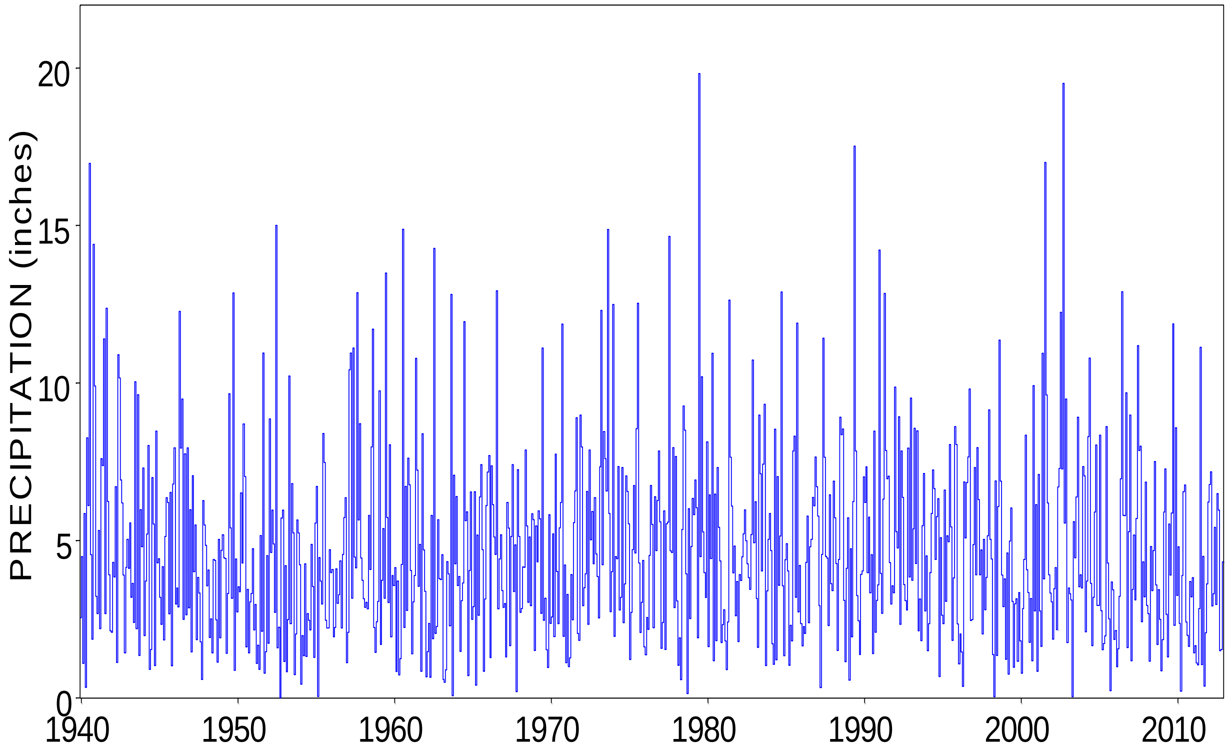
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 812



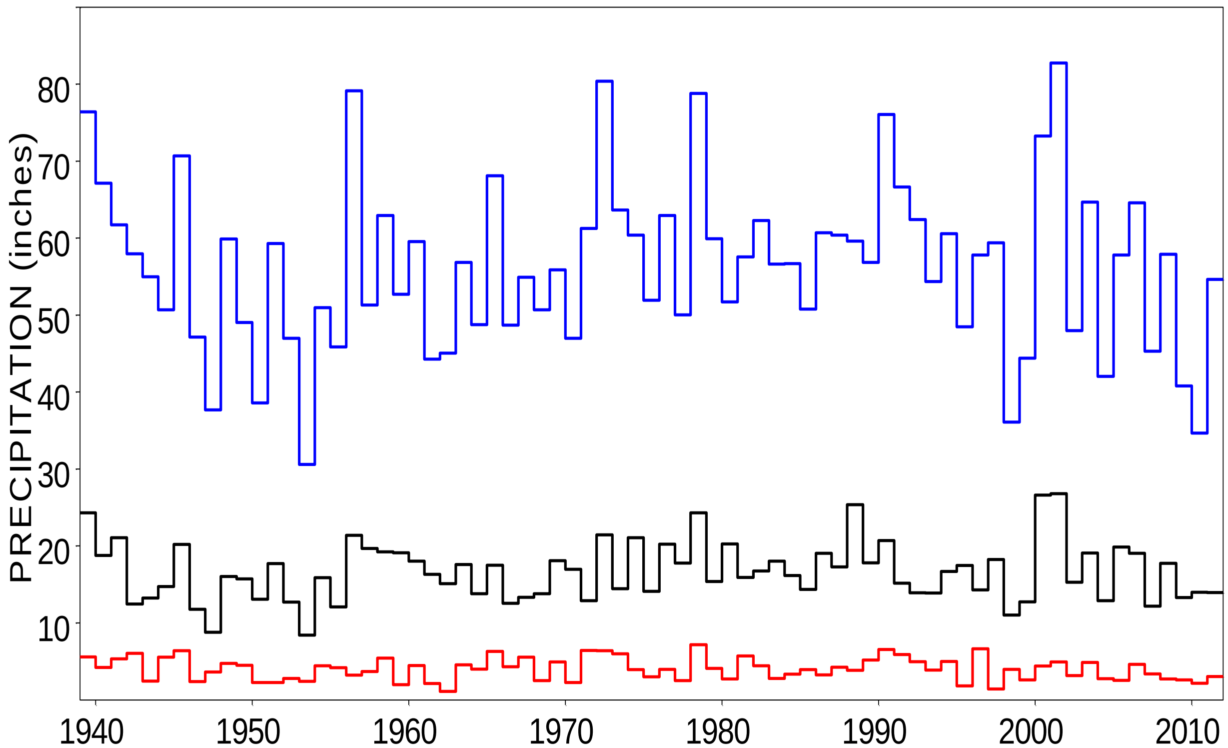
Monthly Precipitation for Quadrangle 813



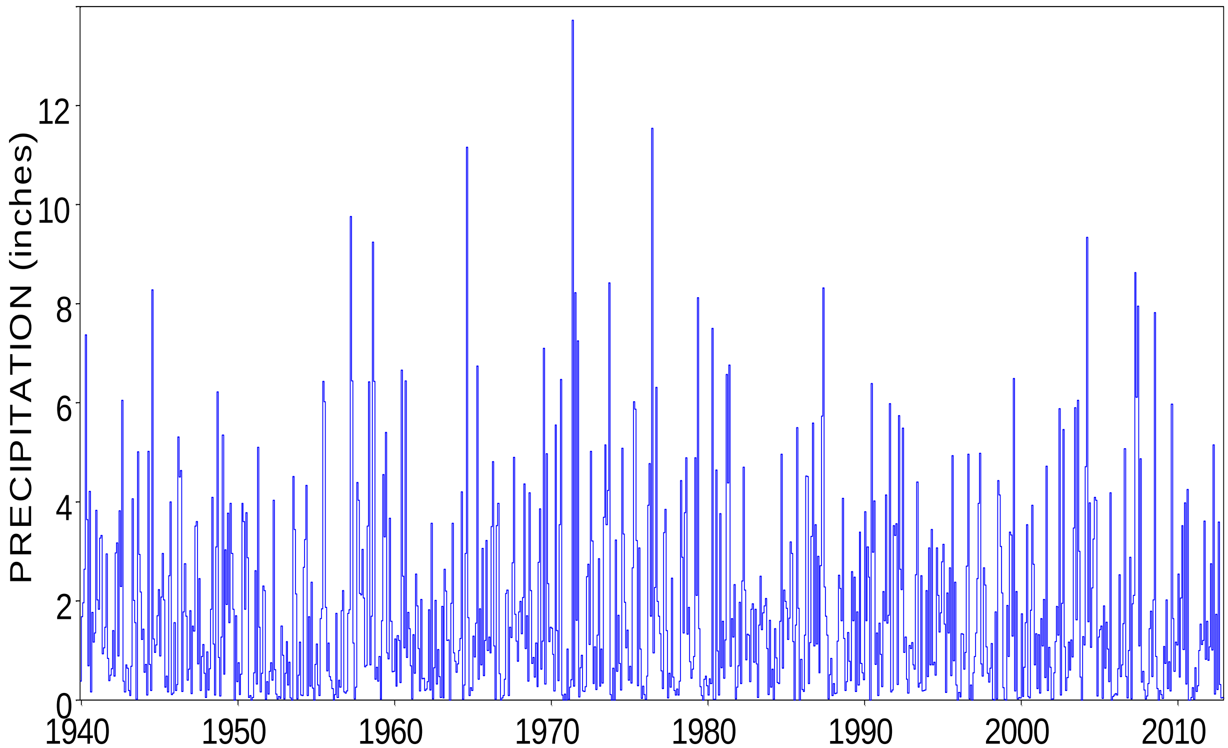
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 813



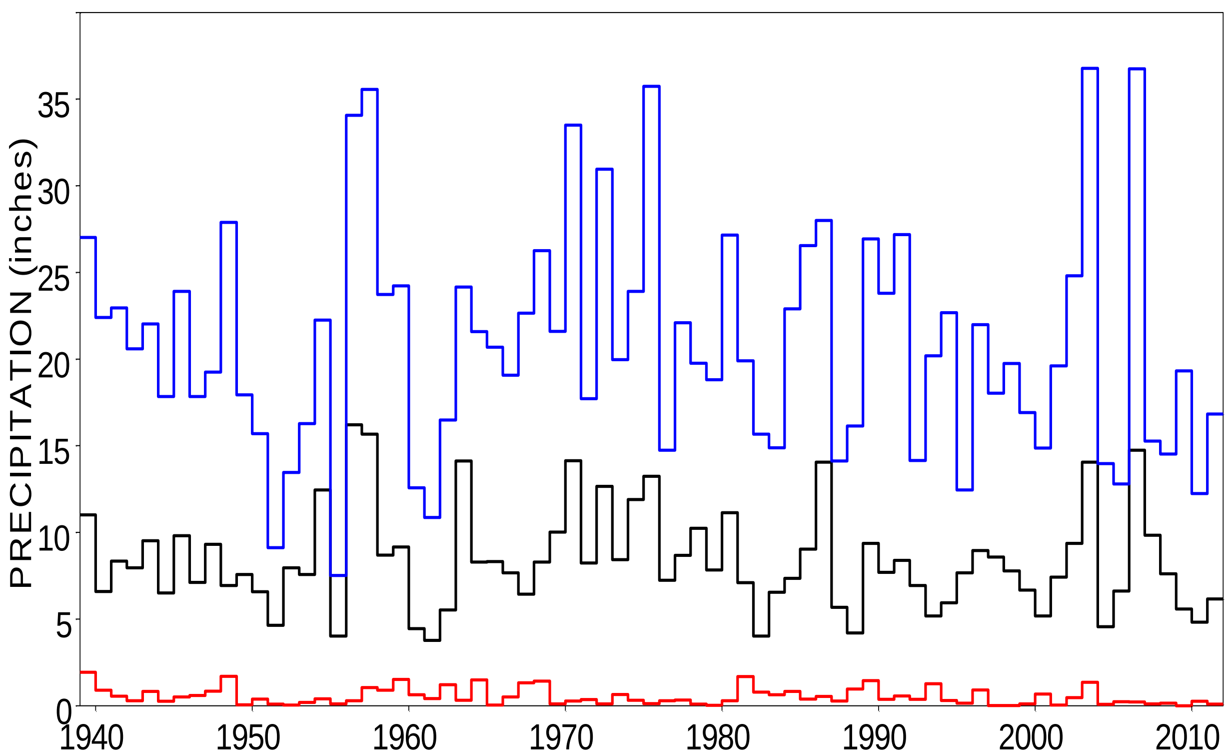
Monthly Precipitation for Quadrangle 814



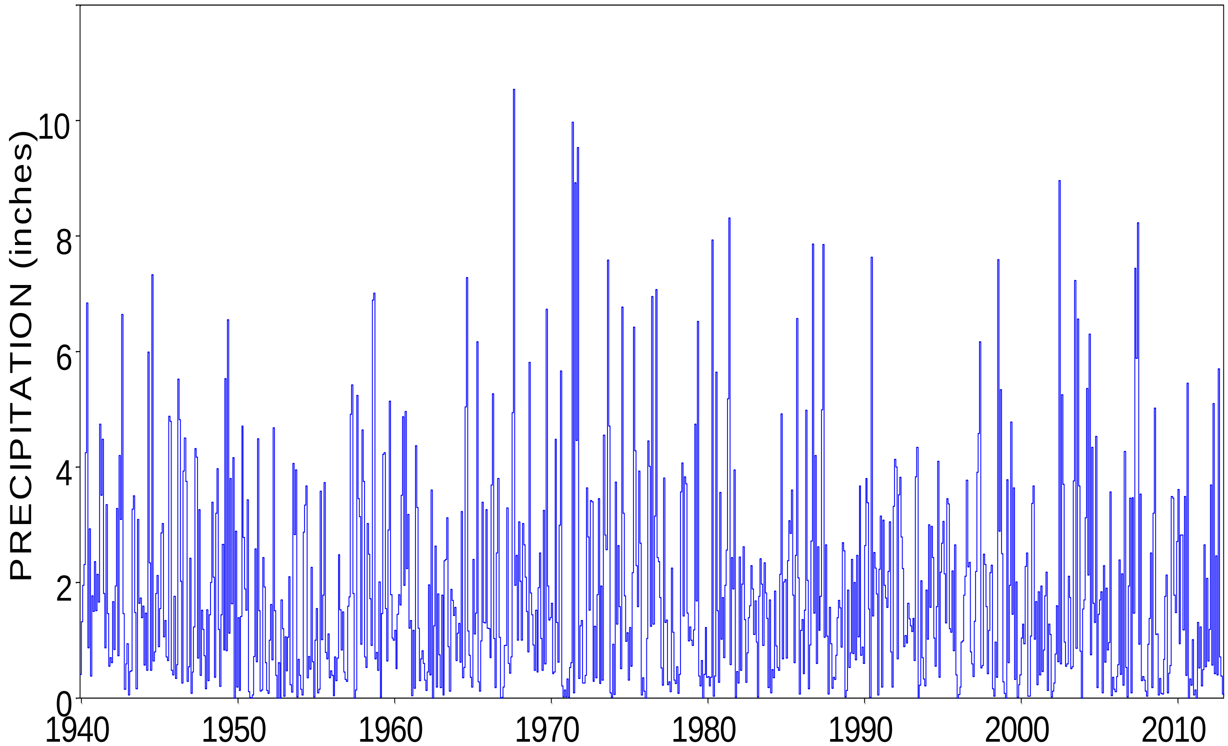
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 814



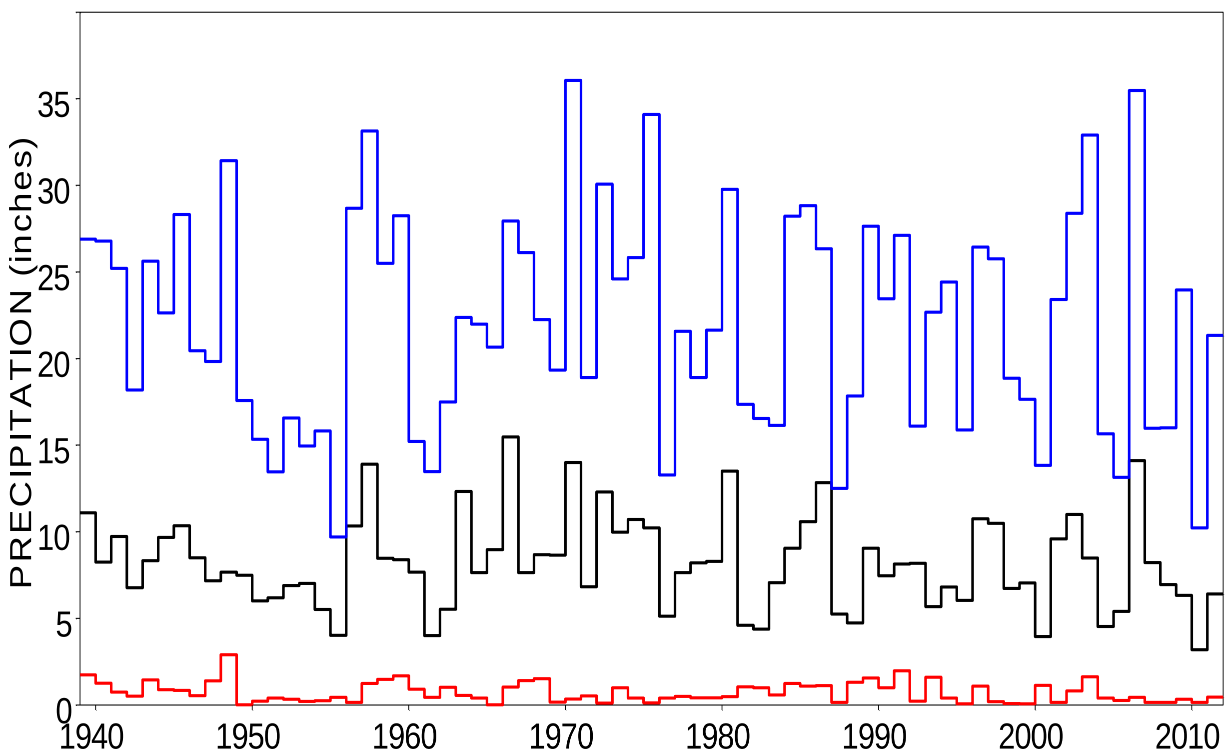
Monthly Precipitation for Quadrangle 907



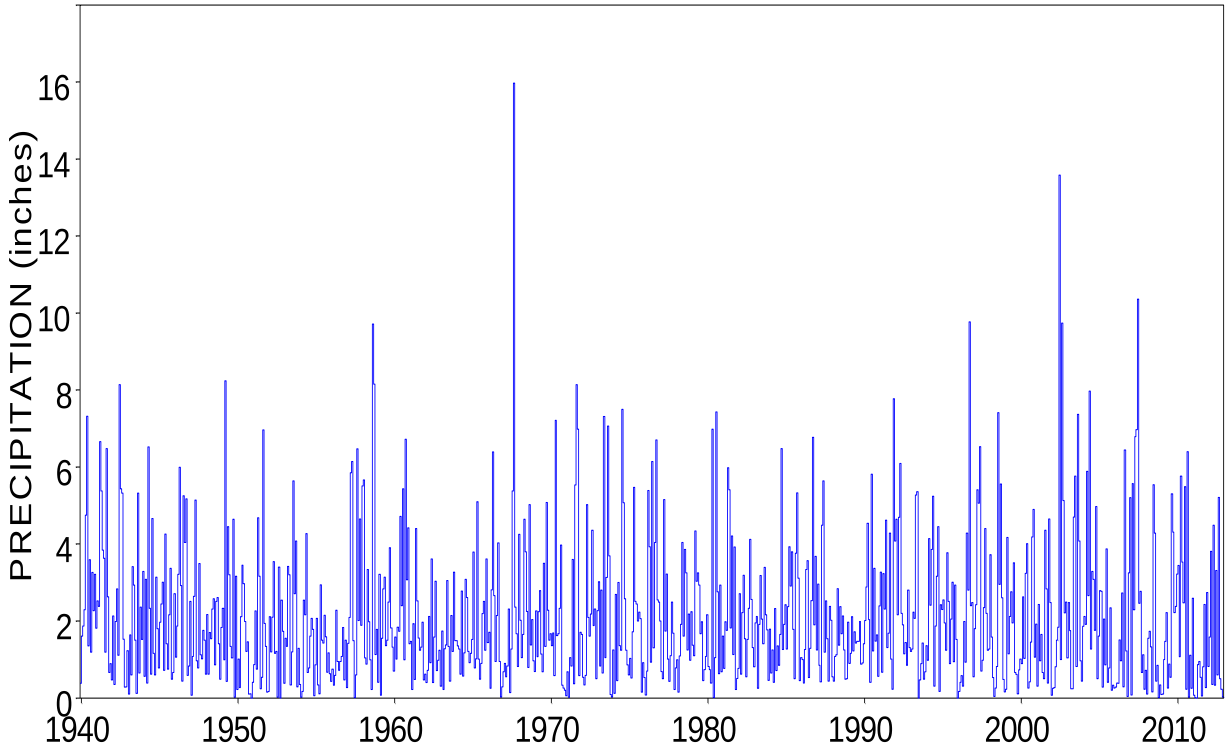
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 907



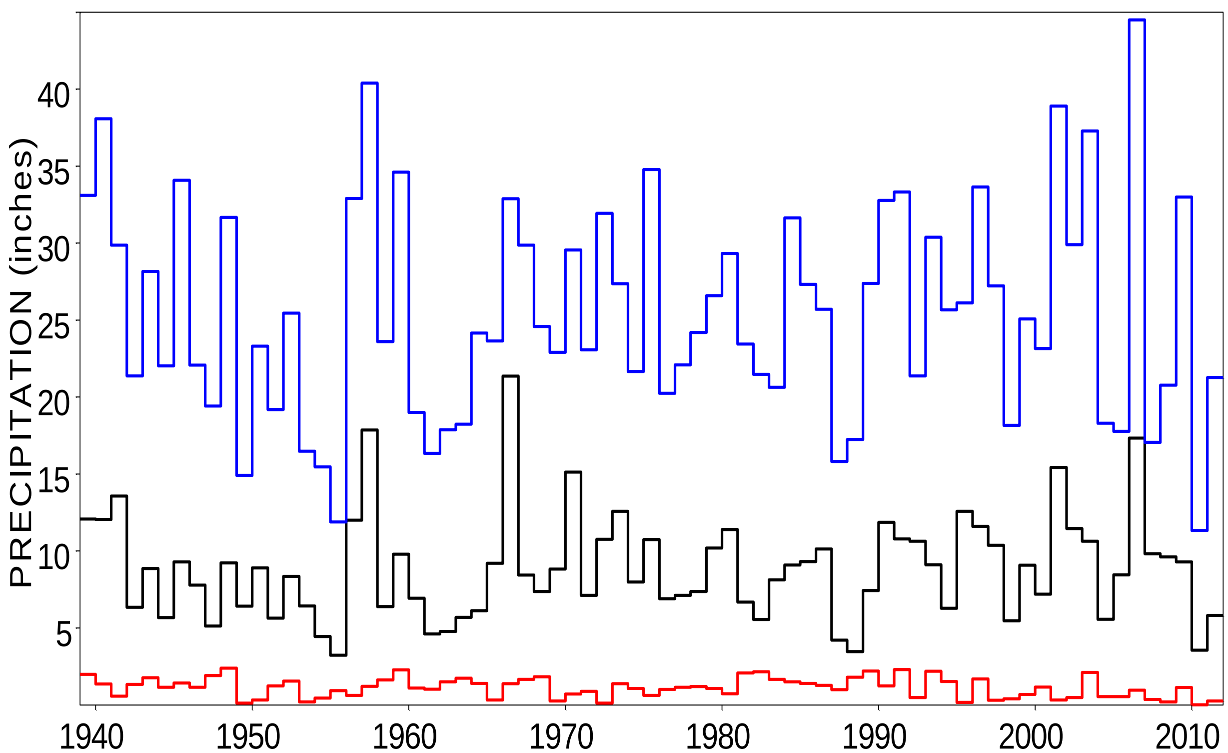
Monthly Precipitation for Quadrangle 908



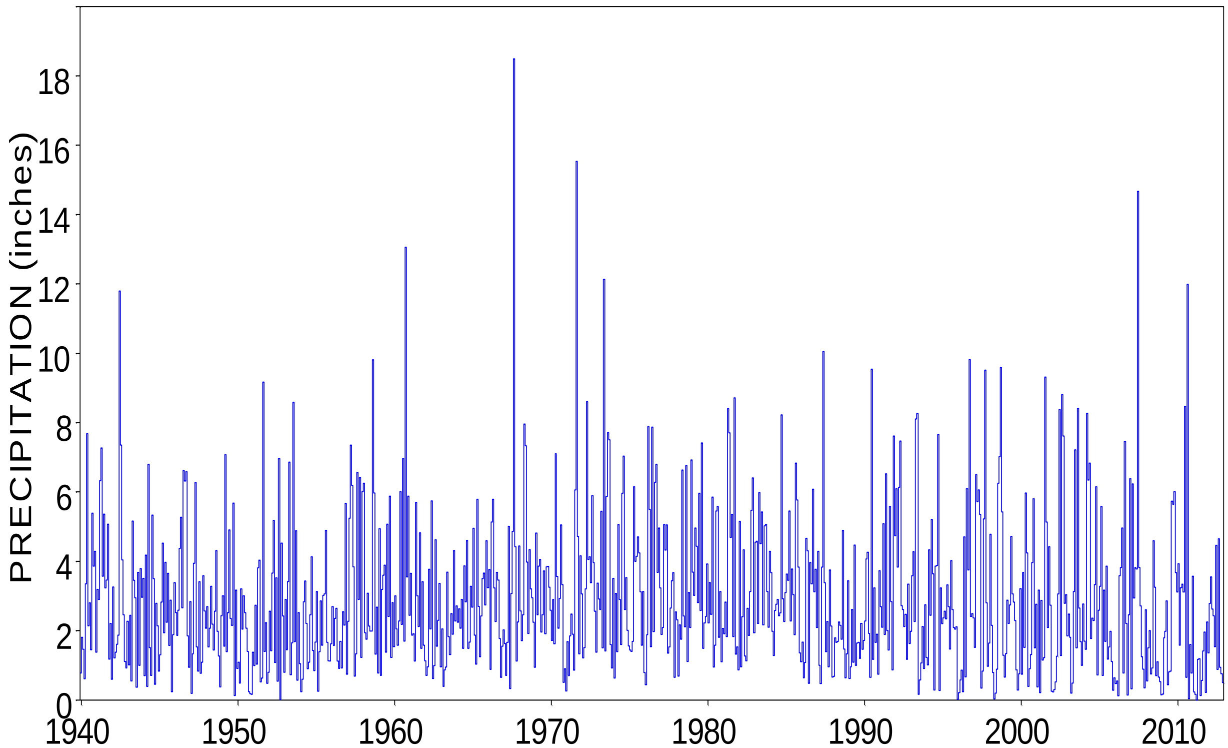
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 908



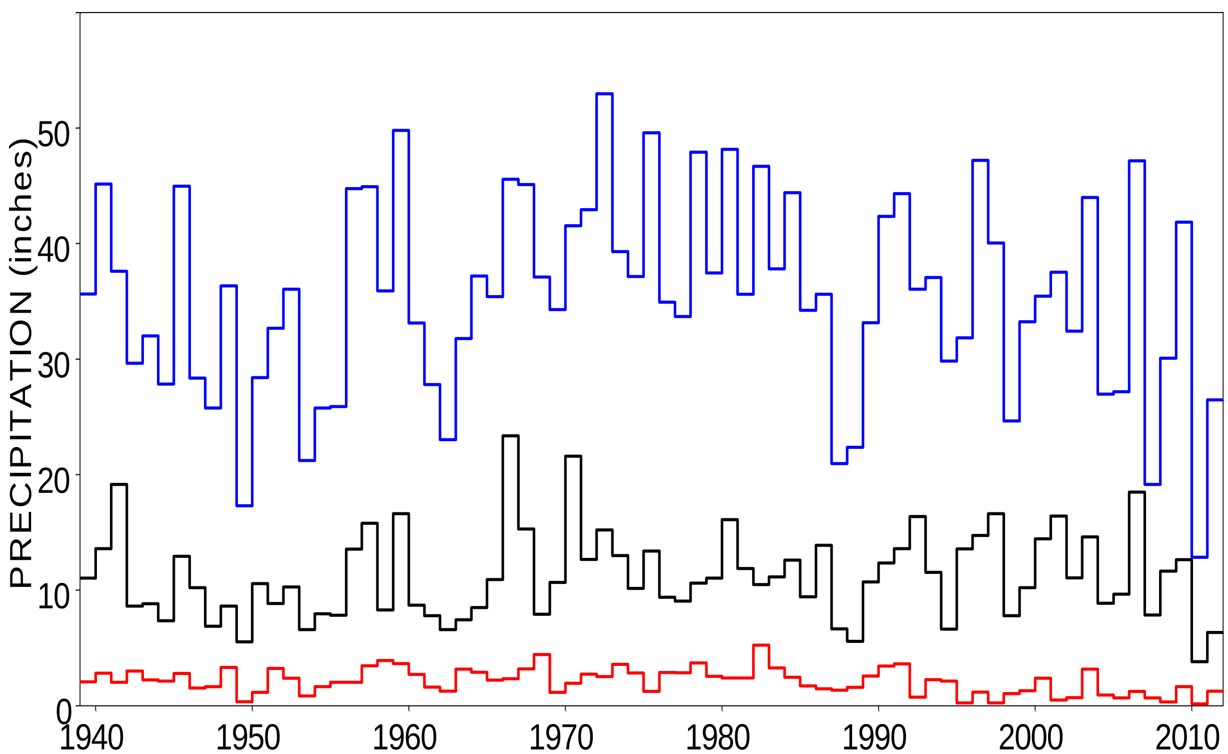
Monthly Precipitation for Quadrangle 909



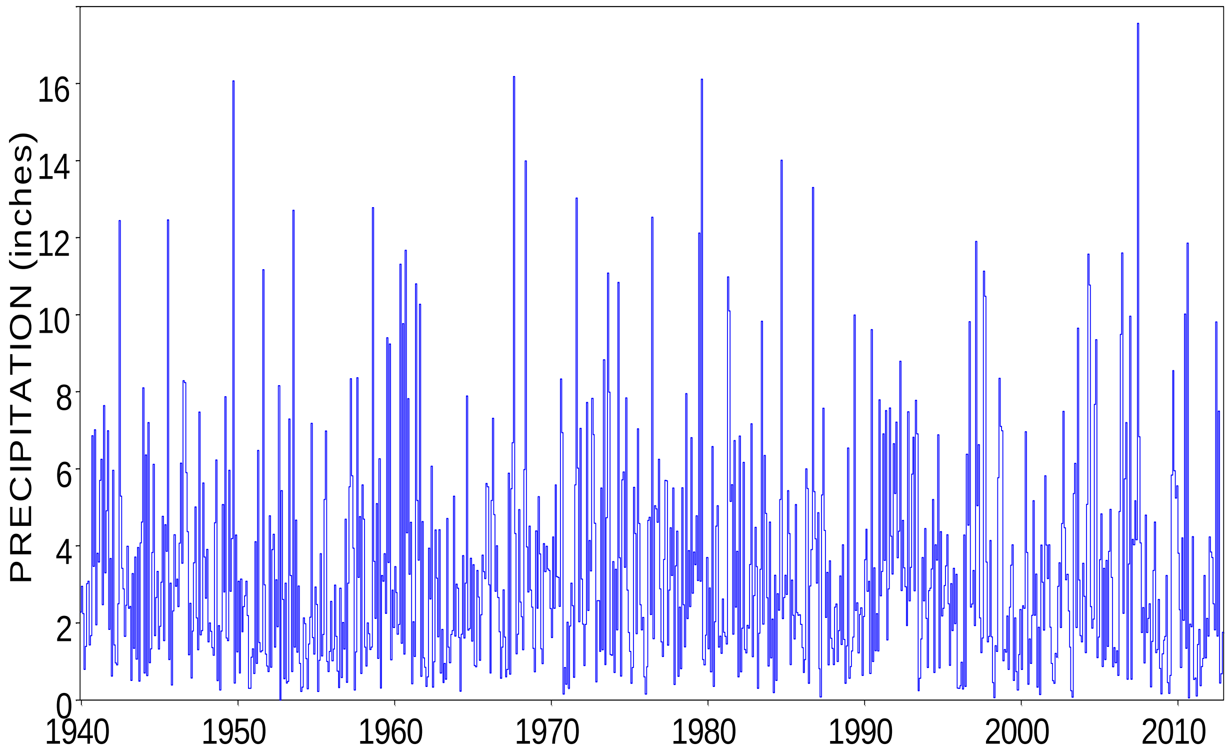
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 909



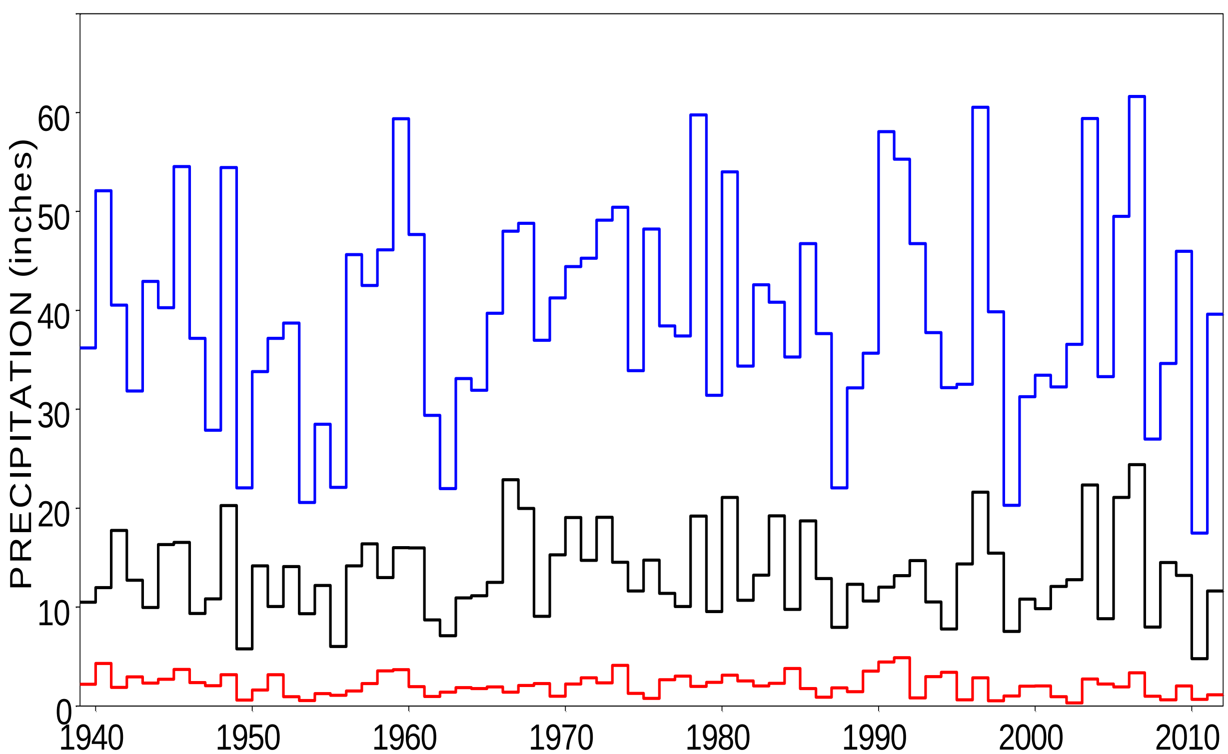
Monthly Precipitation for Quadrangle 910



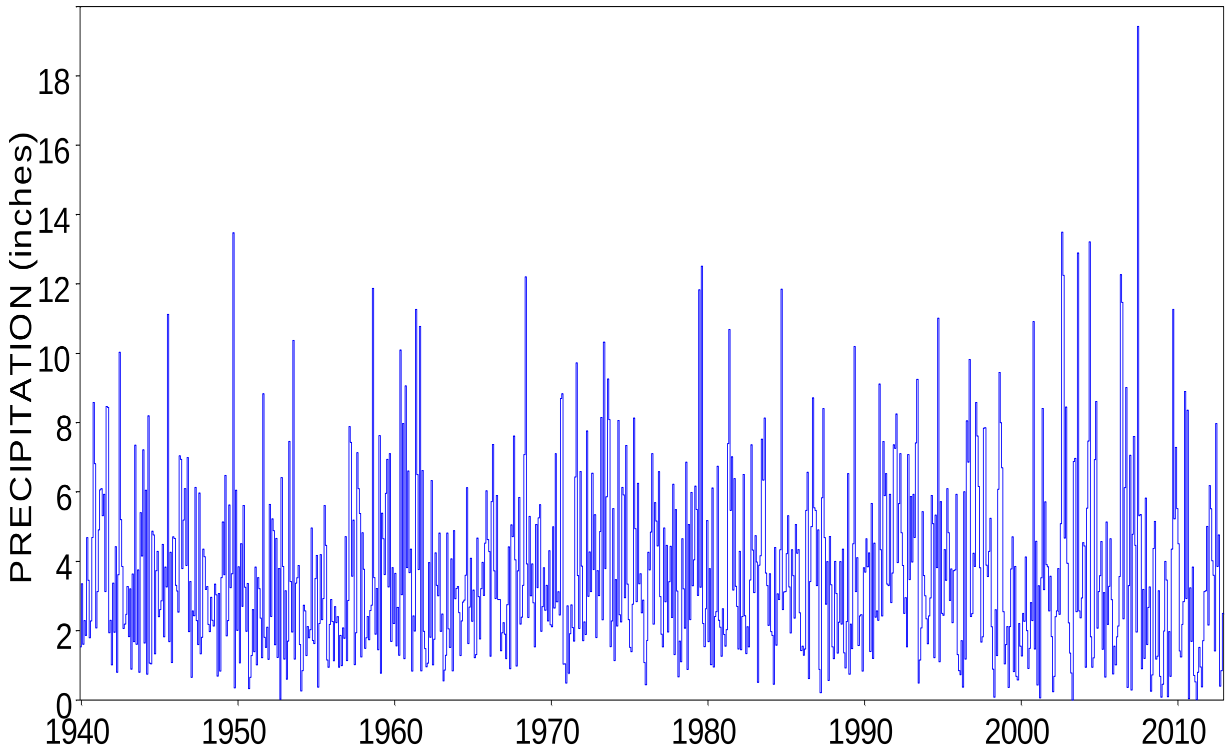
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 910



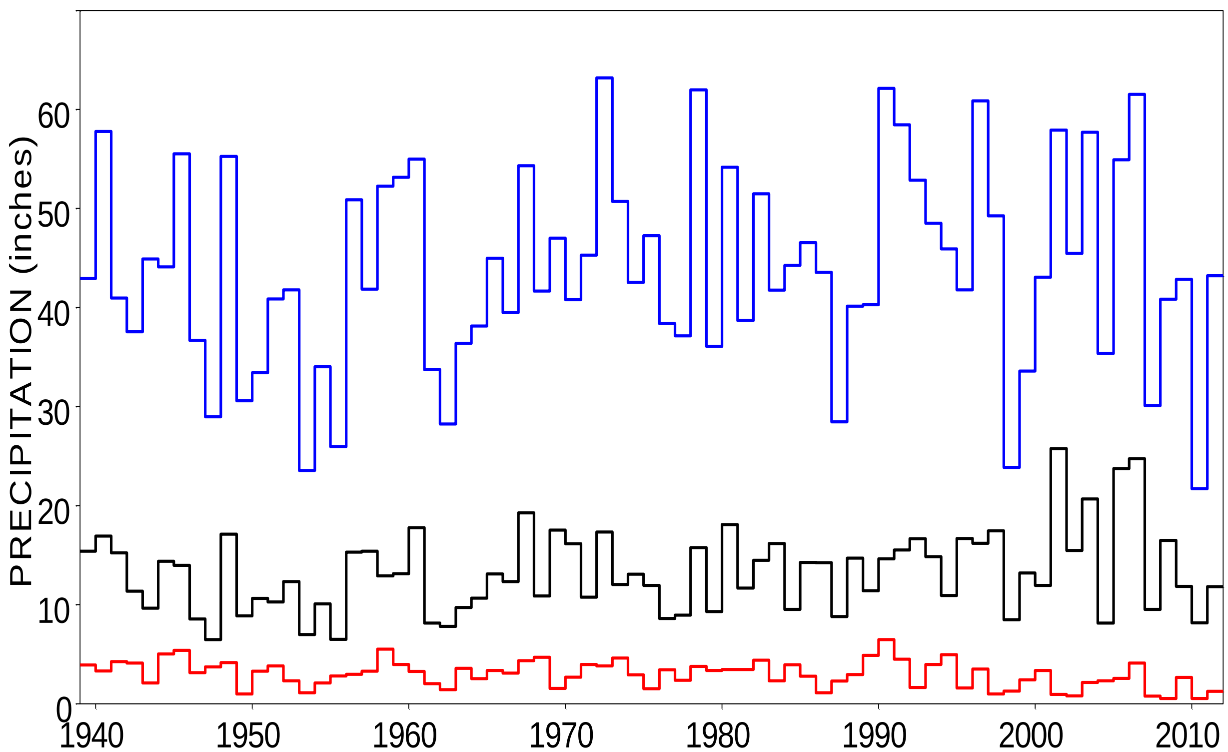
Monthly Precipitation for Quadrangle 911



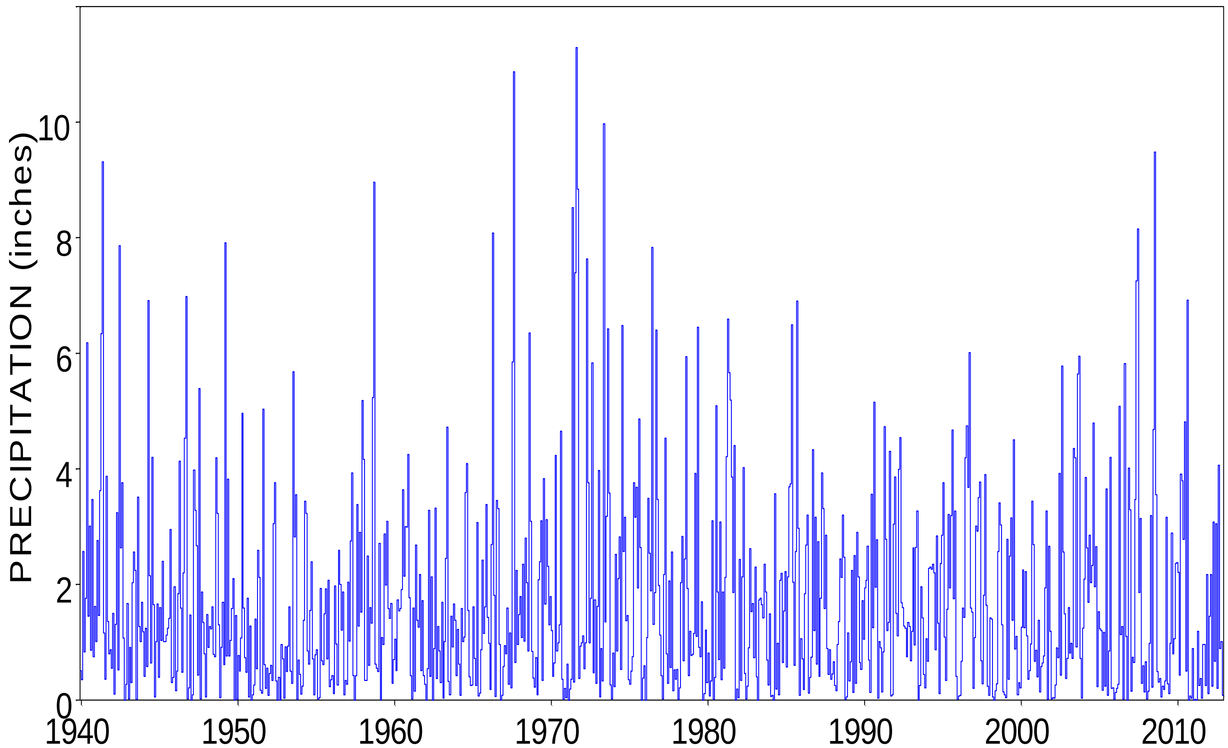
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 911



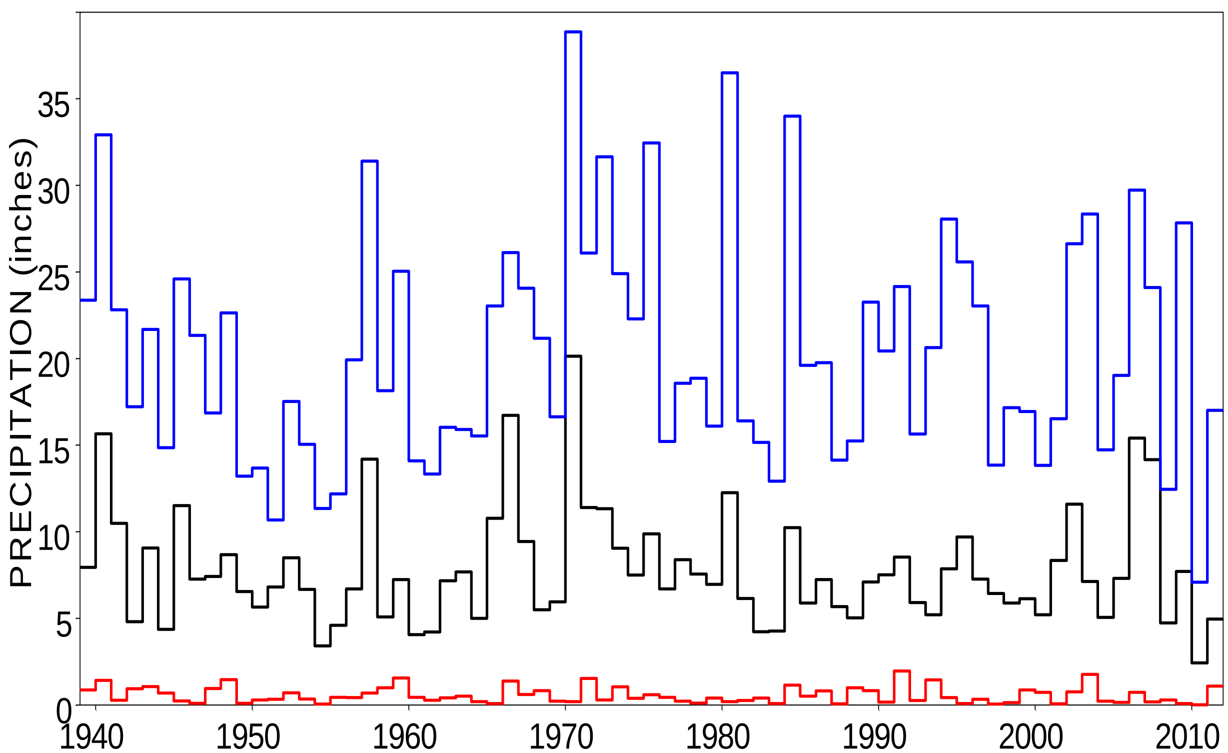
Monthly Precipitation for Quadrangle 912



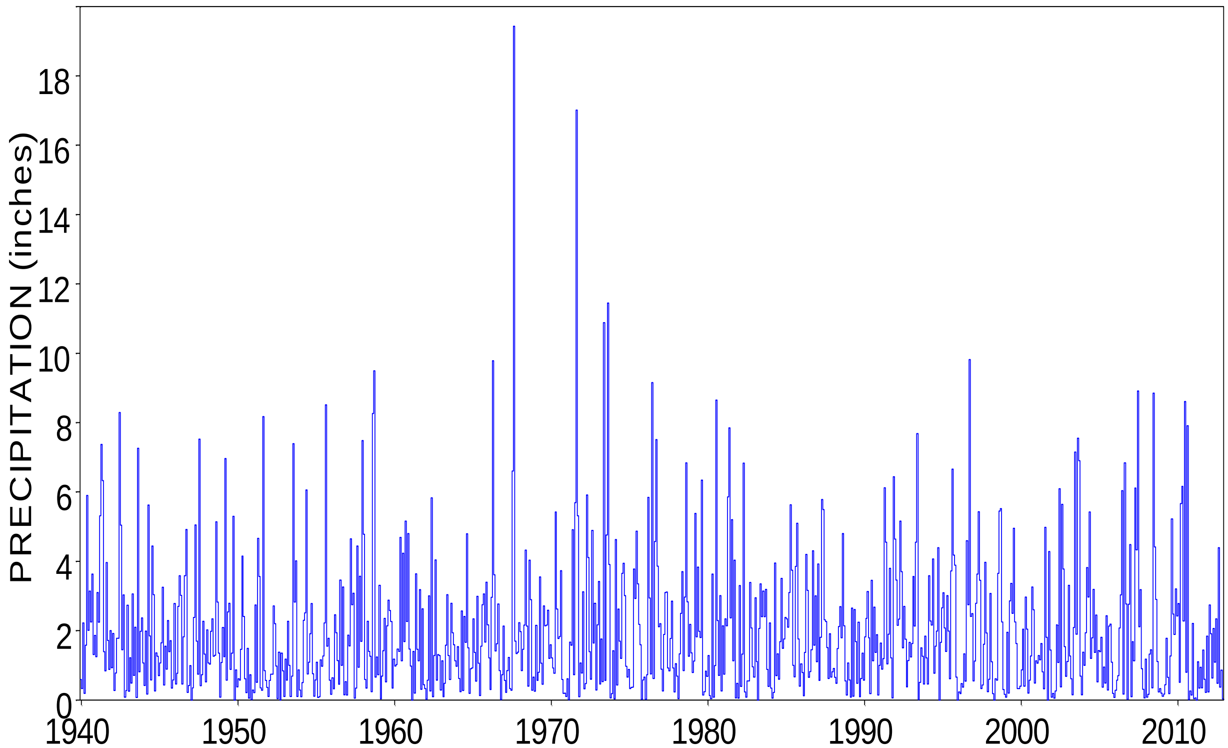
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 912



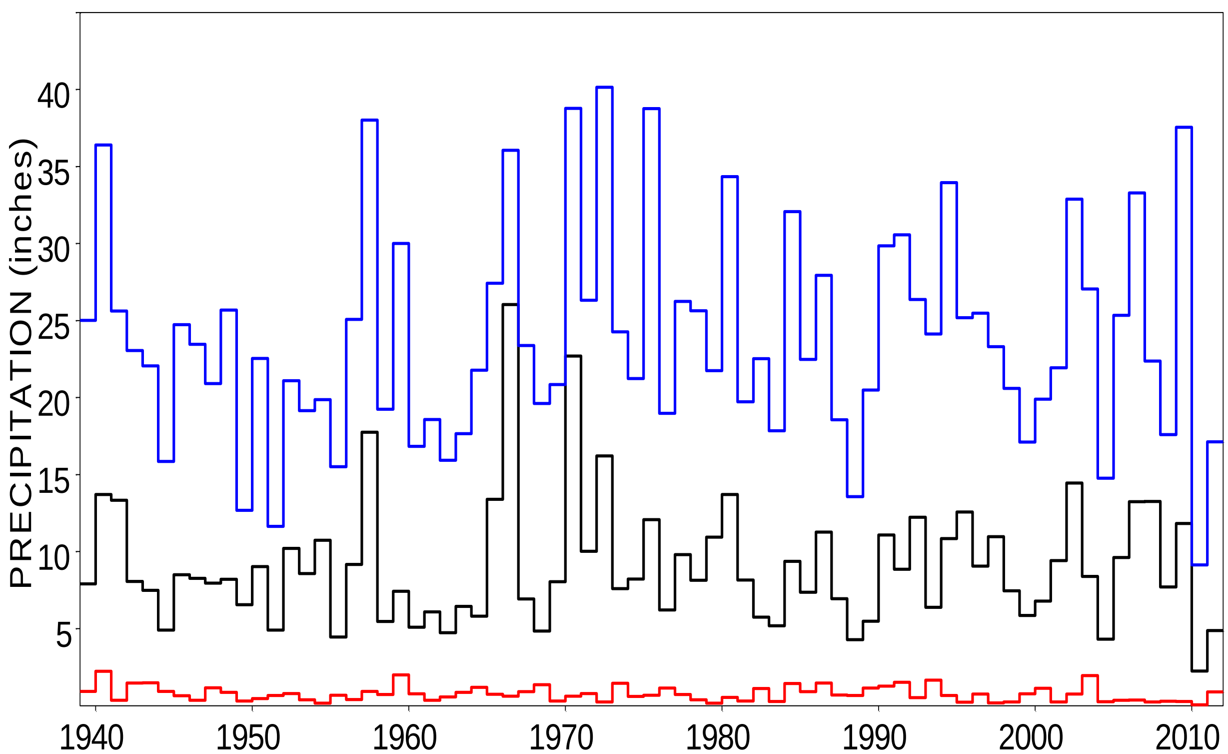
Monthly Precipitation for Quadrangle 1008



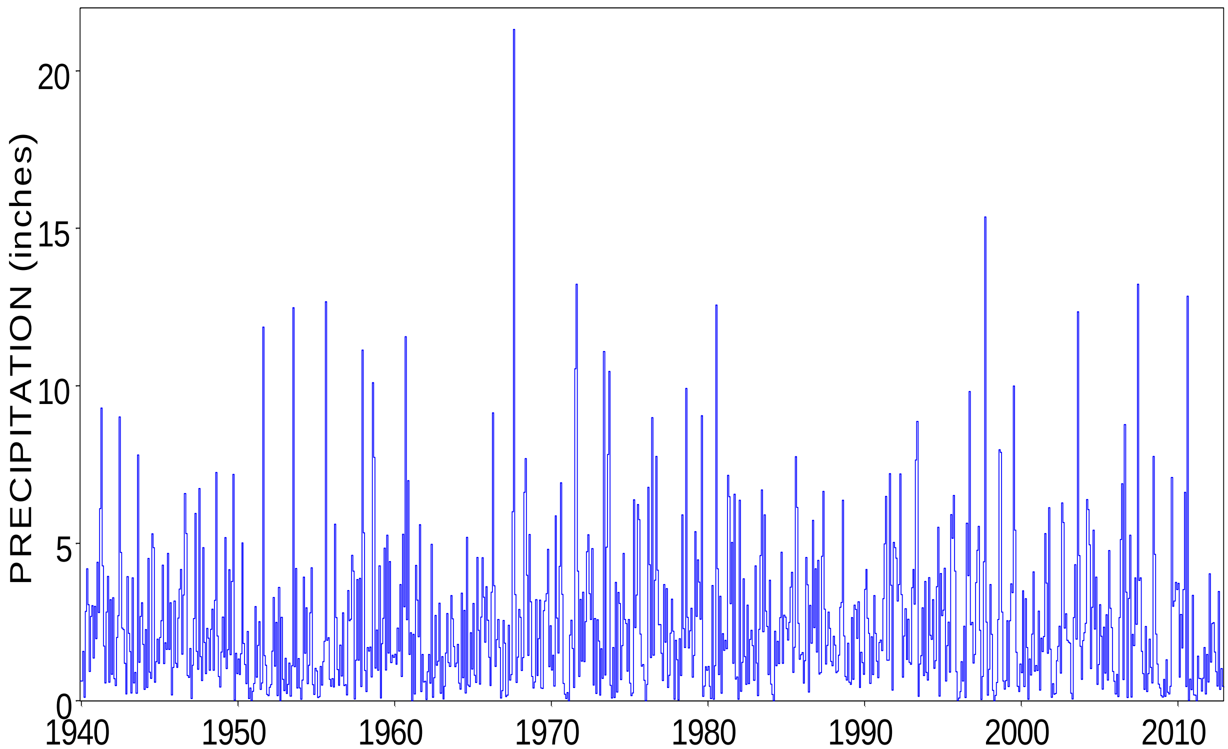
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 1008



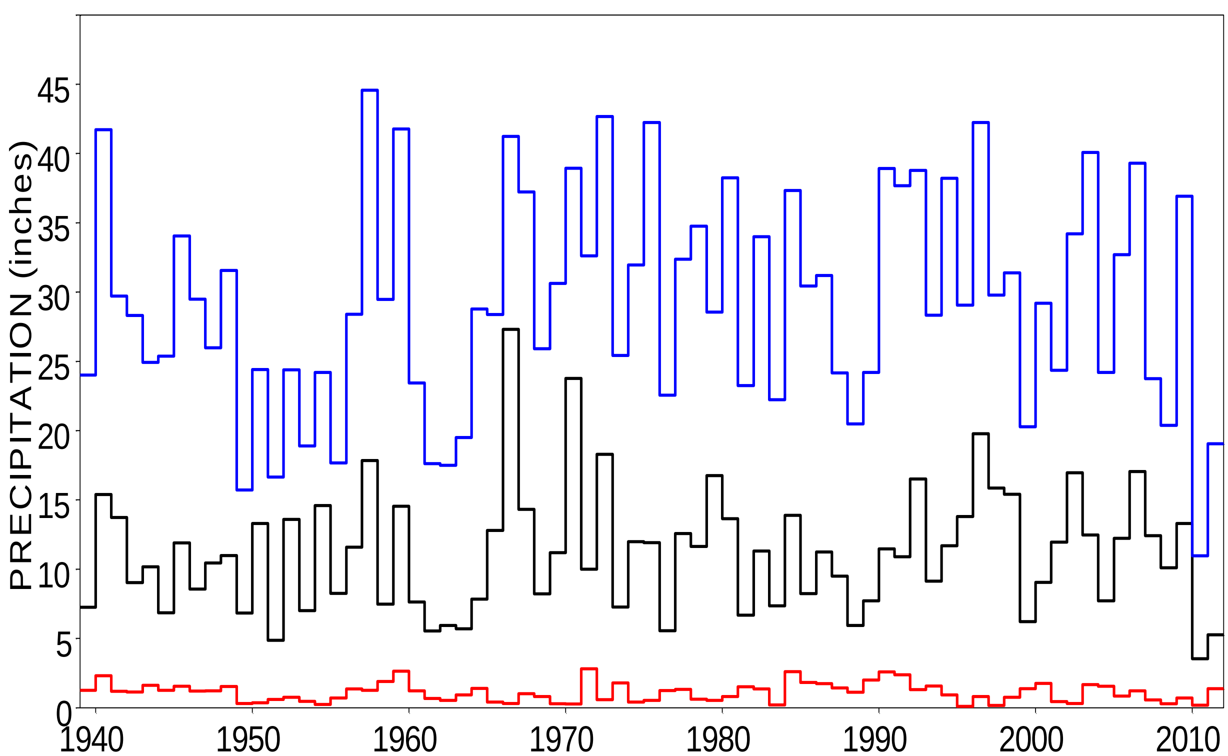
Monthly Precipitation for Quadrangle 1009



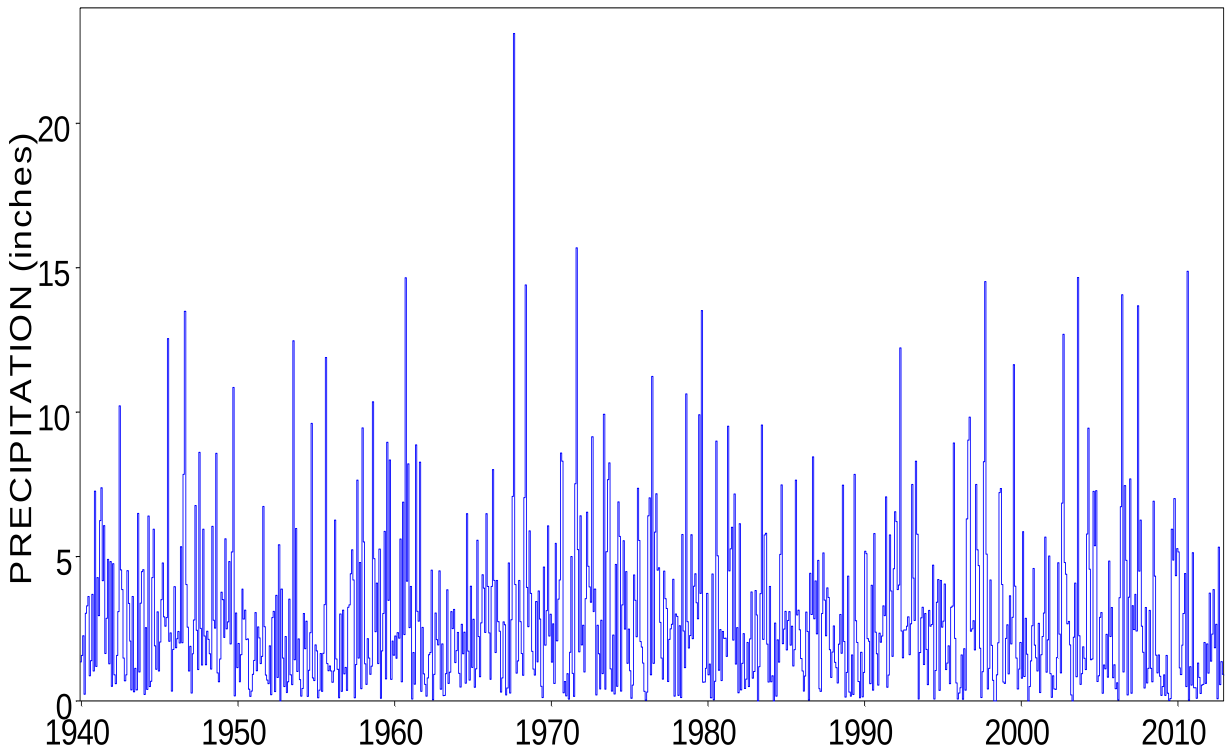
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 1009



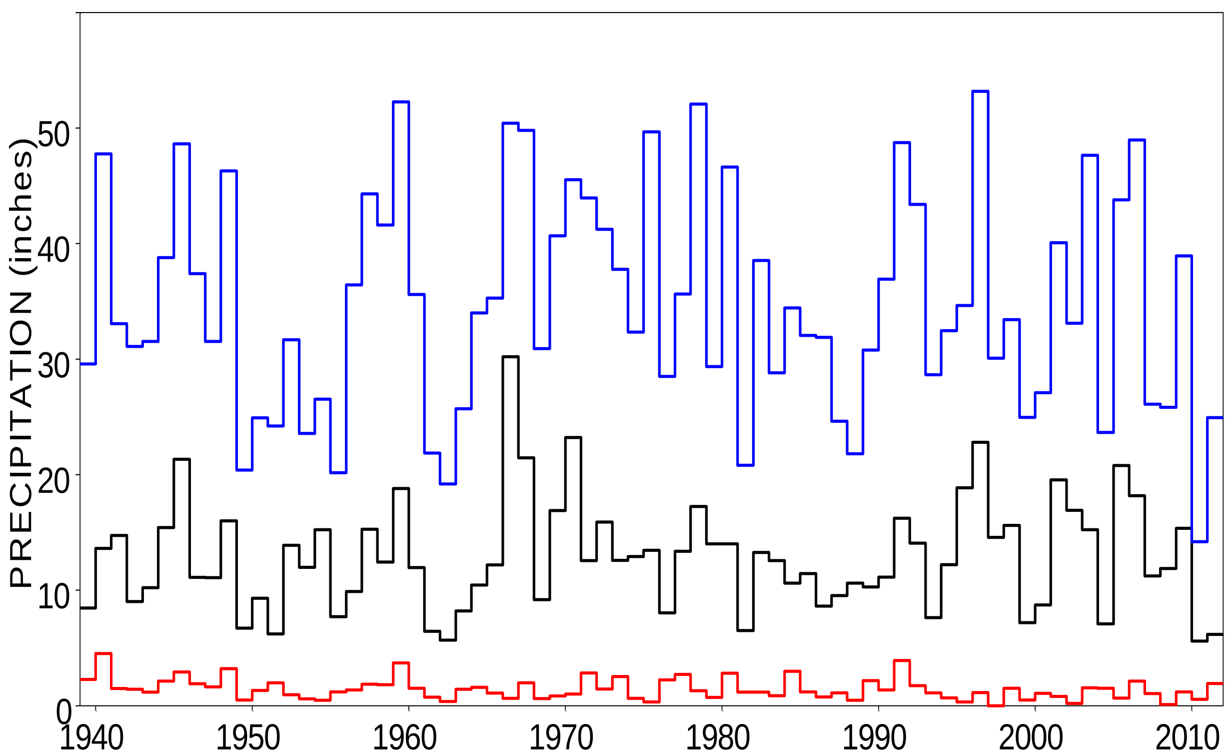
Monthly Precipitation for Quadrangle 1010



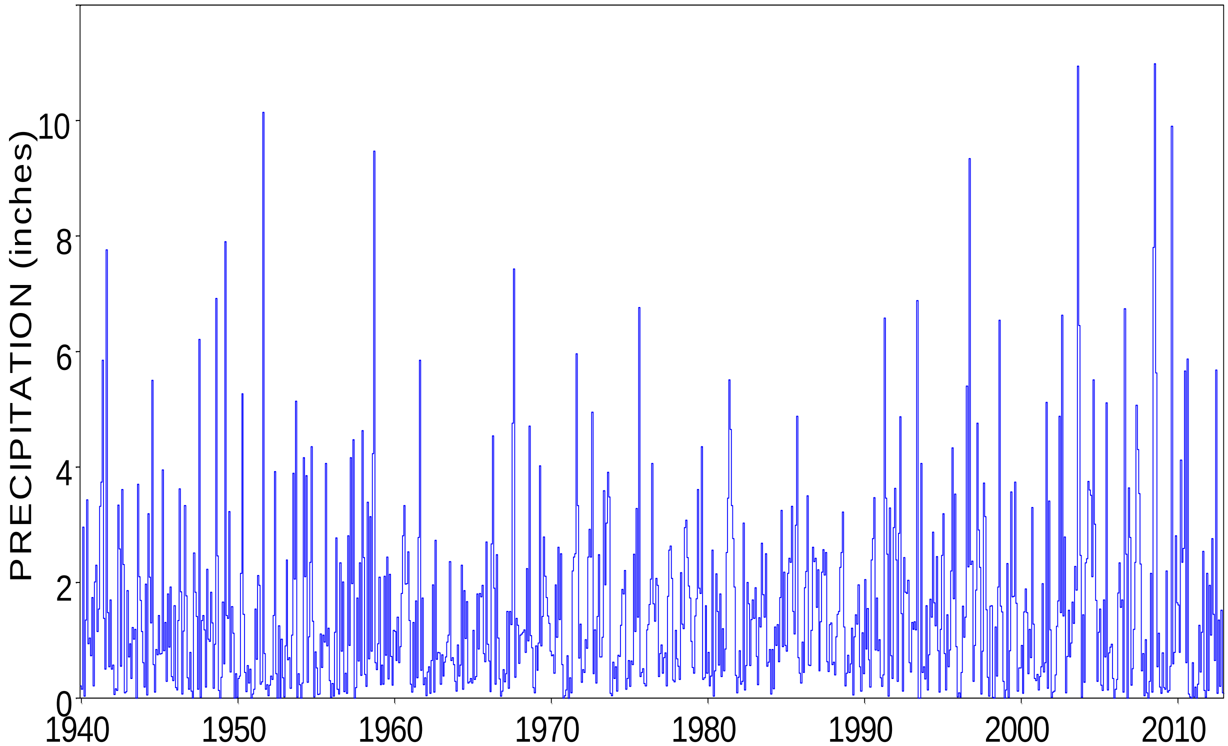
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 1010



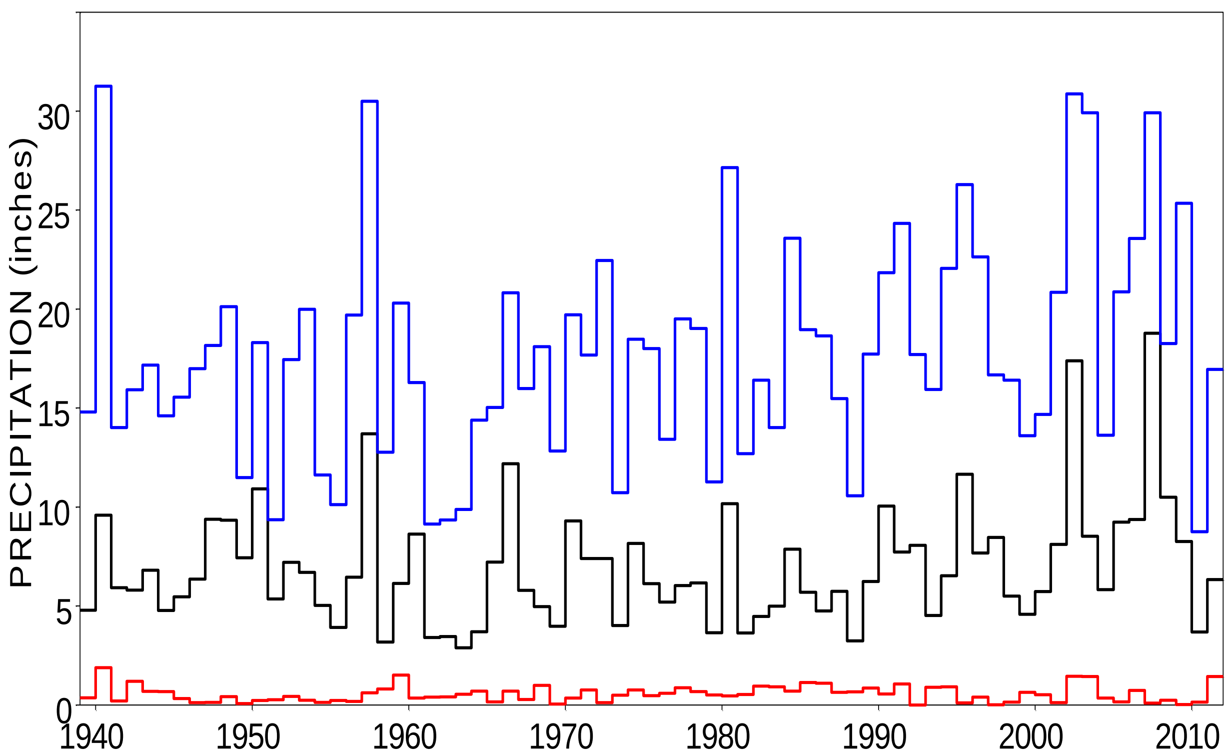
Monthly Precipitation for Quadrangle 1011



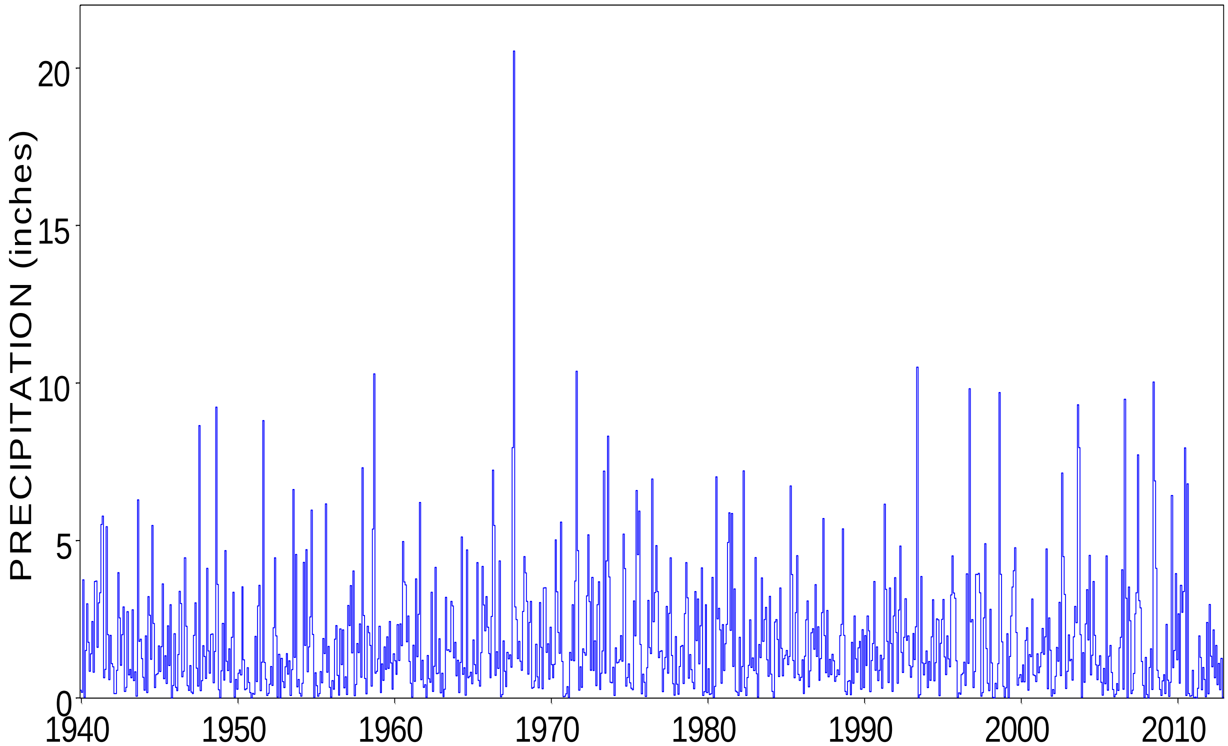
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 1011



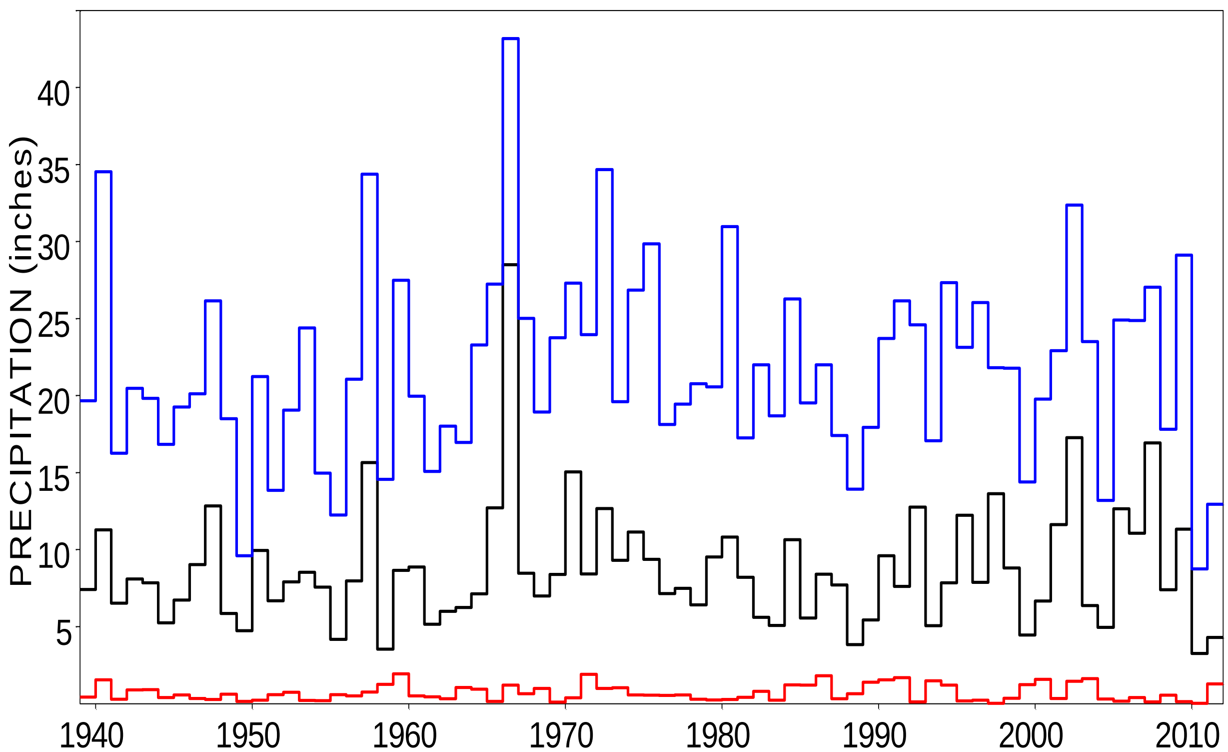
Monthly Precipitation for Quadrangle 1108



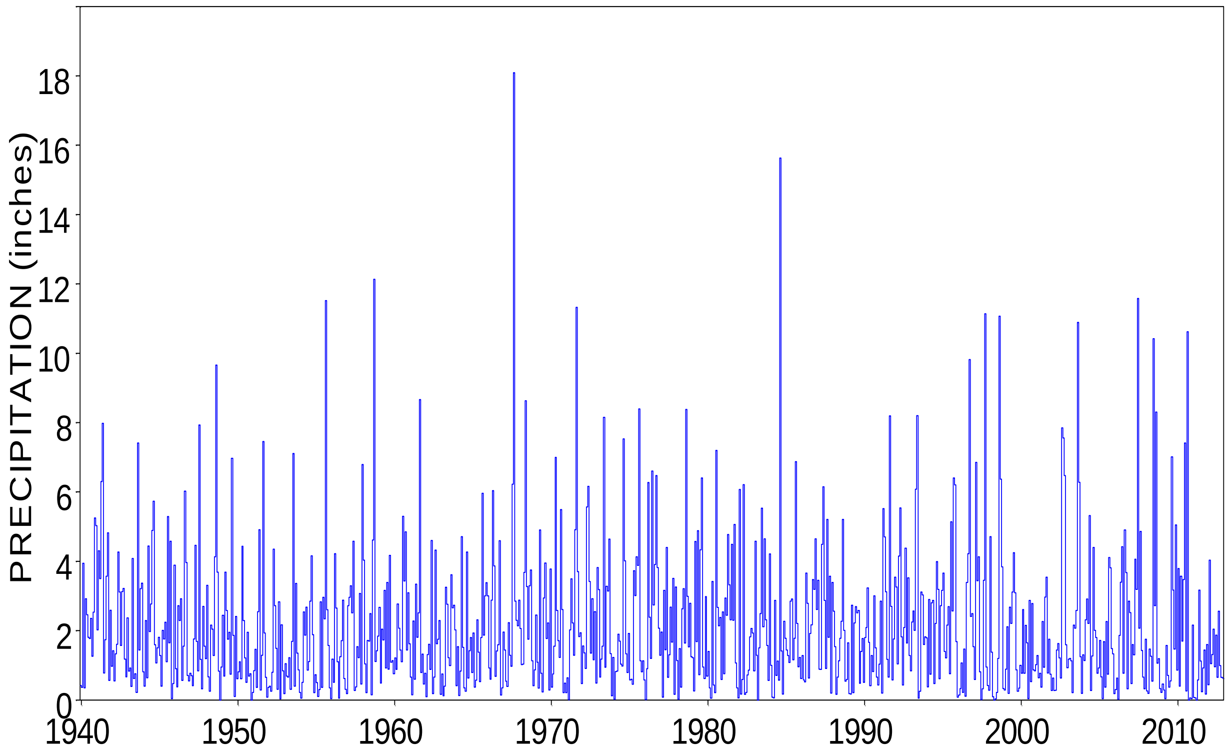
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 1108



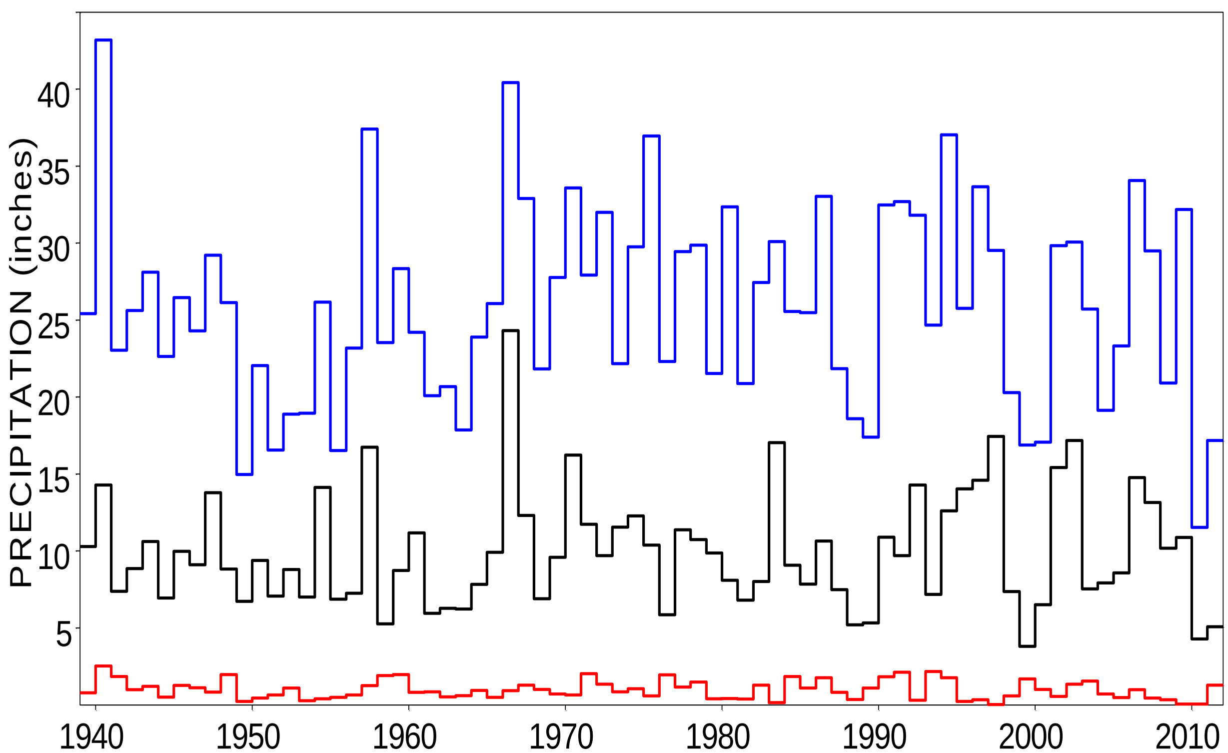
Monthly Precipitation for Quadrangle 1109



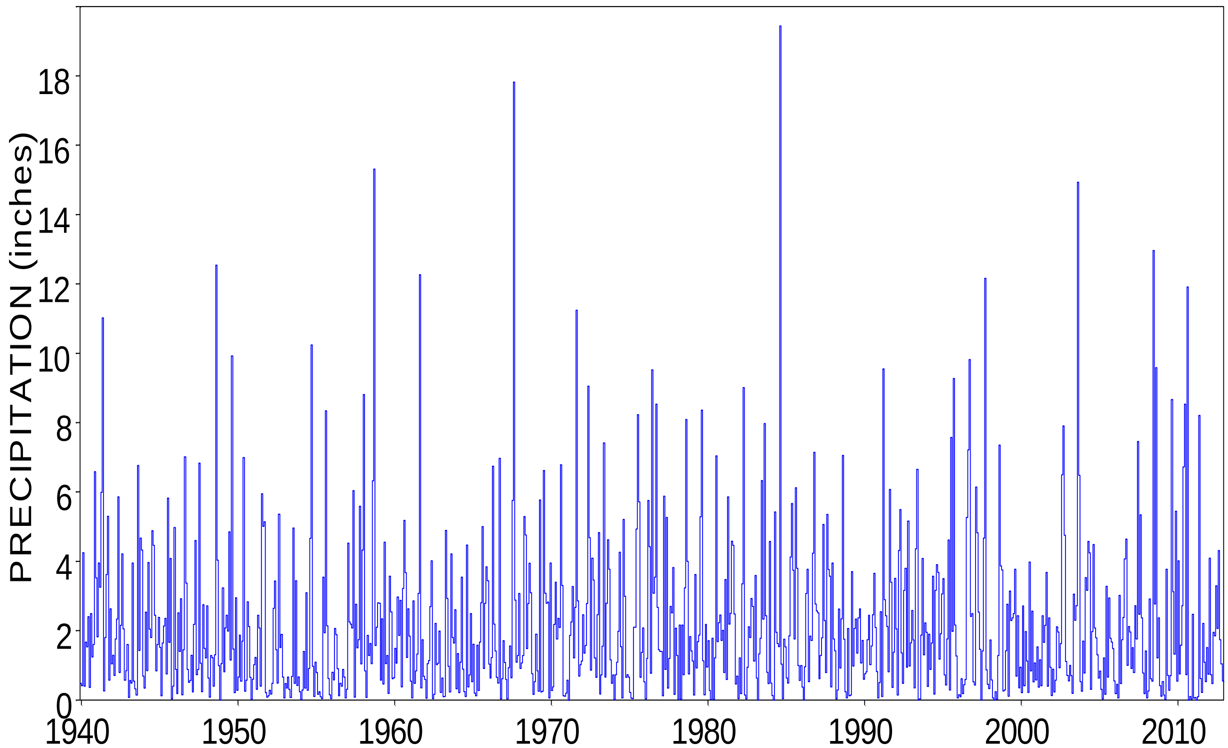
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 1109



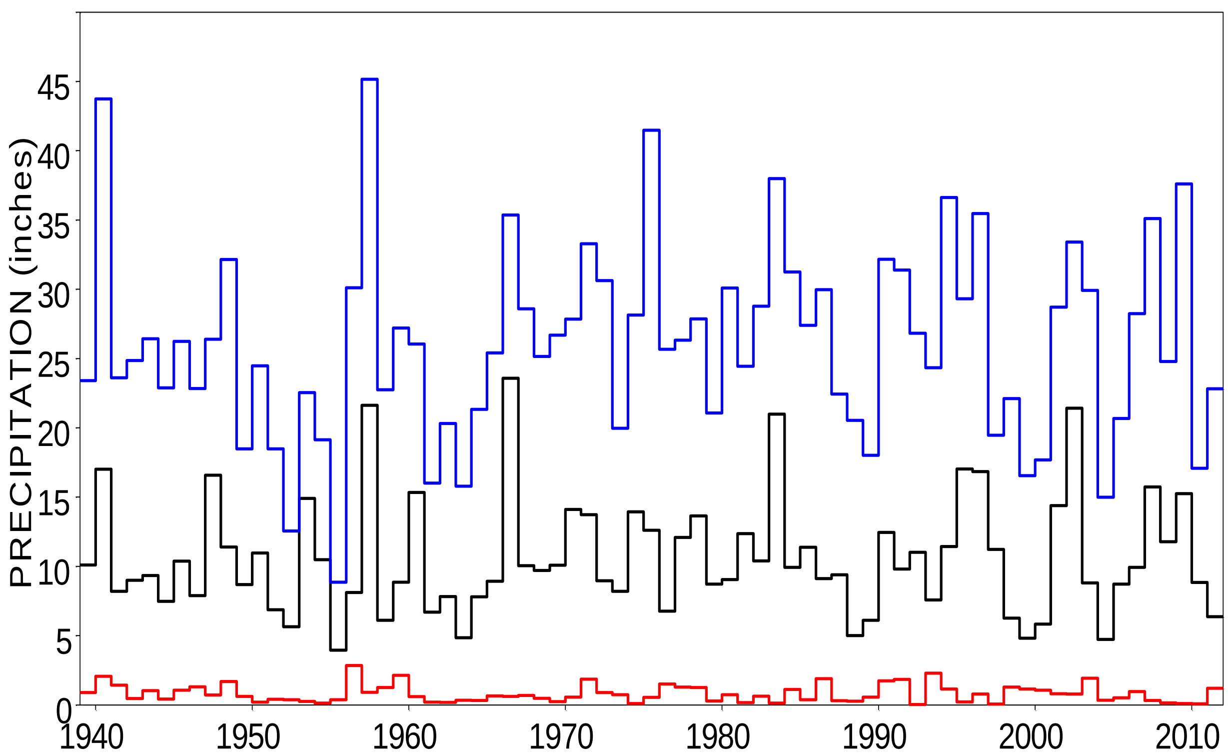
Monthly Precipitation for Quadrangle 1110



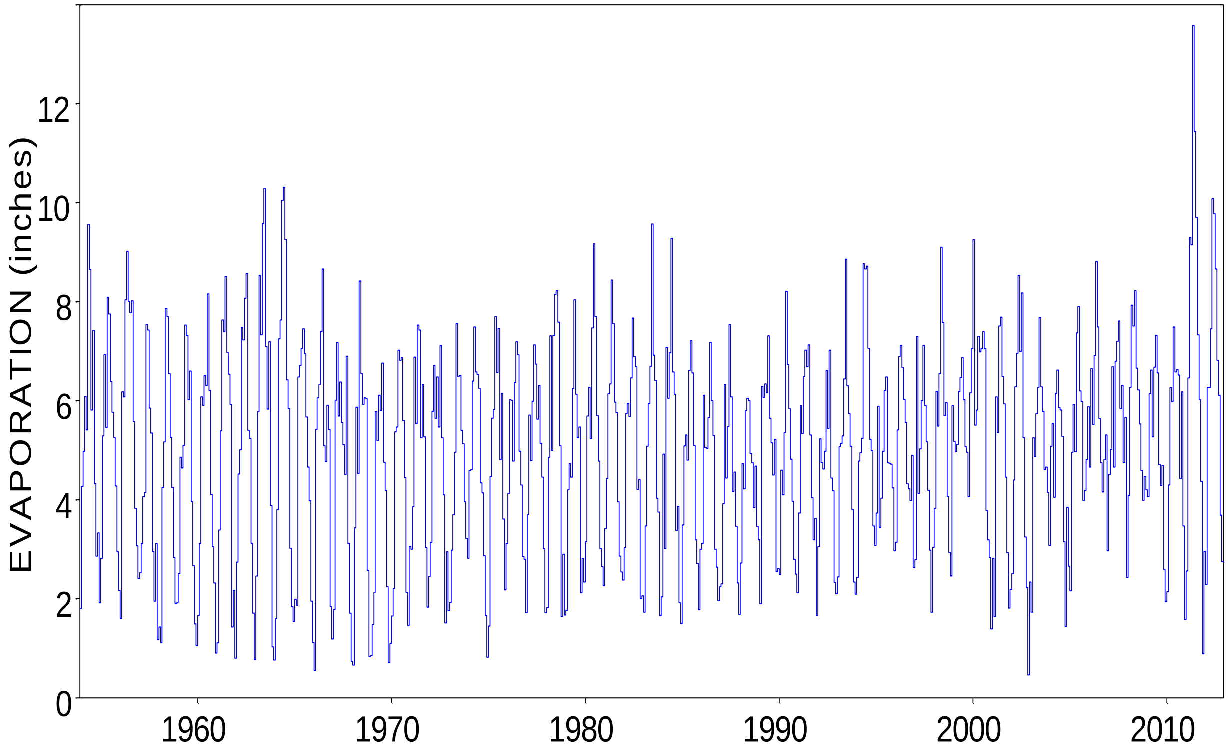
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 1110



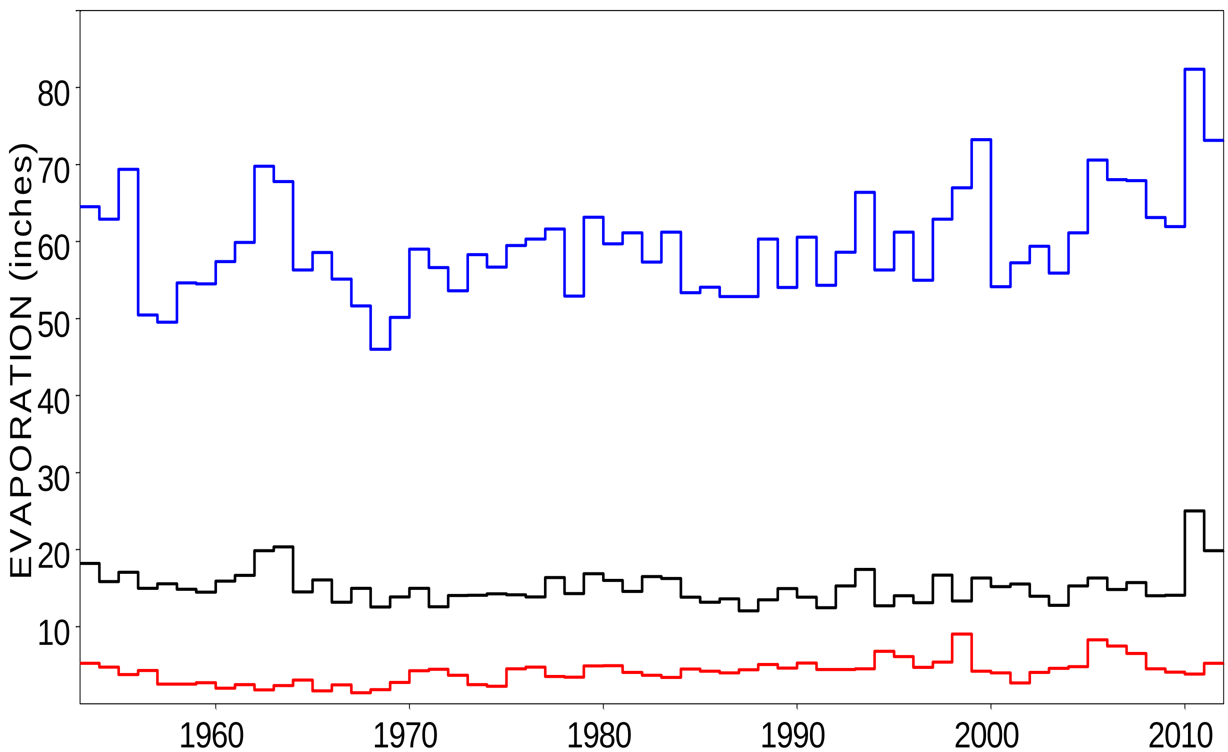
Monthly Precipitation for Quadrangle 1210



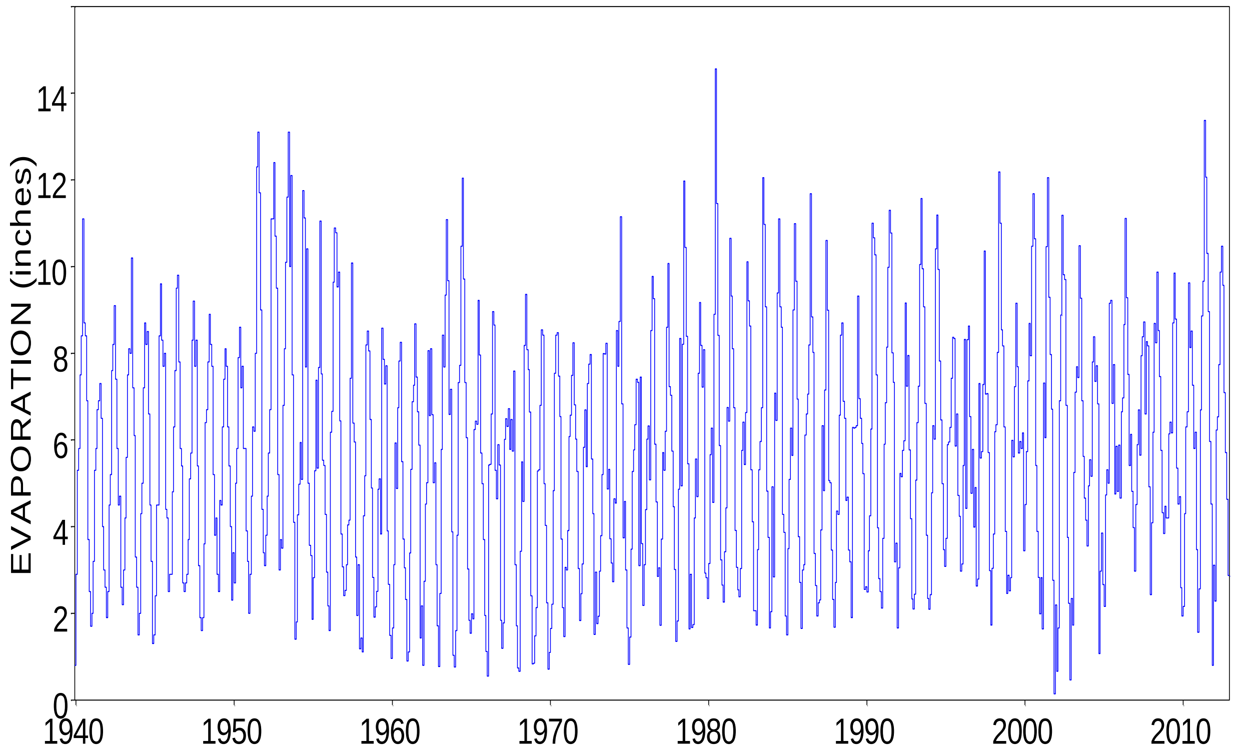
Annual Total, 2-Month Maximum, and 2-Month Minimum Precipitation for Quadrangle 1210



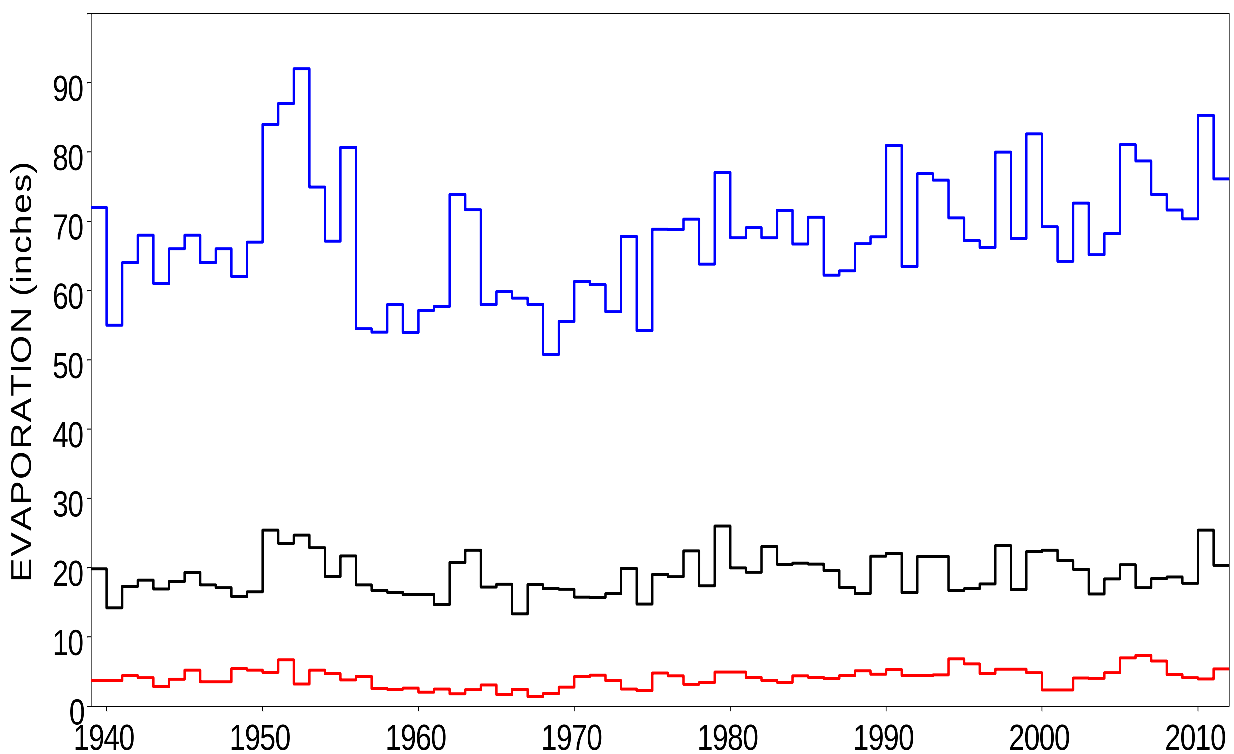
Monthly Evaporation for Quadrangle 104



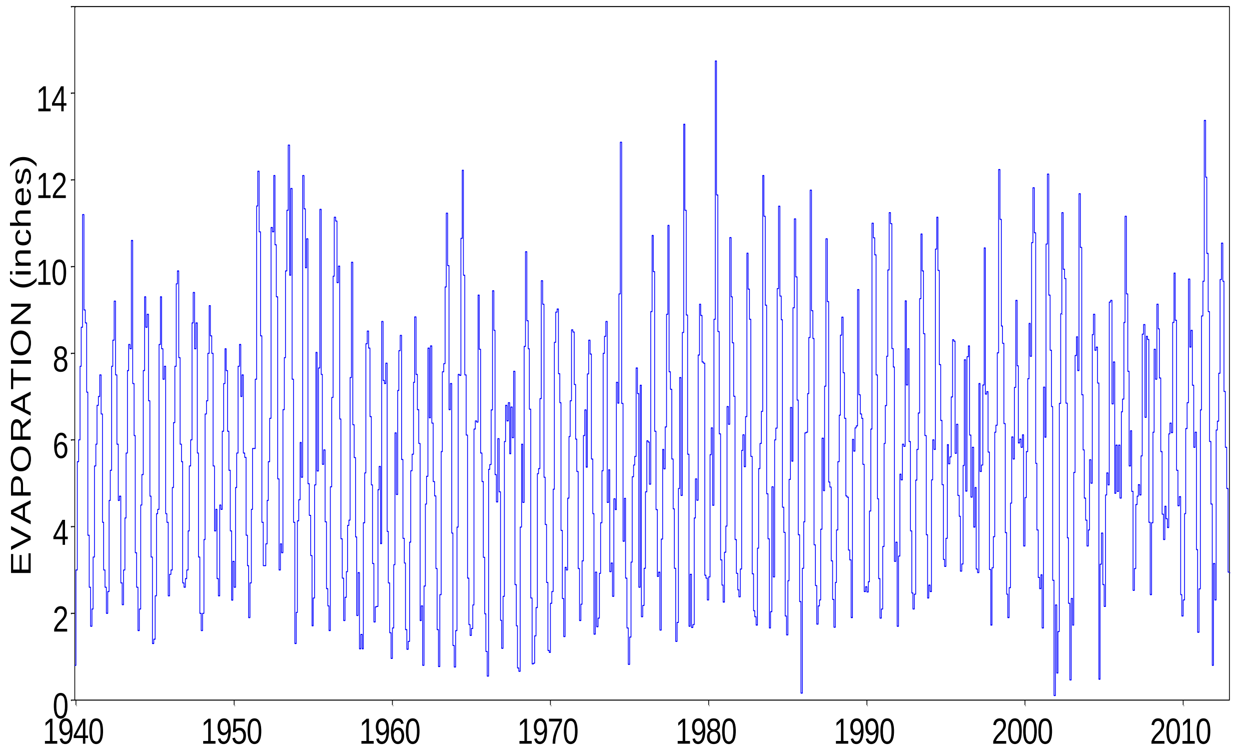
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 104



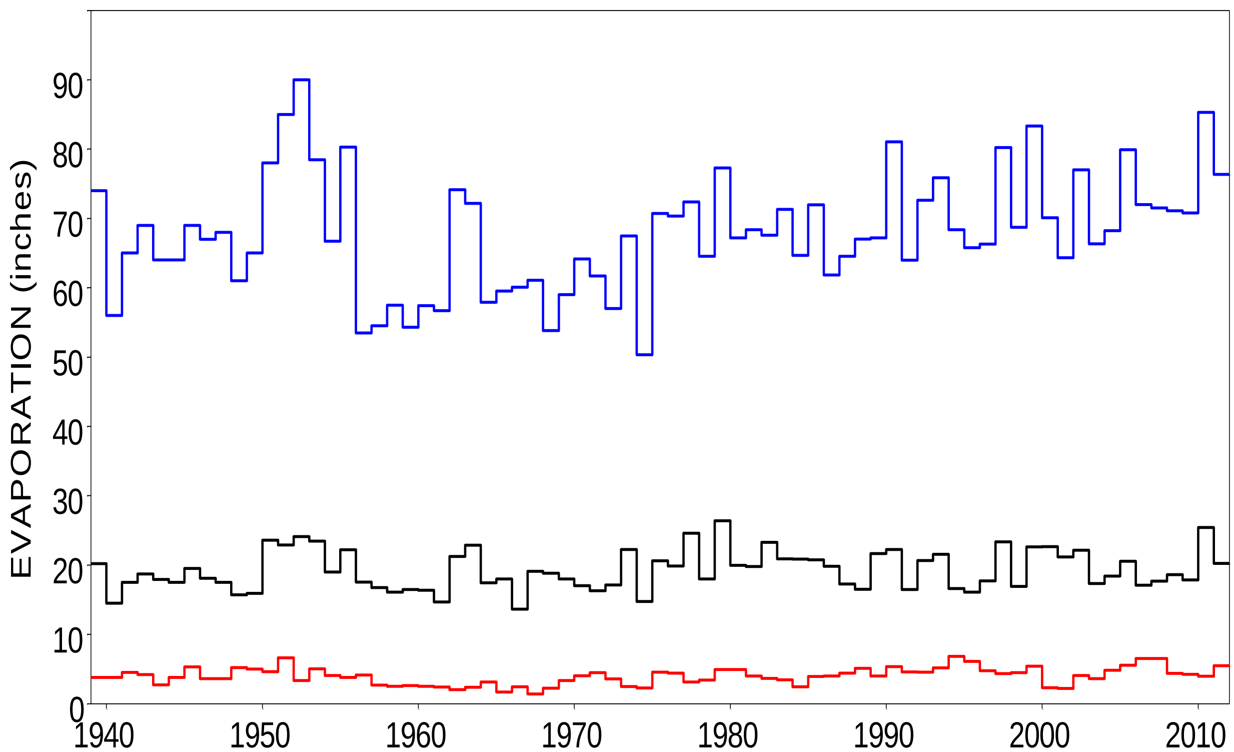
Monthly Evaporation for Quadrangle 105



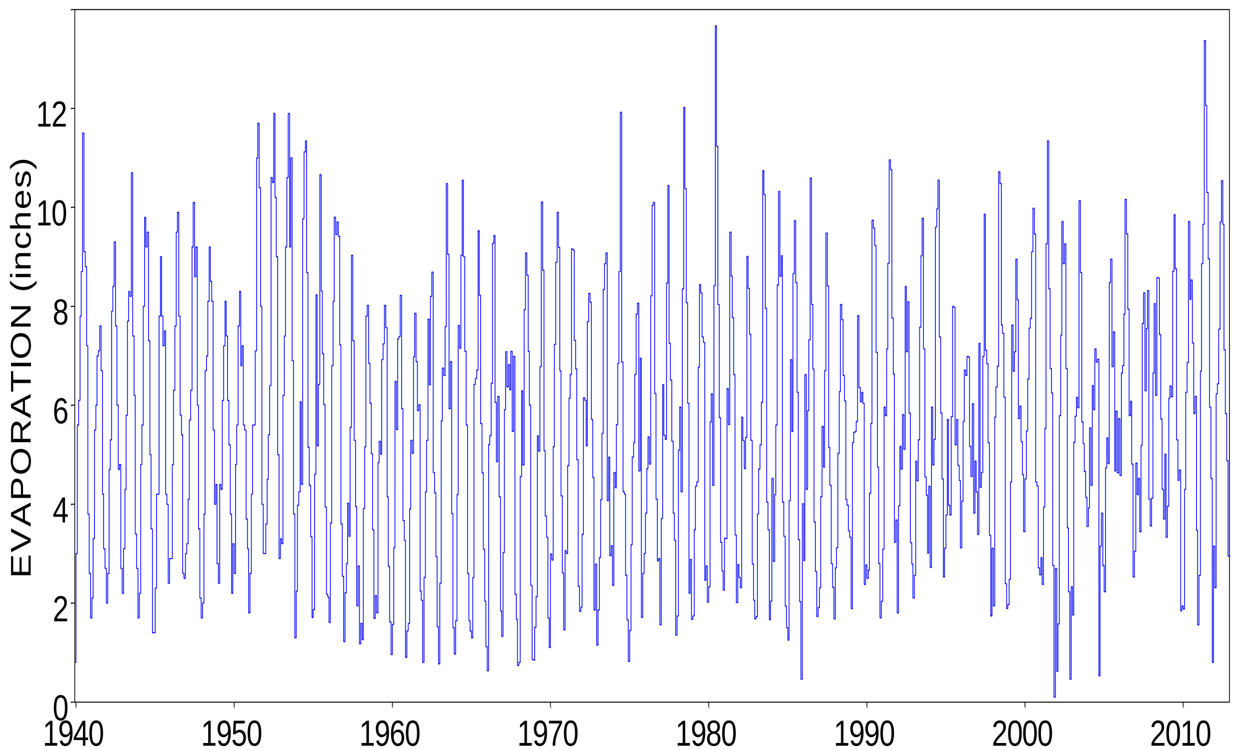
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 105



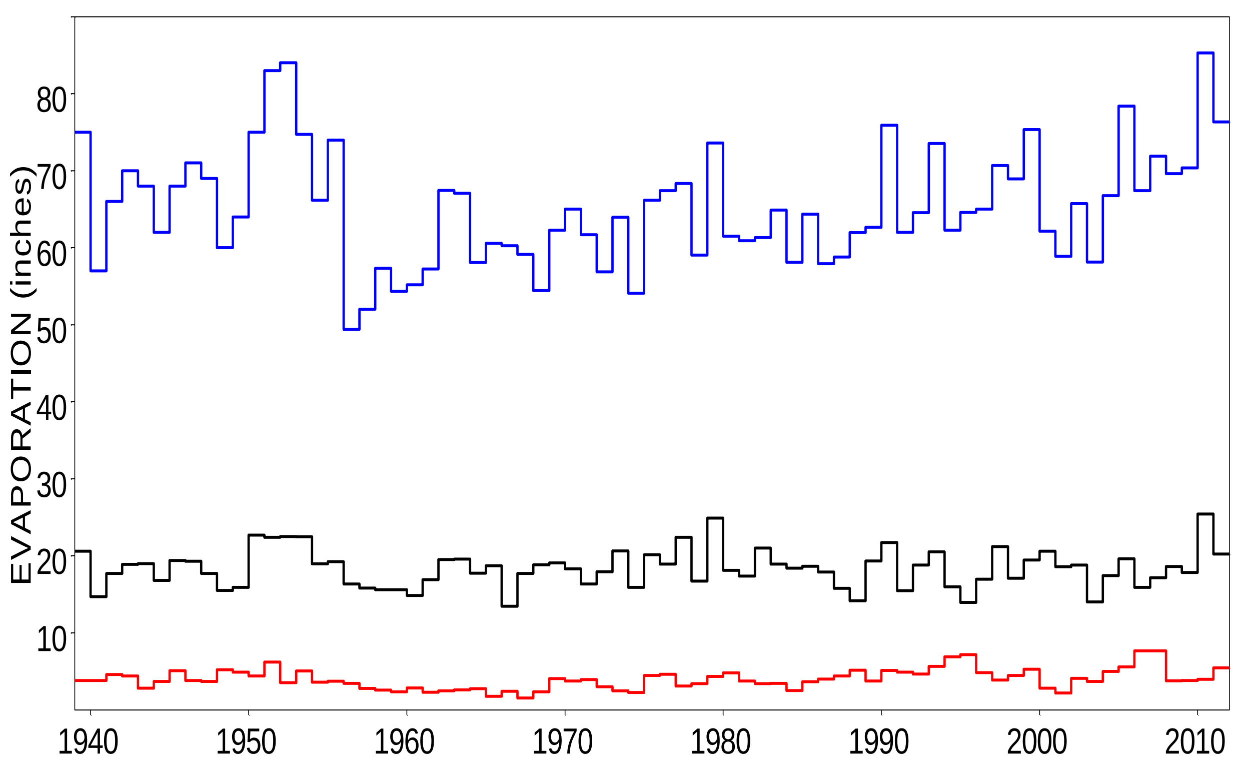
Monthly Evaporation for Quadrangle 106



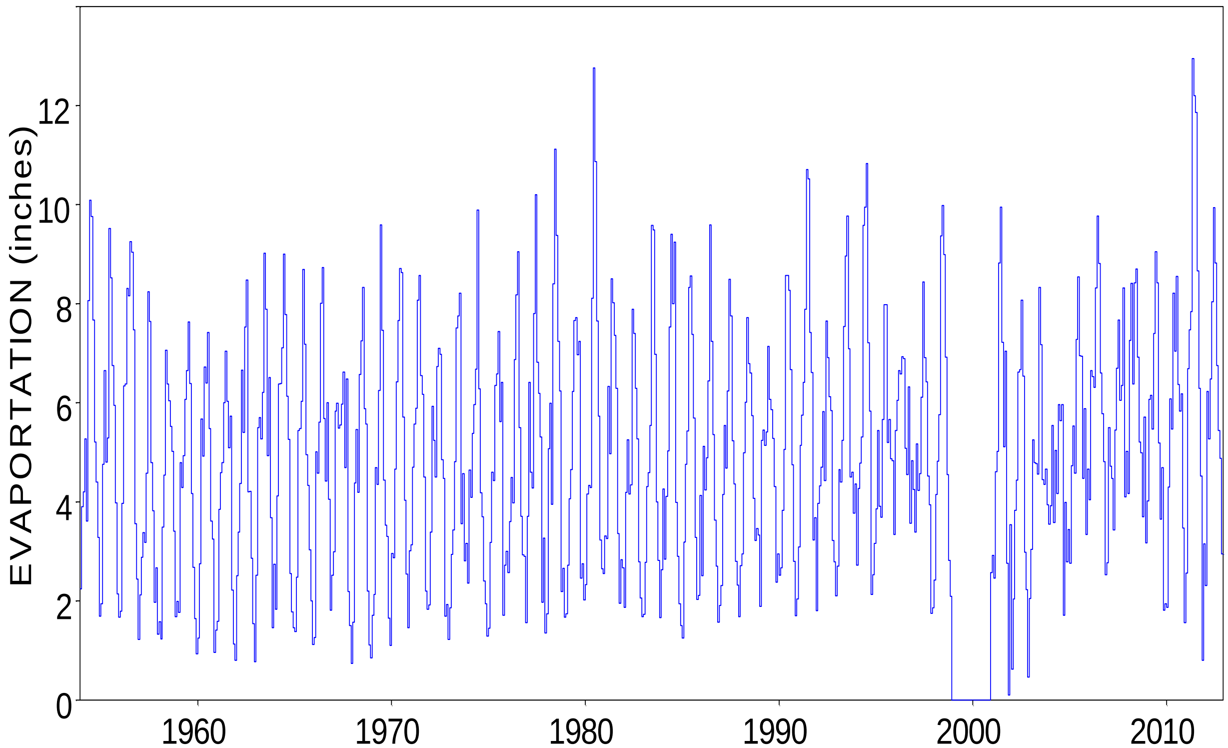
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 106



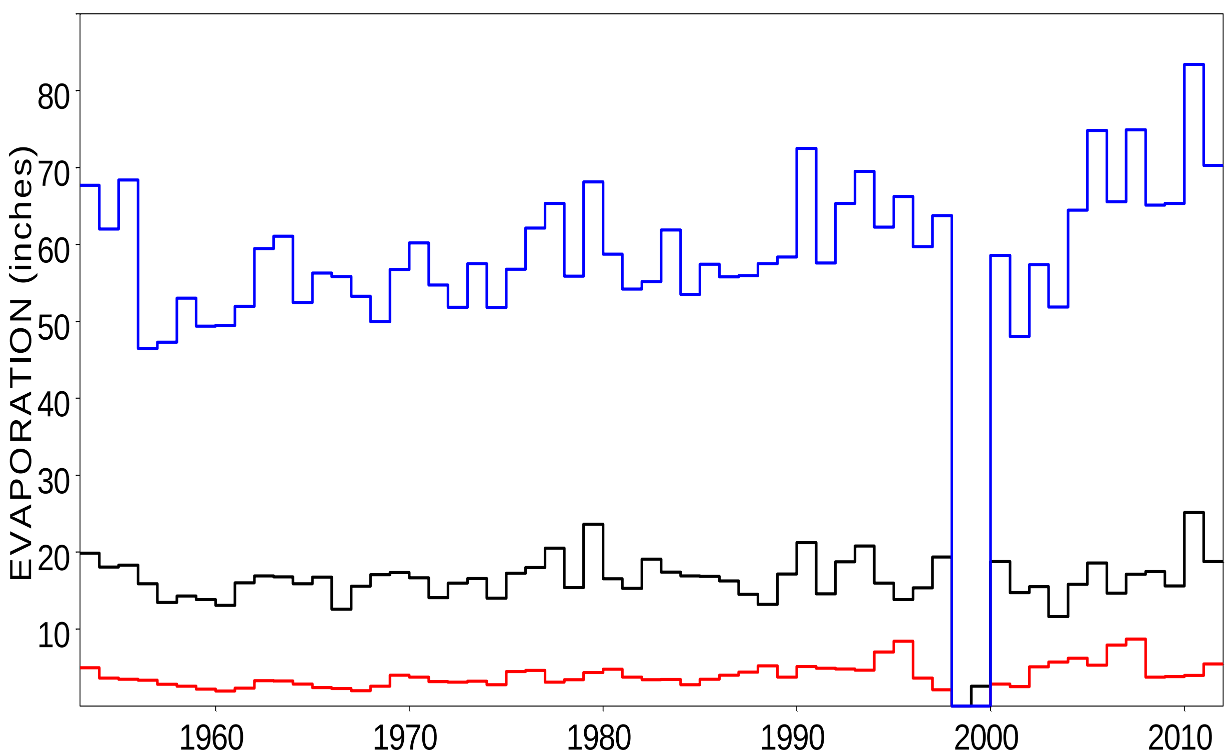
Monthly Evaporation for Quadrangle 107



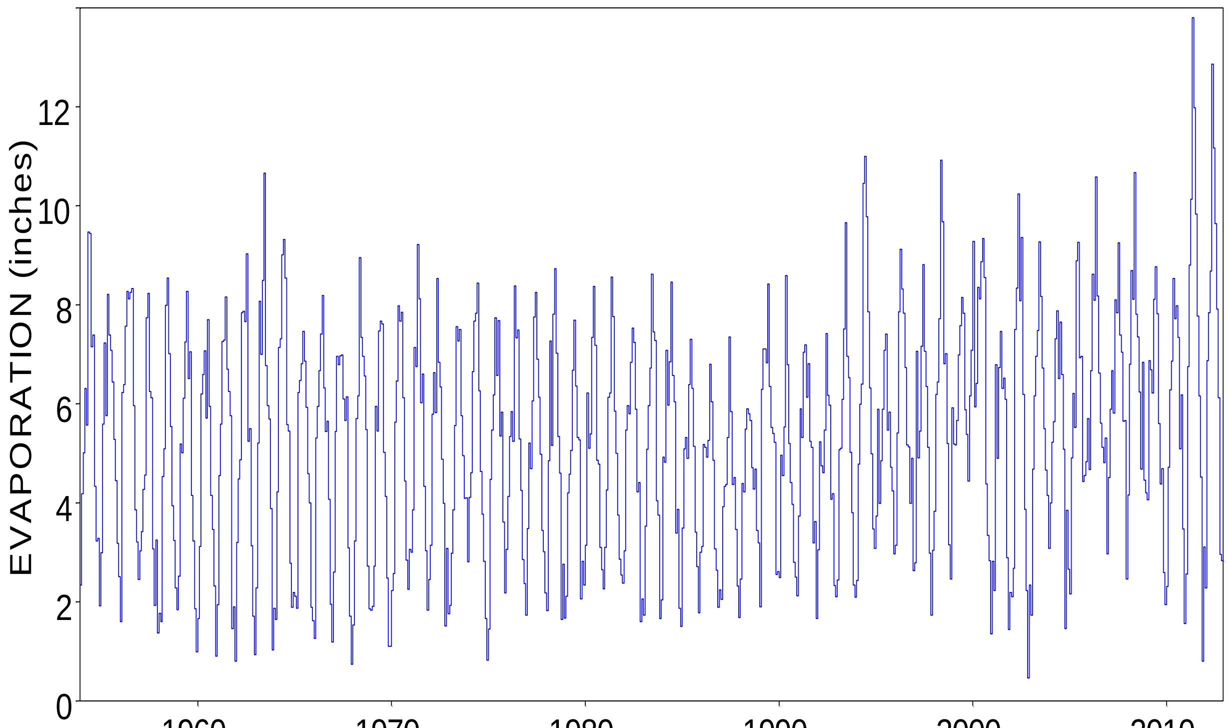
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 107



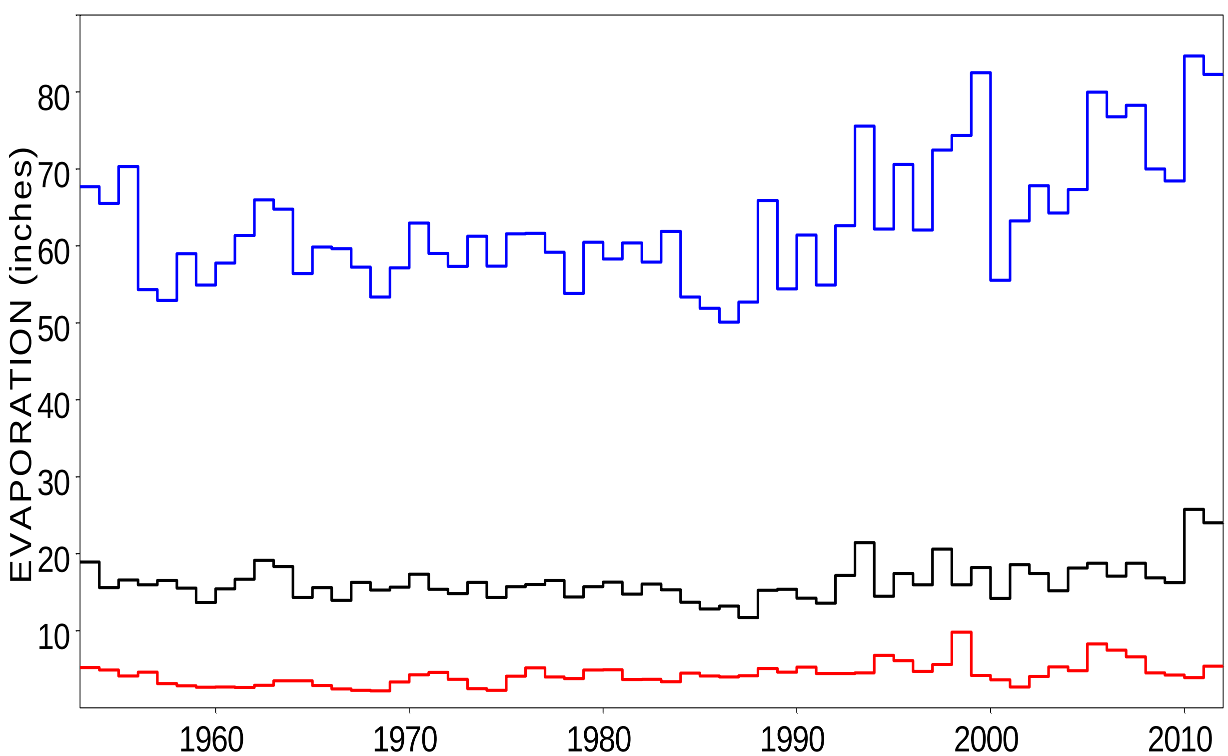
Monthly Evaporation for Quadrangle 108 (missing data from 1999-2000)



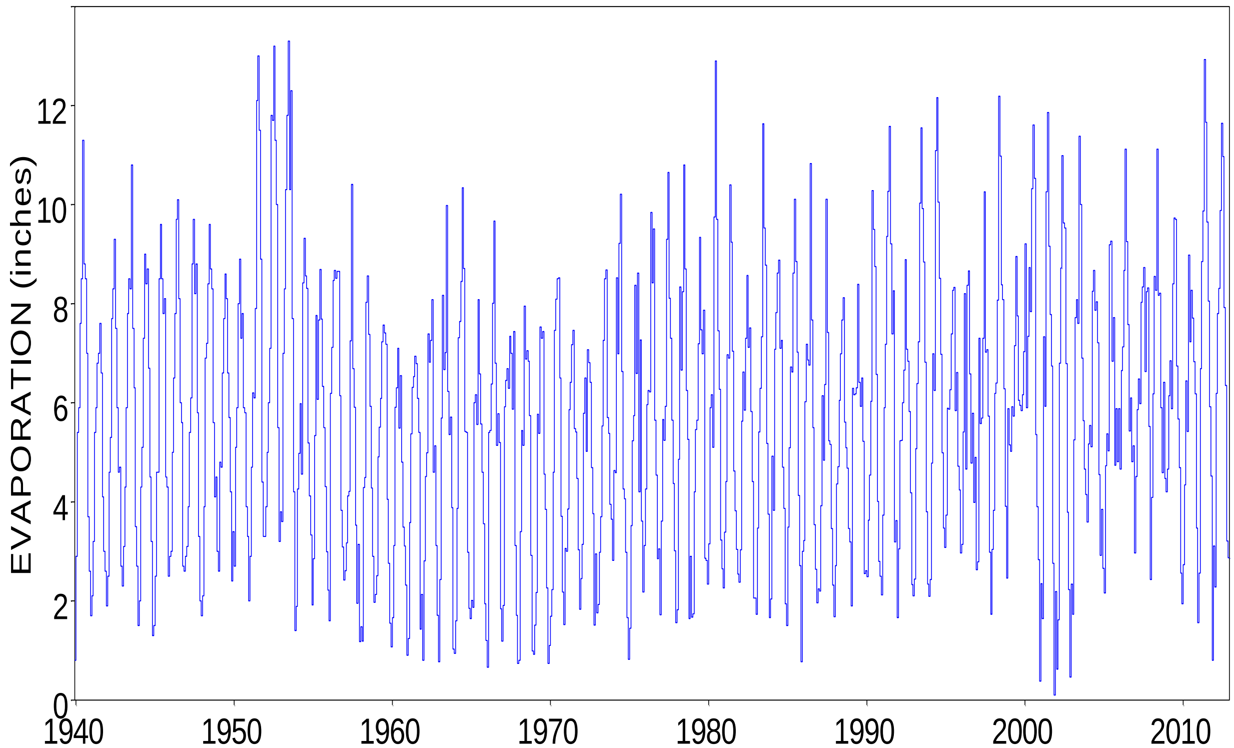
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 108 (missing data from 1999-2000)



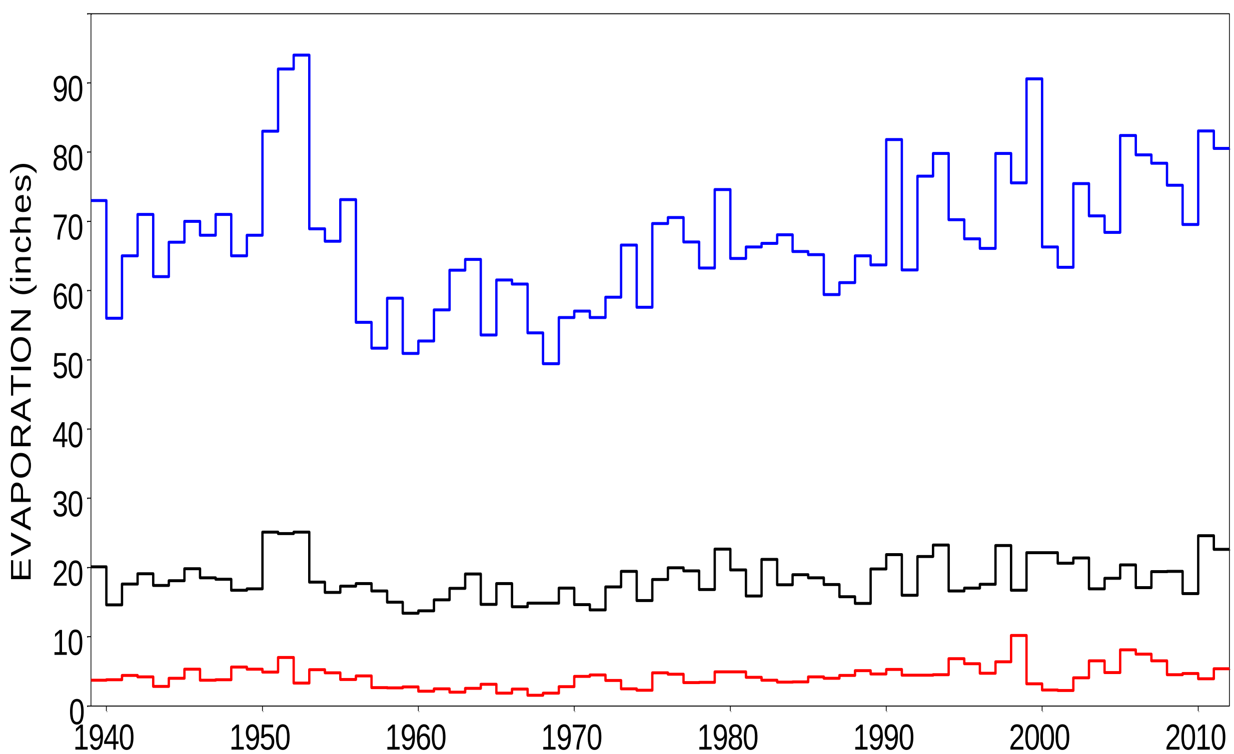
Monthly Evaporation for Quadrangle 204



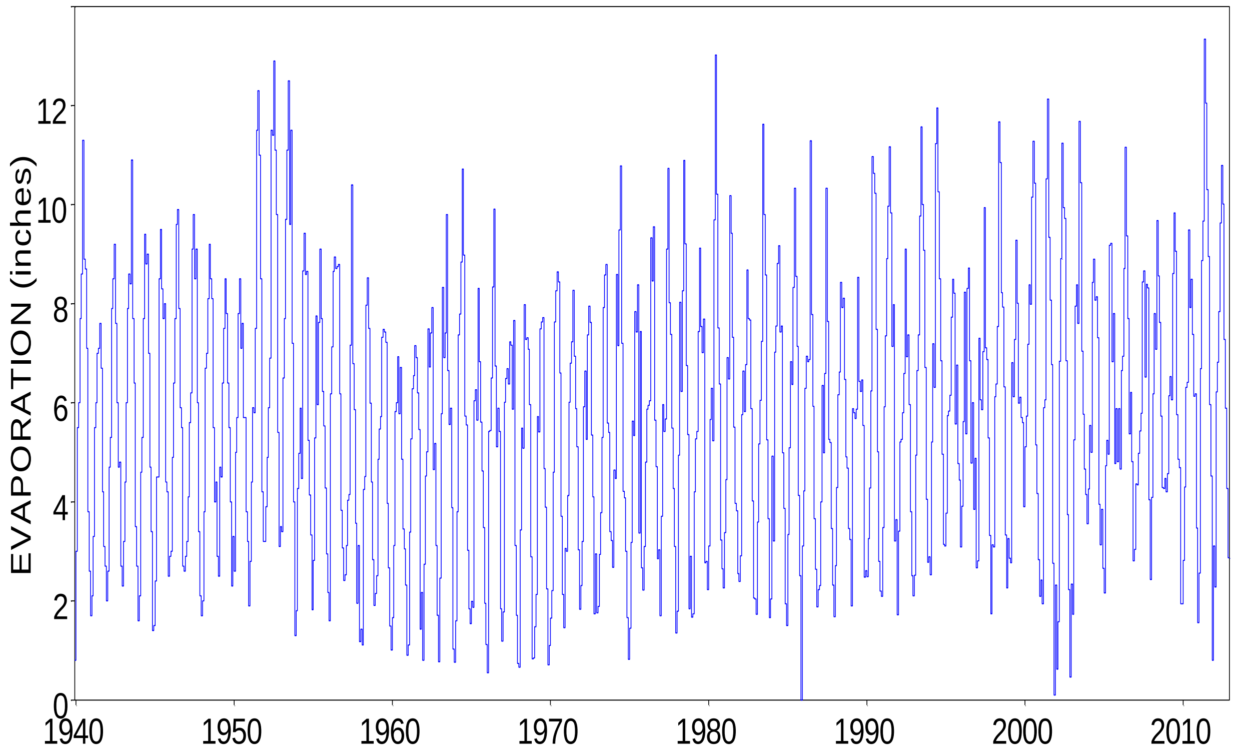
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 204



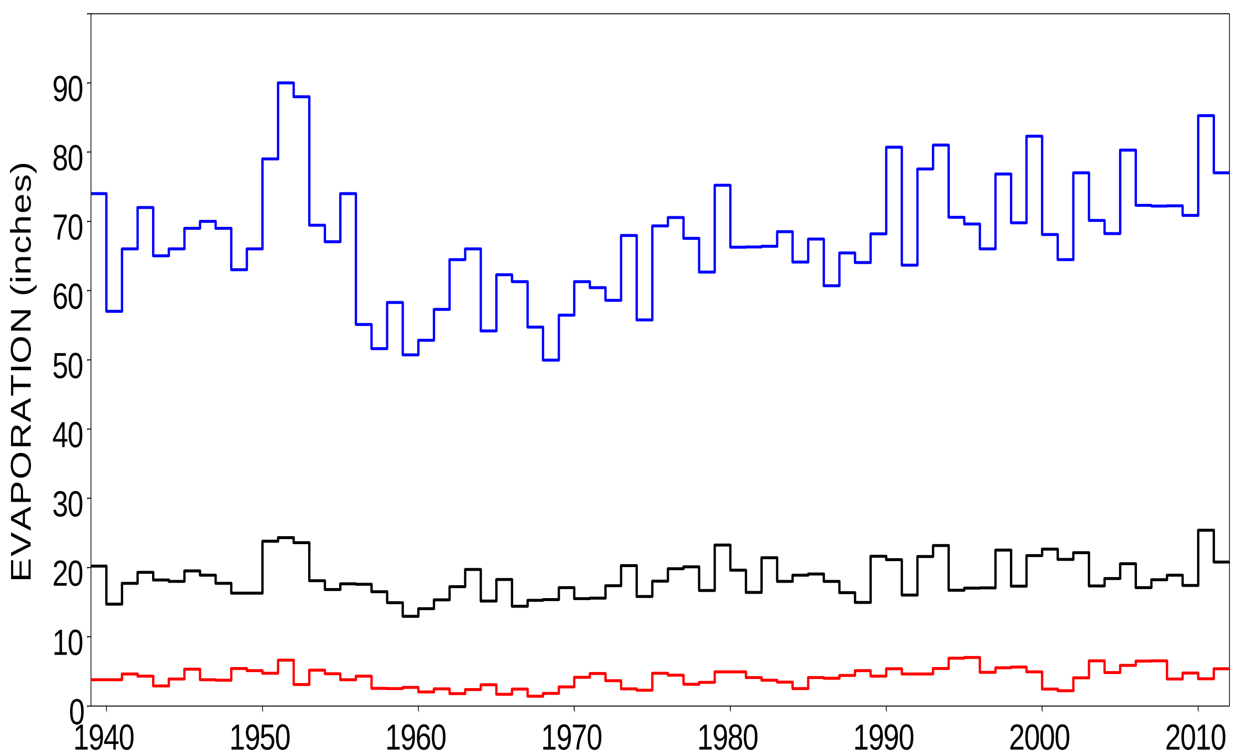
Monthly Evaporation for Quadrangle 205



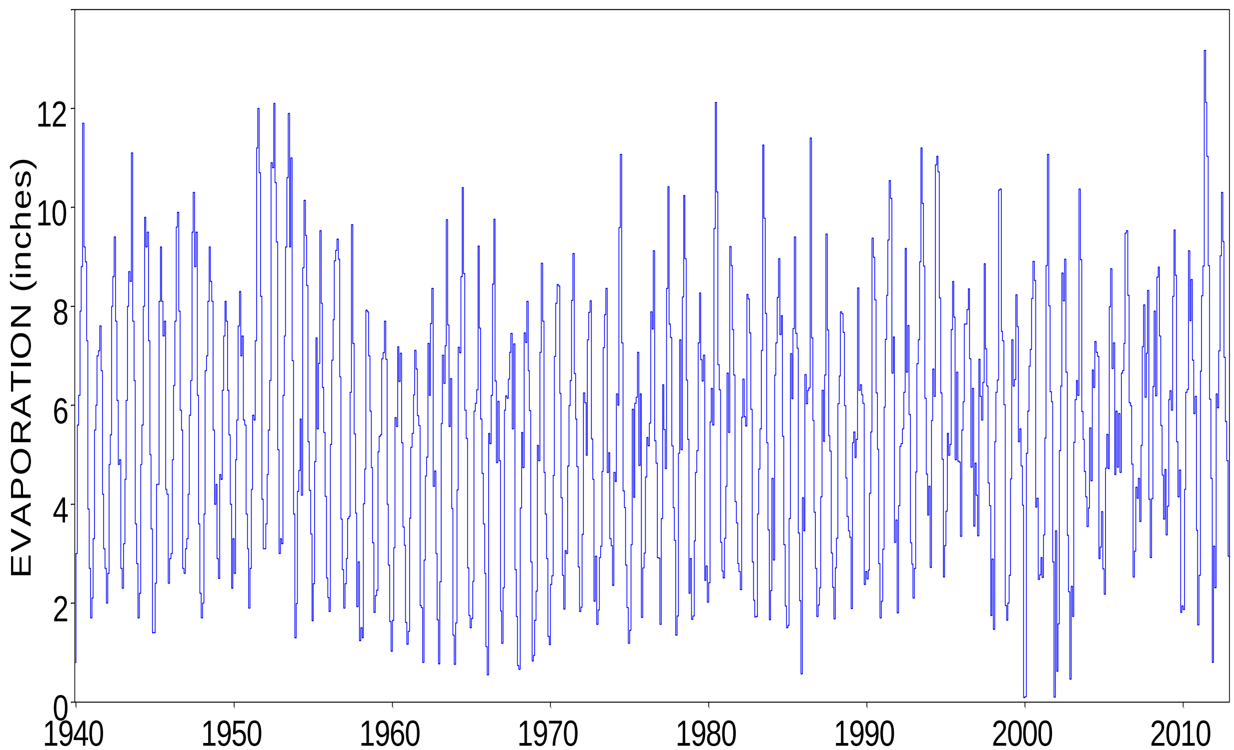
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 205



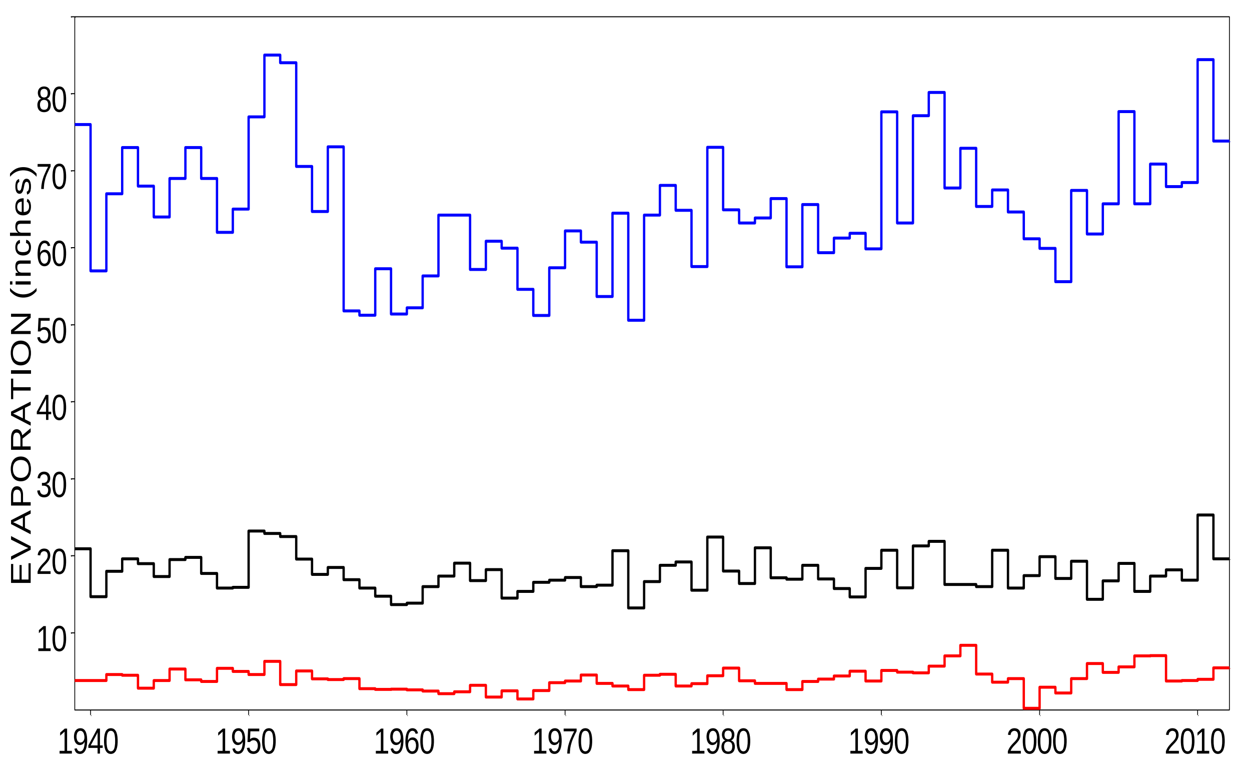
Monthly Evaporation for Quadrangle 206



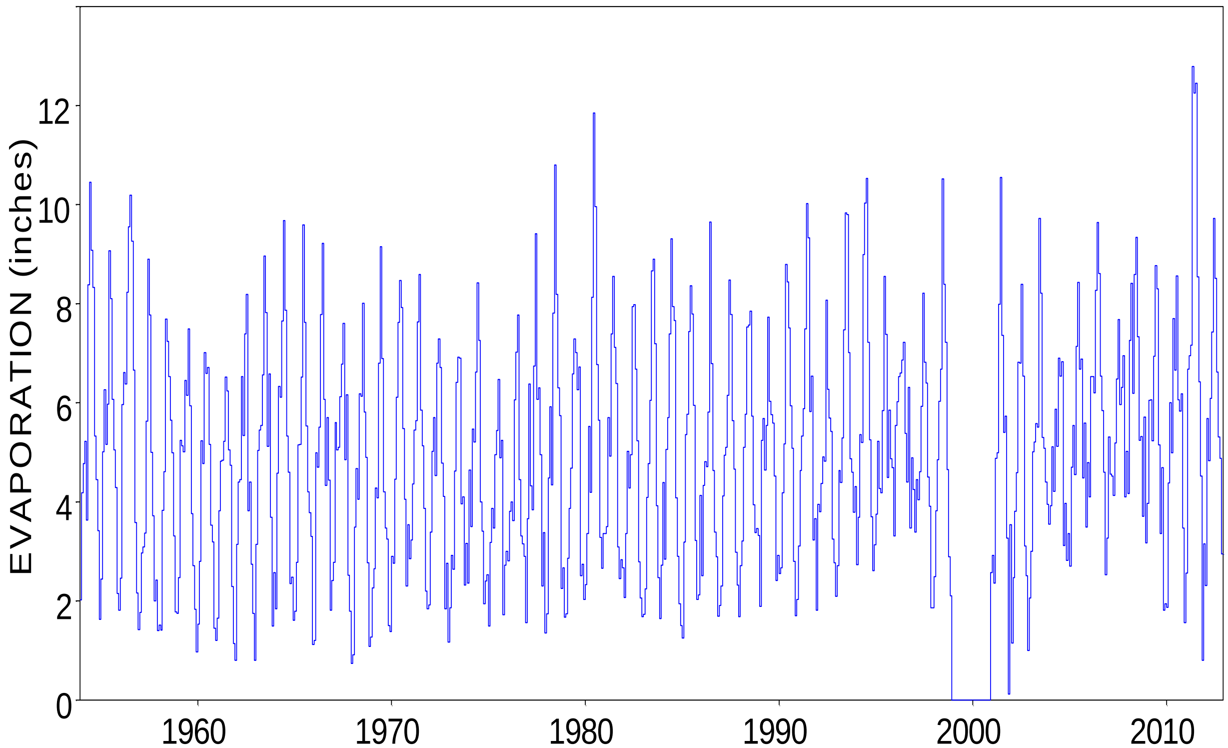
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 206



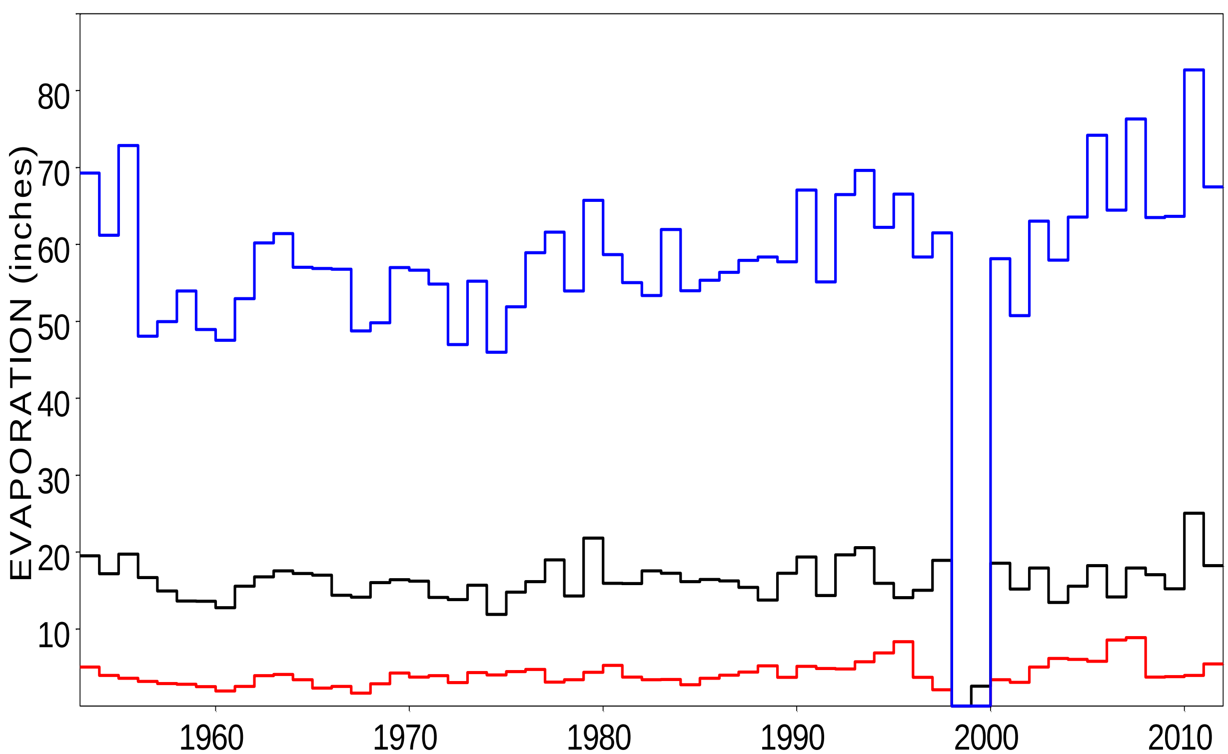
Monthly Evaporation for Quadrangle 207



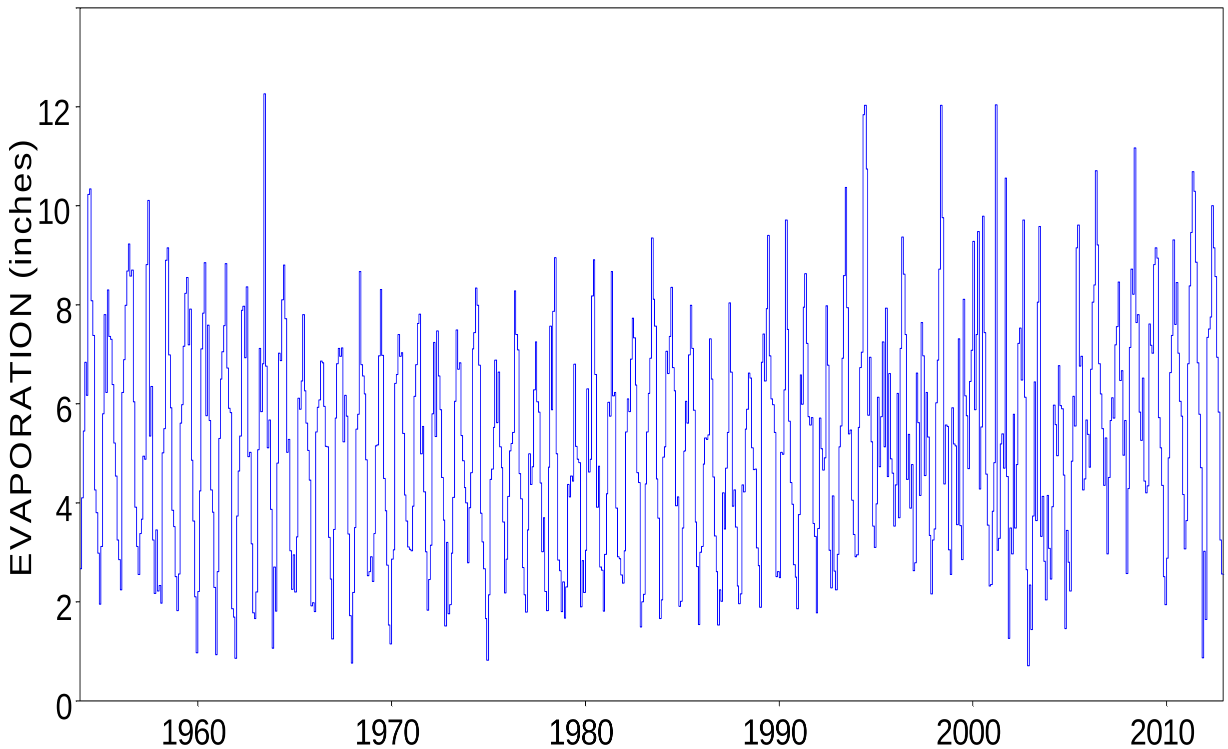
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 207



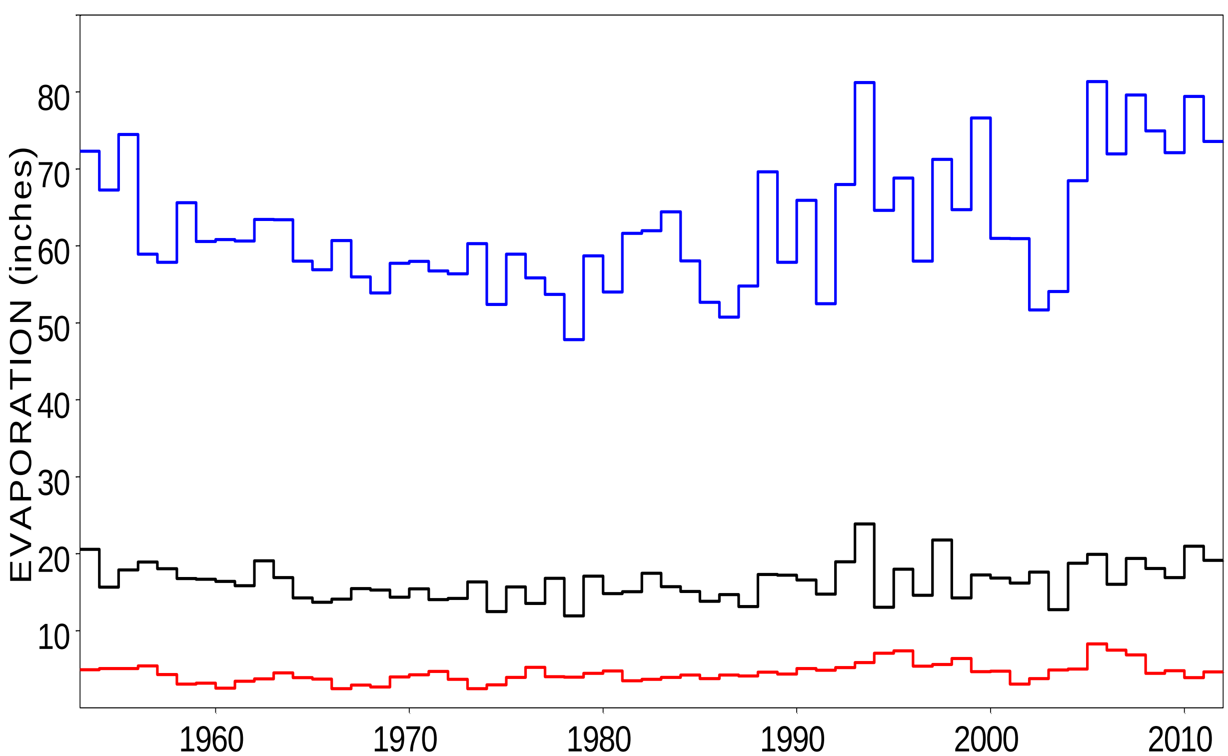
Monthly Evaporation for Quadrangle 208(missing date form 1999-2000)



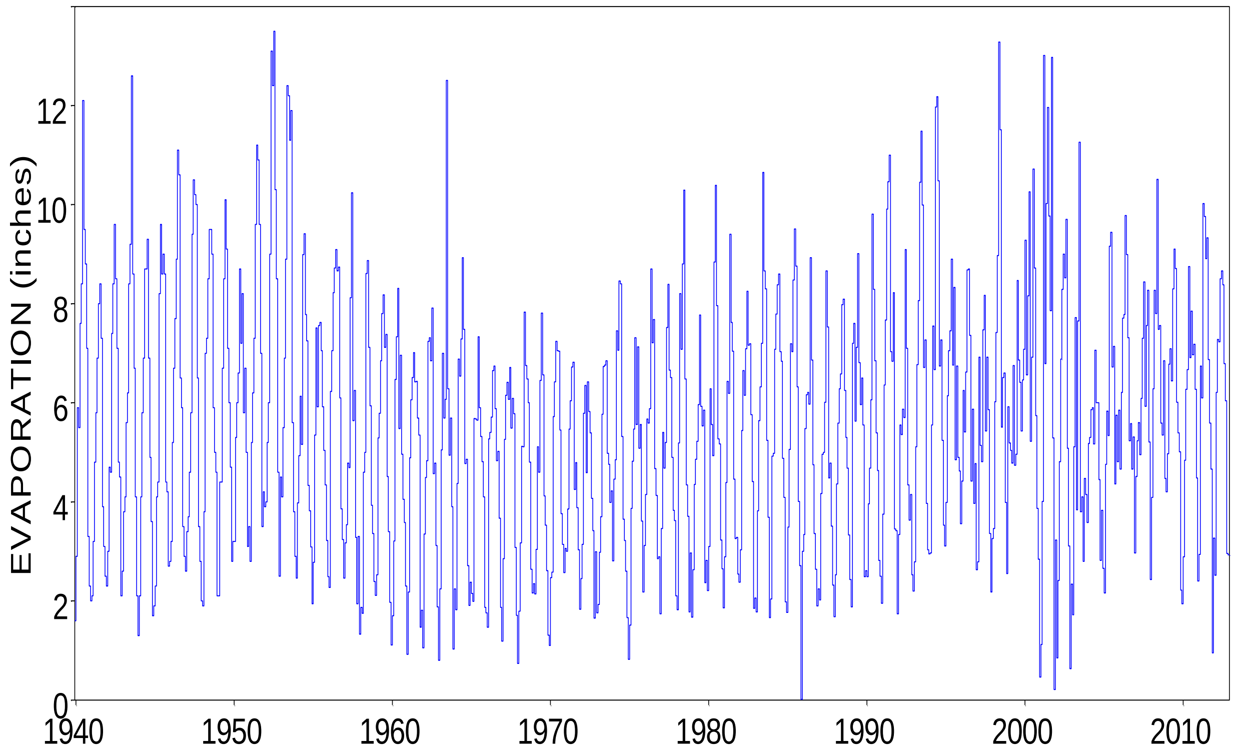
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 208 (missing date form 1999-2000)



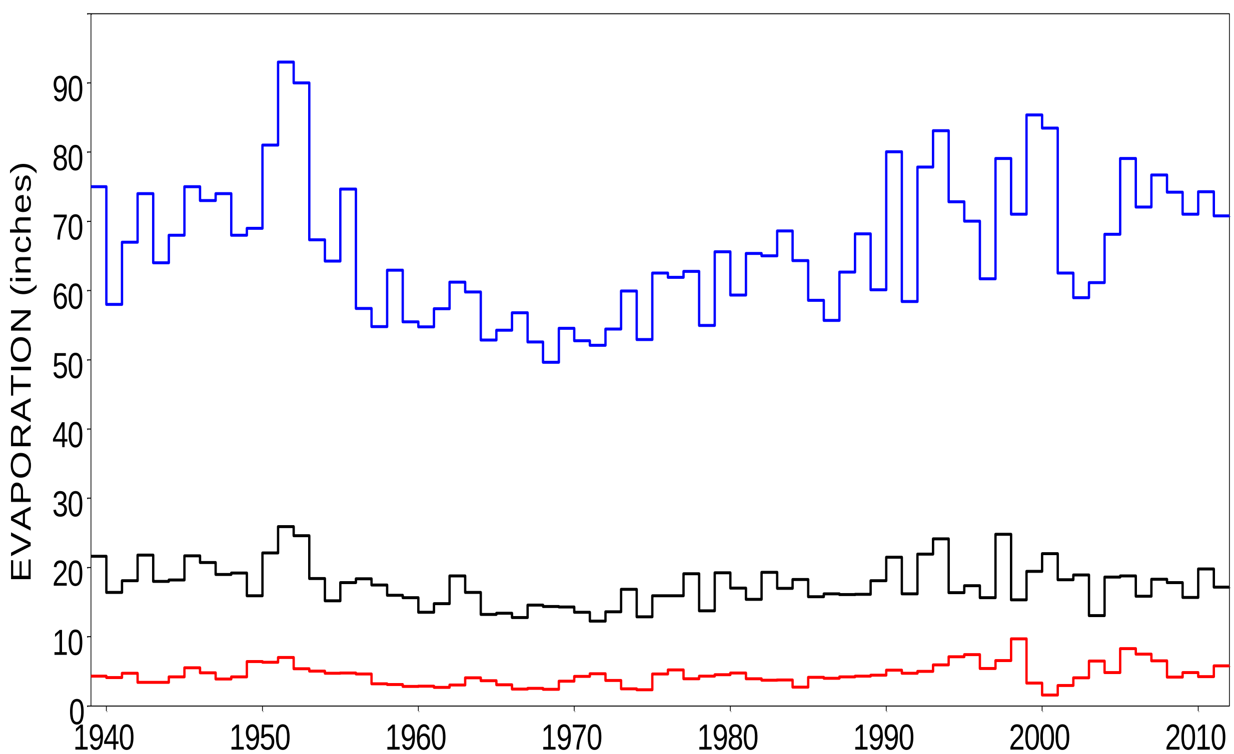
Monthly Evaporation for Quadrangle 304



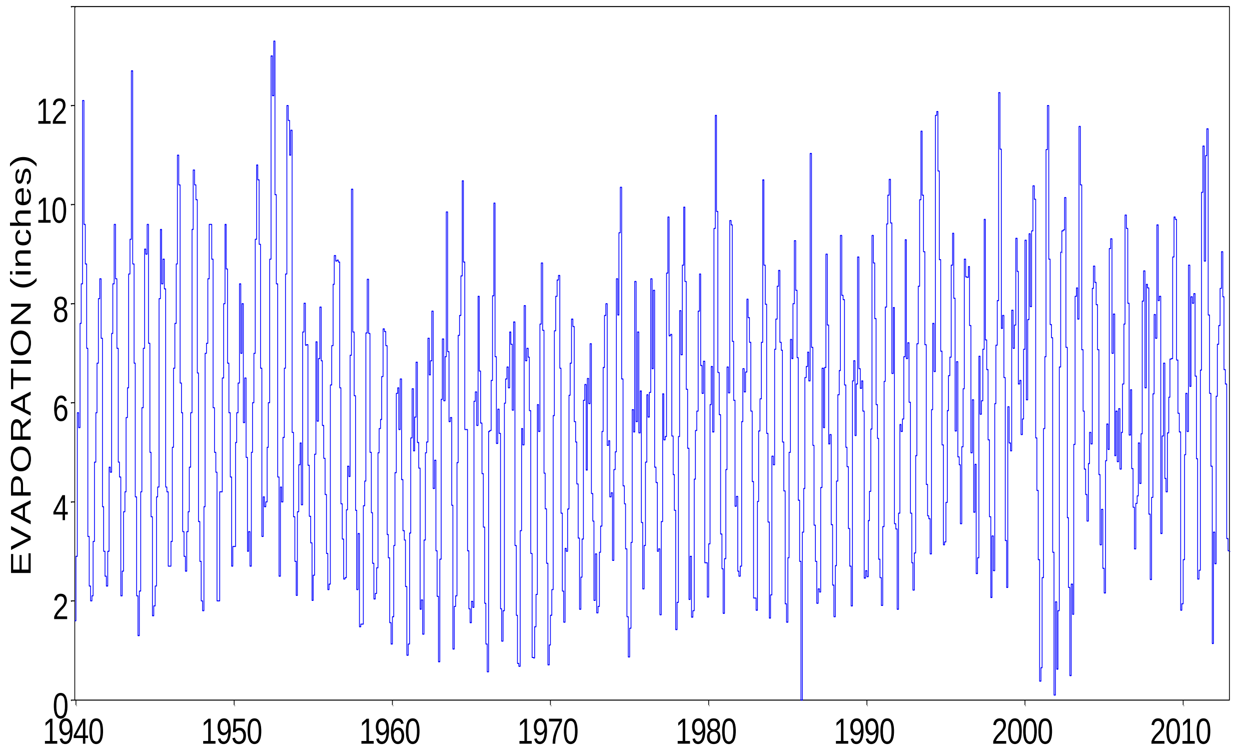
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 304



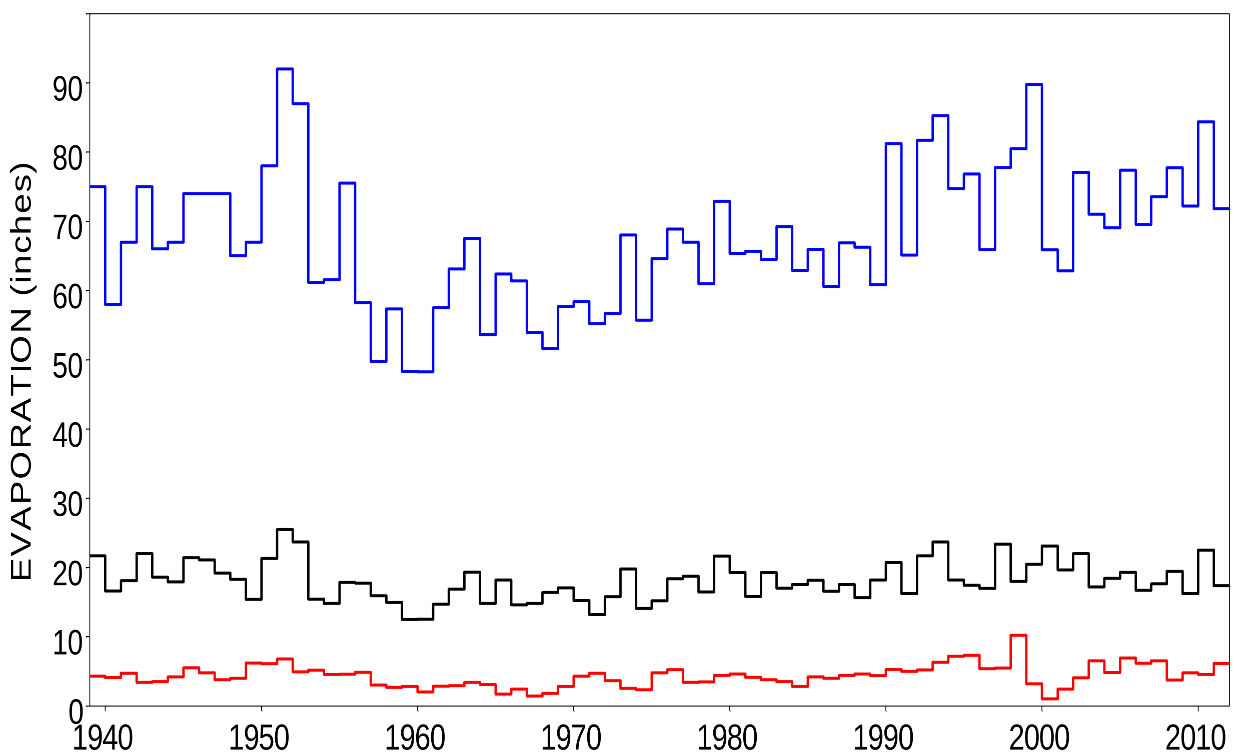
Monthly Evaporation for Quadrangle 305



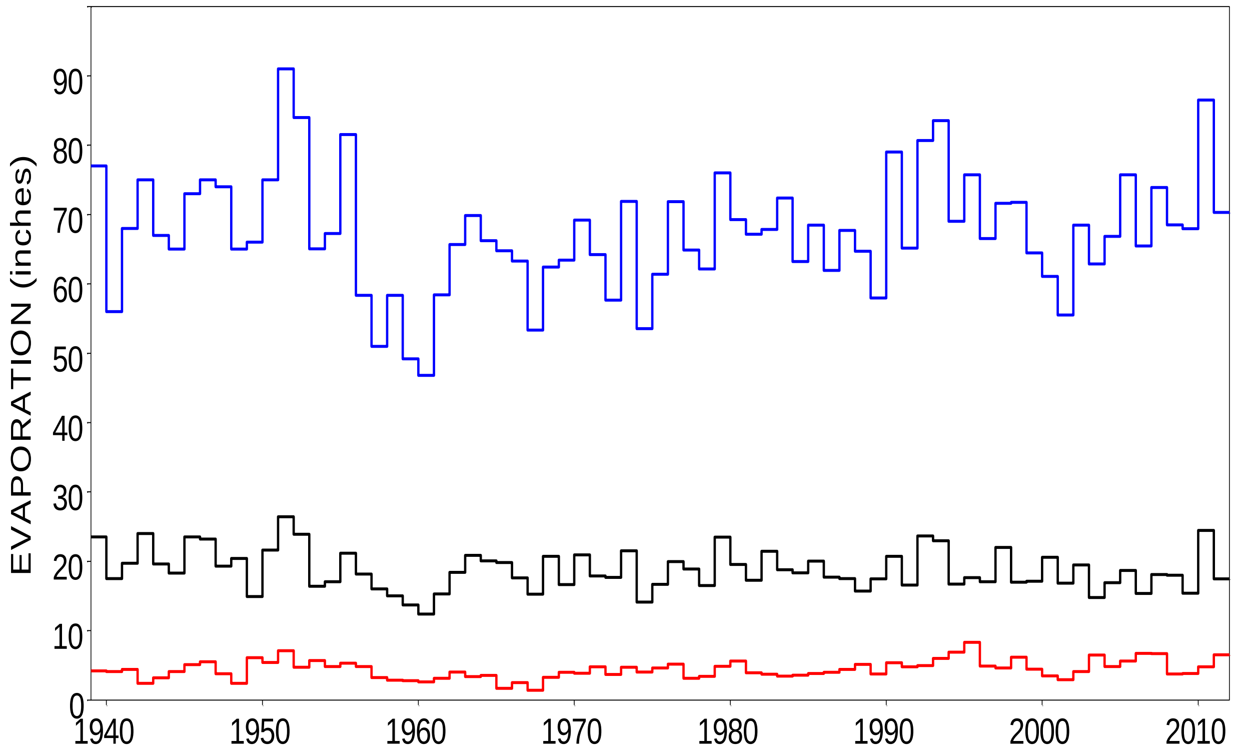
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 305



