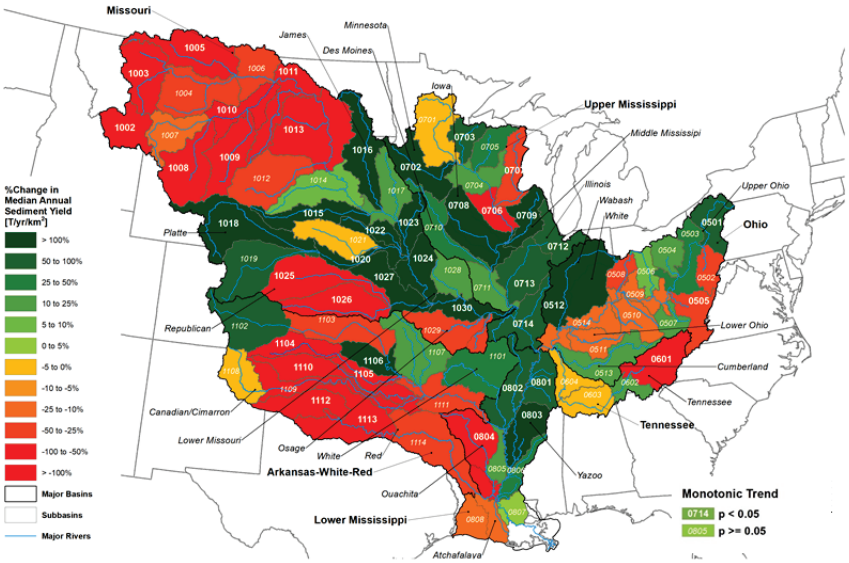
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Changes in Hydrology and Suspended-Sediment Transport in the Mississippi River Basin over the Past Century

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Mississippi River Geomorphology & Potamology Program

Report prepared for the Mississippi River Commission

Mississippi River Geomorphology &
Potamology Program

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Abstract

Since about 1900, widespread changes in hydrology across the Mississippi River Basin have occurred, resulting in important changes in the delivery of water and sediment to the Lower Mississippi River (LMR). This is due to a combination of natural and anthropogenic factors. There have been increases in annual precipitation and 1- to 7-day totals over large parts of the basin. Changes in seasonal distributions were also identified, as were increases in hurricane-related rainfall.

Streamflow to the LMR has increased significantly over the past 100 years. Median water yields have increased across most of the mid-continent and decreased in the western-most parts of the Missouri and Arkansas River basins. Suspended-sediment loads to the LMR have dramatically declined. The Lower Mississippi River is receiving about 500 million tonnes per year less suspended sediment today than in the 1940s (616 Mt/y to 98 Mt/y).

Human impacts on hydrology and sediment transport throughout the basin are important. In the mid-continent, water yield per unit precipitation showed increases, but markedly decreased in the western parts of the basin. Decreases can be attributed to the construction of thousands of dams, associated flow regulation, withdrawals for agriculture, and to a lesser extent, the increased evaporation behind impoundments.

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Contents

Abstract ii

Figures and Tables v

Preface xi

1 Introduction 1

Background 1
Objectives 3
Approach 4
Spatial divisions 5
Temporal divisions 9

2 Data Requirements, Sources, and Availability 10

Daily precipitation data 10
Mean-daily streamflow and peak-annual streamflow 11
Suspended-sediment concentrations 12
National inventory of dams 13
Daily pan-evaporation observations 13
Geospatial data 14

3 Methodology 15

Precipitation analysis 15
Streamflow analysis 17
Calculation of water yield and precipitation-weighted water yield 18
Trend analyses 19
Peak-streamflow analysis 20
Annual-evaporation rates 20
Determination of annual suspended-sediment yields 21

4 Results and Discussion 25

Precipitation trends 25
Annual trends 25
Peak annual trends 26
Seasonal trends 31
Peak seasonal trends 37
Hurricane-related precipitation trends 44
Summary of precipitation results 49
Water yield trends 50
Annual trends 50
Peak annual trends 51
Seasonal trends 55
Peak seasonal trends 60
Summary of water-yield results 65

Trends in precipitation-weighted water yield 67
Annual trends *67*
Potential evaporation from NID impoundments *74*
Peak annual trends *79*
Seasonal trends *82*
Peak seasonal trends *87*
Summary of precipitation-weighted water yield results: anthropogenic influences *89*
Streamflow trends from index stations 90
All index stations *90*
Major (HUC-2) index stations *96*
Summary of streamflow trends from index stations results *105*
Peak streamflow from HUC-4s 106
Sediment yield 108
Values and trends at the effective ($Q_{1.5}$) discharge *109*
Annual trends *114*
Trends in annual sediment delivery to the Lower Mississippi from major index stations *119*
Summary of sediment-yield results *122*

5 Summary 124

References 126

Appendix A: GHCND Gages 132

Appendix B: USGS Gage Information 134

Appendix C: National Inventory of Dams 139

Appendix D: Average Monthly Evaporation at NID Impoundments 142

Appendix E: Precipitation Trends by HUC-4 148

Appendix F: Water Yield Trends by HUC-4 184

Appendix G: Precipitation-Weighted Water Yield Trends by HUC-4 214

Appendix H: Streamflow Trends at Index Stations 232

Appendix I: Peak Streamflow Analysis by HUC-4 268

Appendix J: Suspended-Sediment Yields 271

Unit Conversion Factors 282

Acronyms and Abbreviations 283

Report Documentation Page

Figures and Tables

Figures

Figure 1. Major hydrologic regions (2-digit hydrologic unit codes) and sub-regions (4-digit hydrologic unit codes) of the Mississippi River Basin. 7
Figure 2. Location of GHCND precipitation gages used in this study. 10
Figure 3. Location of USGS mean-daily streamflow gages used in this study. 11
Figure 4. Location of USGS peak-streamflow gages used in this study. 12
Figure 5. Location of USGS suspended-sediment stations used in this study. 13
Figure 6. Location of GHCND pan evaporation gages used in this study. 14
Figure 7. Hurricane tracks affecting the Mississippi River Basin (1950–2014). 16
Figure 8. Location of streamflow index stations. 18
Figure 9. Annual streamflow along the Mississippi River at St. Louis, Missouri. 20
Figure 10. Examples of decadal shifts in sediment-transport ratings (including equations) from index stations along the Arkansas (top) and Missouri Rivers (bottom). The vertical black line represents the $Q_{1.5}$. 24
Figure 11. Percent change in annual rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 28
Figure 12. Percent change in maximum, annual 24-hour rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 29
Figure 13. Percent change in maximum, annual 7-day rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 30
Figure 14. Percent change in winter rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 33
Figure 15. Percent change in spring rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 34
Figure 16. Percent change in summer rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 35
Figure 17. Percent change in fall rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (Bottom), with significant trends shown in blue. 36
Figure 18. Percent change in maximum daily winter rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 38
Figure 19. Percent change in maximum daily spring rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 39

Figure 20. Percent change in maximum summer daily rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 40
Figure 21. Percent change in daily fall rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue....42
Figure 22. Percent change in maximum 7-day fall rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 43
Figure 23. Changes in maximum annual, continuous days of hurricane anomaly. 45
Figure 24. Changes in total annual days of hurricane anomaly. 46
Figure 25. Changes in annual hurricane anomaly. 47
Figure 26. Changes in maximum annual, daily hurricane anomaly. 48
Figure 27. Changes in maximum annual, 7-day total hurricane anomaly. 48
Figure 28. Percent change in annual water yield (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (Bottom), with significant trends shown in blue. 52
Figure 29. Percent change in annual maximum-daily water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 53
Figure 30. Percent change in 7-day maximum water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 54
Figure 31. Percent change in winter water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 56
Figure 32. Percent change in spring water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 57
Figure 33. Percent change in summer water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 58
Figure 34. Percent change in fall water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 59
Figure 35. Percent change in maximum-daily spring water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 61
Figure 36. Percent change in maximum-daily summer water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 63
Figure 37. Percent change in maximum-daily fall water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 64
Figure 38. Maximum fall 7-day total water yield for select HUC-4s. 65

Figure 39. Percent change in annual precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 70
Figure 40. Annual trends in HUC 0712 (Upper Illinois). Precipitation (top), water yield (middle), and precipitation-weighted water yield (bottom). 71
Figure 41. Annual trends in HUC1002 (Missouri Headwaters). Precipitation (top), water yield (middle), and precipitation-weighted water yield (bottom). 72
Figure 42. Annual trends in HUC1112 (Red Headwaters). Precipitation (top), water yield (middle), and precipitation-weighted water yield (bottom). 73
Figure 43. Precipitation-weighted water yield in HUC1009 (Powder-Tongue). 74
Figure 44. NID impoundments in Iowa by completion date (left) and cumulative surface area of NID impoundments in HUC 0511 (green; right). 75
Figure 45. Number and cumulative surface-area of impoundments by decade and by HUC-2 since 1900. 75
Figure 46. Average annual evaporation from NID impoundments. 76
Figure 47. Average-annual potential evaporation from impoundments, by decade. 77
Figure 48. Percentage of average-annual potential evaporation from HUC-4s relative to decadal average-annual rainfall by decade. 78
Figure 49. Percent change in maximum-daily precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for All HUC-4s (bottom), with significant trends shown in blue. 80
Figure 50. Consumptive water use in the conterminous United States (from Moore et al. 2015). 81
Figure 51. Percent change in winter precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 83
Figure 52. Percent change in spring precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 84
Figure 53. Percent change in summer precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 85
Figure 54. Percent change in fall precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue. 86
Figure 55. Seasonal estimates of consumptive water use (from Moore et al. 2015). 88
Figure 56. Change in annual streamflow at index stations with significant trends over the past century. 92
Figure 57. Change in maximum-daily streamflow at index stations with significant trends. 93
Figure 58. Change in winter streamflow at index stations with significant trends. 94
Figure 59. Change in spring streamflow at index stations with significant trends. 94
Figure 60. Change in summer streamflow at index stations with significant trends. 95

Figure 61. Change in fall streamflow at index stations with significant trends.....95
Figure 62. Change in annual total and annual average streamflow at major index stations.....97
Figure 63. Change in maximum daily streamflow at major index stations.....99
Figure 64. Change in seasonal streamflow at major index stations. 100
Figure 65. Change in maximum winter streamflows at major index stations. 101
Figure 66. Change in maximum spring streamflows at major index stations. 102
Figure 67. Change in maximum summer streamflows at major index stations. 103
Figure 68. Change in maximum fall streamflows at major index stations. 104
Figure 69. Median drainage area-weighted $Q_{1.5}$ by HUC-4. 107
Figure 70. Median drainage area-weighted Q_{10} by HUC-4. 107
Figure 71. Median drainage area-weighted Q_{100} by HUC-4. 108
Figure 72. Median suspended-sediment yield at the $Q_{1.5}$ by sub-region (HUC-4). 110
Figure 73. Suspended-sediment load at the $Q_{1.5}$ for the earliest decade of data at sediment index stations (see Table J-2 for dates). 111
Figure 74. Sediment load at the $Q_{1.5}$ for the latest decade of data at sediment index stations (see Table J-2 for dates)..... 111
Figure 75. Change in suspended-sediment load at the $Q_{1.5}$ at sediment index stations, expressed as a percent. Blank areas represent a lack of index stations. 112
Figure 76. Change in suspended-sediment load at the $Q_{1.5}$ at sediment index stations, Expressed in tonnes per day. Blank areas represent a lack of index stations..... 113
Figure 77. Frequency distribution of changes in suspended-sediment load at the $Q_{1.5}$ from sub-regions at sediment index stations. 114
Figure 78. Frequency distribution of annual suspended-sediment yields for all sub-regions (HUC-4s) in the Mississippi River Basin. 115
Figure 79. Median annual sediment yield by gage. 116
Figure 80. Average annual suspended-sediment yield by HUC-4 from gage medians. 117
Figure 81. Changes in median-annual suspended-sediment yields over the period of record by HUC-4. 118
Figure 82. Trends in annual sediment delivery to the Lower Mississippi at major index stations using decadal transport curves (see Table 5 for details)..... 121
Figure 83. Decline in average annual delivery of suspended-sediment to the LMR..... 122
Figure D-1. Average January evaporation from NID impoundments. 142
Figure D-2. Average February evaporation from NID impoundments. 142
Figure D-3. Average March evaporation from NID impoundments..... 143
Figure D-4. Average April evaporation from NID impoundments. 143
Figure D-5. Average May evaporation from NID impoundments..... 144
Figure D-6. Average June evaporation from NID impoundments..... 144
Figure D-7. Average July evaporation from NID impoundments. 145

Figure D-8. Average August evaporation from NID impoundments. 145
Figure D-9. Average September evaporation from NID impoundments. 146
Figure D-10. Average October evaporation from NID impoundments. 146
Figure D-11. Average November evaporation from NID impoundments. 147
Figure D-12. Average December evaporation from NID impoundments. 147

Tables

Table 1. HUC-4s in the Mississippi River Basin. 8
Table 2. HUC-4s with greater than 5% of potential evaporation relative to annual rainfall 78
Table 3. Changes and percent contributions in discharge between 1930 and 2014 from the major (HUC-2) index stations as derived from the linear regressions of annual data 98
Table 4. Decadal average annual sediment delivery to the Lower Mississippi. 119
Table 5. Trends in annual sediment delivery to the Lower Mississippi at major index stations using decadal transport curves. 120
Table A-1. Timeframe for precipitation analysis by HUC-4. 132
Table B-1. Timeframe for water-yield analysis by HUC-4. 134
Table B-2. Timeframe for precipitation-weighted water yield analysis by HUC-4. 135
Table B-3. Index stations selected for calculating suspended-sediment yields at the $Q_{1.5}$ for sub-regions. 136
Table C-1. Number and size of NID impoundments used in this study. 139
Table E-1. Change in annual rainfall by HUC-4. 148
Table E-2. Change in maximum annual daily rainfall by HUC-4. 151
Table E-3. Change in maximum annual 7-day rainfall total by HUC-4. 154
Table E-4. Change in winter rainfall by HUC-4. 157
Table E-5. Change in spring rainfall by HUC-4. 160
Table E-6. Change in summer rainfall by HUC-4. 163
Table E-7. Change in fall rainfall by HUC-4. 166
Table E-8. Change in maximum daily winter rainfall by HUC-4. 169
Table E-9. Change in maximum daily spring rainfall by HUC-4. 172
Table E-10. Change in maximum daily summer rainfall by HUC-4. 175
Table E-11. Change in maximum daily fall rainfall by HUC-4. 178
Table E-12. Change in maximum 7-day fall rainfall by HUC-4. 181
Table F-1. Change in annual water yield by HUC-4. 184
Table F-2. Change in maximum annual daily water yield by HUC-4. 187
Table F-3. Change in maximum annual 7-day water yield totals by HUC-4. 190
Table F-4. Change in winter water yield by HUC-4. 193
Table F-5. Change in spring water yield by HUC-4. 196
Table F-6. Change in summer water yield by HUC-4. 199

Table F-7. Change in fall water yield by HUC-4. 202
Table F-8. Change in maximum daily spring water yield by HUC-4. 205
Table F-9. Change in maximum daily summer water yield by HUC-4. 208
Table F-10. Change in maximum daily fall water yield by HUC-4. 211
Table G-1. Change in annual precipitation-weighted water yield by HUC-4. 214
Table G-2. Change in maximum annual daily precipitation-weighted water yield by HUC-4. 217
Table G-3. Change in winter precipitation-weighted water yield by HUC-4. 220
Table G-4. Change in spring precipitation-weighted water yield by HUC-4. 223
Table G-5. Change in summer precipitation-weighted water yield by HUC-4. 226
Table G-6. Change in fall precipitation-weighted water yield by HUC-4. 229
Table H-1. Change in annual streamflow at index stations with significant trends. 232
Table H-2. Change in maximum annual daily streamflow at index stations with significant trends. 238
Table H-3. Change in winter streamflow at index stations with significant trends. 244
Table H-4. Change in spring streamflow at index stations with significant trends. 250
Table H-5. Change in summer streamflow at index stations with significant trends. 255
Table H-6. Change in fall streamflow at index stations with significant trends. 261
Table I-1. Median drainage area-weighted peak discharge (water yield) ($m^3/s/km^2$) by HUC-4 for all recurrence intervals. 268
Table J-1. Median suspended-sediment yield at the $Q_{1.5}$ for each HUC-4 along with the number of gages and standard error. 271
Table J-2. Suspended-sediment load at the $Q_{1.5}$ showing changes between the first and latest decades of data collection at sediment index stations. Shaded rows denote the downstream-most stations for each region (HUC-2). 273
Table J-3. Median and average annual suspended-sediment loads by HUC-4. 276
Table J-4. Summary of changes in median annual suspended-sediment yields within each HUC-4 for the period of record. 279

Preface

This study was conducted for the US Army Corps of Engineers (USACE) as part of the Mississippi River Geomorphology and Potamology (MRG&P) Program, under Project 127672; "Mississippi River Geomorphology and Potamology Program." The MRG&P is part of the Mississippi River and Tributaries Project and is managed by the USACE, Mississippi Valley Division (MVD), and districts. At the time of publication of this report, the MRG&P Program Director was Dr. James W. Lewis. The MVD Commander was MG R. Mark Toy. The MVD Director of Programs was Mr. Edward E. Belk.

The work was performed by Cardno, Oxford, MS, and the Department of Geography and Environment; University of Southampton; Highfield, Southampton UK.

The work was performed under the direction of the River and Estuaries Engineering Branch of the Flood and Storm Protection Division, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL).

At the time of publication of this report, Mr. David. P. May was Chief of the River and Estuaries Engineering Branch; Dr. Cary Talbot was Chief of the Flood and Storm Protection Division. The Deputy Director of ERDC-CHL was Mr. Jeffrey R. Eckstein, and the Director was Dr. Ty V. Wamsley.

The Commander of ERDC was COL Teresa A. Schlosser, and the Director was Dr. David W. Pittman.

1 Introduction

Background

River management and channel-improvement operations on the Mississippi River are focused on three primary goals: maintaining a navigation channel, flood control, and preservation and restoration of its environmental resources (e.g., fish and wildlife habitats). In recent years, significant hydrologic events have affected the Mississippi River Basin. During the 2011 flood, the peak discharge at Vicksburg was approximately 65,000 cubic meters per second (m^3/s) (2.3 million cubic feet per second [ft^3/s]),[1] which eclipsed the 1927 flood. Historic flood levels were observed along the Mississippi River again in late 2015. At Cape Girardeau, Missouri, flood levels rose above the record crest of the Great Flood of 1993. At St. Louis, Missouri, flood levels were at a record third highest after the 1973 and 1993 floods, respectively.

Flood protection on the Lower Mississippi River (LMR), below where it merges with the Ohio River near Cairo, Illinois, is a major focus of the Mississippi Valley Division (MVD), U.S. Army Corps of Engineers (USACE). An important component of this objective is understanding how peak-streamflow discharges for the LMR have changed with time.

Changes in hydrological conditions have been occurring in the Mississippi River Basin and the rest of the United States for a long time and certainly longer than the period of available data. For this study, the start of the data collection and beginning of the analysis is quite variable but typically coincides with the turn of the twentieth century. Hydrologic changes that affect discharges to the LMR are a result of changes in precipitation and rainfall-runoff relations that play a role in the magnitude and frequency of hydrologic events. Contributing to shifting hydrologic patterns are human-induced changes to the natural environment such as agriculture, urbanization, channelization, and dam construction. The latter affects annual, maximum-daily streamflows in

[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to U.S. Government Publishing Office Style Manual, 31st ed. (Washington, DC: U.S. Government Publishing Office, 2016), 248-52, *https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf*.

every region of the United States but most severely in the Great Plains and Southwest (Fitzhugh and Vogel 2011).

Numerous studies have shown the significance of recent changes in extreme weather events and their impact on peak flows, low-flows, and flooding, etc. Many of the previous studies on trends and variability of precipitation and streamflow have focused on the latter half of the twentieth century over the conterminous United States (e.g., McCabe and Wolock 2002; Sagarika et al. 2014) although Qian et al. (2007) did focus on the Mississippi River Basin. In general, precipitation during that time frame increased (e.g., Pryor and Schoof 2008; de Martino et al. 2013); droughts have become shorter and less frequent, except in the interior of the West (Andreadis and Lettenmaier 2006); pan evaporation decreased (Peterson et al. 1995) while evapotranspiration increased (Szilagyi et al. 2001) from May-October; and annual and monthly moderate-to-low streamflows increased (e.g., Lettenmaier et al. 1994; Lins and Slack 1999; Douglas et al. 2000).

Average, annual increases in precipitation during the period 1982–2011 as compared to 1901–2011 range from 3.7% for the Red River Basin above Alexandria to 6.6% for the Upper Mississippi River above Grafton, Illinois[1]. Peak streamflows, however, are the result of peak rainfall or extreme events. This unpublished report by B. Frederick[1] also shows important increases in heavy-precipitation events (2-day events in excess of the 5-year recurrence interval) since the 1970s with a sharp increase in the 1990s while Kunkel et al. (2013) show the increase to begin the 1960s and similarly jump in the 1990s. Some of the most pronounced increases in heavy rainfall events (more than 30% above the long-term average) have occurred in parts of the Mississippi River Basin encompassed by the upper Midwestern states east of a north-south line defined by Kansas, Nebraska, and the Dakotas (Karl et al. 2009).

It seems however, that discharge increased more in the Mississippi River Basin than increased precipitation alone could explain (Raymond et al. 2008; Zhang and Schilling 2006). Zhang and Schilling (2006) cited land-use changes as a leading cause of increased baseflow and overall streamflow along the Mississippi River since the 1940s. Schilling et al.

[1] B. Frederick, National Weather Service, personal communication, 2018.

(2010) extended that analysis by examining the relationship between streamflow and soybean acreage in the Upper Mississippi Basin.

Other important factors to high streamflow include hurricane landfalls along the Atlantic and Gulf coasts. Some of the most devastating floods of the twentieth century have been related to hurricane landfall (Barlow 2011). Hurricane season in the Atlantic is considered to be June 1 to November 30, with hurricane-related precipitation peaking during mid-August through early October (Larson et al. 2005). In September, the hurricane-related portion of monthly precipitation reaches a maximum of up to 15 percent along the Gulf and East Coasts (Larson et al. 2005). Hurricane-related precipitation is therefore likely to impact streamflows in the Mississippi River Basin, especially during the fall season and when hurricane tracks cross into the interior of the continent.

Imposed changes in flow regime through anthropogenic and natural factors, as well as changes in basin characteristics, result in adjustments to sediment loads and sediment delivery. Both the fine (silt and clay) and coarse (sand and gravel) fractions are important. This is because the fine fraction is generally transported farther downstream, has the ability to transport adsorbed constituents, and can cause downstream water-quality problems. The coarse fraction is important because it is hydraulically controlled, is limited by the transport capacity of the flow, and provides sediment for downstream deposition. Many of the changes in sediment load have involved significant channel erosion in alluvial systems, deposition behind dams, and in many cases has led to the evolution of entire channel systems. Thus, the magnitude and temporal and spatial loci of sediment production and delivery may have changed over the last century from the uplands and fields to the channel systems. As such, this study aims to support the MVD mission by determining how hydrologic variables such as precipitation, streamflow, and sediment contributions have changed over the past century across the Mississippi River Basin.

Objectives

The primary objectives of this work were to compile and interpret data on precipitation, flow and suspended-sediment transport over the period of record for the entire Mississippi River Basin, and to detect and determine regional variations and changes over time and space. In keeping with this overall purpose, the project aimed to evaluate temporal changes in the delivery of water and suspended sediment from the LMR's major tributary

rivers and how those changes contributed to changes in flow and sediment discharge in the LMR. Temporal changes and spatial differences in the production of runoff (flow) and sediment at smaller, sub-regional scales were of particular interest to help identify regional patterns.

Approach

The approach used in this study is entirely empirical. That is, to use available, raw data (collected by United States Government agencies) representing important aspects of the hydrologic cycle and suspended-sediment transport to interpret spatial and temporal variability and changes across the Mississippi River Basin. As such, there is no numerical modeling or modeling data relied on in this study. A benefit of this approach is that any uncertainty related to model algorithms and associated predictions from watershed or climate simulations does not influence interpretations of the data included herein.

To undertake such a large-scale effort, a massive data mining and analysis approach, coupled with a logical hydro-geographic framework, was required. A similar approach, using Level-III Ecoregions as differentiators of regional hydrology and sediment-transport characteristics, was used to investigate regional differences in the 1.5-year flow ($Q_{1.5}$) and suspended-sediment sediment yields Simon et al. (2004) and by Simon and Klimetz (2010). The Level-III Ecoregion framework is a preferred method of the U.S. Environmental Protection Agency. This system groups areas of similar geology, soils, vegetation, climate, wildlife, land use, and hydrology (Omernik 1995; Omernik and Griffith 2014). Within the continental United States, there are 105 Level-III ecoregions, with the Mississippi River Basin encompassing 41 of these ecoregions.

Results of ongoing research on trends in annual precipitation conducted by MVD are in general agreement with the findings of Simon and Klimetz (2010), showing a moderate increase in precipitation across the region. Recently, Rice et al. (2016) examined streamflow over the continental United States from 1940 to 2009 using a frequency domain method and summarizing results at the scale of Level-II Ecoregions. However, since the objectives of this study focus on the delivery of water and sediment as well as flood protection and conveyance, a drainage basin approach was deemed more appropriate, and the concept of hydrologic units was adopted. Further, these previous efforts were geographically based,

focusing on determining regional differences and not change with respect to time as this current study is.

Data mining and analyses were conducted in the context of using a range of hydrologic metrics that could be used to enhance knowledge of spatial and temporal trends to inform river managers charged with flood protection. As described in the following paragraphs, this required the use of a range of spatial scales and parameterizing aspects of hydrology (precipitation and discharge) related to the production of peak flows.

The data employed in this study and the associated analysis relies on fundamental hydrologic data that are presented in logical order as might occur on the landscape:

1. rainfall being supplied to the landscape
2. runoff production (flow or stream discharge)
3. evaporation from impoundments
4. production of suspended sediment.

Thus, this report starts with an analysis of precipitation across the basin, looking at a range of metrics to characterize magnitude and distribution. These include annual and seasonal totals as well as maximums over a range of durations. Discharge is evaluated in terms of absolute values from the downstream-most stations and as a water yield (per unit drainage area) and as a water yield per unit precipitation for all stations. These flow metrics are again analyzed as average-annual and seasonal values, as well as peak discharges and yields over a range of durations (1 to 7 days). Evaporation is evaluated on an annual basis from impoundments within selected regional areas (defined below).

Finally, sediment production and yields (loads per unit area) are investigated using metrics related to average, annual values distributed across the basin and as loads at the $Q_{1.5}$. Less suspended-sediment data are available than for either precipitation or discharge limiting analysis of temporal trends to decadal rends and overall changes.

Spatial divisions

The continental United States is divided into 18 major drainage basins or hydrologic units by the U.S. Geological Survey (USGS) and further subdivided into sub-regions, accounting units, and cataloging units. Each

hydrologic unit is identified by a hydrologic unit code (HUC) that consists of 2 to 14 digits based on the level of classification. Smaller HUCs represent larger regions while larger unit HUCs represent respective smaller sub-regions and cataloging units that are nested within the regional HUC. For example, the largest sub-basins such as the Ohio and Missouri Rivers are cataloged as HUC-2s. Boundaries of a HUC are defined by topographic as well as hydrographic criteria that delineate an area upstream of a river, stream or similar surface waters. In addition to precipitation falling directly on a HUC, a HUC can accept surface water directly from upstream drainage areas.

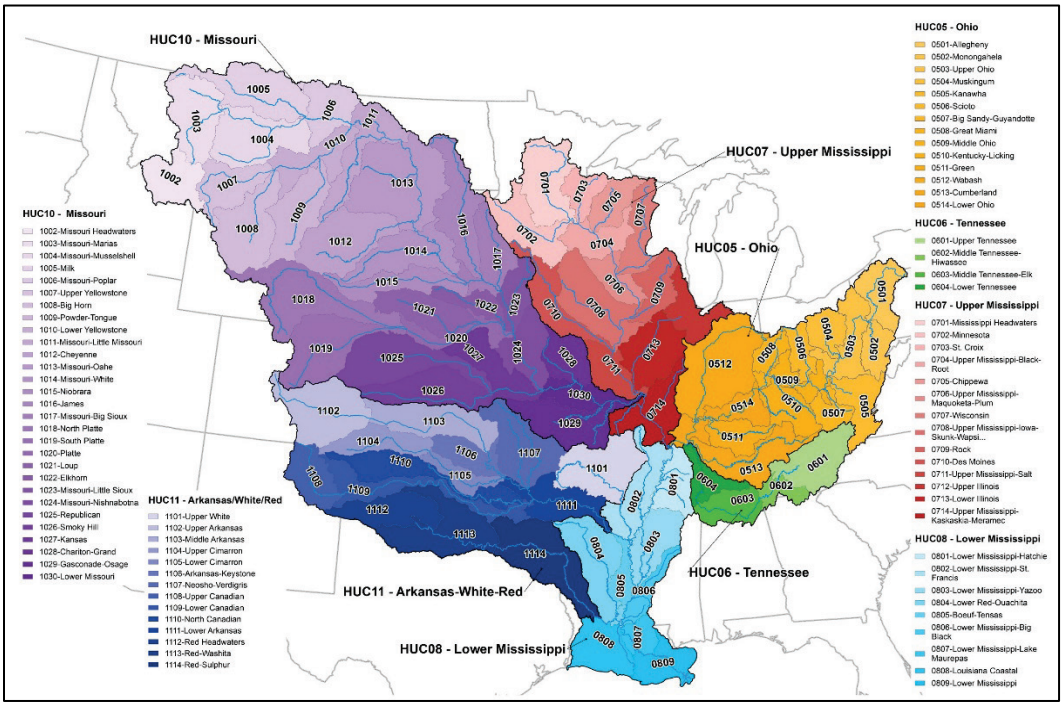
The LMR receives flow and materials from its major tributary basins including the following (Figure 1):

- HUC-02: Upper Mississippi River
- HUC-05: Ohio River
- HUC-06: Tennessee River
- HUC-10: Missouri River
- HUC-11: Arkansas, White, and Red Rivers.

Other, smaller tributaries such as the Yazoo River drain directly to the LMR.

To better understand the temporal and spatial distribution of hydrologic and sediment contributions to the LMR, results are summarized at the regional (HUC-2) and sub-regional (HUC-4) levels, of which there are 84 in the Mississippi River Basin (Figure 1; Table 1). The geographic location of an individual gage determines its associated HUC-4, regardless of the size of the drainage area. For example, both the Mississippi River gage at Vicksburg, Mississippi (USGS 07289000), with a drainage area of 2.95 million square kilometers (km^2), and Clear Creek in Oxford, Mississippi (USGS 07271000), with a drainage area of 26.7 km^2, fall into HUC 0803, the Lower Mississippi-Yazoo.

Figure 1. Major hydrologic regions (2-digit hydrologic unit codes) and sub-regions (4-digit hydrologic unit codes) of the Mississippi River Basin.



Sub-regional results of streamflow in this study are presented as water yields to make comparisons of streams of different drainage areas appropriate. Traditionally, water yield was used in forestry and agricultural settings to describe the amount of runoff generated per unit area, per unit time as a depth (e.g., Hibbert 1969; McMinn and Hewlett 1975; Bosch and Hewlett 1982; Hornbeck et al. 1993). For example, Stednick (1996) summarized results of watershed studies in the Central Plains that suggest 100% harvesting of a forested watershed resulted in 306–752 millimeter (mm) increases in annual water yield. Here, water yield is presented in units of $m^3/s/km^2$ so that data from basins of different sizes can be readily combined to obtain a value for a larger region (e.g., a HUC). Once water yields are generated for a given flow parameter (i.e., peak value, annual value), median values representative of the HUC-4 are computed as long as there are three or more gages within a given HUC-4 for a given year (or season). Years or seasons of a given year with fewer than three gages (for that period) were excluded from sub-regional analyses.

Table 1. HUC-4s in the Mississippi River Basin.

HUC-4	HUC-4 Name
0501	Allegheny
0502	Monongahela
0503	Upper Ohio
0504	Muskingum
0505	Kanawha
0506	Scioto
0507	Big Sandy-Guyandotte
0508	Great Miami
0509	Middle Ohio
0510	Kentucky-Licking
0511	Green
0512	Wabash
0513	Cumberland
0514	Lower Ohio
0601	Upper Tennessee
0602	Middle Tennessee-Hiwassee
0603	Middle Tennessee-Elk
0604	Lower Tennessee
0701	Mississippi Headwaters
0702	Minnesota
0703	St. Croix
0704	Upper Mississippi-Black-Root
0705	Chippewa
0706	Upper Mississippi-Maquoketa-Plum
0707	Wisconsin
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon
0709	Rock
0710	Des Moines
0711	Upper Mississippi-Salt
0712	Upper Illinois
0713	Lower Illinois
0714	Upper Mississippi-Kaskaskia-Meramec
0801	Lower Mississippi-Hatchie
0802	Lower Mississippi-St. Francis
0803	Lower Mississippi-Yazoo
0804	Lower Red-Ouachita
0805	Boeuf-Tensas
0806	Lower Mississippi-Big Black
0807	Lower Mississippi-Lake Maurepas
0808	Louisiana Coastal
0809	Lower Mississippi
1002	Missouri Headwaters

HUC-4	HUC-4 Name
1003	Missouri-Marias
1004	Missouri-Musselshell
1005	Milk
1006	Missouri-Poplar
1007	Upper Yellowstone
1008	Big Horn
1009	Powder-Tongue
1010	Lower Yellowstone
1011	Missouri-Little Missouri
1012	Cheyenne
1013	Missouri-Oahe
1014	Missouri-White
1015	Niobrara
1016	James
1017	Missouri-Big Sioux
1018	North Platte
1019	South Platte
1020	Platte
1021	Loup
1022	Elkhorn
1023	Missouri-Little Sioux
1024	Missouri-Nishnabotna
1025	Republican
1026	Smoky Hill
1027	Kansas
1028	Chariton-Grand
1029	Gasconade-Osage
1030	Lower Missouri
1101	Upper White
1102	Upper Arkansas
1103	Middle Arkansas
1104	Upper Cimarron
1105	Lower Cimarron
1106	Arkansas-Keystone
1107	Neosho-Verdigris
1108	Upper Canadian
1109	Lower Canadian
1110	North Canadian
1111	Lower Arkansas
1112	Red Headwaters
1113	Red-Washita
1114	Red-Sulphur

Temporal divisions

Temporal variability was evaluated over the entire period of record as the difference between conditions at the beginning and end of the recorded period (i.e., 1900-present). Throughout this investigation, a variety of temporal scales were used to parameterize the hydrologic data, ranging from instantaneous peaks for the outlets of the major HUC-2 basins to annual values of water yield. Throughout this study, calendar years were used. Seasonal trends are an important metric for river management to identify precipitation and associated changes in flow throughout a year. The four seasons are defined as follows:

- Winter: December (from previous year) – February
- Spring: March – May
- Summer: June – August
- Autumn: September – November.

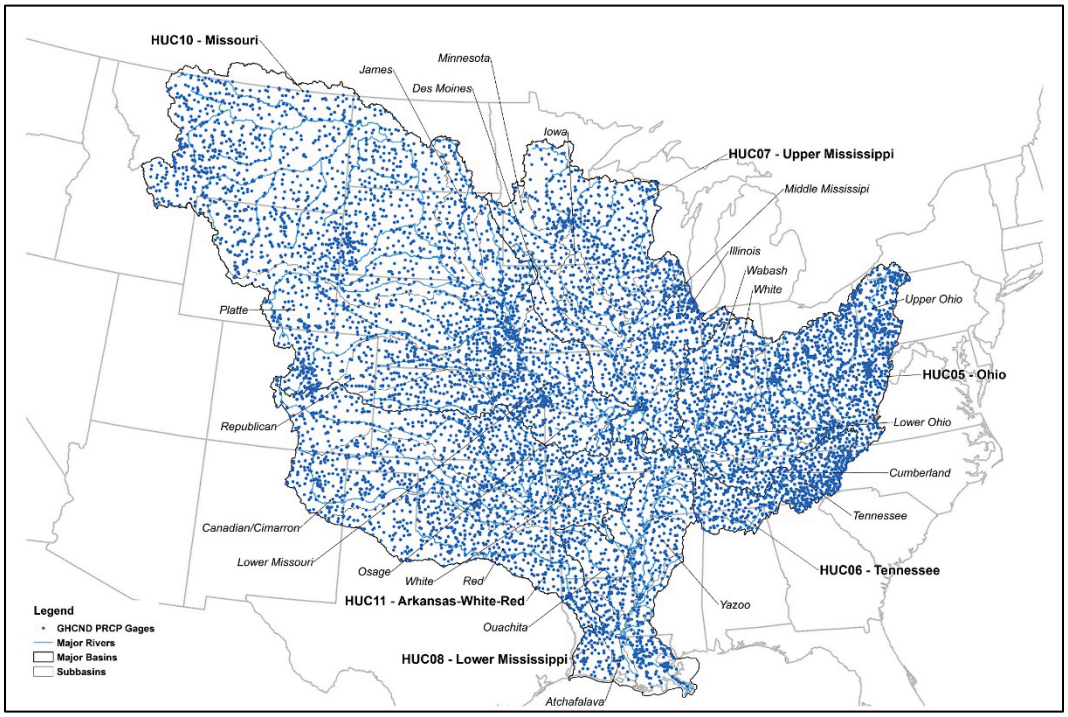
Given that this study is also focused on peak-flow values and how they relate to discharges in the LMR, maximum flow rates over 1, 3, 5, and 7 days were also investigated. Focus is given to the 1-day and 7-day totals. Insight into the general timing of annual peak discharges is obtained from analysis of seasonal extreme discharges.