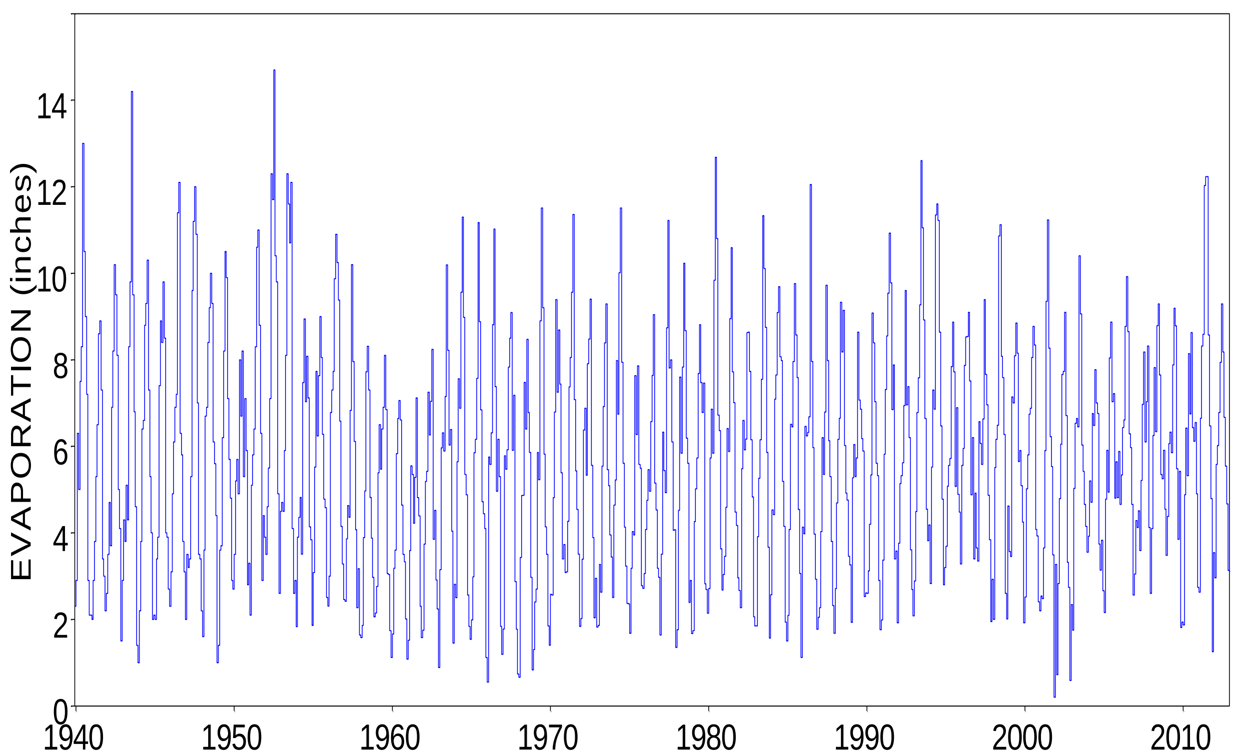
Monthly Evaporation for Quadrangle 306



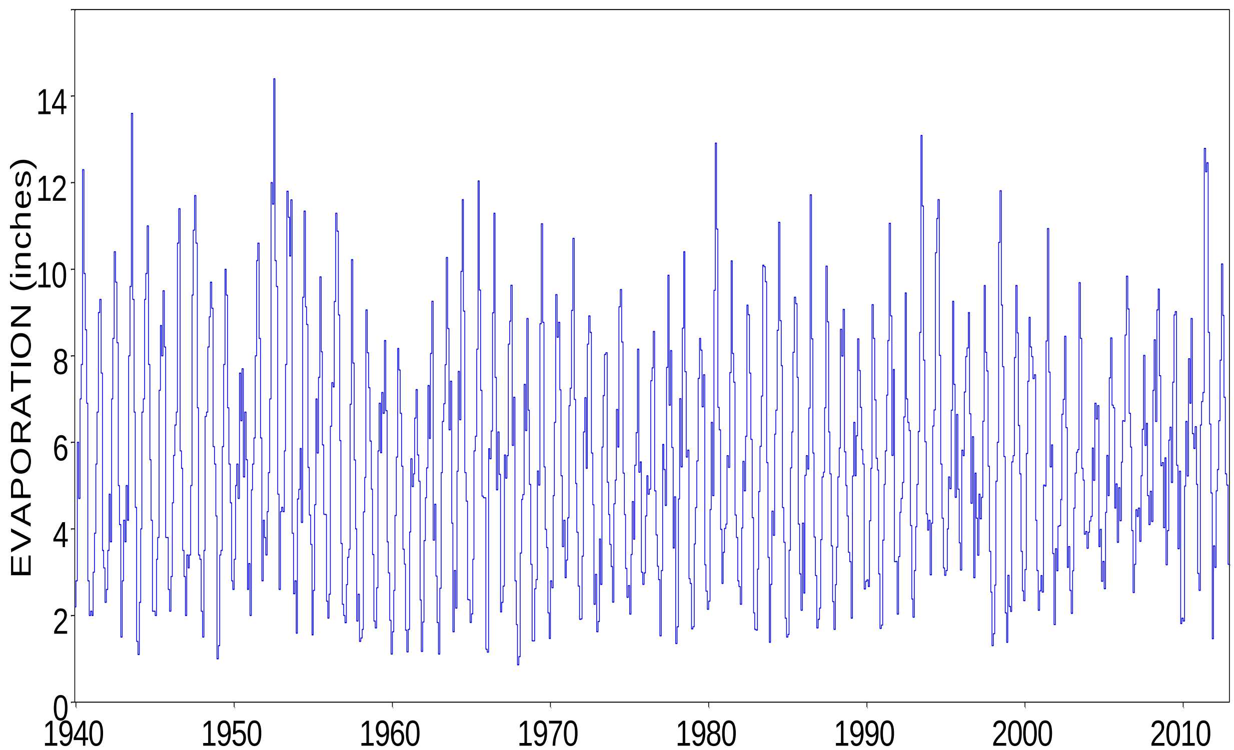
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 306



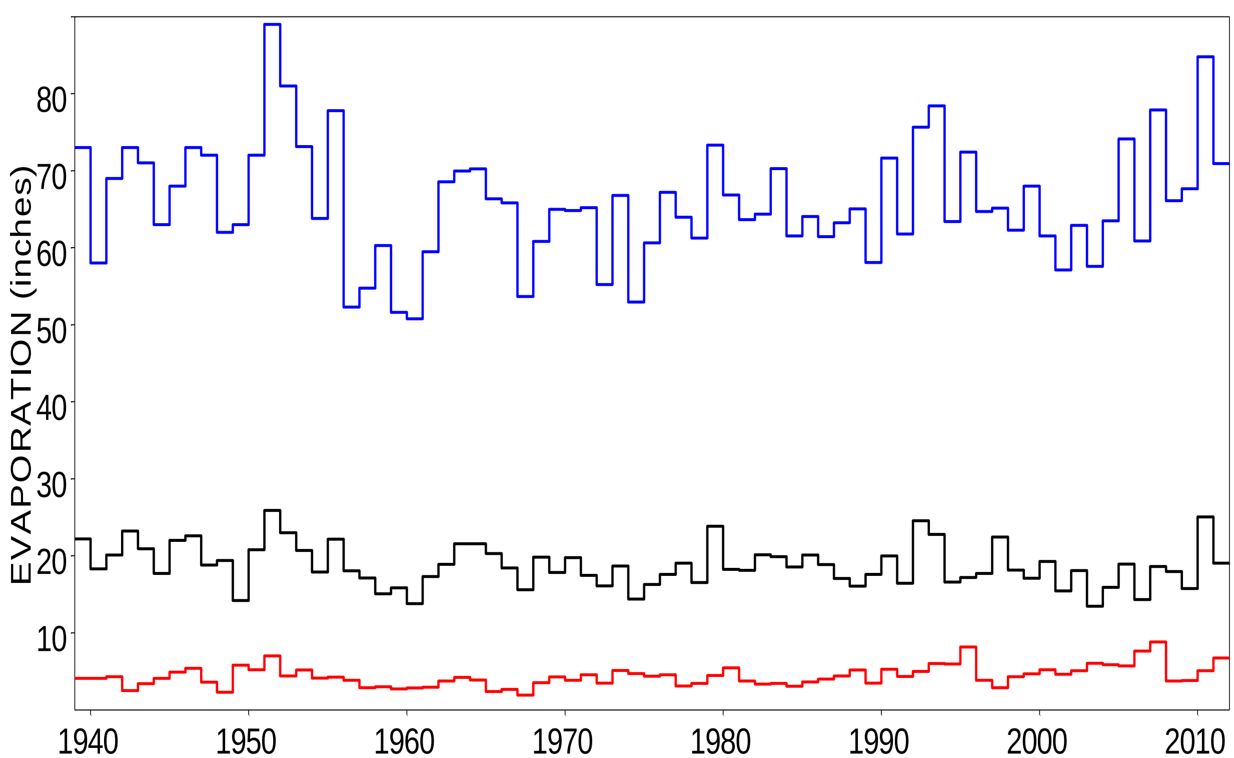
Monthly Evaporation for Evaporation 307



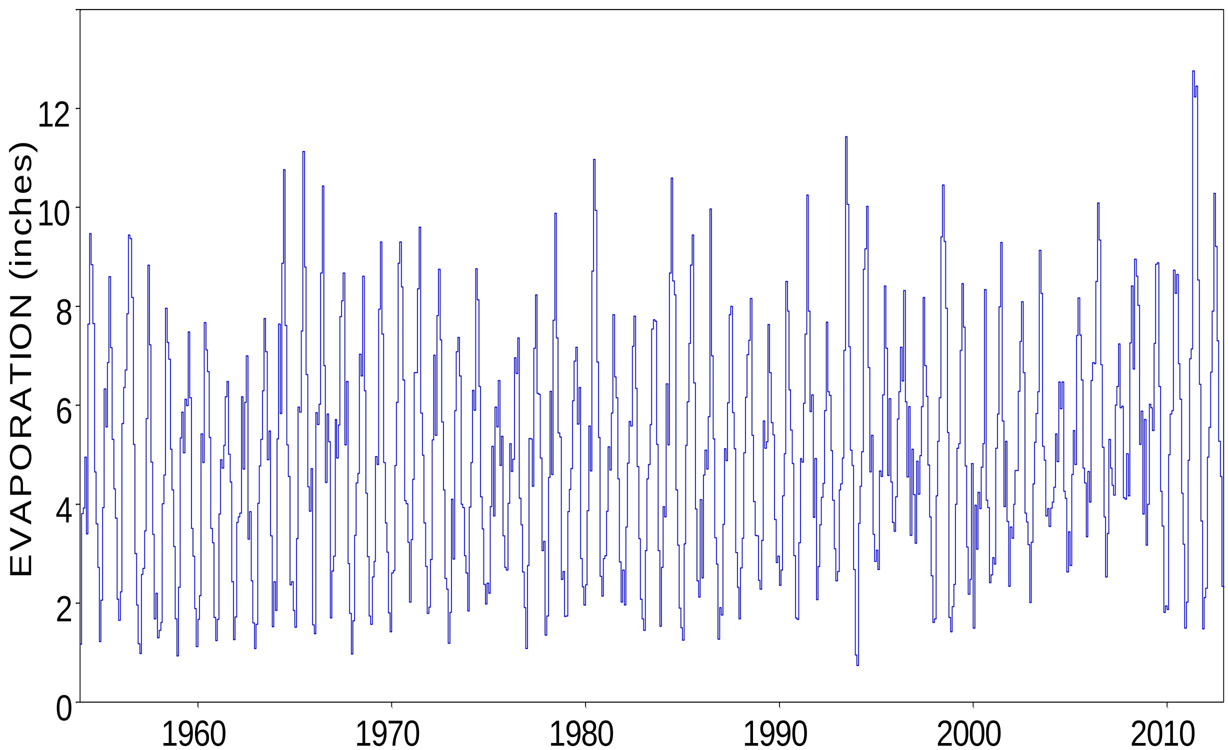
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 307



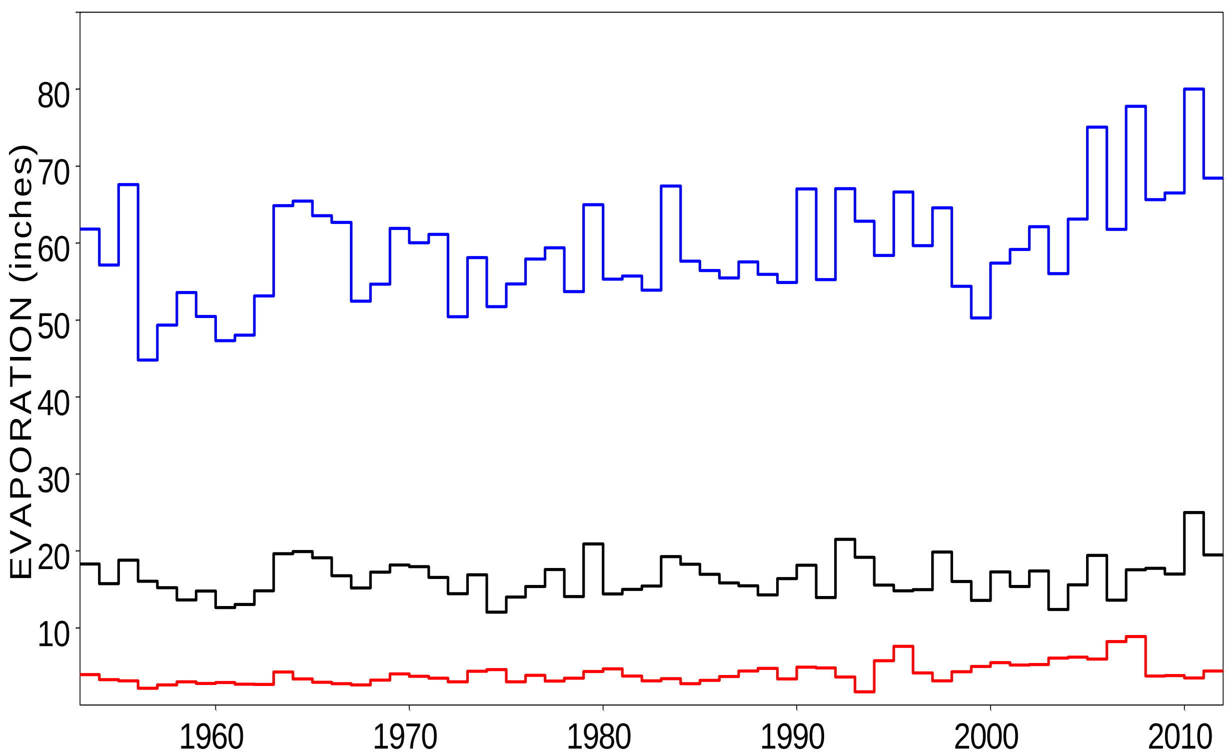
Monthly Evaporation for Quadrangle 308



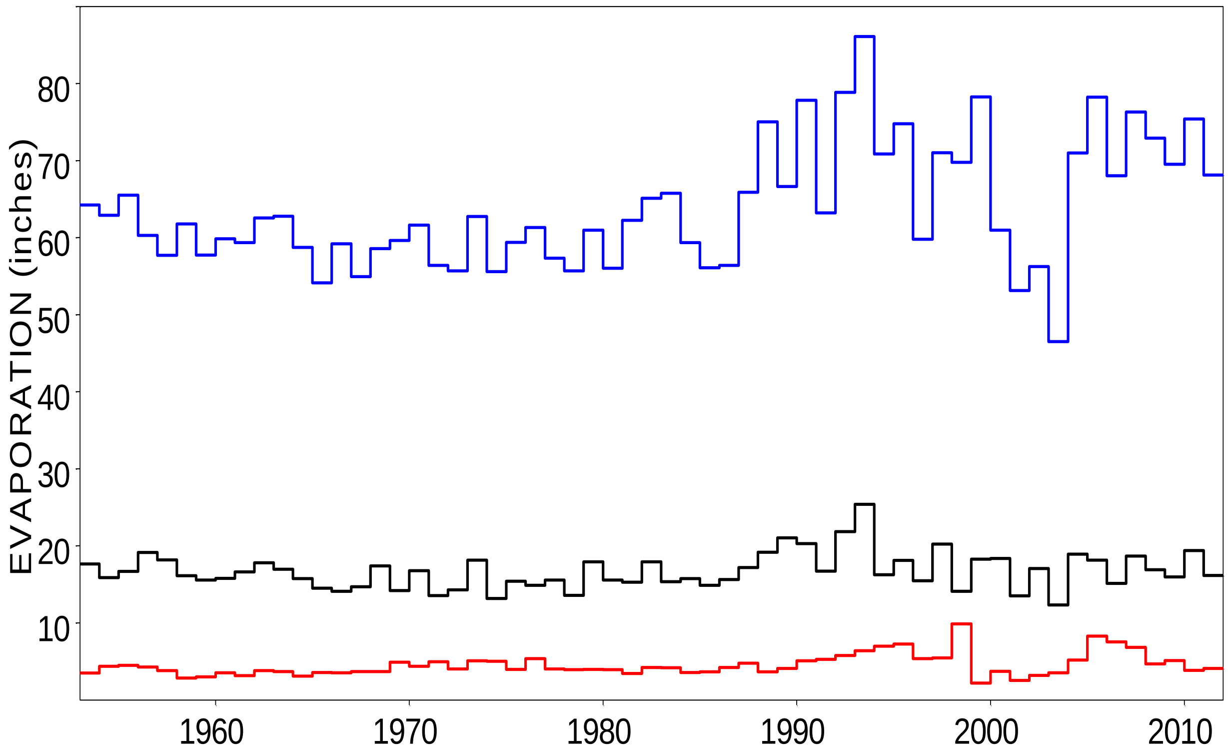
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 308



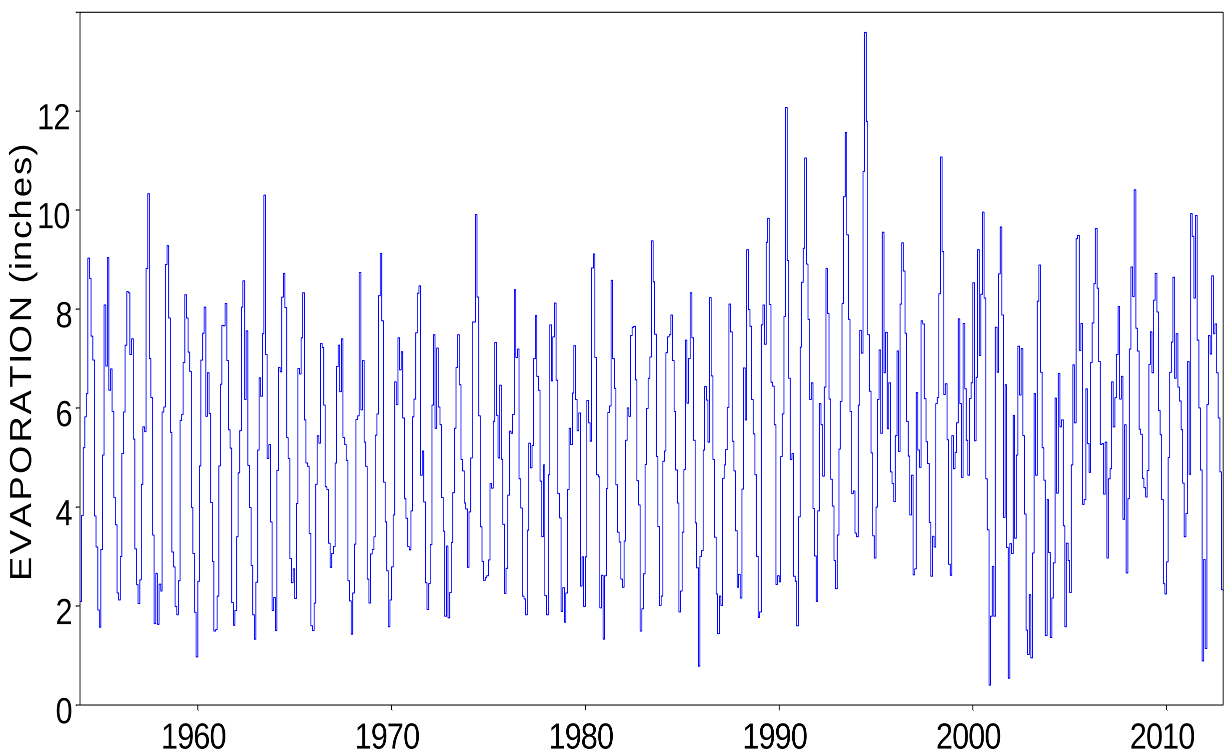
Monthly Evaporation for Quadrangle 309



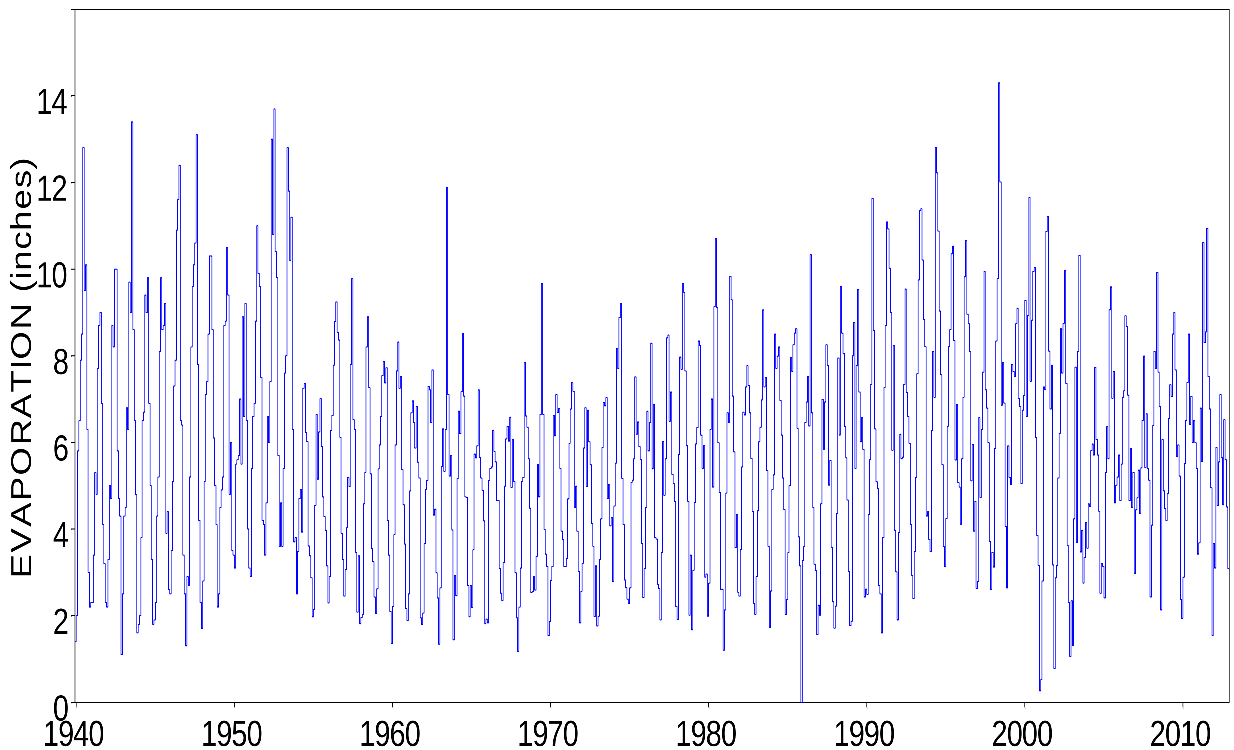
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 309



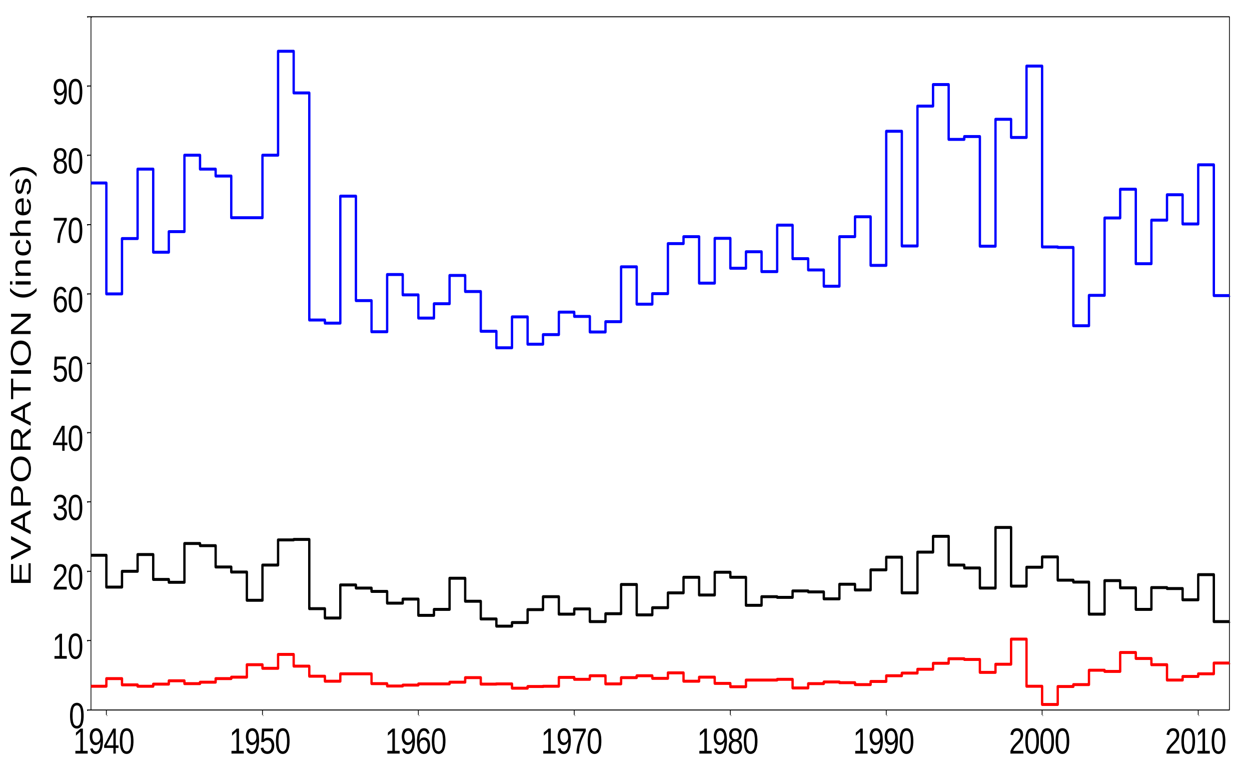
Monthly Evaporation for Quadrangle 404



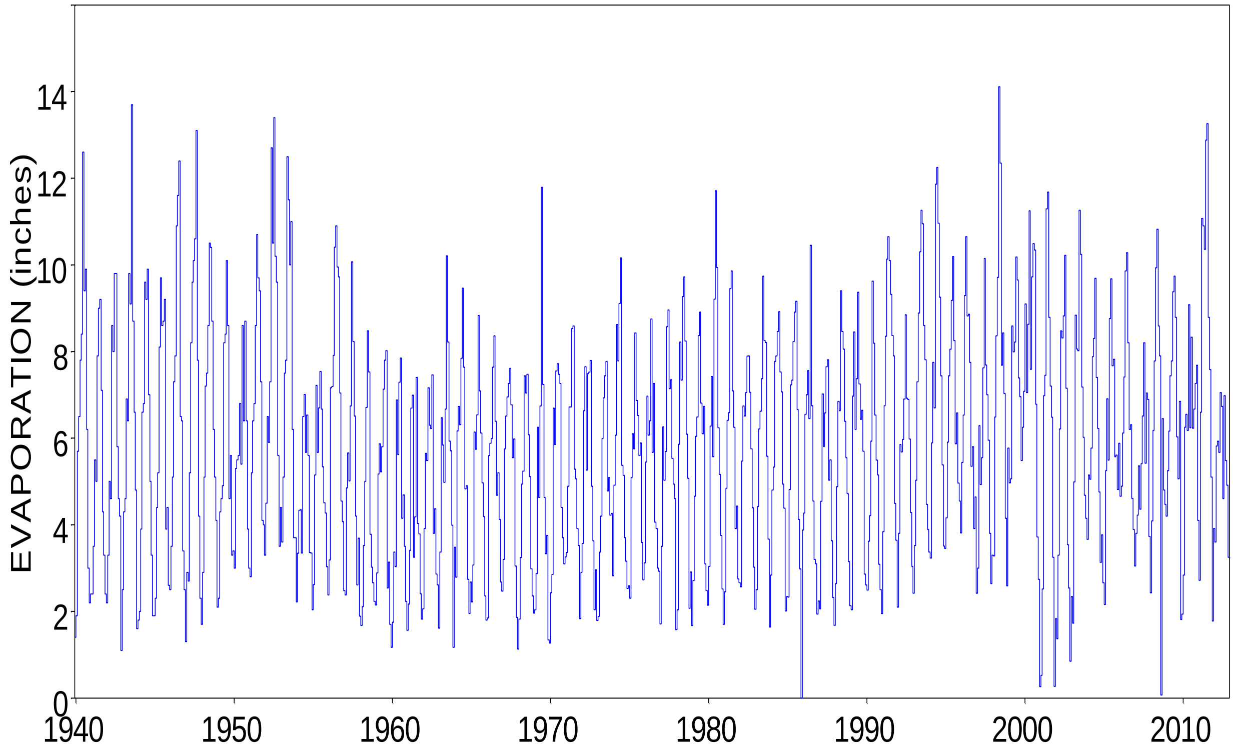
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 404



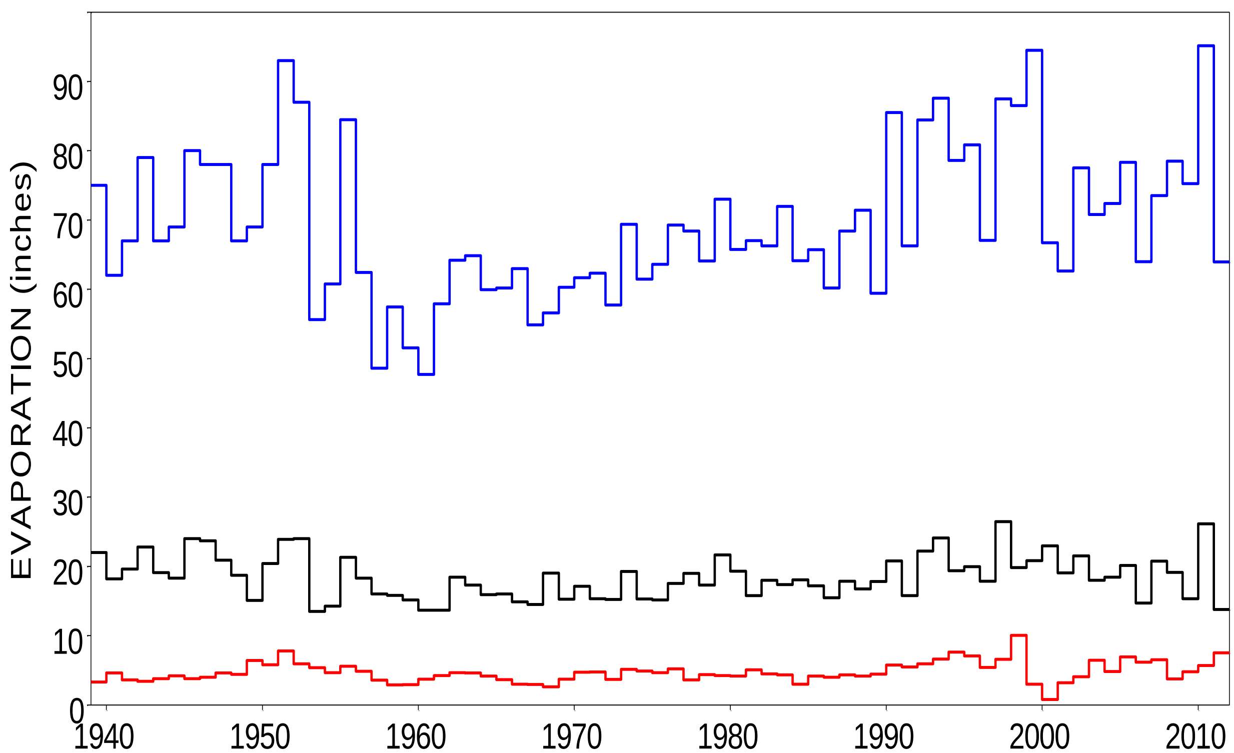
Monthly Evaporation for Quadrangle 405



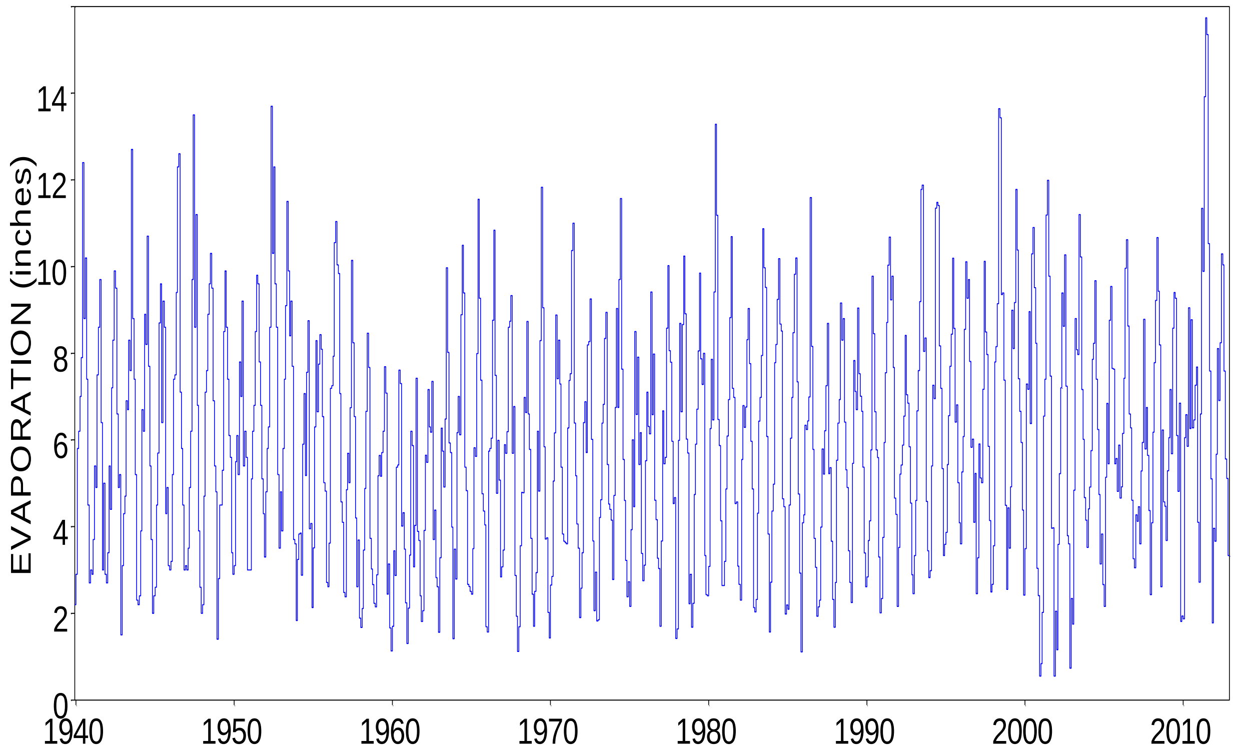
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 405



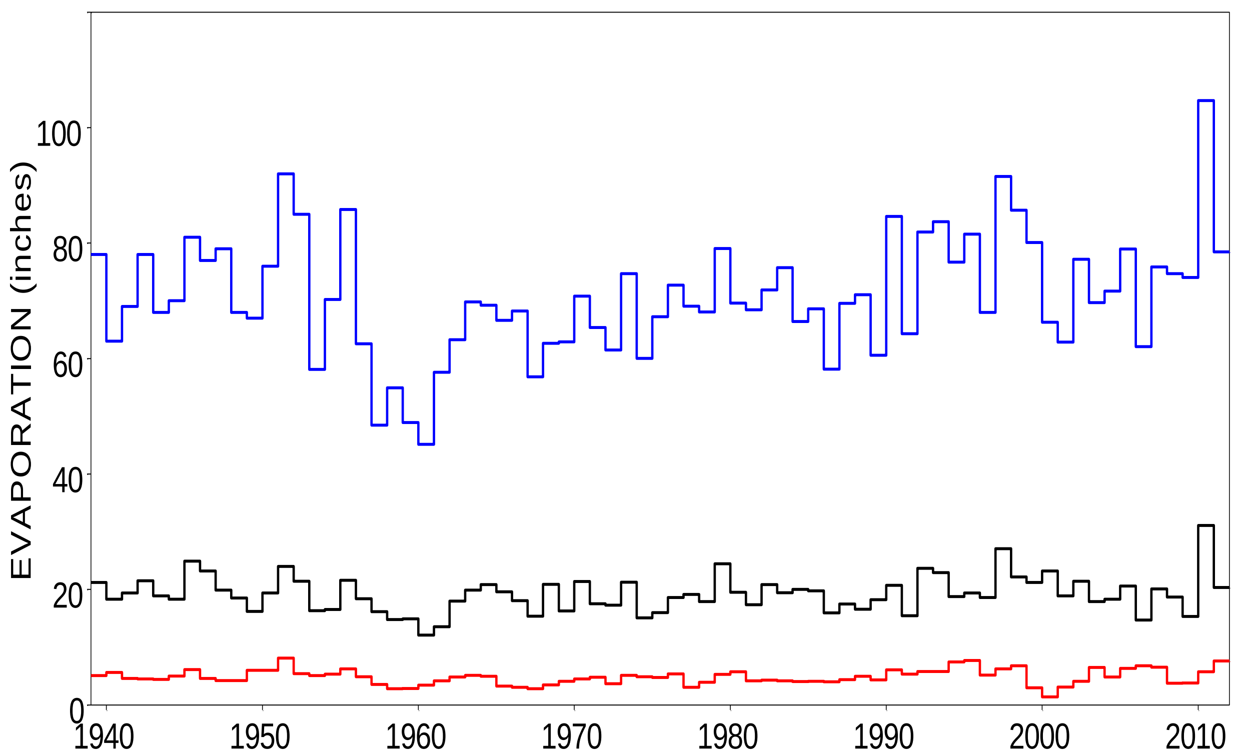
Monthly Evaporation for Quadrangle 406



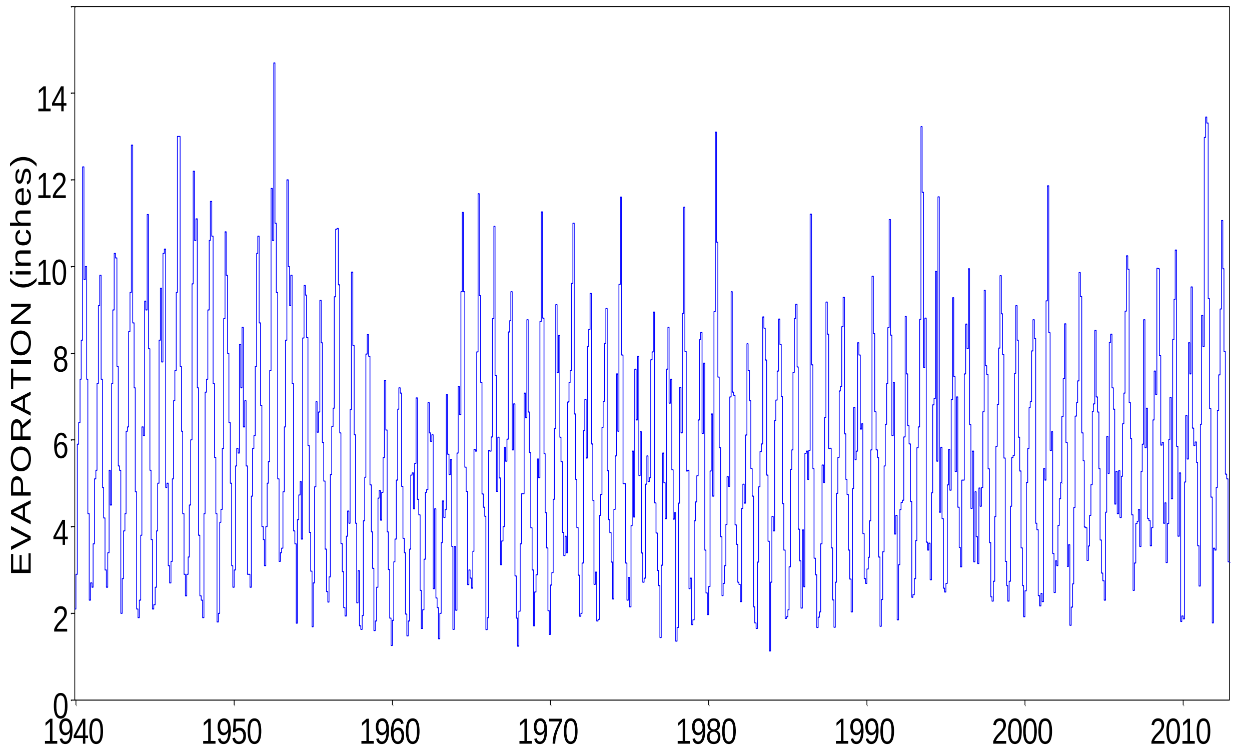
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 406



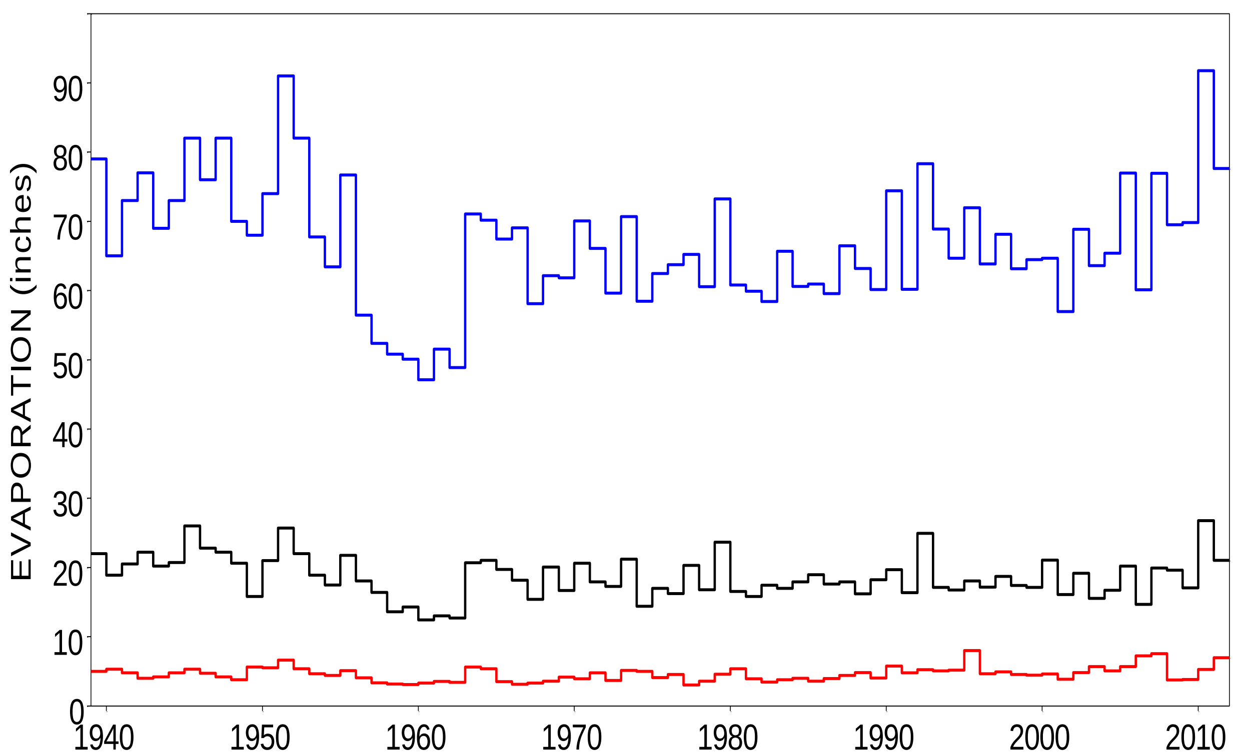
Monthly Evaporation for Quadrangle 407



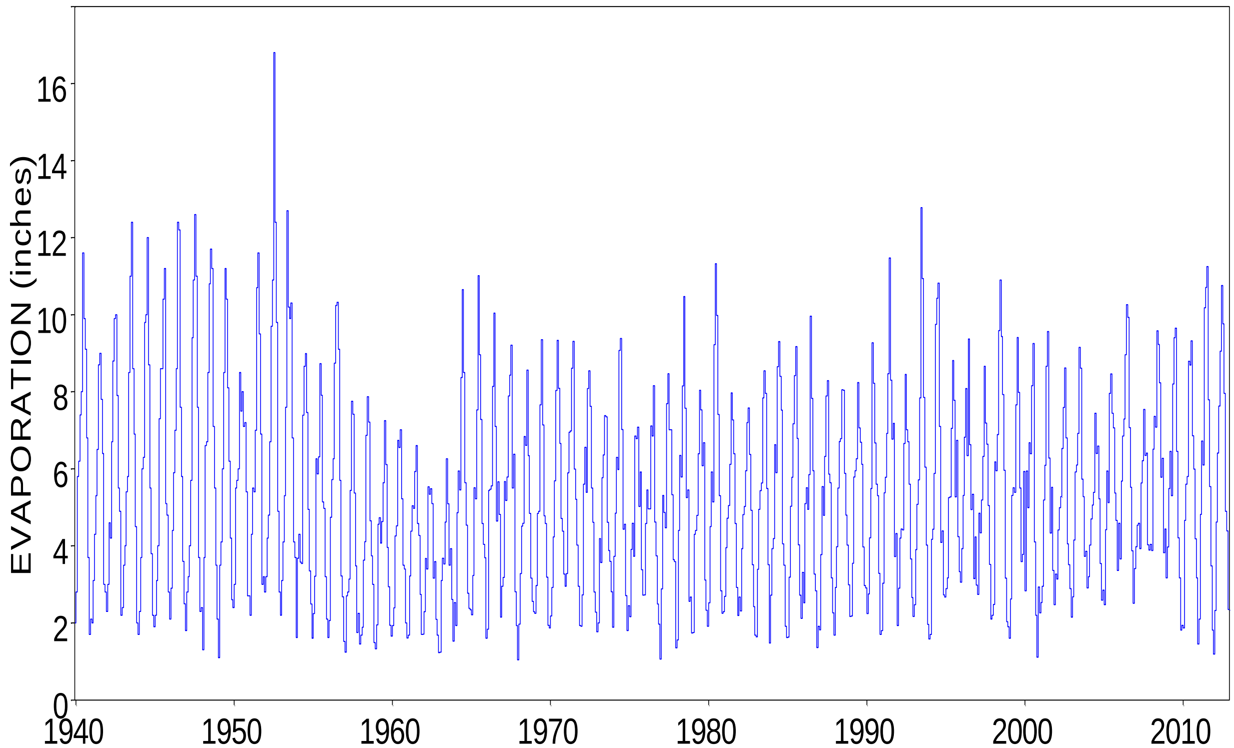
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 407



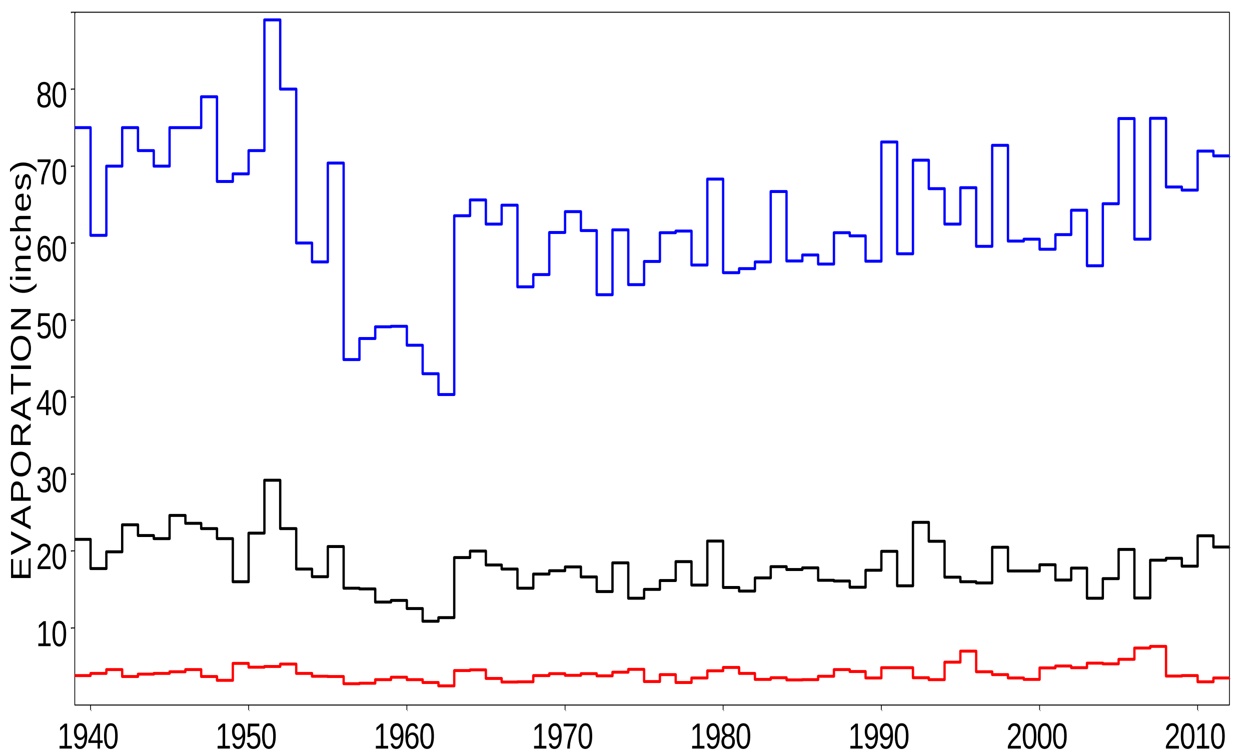
Monthly Evaporation for Quadrangle 408



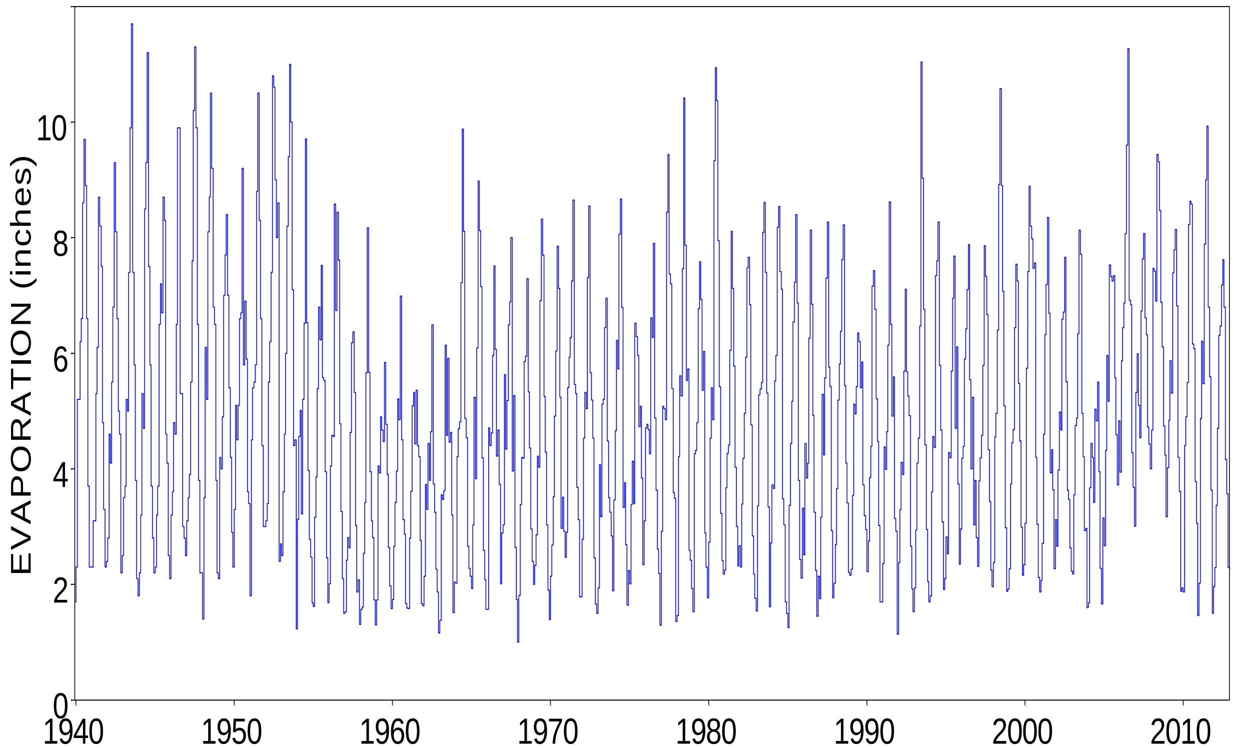
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 408



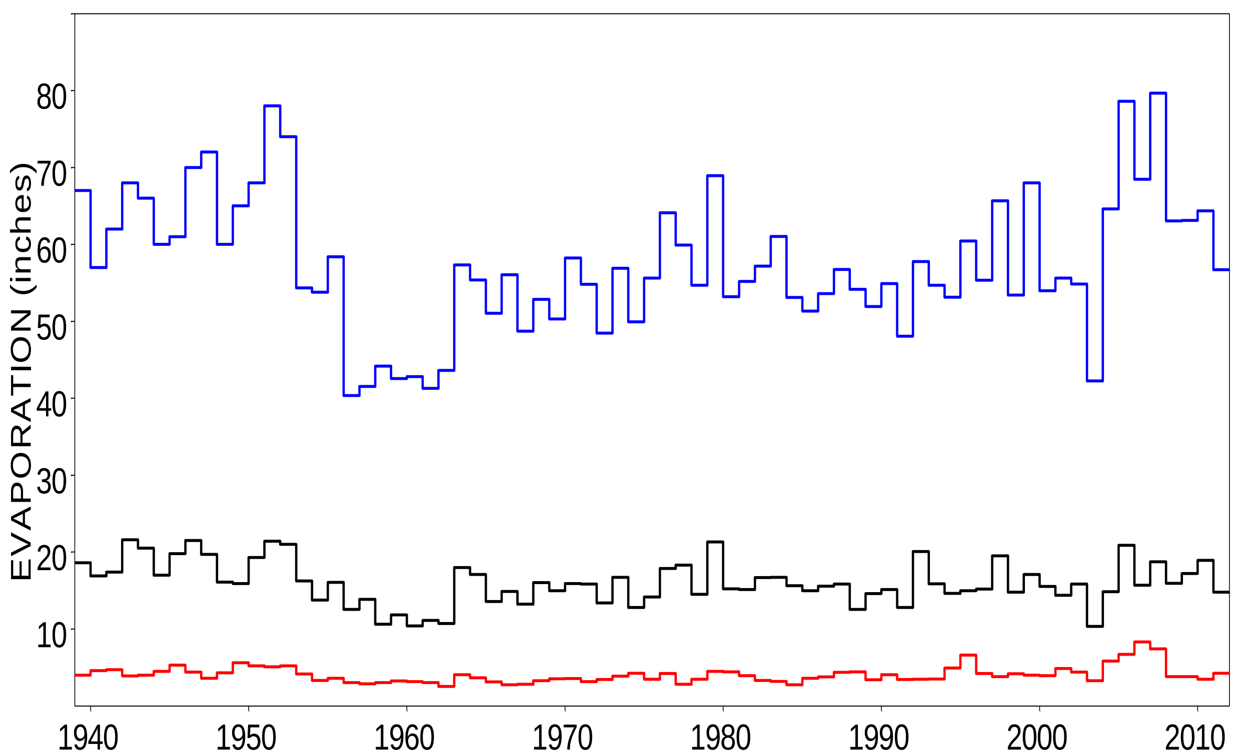
Monthly Evaporation for Quadrangle 409



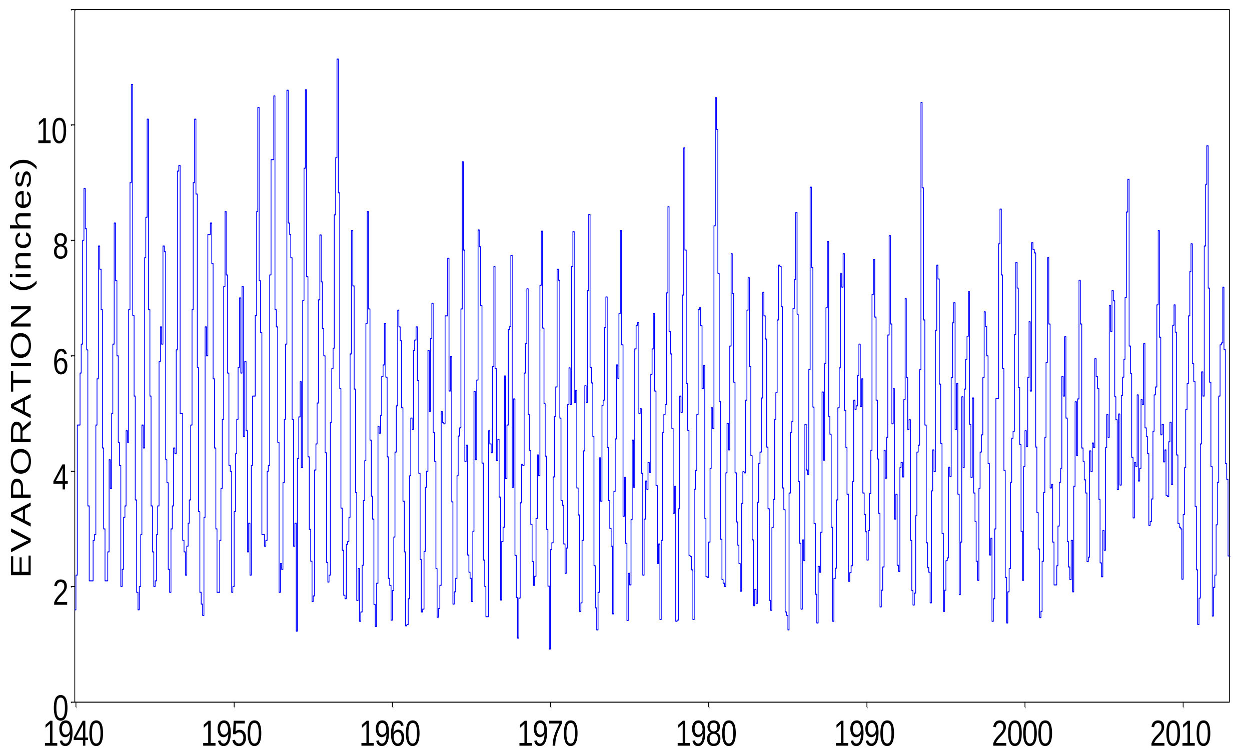
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 409



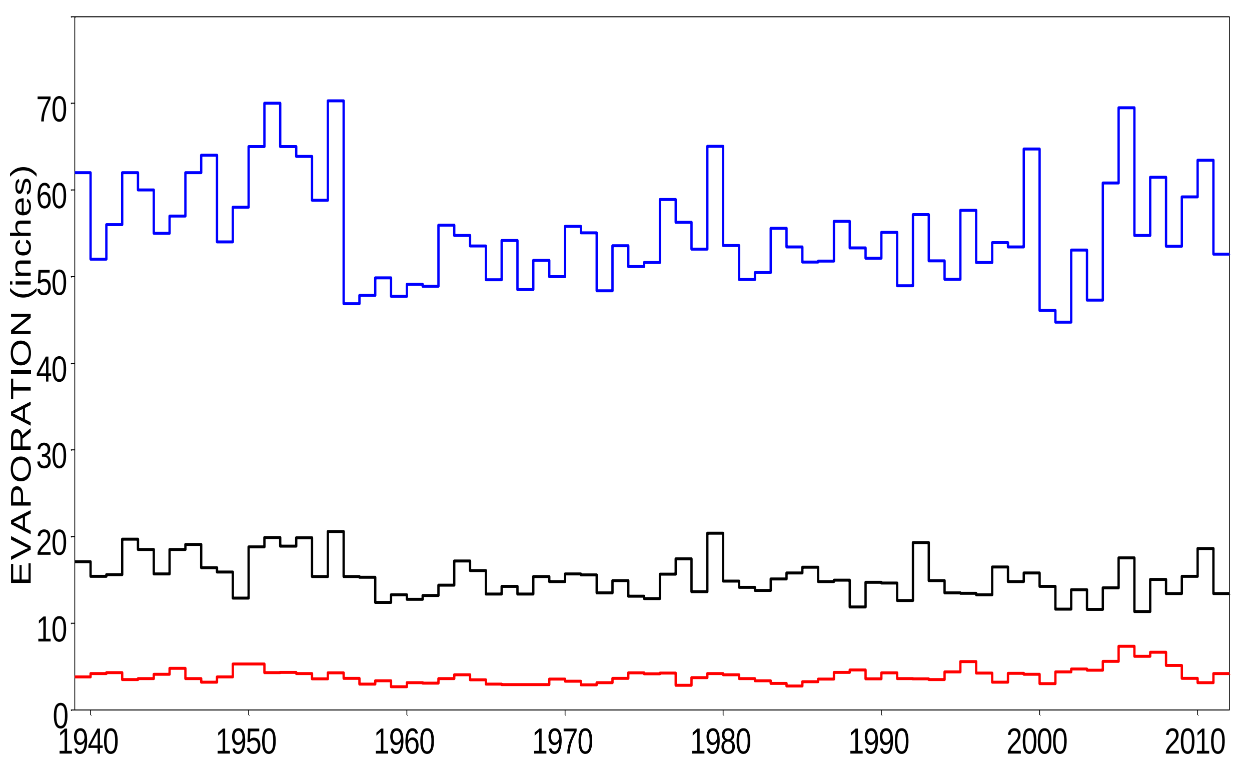
Monthly Evaporation for Quadrangle 410



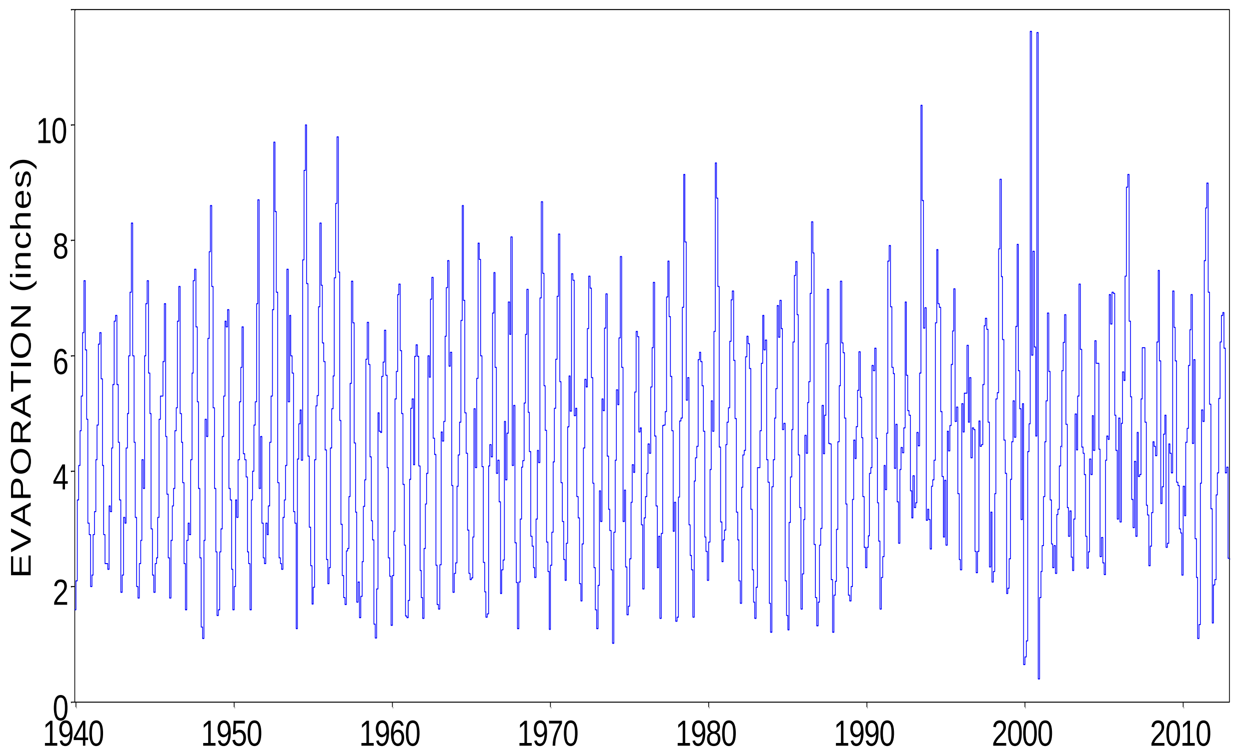
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 410



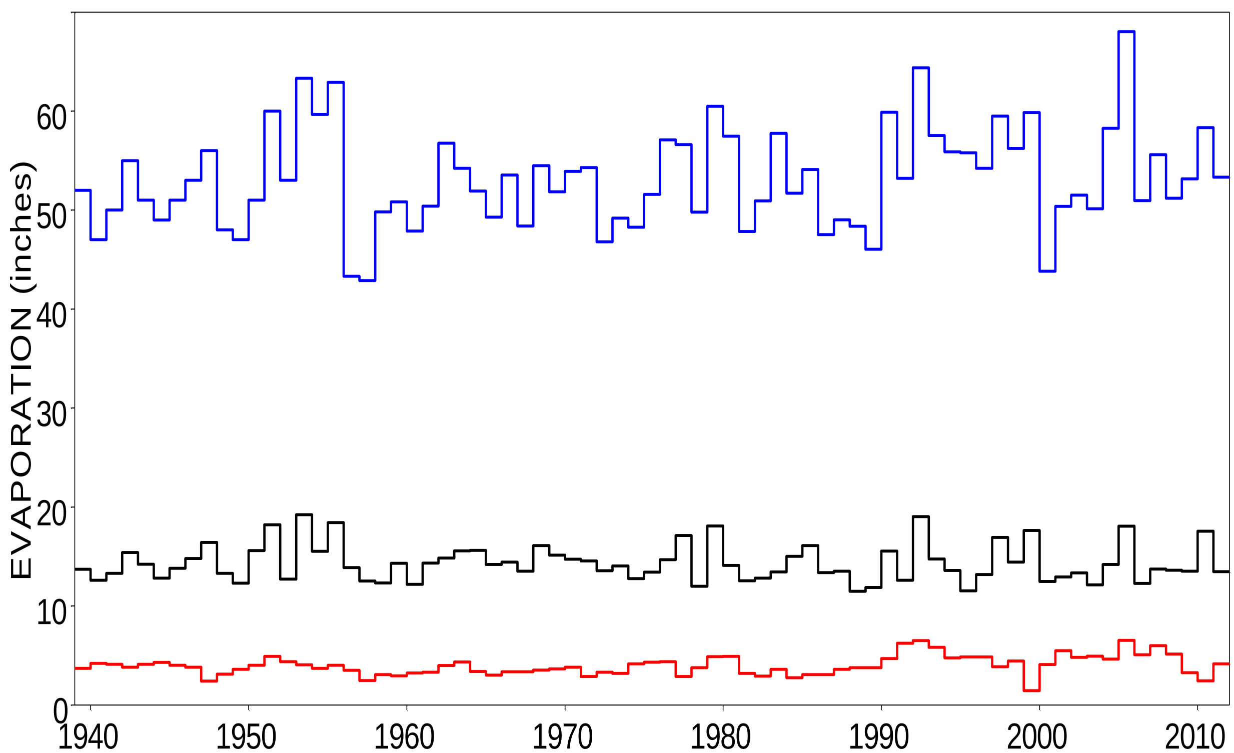
Monthly Evaporation for Quadrangle 411



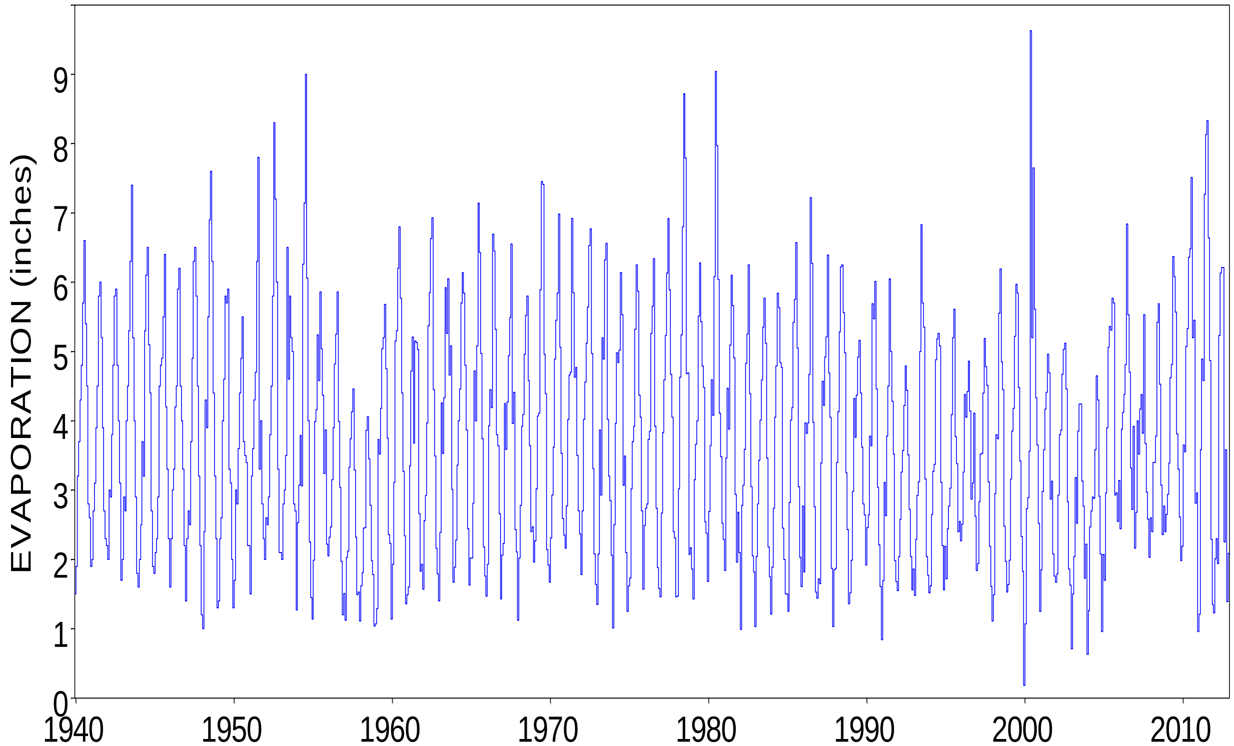
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 411



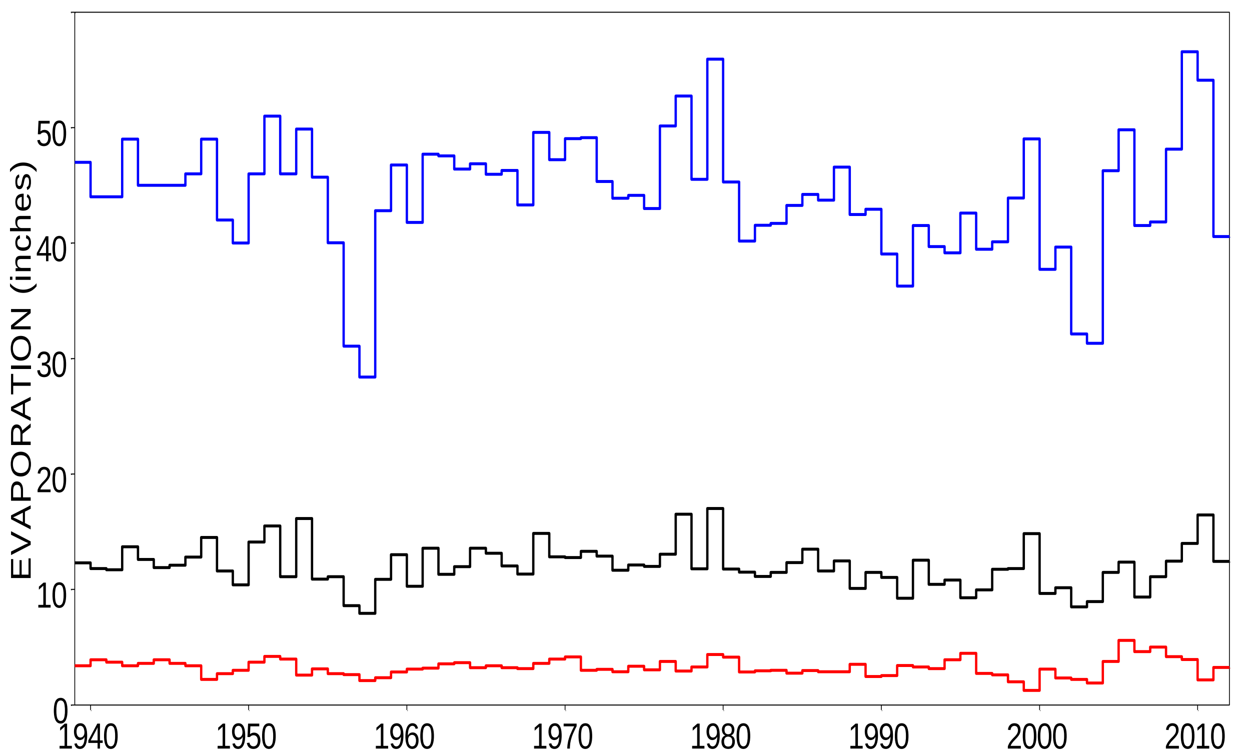
Monthly Evaporation for Quadrangle 412



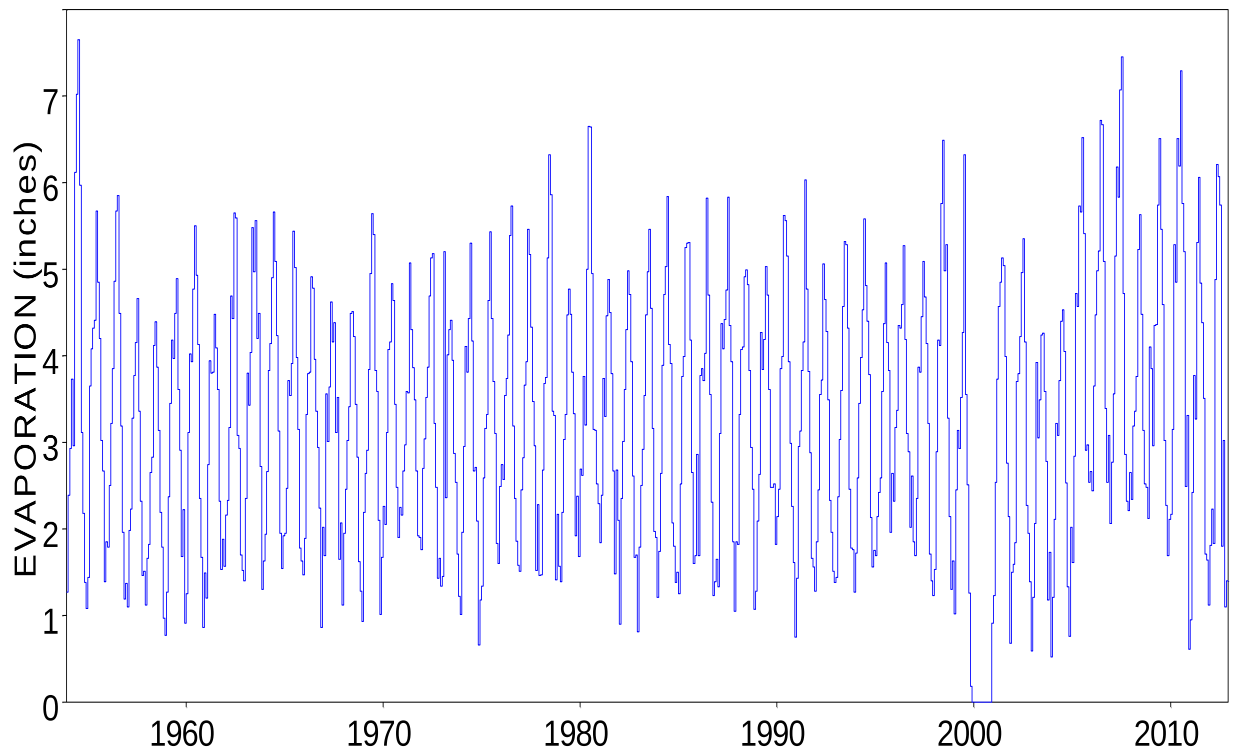
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 412



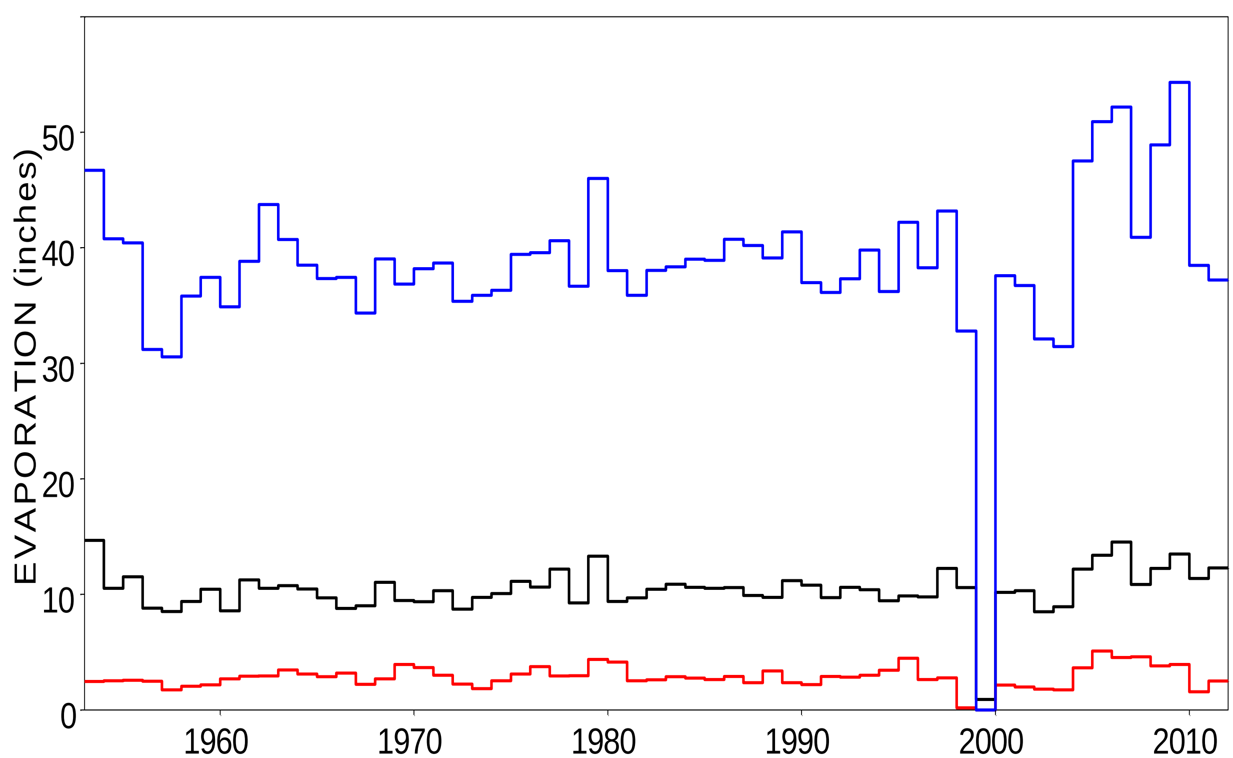
Monthly Evaporation for Quadrangle 413



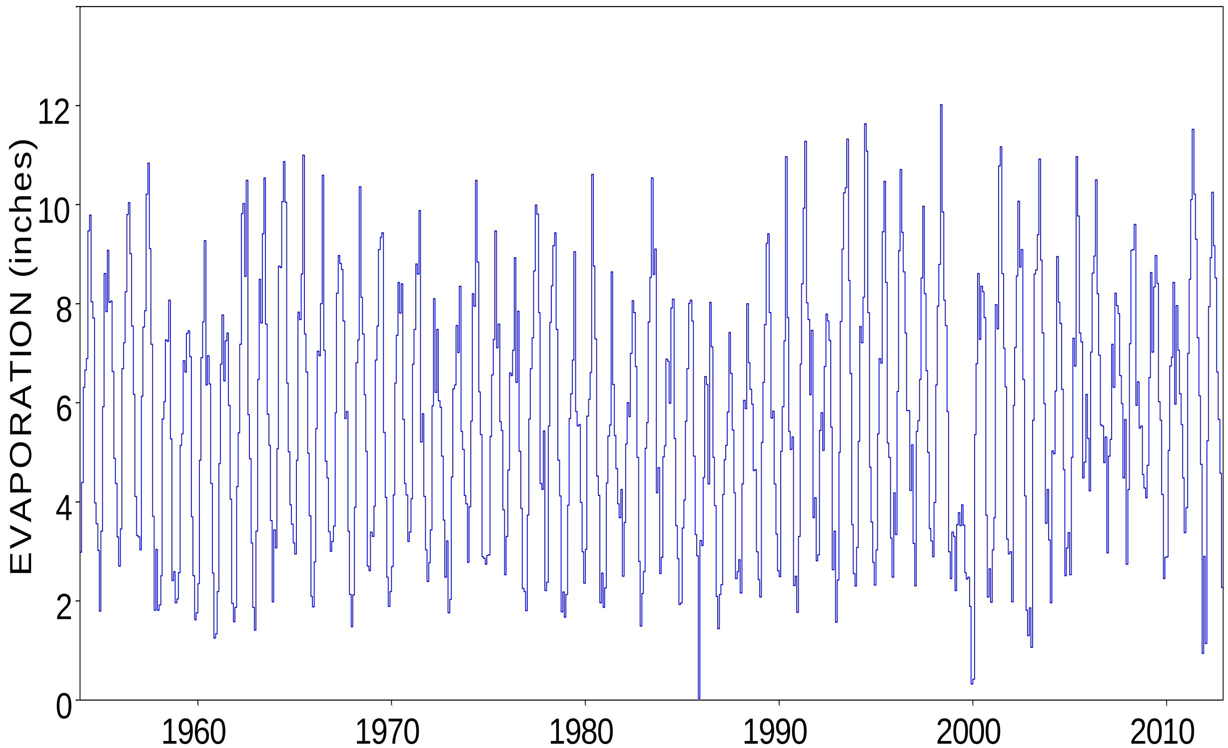
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 413



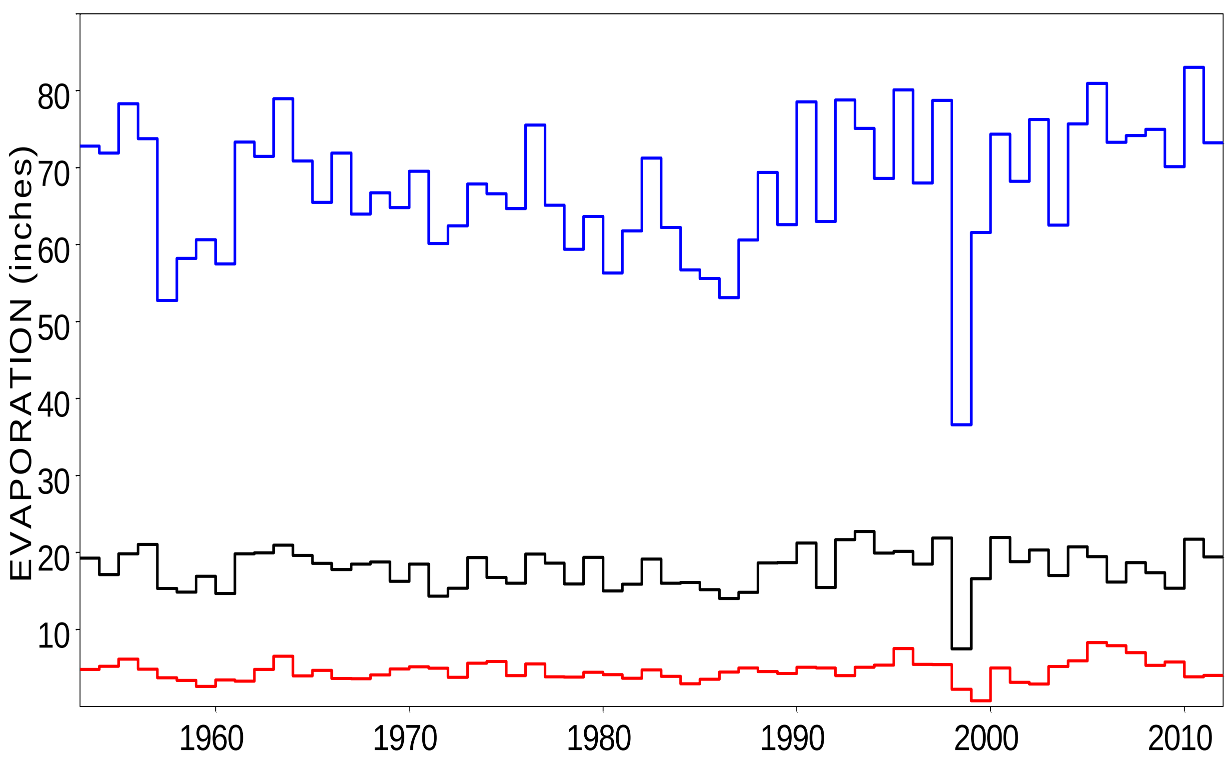
Monthly Evaporation for Quadrangle 414(missing date in 2000)



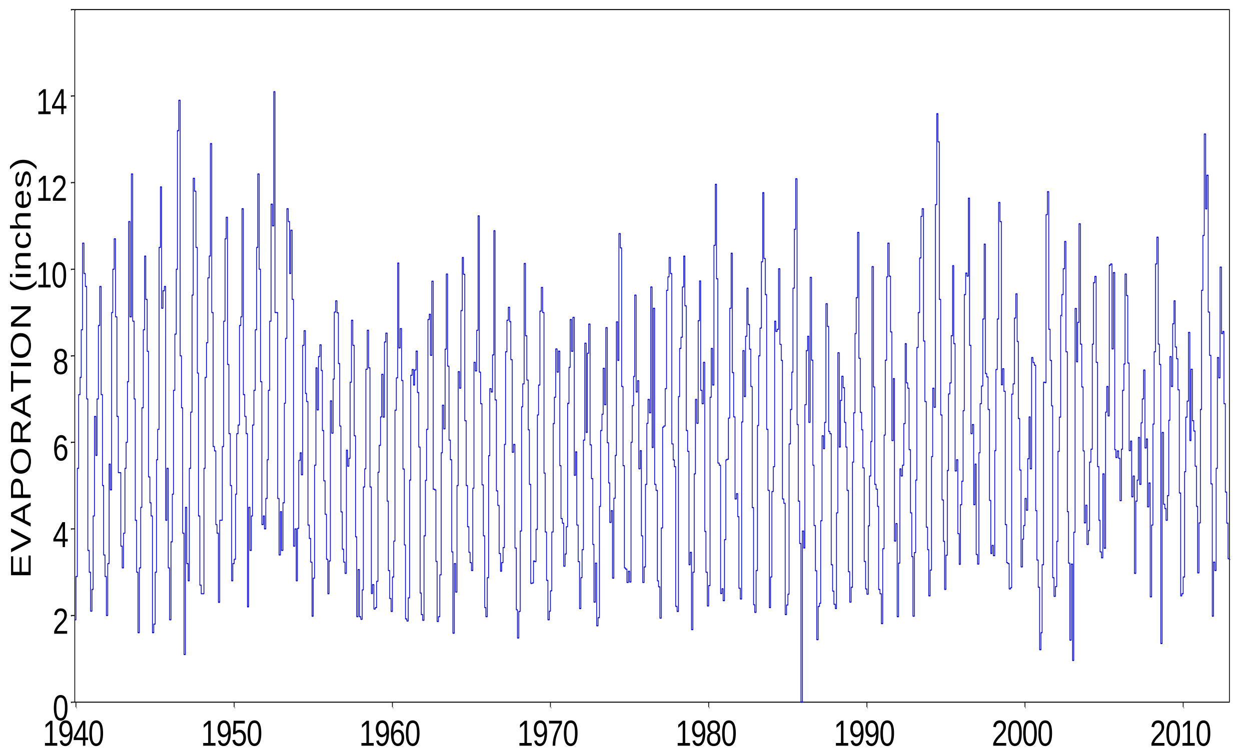
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 414 (missing date in 2000)



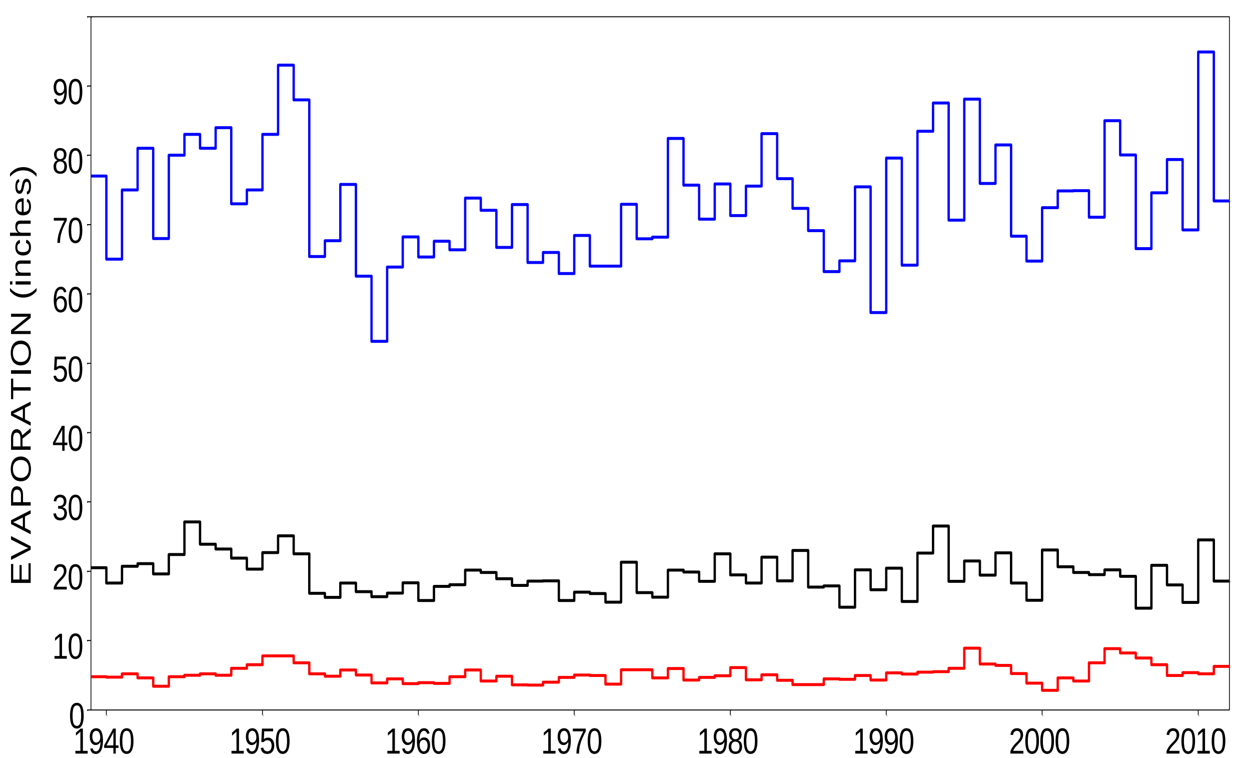
Monthly Evaporation for Quadrangle 504



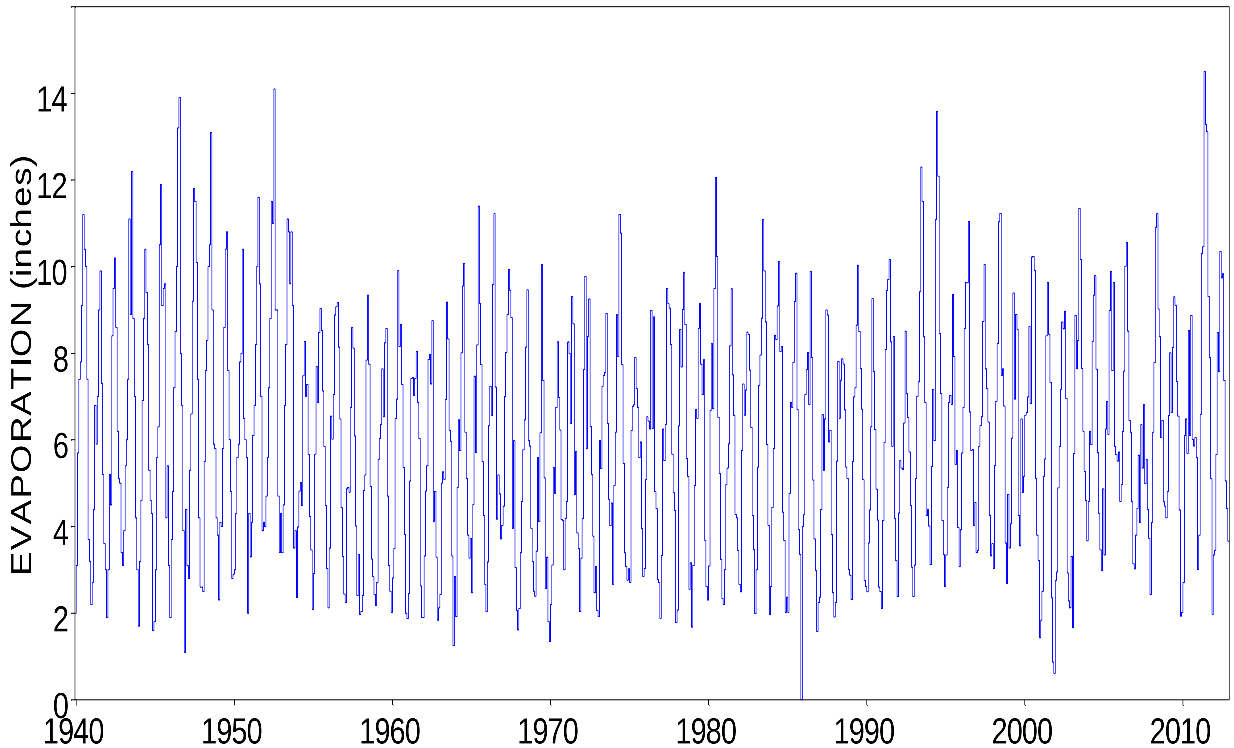
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 504



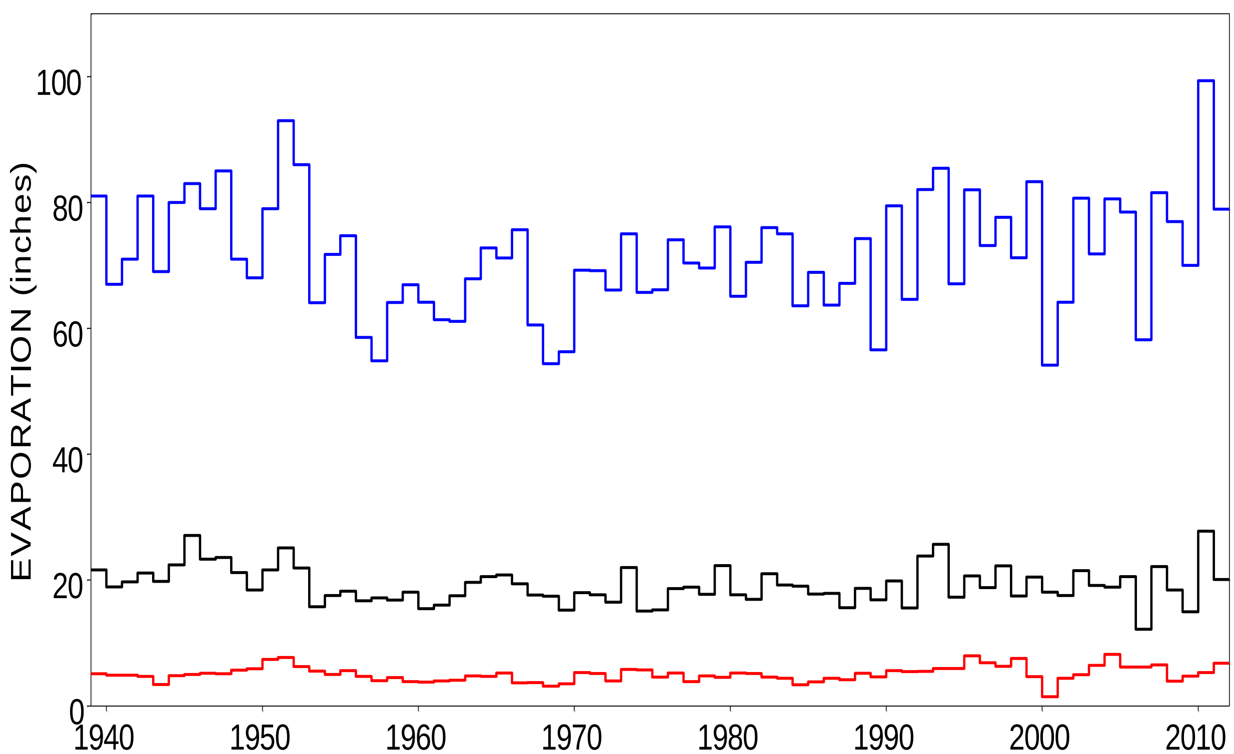
Monthly Evaporation for Quadrangle 505



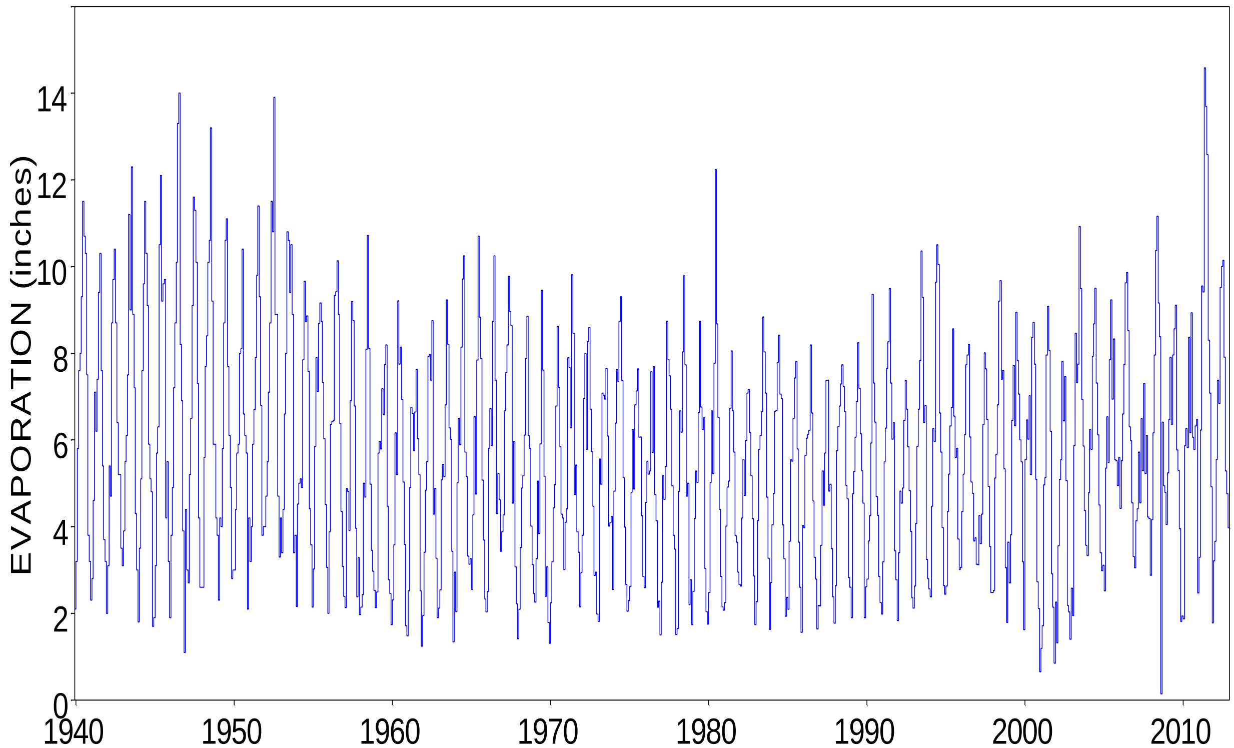
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 505



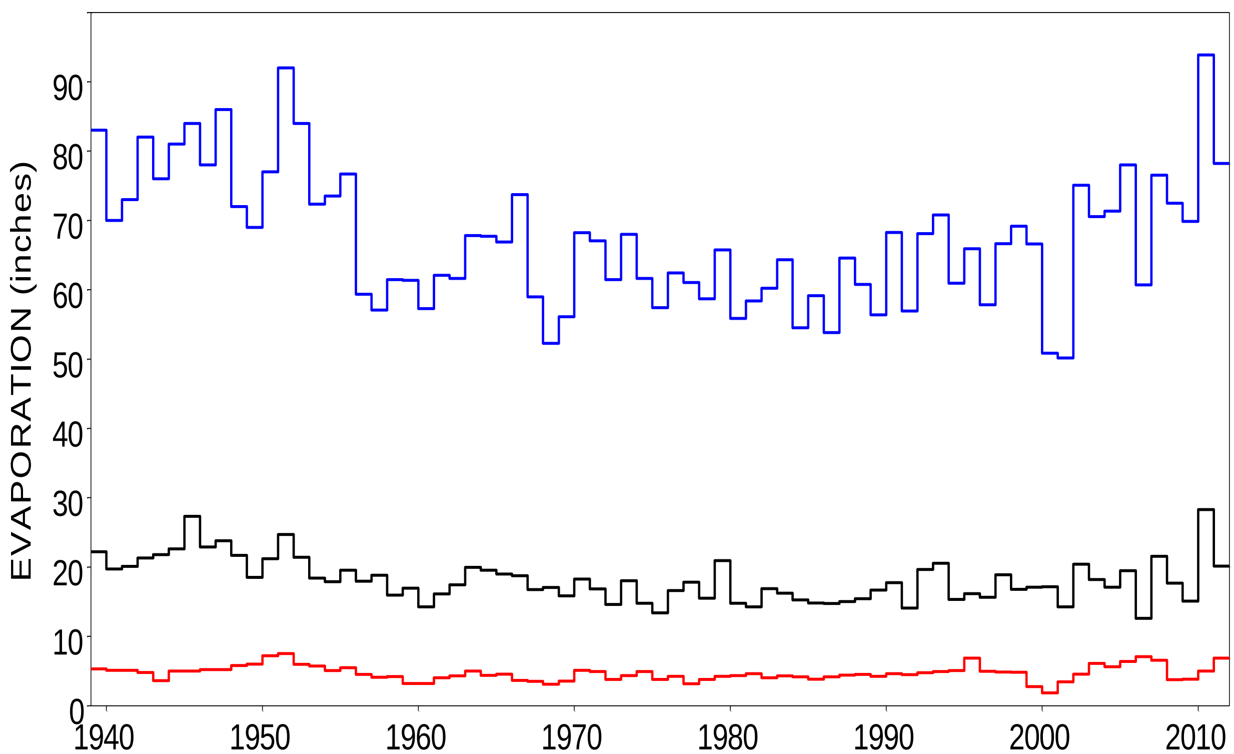
Monthly Evaporation for Quadrangle 506



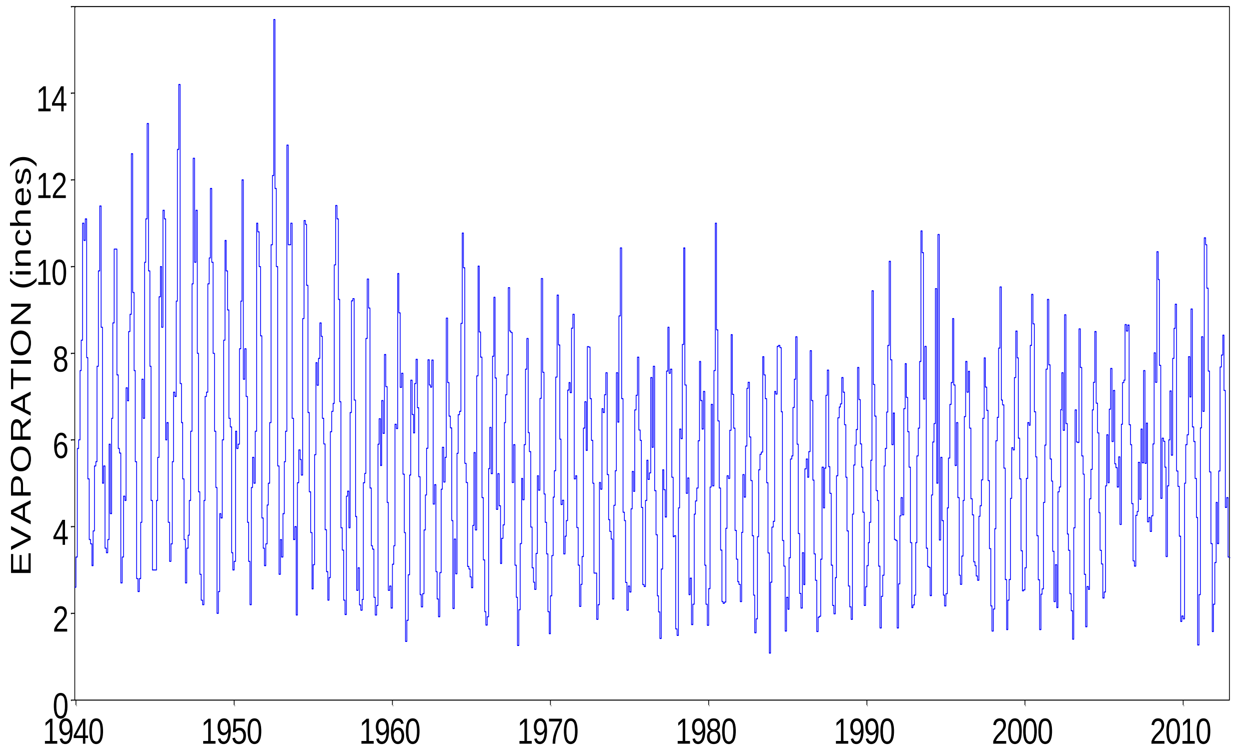
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 506



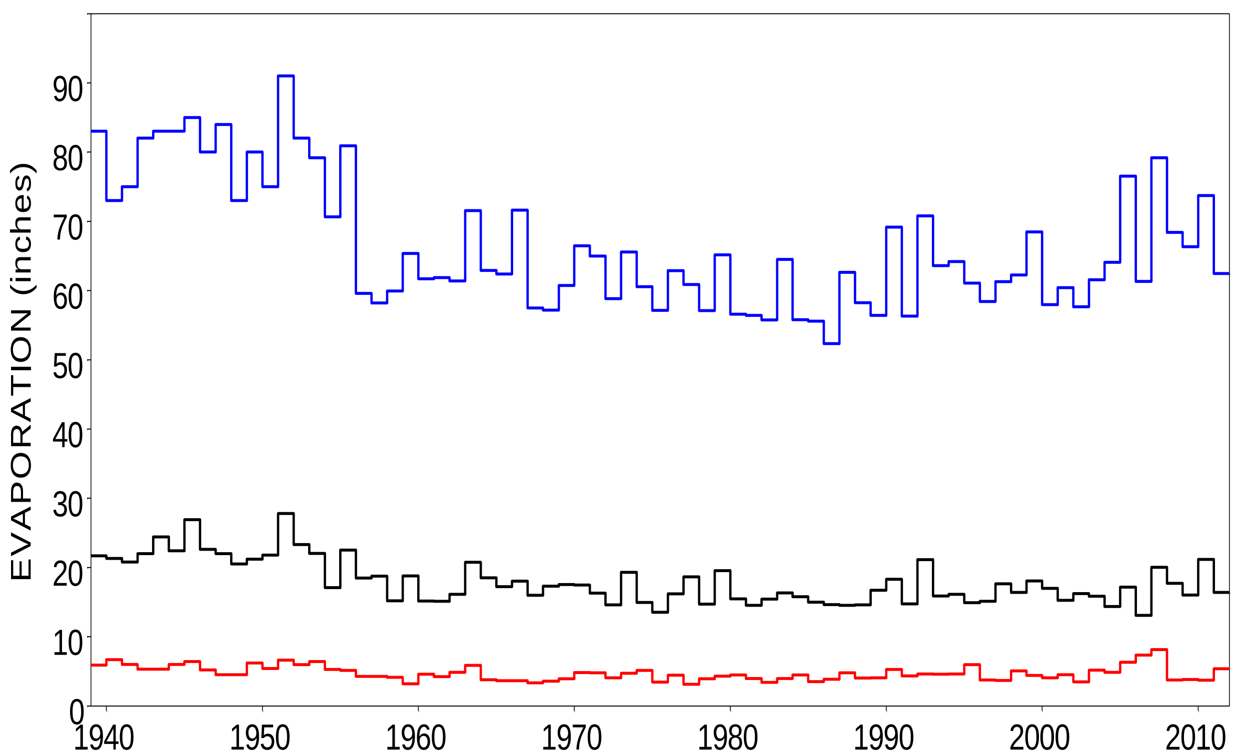
Monthly Evaporation for Quadrangle 507



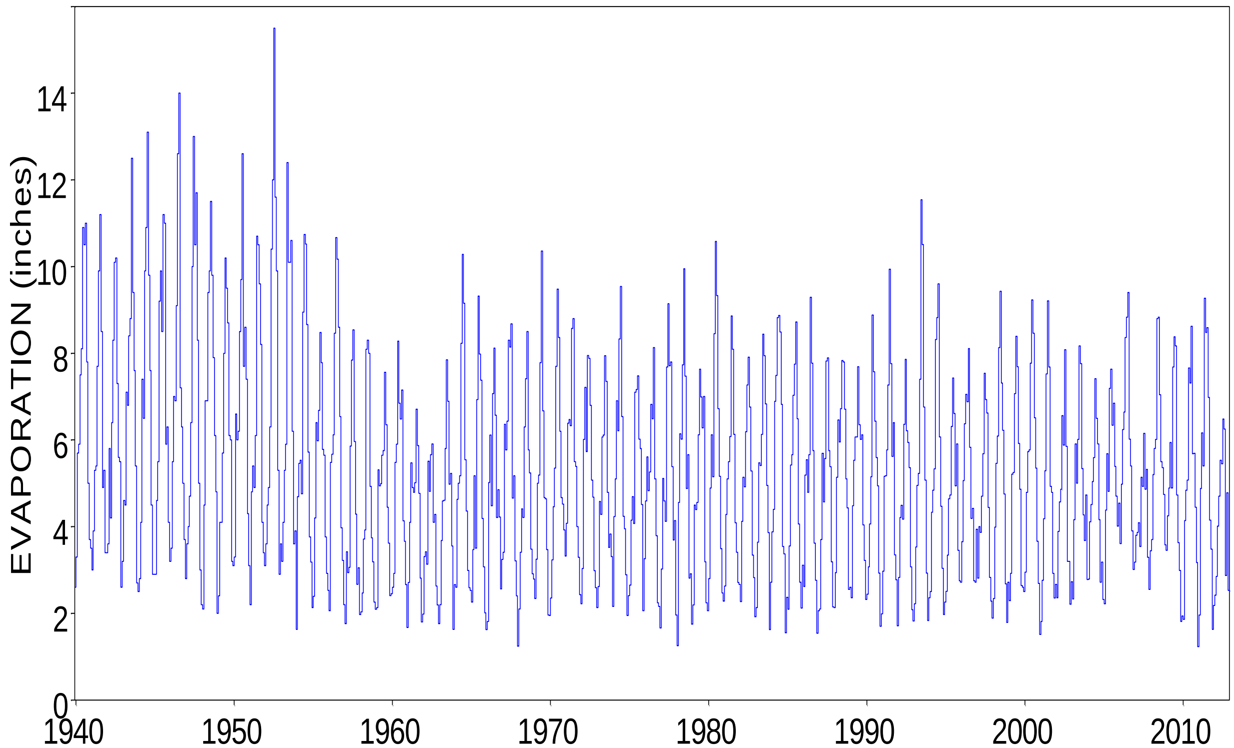
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 507



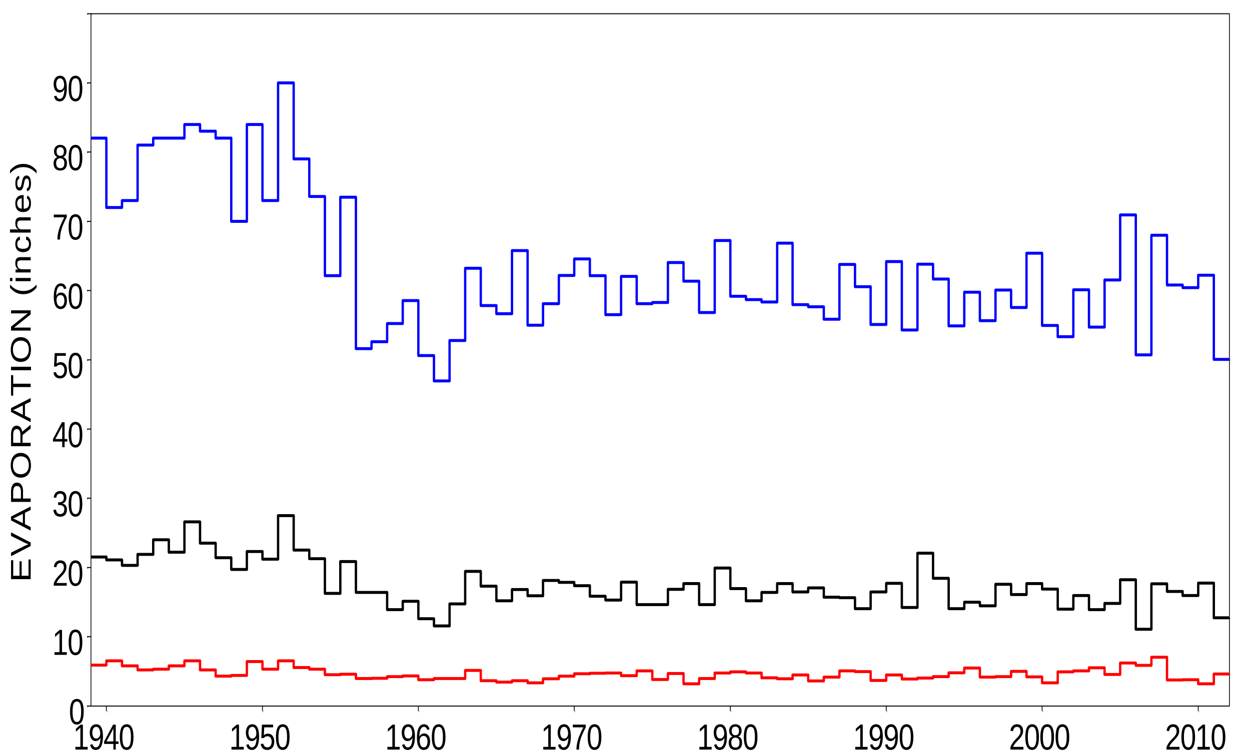
Monthly Evaporation for Quadrangle 508



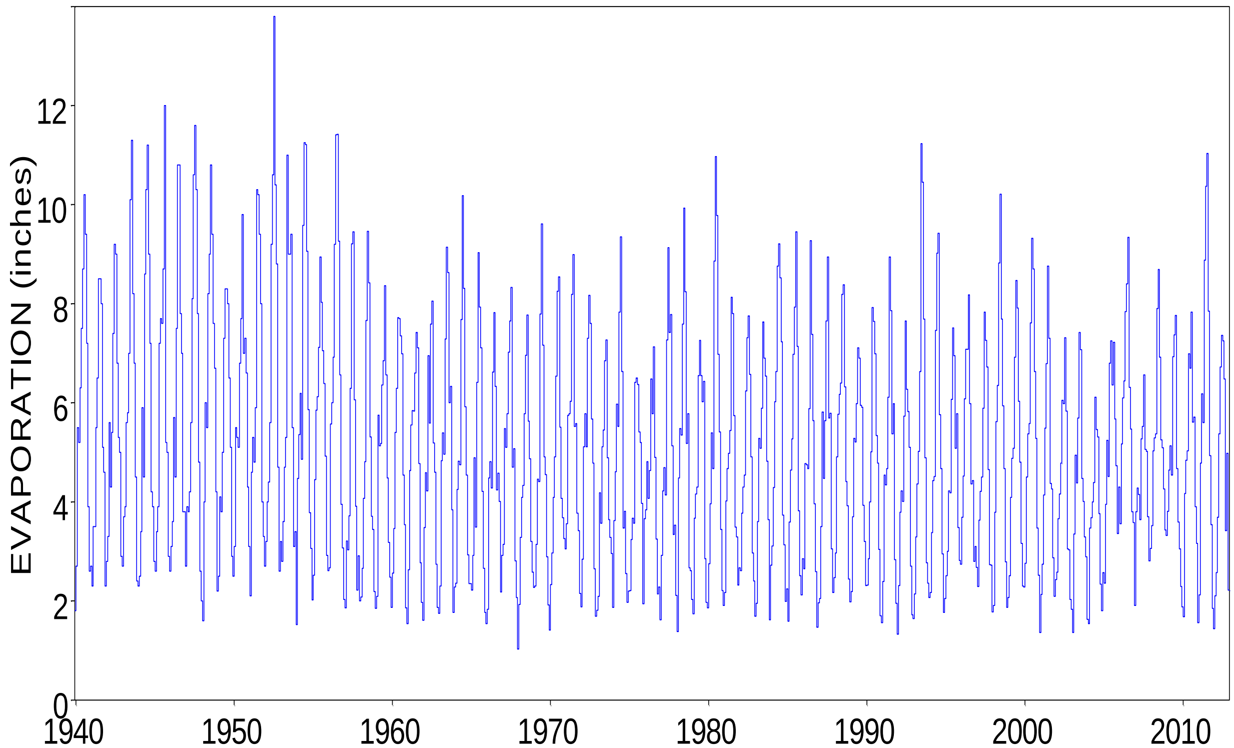
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 508



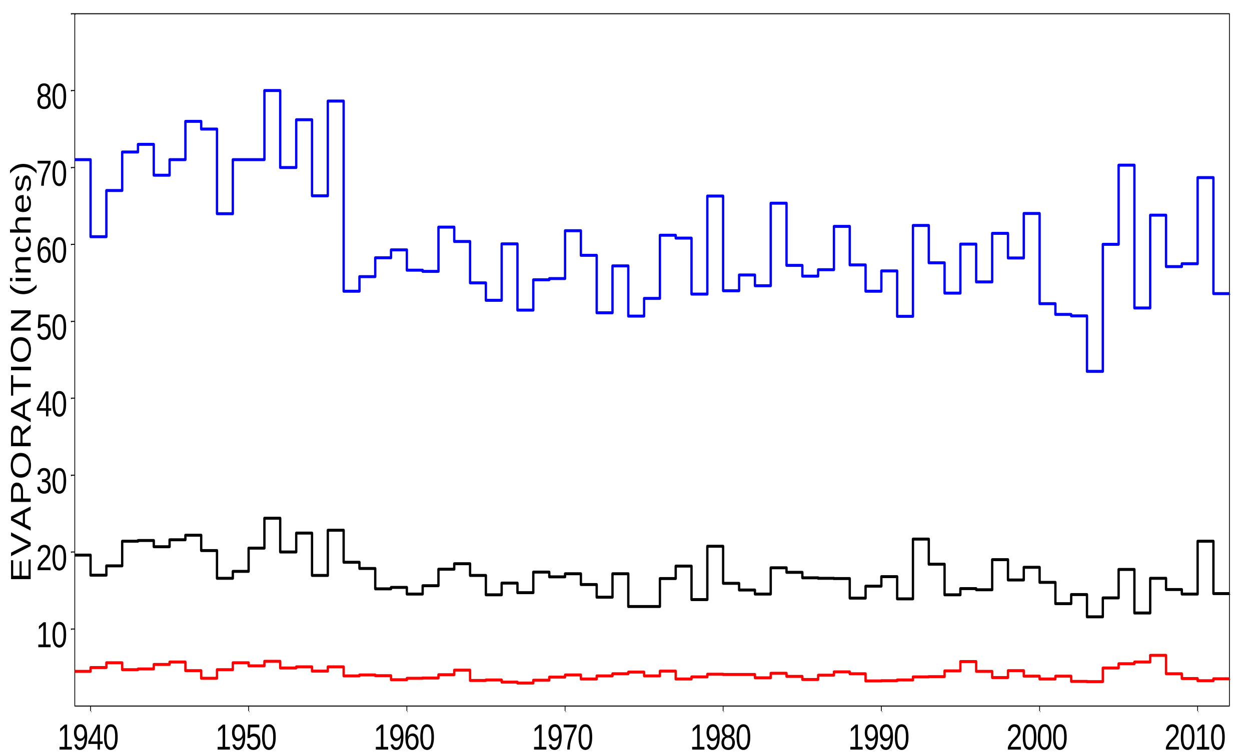
Monthly Evaporation for Quadrangle 509



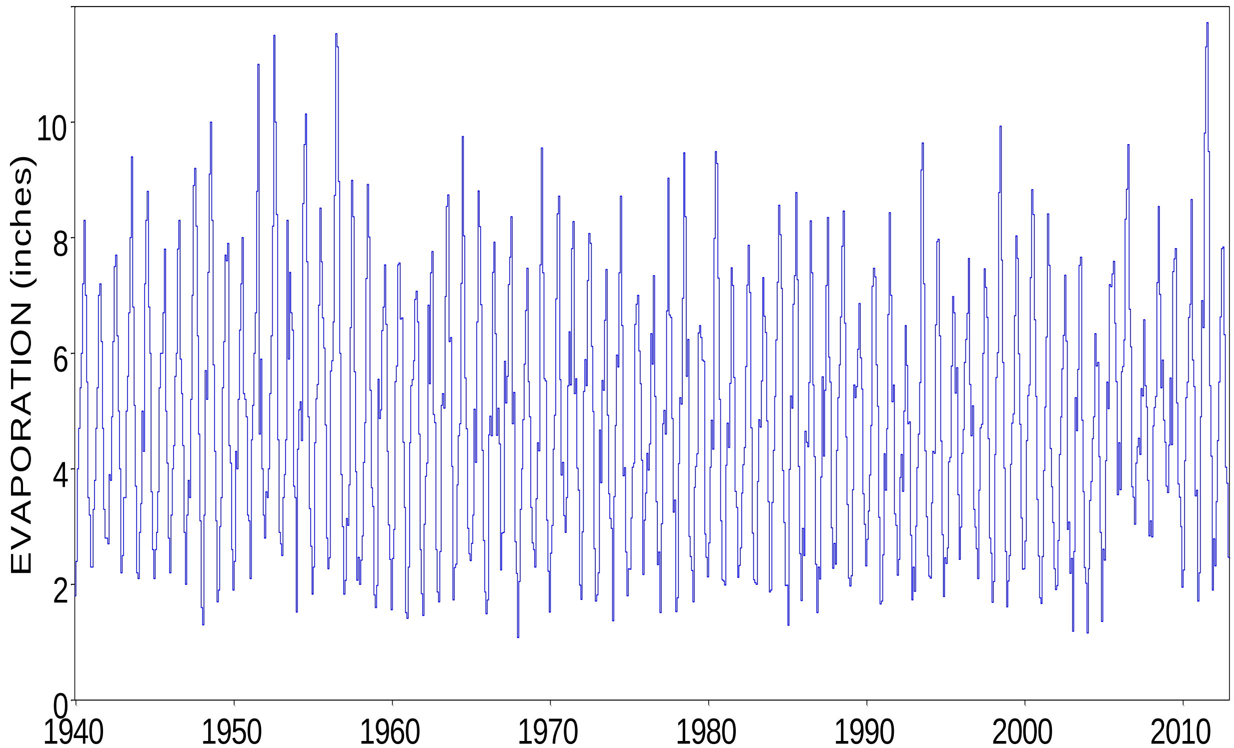
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 509



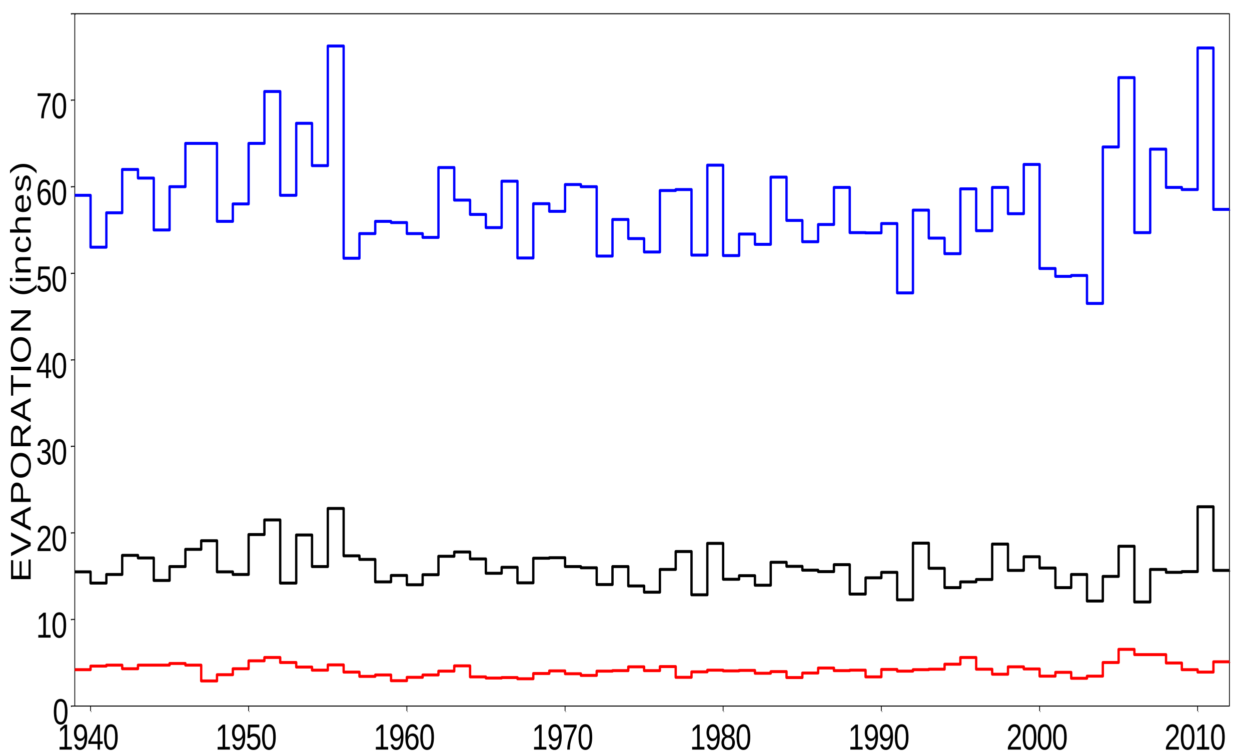
Monthly Evaporation for Quadrangle 510



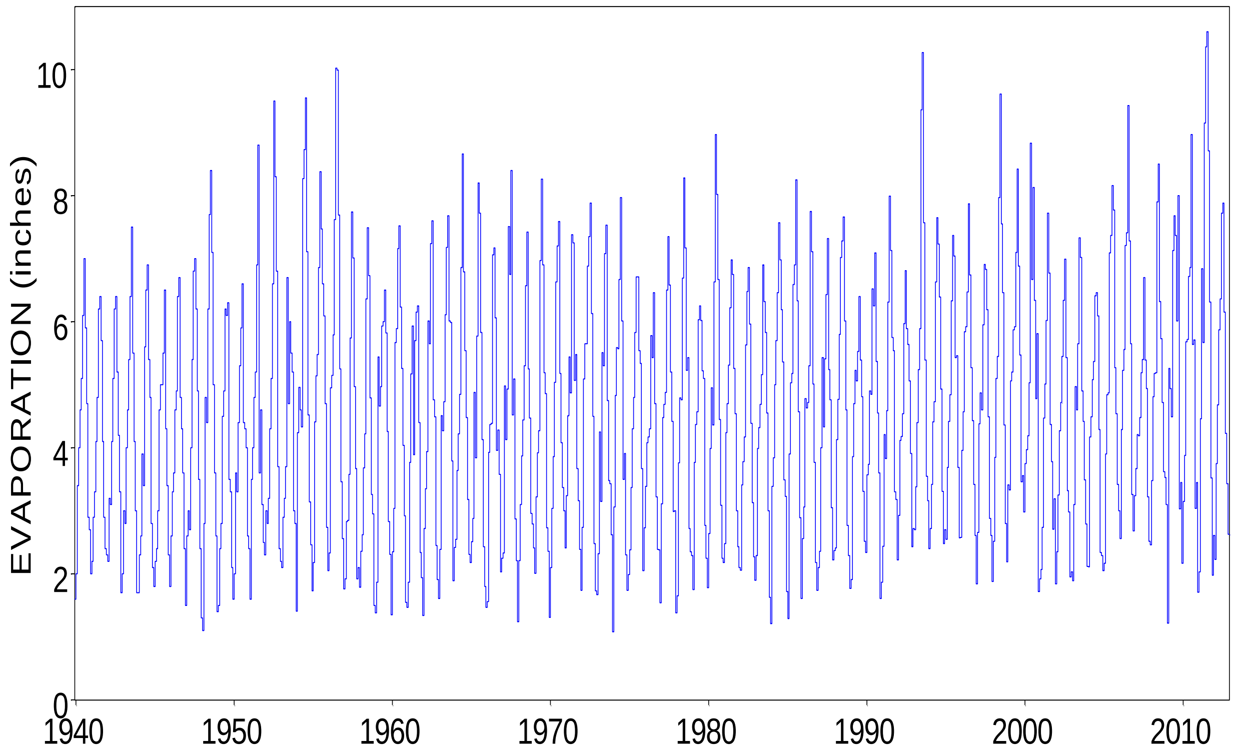
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 510



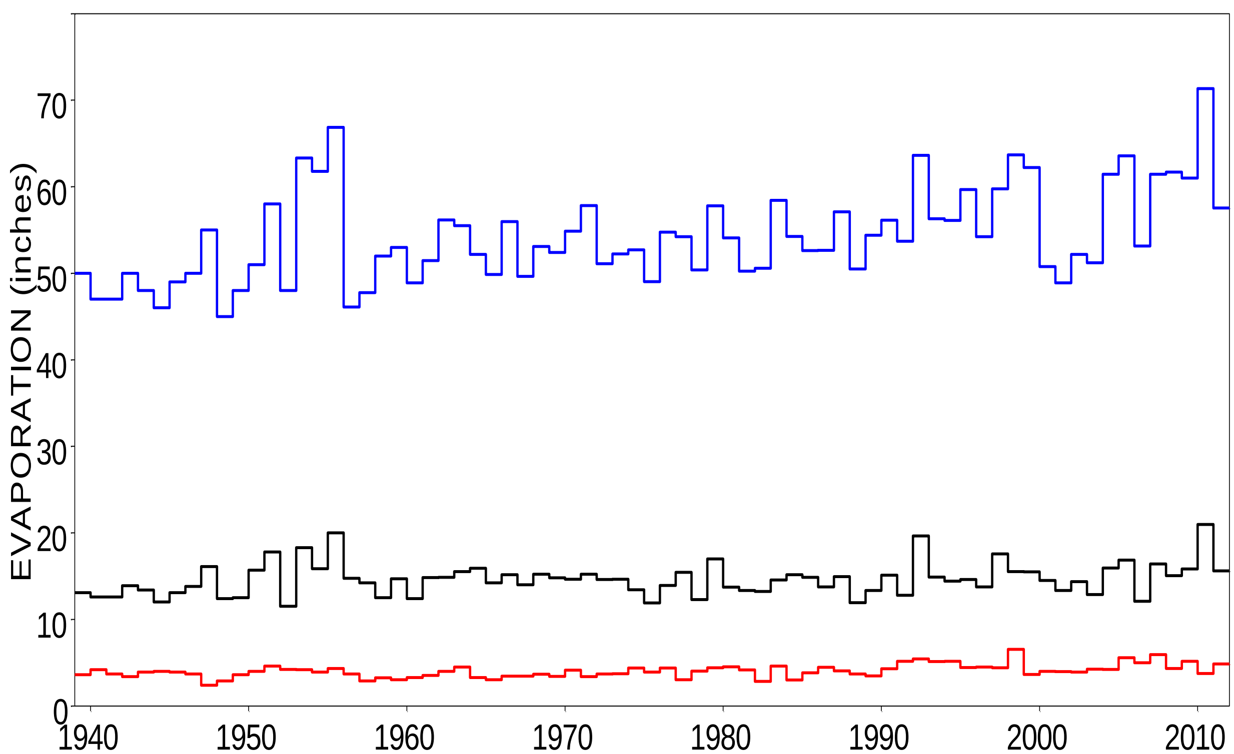
Monthly Evaporation for Quadrangle 511



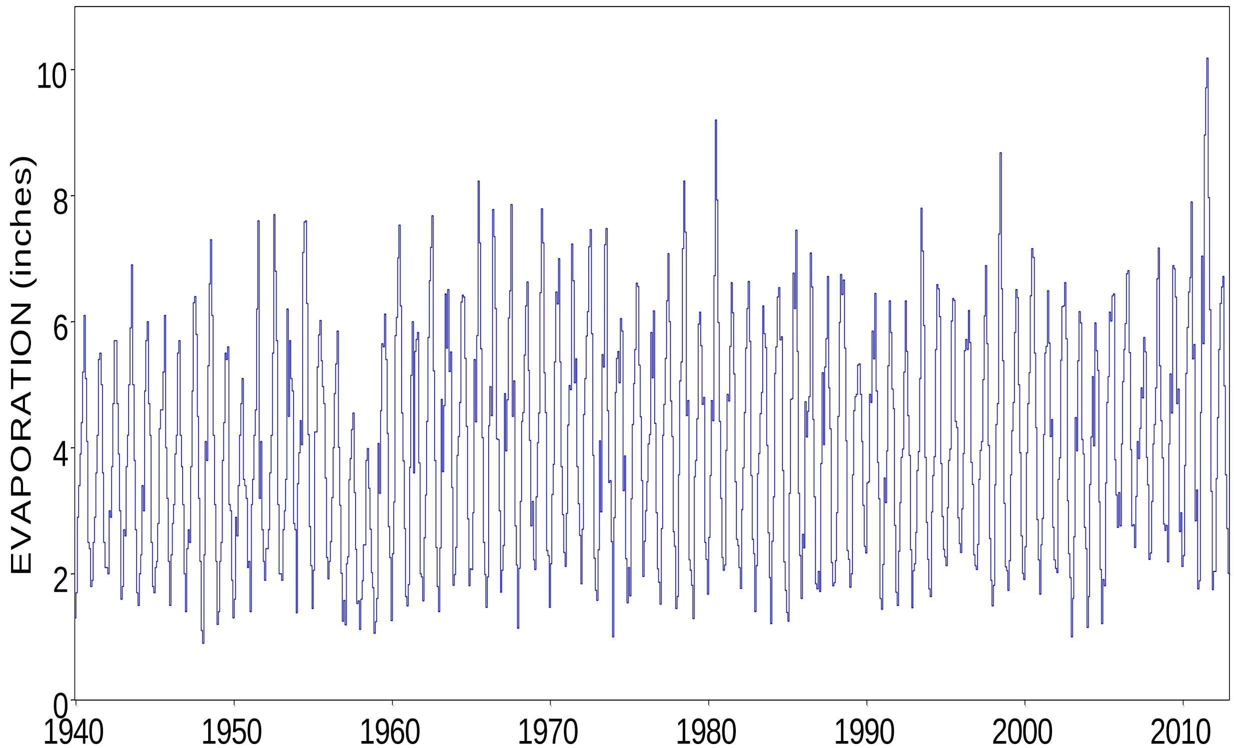
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 511



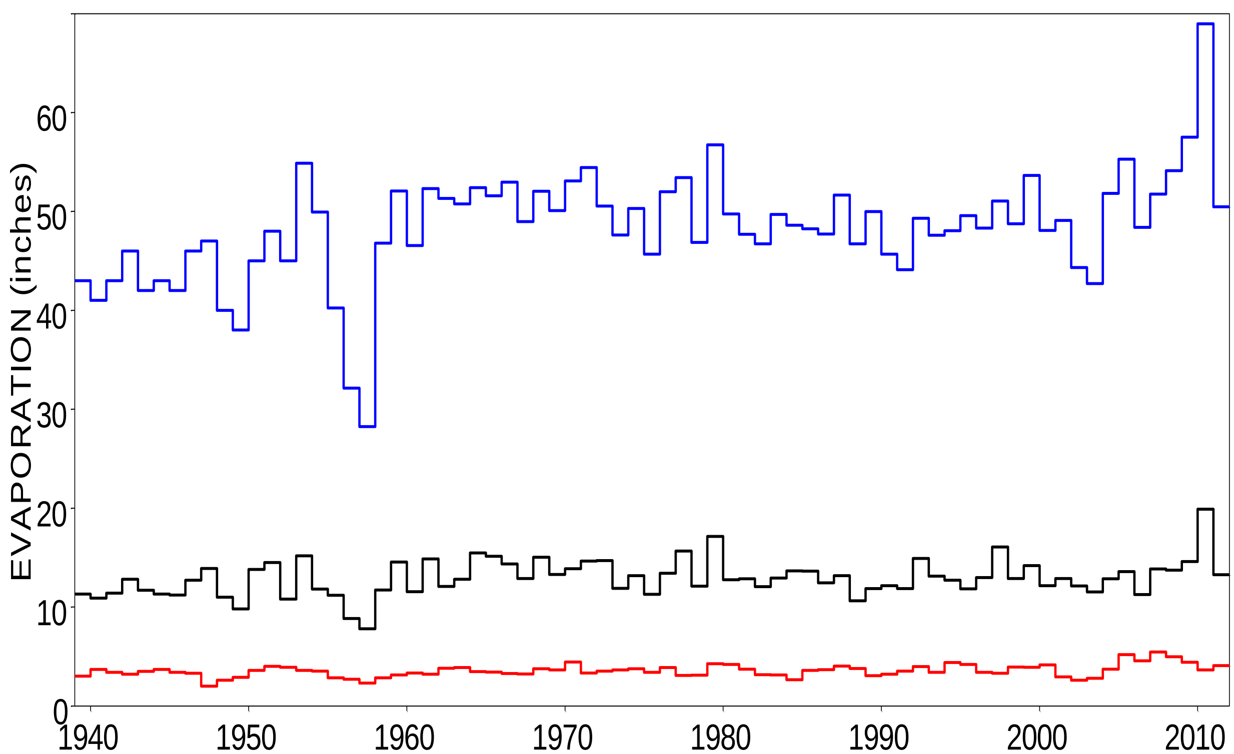
Monthly Evaporation for Quadrangle 512



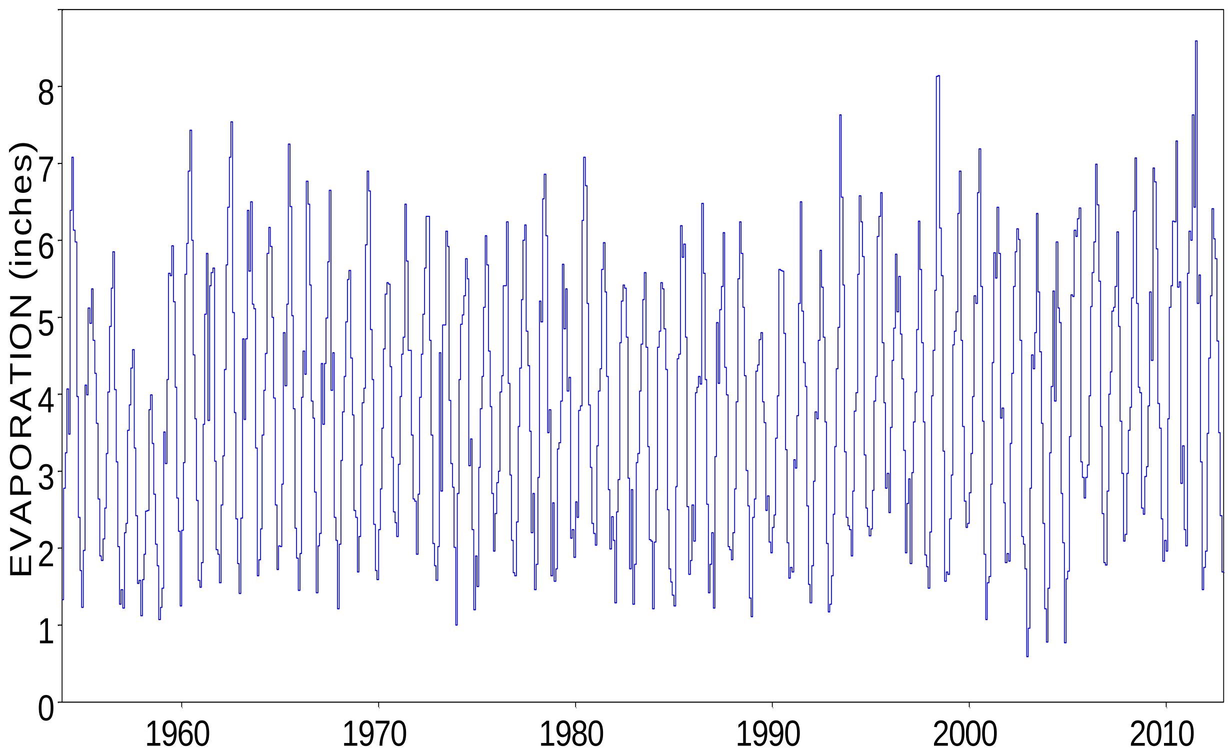
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 512



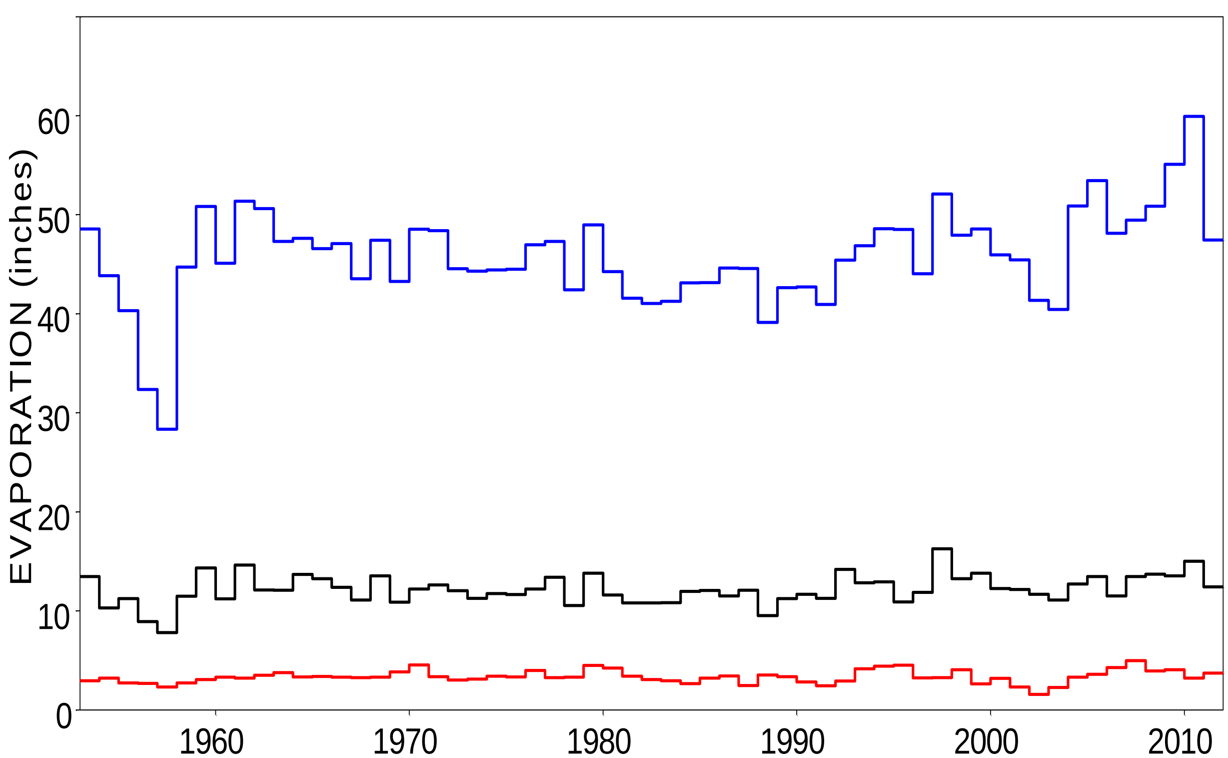
Monthly Evaporation for Quadrangle 513



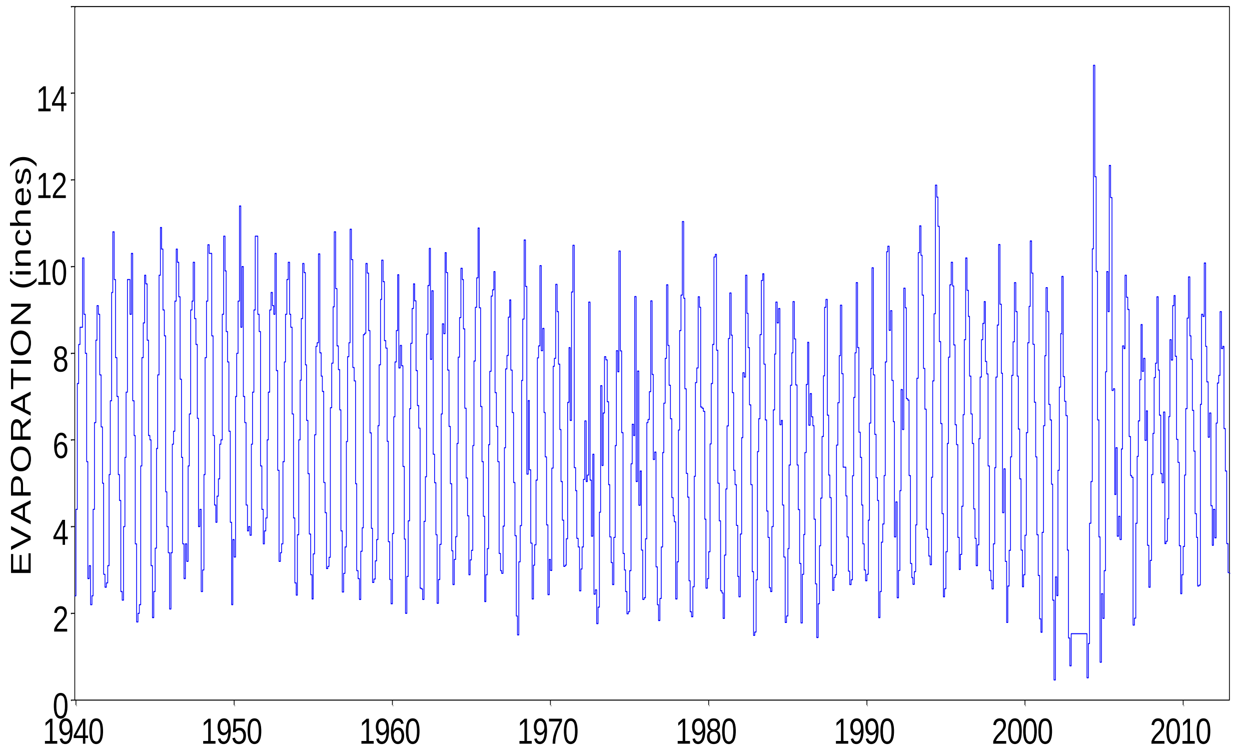
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 513



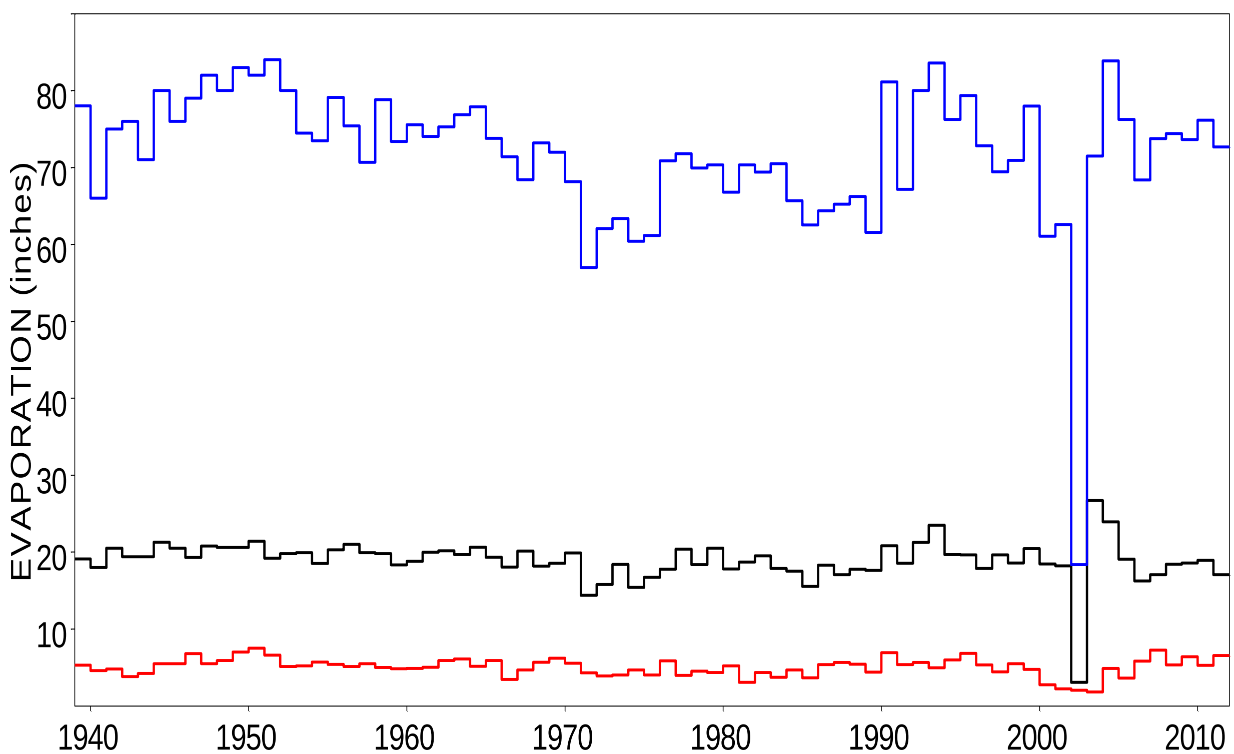
Monthly Evaporation for Quadrangle 514



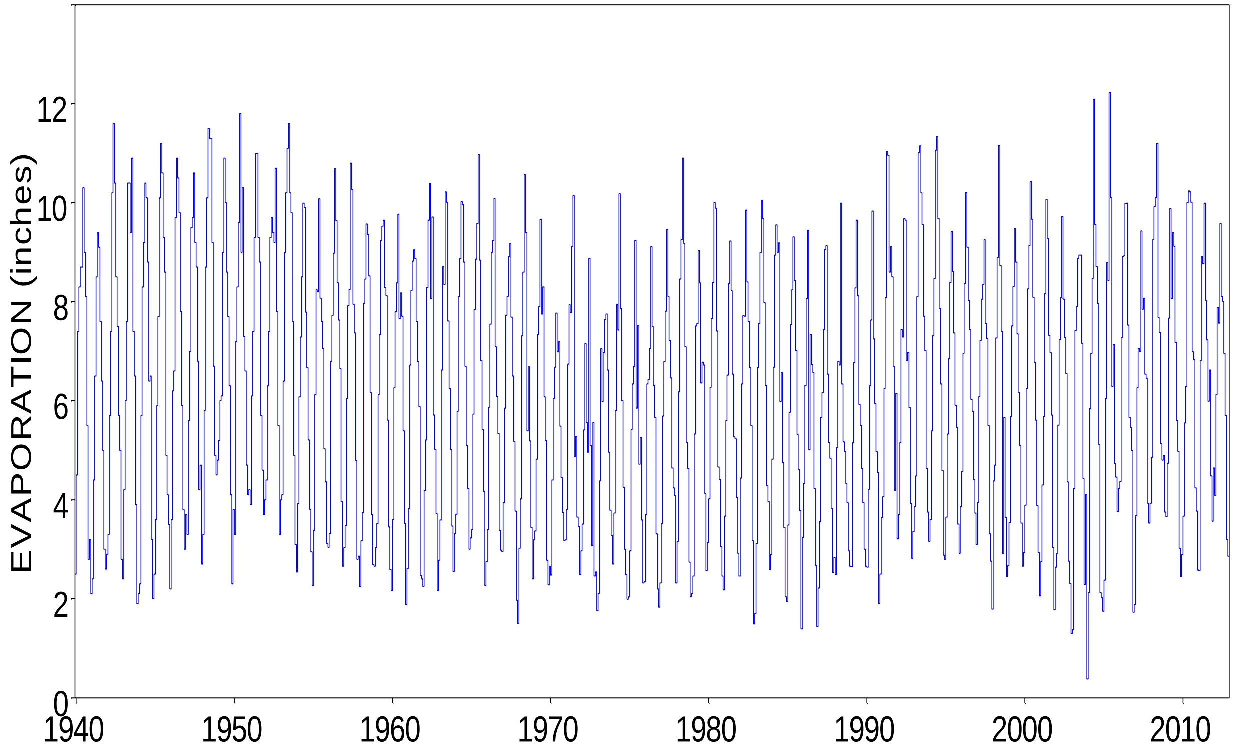
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 514



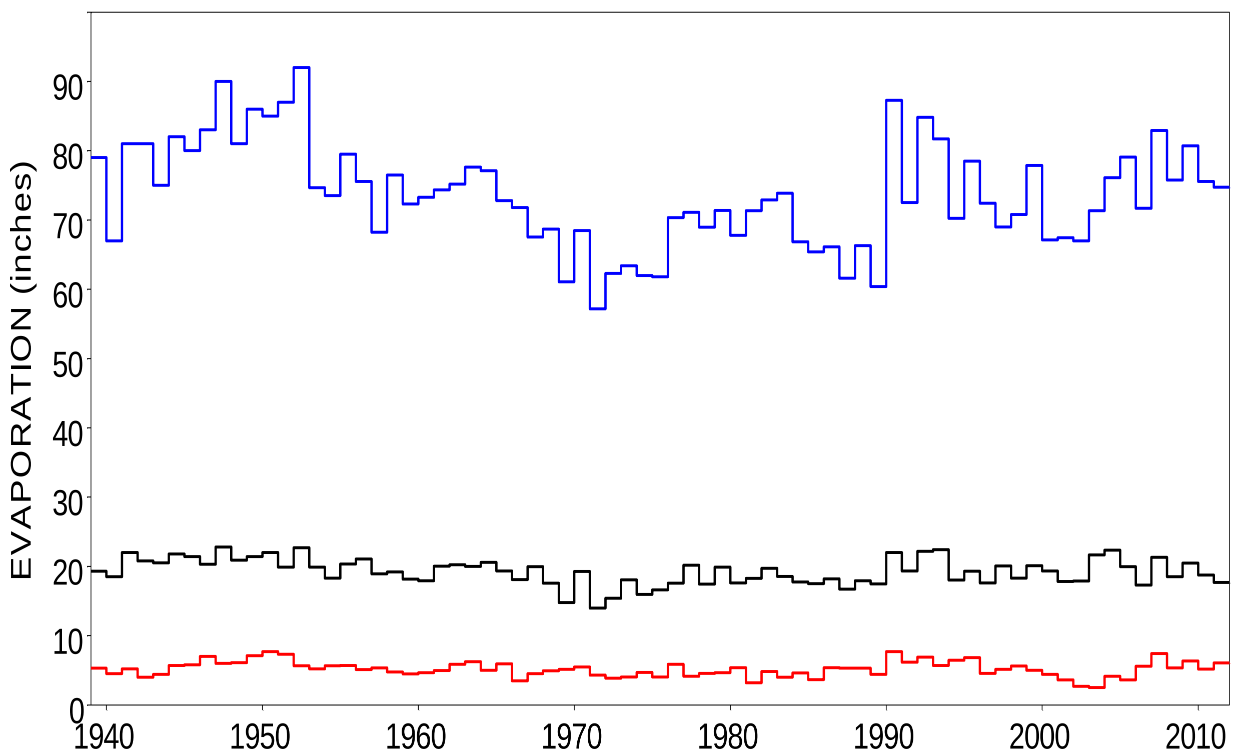
Monthly Evaporation for Quadrangle 601



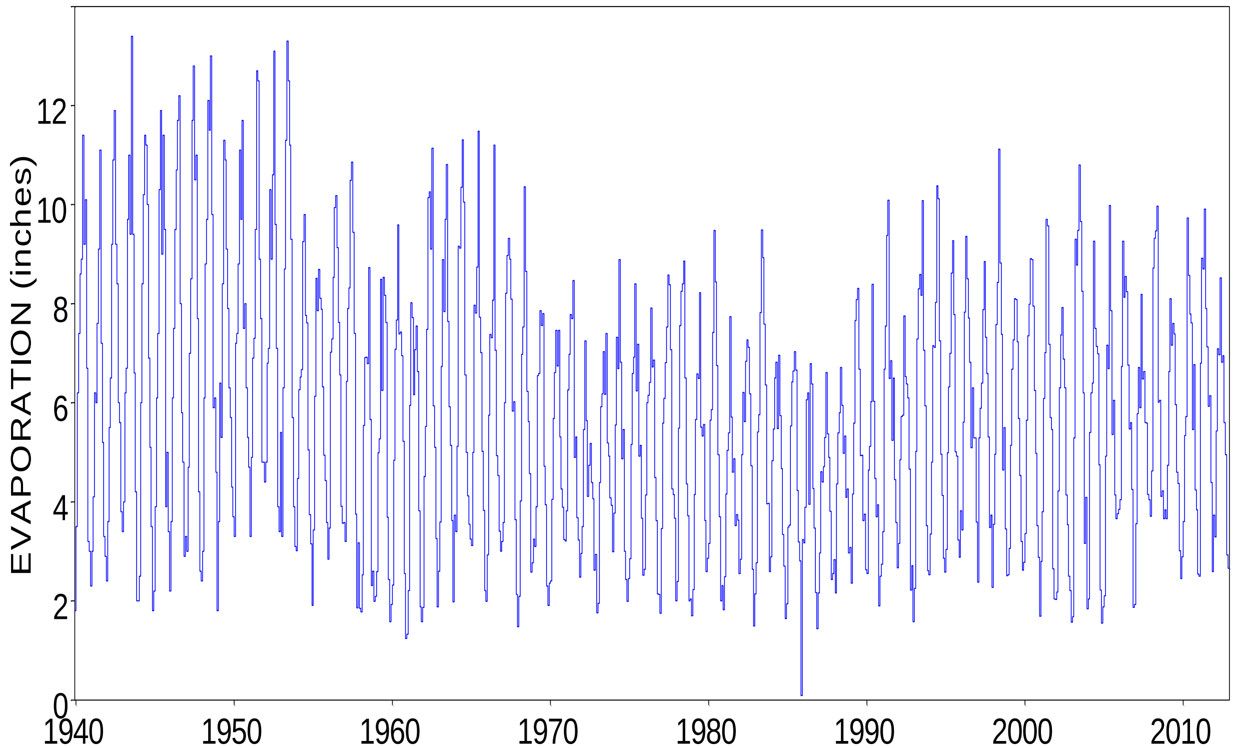
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 601



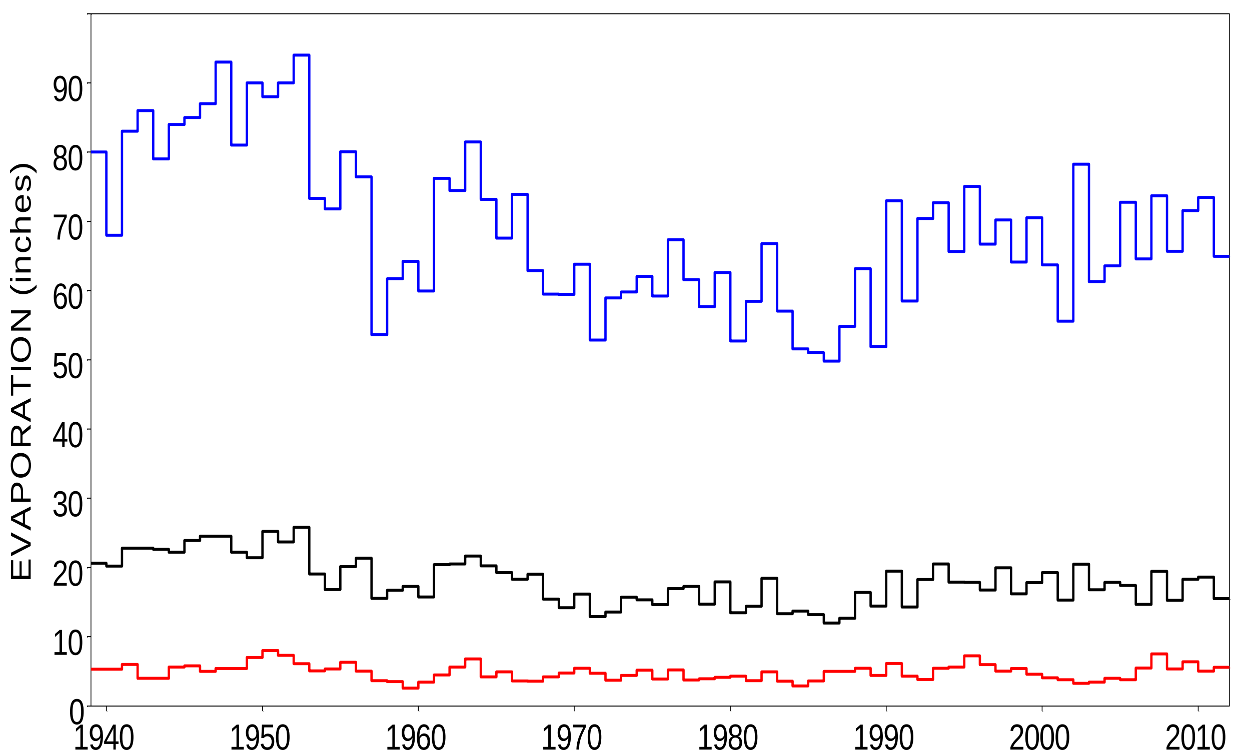
Monthly Evaporation for Quadrangle 602



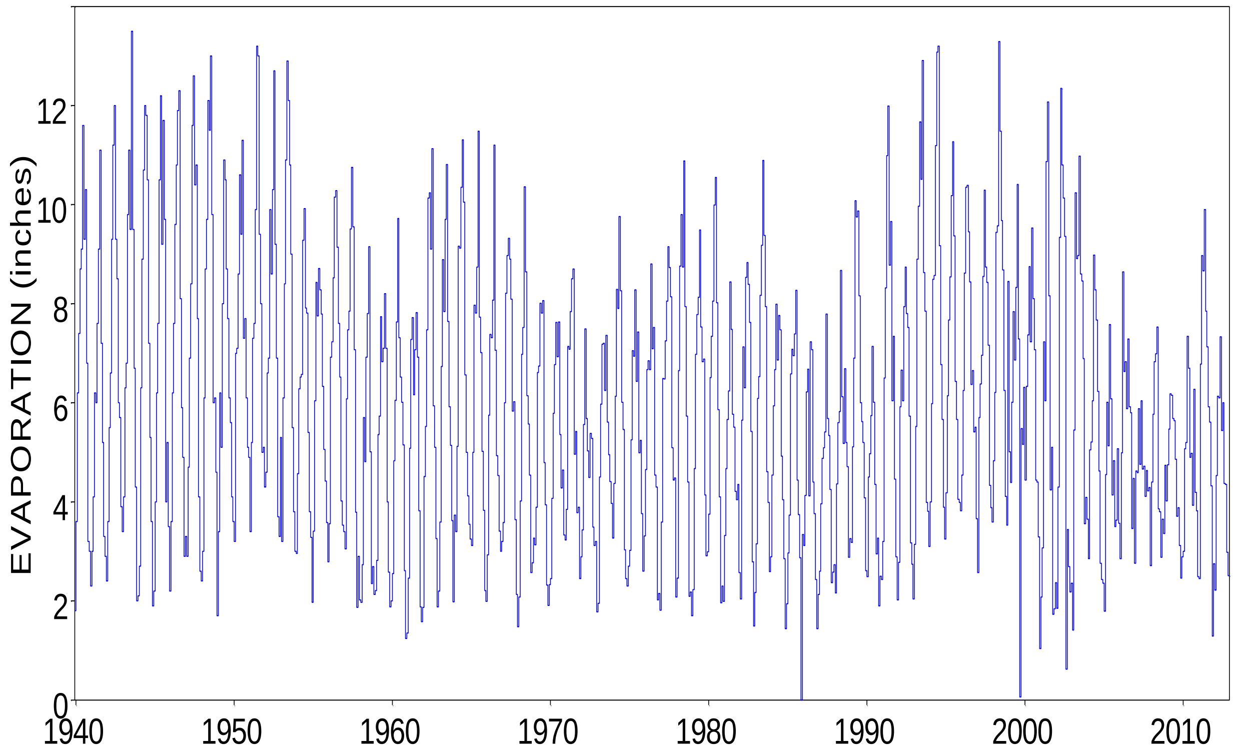
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 602



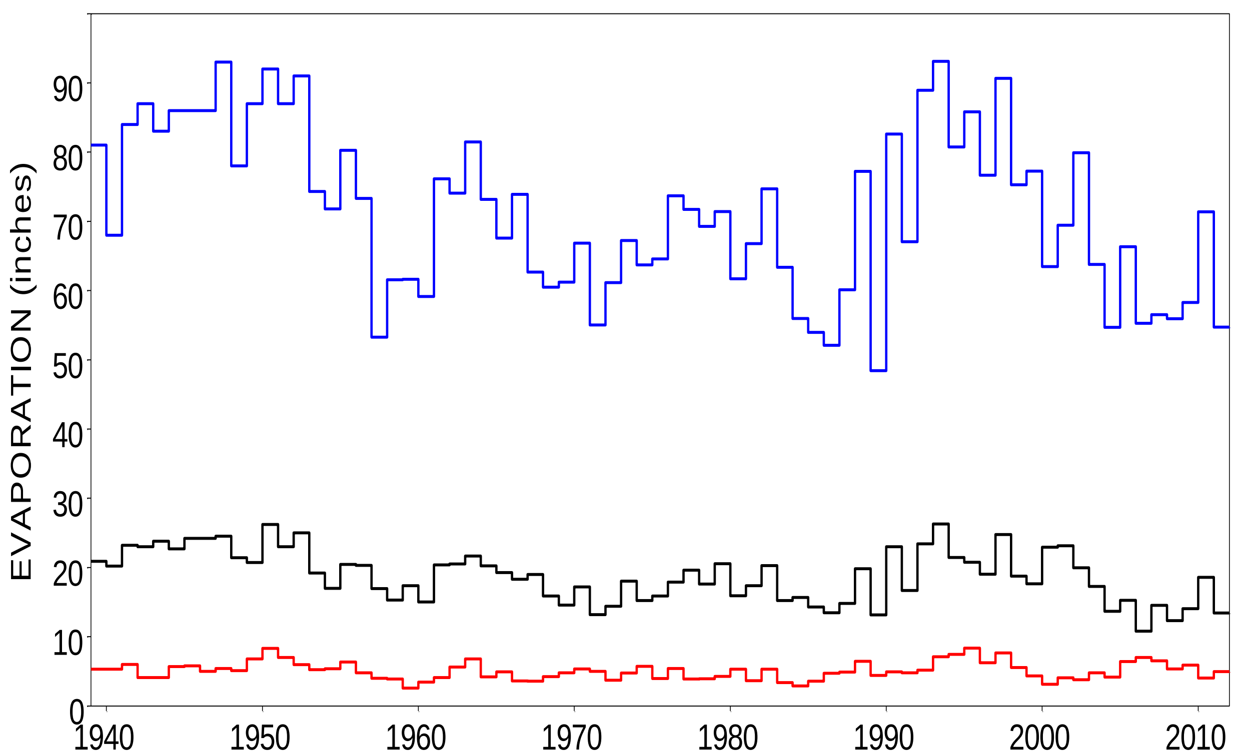
Monthly Evaporation for Quadrangle 603



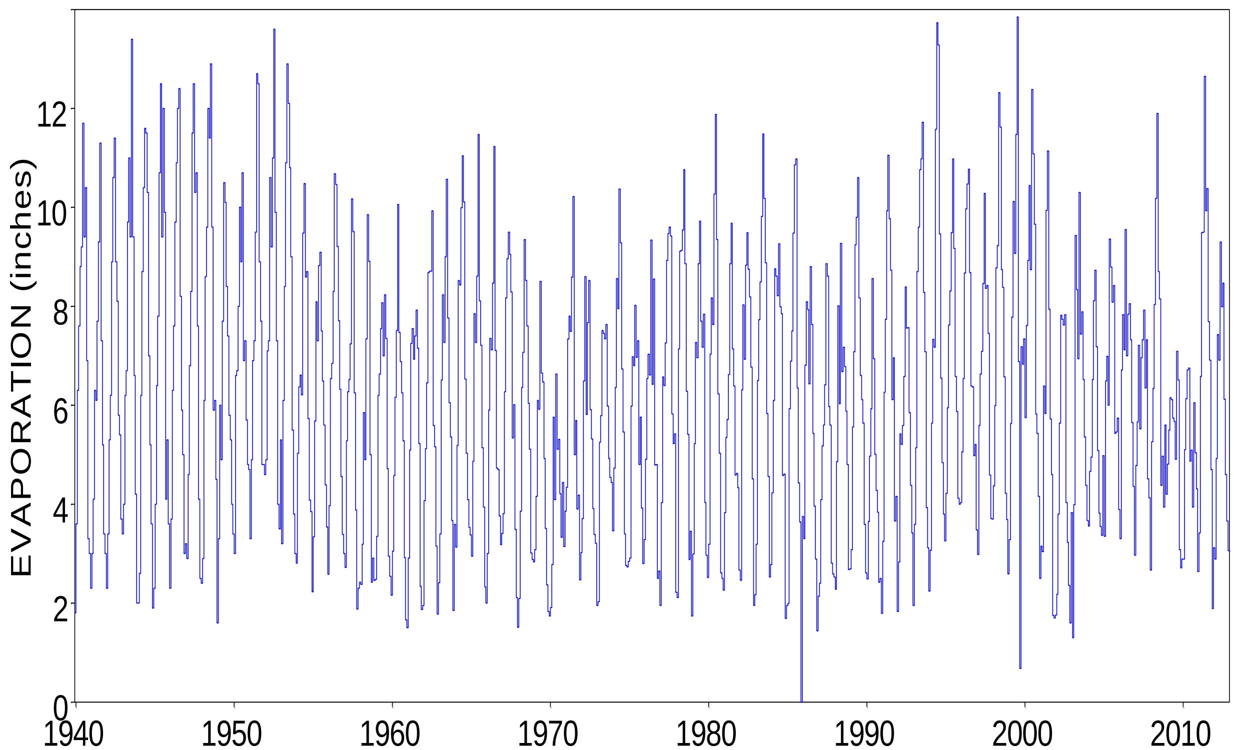
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 603



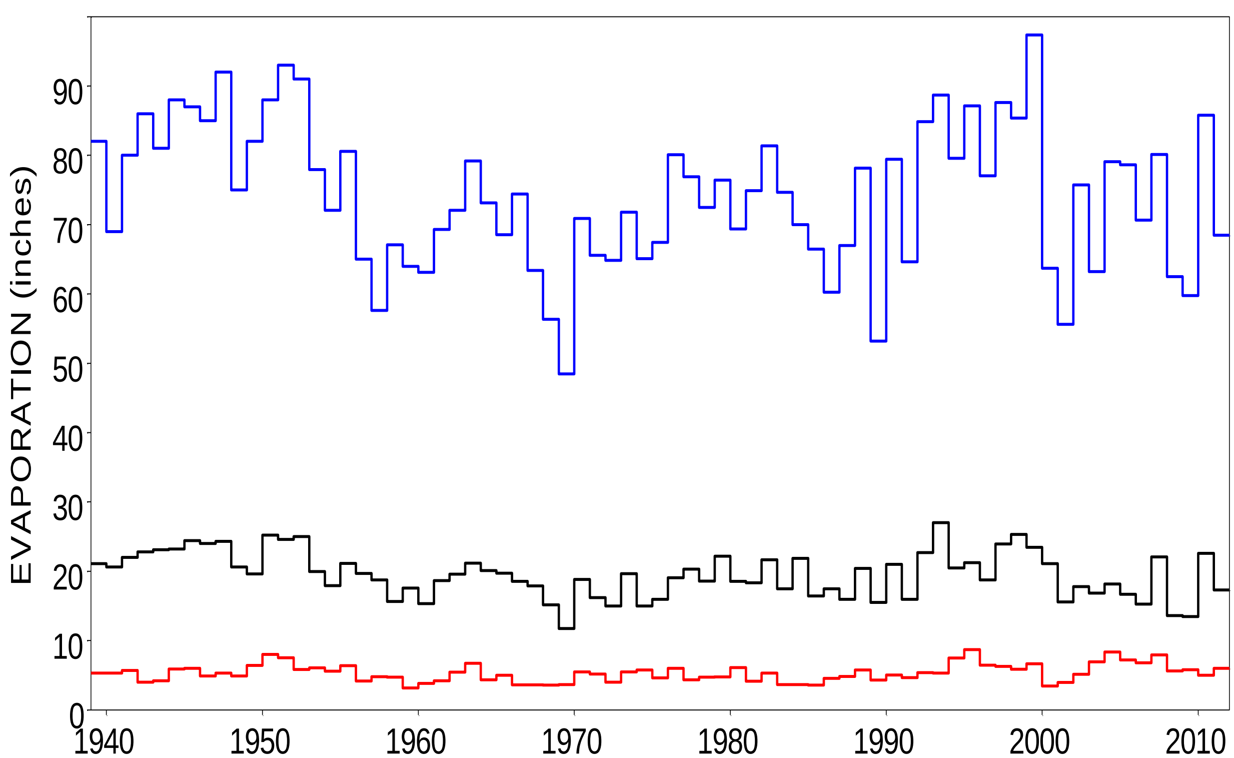
Monthly Evaporation for Quadrangle 604



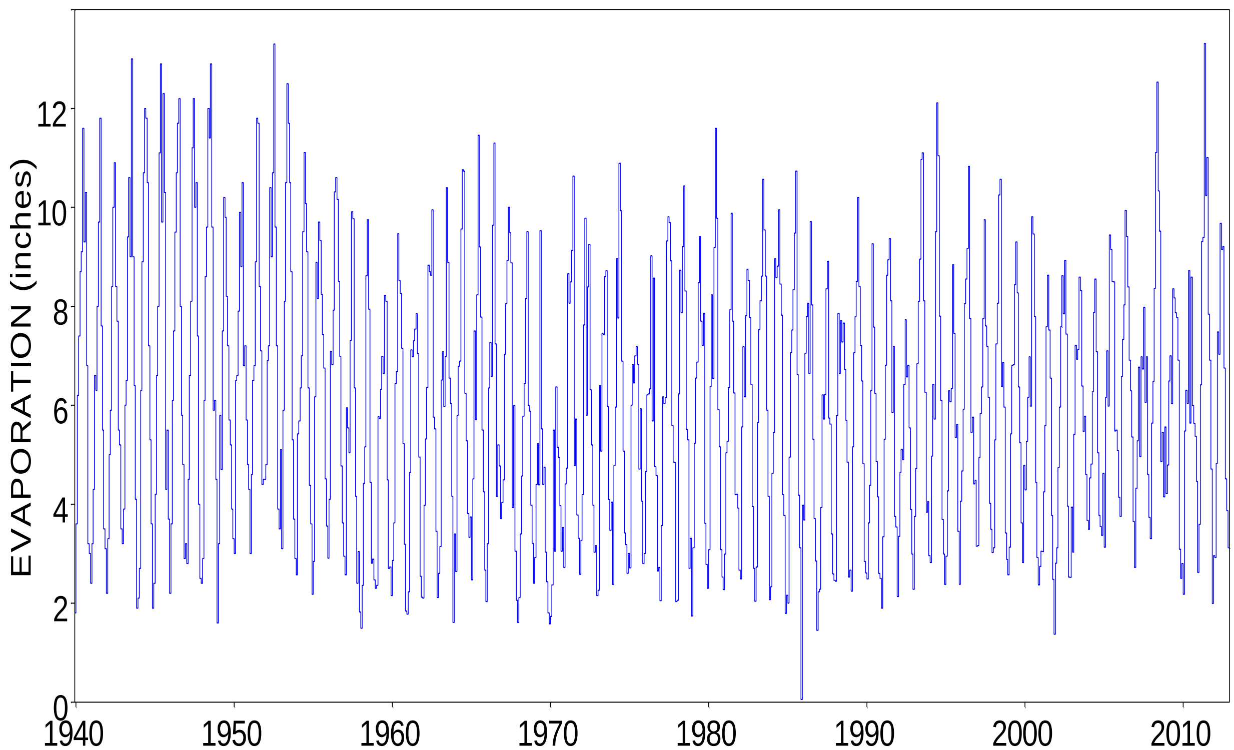
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 604



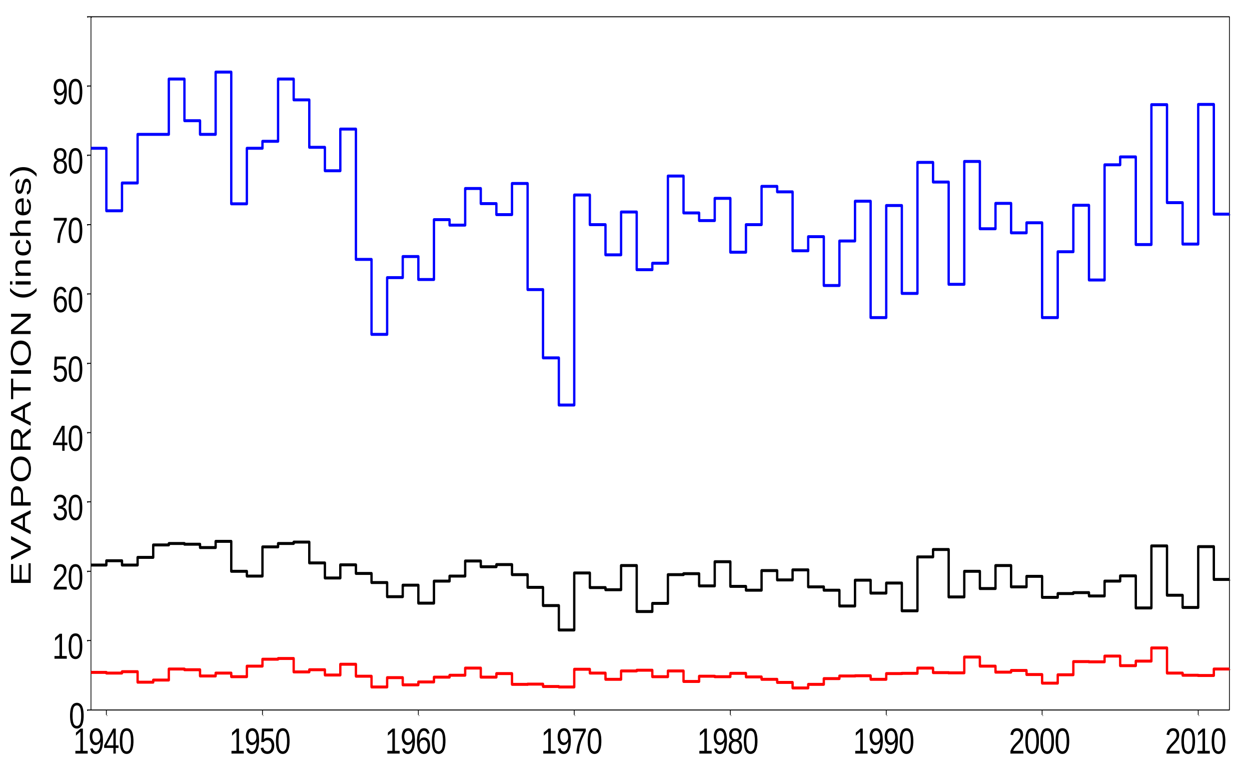
Monthly Evaporation for Quadrangle 605



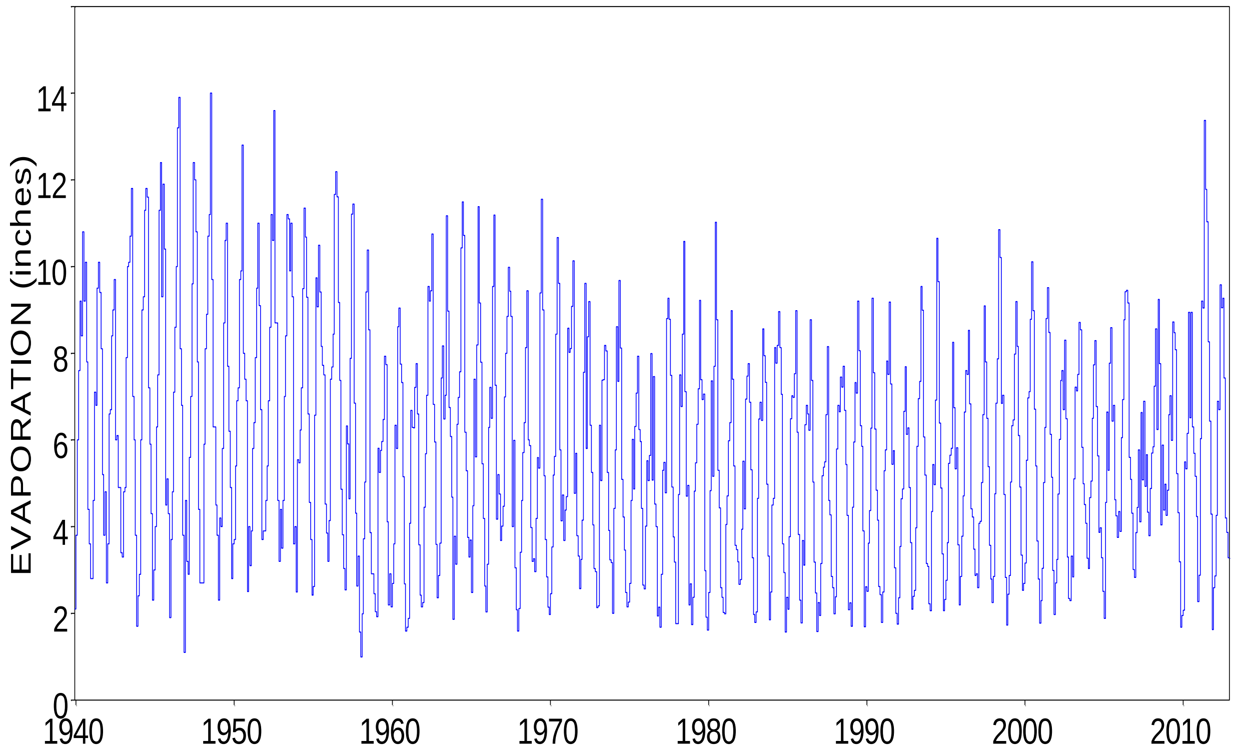
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 605



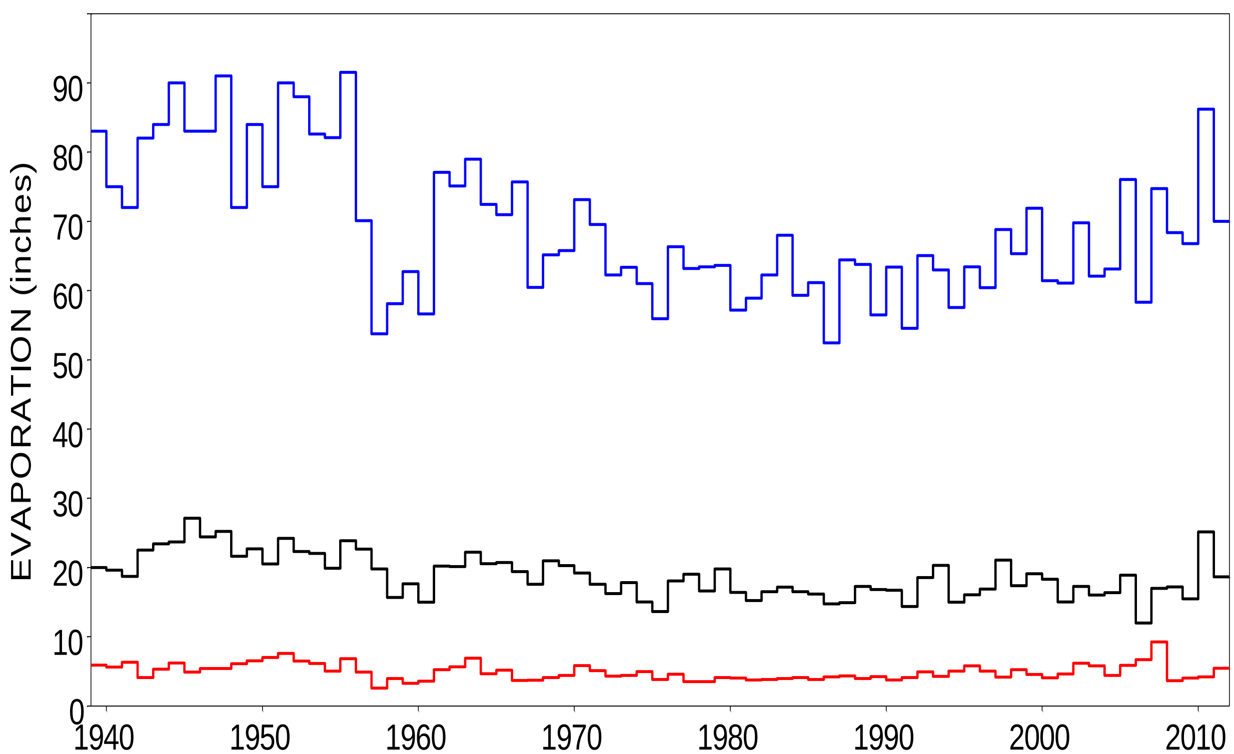
Monthly Evaporation for Quadrangle 606



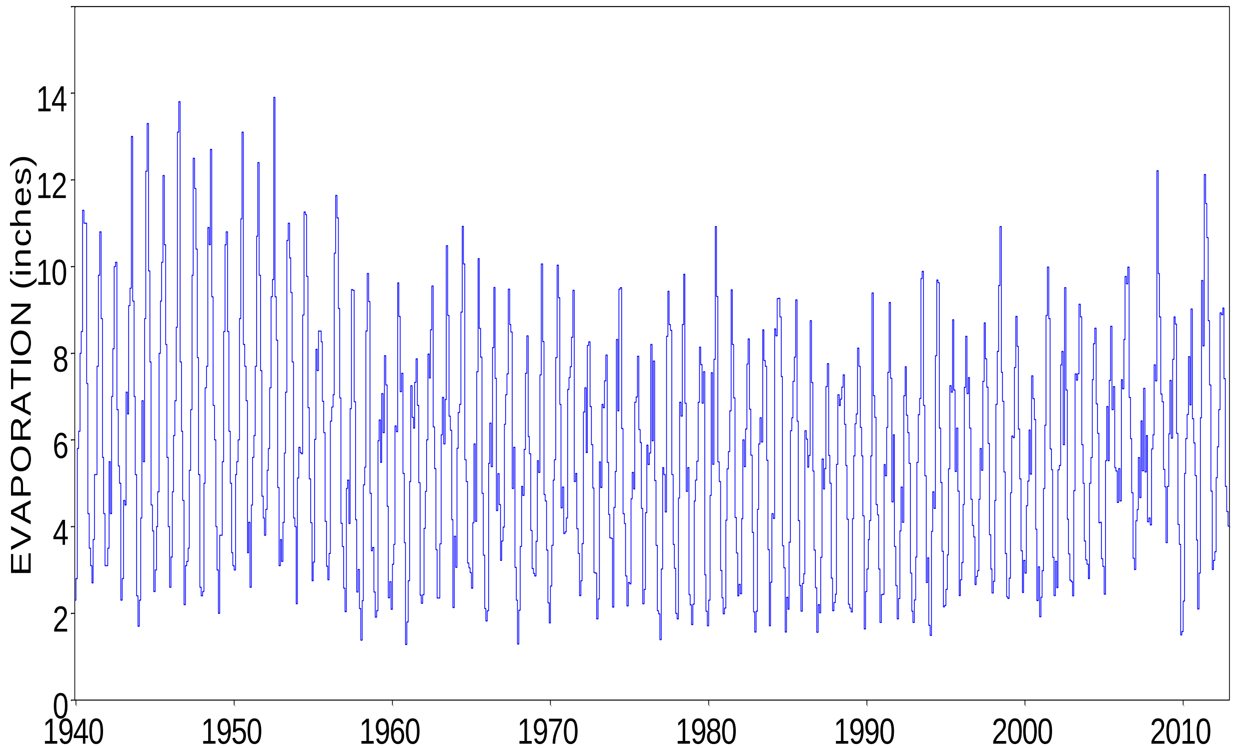
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 606



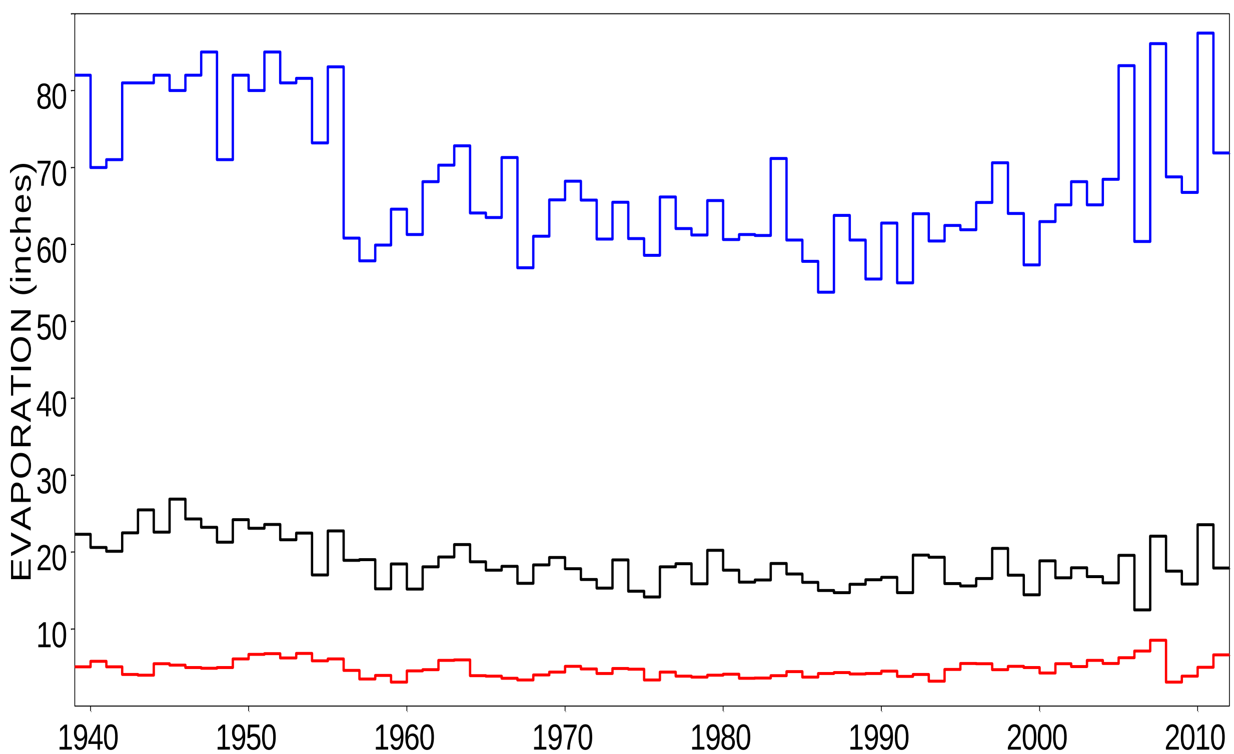
Monthly Evaporation for Quadrangle 607



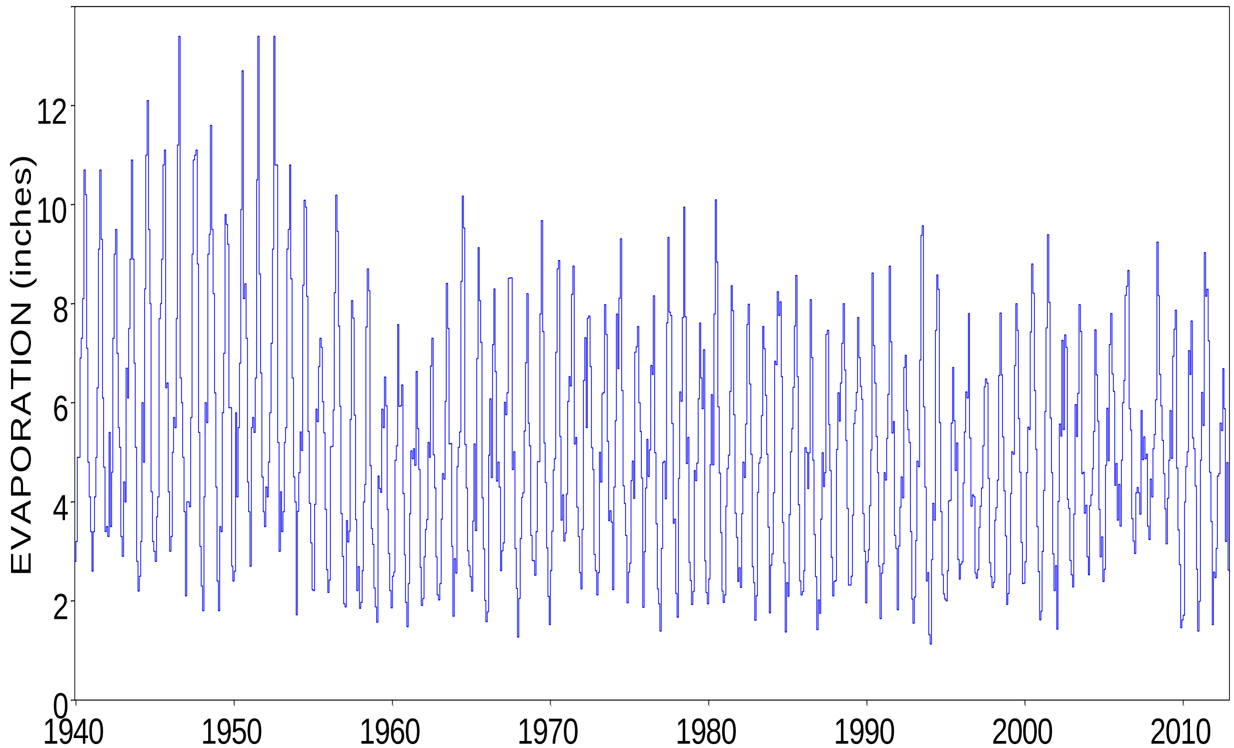
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 607



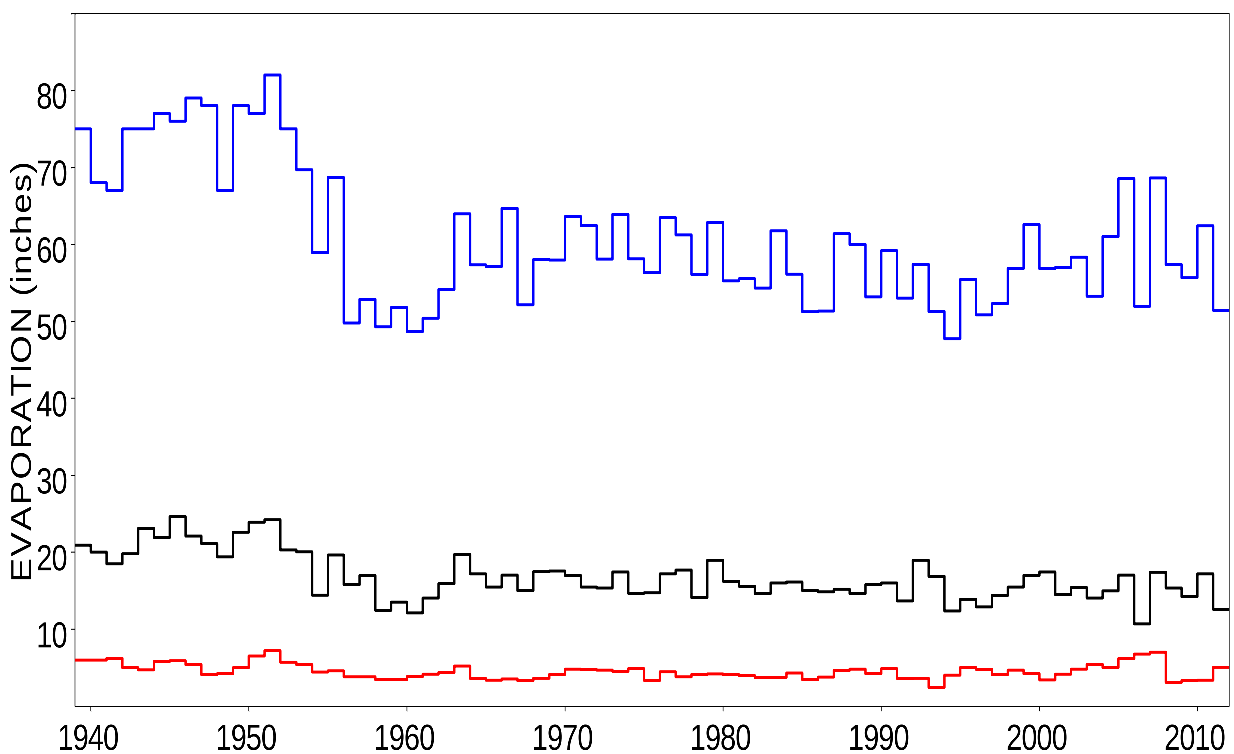
Monthly Evaporation for Quadrangle 608



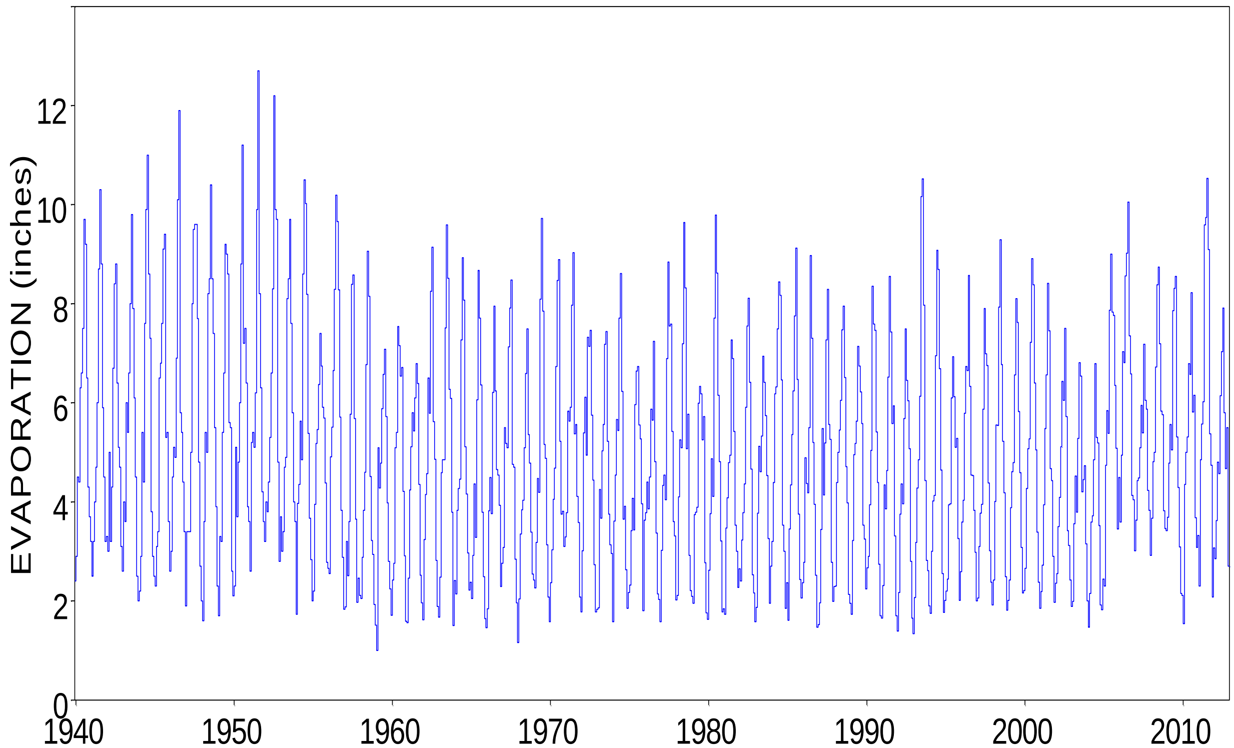
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 608



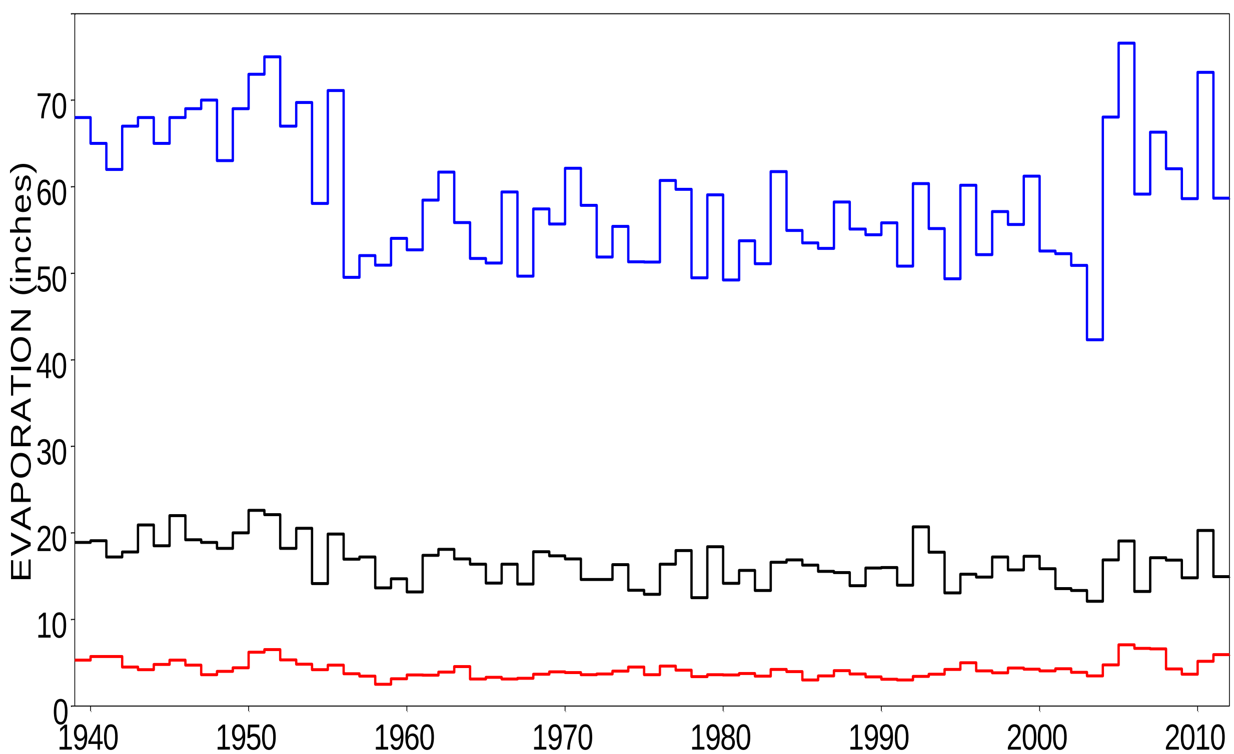
Monthly Evaporation for Quadrangle 609



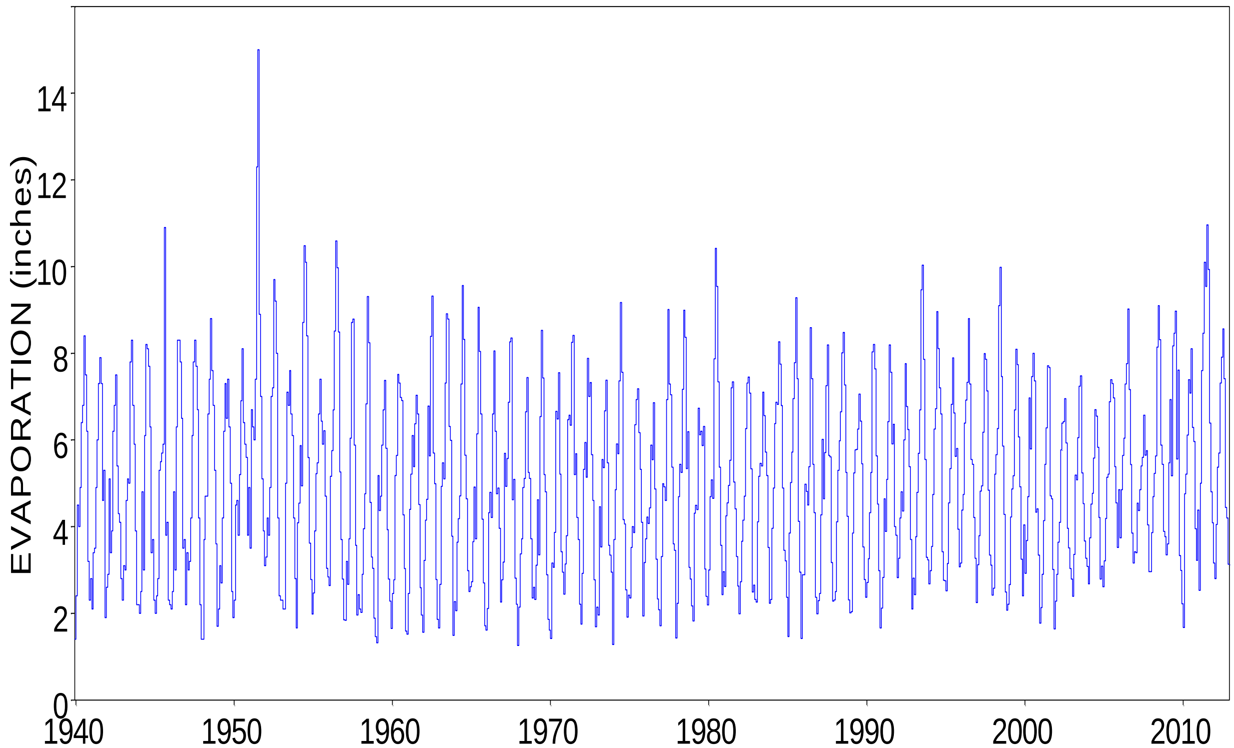
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 609



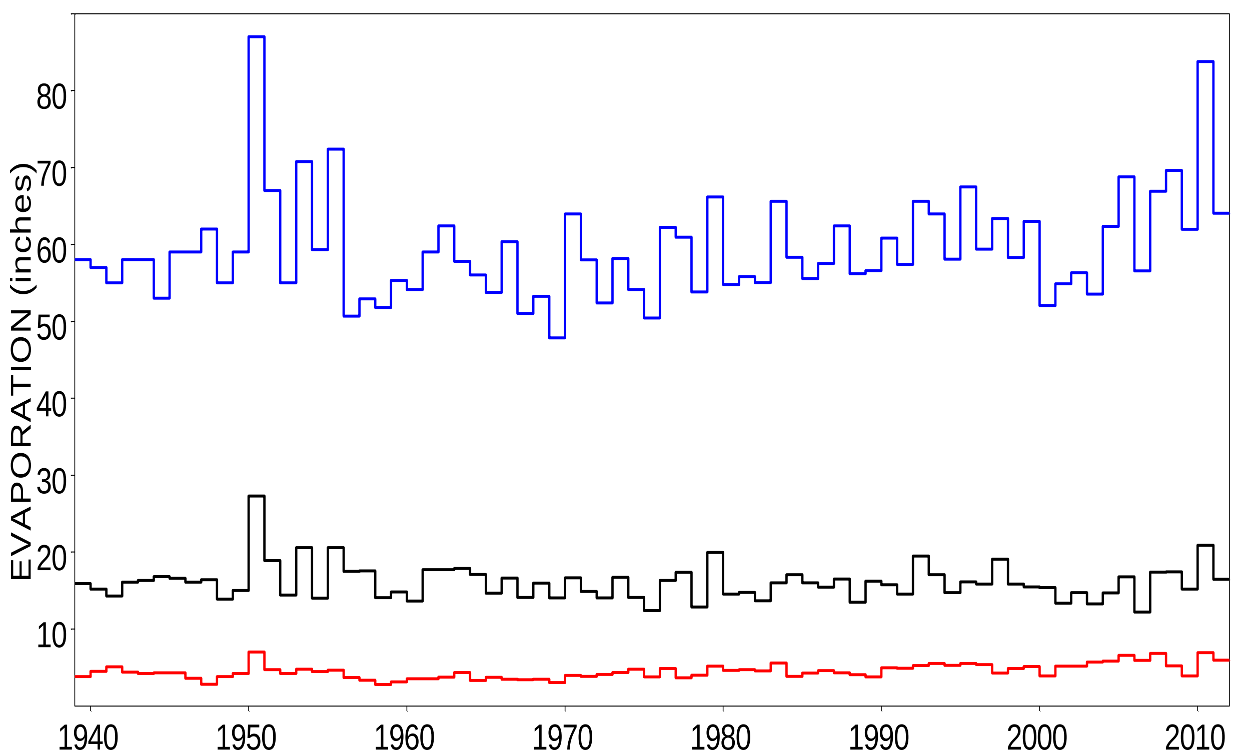
Monthly Evaporation for Quadrangle 610



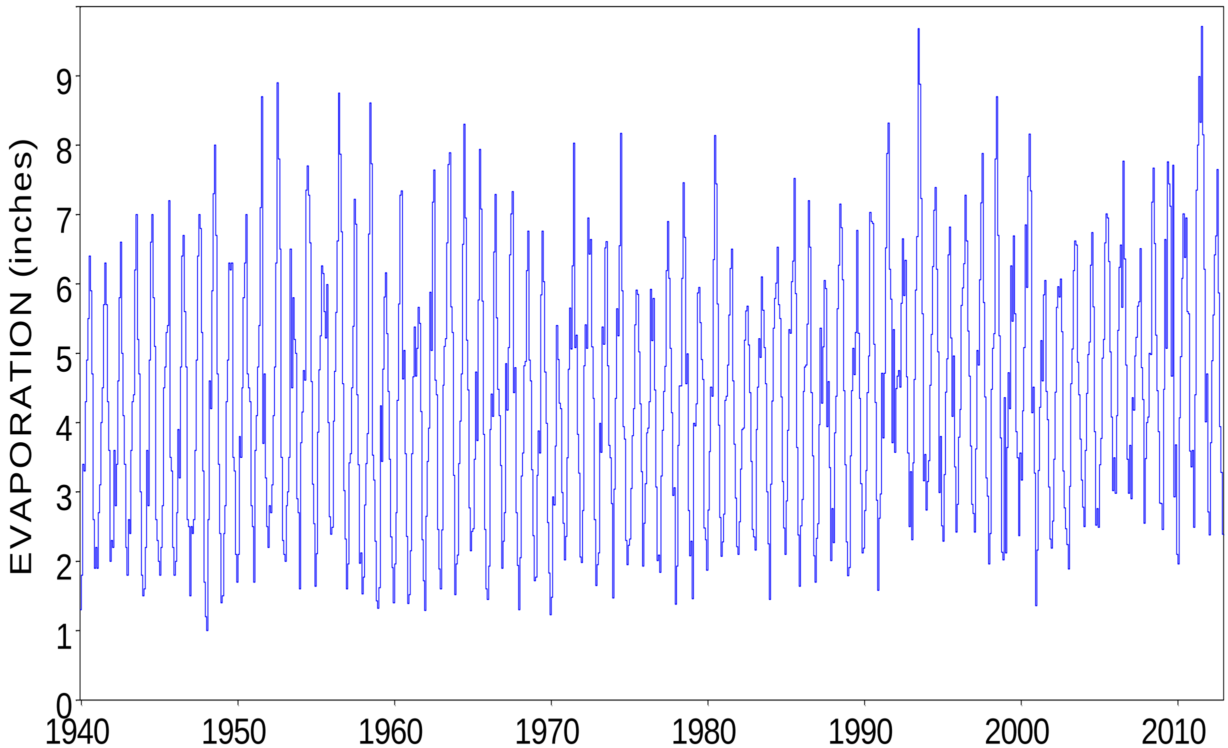
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 610



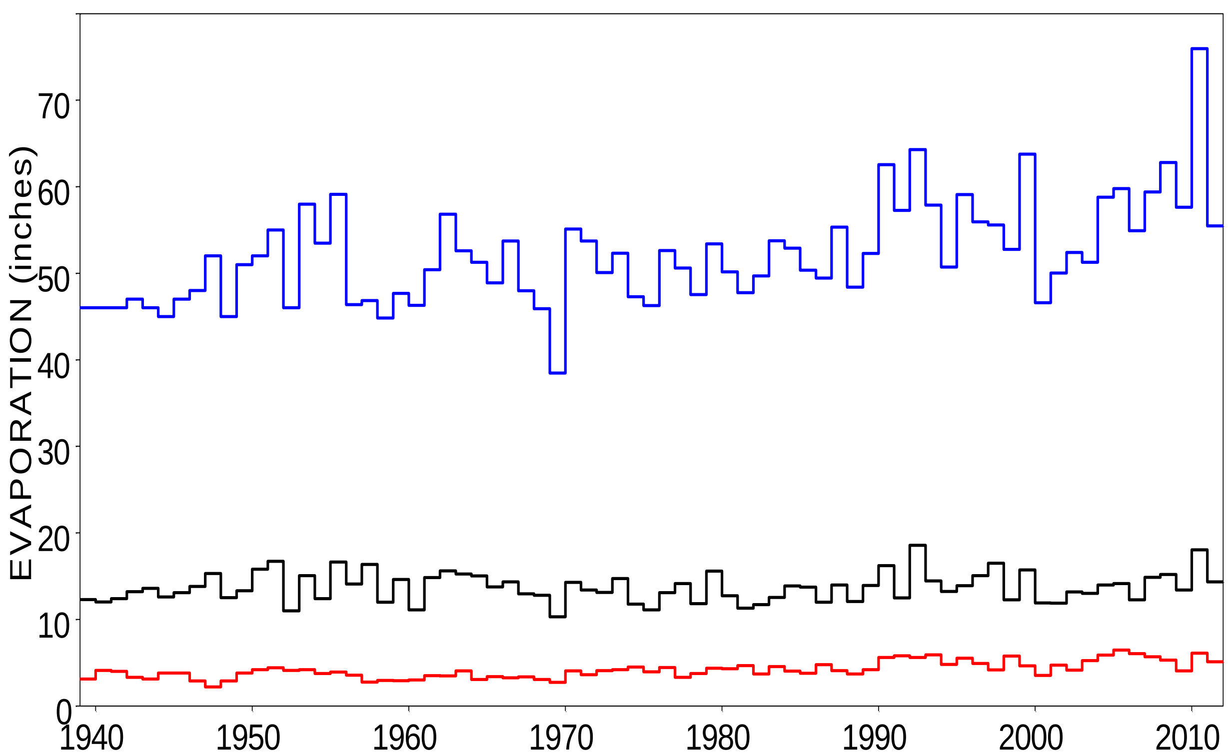
Monthly Evaporation for Quadrangle 611



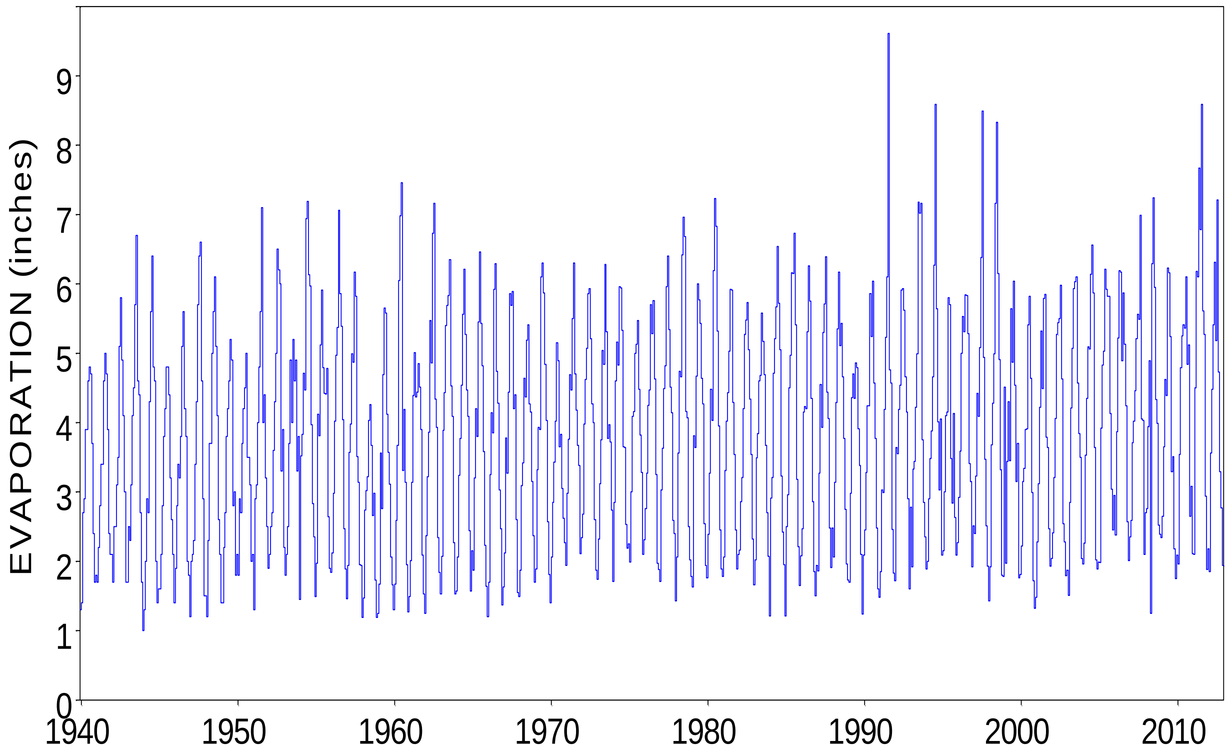
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 611



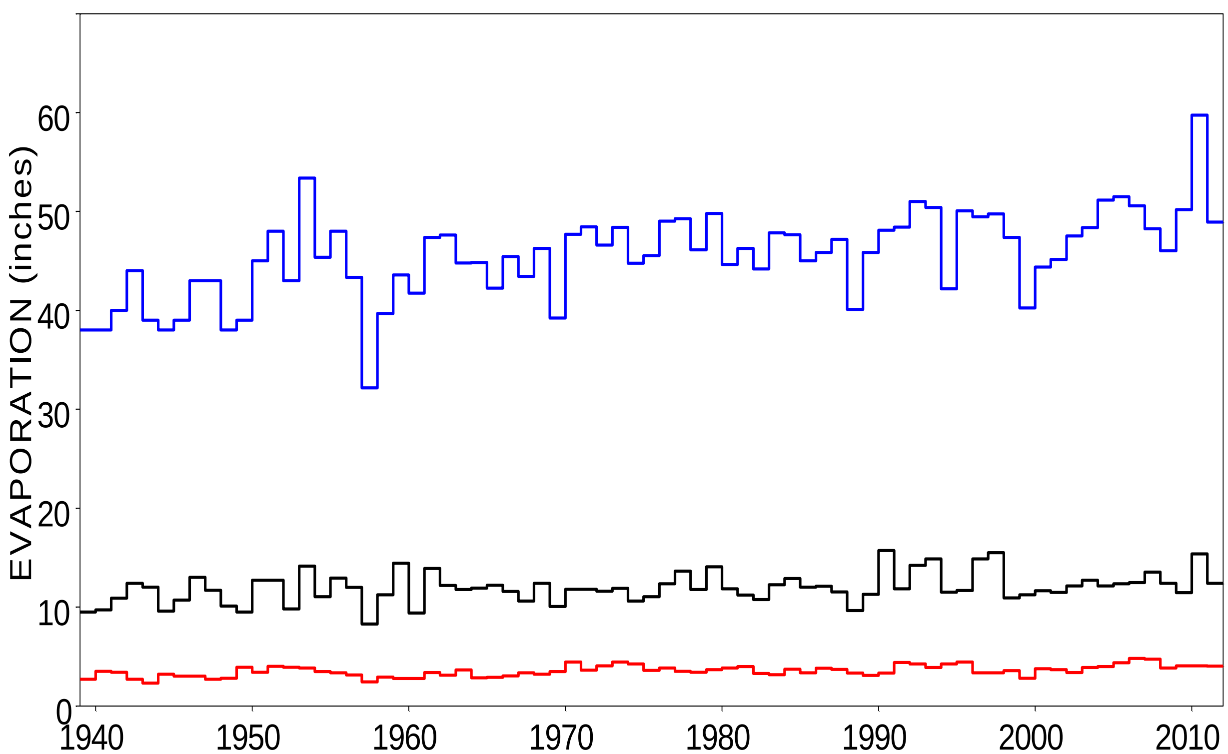
Monthly Evaporation for Quadrangle 612



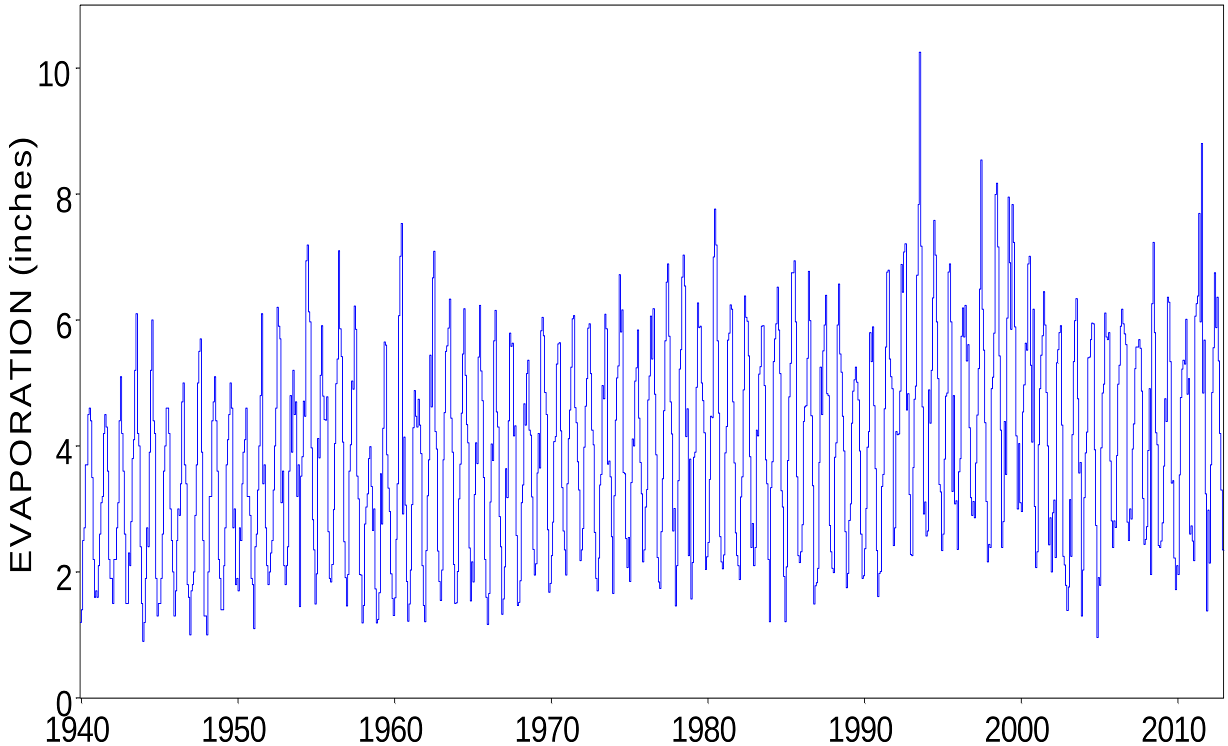
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 612



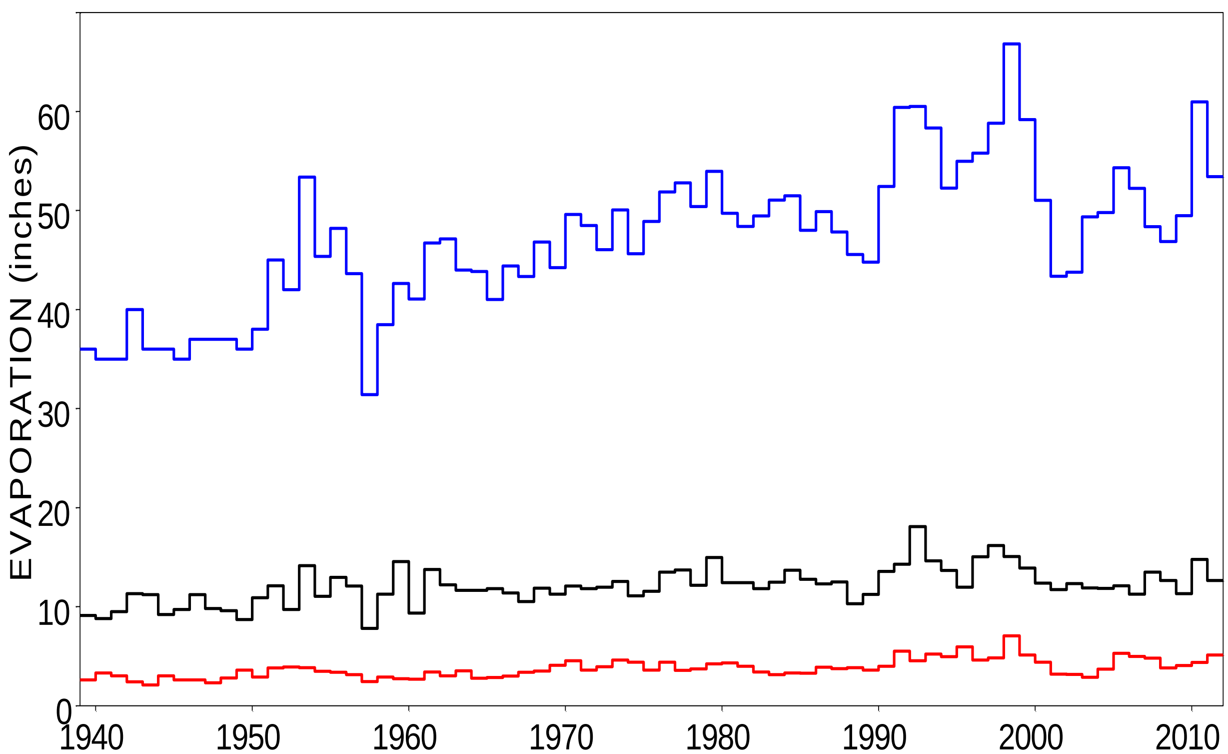
Monthly Evaporation for Quadrangle 613



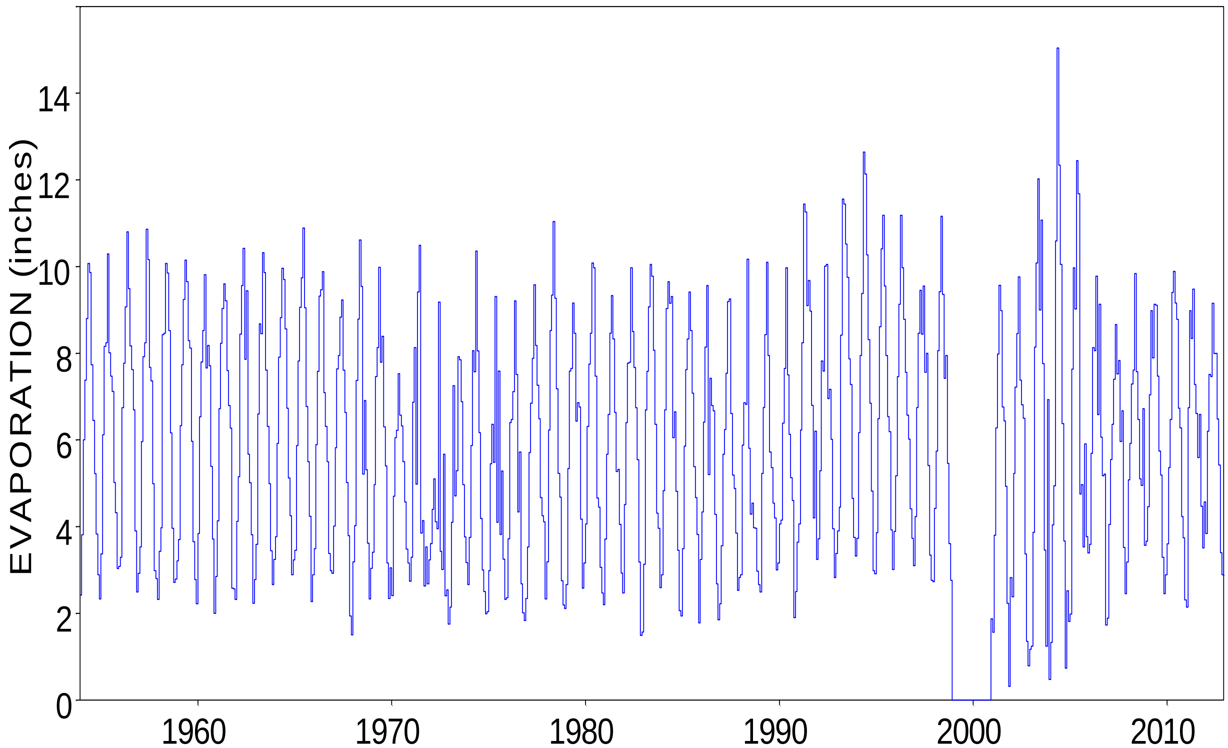
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 613



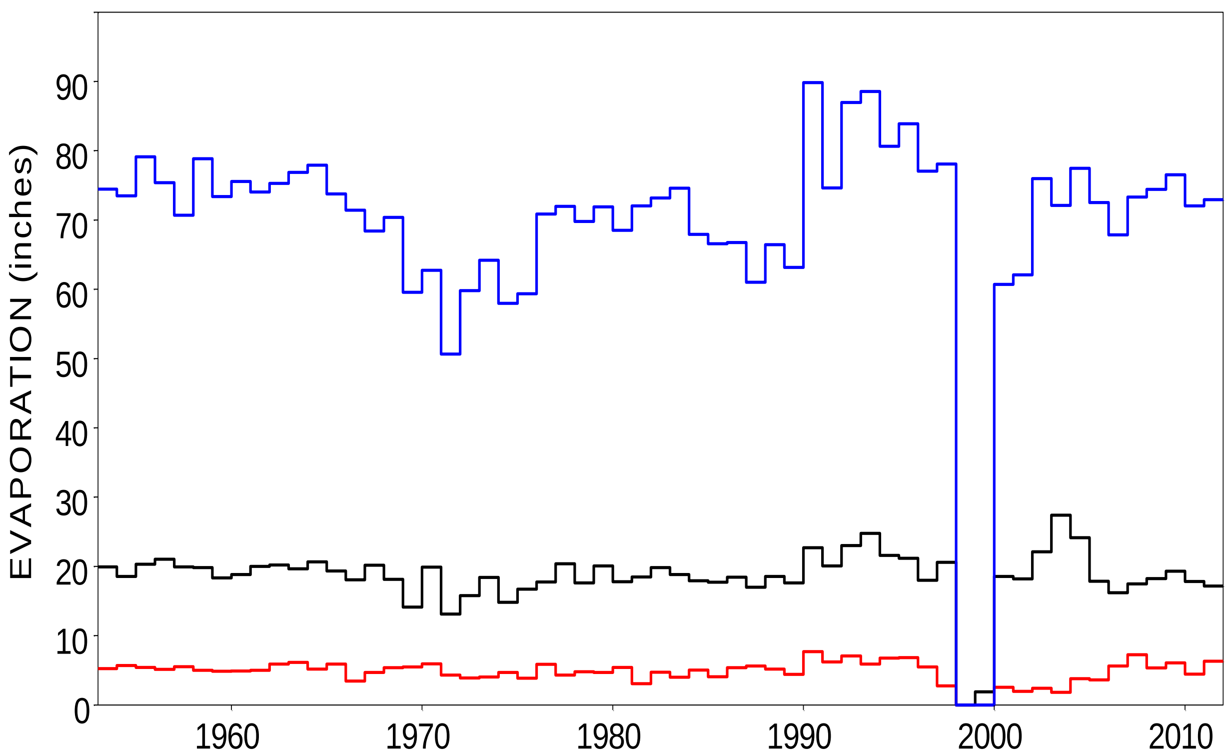
Monthly Evaporation for Quadrangle 614



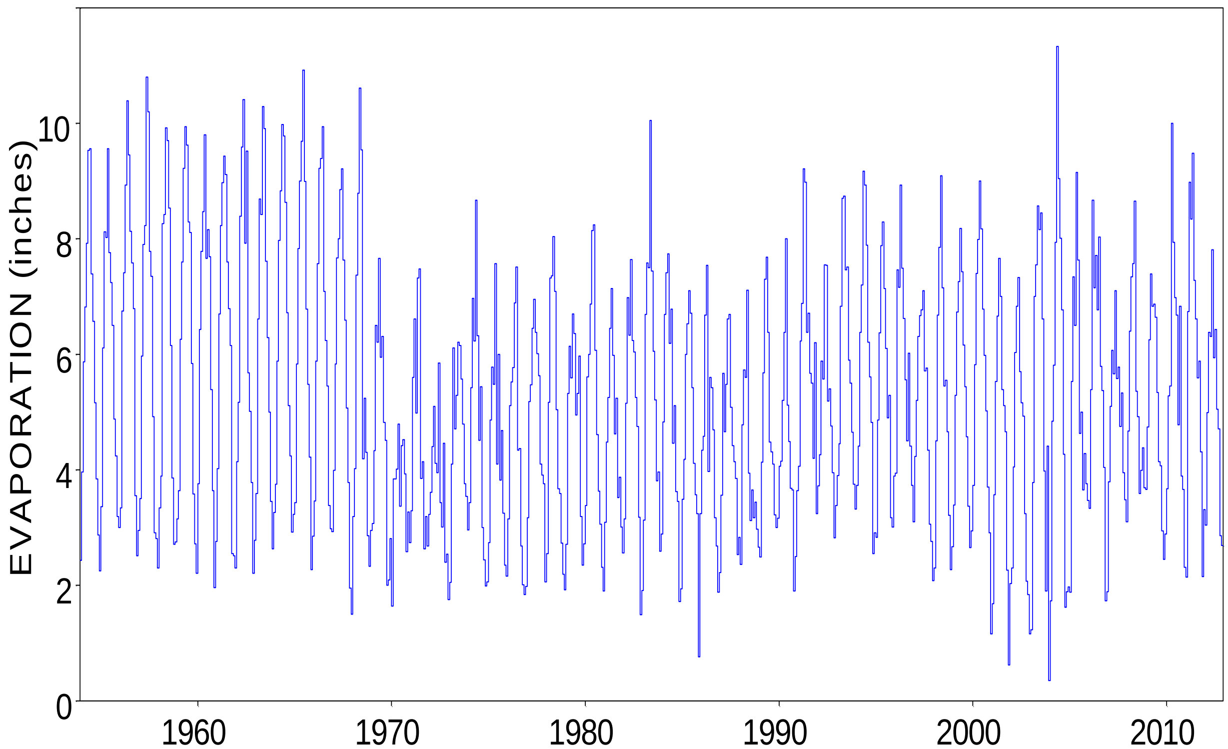
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 614



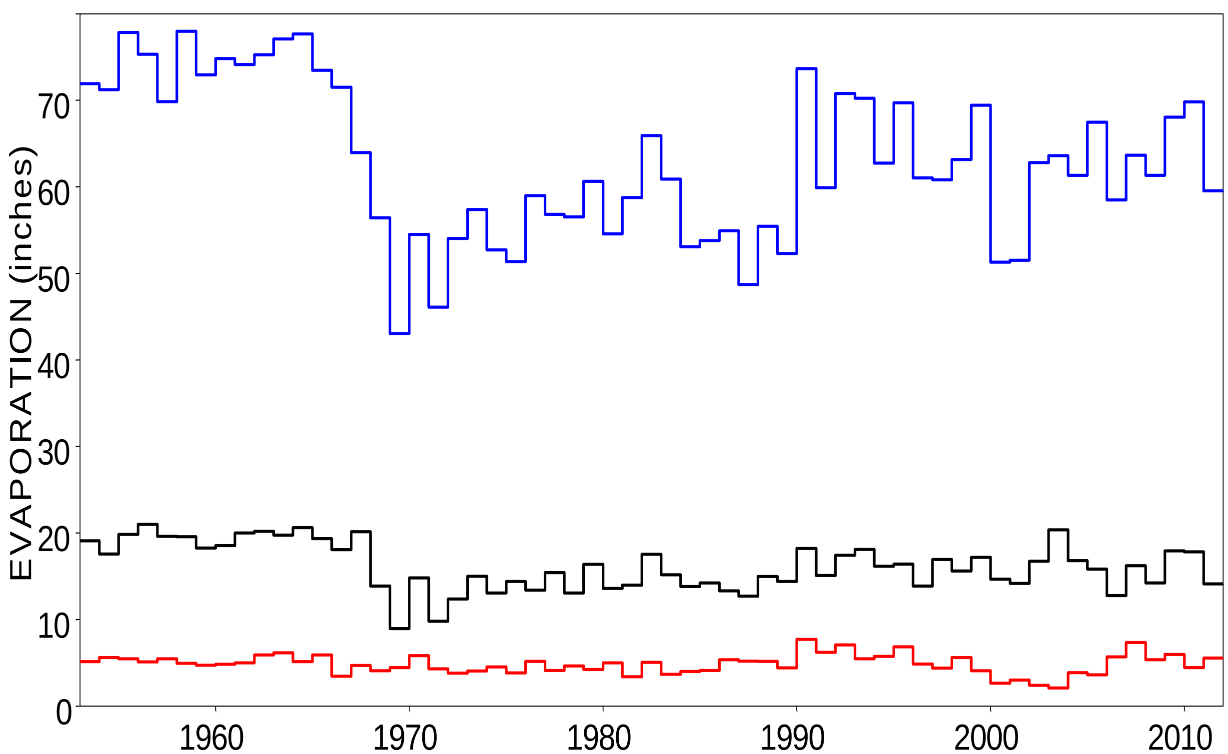
Monthly Evaporation for Quadrangle 701(missing date form 1999-2000)



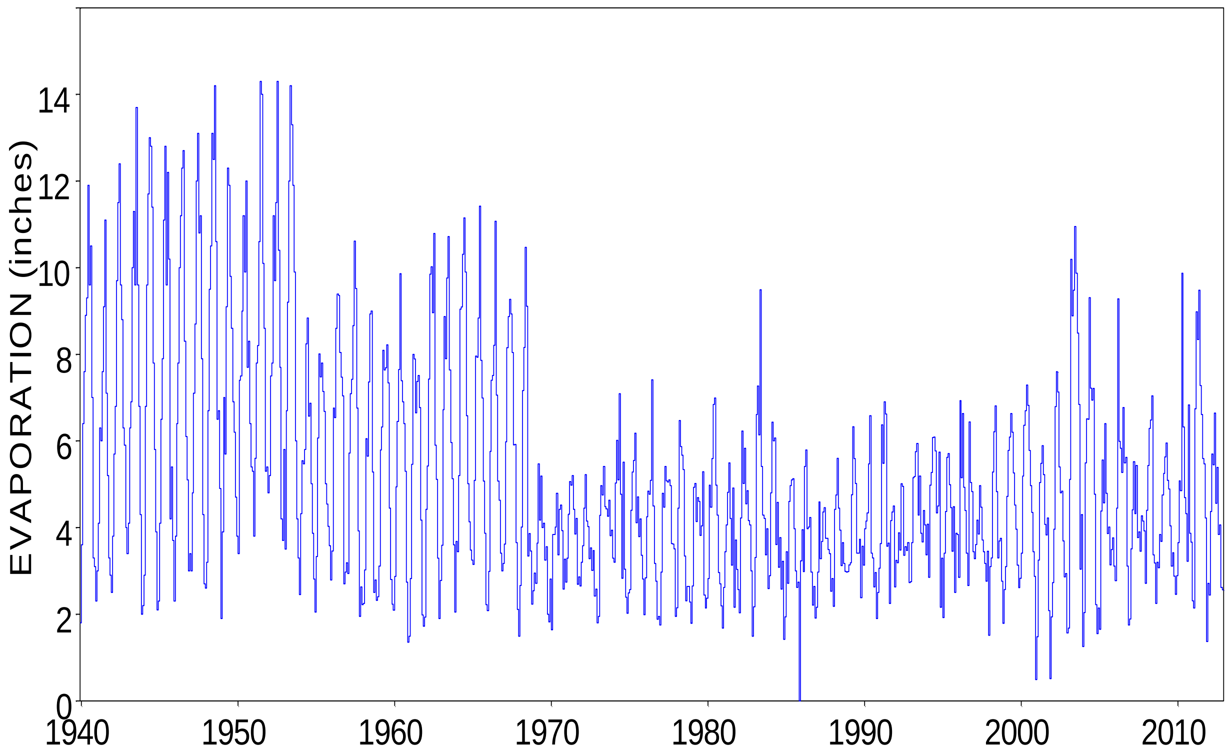
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 701 (missing date form 1999-2000)



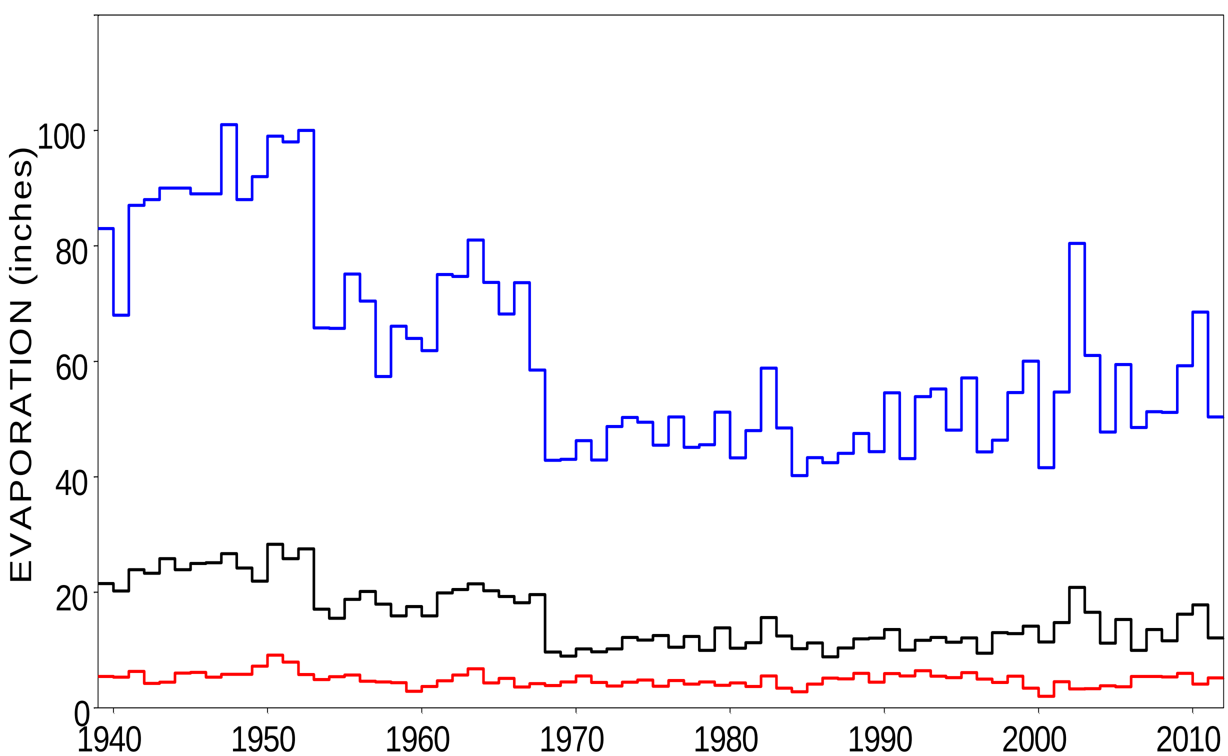
Monthly Evaporation for Quadrangle 702



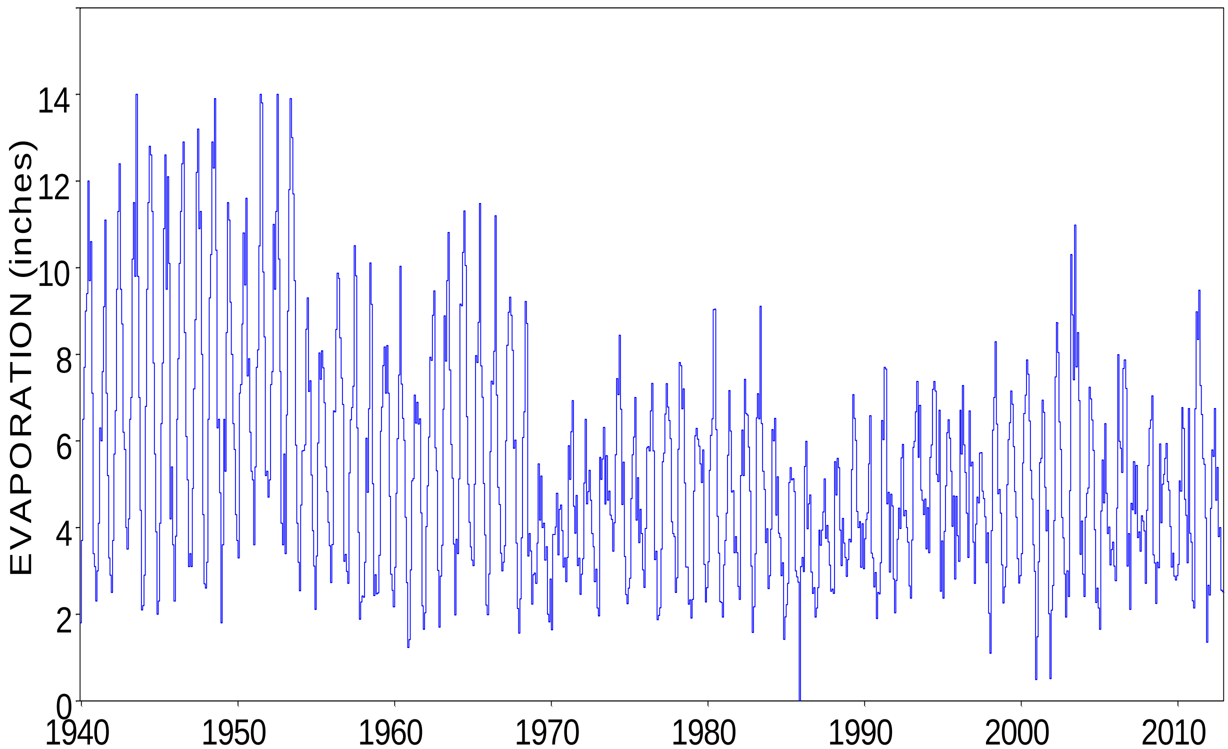
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 702



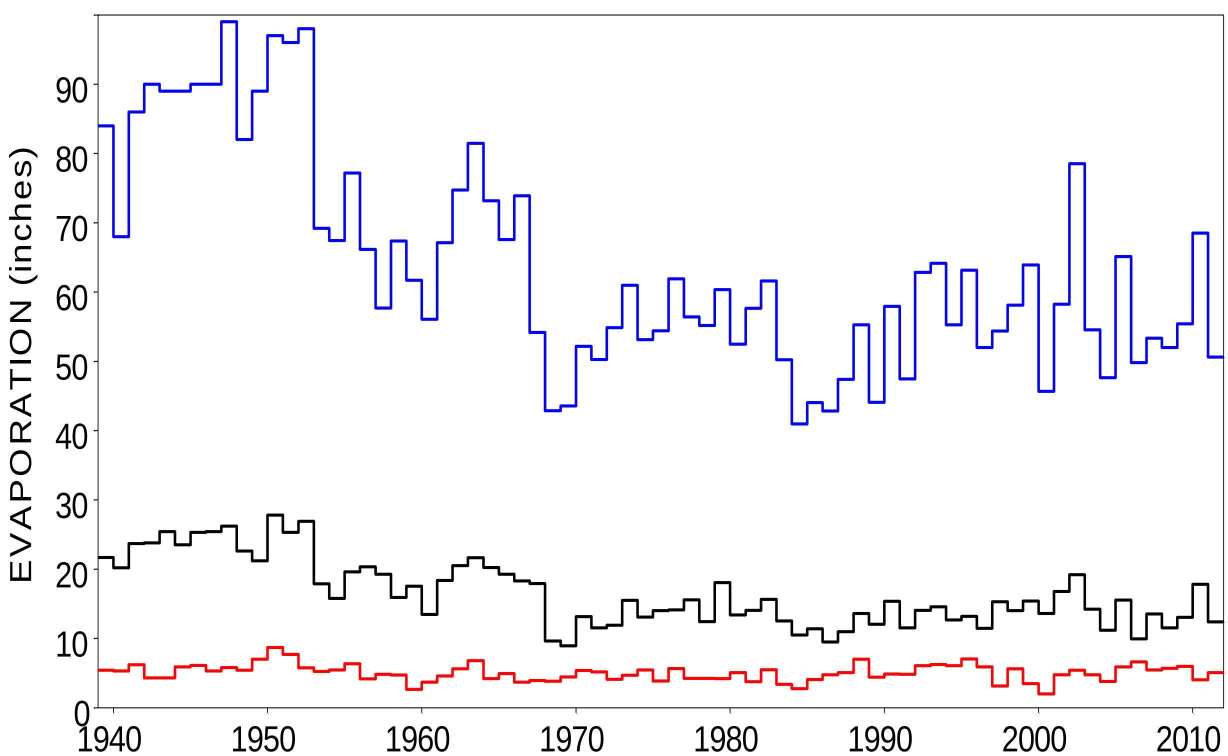
Monthly Evaporation for Quadrangle 703



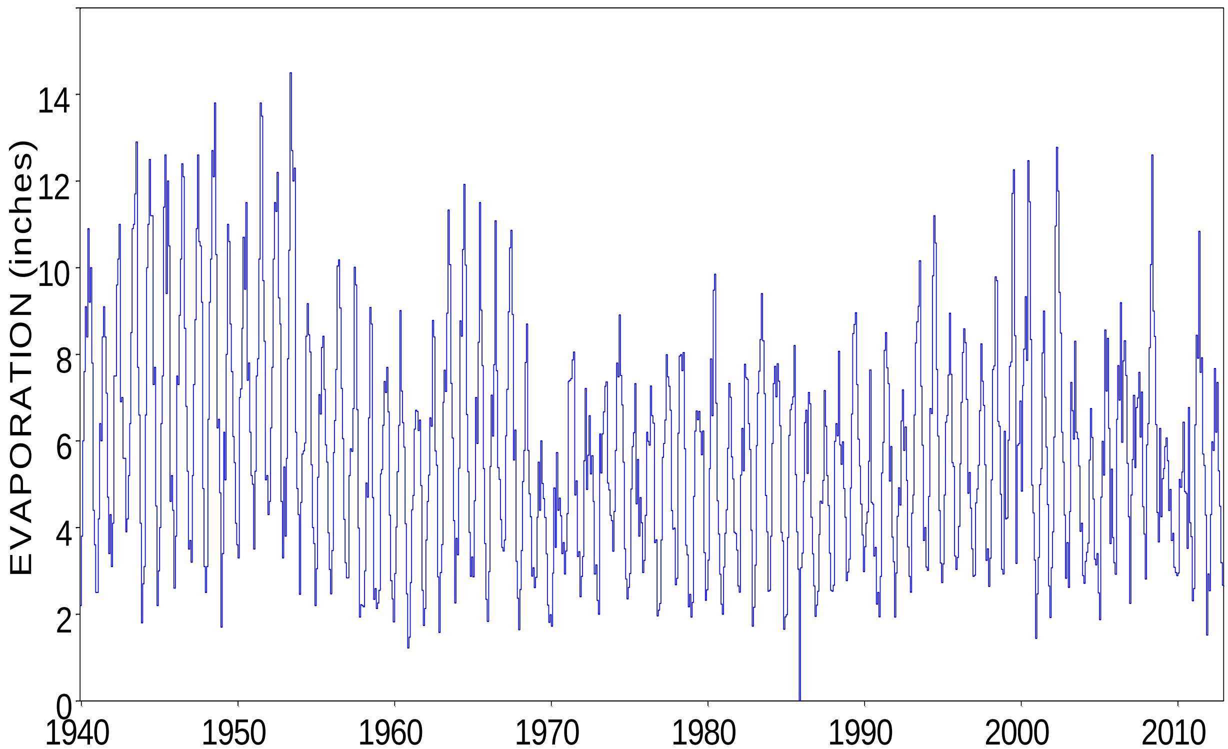
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 703



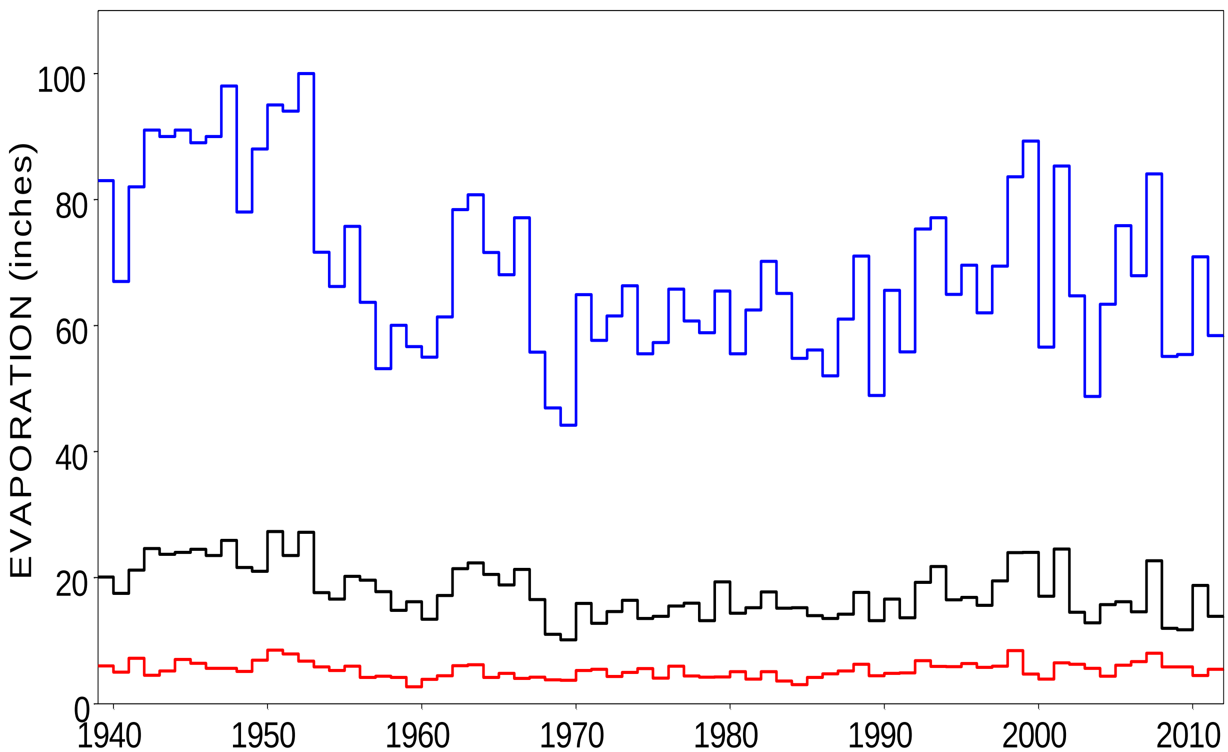
Monthly Evaporation for Quadrangle 704



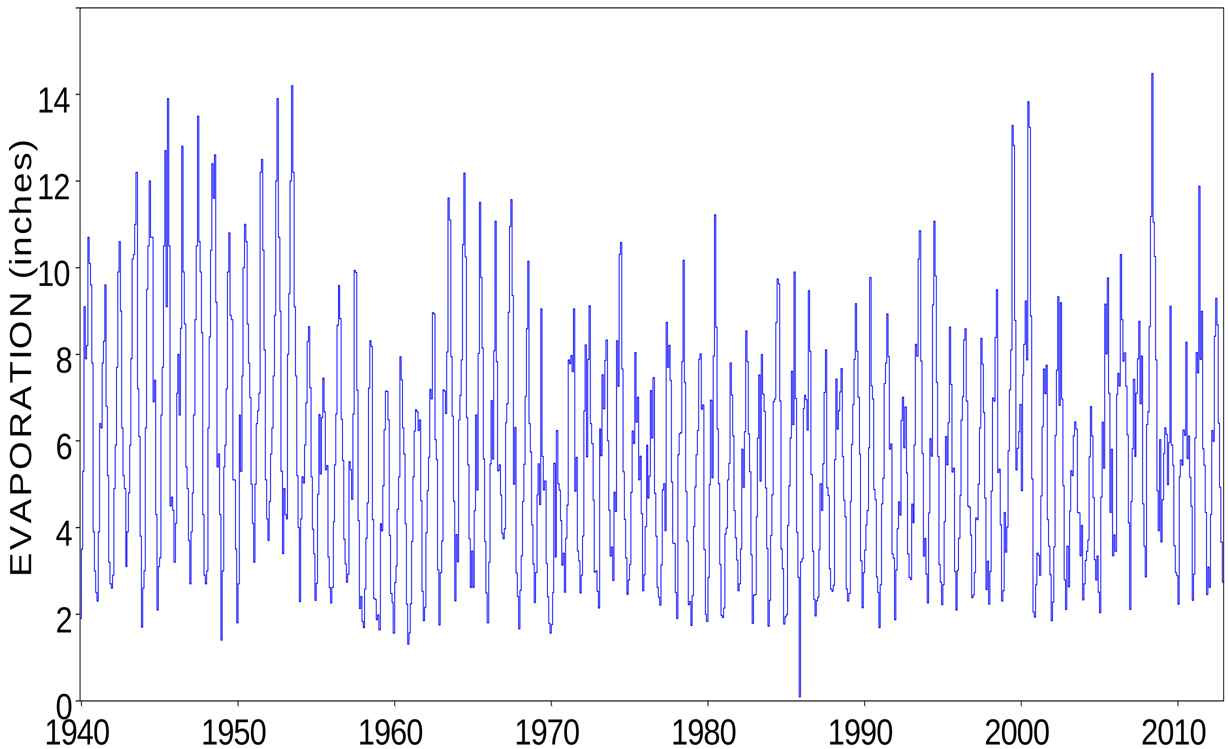
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 704



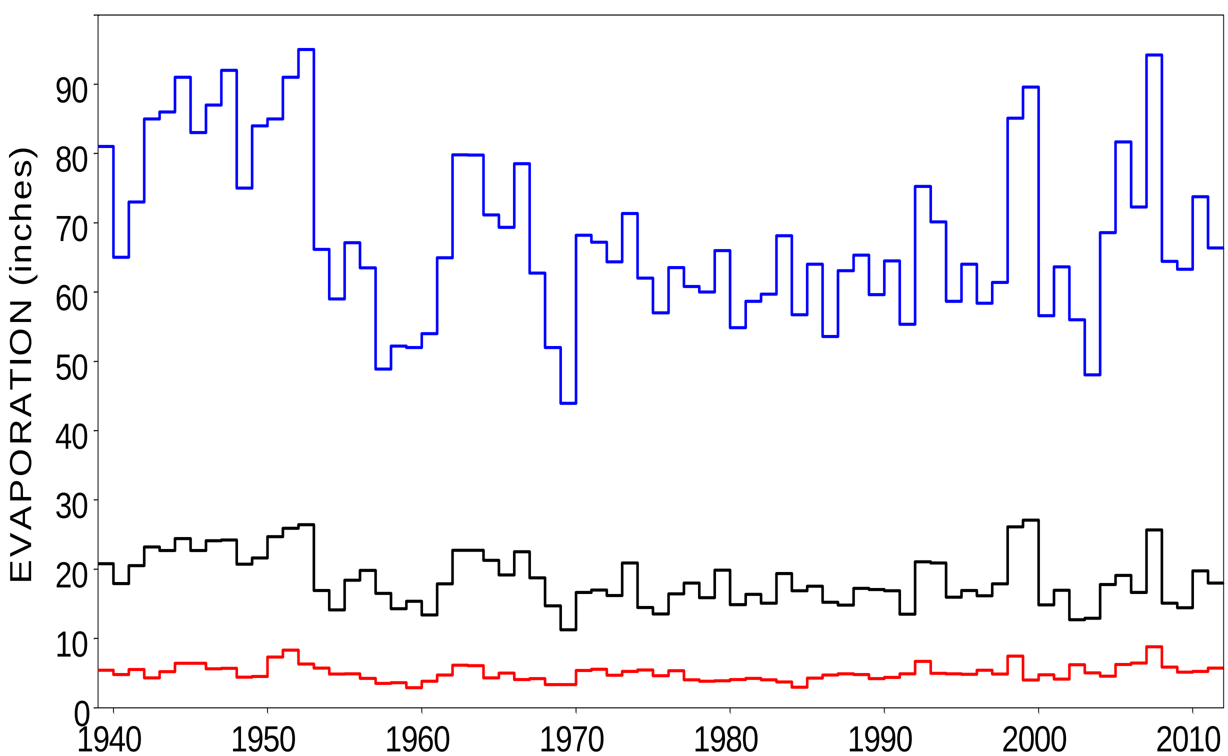
Monthly Evaporation for Quadrangle 705



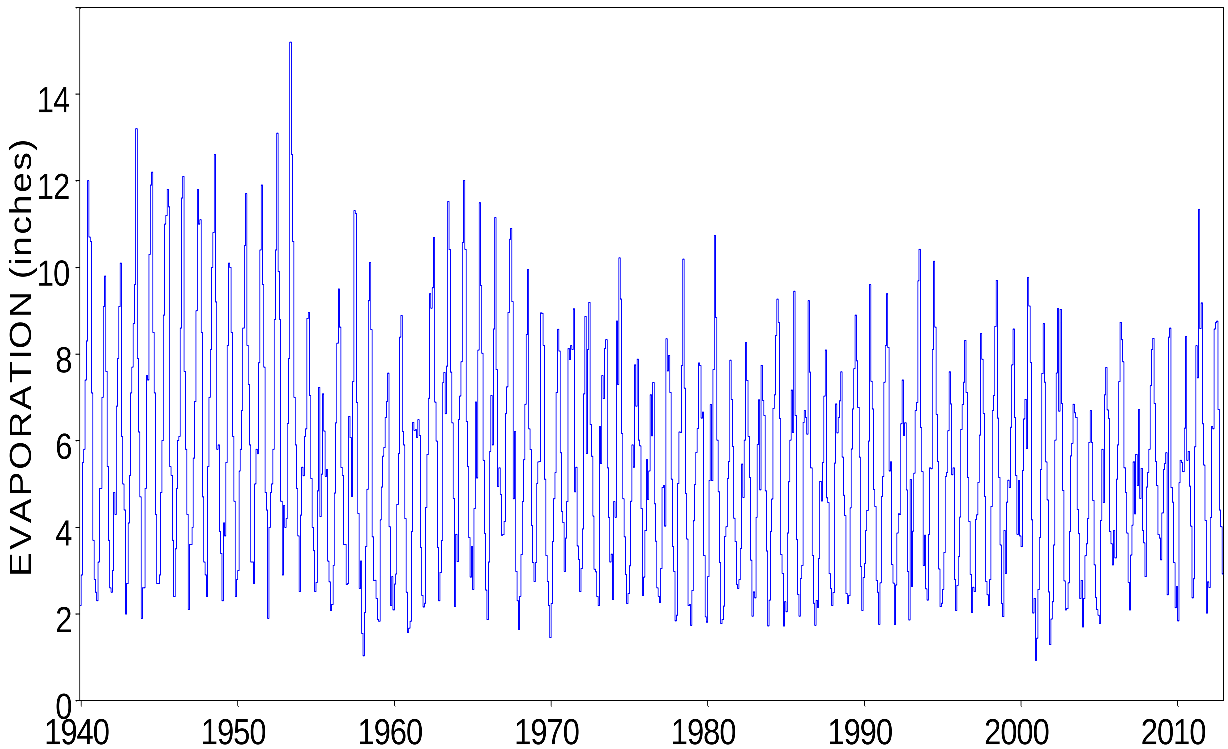
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 705



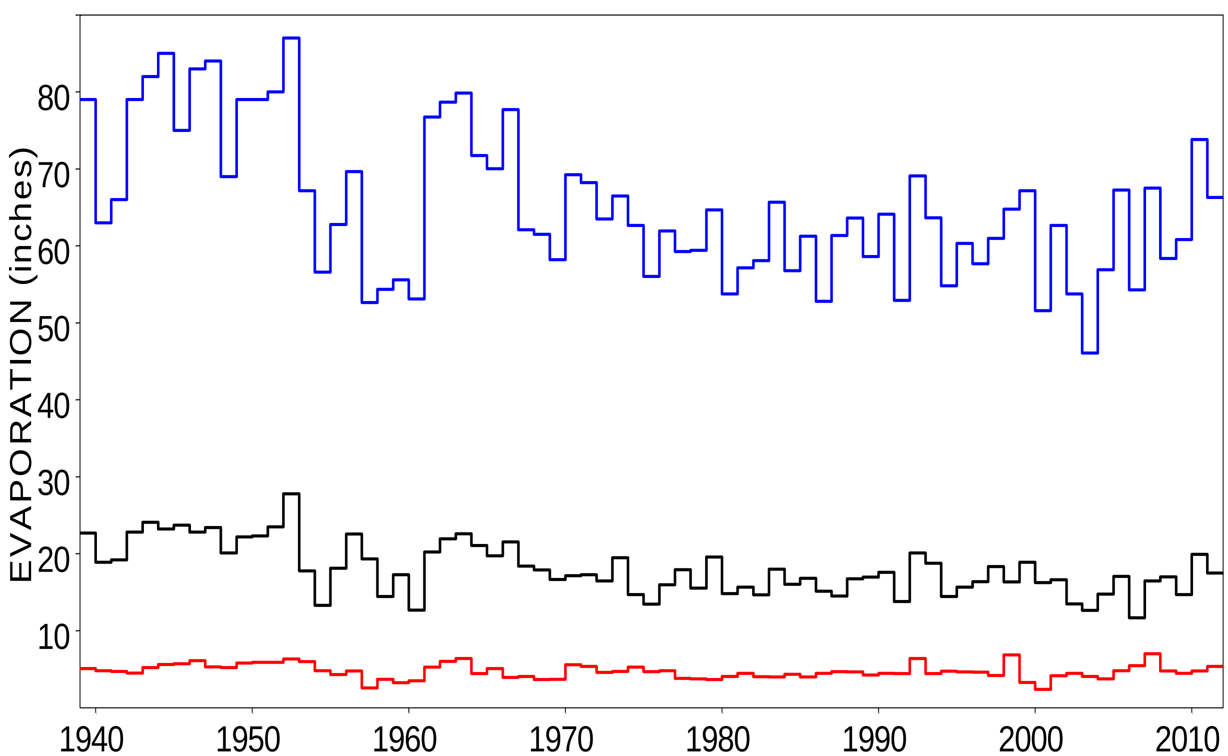
Monthly Evaporation for Quadrangle 706



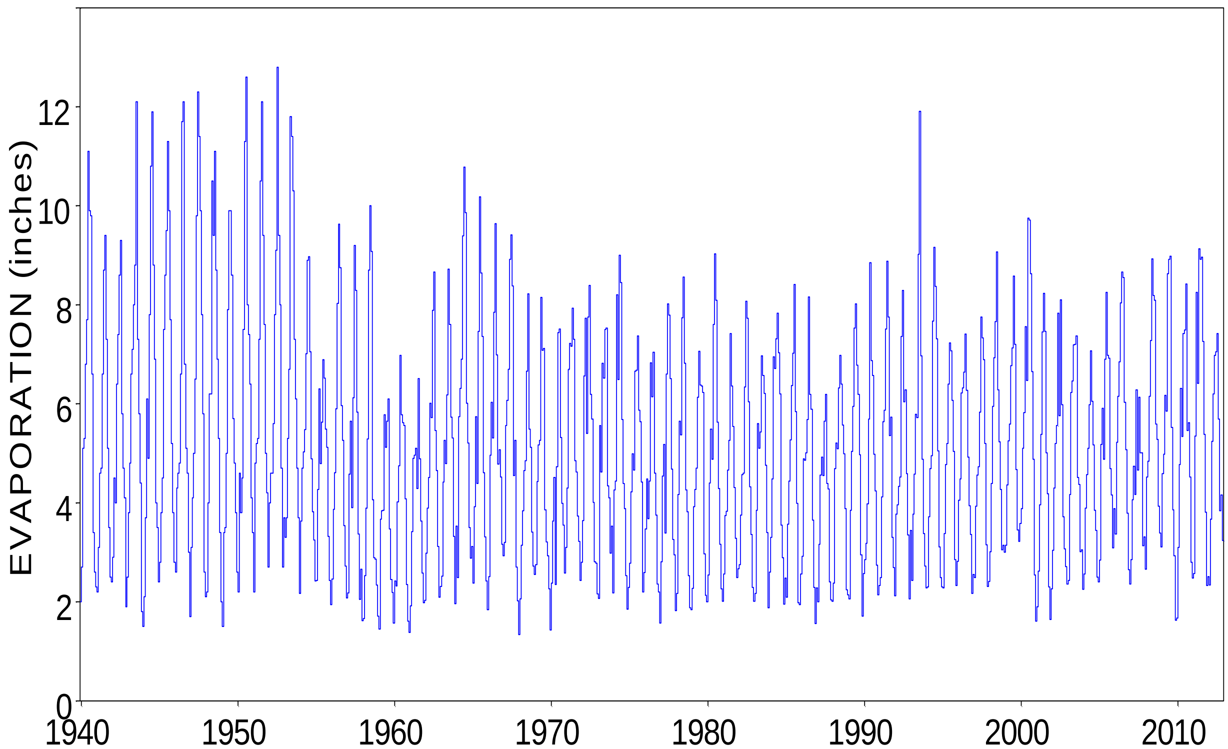
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 706



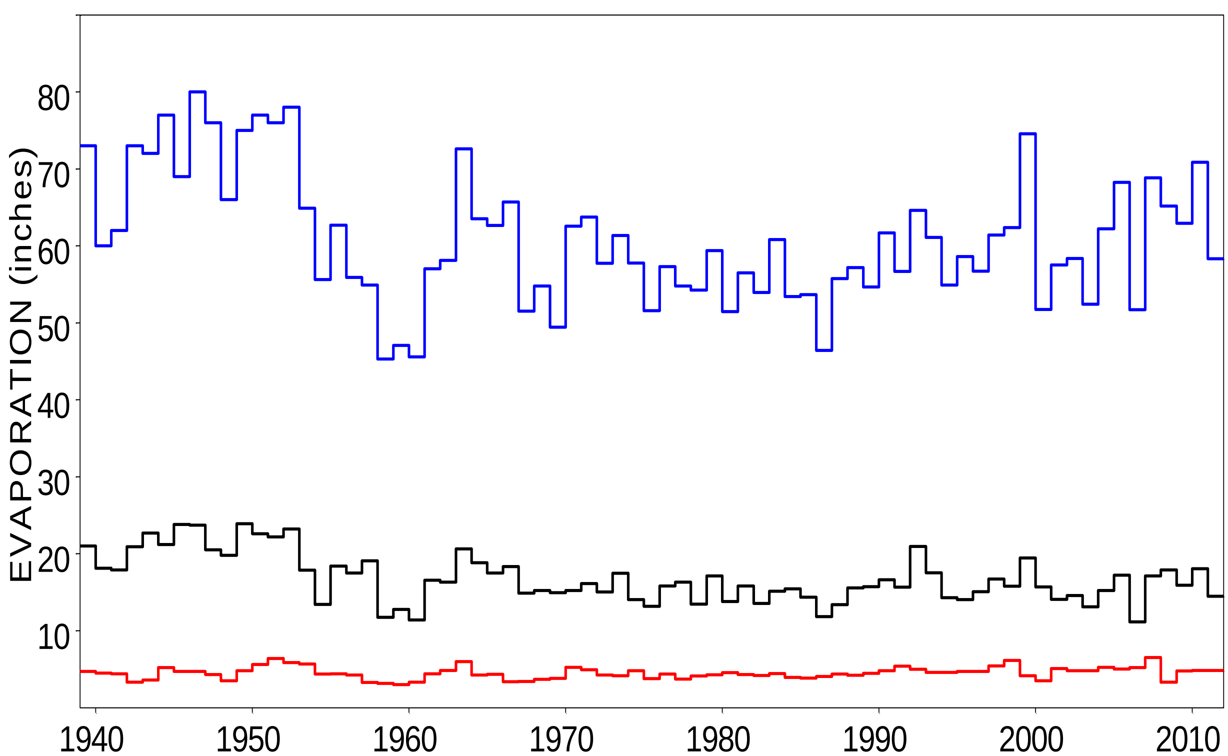
Monthly Evaporation for Quadrangle 707



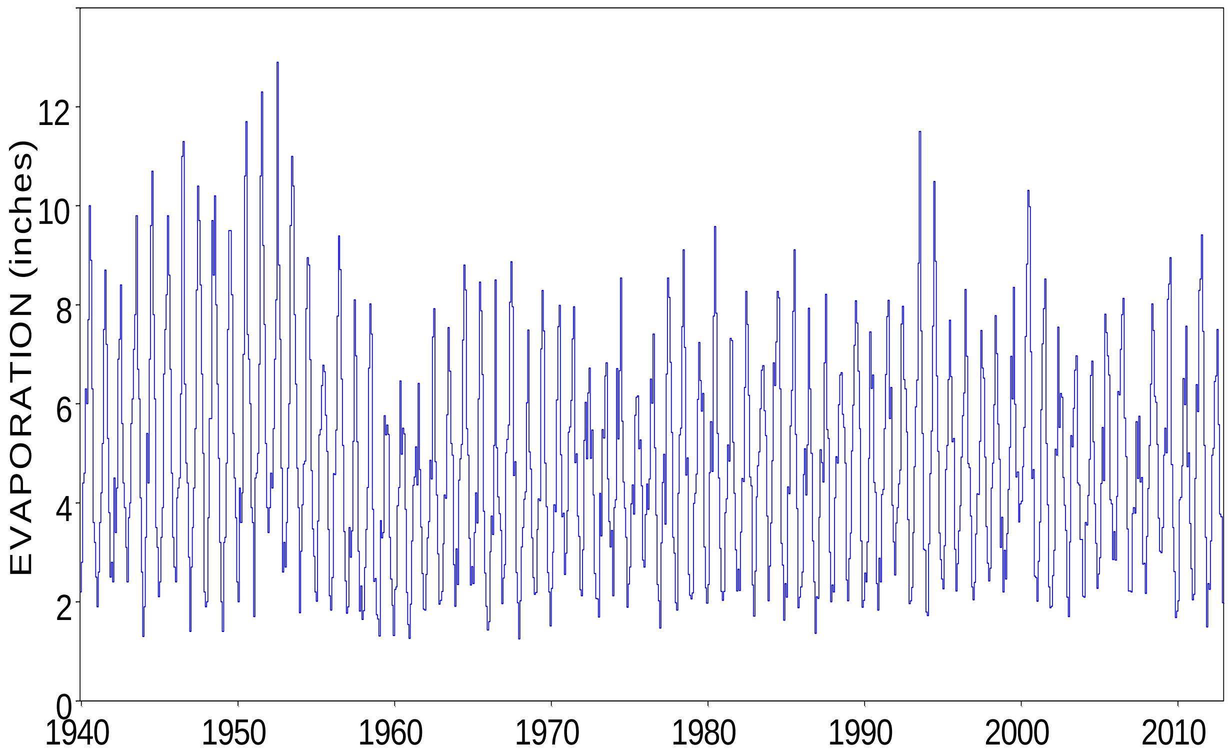
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 707



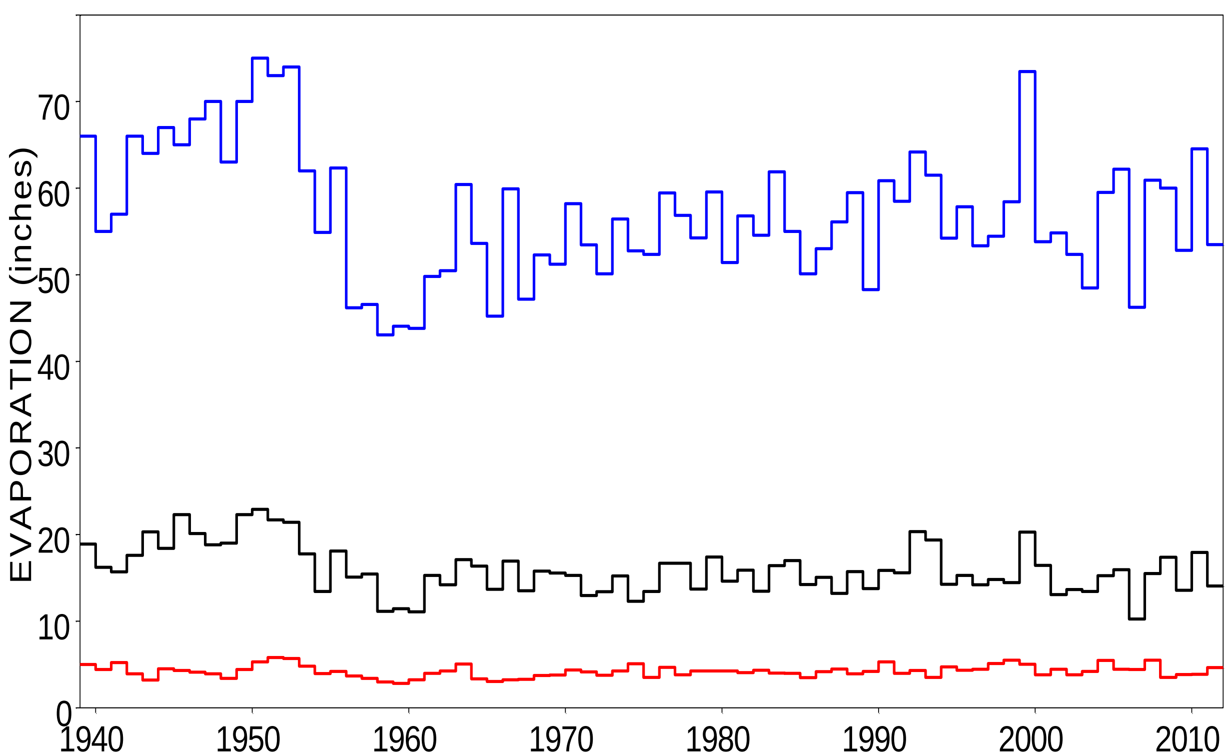
Monthly Evaporation for Quadrangle 707



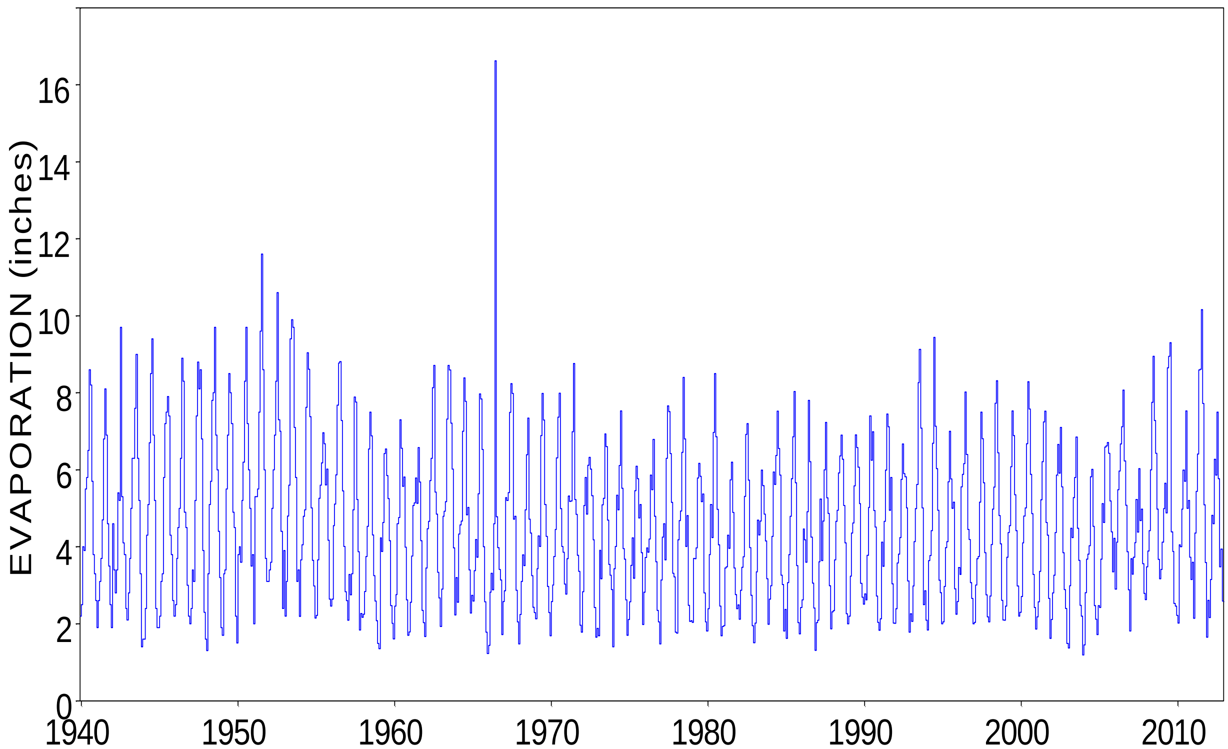
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 708



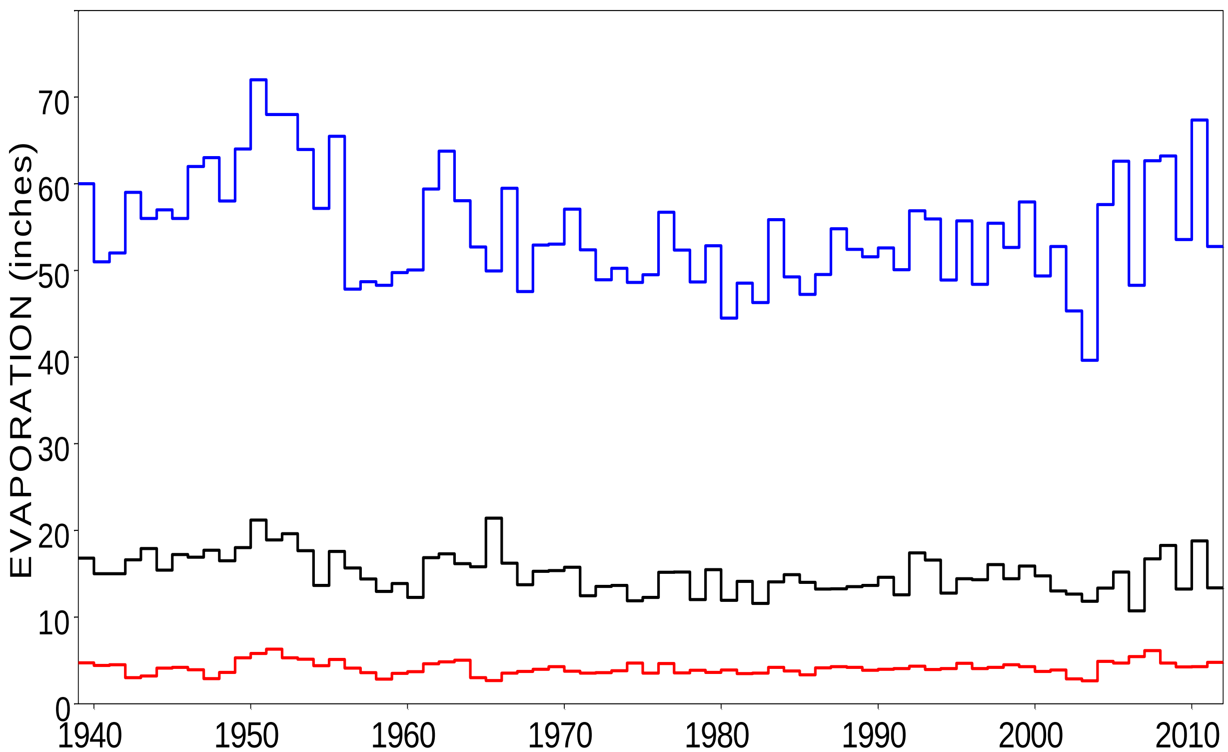
Monthly Evaporation for Quadrangle 709



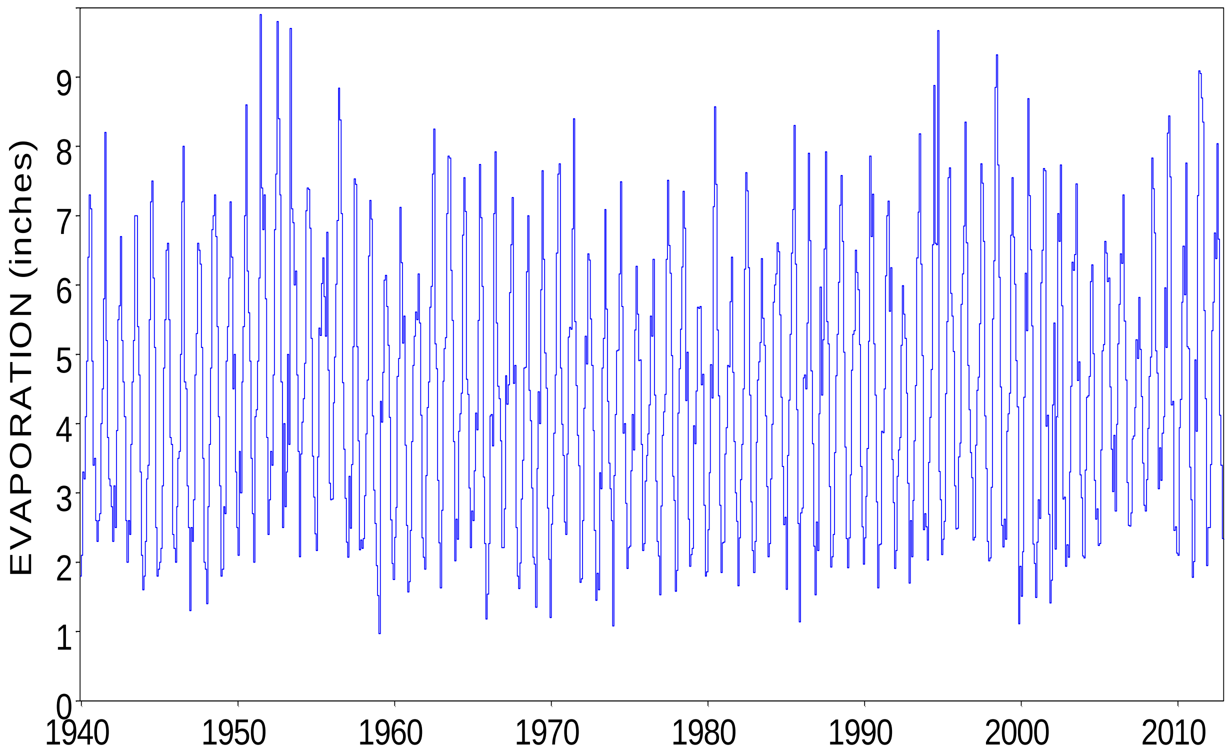
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 709



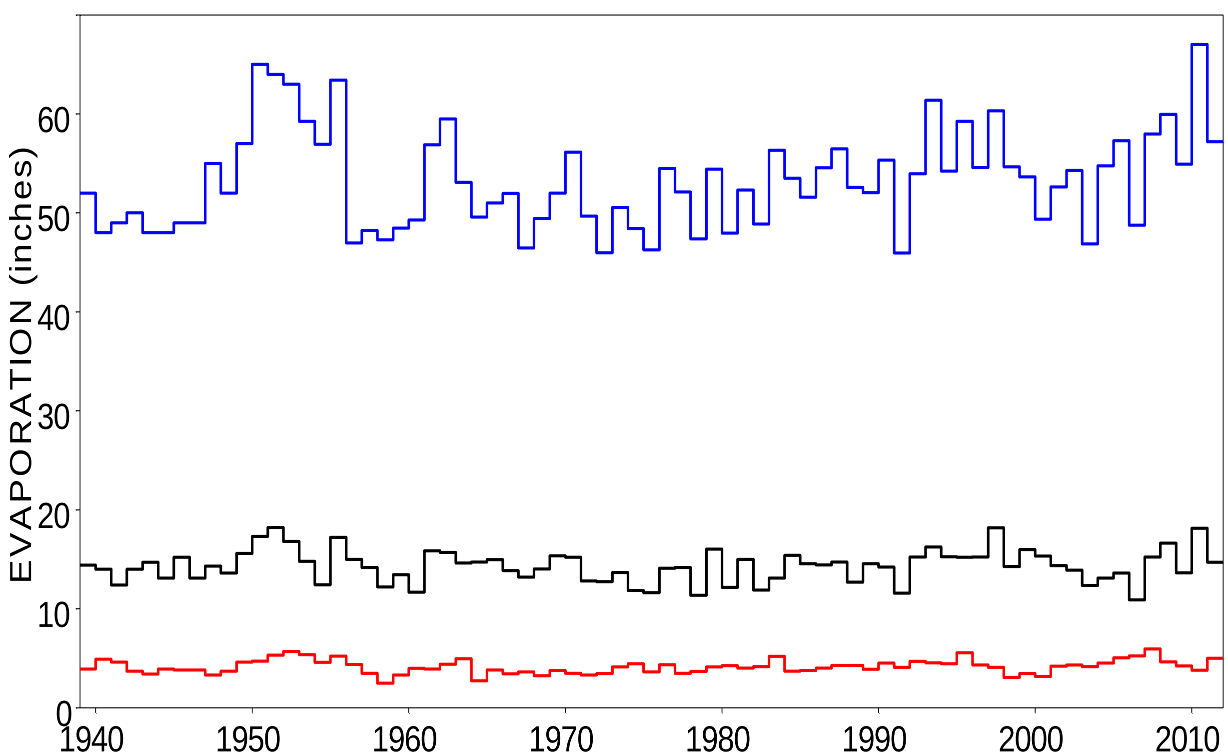
Monthly Evaporation for Quadrangle 710



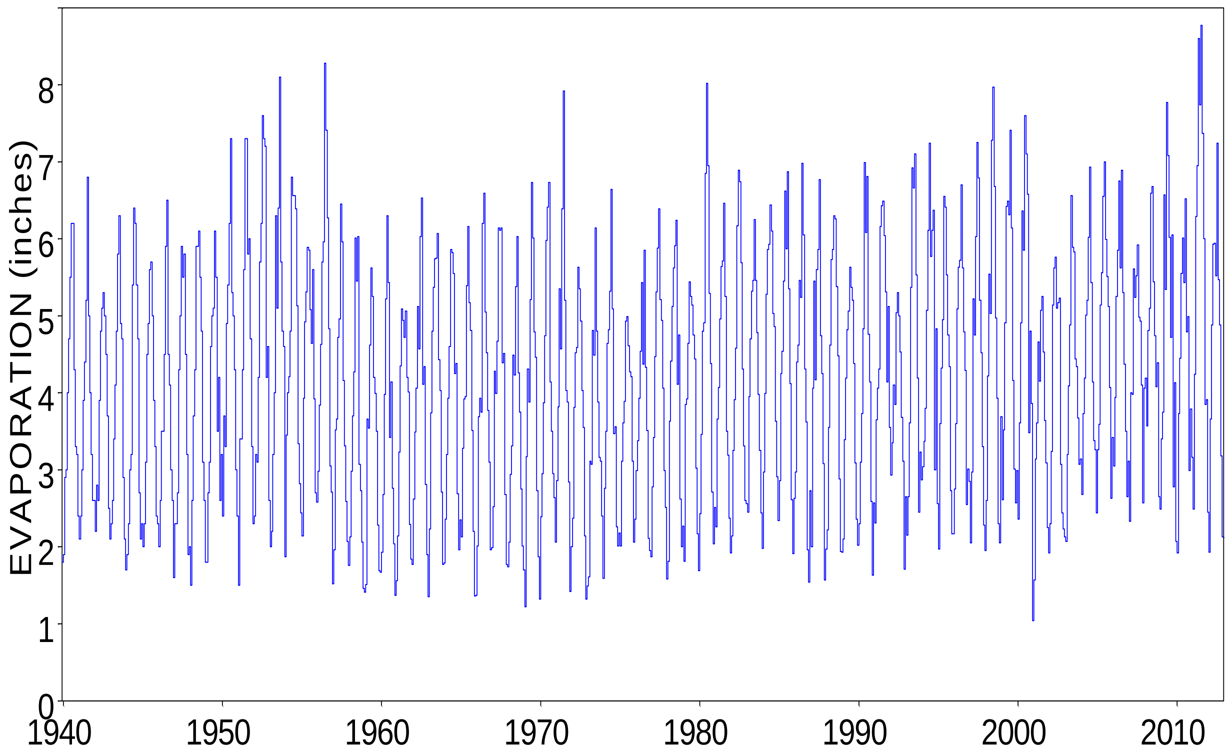
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 710



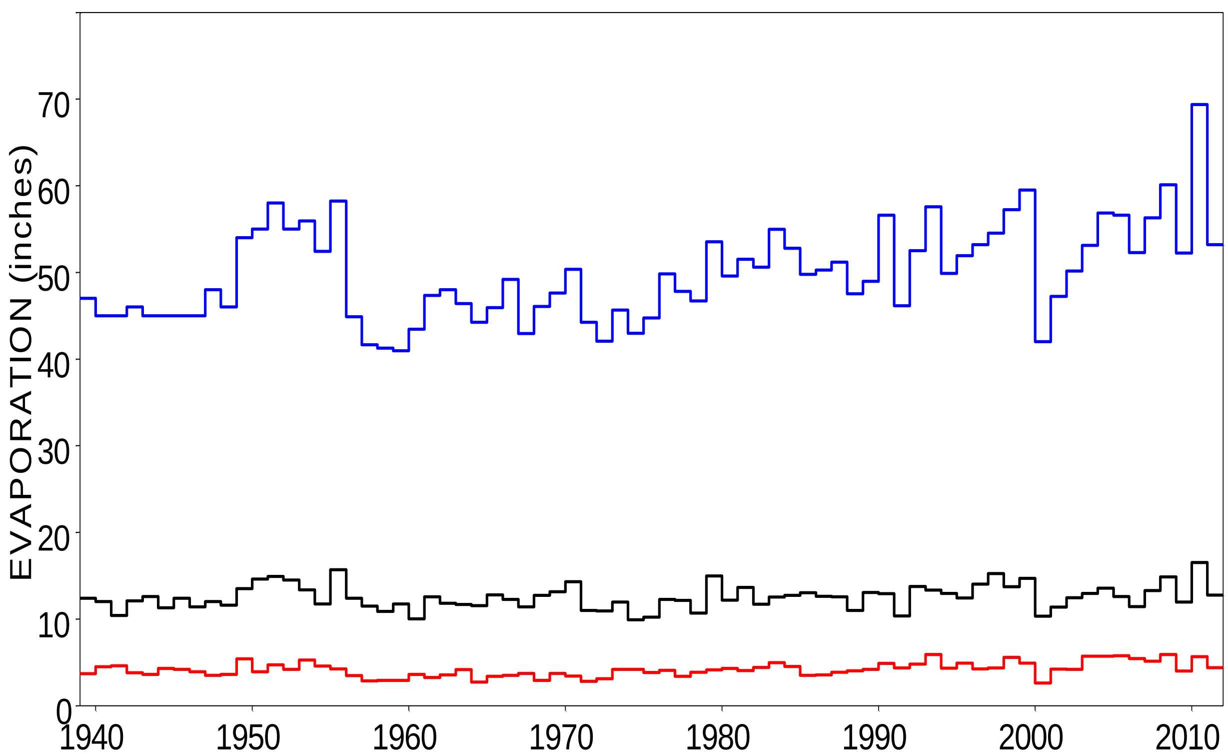
Monthly Evaporation for Quadrangle 711



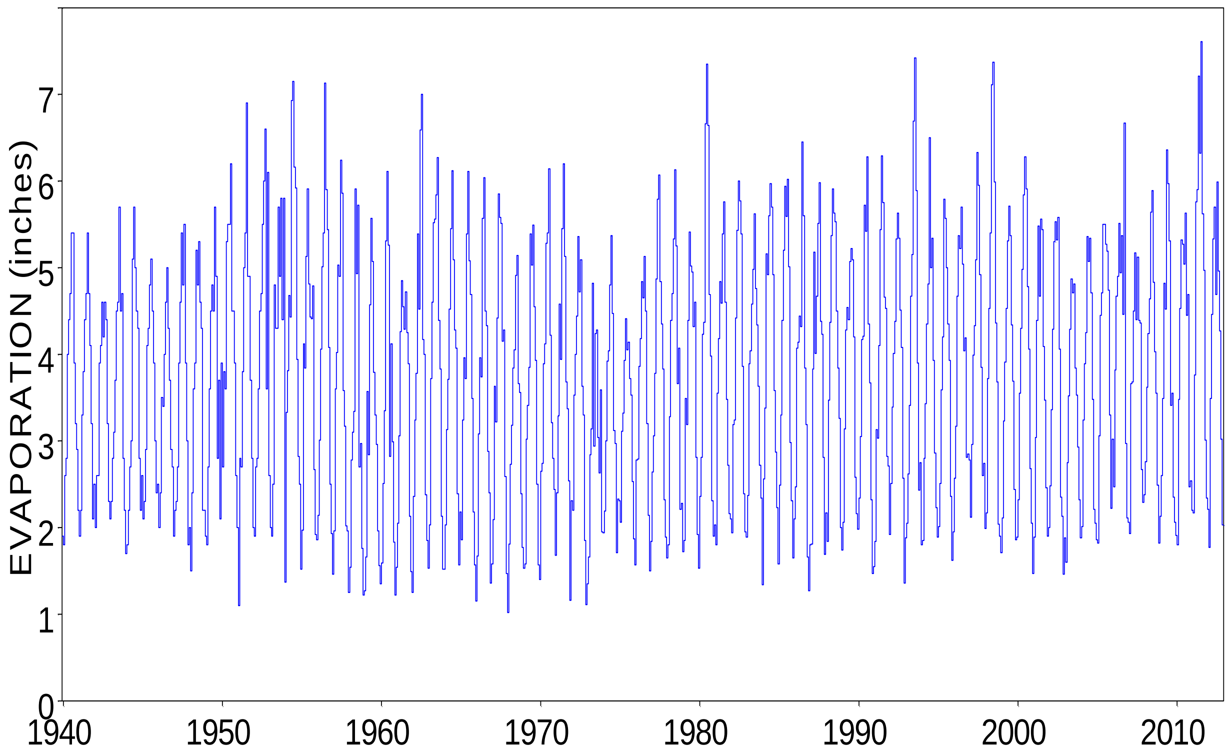
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 711



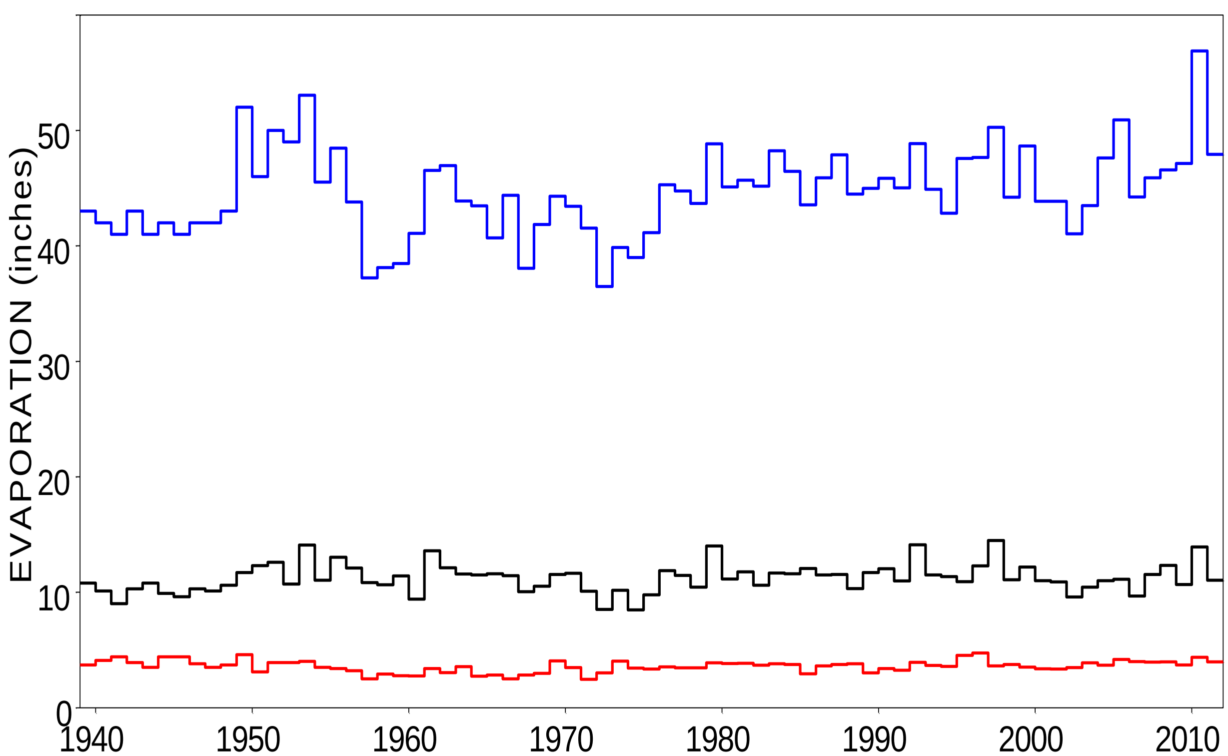
Monthly Evaporation for Quadrangle 712



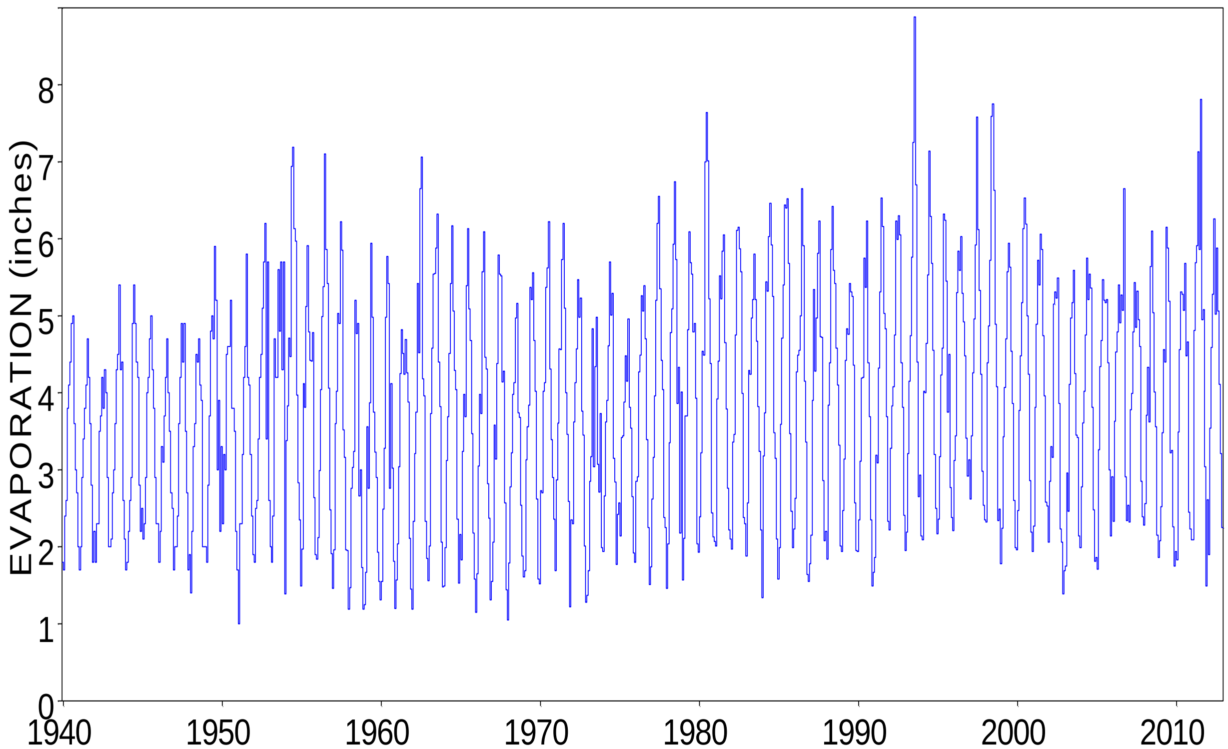
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 712



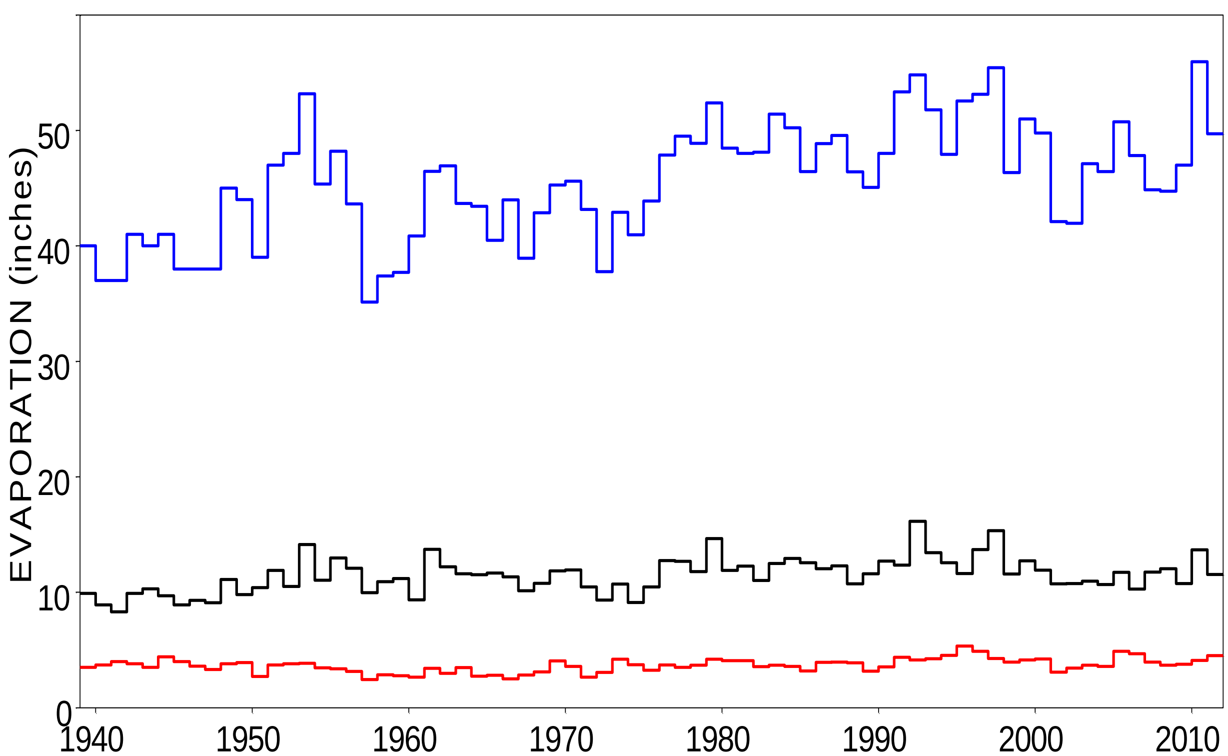
Monthly Evaporation for Quadrangle 713



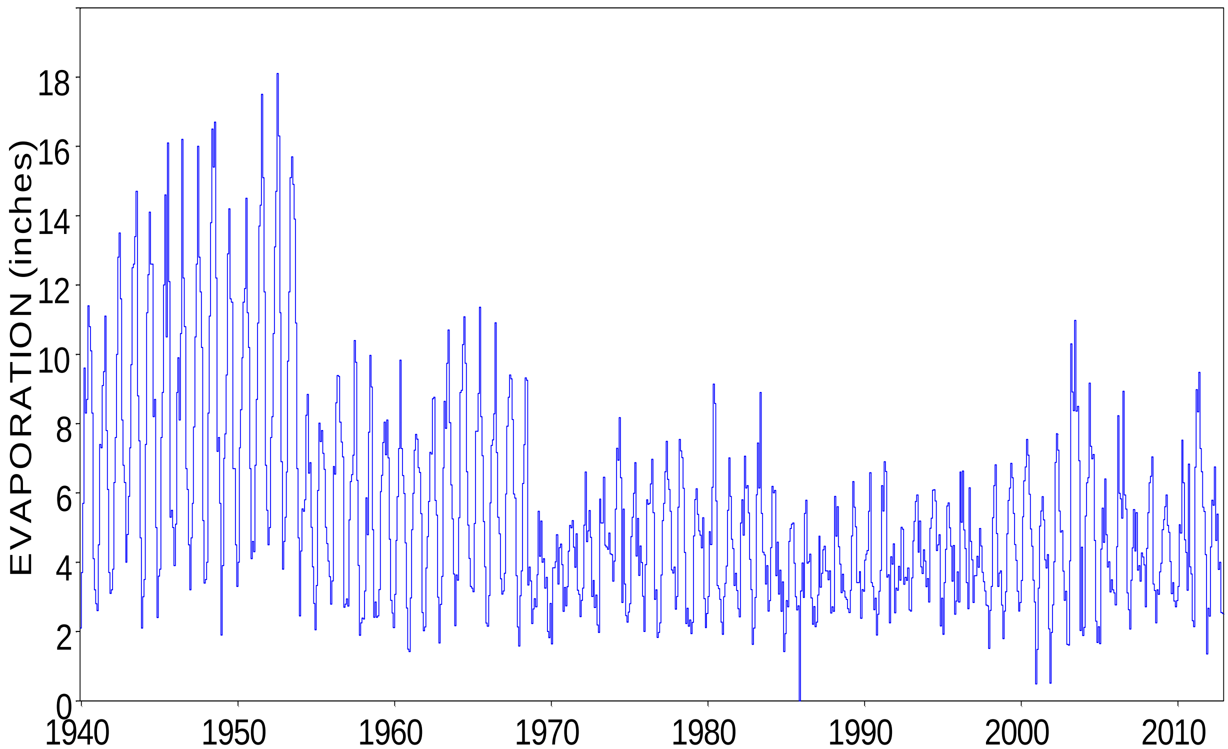
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 713



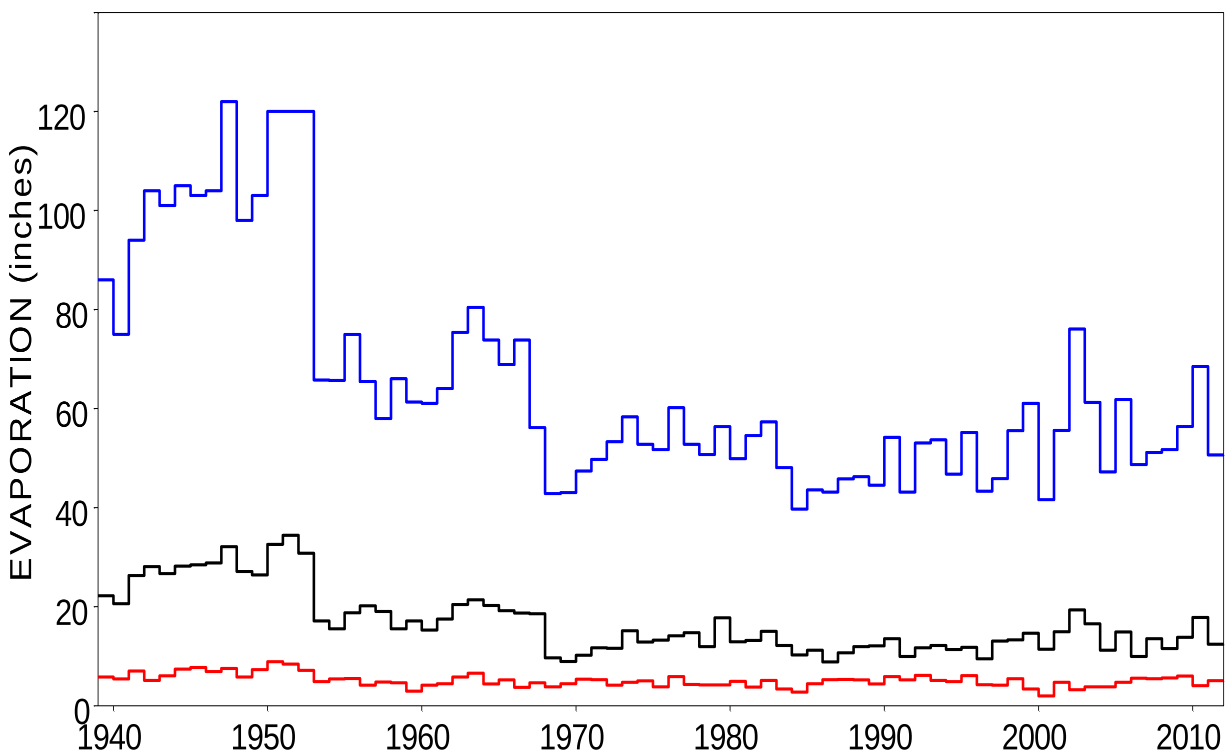
Monthly Evaporation for Quadrangle 714



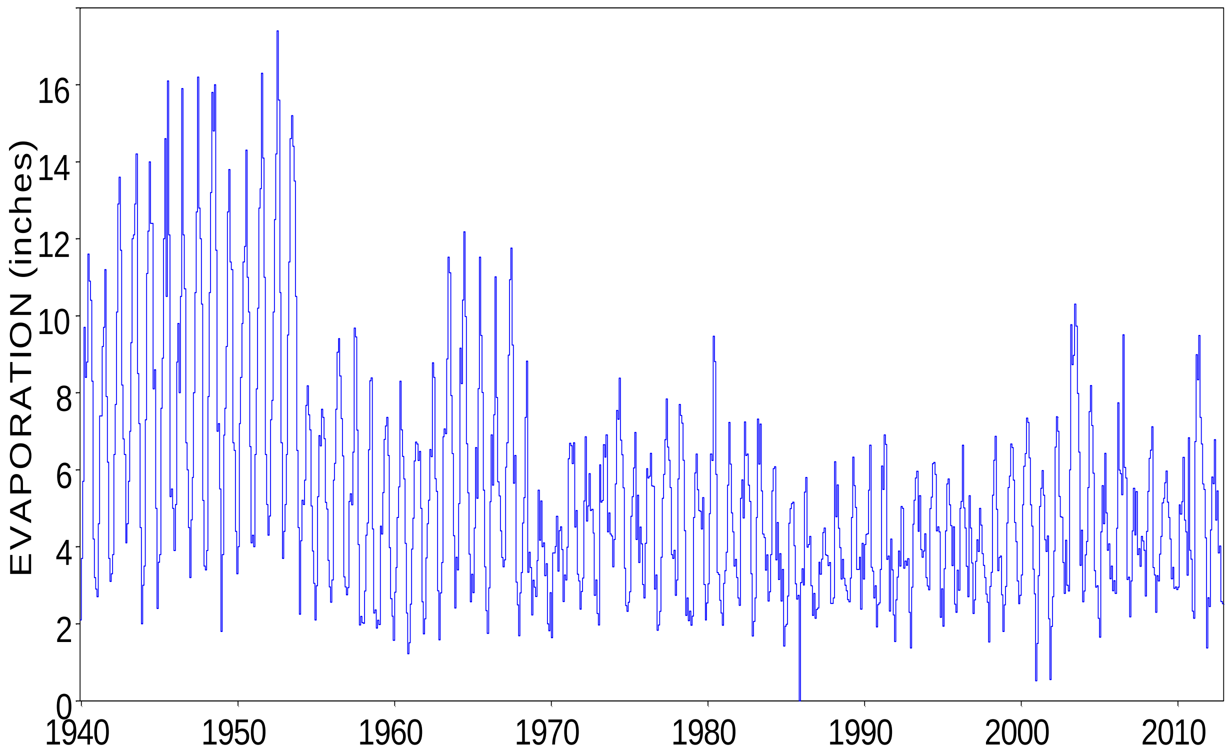
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 714



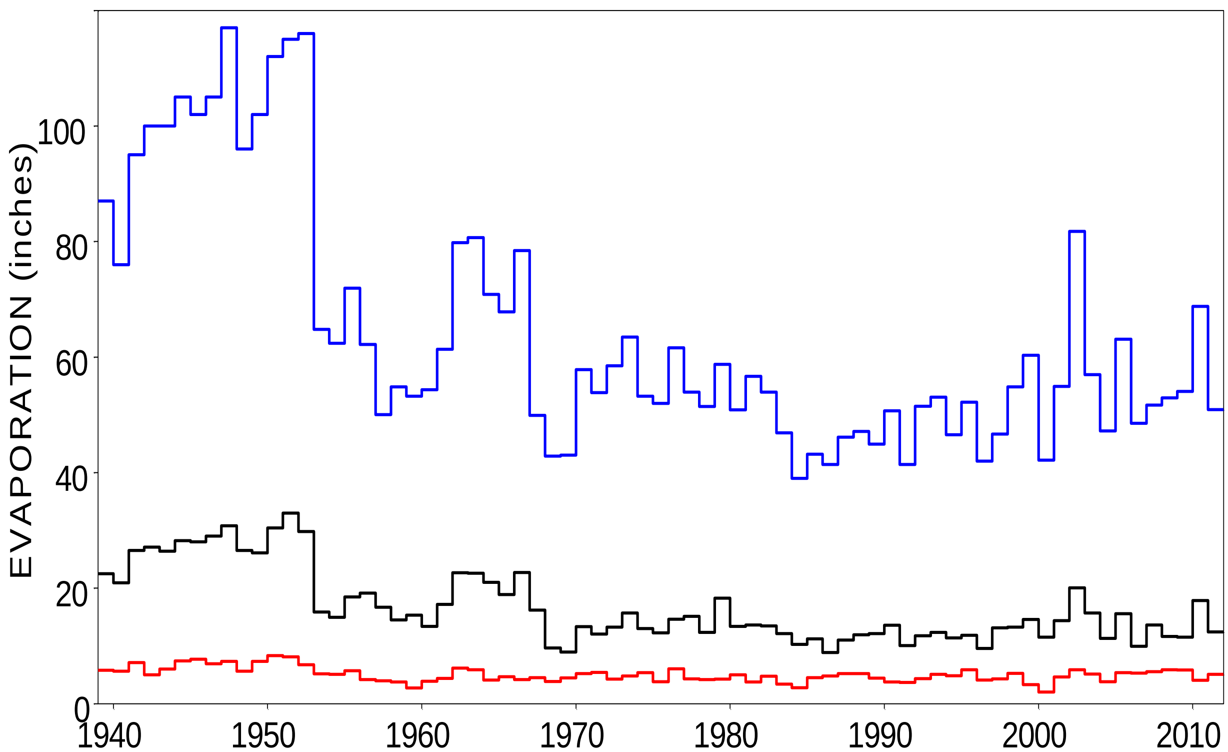
Monthly Evaporation for Quadrangle 803



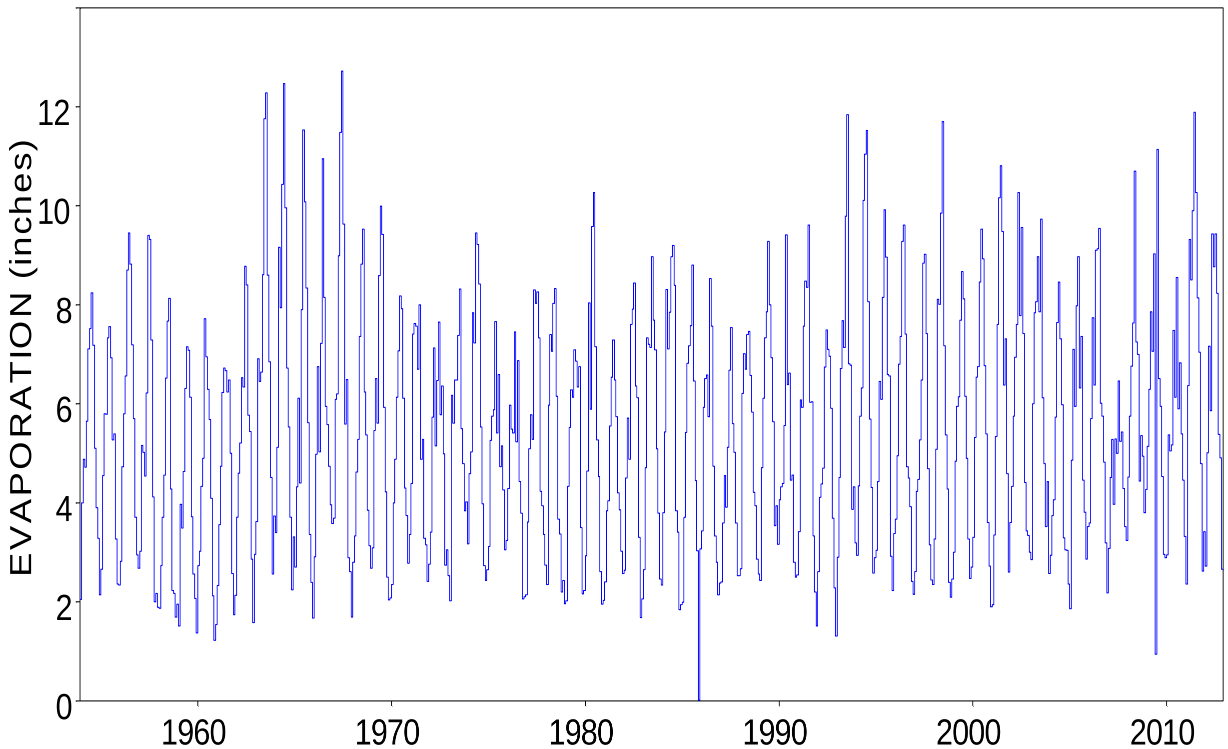
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 803



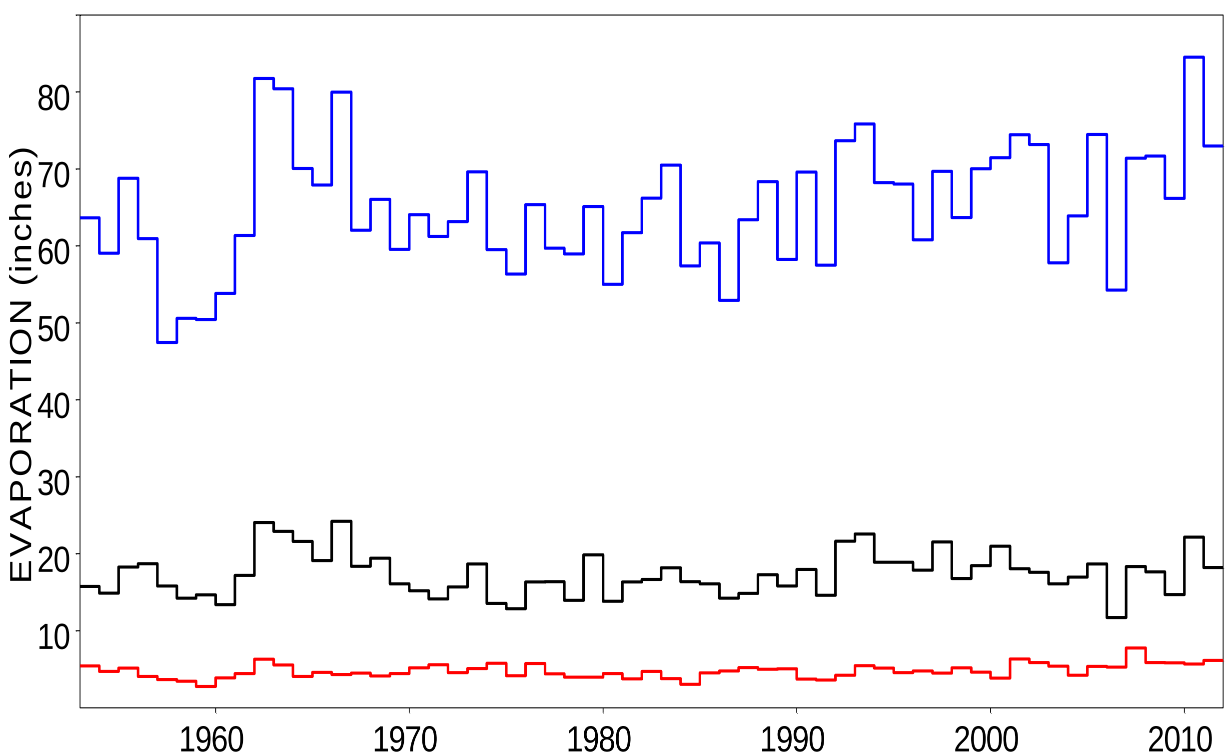
Monthly Evaporation for Quadrangle 804



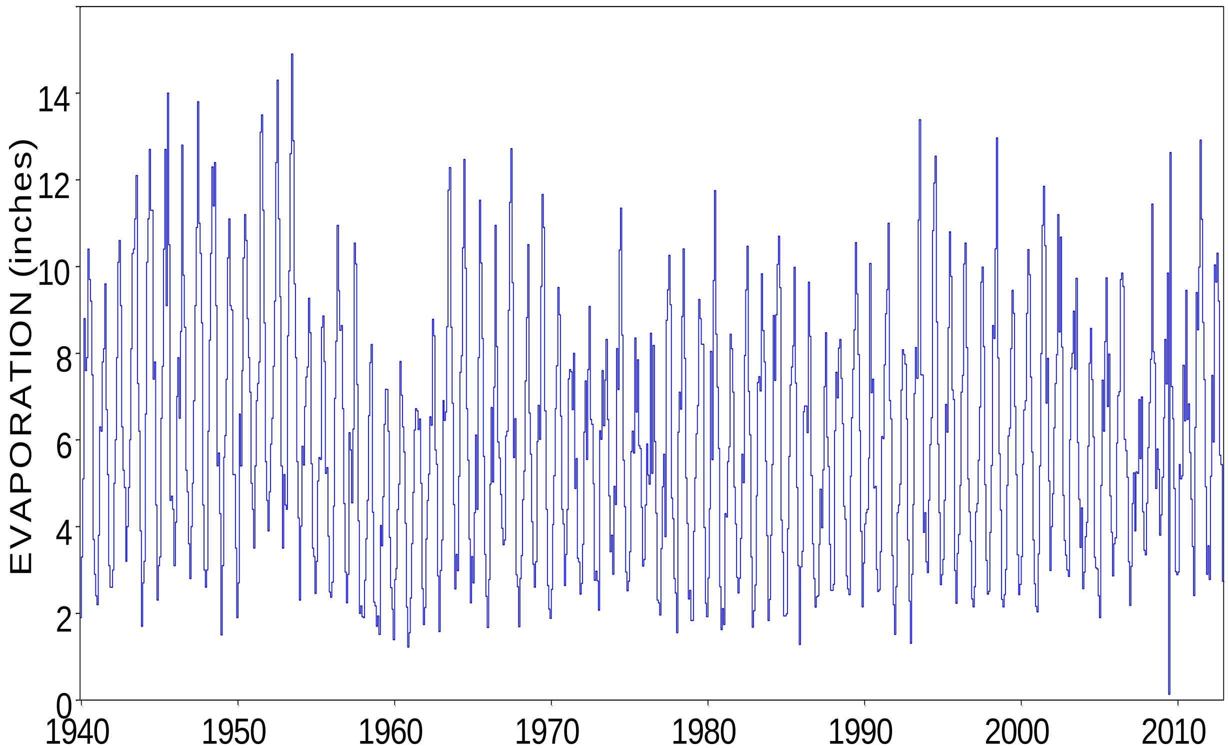
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 804



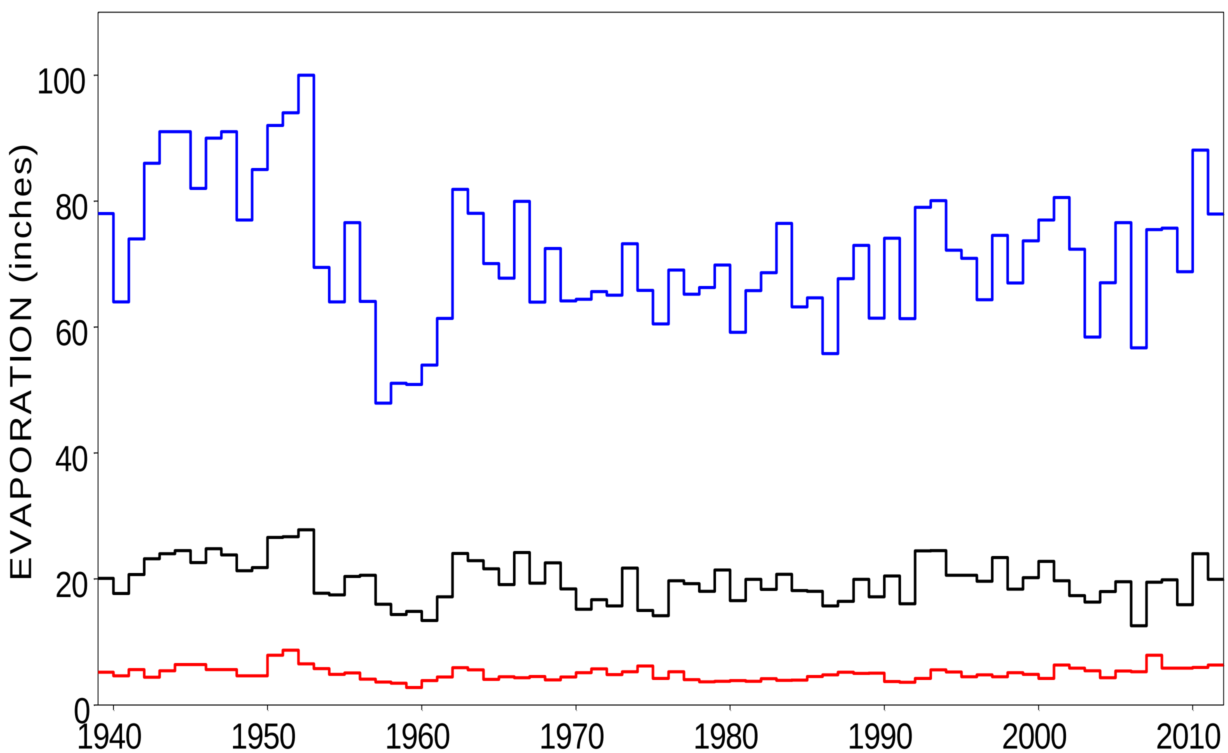
Monthly Evaporation for Quadrangle 805



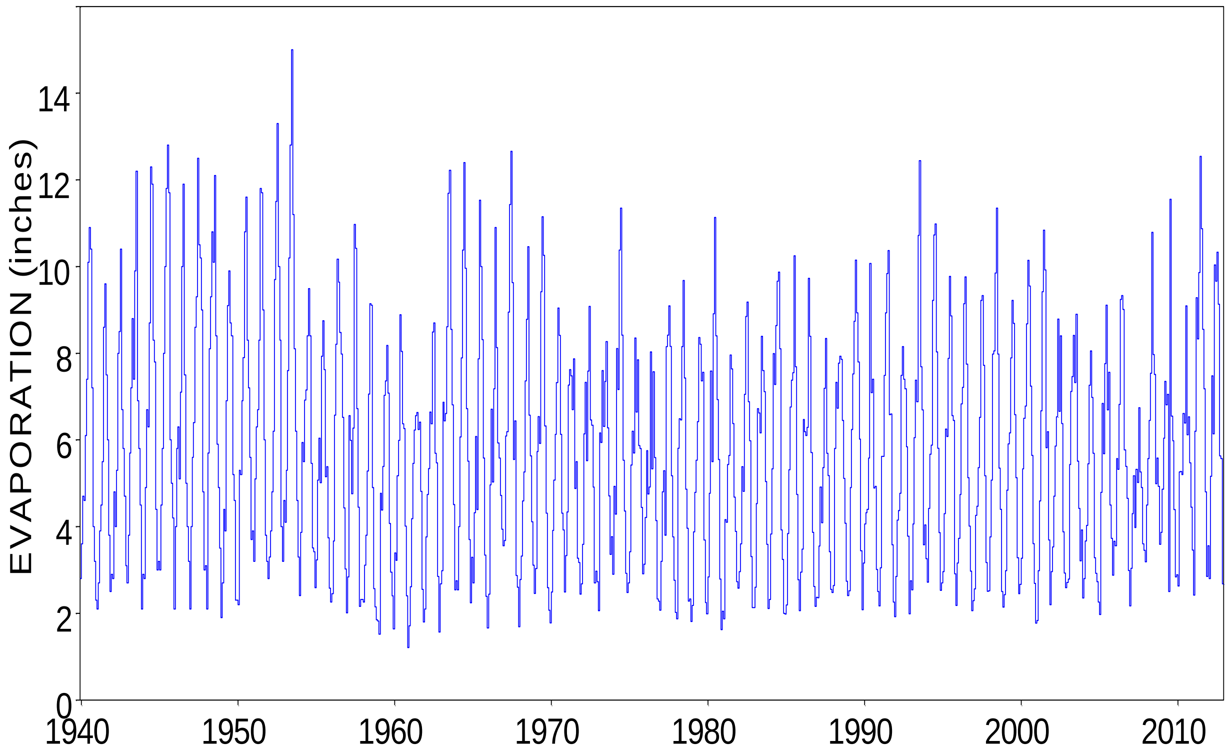
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 805



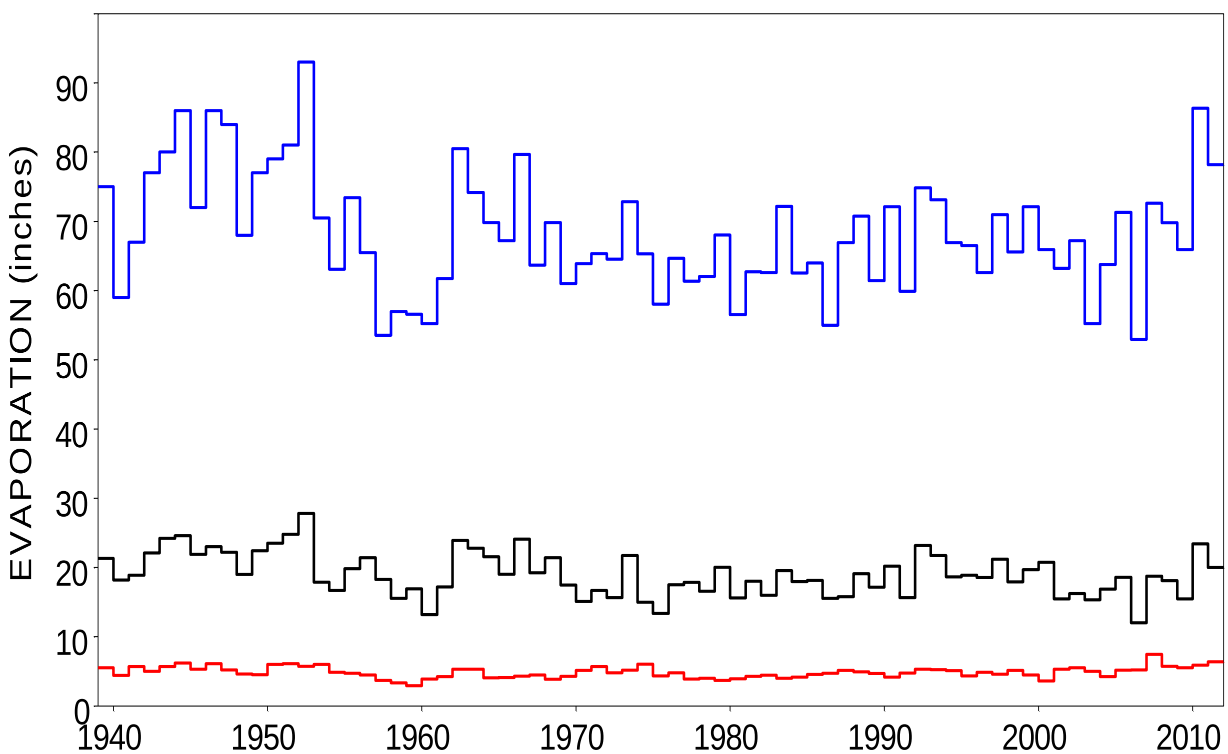
Monthly Evaporation for Quadrangle 806



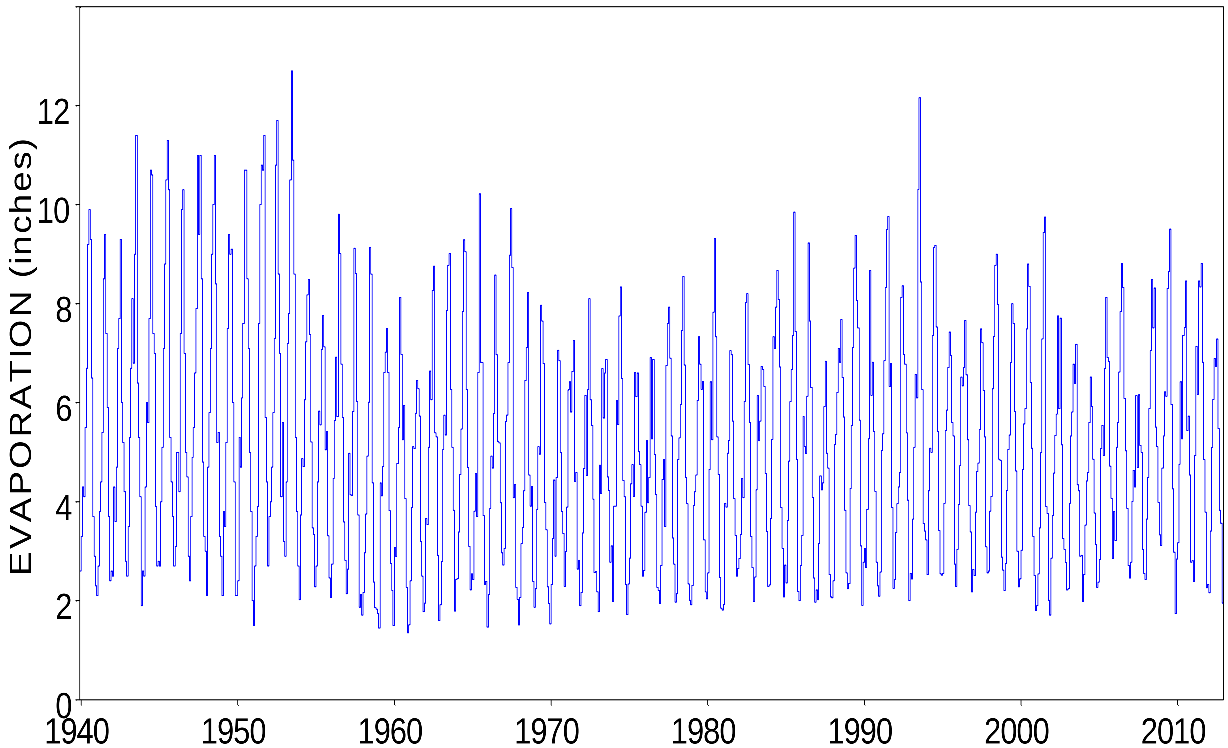
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 806