2 Data Requirements, Sources, and Availability

Daily precipitation data

The fundamental data unit for precipitation that was available for this study was daily climate data, some dating back to the mid- to late-1800s and available through the Global Historical Climatology Network-Daily (GHCND). These were accessed online through the National Oceanic Atmospheric Administration (NOAA) National Climatic Data Center. The entire GHCND database was downloaded, and data for all stations within the study area were extracted for the parameter PRCP (precipitation). Figure 2 shows the location of the 6,815 GHCND precipitation gages with at least one complete calendar year of data that were used in this study. (Additional information on the GHCND database and its contents are available online at http://www1.ncdc.noaa.gov/pub/ data/ghcn/daily/ghcnd-stations.txt). A complete list of GHCND gages used in this study can be found in Appendix A.

Figure 2. Location of GHCND precipitation gages used in this study.



Mean-daily streamflow and peak-annual streamflow

Mean-daily discharge data were obtained through batch downloads using the U.S. Geological Survey (USGS) Water Services Tool (https://waterservices.usgs.gov/rest/DV-Test-Tool.html). There are 6,186 flow stations with at least one complete calendar year of data within the study area (Figure 3). For the majority of these gages, the drainage or contributing area to the gage is published. Where drainage areas were not defined, areas were estimated using either the USGS online tool, StreamStats version 4 Beta Application (https://streamstatsags.cr.usgs.gov/streamstats/) or for smaller basins, delineating the basin area using a geographic information system (GIS). Additional mean-daily discharge data at gages along the Mississippi River main stem were obtained through the USACE River Gages website (http://rivergages.mvr.usace.army.mil/ WaterControl/new/layout.cfm).

Instantaneous, peak-annual discharge data are available at 8,210 USGS gages. However, only 7,118 gages have at least 10 annual observations, which was considered the minimum number required for flood frequency analysis (Figure 4). (A complete list of USGS gages used in this study can be found in Appendix B.)

Figure 3. Location of USGS mean-daily streamflow gages used in this study.

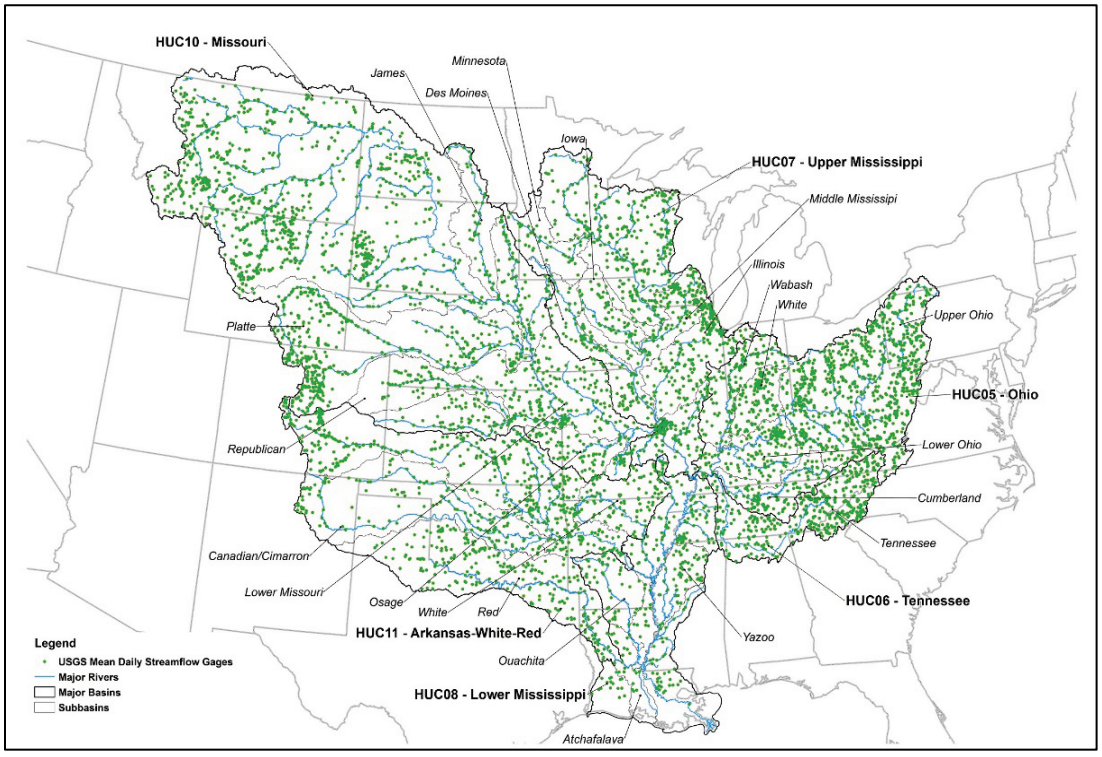
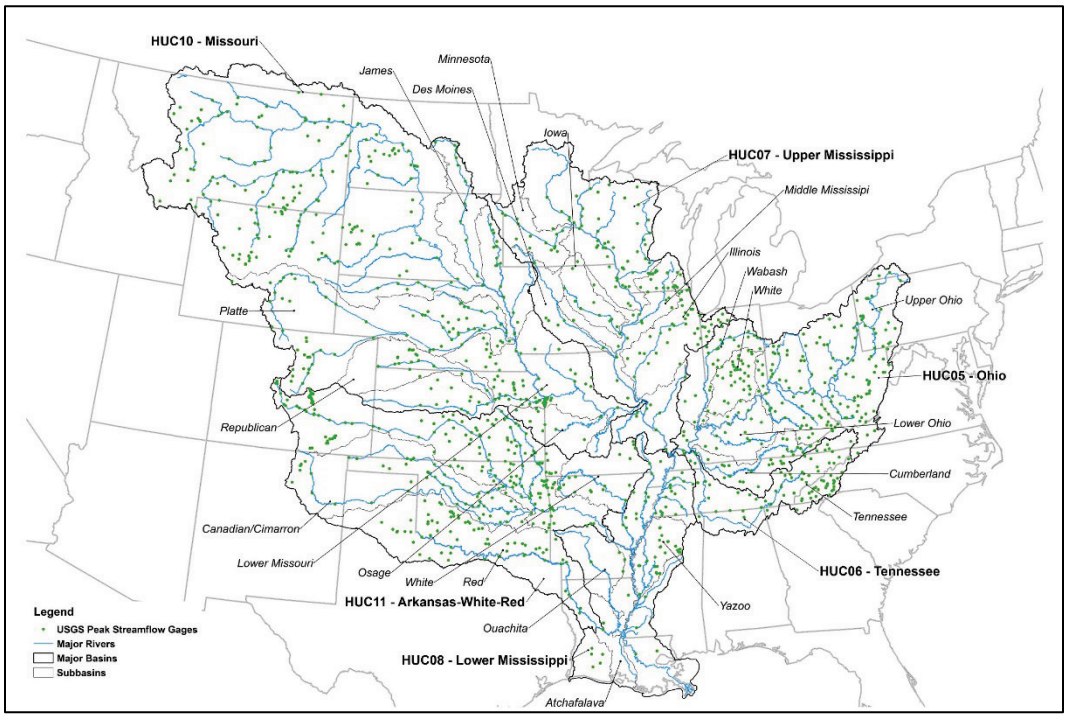


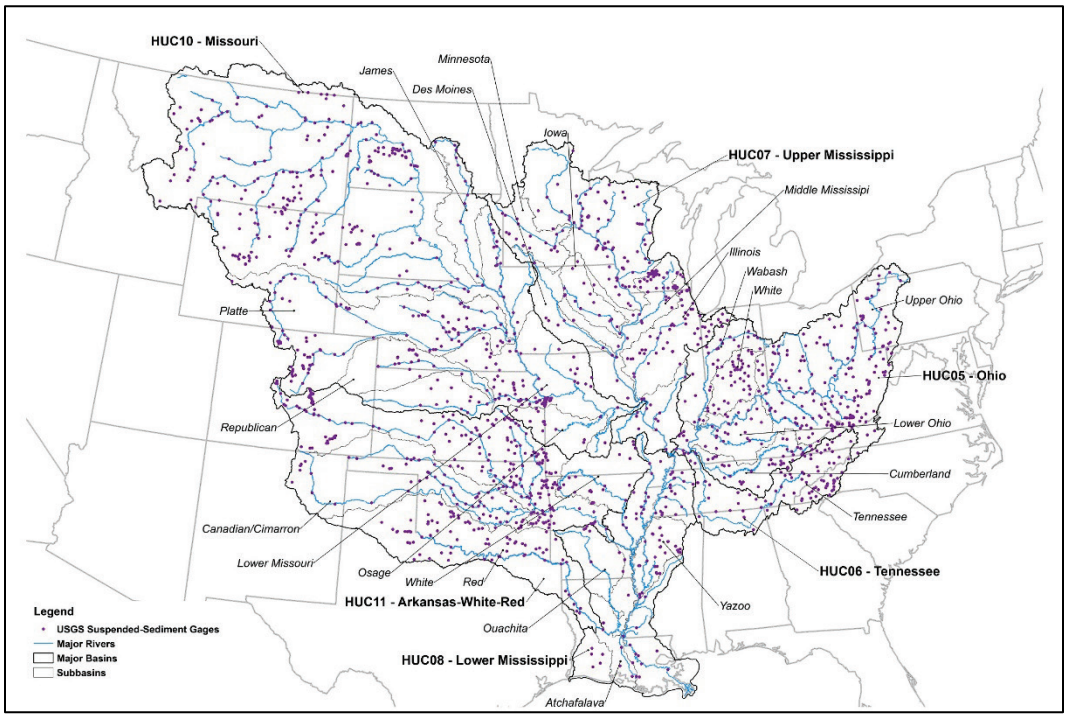
Figure 4. Location of USGS peak-streamflow gages used in this study.



Suspended-sediment concentrations

To analyze the spatial distribution of suspended-sediment loads and to investigate how these have changed with time, it was decided to use the raw concentration and associated discharge data from the time of sampling. Discrete suspended-sediment concentration with corresponding instantaneous flow data was obtained using the USGS Sediment Data Portal (https://cida.usgs.gov/sediment/). Within the study area, there are 1,638 gages with at least 10 samples (Figure 5), which was considered the absolute minimum number required for generating sediment transport-rating relations. Figure 5 shows location of all sediment stations used in this study. (See Appendix B for a complete list of USGS sediment stations used in this study.)

Figure 5. Location of USGS suspended-sediment stations used in this study.



National inventory of dams

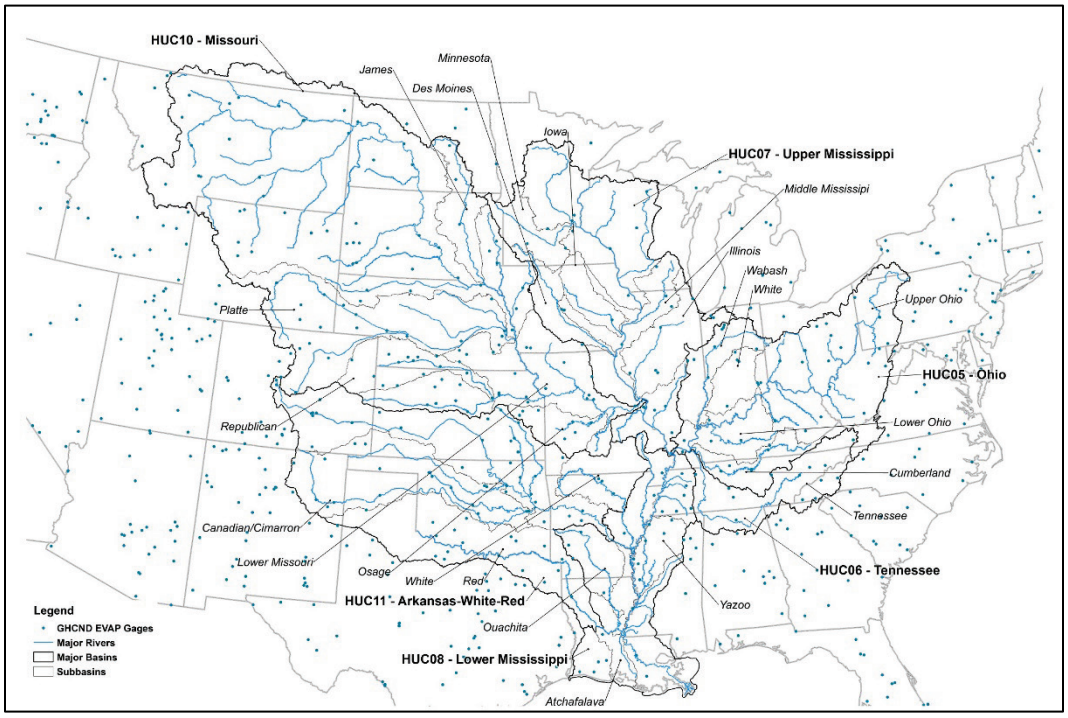
Information on the location, characteristics, and construction date of dams is important to the investigation both in terms of understanding changes in flow regimes at particular gages and in determining their role in trends in evaporation and water yield. These data were obtained from the USACE National Inventory of Dams (NID). Within the study area there are 13,629 impoundments listed in the NID database with published completion dates and data on the surface area of impounded water. This excludes privately owned dams and only considers dams owned by the federal, state, or local government(s) as well as those owned by public utilities or whose ownership type is not listed. The impoundments (at normal pool) from the dams in this database and used in this study range in size from the Lake Afton Dam in Kansas at 0.00004 km^2 (KS02553) to Bull Shoals in Arkansas, at 1,839 km^2 (AR00160). (A list of the number and size of NID impoundments used in this study within each HUC-4 can be found in Appendix C.)

Daily pan-evaporation observations

To achieve a better understanding of the role of impoundments in altering hydrology and water availability, evaporation data were required across

the basin. In addition to precipitation data, the GHCND database contains Class A pan-evaporation observations stored under the parameter EVAP. Pan evaporation is an empirical measurement of evaporation, which is a function of temperature, wind, humidity, and solar radiation. This parameter can be used to estimate evaporation from open bodies of water (WMO 1966; Farnsworth and Thompson 1982). Unlike GHCND precipitation data, pan-evaporation data from the entire continental United States were used, with 830 gages having sufficient data for this study (Figure 6). (The GHCND pan-evaporation gages used in this study can be found in Table A1 in Appendix A.)

Figure 6. Location of GHCND pan evaporation gages used in this study.



Geospatial data

Additional sources of geospatial data were obtained from the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) Geospatial Data Gateway (https://datagateway.nrcs.usda.gov/). This included delineations of HUC-2s and HUC-4s from the USGS Watershed Boundary Dataset as well as 1:24,000 hydrography networks. All spatial data presented in this study are projected using the Albers equal-area conic projection, USGS version.

3 Methodology

Precipitation analysis

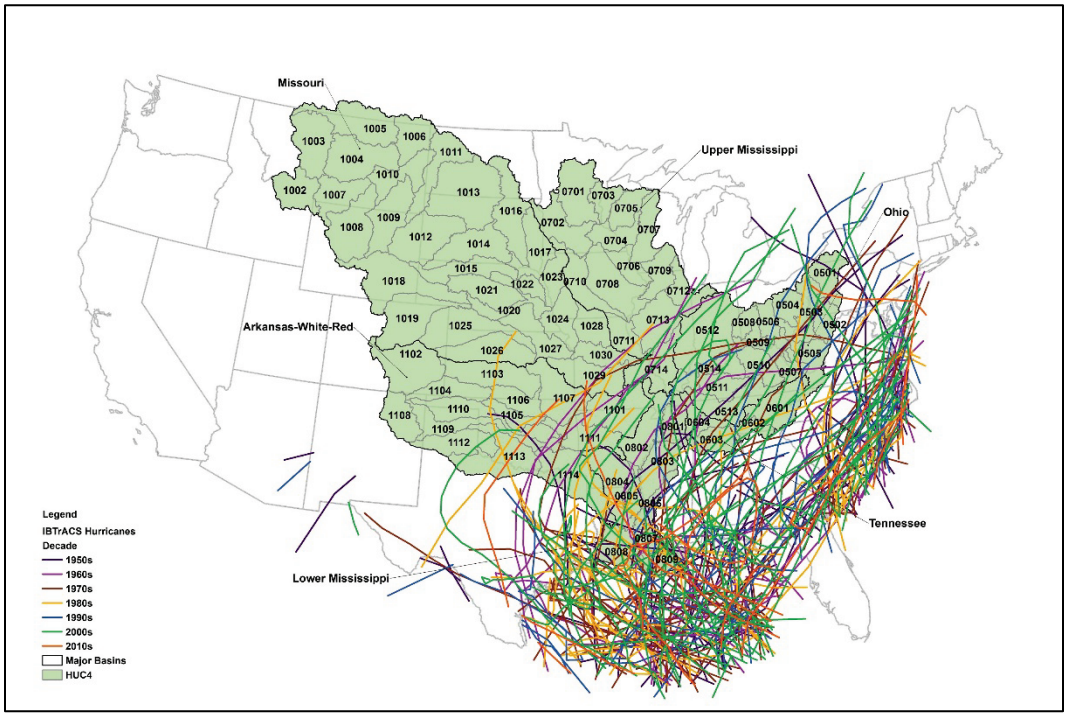
To evaluate changes for a variety of precipitation metrics, only GHCND gages within the study area with complete calendar years of data were used in the analysis. For each complete year of record, annual totals and maximum values (1-day, 3-day, etc.), and seasonal totals and their respective maximum values were computed as discussed in the earlier section Geospatial and Temporal Context. For a given year or season, if there were three or more gages with data within the HUC-4, a median precipitation value was calculated and included in the analysis. A minimum of 30 (non-continuous) annual or seasonal values were required for trend analysis. Table A-1 in Appendix A lists the minimum, maximum, and total number of years with three or more usable precipitation gages.

Evidence of changes in the frequency and intensity of hurricanes that impact the Gulf and east coasts of the United States provided impetus to investigate their influence on precipitation trends and patterns in parts of the Mississippi River Basin. Barlow (2011) examined the influence of hurricanes in the continental United States during the period 1975–1999 and demonstrated that the impact of hurricanes extends well beyond coastal areas and into the mid-continent. During this 25-year period, the Gulf Region experienced the greatest number of days with heavy precipitation exceeding 101.6 mm (4 inches [in.]). The percentage of these days in the Gulf Region that were associated with hurricanes, however, ranged from 67% to less than 33%. Along the east coast and up into the Ohio River Basin, the percentage of heavy precipitation days associated with hurricanes was often greater than 67%.

Hurricane-related rainfalls were estimated following the methodology outlined in Darby et al. (2013, 2016) using the NOAA International Best Track Archive for Climate Stewardship (IBTrACS) database (version v03r02) (Knapp et al. 2010; available online: https://www.ncdc.noaa.gov/ibtracs/). IBTrACS was used to locate the paths of all recorded hurricanes (at daily time-steps) intersecting or passing near the Mississippi Basin for the available period of record, 1950–2014 (Figure 7). The IBTrACS data comprise six hourly best-track positions and intensity estimates. Only storms designated as being in a tropical phase with 1-minute maximum,

sustained surface-wind speeds exceeding 34 knots (17.5 m/s) are included in the analysis.

Figure 7. Hurricane tracks affecting the Mississippi River Basin (1950–2014).



Rainfall anomalies associated with these storm paths were defined by first interpolating, using the nearest neighbor, daily rainfall values observed at a network of 151 precipitation stations across the Mississippi River Basin onto a 0.1° (~11 km²) resolution grid. Next, all rainfall stations located within a 500 km search radius (Rodgers et al. 2000; Englehart and Douglas 2001) from the centroid of the storm on that date were identified. These identified stations were then temporarily (for the specific time-step) removed from the analysis, and an updated rainfall surface (minus the identified stations) was re-interpolated onto the same 0.1° grid. A rainfall anomaly surface, representing estimated rainfall associated with the identified storm and time-step, was then obtained by differencing the original and updated surfaces. This process was repeated for each daily time-step, allowing the observed rainfall series at each meteorological station to be adjusted by subtracting rainfall anomalies within the grid square specific to each gage from the observed daily rainfall totals.

Trend analysis of hurricane-related rainfall anomalies was conducted at a given GHCND gage if it was impacted by hurricanes during 10 or more non-sequential years. In addition to examining annual-total and annual-

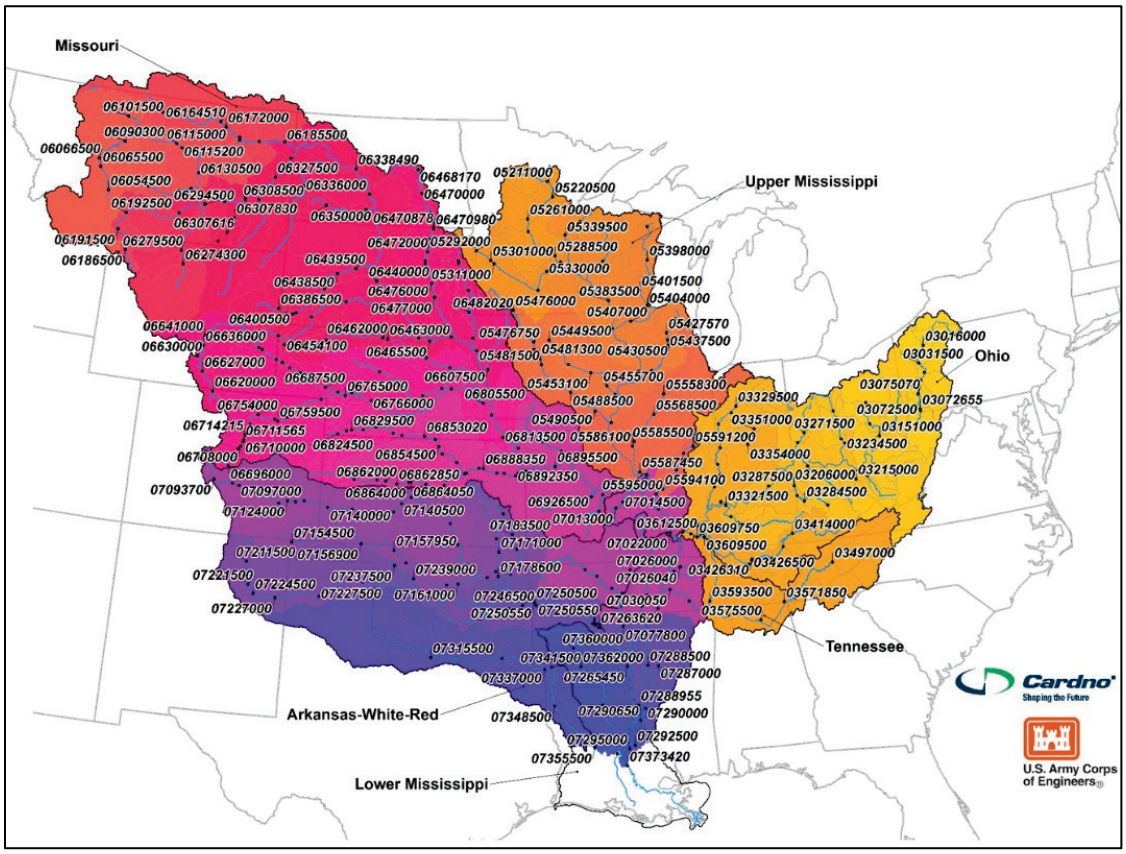
maximum total trends, trends in the total number of days of hurricane anomaly and maximum number of consecutive days of anomaly were investigated.

Streamflow analysis

To evaluate changes in absolute values of water discharge (not water yield) provided at the outlets of each HUC-4 and particularly the HUC-2's, trends in streamflow (in m^3/s) were examined at select *index* stations. These stations were chosen based on their location along the major rivers or tributaries, period of record, and approximate drainage area. Where drainage area was approximately equal to the drainage area of its encompassing HUC-4 or if smaller, the first upstream gage with an adequate record was selected. Approximately 400 gages where chosen to represent regional (HUC-2) and sub-regional (HUC-4) changes in streamflow (Figure 8). Annual streamflow and seasonal streamflows were computed as the sum of the mean-daily flows in each period.

Several of the index stations represent the major HUC-2 basins draining to the LMR and include the Missouri River at Hermann, Missouri (USGS 06934500), Ohio River at Metropolis, Illinois (USGS 03611500), and the Mississippi River at Thebes, Illinois (USGS 07022000). In general, the relative contributions of streamflow to the Mississippi River from its major rivers and tributaries are well known. The majority of the streamflow to the LMR (~60%) originates in the Ohio River Basin. Contributions from the Upper Mississippi River (including the Illinois River) was computed as the difference between flows at Thebes, Illinois, and Hermann, Missouri. The USACE gage at Hickman, Kentucky (MS113D), was chosen to represent the flows at the upstream boundary of the LMR just below the confluence with the Ohio River. Meanwhile, flows at the USACE gage at Tarbert Landing, Louisiana (01100Q), were used to represent flows along the LMR, downstream of the confluence with the Arkansas River and the Old River Control Complex.

Figure 8. Location of streamflow index stations.



Calculation of water yield and precipitation-weighted water yield

Water yield, the amount of runoff (or discharge) per unit drainage area, is a convenient metric to compare stations of different sizes providing a measure of runoff production for a given area. Temporal trends in water yield reflect hydrologic changes resulting from the combined effects of changing precipitation regimes as well as landscape and direct changes imposed by humans.

As with precipitation, a minimum of three gages were needed to determine annual or seasonal values of water yield for a given HUC-4, and a minimum of 30 non-continuous years of median values were required for trend analysis. All HUCs, except HUC-0809, had sufficient data for analyses of water yield. Data collection at many of these gages started approximately at the beginning of the twentieth century, providing a 100-year record of flows. Another large group of stations were initiated in the 1930s. The timeframe for the water-yield analysis for each HUC-4, based on the period of record of the gages contained within their boundaries, is summarized in Table B-1 in Appendix B.

To reveal the level of anthropogenic effects on changes in discharge and runoff production and potentially, sediment yields, water yield was normalized (divided) by total annual precipitation, thus removing the influence of altered precipitation regimes. Since precipitation-weighted water yield relies on coupled observations of flow and precipitation, the timeframe for analysis is slightly different from the separate precipitation and water-yield analyses. These are listed in Table B-2 in Appendix B.

Trend analyses

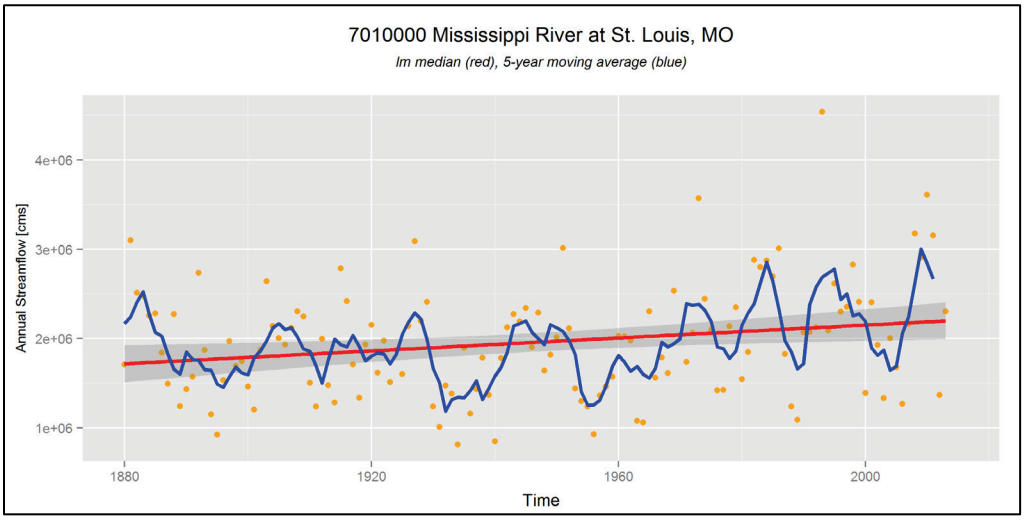
Temporal changes over the period of available data within each HUC-4 were assessed using statistical analyses of monotonic trends. Such analyses provide an indication of the magnitude and direction of changes at specific stations that, when taken collectively, can explain net changes at the HUC-4 scale. More importantly, this analysis provides evidence as to whether computed trends are reliable (statistically significant).

Monotonic trends (increases or decreases without reversals) of annual and seasonal data were determined using the Kendall tau test at a significance level (p-value) of 0.05. The Kendall tau trend test is a non-parametric test based on Kendall's tau statistic (Kendall 1975) with a continuity correction and was implemented using the statistical package R using the function kendallTrendTest in the package EnvStats (Millard 2013). It is a common metric utilized by the USGS to assess trends in water quality (Hirsch et al. 1982; Hirsch and Slack 1984) and is suitable for detecting trends in hydrological time series, which are typically skewed and contain outliers. In the test, the null hypothesis is that tau is equal to zero while the alternative hypothesis is that the true tau is not equal to zero, where positive values of tau indicate an increasing monotonic trend and negative values indicate a decreasing trend. The test statistic itself is z, and the p-value of z allows the user to accept or reject the null hypothesis.

To quantify the magnitude and rate of change over the period of record, a robust linear regression was fit through the data, and the difference between the first and last years of record were estimated from the linear fit. This procedure was selected rather than simply taking the difference between the first and last points, one of which could potentially be an outlier. The robust linear regression (function *rlm*) was implemented using the *R* library *MASS* (Venables and Ripley 2002). For example, annual streamflow for the Mississippi River at St. Louis, Missouri, significantly increased ($p < 0.05$) between 1863 and 2013 by

approximately 438,000 m^3/s based on the linear trend shown in red (Figure 9).

Figure 9. Annual streamflow along the Mississippi River at St. Louis, Missouri.



Peak-streamflow analysis

To obtain an understanding of the spatial distribution of instantaneous peak flows, frequency statistics for gages with greater than 10 annual-peak observations were batch calculated using a program written in *R*. For quality assurance, the program was first made to replicate results from the Excel workbook FreqCurves_ver306.xlsm (available online: http://go.usa.gov/KS6). This was developed by the NRCS Water Quality and Quantity Technology Development Team, which reproduced the results from Bulletin 17b, *Guidelines for Determining Flood Flow Frequency* (Interagency Advisory Committee on Water Data 1981).

Flows at the 1.5-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals were computed for each gage using the entire period of record. Once frequency estimates were computed for all gages, results were normalized by drainage area then summarized by HUC-4.

Annual-evaporation rates

To provide a simple evaluation of the role of dams on water losses due to evaporation, an investigation was carried out to combine information on the total surface area impounded at *normal pool* with available data on evaporation rates. There are 791 GHCND stations in the continental United States with sufficient pan evaporation data (see Appendix A). Note

that gages within the Mississippi River Basin are assigned a 4-digit HUC; elsewhere, the HUC-4 is listed as "NA." The methodology used was based on the original methodology of Farnsworth et al. (1982) (TR-34). Months with fewer than 20 observations were excluded from the analysis. Individual monthly sums were computed by multiplying the daily average evaporation by the number of days in the month. Monthly evaporation means were computed for months with greater than 5 years of record.

In TR-34, annual average evaporation totals were computed as the sum of the individual monthly means. However, in this study, the focus was estimation of evaporation from NID impoundments. As such, kriging with maximum GHCND EVAP values was used to estimate monthly evaporation averages at each NID impoundment. Annual average evaporation totals were then summed from the individual monthly evaporation estimates. Average annual evaporation volumes were then computed by multiplying the published surface area by the evaporation rate.

Annual evaporation volumes at the HUC-4 level were computed by summation of the cumulative evaporation volume for all NID impoundments within the HUC. For simplicity, it was assumed that the annual evaporation volume at each impoundment was static over time and would count towards the total evaporation volume from the HUC after the published year of completion.

Assuming pan evaporation is a perfect estimator of potential evaporation, inferences about actual evapotranspiration can be made by the following:

$$\boldsymbol{ET = 2ET_W - E_p} \quad (1)$$

where:

ET_W = wet-surface evapotranspiration
E_p = potential evaporation.

Determination of annual suspended-sediment yields

Annual suspended-sediment yields at the sub-regional (HUC-4) level were determined using two separate methods. The first method involved calculating the suspended-sediment yield at a discharge that could be used to compare with other sites and that represented a meaningful geomorphic condition. The discharge selected for this purpose was the $Q_{1.5}$, a flow rate that is commonly used to represent the "effective discharge" (Leopold et al.

1964; Dunne and Leopold 1978; Williams 1978; Castro and Jackson 2001; Simon et al. 2004). Of course, there can be substantial variability around this average value (Williams 1978), but it has been shown to be a good measure of this parameter for ecoregions across the United States (Simon et al. 2004). To calculate representative sediment yields at the $Q_{1.5}$ for each sub region (HUC-4), the following procedure was used:

- Select an *index* station for each of the HUC-4 sub-regions representing the most downstream site with an extensive data set
- Develop a first-approximation sediment-transport rating using a single power function from instantaneous discharge and concentration data
- Solve the resulting sediment-transport relation using the $Q_{1.5}$ for that station
- Divide by drainage area to obtain a suspended-sediment yield in tonnes per year per square kilometer ($t/y/km^2$).

Using a constant value of flow frequency allowed direct comparison between sites and sub-regions as well as investigating how suspended-sediment yield had varied at a single site (sub-region) over time. The earliest sampled decade for index stations representing the HUC-4s is the 1930s. Many regions do not have sufficient sampling to determine temporal trends until the 1970s. A list of these stations and their applicable decades is provided in Table B4 in Appendix B.

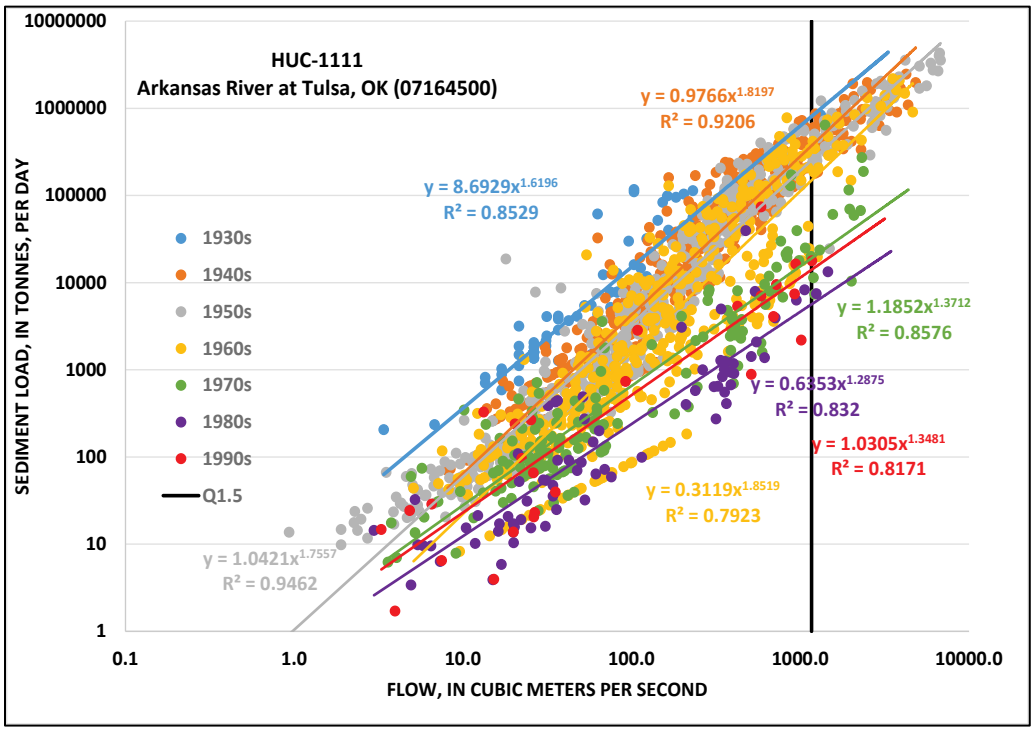
The sediment station in each HUC-4 with the greatest drainage area, greatest number of suspended-sediment samples, and longest period of record was selected at the representative index station. Transport ratings were developed for each decade of available data to determine whether the transport ratings were shifting (changing) with time. Examples from the Arkansas and Missouri Rivers are shown in Figure 10. The change in sediment load can be easily visualized by noting where the black vertical line (representing the $Q_{1.5}$) crosses each regression line. Using results from only the first and last decades of suspended-sediment observation, load (and yield) at the $Q_{1.5}$ was computed to quantify net change over the period. If a sediment station did not have a calculated $Q_{1.5}$ value from the peak-flow analysis at the same gage, the $Q_{1.5}$ was estimated based on a relation between drainage area and $Q_{1.5}$ for gages within the corresponding HUC-4.