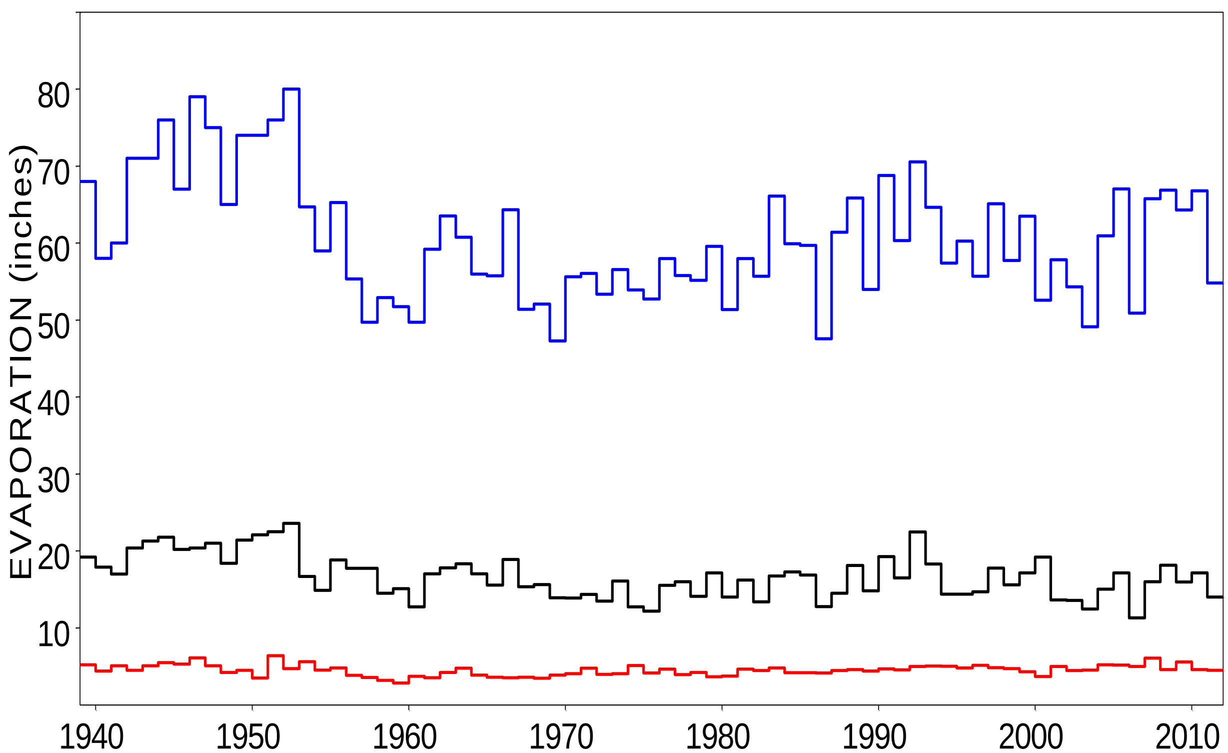
Monthly Evaporation for Quadrangle 807



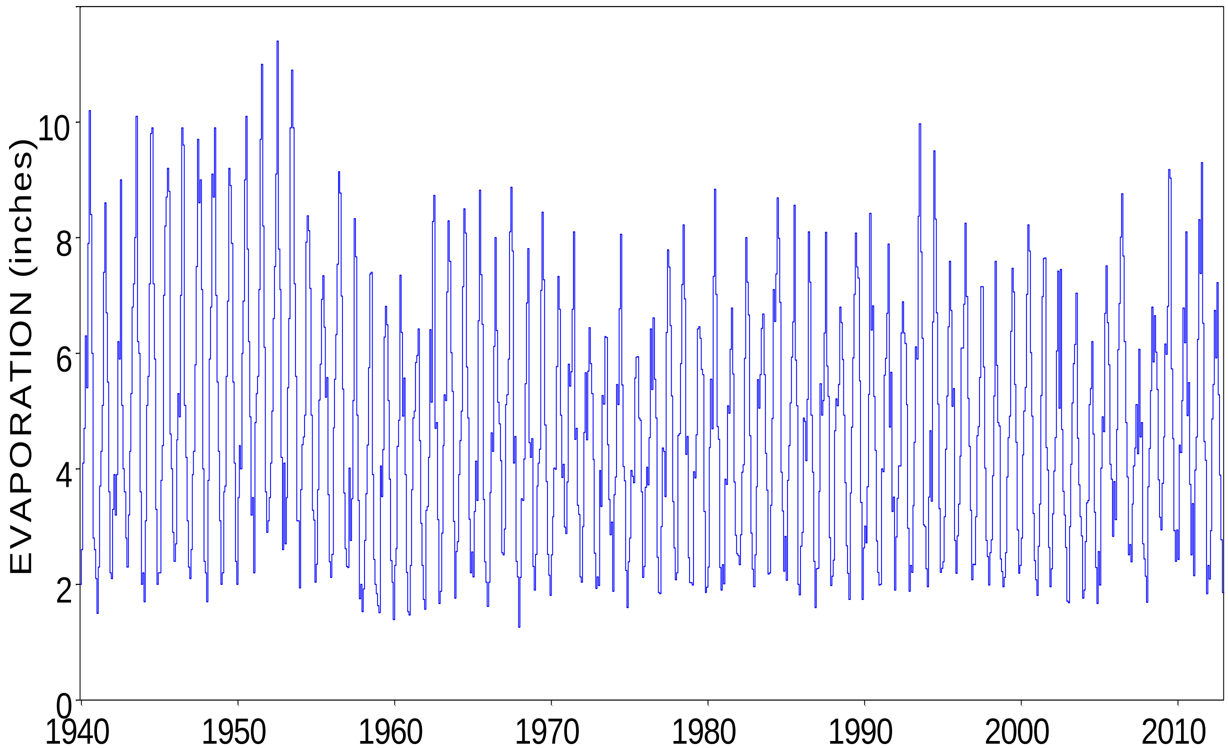
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 807



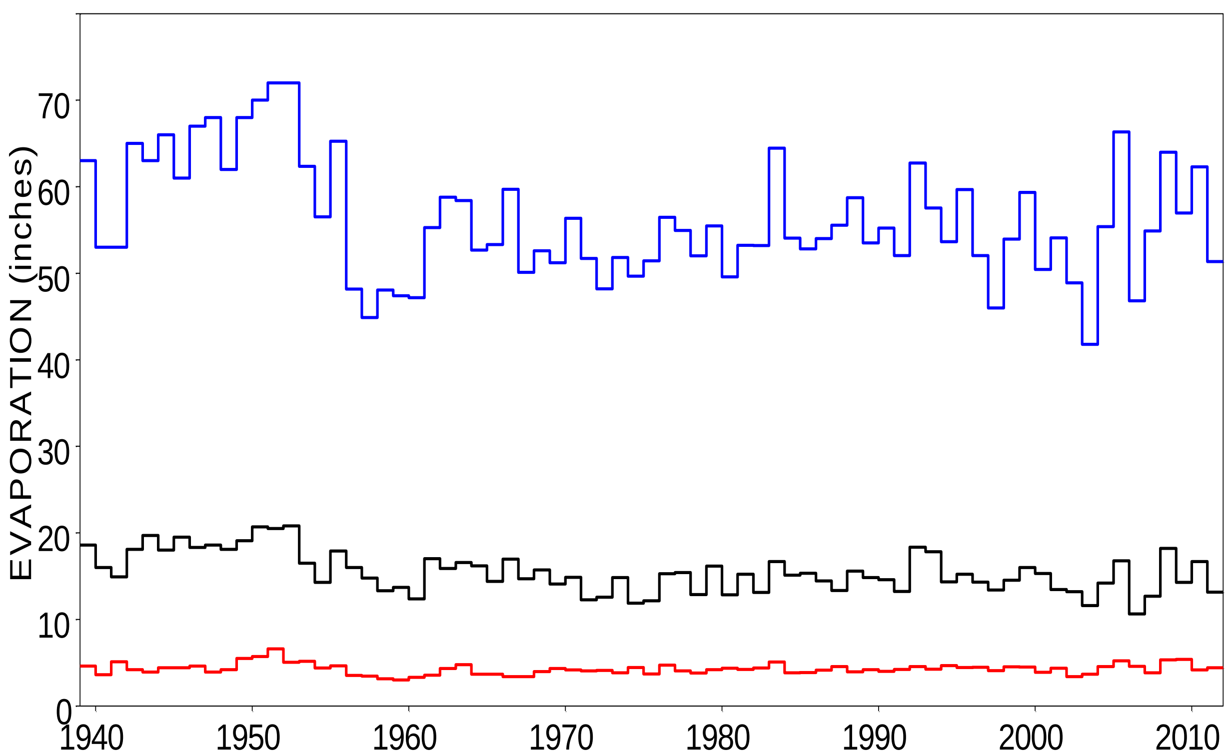
Monthly Evaporation for Quadrangle 808



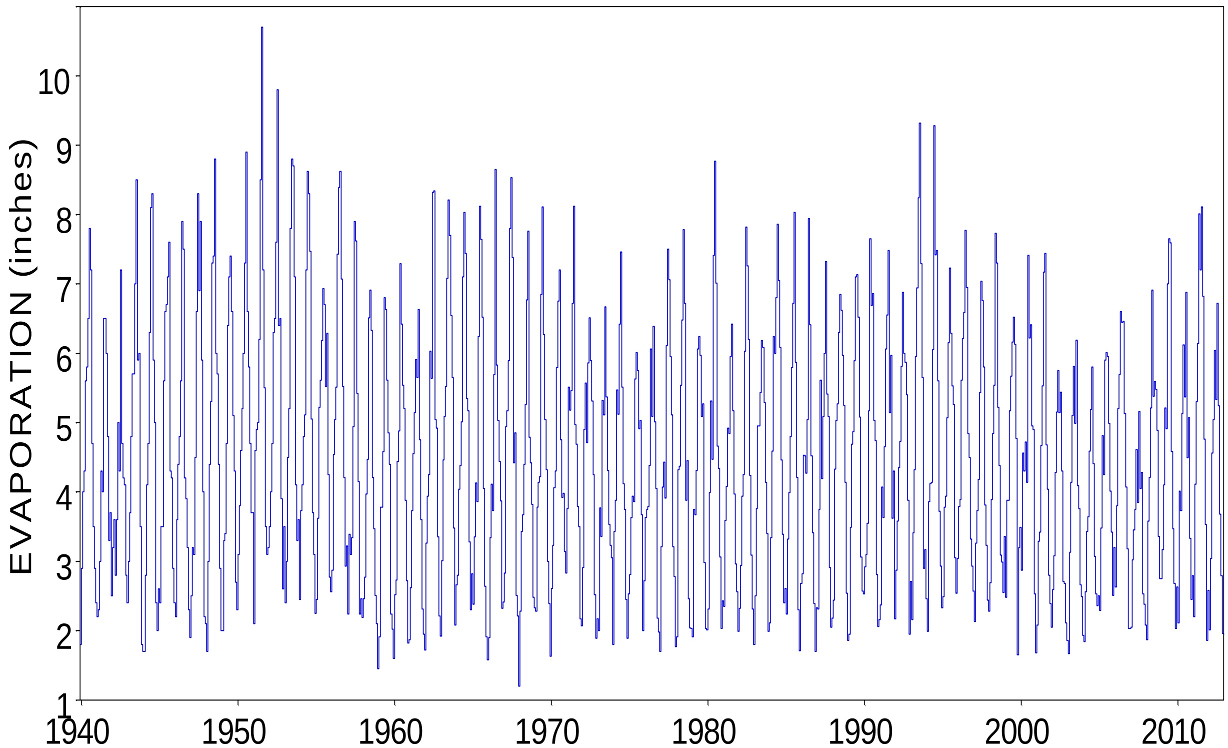
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 808



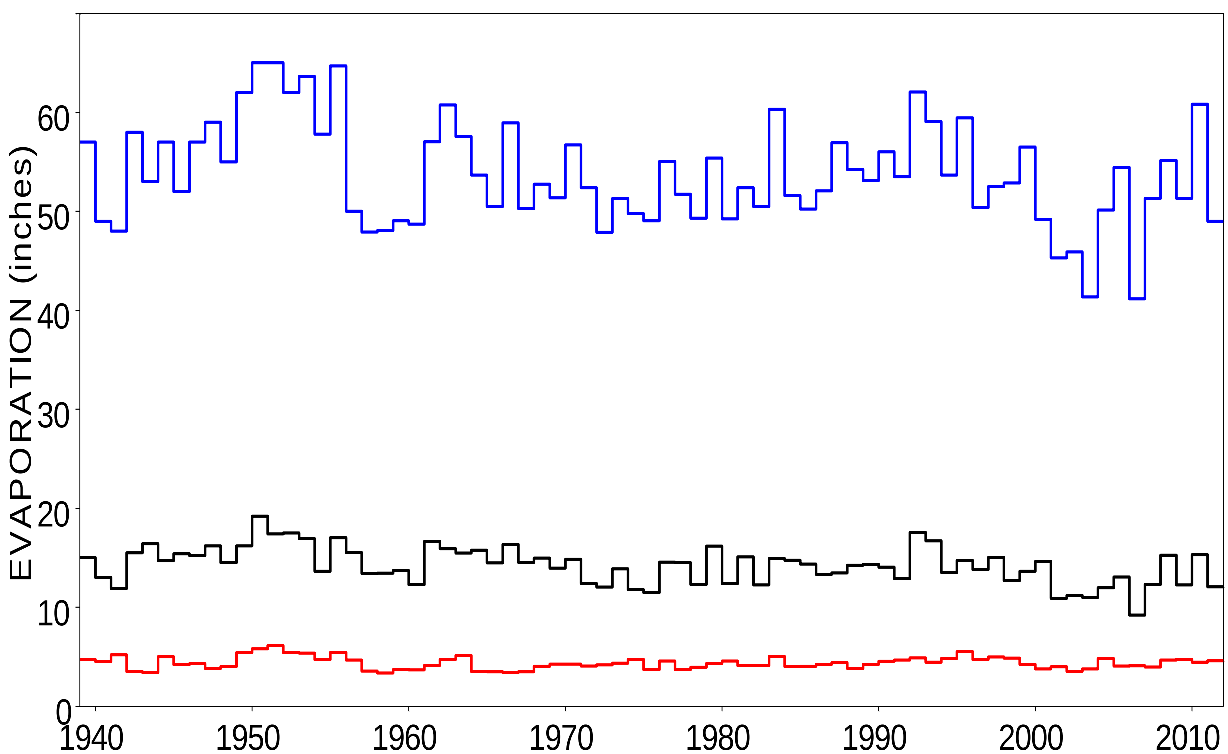
Monthly Evaporation for Quadrangle 809



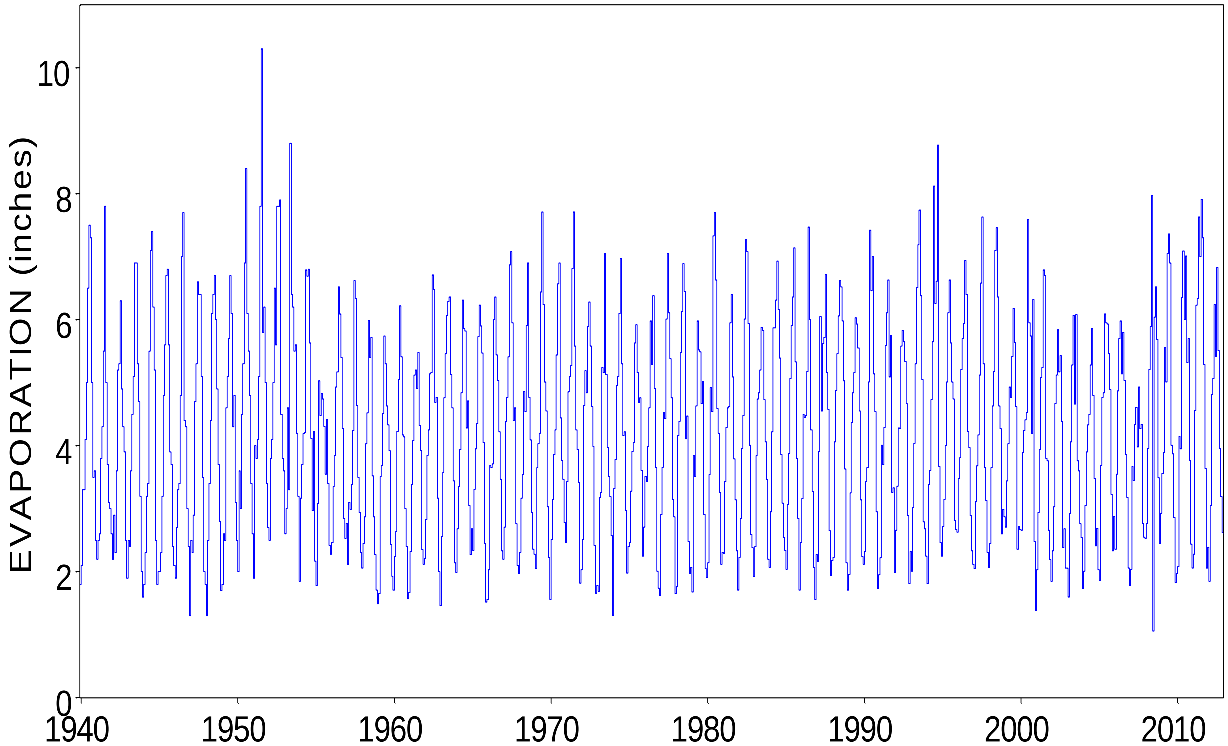
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 809



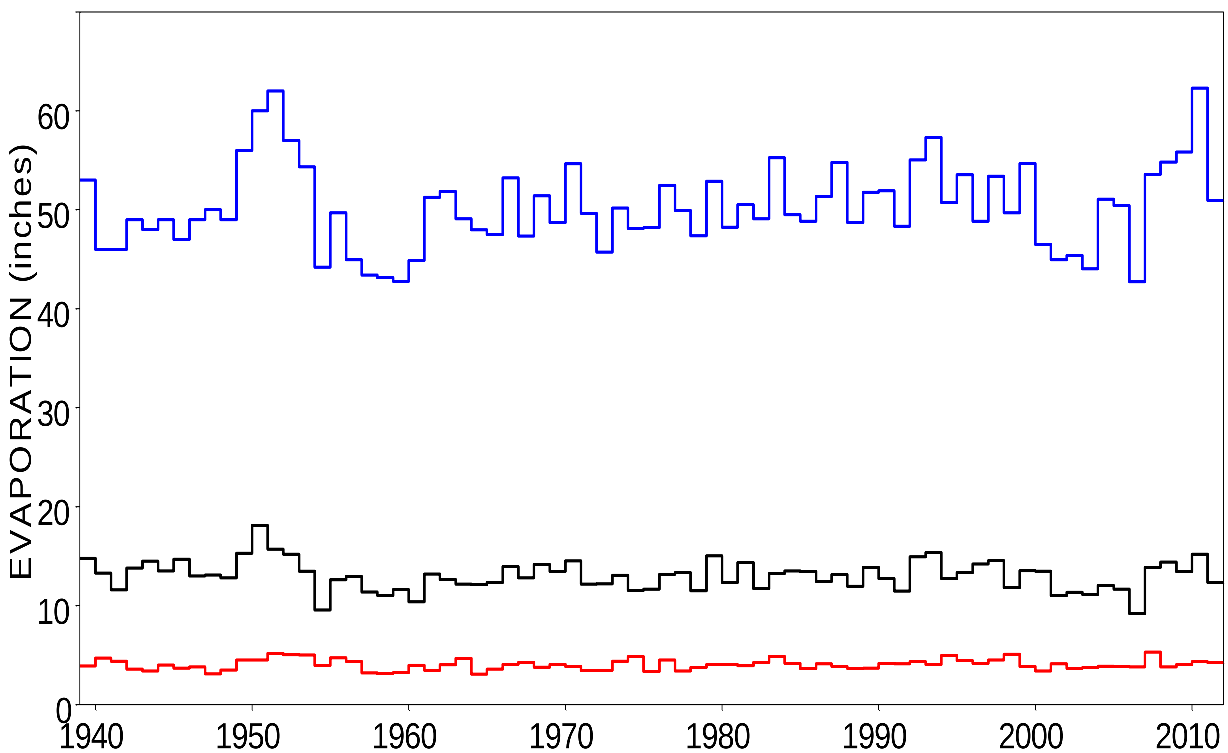
Monthly Evaporation for Quadrangle 810



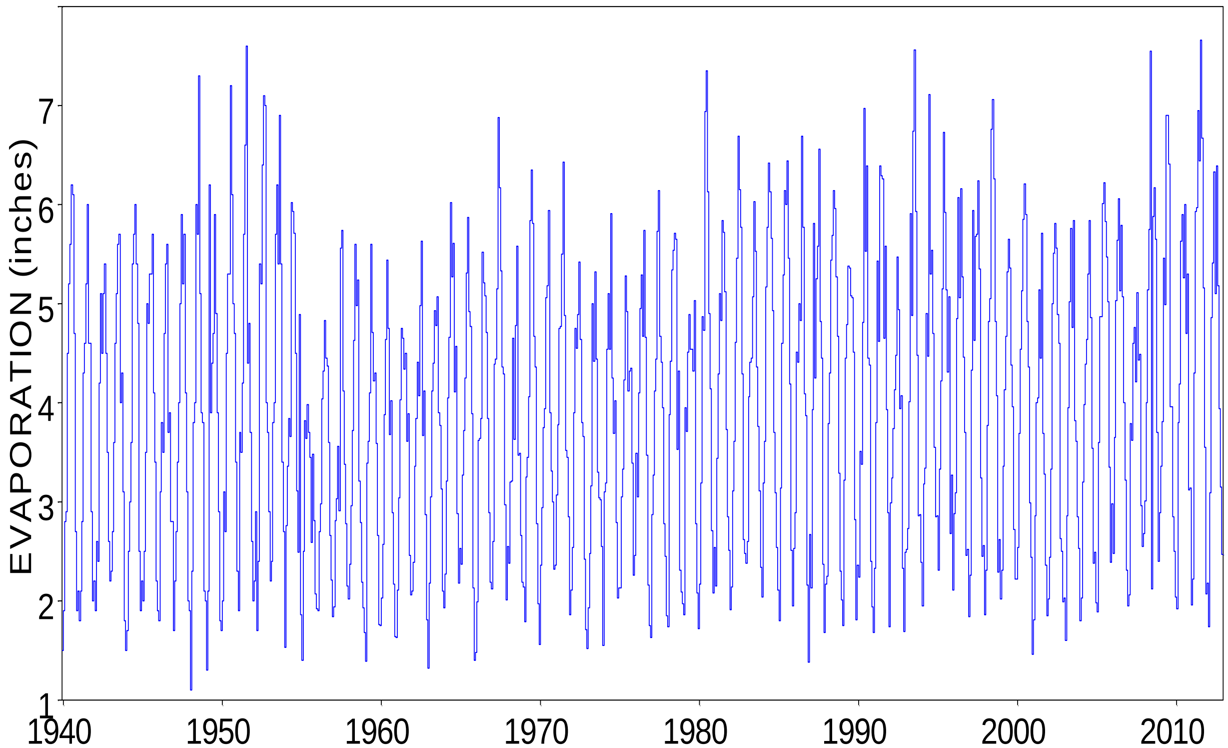
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 810



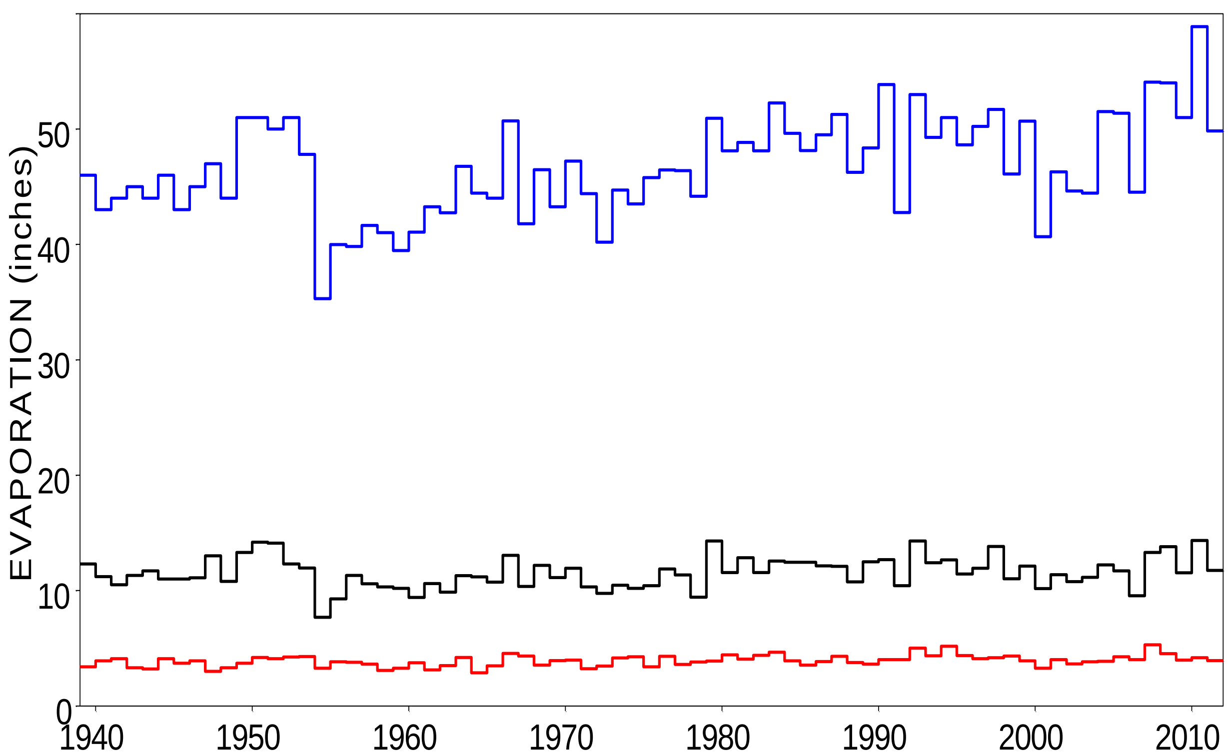
Monthly Evaporation for Quadrangle 811



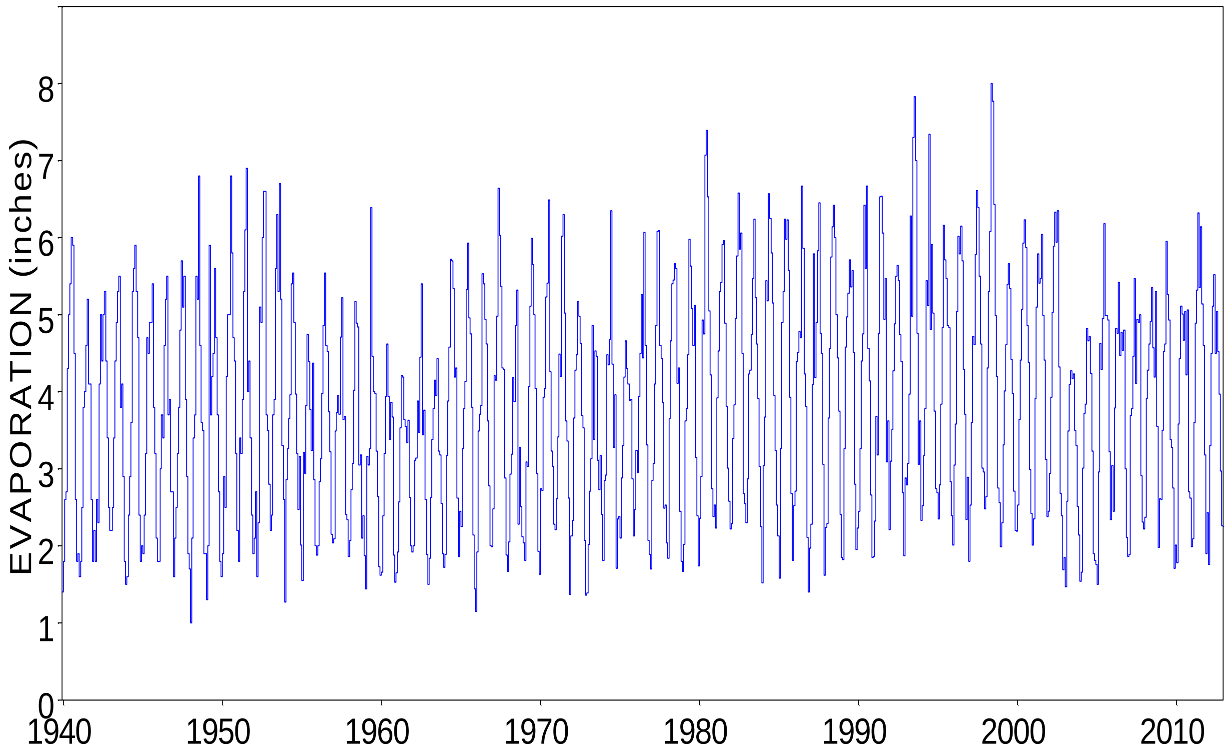
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 811



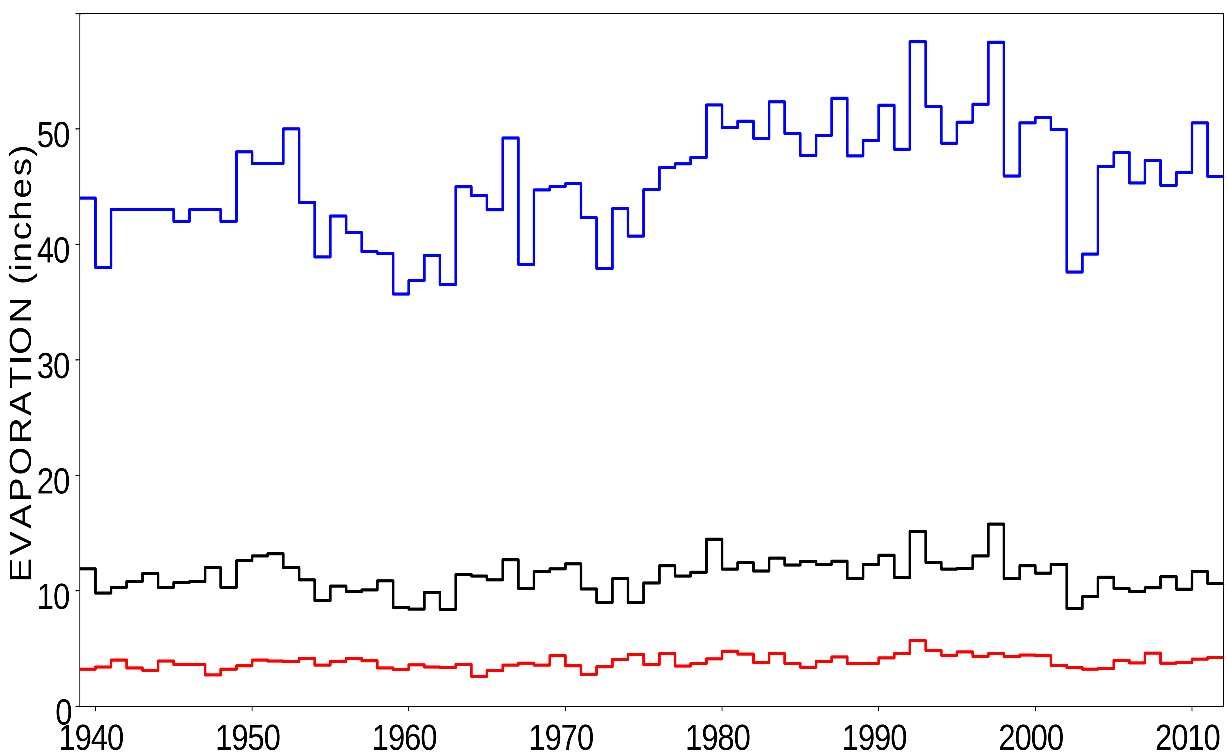
Monthly Evaporation for Quadrangle 812



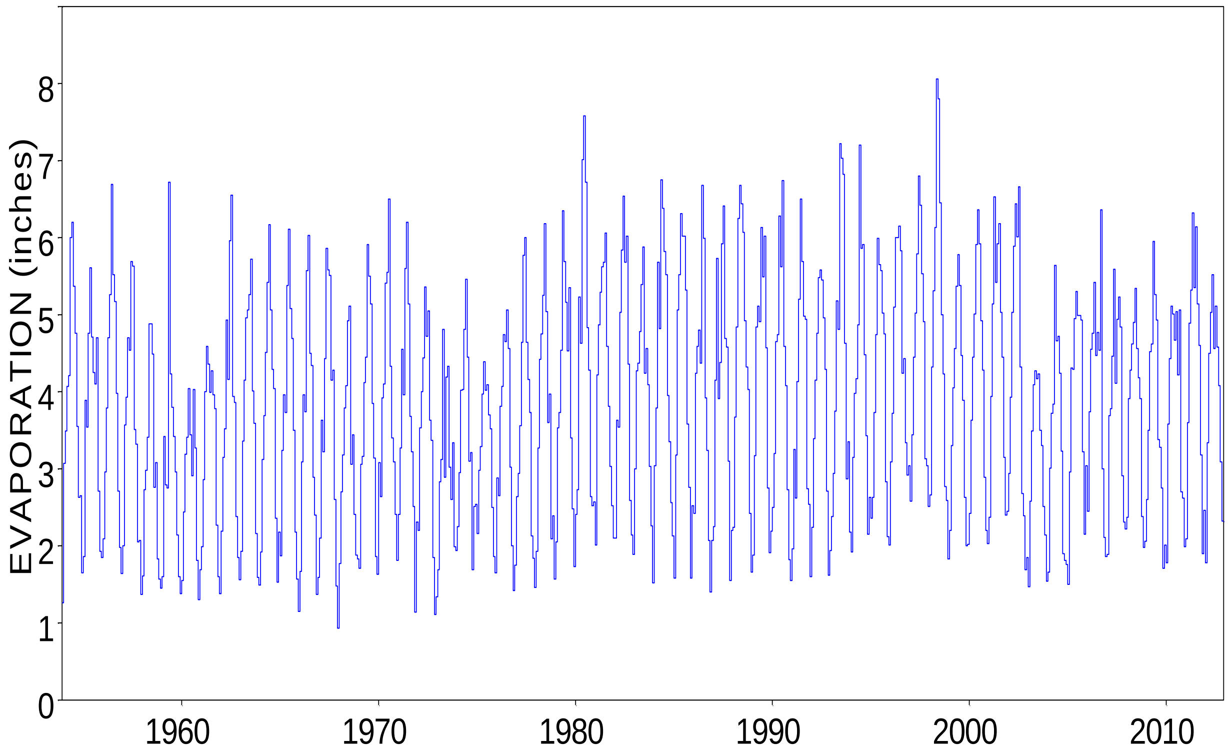
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 812



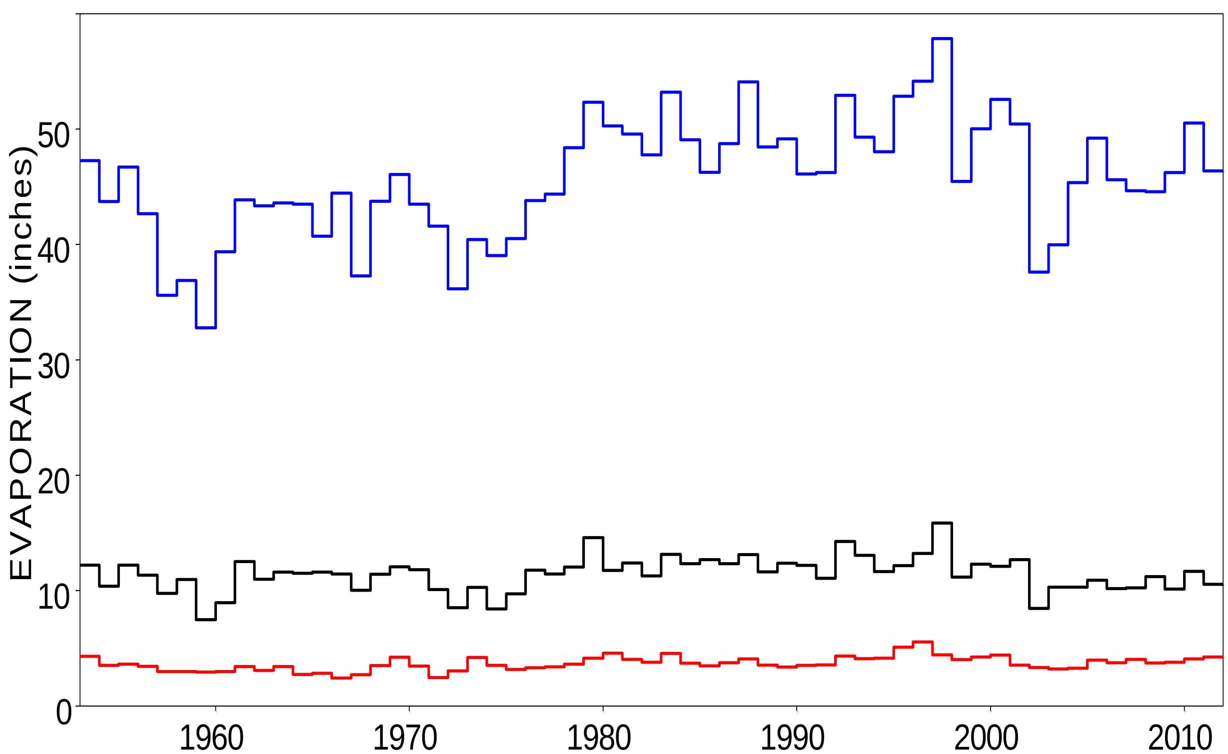
Monthly Evaporation for Quadrangle 813



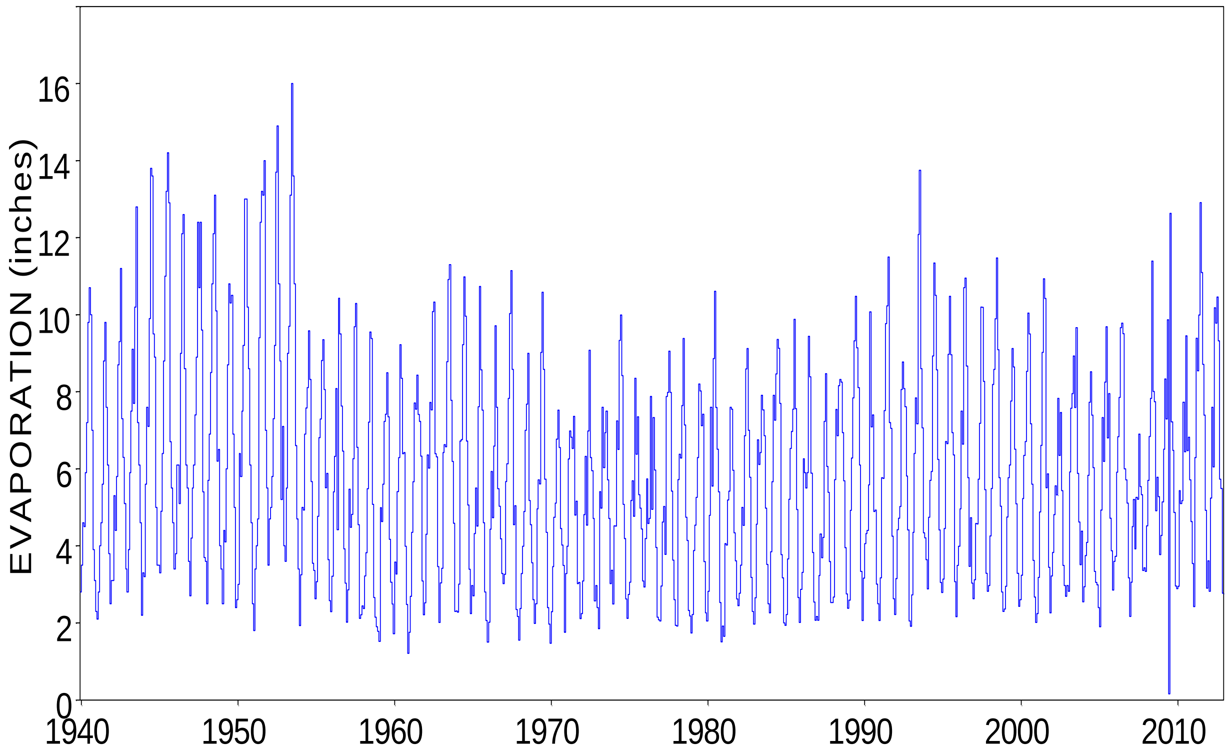
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 813



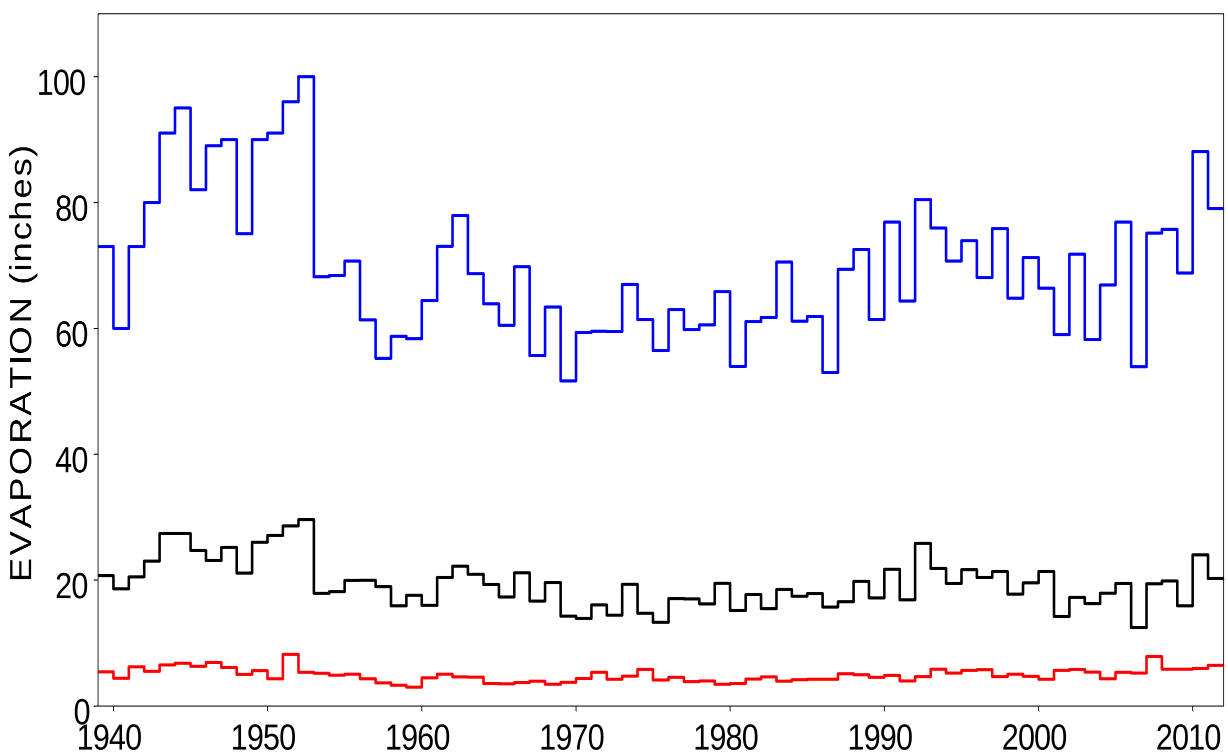
Monthly Evaporation for Quadrangle 814



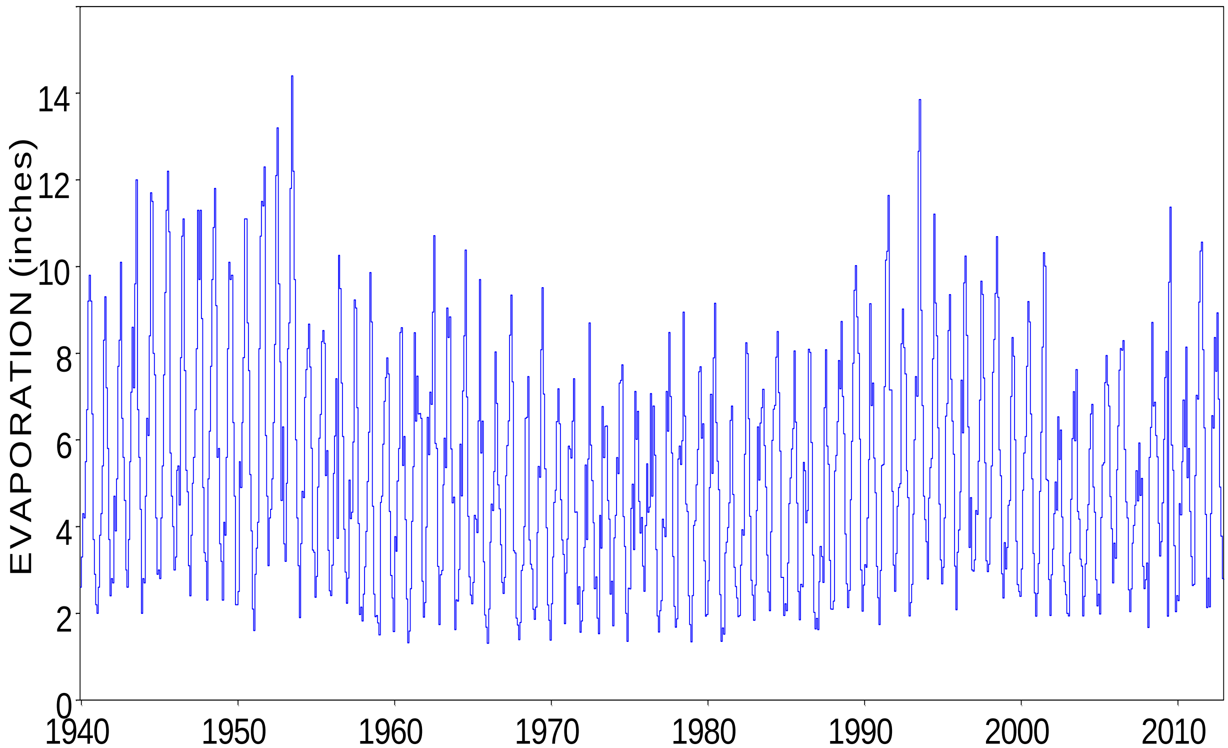
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 814



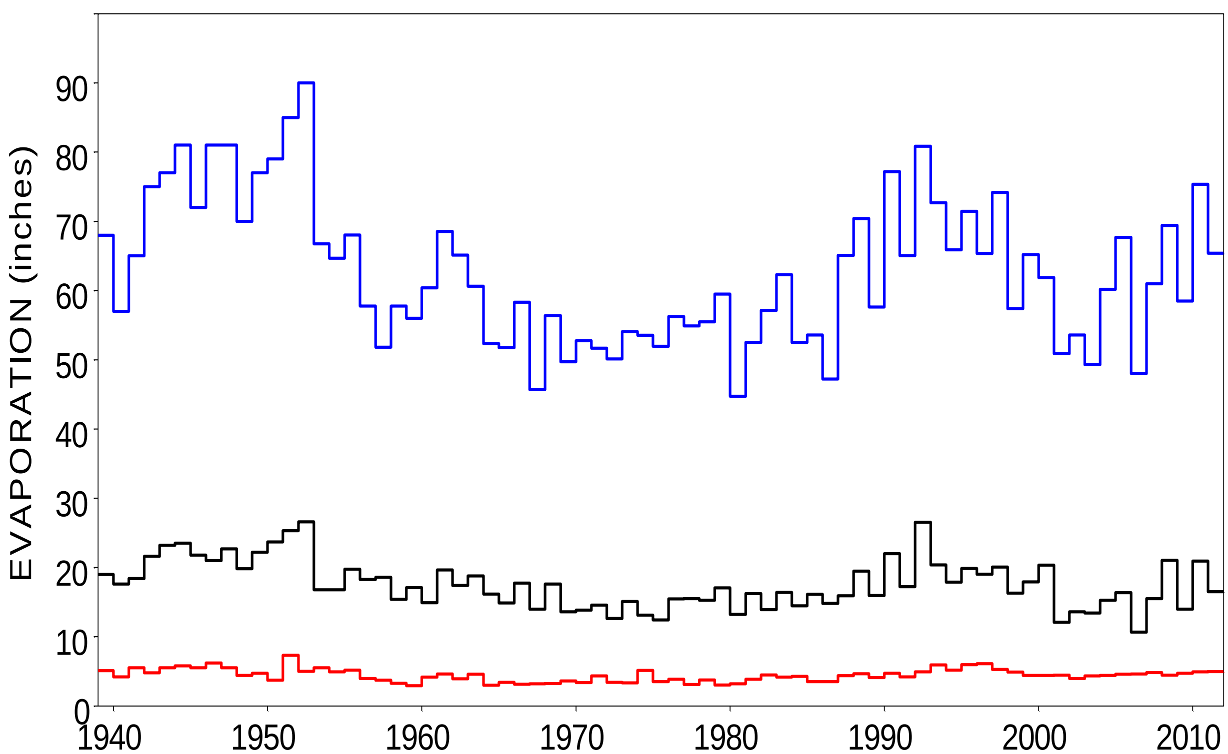
Monthly Evaporation for Quadrangle 907



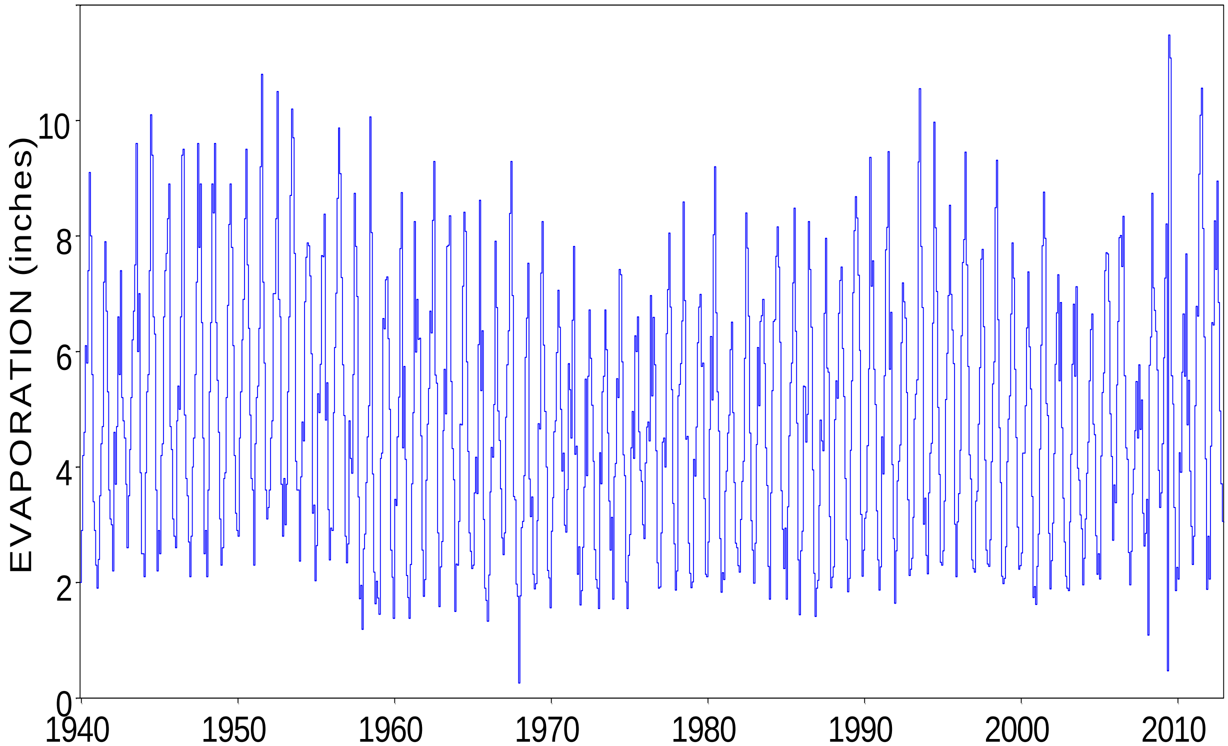
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 907



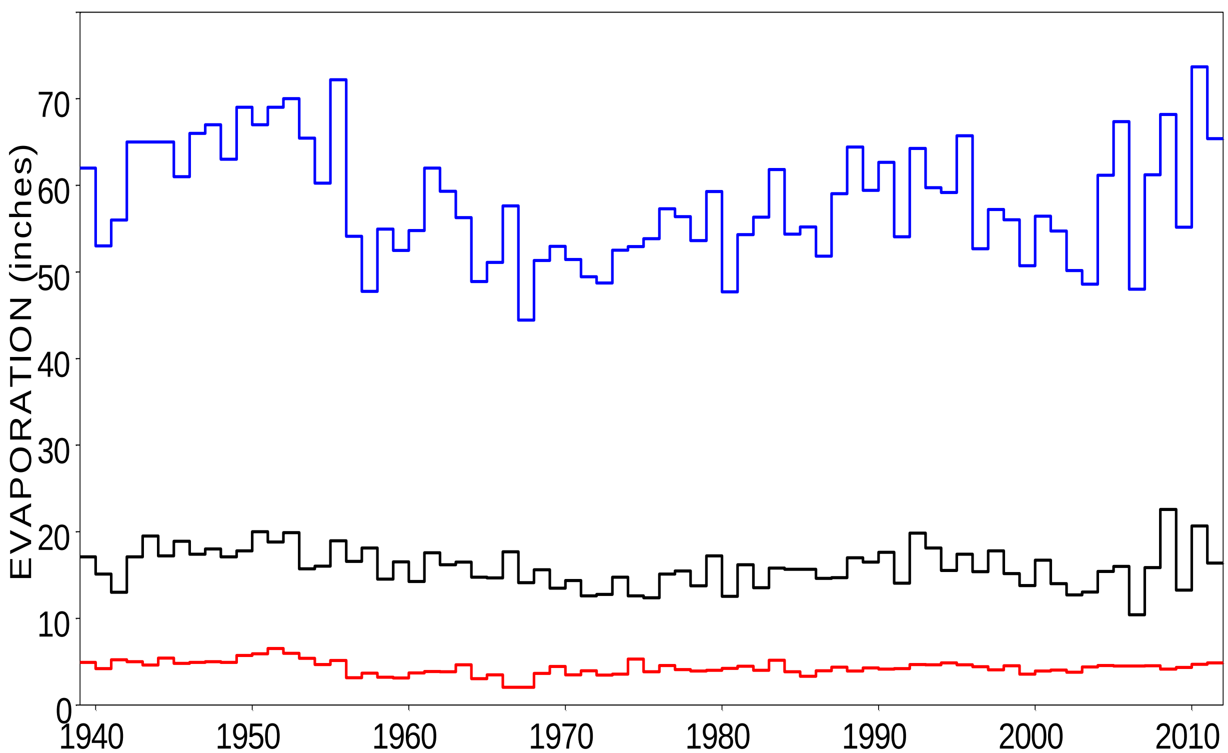
Monthly Evaporation for Quadrangle 908



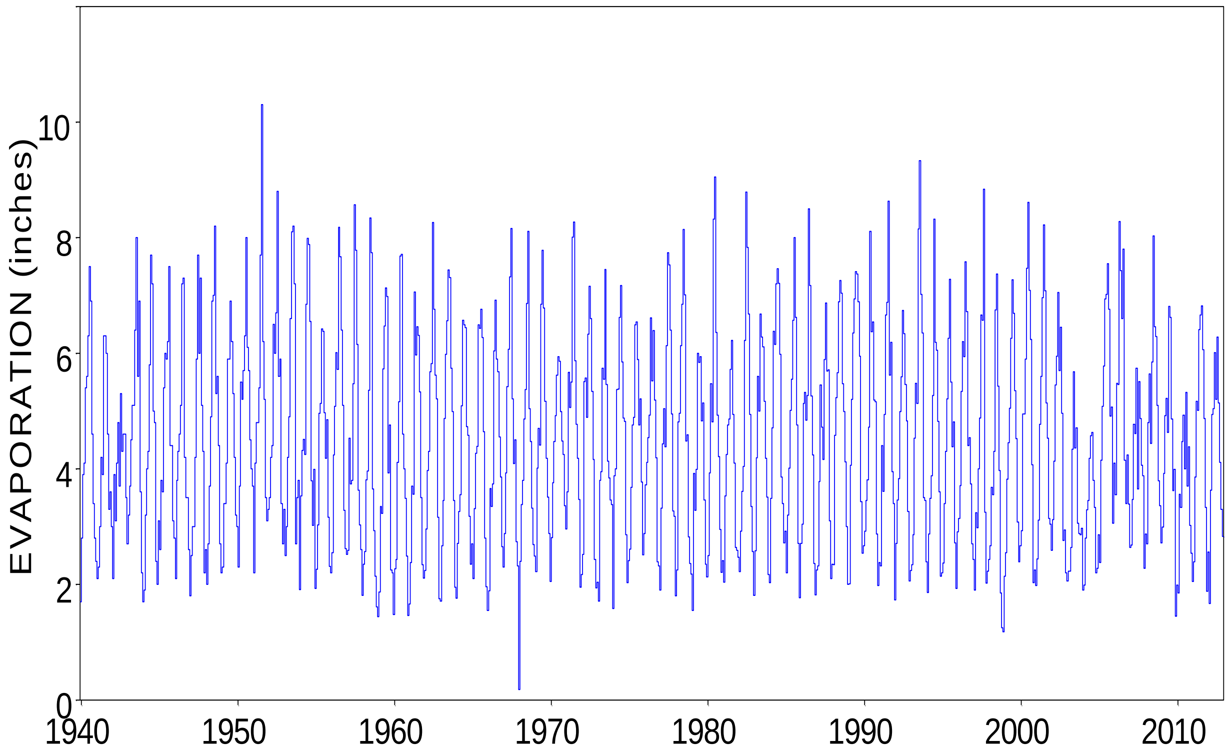
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 908



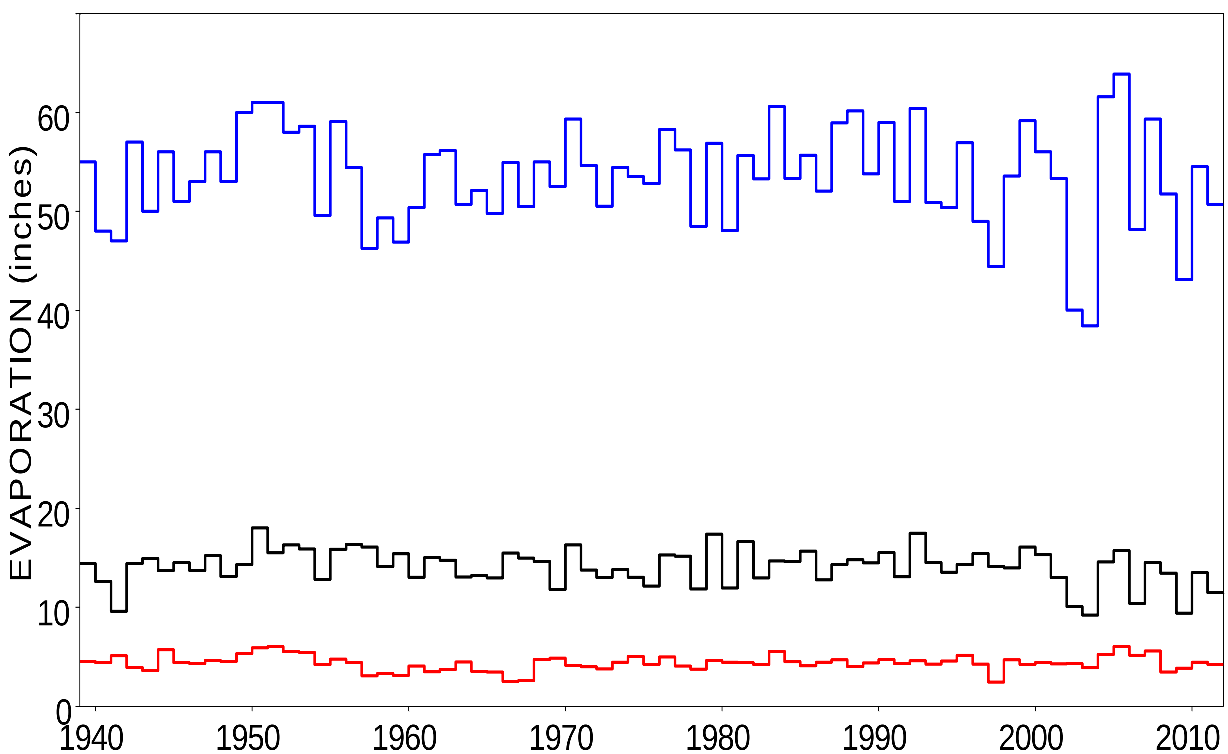
Monthly Evaporation for Quadrangle 909



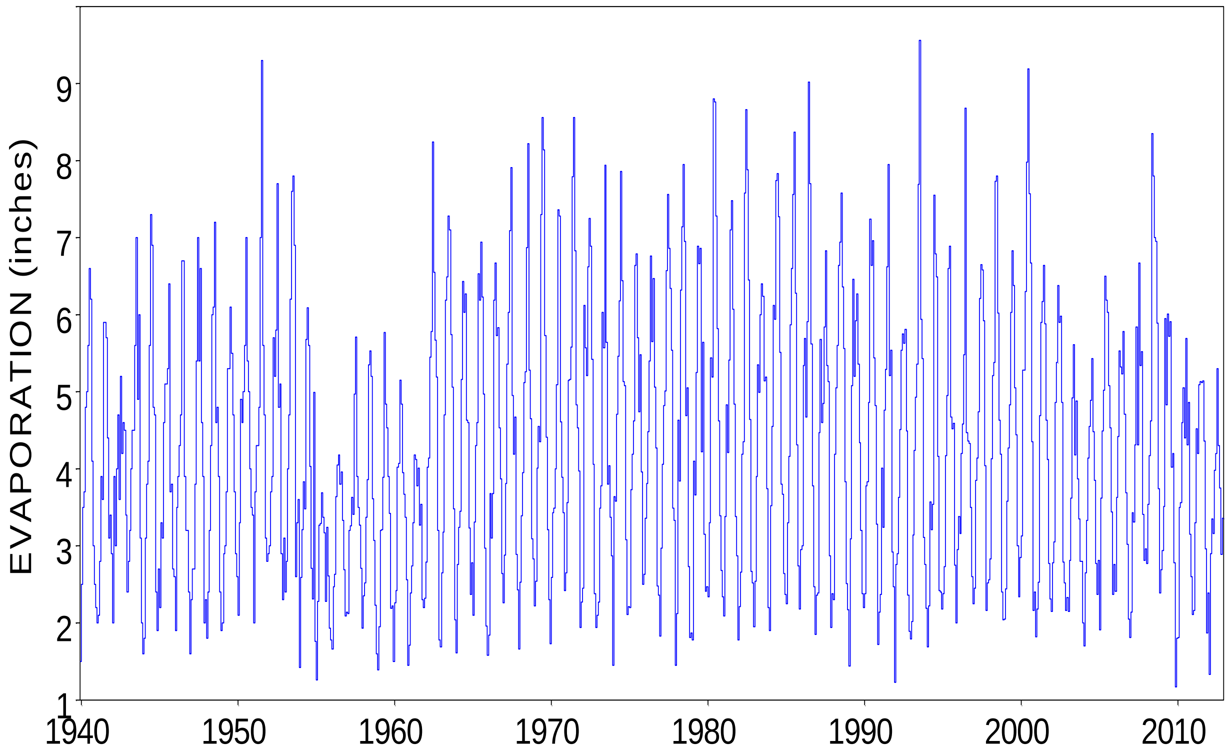
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 909



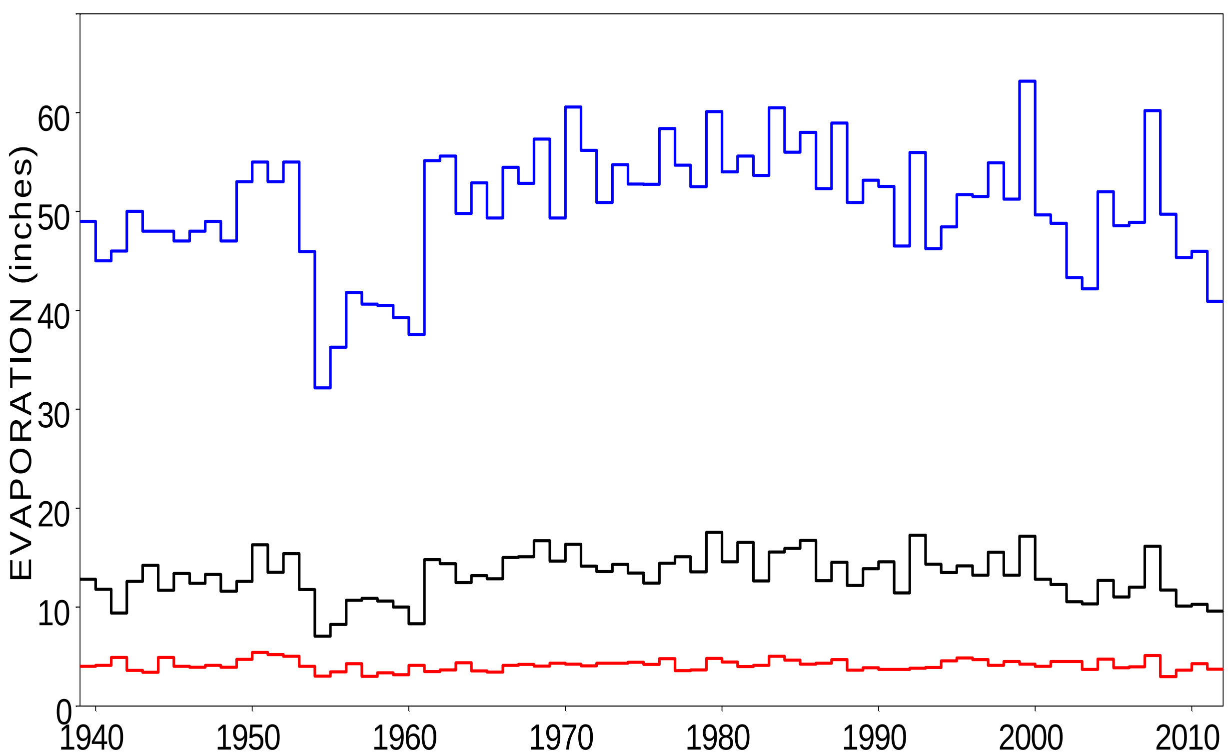
Monthly Evaporation for Quadrangle 910



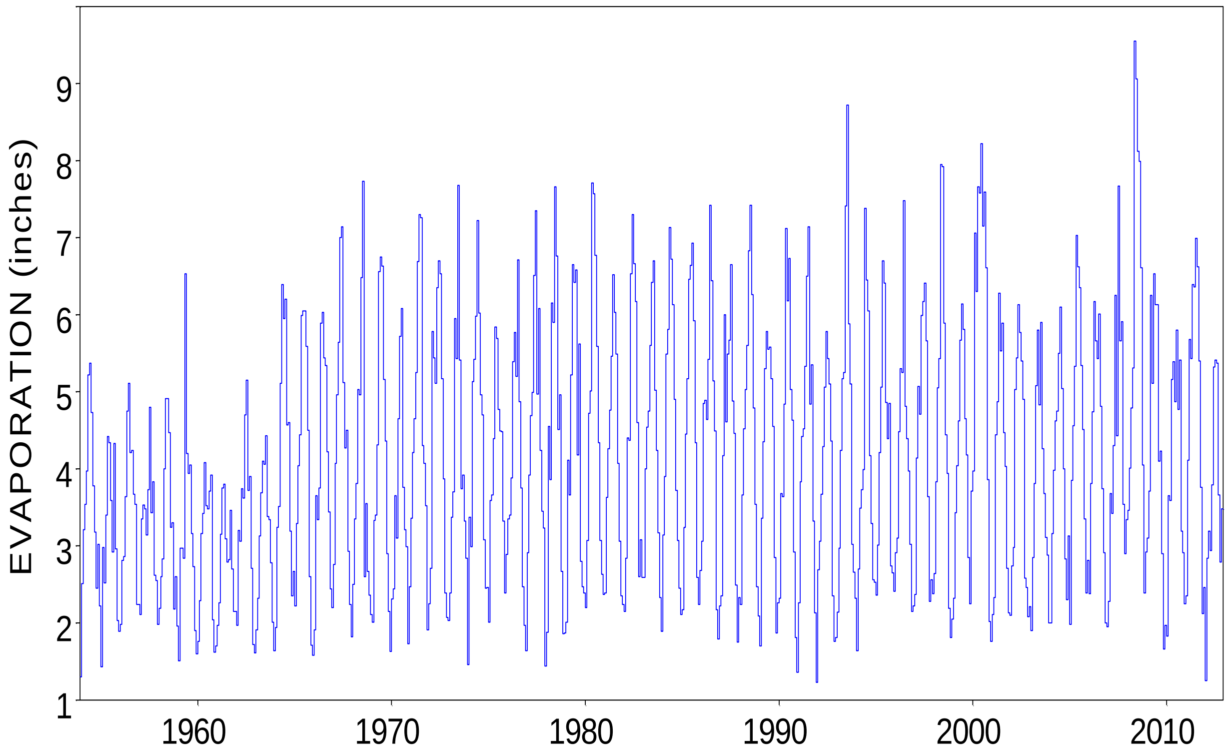
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 910



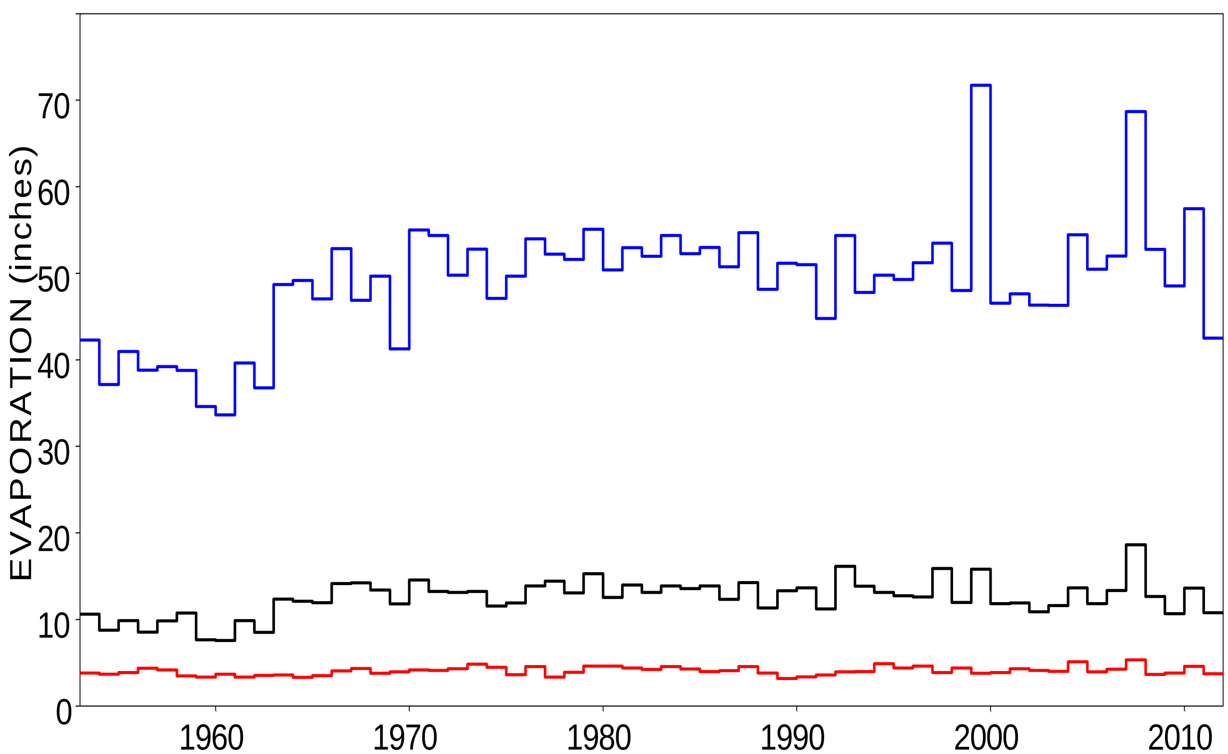
Monthly Evaporation for Quadrangle 911



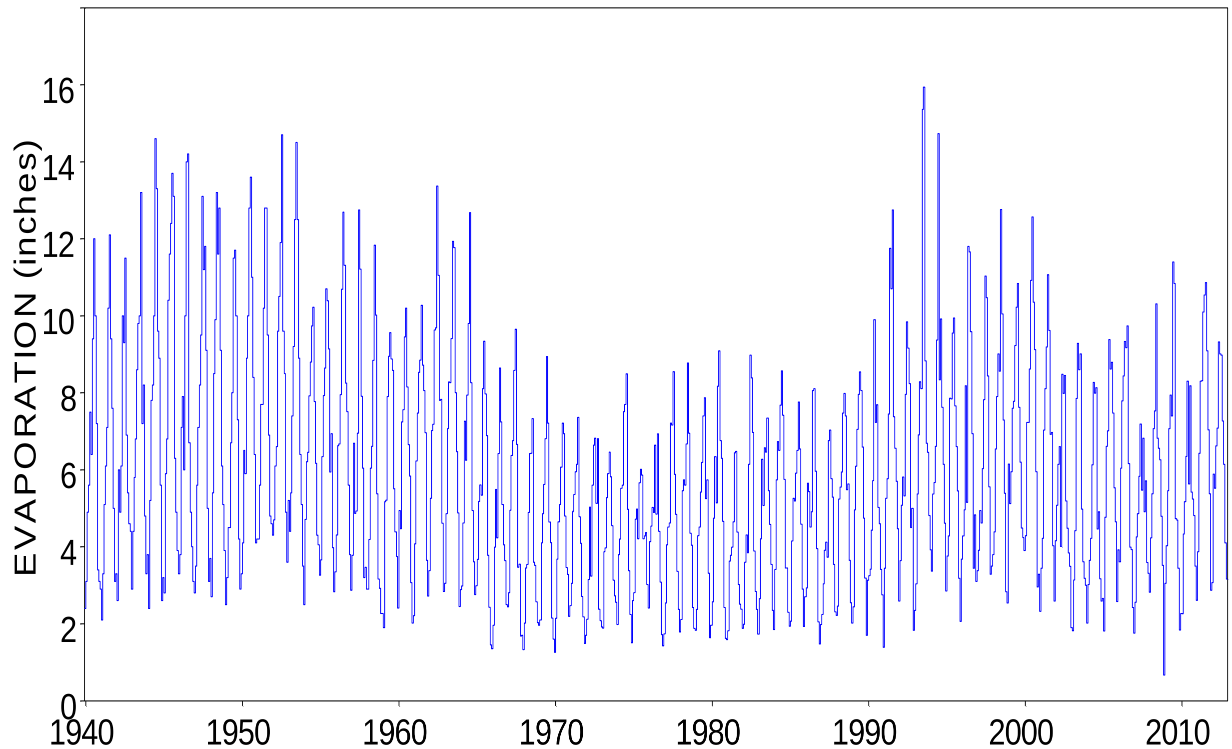
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 911



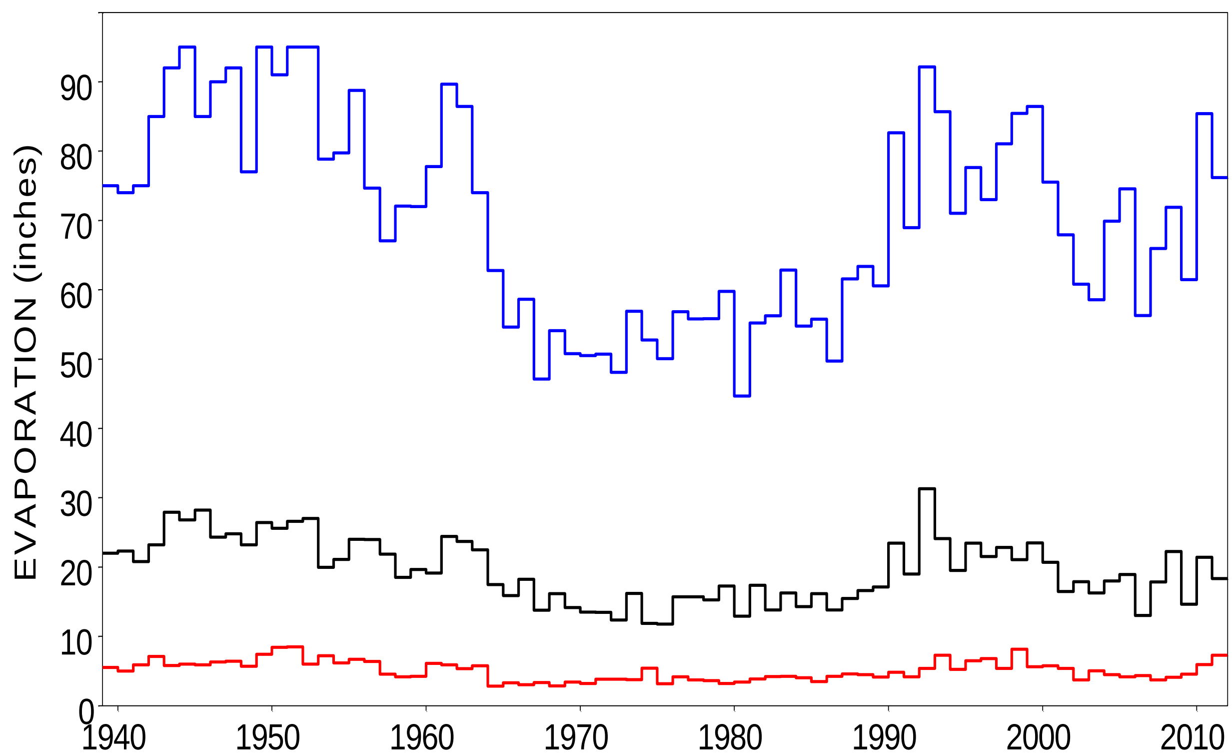
Monthly Evaporation for Quadrangle 912



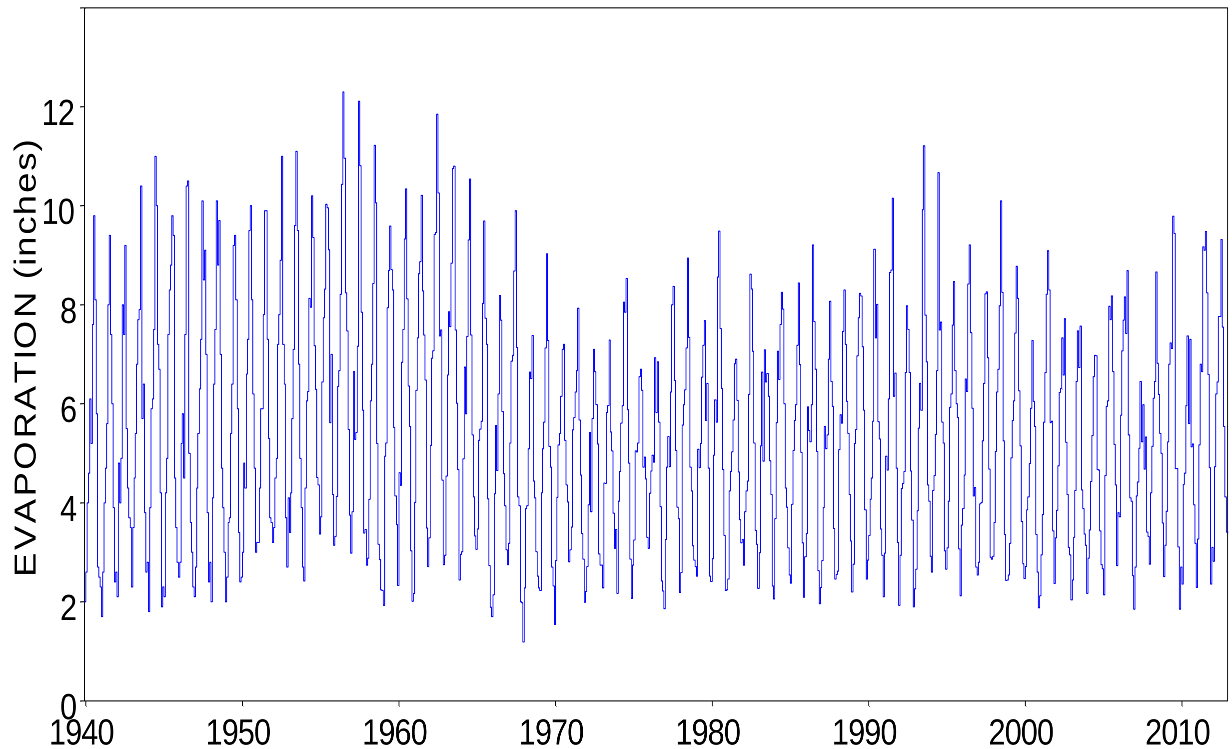
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 912



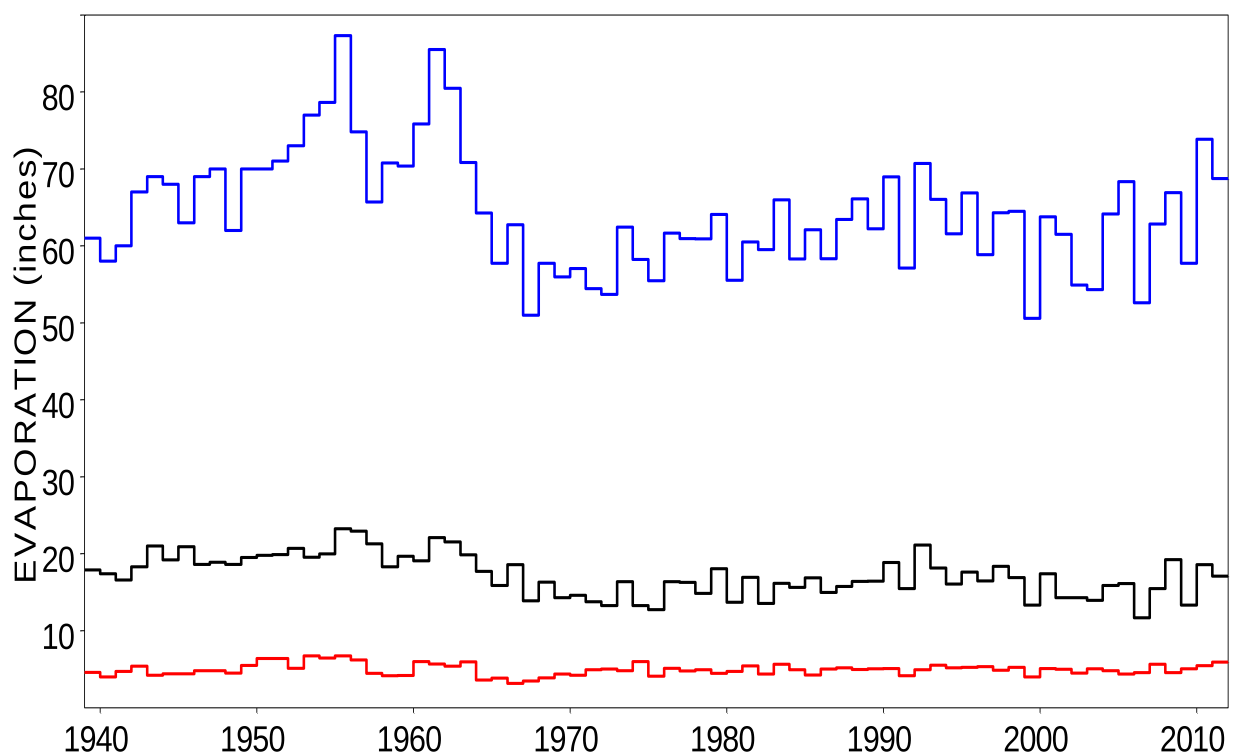
Monthly Evaporation for Quadrangle 1008



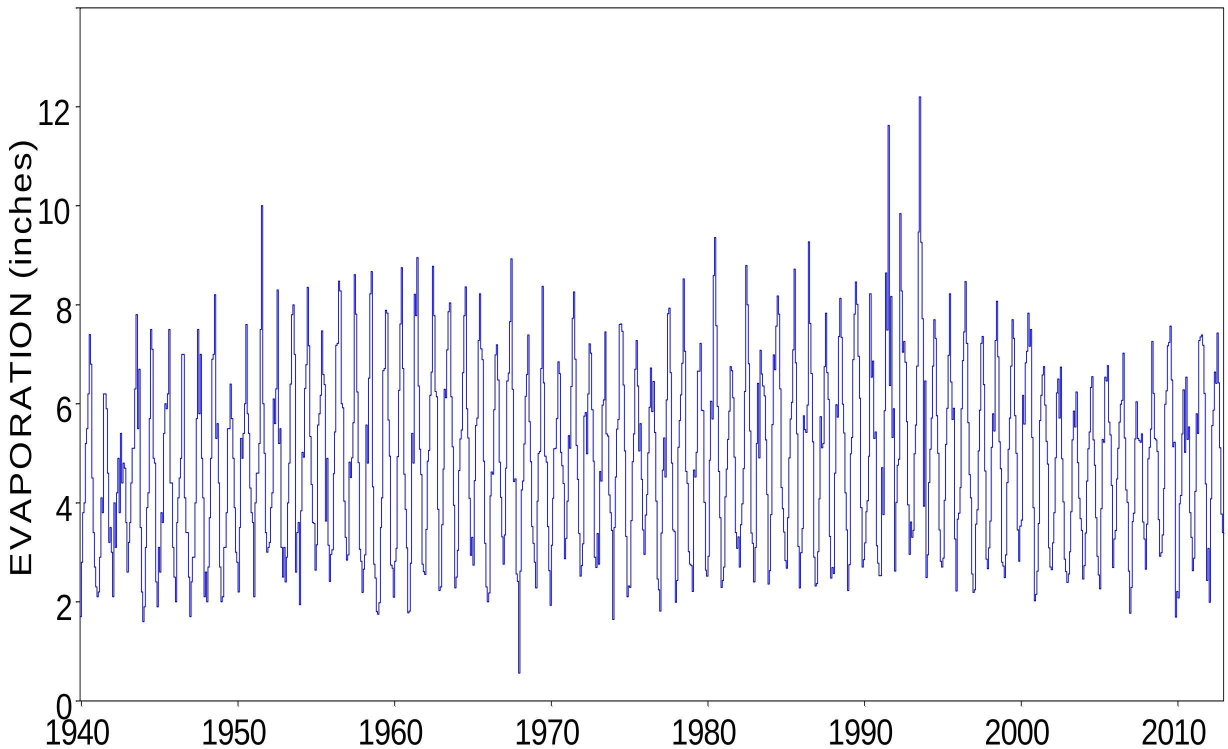
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 1008



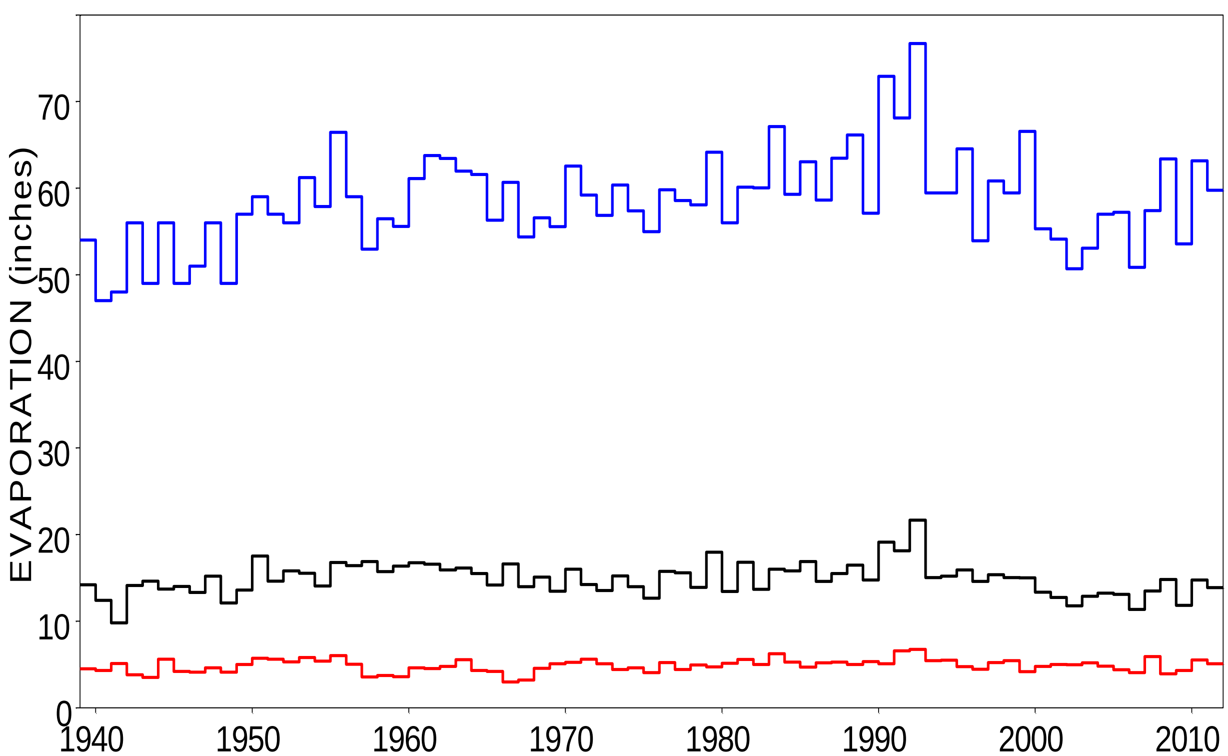
Monthly Evaporation for Quadrangle 1009



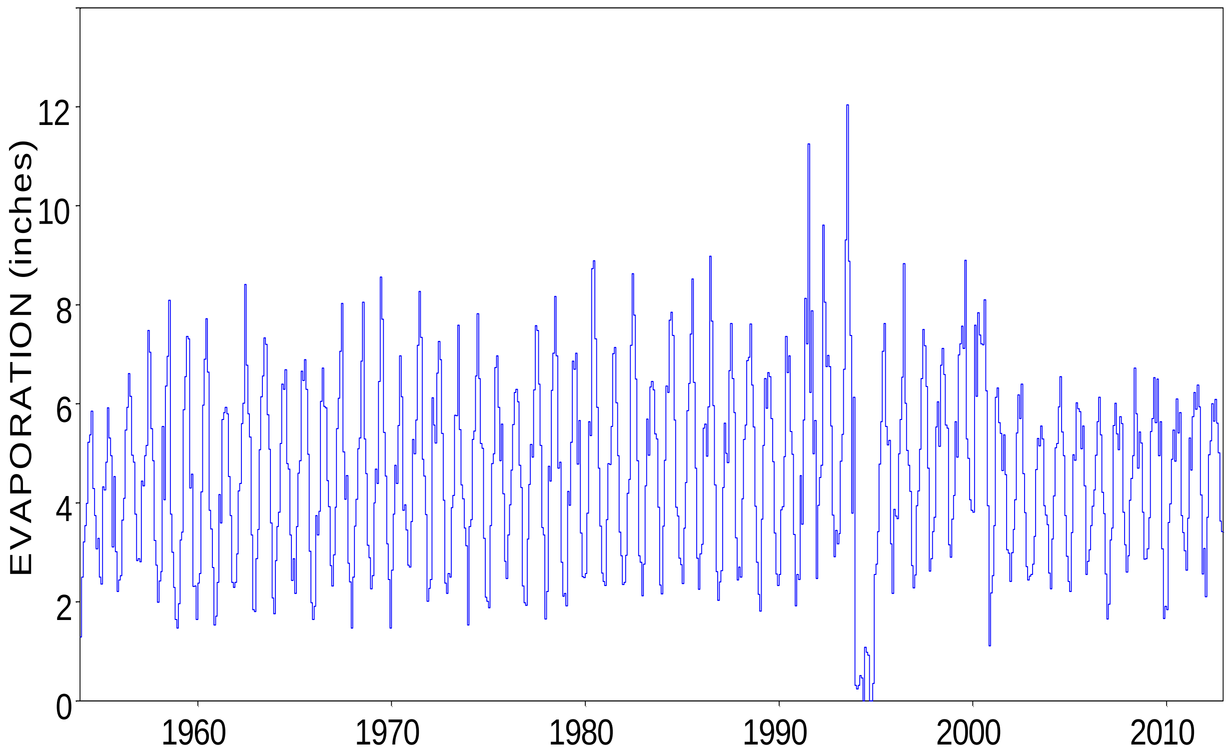
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 1009



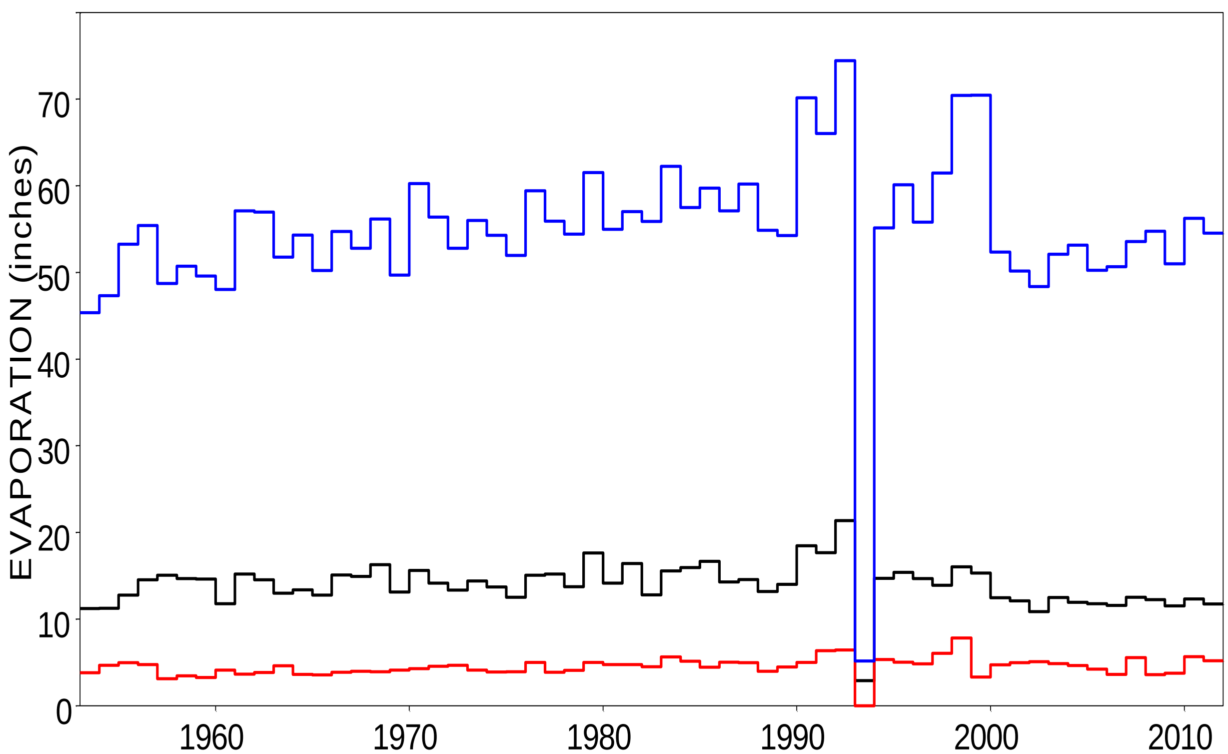
Monthly Evaporation for Quadrangle 1010



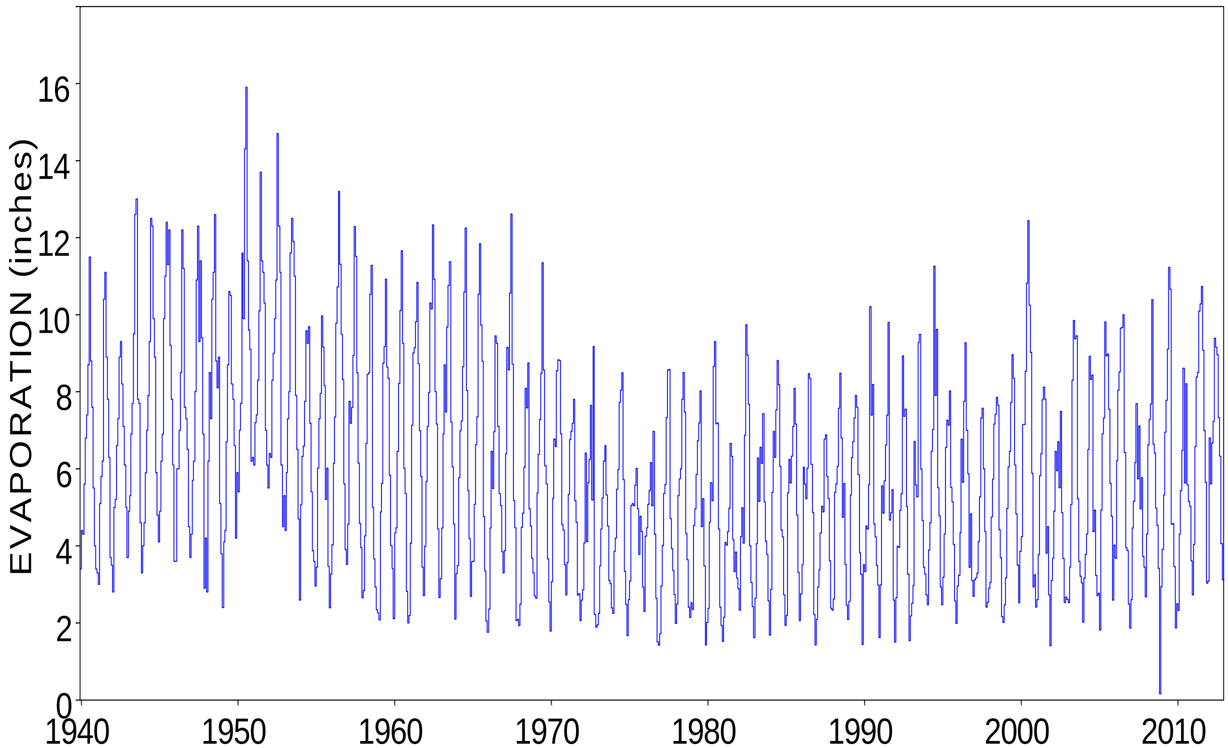
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 1010



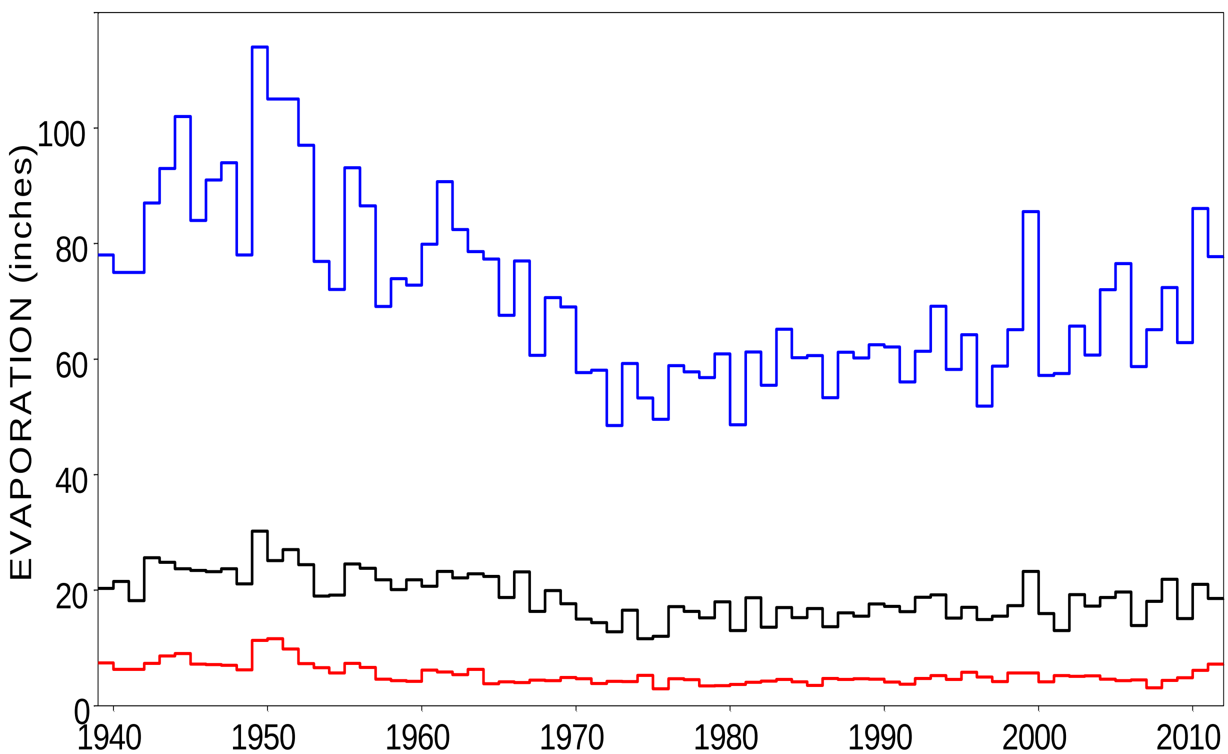
Monthly Evaporation for Quadrangle 1011



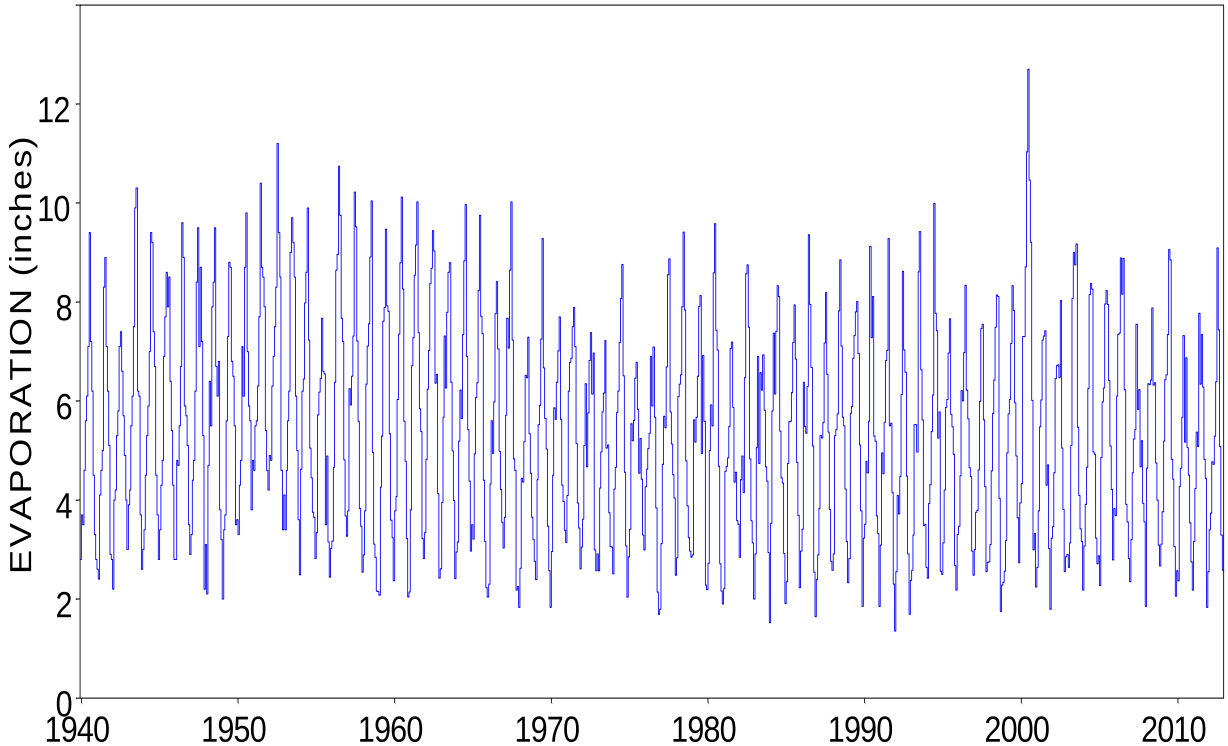
Monthly Evaporation for Quadrangle 1011



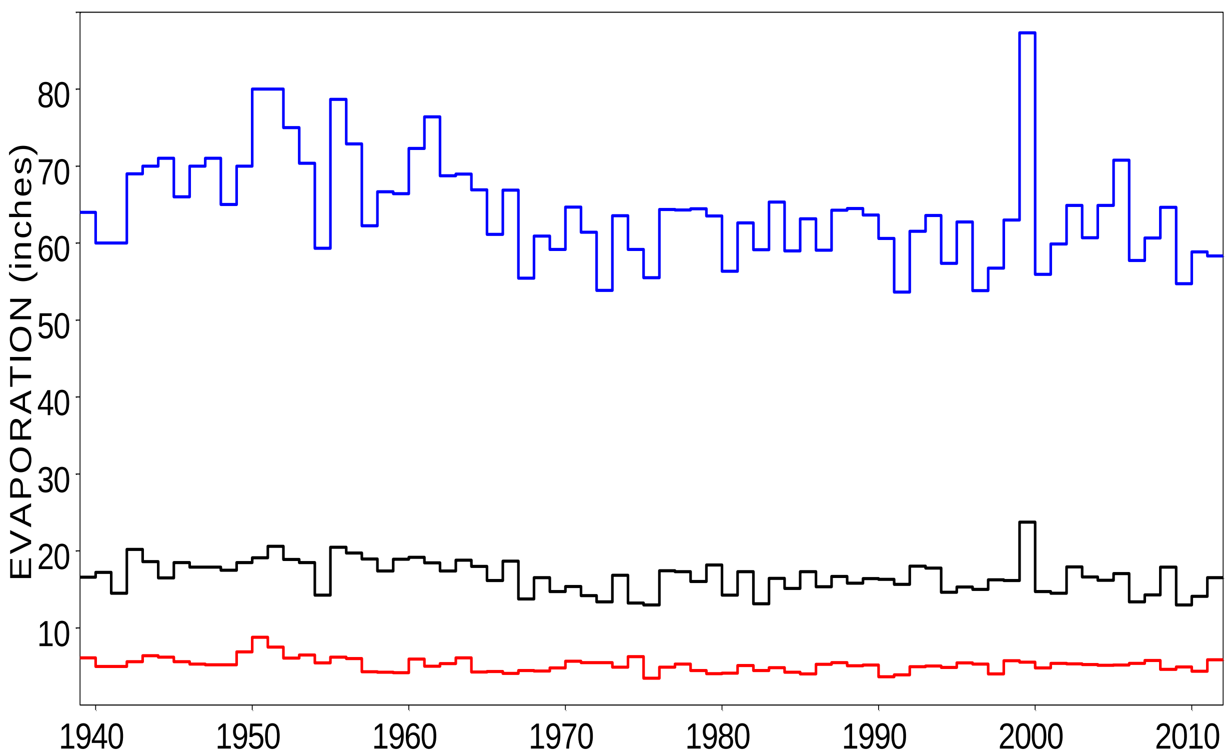
Monthly Evaporation for Quadrangle 1108



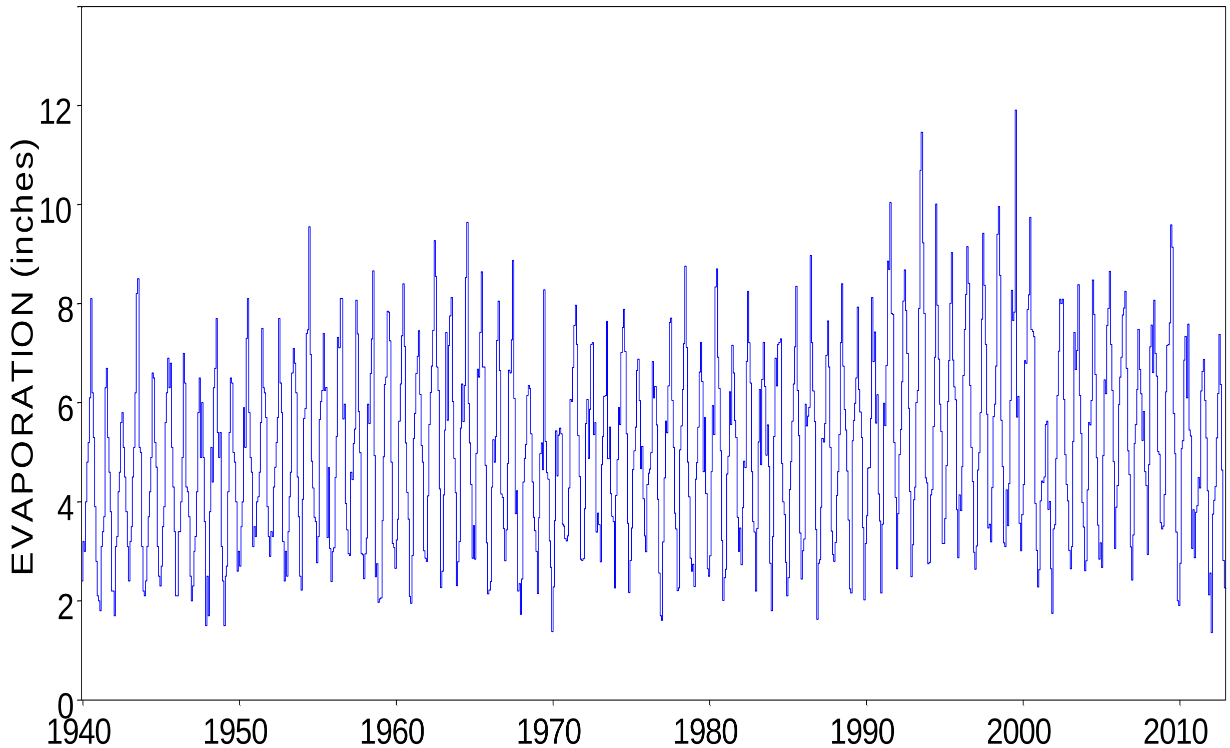
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 1108



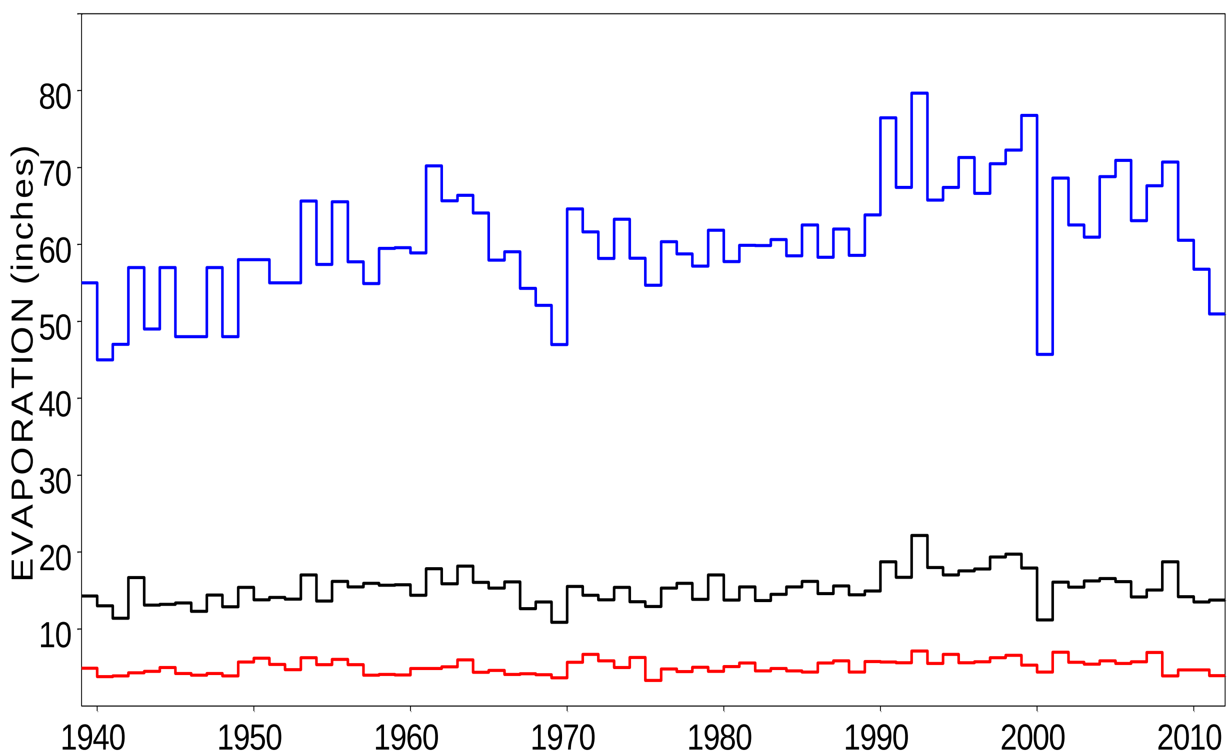
Monthly Evaporation for Quadrangle 1109



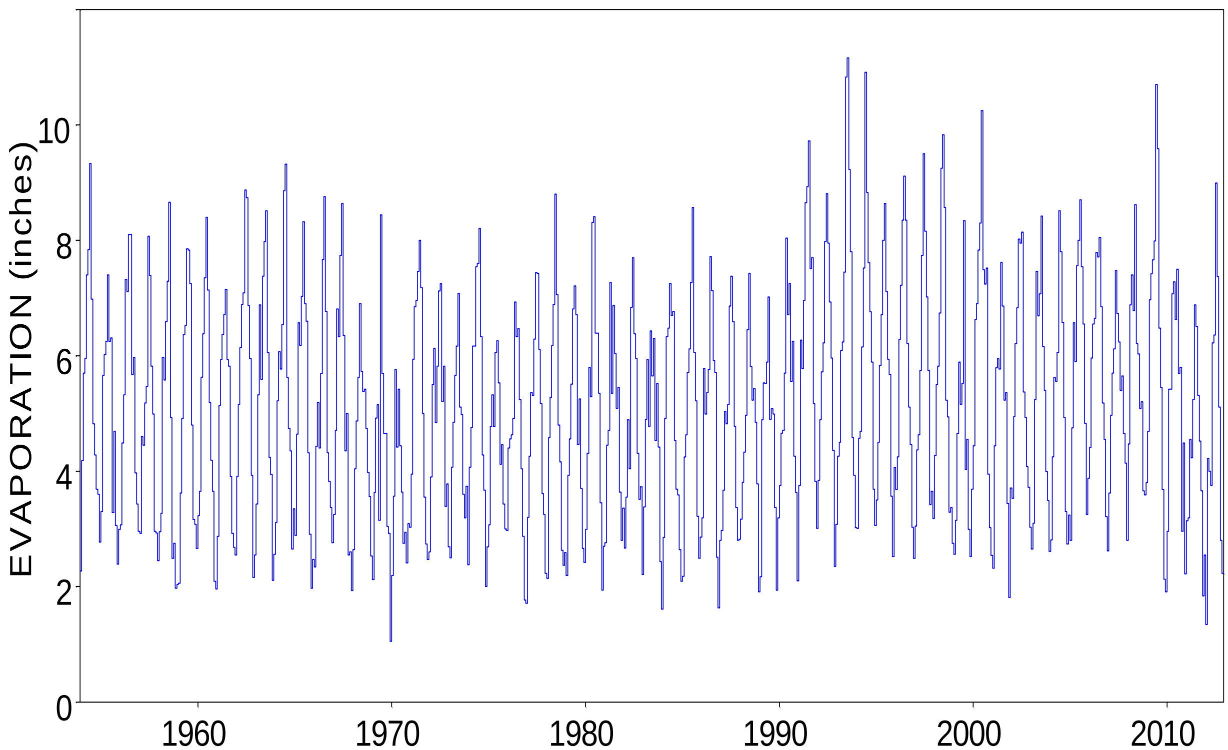
Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 1109



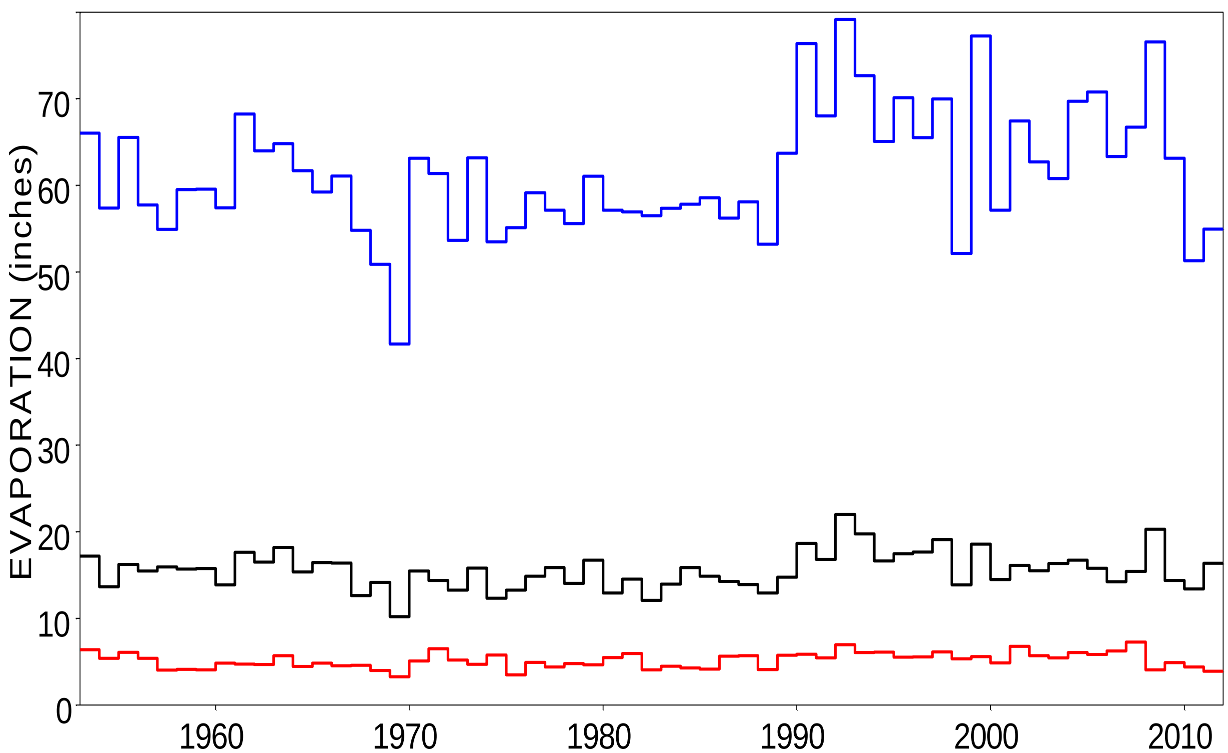
Monthly Evaporation for Quadrangle 1110



Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 1110



Monthly Evaporation for Quadrangle 1210



Annual Total, 2-Month Maximum, and 2-Month Minimum Evaporation for Quadrangles 1210

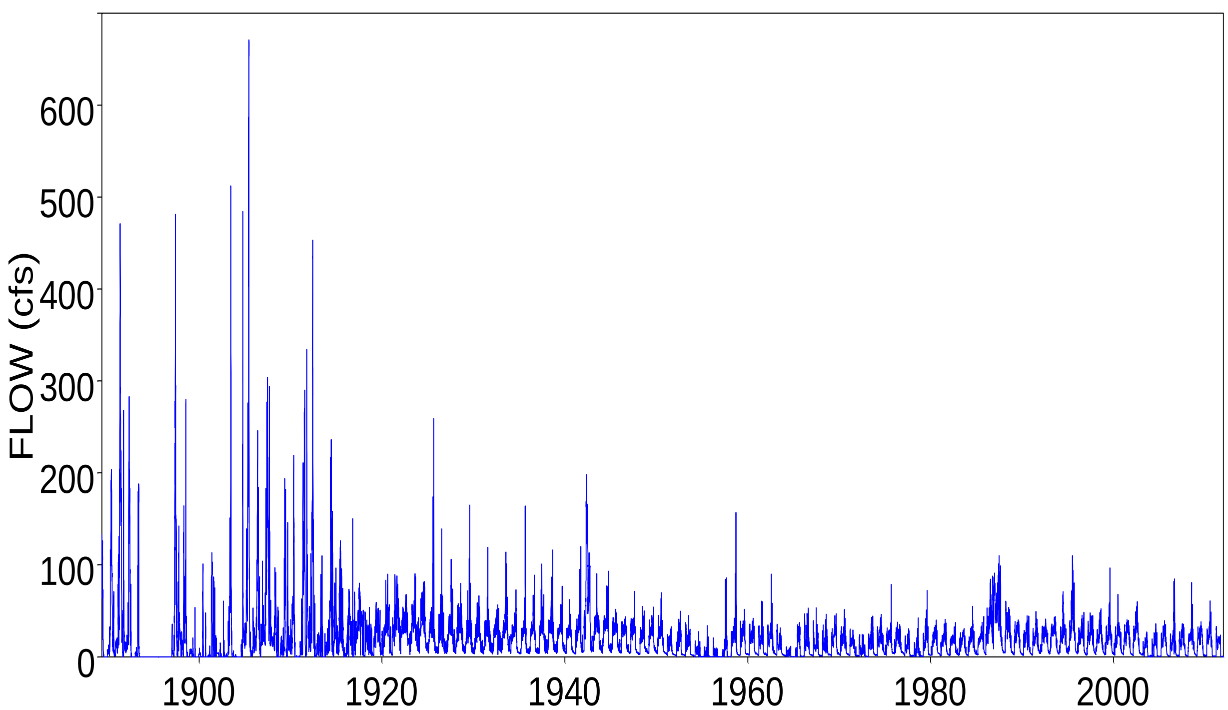
1
Rio Grande at El Paso

IBWC gage 08-3640.00
El Paso County, Texas
Latitude 31°48'10", Longitude 106°32'25"
Gage datum 1,134.6 feet above msl

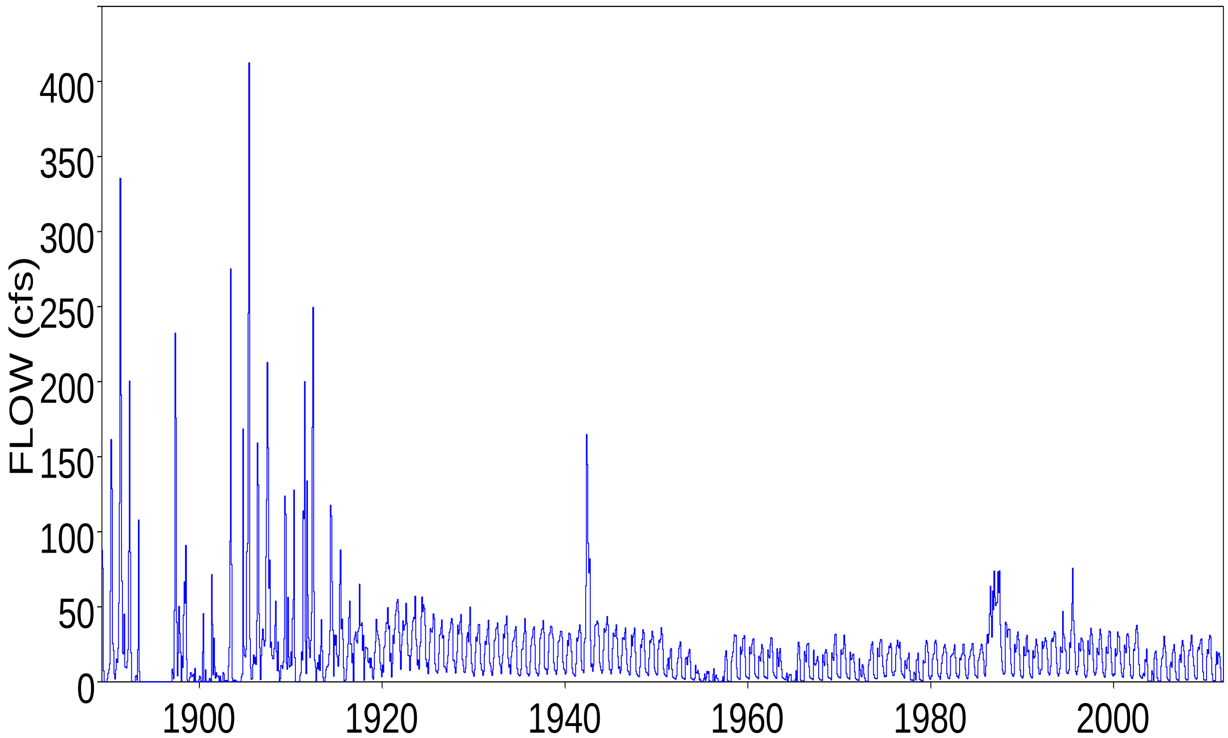
This gage is located on the Rio Grande 1,256 river miles above its outlet at the Gulf of Mexico, 5.5 miles above the del Norte Bridge between El Paso and Juarez, and 1.7 miles above the American Dam at El Paso.

Elephant Butte Reservoir on the Rio Grande 125 miles upstream of El Paso accounts for most of the conservation storage controlling flows at this gage site. With a storage capacity of 2,065,000 acre-feet, this is the largest reservoir in New Mexico. Elephant Butte Reservoir is operated by the U.S. Bureau of Reclamation primarily to supply irrigation. Initial impoundment was in 1915.

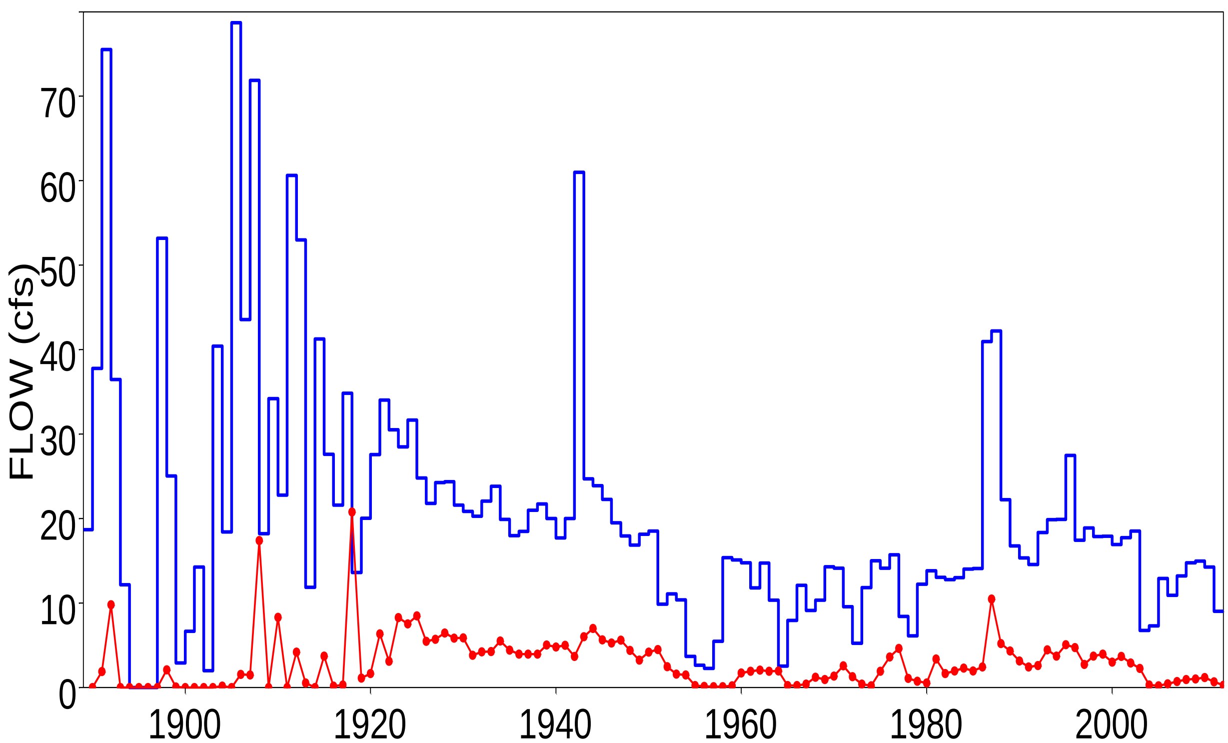
Period-of-record of daily flows: 1889/5/10 to 2011/12/31



Daily Flows of Rio Grande at El Paso



Monthly Flows of Rio Grande at El Paso



Annual Flows and the Minimum Monthly Flow Each Year

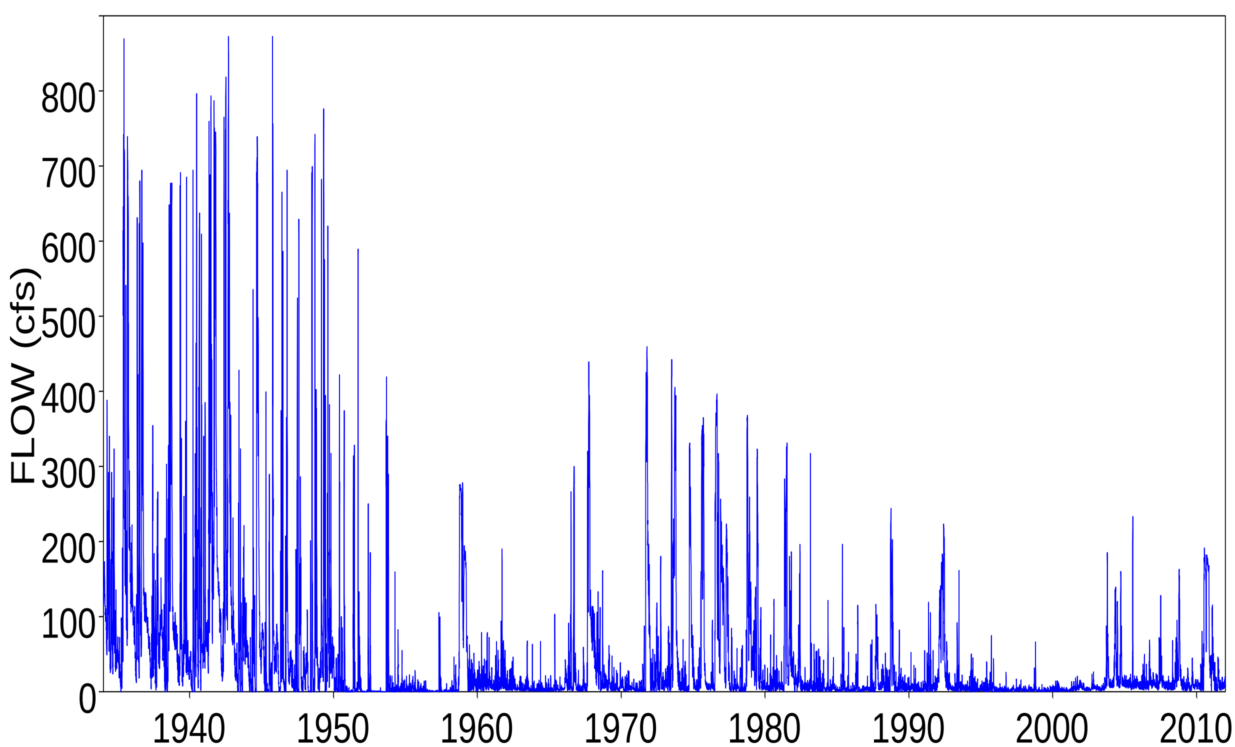
2
Rio Grande at Brownsville

IBWC gage 08-4750.00
Cameron County, Texas
Drainage area 356,000 square miles
Contributing drainage area 176,000 square miles

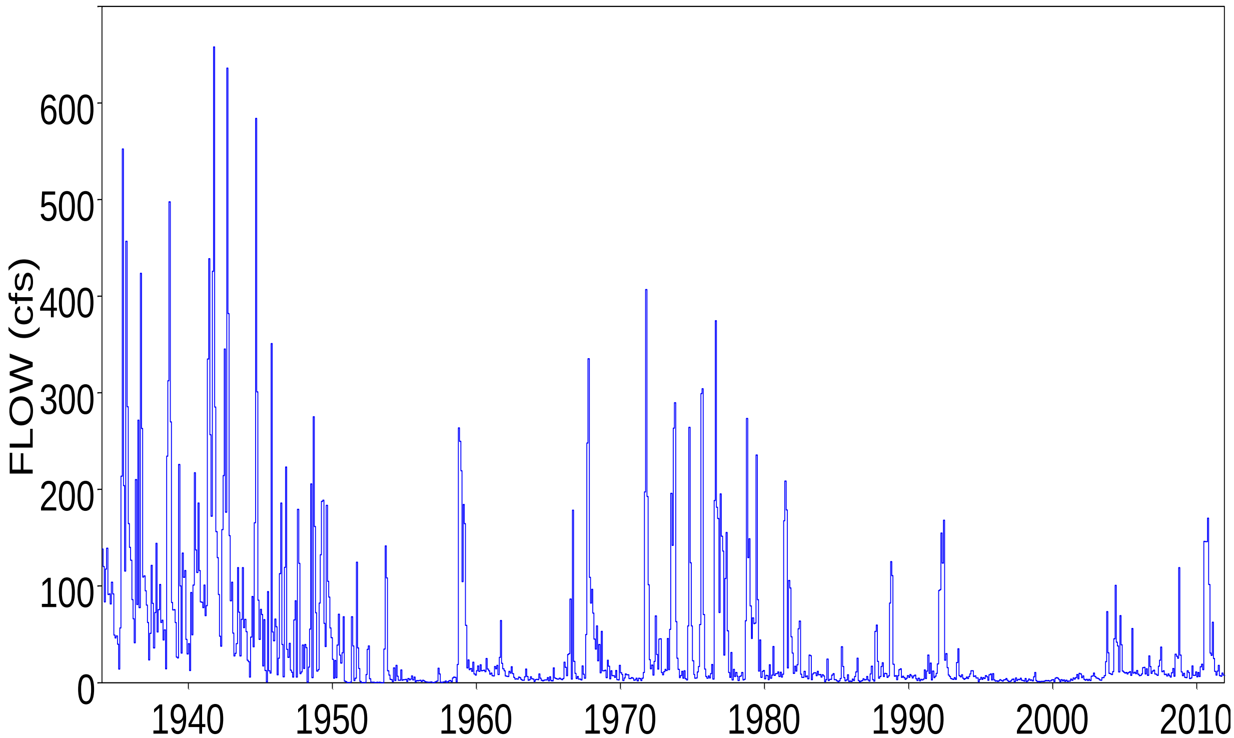
Latitude 25°52'33", Longitude 97°27'18"
Gage datum is at mean sea level.

This gage is located on the Rio Grande 49 river miles above the river outlet at the Gulf of Mexico, 0.2 mile downstream of El Jardin pumping plant, 7 miles downstream of the international bridge between Brownsville, Texas and Matamoros, Tamaulipas, and 226 miles below Falcon Dam. Flows of the Lower Rio Grande are regulated by International Falcon and Amistad Reservoirs. Falcon and Amistad Dams at river miles 275 and 574 on the Rio Grande have conservation storage capacities of 2,654,000 and 3,151,000 acre-feet and flood control capacities of 510,000 and 2,654,000 acre-feet. The projects are operated by the International Boundary and Water Commission (IBWC) for water supply, hydropower, and flood control. Initial impoundment of Falcon and Amistad Reservoirs occurred in 1953 and 1969.

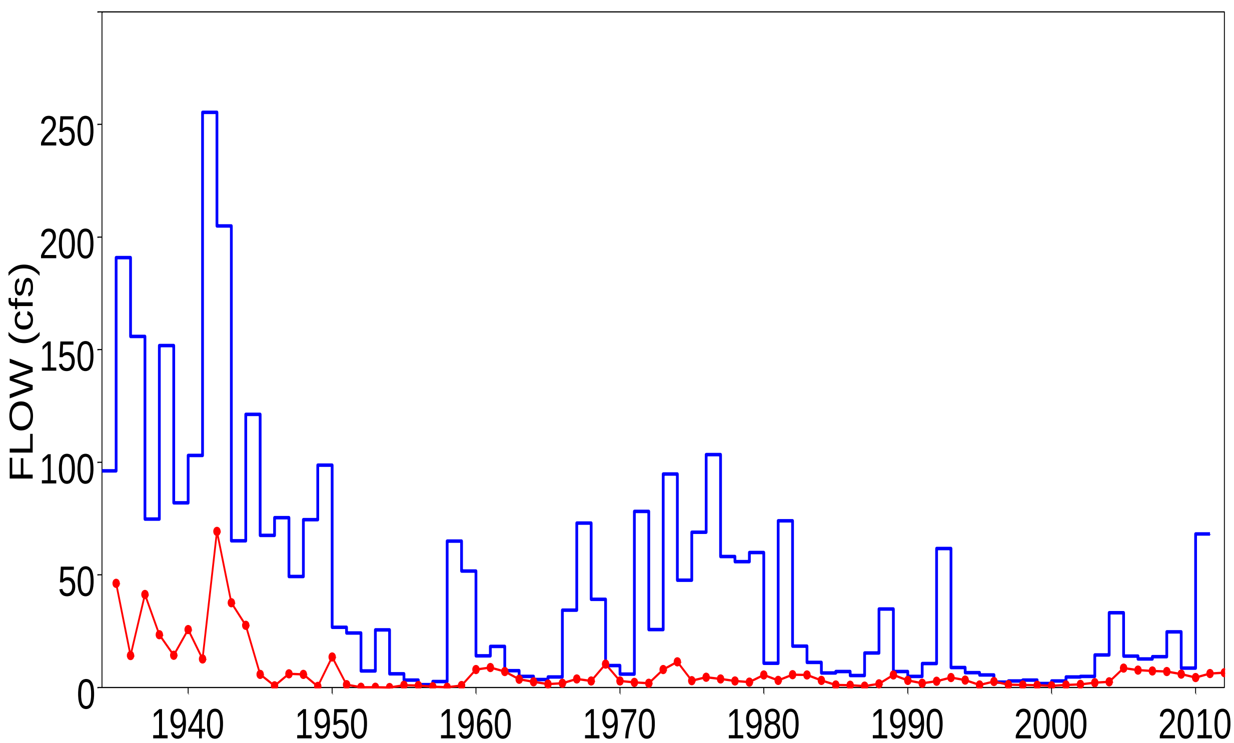
Period-of-record of daily flows: 1933/5/10 to 2011/12/31



Daily Flows of Rio Grande at Brownsville



Monthly Flows of Rio Grande at Brownsville



Annual Flows and the Minimum Monthly Flow Each Year

3
Pecos River at Orla

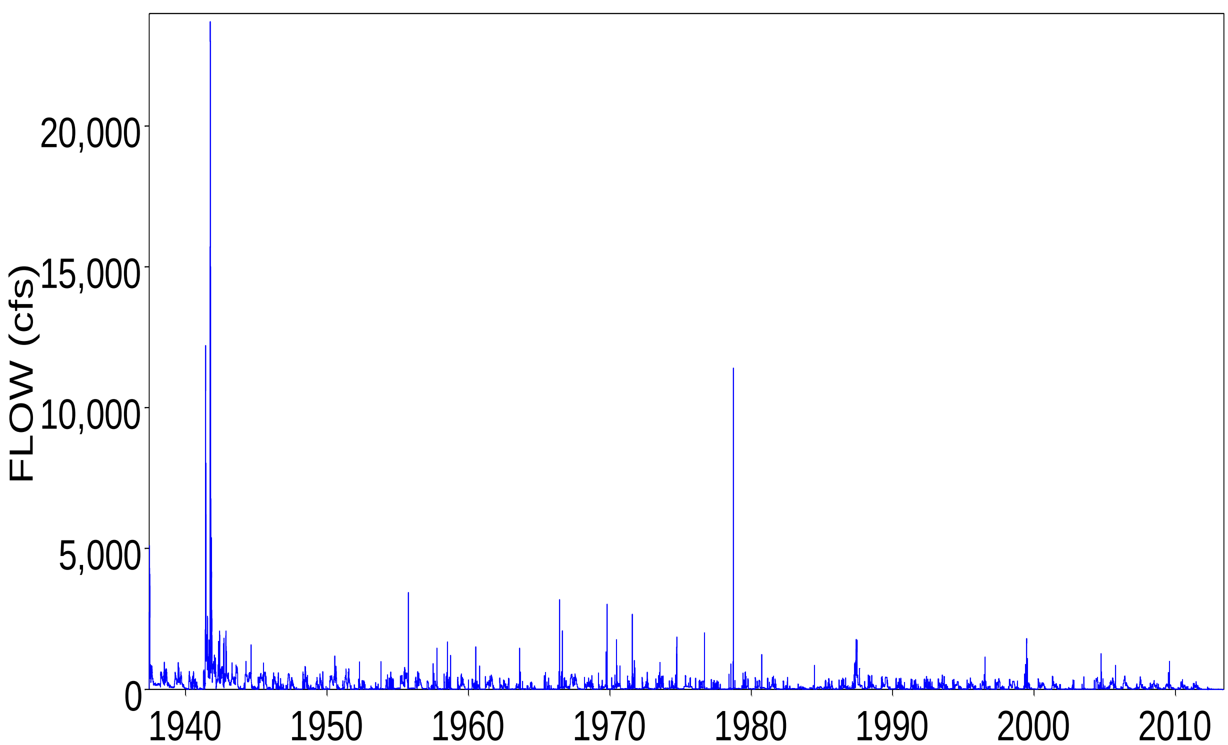
USGS 08412500
Reeves County, Texas

Drainage area 25,070 square miles
Contributing drainage area 21,229 square miles

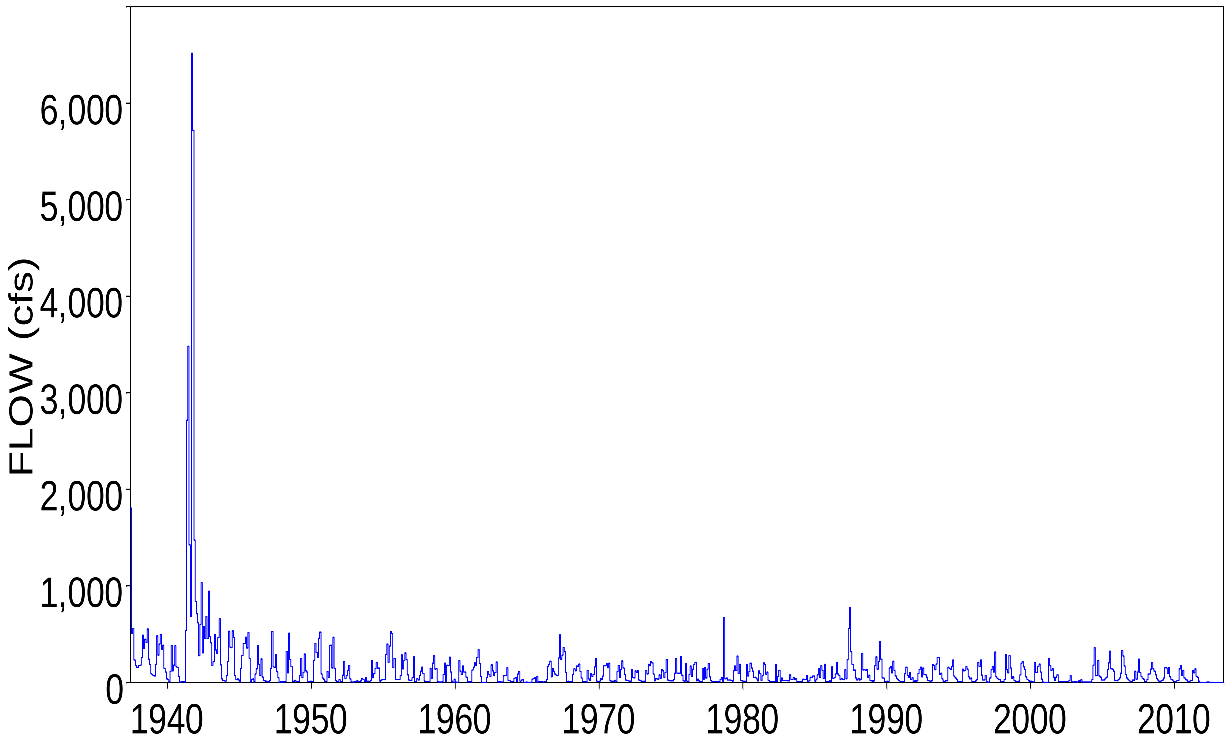
Latitude 31°52'21", Longitude 103°49'52" NAD27
Gage datum 2,730.86 feet above NGVD29

The gage is located below FM Highway 652 about ten miles below Red Bluff Dam.

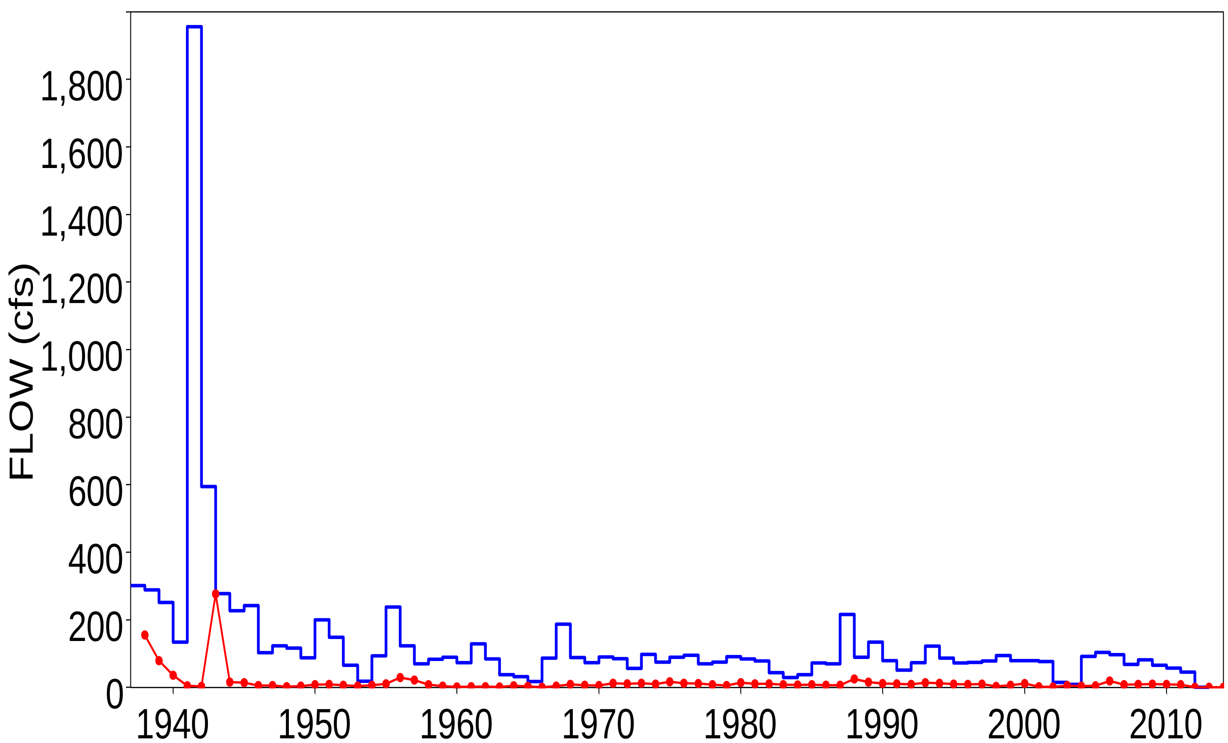
Period-of-record of daily flows: 1937/6/1 to present (2013/6/1)



Daily Flows of Pecos River at Orla



Monthly Flows of Pecos River at Orla



Annual Flows and the Minimum Monthly Flow Each Year

4
Nueces River at Three Rivers

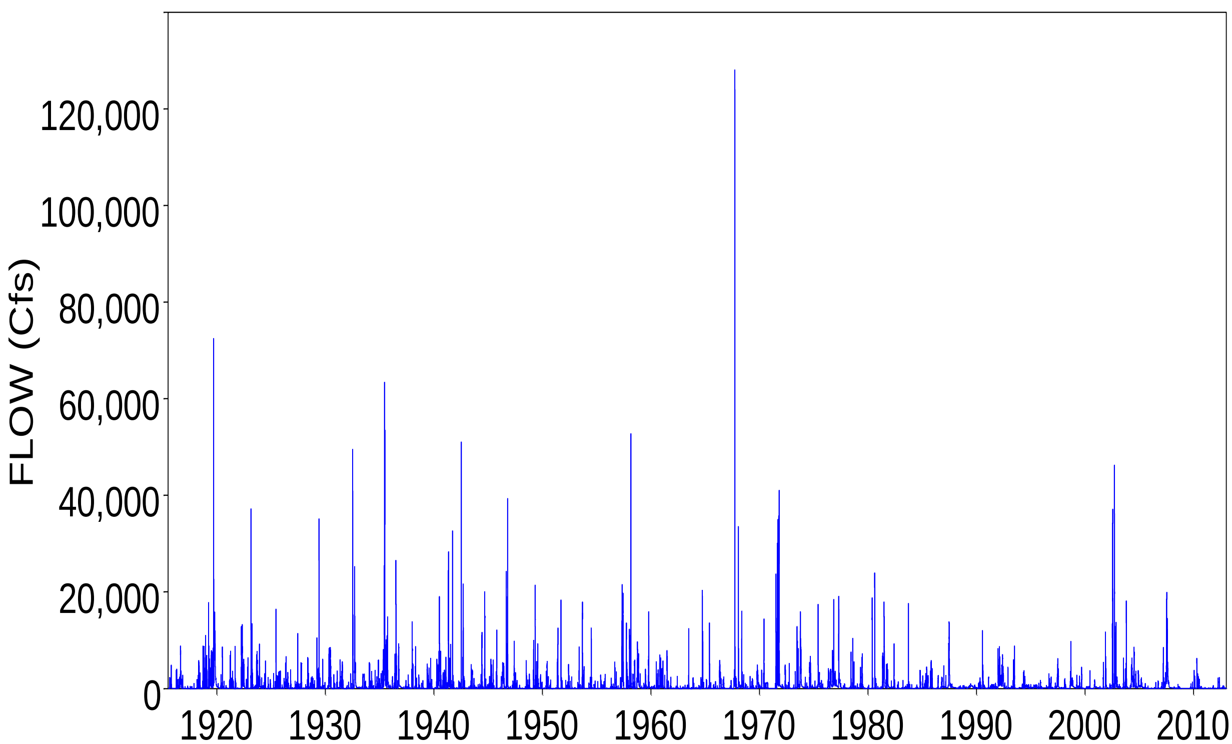
USGS 08210000
Live Oak County, Texas

Drainage area 15,427 square miles
Contributing drainage area 15,427 square miles

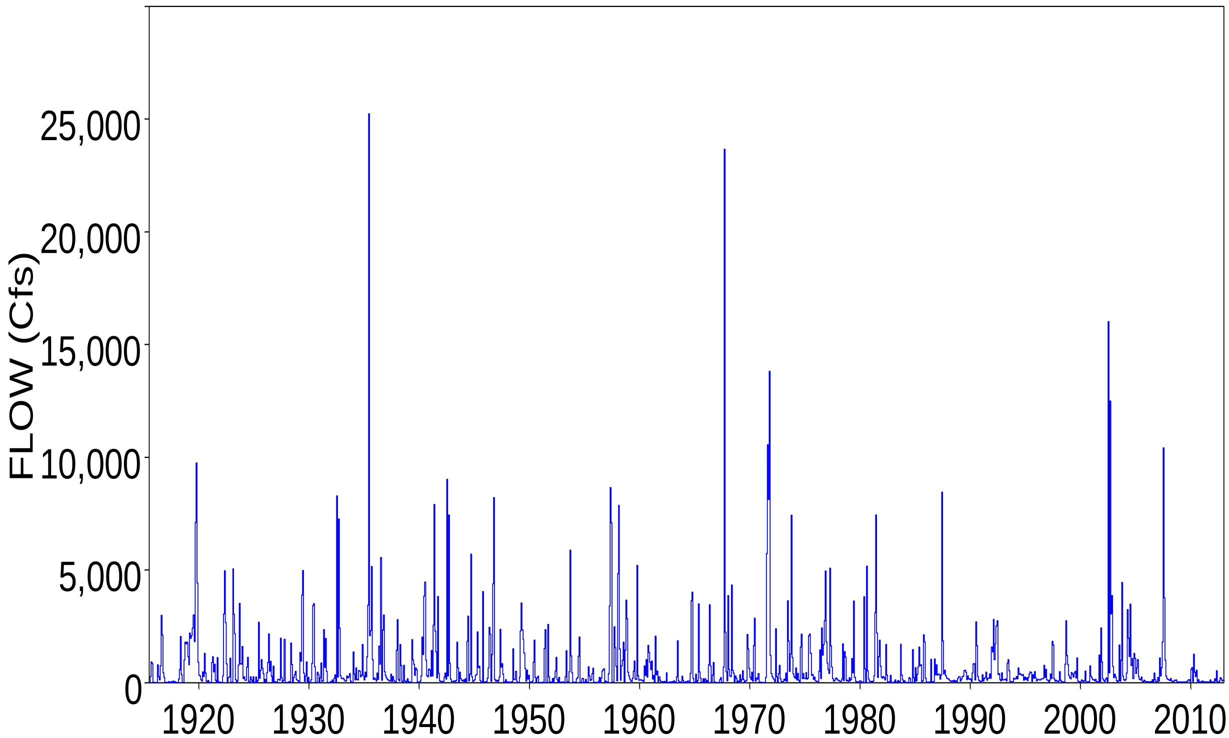
Latitude 28°25'38", Longitude 98°10'40" NAD27
Gage datum 99.26 feet above NGVD29

The gage on the Nueces River is just below the Frio River confluence south (downstream) of the city of Three Rivers. Choke Canyon Reservoir is located upstream of Three Rivers.

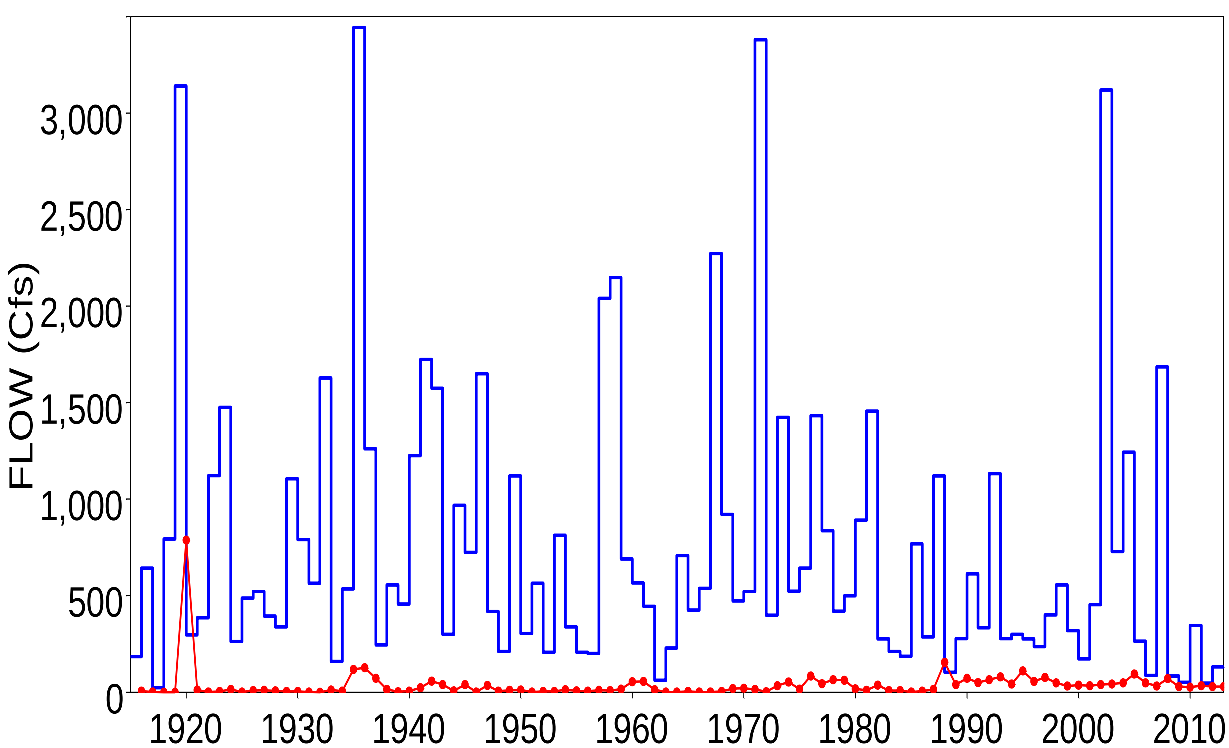
Period-of-record of daily flows: 1915/7/01 to present (2012/12/31)



Daily Flows of the Nueces River at Three Rivers



Monthly Flows of the Nueces River at Three Rivers



Annual Flows and the Minimum Monthly Flow Each Year

5
Nueces River at Mathis

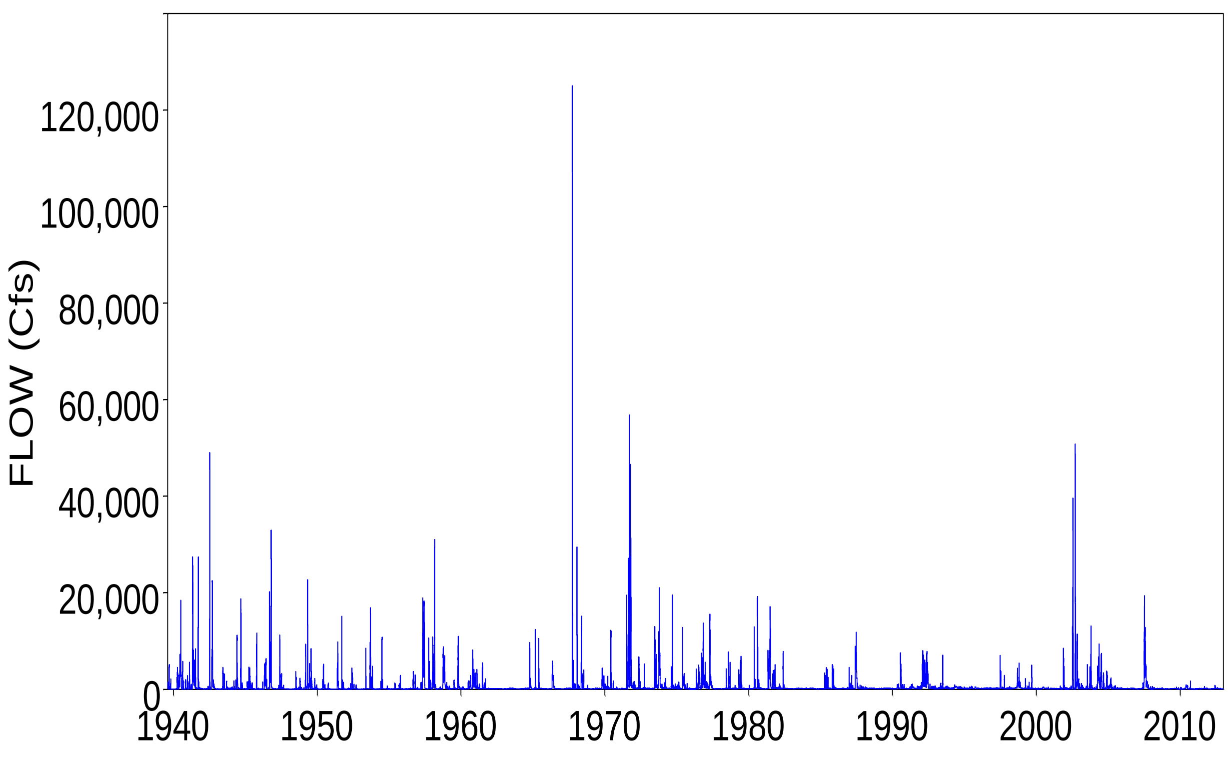
USGS 08211000
San Patricio County, Texas

Drainage area 16,503 square miles
Contributing drainage area 16,503 square miles

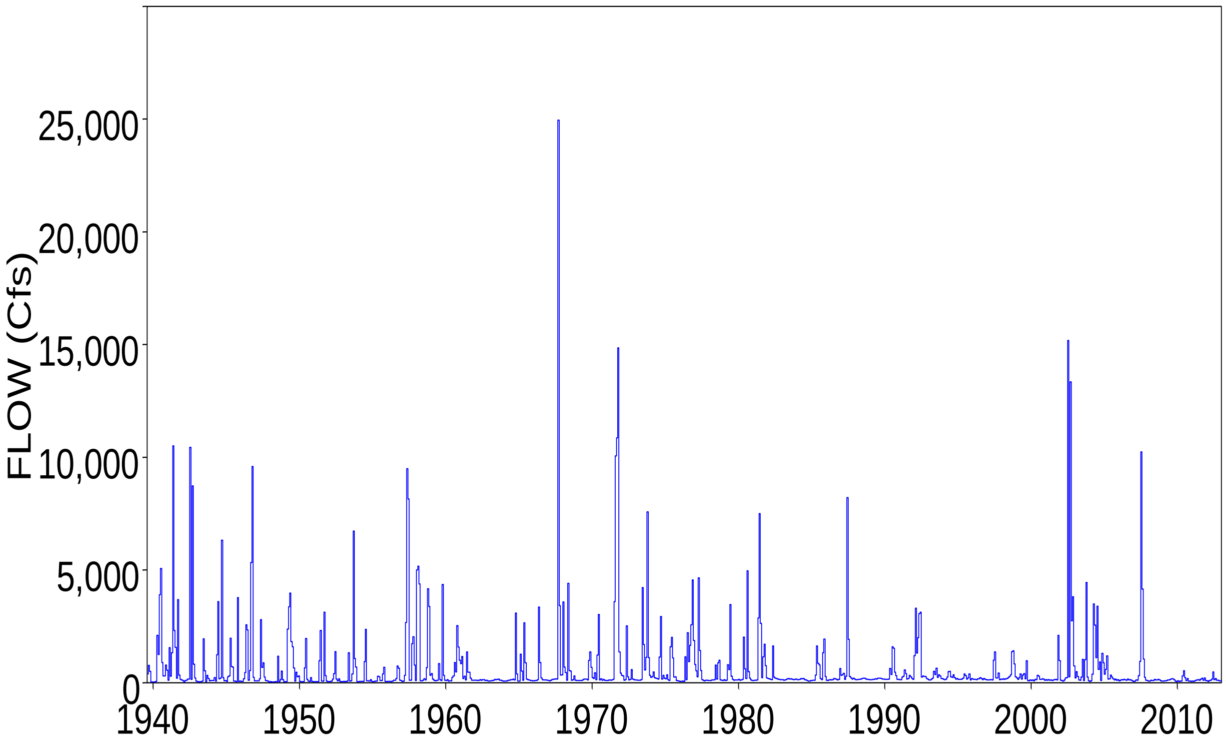
Latitude 28°02'17", Longitude 97°51'36" NAD27
Gage datum 26.53 feet above NGVD29

The gage is below Hwy 359 about a half mile below Mathis Dam and Lake Corpus Christi.