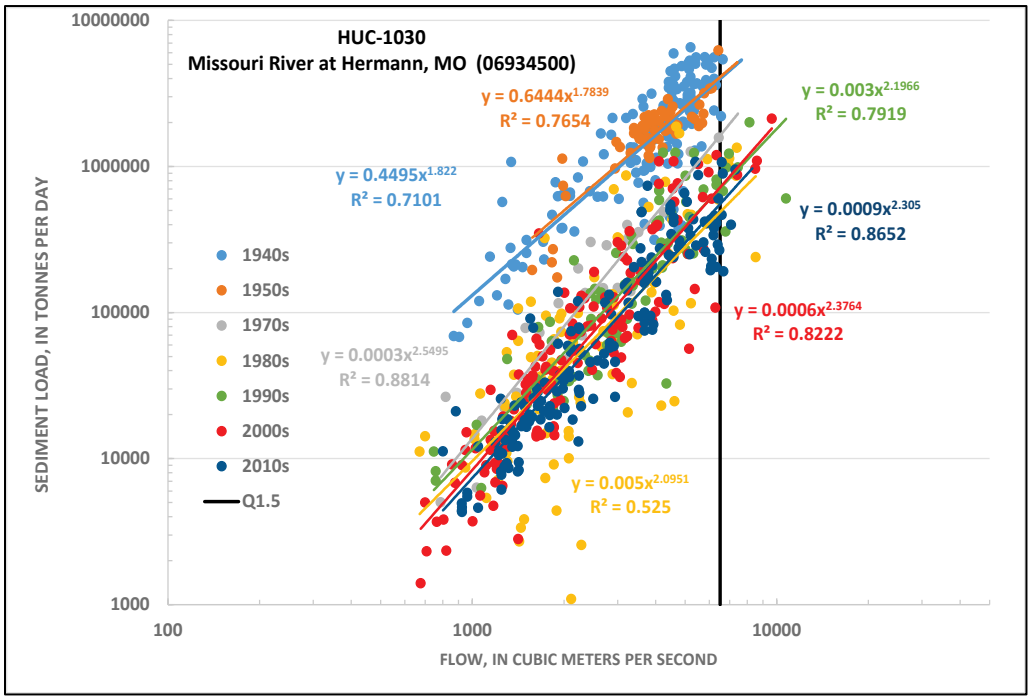
The second method was aimed at providing mean-annual suspended-sediment loads and yields for each sub-region to obtain a spatial

distribution of sediment contributions across the basin. In this case, suspended-sediment transport ratings were developed for every sediment station in the database. Instead of automatically accepting the first-approximation rating relation based on a single power function, every relation was visually inspected to determine if in fact, a more accurate representation of the general relation between flow and concentration could be attained using several linear segments (in log-log space). Where necessary, the rating relations were adjusted using one or more additional segments. For sediment stations with associated mean-daily flows (minimum of one complete year), daily sediment loads were calculated. These values were then summed for each year to obtain annual loads, divided by the number of years to obtain an average, and then divided by drainage area to obtain average, annual sediment yield for each station. To then characterize suspended-sediment yields at the HUC-4 level, the median value from all of the stations in the sub-region was reported.

The data set of sampled suspended-sediment concentrations at each station was considered sufficient if there was a minimum of 10 observations and if the maximum sampled flow was at least 75% of the calculated or estimated $Q_{1.5}$.

Figure 10. Examples of decadal shifts in sediment-transport ratings (including equations) from index stations along the Arkansas (top) and Missouri Rivers (bottom). The vertical black line represents the $Q_{1.5}$.





4 Results and Discussion

Precipitation trends

Annual trends

Results show that over the past century there have been important increases in average annual precipitation across the Mississippi River Basin. Statistically significant trends of increasing precipitation (at the 0.05 level) are typically in the order of 10%–25% (Figure 11, top right), ranging from 53.6 to 232 mm more annual rainfall now than a century ago. In fact, much of the Mississippi River Basin is experiencing more rainfall now than it did 100 years ago. Figure 11 (top left) shows this very clearly, with only a few HUC4s, mostly on the western margins of the basin indicating decreases. Because of the strict requirements in denoting statistically significant trends at the $p<0.05$ level, fewer HUC4s are identified in Figure 11 (top right), but still, all but one show increases. As a cautionary note in interpreting this and similar figures to follow is that the map represents changes expressed in percent while the bar charts show the absolute values of the changes, in millimeters, over the approximate 100-year time period.

A statistically significant decrease in annual precipitation was observed only in HUC-1002, the Missouri Headwaters, which showed a reduction of 10%–25% or 77 mm. The greatest increases in annual precipitation (25%–50%) were observed in HUCs 0703 (St. Croix), 1109 (Lower Canadian), and 1112 (Red River Headwaters), where the average-annual increase was ~165 mm per year.

Large swaths of sub-regions comprising the Upper Mississippi, the Tennessee and the Lower Mississippi Basin show relatively large increases in annual precipitation, in excess of 150 mm (approximately 6 in.). Large percentage increases in annual precipitation for some sub-regions in the Missouri Basin represent increases of generally less than 100 mm. Previous studies have also noted statistically significant increases in annual precipitation totals in South Dakota, Nebraska (de Martino et al. 2013), and Kansas (de Martino et al. 2013; Rahmani et al. 2016). Studies of national scope that quote average increases of 4%–5% across the contiguous United States show greater increases in large parts of the Lower Missouri and Upper Mississippi River Basins (Karl et al. 2009;

Walsh et al. 2014)[1]. As a reminder, this current study uses a different methodology to define change over time, which is a linear regression between the earliest and the latest available data. Most of the other studies that are cited here compare differences in two average values, one being some recent period and the other being either the period of record (e.g., 1901–2015) or an earlier period.

Peak annual trends

With most of the Mississippi River Basin experiencing more rainfall than it did 100 years ago, it is particularly germane to evaluate how peak rainfall totals may have changed over the period. Given the enormous size of the basin, it was not just the 24-hour peak values that were of interest but the total maximum rainfall amounts over periods of up to 7 days. These results approximate the change in intensity and duration of maximum, annual rainfall events. Only results for the 1- and 7-day peaks are displayed in the report maps in an effort to conserve space. In general, it was found that on an annual basis, peak rainfall amounts have increased across the basin with the exception of some western areas of the basin including the upper Platte, upper Cimarron, the Republican, and the upper Arkansas River Basins (Figure 12–13).

Although much of the basin displays increases in peak precipitation totals, statistically significant trends in maximum, daily (24-hour) precipitation totals are less common. These increases range 10%–25% and 25–50%, or 6.9 mm in HUC 0708 (Upper Mississippi-Iowa-Skunk-Wapsipinicon) to 24.5 mm in HUC 0807 (Lower Mississippi-Lake Maurepas) (Figure 12). Increases in 7-day total (Figure 13) were also typically on the order of 10%–25% and 25%–50%. HUC 0807 had the greatest magnitude of increases in daily, 3-day (366 mm), 5-day (388 mm), and 7-day (416 mm) precipitation totals. Other sub-regions along the LMR also showed some of the largest increases in peak-rainfall amounts. The increases in the 7-day peak precipitation values are particularly important in the context of potential increases in runoff in the larger basins as they occur over broad areas.

These increases are corroborated by an earlier study from Groisman et al. (2012) who focused on patterns of moderately heavy (12.7–25.4 mm/day), heavy (25.4–76.2 mm/day), and very heavy (76.2–155 mm/day), and extreme (> 155 mm/day) precipitation events in the central United States.

[1] B. Frederick, National Weather Service, personal communication, 2018.

Their results showed (1) no change in moderately heavy events, (2) increases in the frequency of heavy events, and (3) a pronounced increase (40%) in extreme precipitation events.

By themselves, these results indicate that inputs of precipitation have become more intense across much of the basin, particularly in the lower Mississippi along the Gulf Coast, but also in the Tennessee, lower Arkansas, lower Missouri and the upper Mississippi. Subsequent sections will focus on how these overall increases are distributed throughout the year and how they translate into changes in runoff production.

Figure 11. Percent change in annual rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

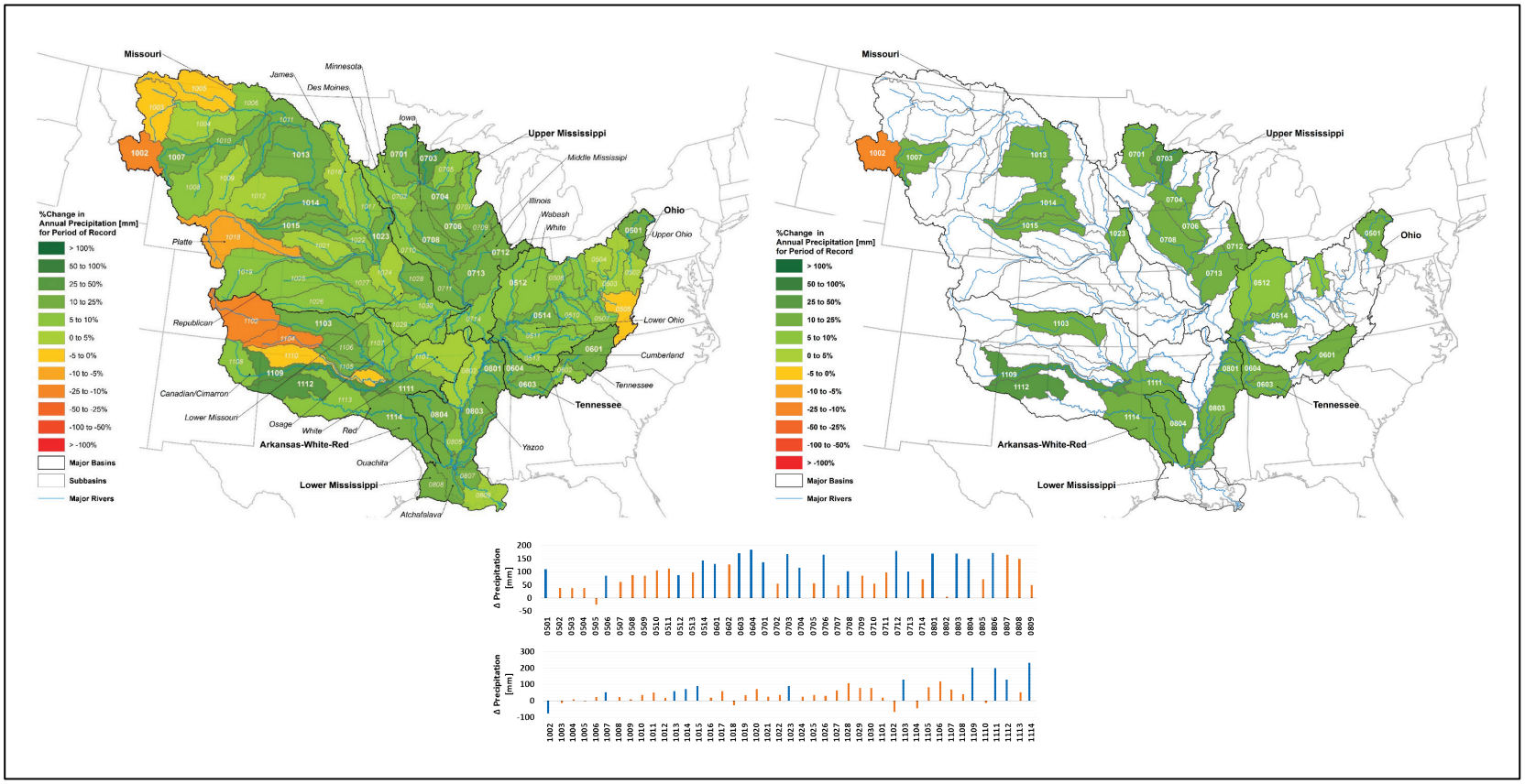


Figure 12. Percent change in maximum, annual 24-hour rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

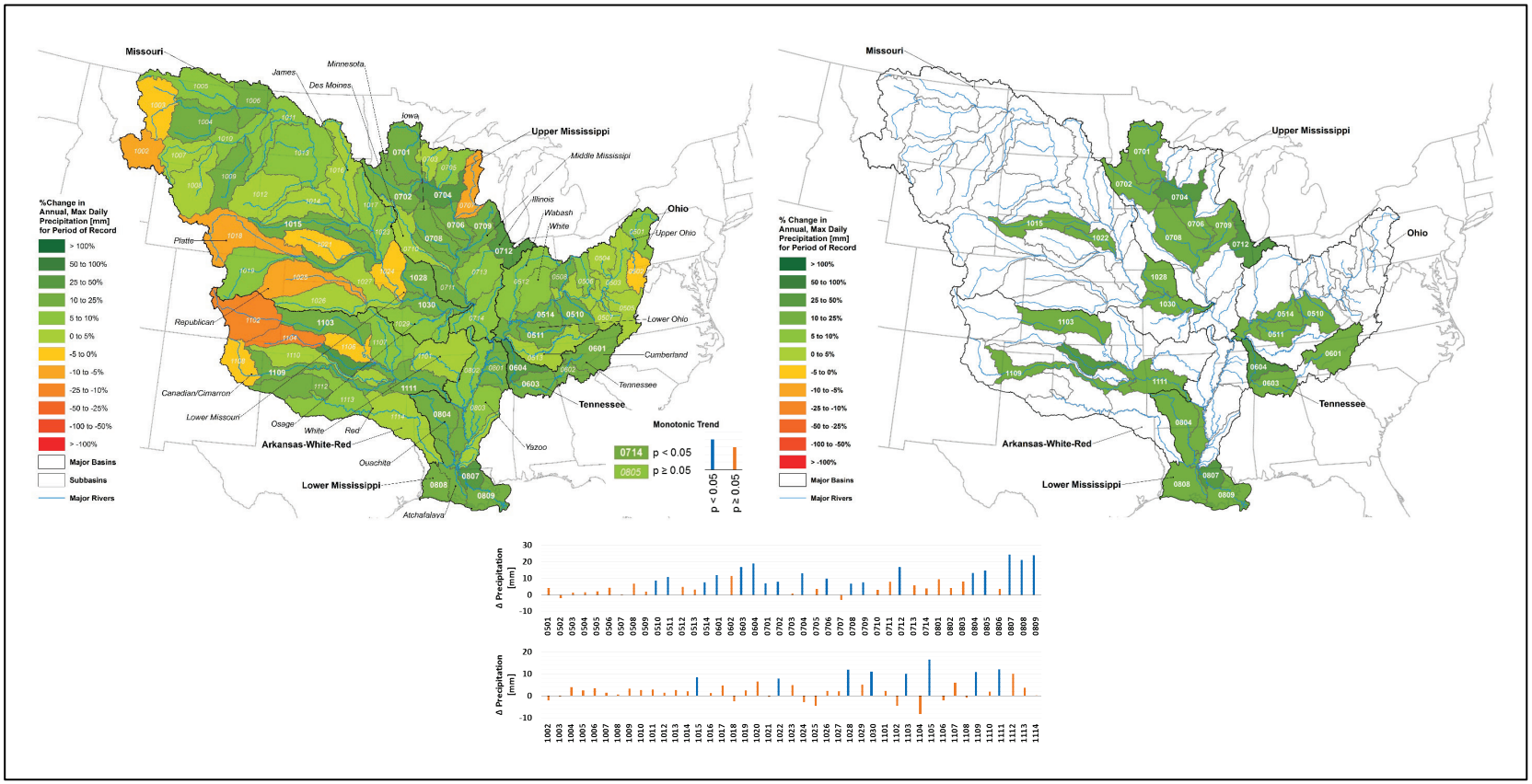
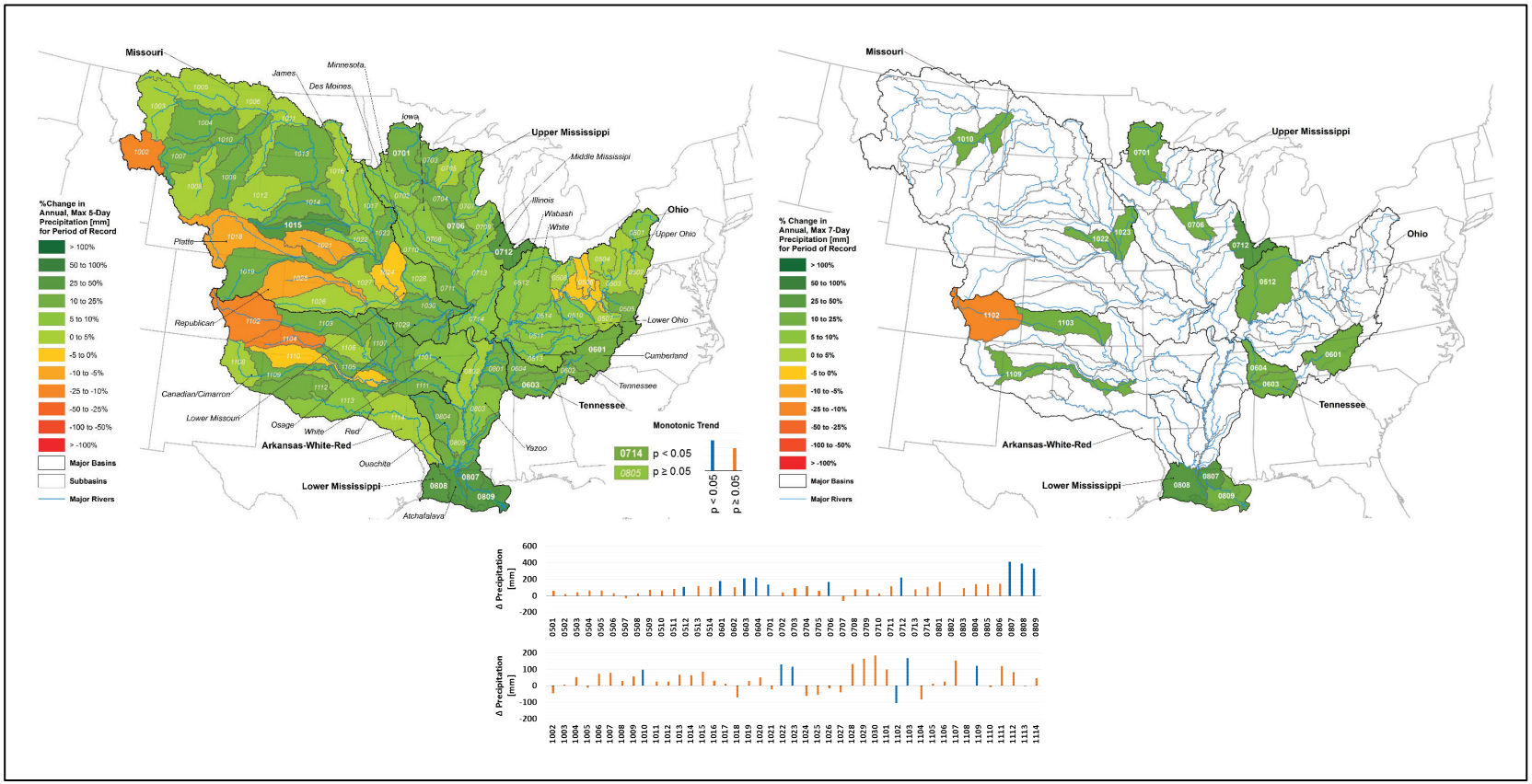


Figure 13. Percent change in maximum, annual 7-day rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.



Seasonal trends

Changes in seasonal precipitation identify shifts in the timing of hydrologic inputs and influences partitioning of rainfall into runoff, evapotranspiration, and/or infiltration. This in turn may have important implications for water availability and irrigation, flood control, power generation, and overall river management. Groisman et al. (2001) reported significant increases of 7%–15% in area-weighted, mean precipitation during the spring, summer, and fall across the continental United States for the period 1910–1996. No changes were shown during winter. Within the Mississippi River Basin, data[1] show that the largest average, recent (1982–2011) seasonal increases have occurred during the fall (8.9%), from 7.8% above the Missouri River at Hermann to 11.4% above the Ohio River at Metropolis. Average increases in spring precipitation above some of the major gauging stations were the second greatest for this period, at 4.1%.

Results using non-weighted point observations from the GHCND in this study identified changes in seasonal precipitation that are in general agreement with those cited above. The most dramatic changes (increases) have taken place during the spring and particularly the fall. The changes are summarized as follows:

- Winter: Moderate increases in the upper Mississippi and Tennessee Basins, decreases in the Ohio, and little change in the Missouri (Figure 14)
- Spring: Moderate increases across the entire basin with the exception of the Red River Basin and upstream areas of the Arkansas River (Figure 15)
- Summer: Small decreases throughout the Missouri and Tennessee Basins, small increases in the Ohio, and moderate increases in the Upper Mississippi, Arkansas, and Red River Basins (Figure 16)
- Fall: Dramatic increases (up to approximately 150 mm) are shown south and east of a line extending from south-central Oklahoma to southwestern New York. This area includes much of the Ohio River Basin, the Tennessee River, the LMR, and the lower Arkansas and Red River Basins (Figure 17). The spatial distribution of these increases is similar to those shown by B. Frederick[1]. Further, much of these

[1] B. Frederick, National Weather Service, personal communication, 2018.

increases may be related to changes in hurricane characteristics in this region over the past century.

Statistically significant trends in winter precipitation were identified in the Arkansas (1102) and Missouri headwater areas (HUCs 1002, 1003, 1005) (Figure 14). Significant trends in spring precipitation were detected in parts of all HUC-2s except the Lower Mississippi (Figure 15). Significant increasing trends in fall precipitation were detected throughout much of the southern and eastern parts of the study area (Figure 17). During the summer, precipitation increased in northern Colorado (HUC-1019) and in parts of the Midwest while decreasing in HUCs 0505 (Kanawha) and 1101 (Upper White) (Figure 16).

Figure 14. Percent change in winter rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

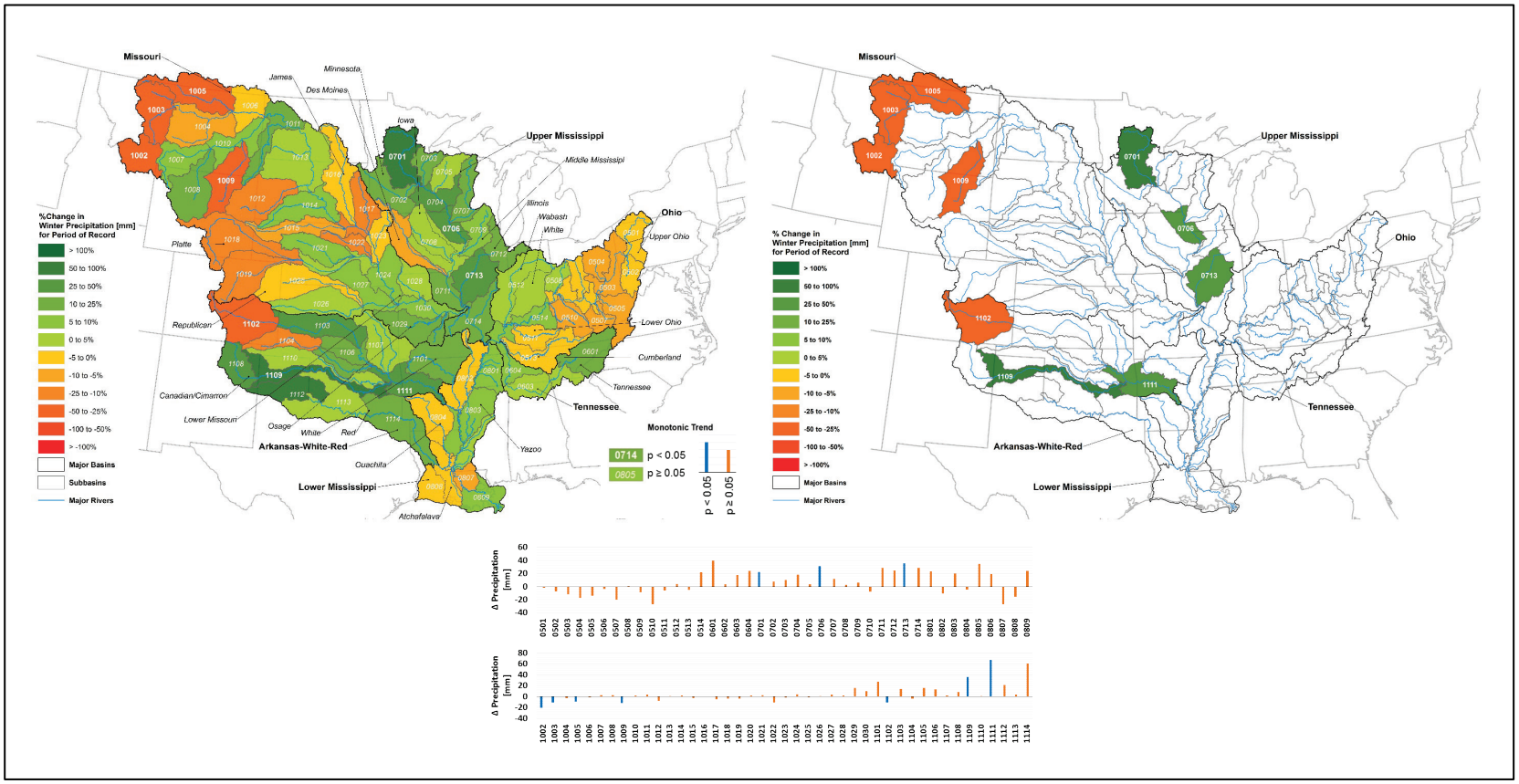


Figure 15. Percent change in spring rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

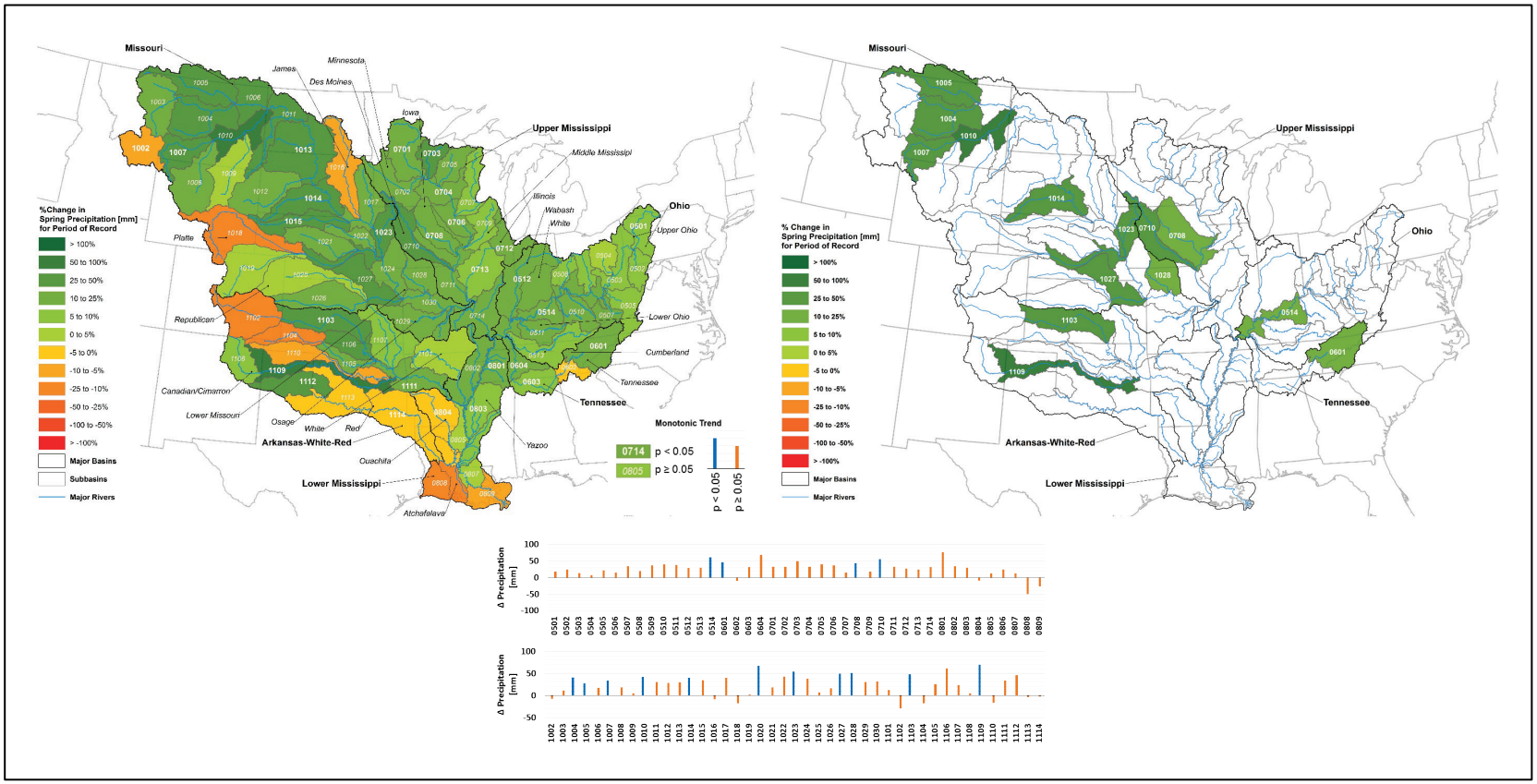


Figure 16. Percent change in summer rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

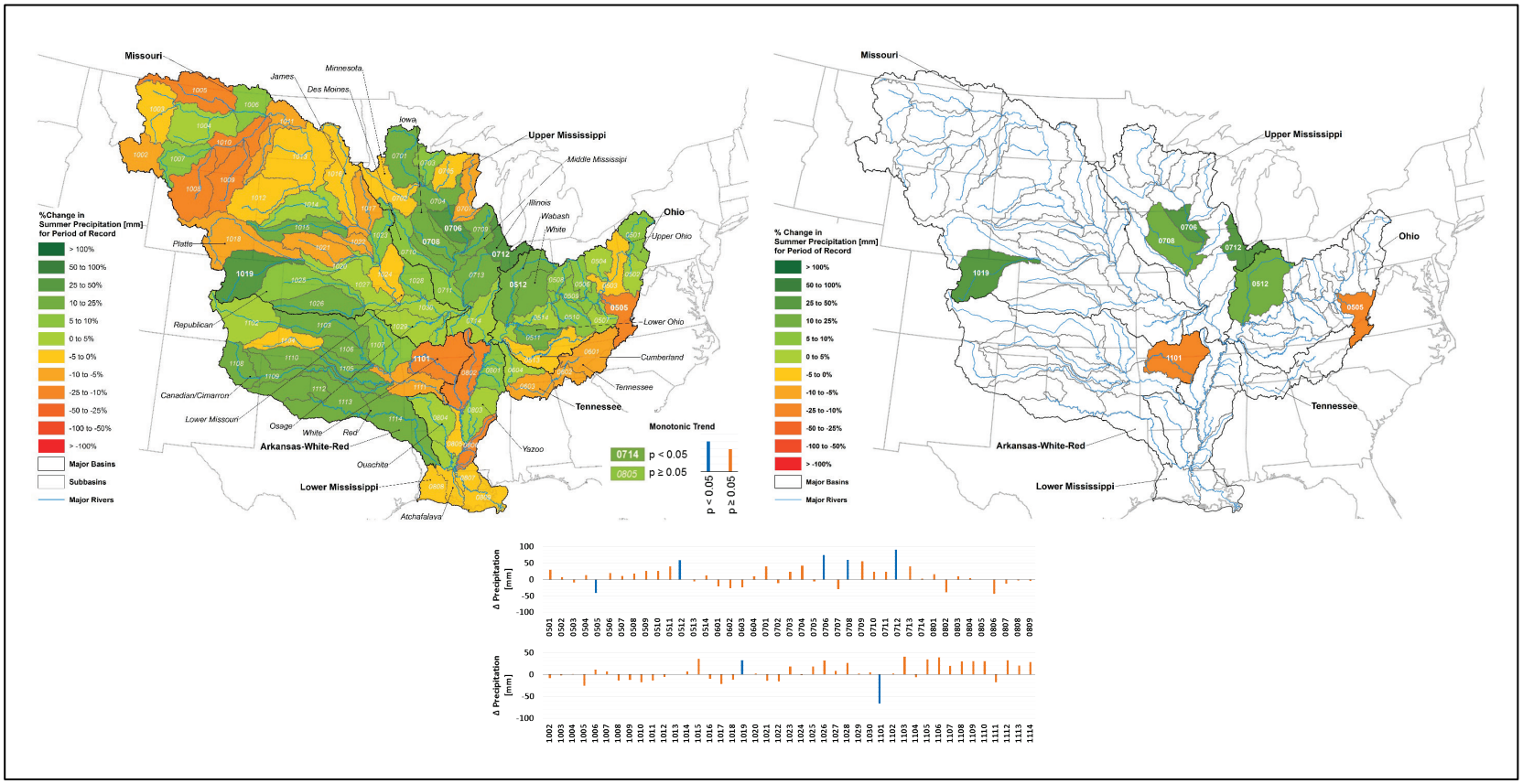
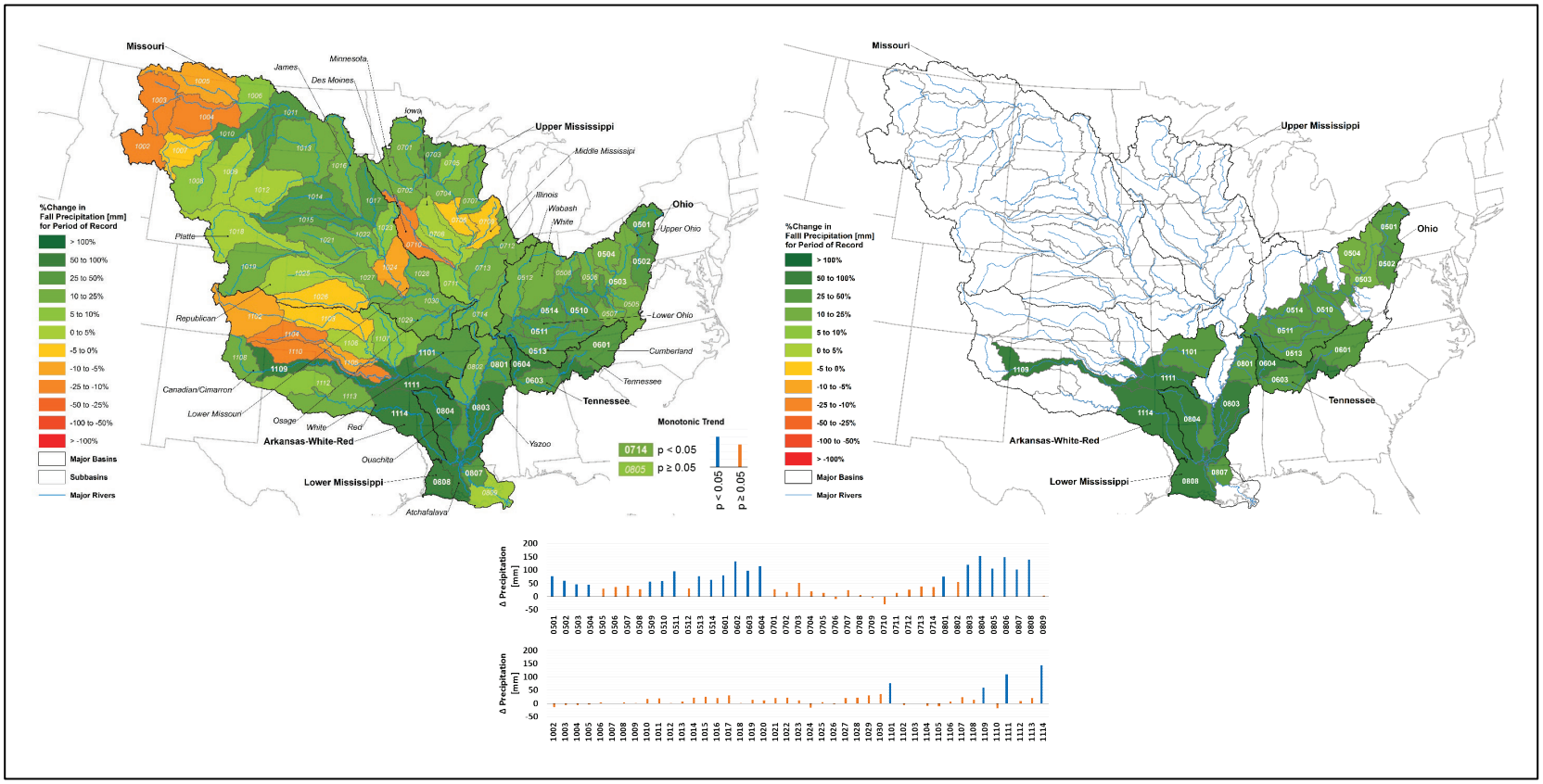


Figure 17. Percent change in fall rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (Bottom), with significant trends shown in blue.