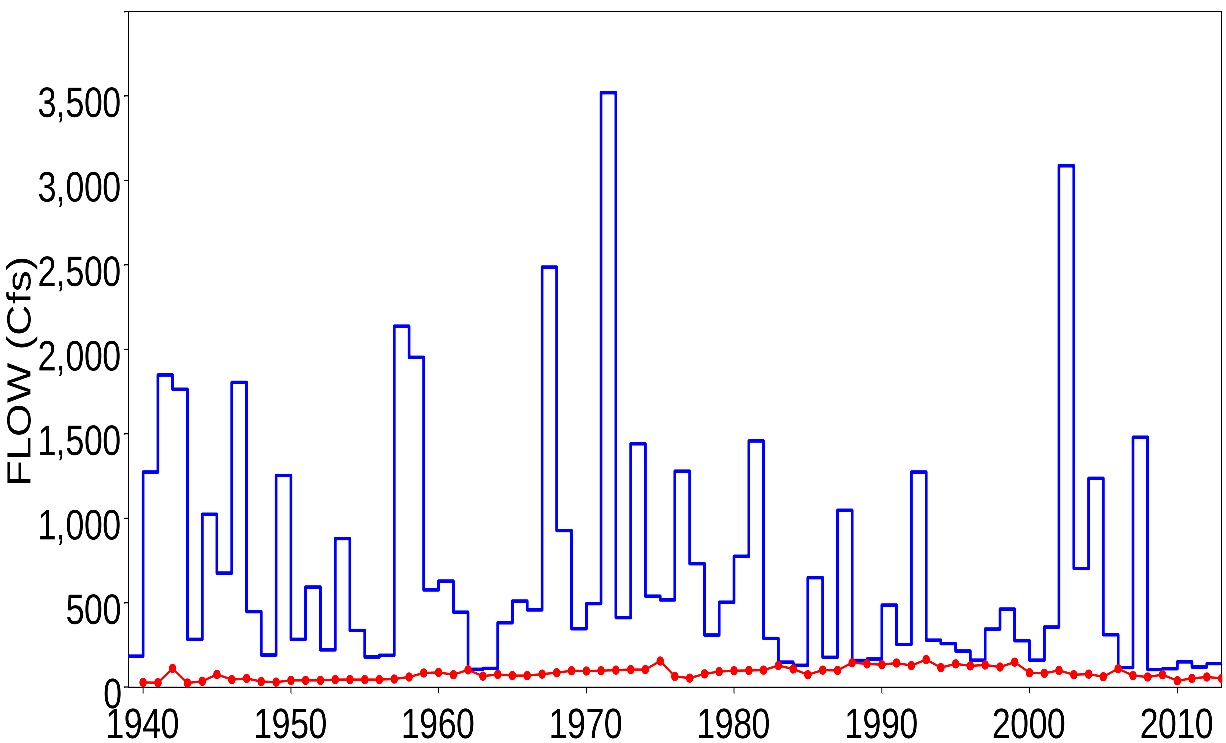
Period-of-record of daily flows: 1939/8/01 to present (2012/12/31)



Daily Flows of the Nueces River at Mathis



Monthly Flows of the Nueces River at Mathis



Annual Flows and the Minimum Monthly Flow Each Year

6
San Antonio River at Falls City

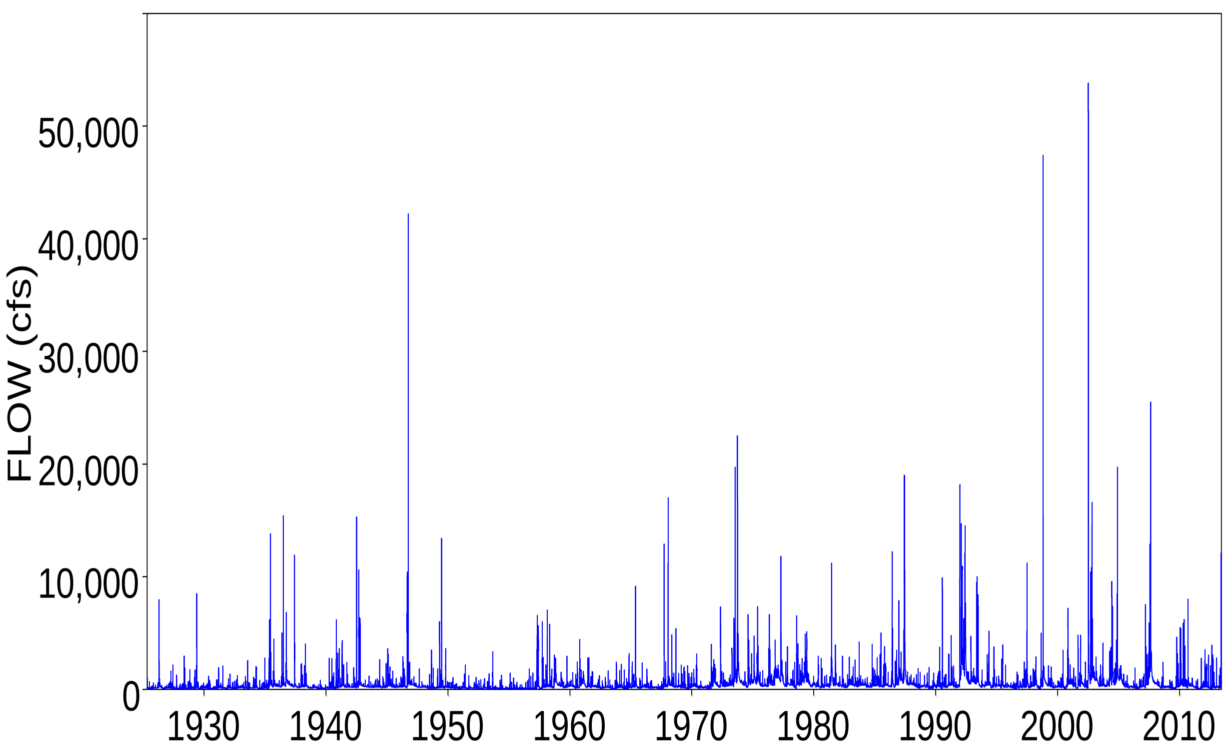
USGS 08183500
Karnes County, Texas

Drainage area 2,113 square miles
Contributing drainage area 2,113 square miles

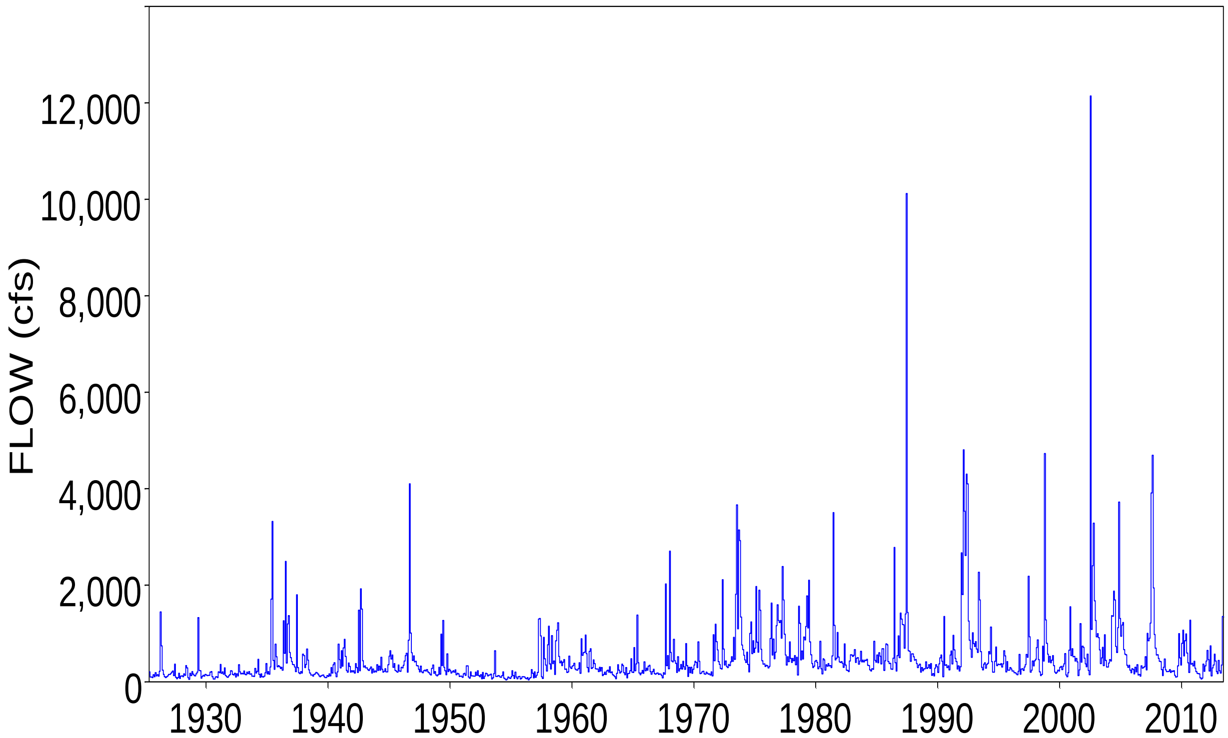
Latitude 28°57'05", Longitude 98°03'50" NAD27
Gage datum 285.49 feet above NGVD29

The gage is at FM Hwy 791 about fifty miles downstream of downtown San Antonio.

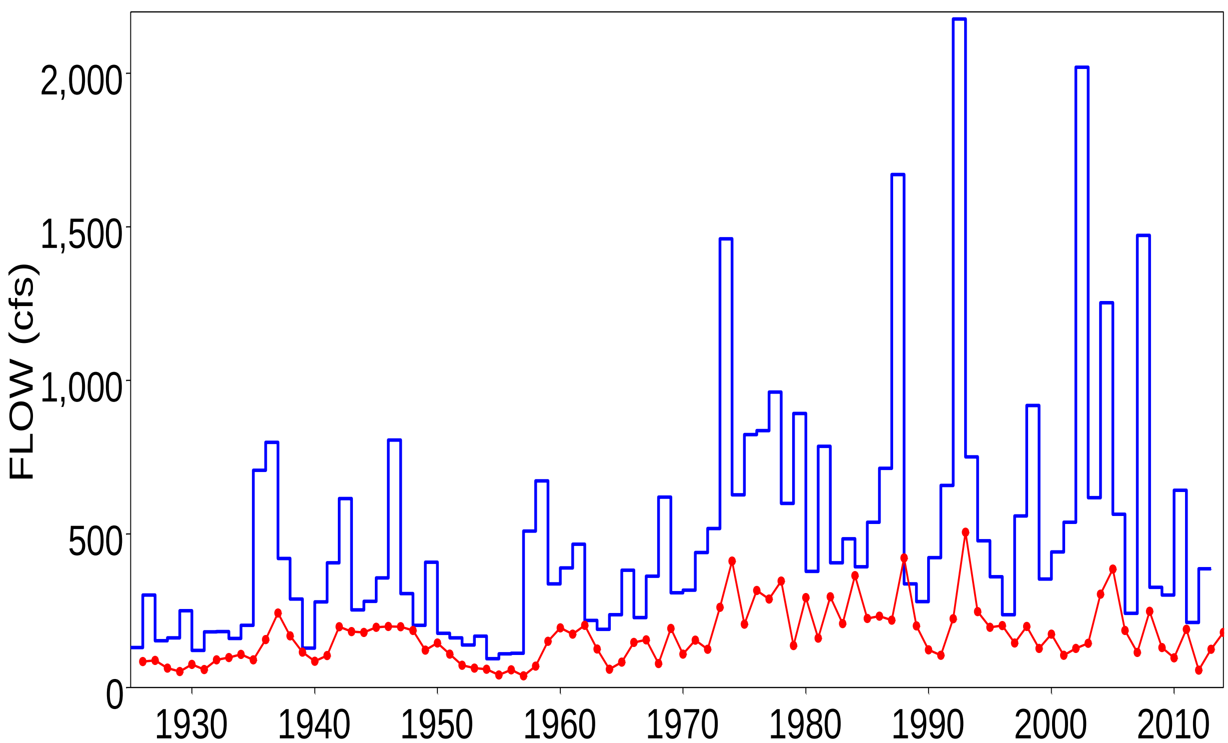
Period-of-record of daily flows: 1925/5/01 to present (2013/6/1)



Daily Flows of San Antonio River at Falls City



Monthly Flows of San Antonio River at Falls City



Annual Flows and the Minimum Monthly Flow Each Year

7
San Antonio River at Goliad

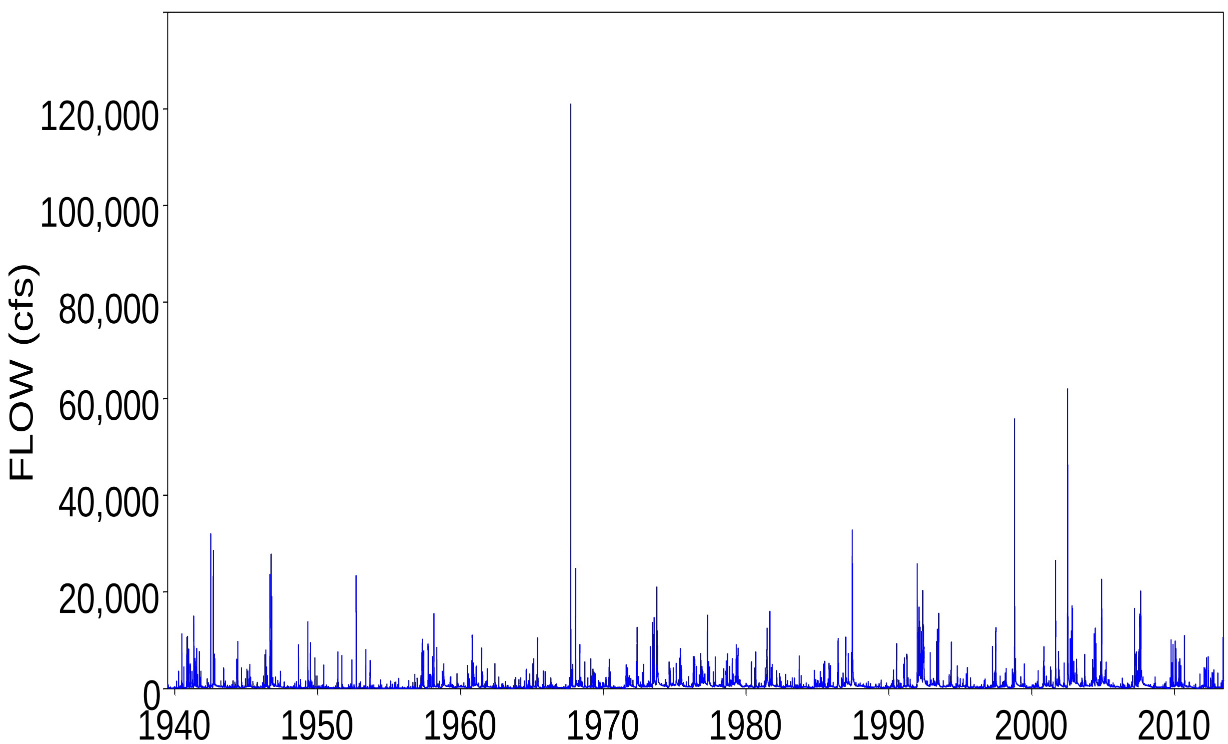
USGS 08188500
Goliad County, Texas

Drainage area 3,921 square miles
Contributing drainage area 3,921 square miles

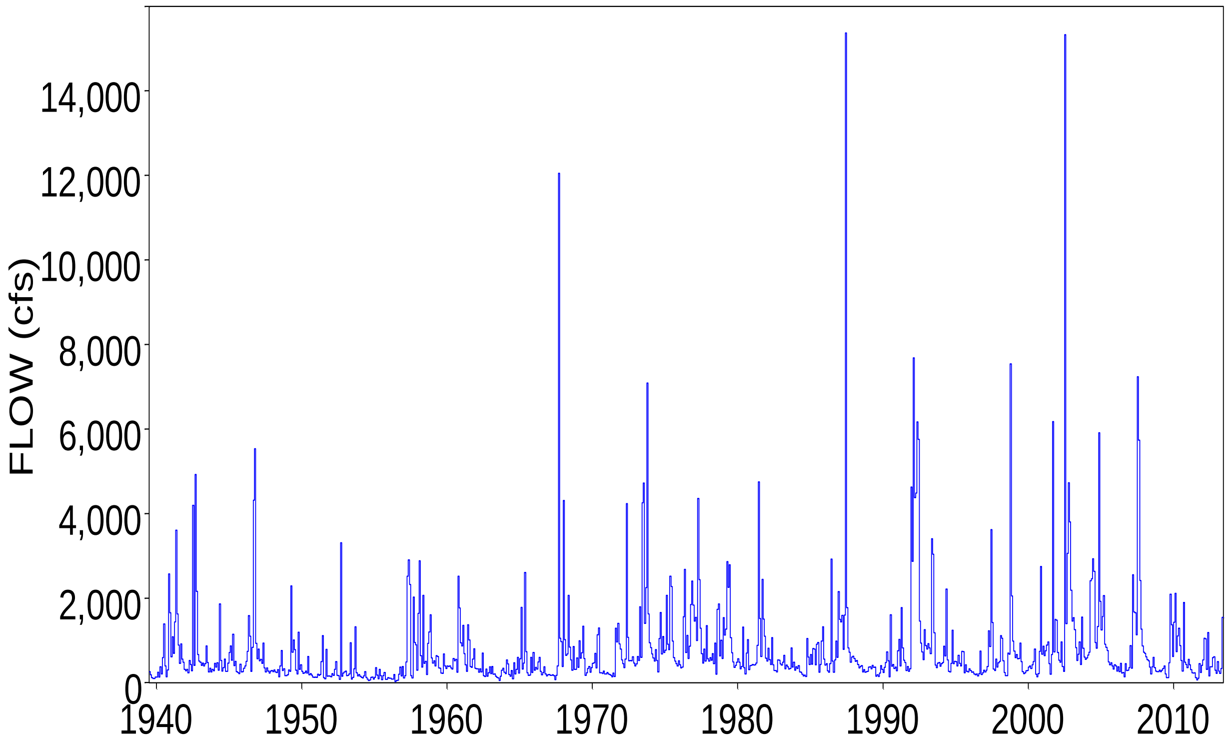
Latitude 28°38'57.43", Longitude 97°23'05.49" NAD83
Gage datum 91.08 feet above NGVD29

The gage is at Hwy 183 five miles downstream of Hwy 59 about forty miles above the confluence with the Guadalupe River.

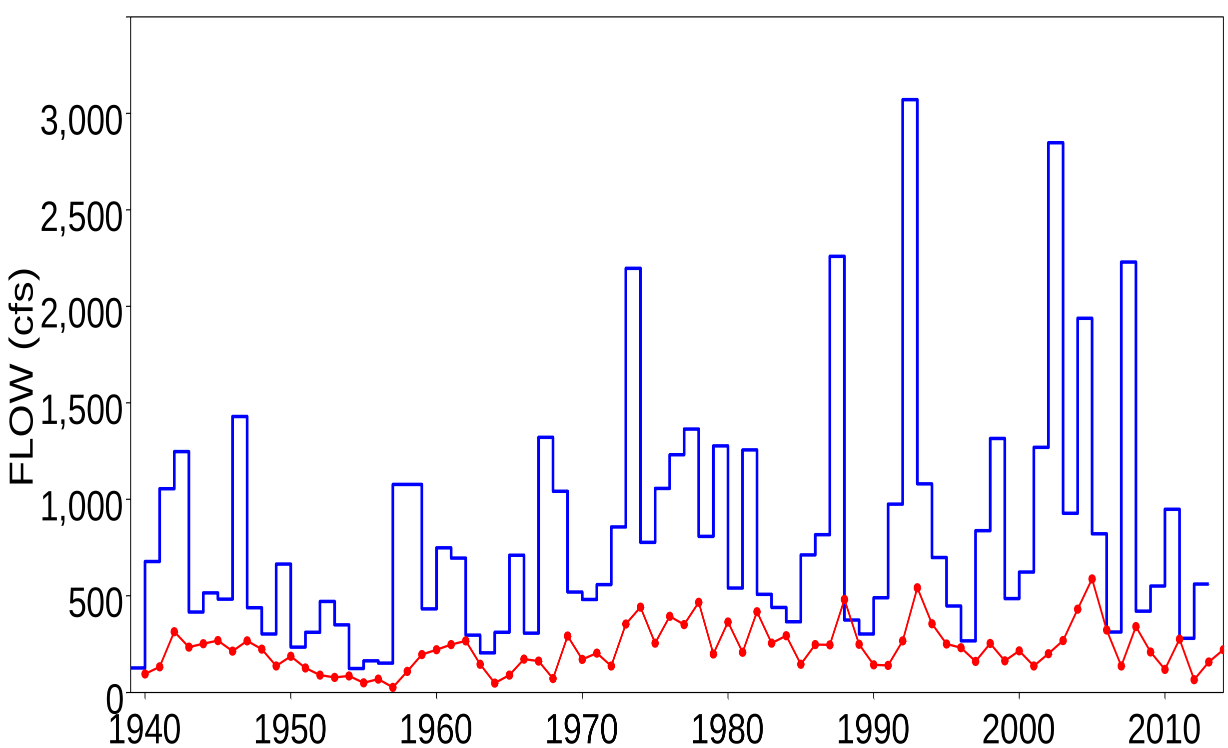
Period-of-record of daily flows: 1939/7/01 to present (2013/6/1)



Daily Flows of San Antonio River at Goliad



Monthly Flows of San Antonio River at Goliad



Annual Flows and the Minimum Monthly Flow Each Year

8
Guadalupe River at Spring Branch

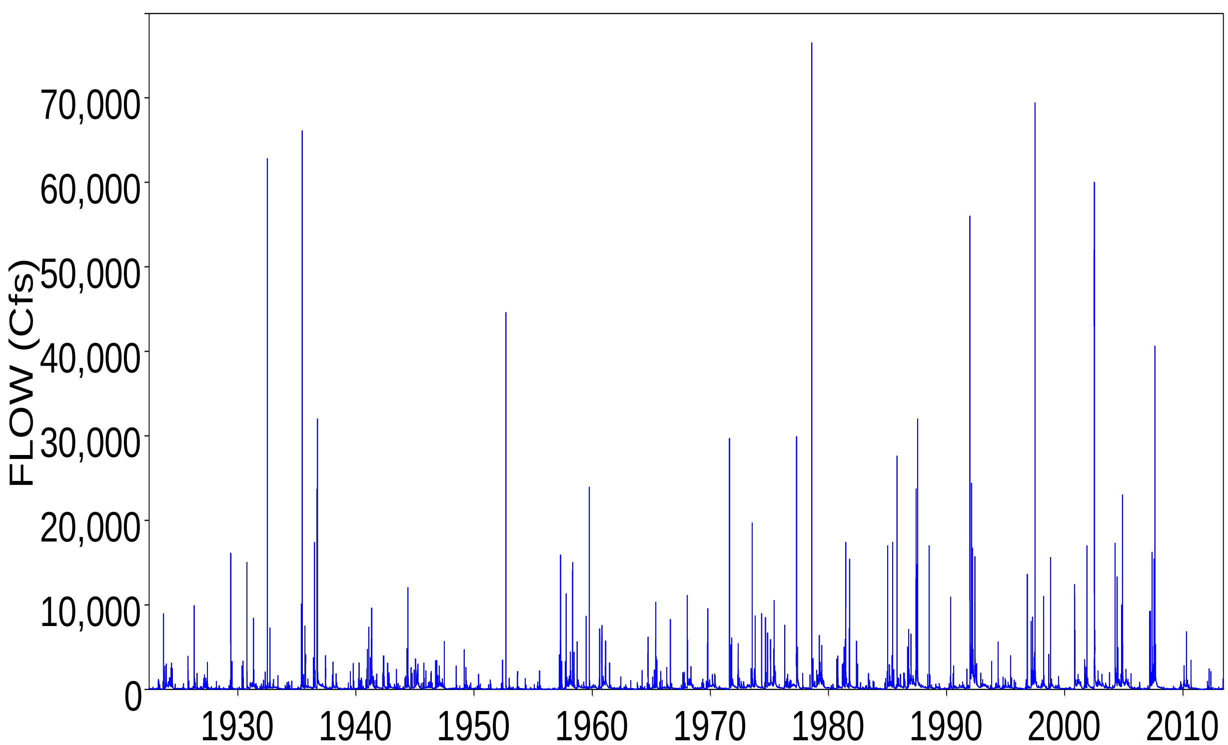
USGS 08167500
Comal County, Texas

Drainage area 1,315 square miles
Contributing drainage area 1,315 square miles

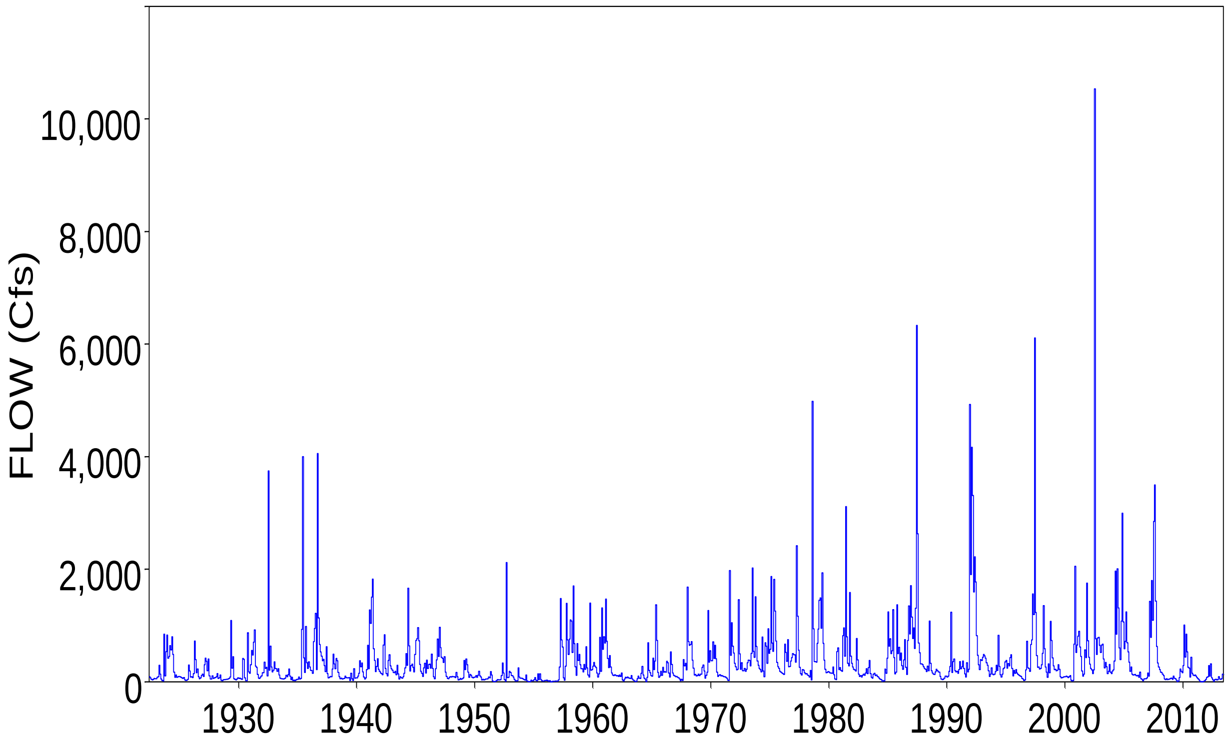
Latitude 29°51'37", Longitude 98°23'00" NAD27
Gage datum 948.10 feet above NGVD29

The gage is one mile below Hwy 281 and several miles above Canyon Lake.

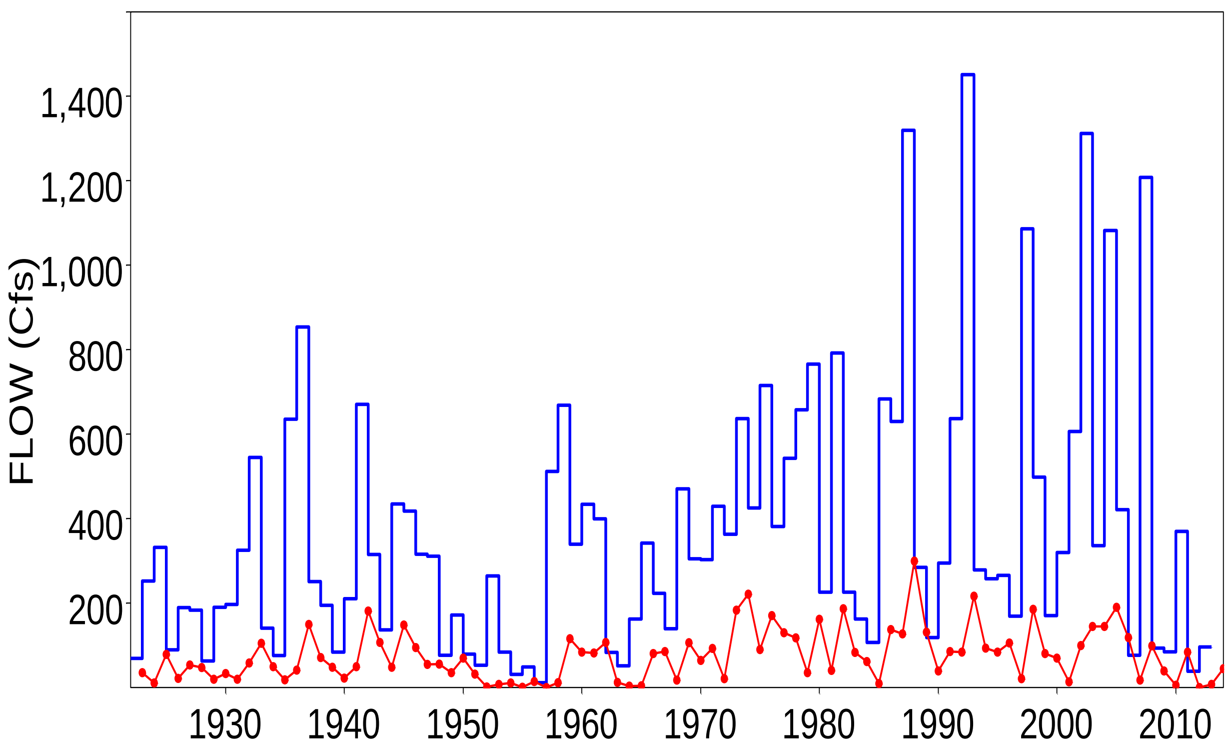
Period-of-record of daily flows: 1922/6/01 to present (2012/6/1)



Daily Flows of Guadalupe River at Spring Branch



Monthly Flows of Guadalupe River at Spring Branch



Annual Flows and the Minimum Monthly Flow Each Year

9
Guadalupe River at Victoria

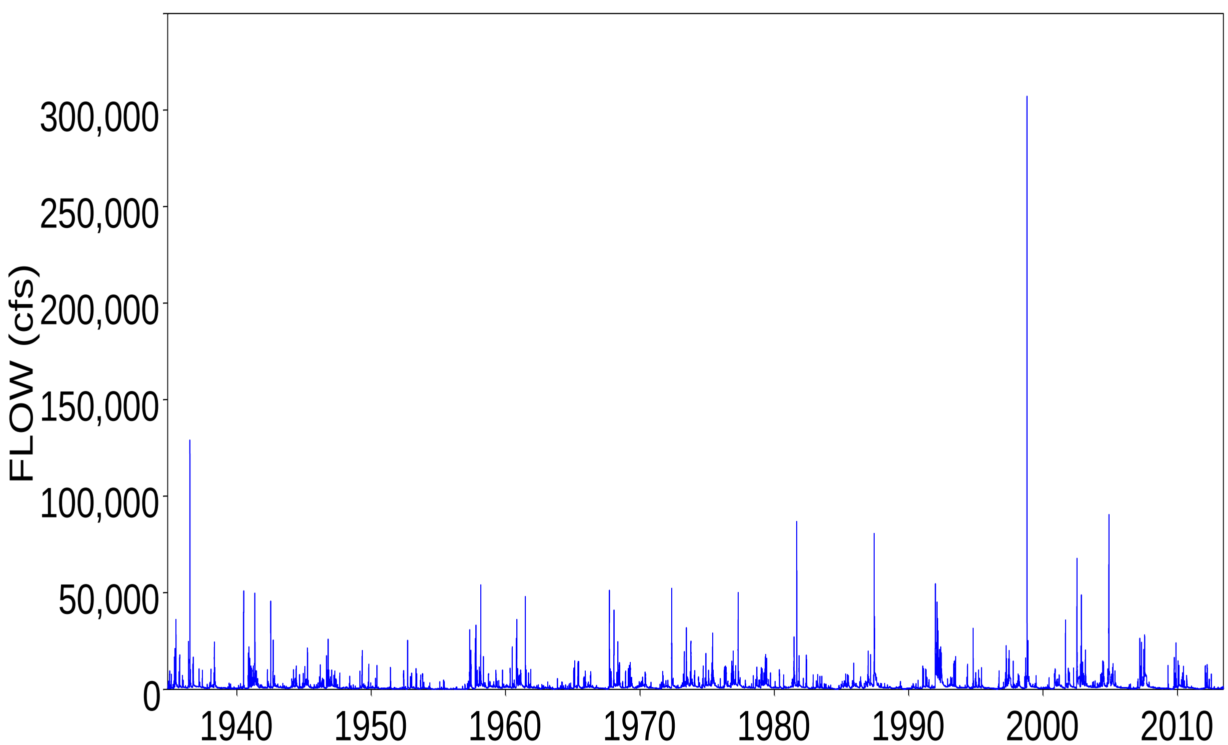
USGS 08176500
Victoria County, Texas

Drainage area 5,198 square miles
Contributing drainage area 5,198 square miles

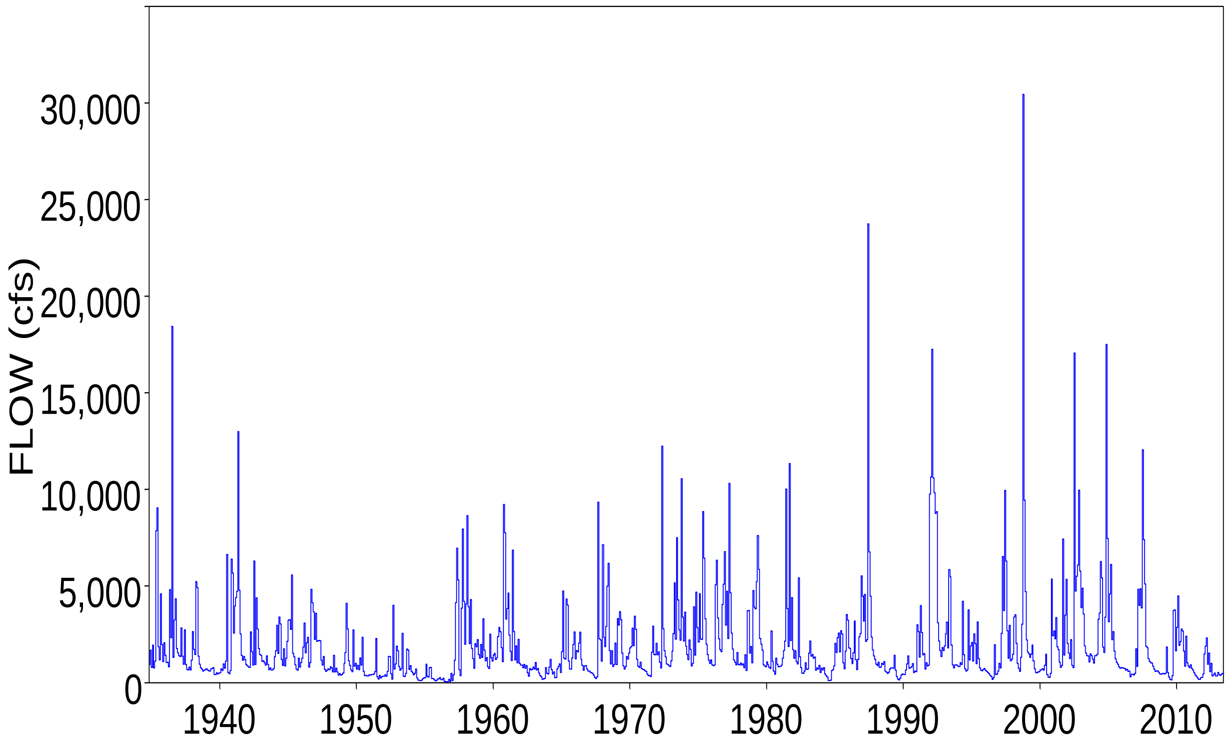
Latitude 28°47'34", Longitude 97°00'46" NAD27
Gage datum 29.15 feet above NGVD29

The gage is at Hwy 59 in Victoria thirty miles above the San Antonio River confluence.

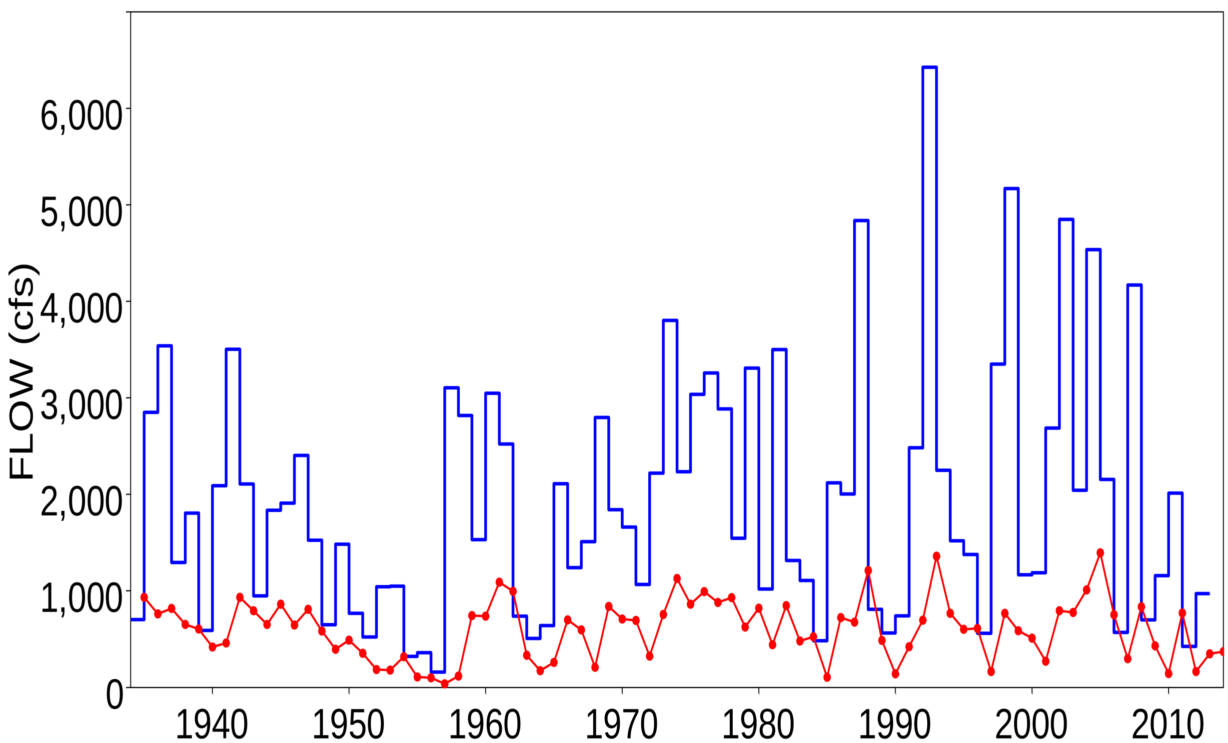
Period-of-record of daily flows: 1934/11/01 to present (2013/6/1)



Daily Flows of Guadalupe River at Victoria



Monthly Flows of Guadalupe River at Victoria



Annual Flows and the Minimum Monthly Flow Each Year

10
Lavaca River near Edna

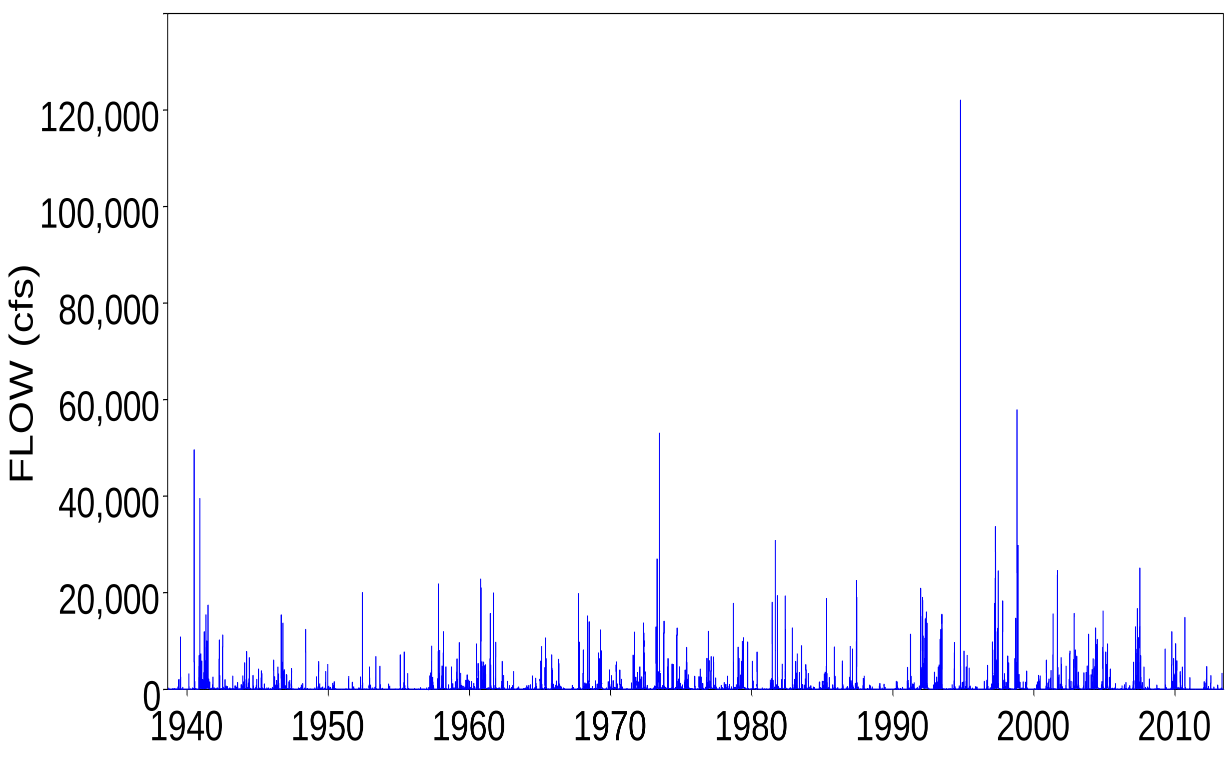
USGS 08164000
Jackson County, Texas

Drainage area 817 square miles
Contributing drainage area 817 square miles

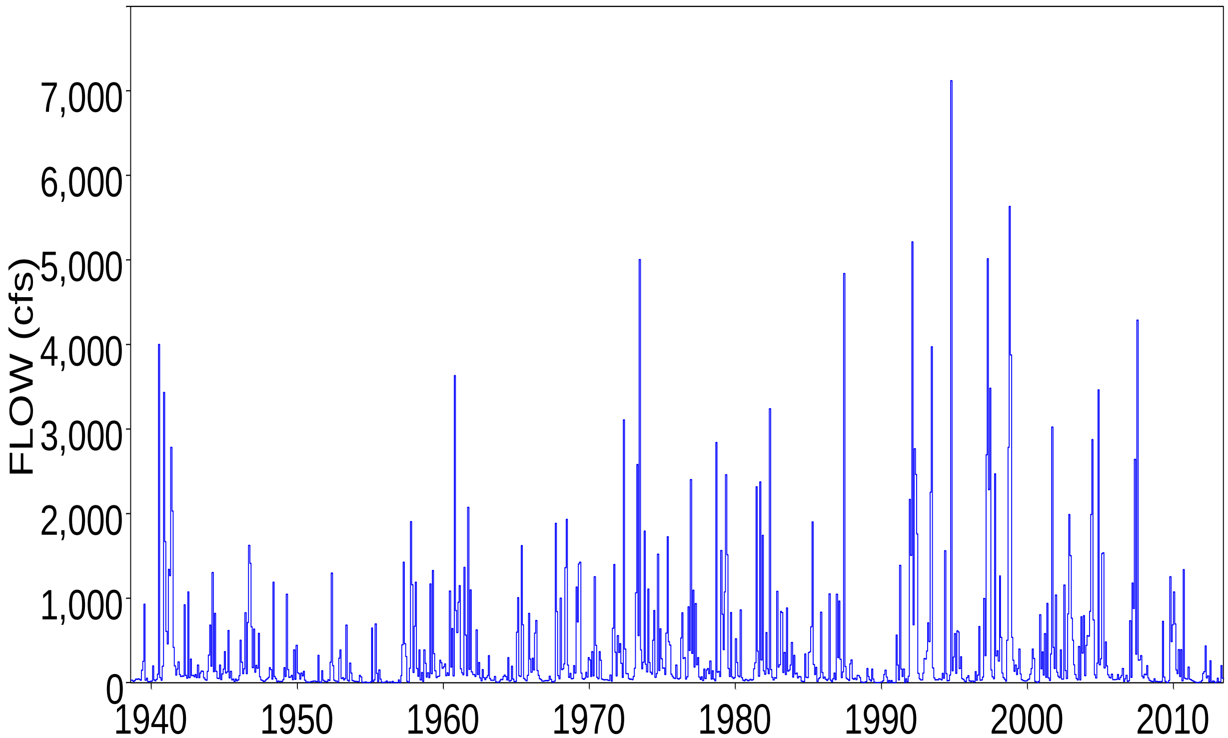
Latitude 28°57'35", Longitude 96°41'10" NAD27
Gage datum 14.10 feet above NGVD29

The gage is at Hwy 59 ten miles above the Navidad River confluence.

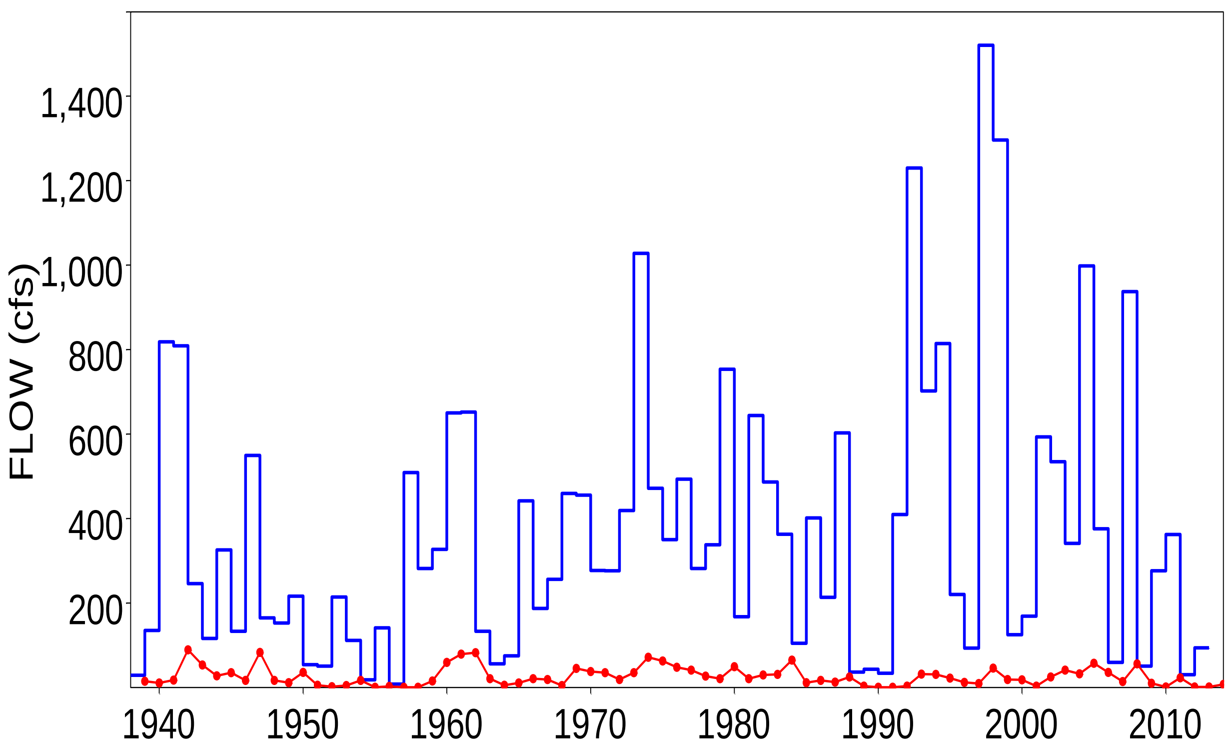
Period-of-record of daily flows: 1938/8/01 to present (2013/6/1)



Daily Flows of Lavaca River near Edna



Monthly Flows of Lavaca River near Edna



Annual Flows and the Minimum Monthly Flow Each Year

11
Colorado River near San Saba

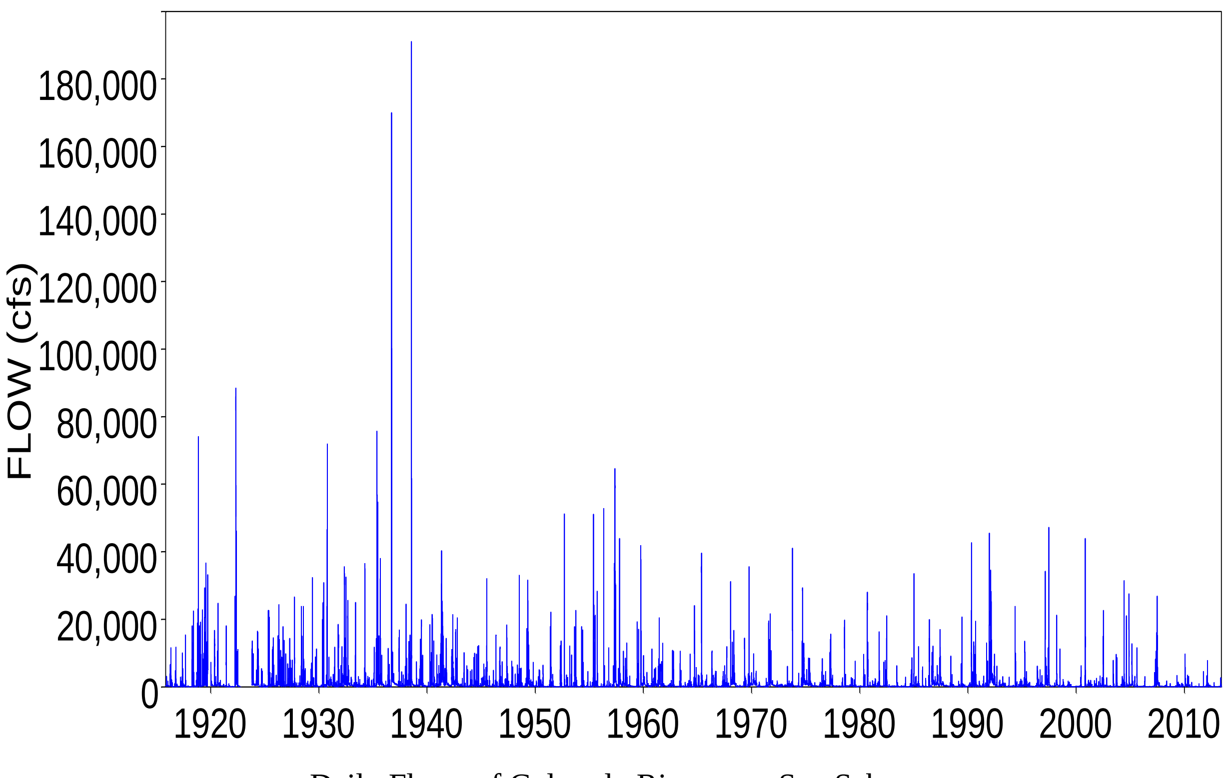
USGS 08147000
Lampasas County, Texas

Drainage area 31,217 square miles
Contributing drainage area 19,819 square miles

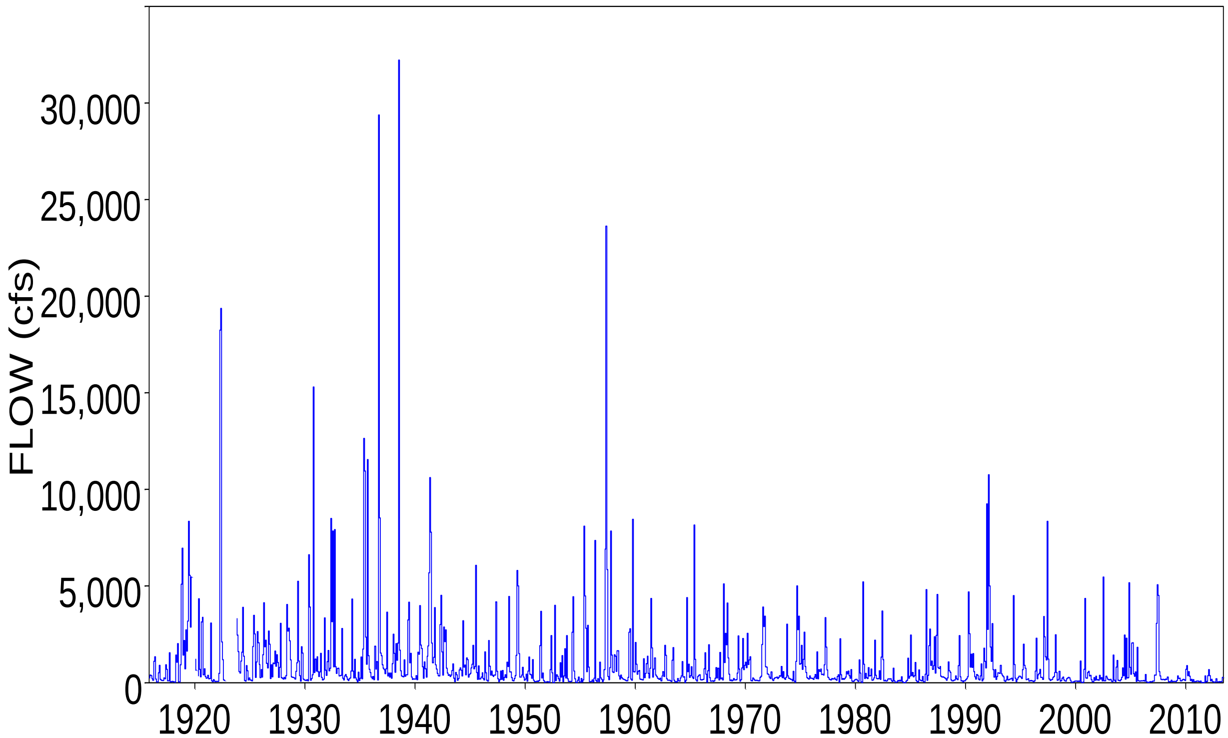
Latitude 31°13'04", Longitude 98°33'51" NAD27
Gage datum 1,096.22 feet above NGVD29

The gage is at Hwy 190 about sixty miles upstream of Buchanan Dam.

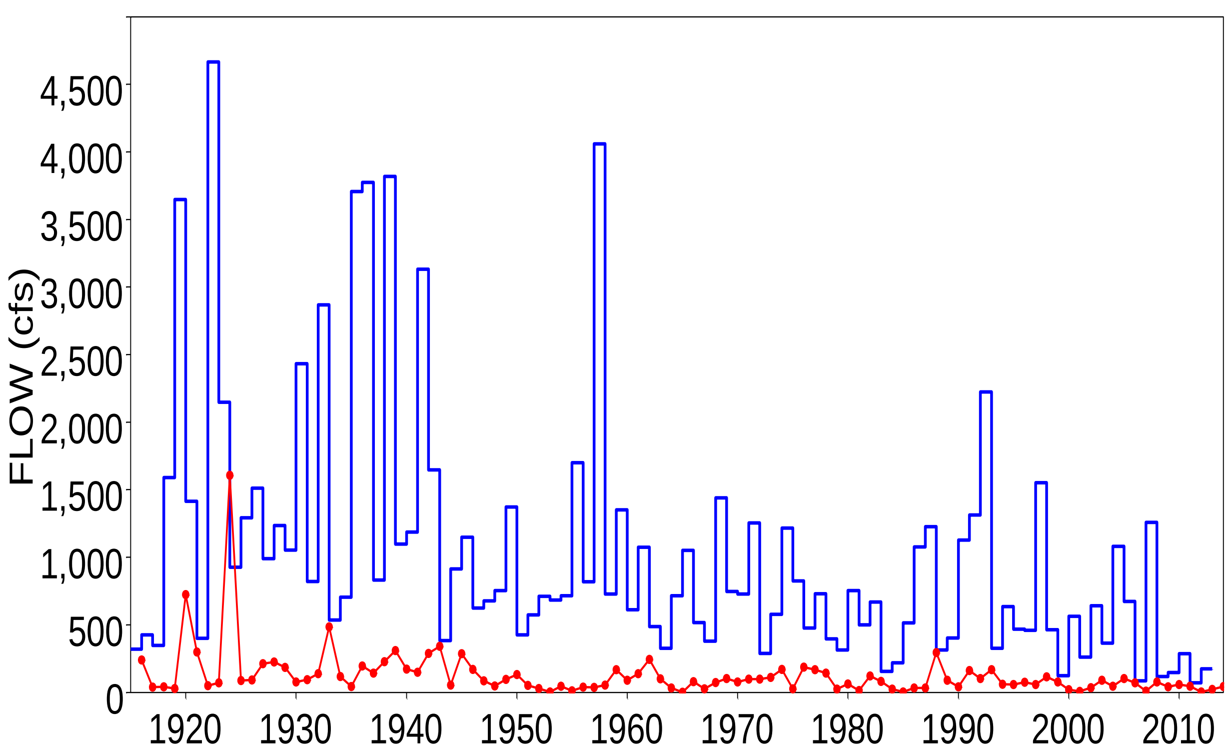
Period-of-record of daily flows: 1915/11/1 to present (2013/6/1)



Daily Flows of Colorado River near San Saba



Monthly Flows of Colorado River near San Saba



Annual Flows and the Minimum Monthly Flow Each Year

12
Colorado River at Austin

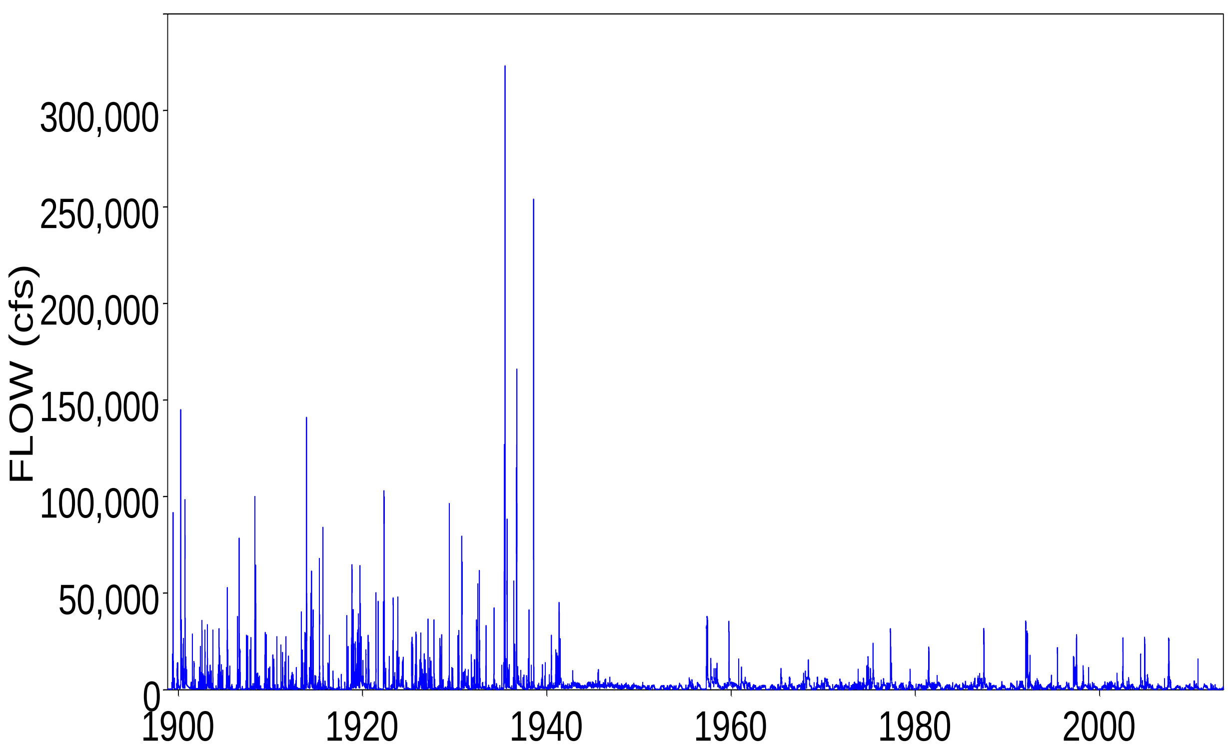
USGS 08158000
Travis County, Texas

Drainage area 39,009 square miles
Contributing drainage area 27,606 square miles

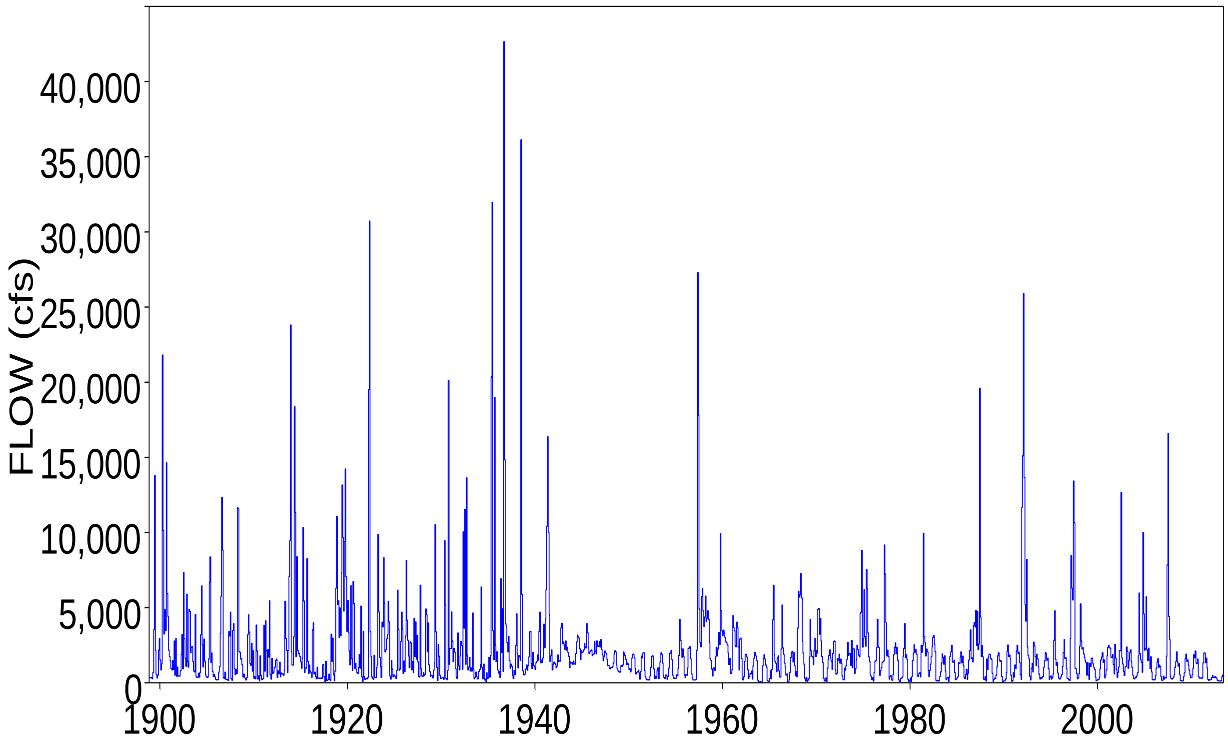
Latitude 30°14'46.1", Longitude 97°40'48.2" NAD83
Gage datum 391.96 feet above NAVD88

The gage site is near downtown Austin a half mile below Hwy 183. Flows at this site are regulated by Lakes Buchanan, Inks, LBJ, Marbles Falls, Travis, and Austin on the Colorado River operated by the Lower Colorado River Authority. Many other reservoirs on tributaries entering the Colorado River upstream of Austin are operated by other entities.

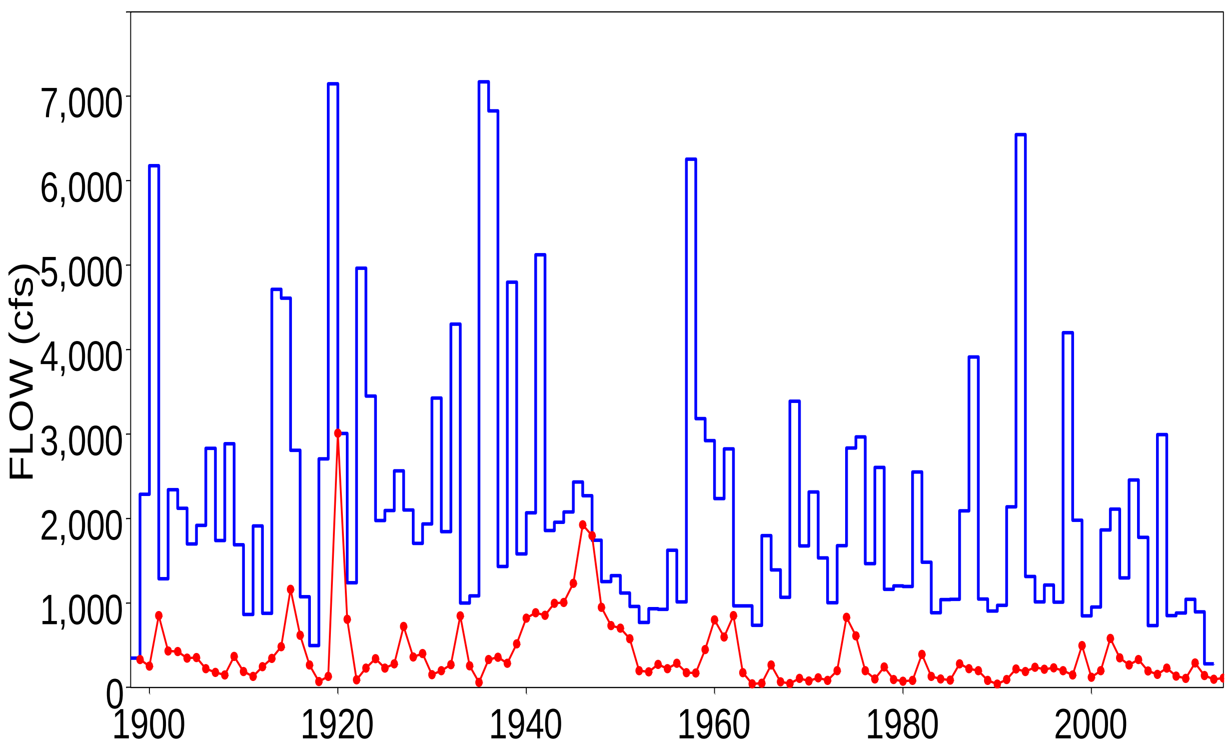
Period-of-record of daily flows: 1898/3/01 to present (2013/6/1)



Daily Flows of Colorado River at Austin



Monthly Flows of Colorado River at Austin



Annual Flows and the Minimum Monthly Flow Each Year

13
Colorado River at Columbus

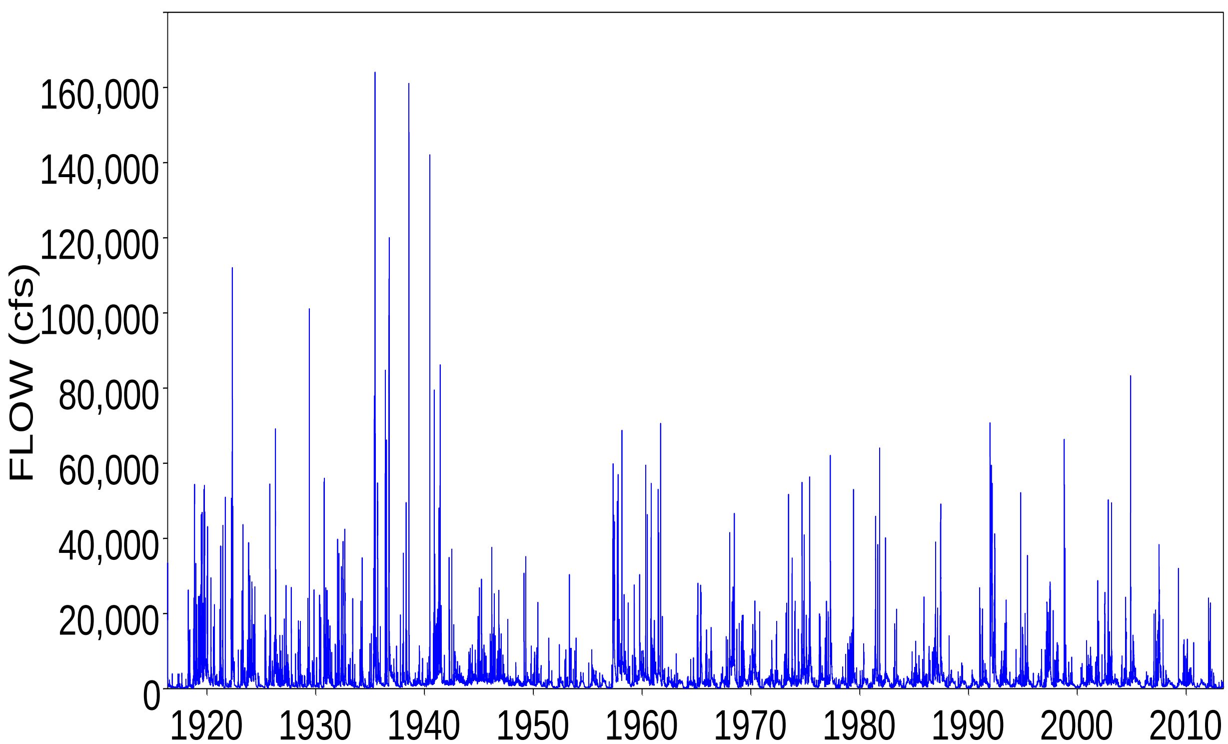
USGS 08161000
Colorado County, Texas

Drainage area 41,640 square miles
Contributing drainage area 30,237 square miles

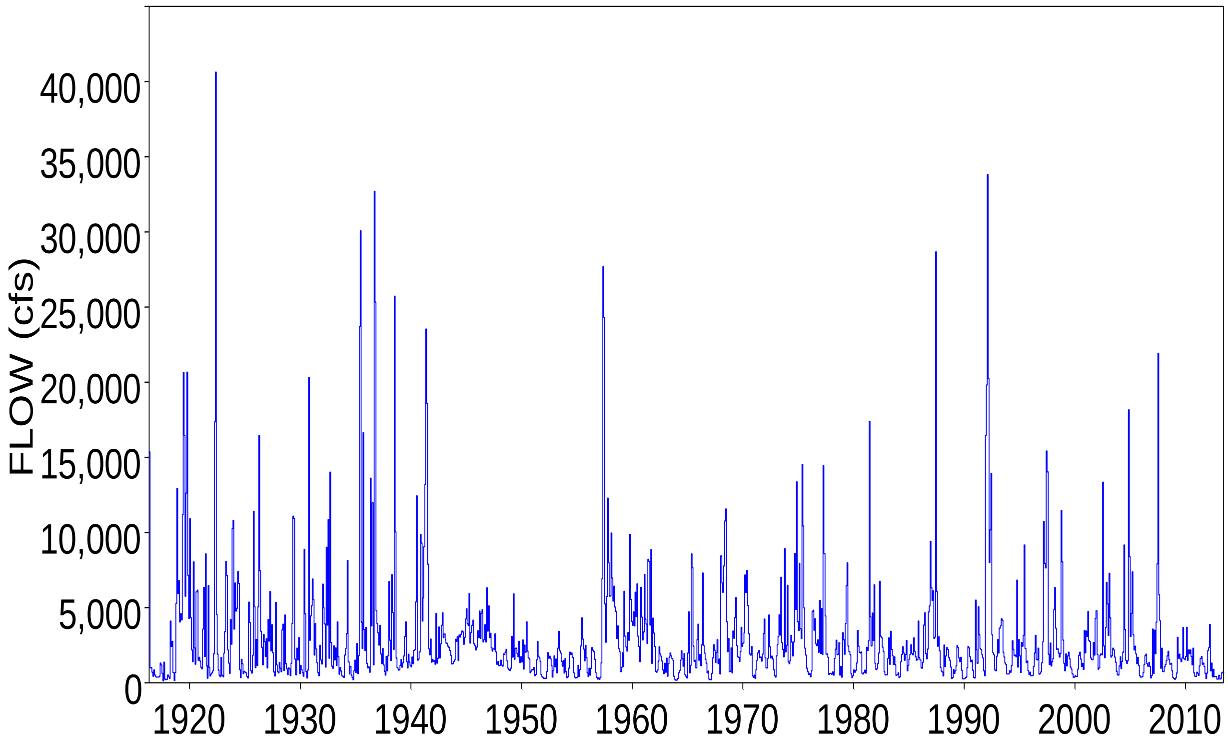
Latitude 29°42'22", Longitude 96°32'12" NAD27
Gage datum 145.52 feet above NGVD29

The gage is at Hwy 90 upstream of IH 10 in Columbus about a hundred miles below Austin and sixty miles upstream of Bay City.

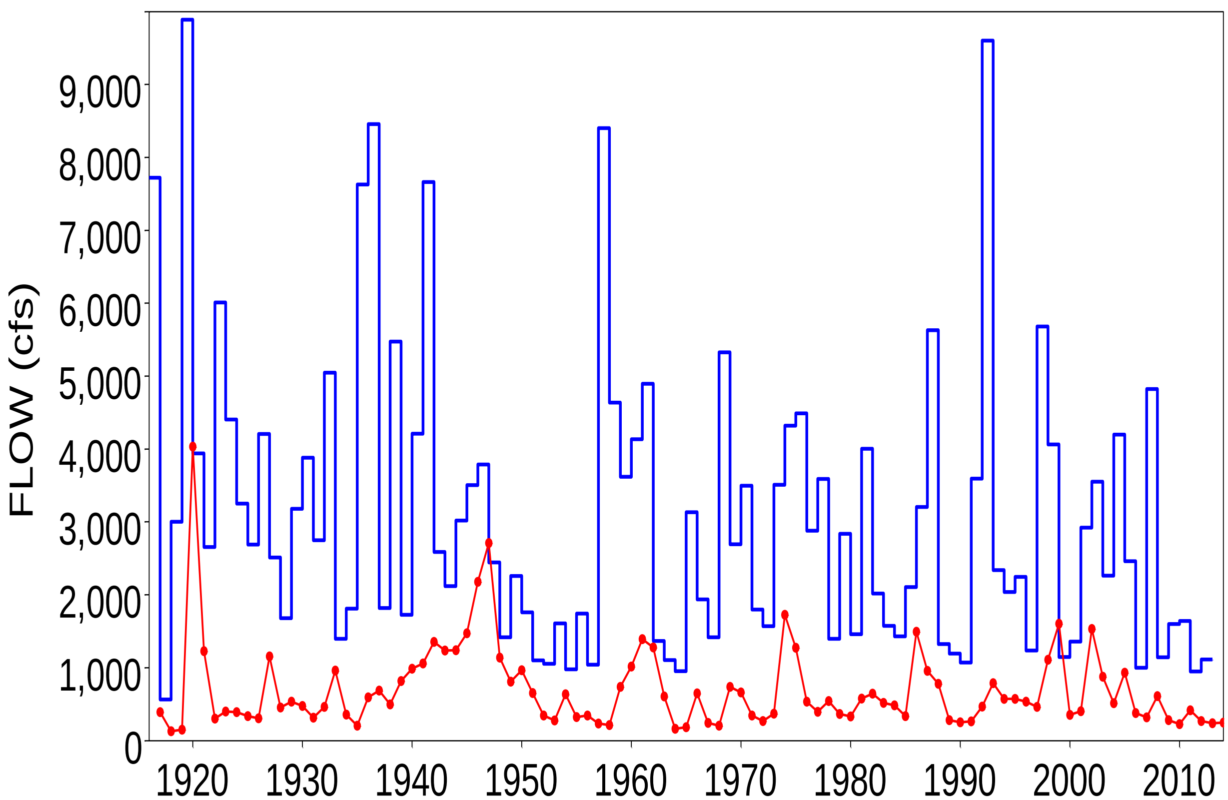
Period-of-record of daily flows: 1916/5/01 to present (2013/6/1)



Daily Flows of Colorado River at Columbus



Monthly Flows of Colorado River at Columbus



Annual Flows and the Minimum Monthly Flow Each Year

14
Colorado River near Bay City

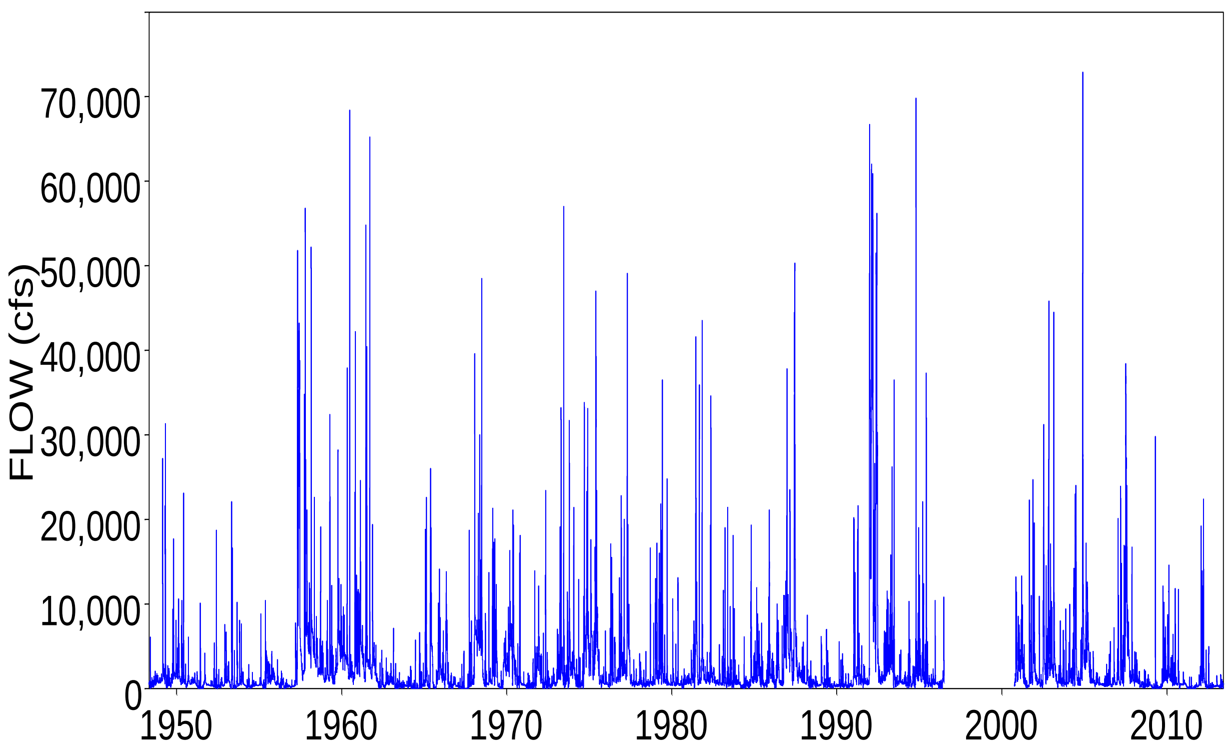
USGS 08162500
Matagorda County, Texas

Drainage area 42,240 square miles
Contributing drainage area 30,837 square miles

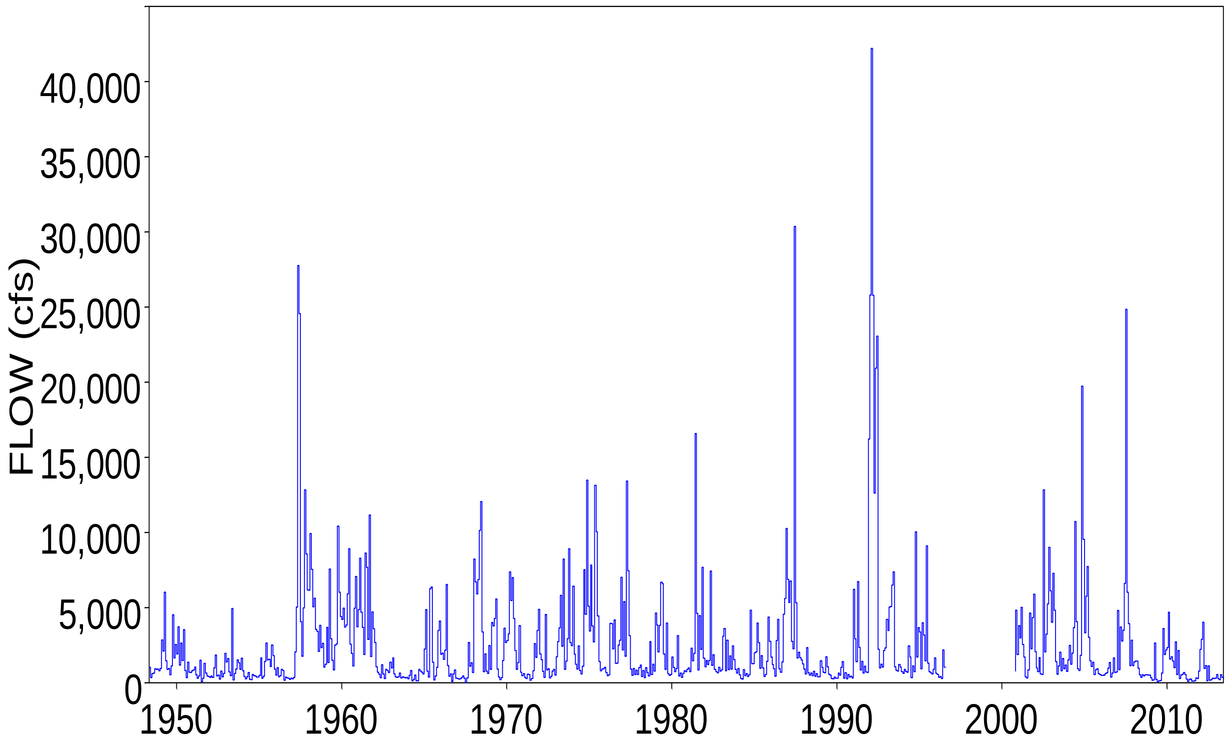
Latitude 28°58'26", Longitude 96°00'44" NAD27
Gage datum 0 feet above NGVD29

The gage is below Hwy 35 thirty miles above the river outlet at Matagorda Bay south of Bay City.

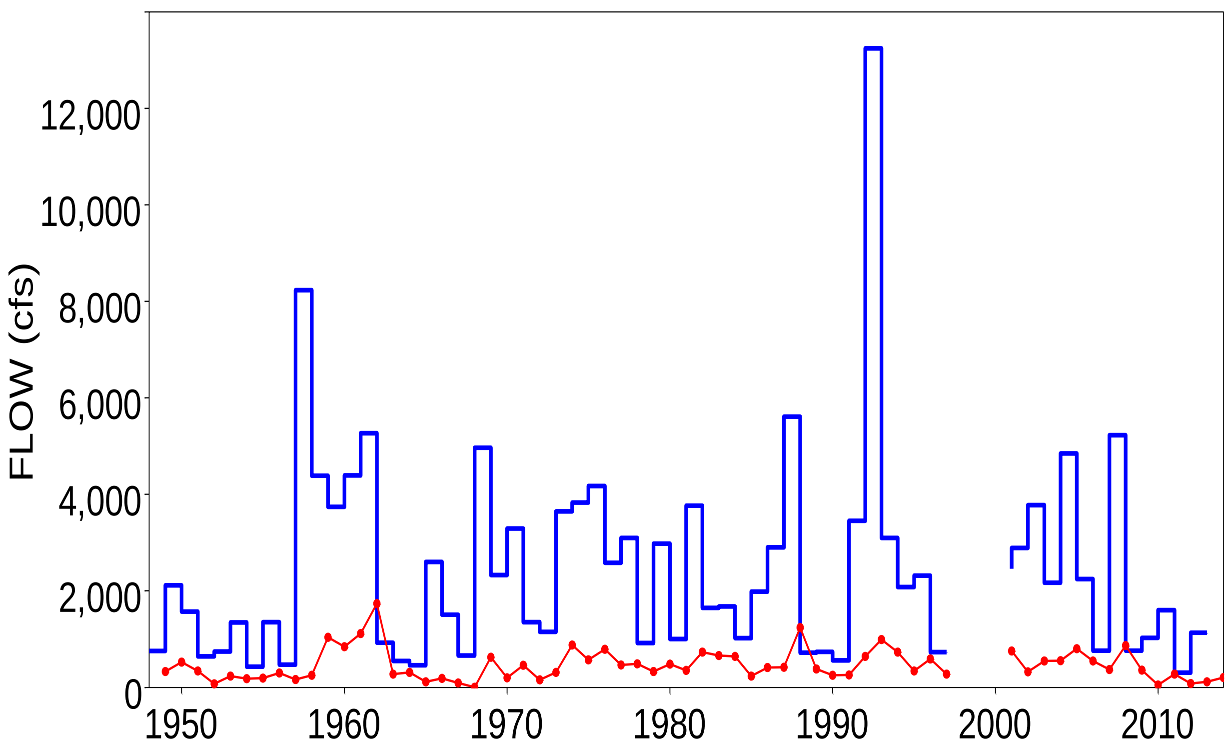
Period-of-record of daily flows: 1942/5/01 to present (2013/6/1)



Daily Flows of Colorado River near Bay City



Monthly Flows of Colorado River near Bay City



Annual Flows and the Minimum Monthly Flow Each Year

15
Brazos River at Seymour

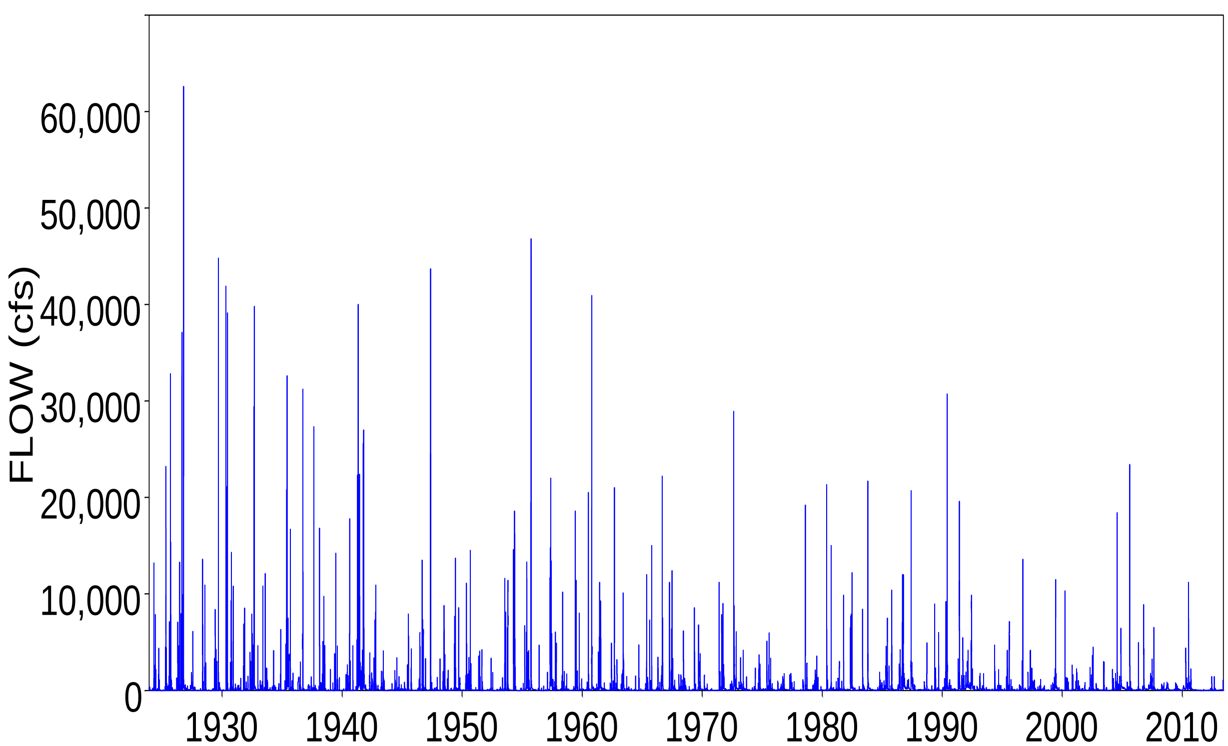
USGS 08082500
Baylor County, Texas

Drainage area 15,538 square miles
Contributing drainage area 5,972 square miles

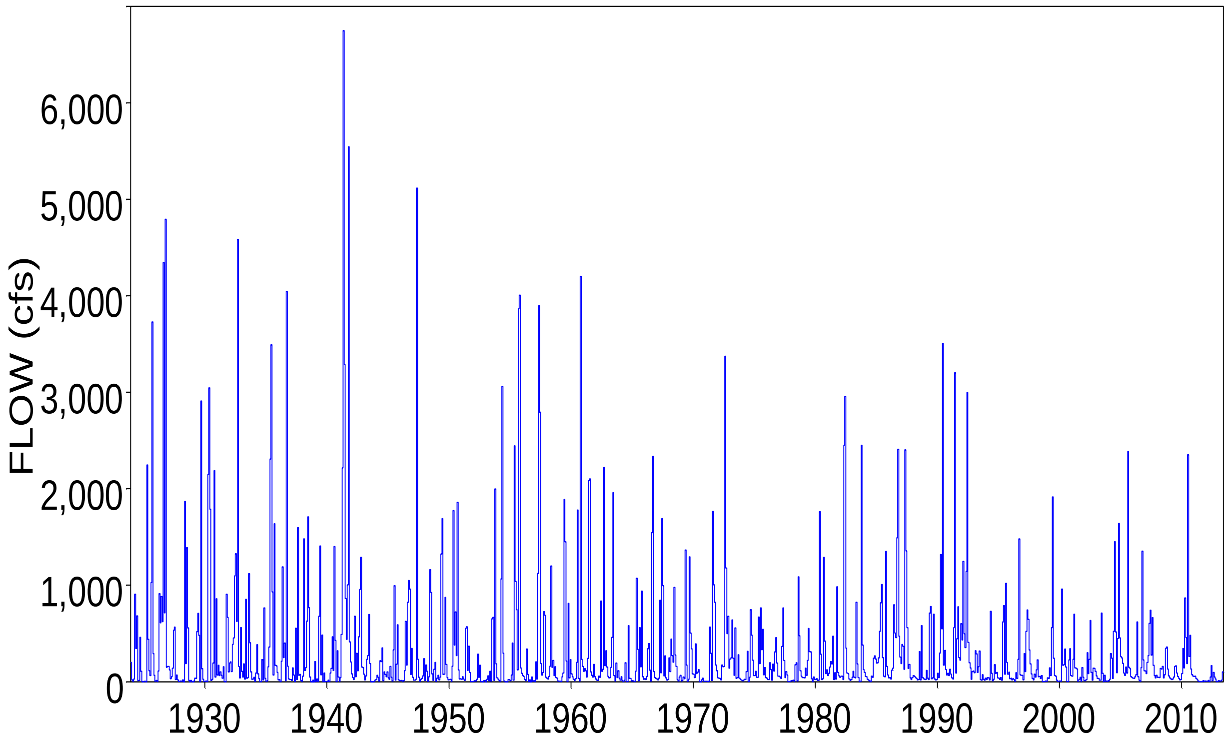
Latitude 33°34'51", Longitude 99°16'02" NAD27
Gage datum 1,238.97 feet above NGVD29

The gage is at County Road 403 just north of Hwy 277. The gage is on the Brazos River about sixty miles above the Hubbard Creek confluence and fifty miles below the confluence of the Salt Fork and Double Mountain Fork of the Brazos River.

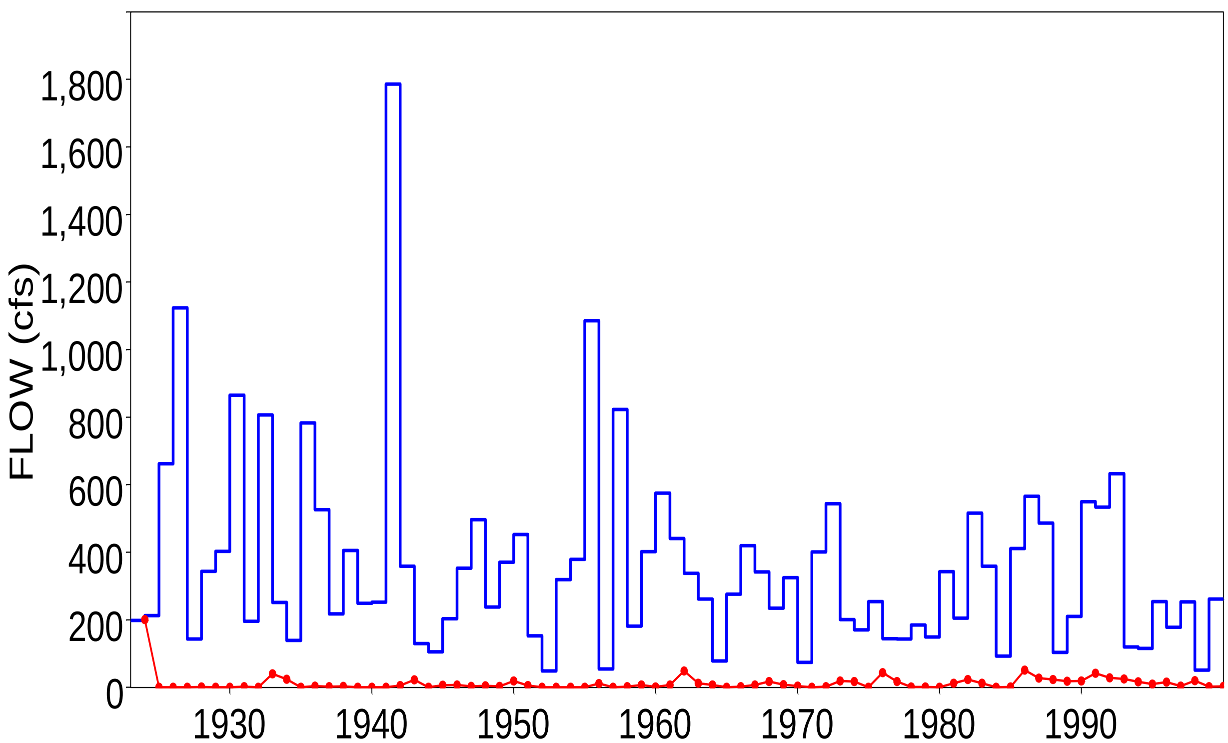
Period-of-record of daily flows: 1923/12/01 to present (2013/6/1)



Daily Flows of Brazos River at Seymour



Monthly Flows of Brazos River at Seymour



Annual Flows and the Minimum Monthly Flow Each Year

16
Brazos River at Waco

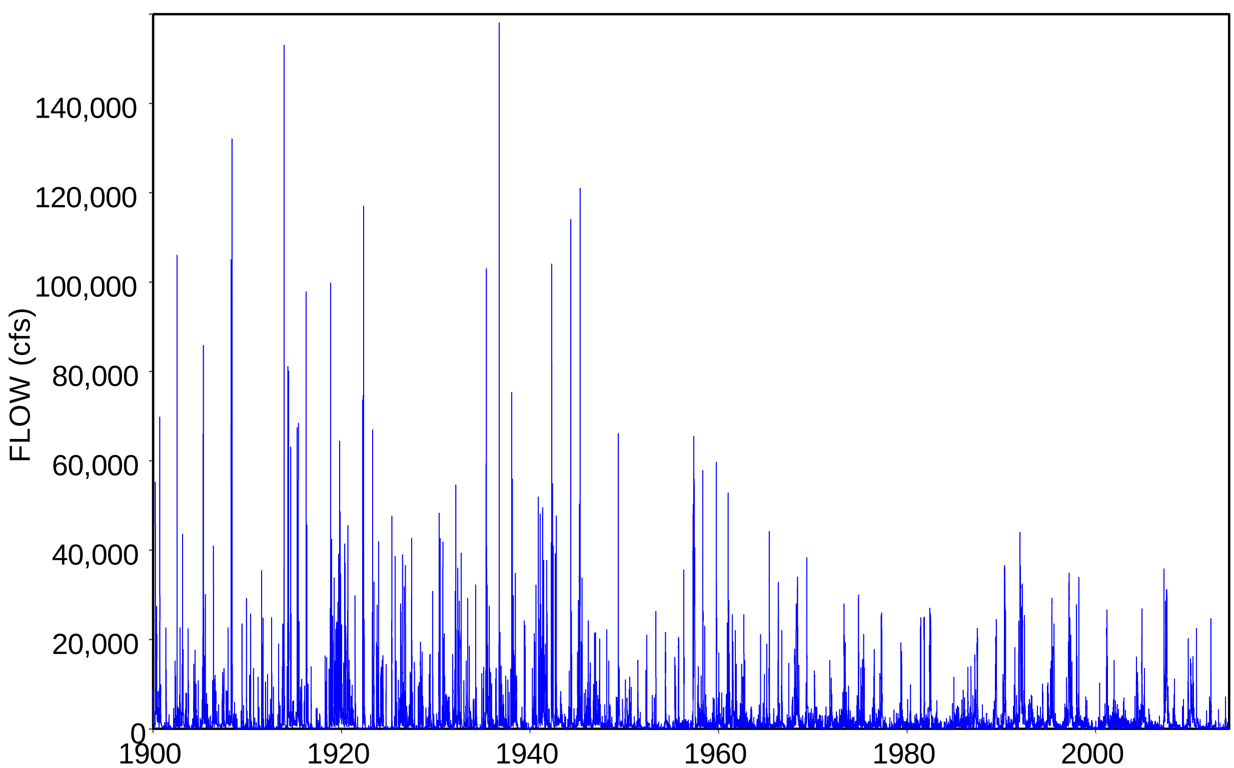
USGS 08096500
Mclennan County

Drainage area 29,559 square miles
Contributing drainage area 19,983 square miles

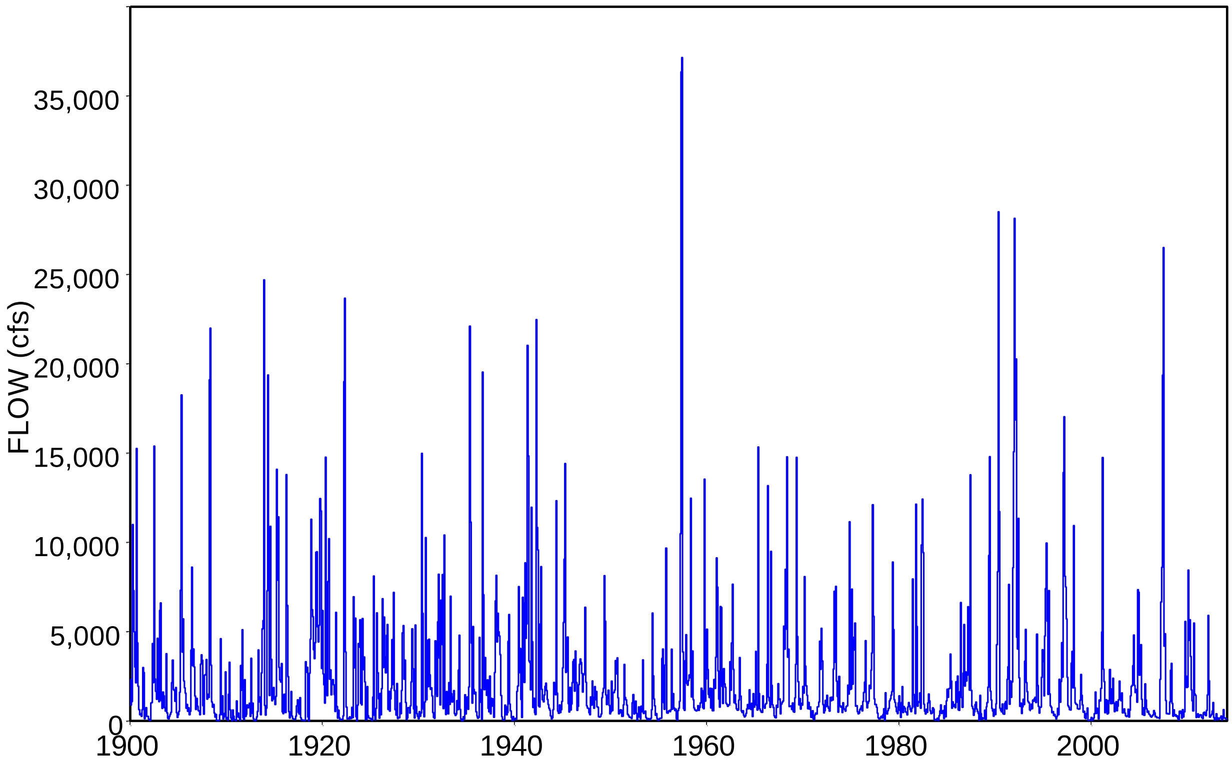
The gage site on the Brazos River is just downstream of the City of Waco and about five miles downstream of the Bosque River confluence. The gage is at the South Loop 340 Highway about a mile south of Texas Highway 6.

A maximum allowable non-flooding discharge of 25,000 cfs at the Brazos River gage at Waco is designated by the U.S. Army Corps of Engineers (USACE) Fort Worth District (FWD) for purposes of reservoir flood control operations. The USACE FWD uses this gage along with other downstream gages on the Brazos River in operating the flood control pools of the multipurpose Lakes Waco, Aquilla, and Whitney which are located upstream of this site. Many other water supply reservoirs are also located upstream of this gage site.

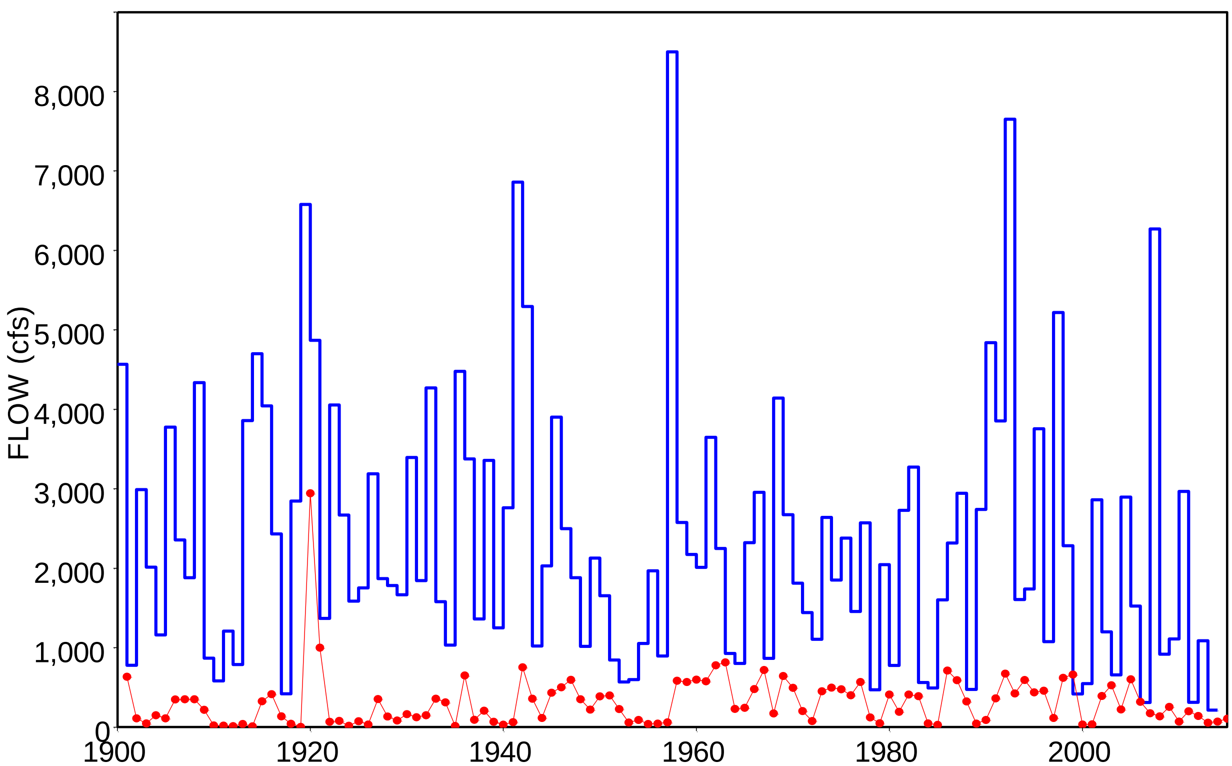
Period-of-record of daily flows: 1898/10/01 to present (2013/6/1)



Daily Flows of the Brazos River at the Gage at Waco



Monthly Flows of the Brazos River at the Gage at Waco



Annual Flows and the Minimum Monthly Flow Each Year

17
Little River at Cameron

USGS 08106500
Milam County, Texas

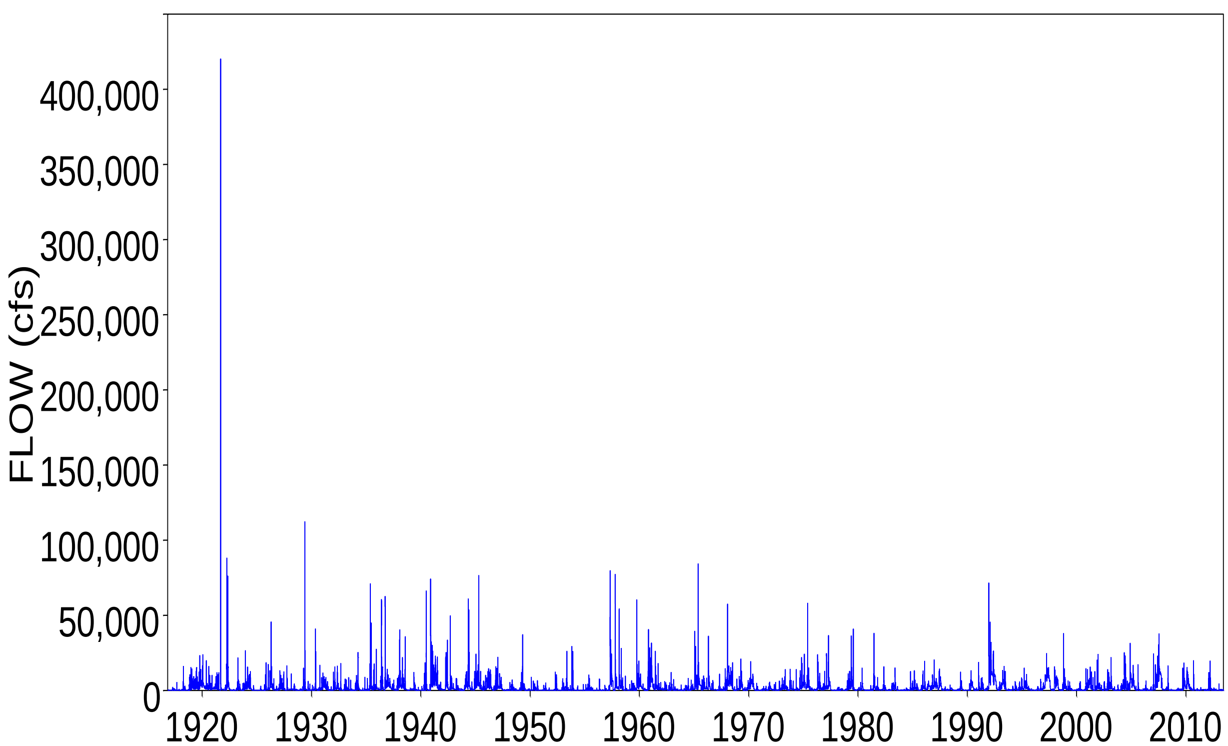
Drainage area 7,065 square miles
Contributing drainage area 7,065 square miles

Latitude 30°50'06", Longitude 96°56'47" NAD27
Gage datum 281.89 feet above NGVD29

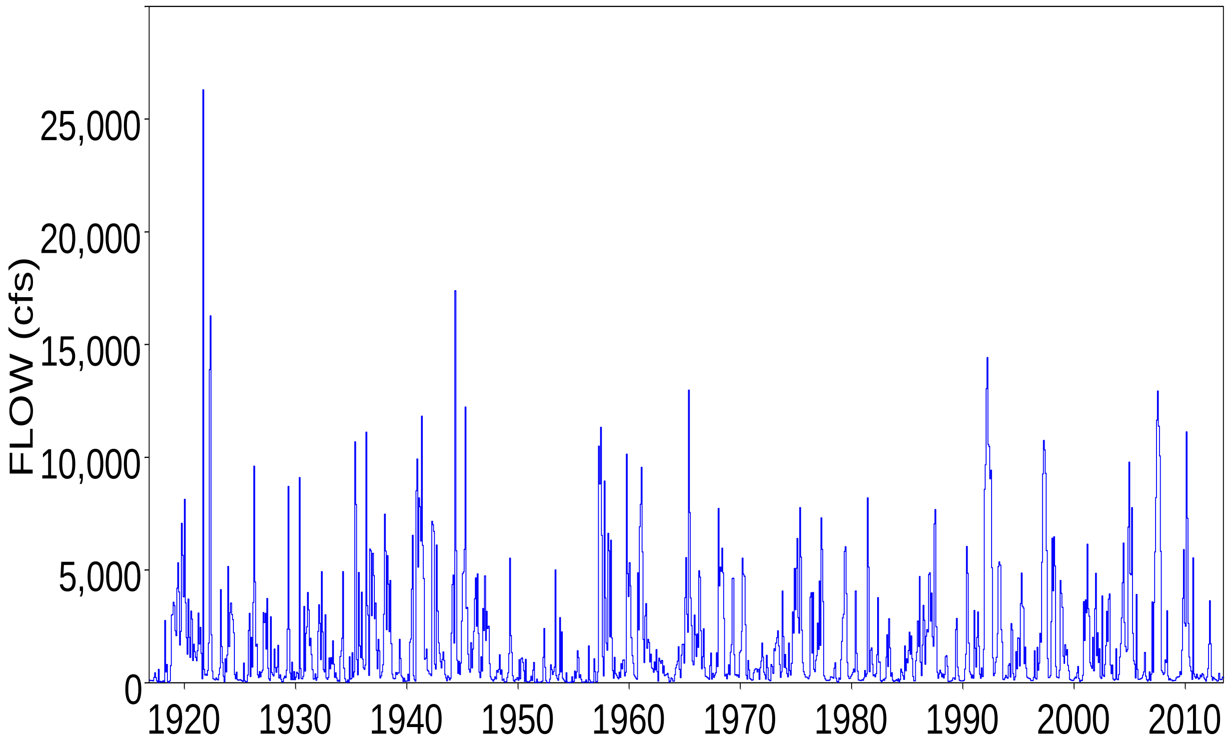
The gage is at Hwy 190 about eight miles below the San Gabriel River confluence and thirty miles above the outlet at the Brazos River.

A maximum allowable non-flooding discharge of 10,000 cfs at the Little River gage at Cameron is designated by the U.S. Army Corps of Engineers (USACE) Fort Worth District (FWD) for purposes of reservoir flood control operations. The USACE FWD uses this gage along with other gage sites in operating the flood control pools of the multipurpose Lakes Proctor, Belton, Stillhouse Hollow, Georgetown, and Granger which are located upstream of this site.

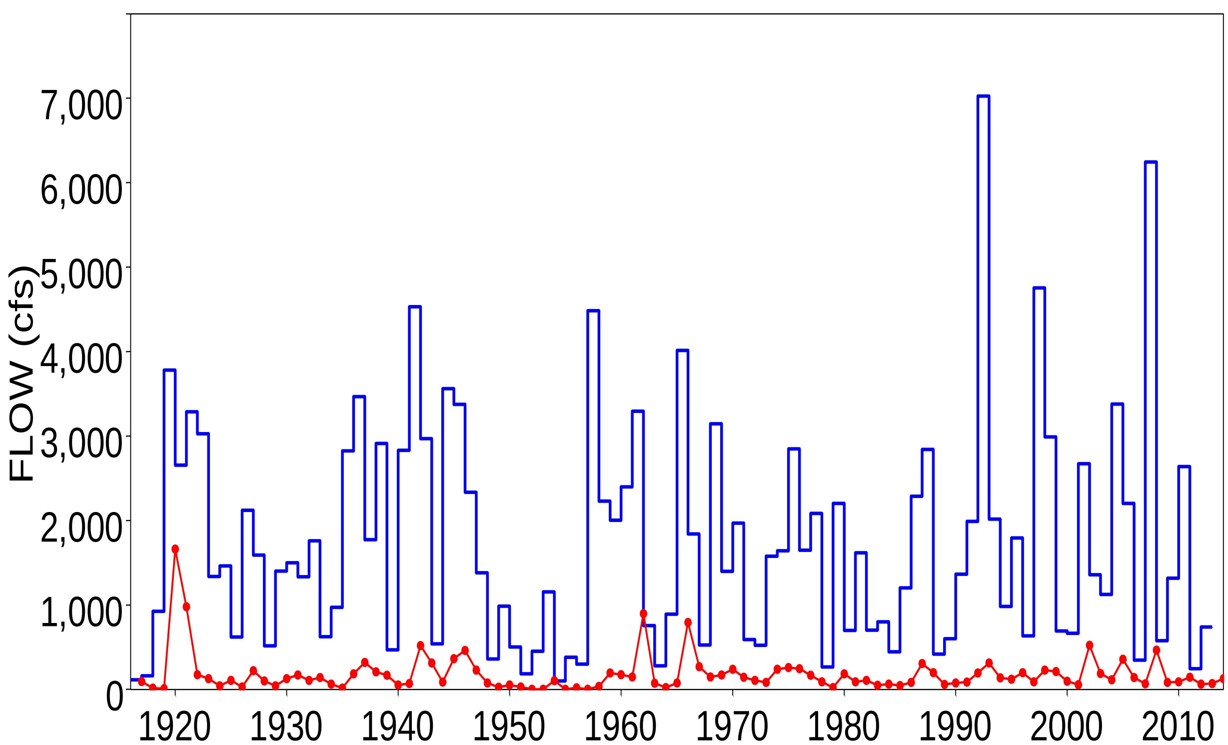
Period-of-record of daily flows: 1916/11/01 to present (2013/6/1)



Daily Flows of Little River at Cameron



Monthly Flows of Little River at Cameron



Annual Flows and the Minimum Monthly Flow Each Year

18
Navasota River at Easterly

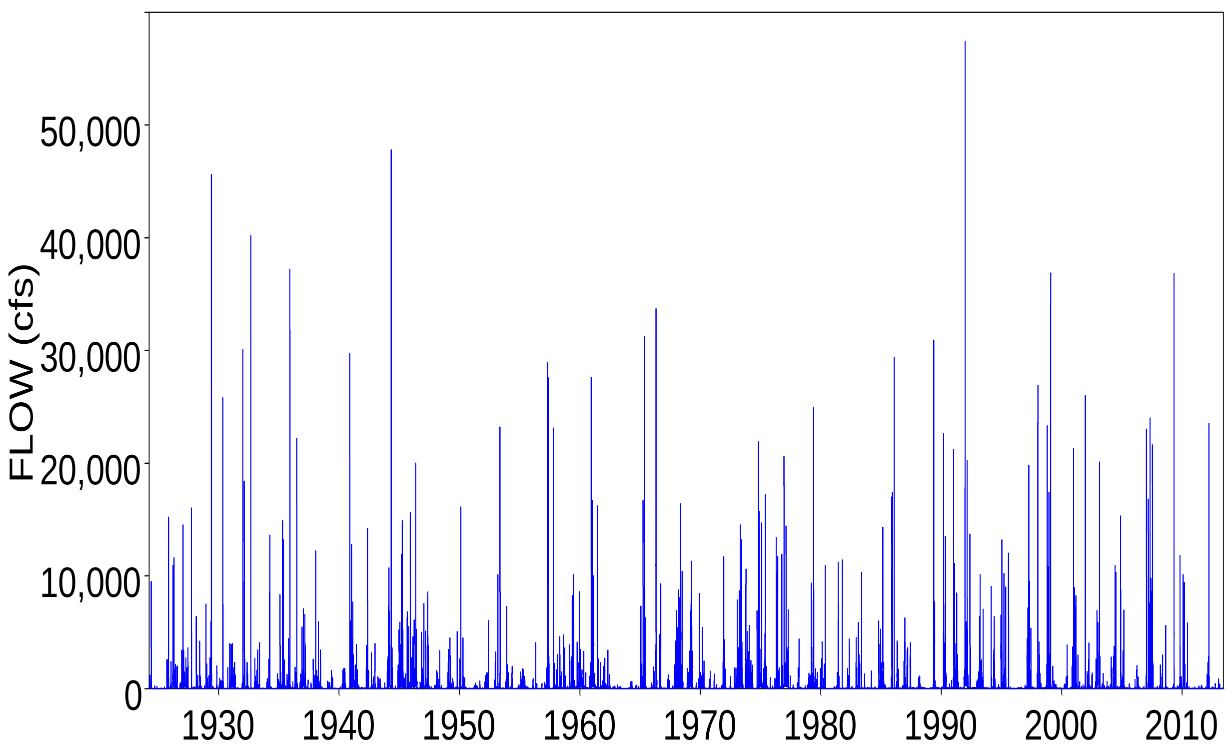
USGS 08110500
Leon County, Texas

Drainage area 968 square miles
Contributing drainage area 968 square miles

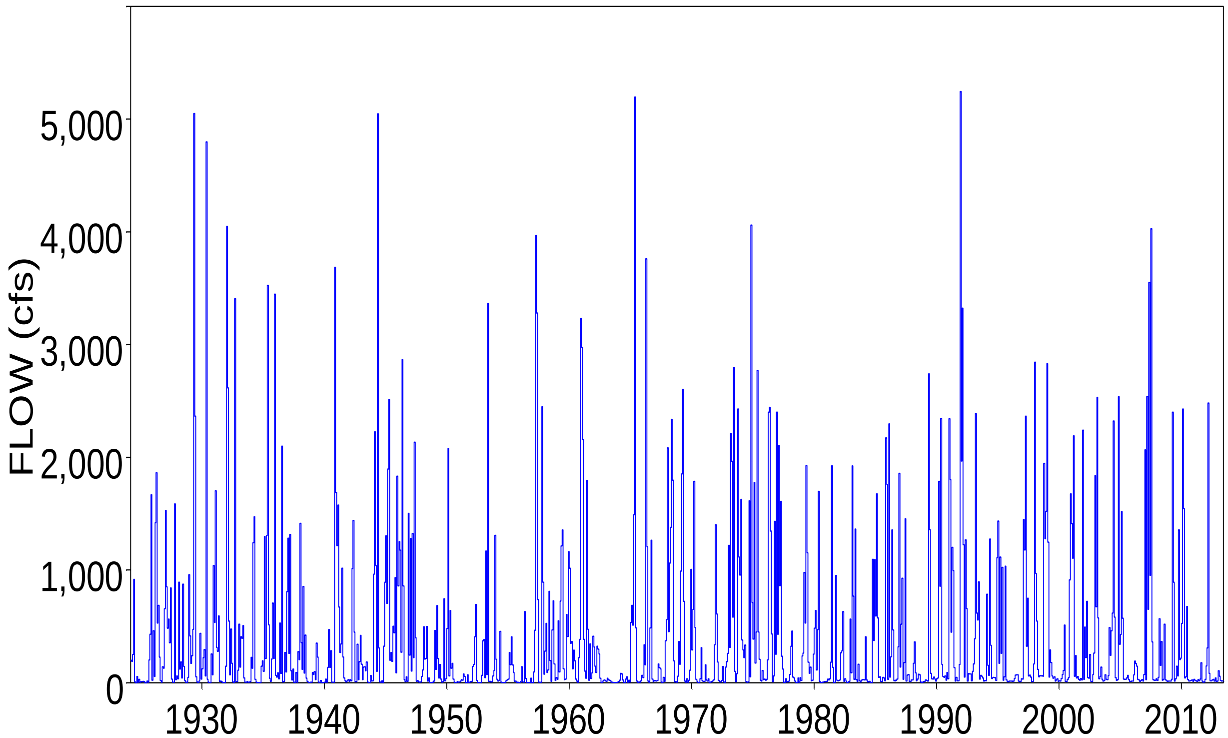
Latitude 31°10'12", Longitude 96°17'51" NAD27
Gage datum 271.46 feet above NGVD29

The gage is at Hwy 79 about eleven miles below Limestone Dam which is operated by the Brazos River Authority for water supply.

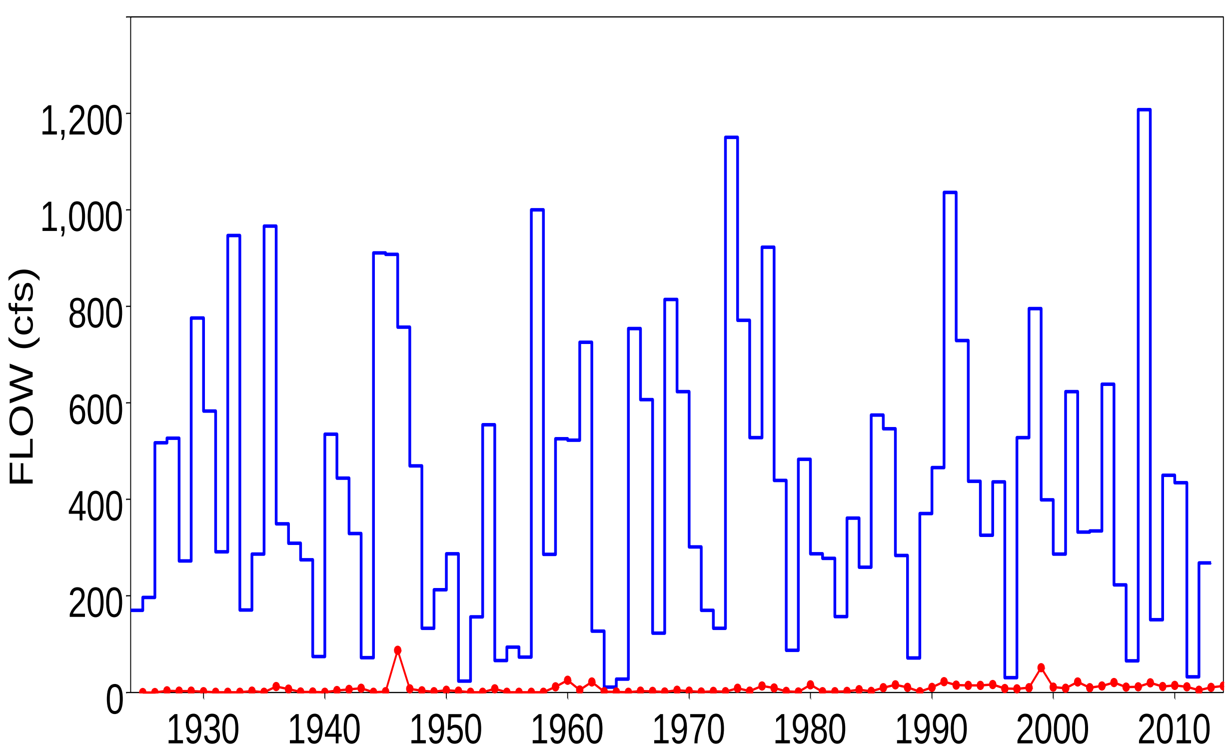
Period-of-record of daily flows: 1924/3/27 to present (2013/6/1)



Daily Flows of Navasota River at Easterly



Monthly Flows of Navasota River at Easterly



Annual Flows and the Minimum Monthly Flow Each Year

19
Brazos River at Richmond

USGS 08114000
Fort Bend County, Texas

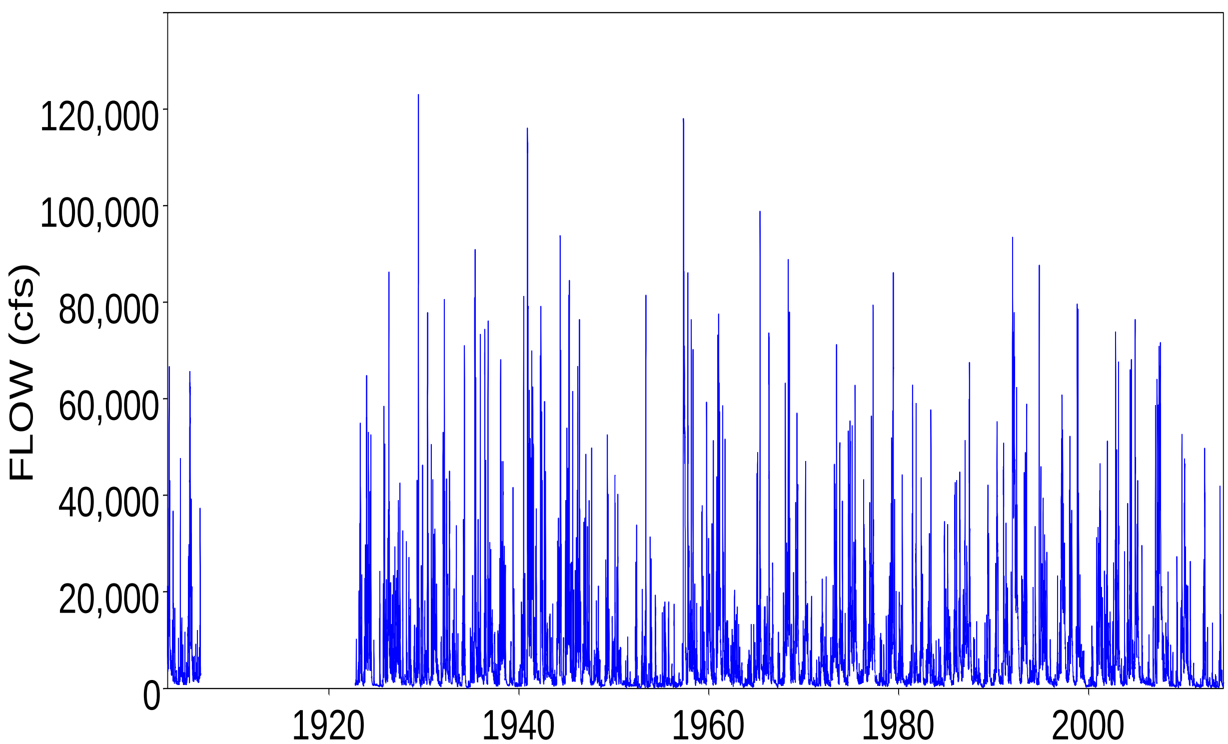
Drainage area 45,107 square miles
Contributing drainage area 35,541 square miles

Latitude 29°34'56", Longitude 95°45'27" NAD27
Gage datum 27.94 feet above NGVD29

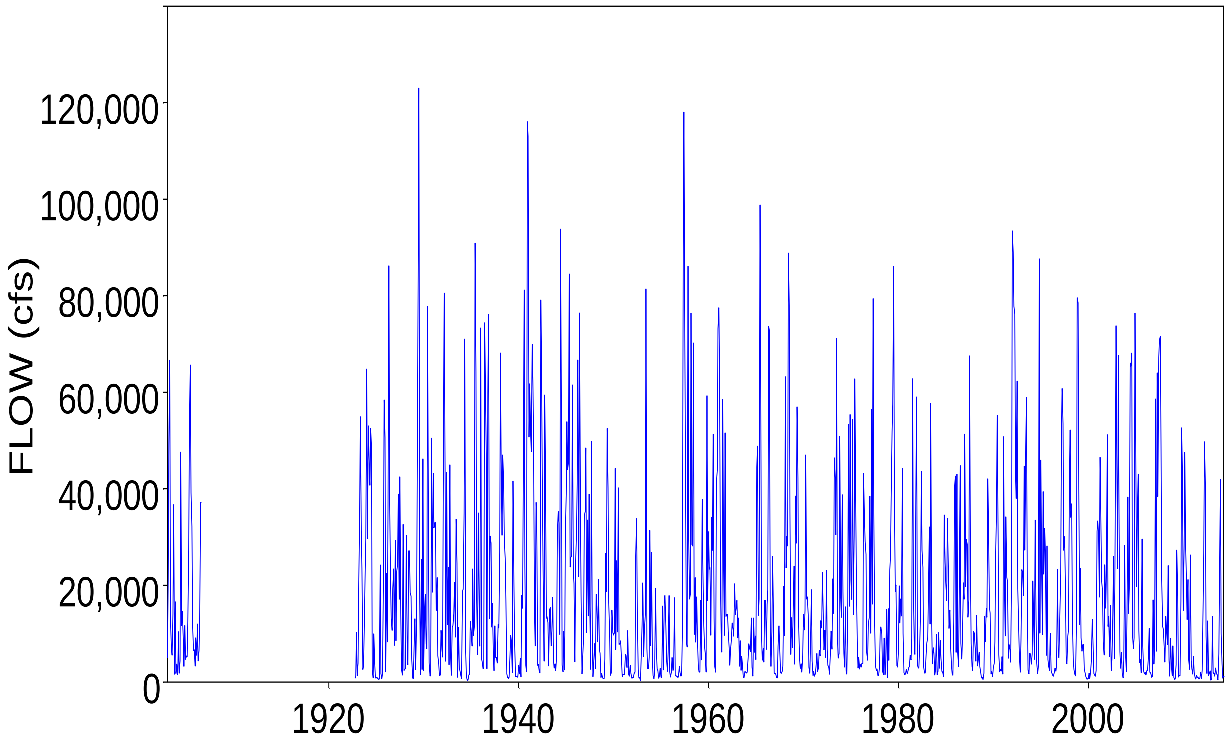
The gage is near Hwy 90 about 60 miles above the Brazos River outlet near Freeport.

A maximum allowable non-flooding discharge of 60,000 cfs at the Brazos River gage at Richmond is designated by the U.S. Army Corps of Engineers (USACE) Fort Worth District (FWD) for purposes of reservoir flood control operations. The USACE FWD uses this gage along with other gage sites in operating the flood control pools of the system nine federal multipurpose reservoirs located on the Brazos River and its tributaries. Many other nonfederal water supply reservoirs are located upstream of this gage site.

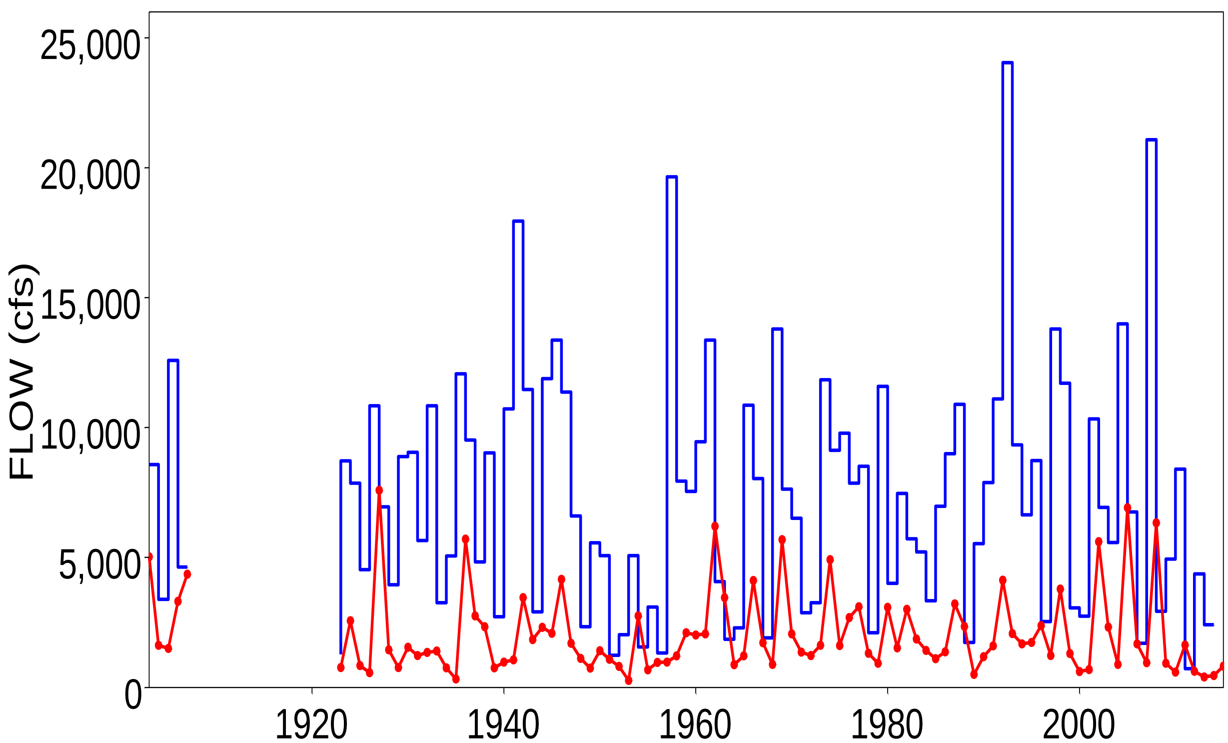
Period-of-record of daily flows: 1903/11/01 to present (2014/3/8)



Daily Flows of Brazos River at Richmond



Monthly Flows of Brazos River at Richmond



Annual Flows and the Minimum Monthly Flow Each Year

20
Buffalo Bayou in Houston

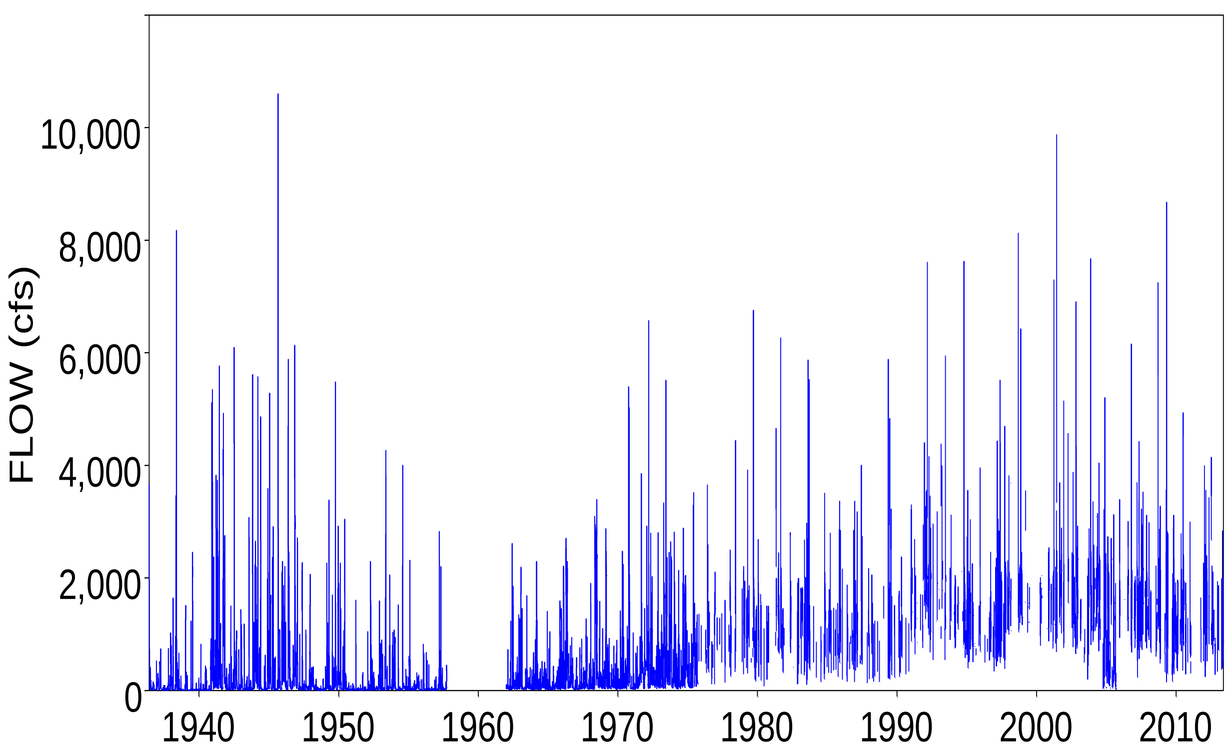
USGS 08074000
Harris County, Texas

Drainage area 336 square miles
Contributing drainage area 336 square miles

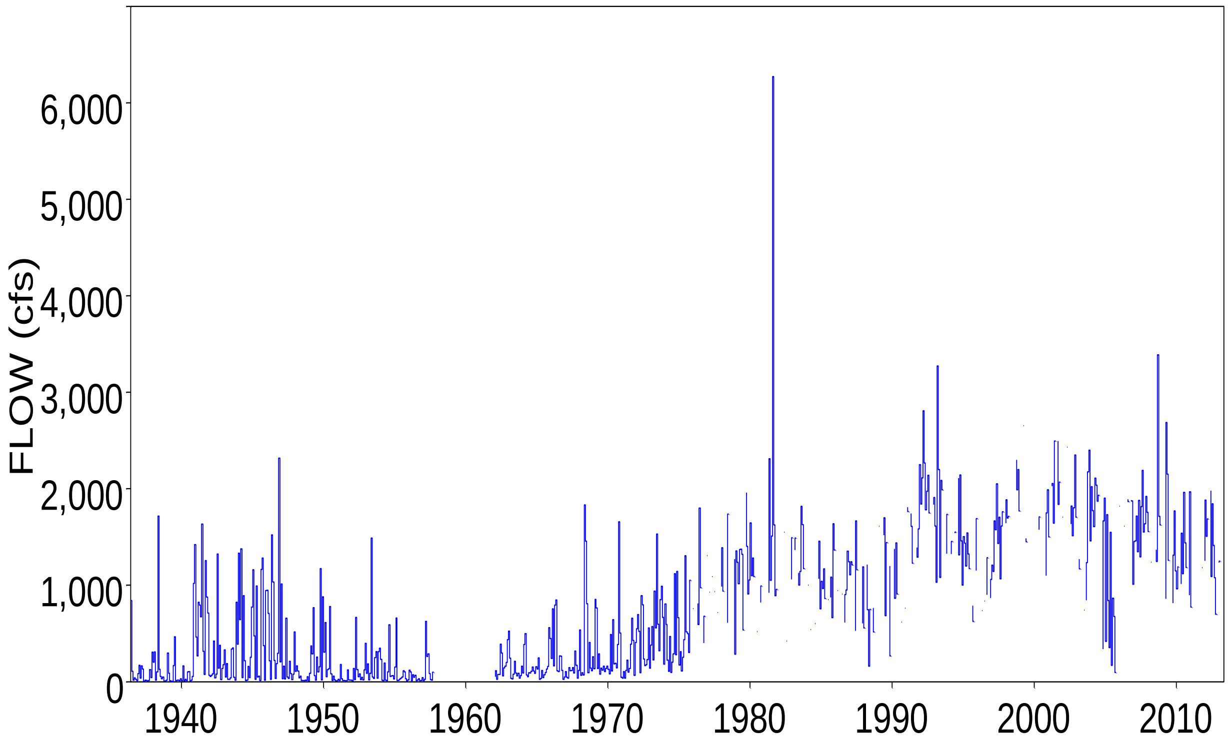
Latitude 29°45'36", Longitude 95°24'30" NAD27
Gage datum 0.00 feet above NAVD88

The gage is at Shepard Drive west (upstream) of downtown Houston three miles east (downstream) of IH 610. Barker and Addicks Dams are about sixteen miles upstream of the gage. Barker and Addicks Dams are operated only for flood control with no storage for water supply.

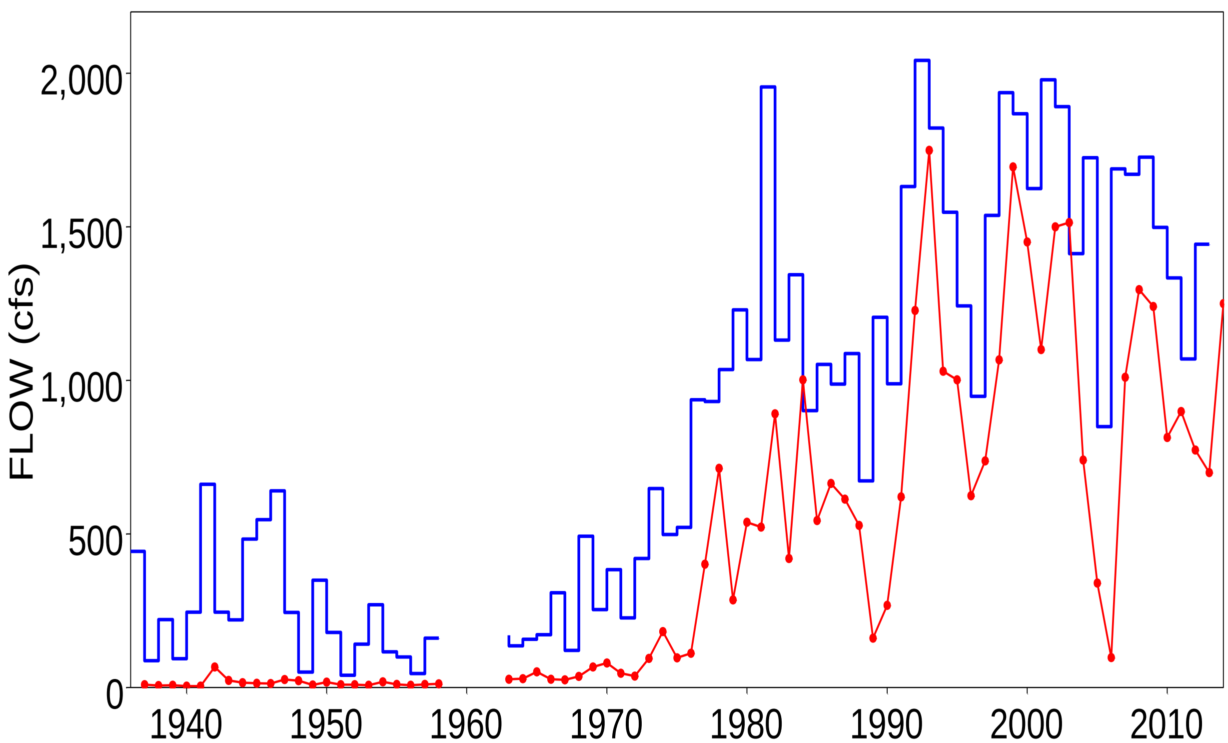
Period-of-record of daily flows: 1936/6/01 to present (2013/5/19)



Daily Flows of Buffalo Bayou in Houston



Monthly Flows of Buffalo Bayou in Houston



Annual Flows and the Minimum Monthly Flow Each Year

21
West Fork San Jacinto River near Conroe

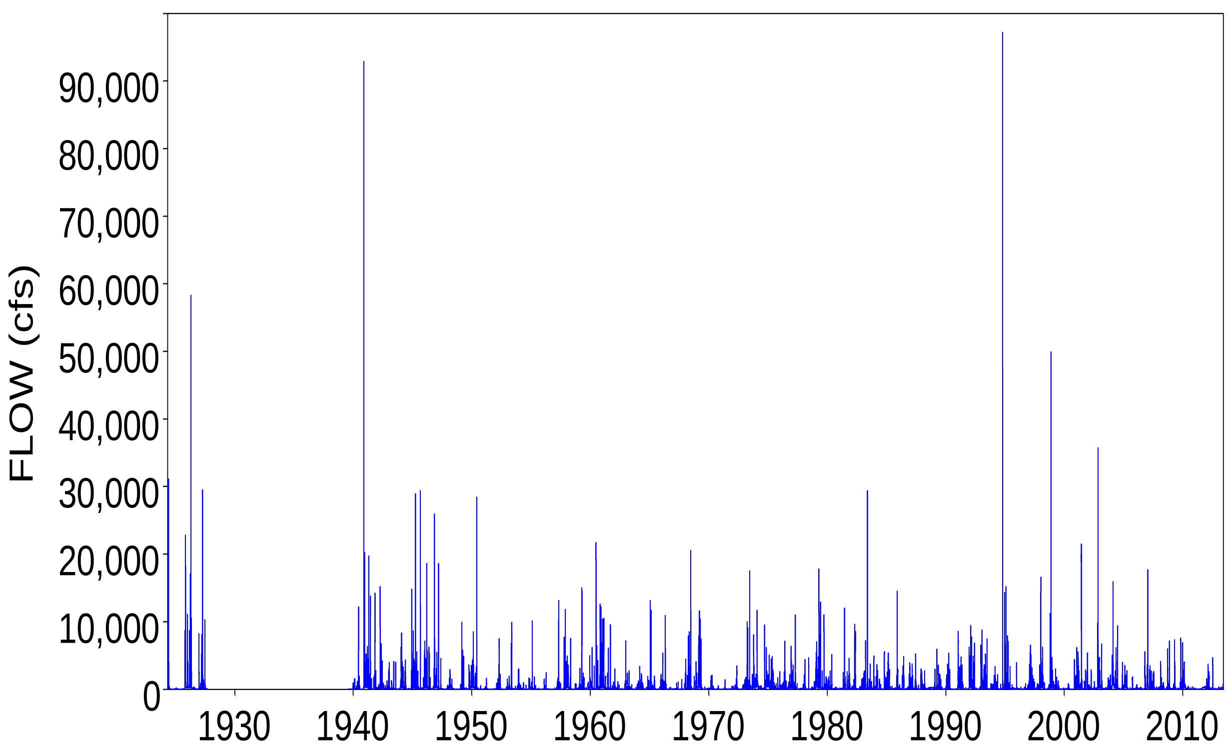
USGS 08068000
Montgomery County, Texas

Drainage area 828 square miles
Contributing drainage area 828 square miles

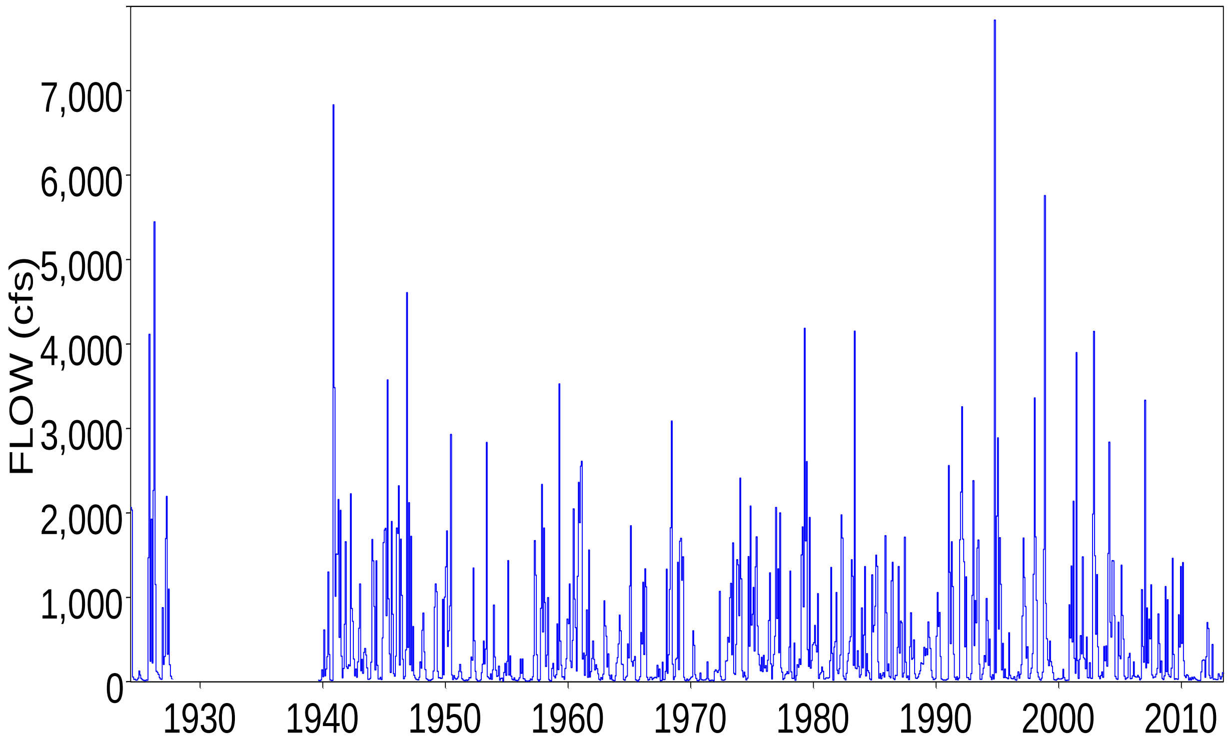
Latitude 30°14'40", Longitude 95°27'25" NAD27
Gage datum 00.00 feet above NAVD88

The gage is at IH 45 ten miles below the dam at Lake Conroe.

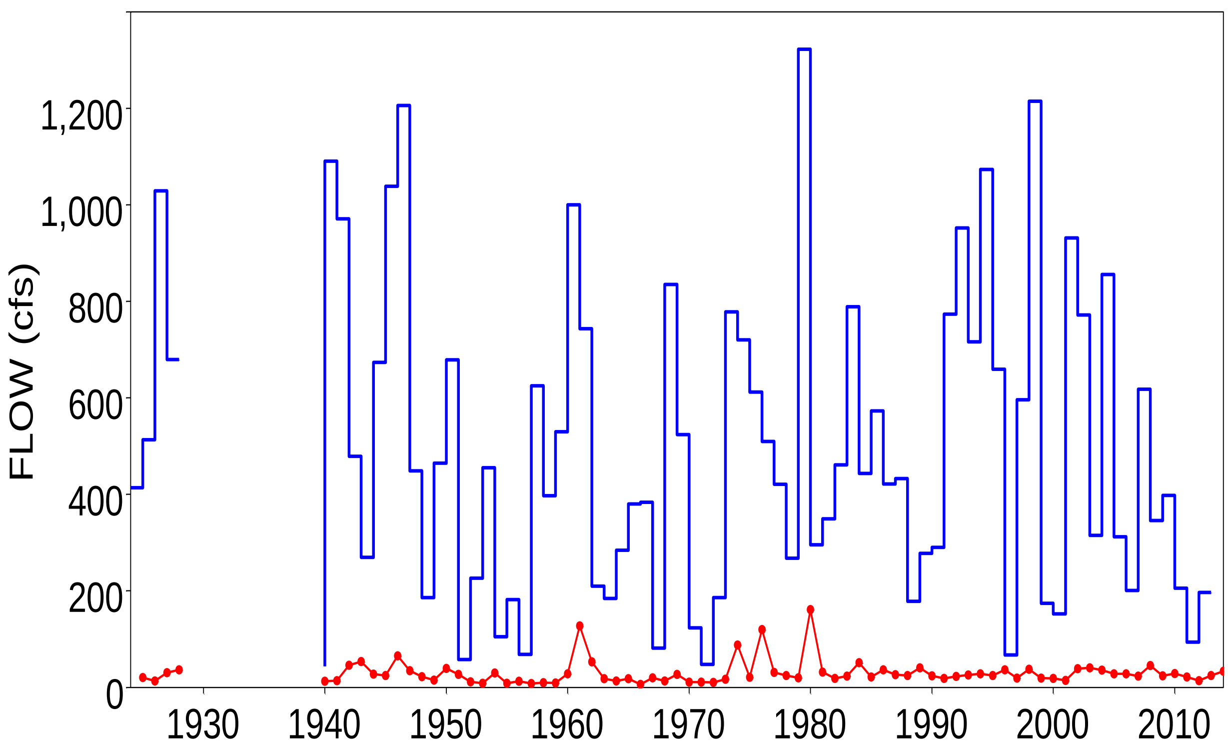
Period-of-record of daily flows: 1924/5/01 to present (2013/6/1)



Daily Flows of West Fork San Jacinto River near Conroe



Monthly Flows of West Fork San Jacinto River near Conroe



Annual Flows and the Minimum Monthly Flow Each Year

22
West Fork of the Trinity River at Fort Worth

USGS 08048000
Tarrant County, Texas

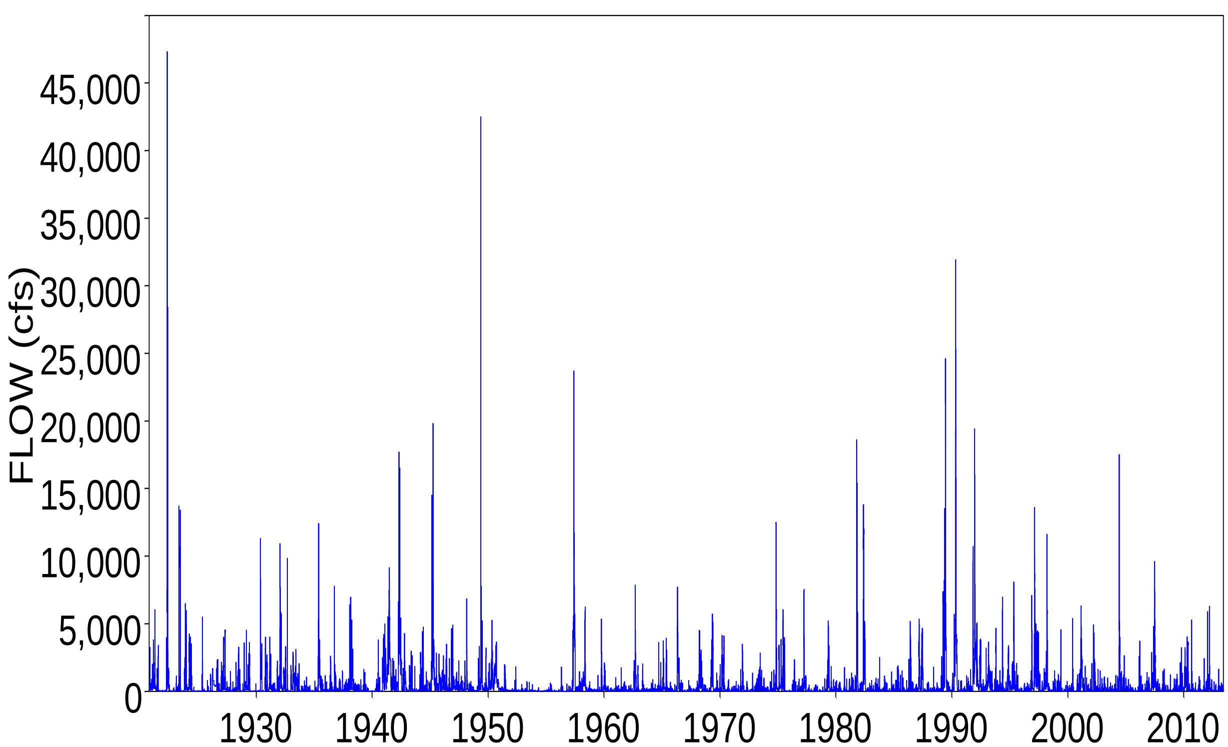
Drainage area 2,615 square miles
Contributing drainage area 2,615 square miles

Latitude 32°45'39", Longitude 97°19'56" NAD27
Gage datum 519.24 feet above NGVD29

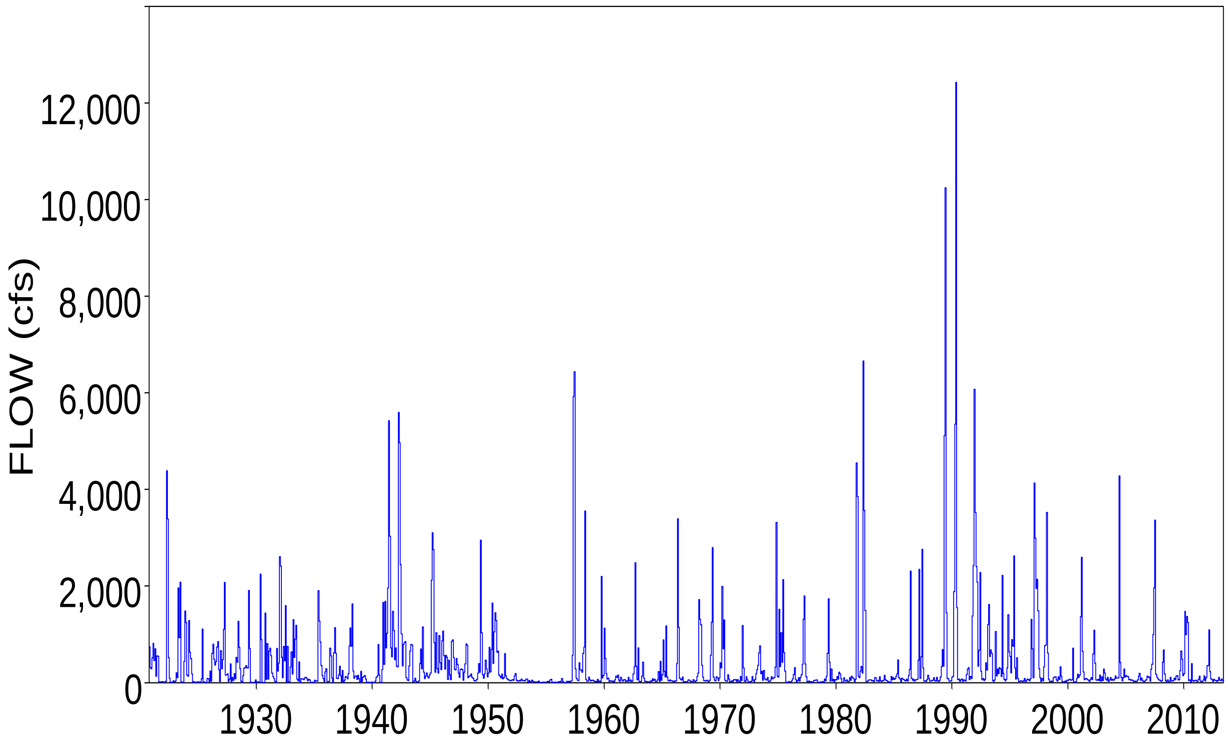
The gage is south of Hwy 287 north of downtown Fort Worth.

A maximum allowable non-flooding discharge of 3,000 cfs at this gage site is designated by the U.S. Army Corps of Engineers (USACE) Fort Worth District (FWD) for purposes of reservoir flood control operations. The USACE FWD uses this gage along with other gage sites in operating the flood control pool Ben Brook Reservoir.

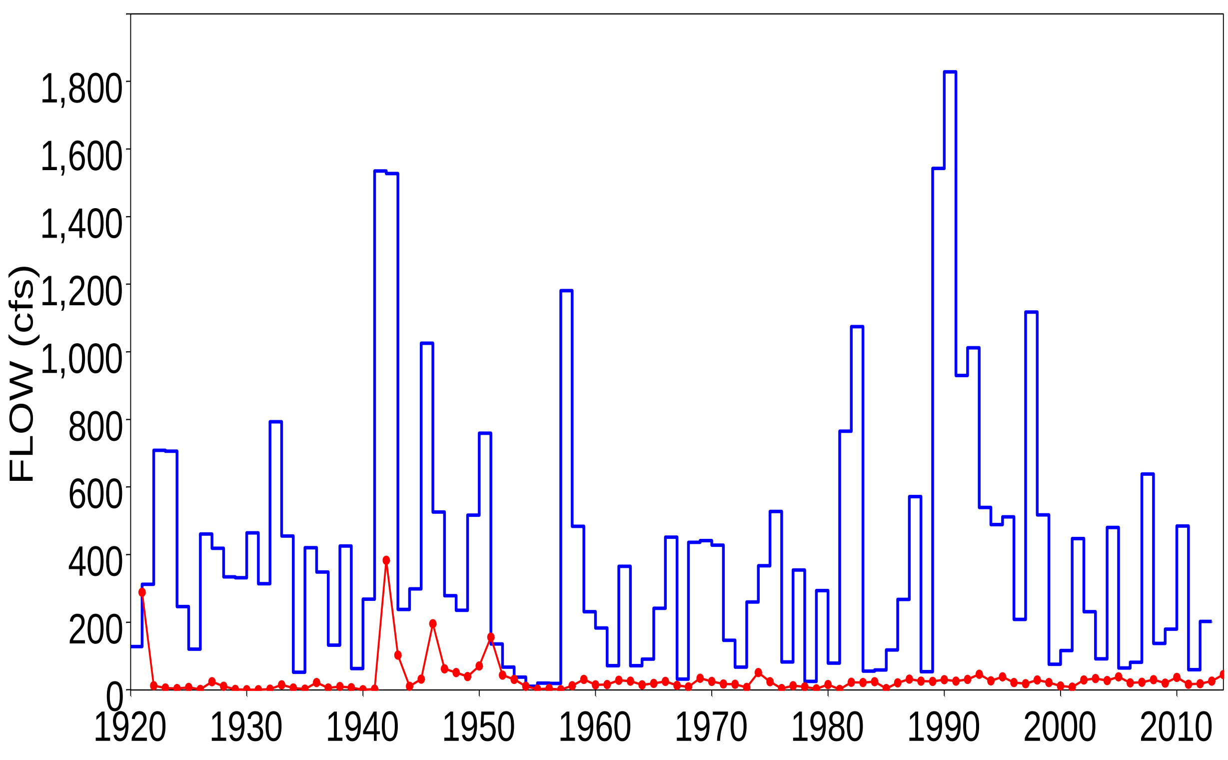
Period-of-record of daily flows: 1920/10/01 to present (2013/6/1)



Daily Flows of West Fork Trinity River at Fort Worth



Monthly Flows of West Fork Trinity River at Fort Worth



Annual Flows and the Minimum Monthly Flow Each Year

23
Trinity River at Dallas

USGS 08057000
Dallas County, Texas

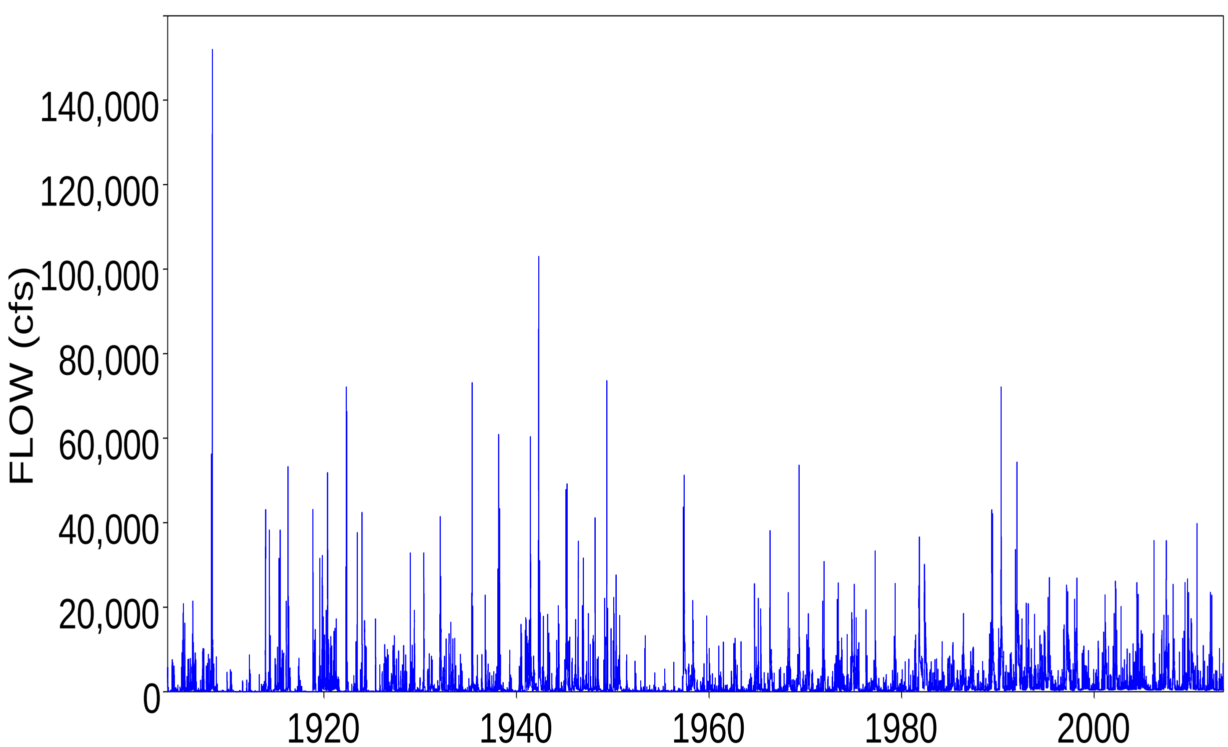
Drainage area 6,106 square miles
Contributing drainage area 6,106 square miles

Latitude 32°46'29", Longitude 96°49'18" NAD27
Gage datum 368.02 feet above NGVD29

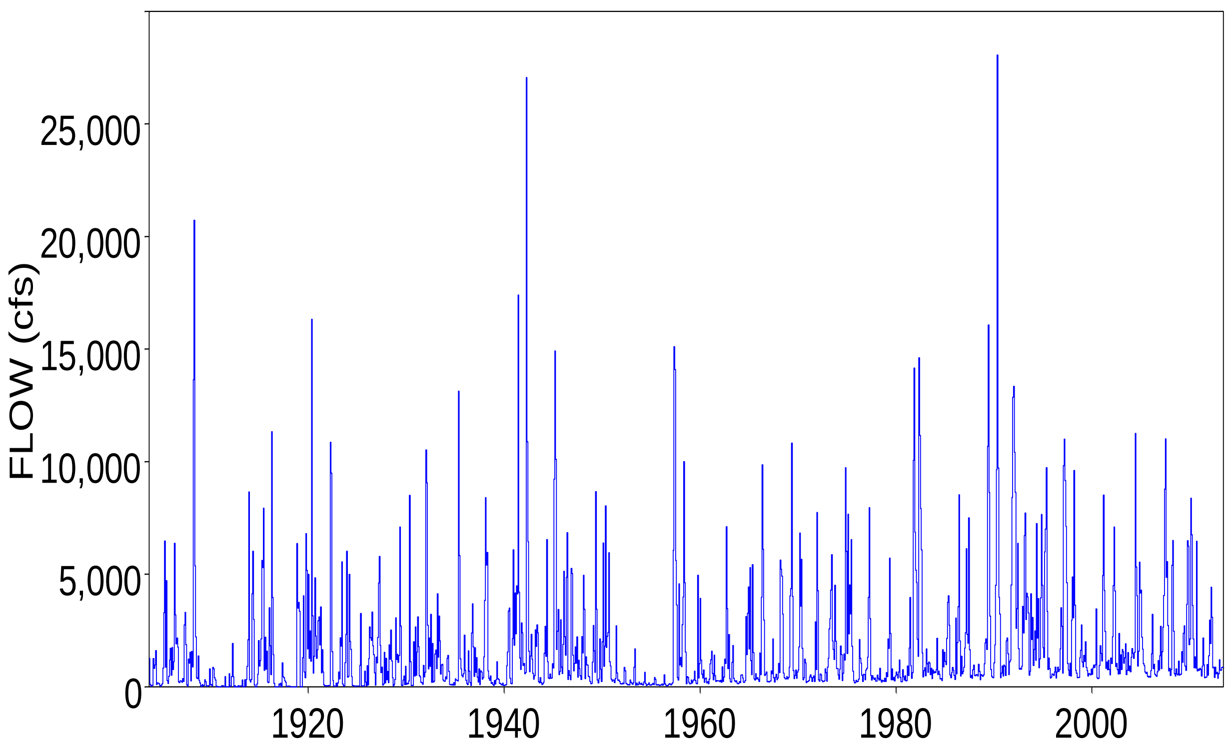
The gage is at West Commerce Street west of IH 35 and north of IH 30 just west of downtown.

A maximum allowable non-flooding discharge of 13,000 cfs at this gage site is designated by the Corps of Engineers for purposes of reservoir flood control operations. The USACE FWD uses this gage along with other gage sites in operating the flood control pools of the federal multiple-purpose Lakes Benbrook, Joe Pool, Ray Roberts, Lewisville, and Grapevine located upstream. A number of nonfederal water supply reservoirs are also located upstream of this gage site.