Peak seasonal trends

Winter trends

Results for trends in peak, winter precipitation showed a regional decline in daily (Figure 18), 3-day, and 5-day totals along the Rocky Mountains and across much of the Missouri River Basin. Some of these decreases as with the headwaters of the North Platte (HUC 1018) and Arkansas Rivers (HUC 1102) are statistically significant. The Missouri River headwaters (HUCs 1002, 1003, and 1005) also showed statistically significant declines in the 7-day winter totals. Small to moderate increases were detected through a broad area of the mid-continent, with significant increases in peak winter precipitation in HUCs 0701 (Mississippi Headwaters), 0601 (Upper Tennessee), 0713 (Lower Illinois), and 1109 (Lower Canadian). Groisman et al. (2001) did not find significant changes in winter precipitation and in snow cover over the Upper Mississippi and Midwest over the last half of the twentieth century.

Spring trends

As with changes in total spring precipitation, peak spring precipitation also showed general increases across the entire basin. Daily increases of 5–10 mm were typical in many sub-regions. The only statistically significant trends that were detected for all four time periods were positive. Changes in the maximum daily totals are shown in Figure 19. Maximum increases in multi-day, spring rainfall totals were in excess of 150 mm. Like total spring precipitation, there were some sub-regions that indicated slight decreases, but these were distributed across the river basin.

Summer trends

Changes in peak summer precipitation show a general pattern of small decreases in the Missouri River Basin, the central-lower Mississippi (HUC 0802), and the upper reaches of the Upper Mississippi. In general, all other regions showed mild increases (~ 5 mm). Because changes in summer peak rainfall were small, only a few HUCs showed significant trends in either direction for all of the durations. The 1-day distributions are shown in Figure 20.

Figure 18. Percent change in maximum daily winter rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

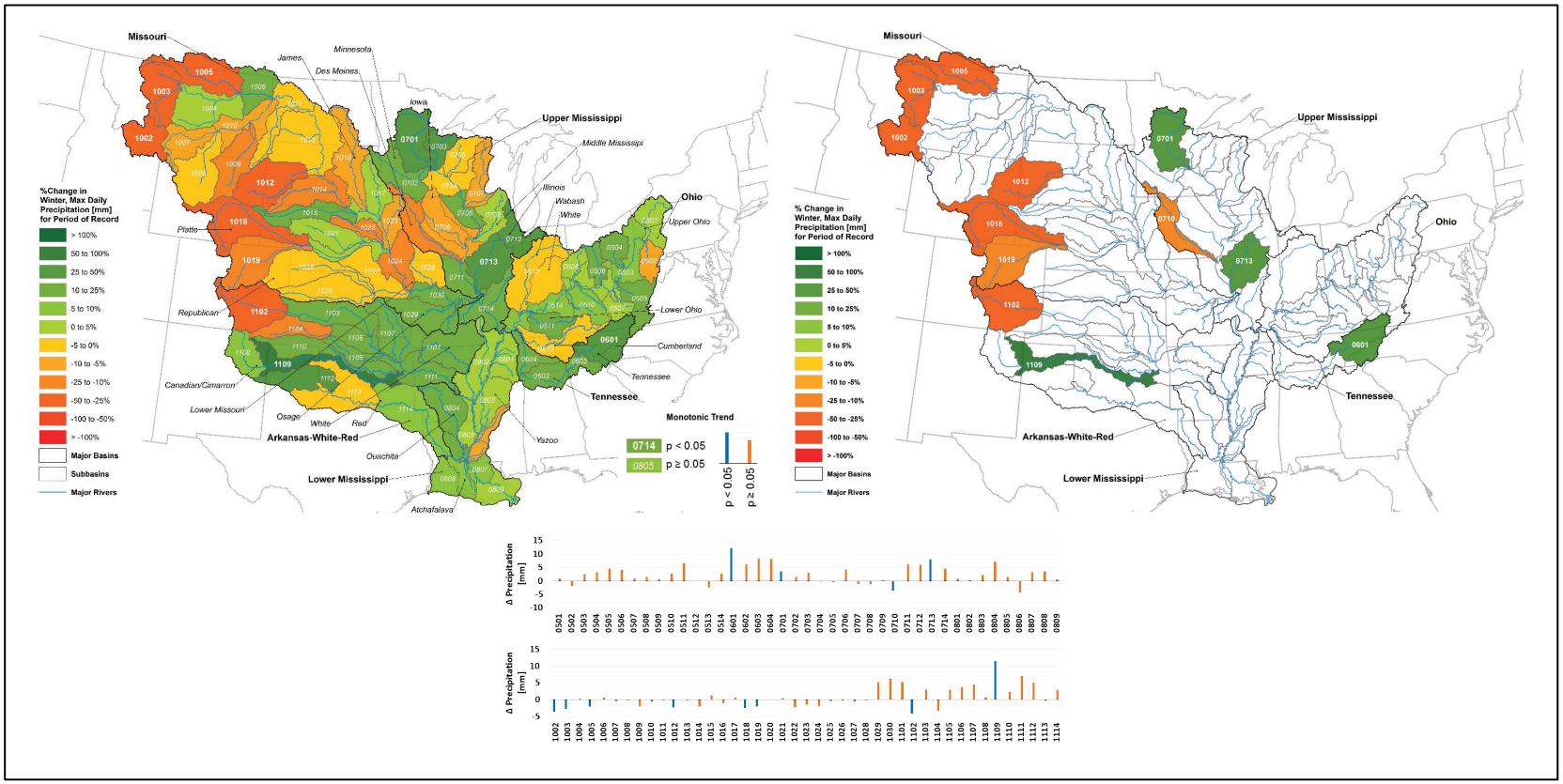


Figure 19. Percent change in maximum daily spring rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

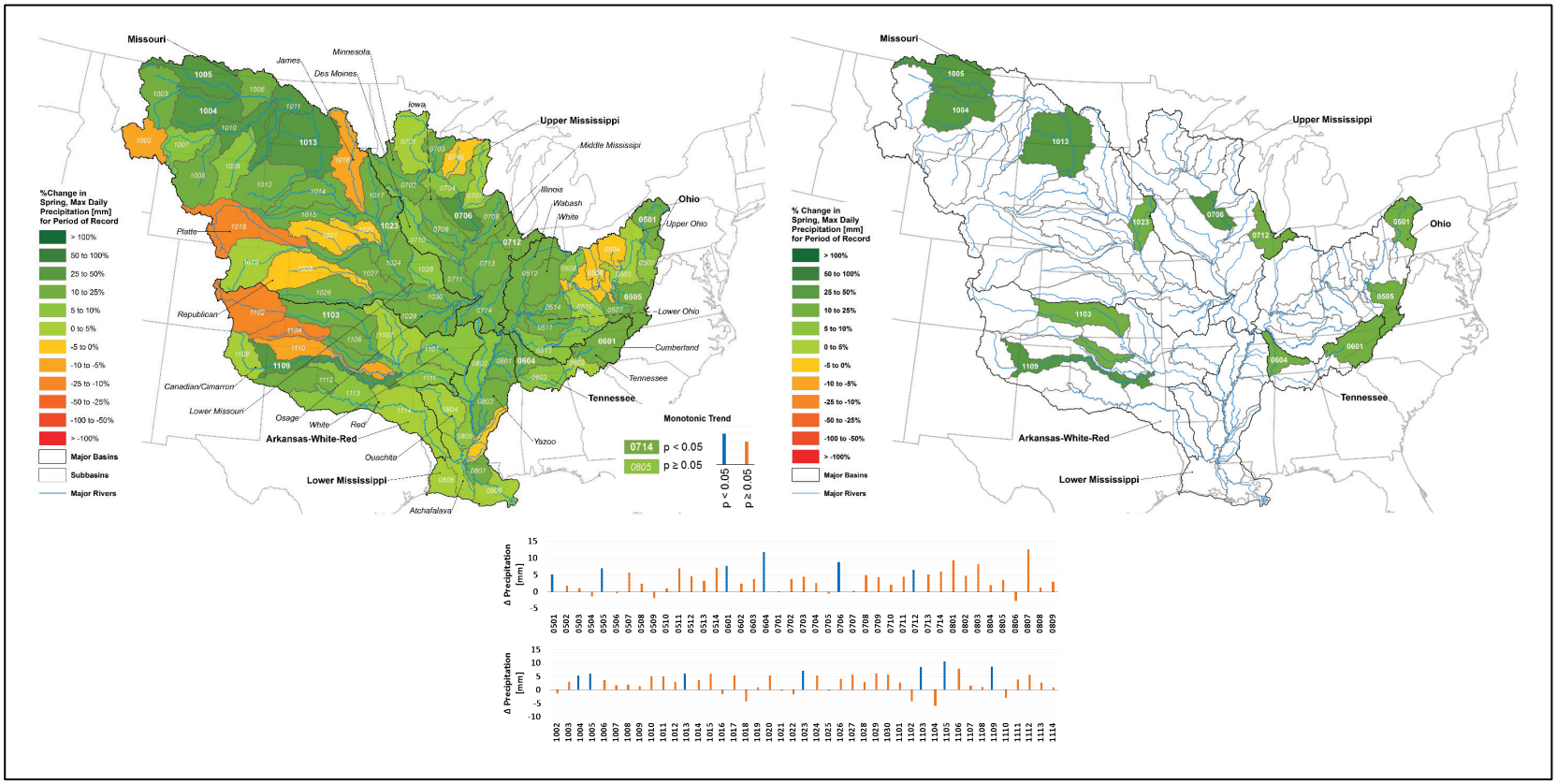
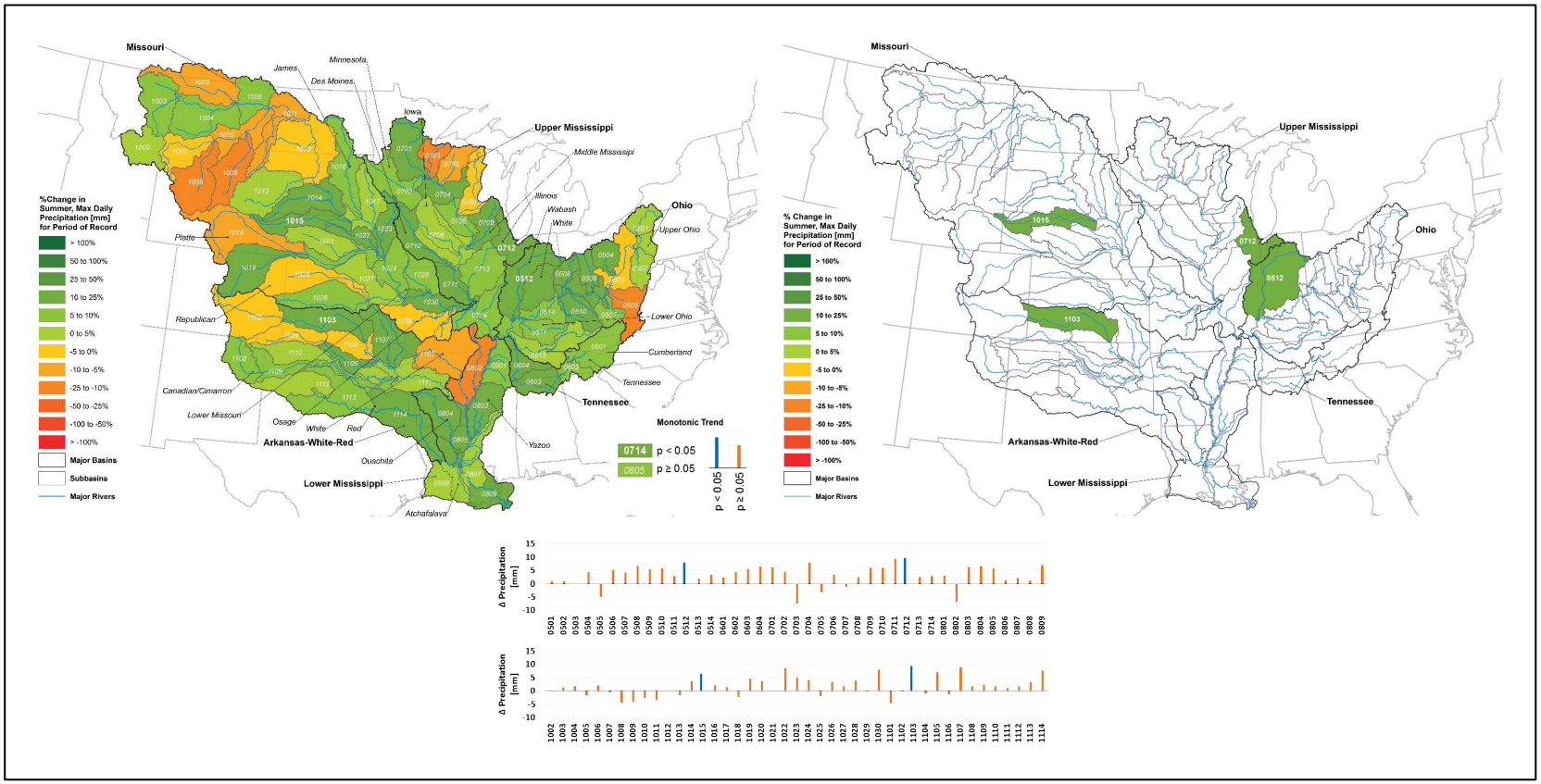


Figure 20. Percent change in maximum summer daily rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.



Fall trends

Some of the most drastic changes in precipitation over the past century have occurred in the fall across the southern and eastern parts of the basin. As with the increases in total fall precipitation, these sizeable increases in peak fall rainfall extend from the very southwestern part of the basin, northeast along the Appalachian Mountains, and areas south and east of there. One- and three-day peak rainfalls have increased, respectively, as follows:

- Tennessee River Basin: ~15 mm, ~200 mm
- LMR Basin: ~20-30 mm, ~100-400 mm
- Lower Arkansas River: ~15-20 mm; ~200-250
- Ohio River Basin: ~10-20 mm; ~100-200 mm.

These are important increases in peak precipitation totals, particularly for the 3-day duration, and indicate that storm events are getting more severe during this time of year in these parts of the basin. The implications are that corresponding runoff events will be larger as well. Further, the spatial distribution of these increases in peak fall precipitation again point towards an increased influence of hurricanes in peak-rainfall totals and hence, peak discharges in these sub-regions. The changes in peak rainfall are shown in Figure 21 for daily maximums and Figure 22 for 7-day maximums.

Additional details/results of the sub-regional precipitation analyses can be found in Appendix E.

Figure 21. Percent change in daily fall rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

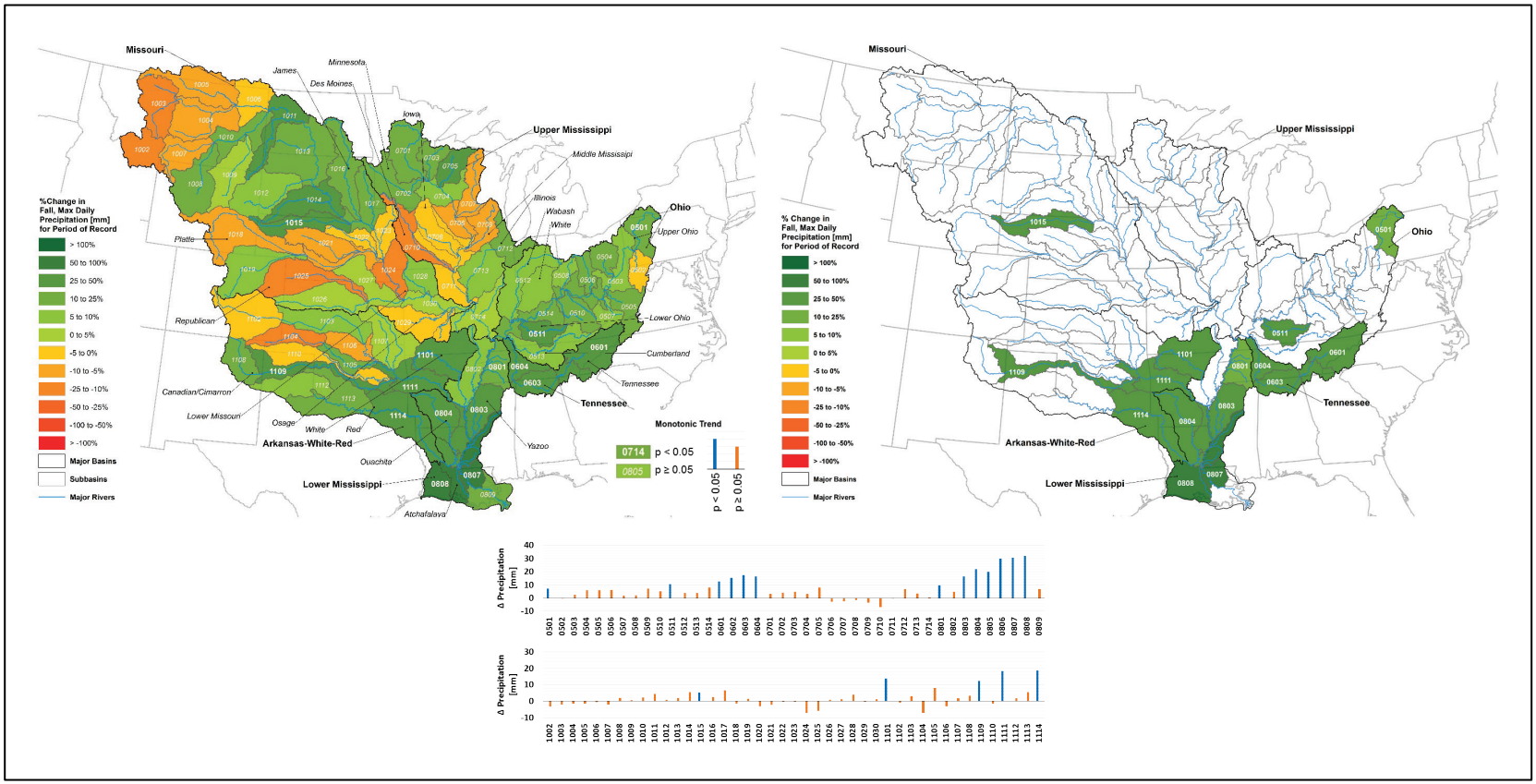
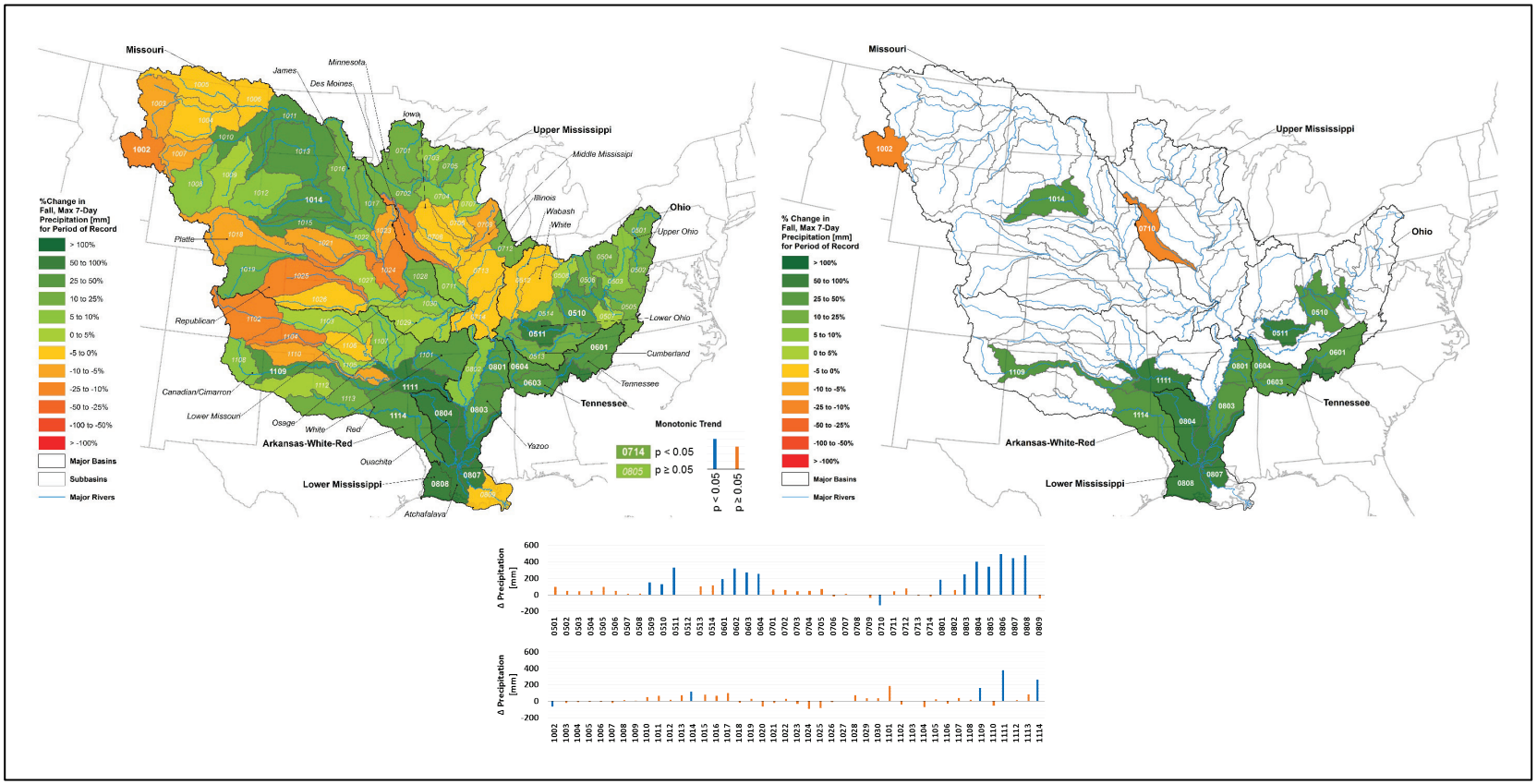


Figure 22. Percent change in maximum 7-day fall rainfall for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.



Hurricane-related precipitation trends

Hurricanes make landfall in the United States generally along the Gulf and Atlantic Coasts (Figure 7). Many hurricanes, particularly those that skirt the Atlantic Coast, do not impact the Mississippi River Basin. Those that make landfall along the Gulf Coast, however, impact sub-regions of the Mississippi River Basin as they start tracking north and northeast into the LMR Valley. Others track slightly farther to the east and do not cross into the Mississippi River Basin until they reach the Tennessee River Basin before heading out to sea. Fewer reach the basin traveling north-northeast across Texas, entering the basin in Oklahoma, Louisiana, and Arkansas. Hurricane-related precipitation can be extreme over short durations, producing annual-maximum values.

The Atlantic hurricane season is generally considered to span the period June 1 through November 30, although only 5 hurricanes (out of 294) have made landfall in the United States in November since 1951 (NOAA 2019). The period when most hurricanes make landfall is August through October, with the peak month being September. Between 1951 and 2018, 42% of the landfalls have occurred during the summer months while 58% have occurred during the fall (37% in September). This would indicate that hurricane-related precipitation would generally span summer and fall but on average, may be most pronounced in the fall.

Based on precipitation anomalies identified in the precipitation record, a set of metrics were established to evaluate how the impact of hurricanes on precipitation totals has changed since 1950. These include the following:

- number of continuous days of hurricane activity (per year)
- total number of days with hurricane activity (per year)
- total annual precipitation anomaly due to hurricanes
- maximum 1-day, 3-day, 5-day, and 7-day rainfall anomalies due to hurricanes.

In the series of figures that follow, precipitation gages with statistically significant trends in precipitation anomalies ($p < 0.1$) are shown as larger circles. Similar to the previous discussion and maps of trends in seasonal, particularly fall precipitation, a band of increased precipitation anomalies can be observed stretching southwest to northeast through the basin. Areas in the Ohio River Basin, especially along the Appalachians, are

experiencing prolonged exposure to hurricanes (Figure 23 and Figure 24). Significant increases in duration are also observed in the Mississippi Delta. Still, a few gages with statistically significant decreases in the number of days and total duration of hurricane-related precipitation were also observed.

Figure 23. Changes in maximum annual, continuous days of hurricane anomaly.

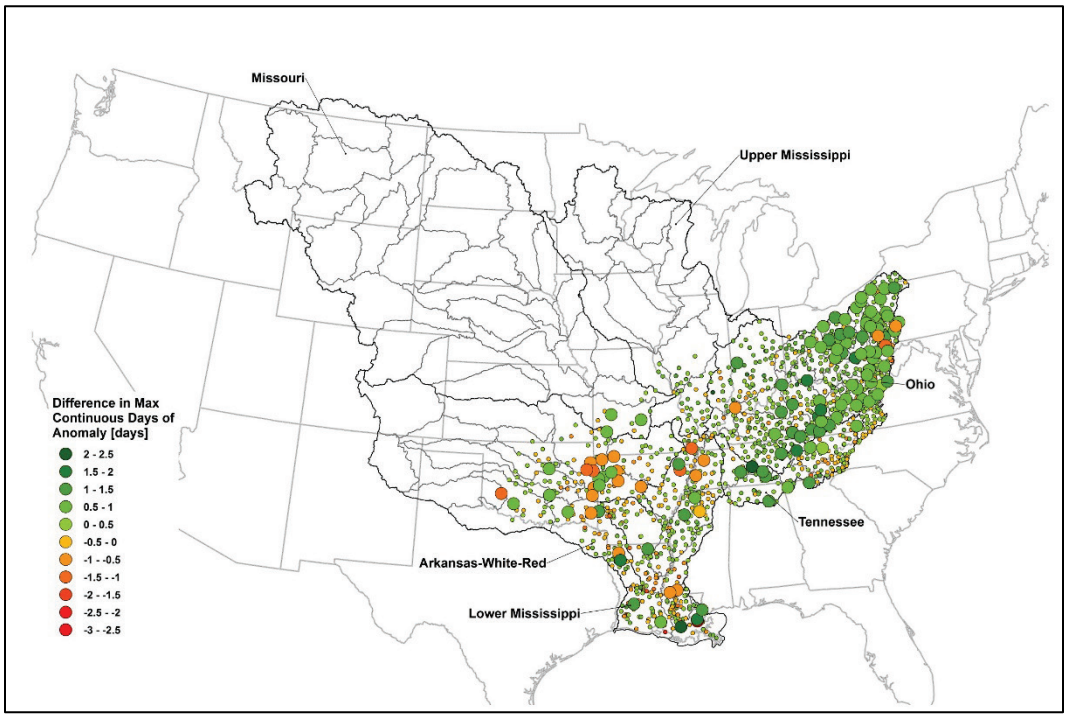
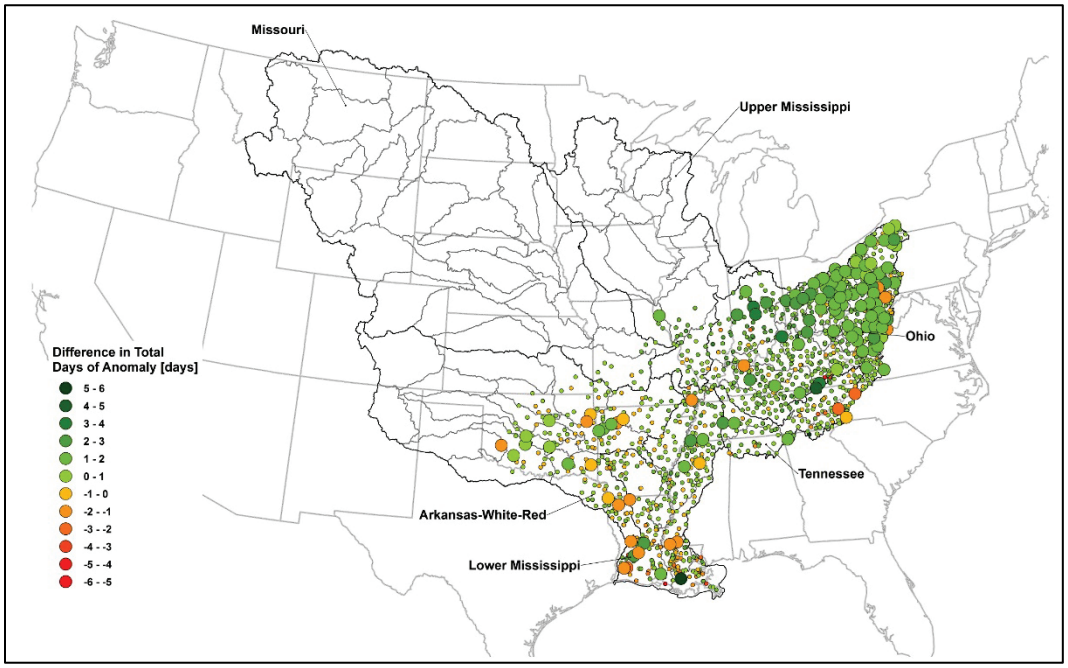
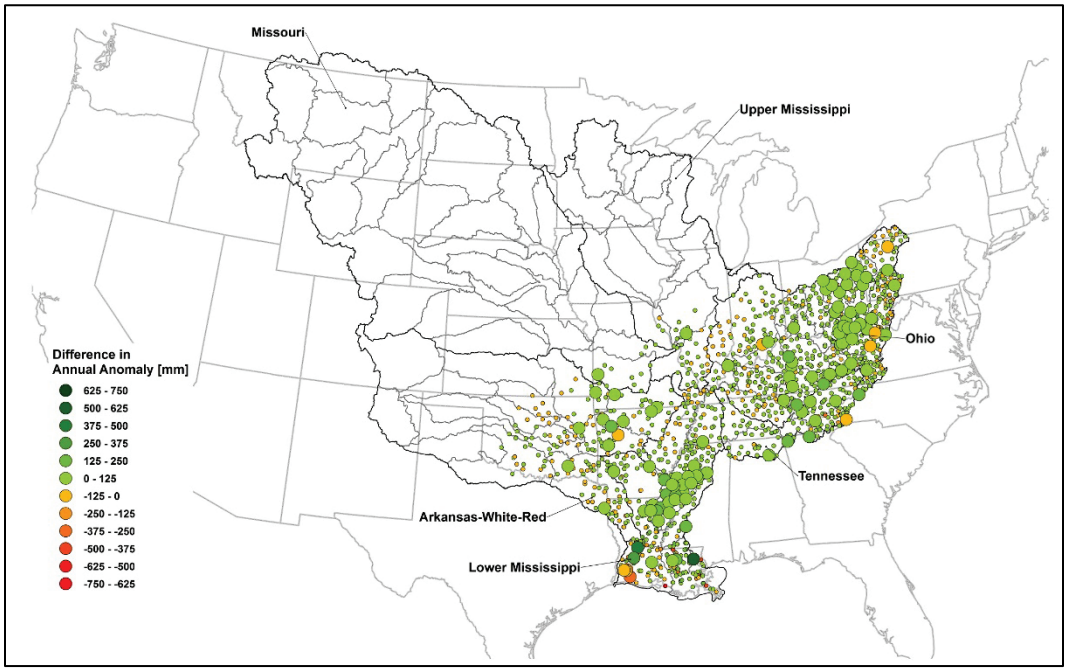


Figure 24. Changes in total annual days of hurricane anomaly.



Shifting the focus from frequency and duration to actual changes in the amount of annual hurricane-related precipitation, important and statistically significant increases are apparent throughout the Lower Mississippi and Ohio River Basins (Figure 25). On average, these increases fall within the 0–125 mm class. A maximum recorded increase of 592 mm was detected at a gage in HUC 0809. Note that not all hurricane-related precipitation is captured by these GHCND gages. The numbers reflect the amount of anomaly recorded if a gage were continuously recording precipitation between 1950 and 2014, which is not the case for majority of the gages. Still, the spatial trend is for a general increase in hurricane-related precipitation on an annual basis across the southeast and extending into the Ohio River Basin. This may help explain the calculated increases in fall total and peak precipitation in these regions.

Figure 25. Changes in annual hurricane anomaly.



Expanded statistical significance of increases in hurricane-related precipitation is seen for peak-rainfall events ranging from 1 to 7 days (Figure 26–Figure 27). Multi-day increases of ~100–300 mm (since 1950) is typical at many of these gages with some significant values as high as ~400–600 mm. The results of this analysis indicate that the hurricanes that are making landfall and impacting the Mississippi River Basin are, on average, producing more rainfall on both an annual basis and over 1- to 7-day periods than they did in 1950.

Figure 26. Changes in maximum annual, daily hurricane anomaly.

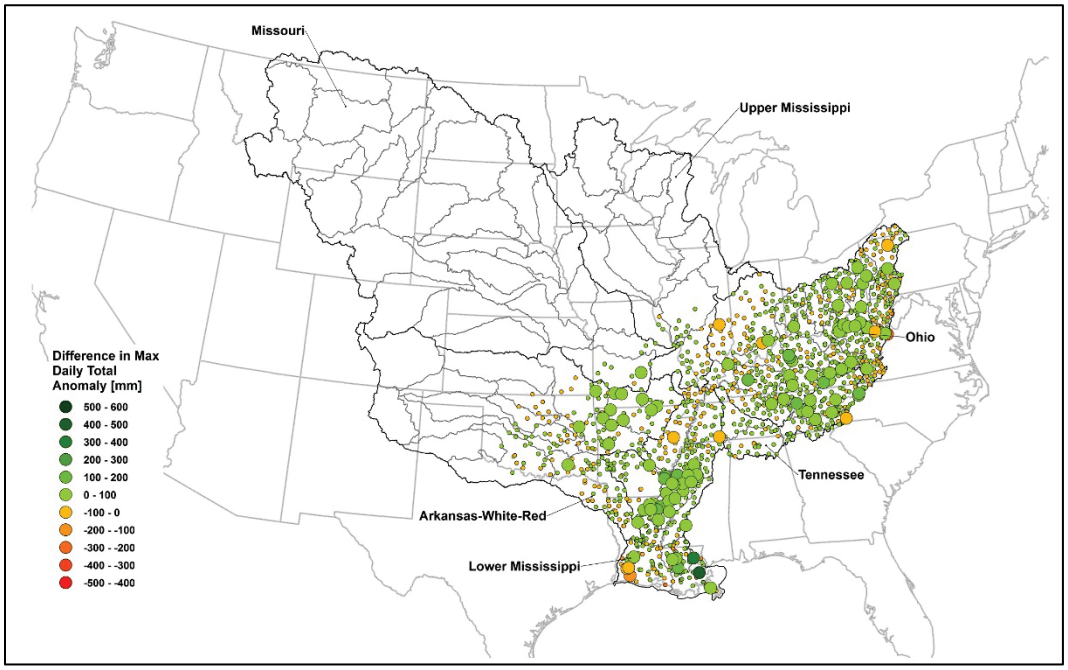
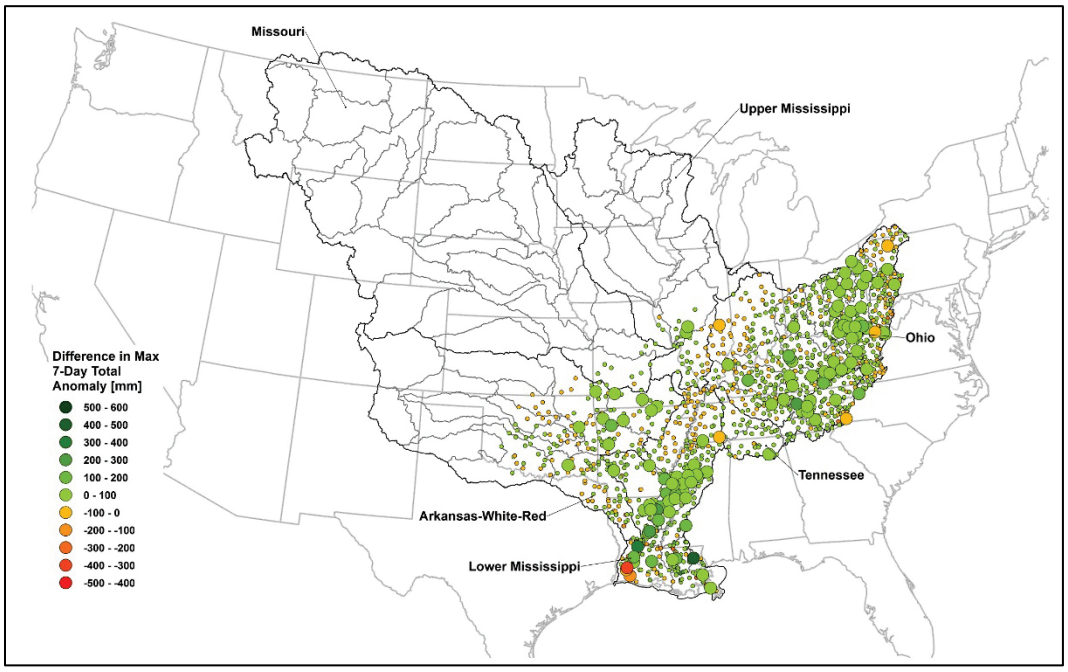


Figure 27. Changes in maximum annual, 7-day total hurricane anomaly.



The spatial distribution of these changes seems to indicate a combination of effects related to general circulation patterns and a potential orographic effect from the Appalachian Mountains. Finally, there seems to be a curious lack of significant increases in hurricane-related duration or precipitation amounts in the region best described as along the northern

Alabama border. It requires further investigation as to whether this perceived pattern is real and whether it is related to a similar combination of circulation and topographical conditions.

Summary of precipitation results

On an average annual basis, most of the Mississippi River Basin receives more rainfall than it did 100 years ago. Typical increases are in the range of 10%–25%. The largest increases have occurred in the Upper and Lower Mississippi and the Tennessee River Basins and may exceed 150 mm (approximately 6 in.). Large percent increases in the Missouri River Basin represent increases of less than 100 mm (approximately 4 in.) per year. A few of the far-western HUC-4s show decreases in annual precipitation. Peak annual rainfall totals over 1, 3, 5, and 7 days also show increases over most of the basin indicating that inputs of precipitation have become more intense.

On a seasonal basis, there were the following:

- Dramatic and significant increases in seasonal precipitation during the fall, with up to 150 mm (approximately 6 in.) more rainfall in some HUC-4s. Statistically significant increases are recorded for HUC-4s south and east of a line extending from south-central Oklahoma to southwestern New York. This spatial pattern is similar to the changes (increases) identified in hurricane-related precipitation.
- Moderate increases during spring across the entire basin with decreases in the Red River and upstream areas of the Arkansas.
- Moderate increases during winter in the upper Mississippi and Tennessee, decreases in the Ohio, and little change in the Missouri.
- During summer, small decreases throughout the Missouri and Tennessee, small increases in the Ohio, and moderate increases in the Upper Mississippi, Arkansas and Red River Basins.

Seasonal peak precipitation mirrors the changes in total precipitation with the exception of important declines in peak winter precipitation in the Rockies and much of the Missouri Basin. The dramatic increases in fall precipitation along the Appalachians is reinforced by increases in peak values. Three-day totals increased by hundreds of millimeters. These results point to an increasing influence of hurricanes in the southeast and the Ohio River Basin. Hurricanes that are making landfall and impacting

the Mississippi River Basin are, on average, producing more rainfall on both an annual basis and over 1- to 7-day periods than they did in 1950.

Water yield trends

Annual trends

Water yield is an expression of the generation of runoff per unit drainage area. Although precipitation represents the fundamental hydrologic input, discharge is the expression of that atmospheric input that is of particular interest to river managers. By using water yield as opposed to actual discharge, basins of different size and from different hydro-physiographic settings can be readily compared. This metric provides insight into how changes in precipitation along with anthropogenic activities have affected streamflows. Changes expressed as a percent are somewhat easier to understand for water yield than the absolute value because of the unfamiliarity in considering values comprised of these units (cubic meters/cubic kilometers). Later sections will focus specifically on the absolute value of discharges (expressed in cubic meters) emanating from index stations.

Results on an annual basis show important and consistent increases in water yield across most of the Central Lowland province of the Interior Plains (Figure 28). Sankarasubramanian et al. (2001) found that the regional sensitivity of streamflow to changes in precipitation is highest in this region. In part, this could be due to large-scale programs of channelization that provided for much more efficient conveyance of flows as well as construction of tile drains to improve drainage. Statistically significant increases were also identified in parts of the lower Ohio Basin. Previous studies have also documented significant increases in annual minimum 7-day flow (low flows) throughout the Ohio River Basin, the Upper Mississippi, and lower Missouri (e.g., Douglas et al. 2000; Ahn and Palmer 2015). These findings indicate that more water is being delivered on an annual basis to the upstream boundary of the LMR than previous.

In contrast, annual water yields emanating from the sub-regions in the western-most parts of the basin have seen marked declines. Given that many of these areas have seen increases in annual and peak rainfall amounts, these declines may be related to significant anthropogenic effects, particularly water withdrawals for irrigation. This is likely the case with the declines indicated for the sub-regions in southern Louisiana.

Caution is encouraged when interpreting results for water yield for HUCs whose period of record begin during the "dust bowl" era of the 1930s (see Table B in Appendix B).

Although this research and others document significant increases in precipitation, lengthy *dry* periods have also been detected in the latter half of the twentieth century in the southwest (Groisman and Knight 2008). This plays a role in decreasing trends in annual water yields observed across much of the Great Plains with the exception of HUCs 1012 (Cheyenne) and 1015 (Niobrara).

Peak annual trends

Changes in peak annual water yield are a proxy for how peak annual flood flows have changed over the study period. For the longer duration metrics such as the 5- and 7-day totals, peak water yields might reflect multiple pulses of flood waves. Again, throughout much of the mid-continent, peak flows have increased. This is in keeping with the general increases in precipitation and the enhanced drainage conditions (channelization and tile drainage) imposed in these areas (Figure 29–Figure 30). Reductions in western peak flows are readily apparent, probably reflecting not only withdrawals for irrigation in the region but flow control by dams. In these semi-arid regions, peak flows represent a large part of the total annual water yields. The negative trends in peak water yields across all four durations have been associated to increases in temperature (Mauget 2003), leading to overall declines in streamflow (Rood et al. 2005). It is also quite possible that changes in hydrologic regimes through dam operations that tend to suppress high flow magnitudes, water withdrawals for irrigation and greater evaporative losses are important factors in the decreasing peaks in the western HUCs.

This study uses many more gages in the central United States than those used by Groisman et al. (2001). Those authors concluded that only the eastern third of the country demonstrated correlation between the interannual/interdecadal variability of maximum-annual events of streamflow and precipitation. Here, results show that throughout the Midwest, streamflow and thus water yield have increased. Meanwhile, water yield in parts of the upper Ohio have decreased. Findings on annual, maximum water yields are consistent with those of Rahmani et al. (2016), who studied extreme precipitation and flooding in the central United States using data from 1890 to 2013.

Figure 28. Percent change in annual water yield (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (Bottom), with significant trends shown in blue.

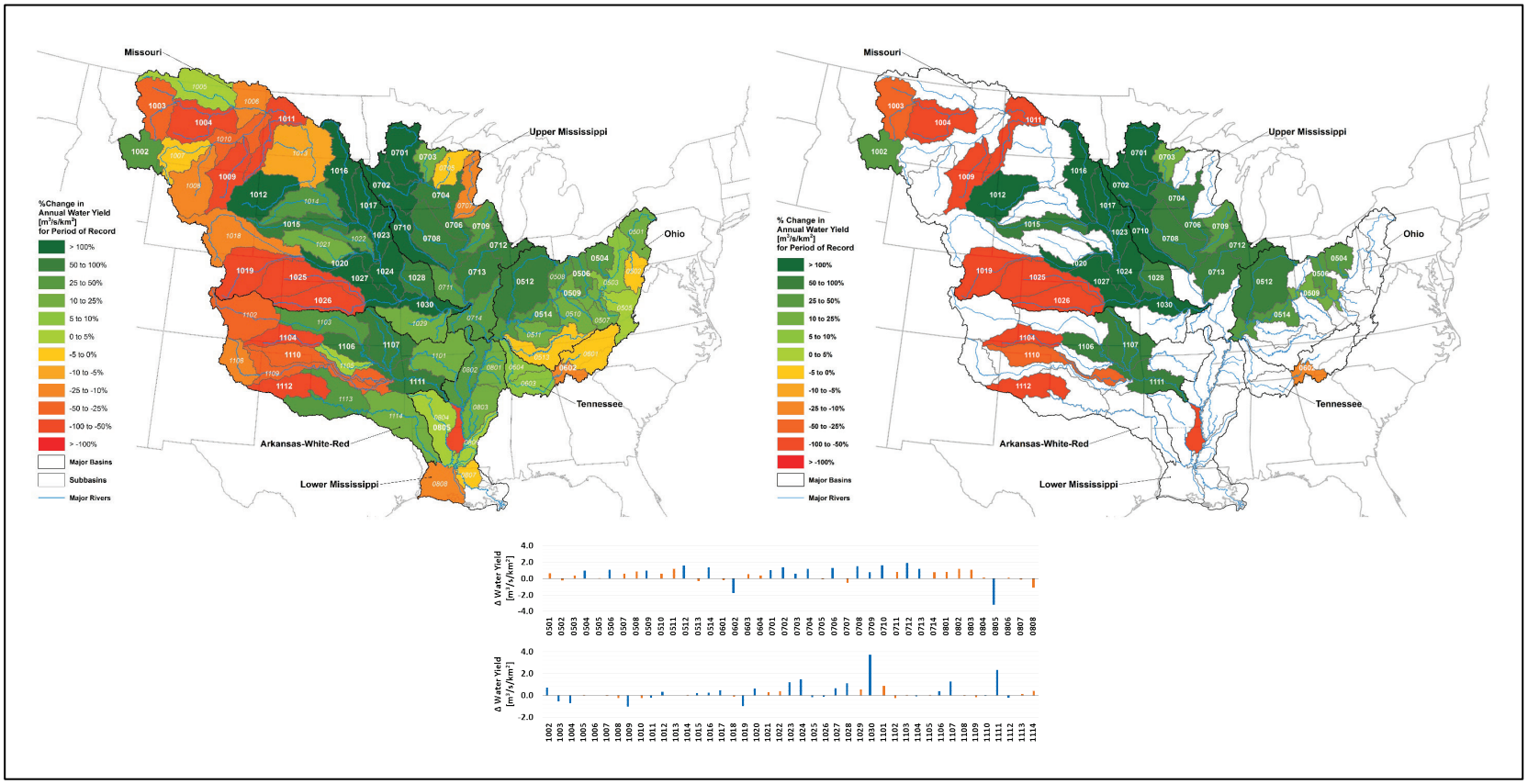


Figure 29. Percent change in annual maximum-daily water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

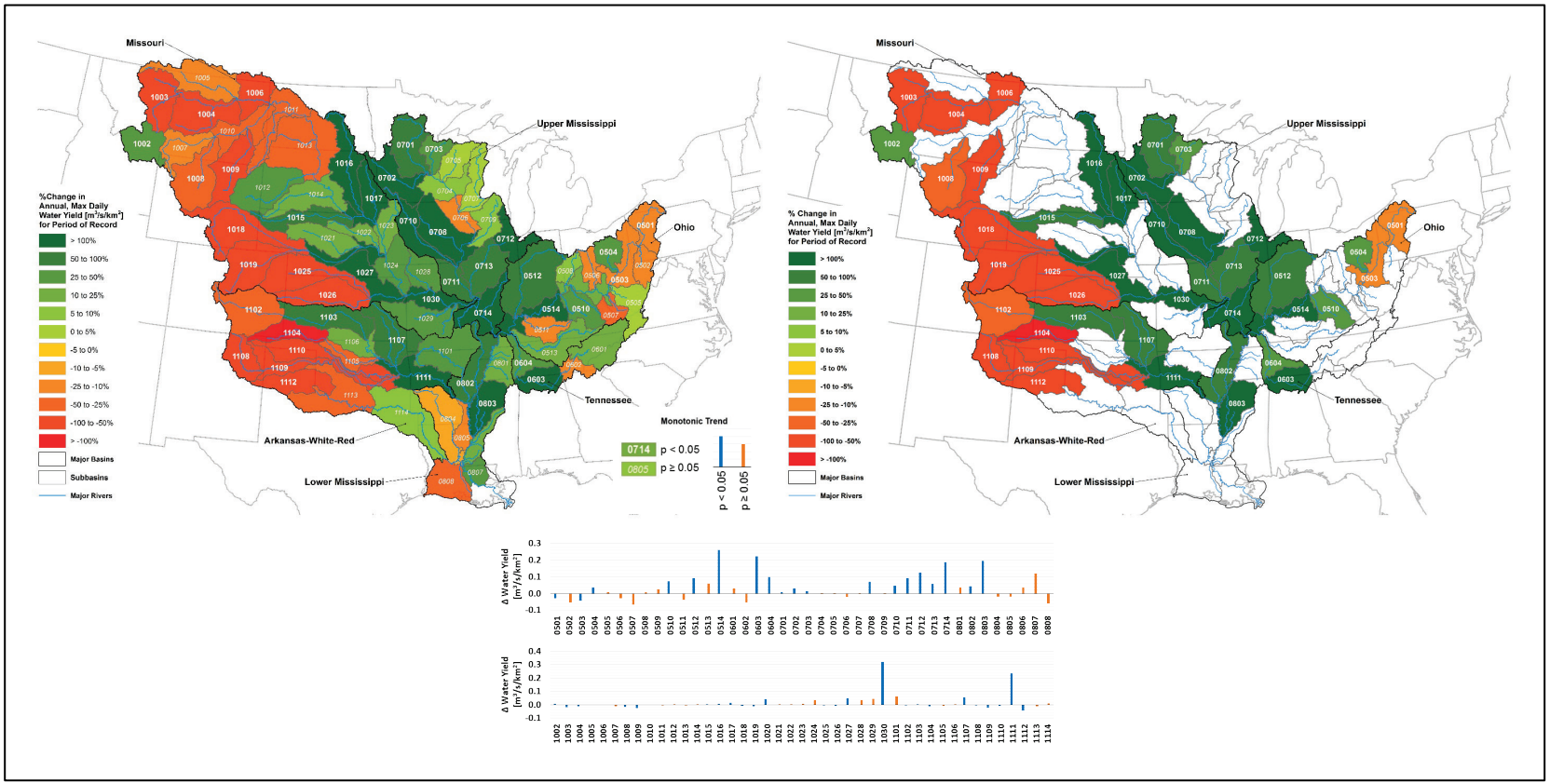
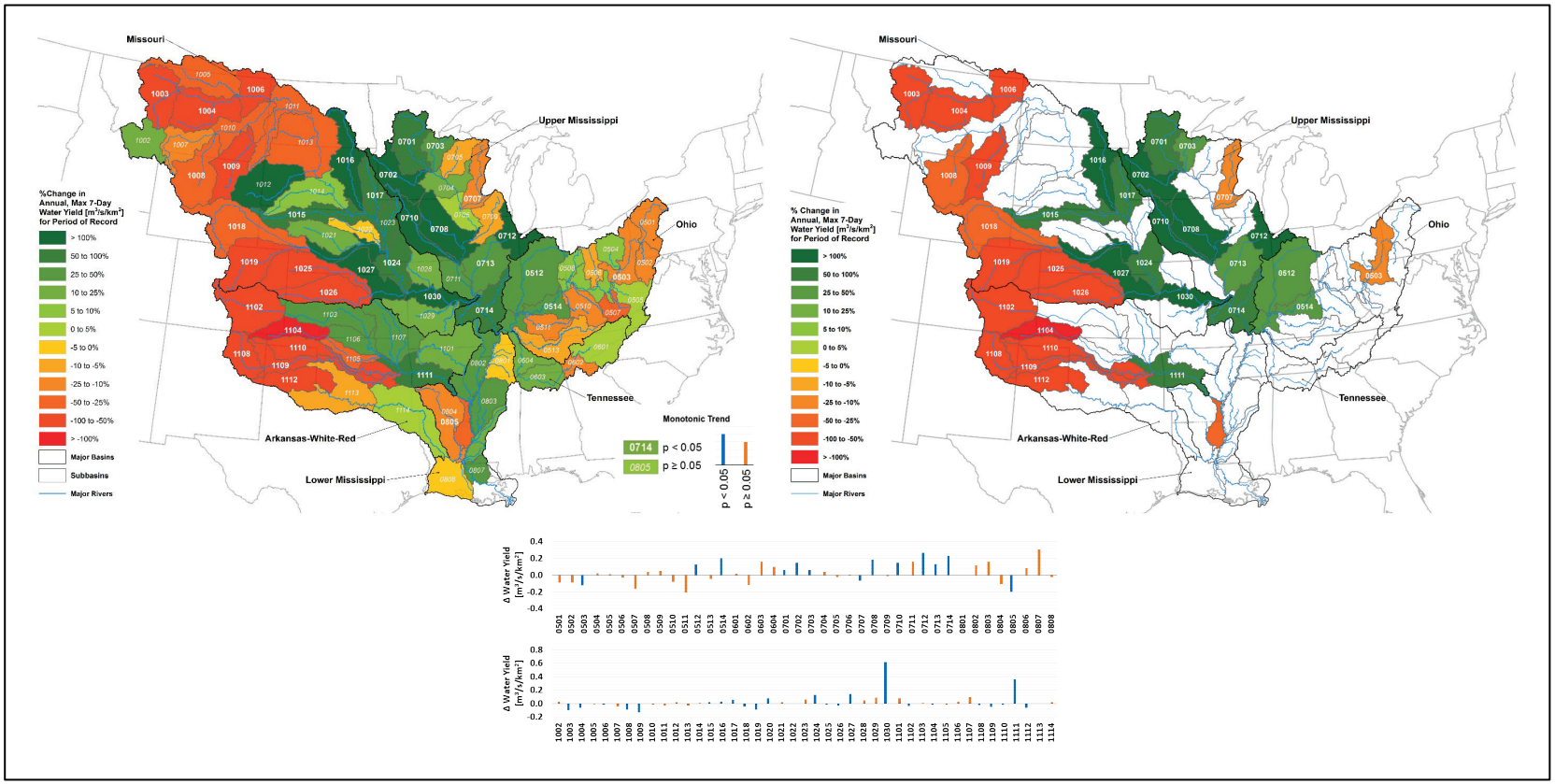


Figure 30. Percent change in 7-day maximum water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.



Seasonal trends

Seasonal changes in water yield over the past century reflect changes in seasonal precipitation and seasonally variable anthropogenic influences such as operation of impoundments and water withdrawals for irrigation. In general, the spatial distribution of seasonal water yields again shows the increased discharges in the mid-continent and the decreases in the western-most parts of the basin. Winter and fall tend to show the greatest areal extent of increases while irrigation withdrawals that peak during the summer months in large parts of the upper Missouri and upper Arkansas and Tennessee Basins have resulted in important decreases in summer water yields. Temperature increases and evaporative losses behind impoundments may also play a role in the decrease in summer yields.

Statistically significant decreases in winter water yield were found in several areas of the Great Plains and Southern Rockies (Figure 31). This could reflect decreases in snowfall totals. In HUC 1104 (Upper Cimarron), water yields were 0.012 $m^3/s/km^2$ less than those observed 70 years ago, representing a decrease of greater than 100%. The greatest decrease in winter yields was in HUC 0805 (Beouf-Tensas), of nearly 1.0 $m^3/s/km^2$ since 1939. In other areas of the Great Plains and in parts of the Wyoming Basin, Northern Rockies, and Central Lowlands, winter water yields increased. Spring water yields (Figure 32) displayed somewhat similar regional trends with many of the western watersheds showing significant declines. Declining trends were also observed in Wisconsin (HUC 0707) and Middle Tennessee-Hiwassee (HUC 0602). In the Lower Missouri (HUC 1030), median water yields increased by 1.43 $m^3/s/km^2$. Declining trends in summer water yield dominated most of the Great Plains (Figure 33). Water yields in parts of the Ohio River basin during the summer and fall (Figure 34) increased.

Figure 31. Percent change in winter water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

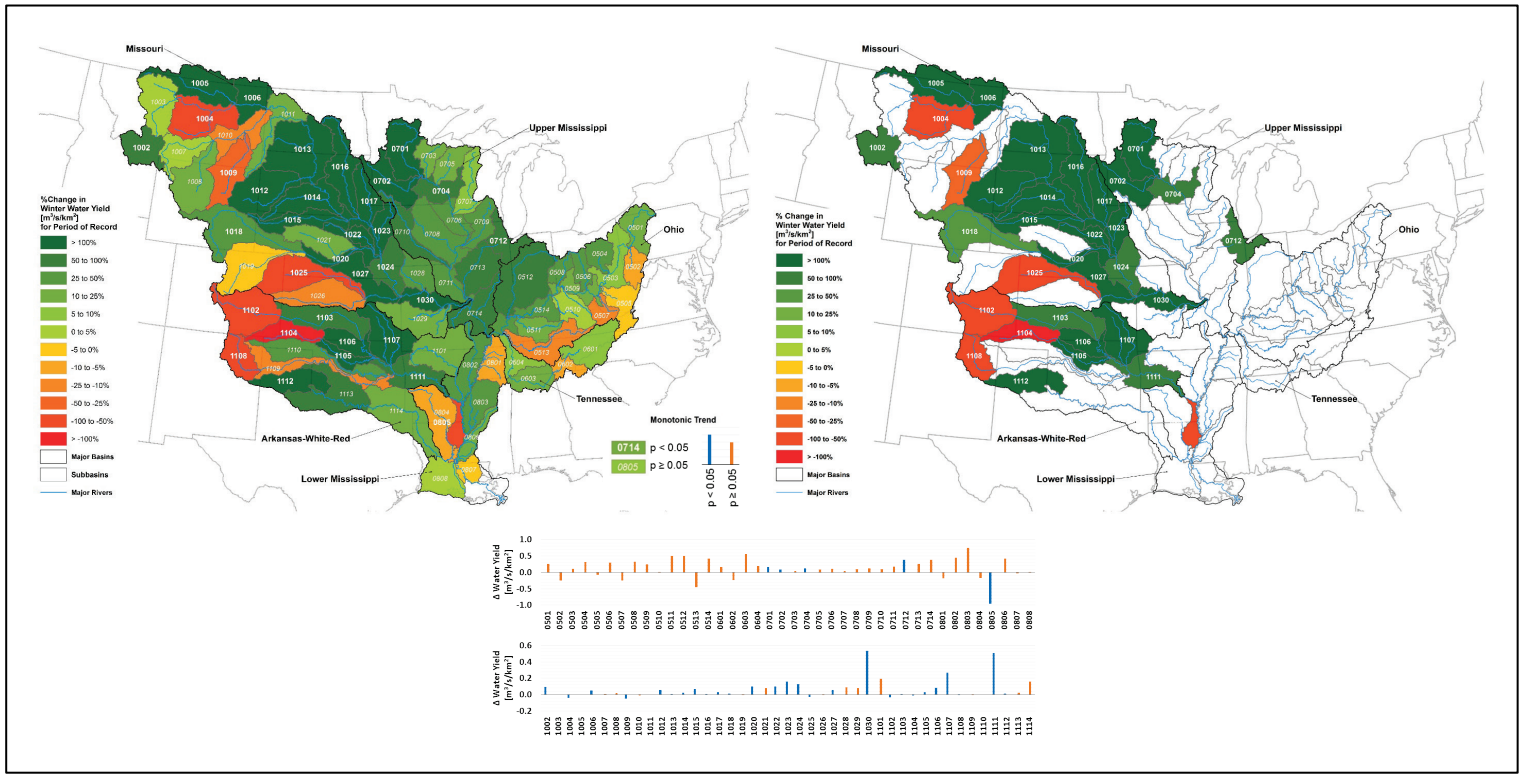


Figure 32. Percent change in spring water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

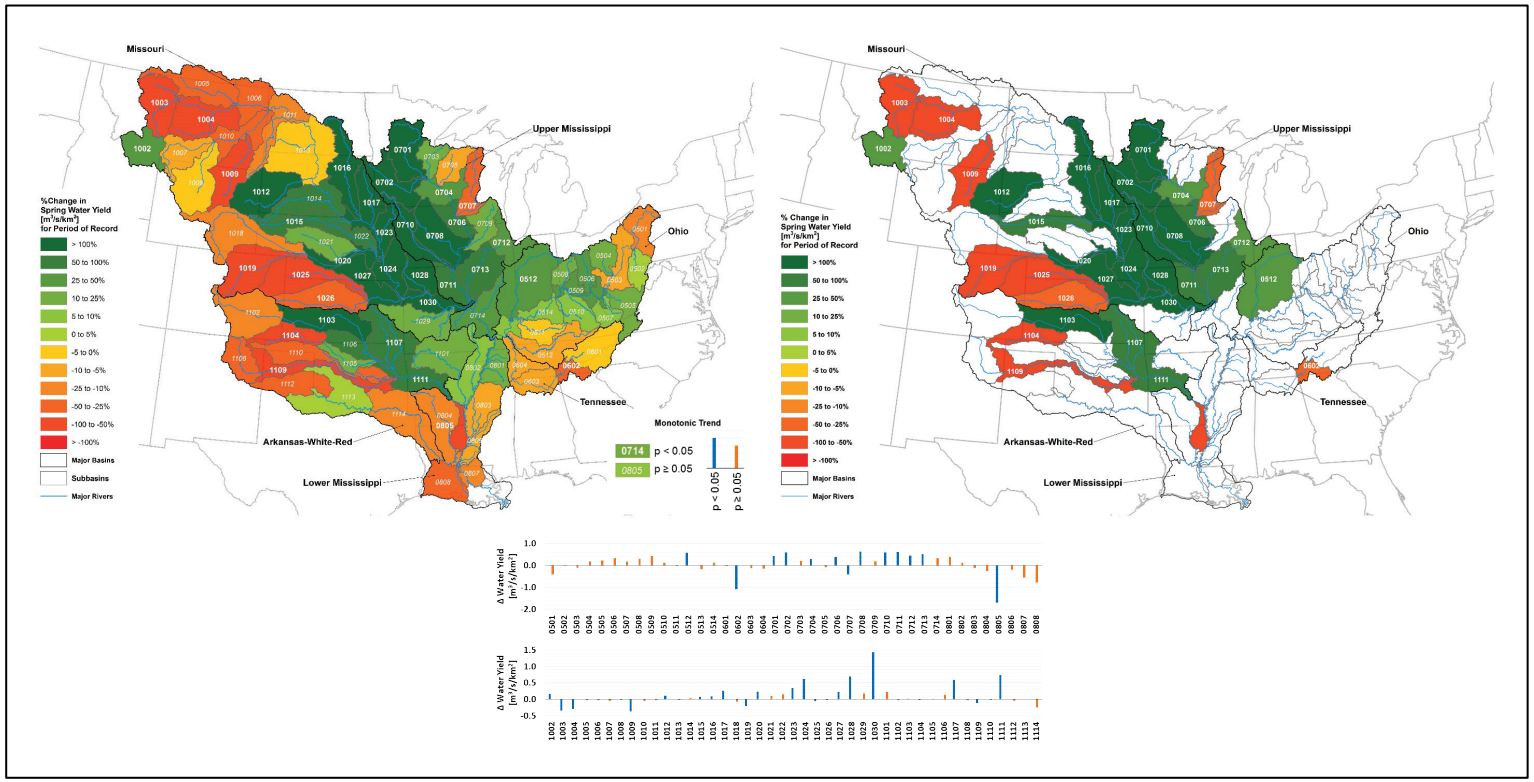


Figure 33. Percent change in summer water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

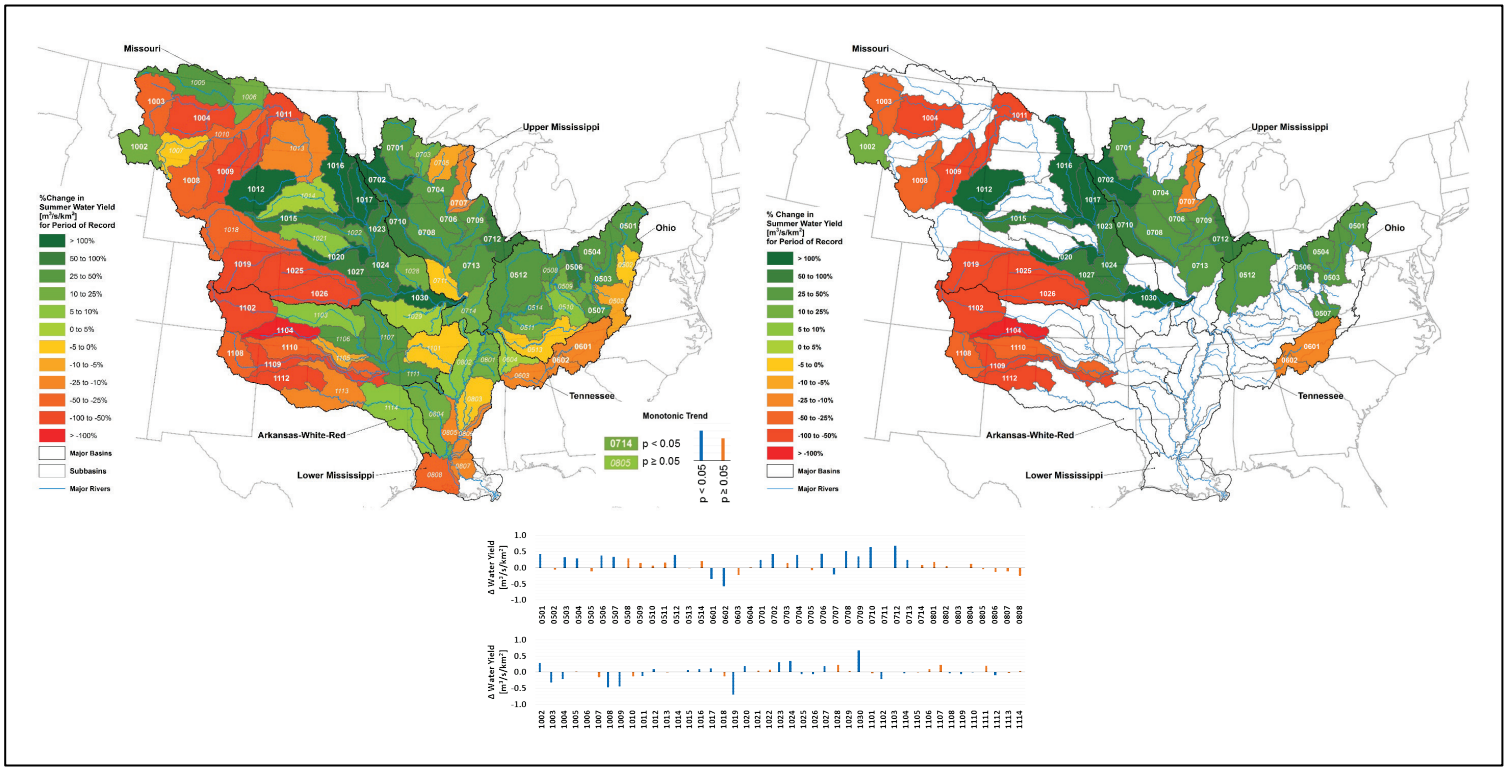
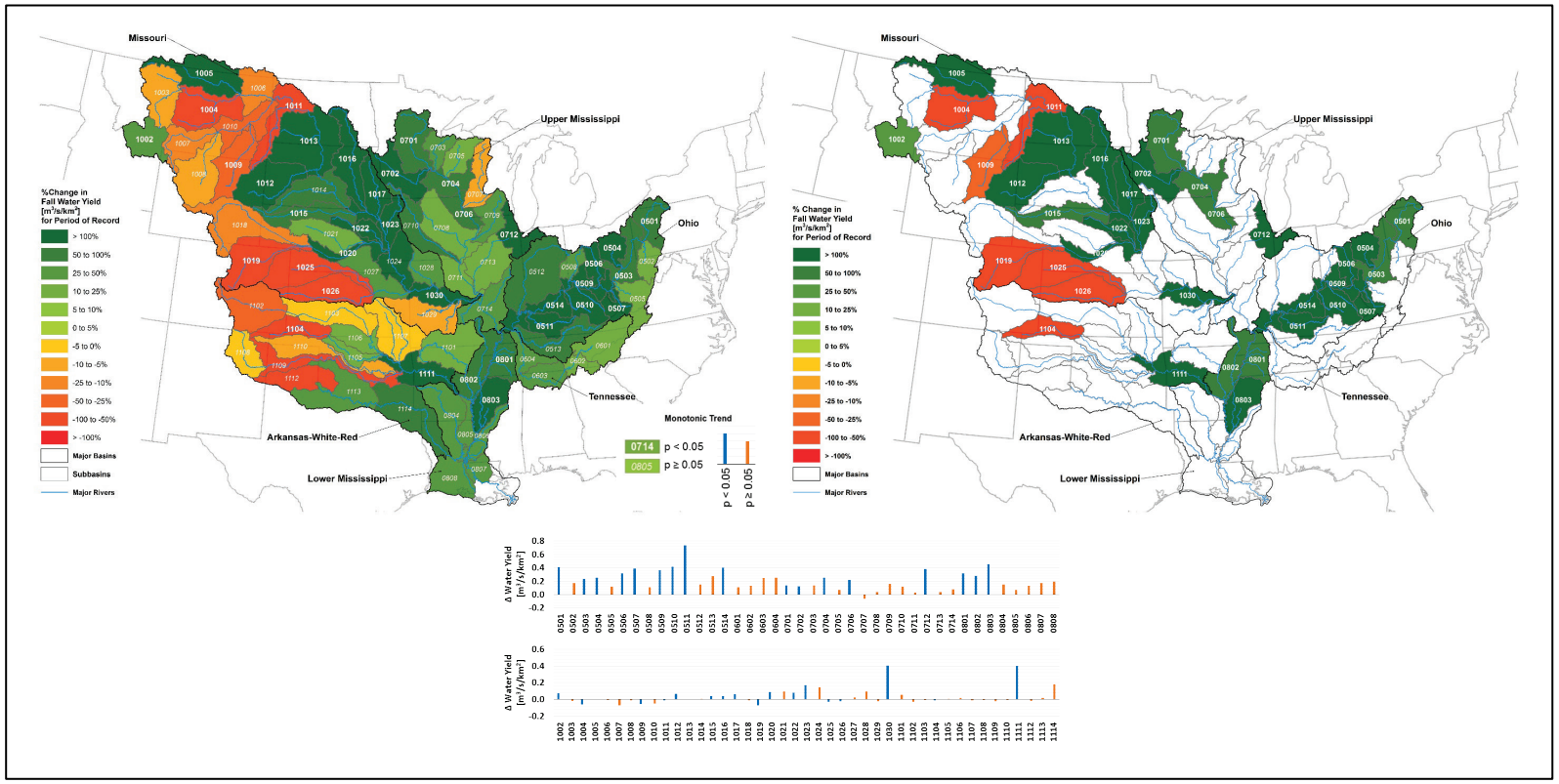


Figure 34. Percent change in fall water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.