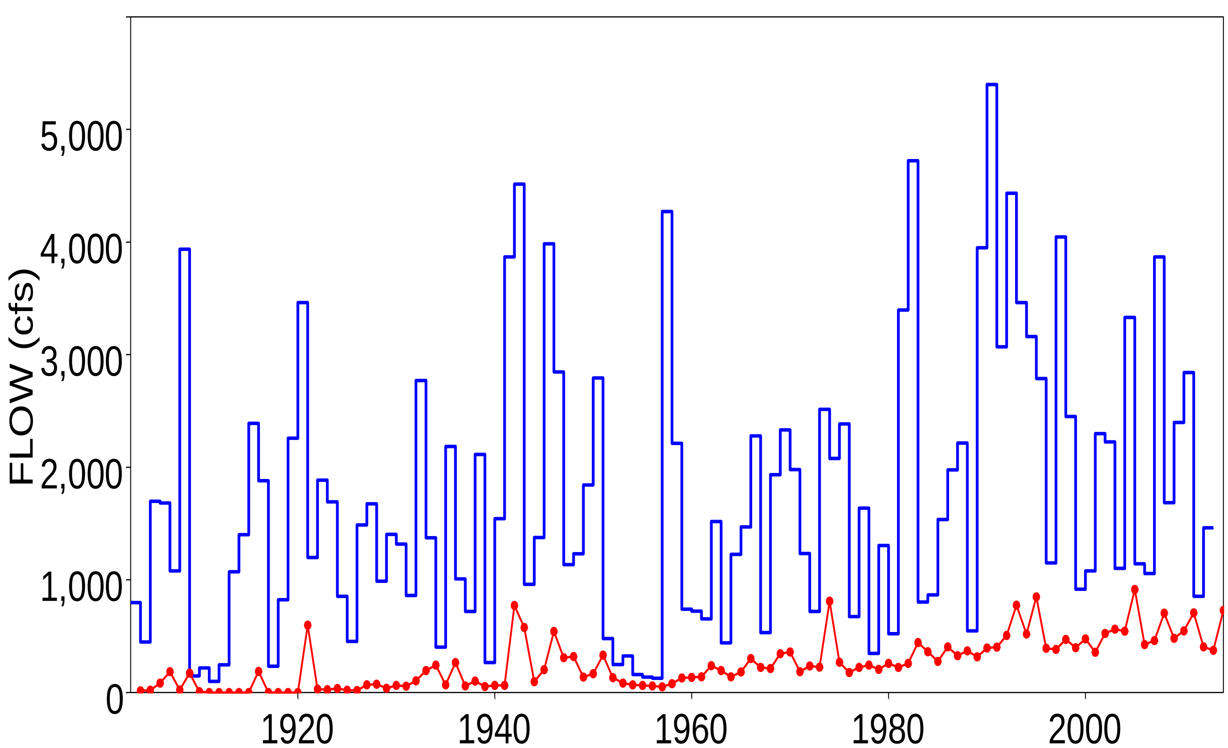
Period-of-record of daily flows: 1903/10/01 to present (2013/6/1)



Daily Flows of Trinity River at Dallas



Monthly Flows of Trinity River at Dallas



Annual Flows and the Minimum Monthly Flow Each Year

24
Trinity River near Rosser

USGS 08062500
Ellis County, Texas

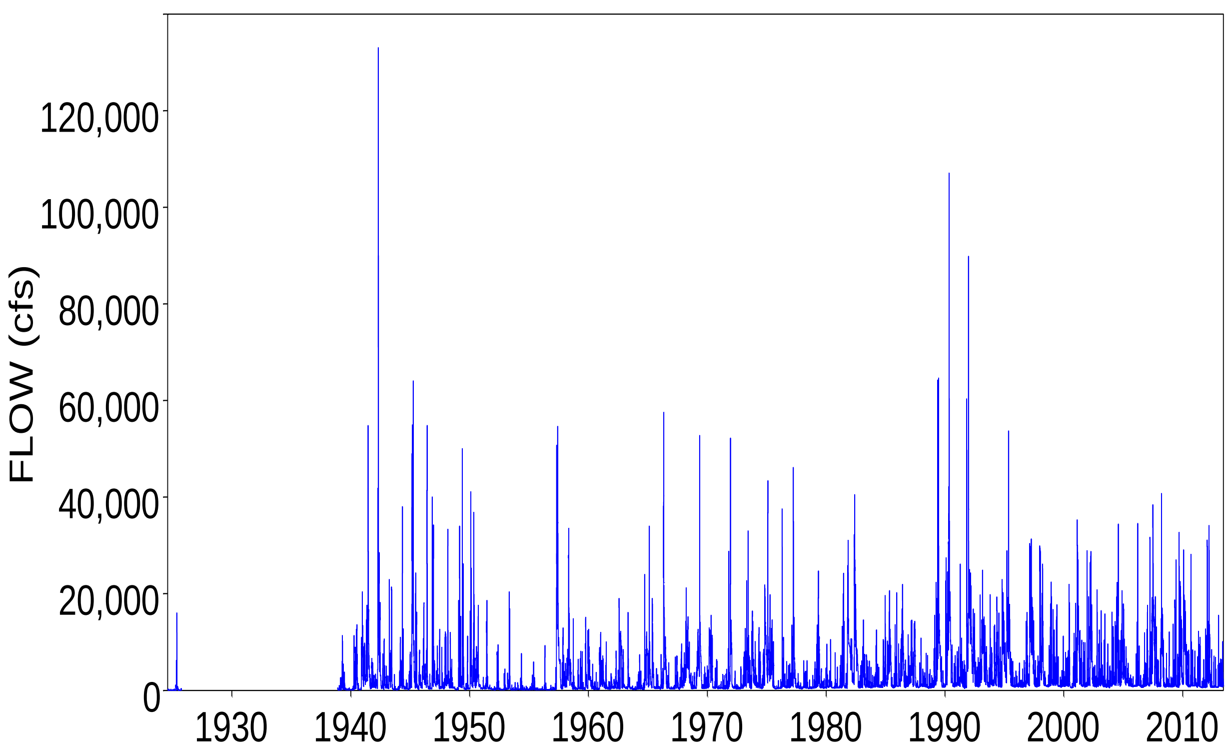
Drainage area 8,147 square miles
Contributing drainage area 8,147 square miles

Latitude 32°25'35", Longitude 96°27'46" NAD27
Gage datum 297.65 feet above NGVD29

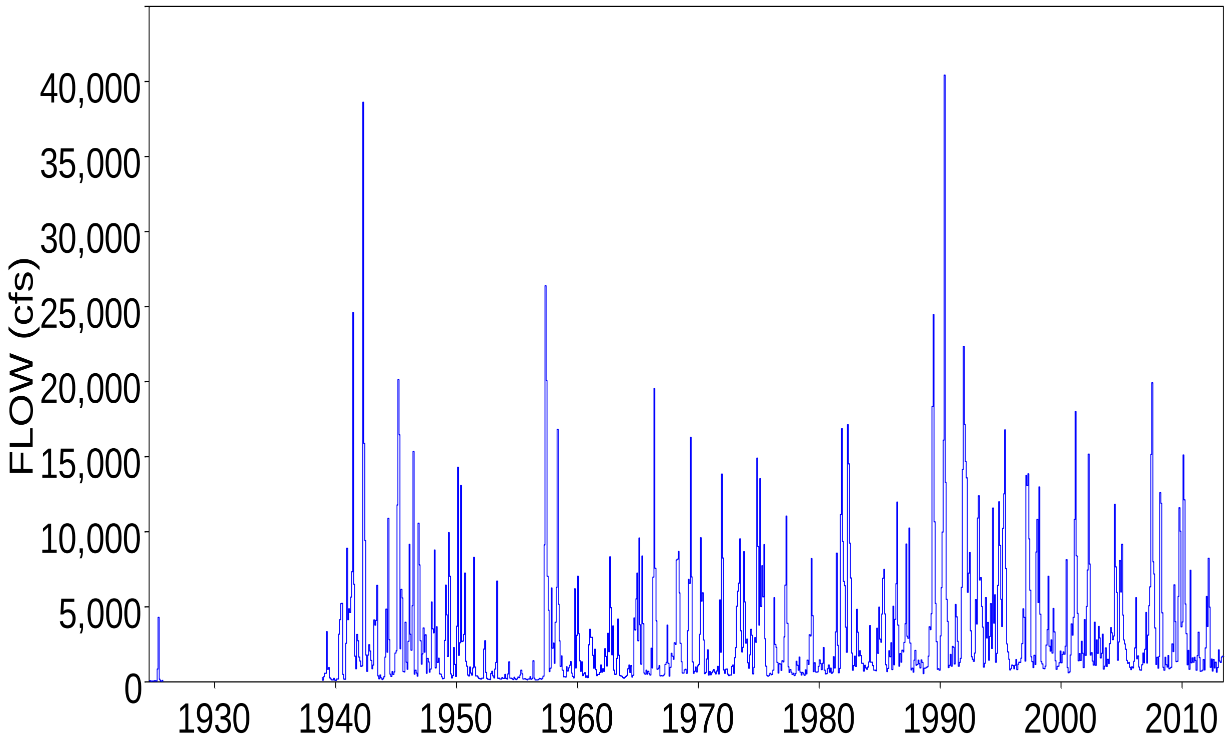
The gage is at Hwy 34 thirty miles downstream of central downtown Dallas and thirty miles upstream of the Cedar Creek confluence with the Trinity River.

A maximum allowable non-flooding discharge of 15,000 cfs at this gage site is designated by the Corps of Engineers for purposes of reservoir flood control operations. The USACE FWD uses this gage along with other gage sites in operating the flood control pools of the federal multiple-purpose Lakes Benbrook, Joe Pool, Ray Roberts, Lewisville, Grapevine, and Lavon located upstream. A number of nonfederal water supply reservoirs are also located upstream of this gage.

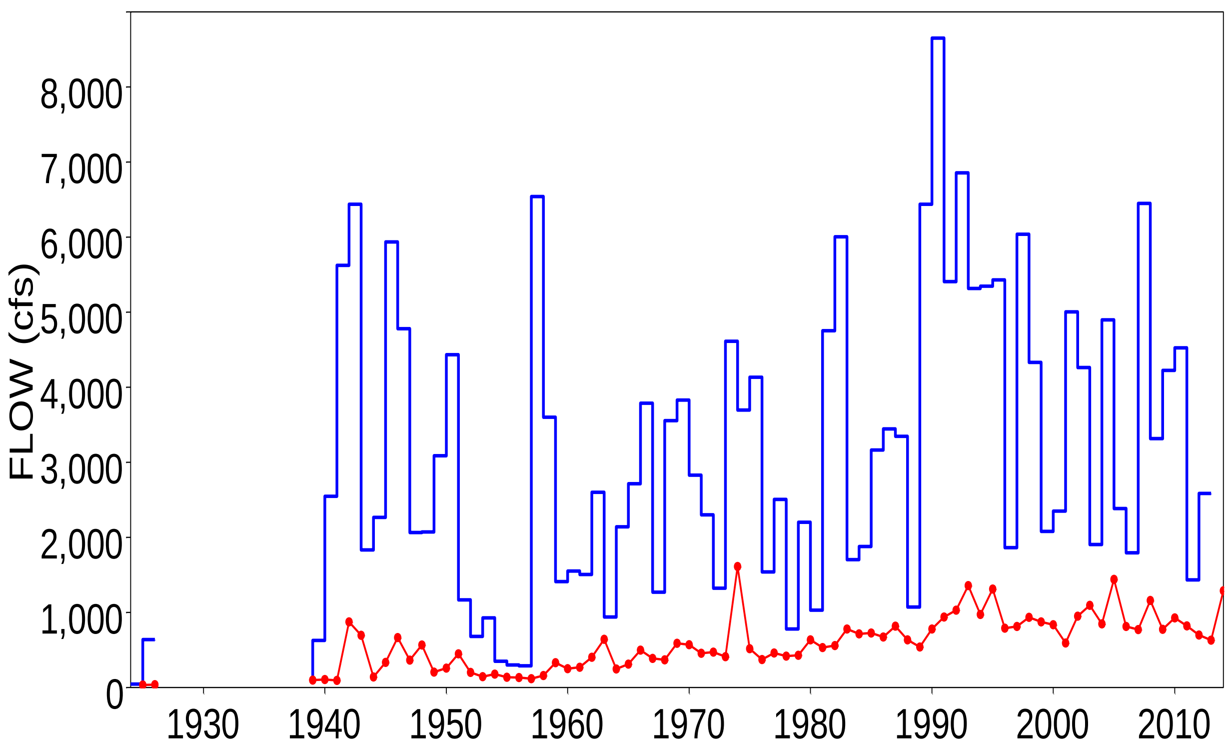
Period-of-record of daily flows: 1924/8/01 to present (2013/6/1)



Daily Flows of Trinity River near Rosser



Monthly Flows of Trinity River near Rosser



Annual Flows and the Minimum Monthly Flow Each Year

25
Trinity River near Oakwood

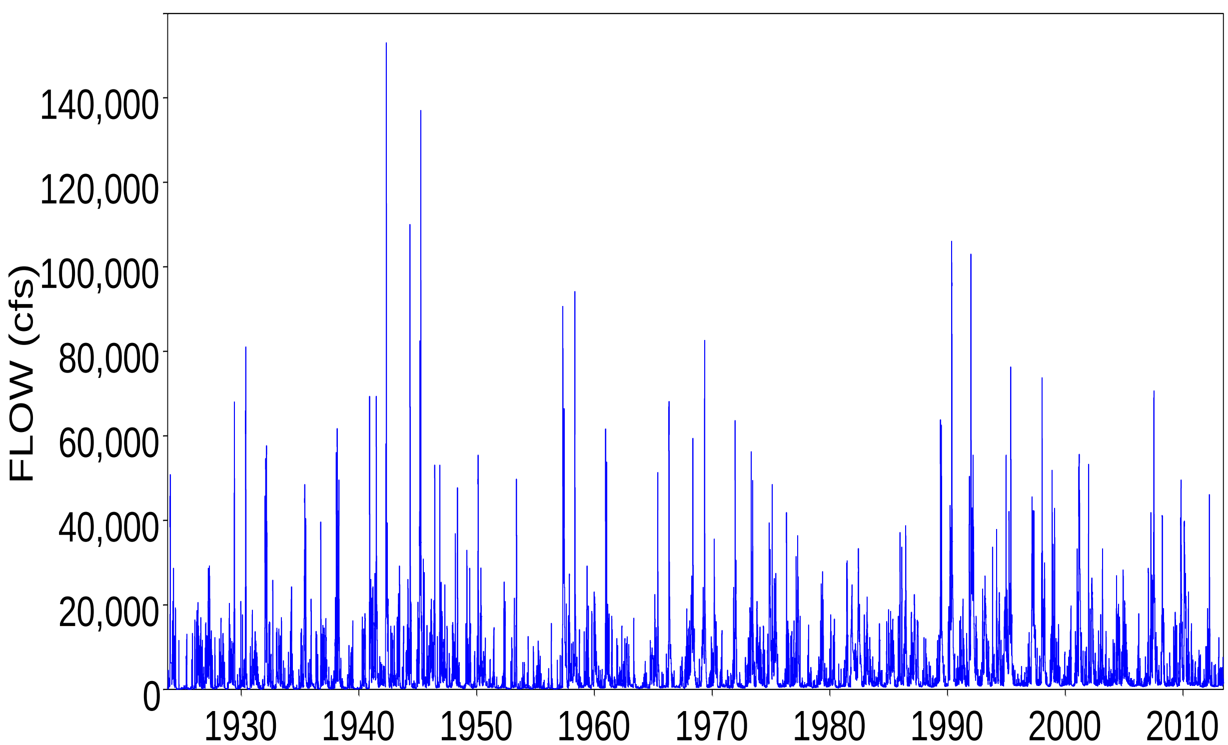
USGS 08065000
Anderson County, Texas

Drainage area 12,833 square miles
Contributing drainage area 12,833 square miles

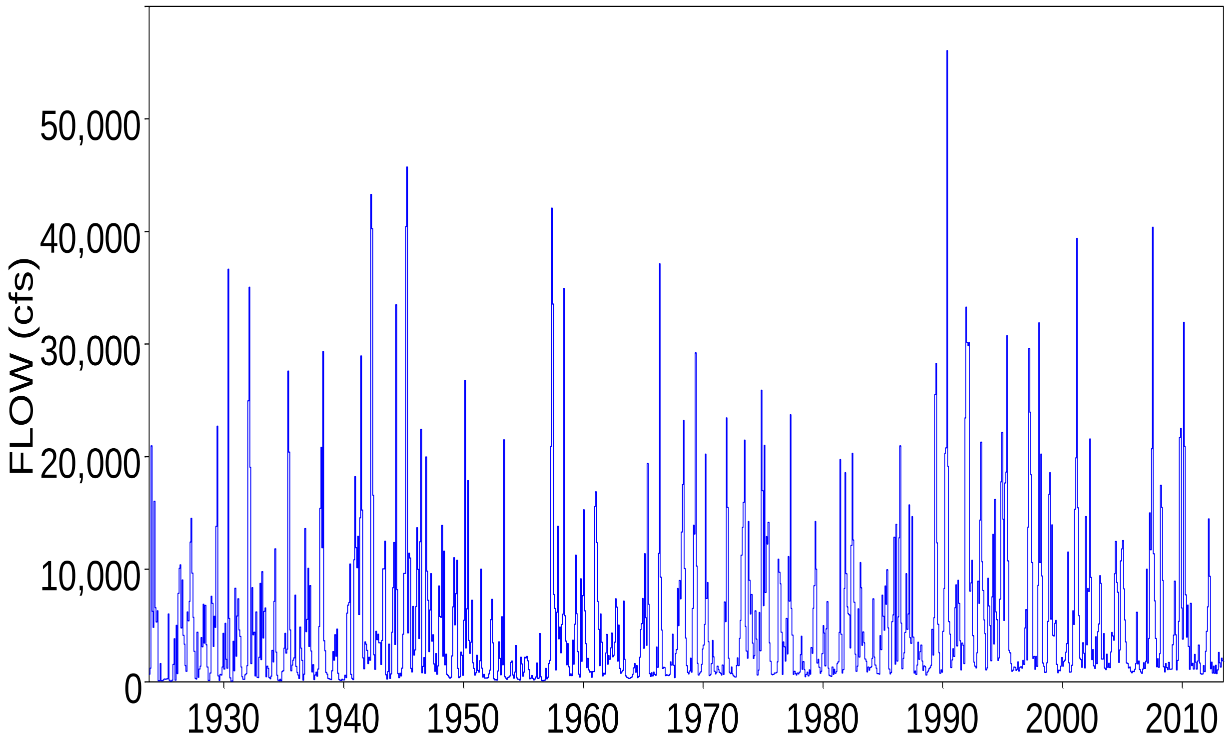
Latitude 31°38'54", Longitude 95°47'21" NAD27
Gage datum 175.06 feet above NGVD29

The gage is at Hwy 79 about forty miles below Richland Chambers Reservoir.

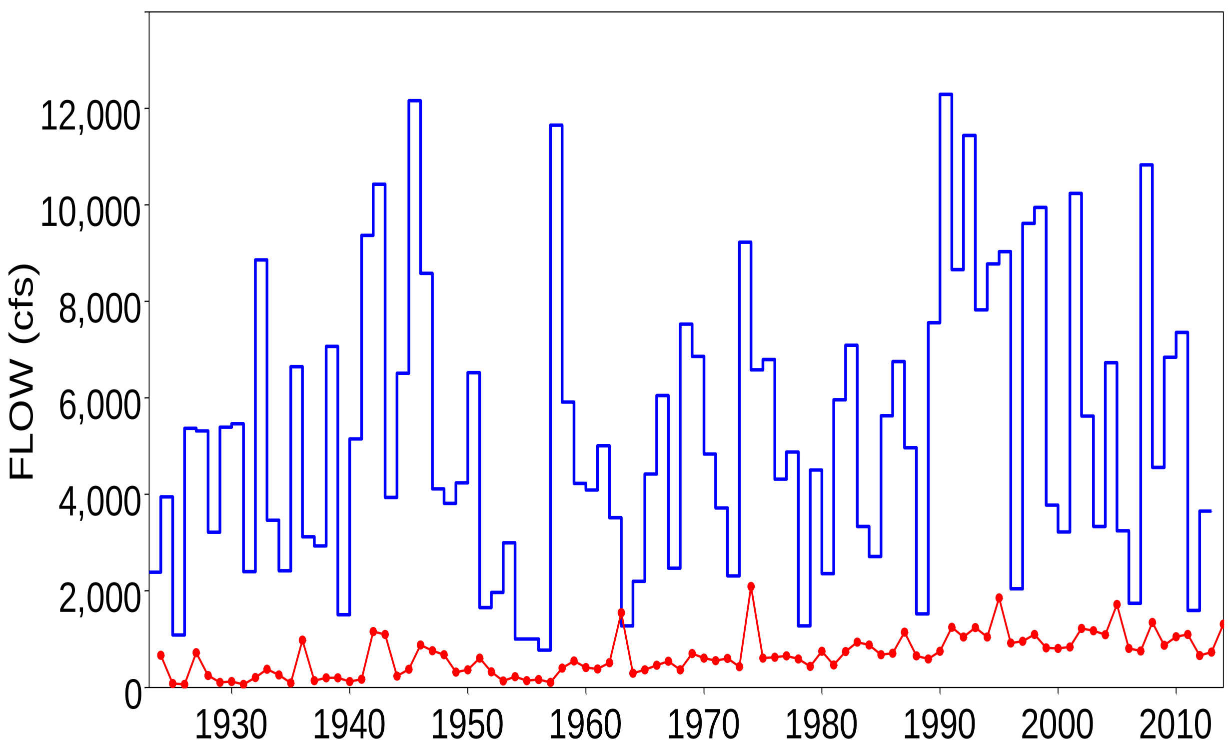
Period-of-record of daily flows: 1923/10/01 to present (2013/6/1)



Daily Flows of Trinity River near Oakwood



Monthly Flows of Trinity River near Oakwood



Annual Flows and the Minimum Monthly Flow Each Year

26
Trinity River at Romayor

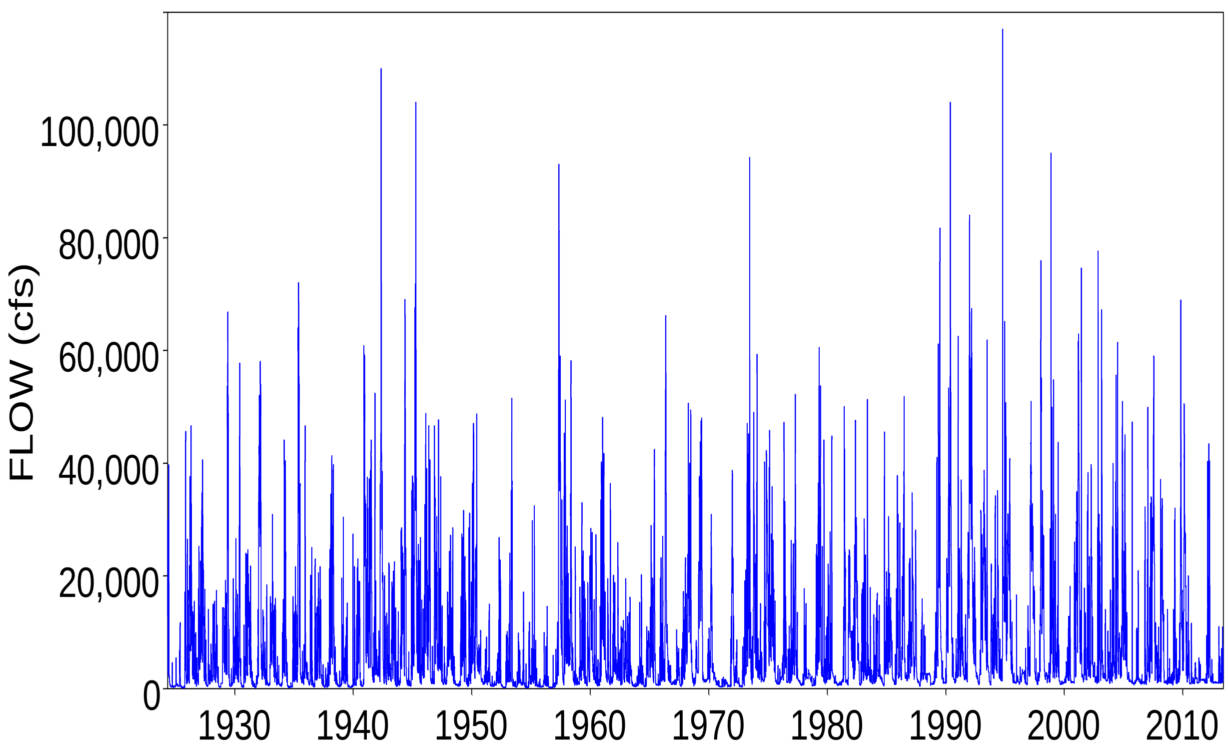
USGS 08066500
Liberty County, Texas

Drainage area 17,186 square miles
Contributing drainage area 17,186 square miles

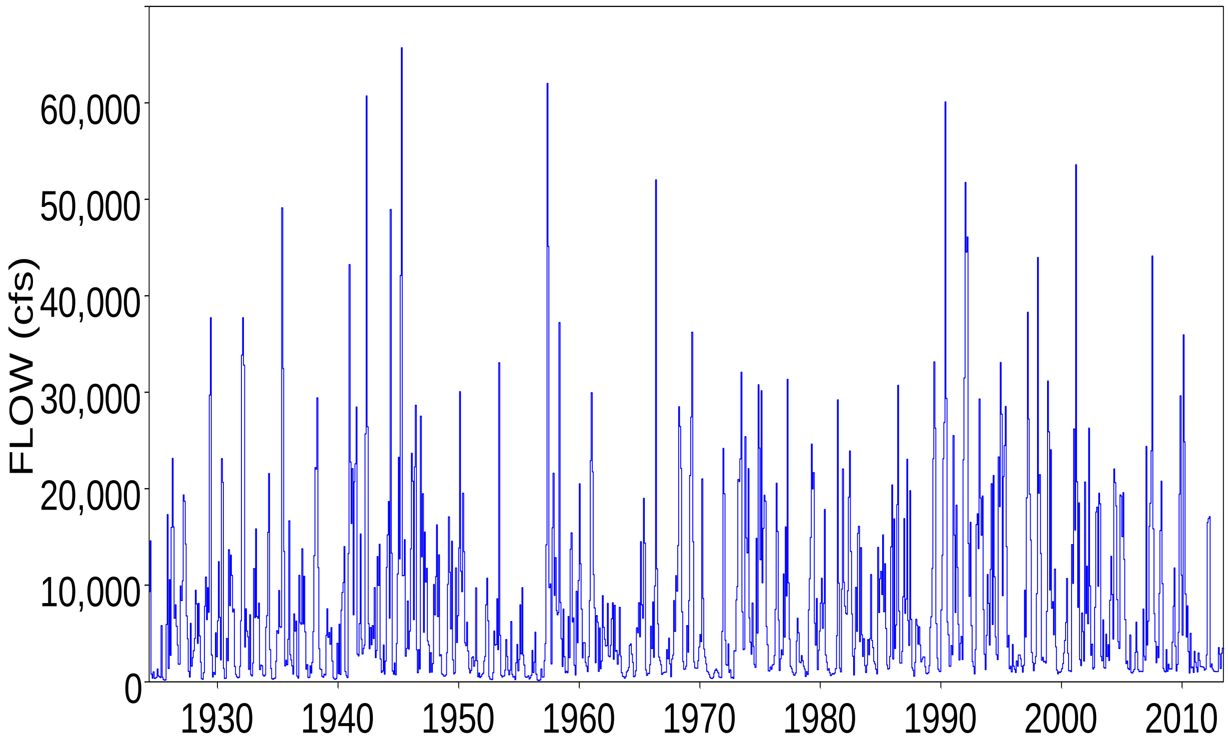
Latitude 30°25'30", Longitude 94°51'02" NAD27
Gage datum 25.92 feet above NGVD29

The gage is at FM 787 twenty miles below the dam at Lake Livingston and fifty miles above the Trinity River outlet at Galveston Bay.

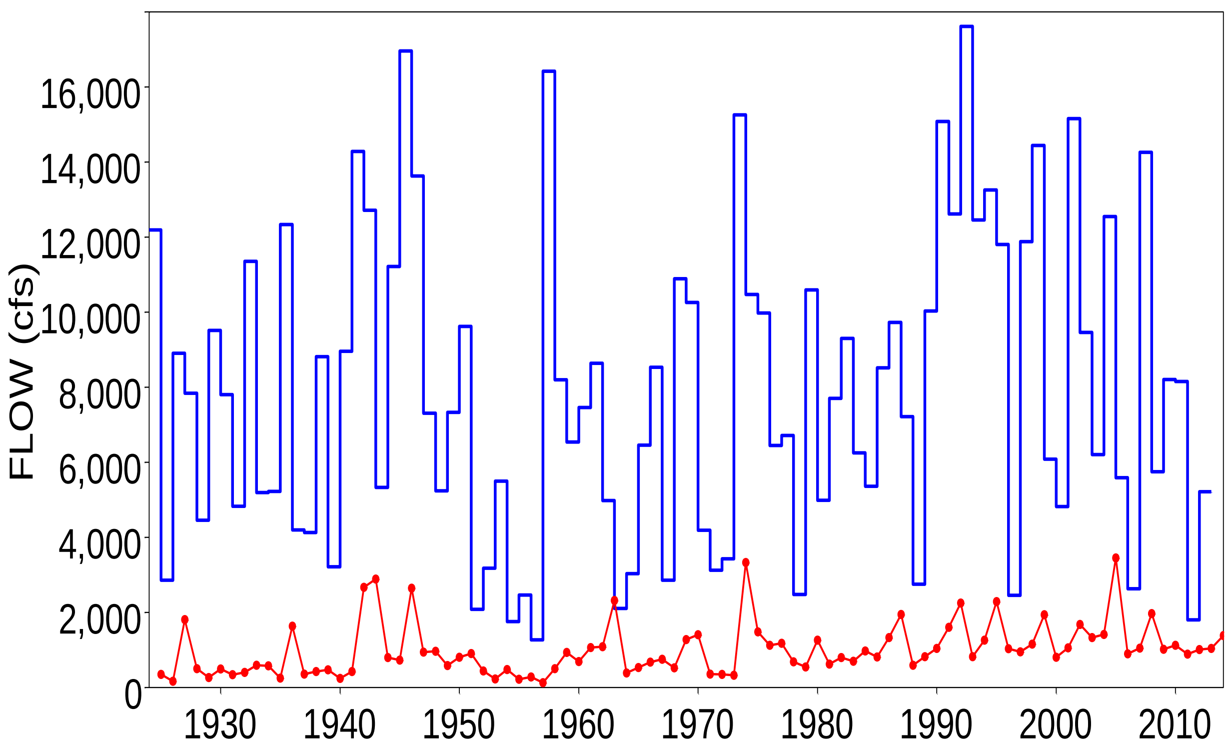
Period-of-record of daily flows: 1924/5/01 to present (2013/6/1)



Daily Flows of Trinity River at Romayor



Monthly Flows of Trinity River at Romayor



Annual Flows and the Minimum Monthly Flow Each Year

27
Neches River near Rockland

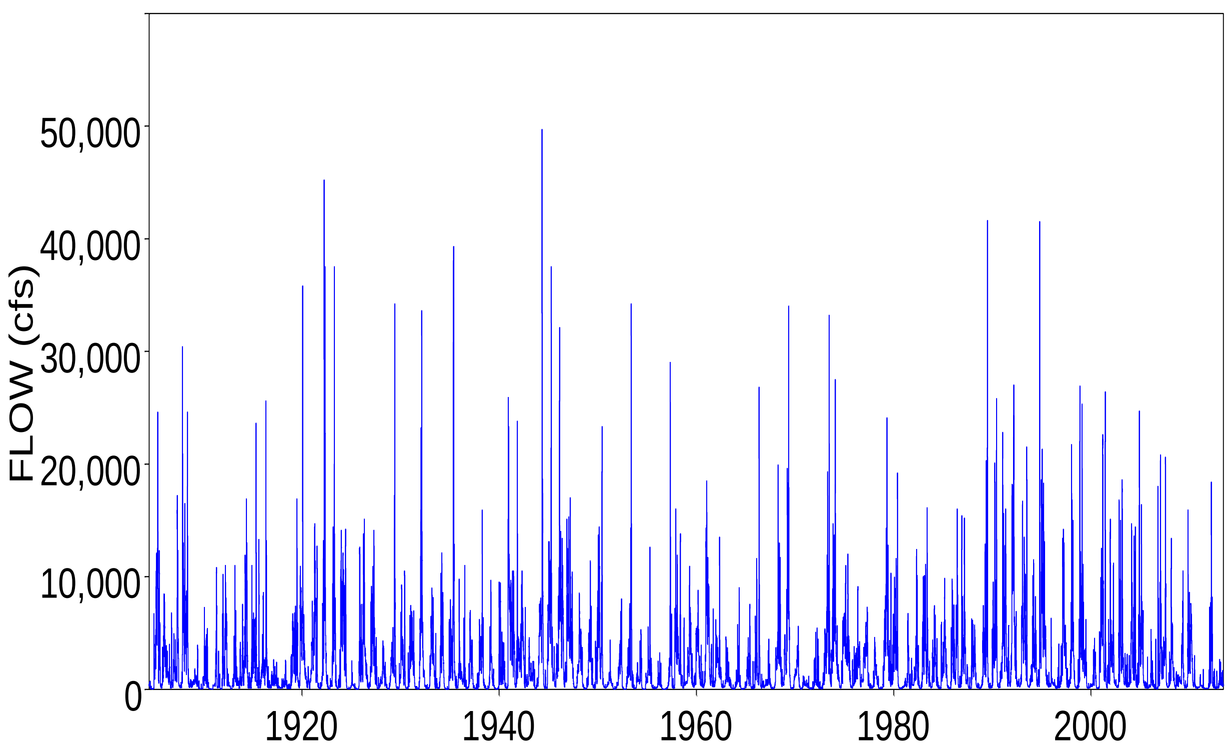
USGS 08033500
Tyler County, Texas

Drainage area 3,636 square miles
Contributing drainage area 3,636 square miles

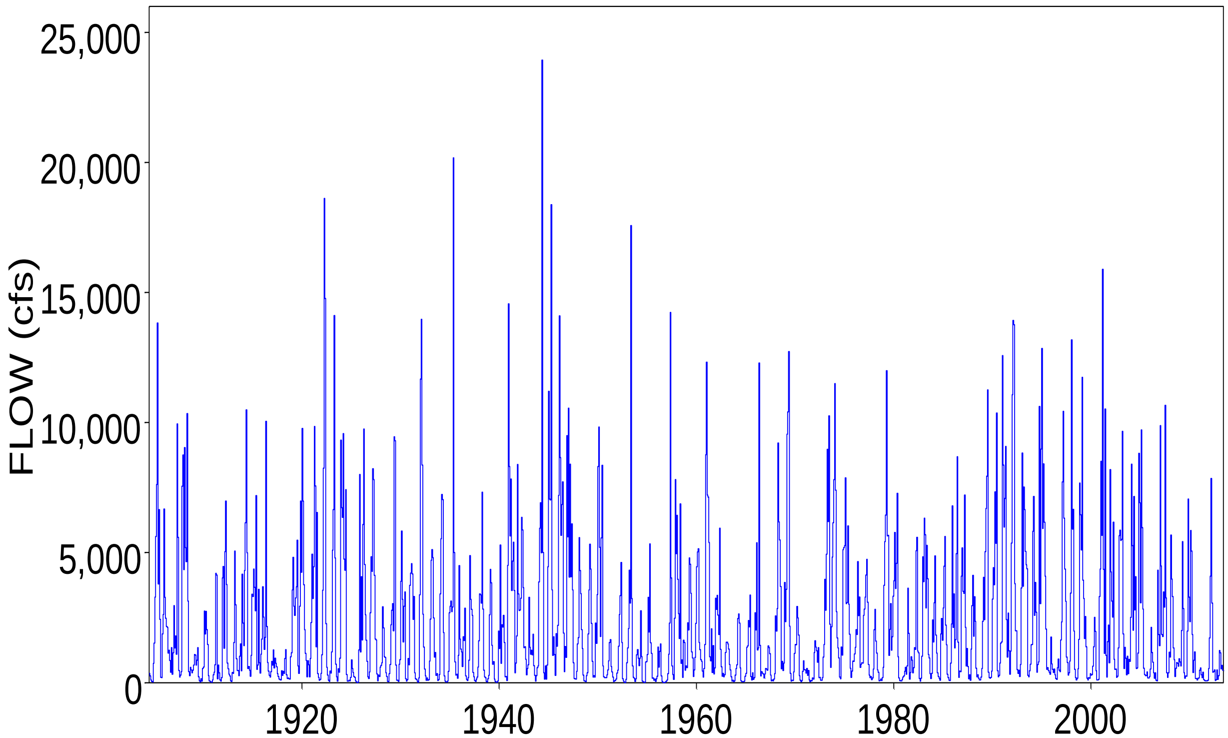
Latitude 31°01'30", Longitude 94°23'58" NAD83
Gage datum 88.41 feet above NGVD29

The gage is at Hwy 69 20 miles upstream of confluence of Angelina River with Neches River.

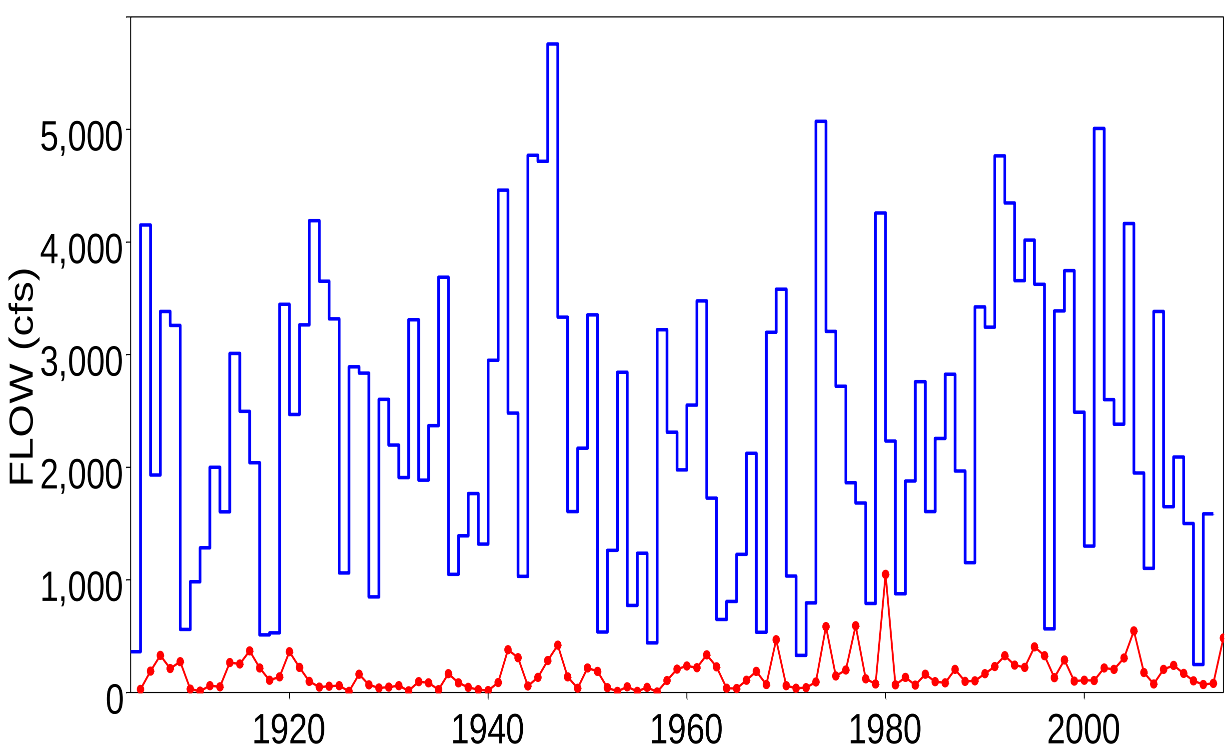
Period-of-record of daily flows: 1904/7/01 to present (2013/6/1)



Daily Flows of Neches River near Rockland



Monthly Flows of Neches River near Rockland



Annual Flows and the Minimum Monthly Flow Each Year

28
Neches River near Evansdale

USGS 08041000
Jasper County, Texas

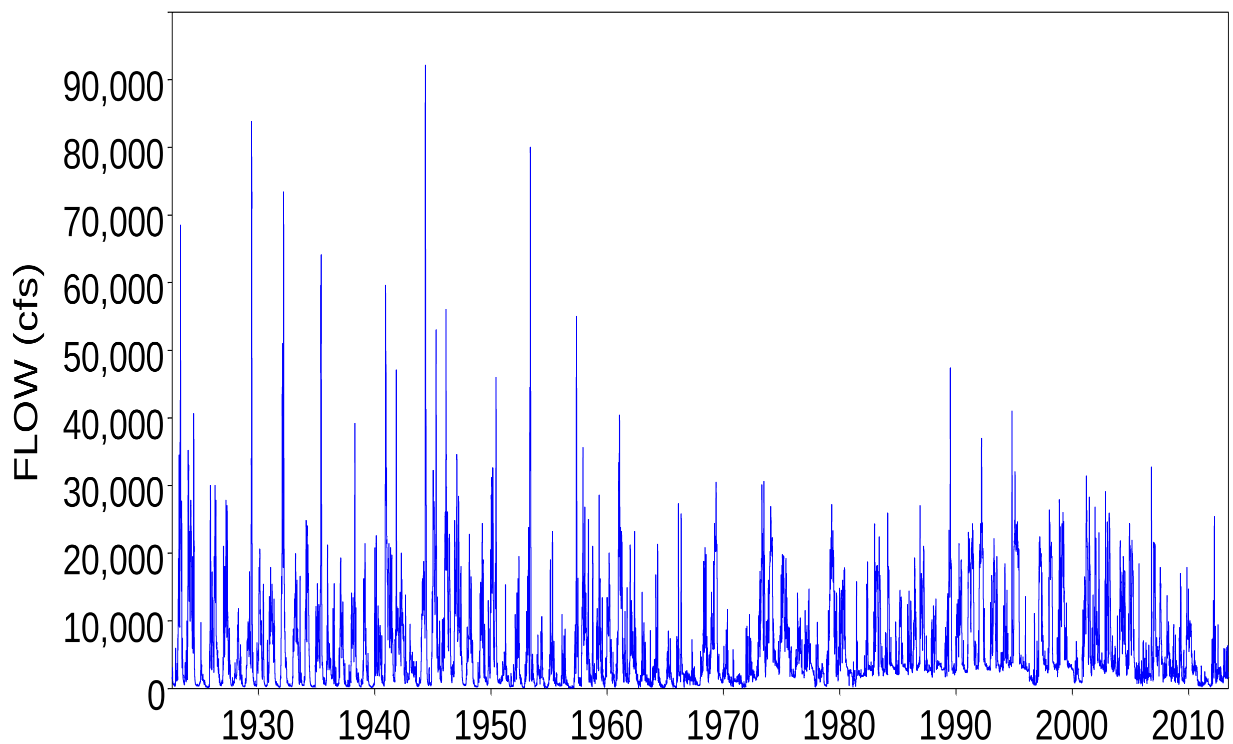
Drainage area 7,951 square miles
Contributing drainage area 7,951 square miles

Latitude 30°21'20", Longitude 94°05'35" NAD27
Gage datum 8.25 feet above NGVD29

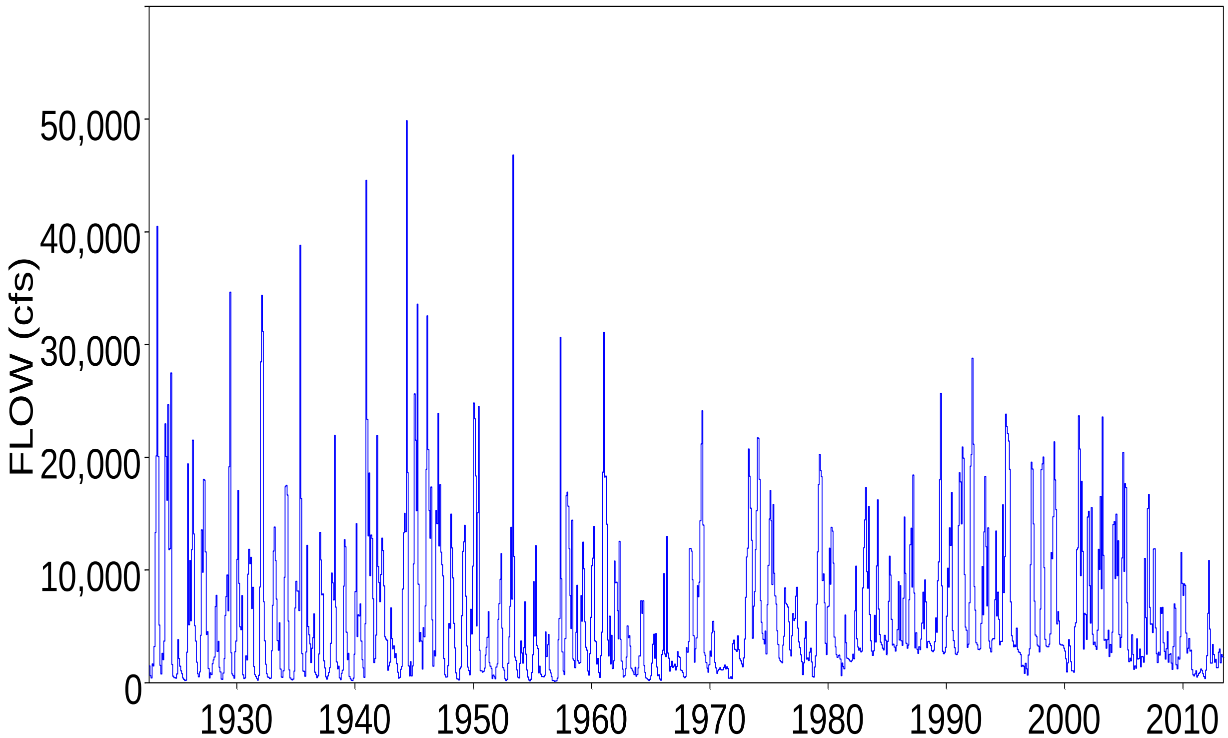
This gage is at Hwy 96 twenty-five miles upstream of IH 10 in Beaumont.

A maximum allowable non-flooding discharge of 20,000 cfs at this gage site is designated by the Corps of Engineers for purposes of reservoir flood control operations of the federal multiple-purpose Sam Rayburn Reservoir located upstream on the Angelina River.

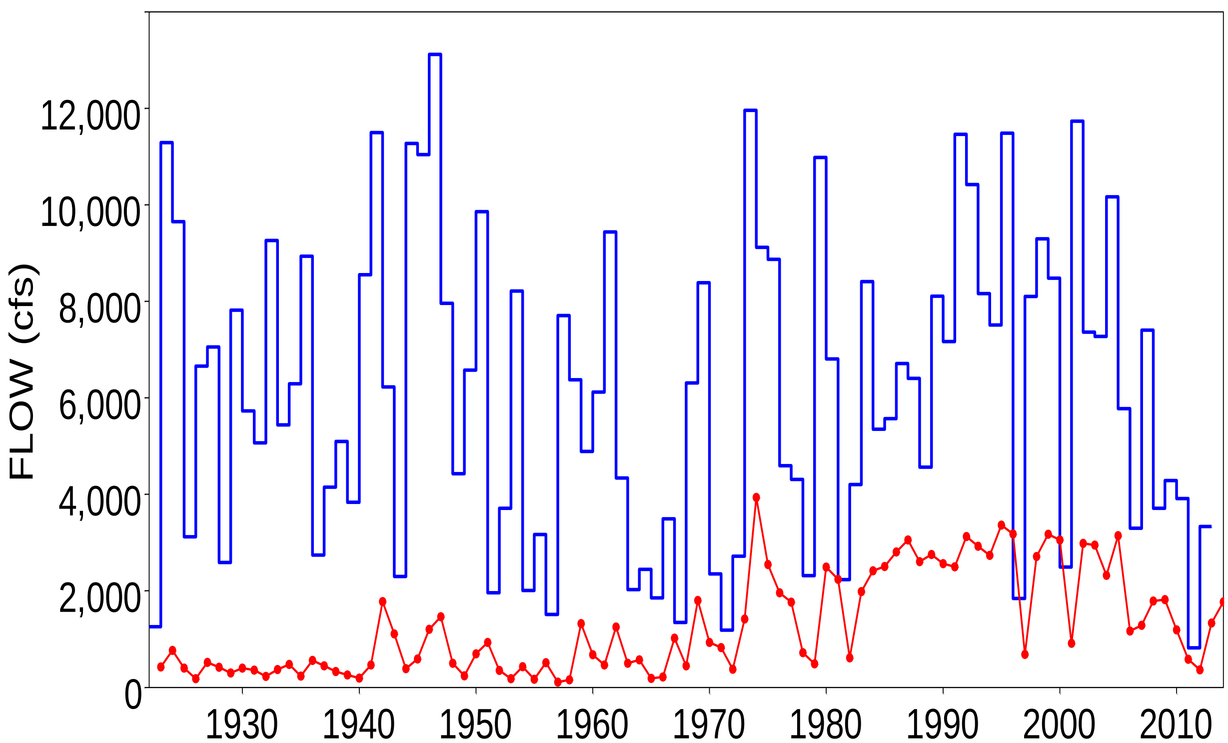
Period-of-record of daily flows: 1922/8/01 to present (2013/6/1)



Daily Flows of Neches River near Evansdale



Monthly Flows of Neches River near Evansdale



Annual Flows and the Minimum Monthly Flow Each Year

29
Sabine River near Beckville

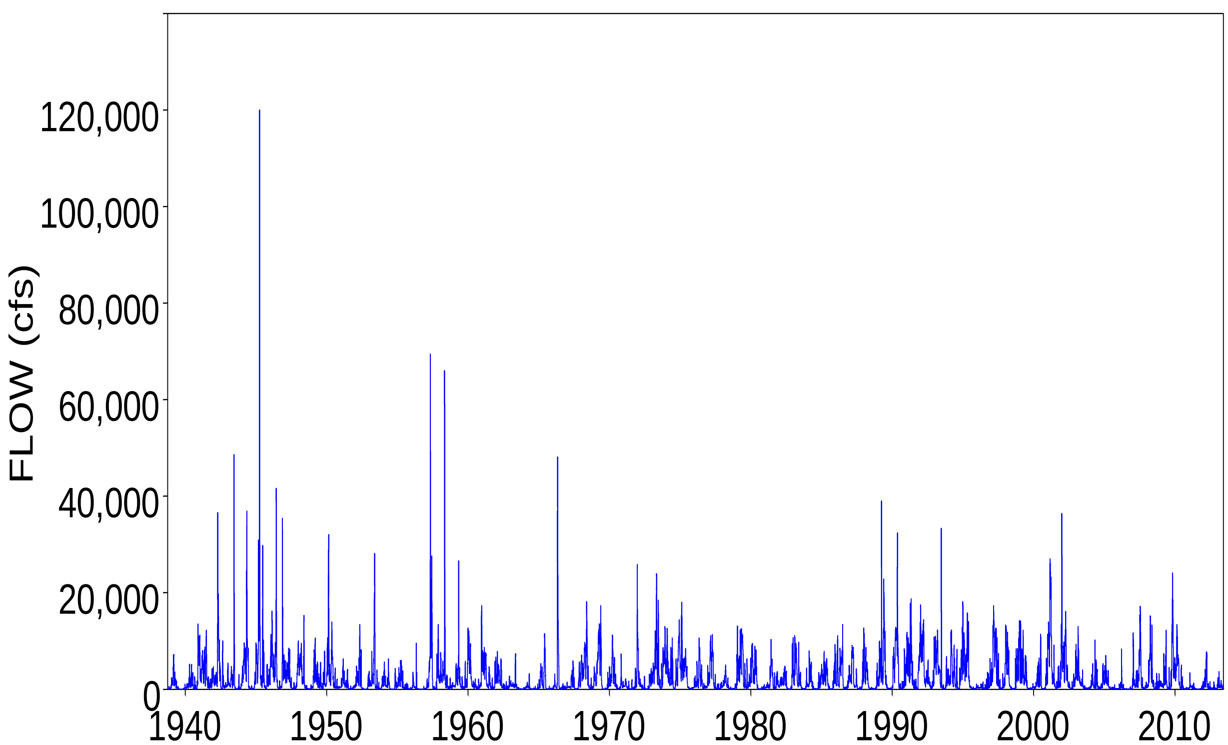
USGS 8022040
Panola County, Texas

Drainage area 3,589 square miles
Contributing drainage area 3,589 square miles

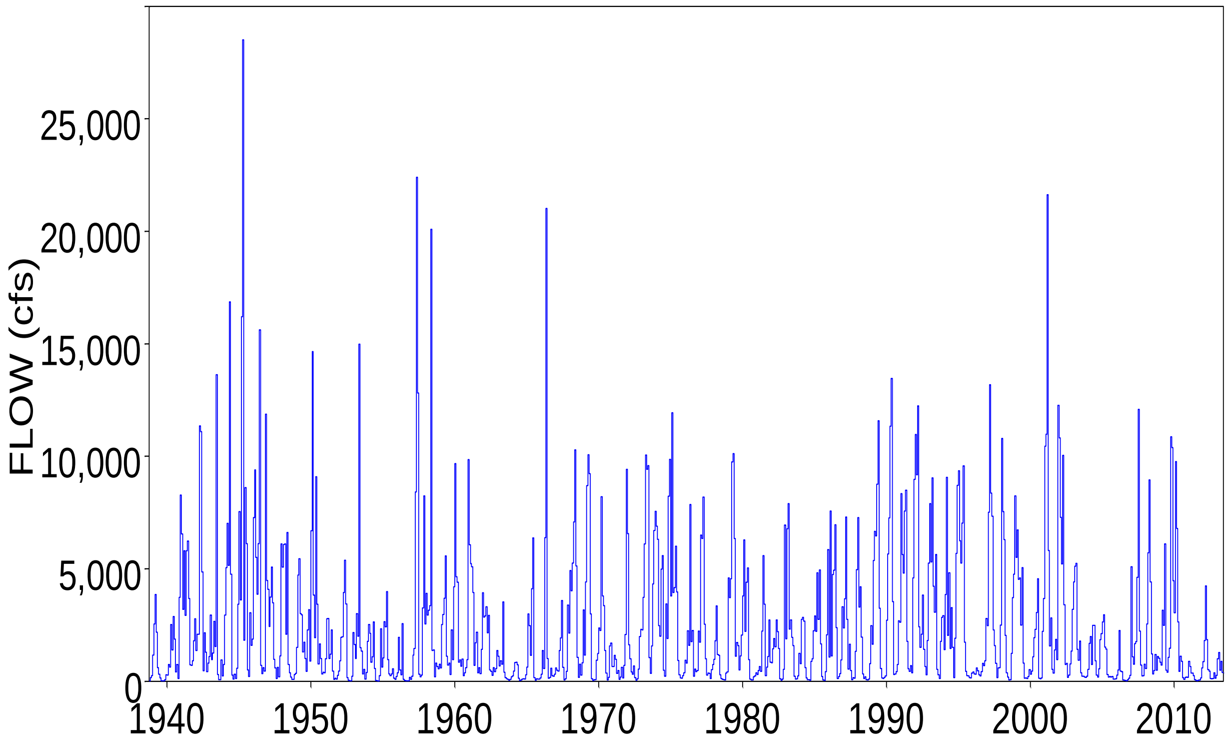
Latitude 32°19'38", Longitude 94°21'12" NAD27
Gage datum 190 feet above NGVD29

The gage is at Hwy 59 about 20 miles downstream of IH 20.

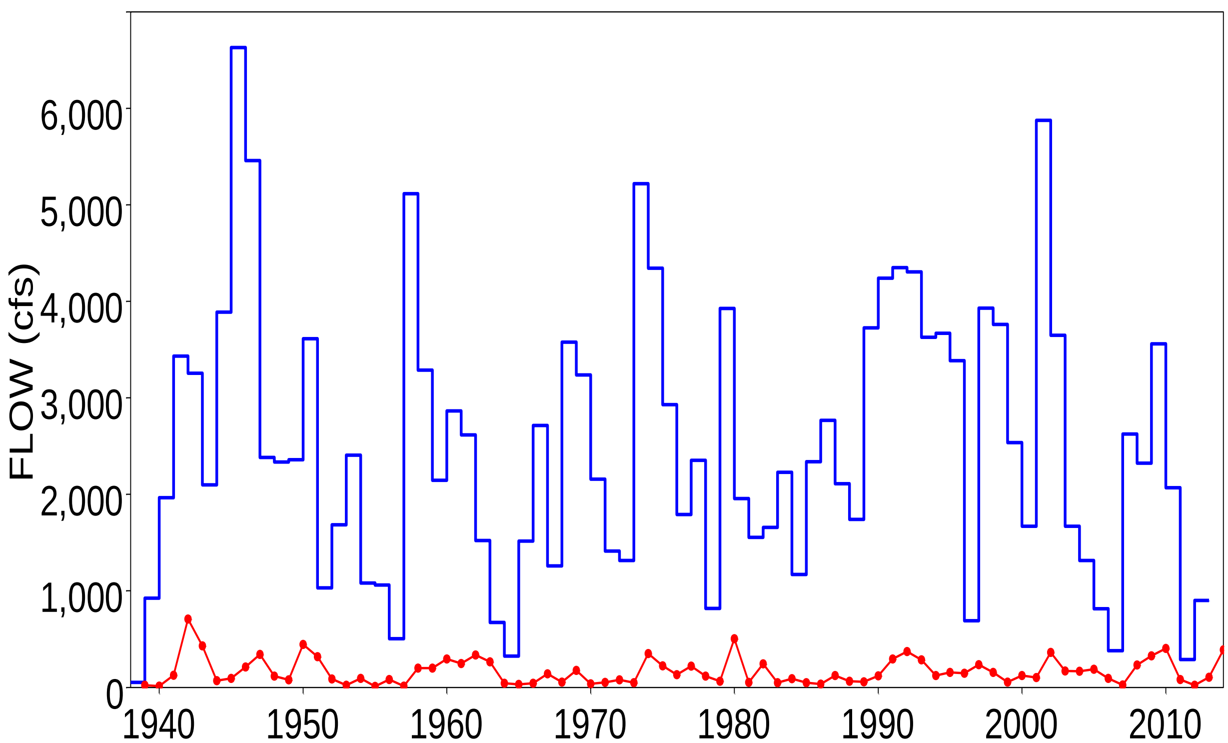
Period-of-record of daily flows: 1938/10/01 to present (2013/6/1)



Daily Flows of Sabine River near Beckville



Monthly Flows of Sabine River near Beckville



Annual Flows and the Minimum Monthly Flow Each Year

30
Sabine River near Ruliff

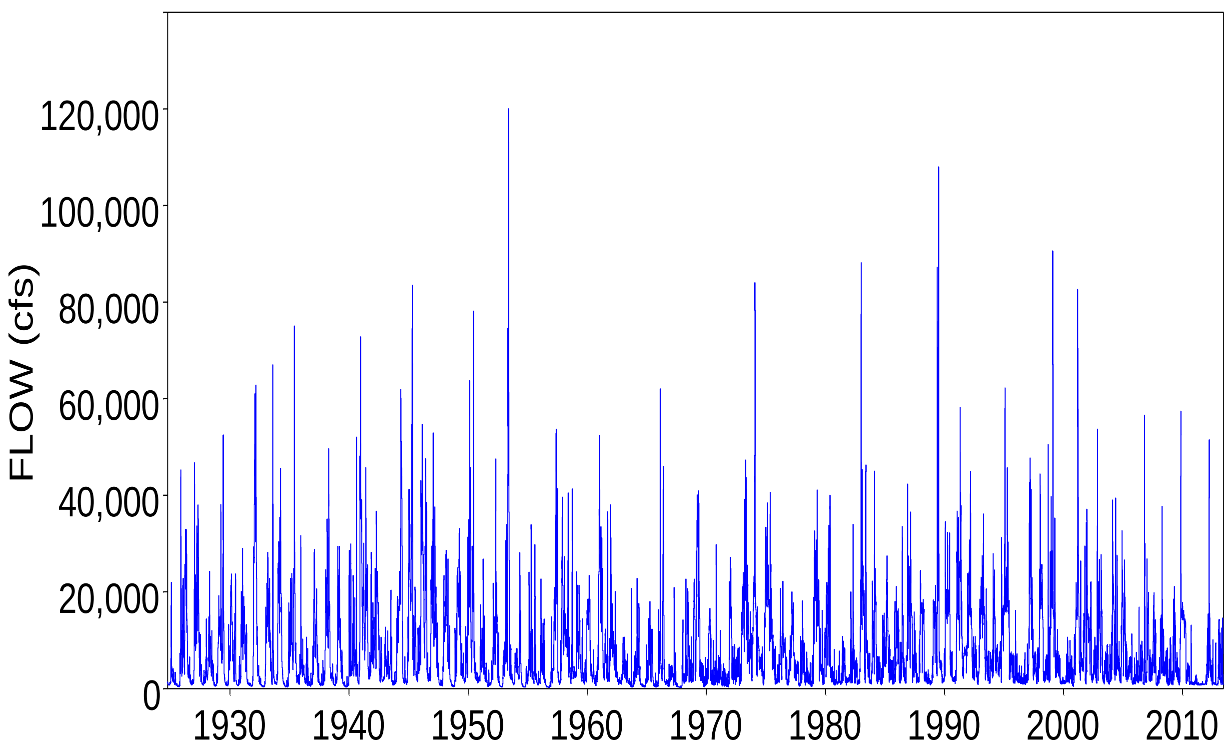
USGS 8030500
Newton County, Texas

Drainage area 9,329 square miles
Contributing drainage area 9,329 square miles

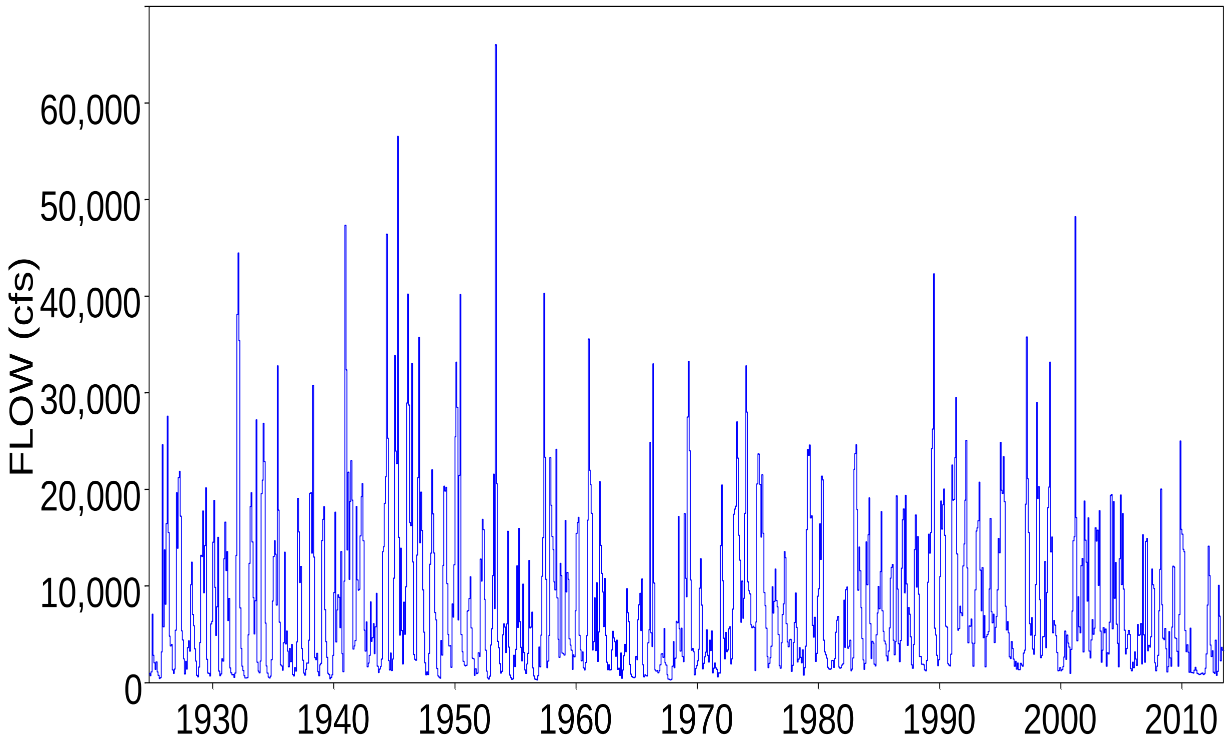
Latitude 30°18'13", Longitude 93°44'37" NAD27
Gage datum -5.92 feet above NGVD29

The gage is at Hwy 12 about 12 miles upstream if IH 10 which connects Beaumont and Lake Charles.

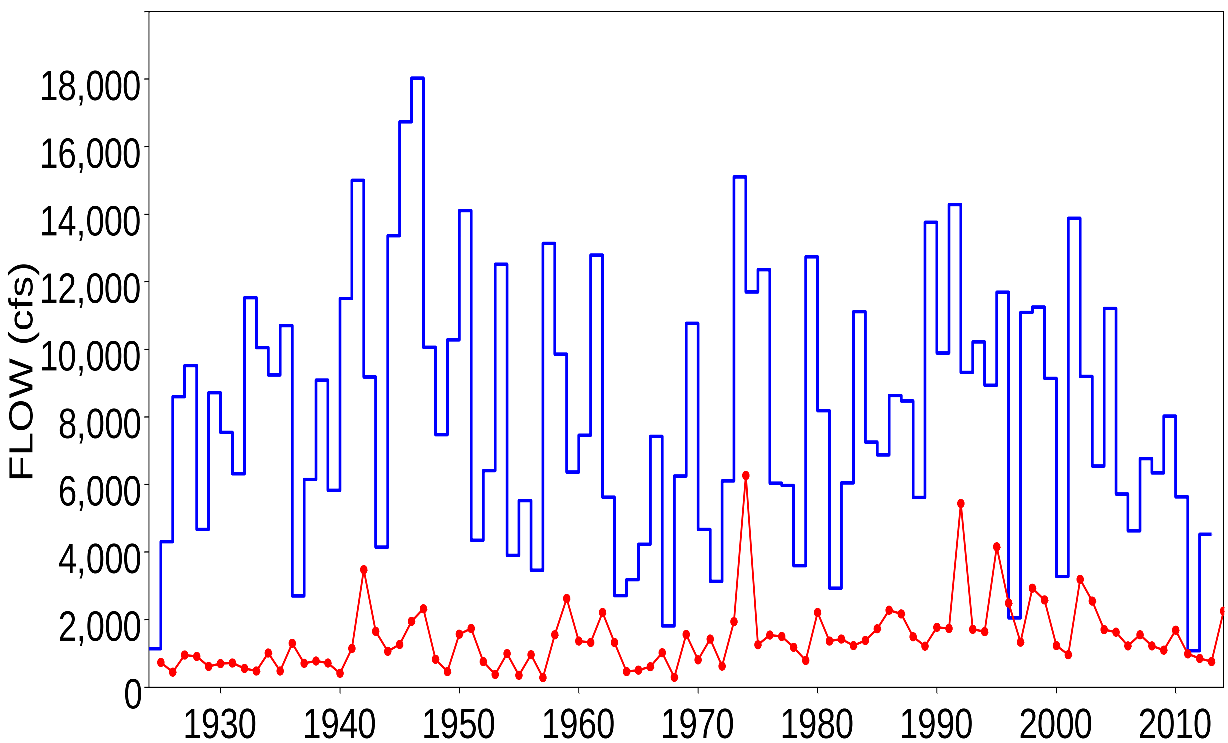
Period-of-record of daily flows: 1924/10/01 to present (2013/6/1)



Daily Flows of Sabine River near Ruliff



Monthly Flows of Sabine River near Ruliff



Annual Flows and the Minimum Monthly Flow Each Year

31
Big Cypress Bayou near Jefferson

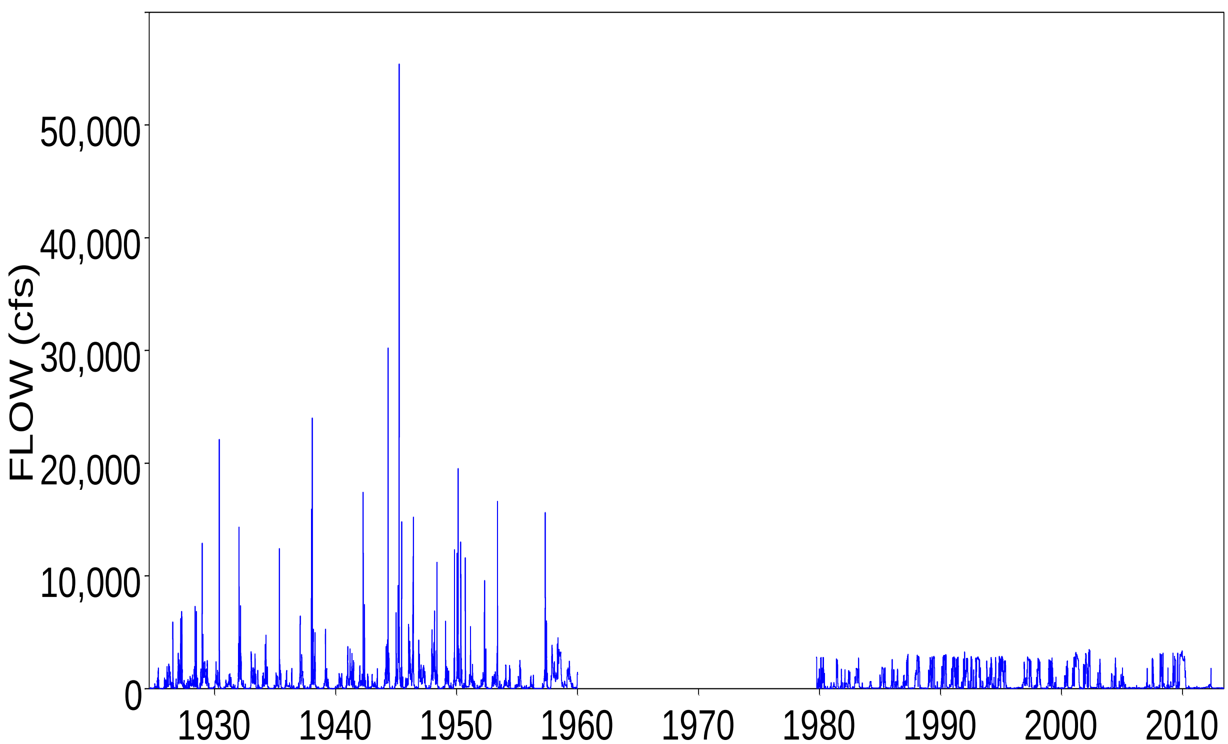
USGS 07346000
Marion County, Texas

Drainage area 850 square miles
Contributing drainage area 850 square miles

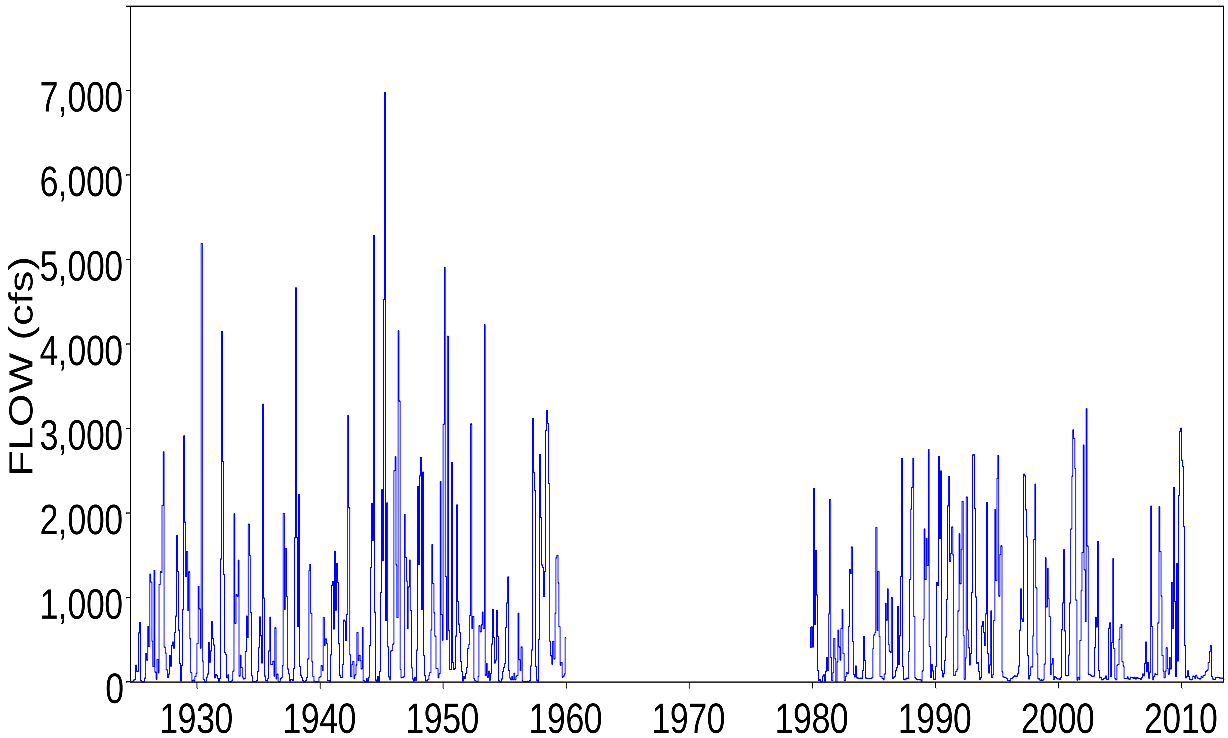
Latitude 32°44'58", Longitude 94°29'55" NAD27
Gage datum 180.00 feet above NGVD29

The gage is below the dam at Lake O the Pines. FM 726 is on the dam. The gage is about thirty miles upstream of the Louisiana border which crosses Caddo Lake.

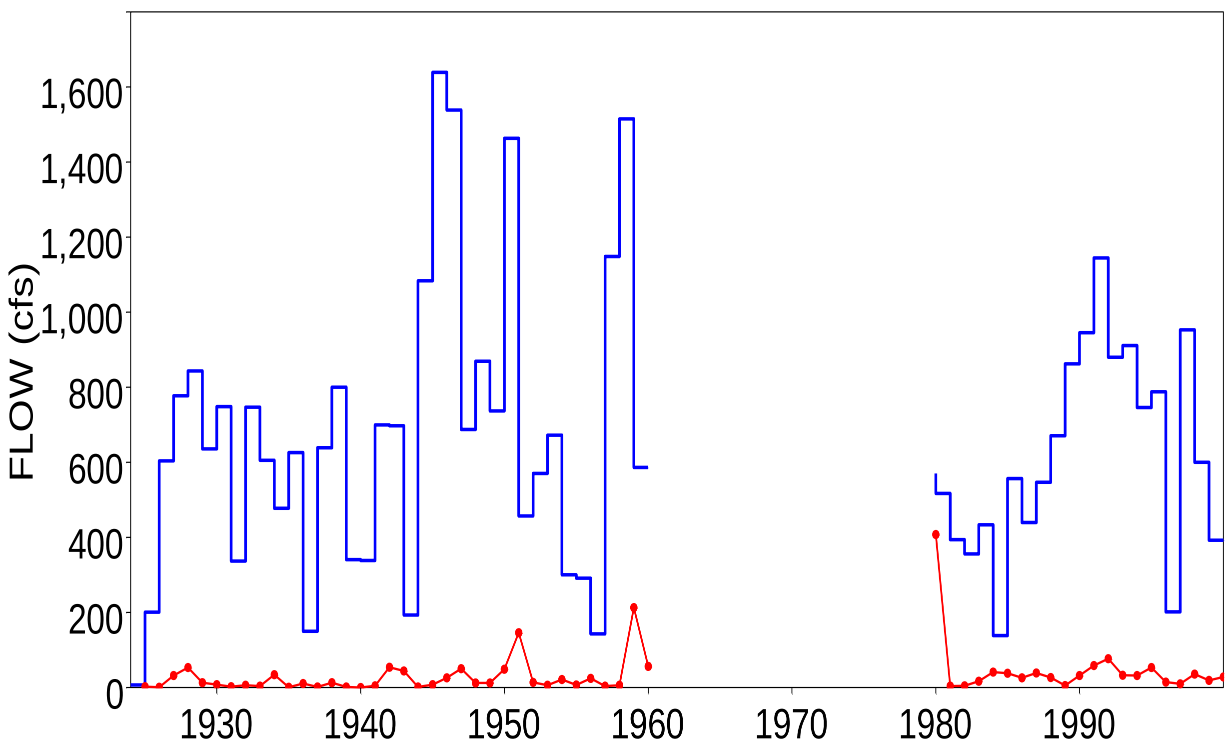
Period-of-record of daily flows: 1924/8/01 to present (2013/6/1)



Daily Flows of Big Cypress Bayou near Jefferson



Monthly Flows of Big Cypress Bayou near Jefferson



Annual Flows and the Minimum Monthly Flow Each Year

32
Red River near Terrel, Oklahoma

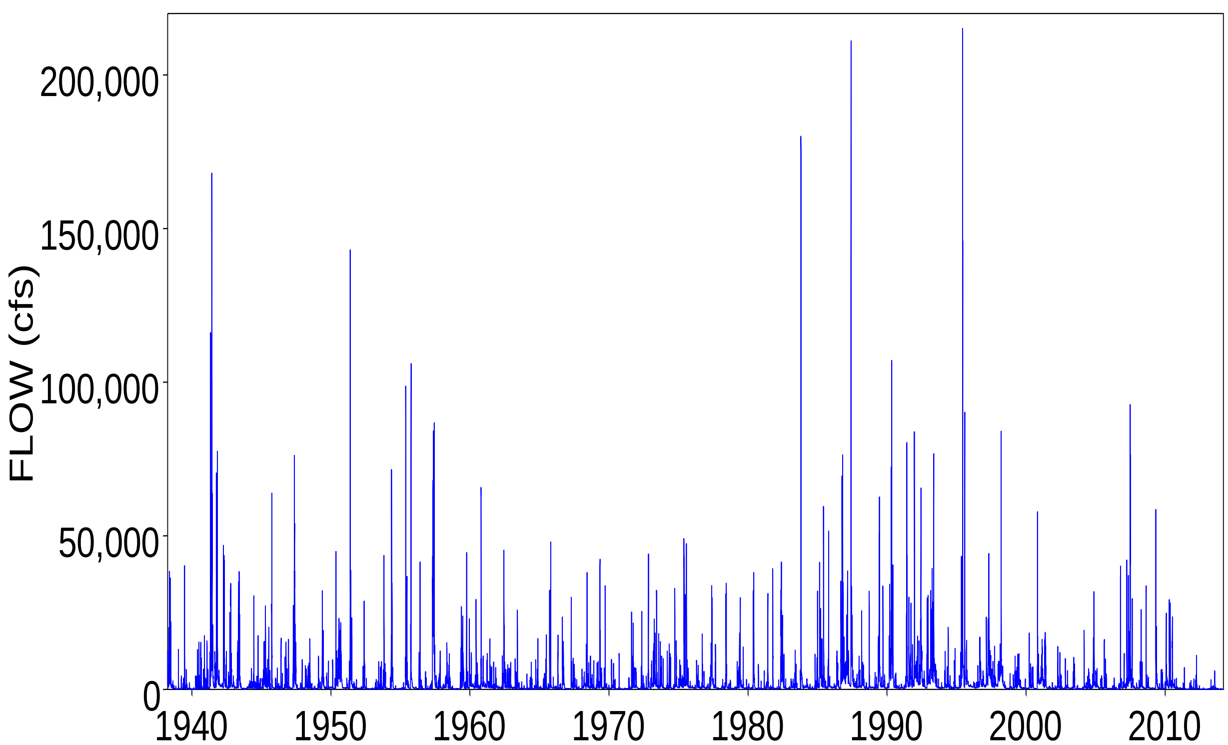
USGS 07315500
Jefferson County, Oklahoma

Drainage area 28,723 square miles
Contributing drainage area 22,787 square miles

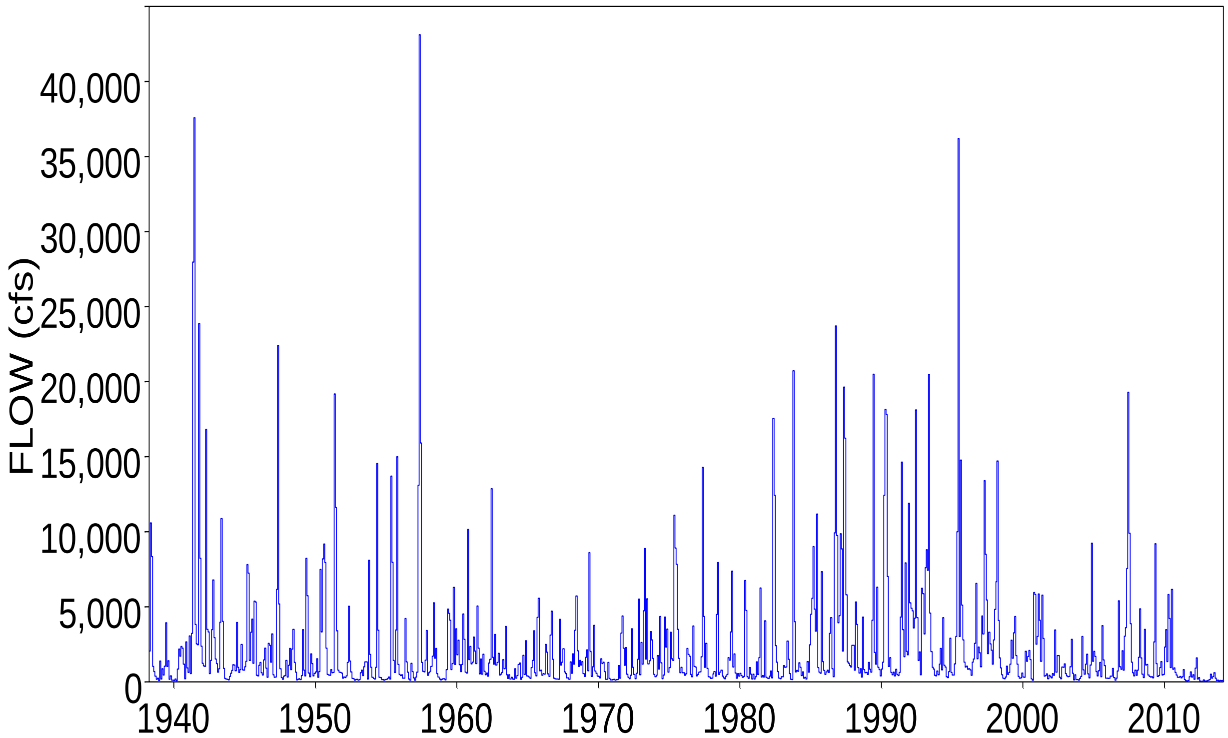
Latitude 33°52'43", Longitude 97°56'03" NAD27
Gage datum 770.31 feet above NGVD29

The gage is at Hwy 81 thirty miles east of the city of Wichita Falls.

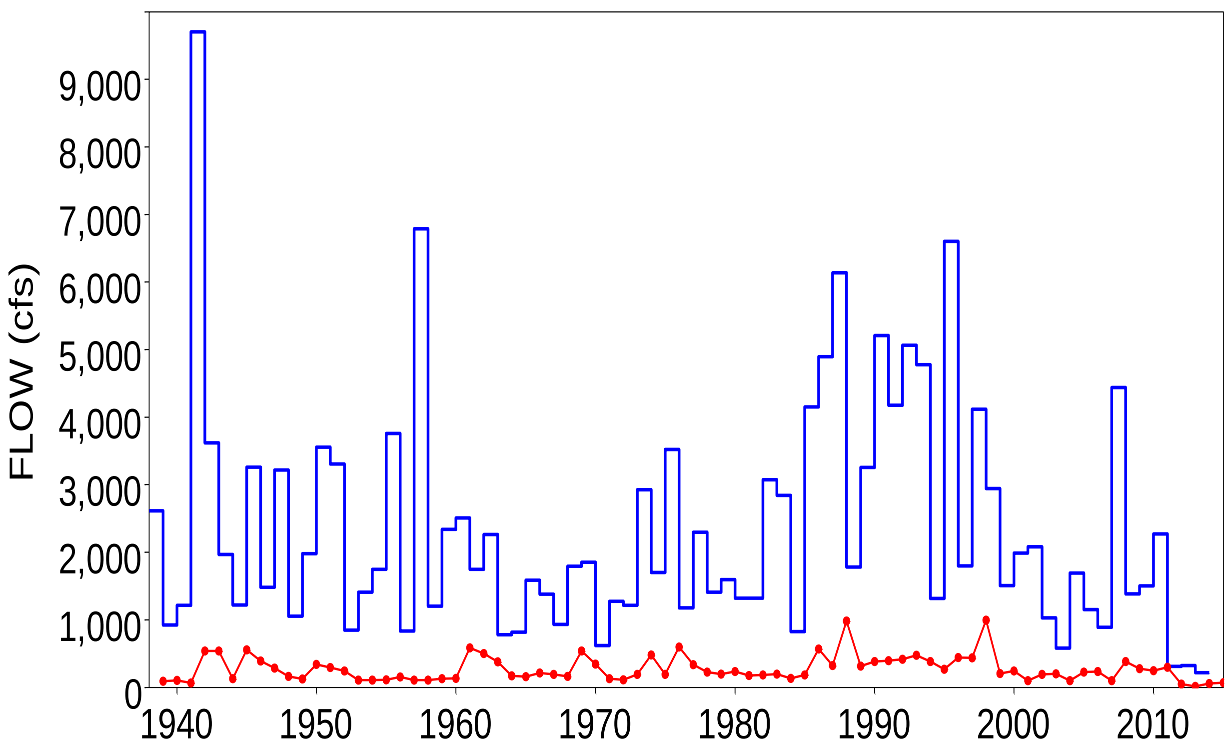
Period-of-record of daily flows: 1938/4/01 to present (2014/3/9)



Daily Flows of Red River near Terrel



Monthly Flows of Red River near Terrel



Annual Flows and the Minimum Monthly Flow Each Year

33
Red River at Arthur City

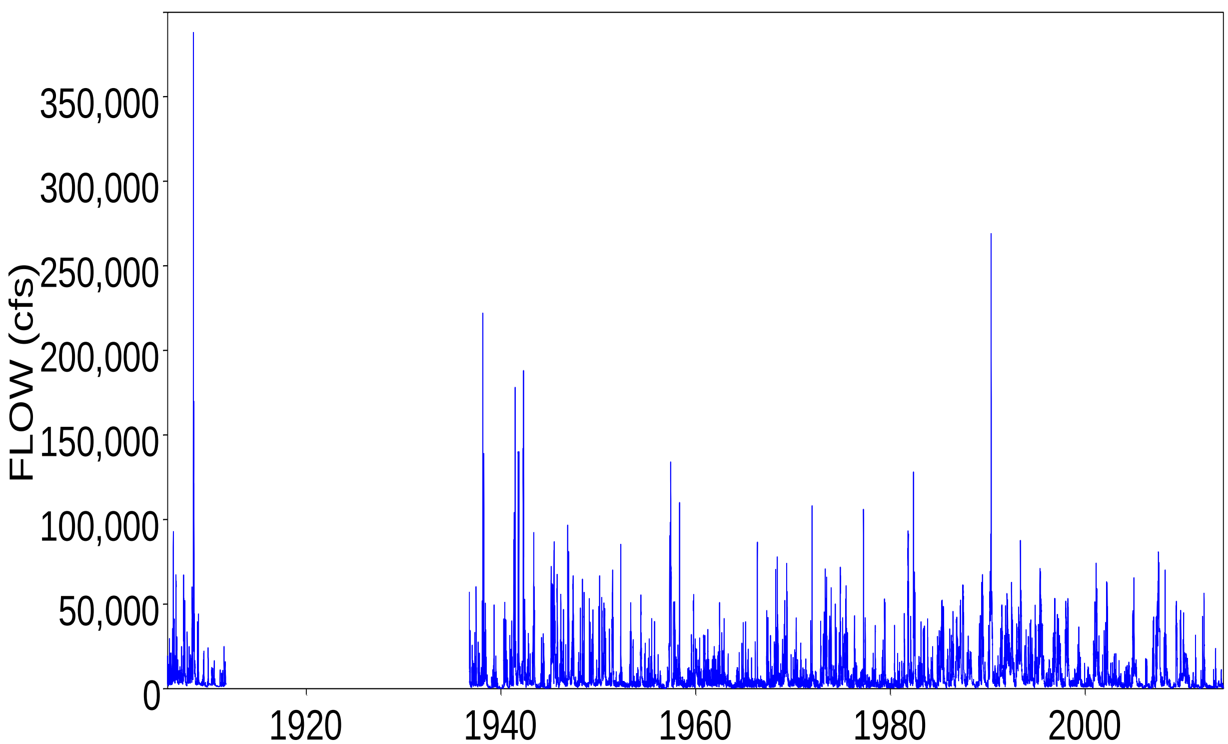
USGS 07335500
Choctaw County, Oklahoma

Drainage area 44,445 square miles
Contributing drainage area 36,517 square miles

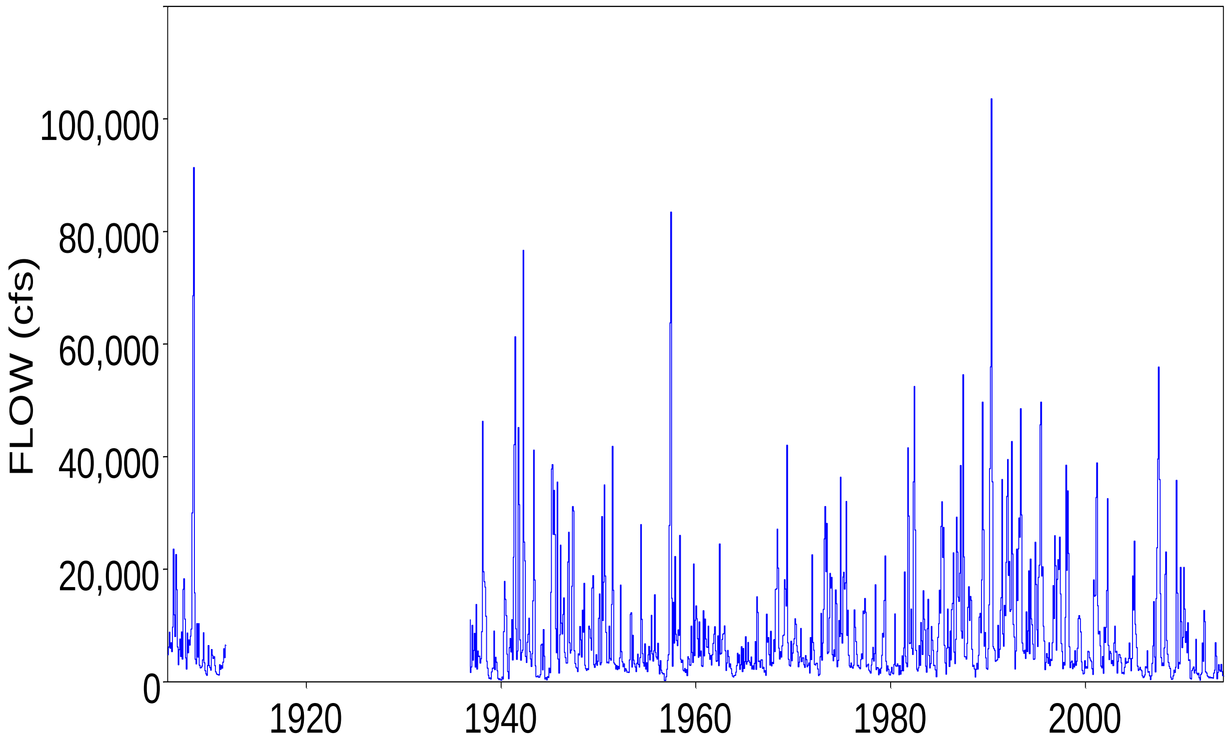
Latitude 33°52'30", Longitude 95°30'06" NAD27
Gage datum 375.07 feet above NGVD29

The gage is at Hwy 271 about 15 miles north of Paris and 60 miles upstream of the Oklahoma border.

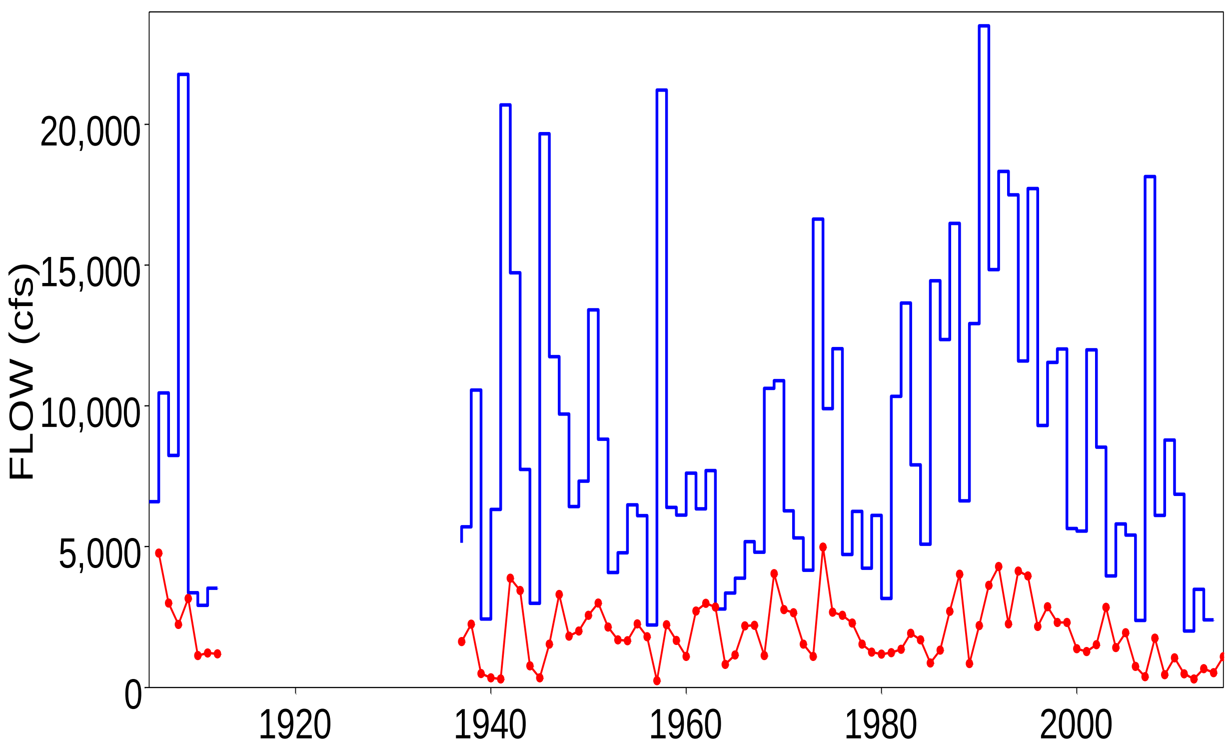
Period-of-record of daily flows: 1905/10/01 to present (2014/3/10)



Daily Flows of Red River at Arthur City



Monthly Flows of Red River at Arthur City



Annual Flows and the Minimum Monthly Flow Each Year

34
Canadian River near Amarillo

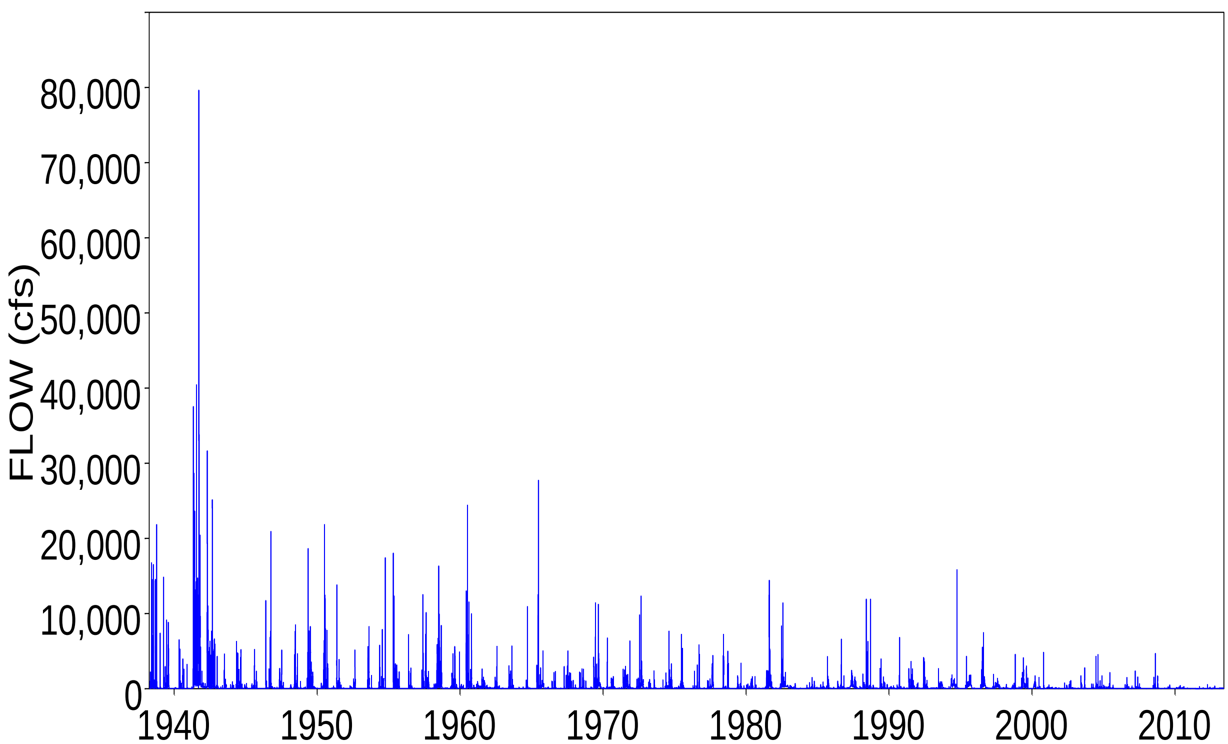
USGS 07227500
Potter County, Texas

Drainage area 19,445 square miles
Contributing drainage area 15,376 square miles

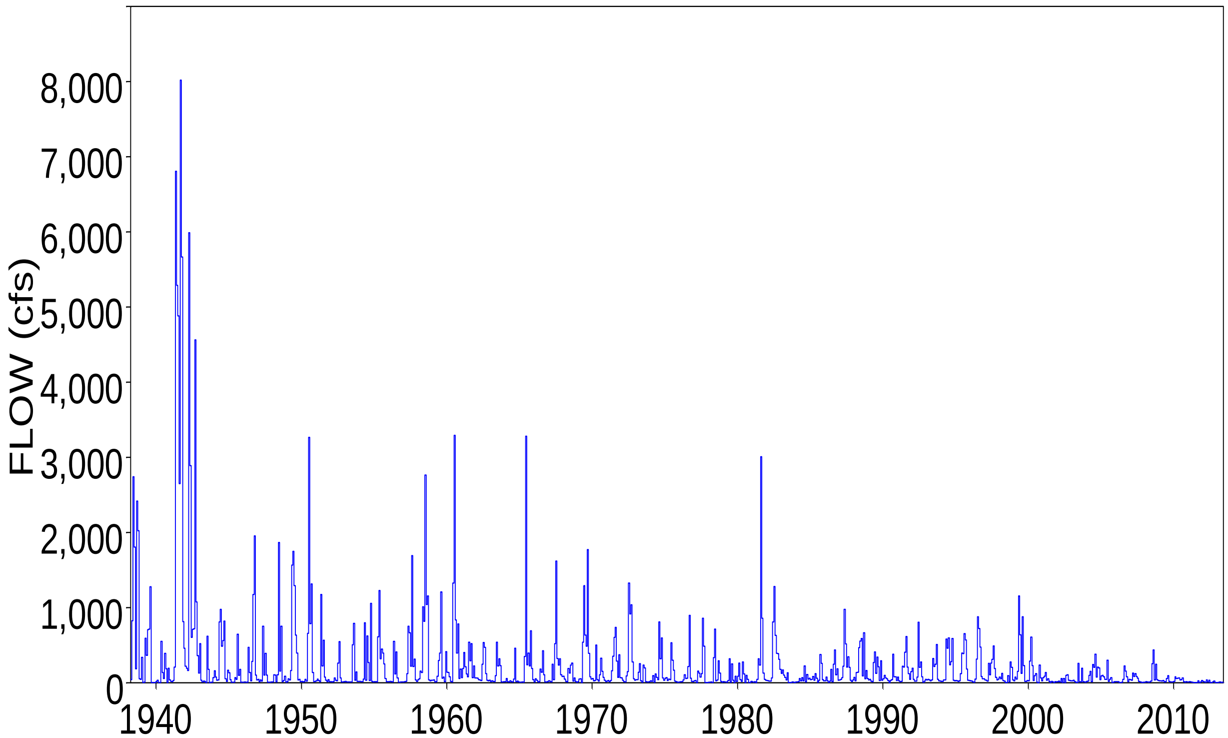
Latitude 35°28'13", Longitude 101°52'45" NAD27
Gage datum 2,989.16 feet above NGVD29

The gage is at Hwy 287 about 30 miles upstream of the dam of Lake Meredith and 80 miles downstream of the New Mexico border.

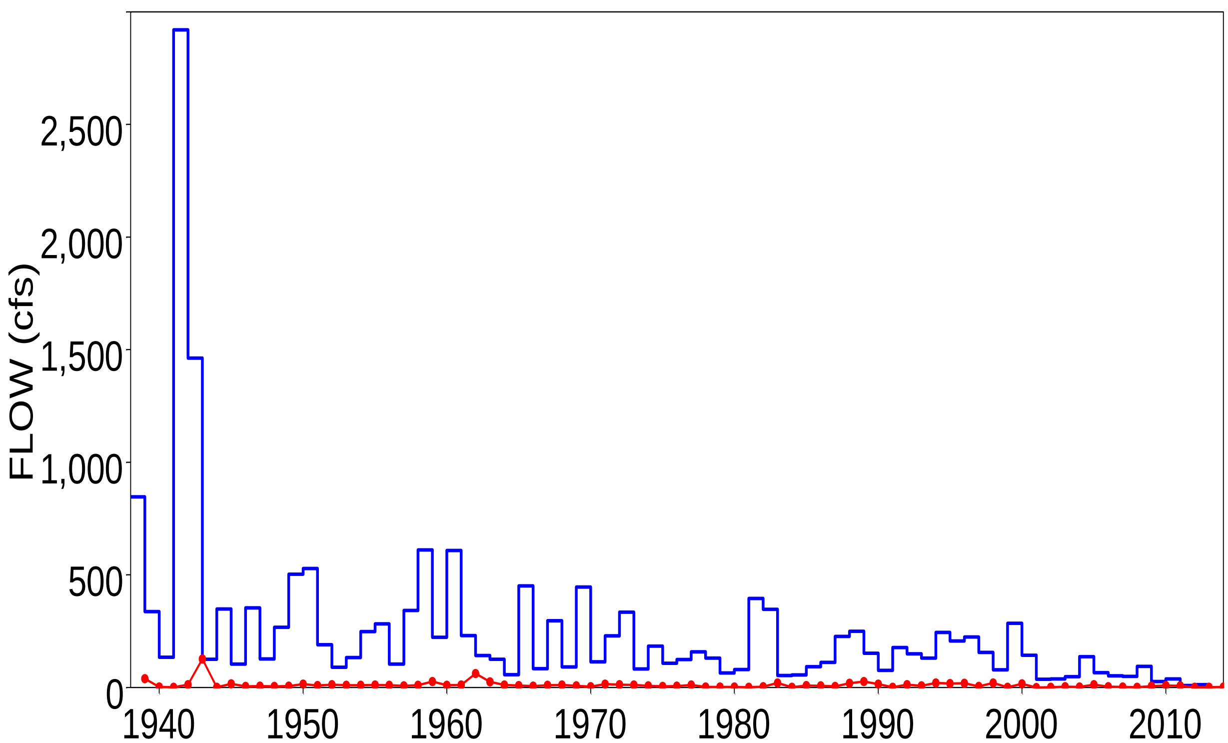
Period-of-record of daily flows: 1938/4/01 to present (2013/6/1)



Daily Flows of Canadian River near Amarillo



Monthly Flows of Canadian River near Amarillo



Annual Flows and the Minimum Monthly Flow Each Year

35
Canadian River near Canadian

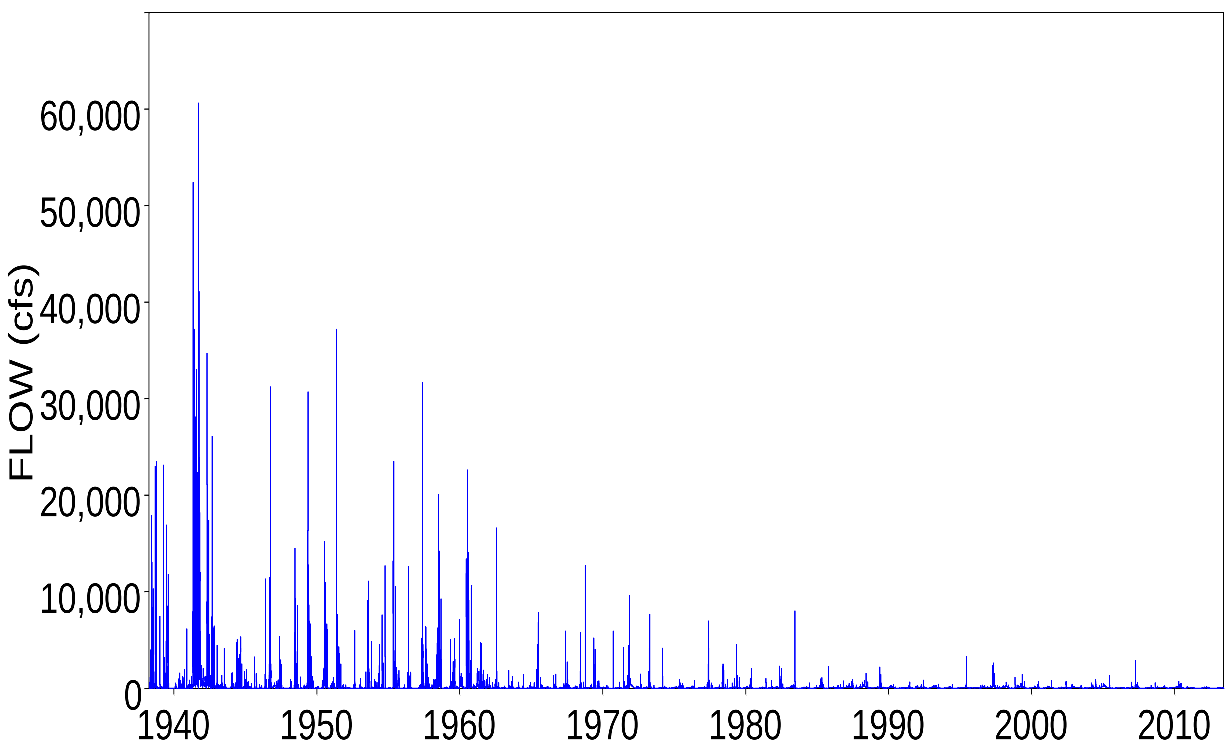
USGS 07228000
Hemphill County, Texas

Drainage area 22,866 square miles
Contributing drainage area 18,178 square miles

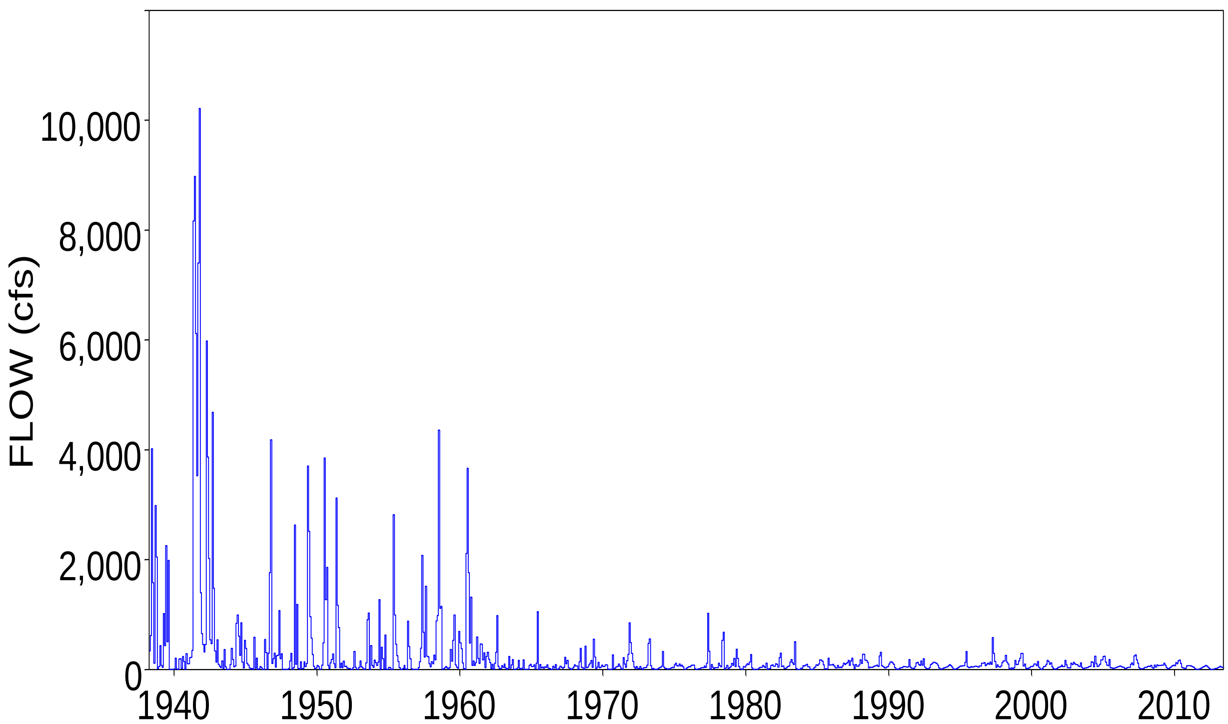
Latitude 35°56'06", Longitude 100°22'13" NAD27
Gage datum 2,301.50 feet above NGVD29

The gage is at Hwy 60 about 70 miles downstream of Lake Meredith and 20 miles upstream of the Oklahoma border.

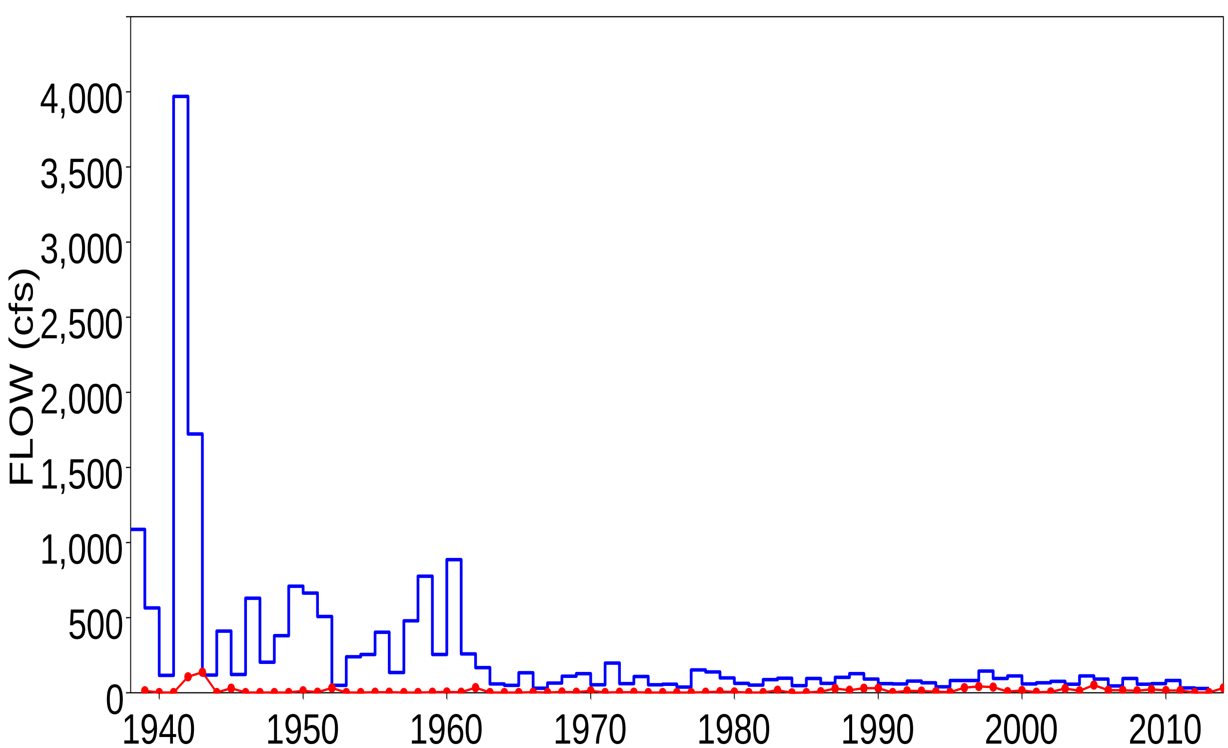
Period-of-record of daily flows: 1938/4/01 to present (2013/6/1)



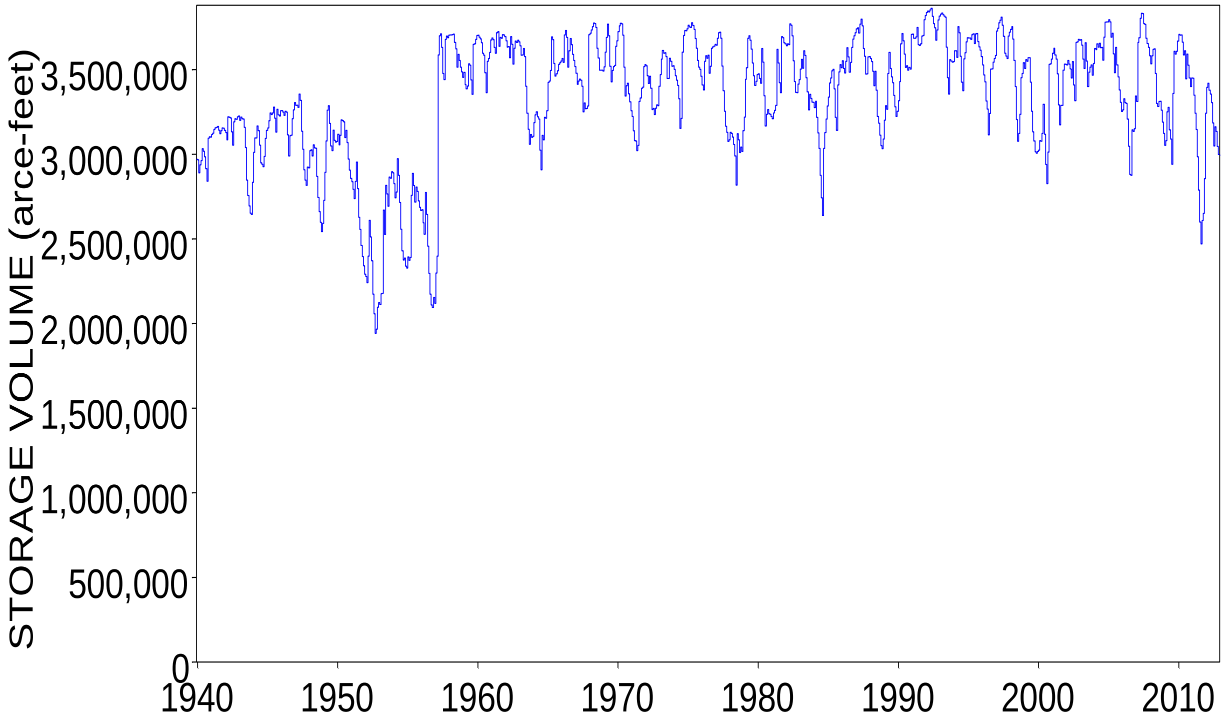
Daily Flows of Canadian River near Canadian



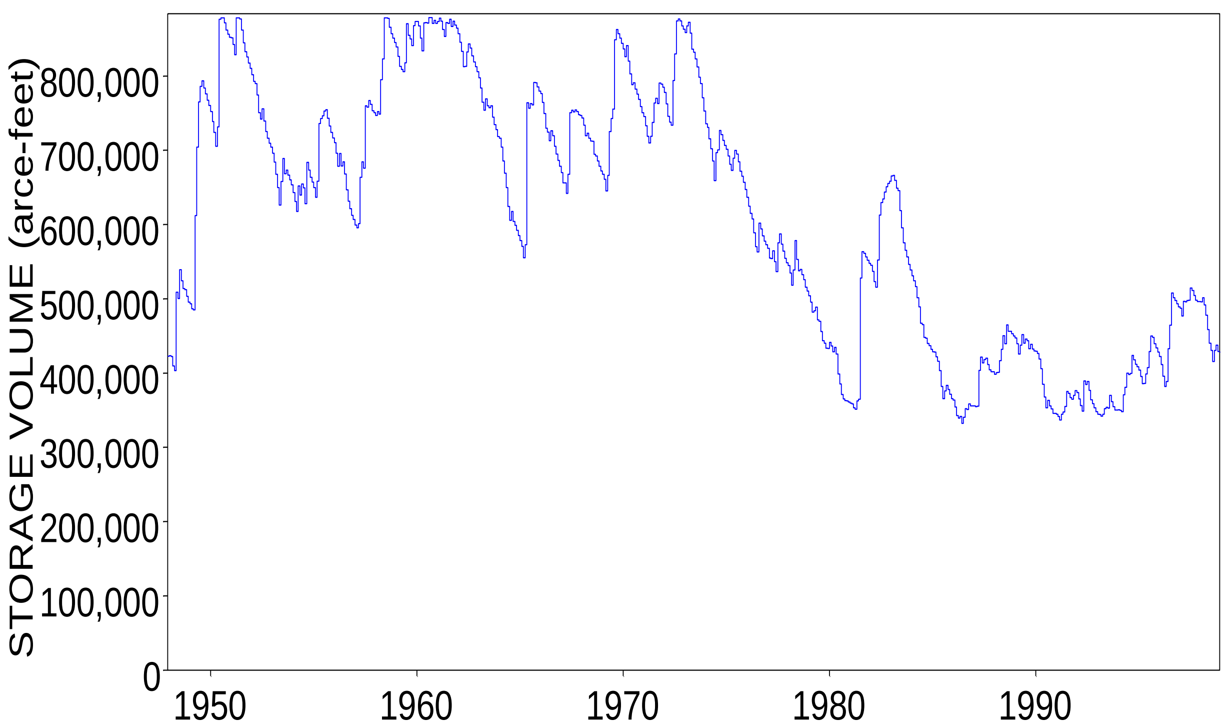
Monthly Flows of Canadian River near Canadian



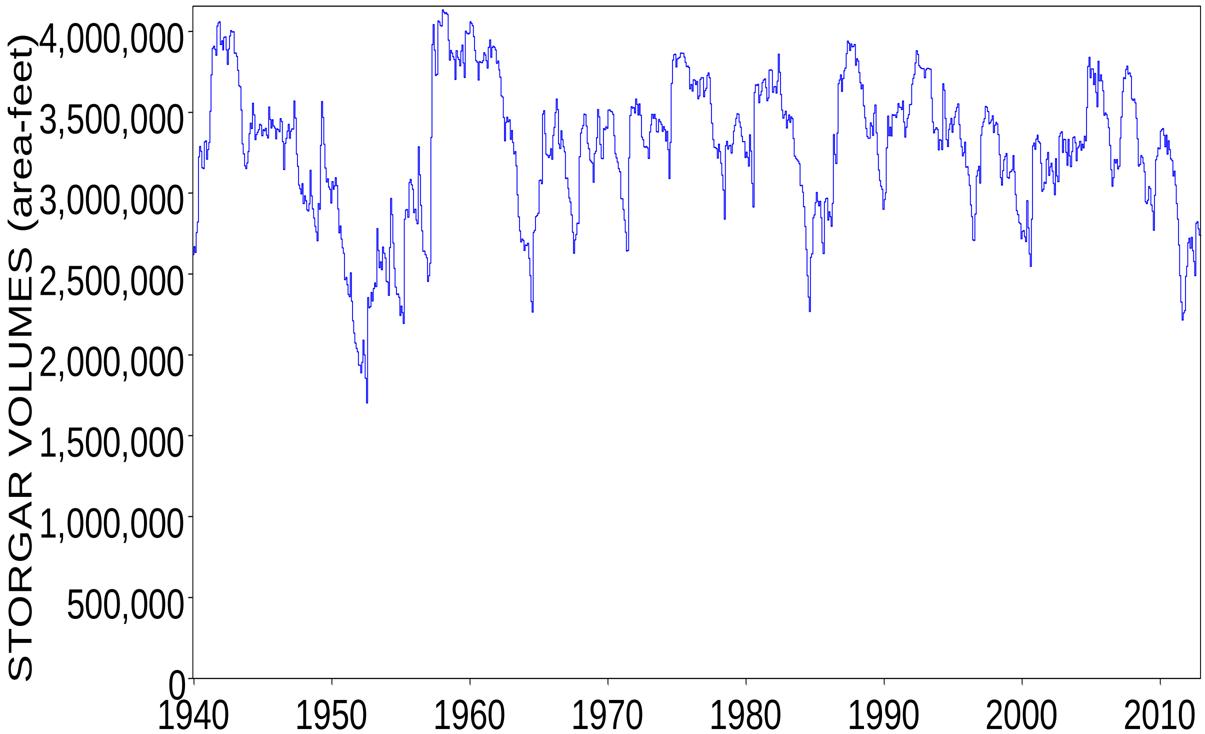
Annual Flows and the Minimum Monthly Flow Each Year



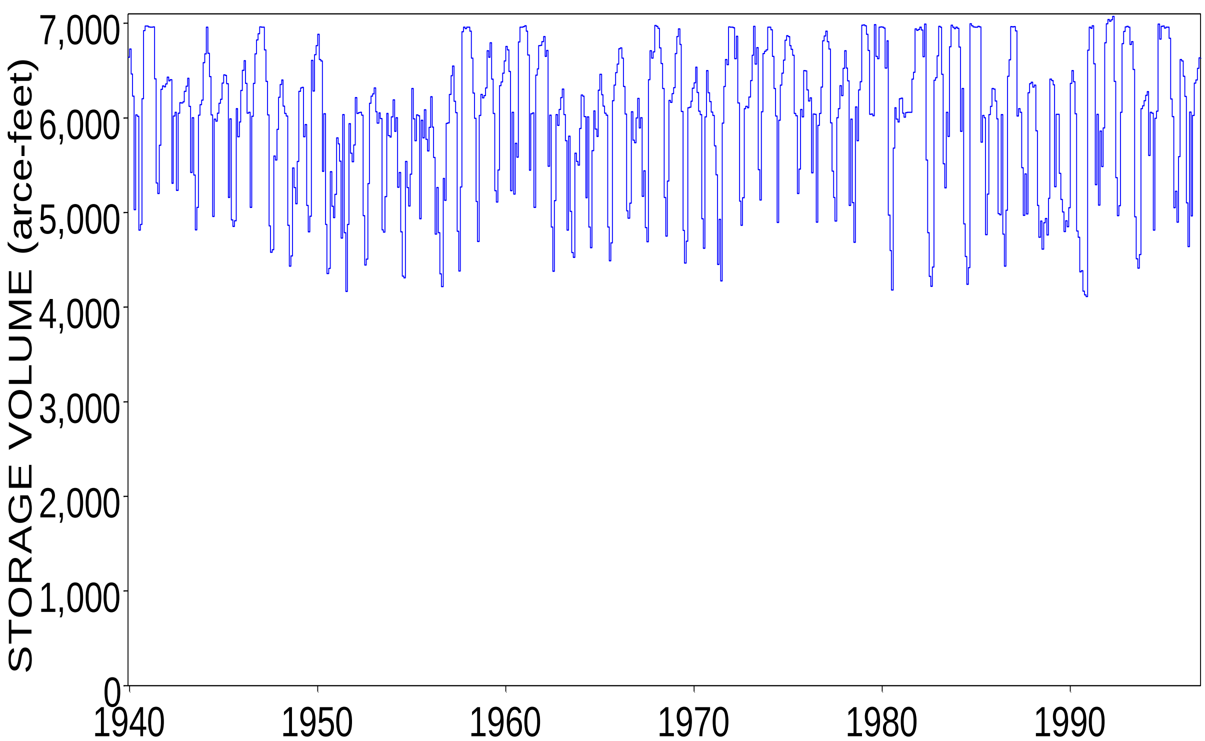
Total Storage all Reservoirs in the Brazos River Basin



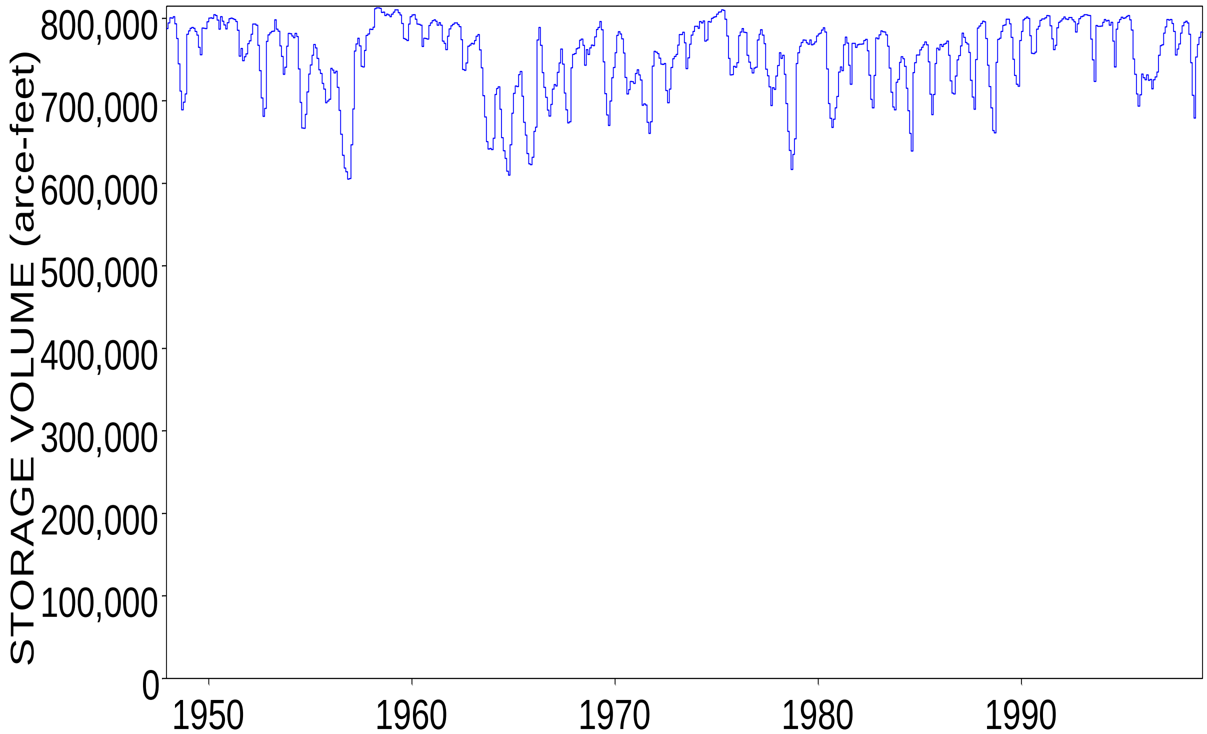
Total Storage all Reservoirs in the Canadian River Basin



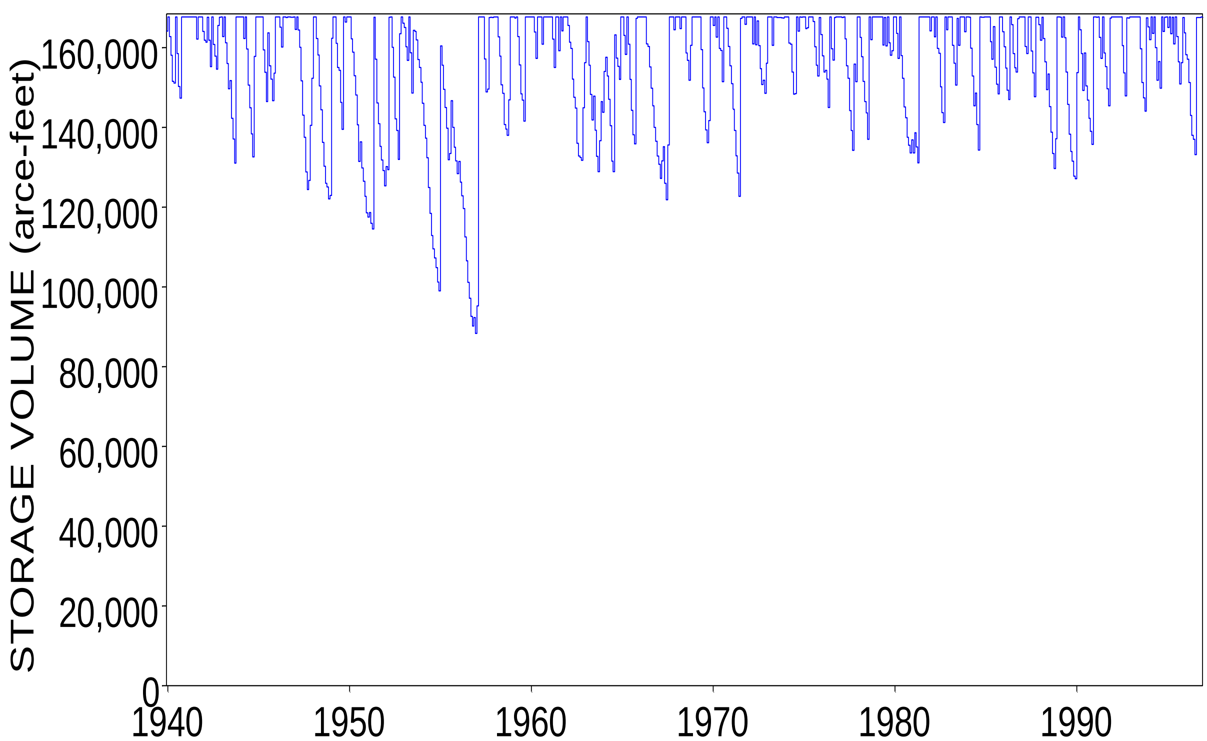
Total Storage all Reservoirs in the Colorado and Brazos-Colorado Coastal Basin



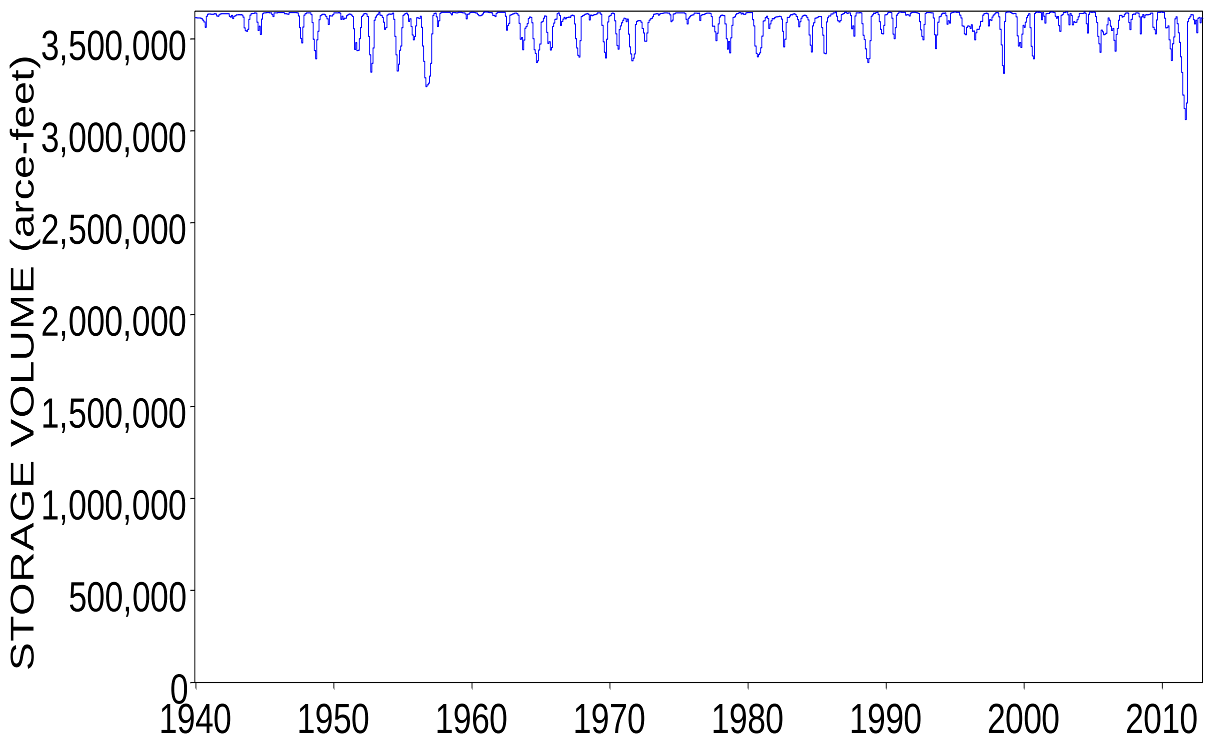
Total Storage all Reservoirs in the Colorado-Lavaca Coastal Basin



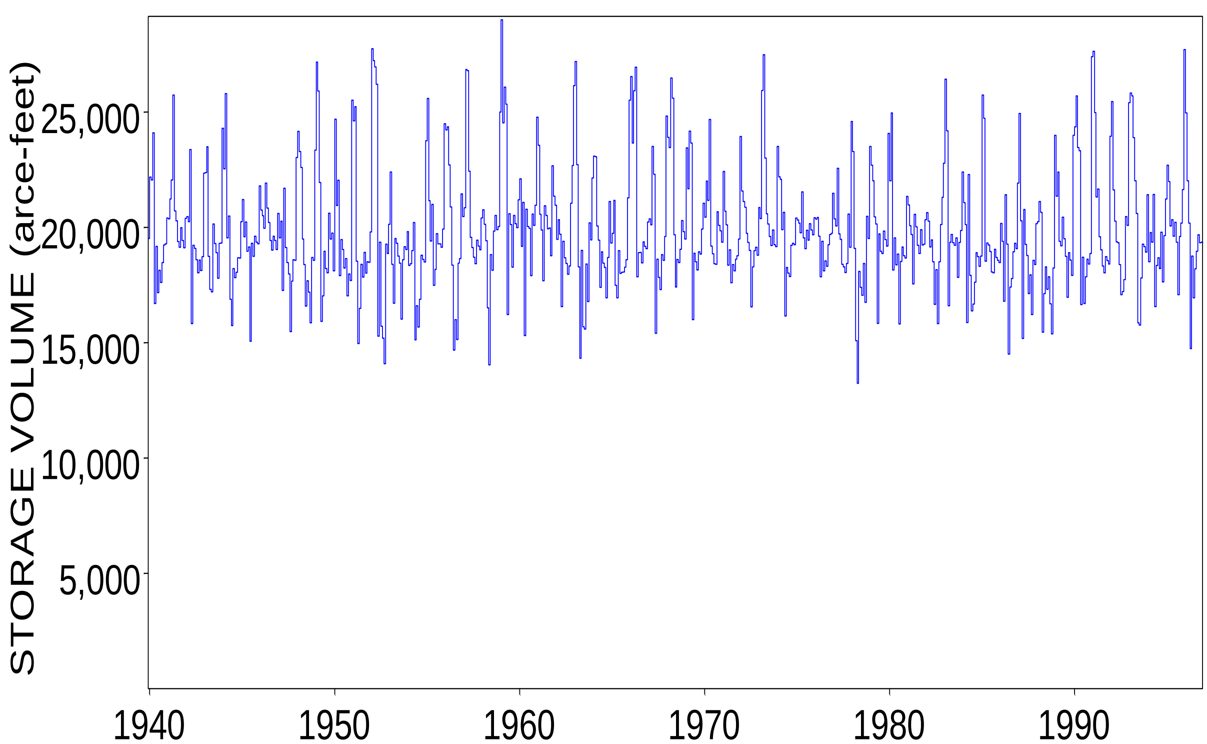
Total Storage all Reservoirs in the Cypress Bayou Basin



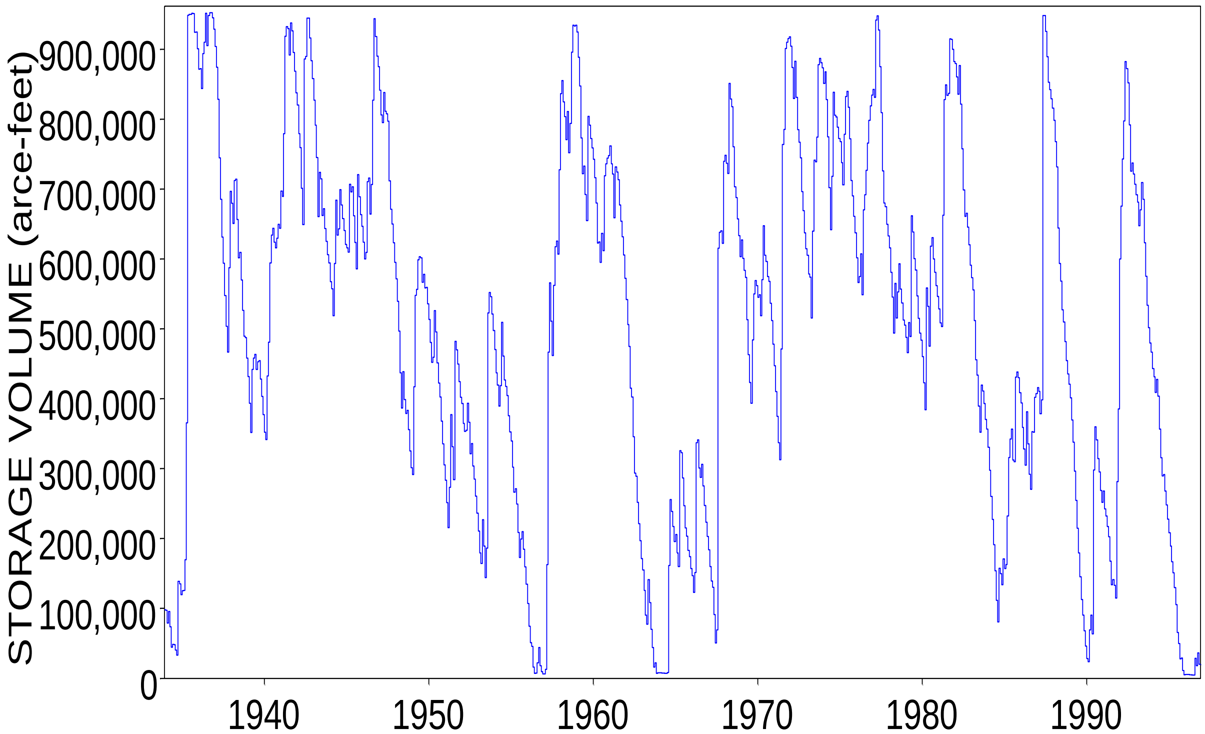
Total Storage all Reservoirs in the Lavaca River Basin



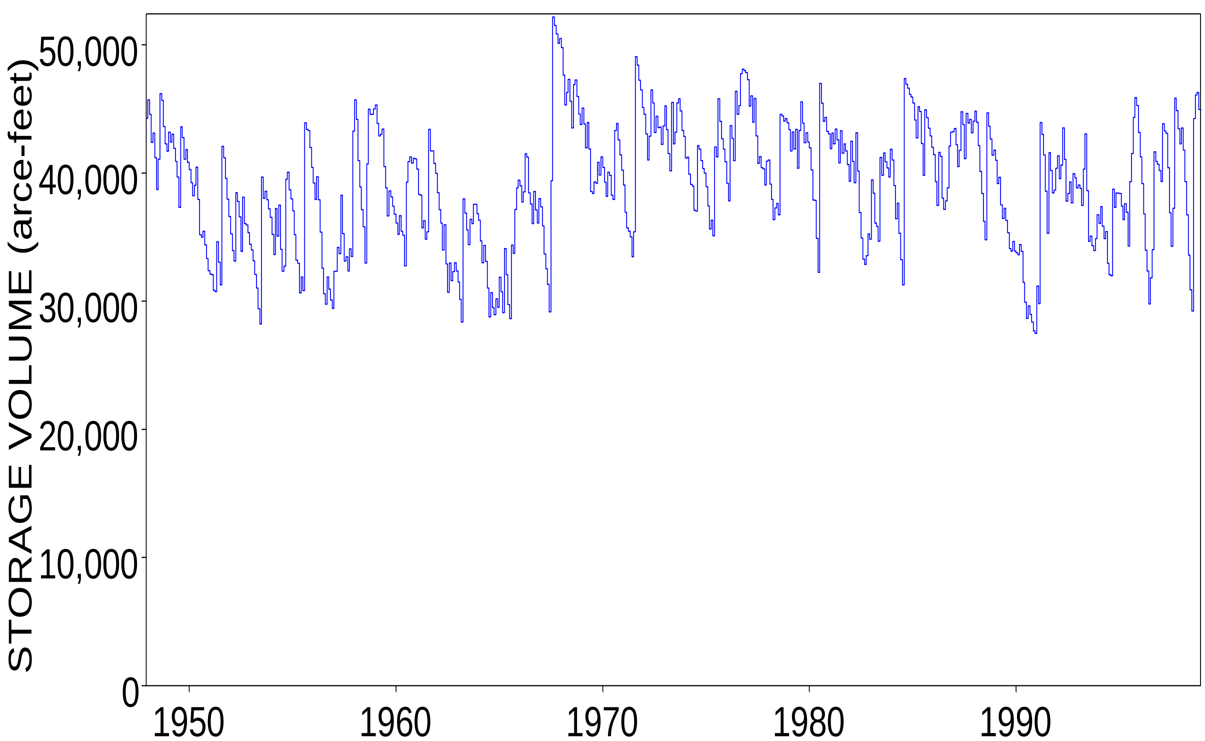
Total Storage all Reservoirs in the Neches River Basin



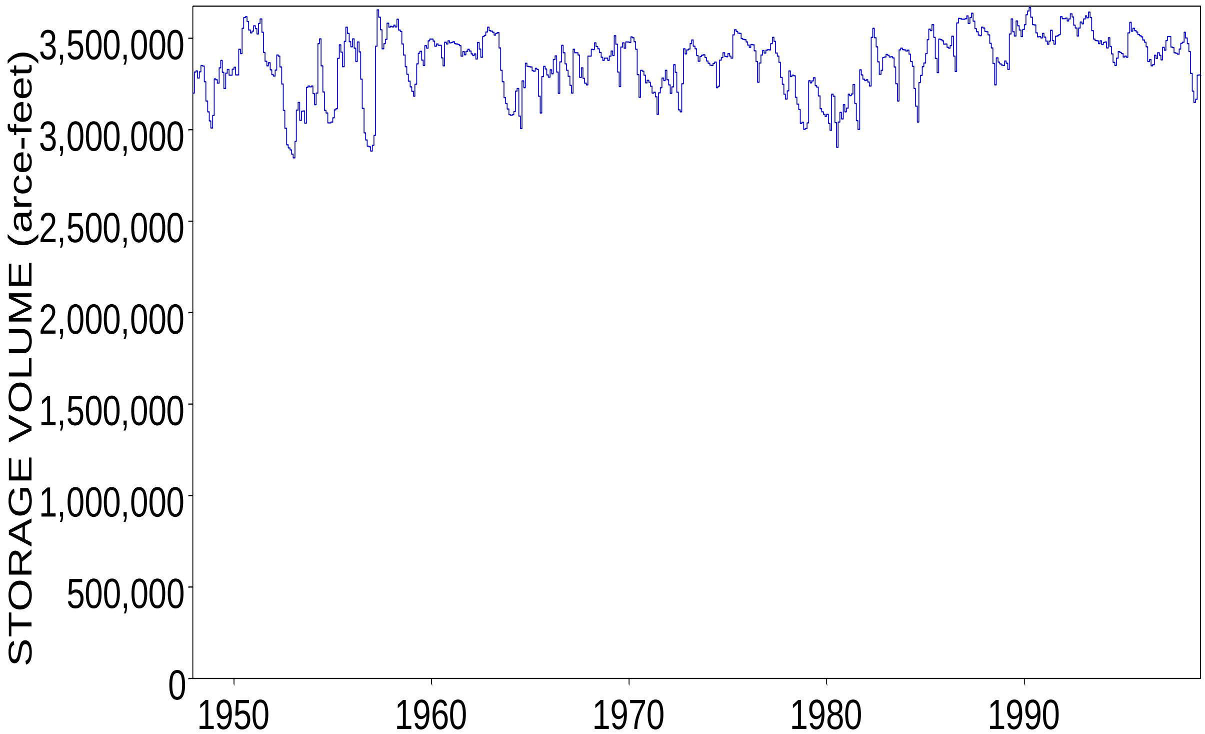
Total Storage all Reservoirs in the Neches-Trinity Coastal Basin



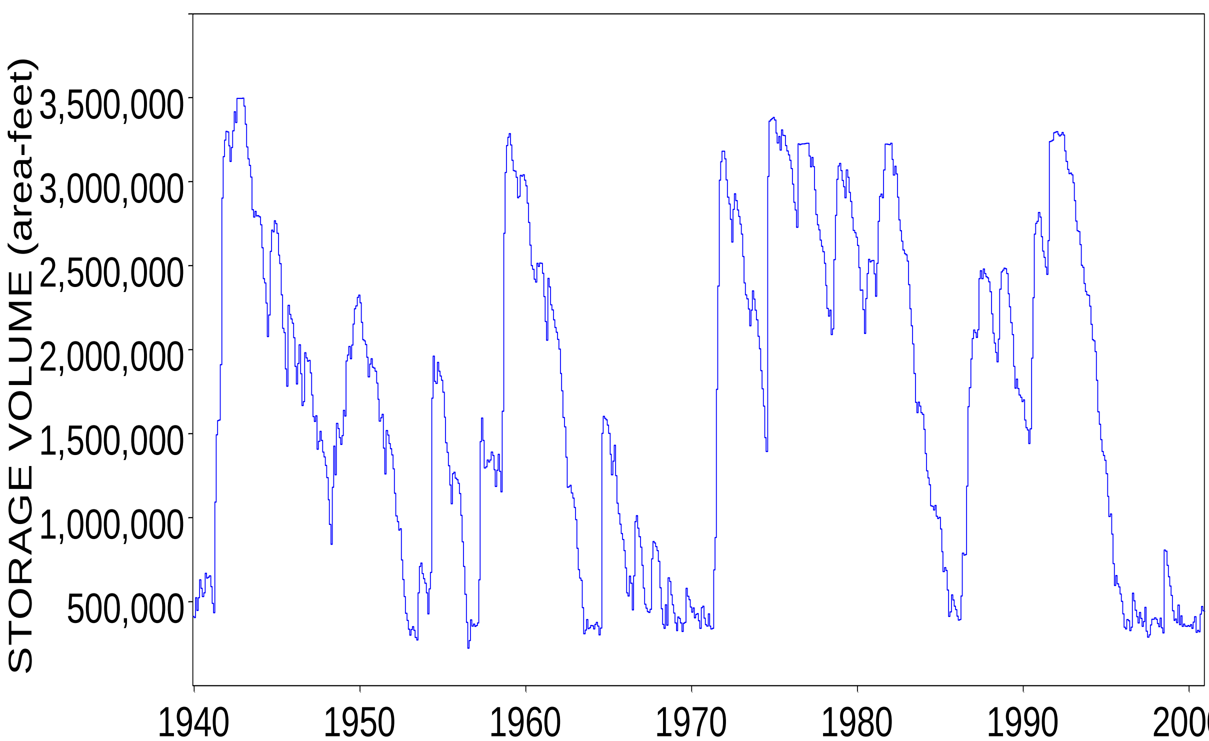
Total Storage all Reservoirs in the Nueces River Basin



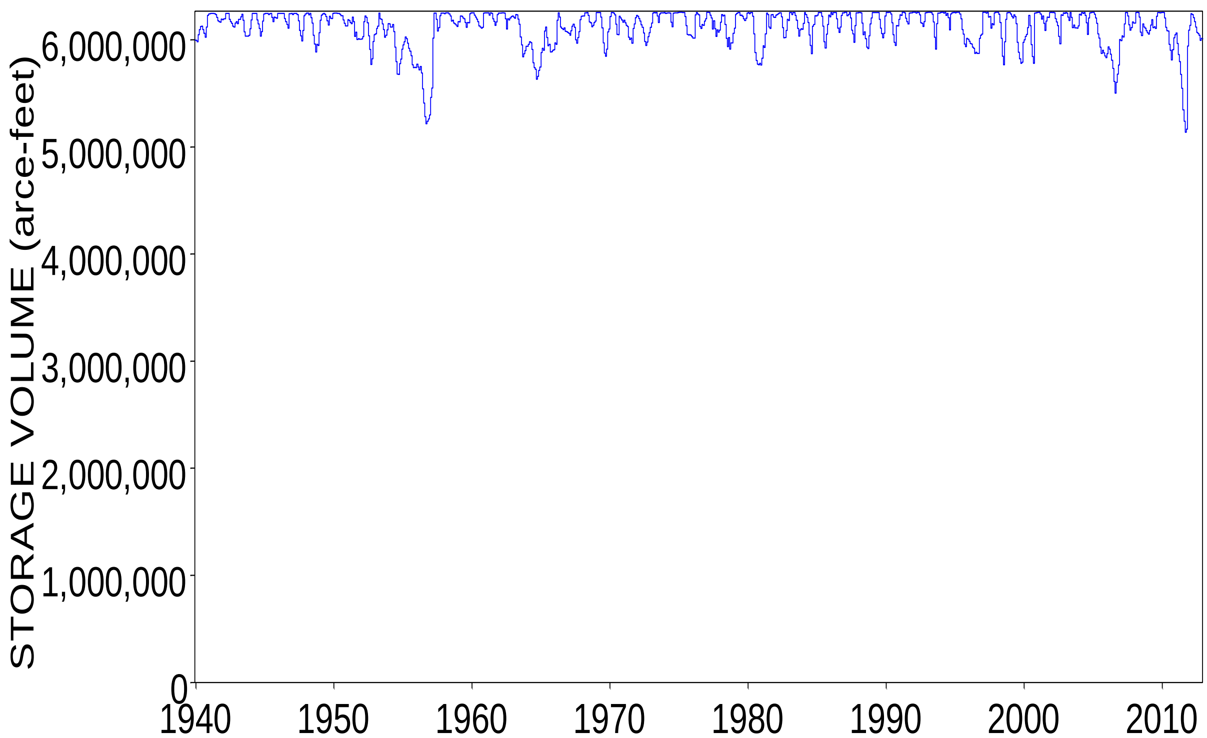
Total Storage all Reservoirs in the Nueces-Rio Grande Coastal Basin



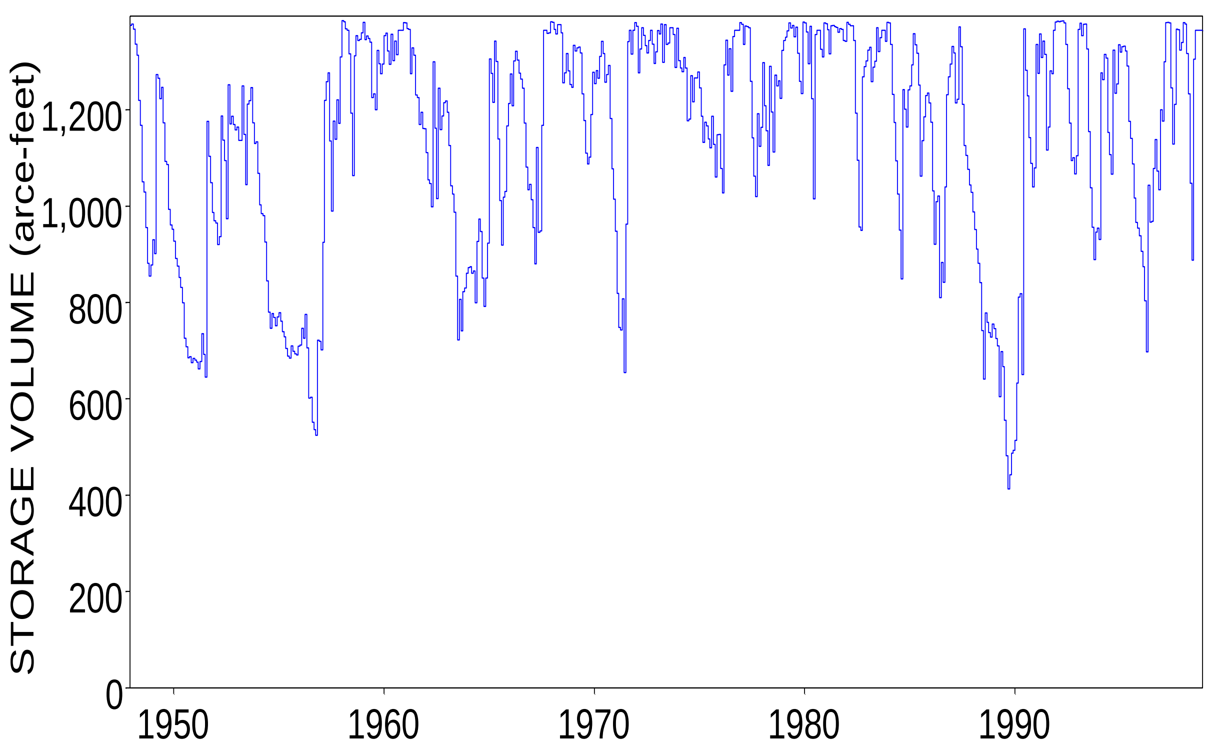
Total Storage all Reservoirs in the Red River Basin



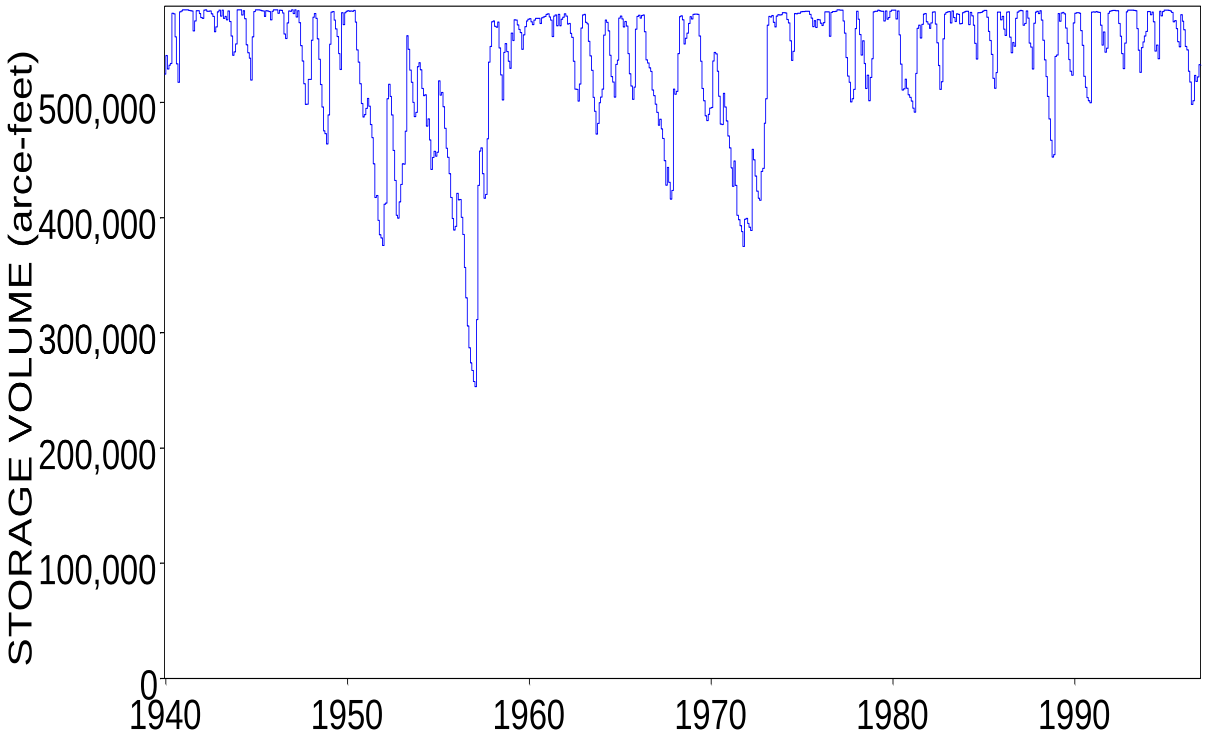
Total Storage all Reservoirs in the Rio Grande River Basin



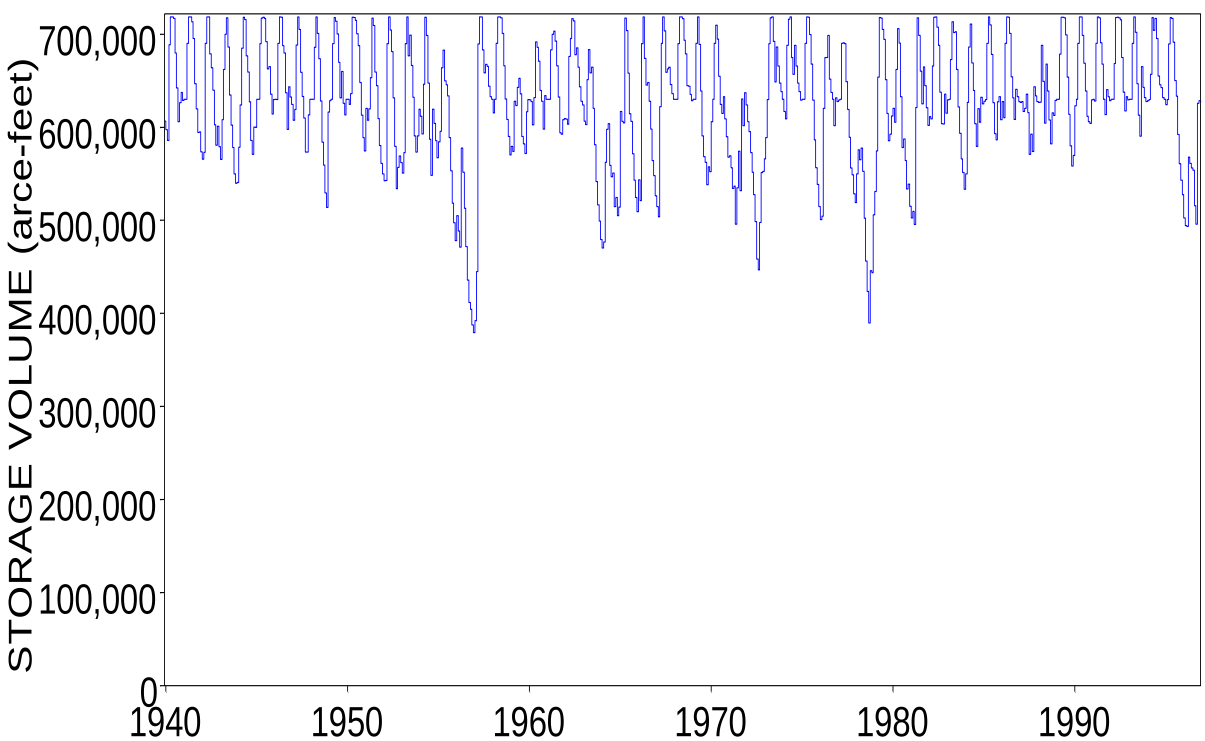
Total Storage all Reservoirs in the Sabine River Basin



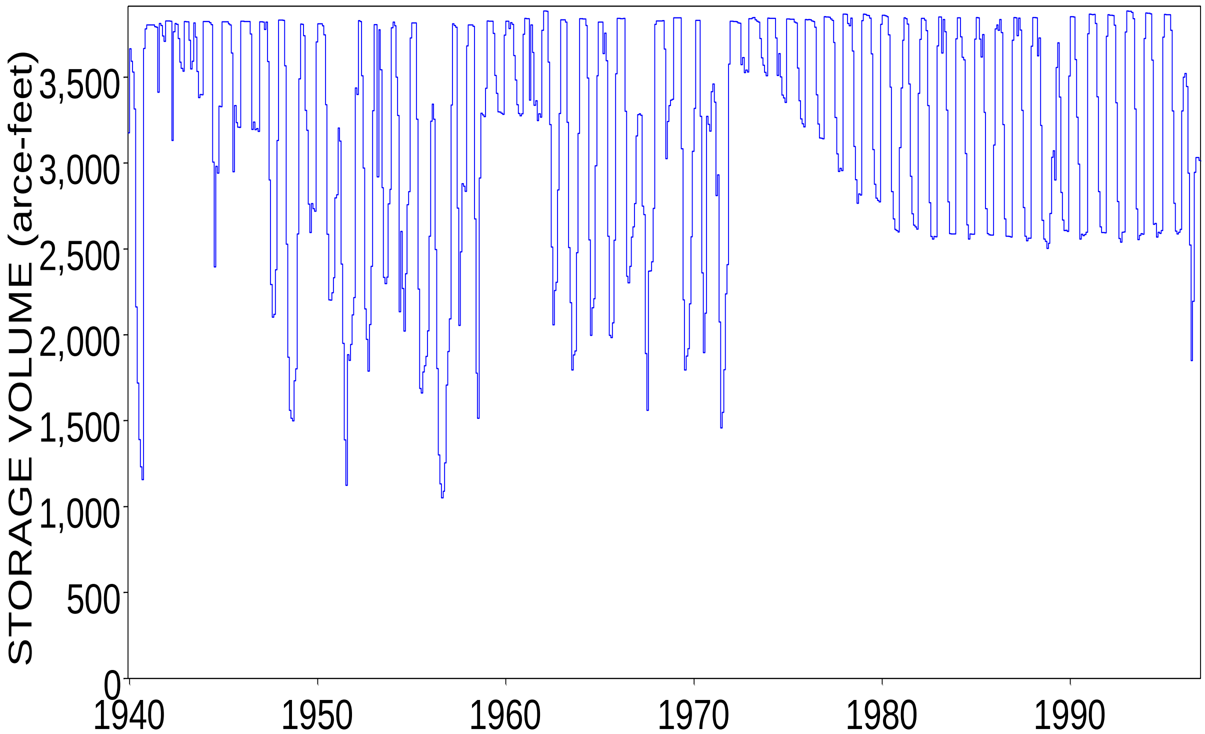
Total Storage all Reservoirs in the San Antonio-Nueces Coastal Basin



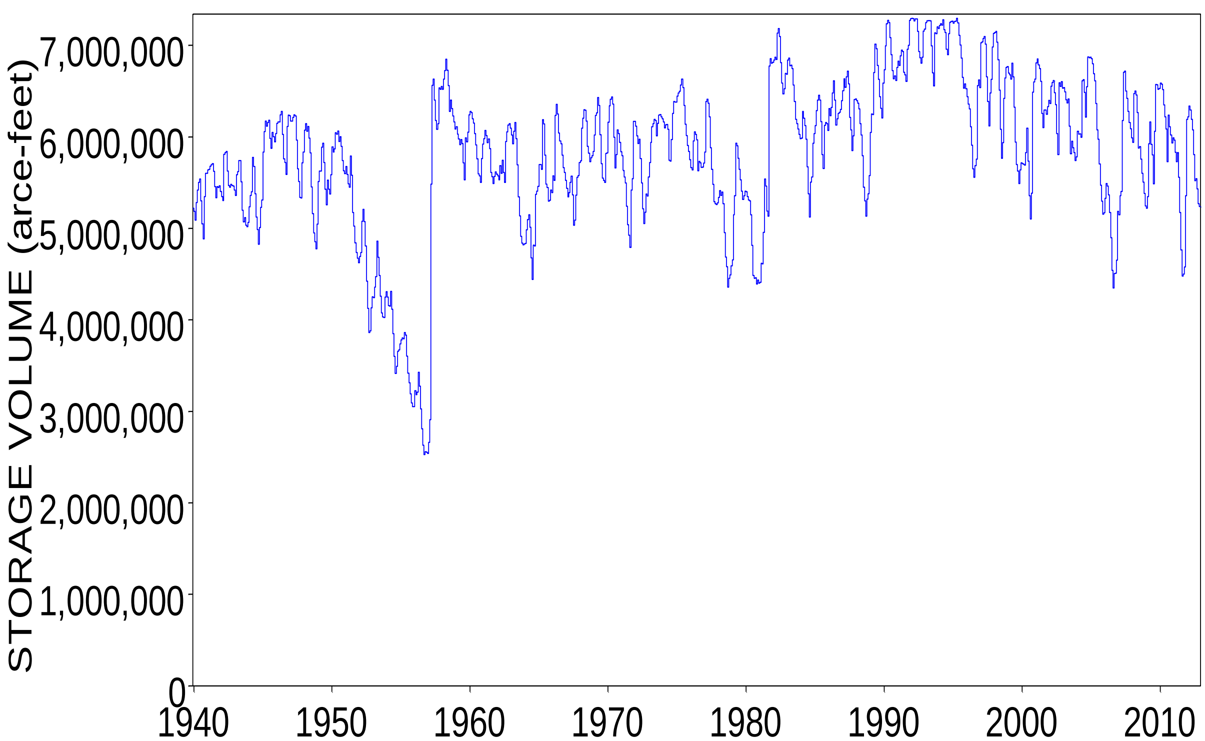
Total Storage all Reservoirs in the San Jacinto River Basin



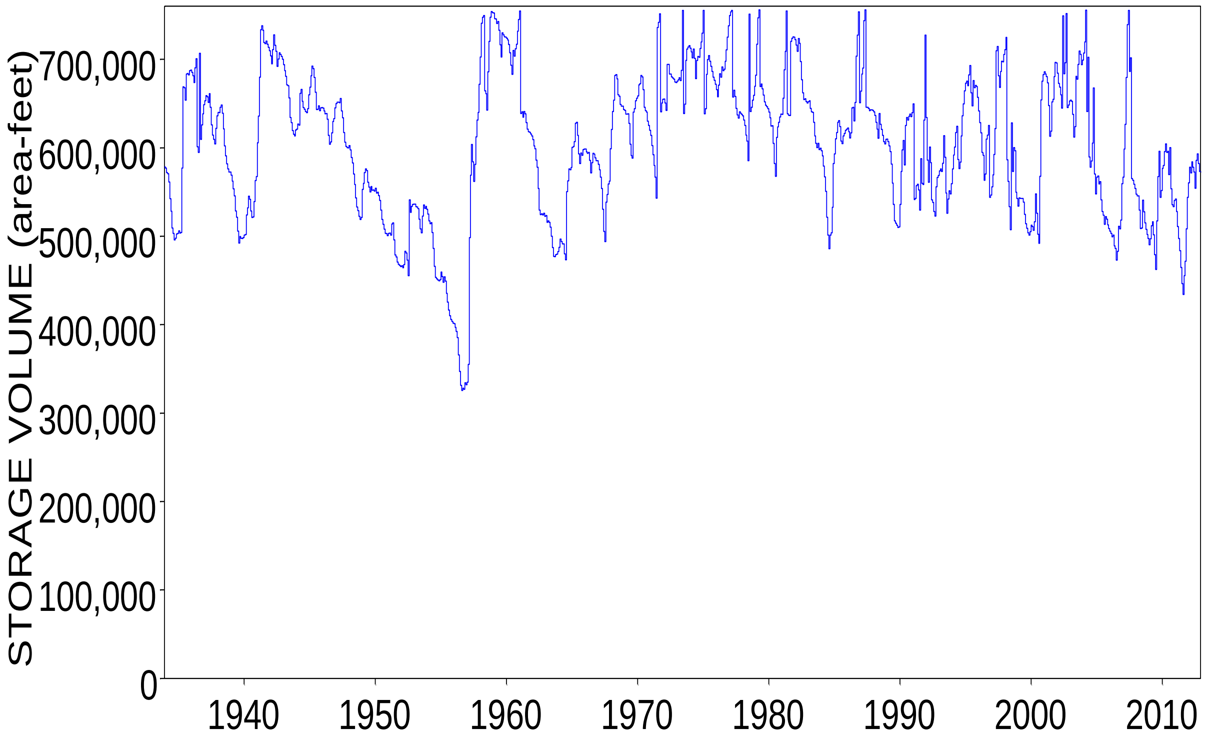
Total Storage all Reservoirs in the Sulphur River Basin



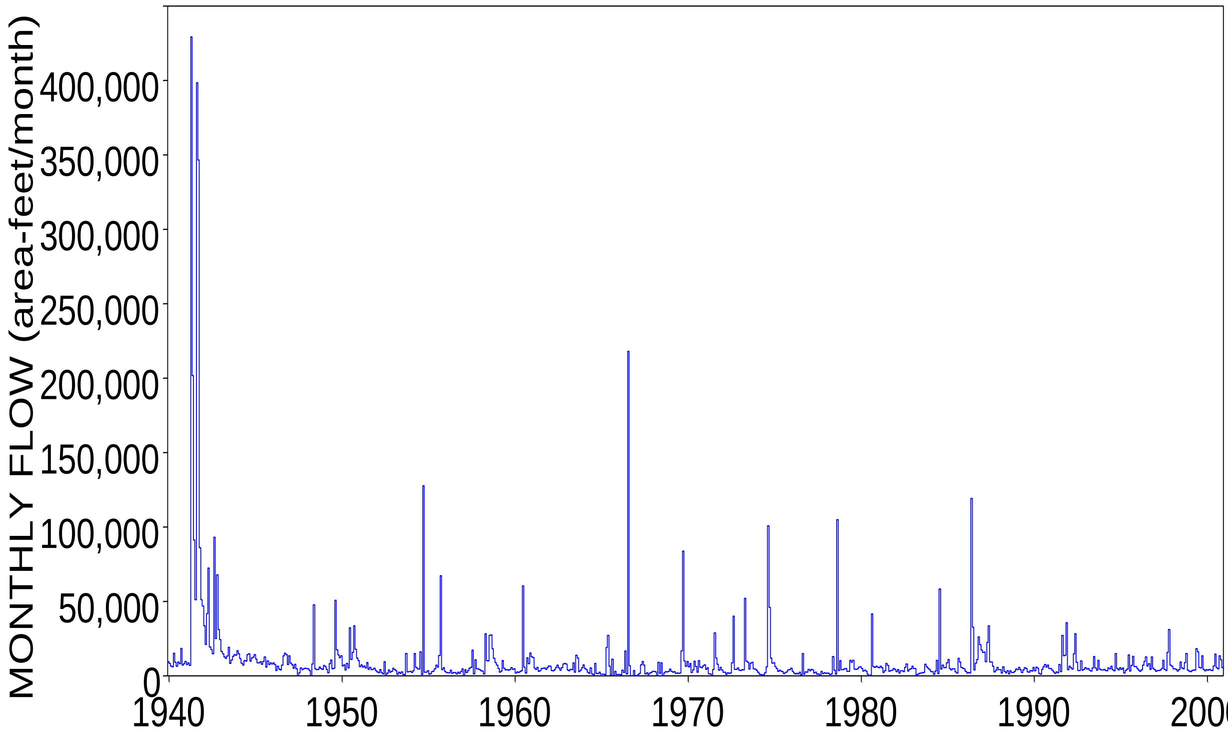
Total Storage all Reservoirs in the Trinity-San Jacinto Coastal Basin



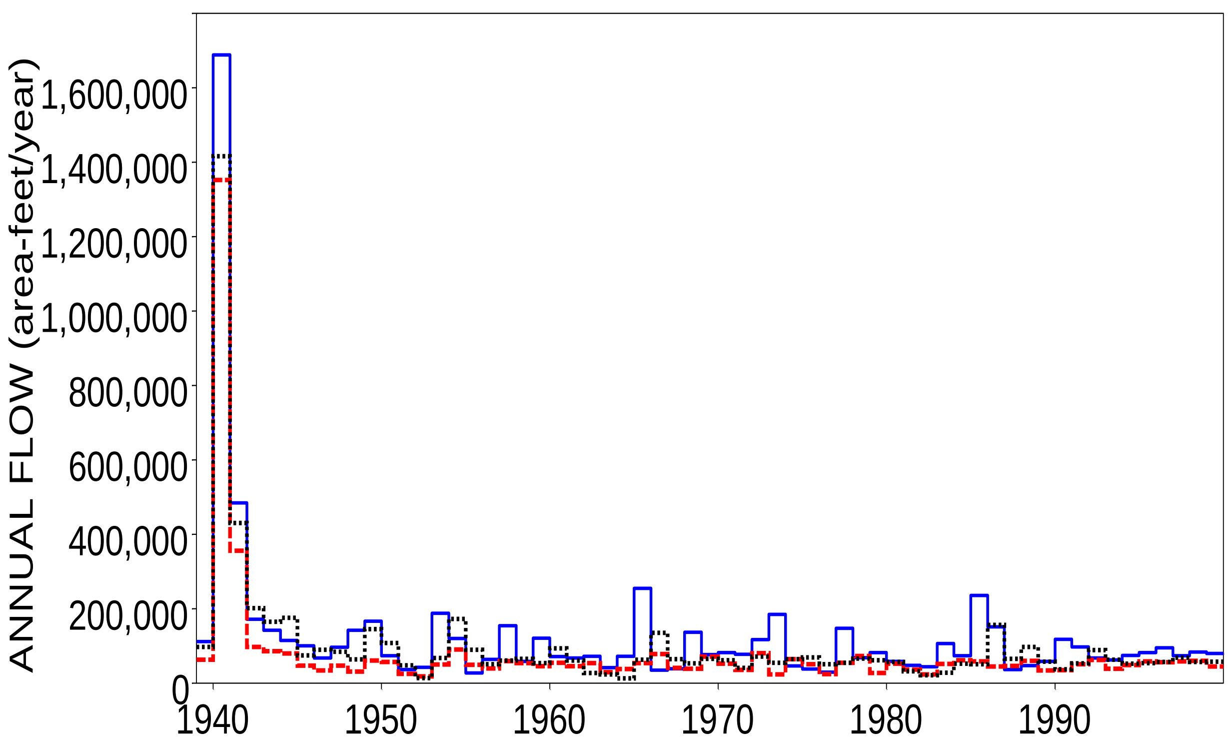
Total Storage all Reservoirs in the Trinity River Basin



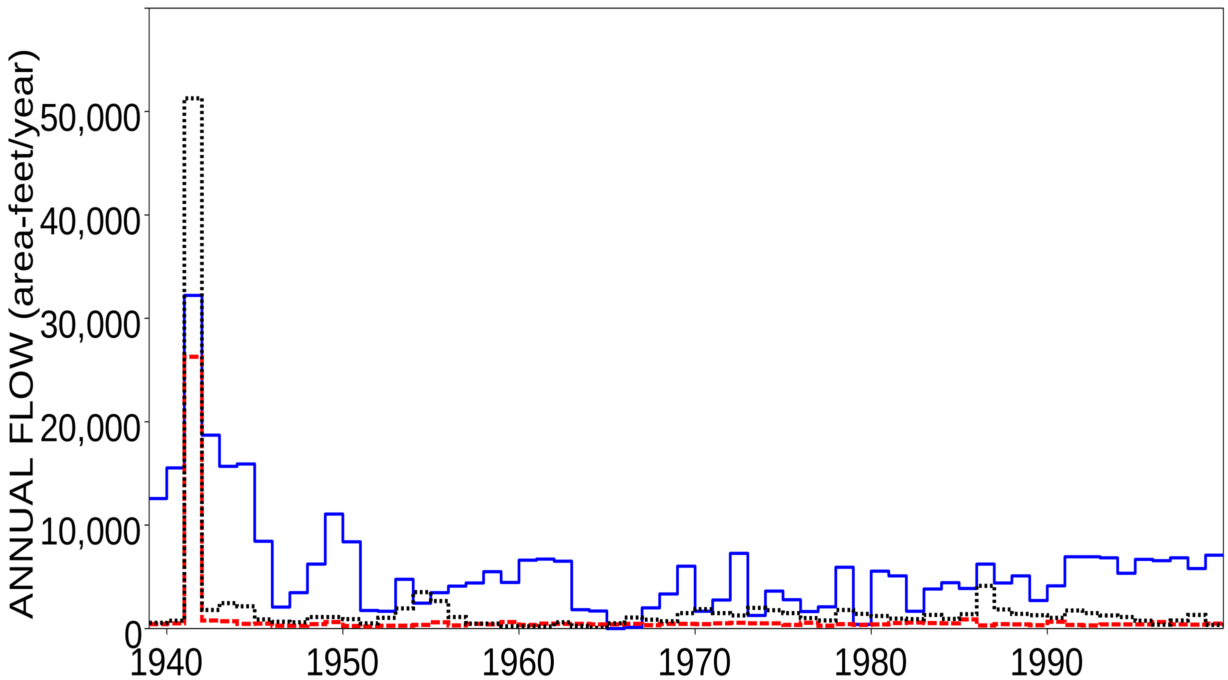
Total Storage all Reservoirs in the Guadalupe and San Antonio River Basin



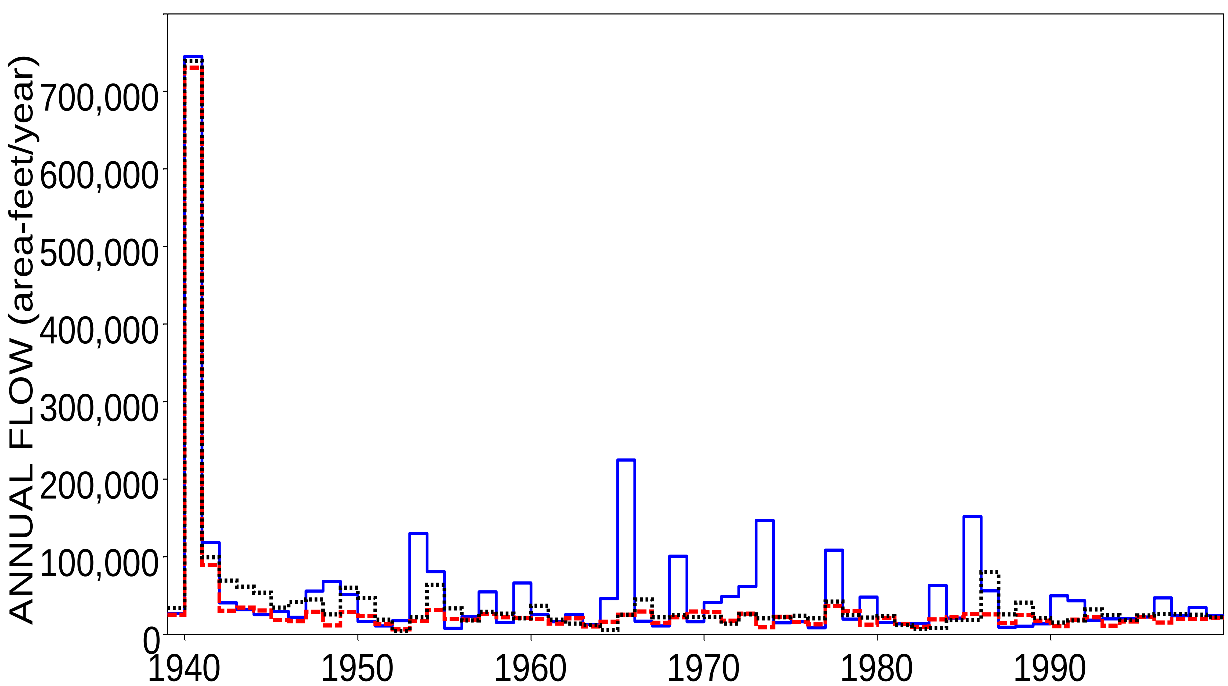
Naturalized Flows of Pecos River at Orla



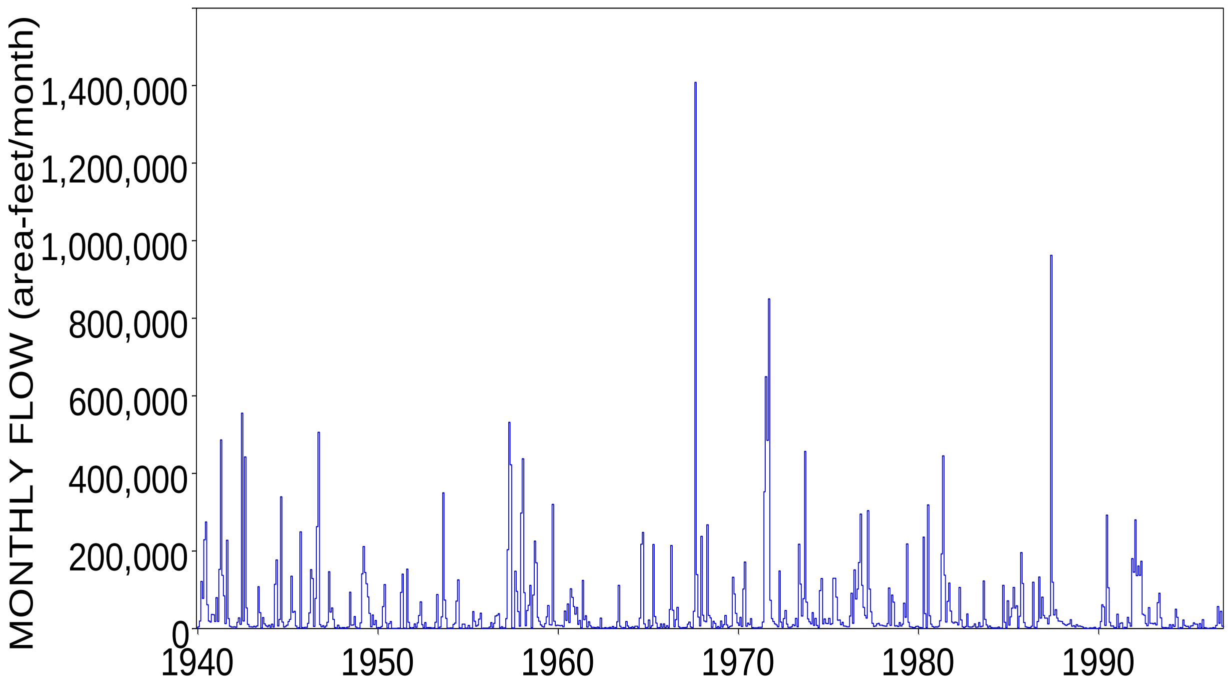
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Pecos River at Orla



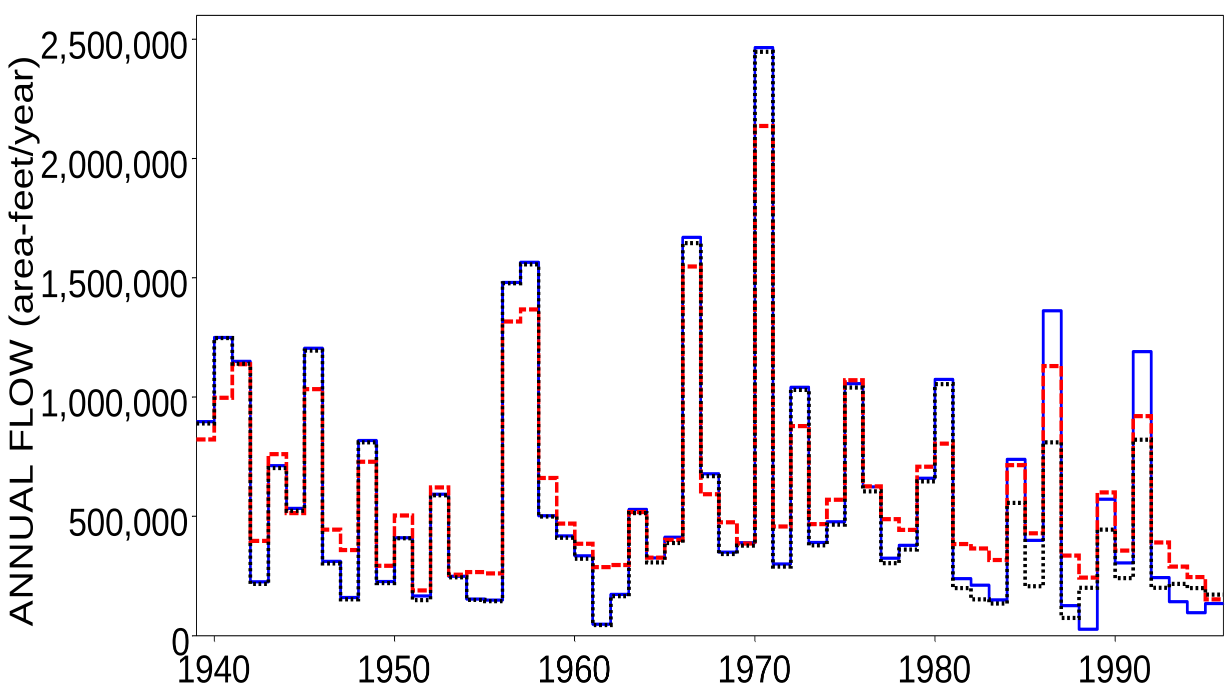
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Pecos River at Orla



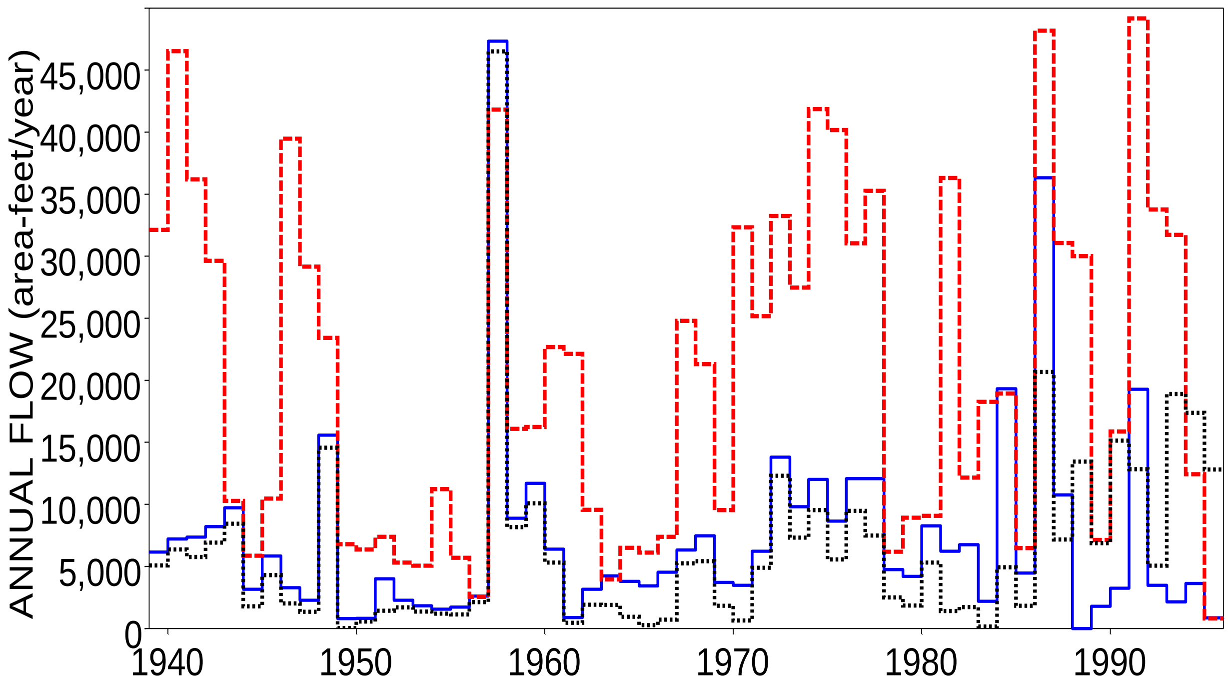
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Pecos River at Orla



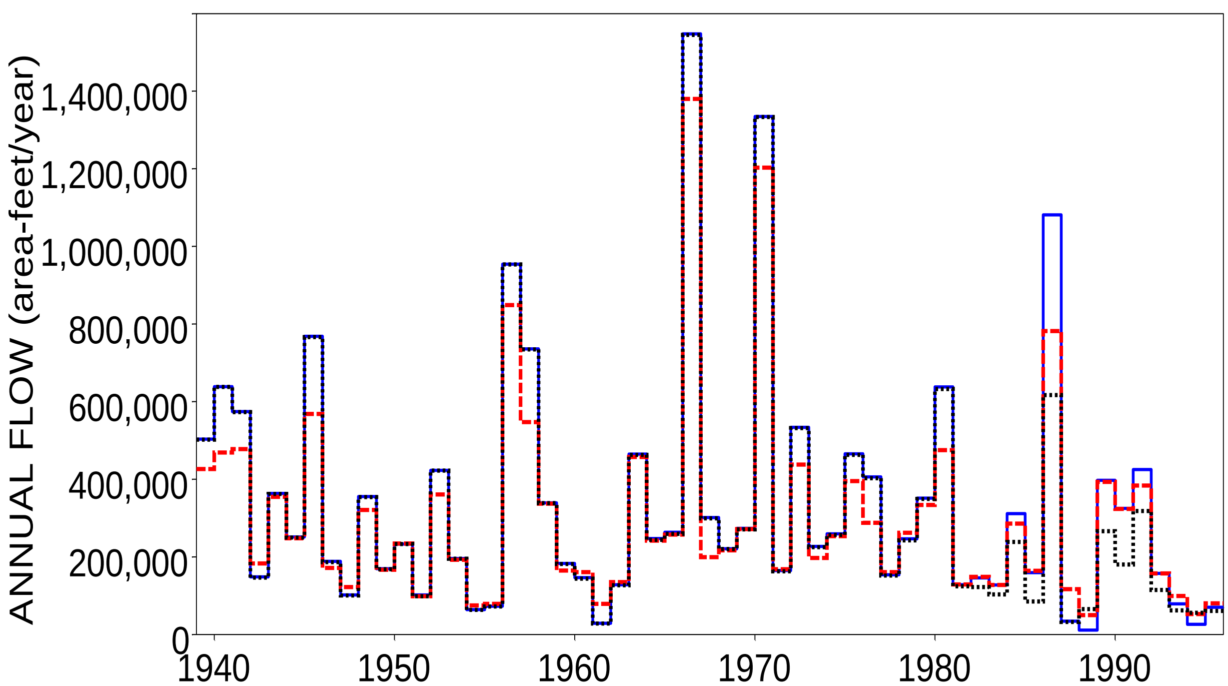
Naturalized Flows of Nueces River at Three Rivers



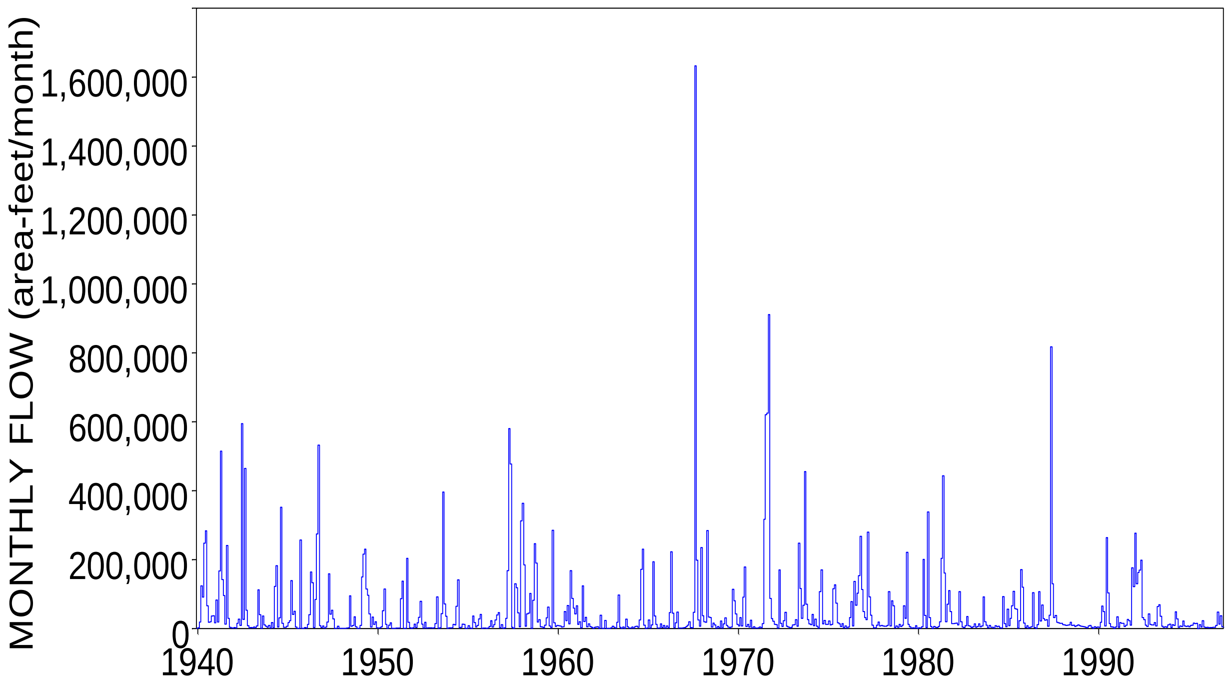
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Nueces River at Three Rivers



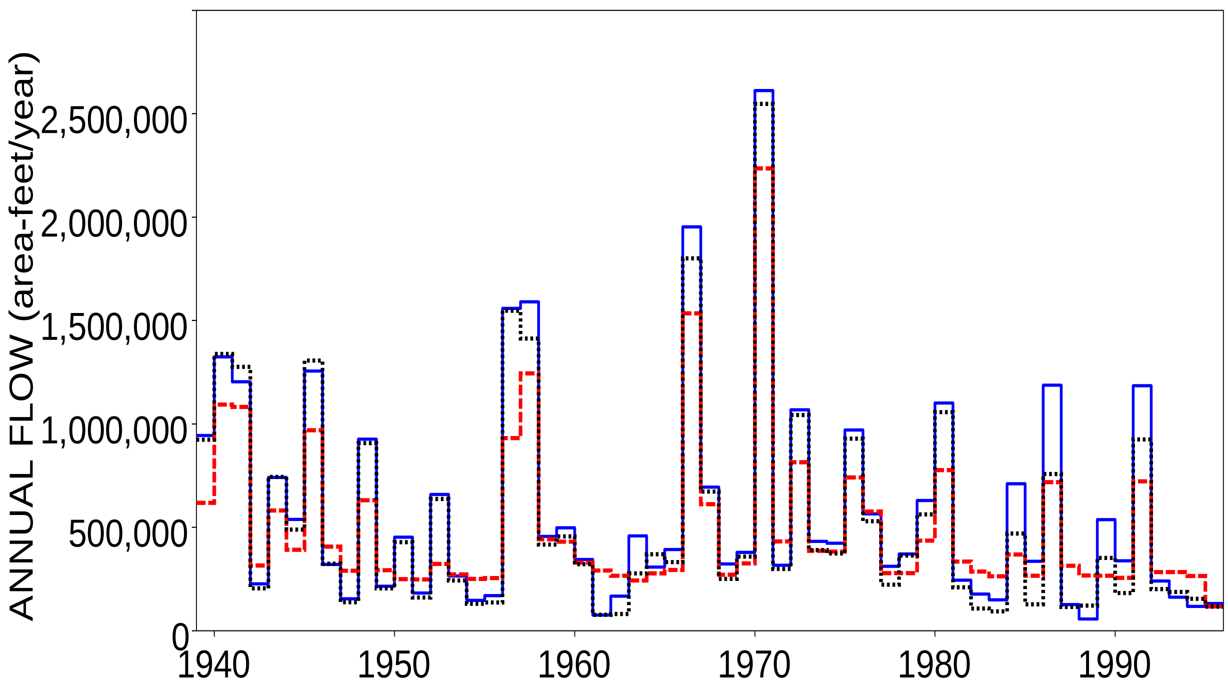
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Nueces River at Three Rivers



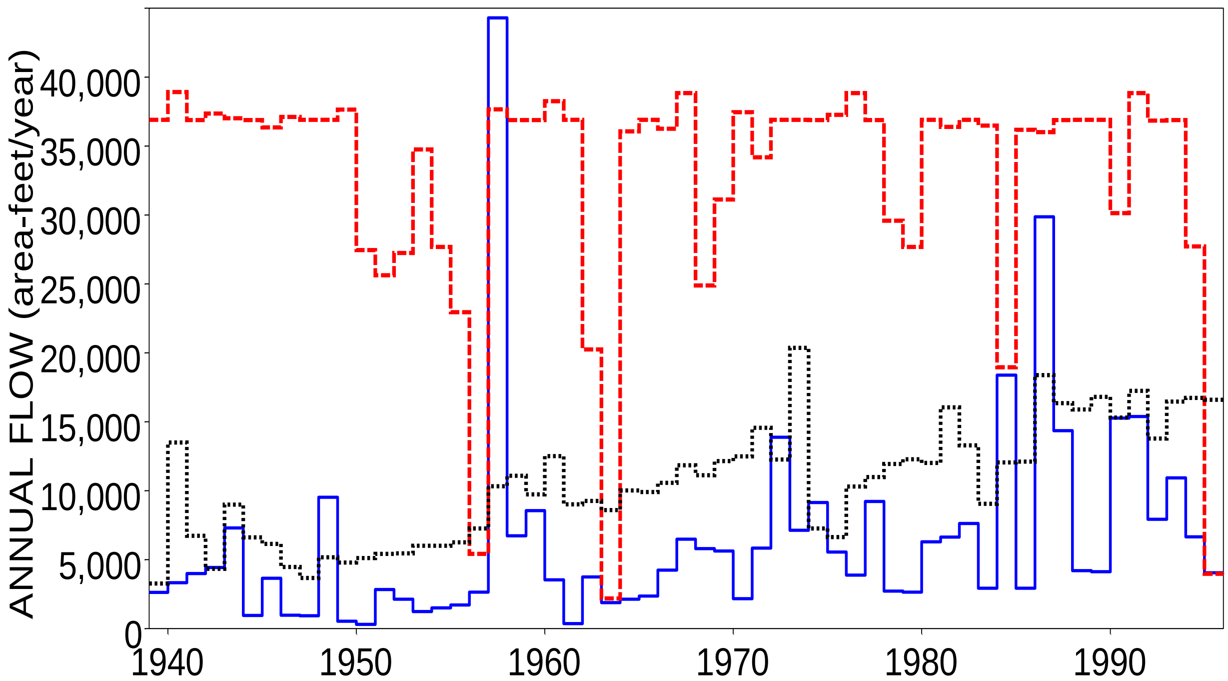
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Nueces River at Three Rivers



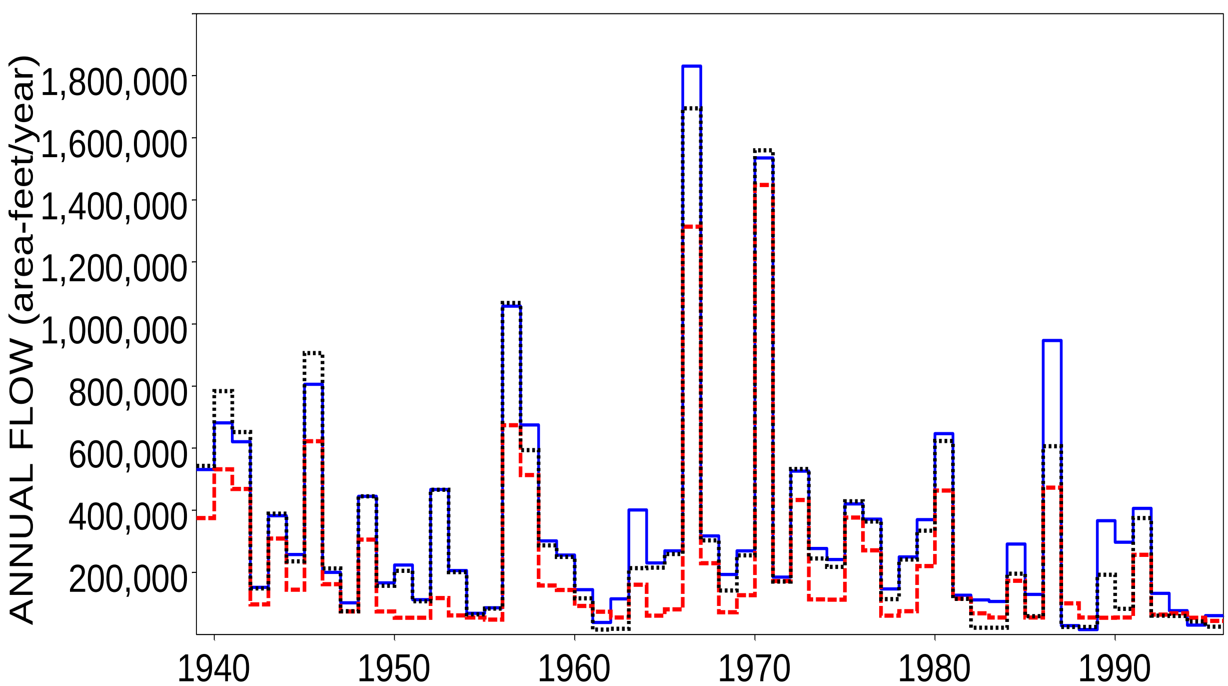
Naturalized Flows of Nueces River at Mathis



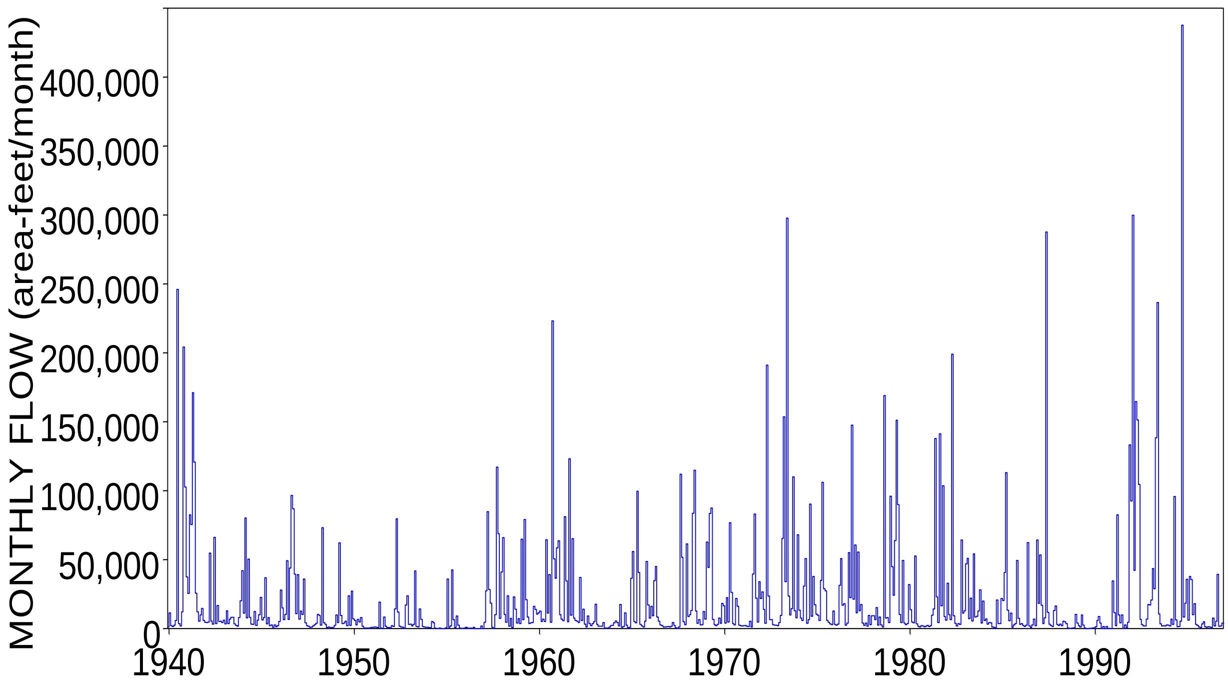
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Nueces River at Mathis



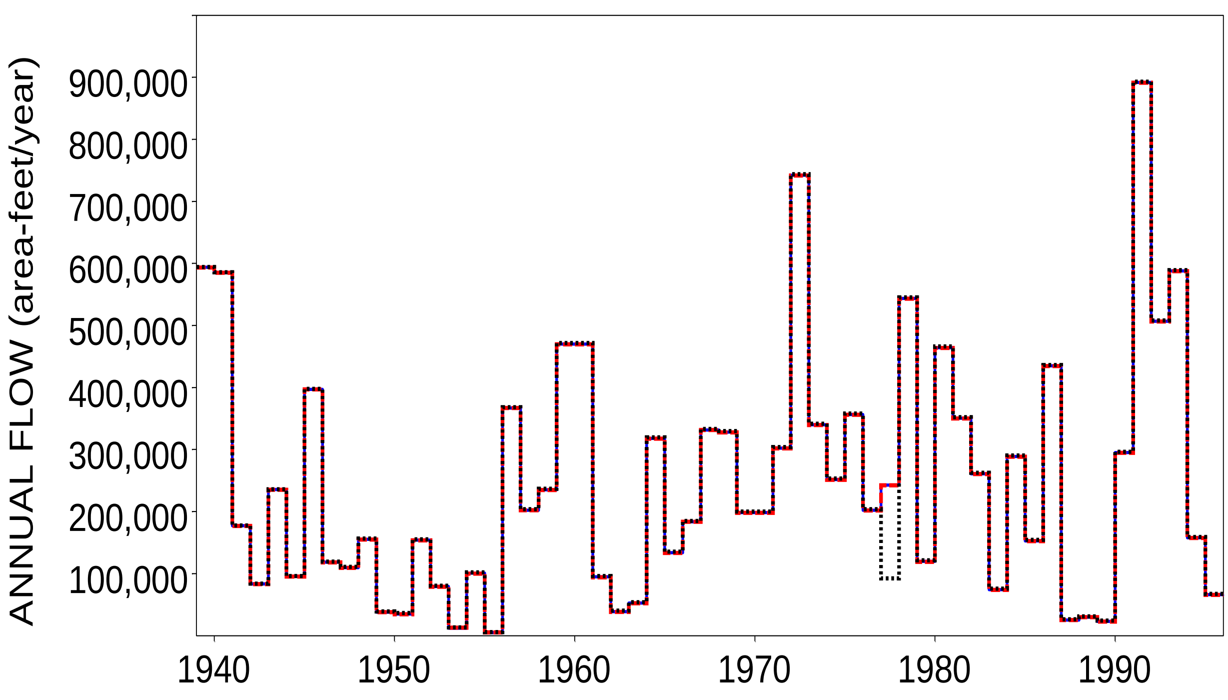
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Nueces River at Mathis



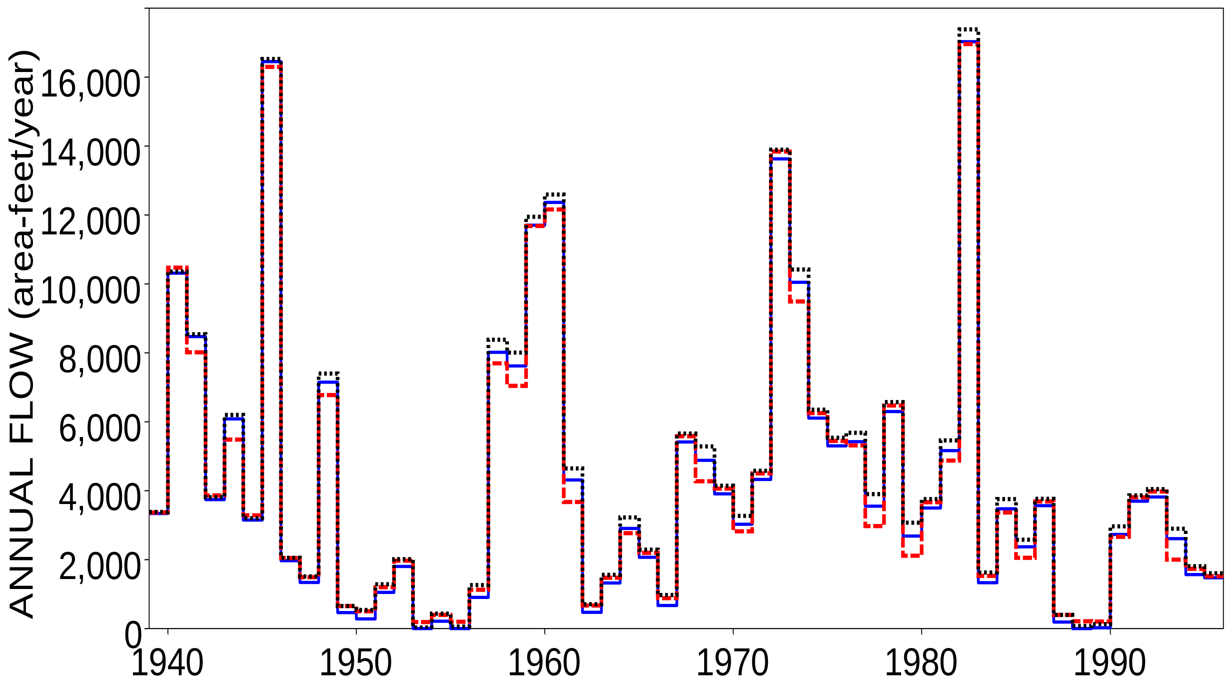
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Nueces River at Mathis



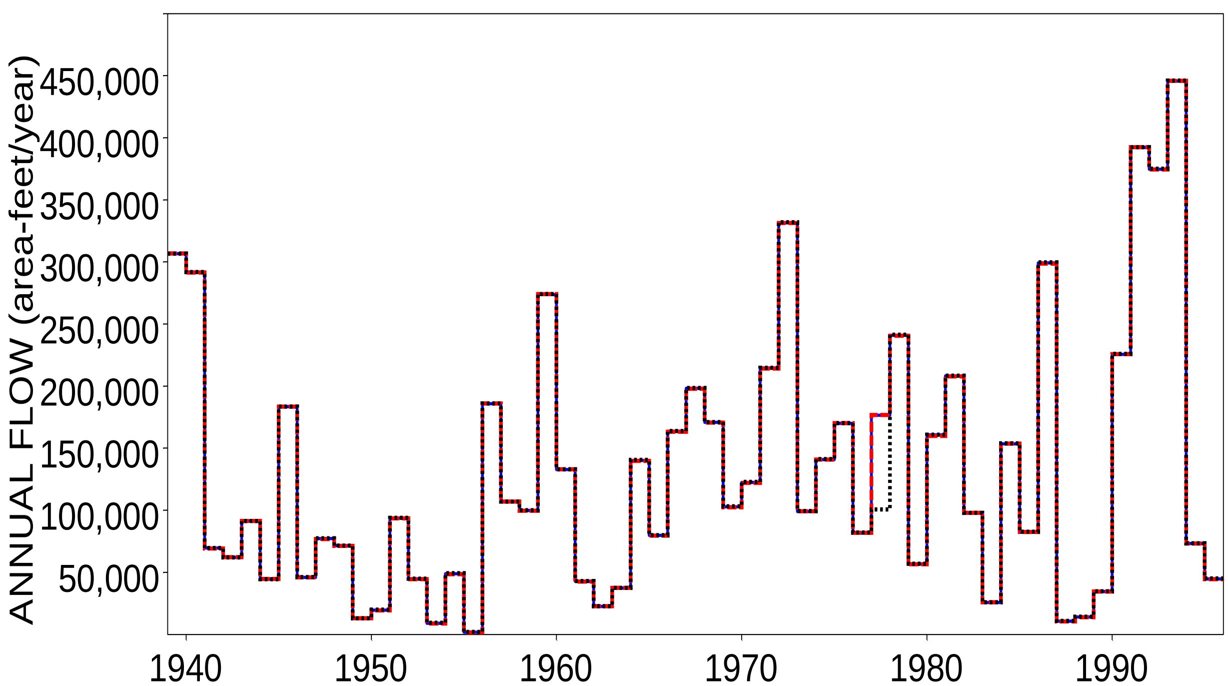
Naturalized Flows of Lavaca River near Edna



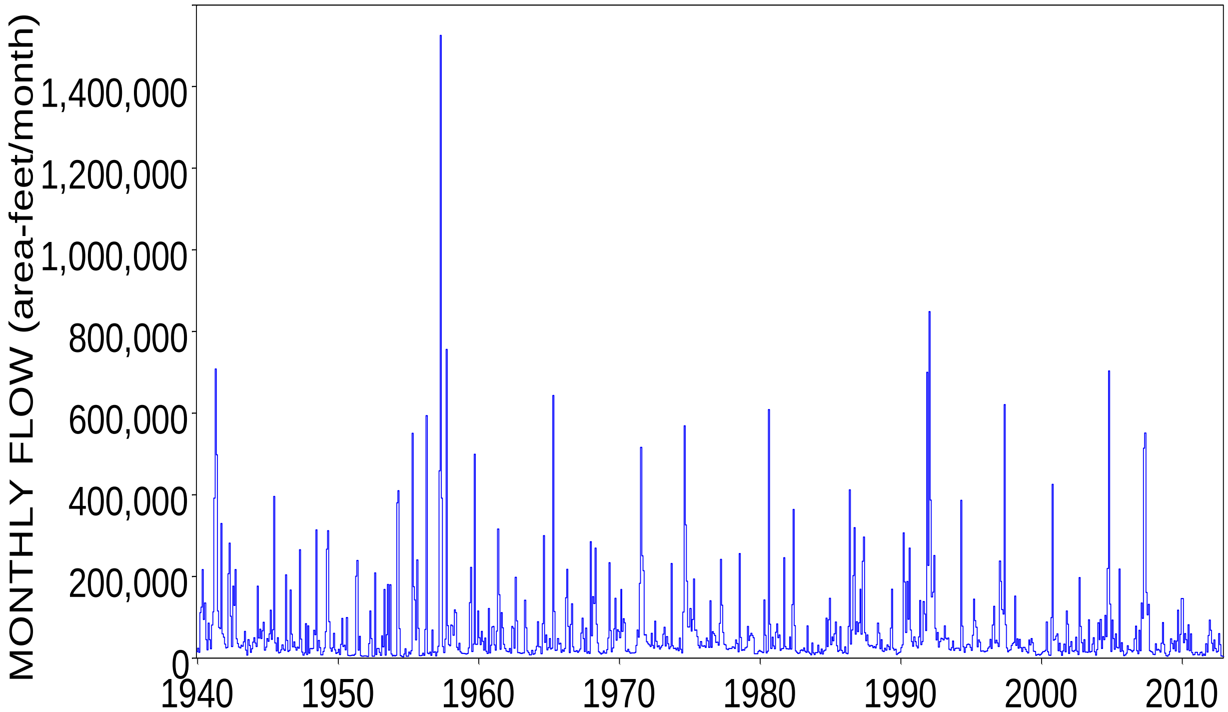
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Lavaca River near Edna



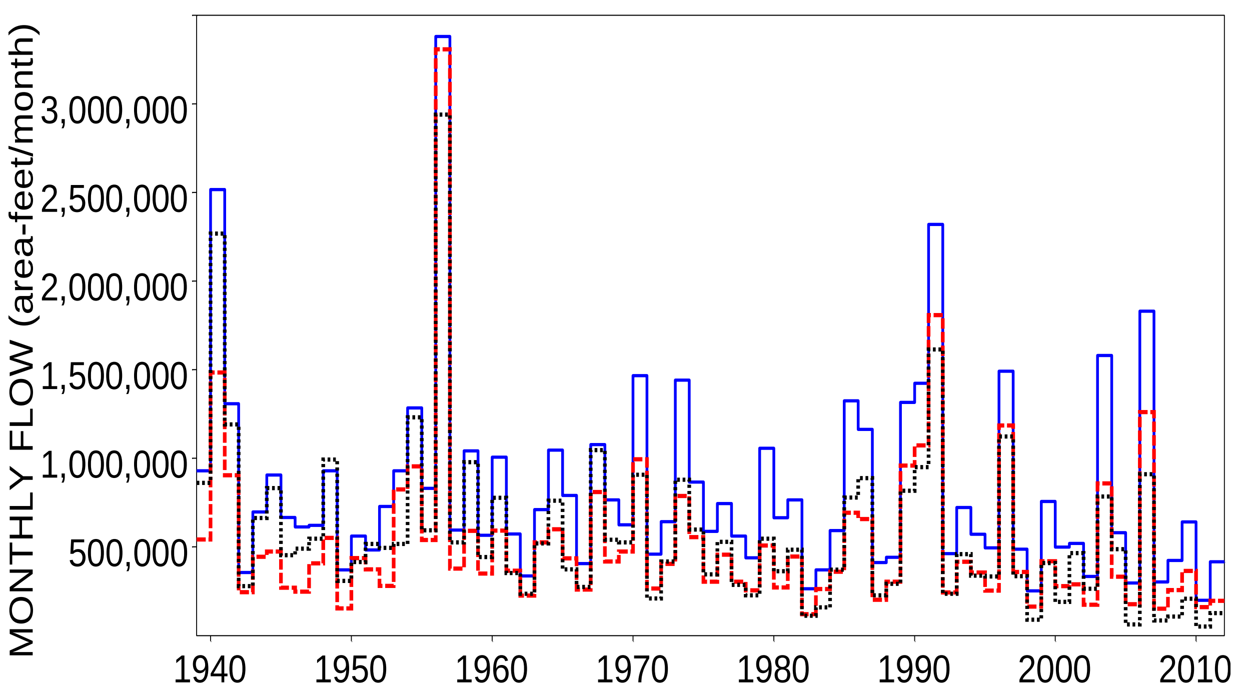
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Lavaca River near Edna



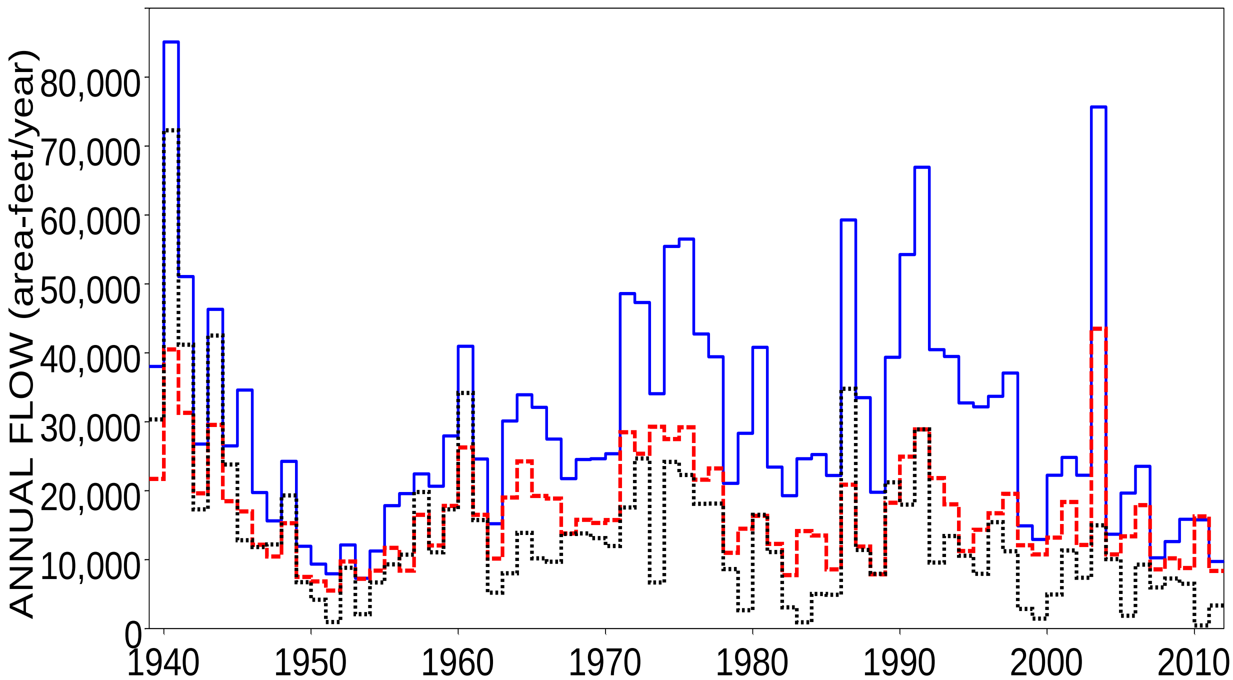
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Lavaca River near Edna



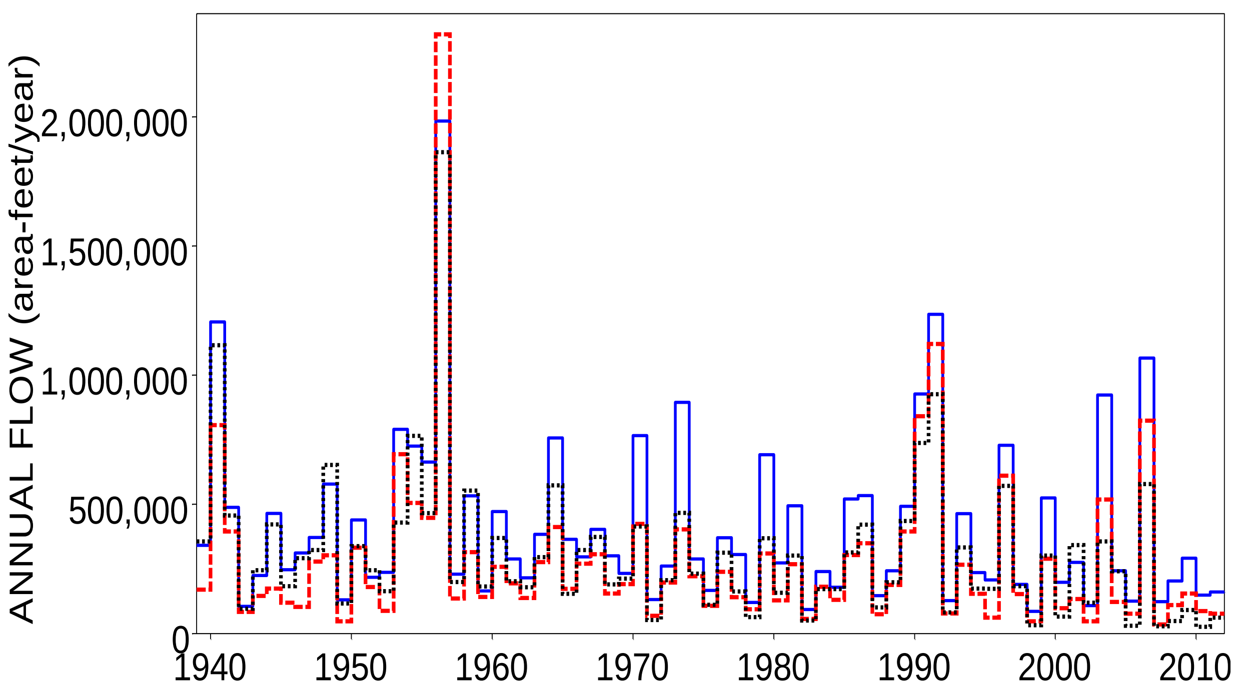
Naturalized Flows of Colorado River near San Saba



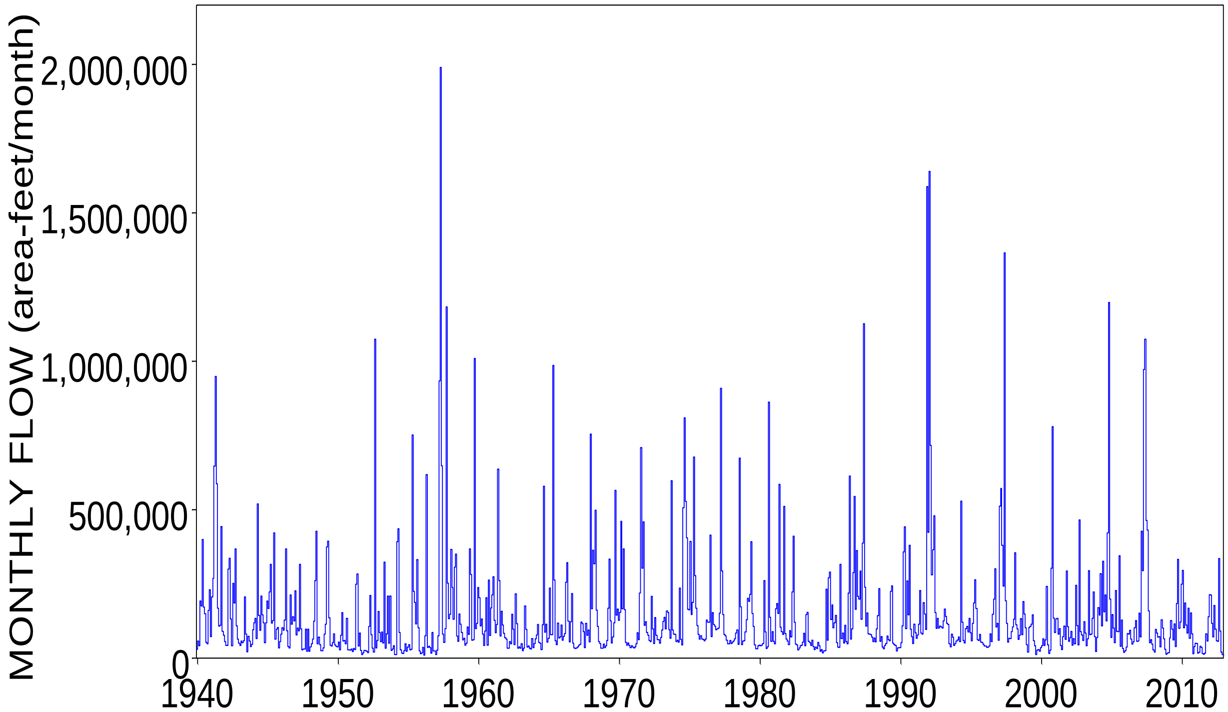
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows
Annual Flows for Colorado River at San Saba gage (F10000)



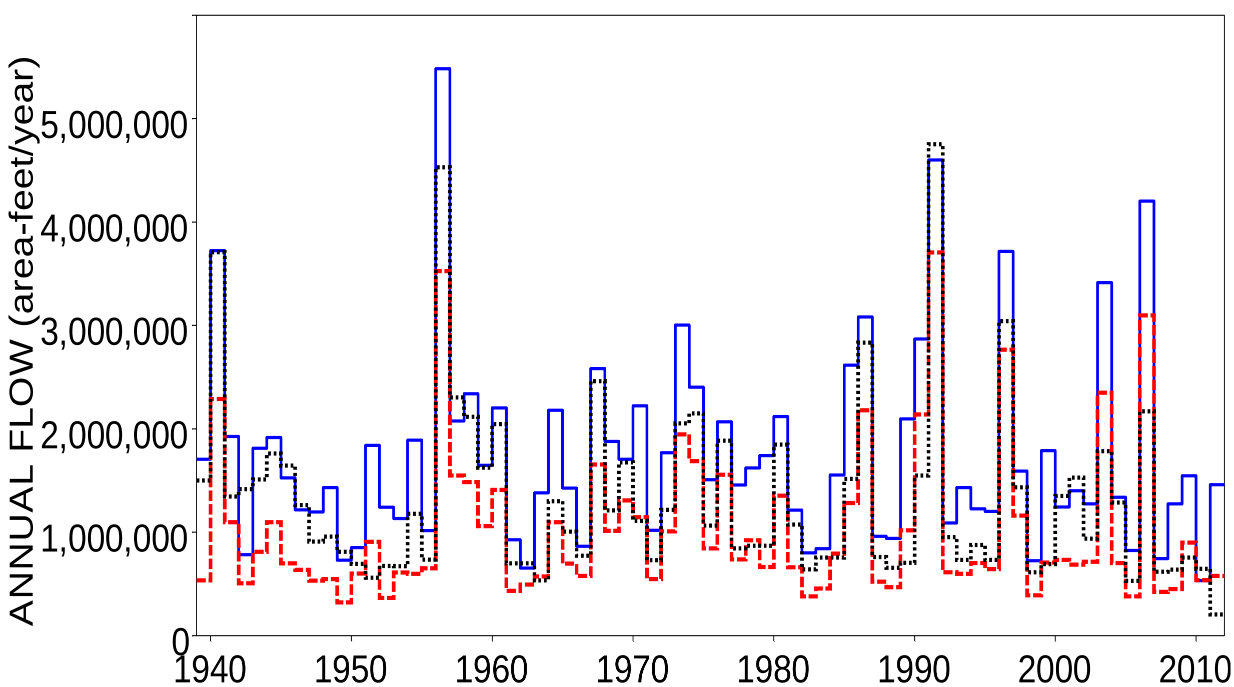
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Colorado River at San Saba gage (F10000)



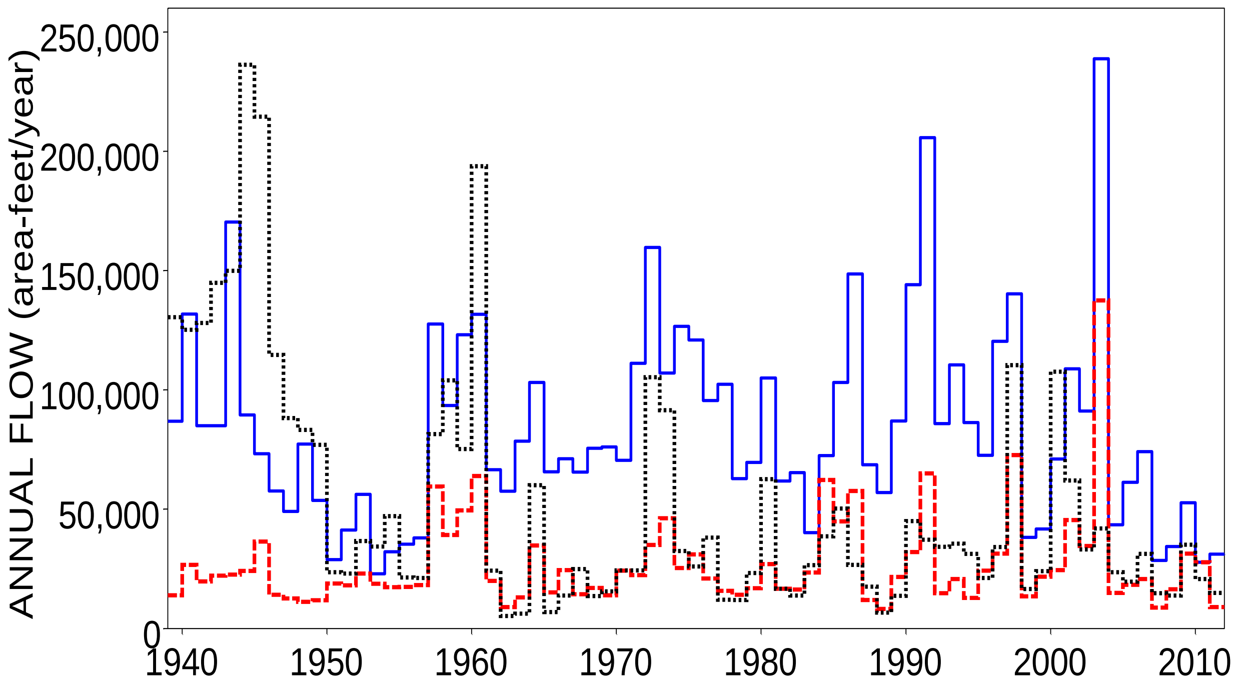
Naturalized (blue solid), Regulated (red dashed), and Observed 2-Month Maximum Annual Flows for Colorado River at San Saba gage (F10000)



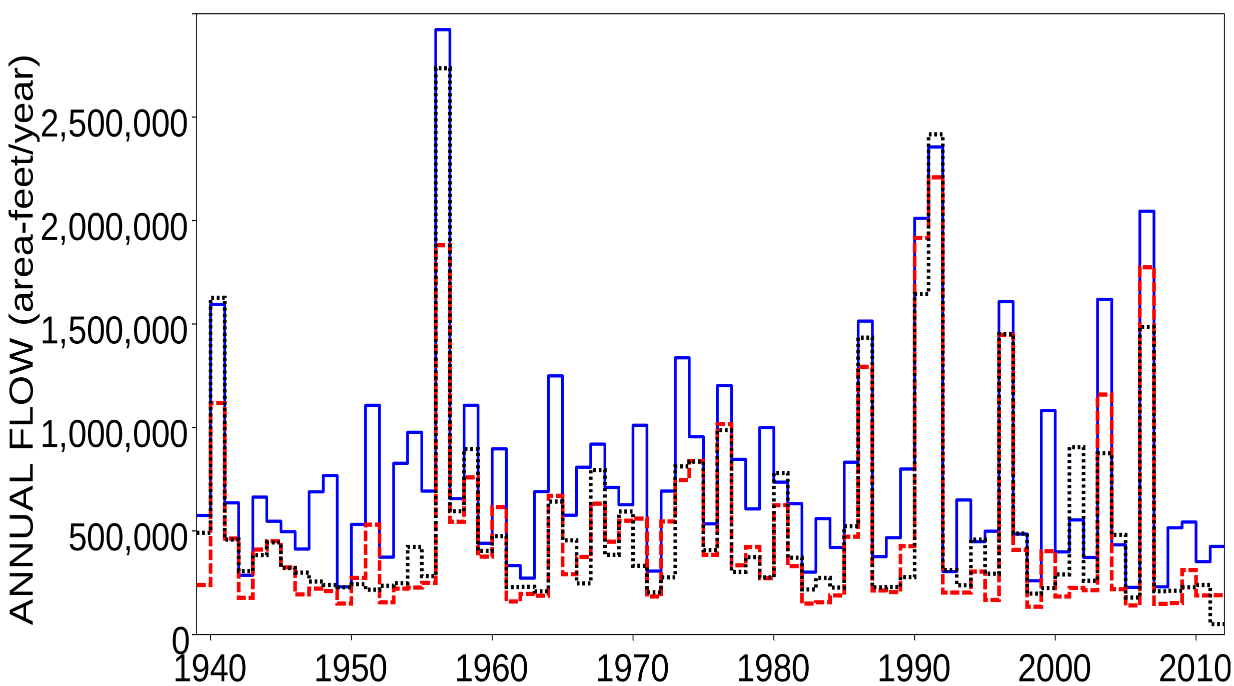
Naturalized Flows of Colorado River at Austin



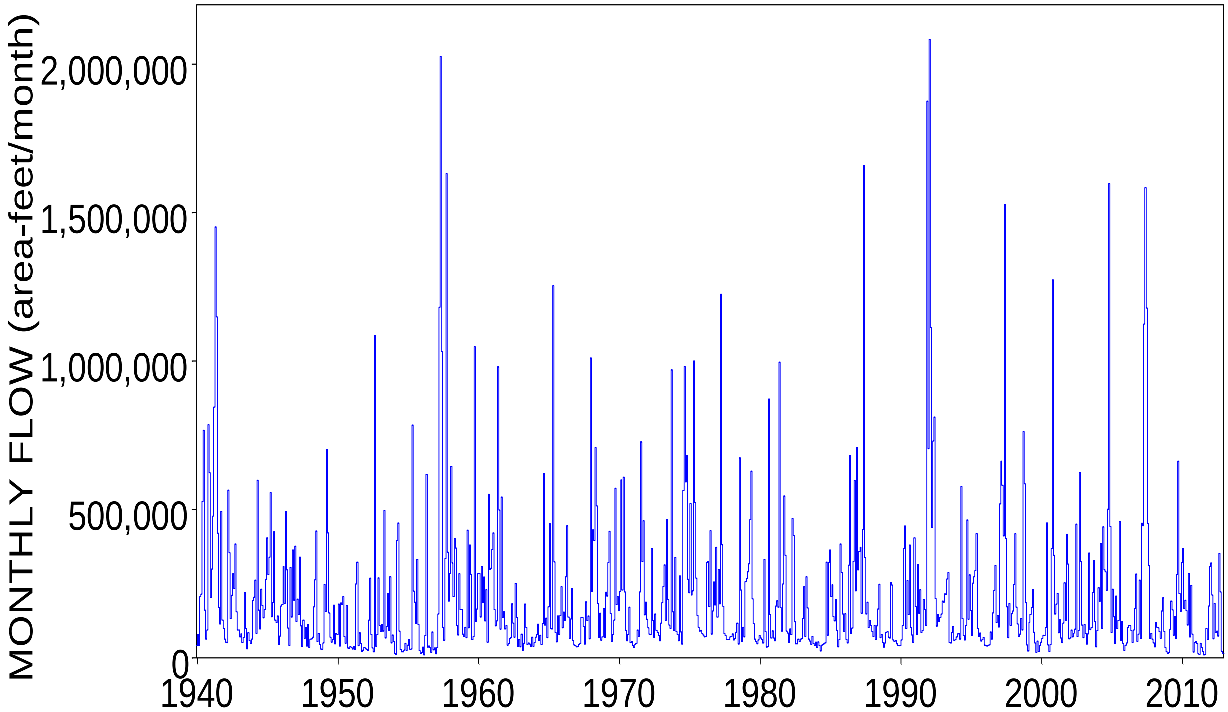
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Colorado River at Austin



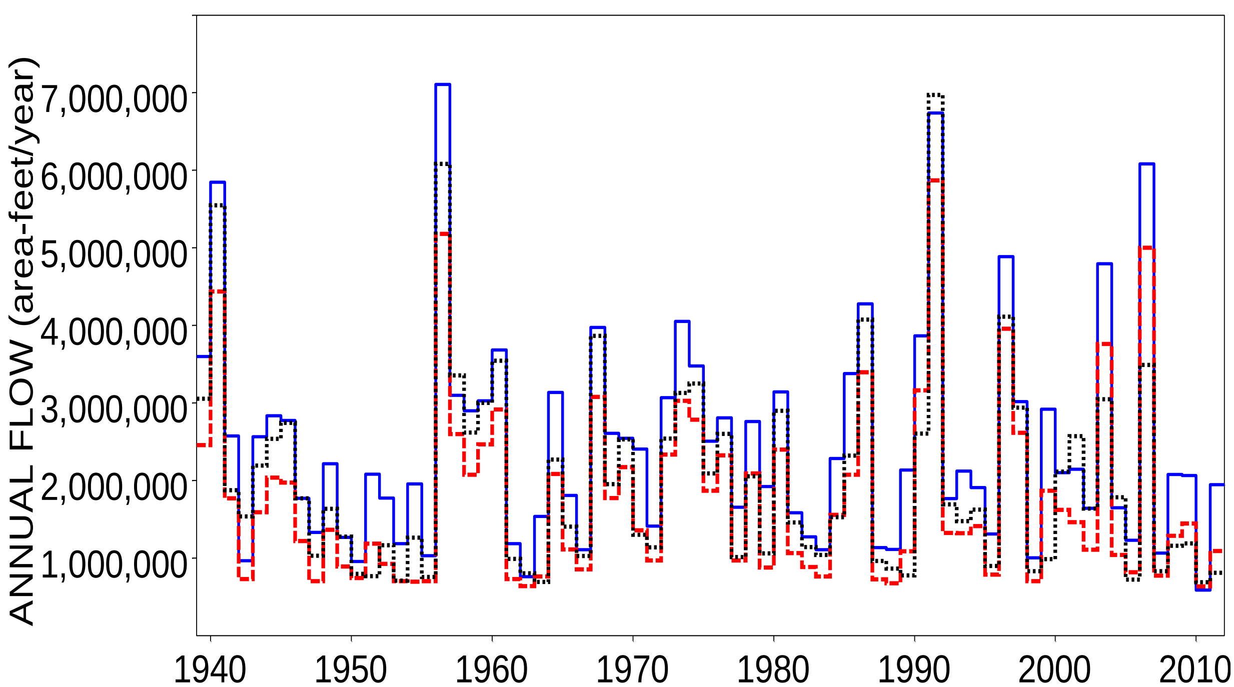
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Colorado River at Austin



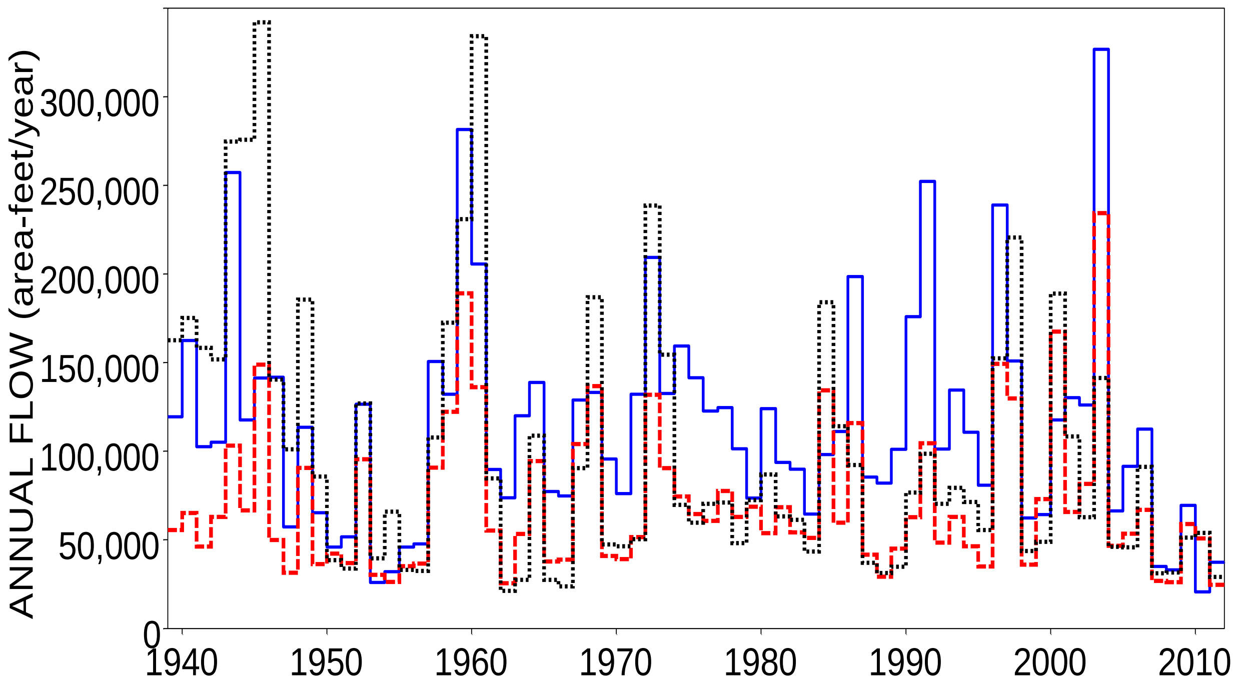
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Colorado River at Austin



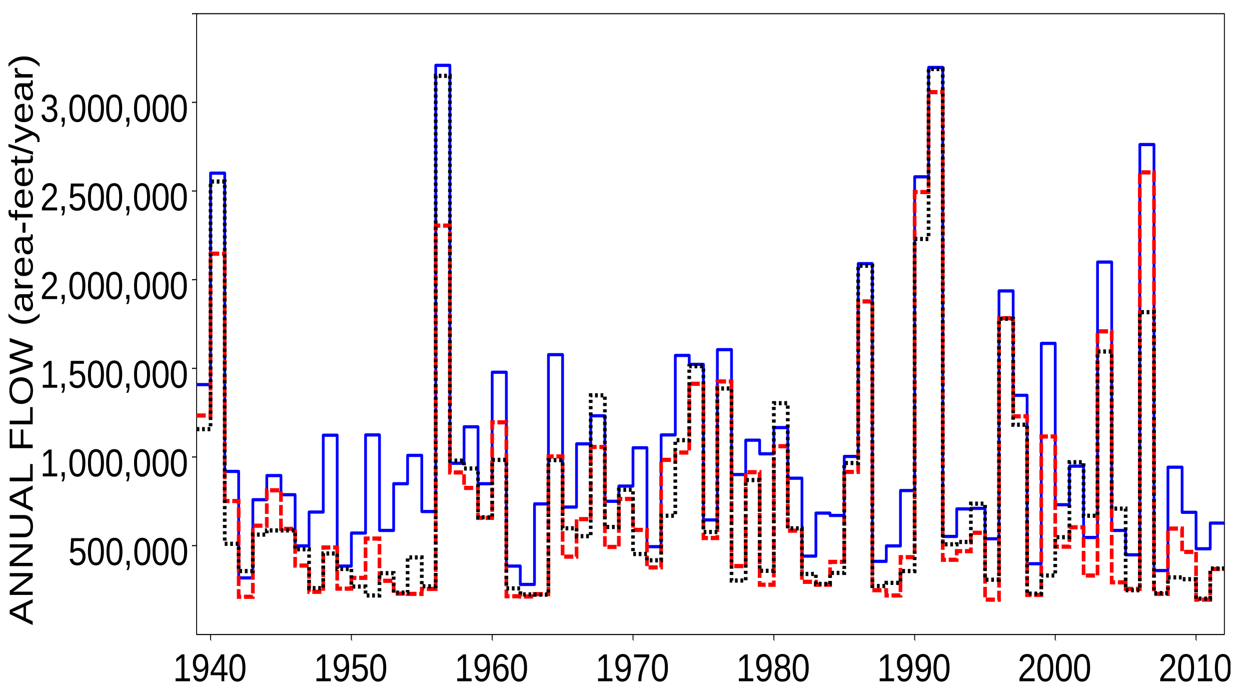
Naturalized Flows of Colorado River at Columbus



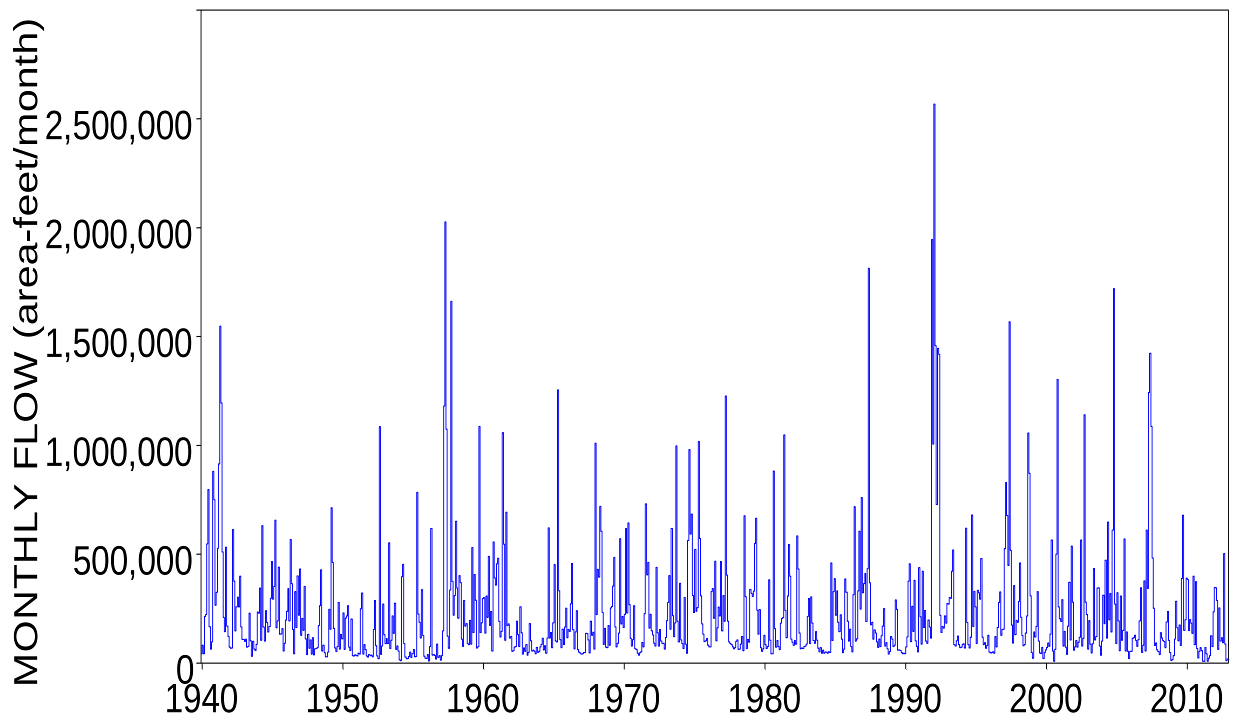
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Colorado River at Columbus



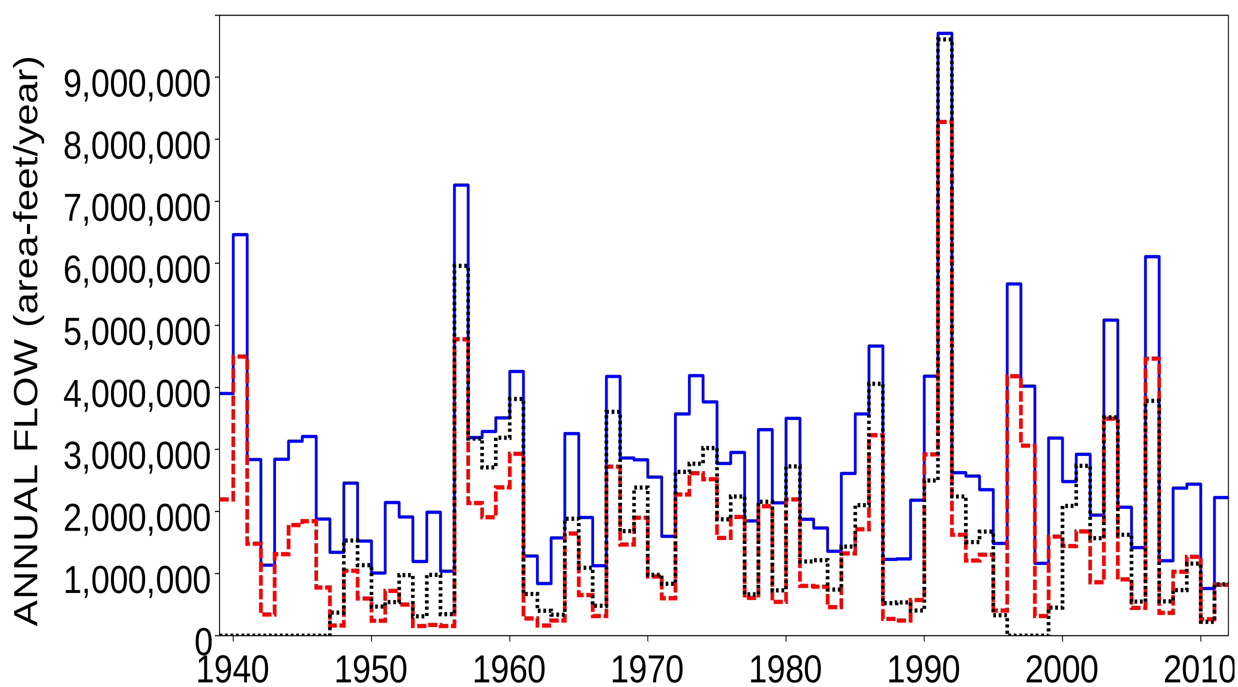
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Colorado River at Columbus



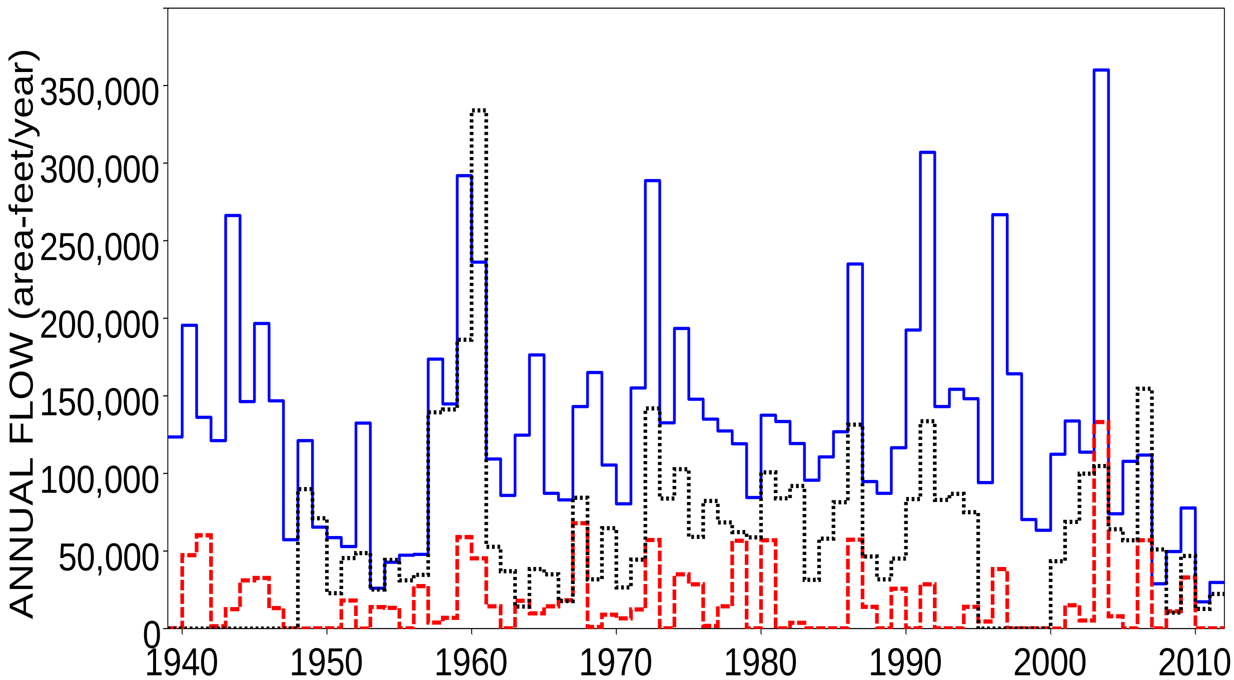
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Colorado River at Columbus



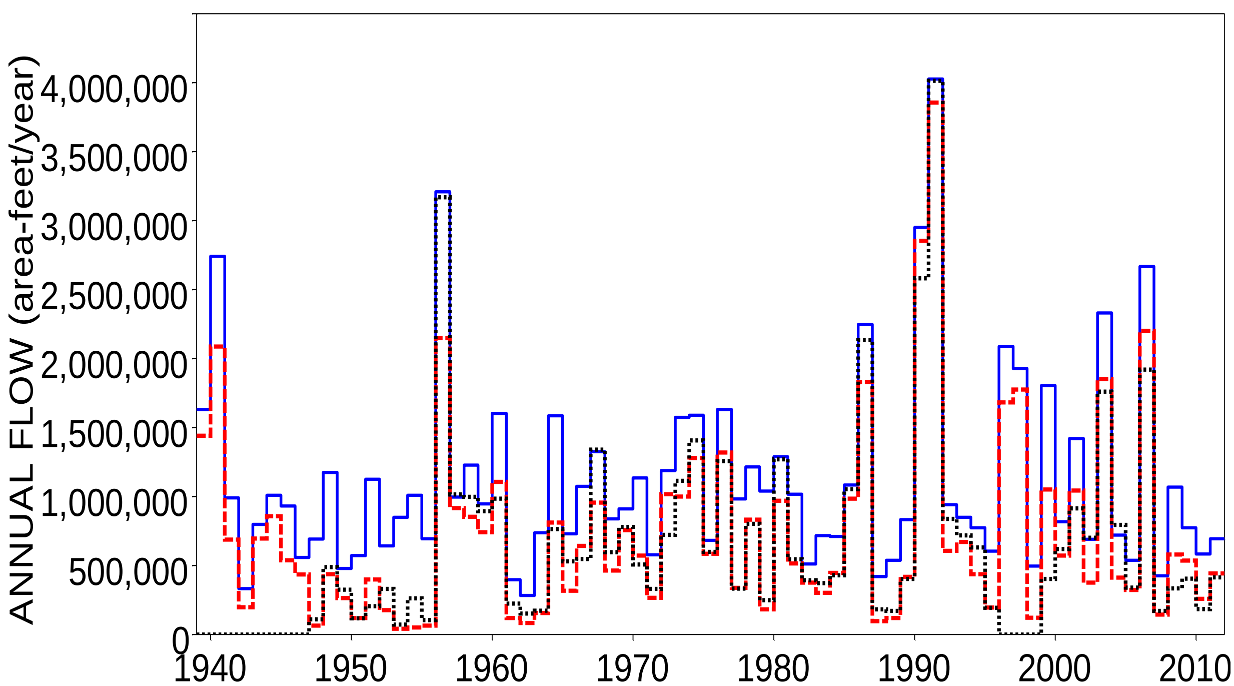
Naturalized Flows of Colorado River near Bay City



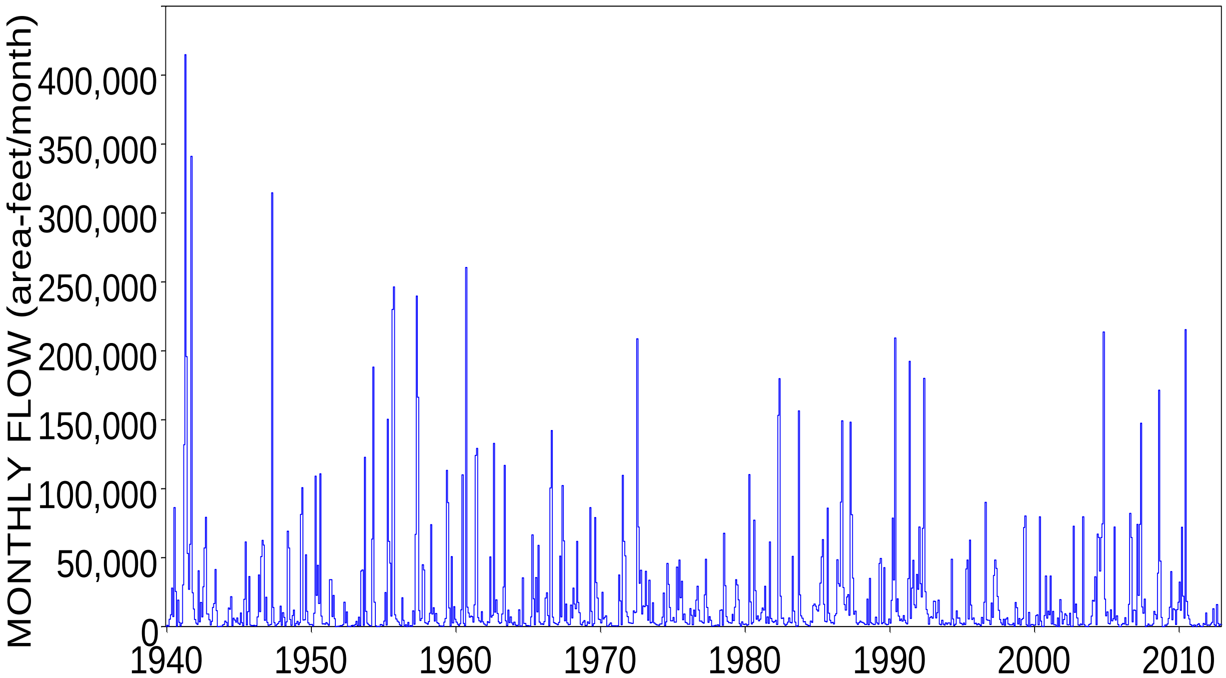
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Colorado River near Bay City



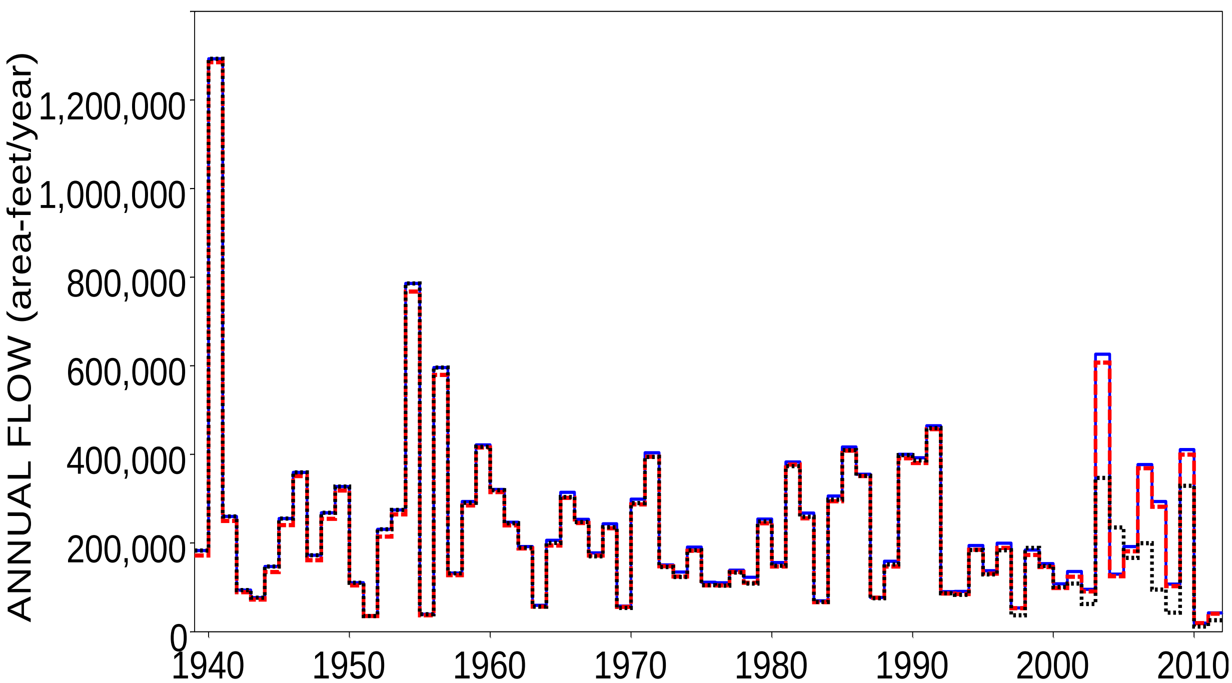
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Colorado River near Bay City



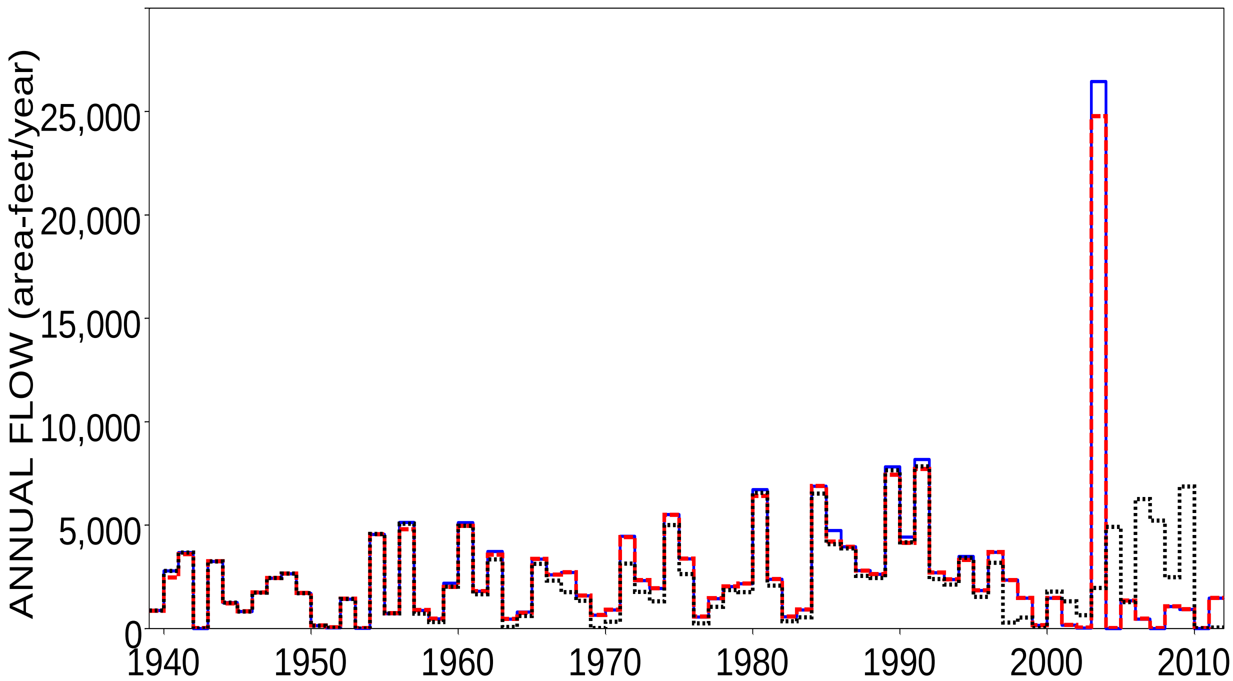
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Colorado River near Bay City



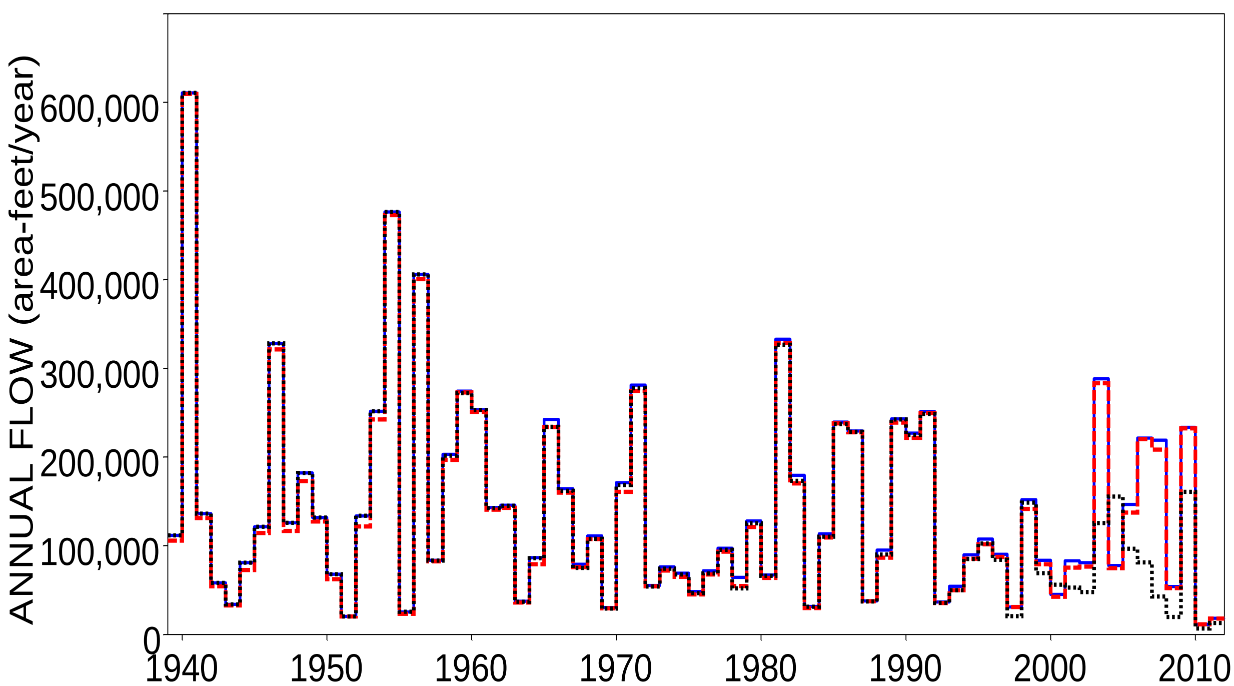
Naturalized Flows of Brazos River at Seymour



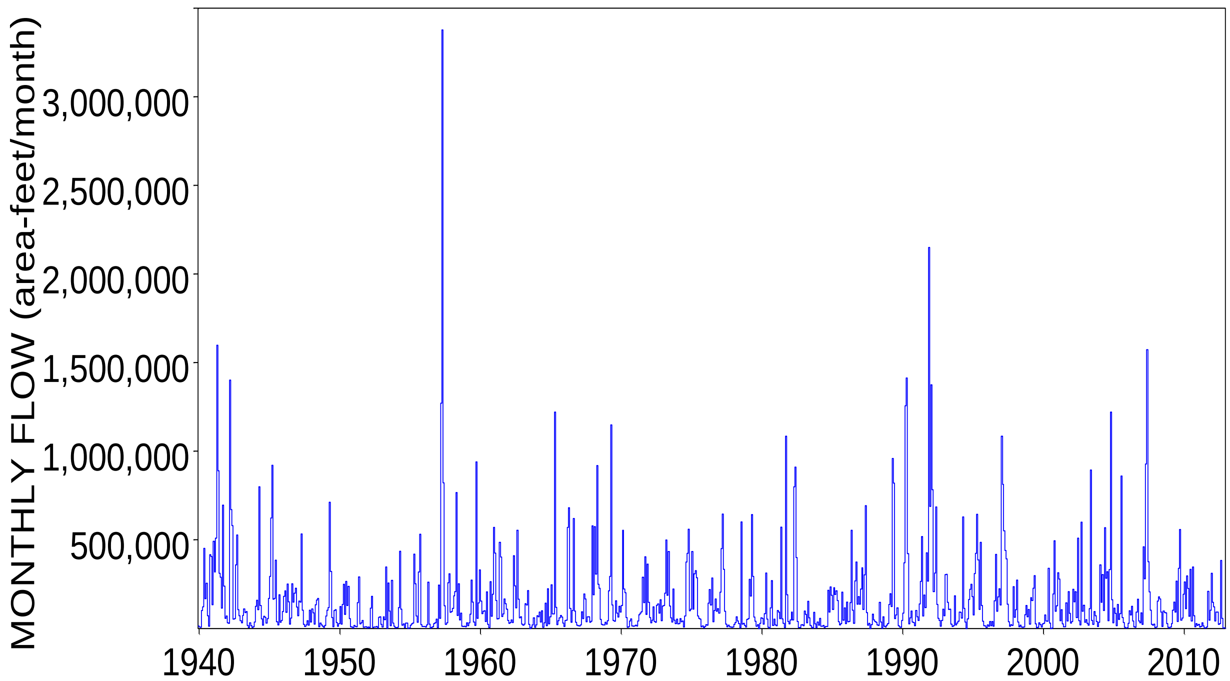
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Brazos River at Seymour



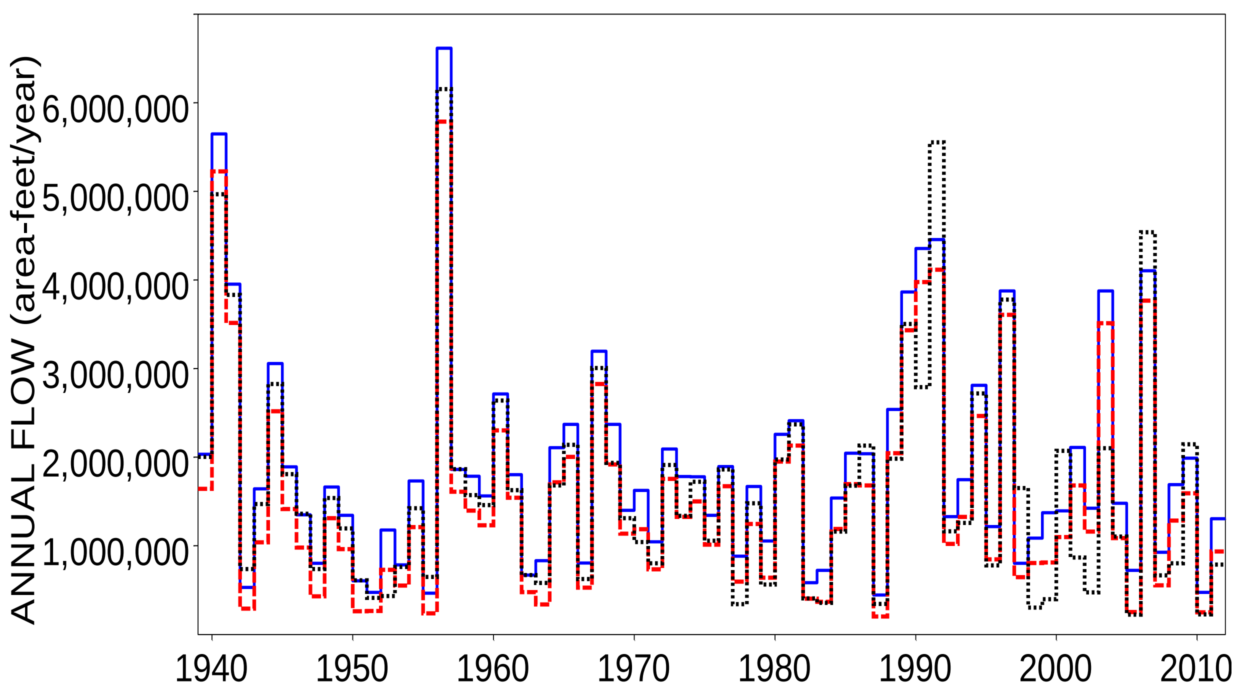
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Brazos River at Seymour



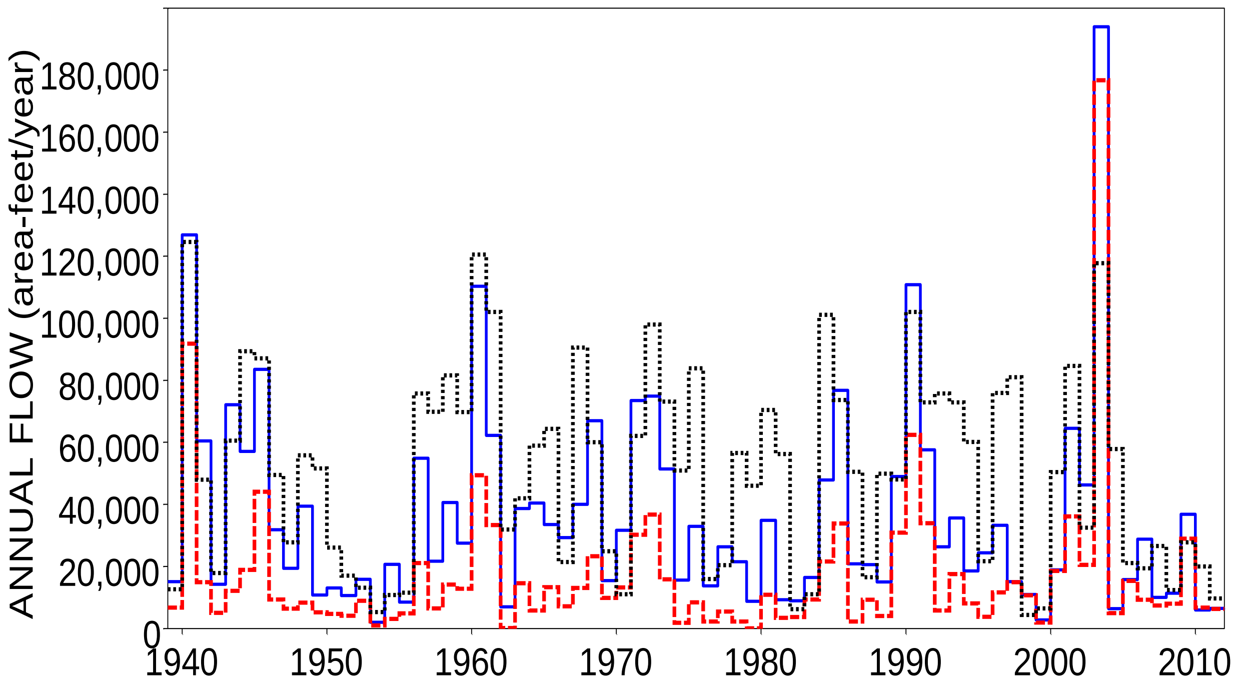
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Brazos River at Seymour



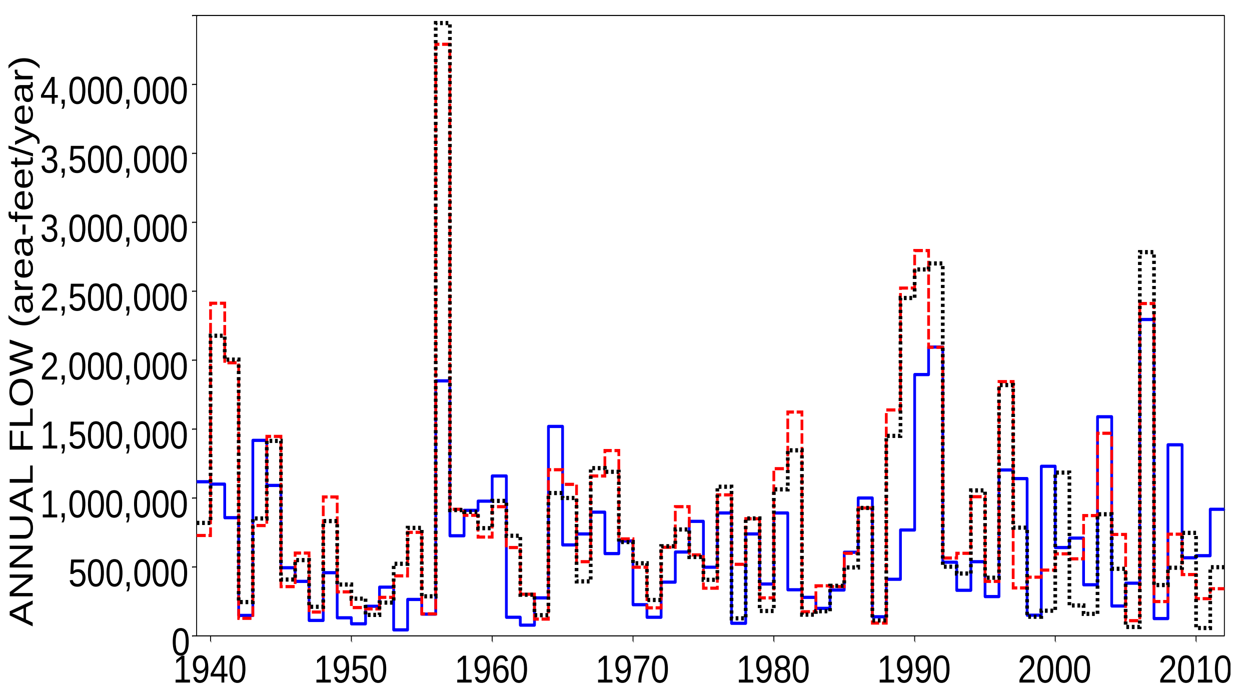
Naturalized Flows of Brazos River Waco



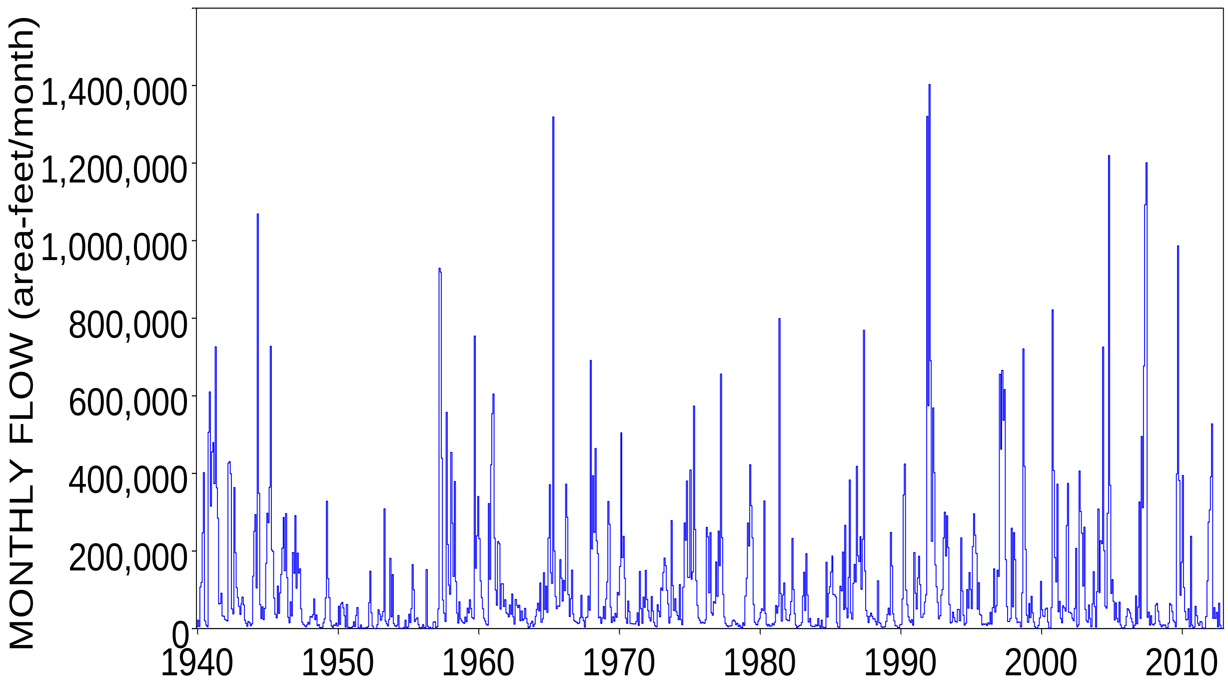
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Brazos River Waco



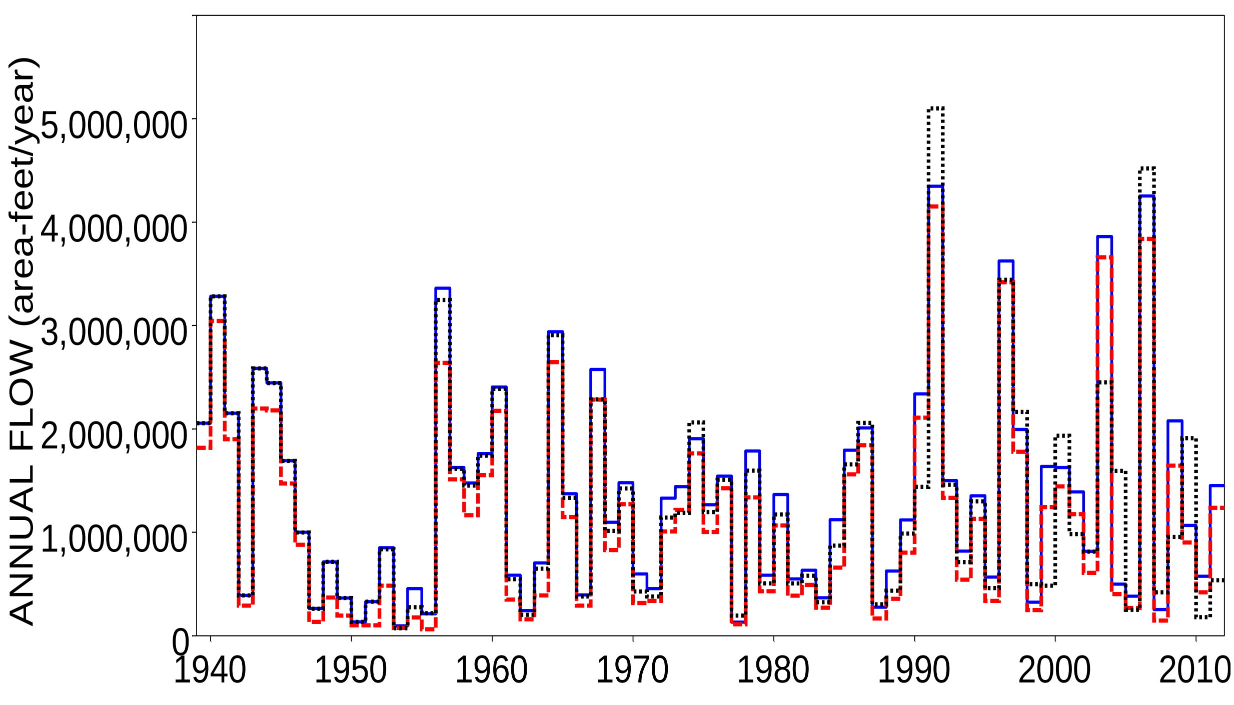
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Brazos River Waco



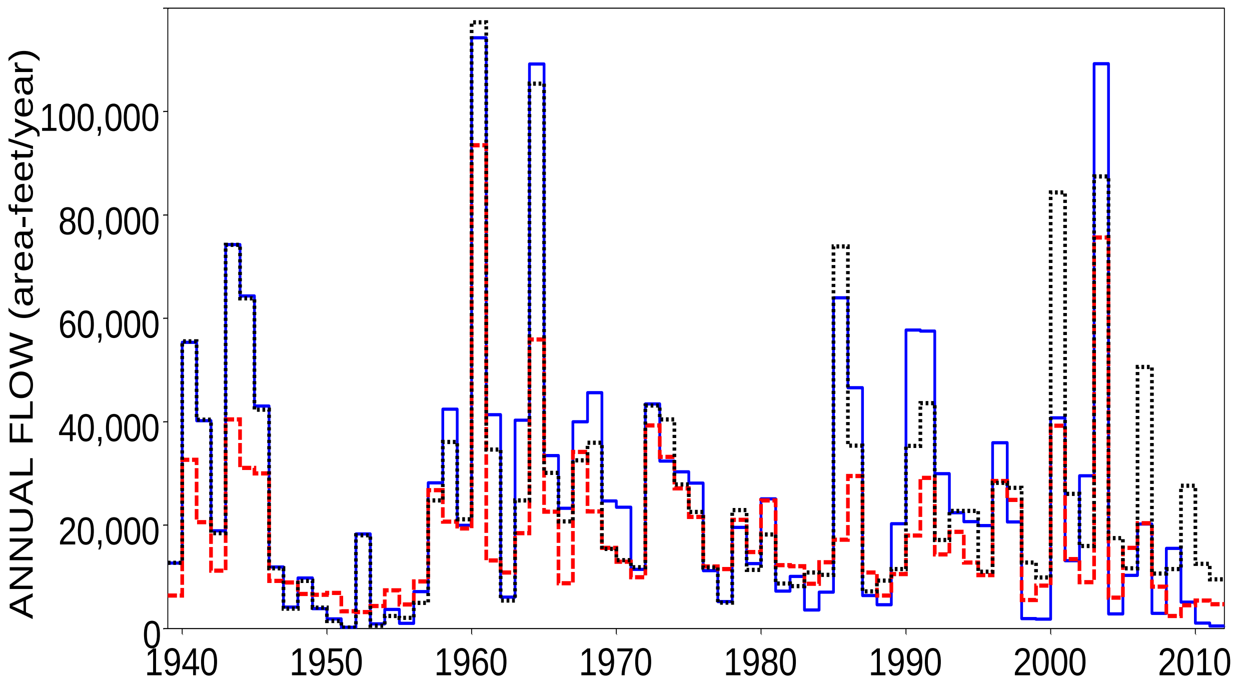
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Brazos River Waco



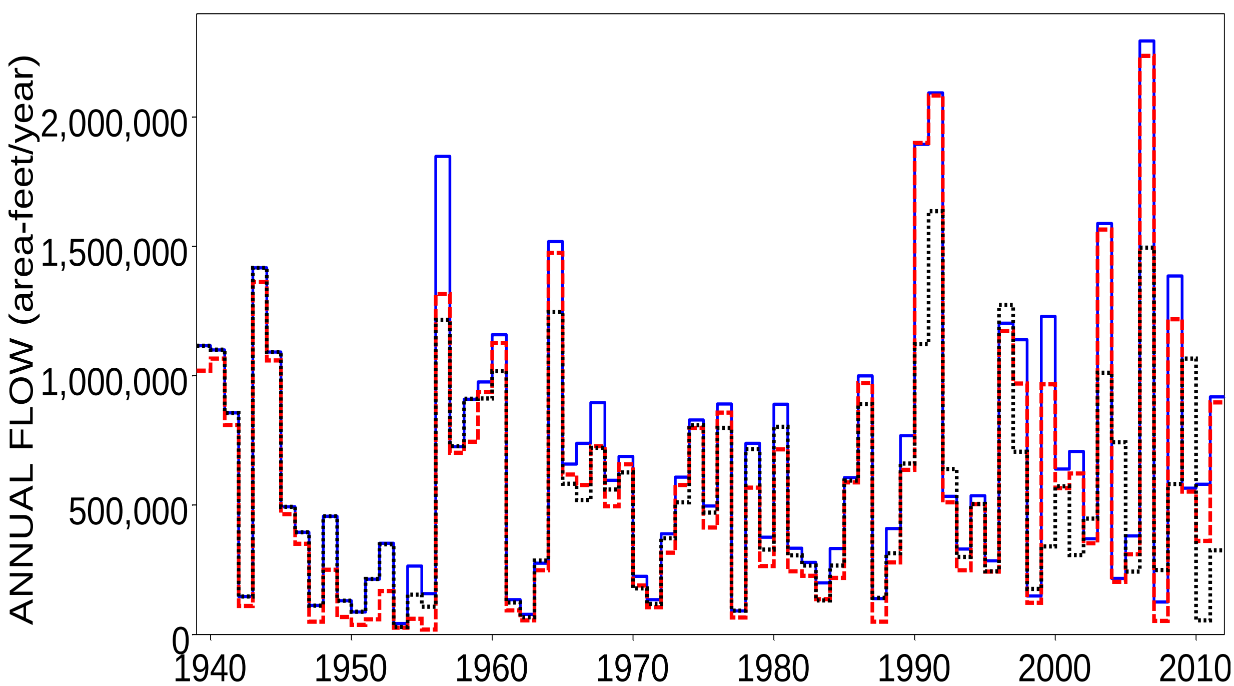
Naturalized Flows of Little River at Cameron



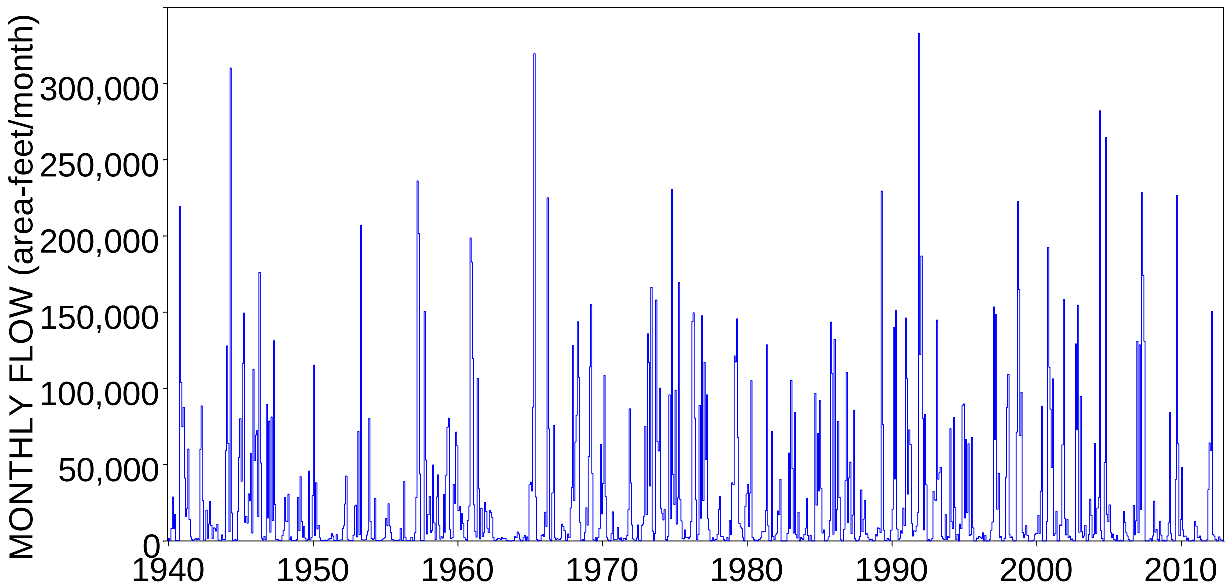
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Little River at Cameron



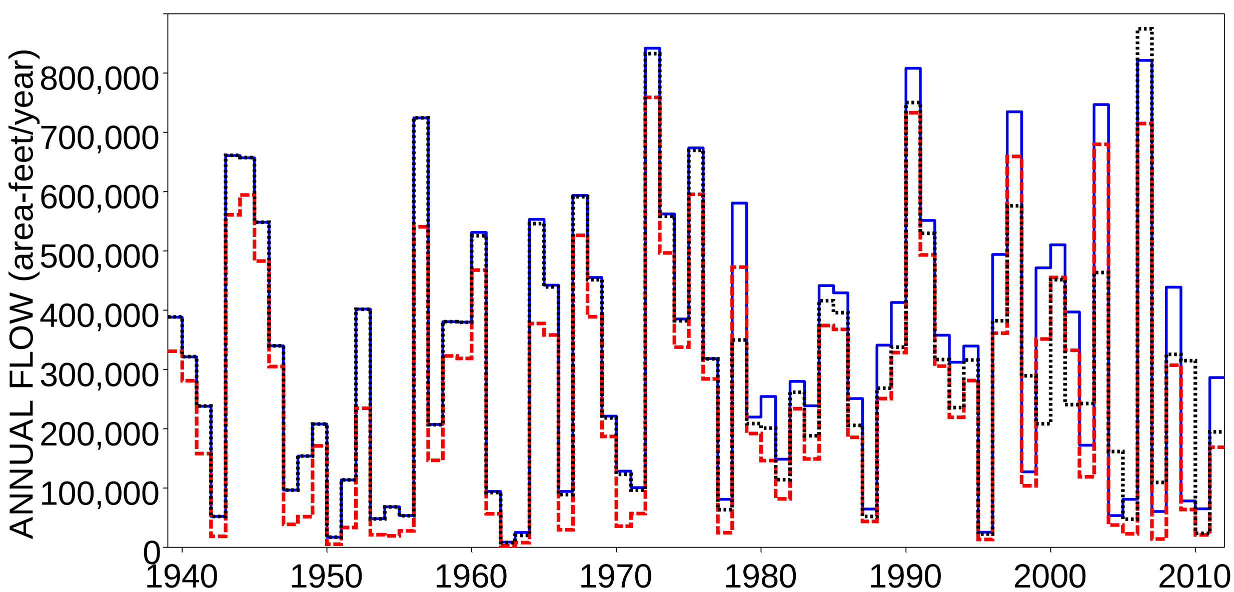
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Little River at Cameron



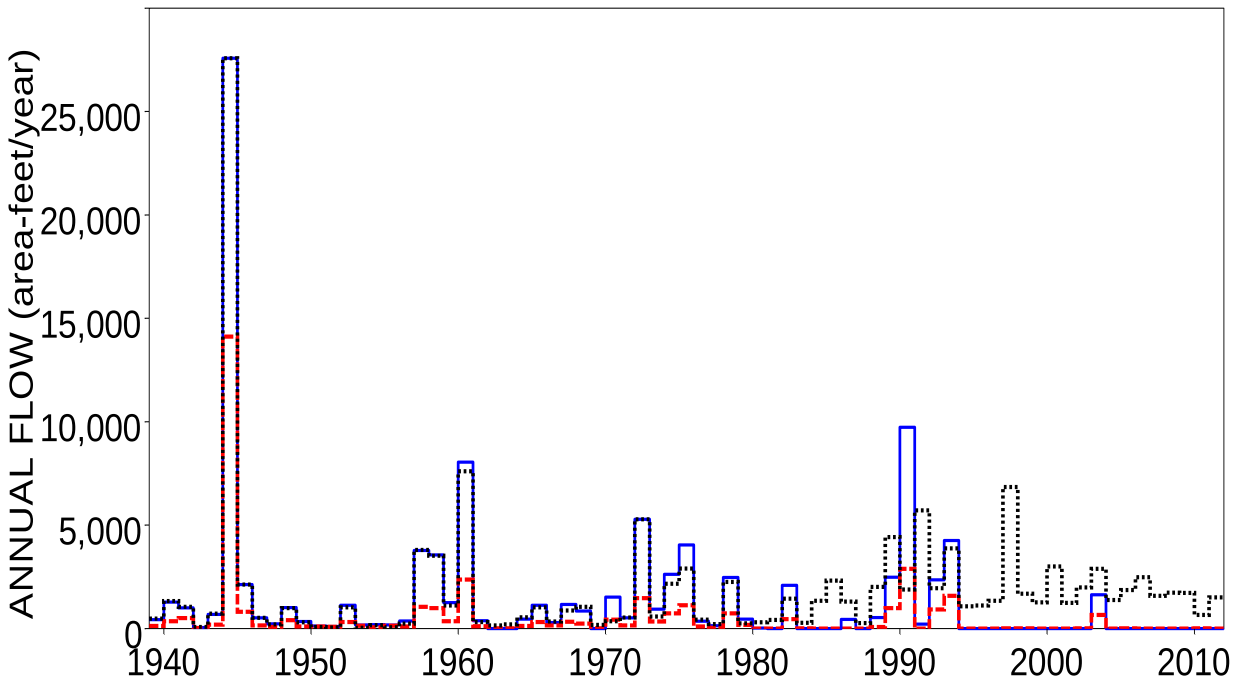
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Little River at Cameron



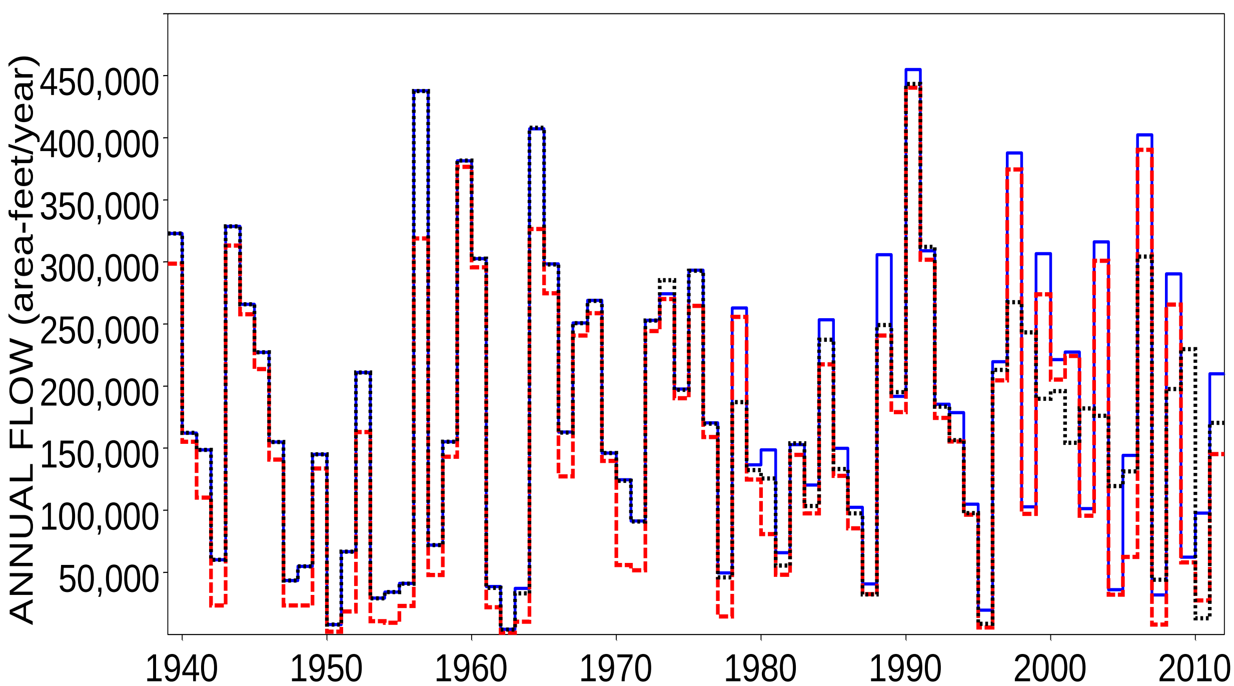
Naturalized Flows of Navasota River at Easterly



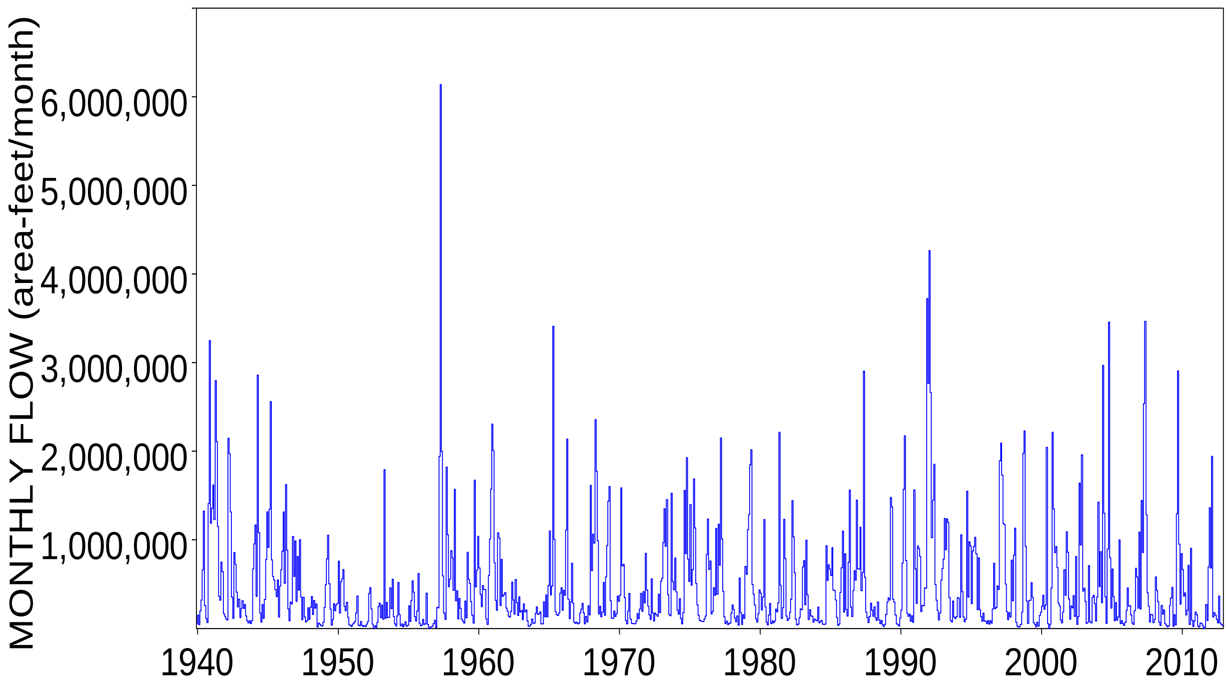
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Navasota River at Easterly



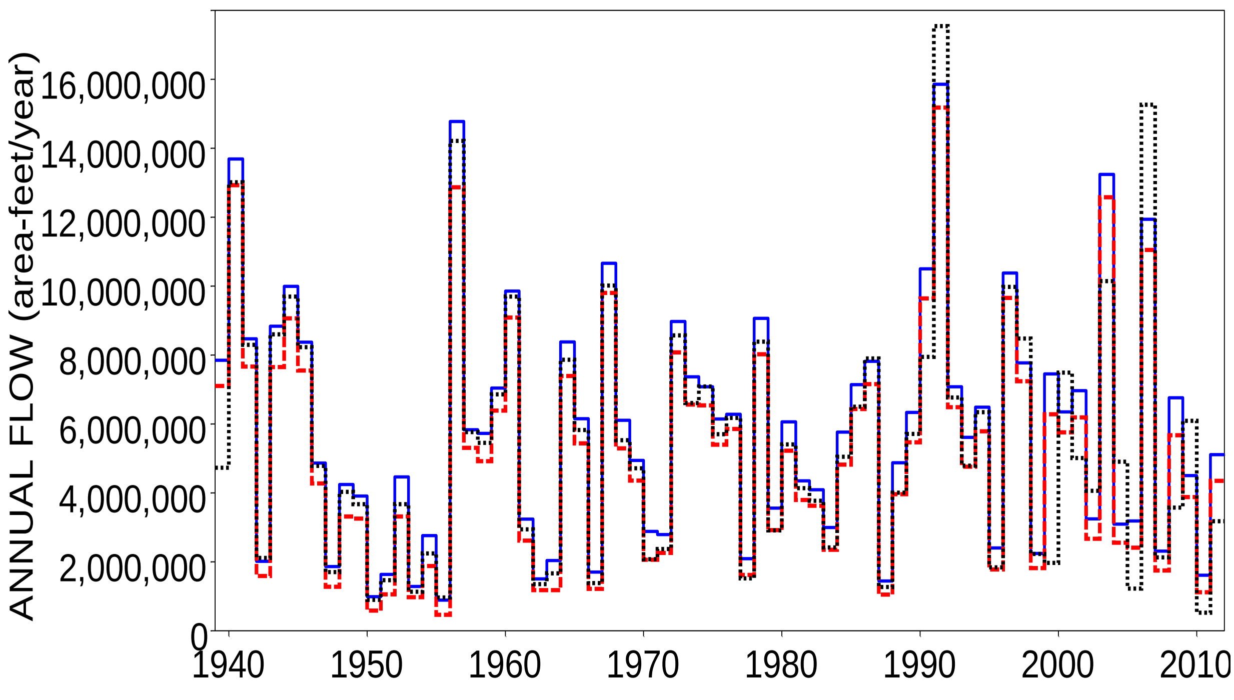
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Navasota River at Easterly



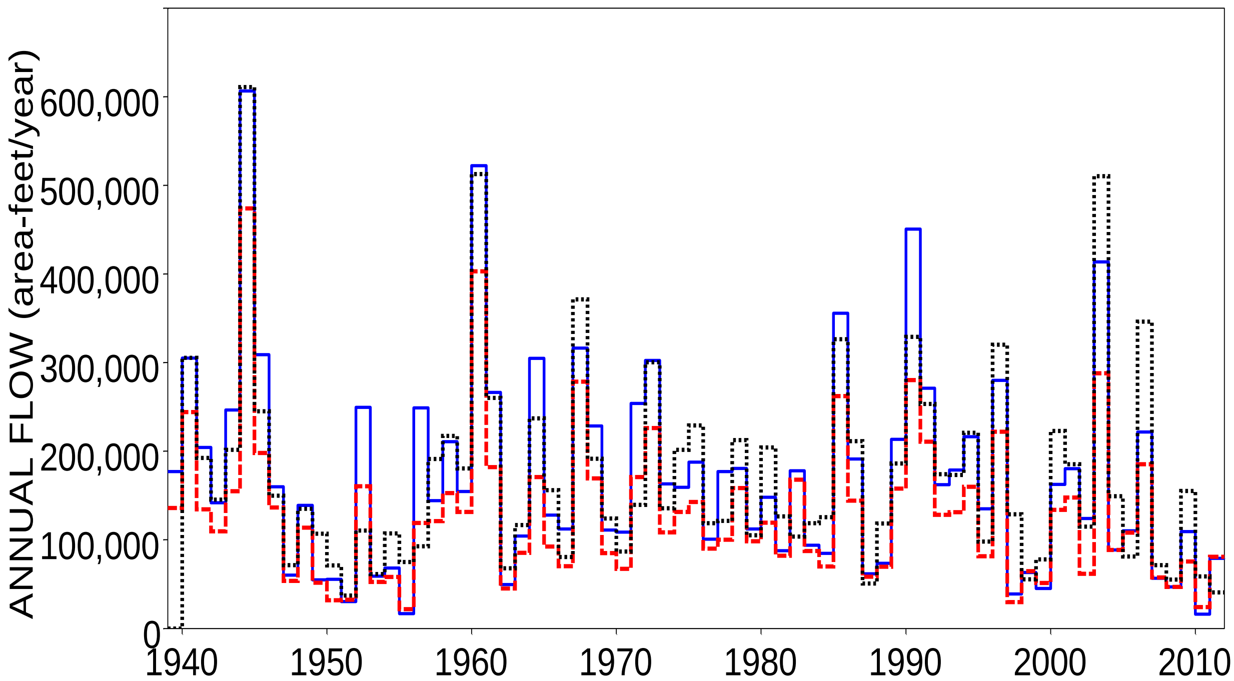
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Navasota River at Easterly



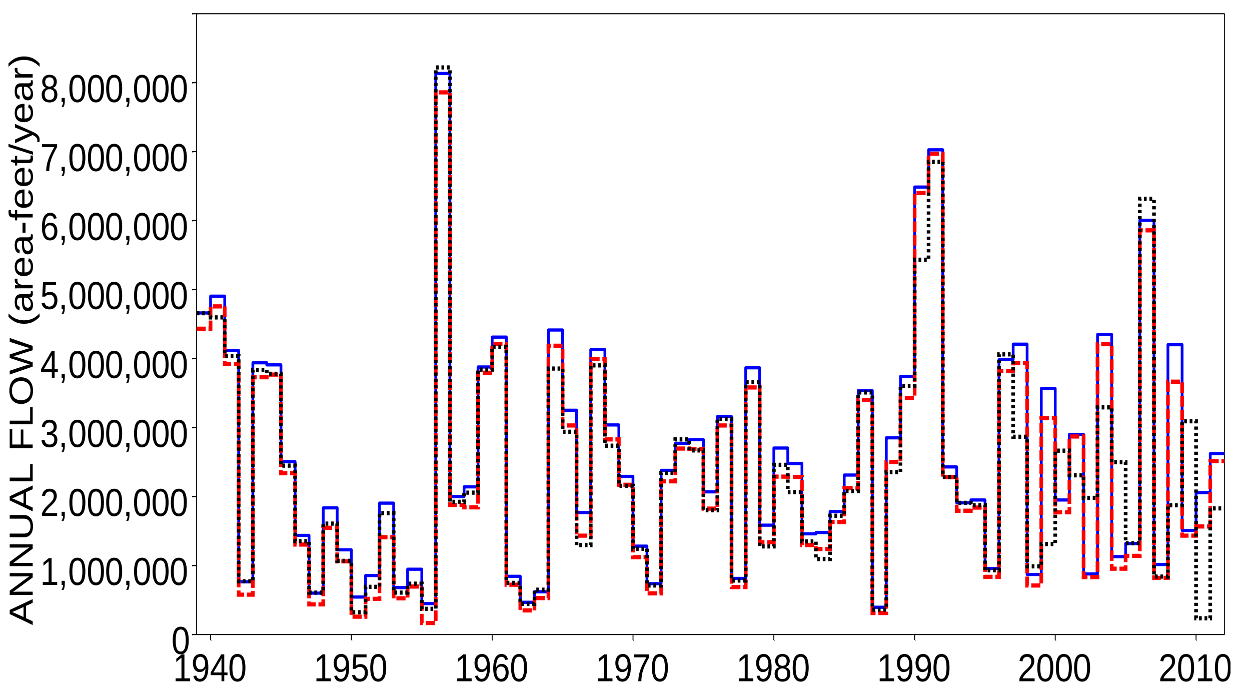
Naturalized Flows of Brazos River at Richmond



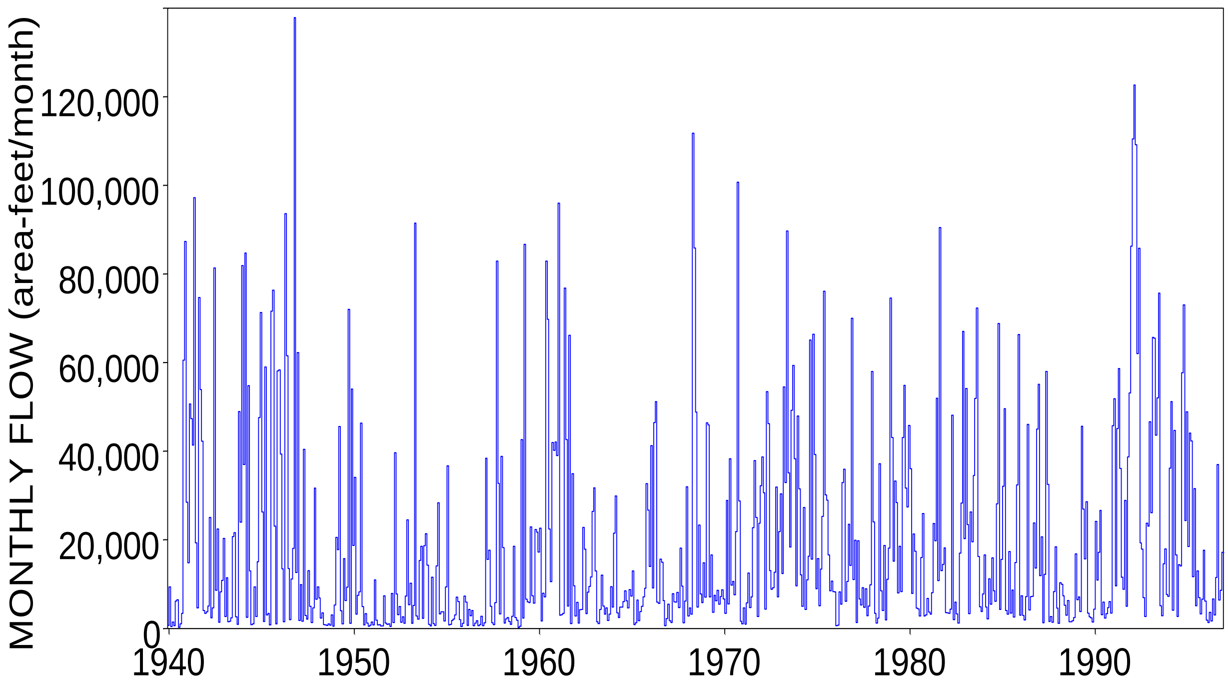
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Brazos River at Richmond



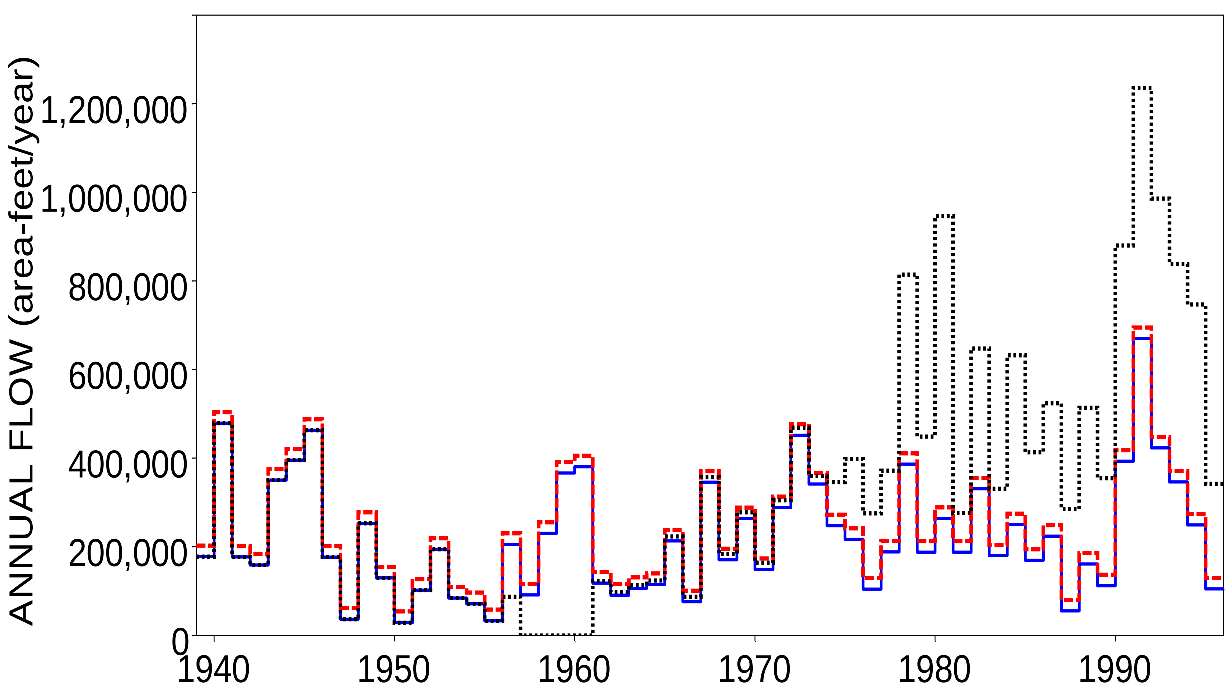
Naturalized (blue solid) and regulated (red dashed) Observed (black dotted) 2-Month Minimum Annual Flows for Brazos River at Richmond



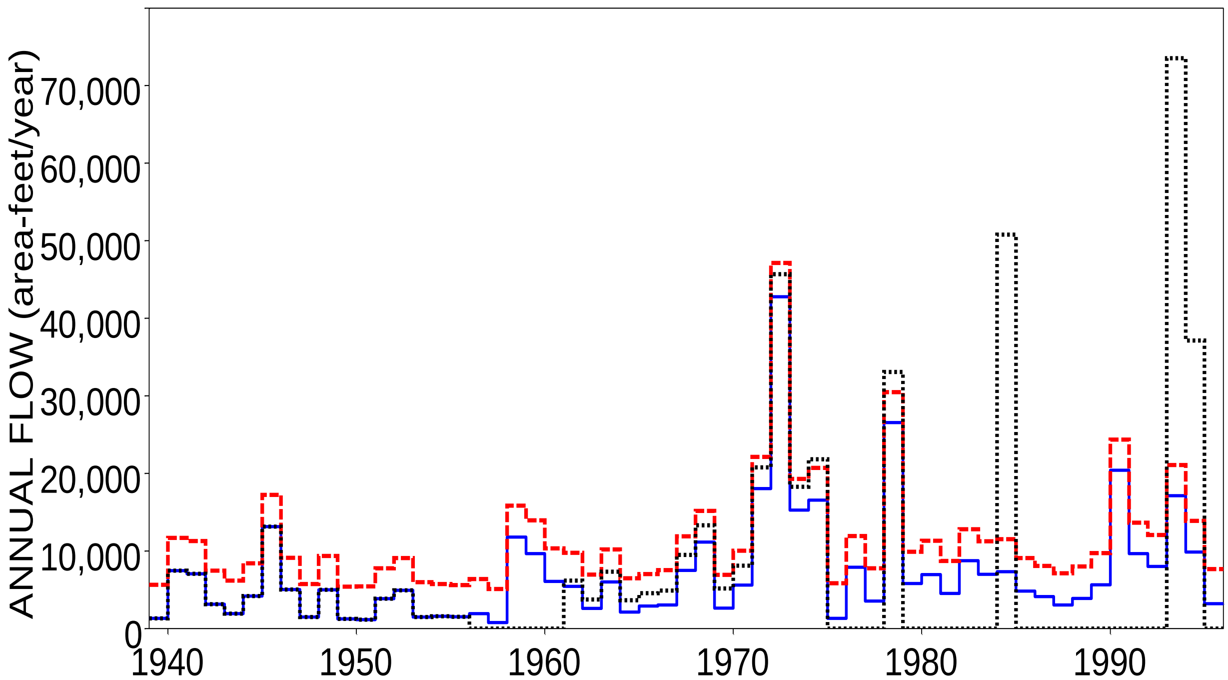
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Brazos River at Richmond



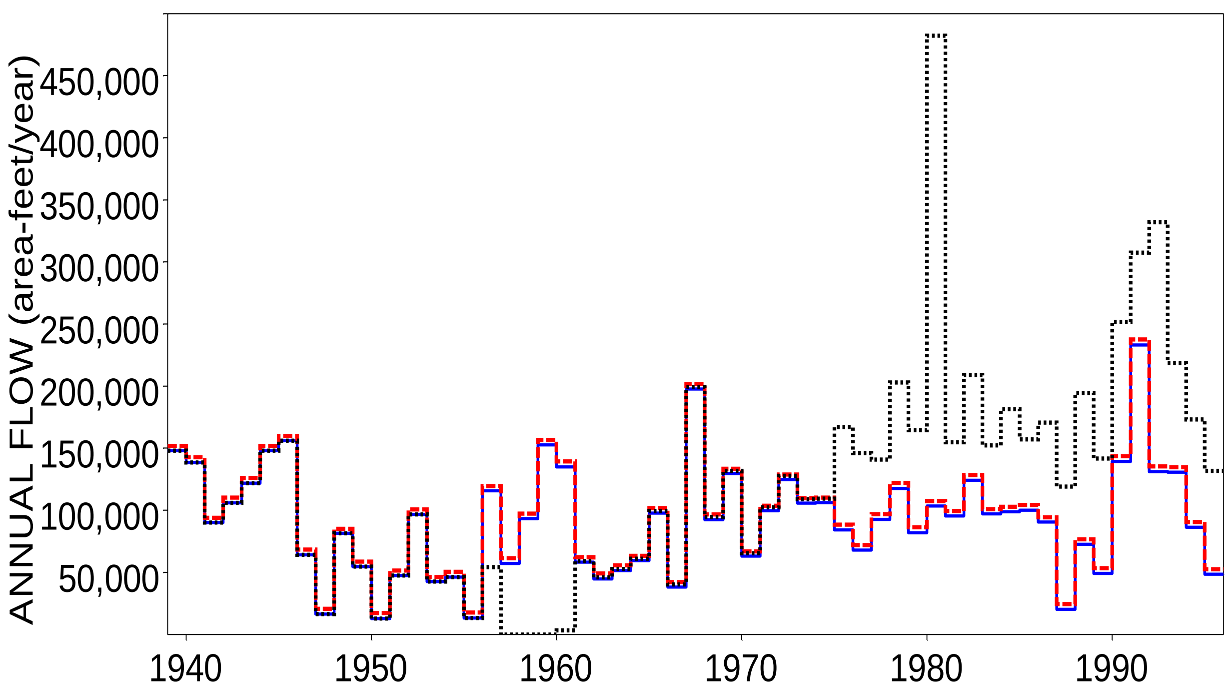
Naturalized Flows of Buffalo Bayou in Houston



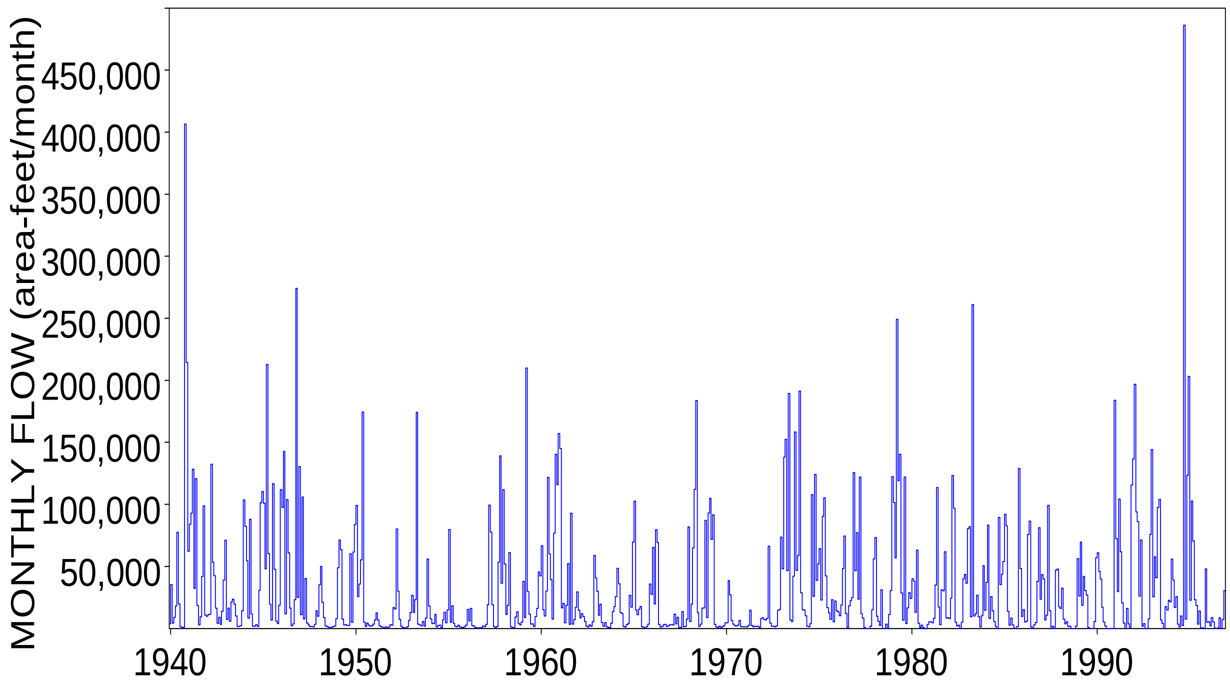
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Buffalo Bayou in Houston



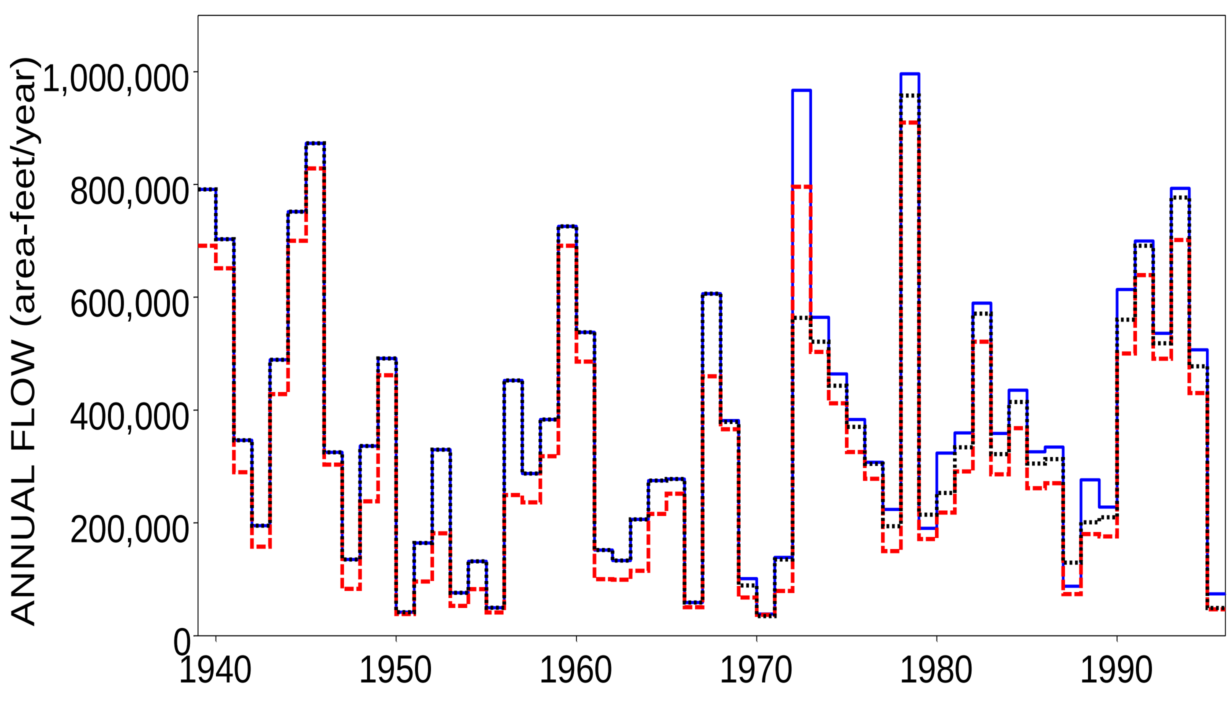
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Buffalo Bayou in Houston



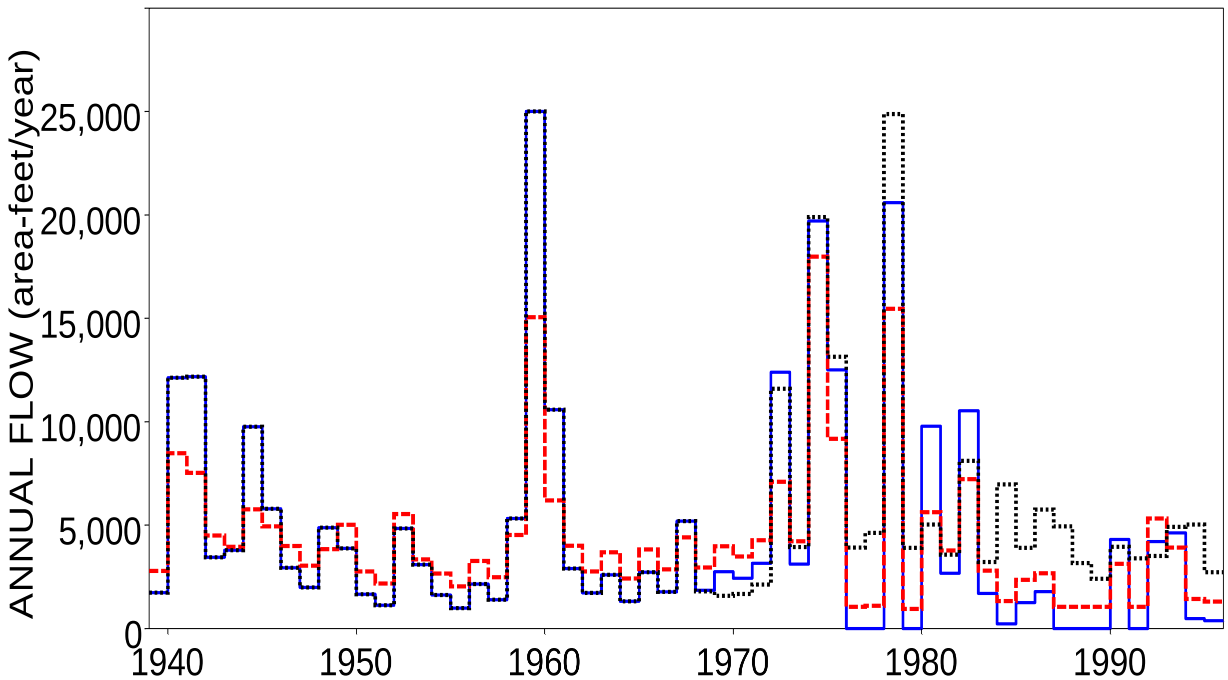
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Buffalo Bayou in Houston



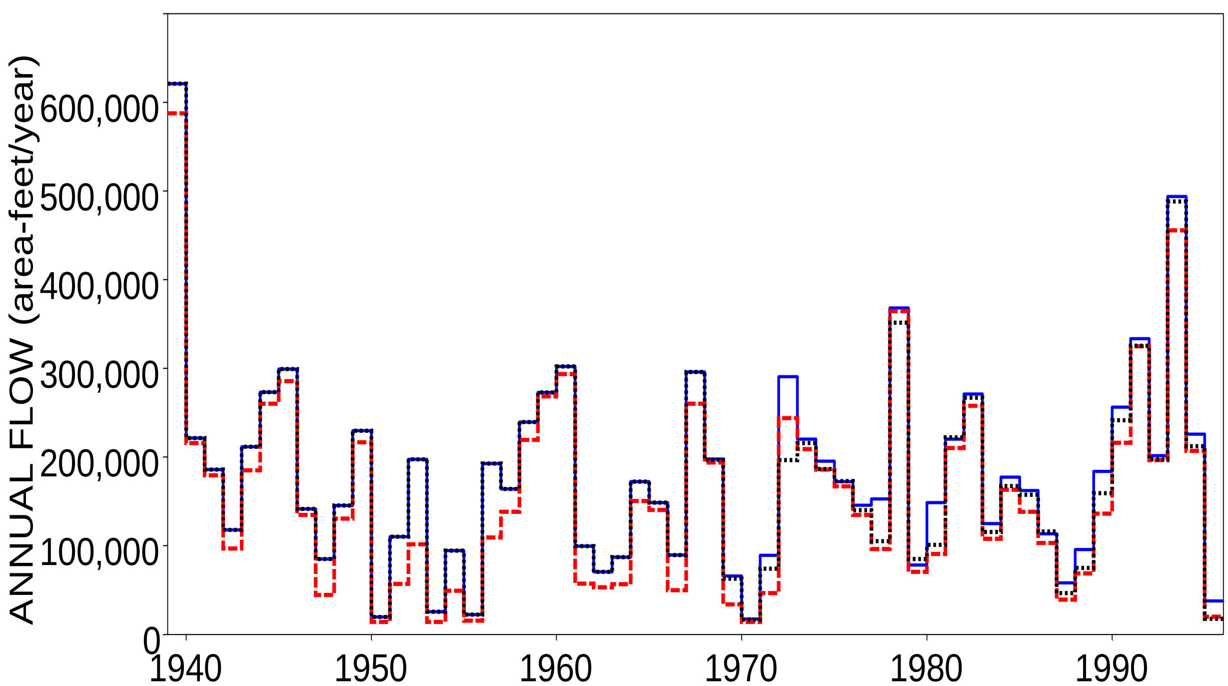
Naturalized Flows of West Fork San Jacinto near Conroe



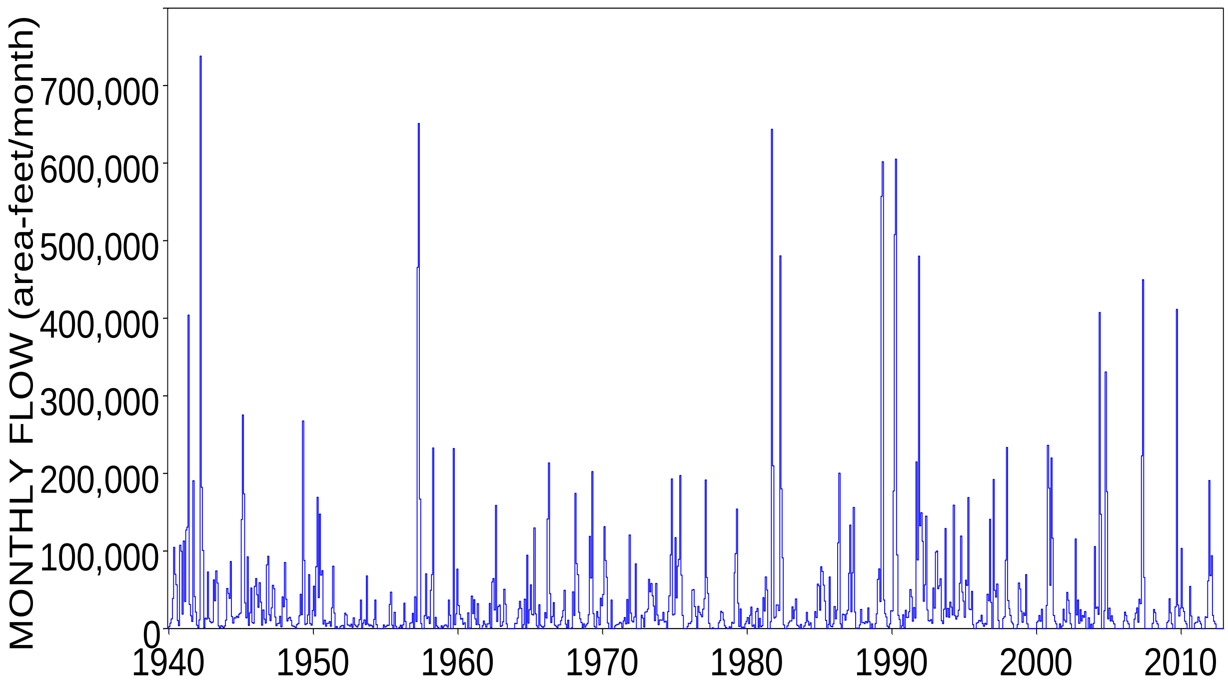
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for West Fork San Jacinto near Conroe



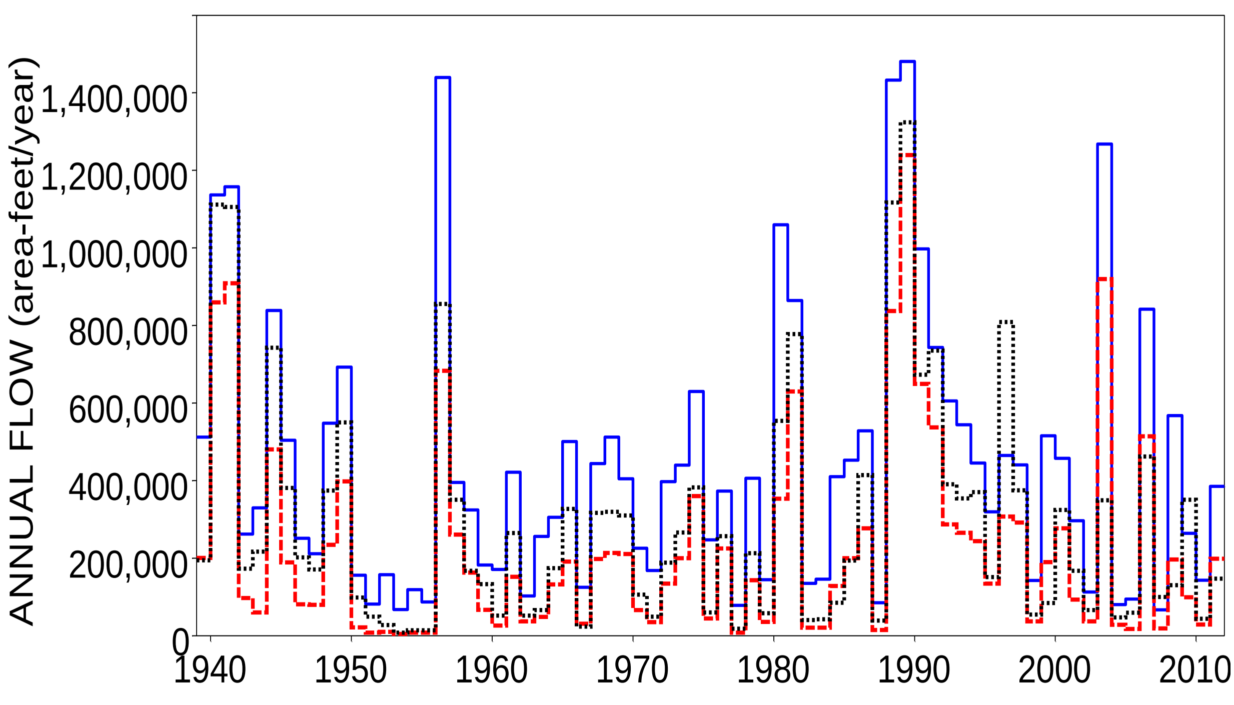
Naturalized (blue solid) and regulated (red dashed) Observed (black dotted) 2-Month Minimum Annual Flows for West Fork San Jacinto near Conroe



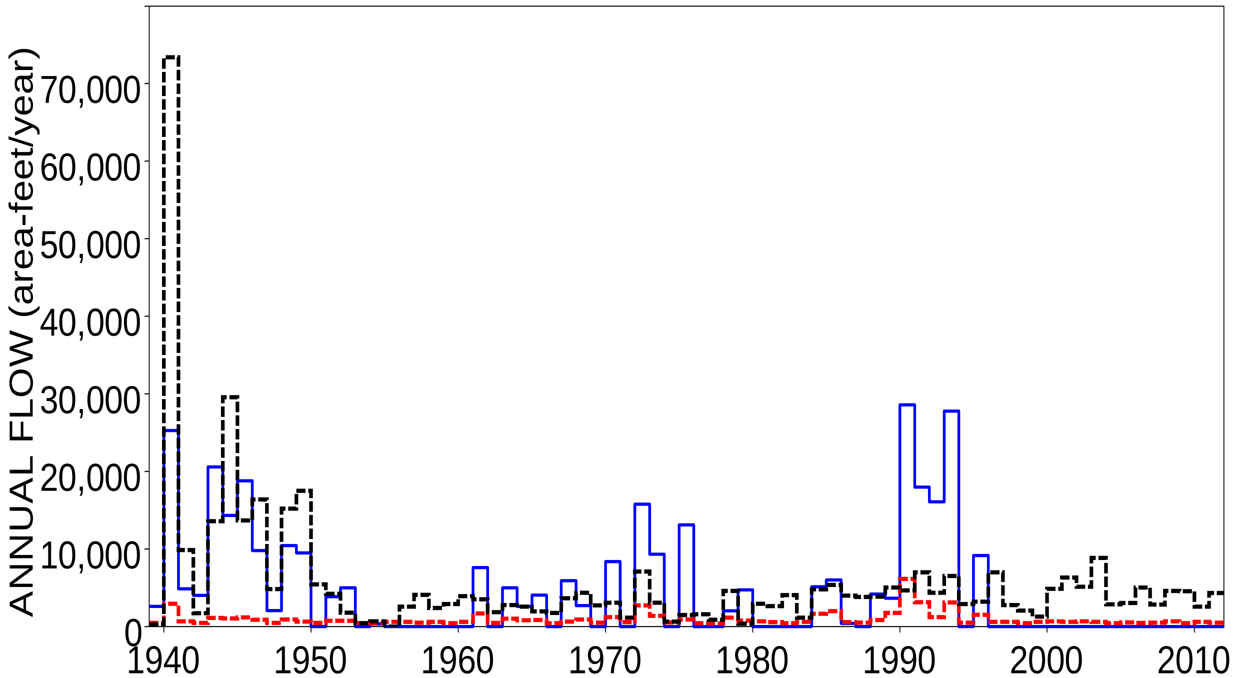
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for West Fork San Jacinto near Conroe