Peak seasonal trends

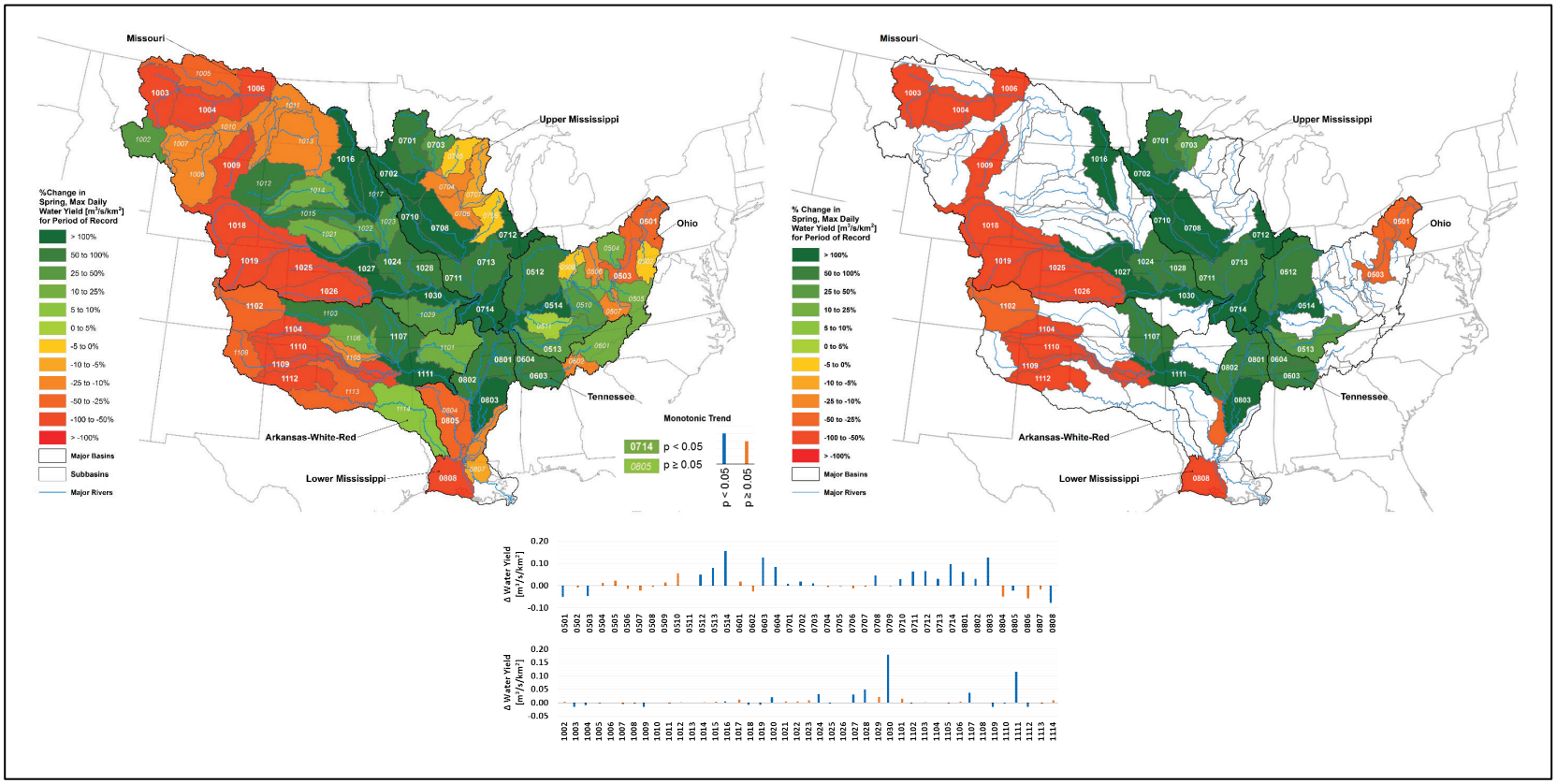
Winter trends

Changes in maximum winter water yields are somewhat misleading for areas such as the Missouri River Basin because the absolute values of the changes are so small. Some sizeable and statistically significant increases have occurred for the 1-day winter peak in parts of the Ohio, upper Mississippi, and lower Mississippi Basins. With increasing durations, more sub-regions within the Ohio Basin show decreases while small increases are detected in the Missouri Basin. In the West, a statistically significant reduction in the extent of snow cover has complicated the relation between heavy precipitation and streamflow (Groisman et al. 2001). In the Missouri River headwaters, snowmelt runoff is occurring earlier than 55 years ago (Moore et al. 2007). Although not addressed in this study, research suggests that the Great Plains and Southern Rockies have longer snow seasons, but annually, the entire United States has seen a widespread decrease in the total number of yearly snow days (Knowles 2015).

Spring trends

Changes in spring maximum daily (Figure 35) water yields are shown below. Spring peak flows in places such as the North Platte (HUC 1018) are strongly influenced by winter precipitation in the high-elevation parts of the watershed. Daniels (2007) found that in the North Platte, basin-averaged precipitation provided a reliable predictor of the annual peak flood and mean annual discharge. In general, peak spring water yields (high flows) decreased in the western-most half of the Mississippi River Basin and increased throughout the central and eastern parts. Of note is the large increase in HUC 1030, the sub-region that encompasses the mouth of the Missouri River. Another HUC-4 of note is the sizeable decrease along the Gulf Coast (HUC 0808), most likely due to withdrawals for irrigation.

Figure 35. Percent change in maximum-daily spring water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.



Summer trends

Most of the western half of the Mississippi River Basin, including the upstream parts of the Missouri, Arkansas, and Red River Basins, exhibit significant decreases in peak water yields during the summer. (Figure 36). Small, but significant increases in these peaks are detected in the Upper Mississippi Basin related possibly to increased peak rainfall and the more efficient conveyance of water during convective storms. Increases are also shown in parts of the Ohio Basin where moderate increases in peak rainfall amounts have been shown. In magnitude, however, the greatest significant increases in water yield across all four of the durations was observed in the Lower Missouri River (HUC 1030).

Fall trends

Again, the typical spatial distribution of changes in peak water yields across the basin are observed, with significant increases across the Ohio, Tennessee, and Lower Mississippi Basins and more moderate increases in the upper Mississippi Basin. These patterns are similar for all of the durations investigated and are displayed for the maximum daily duration only (Figure 37).

Changes within the Missouri Basin become more pronounced as duration increases from 1 day to 7 days but maintains a pattern where there are decreases in fall peaks in the upstream parts of the system combined with increases in the downstream parts. This culminates with the largest increases within the Missouri Basin in HUC 1030. Decreasing peak yields are seen throughout the western sub-basins of the Arkansas and Red Rivers. Significant decreasing trends were also observed in two of these western watersheds: HUC 1104 (Upper Cimarron) and 1109 (Lower Canadian). Despite these decreasing yields, water yield in the most downstream sub-regions of the Arkansas River system (HUC 1111; Lower Arkansas), like its neighbor in the Missouri River, was observed to have significantly increased on the order of >100% across all durations.

Peak water yields during the fall season were all observed to significantly increase over the period of record from the Lower Missouri (1030), Lower Ohio (0514), and Upper Mississippi (0714) to the LMR (Figure 38).

Figure 36. Percent change in maximum-daily summer water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

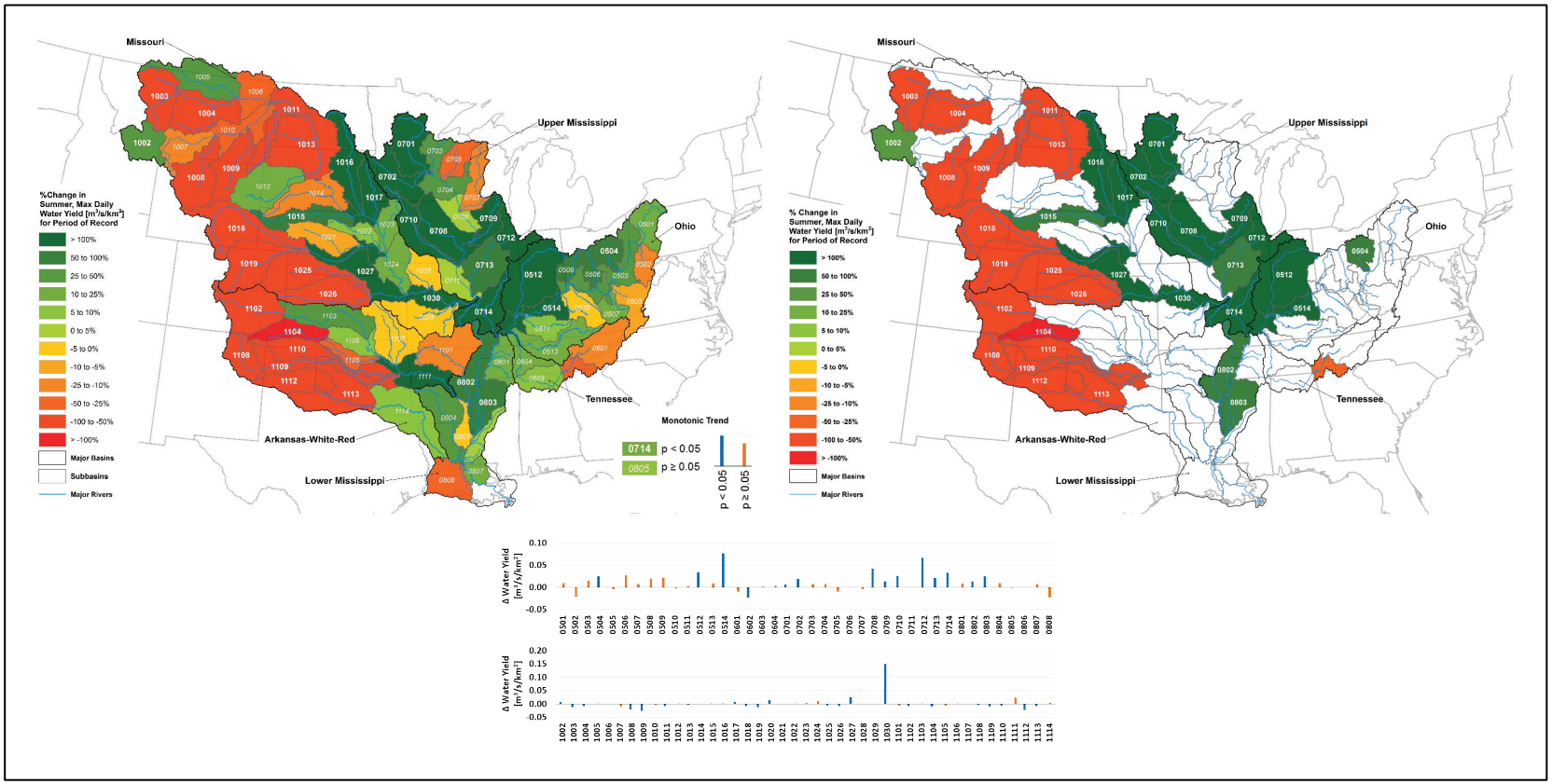


Figure 37. Percent change in maximum-daily fall water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

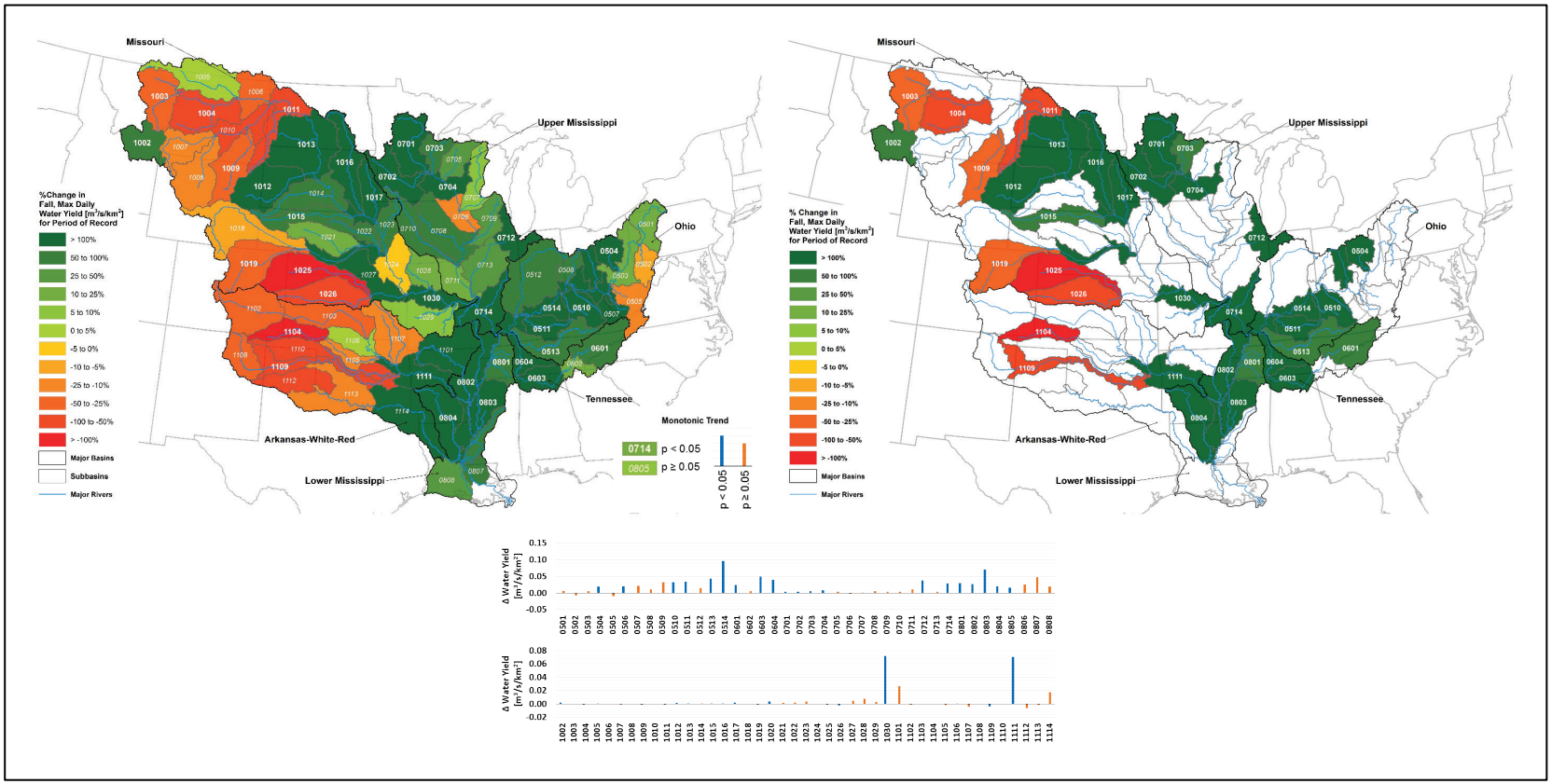
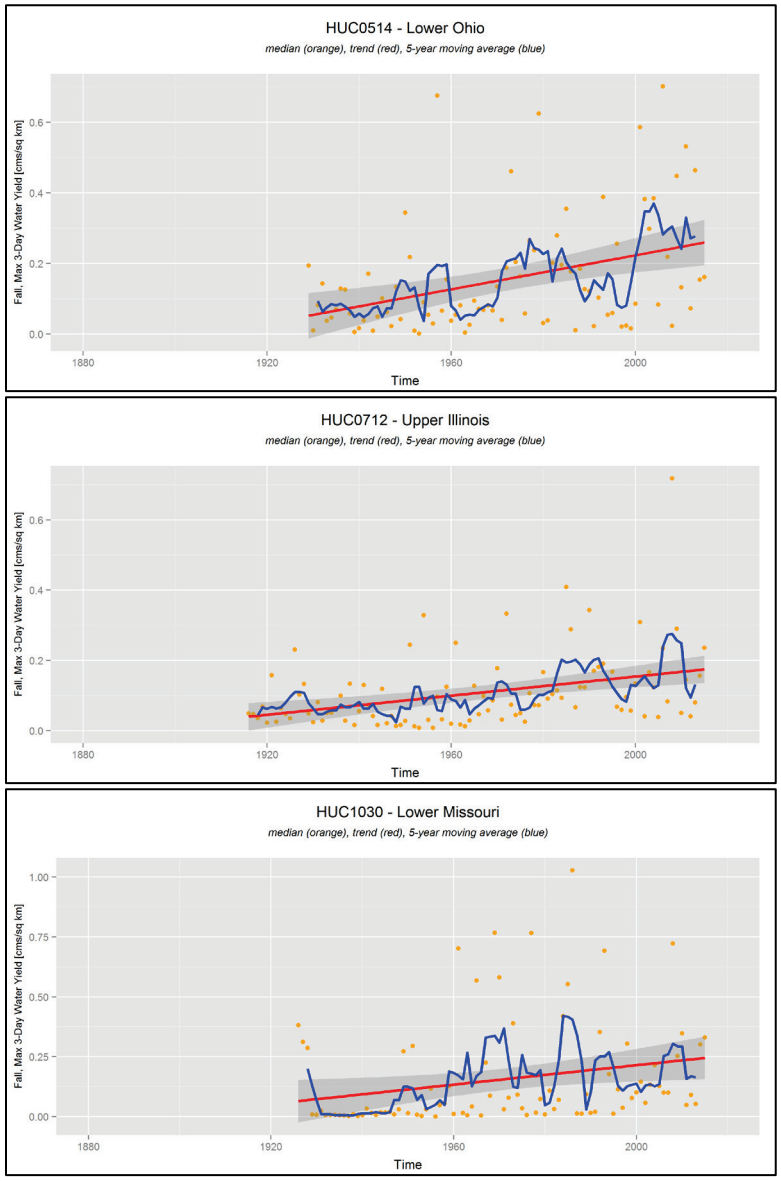


Figure 38. Maximum fall 7-day total water yield for select HUC-4s.



Additional details/results of the sub-regional water yield analyses, including results not shown here, can be found in Appendix F.

Summary of water-yield results

Changes in water yield reflect how discharge regimes have changed over the past century and represent a combination of changes in precipitation and anthropogenic influences. Thus, the spatial patterns are somewhat different than those for precipitation alone.

Average-annual changes in water yield show stark spatial differences between the central part of the basin where important increases have occurred (particularly in the upper Mississippi) and the contributing western basins (upper Missouri, Arkansas and Red River Basins, as well as the western floodplains of the lower Mississippi), which show large percentage decreases in flow. Increases and decreases in these respective regions can be substantial, in the range of 25%–50% or even 50%–100%. Similar spatial trends and magnitudes are apparent for the 1-day and 7-day peak water yields, reflecting vast changes in runoff generation and transmission through the river systems. The importance of water withdrawals and flow regulation in causing decreasing water yields is supported by the knowledge that this has occurred in some HUC4s that have experienced increases in precipitation.

The spatial distribution of changes in seasonal water yields again shows the increase in discharges throughout the mid-continent and the decreases in the western-most parts of the basin. Winter and fall tend to show the greatest areal extent of increases while irrigation withdrawals that peak during the summer months in large parts of the upper Missouri and upper Arkansas and Tennessee Basins, have resulted in important decreases in summer water yields and the amount of water available for ecological processes.

With regard to peak seasonal water yields, there again are stark spatial differences between the western regions showing decreases across the 1- to 7-day durations, and the central and eastern regions that generally showing increasing peak yields. This clear geographic difference is probably mostly related to differences in how human requirements for water vary spatially across the basin relative to the availability of water while recalling that precipitation increases are larger in the mid-continent and southeastern parts of the basin, particularly in the fall. The fact remains though that peak annual and peak seasonal flows have dramatically increased in the central and eastern parts of the basin. This has implications for channel erosion and flood control.

Discussion of the temporal changes in the amount of water being delivered to the LMR from the individual HUC-4s and its major HUC-2 tributaries is the subject of a subsequent section on contributions from index stations.

Trends in precipitation-weighted water yield

Annual trends

Changes in the magnitude and timing of precipitation are not the only influences on water yield. Land-use changes and anthropogenic activities can play an important role in determining how hydrologic inputs such as rain and snow are converted to runoff. Activities that impact hydrologic processes such as infiltration and evapotranspiration can modify rainfall-runoff relations and hence, discharge and water yields. Some of the anthropogenic activities that can have major impacts on rainfall-runoff relations include the change of forests and grasslands to agriculture, urbanization, dams and regulation of flows, evaporation from reservoirs, water withdrawals for irrigation, channelization, tile drainage, etc.

By normalizing the water yield data by the amount of precipitation for the given period that is being investigated, the role of human activities can be isolated. This metric is termed *water-yield, per-unit precipitation*, or precipitation-weighted water yield. Results indicate, therefore, the magnitude of the human-induced changes in water yield across the basin.

The floodplain in the lower Mississippi is water stressed due to large amounts of irrigation-water use associated with domestic and livestock consumptive-water use (Figure 39). Research by Moore et al. (2015) shows similar results associated with water scarcity, the ratio between consumptive water use and runoff. Areas such as the Mississippi River Plain begin relatively unstressed in the winter and become more stressed as irrigation increases and precipitation patterns change throughout the year.

Krakauer and Fung (2008) analyzed streamflow anomalies over the continental United States and found that streamflow increased in the late 1960s with increased precipitation but has not increased since that time. Their analysis was based off of three distinct time periods: 1945–1965, 1970–1990, and 1995–2005. McCabe and Wolock (2002) also detected the increase in streamflows around 1970. Results of this study indicate otherwise. McCabe and Wolock (2014) did note that the increase in streamflows did not extend beyond the year 2000.

Despite trends of increasing annual precipitation (Figure 11), in the central parts of the Mississippi River Basin, normalized, annual water yield still shows statistically significant increases in yield remain (Figure 39). This

indicates that human activities are exacerbating this increase in annual water yield. For instance, in HUC-0712 (Upper Illinois), significant increases in all annual totals of precipitation, water yield, and precipitation-normalized water yield were observed (Figure 40). Presenting the data in this fashion provides a clear picture of the roles of precipitation and human-induced effects as one moves down the figure from trends in precipitation, to see the changes in hydrologic inputs, to water yield to see how that translates to changes in flow and finally, to precipitation weighted water yield, which isolates the anthropogenic effects. In this case, the increases in streamflow met and/or exceeded increases in precipitation and therefore indicates that much of the change can be attributed to human activities.

Other areas with significant increasing trends include the following HUC-4s: 0506 (Scioto), 0512 (Wabash), 0701 (Mississippi Headwaters), 0704 (Upper Mississippi-Black-Root), 0706 (Upper Mississippi-Maquoketa-Plum), 0708 (Upper Mississippi-Iowa-Skunk-Wapsipinicon), 0713 (Lower Illinois), 1015 (Niobrara), 1023 (Missouri-Little Sioux), and 1111 (Lower Arkansas).

More moderate decreasing trends (but not statistically significant) are shown along all the headwater HUC-4s comprising the Ohio and Tennessee River Basins (Figure 39). Decreasing trends are also shown for the HUC-4s along the Gulf Coast and western floodplain of the LMR, further attesting to the role of water withdrawals here on suppressing water yields in the region.

Figure 41 and Figure 42 are provided to show other examples of trends in precipitation that are opposite to trends in water yield due to anthropogenic activities. This is borne out by the trend in precipitation-weighted water yield. Interestingly, HUCs 1002 (Missouri Headwaters) and 1112 (Red Headwaters) exhibited significant changes in precipitation and water yield that trend in opposite directions. HUC 1002 received 77.4 mm less rainfall (-25% to -10%) but observed water yields on the order of 25% to 50% and > 100% higher, respectively (Figure 41). Meanwhile, despite increasing precipitation (129 mm or 25% to 50%), HUC 1112 yielded much less water, -100% to -50% and -50% to -25%, respectively (Figure 42). These are examples of the role of human activities on streamflow.

In HUCs 0514 (Lower Ohio) and 0703 (St. Croix), annual precipitation and water yield significantly increased. However, when normalized by annual precipitation, water yield was not found to be statistically significant. The opposite was true for HUC 1109 (Lower Canadian). It received significantly more rainfall (25% to 50%) over the period of record but did not exhibit any detectable trends in water yield. When normalized by annual precipitation, water yield in HUC 1109 was found to be significantly negative, decreasing by a magnitude of -100% to -50%. Human-induced impacts have resulted in decreases in water yields in upstream reaches of the Missouri and Arkansas River Basins. The large decrease in precipitation-weighted water yield in HUC 1009 (Powder-Tongue) is heavily influenced by a single observation prior to the dust bowl era of the 1930s (Figure 43).

Figure 39. Percent change in annual precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

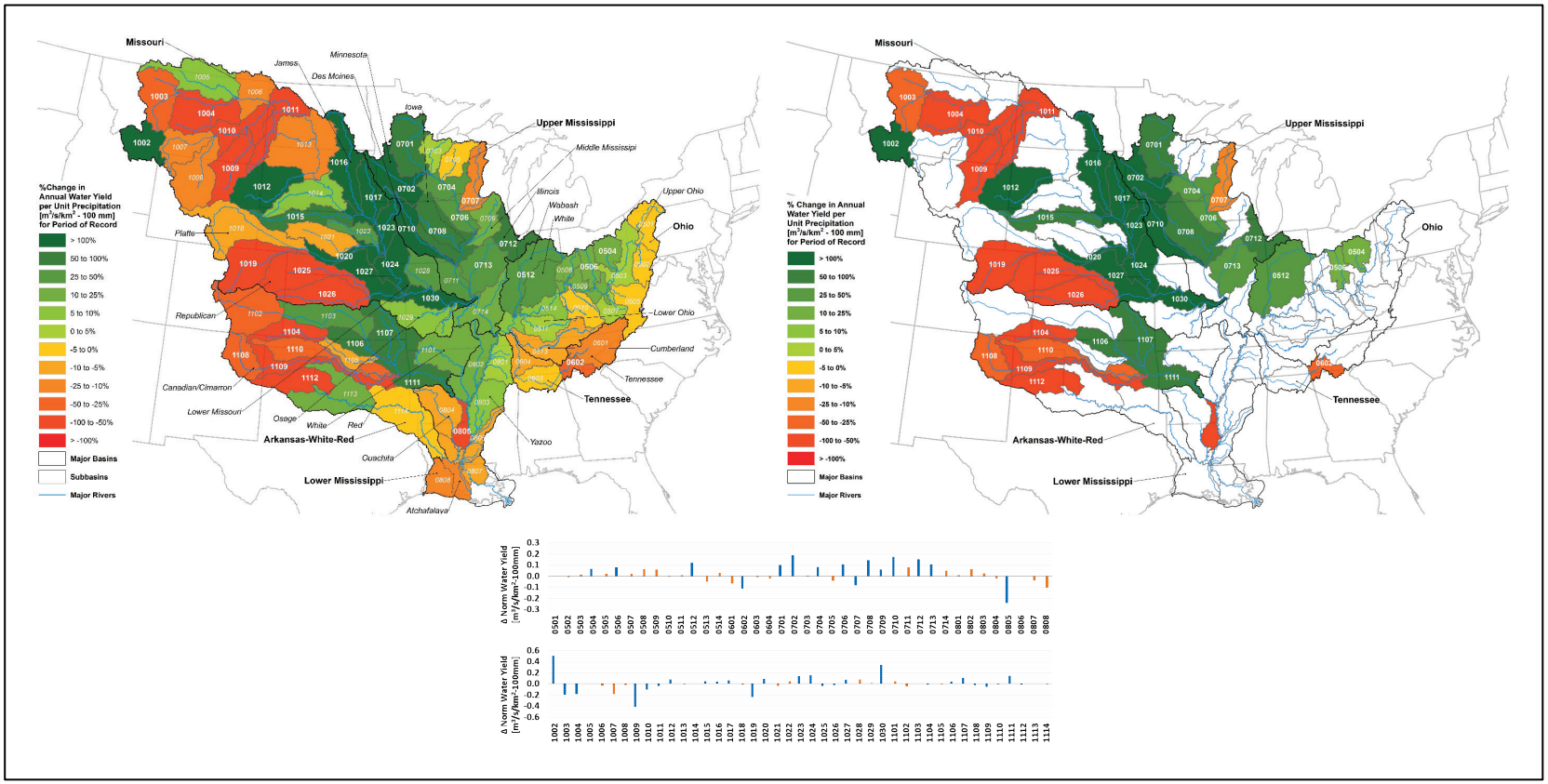


Figure 40. Annual trends in HUC 0712 (Upper Illinois). Precipitation (top), water yield (middle), and precipitation-weighted water yield (bottom).

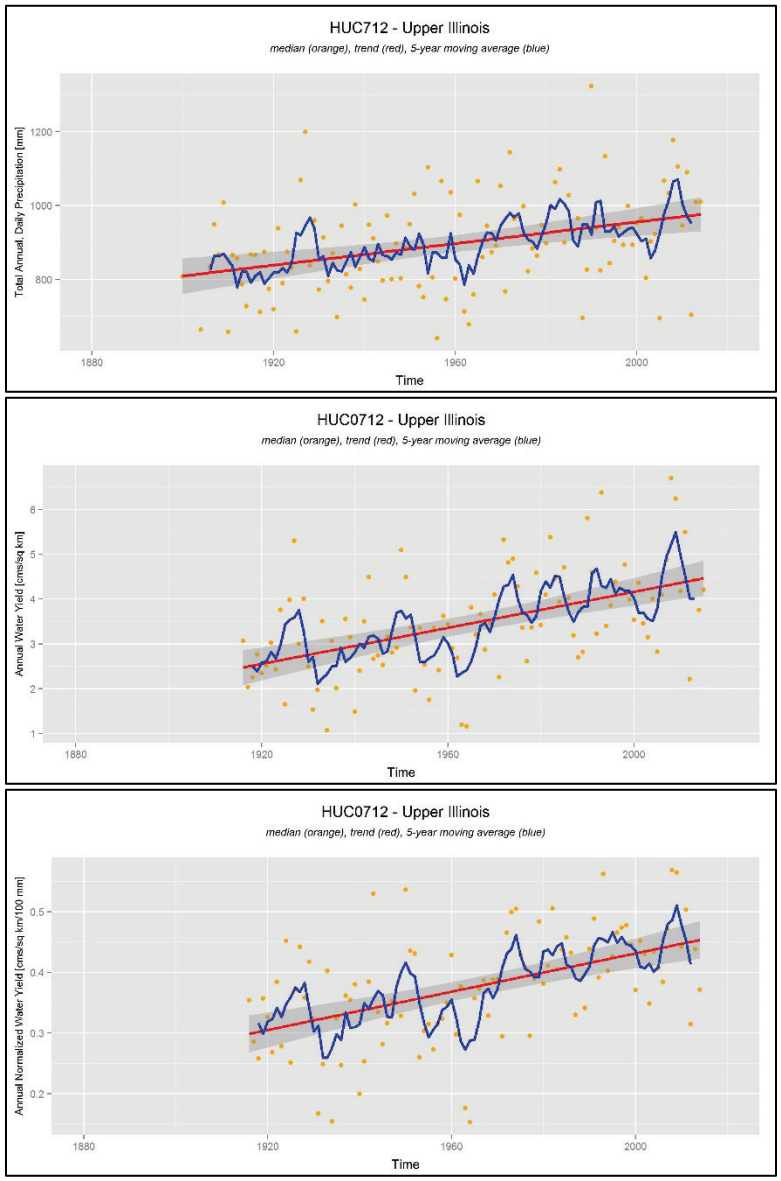


Figure 41. Annual trends in HUC1002 (Missouri Headwaters). Precipitation (top), water yield (middle), and precipitation-weighted water yield (bottom).

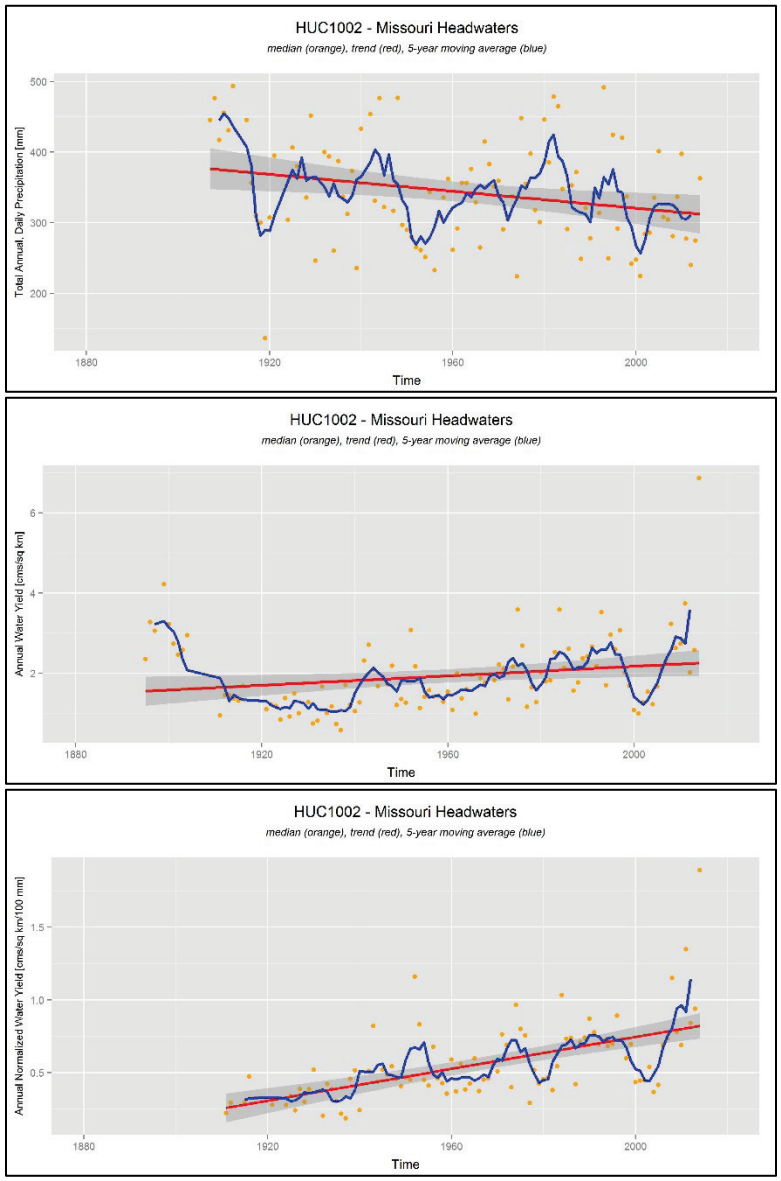


Figure 42. Annual trends in HUC1112 (Red Headwaters). Precipitation (top), water yield (middle), and precipitation-weighted water yield (bottom).

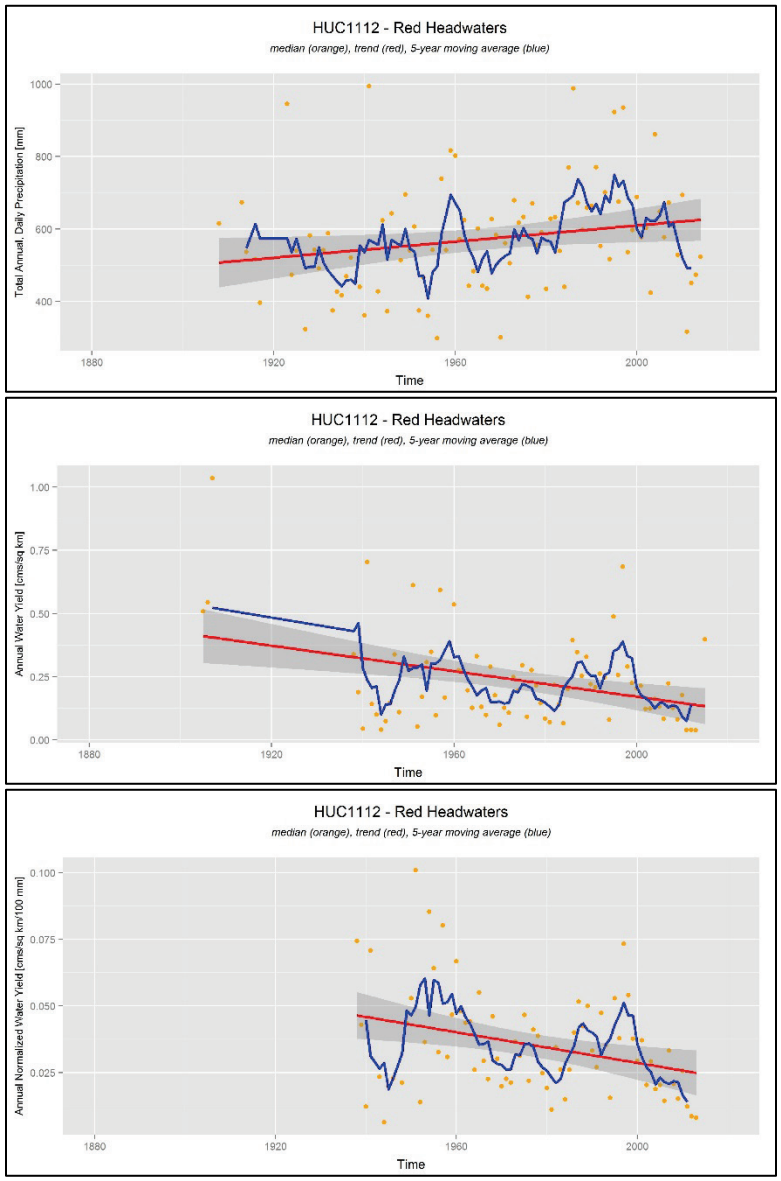
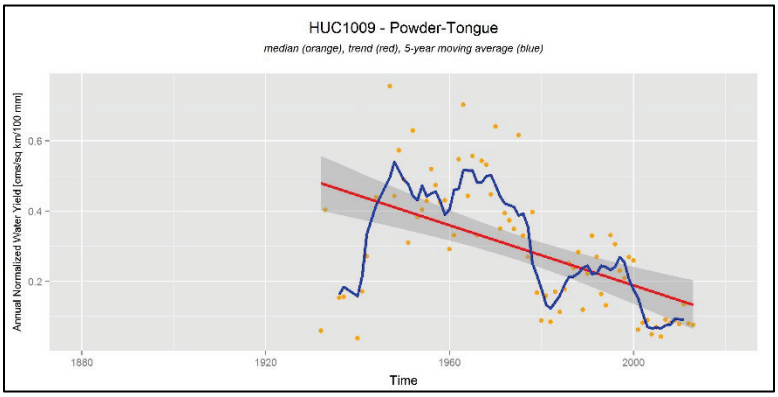


Figure 43. Precipitation-weighted water yield in HUC1009 (Powder-Tongue).