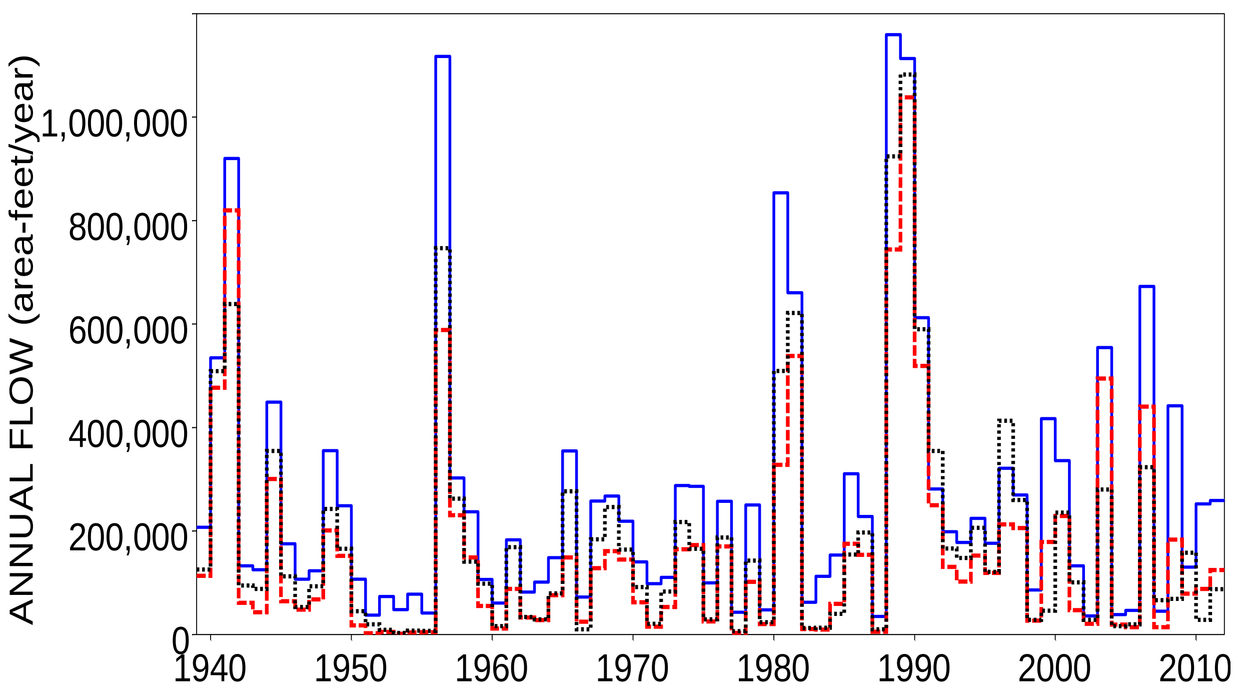
Naturalized Flows of West Fork Trinity at Fort Worth



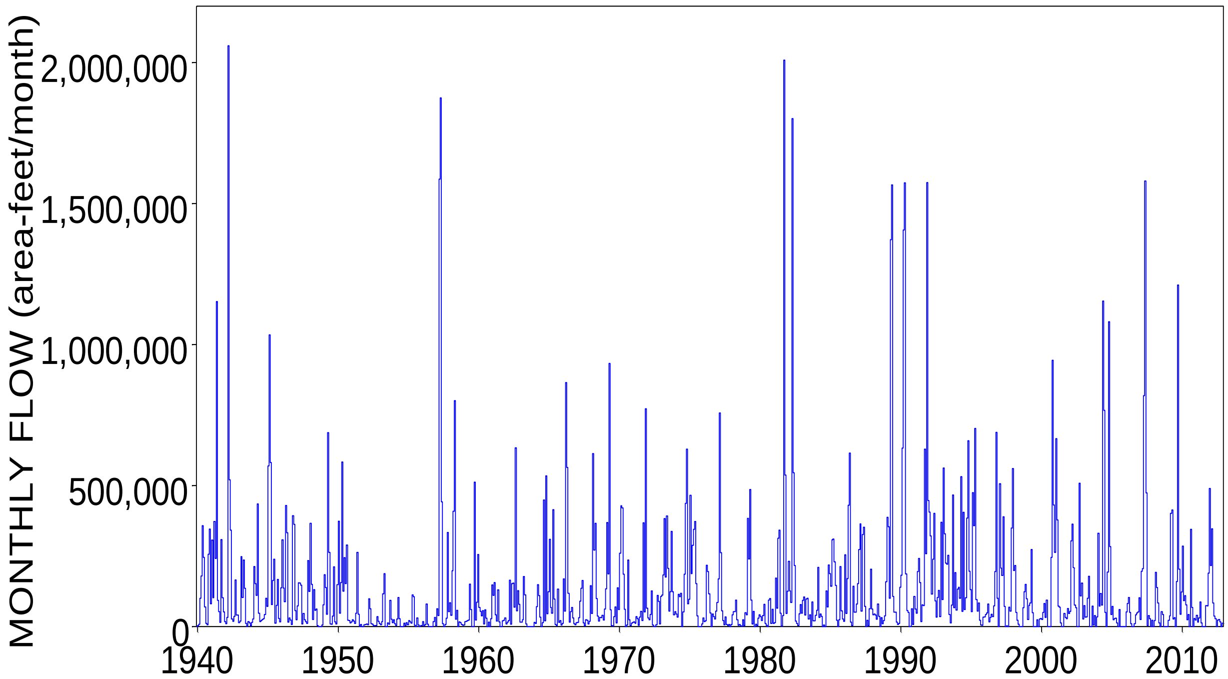
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for West Fork Trinity at Fort Worth



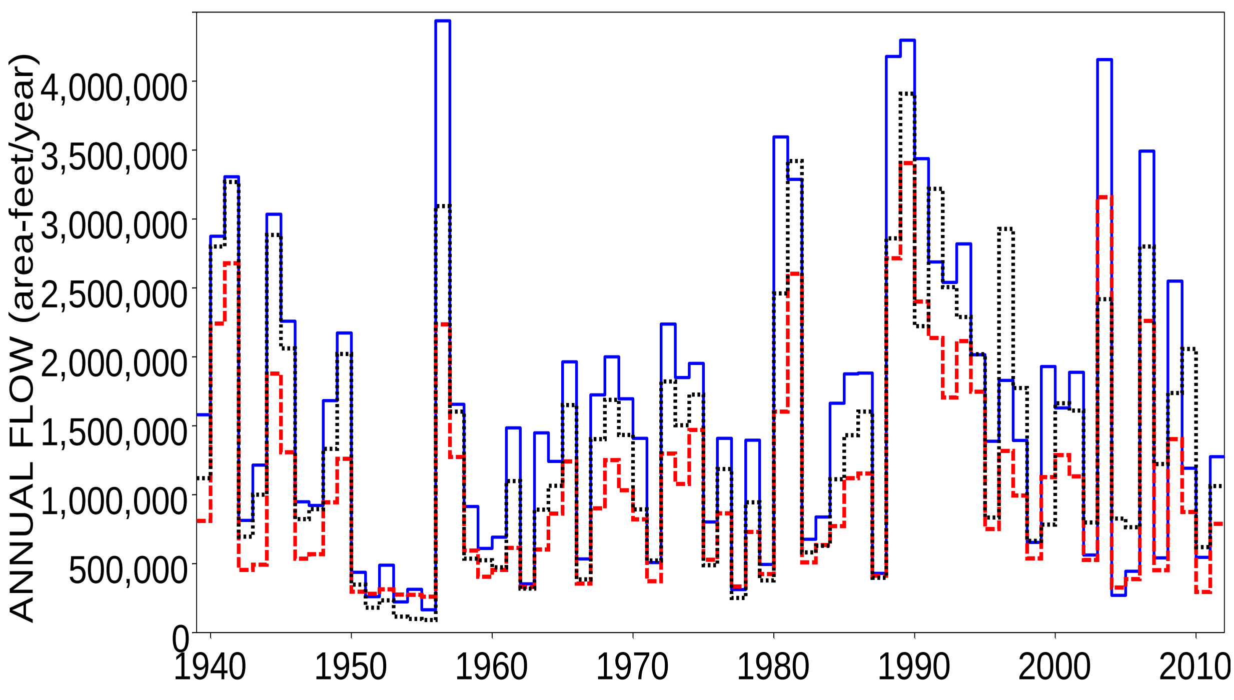
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for West Fork Trinity at Fort Worth



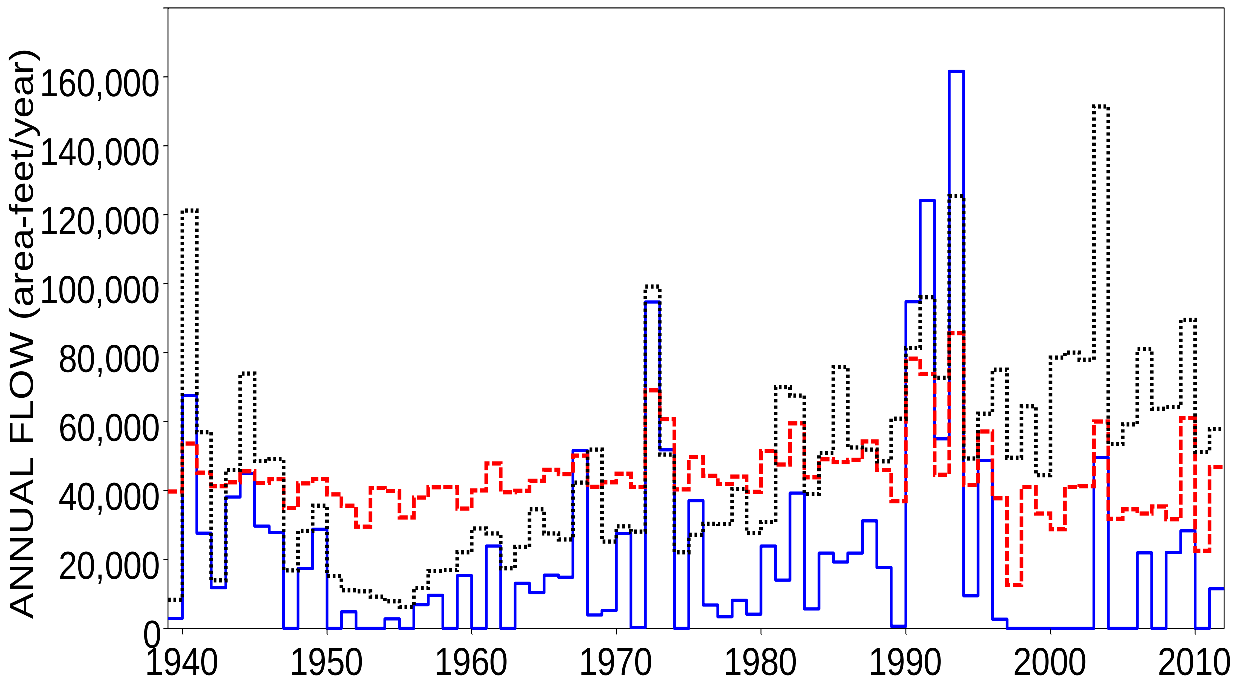
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for West Fork Trinity at Fort Worth



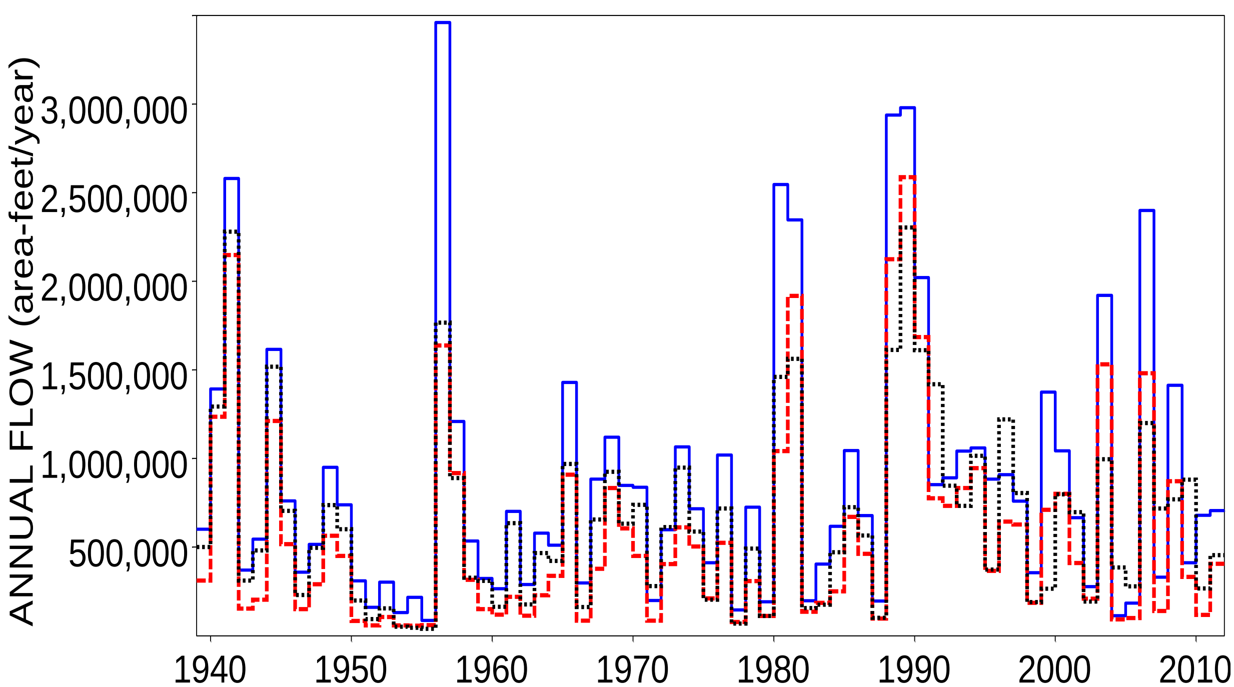
Naturalized Flows of Trinity River at Dallas



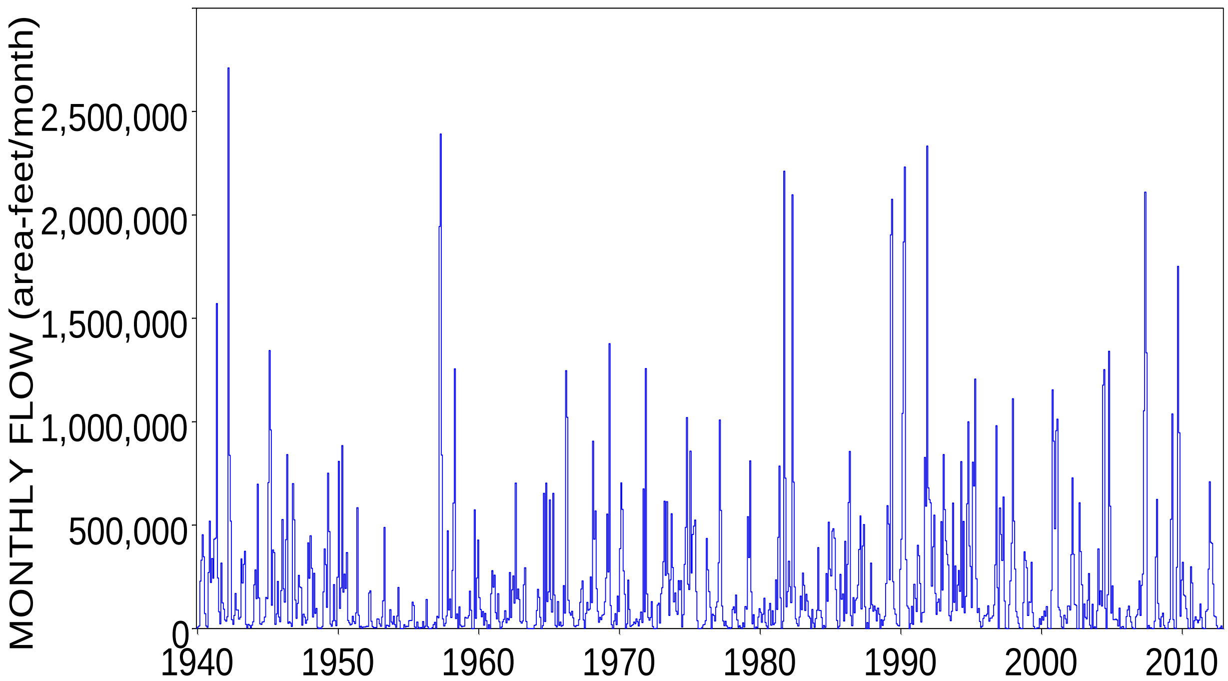
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Trinity River at Dallas



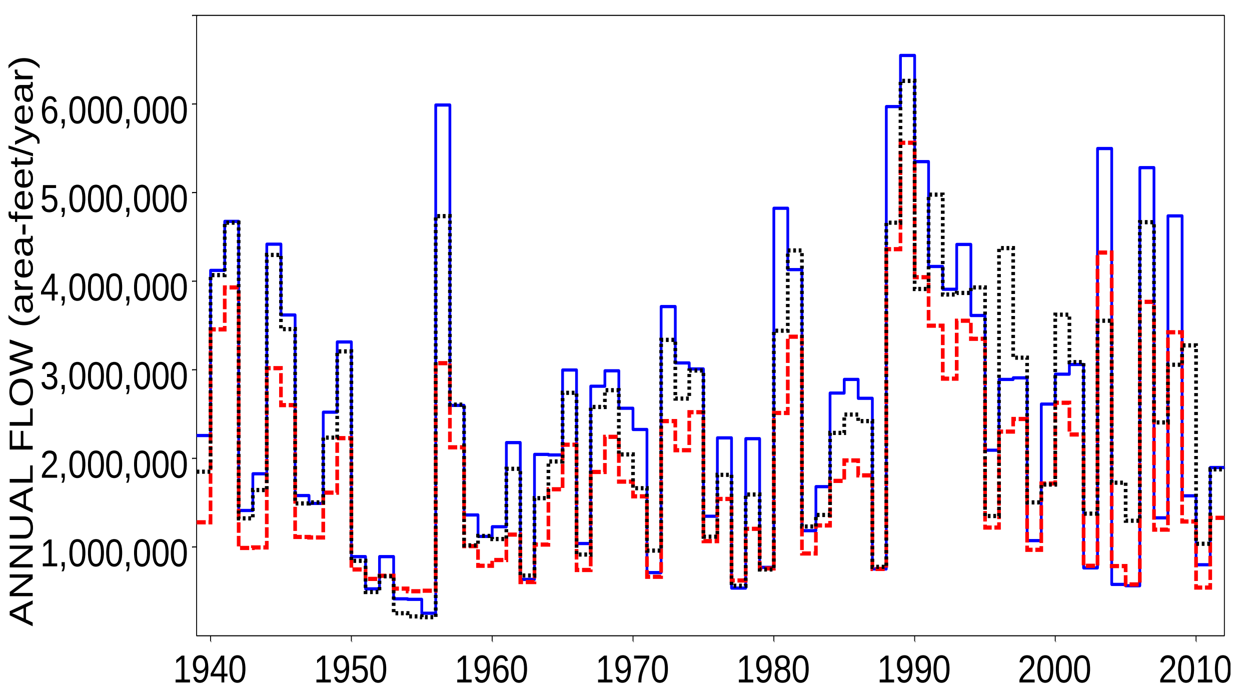
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Trinity River at Dallas



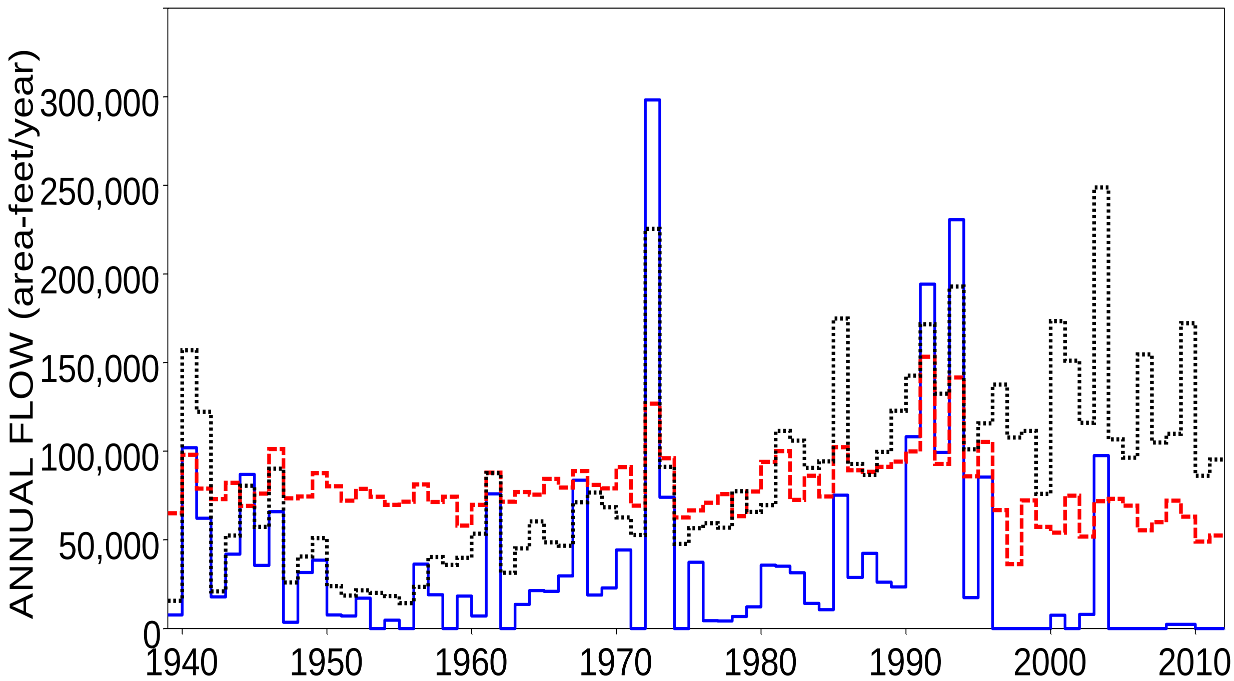
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Trinity River at Dallas



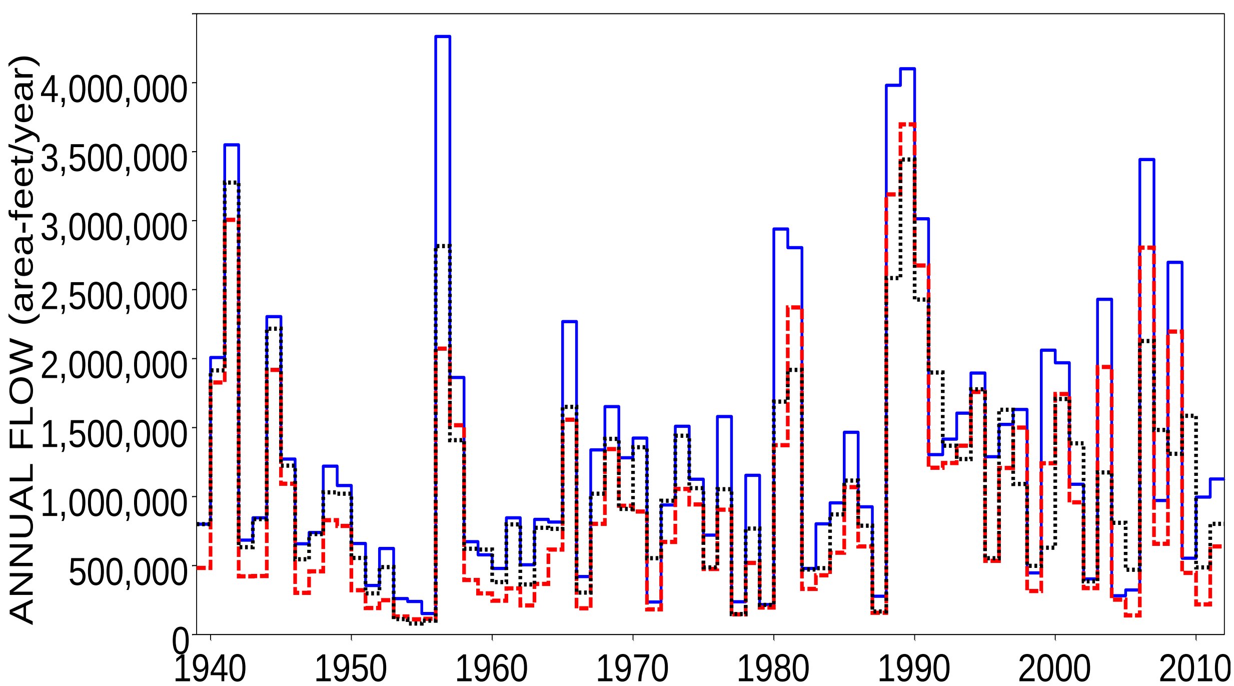
Naturalized Flows of Trinity River near Rosser



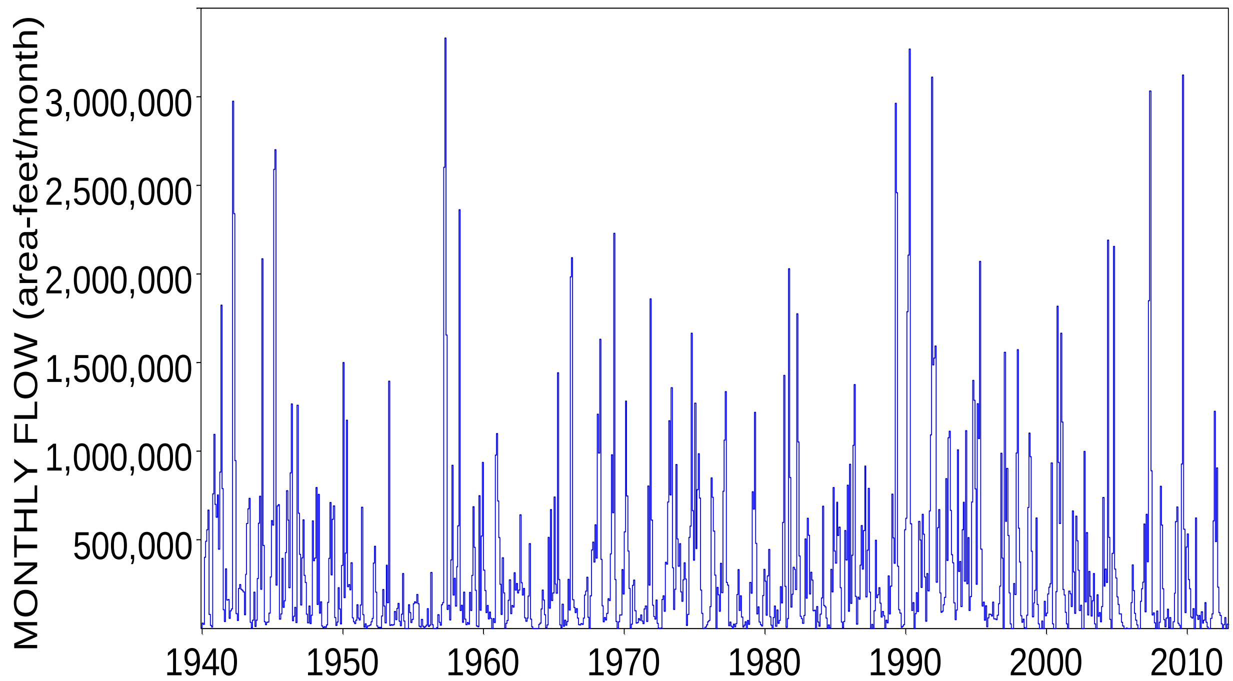
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Trinity River near Rosser



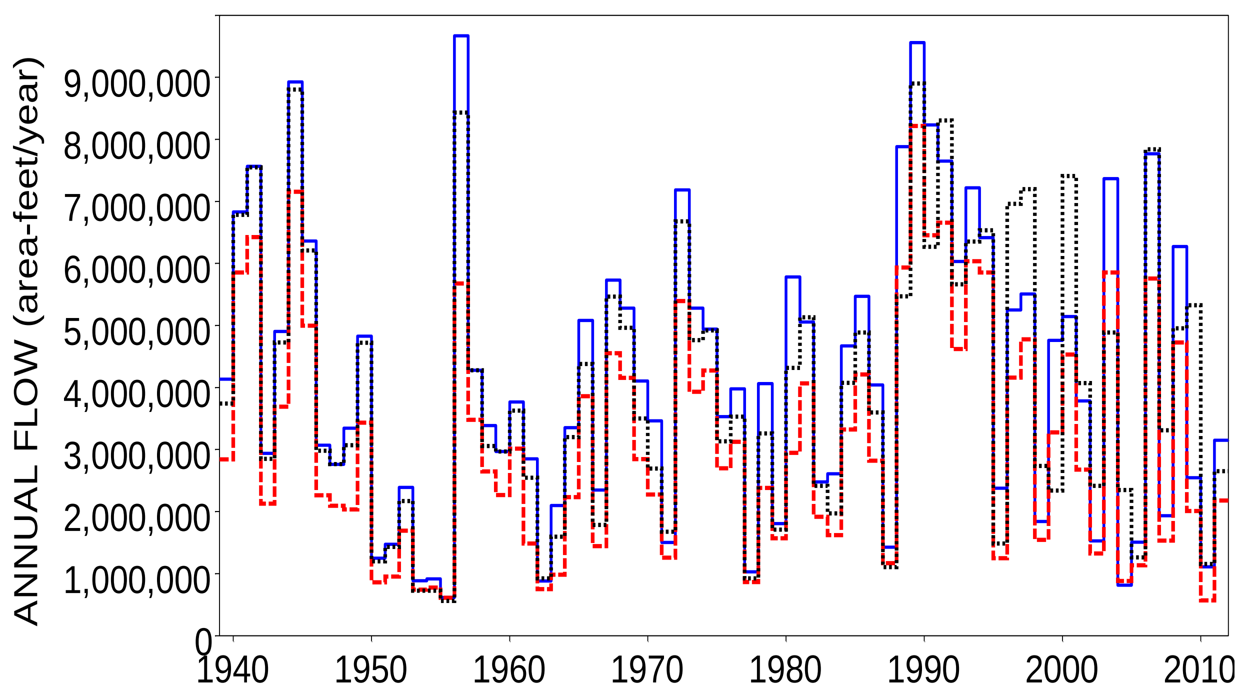
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Trinity River near Rosser



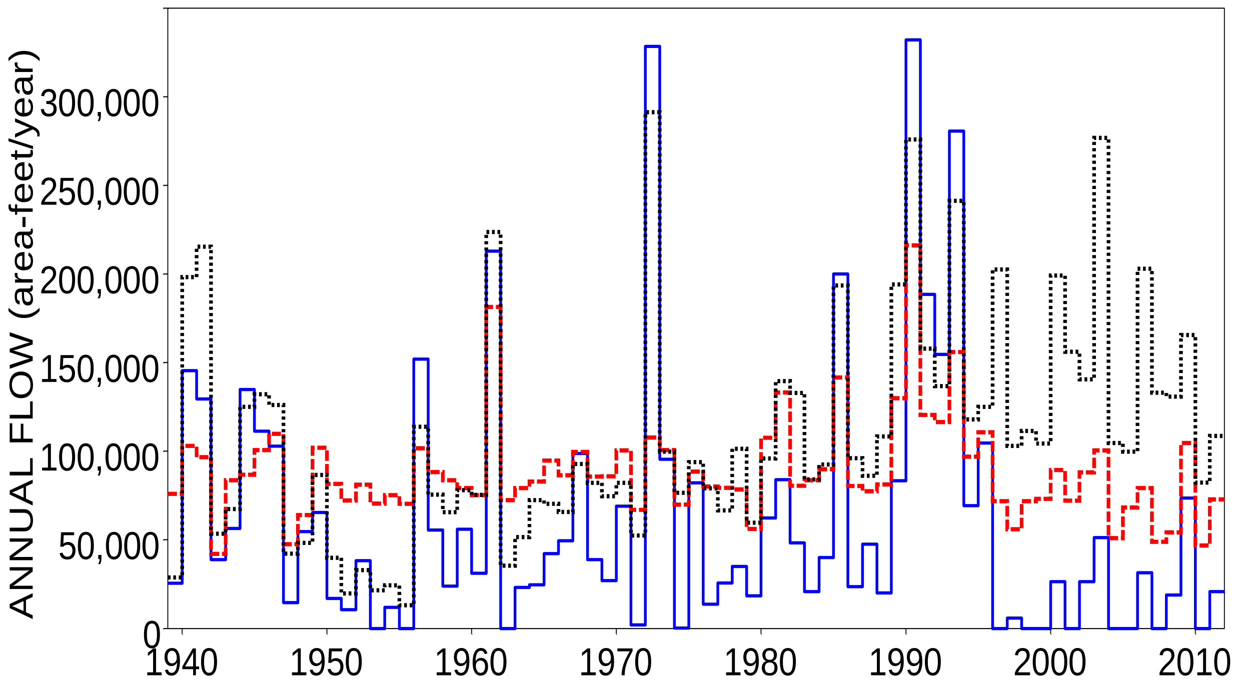
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Trinity River near Rosser



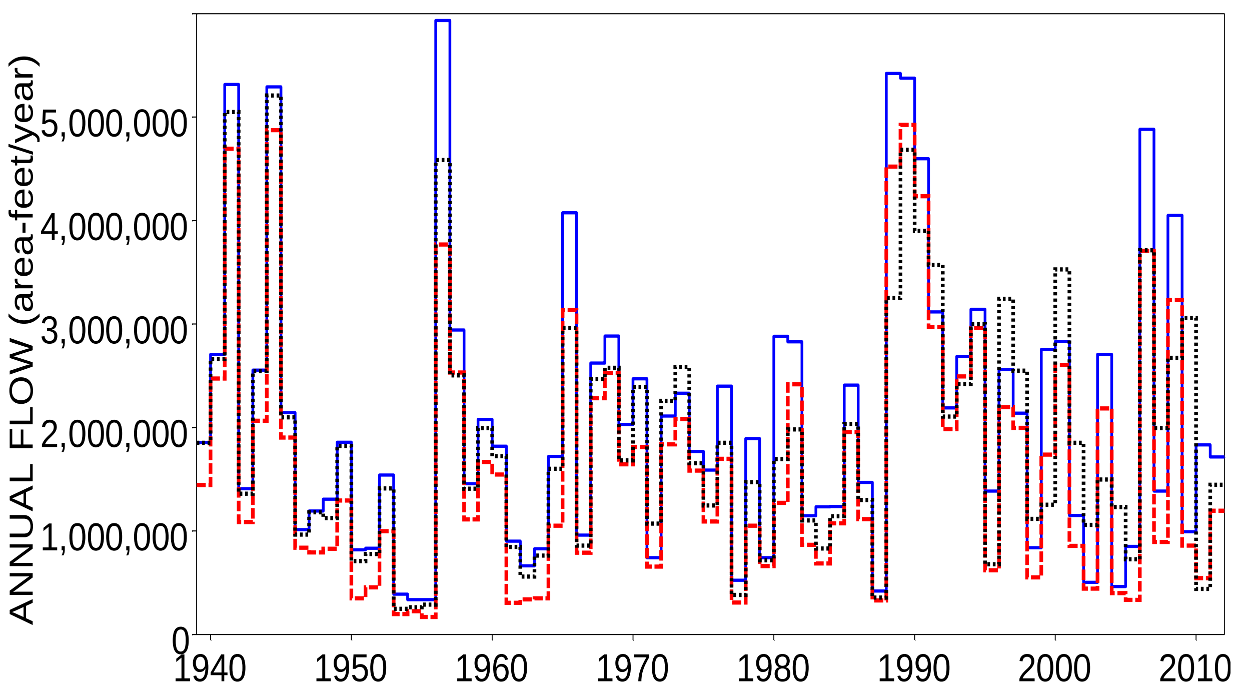
Naturalized Flows of Trinity River near Oakwood



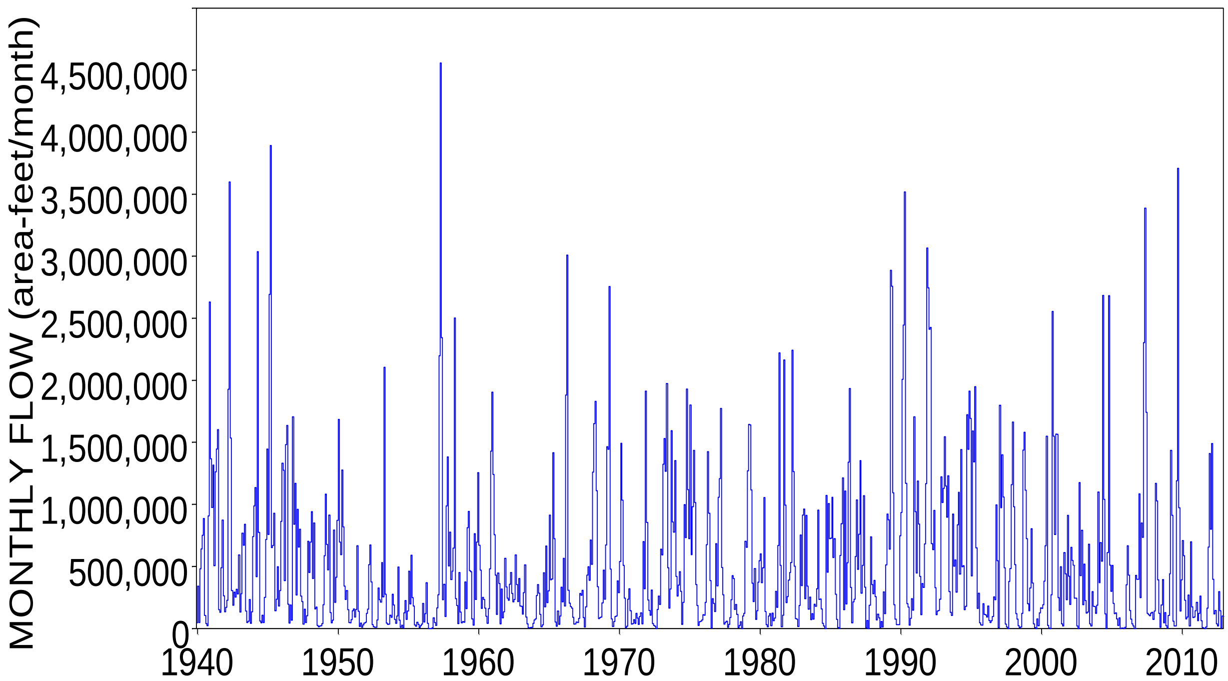
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Trinity River near Oakwood



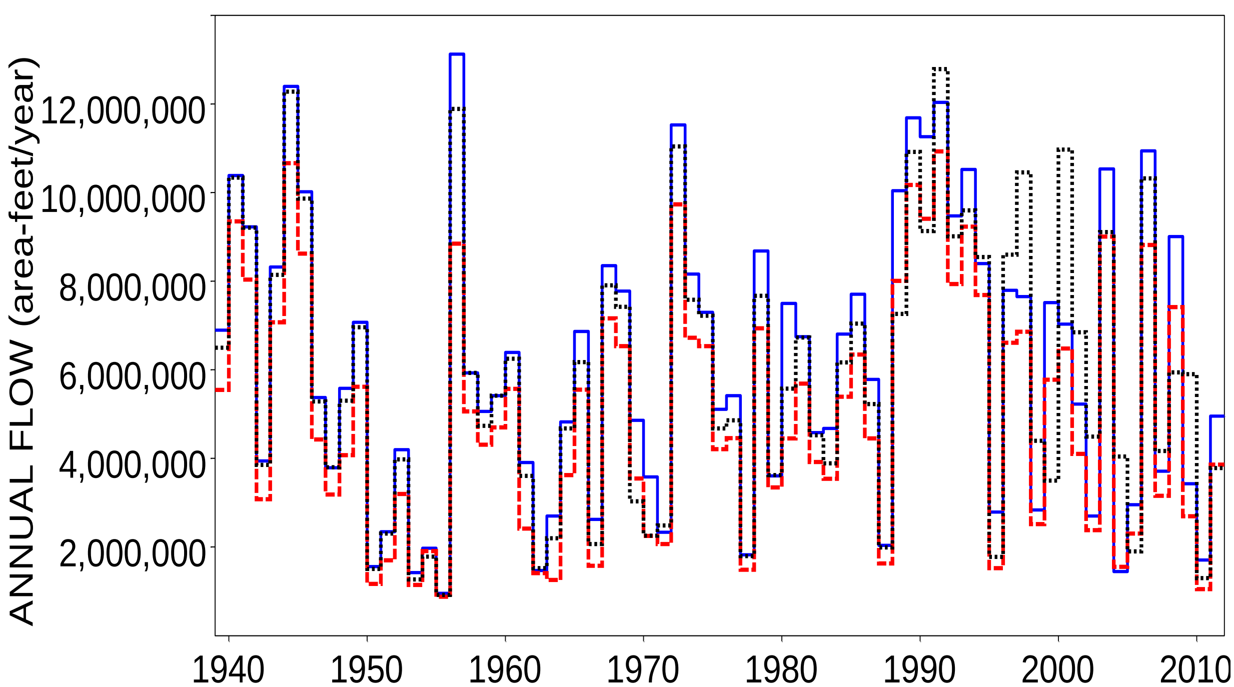
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Trinity River near Oakwood



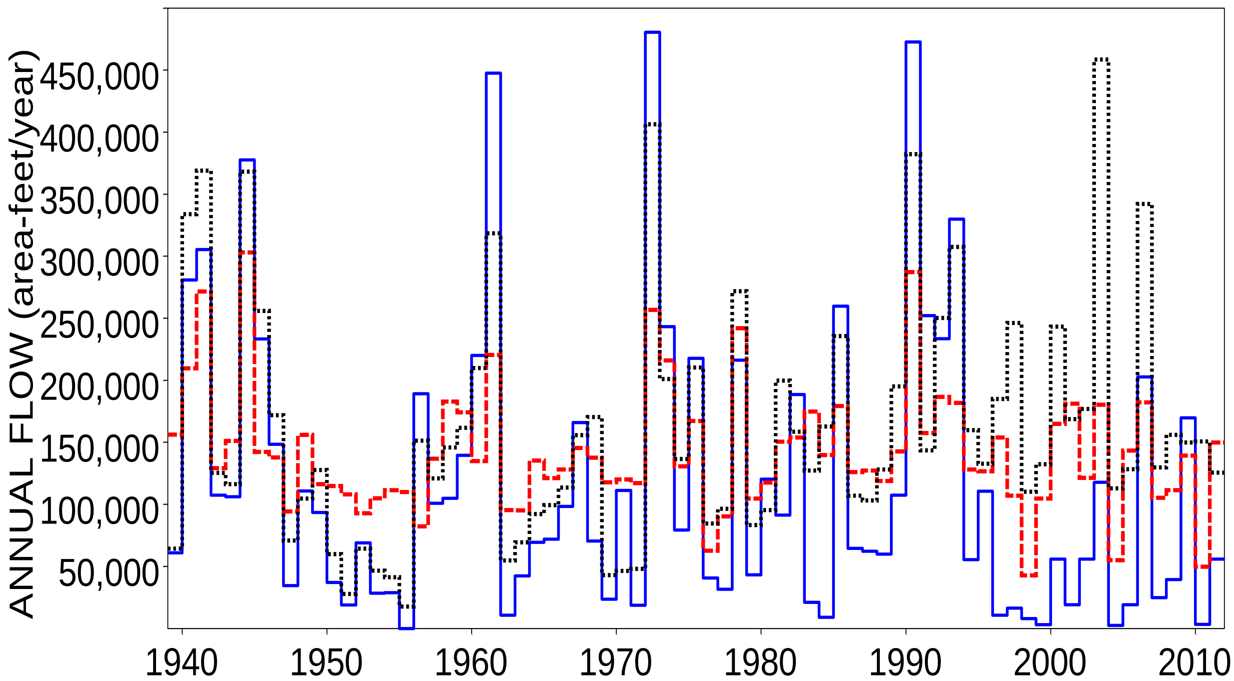
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Trinity River near Oakwood



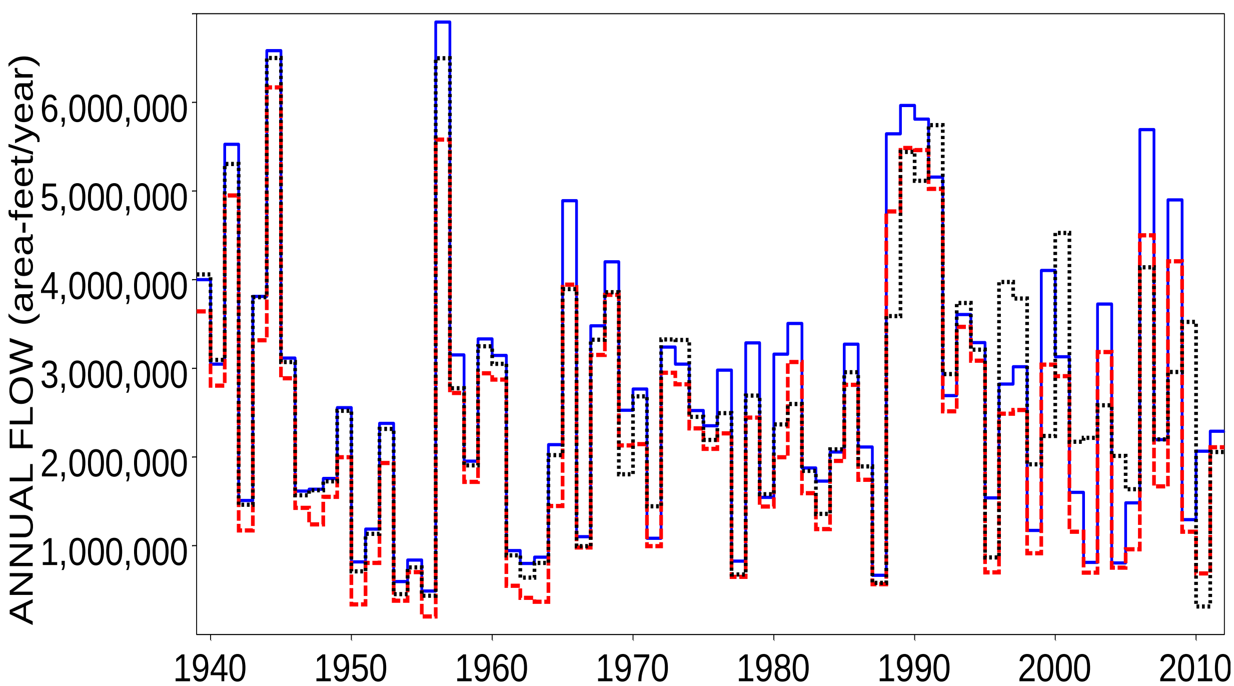
Naturalized Flows of Trinity River at Romayor



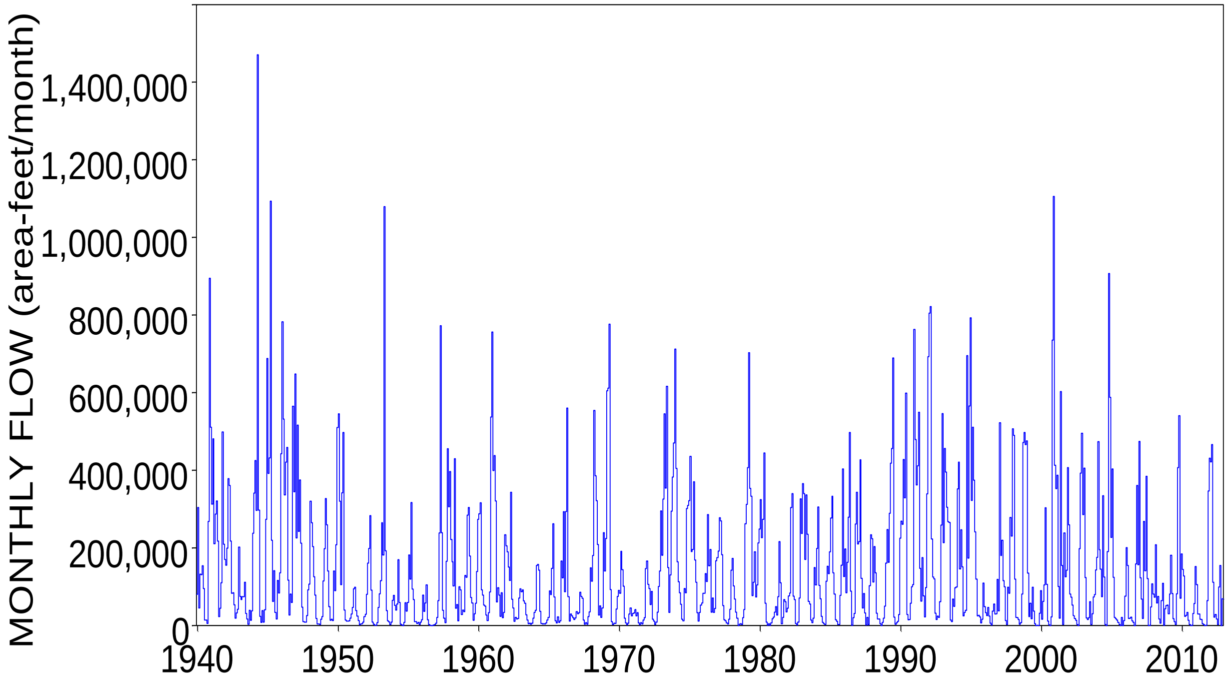
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Trinity River at Romayor



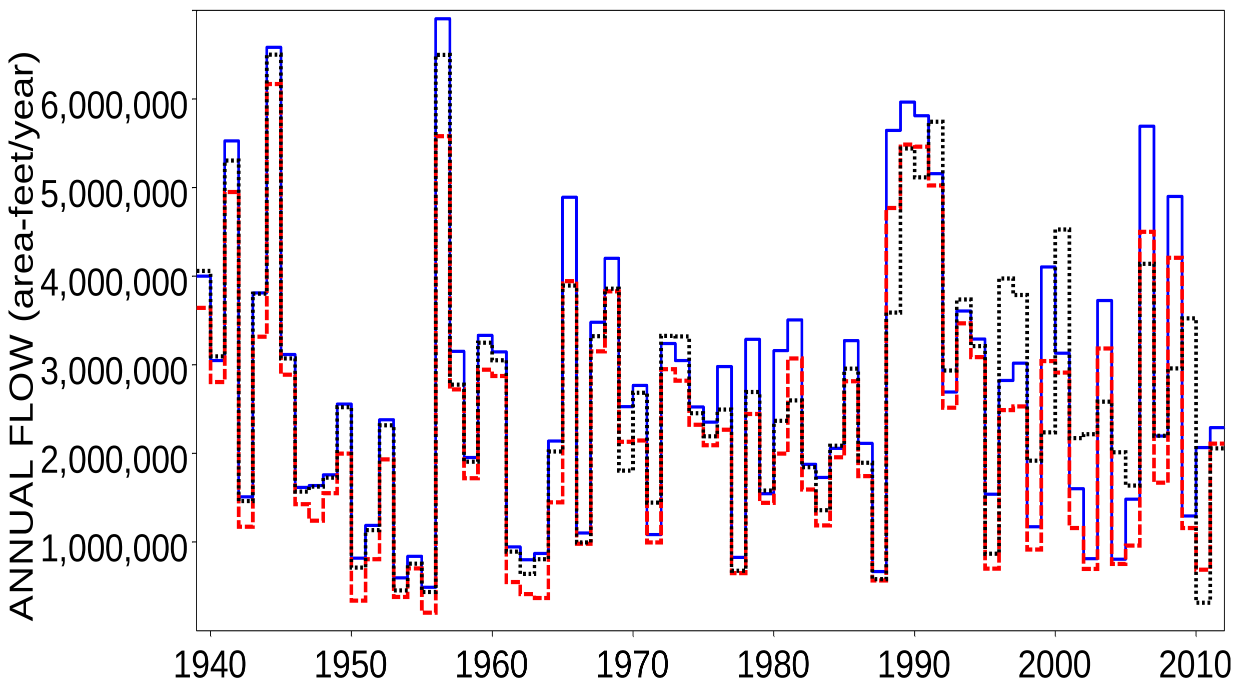
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Trinity River at Romayor



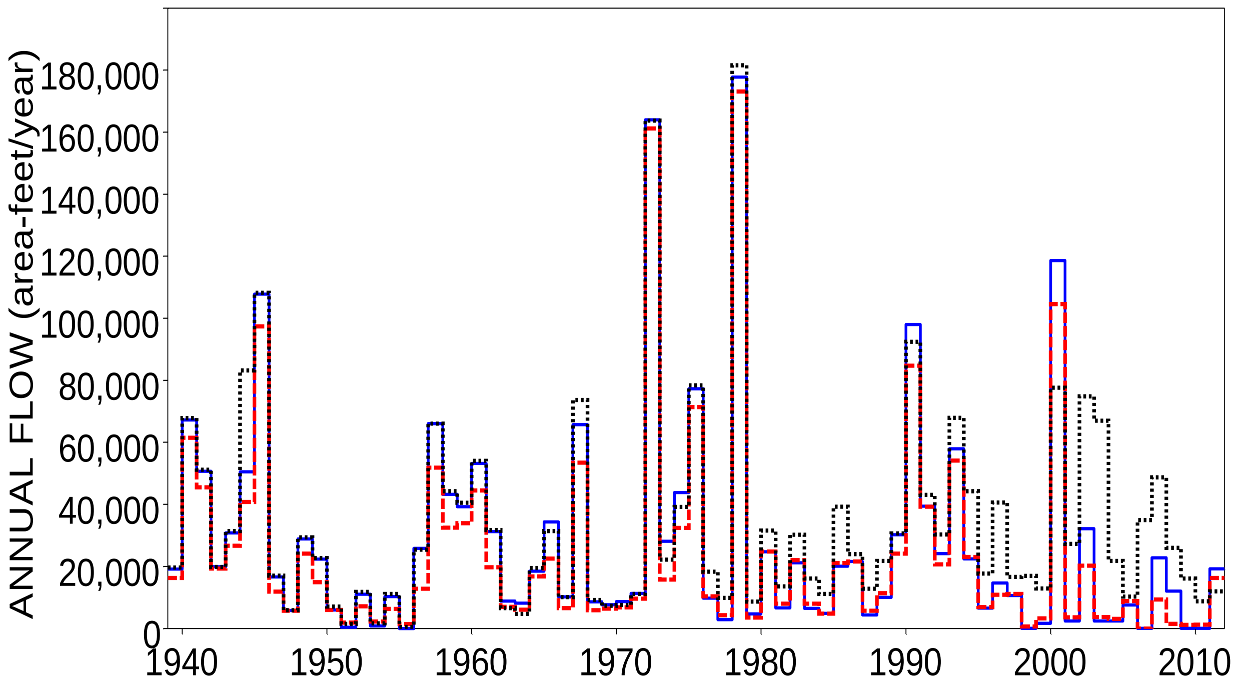
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Trinity River at Romayor



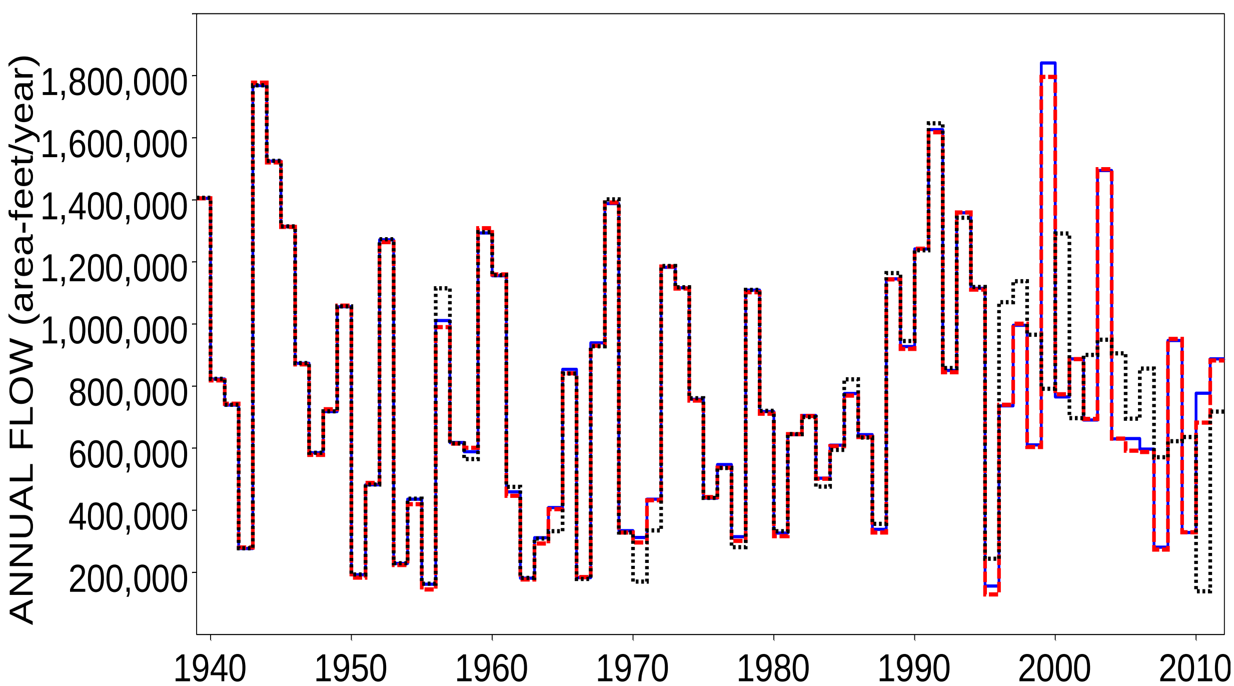
Naturalized Flows of Neches River near Rockland



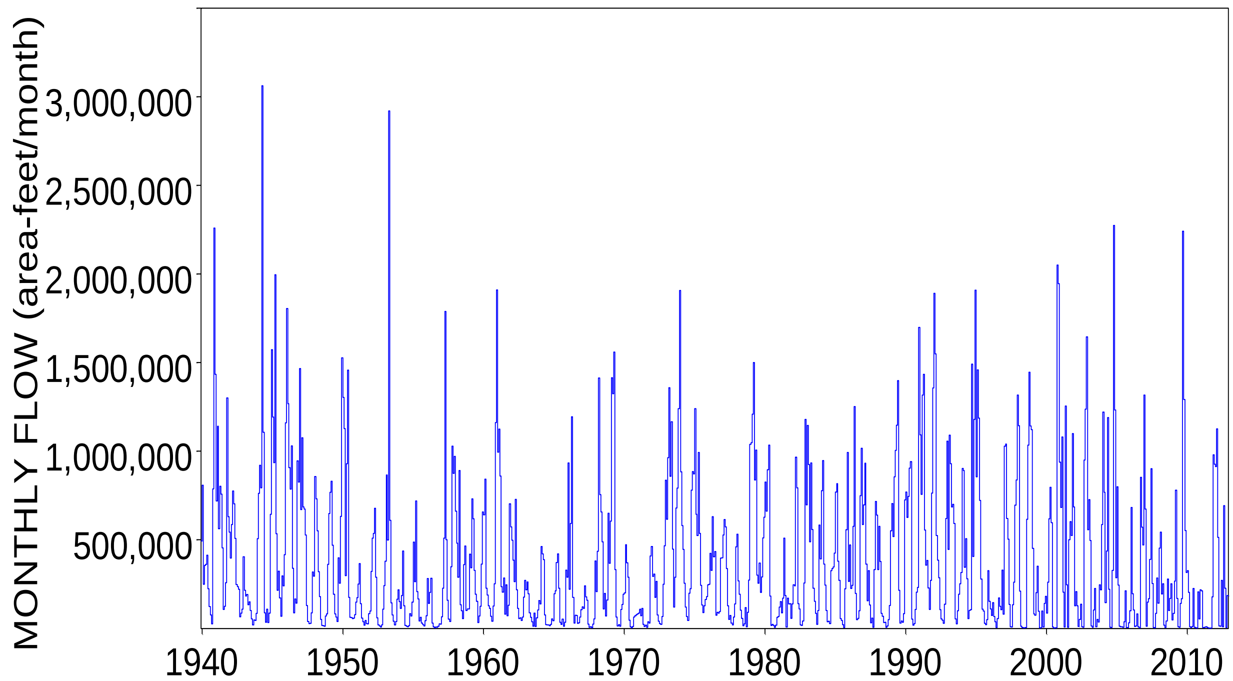
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Neches River near Rockland



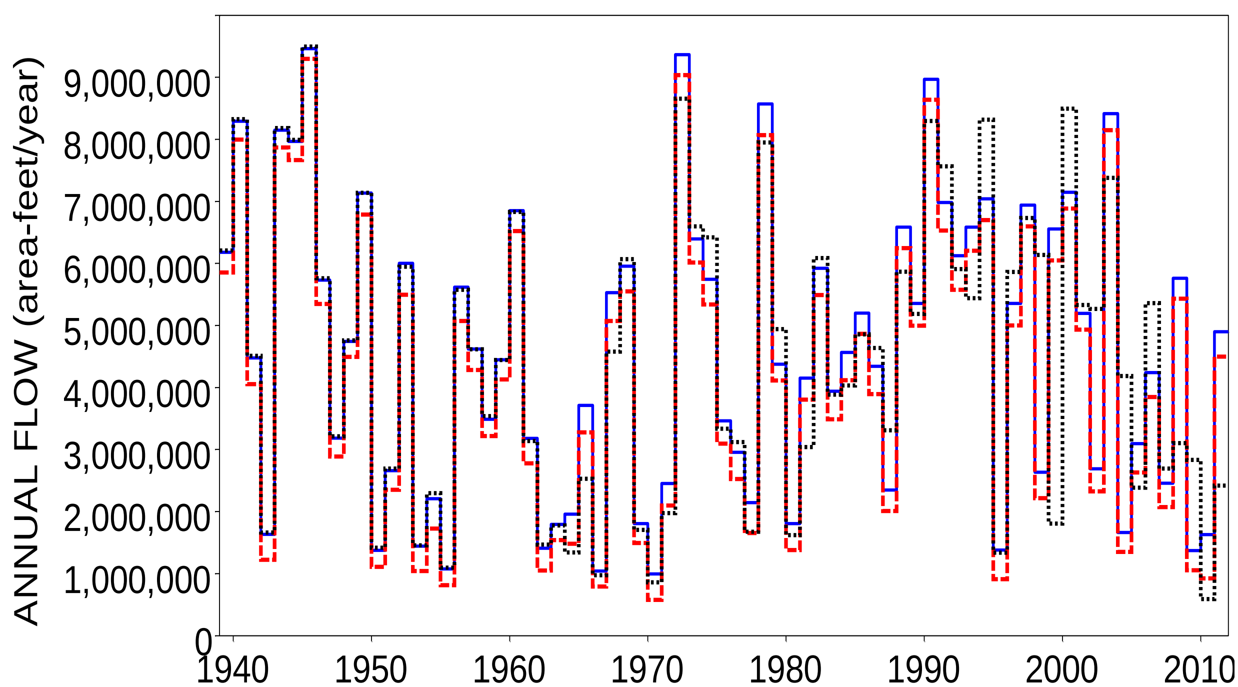
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Neches River near Rockland



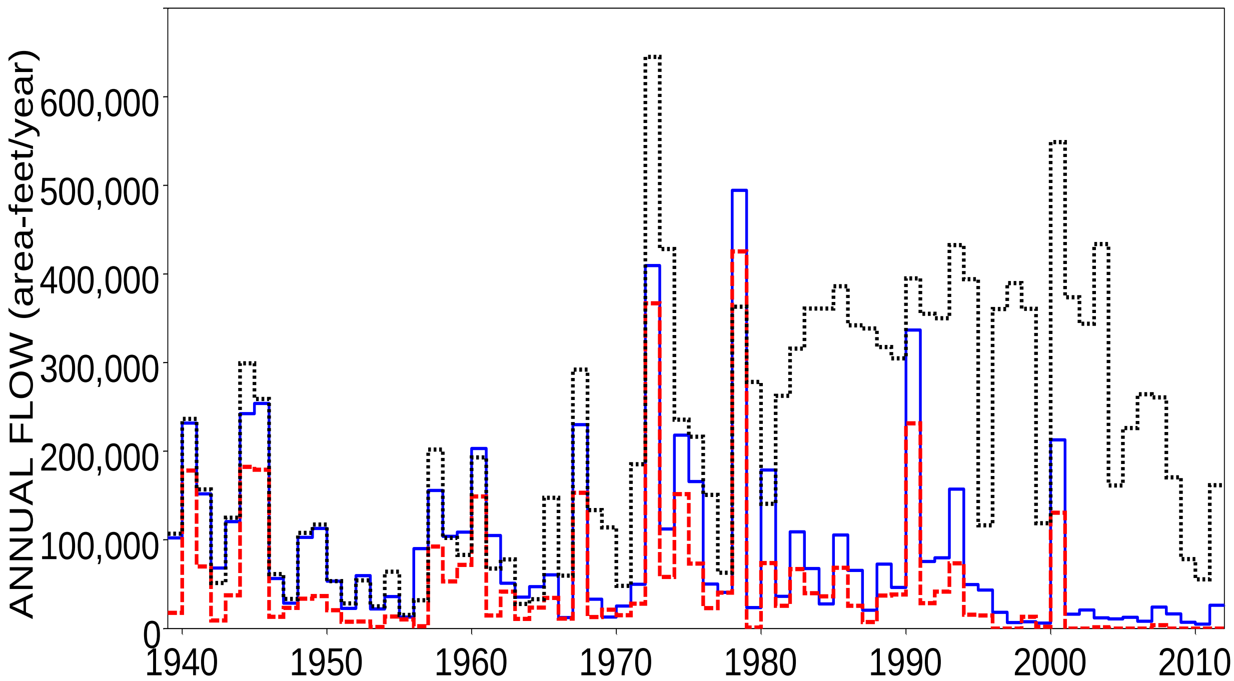
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Neches River near Rockland



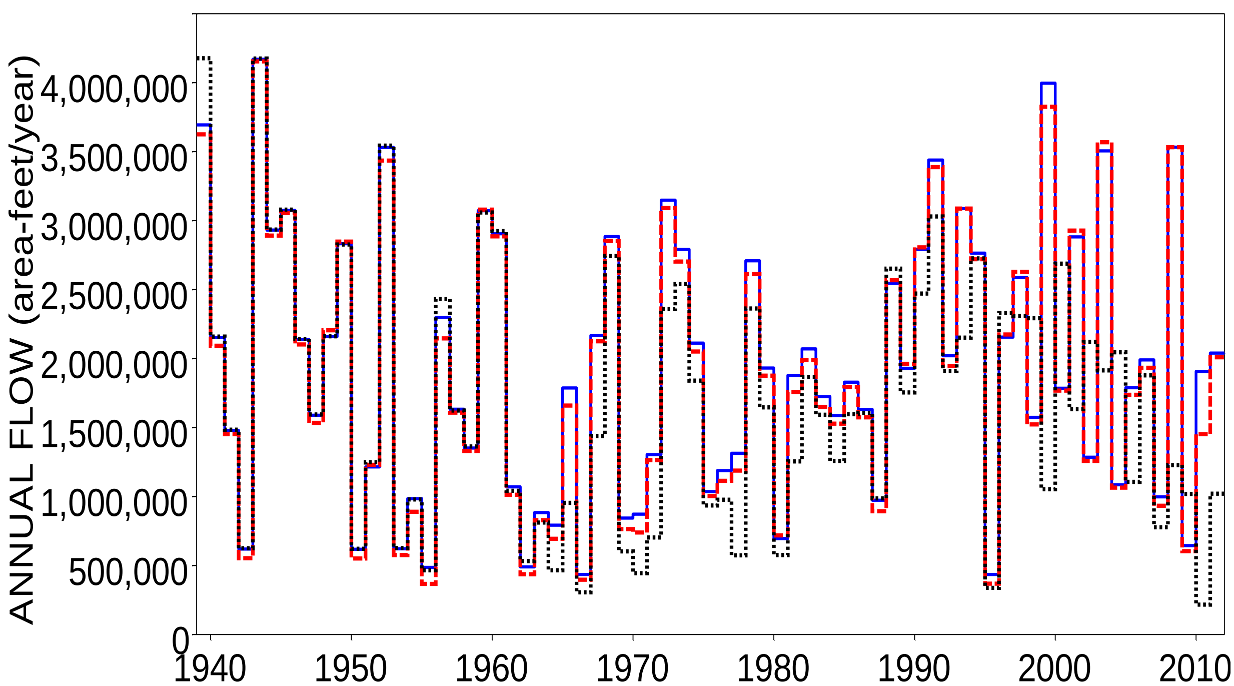
Naturalized Flows of Neches River near Evansdale



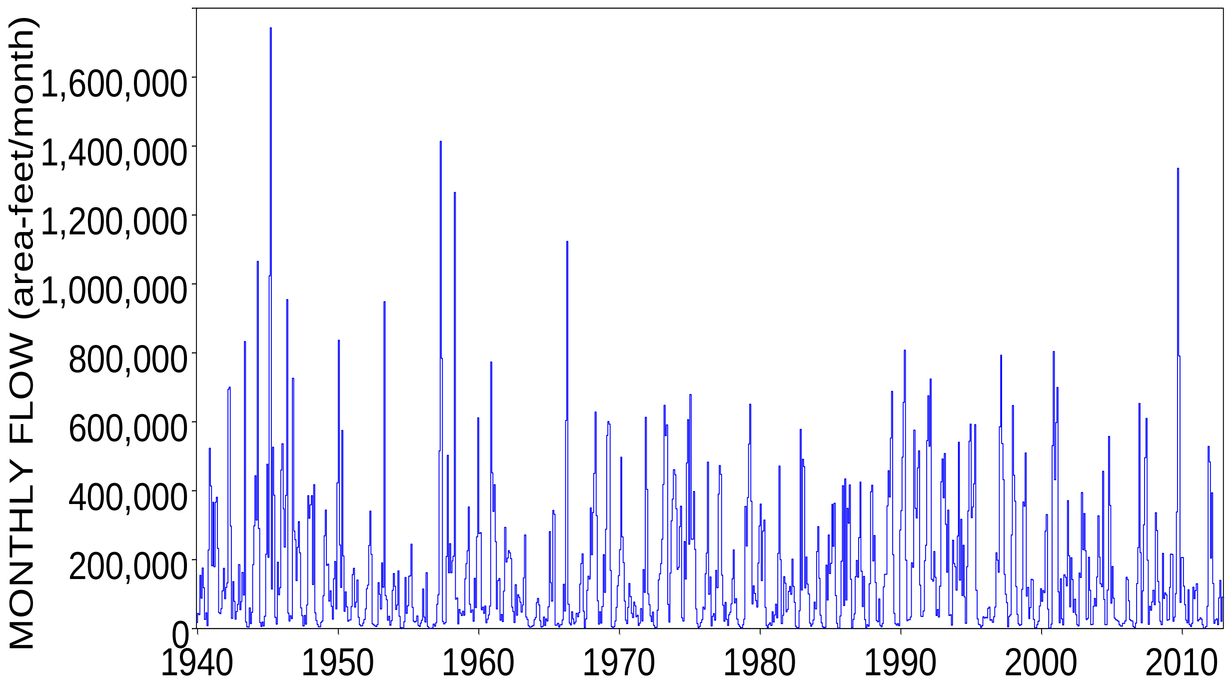
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Neches River near Evansdale



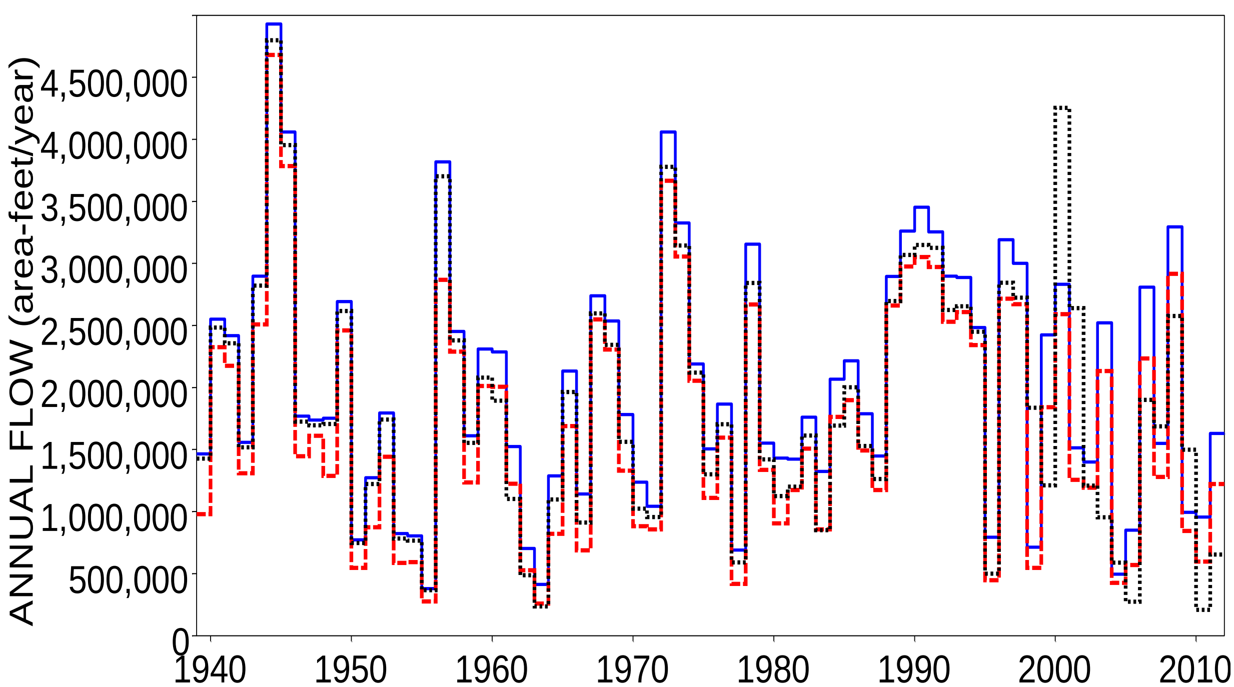
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Neches River near Evansdale



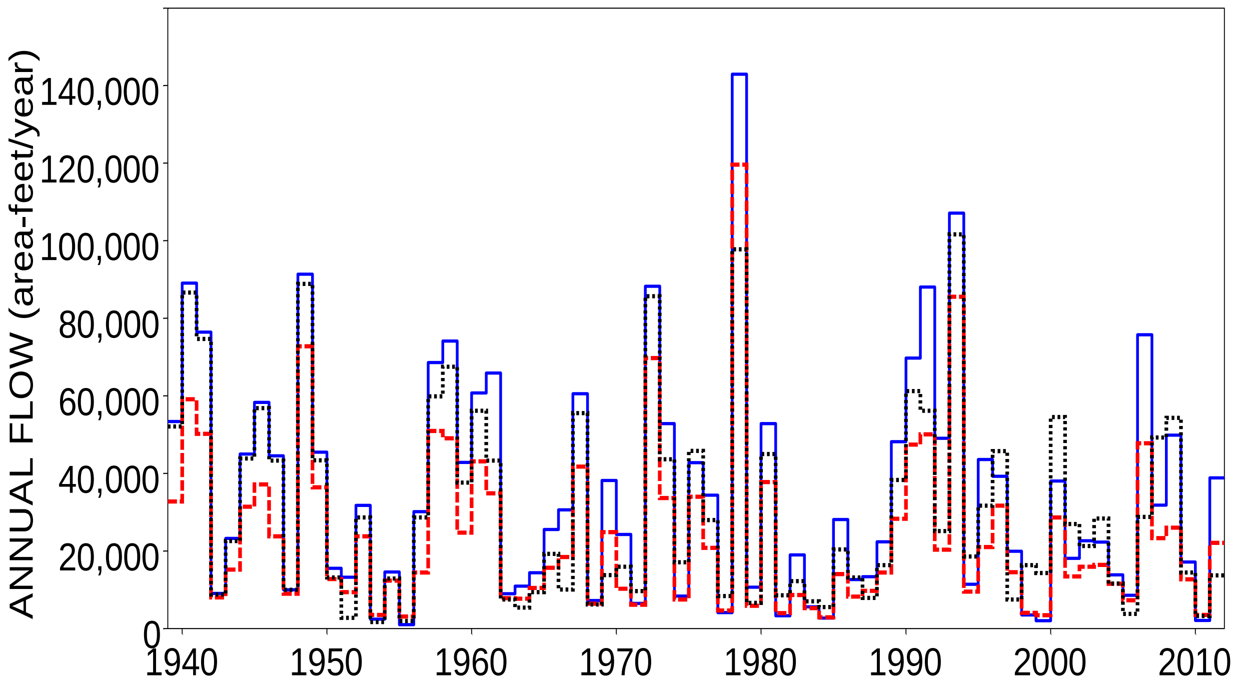
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Neches River near Evansdale



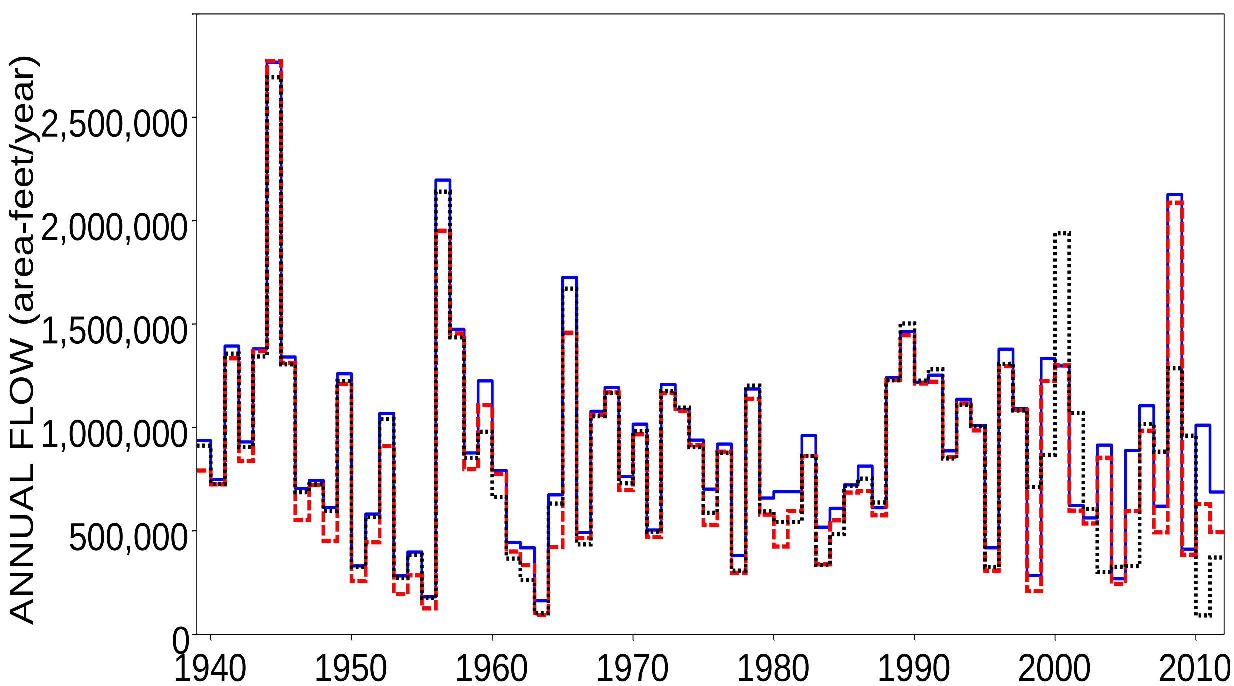
Naturalized Flows of Sabine River near Beckville



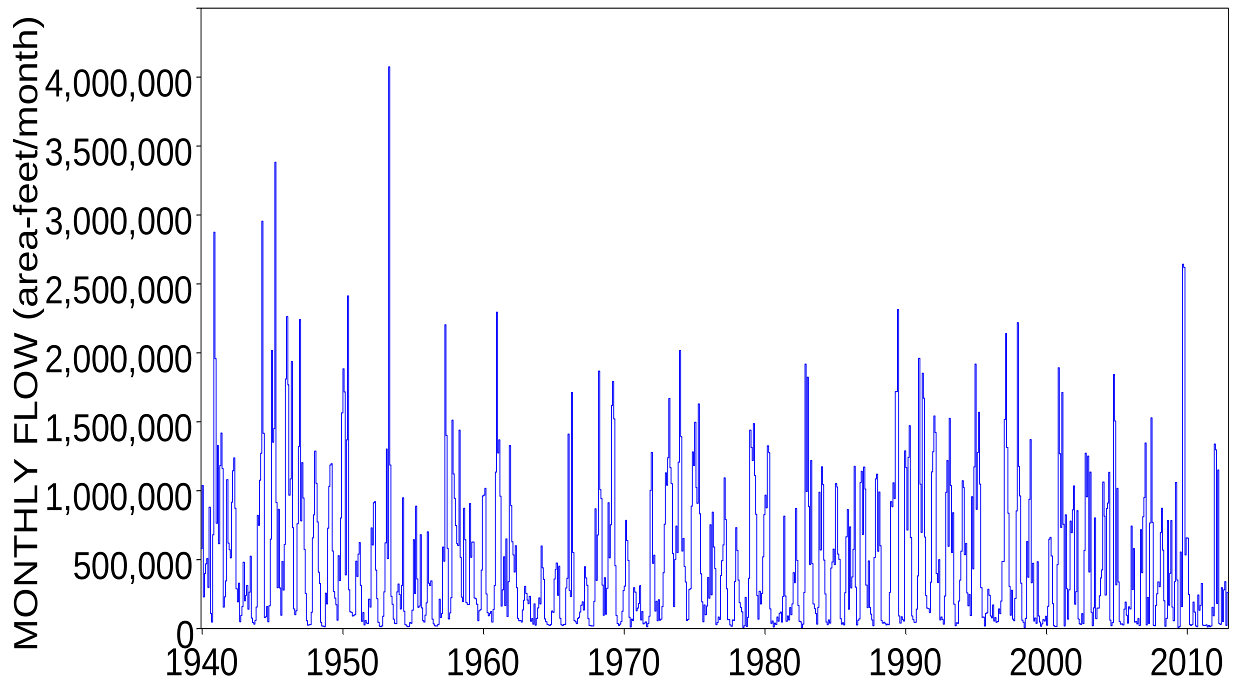
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Sabine River near Beckville



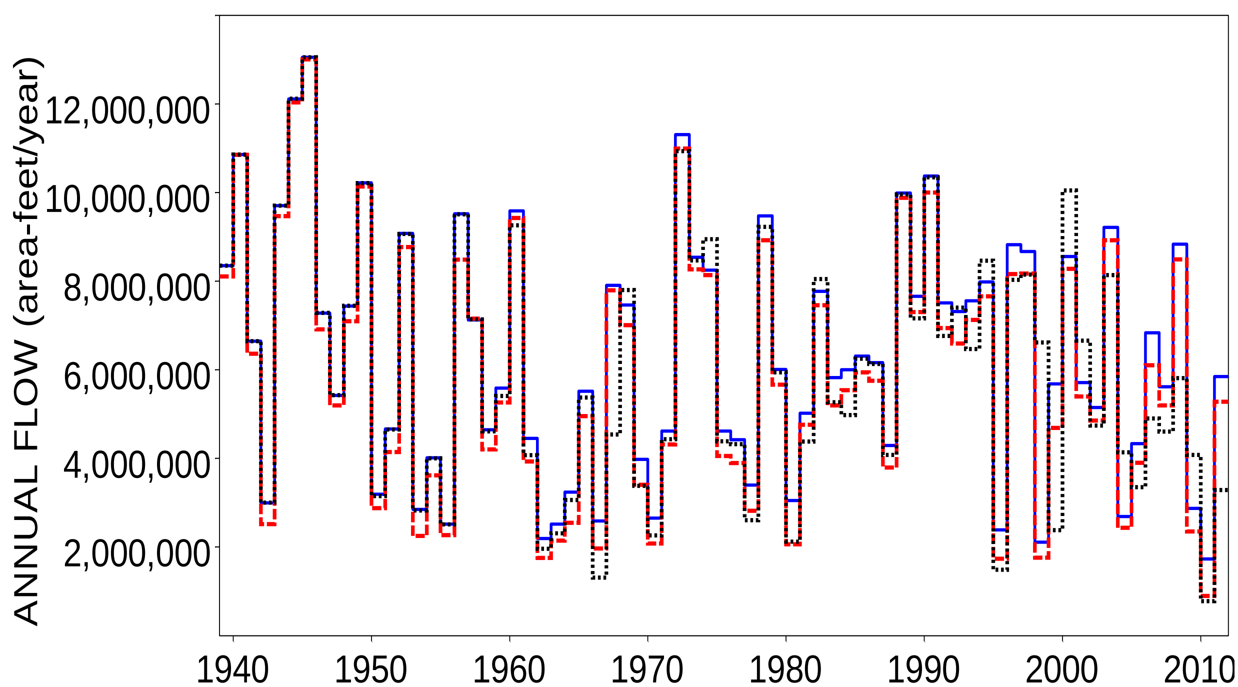
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Sabine River near Beckville



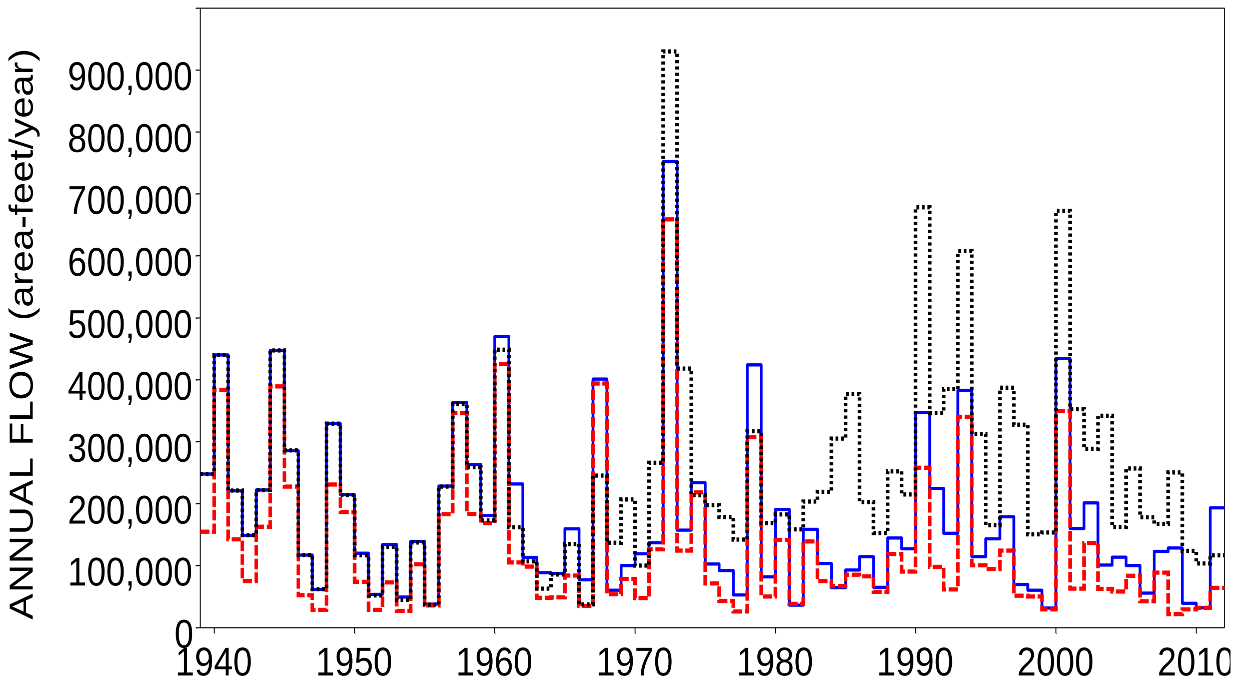
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Sabine River near Beckville



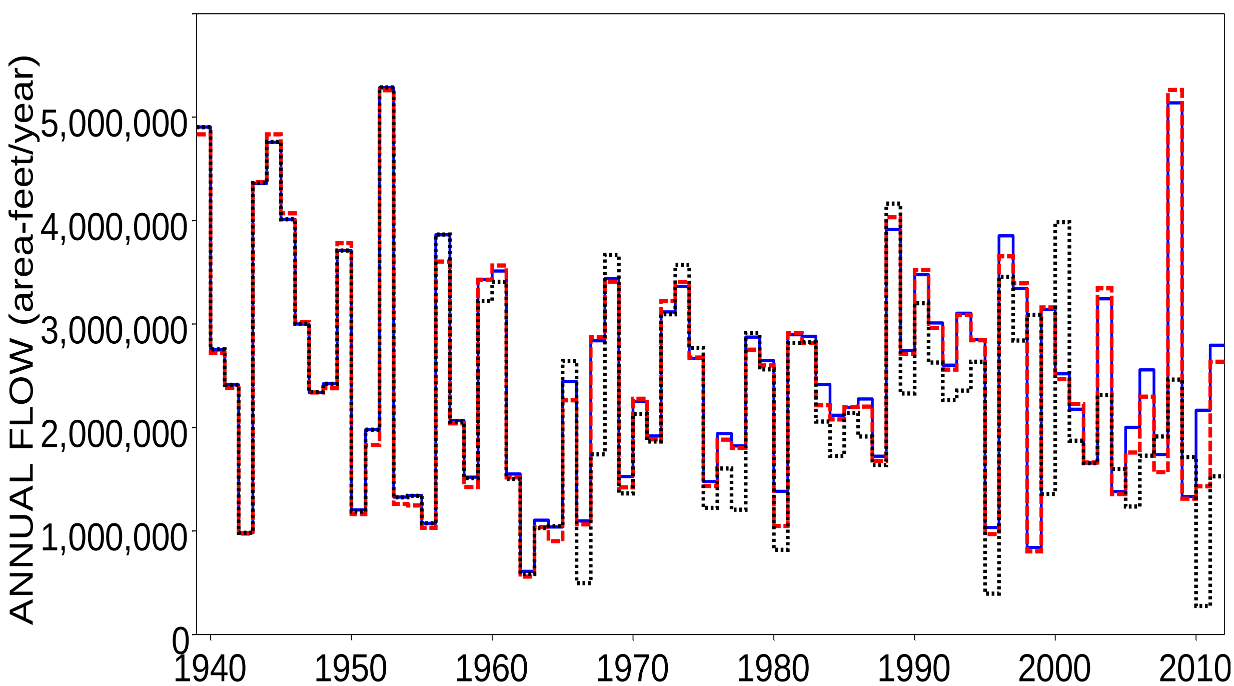
Naturalized Flows of Sabine River near Ruliff



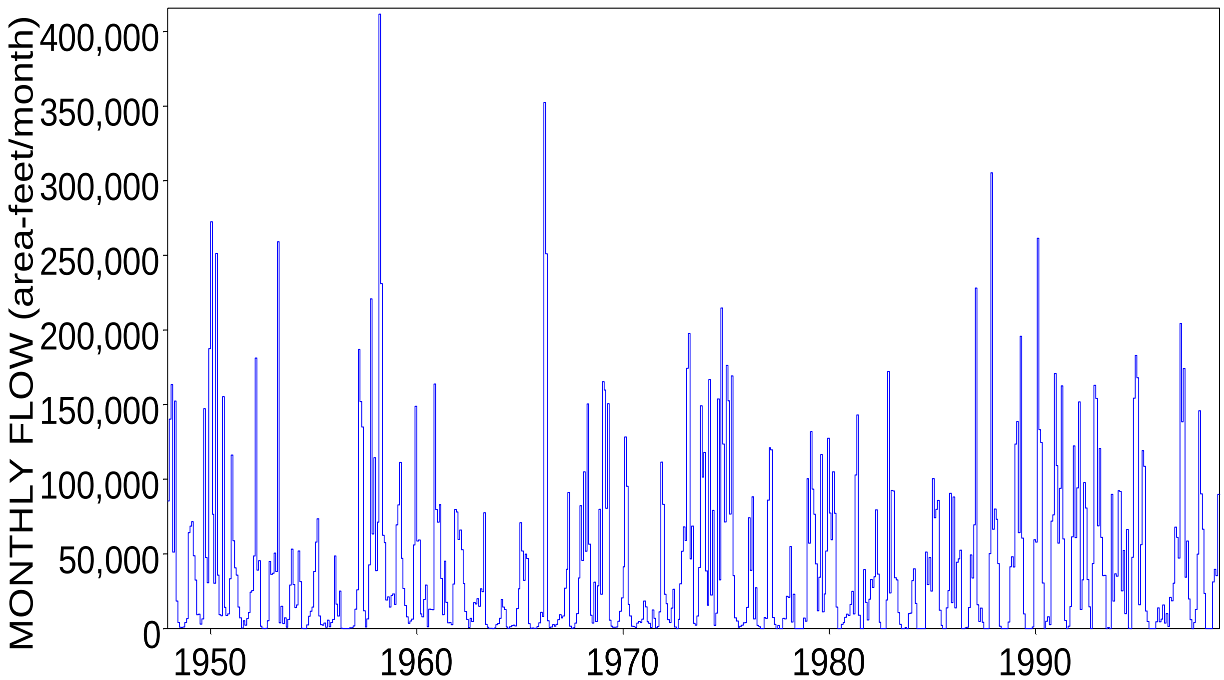
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Sabine River near Ruliff



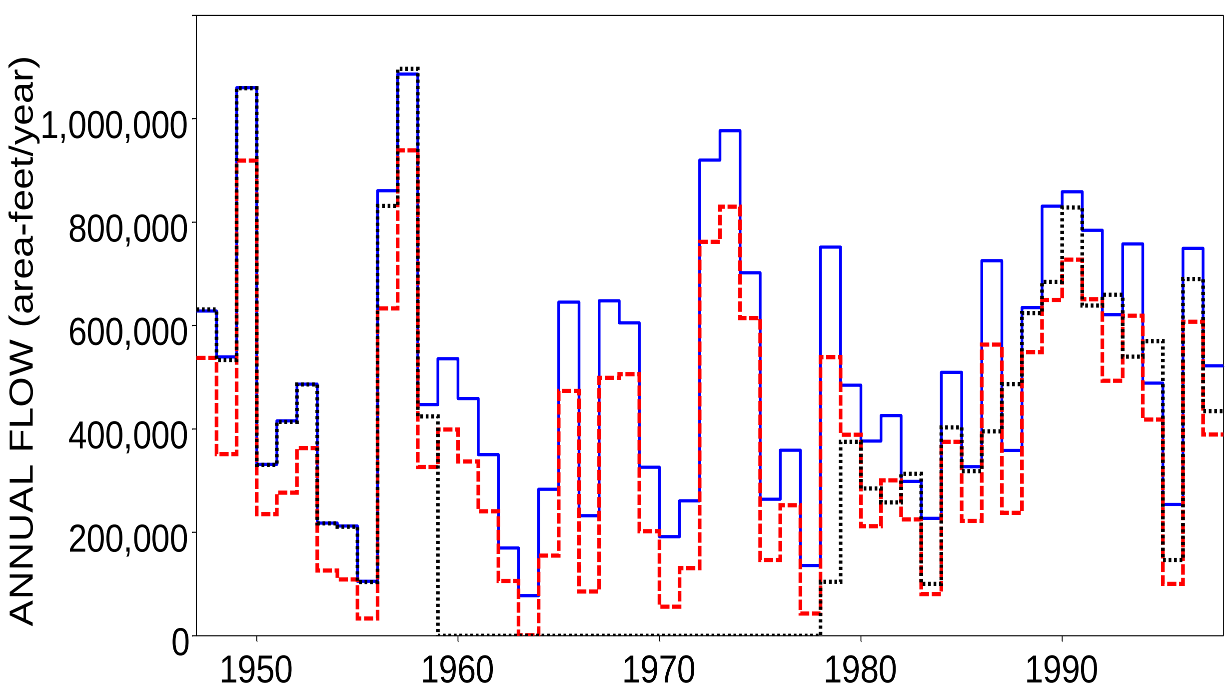
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Sabine River near Ruliff



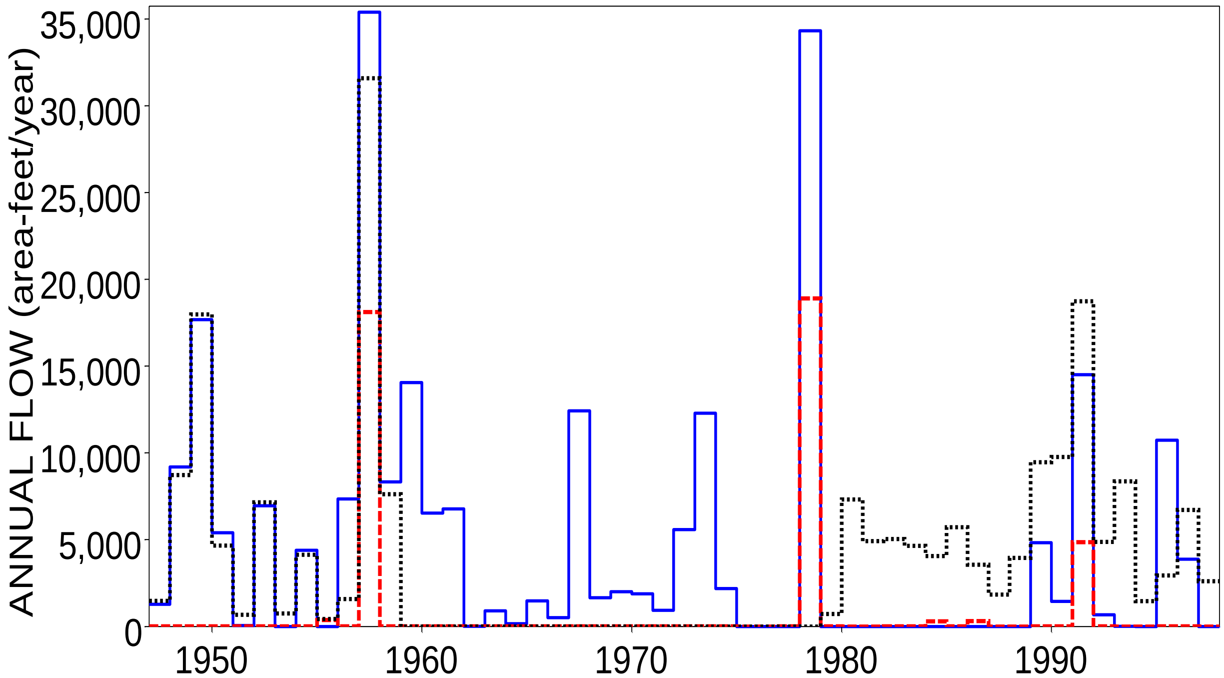
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Sabine River near Ruliff



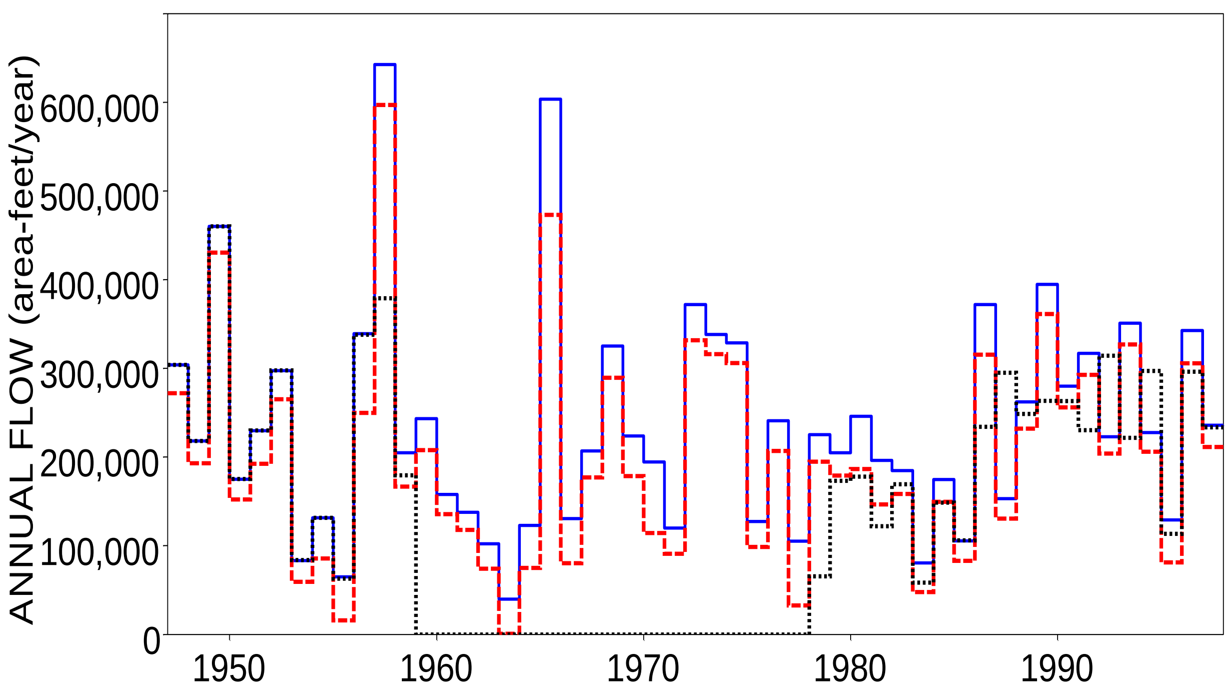
Naturalized Flows of Big Cypress Bayou at Jefferson



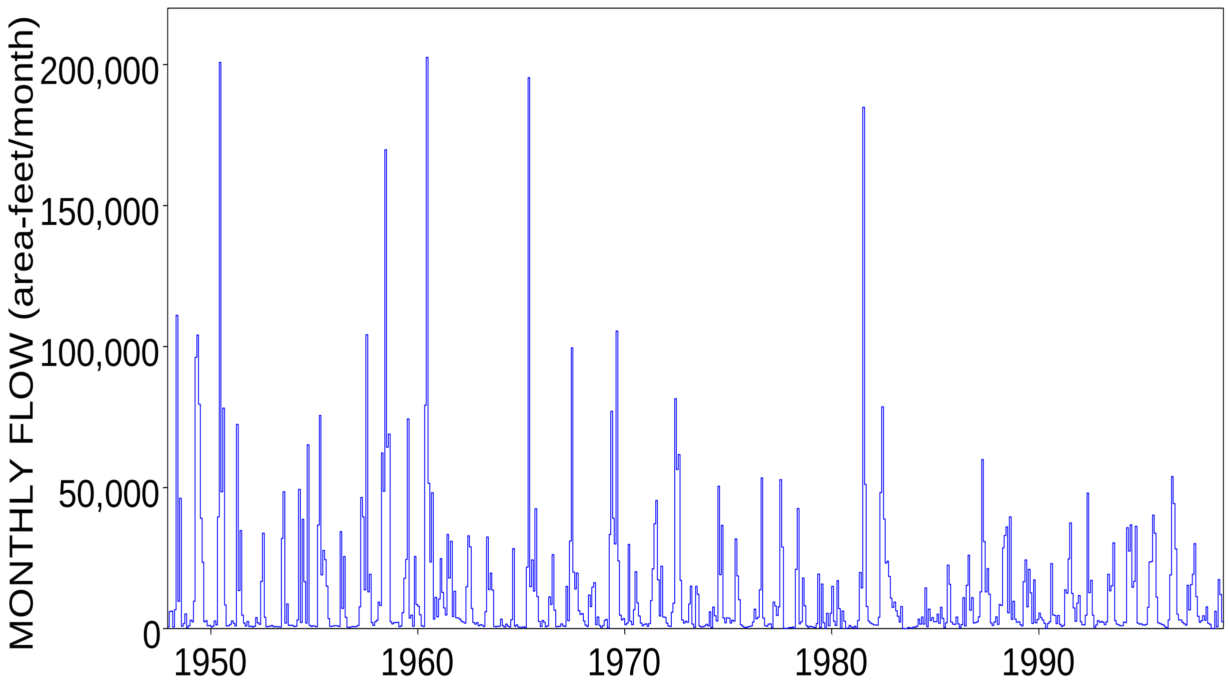
Naturalized (blue solid) and regulated (red dashed) Observed (black dotted) Annual Flows for Big Cypress Bayou at Jefferson



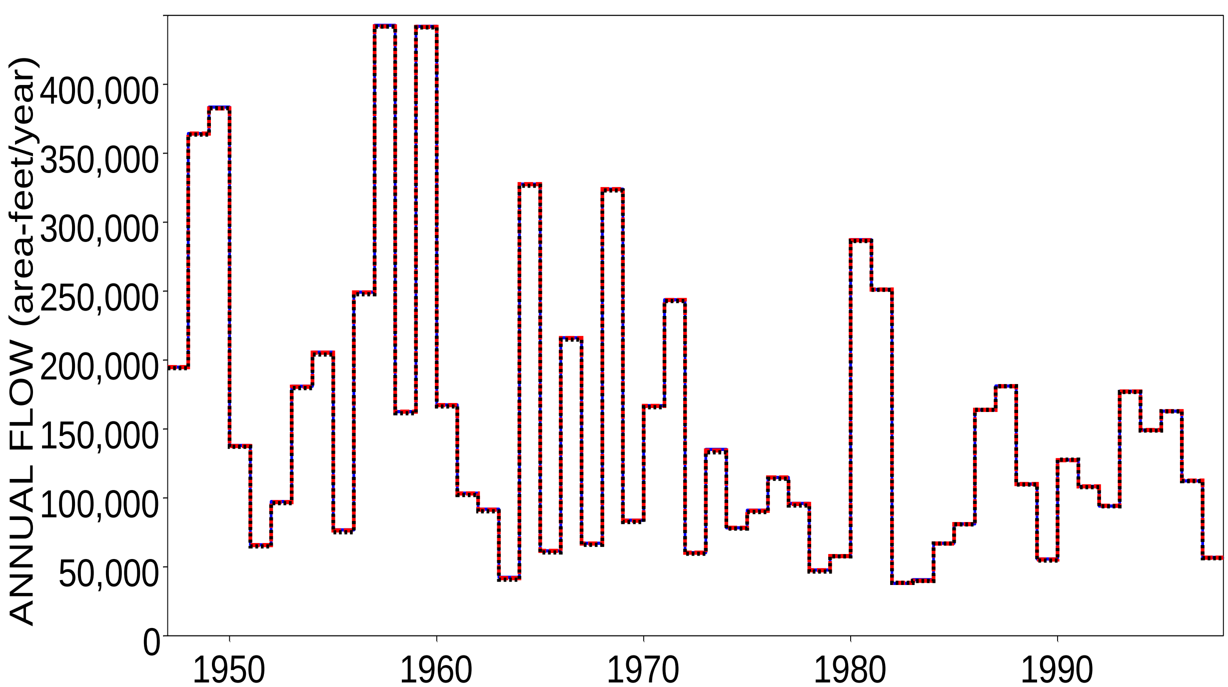
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Big Cypress Bayou at Jefferson



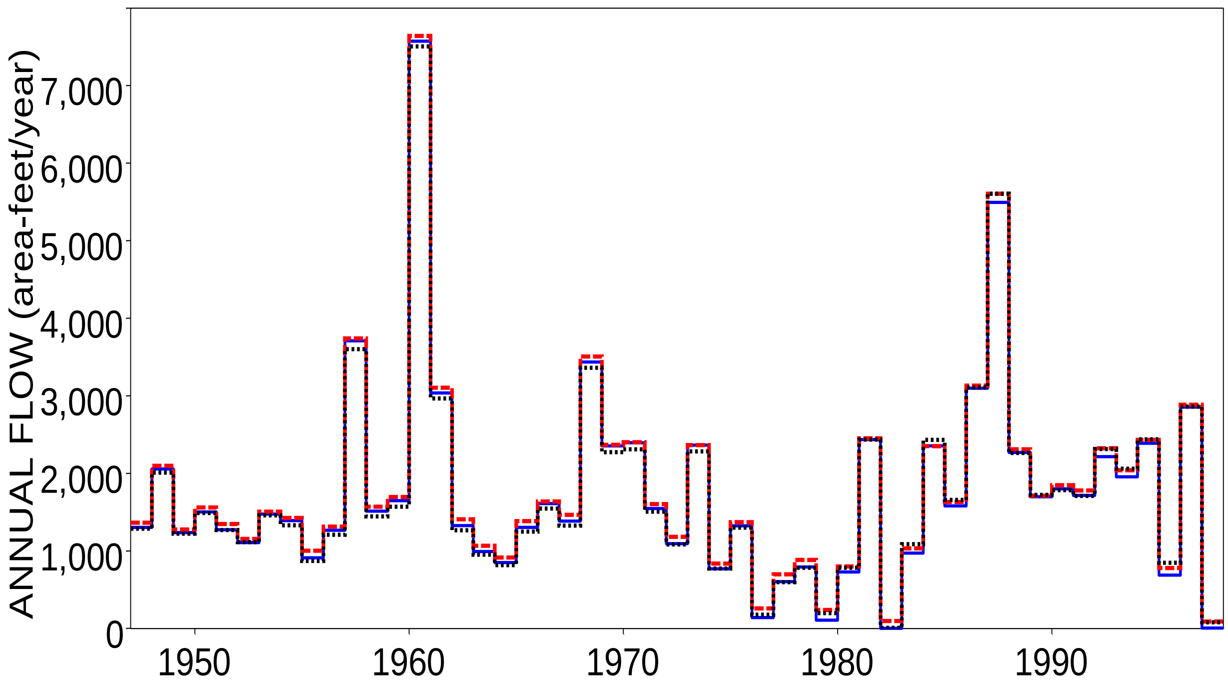
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Big Cypress Bayou at Jefferson



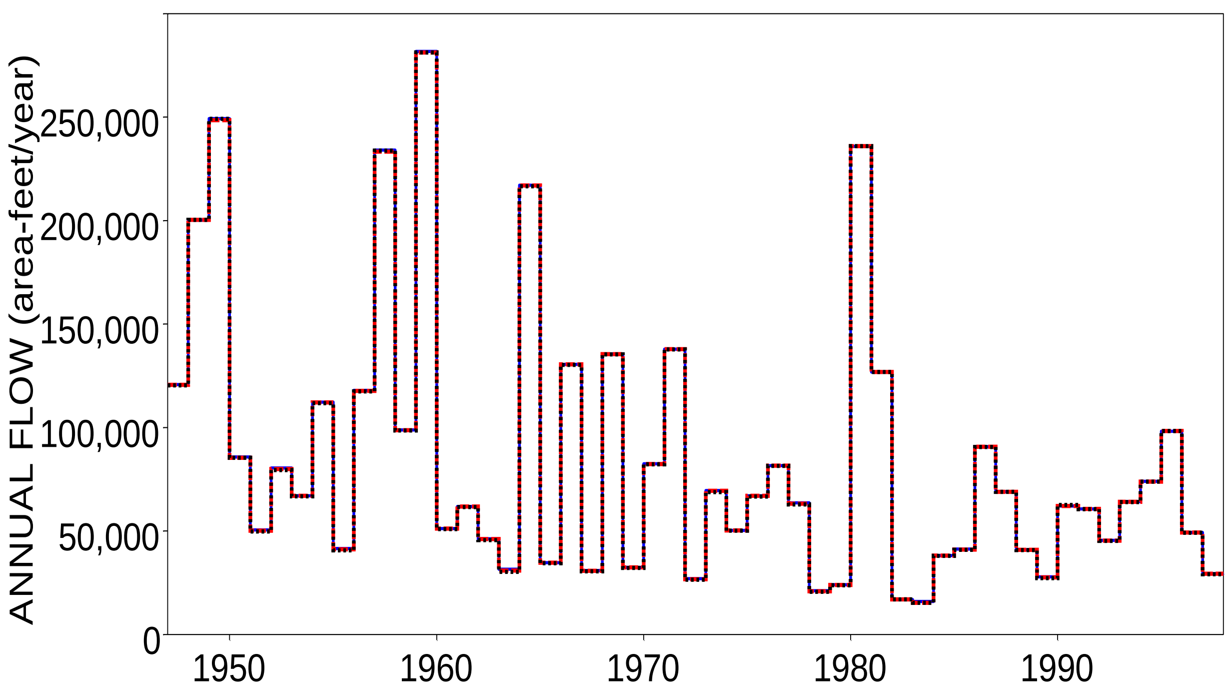
Naturalized Flows of Canadian River near Amarillo



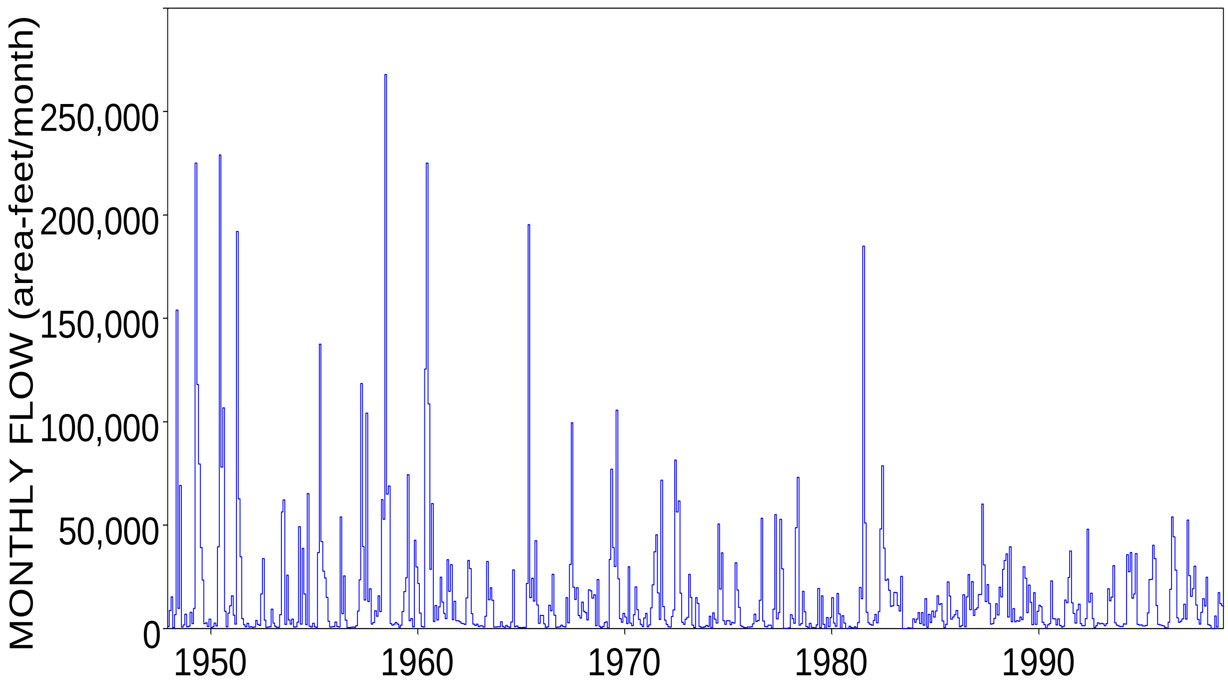
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Canadian River near Amarillo



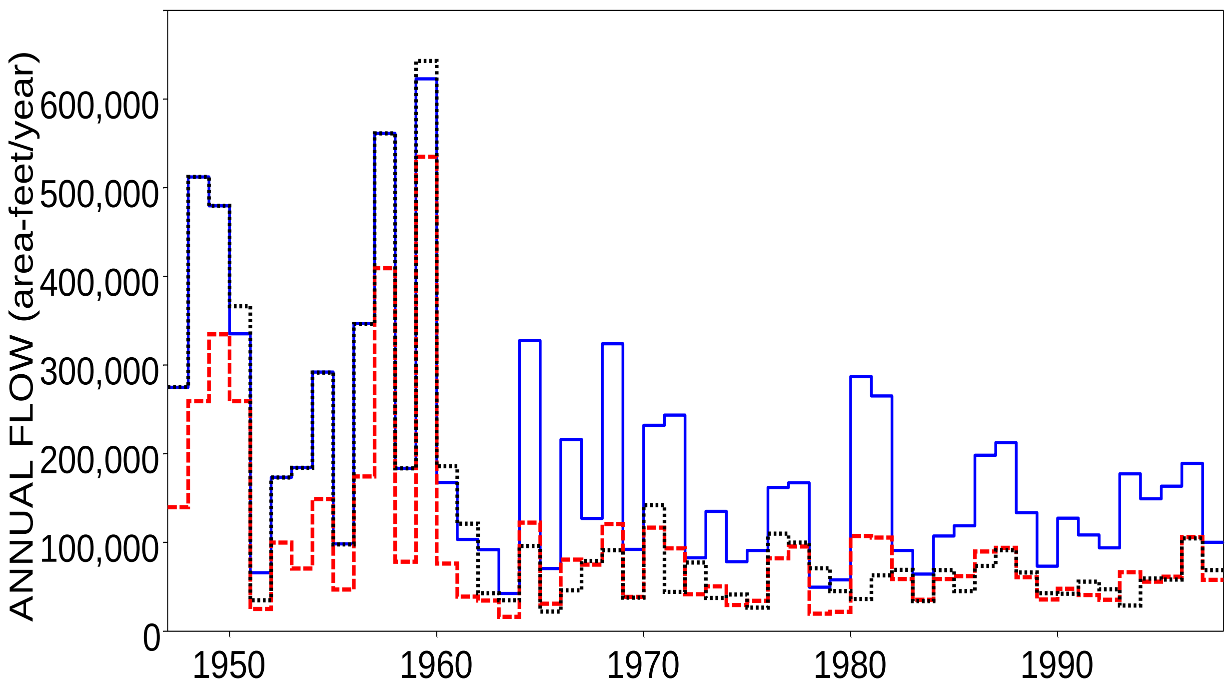
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Canadian River near Amarillo



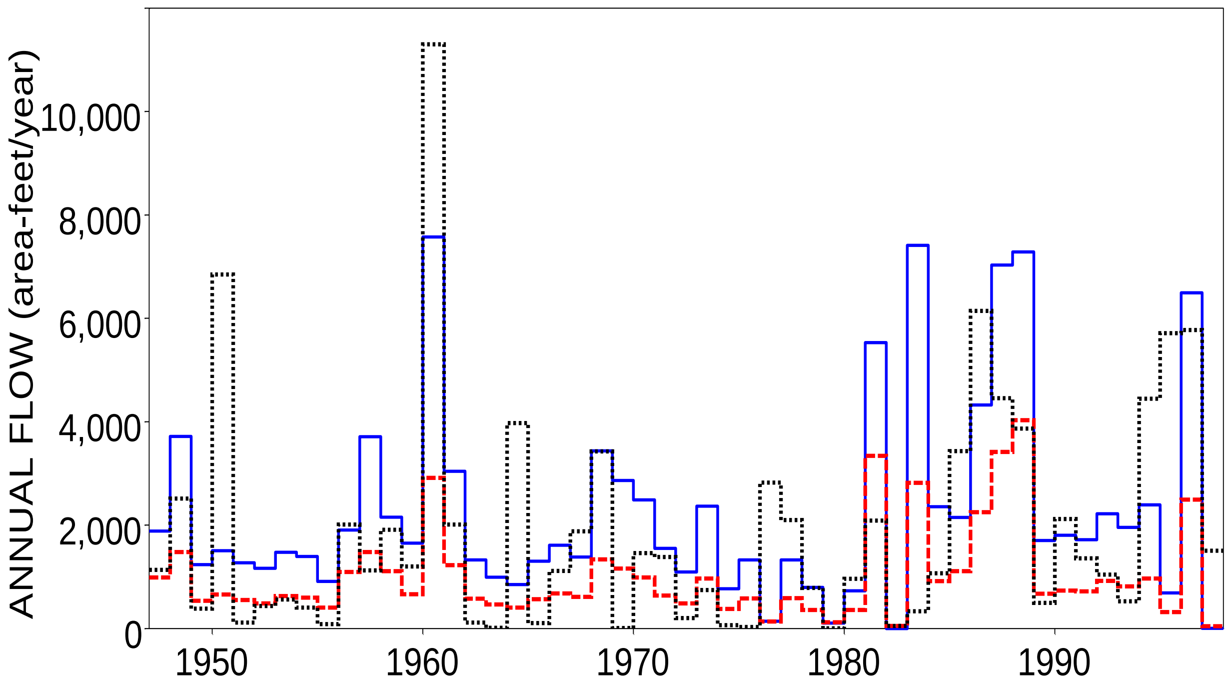
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Canadian River near Amarillo



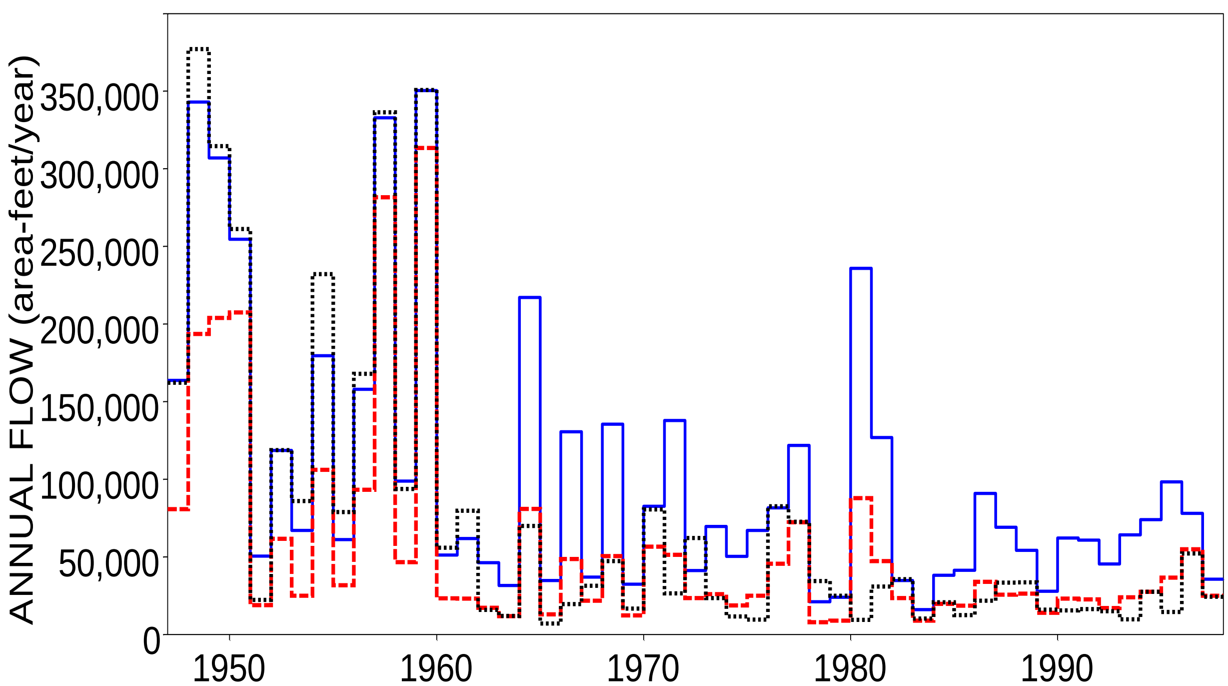
Naturalized Flows of Canadian River near Canadian



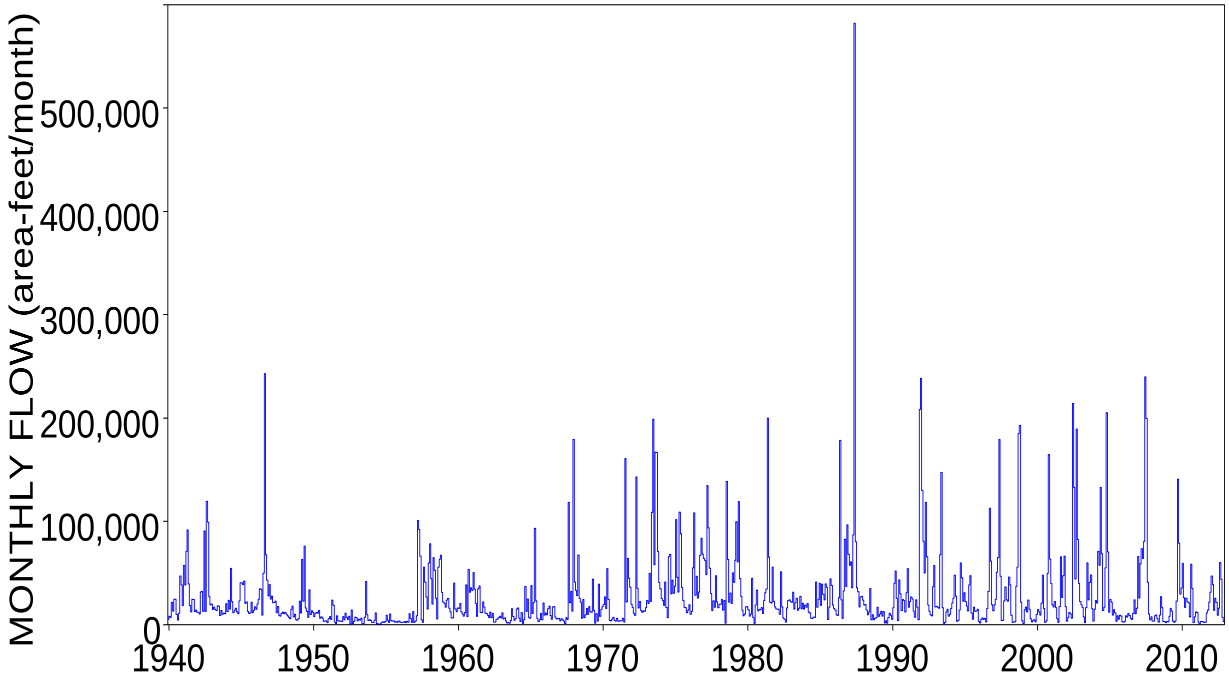
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) Annual Flows for Canadian River near Canadian



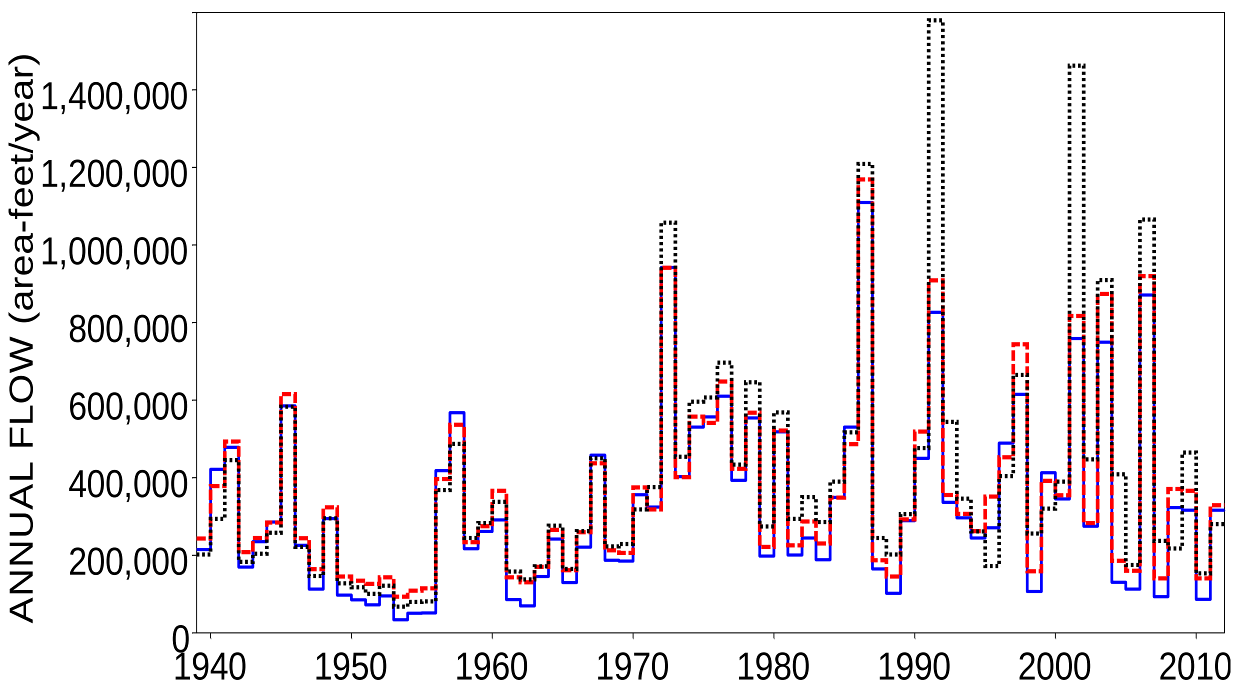
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Minimum Annual Flows for Canadian River near Canadian



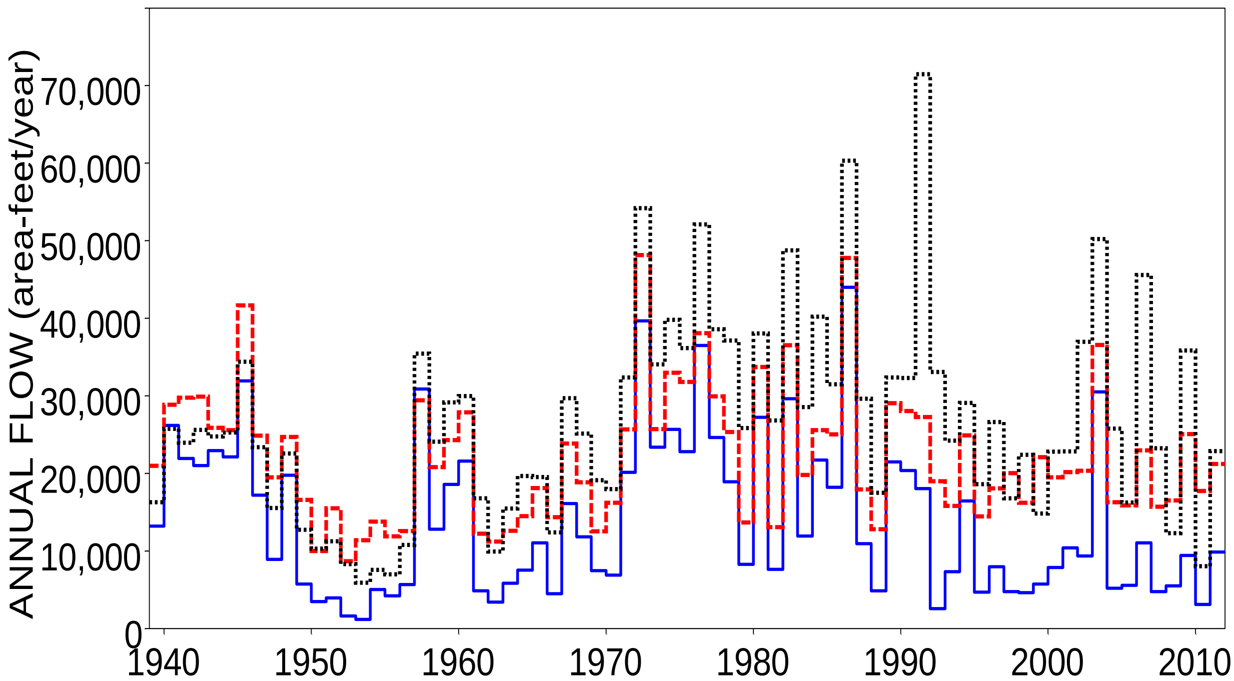
Naturalized (blue solid), Regulated (red dashed), and Observed (black dotted) 2-Month Maximum Annual Flows for Canadian River near Canadian



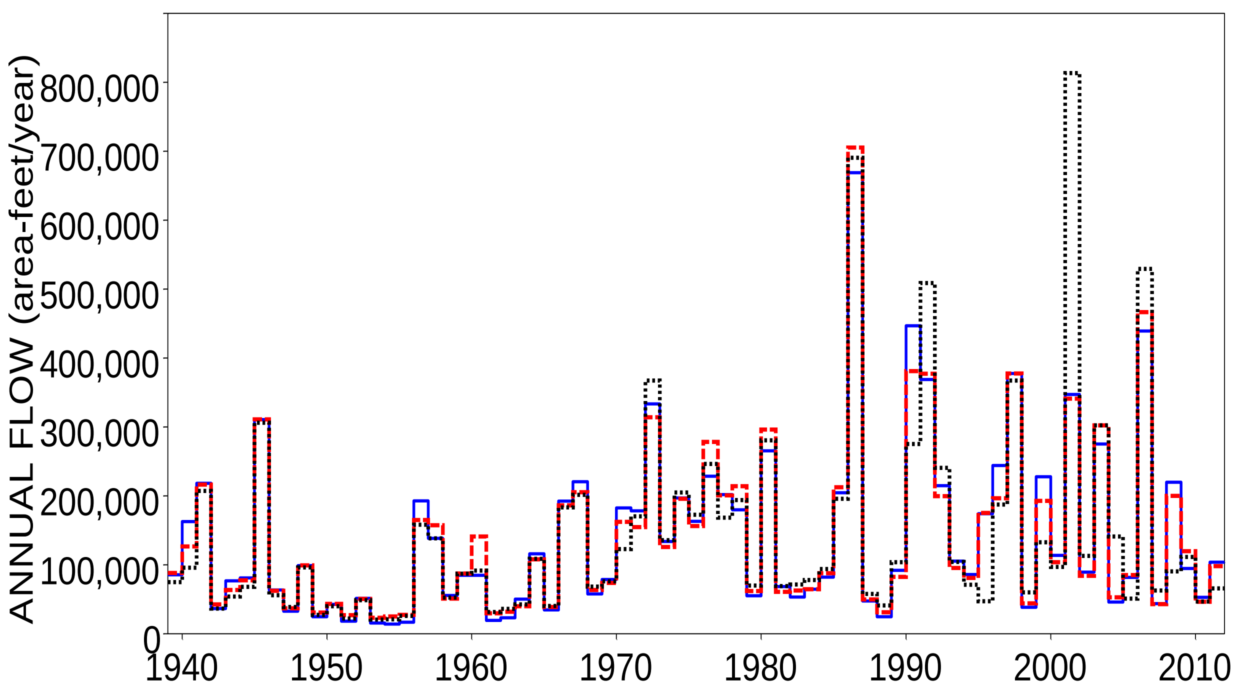
Naturalized Flows of San Antonio River at Falls City



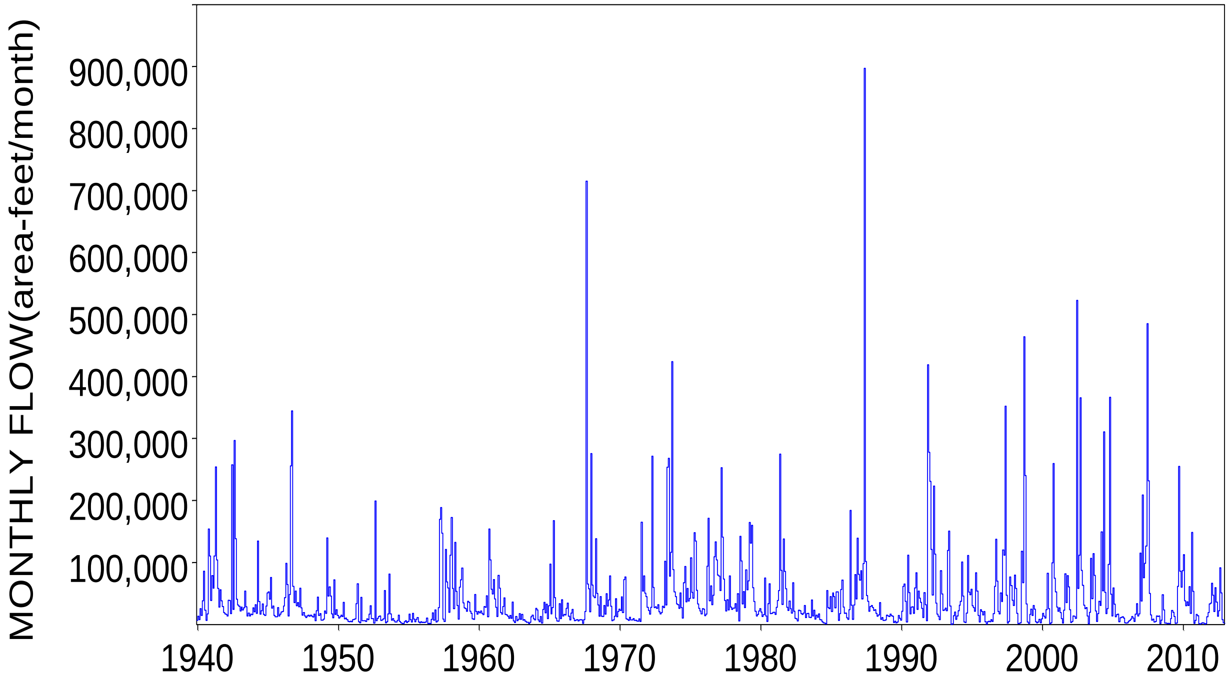
Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) Annual Flows for San Antonio River at Falls City



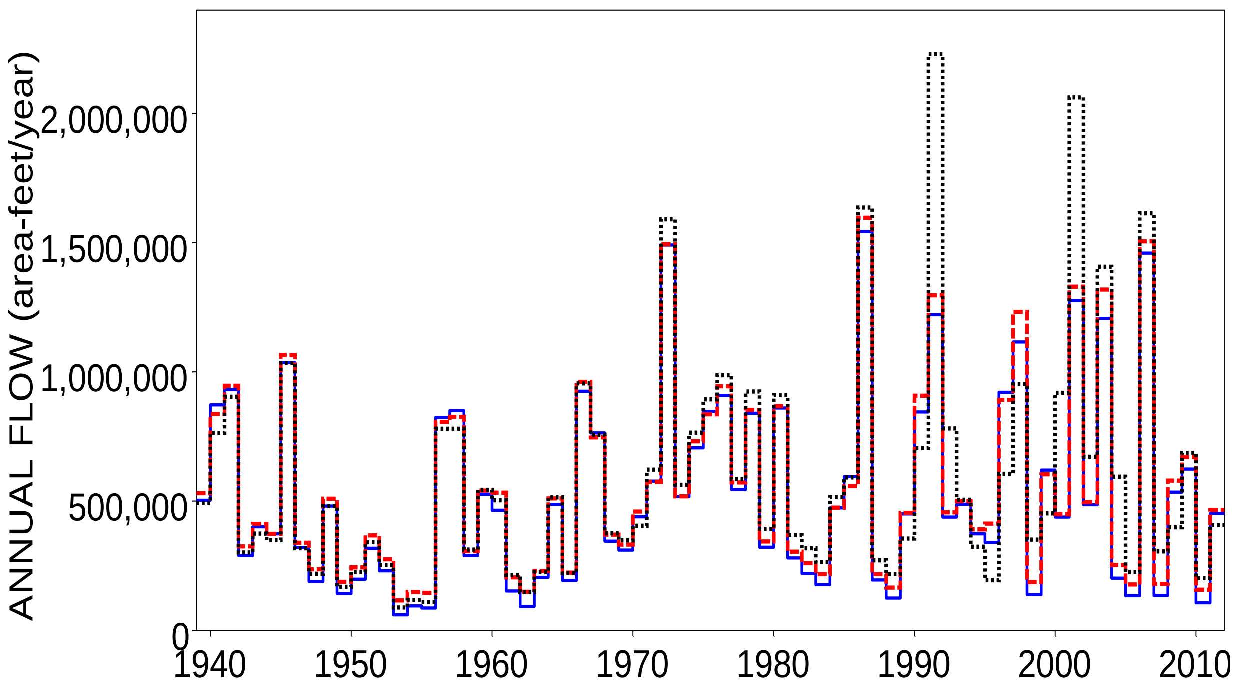
Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) 2-Month Minimum Annual Flows for San Antonio River at Falls City



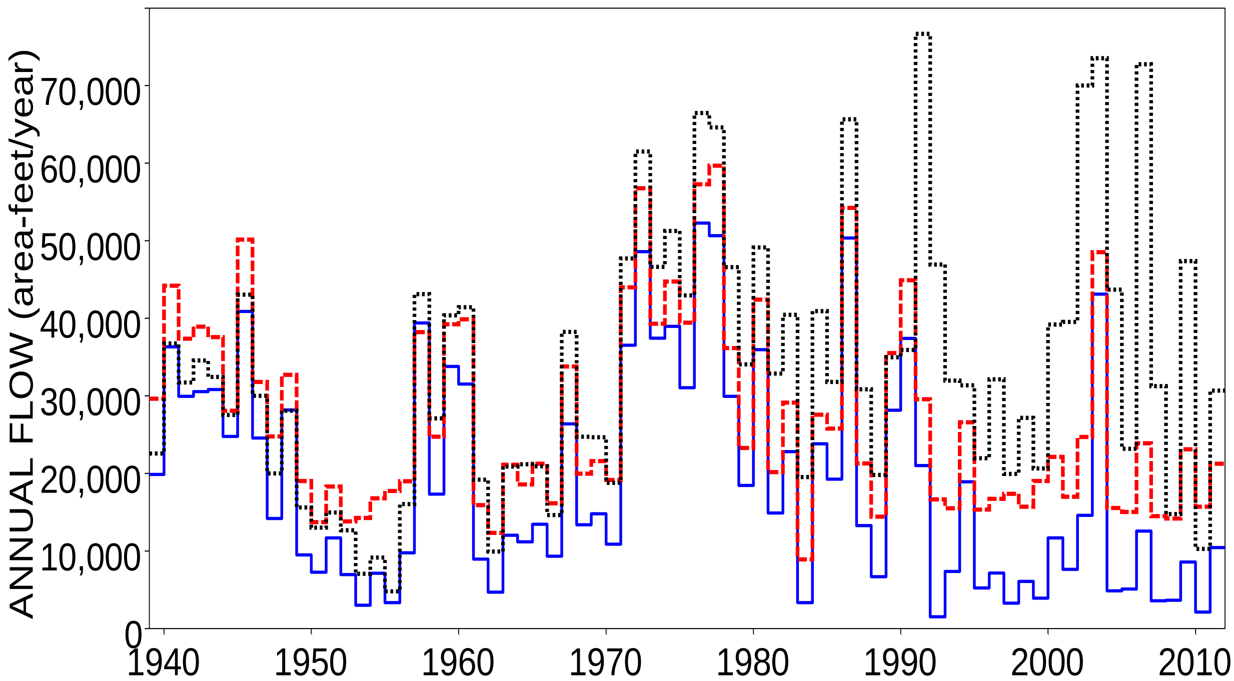
Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) 2-Month Maximum Annual Flows for San Antonio River at Falls City



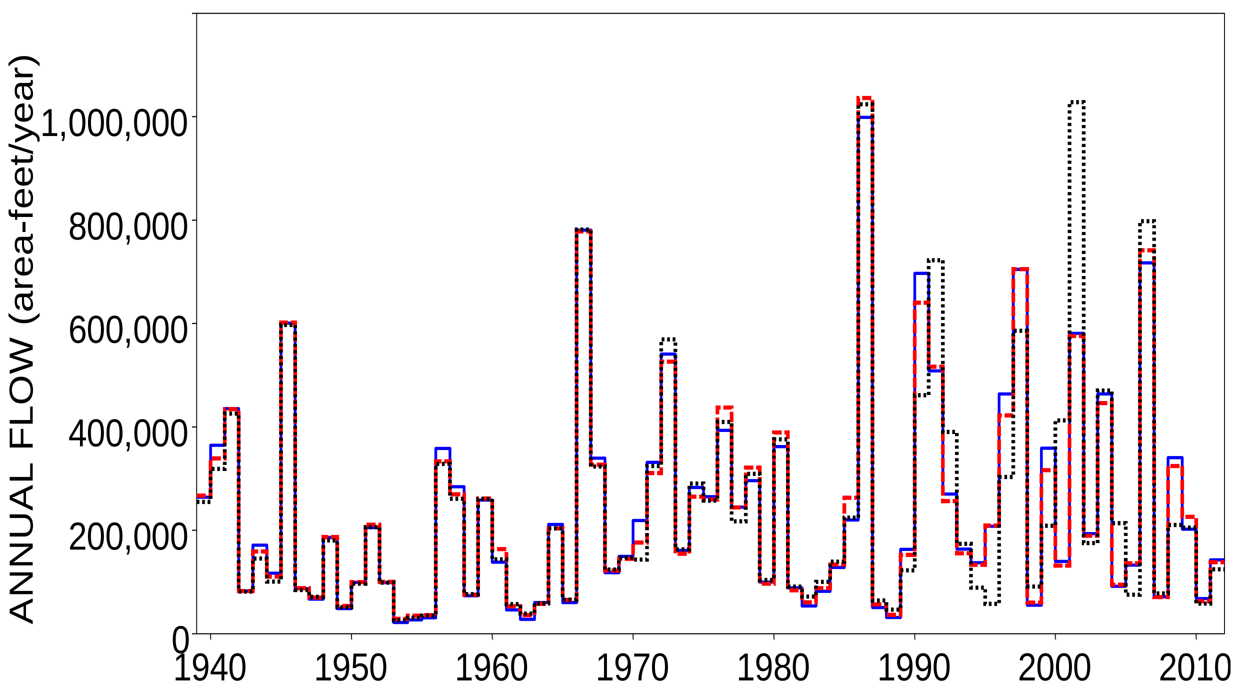
Naturalized Flows of San Antonio River at Goliad



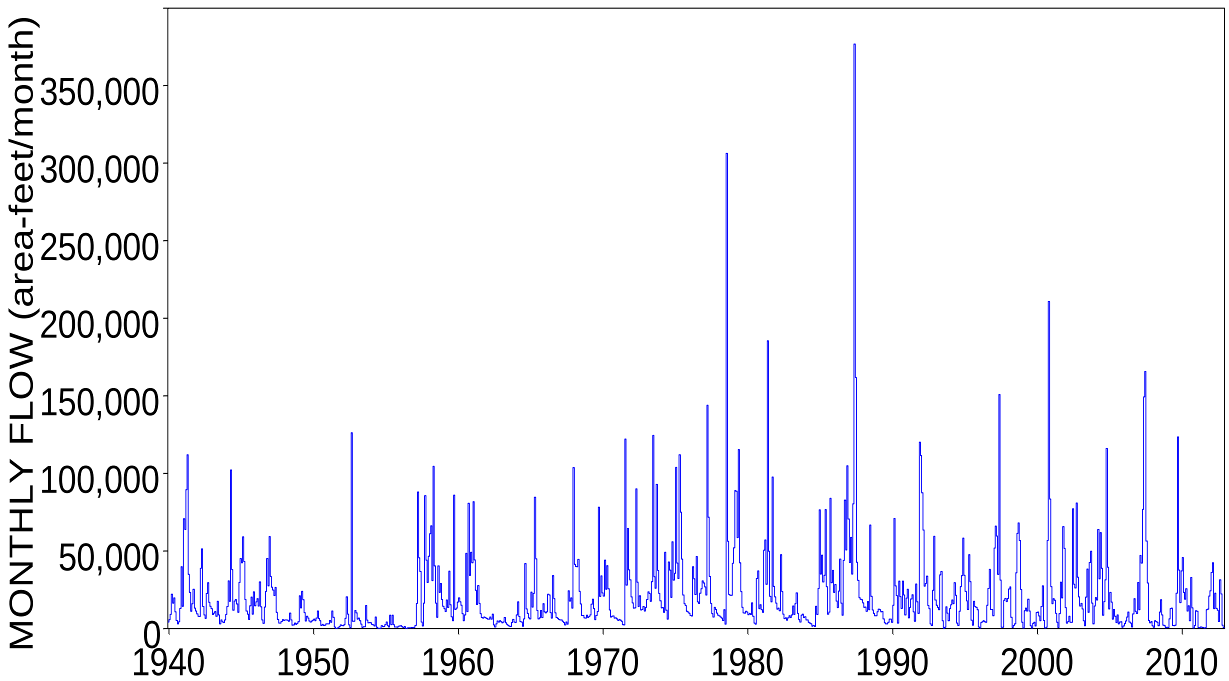
Naturalized (blue solid), Regulated (red dashed) and Observed Annual Flows for San Antonio River at Goliad



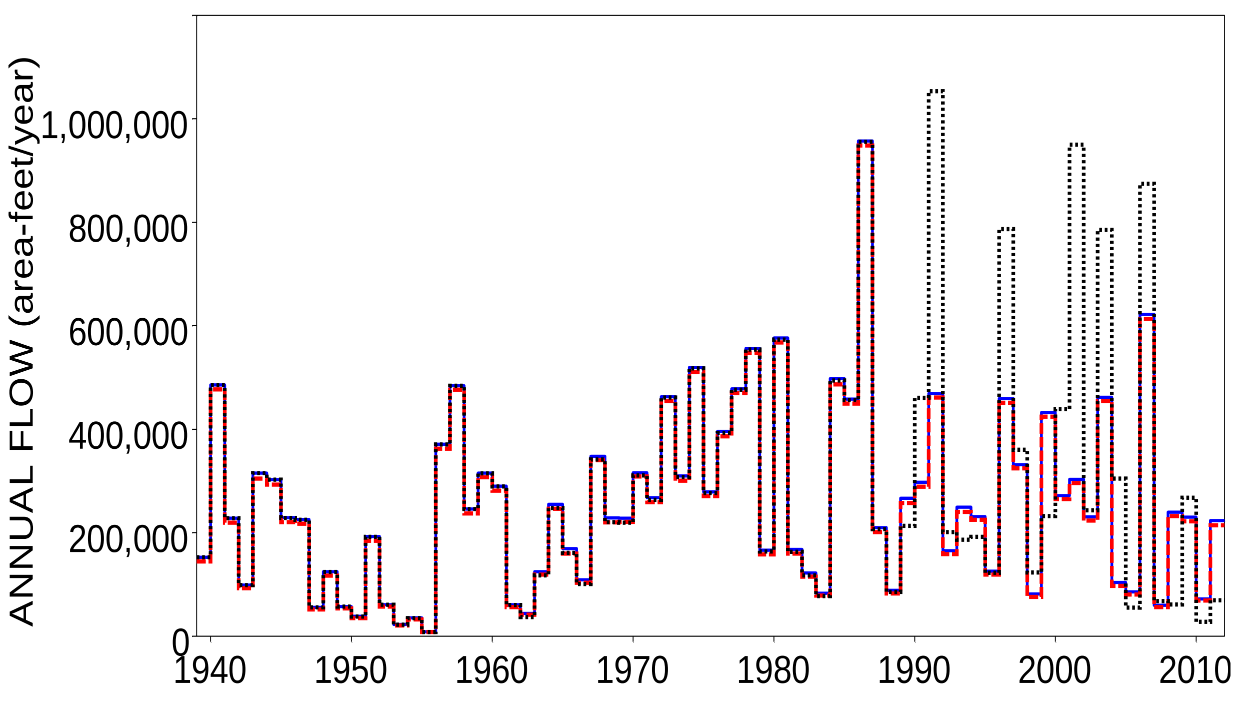
Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) 2-Month Minimum Annual Flows for San Antonio River at Goliad



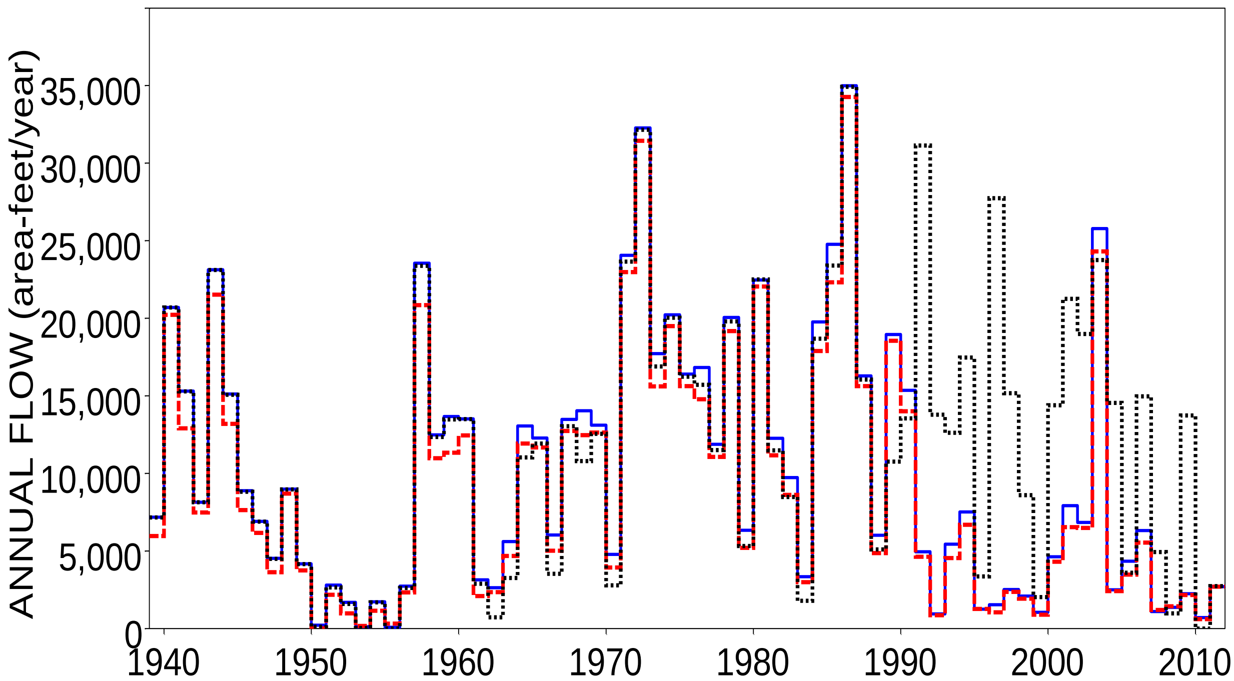
Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) 2-Month Maximum Annual Flows for San Antonio River at Goliad



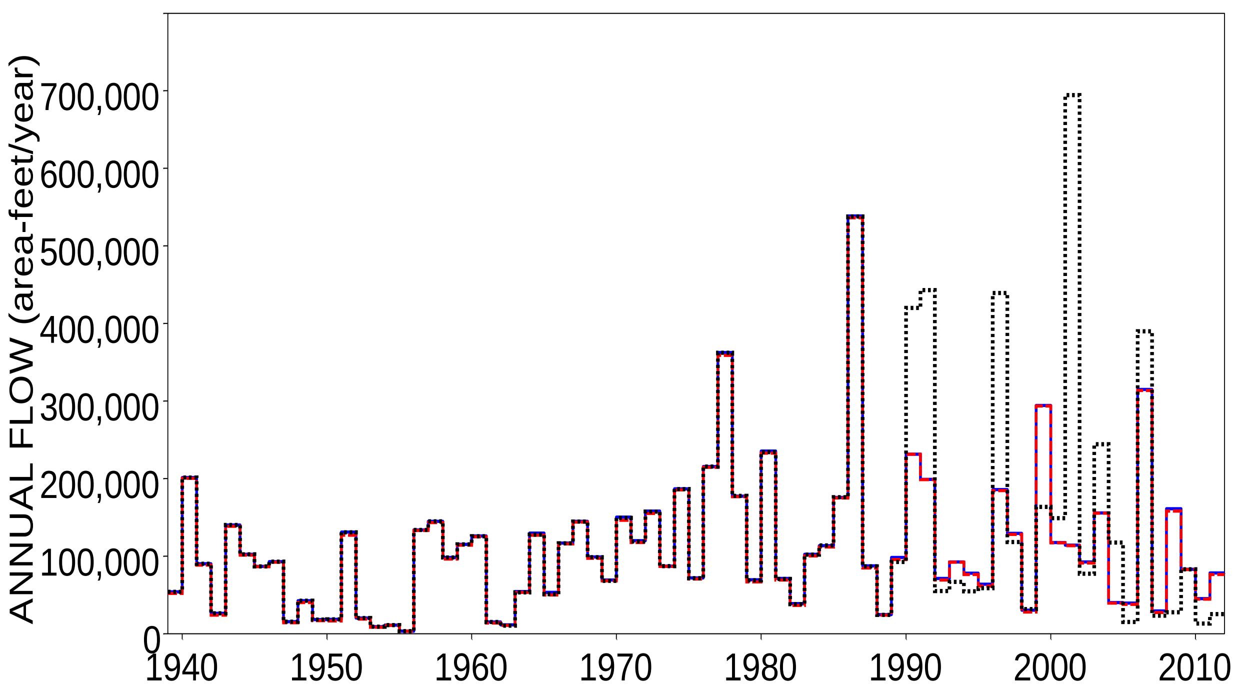
Naturalized Flows of Guadalupe River at Spring Branch



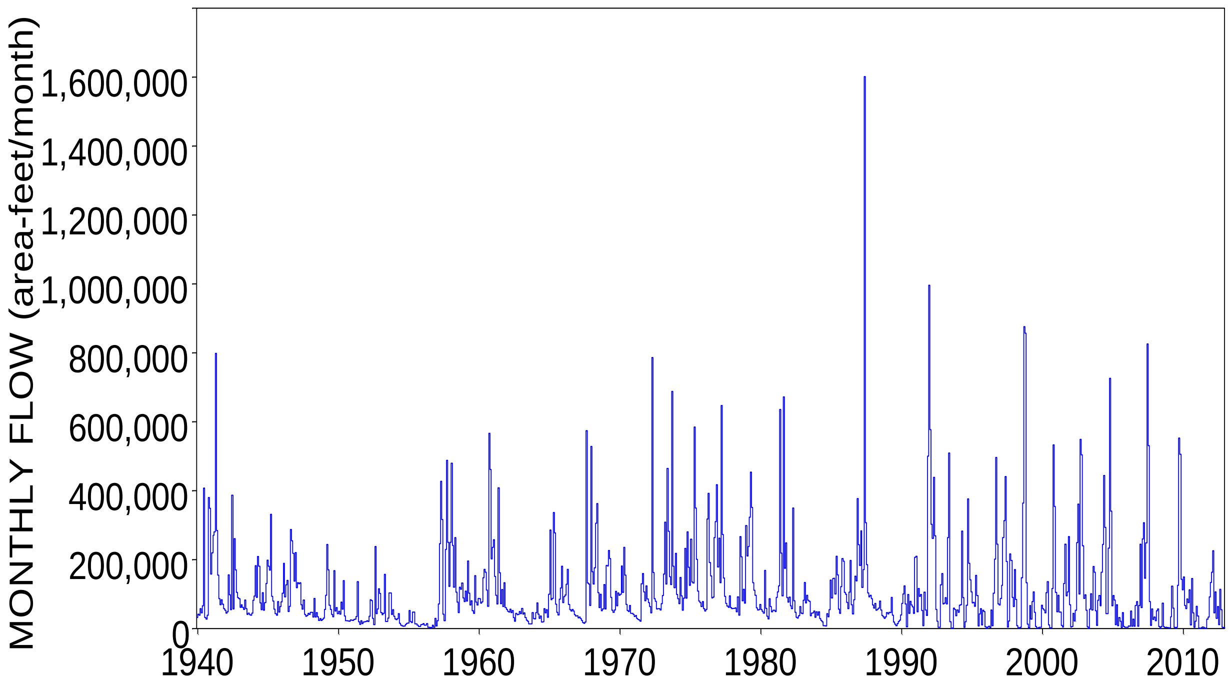
Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) Annual Flows for Guadalupe River at Spring Branch



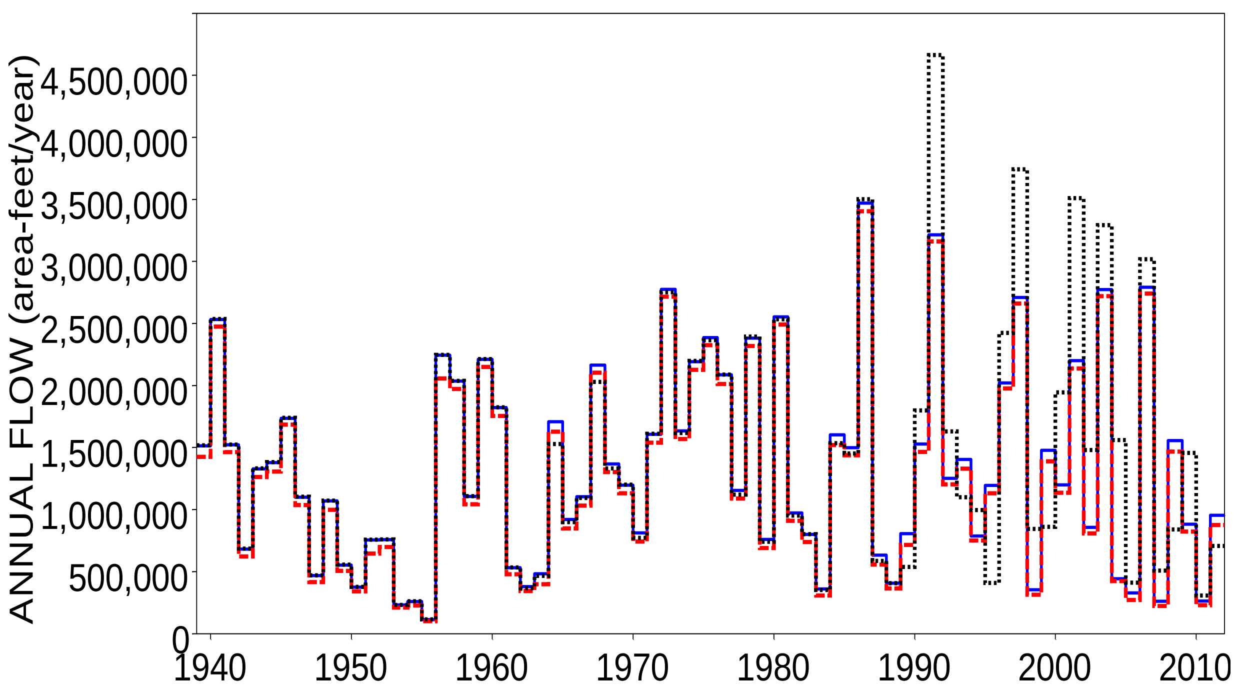
Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) 2-Month Minimum Annual Flows for Guadalupe River at Spring Branch



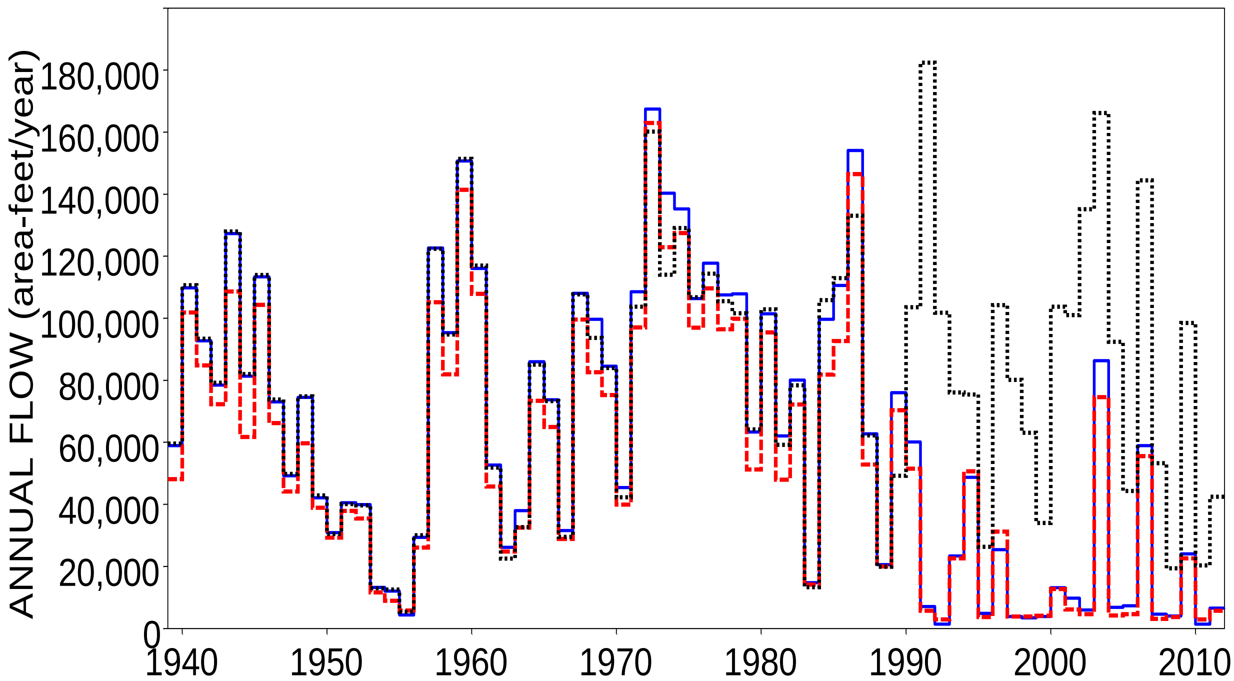
Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) 2-Month Maximum Annual Flows for Guadalupe River at Spring Branch



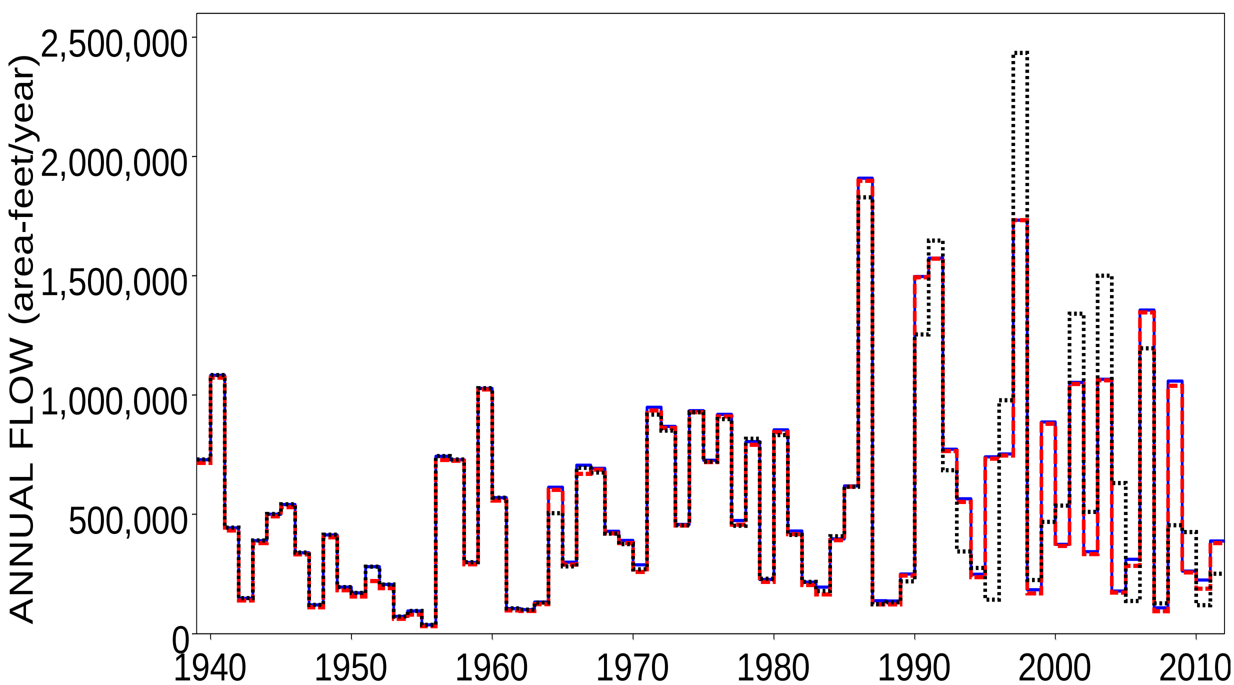
Naturalized Flows of Guadalupe River at Victoria



Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) Annual Flows for Guadalupe River at Victoria



Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) 2-Month Minimum Annual Flows for Guadalupe River at Victoria



Naturalized (blue solid), Regulated (red dashed) and Observed (black dotted) 2-Month Maximum Annual Flows for Guadalupe River at Victoria