Potential evaporation from NID impoundments

Aside from water withdrawals from rivers and reservoirs for irrigation, evaporation from impoundments can potentially be another important source of water losses. As these losses represent the influence of dams throughout the basin, the NID database was used to determine the location and timing of dam construction and areal dimension of the associated pools on a decadal basis starting in 1900. The objective was to estimate evaporation behind dams as the product of the surface area of the impoundment and the rate of evaporation per unit area. Thus, changes in total potential evaporation behind dams over the past century is largely a function of (1) the timing and cumulative pool area of constructed dams and (2) the spatial distribution of pan-evaporation rates.

Examples of the number of dams constructed by decade in the state of Iowa is shown in Figure 44 (Left) along with the cumulative surface area impounded by dams in HUC 0511 (Right). Integrating the NID data across the major HUC-2 basins shows the major era of dam building between the 1950s to 1970s, leading to current levels of impoundment and therefore, maximum levels of evaporation from these regions (Figure 45).

Figure 44. NID impoundments in Iowa by completion date (left) and cumulative surface area of NID impoundments in HUC 0511 (green; right).

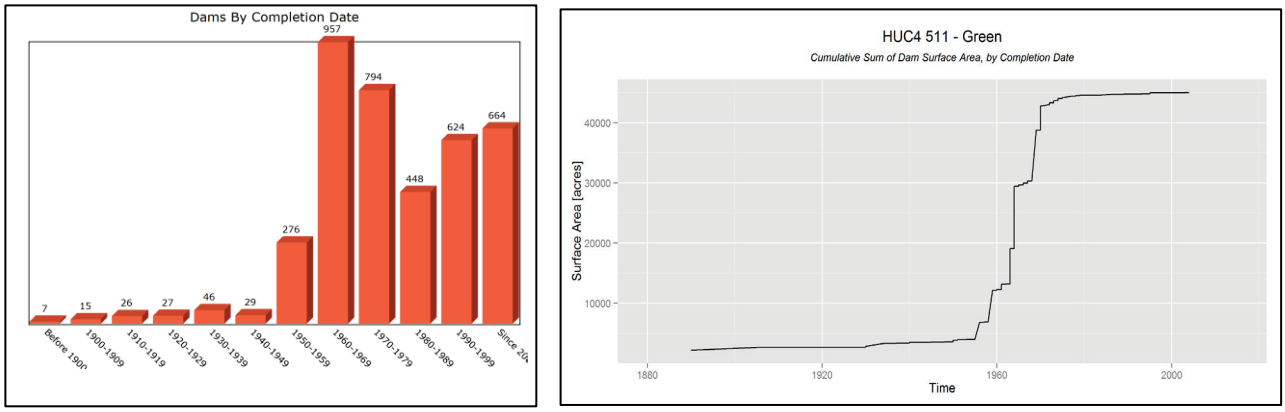
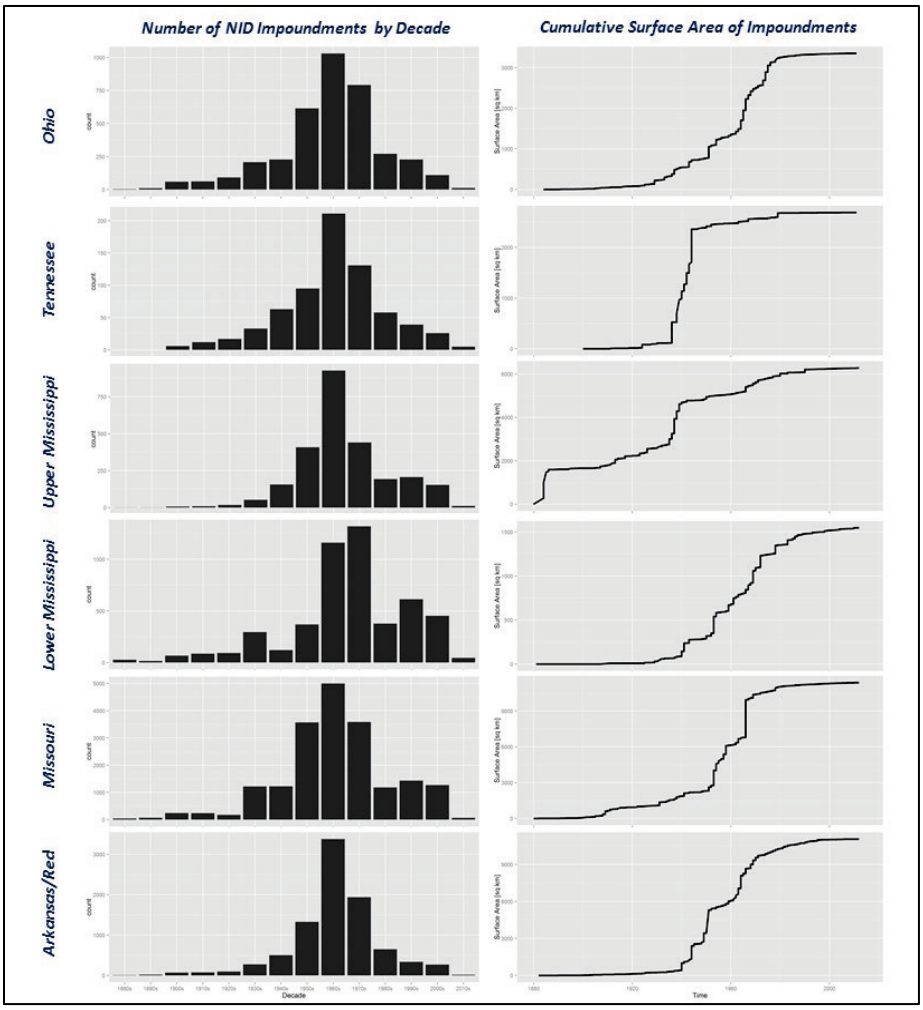


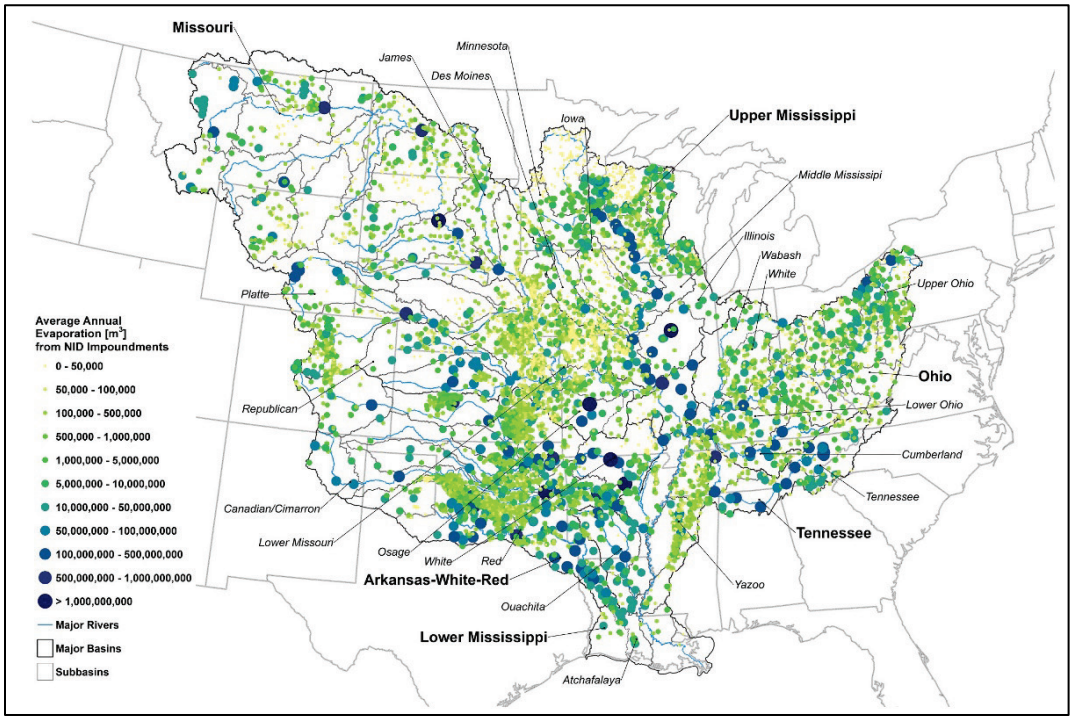
Figure 45. Number and cumulative surface-area of impoundments by decade and by HUC-2 since 1900.



Average annual potential evaporation at NID impoundments across the Mississippi River Basin was estimated from GHCND pan-evaporation observations (Figure 46). For details, see Appendix D for average monthly evaporation from each NID impoundment. These annual estimates are a function of GHCND data availability, location of the impoundment, and surface area at the normal pool elevation of the impoundment. As expected, the largest impoundments along the Mississippi River and its major tributaries have the greatest amounts of potential evaporation, as well as impoundments in the southern half of the river basin.

Although river modification in various parts of the basin began in the early 1800s, rapid and widespread dam construction did not begin in earnest until passage of the Pick-Sloan Flood Control Act in 1944. The cumulative effect of NID impoundments on potential evaporation over time is shown in Figure 47, where the cumulative evaporation is based on the total impounded area at the mid-point of each decade. Clearly, there have been drastic increases in evaporation over the past century across the basin.

Figure 46. Average annual evaporation from NID impoundments.



Assuming that potential evaporation from NID impoundments is roughly equivalent to actual evaporation, average *effective rainfall* can then be estimated by subtracting evaporation from total rainfall. Changes in the percentage of average annual evaporation versus average annual rainfall by HUC-4 is shown in Figure 48.

Figure 47. Average-annual potential evaporation from impoundments, by decade.

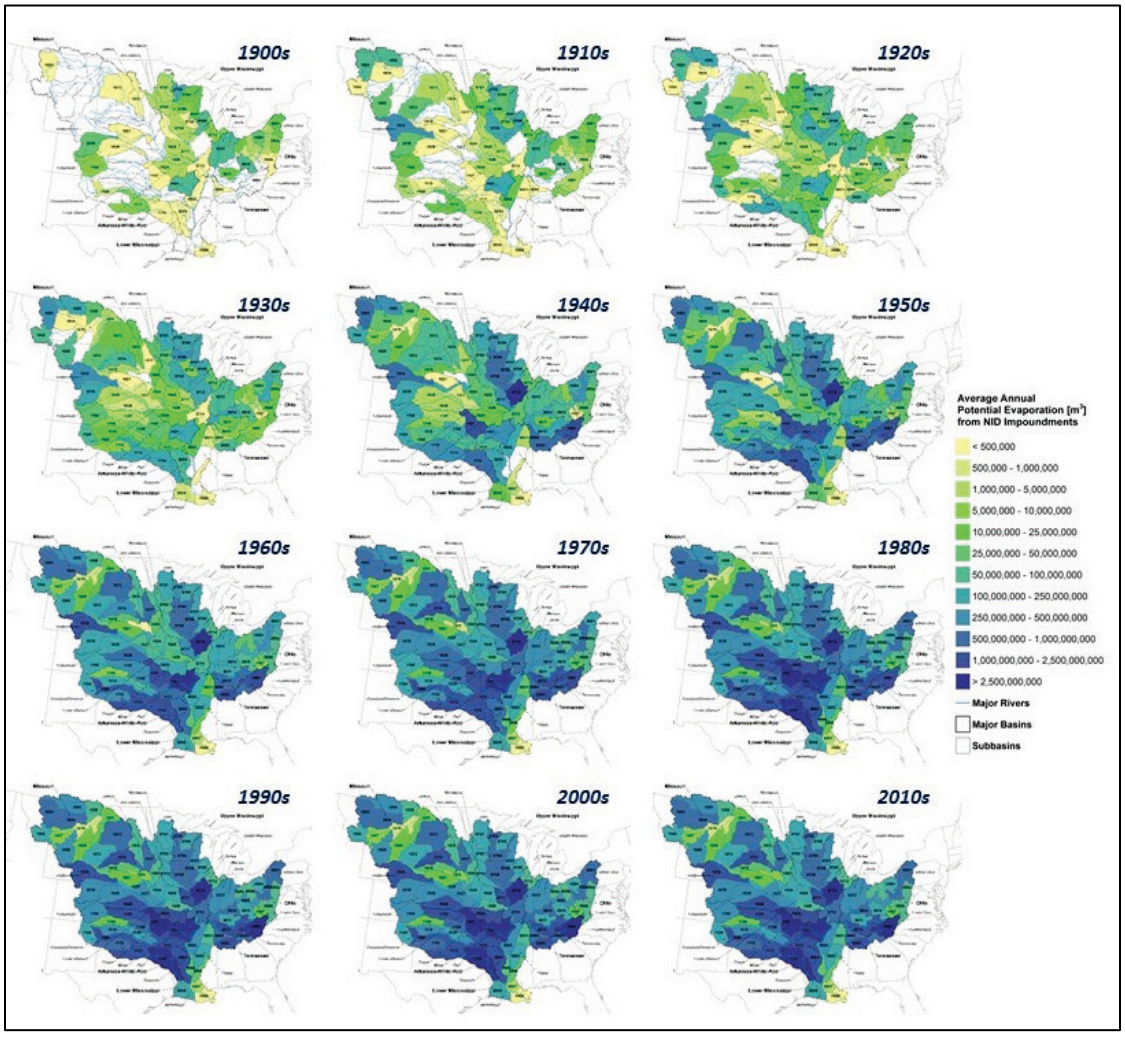
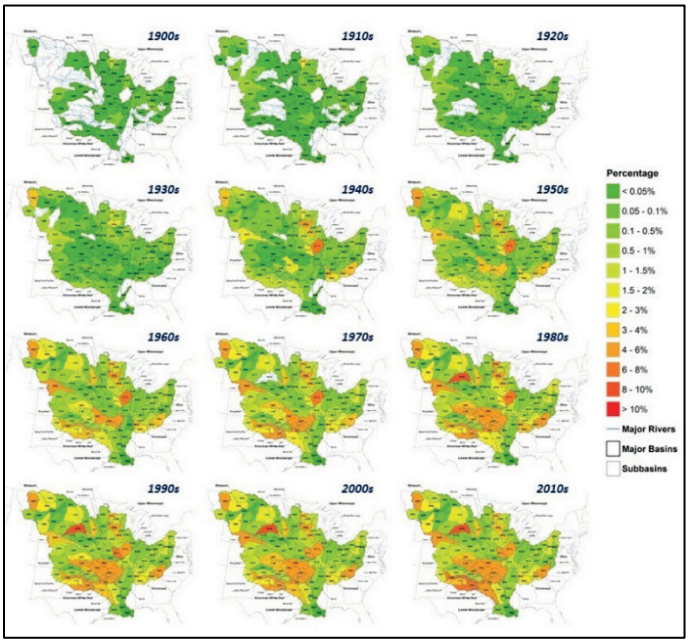


Figure 48. Percentage of average-annual potential evaporation from HUC-4s relative to decadal average-annual rainfall by decade.



At the HUC-2 level, the total potential evaporation of water behind NID dams surpassed 3% of the decadal average rainfall volume in the Tennessee River Basin since the 1940s and in the Arkansas/Red/White Basin since the 1970s. At the basin level, the percentage of NID evaporation compared to total rainfall exceeded 2% starting in the 2000s. In several HUC-4s, the total potential evaporation of water behind NID dams, at some point, reaches a value greater than 5% of the of decadal average rainfall volume (Table 2).

Table 2. HUC-4s with greater than 5% of potential evaporation relative to annual rainfall.

HUC-4	HUC-4 Name	Earliest Decade
0711	Upper Mississippi-Salt	1990s
0713	Lower Illinois	1940s
1003	Missouri-Marias	1960s
1014	Missouri-White	1970s
1101	Upper White	1960s
1107	Neosho-Verdigris	2010s
1109	Lower Canadian	1960s
1113	Red-Washita	1980s

Peak annual trends

Recalling that this analysis identifies human-induced changes, annual, maximum daily (Figure 49), 3-day, 5-day, and 7-day precipitation-weighted water yields showed persistent regional trends of decreasing yields in the western and far eastern parts of the Mississippi River Basin. In the west, it is assumed that this is due to dam operations and withdrawals for irrigation. In contrast, anthropogenic impacts resulted in increasing peaks within the Interior Plains. These increases throughout the mid-continent are generally thought to be the result of large-scale channelization programs which although resulted in incision, widening and increased sediment loads (Simon 1989a,b; Simon 1994; Simon and Rinaldi 2000), did in fact increase conveyance and peak flows by providing for a more efficient hydraulic system. In many sub-regions, agricultural practices are thought to strongly influence the observed precipitation-weighted yields. For example, along the western floodplain of the LMR, the region is dominated by rice production where continuous flooding of fields is a widespread practice (Massey et al. 2014). Indeed, this region is easily identified in the Moore et al. (2015) maps of irrigation-related water use in the United States (Figure 50).

In terms of the percent change, the Upper Cimarron (1104) experienced the greatest decrease in maximum weighted yield across all durations analyzed (> 100%). In areas of the Upper Mississippi and Missouri, such as the Minnesota (0702), Upper Mississippi-Iowa-Skunk-Wapsipinicon (0708), James (1016), Platte (1020), Kansas (1027), and Lower Missouri (1030), precipitation-weighted water yield increased by more than 100% across all durations.

Figure 49. Percent change in maximum-daily precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for All HUC-4s (bottom), with significant trends shown in blue.

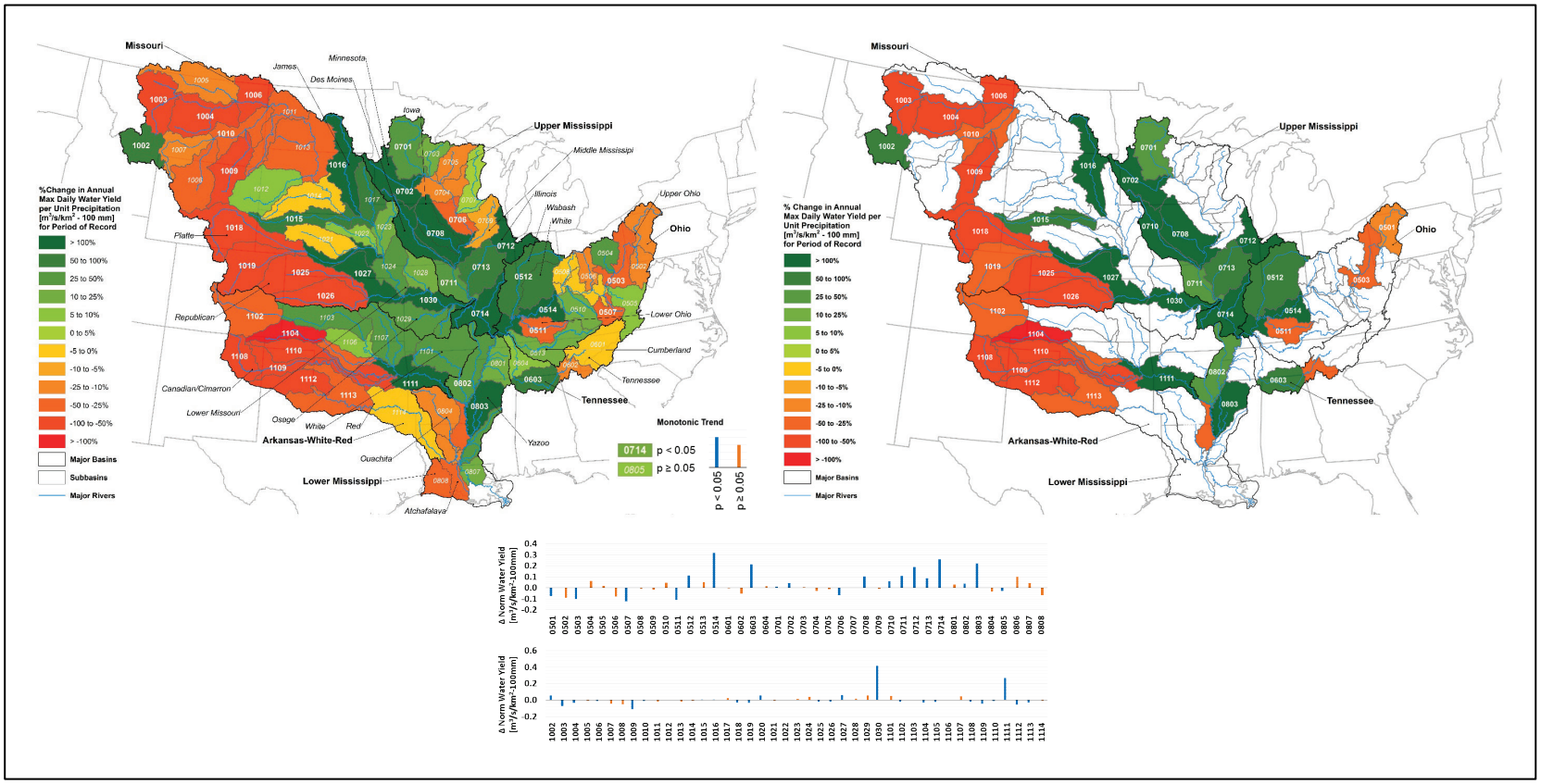
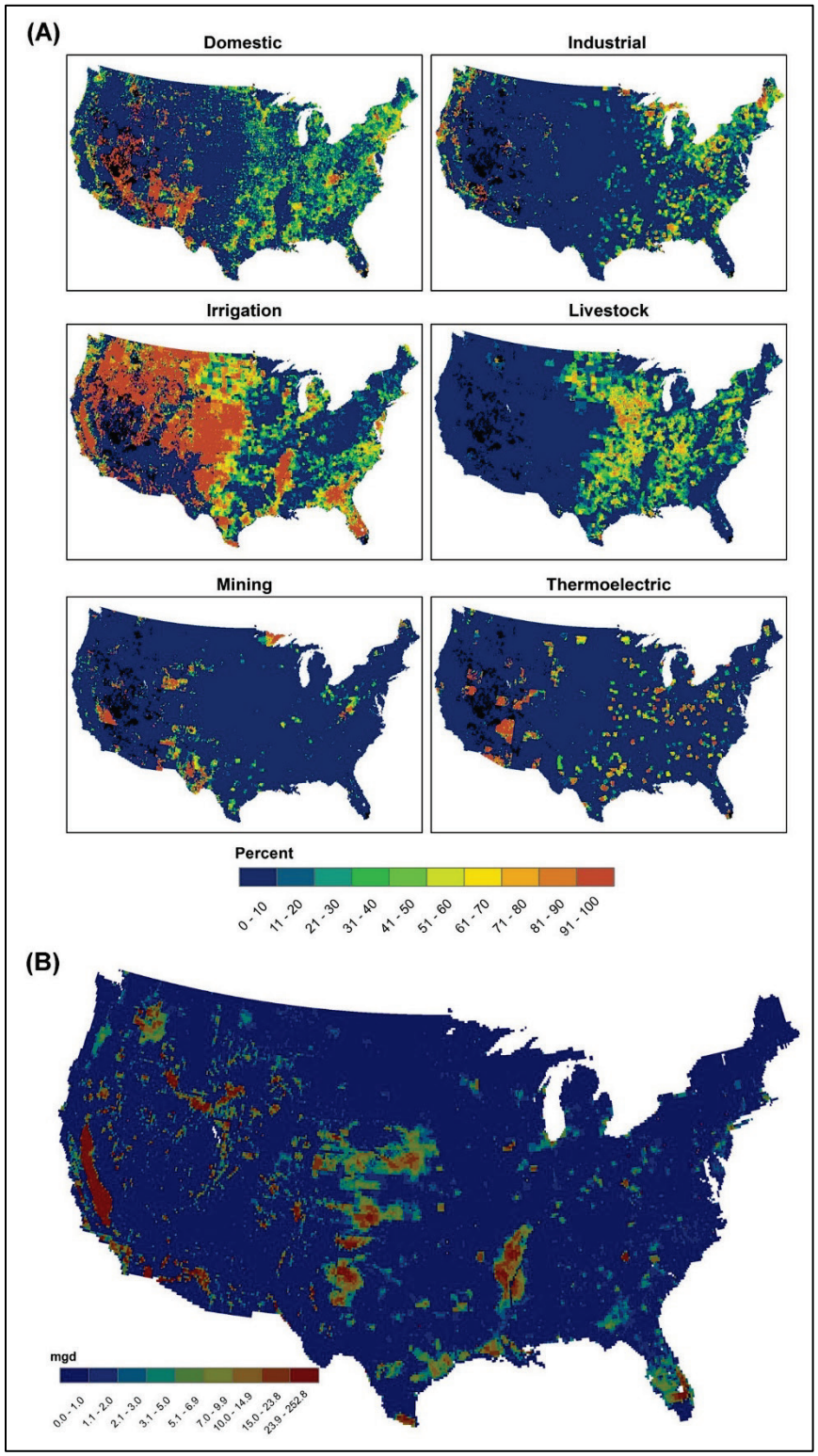


Figure 50. Consumptive water use in the conterminous United States (from Moore et al. 2015).



Seasonal trends

Seasonal trends in precipitation-weighted water yield reflect differences in how anthropogenic influences at different times of the year have effected long-term changes. Thus, seasonal differences in activities such as irrigation and flow regulation may be identified. Year-round, it appears that median, precipitation-weighted water yields from the Lower Missouri have increased Figure 51–Figure 54), probably reflecting the change in winter flow regimes along the release-controlled Missouri River and major tributaries.

Winter water yields have increased across much of the basin, with some HUC-4s in the upper basin (1004, 1009, 1025, and 1104) showing persistent decreases throughout the season. During the spring, weighted yield decreased in the Wisconsin (0707), Allegheny (0501), Green (0511), Cumberland (0513), and across most of the Tennessee River Basin. Increases in water yields across much of the Interior Plains were also observed during the summer and fall. Spatial patterns in the spring and summer show reductions in water yield across vast areas of the basin probably owing to irrigation that reduces the amount of water available for streamflow.

Seasonal patterns of precipitation-weighted water yields are, again, likely highly influenced by agricultural practices. As noted by Kochendorfer and Hubbart (2010), the direction and magnitude of seasonal trends in streamflow in the Upper Mississippi cannot always be explained by precipitation alone and attributed the patterns to *rural land use* (i.e., agricultural) changes. This is also what the precipitation-weighted water yield results contained herein are indicating. If the changes in water yield were directly compared to precipitation-weighted water yield across the basin's sub-regions, it would be found that the differences are not great, indicating that anthropogenic effects are critical, if not the most important, in understanding the changes in hydrology observed over the past century.

Similarly, decreases in fall and winter water yields in HUCs 0807 (Lower Mississippi-Lake Maurepas) and 0808 (Coastal Louisiana) could be due to widespread rice production in the area. Approximately 65% of the rice grown in the United States is produced in the LMR Valley where fields are continuously flooded with irrigation water derived from the Mississippi River Valley alluvial aquifer (Massey et al. 2014).

Figure 51. Percent change in winter precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

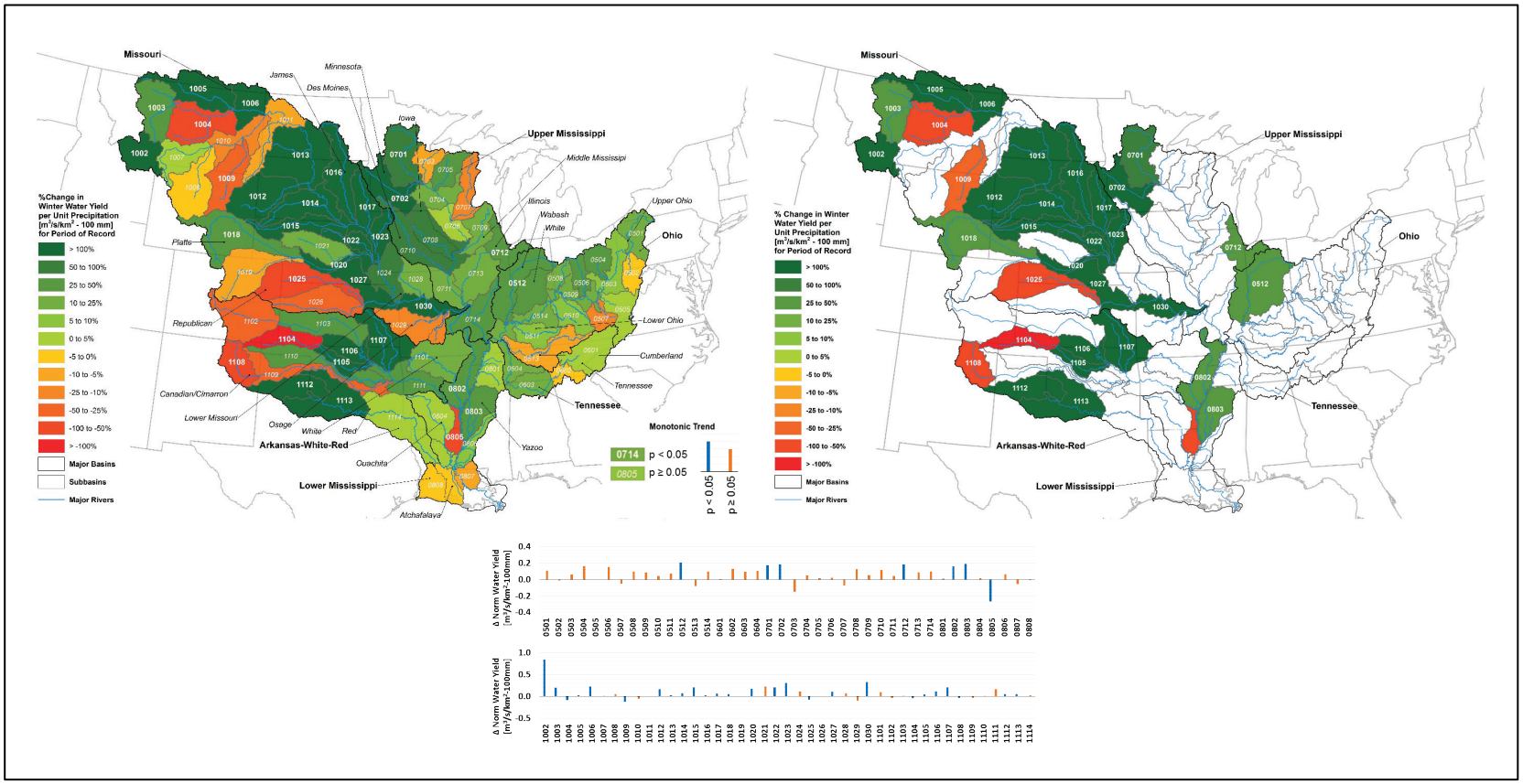


Figure 52. Percent change in spring precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

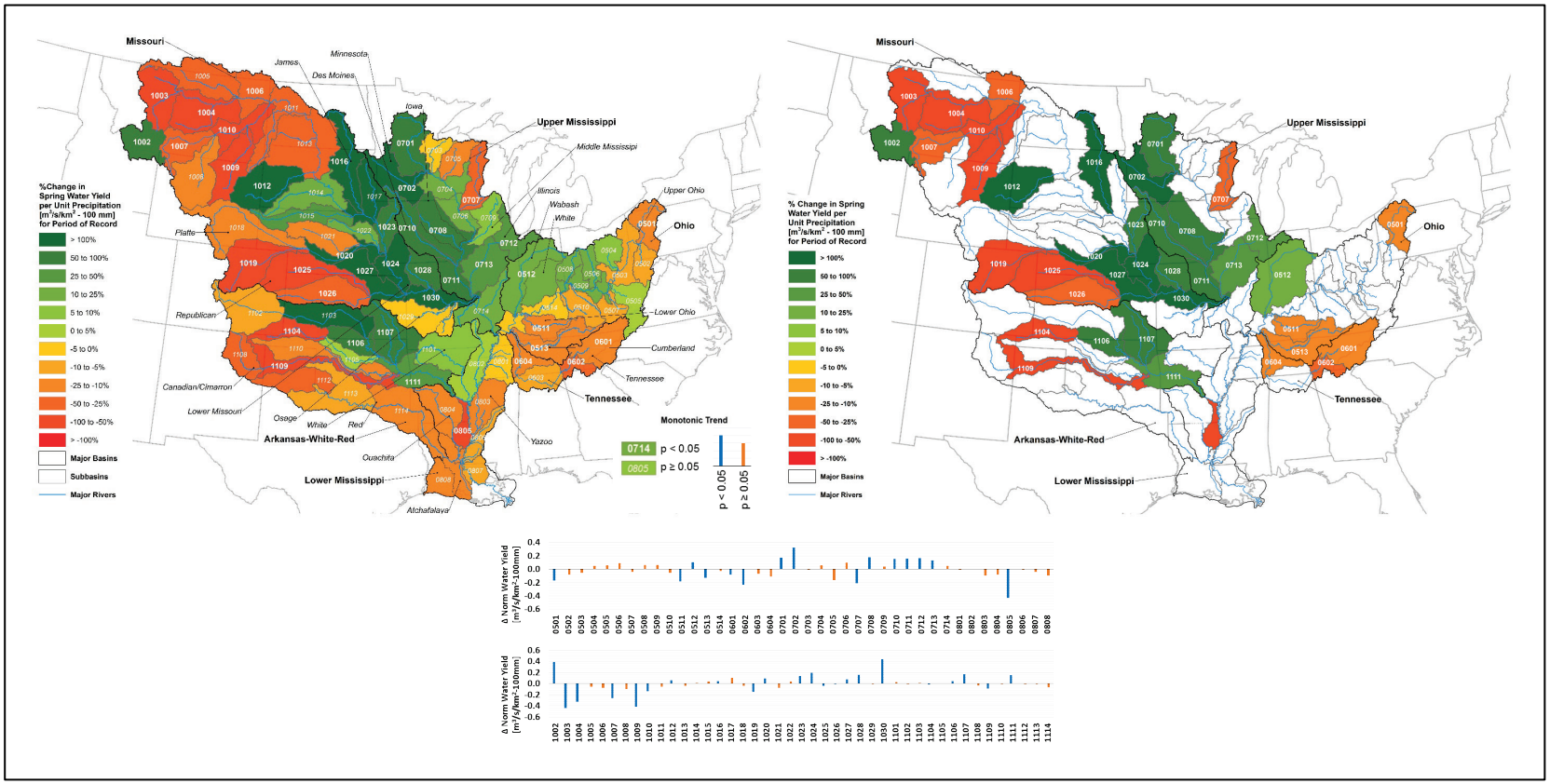


Figure 53. Percent change in summer precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.

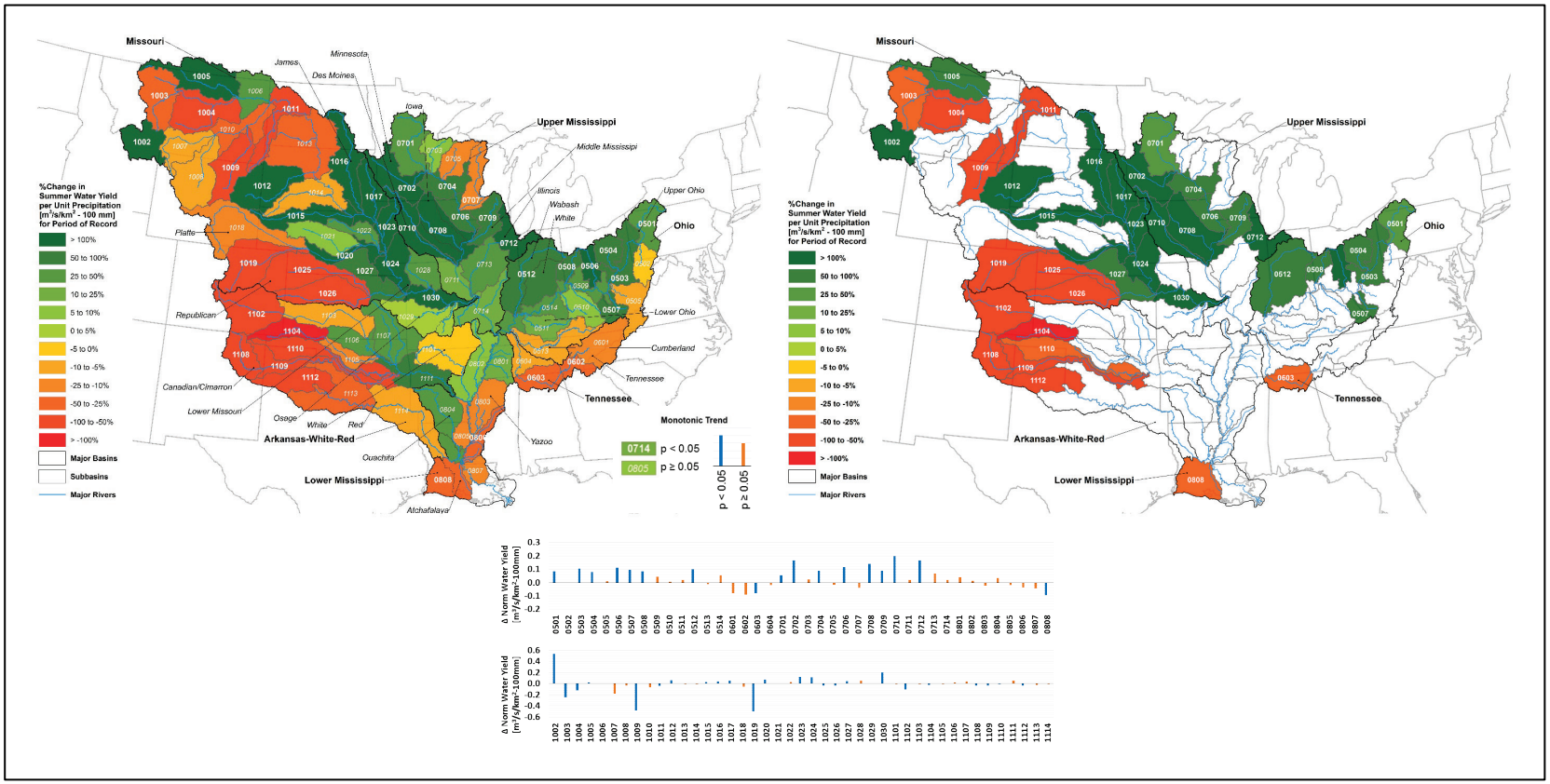
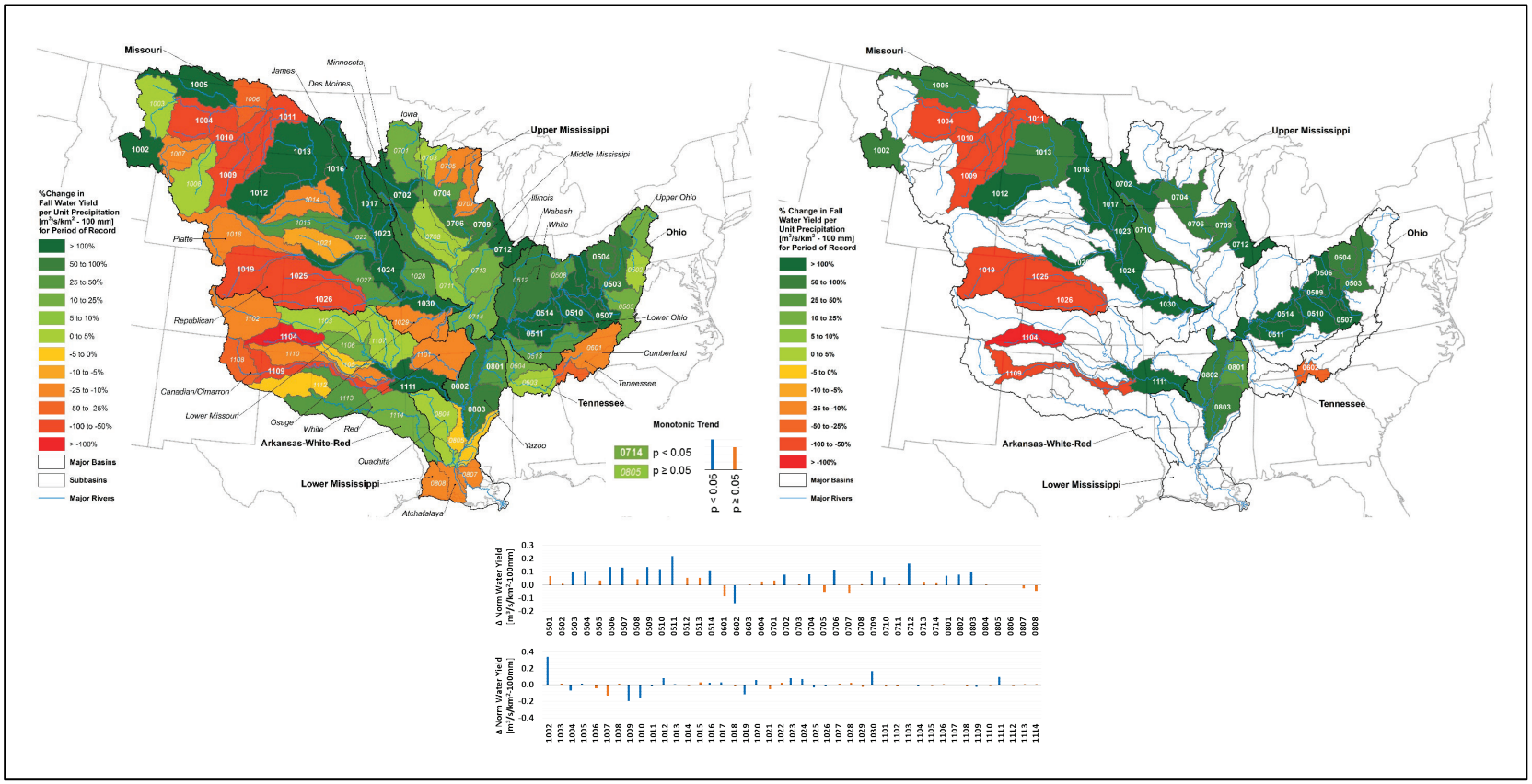


Figure 54. Percent change in fall precipitation-weighted water yield for all HUC-4s (top left) and for HUC-4s with statistically significant trends only (top right). Change for all HUC-4s (bottom), with significant trends shown in blue.



Peak seasonal trends

Results show that there is a distinct spatial shifting of significant influences from season to season. As the spatial patterns of seasonal trends in precipitation-weighted water yield are similar to the distribution for peak values, the authors only provide discussion of these results without the customary supporting maps.

Winter trends

Winter peak water yields have increased across the Great Plains in Wyoming, Nebraska, and the Dakotas as well as sporadically across the Interior Plains. Decreasing trends were observed in Powder-Tongue (1009), Republican (1025), along the Arkansas (1103, 1106), Upper Cimarron (1104), and in the Beouf-Tensas (0805). Aside from decreased yields in the upper Ohio River Basin, regional patterns of peak winter yields are nearly identical to overall winter precipitation-weighted yields.

Spring trends

Increased springtime precipitation-weighted water yields are less ubiquitous than in wintertime in the Interior Plains and shift such that decreased yields dominate the far western half of the river basin and were also observed in the Wisconsin (0707), the upper Ohio (0501, 0503), and parts of the Lower Mississippi.

Spring flood flows in the Minnesota (HUC 0702) increased over the period of record, with rapid increases occurring in the last 20 years. Using a similar technique, Novotny and Stefan (2007) analyzed seven precipitation-weighted streamflow metrics in the Minnesota and observed the same phenomena.

Summer trends

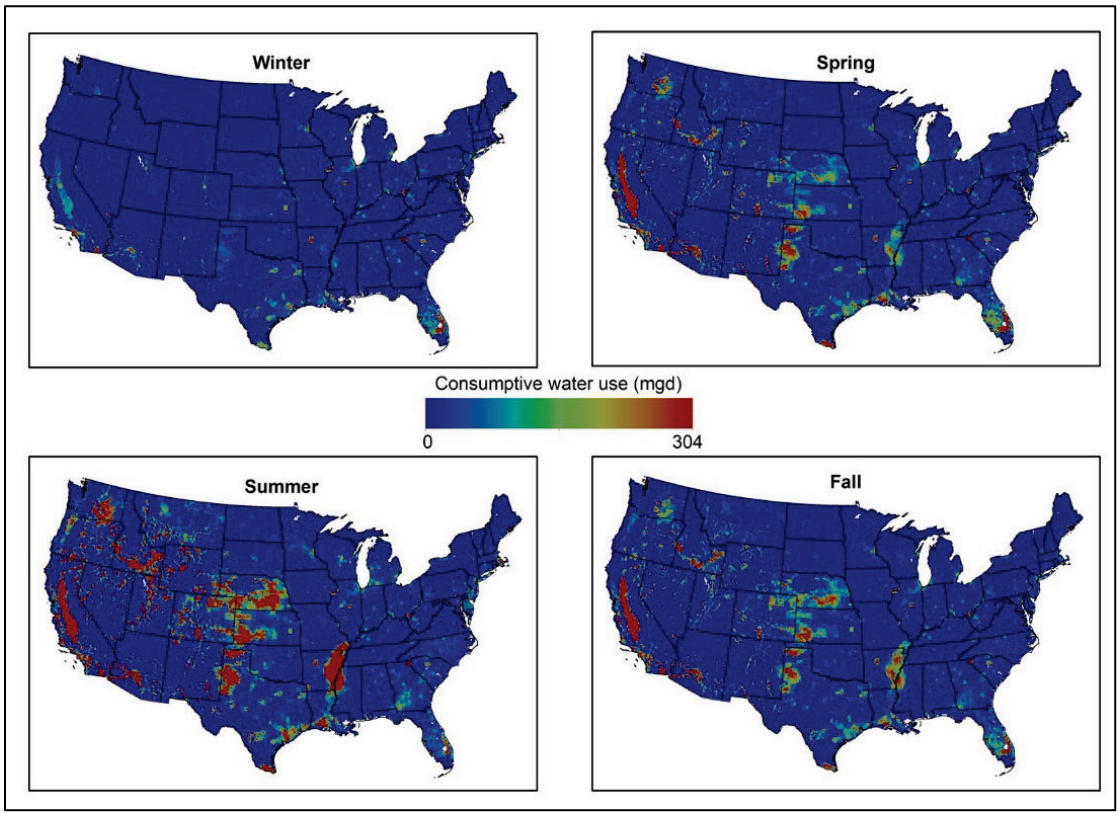
Trends in maximum precipitation-weighted summertime water yields show a distinct divide in trend direction, with decreased yields only in the western parts of the basin (Upper Missouri, Arkansas, and Red Rivers) and increased yields throughout the Interior Plains and extending into the Lower Mississippi. In a recent study on the effects of land use/land cover on streamflows in the Upper Mississippi, Schilling et al. (2010) related increasing flows to increased soybean production based on measurements from the USGS gage in Keokuk, Iowa.

Fall trends

Trends in fall precipitation-weighted maximum water yields increased in the lower and middle Ohio and in the Lower Mississippi across all durations. This could be related to how land use changes in these sub-regions have interacted with the heightened intensity of hurricanes over the period. Regionally, the increases in water yield surpassed increases in fall precipitation (Figure 21–Figure 22).

Regional patterns of decreasing seasonal totals and maximum totals of precipitation-weighted water yields closely resemble the Moore et al. (2015) maps of seasonal consumptive water use (Figure 55). For additional details/results of the sub-regional precipitation-weighted water yield analyses, see Appendix G.

Figure 55. Seasonal estimates of consumptive water use (from Moore et al. 2015).



Summary of precipitation-weighted water yield results: anthropogenic influences

Although the direction of the changes varies across the basin, these effects are widespread and sizeable in magnitude, indicating that anthropogenic influences have been a major determining factor on changes in streamflow regimes over the past century. While anthropogenic activities have resulted in increases in water yield in the central part of the basin, activities at the basin margins have caused decreases in flow. The direction and magnitude of these influences can clearly be sorted by region (Figure 39):

- *Western-most part of the basin - Decreases*: Widespread reductions in water yield due to anthropogenic activities characterize these HUC-4s. Decreases in the range of -25% to -100% are typical. This includes most of the upper Missouri (e.g., main stem Missouri down to Oahe, the Yellowstone, Platte, Republican and Smoky Hill Rivers), upper and middle Arkansas and upper Red Rivers (e.g., Canadian and Cimarron Rivers).

- *Central part of the basin - Increases*: Anthropogenic activities have resulted in significant increases in water yield throughout this region, with the magnitude of the increase generally decreasing from west to east. The largest effects (50%–100%) are seen in the middle and lower sections of the Missouri River, the lower Arkansas and parts of the upper Mississippi (e.g., Minnesota and Des Moines), transitioning to moderate increases (10%–50%) in the mid-continent and tailing off to 0%–10% in the middle Ohio River basin.

- *Eastern-most part of the basin- Decreases*: Human activities have resulted in mild decreases (generally 0% to 10%) in water yield in the upper basins of the Ohio and moderate decreases (-10% to -25% in the upper and middle Tennessee River basins.

- *Southern-most part of the basin - Decreases*: The lower-most sub-basins of the lower Mississippi and Red River have had moderate reductions in water yield as a result of human activities. The greatest decrease has been in the Boeuf-Tensas (0805).

Seasonally, the spatial distribution of anthropogenic influences on water yield look much like those on an annual basis as described in the bulleted points above. There are striking differences during the winter in the

middle and lower Missouri basin and the Red and Washita Rivers, where winter flow releases are significantly greater now (>100%) than under the natural flow regimes before the dams.

Evaporation behind impoundments has increased drastically over the past century with the construction of thousands of dams, which peaked in the 1960s and 1970s. Through the 1930s, evaporation relative to average annual rainfall was approximately 0.1%. Starting in the 1960s and certainly by the 1980s, broad swaths of the Arkansas and Red River basins were losing more than 5% of their rainfall from evaporation behind impoundments.

Streamflow trends from index stations

To this point, this report has dealt with the spatial distribution and magnitude of changes in hydrology for all stations throughout the Mississippi River basin and expressed results as a percent increase or decrease. This section first concentrates on the changes in discharge (in percent) from all index stations representing the HUC-4s before focusing on changes and delivery of water directly to the LMR from the major HUC-2 basins. These results are shown as both percentages and absolute values.

All index stations

Annual trends

Analysis of discharge for index stations (those representing downstream locations in the HUC-4s) provide direct evidence of how contributions from the major drainages in the Mississippi River Basin have changed over time. This analysis spans the entire period of data, conveniently described as starting approximately 1900. In this section, only statistically significant monotonic trends ($p < 0.05$) are considered and presented. The reader is referred to Appendix A for details on the individual USGS streamflow gages used in this analysis, including drainage area and the period of record for each station.

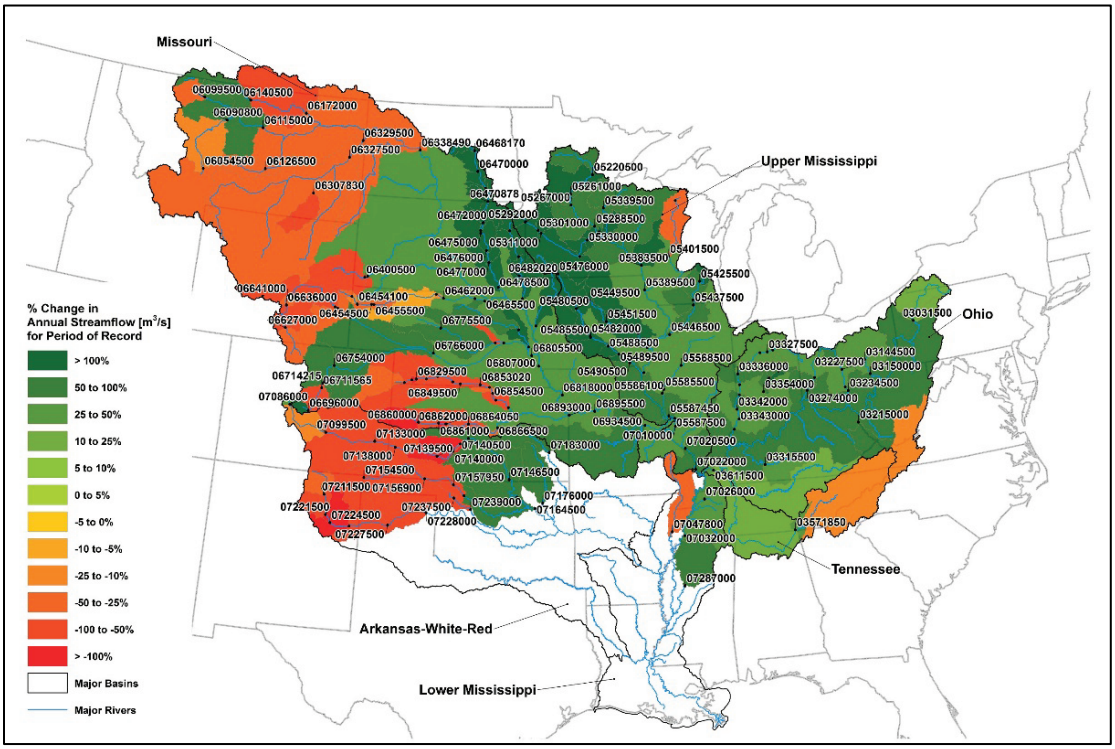
The most important result from this analysis is that much of the interior part of the basin shows important increases in annual streamflow emanating from the HUC-4 basins. That said, some trends of decreasing streamflow for various sub-regions in the upper Missouri and Arkansas

River Basins are identified (Figure 56). Each index station is represented as the footprint of its drainage basin with the largest basins on the bottom and successively smaller contributing basins overlain on top.

Note that significant decreasing trends were observed along the Missouri River at Fort Benton, Montana (USGS 06090800), and at Garrison Dam, North Dakota (USGS 06338490); otherwise, the majority of the index stations show trends of increasing annual streamflow. Likewise, index stations along the upper reaches of the Arkansas River showed decreasing streamflow trends at several locations above Wichita, Kansas. This highlights the fact that increasing flows in the lower parts of the Missouri and Arkansas River Basins outpaced the decrease in flows in the upper reaches, providing a net positive trend in annual streamflows.

One possible explanation for these patterns of streamflow in the central region of the basin is that groundwater pumping for irrigation from the High Plains aquifer (which includes the Ogallala aquifer) running from Nebraska to the panhandle of Texas leads to reduced streamflows and increased evapotranspiration in this area. This in turn causes hydrologic changes to the east of this zone including (1) increased summer precipitation through the atmospheric transfer of water vapor and (2) increased summer streamflows in states such as Illinois, Indiana, Ohio, Kentucky, and Tennessee (Kustu et al., 2011). These results may indeed apply to other states in the interior of the basin as well. The spatial pattern of precipitation provided in this study seem to substantiate these findings. It is clear, however, that there has been an increase in precipitation in this part of the basin and that the increasing water yields associated with this greater hydrologic input as well as more efficient channels and tile drainage can also be responsible for these increases in flow. Results are also in agreement with findings of Sagarika et al. (2014) who examined streamflows from 1951–2010 and detected positive trends in annual streamflows throughout the interior of the Mississippi River Basin.

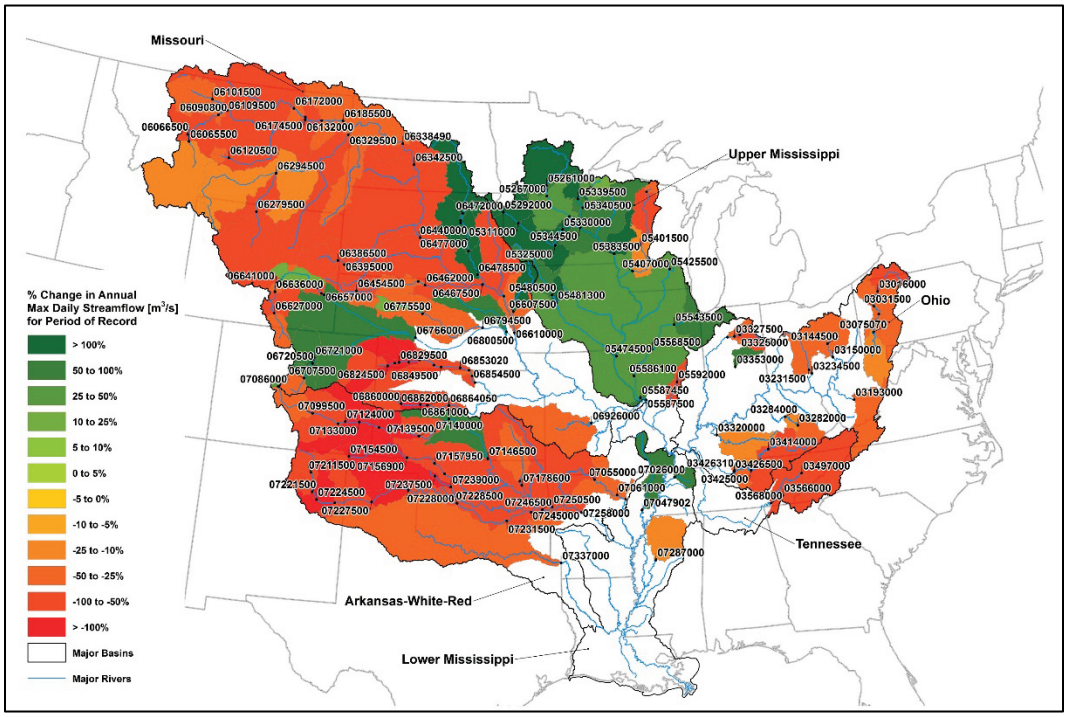
Figure 56. Change in annual streamflow at index stations with significant trends over the past century.



Peak annual trends

Maximum values are derived from mean daily streamflows and not instantaneous peaks. Because of the increasing role of dams with increasing drainage area, changes in peak streamflow from index stations over the past century may largely be the result of upstream impoundments and flow regulation that are often designed to limit downstream flooding. In the upper parts of the Missouri, Arkansas, Ohio, and Tennessee River Basins, maximum daily and 7-day streamflows emanating from the HUC-4 index stations were observed to decrease significantly, probably as a result of effective flood-control efforts by dam operations. Detected trends in the maximum daily streamflows for all index stations are shown in Figure 57. In contrast, flows in parts of the middle Missouri (South Platte and James Rivers) and in the Upper Mississippi showed increasing streamflow trends, the latter probably as a result of increased precipitation and the previously mentioned anthropogenic changes to channel pattern and tile drainage.

Figure 57. Change in maximum-daily streamflow at index stations with significant trends.



Seasonal trends

Results from the HUC-4 index stations show that for the most part, winter streamflows increased across most of the study area (Figure 58), with a few decreasing trends located in the western half. During the spring (Figure 59), summer (Figure 60), and fall (Figure 61), streamflow in the West is actually dominated by decreasing streamflows, possibly due to the practice of storing water behind impoundments for the summer irrigation season. Spring streamflows were also observed to decrease along the Tennessee River, and decreasing summertime flows were observed in the upper Ohio.

Figure 58. Change in winter streamflow at index stations with significant trends.

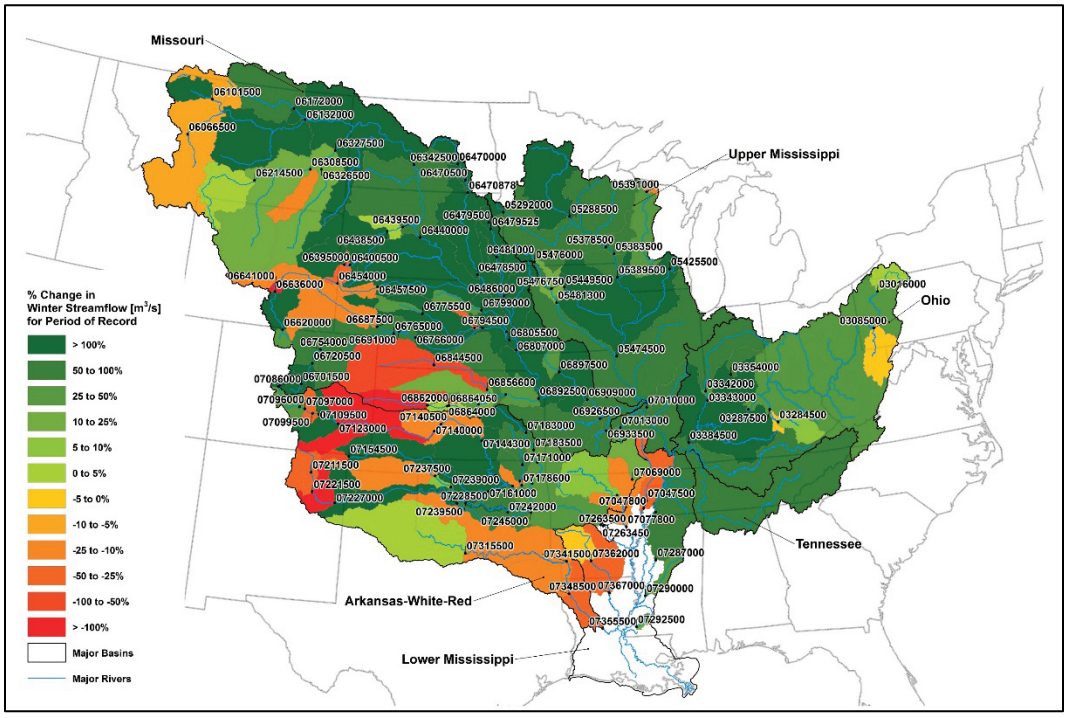


Figure 59. Change in spring streamflow at index stations with significant trends.

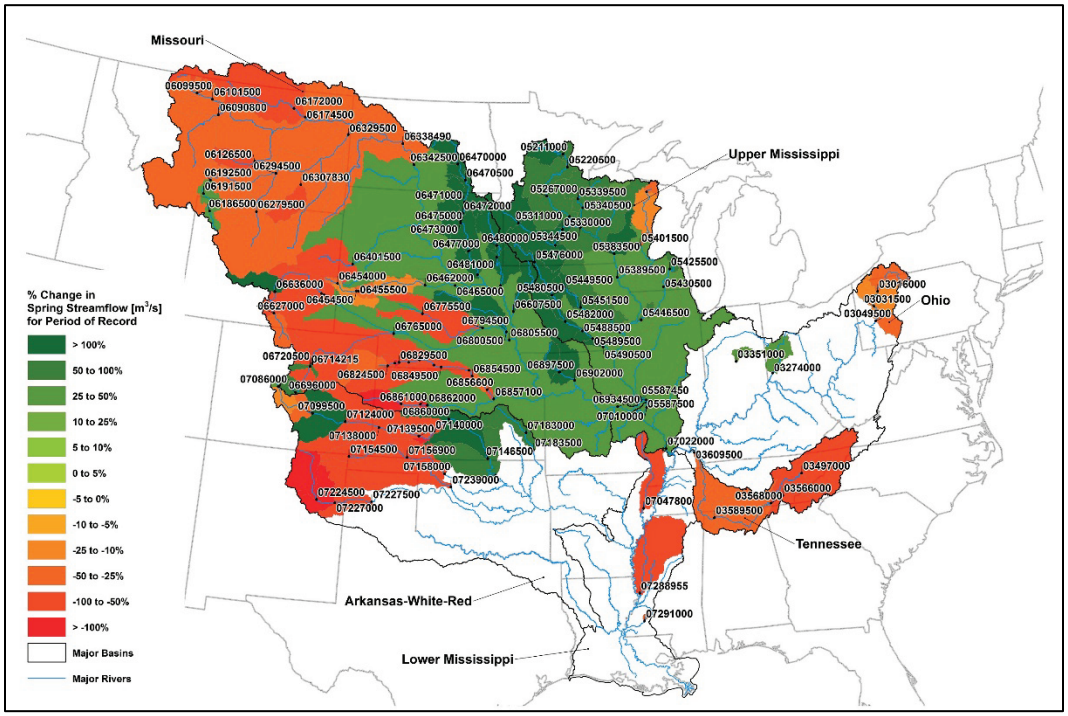


Figure 60. Change in summer streamflow at index stations with significant trends.

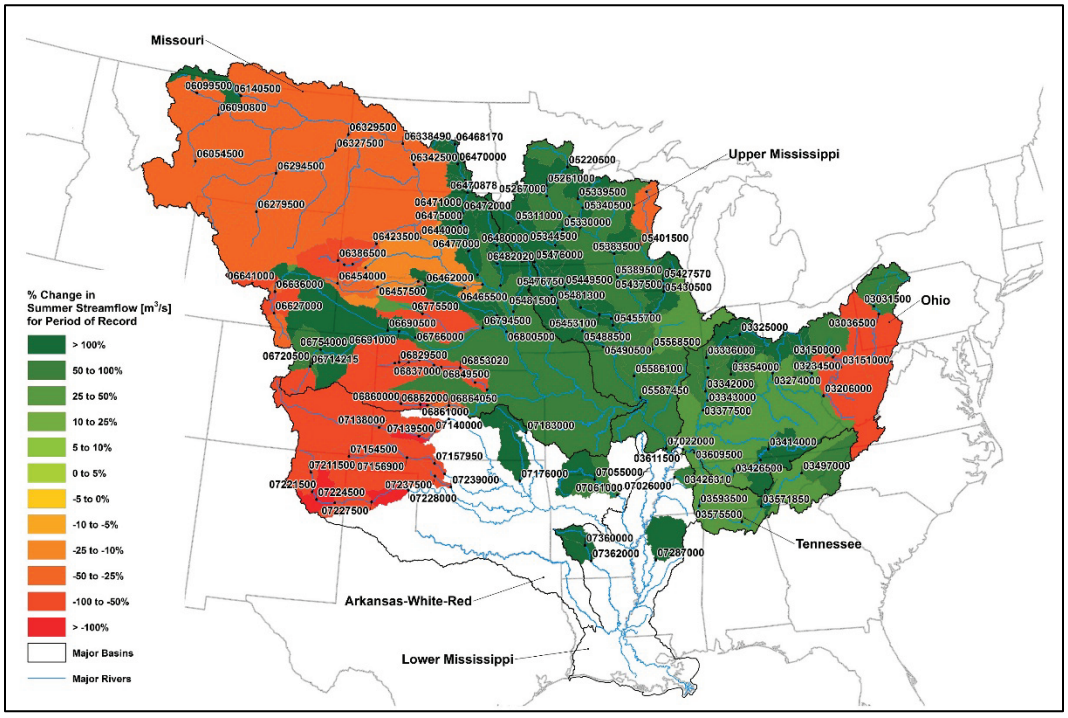
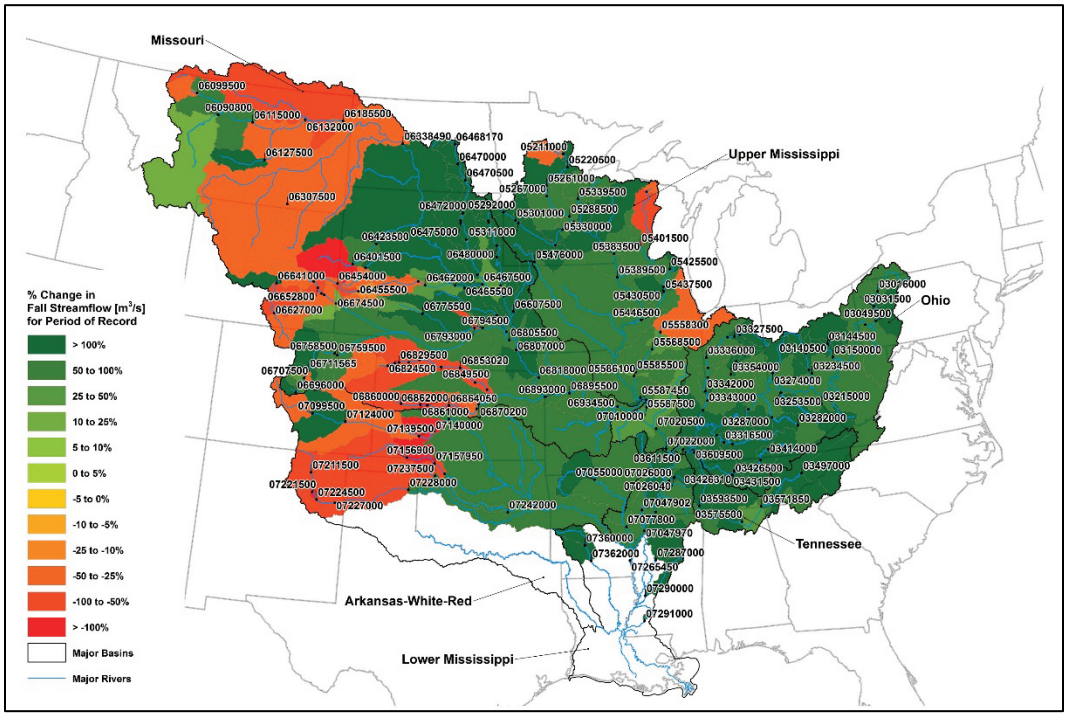


Figure 61. Change in fall streamflow at index stations with significant trends.



Additional details/results of the streamflow analyses from index stations, including results not shown here, can be found in Appendix H.

Major (HUC-2) index stations

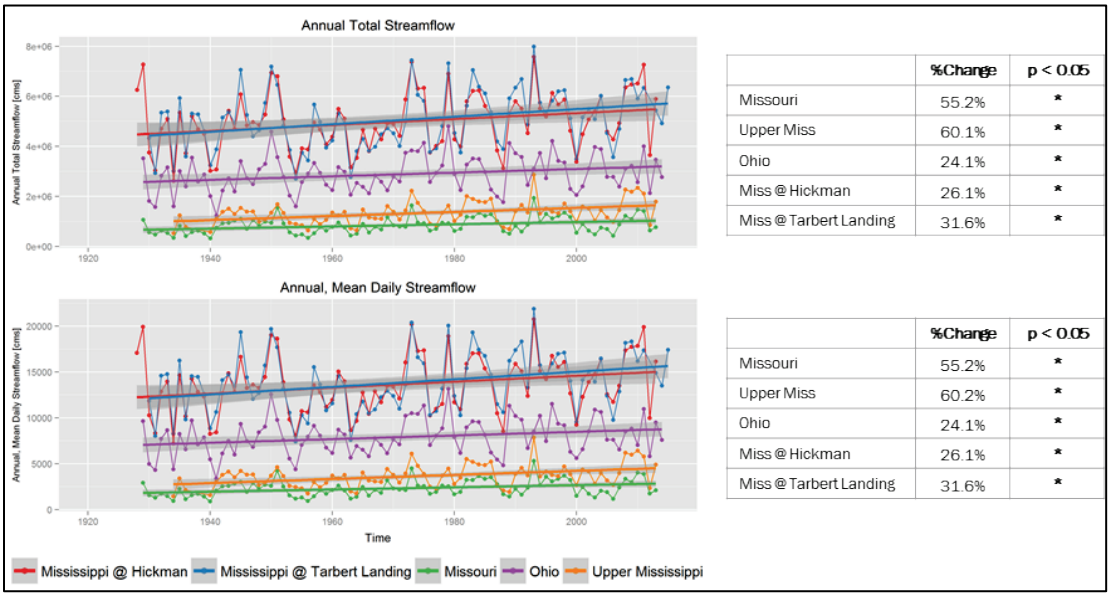
Annual trends

A comparison of the relative flow contributions from the major HUC-2 basins to the LMR were computed over a fixed interval, 1930–2014. Discharges for these 2 years were based on values derived from the linear regression of mean daily and total flow over the period. In 1930, the relative contributions to average- and total-annual flow from the Ohio, Upper Mississippi, and Missouri Rivers were 61%, 23%, and 16%, respectively. By 2014, contributions from these three major suppliers shifted slightly to 55% from the Ohio, 28% from the Upper Mississippi, and 18% from the Missouri. In general, the amount of water being delivered to the LMR has increased over the past century. Total annual and annual average flows have increased at all index stations emanating from the major river basins (or HUC-2s) over the period of record (Figure 62). The percent-change values shown in the small tables associated with this and similar figures to follow will be slightly different than those cited above because these are based on the specific periods of record and not the fixed period of 1930 and 2014. Other than flows from the Upper Mississippi, all records start before the dust bowl era of the 1930s. The actual average increases in mean daily flows from the three main basins to the upstream boundary of the LMR are as follows:

- Ohio River: 1,674 m^3/s (23.8%)
- Upper Mississippi River: 1,767 m^3/s (66.0%)
- Missouri River: 986 m^3/s (54.8%).

This comes to an increase in average mean-daily flows, of approximately 4,427 m^3/s (156,000 ft^3/s). Integrated over an average year and excluding inputs from other smaller tributaries, this brings the average annual increase in flows to the Lower Mississippi to approximately 1.62 million m^3/s (57.2 million ft^3/s).

Figure 62. Change in annual total and annual average streamflow at major index stations.



	%Change	p < 0.05
Missouri	55.2%	*
Upper Miss	60.1%	*
Ohio	24.1%	*
Miss @ Hickman	26.1%	*
Miss @ Tarbert Landing	31.6%	*

	%Change	p < 0.05
Missouri	55.2%	*
Upper Miss	60.2%	*
Ohio	24.1%	*
Miss @ Hickman	26.1%	*
Miss @ Tarbert Landing	31.6%	*

The overall spatial patterns of where increasing and decreasing flows have occurred is consistent with those shown previously using all stations within each HUC-4, with the mid-continent showing general increases and the western basins showing general decreases over the period.

The actual discharge values derived from the start (1930) and end (2014) of the linear regressions (as from Figure 62 for example) are tabulated for these and all other metrics in this section. These data, along with the relative contributions to the LMR from each HUC-2 and for each metric are listed in Table 3.

Peak mean daily trends

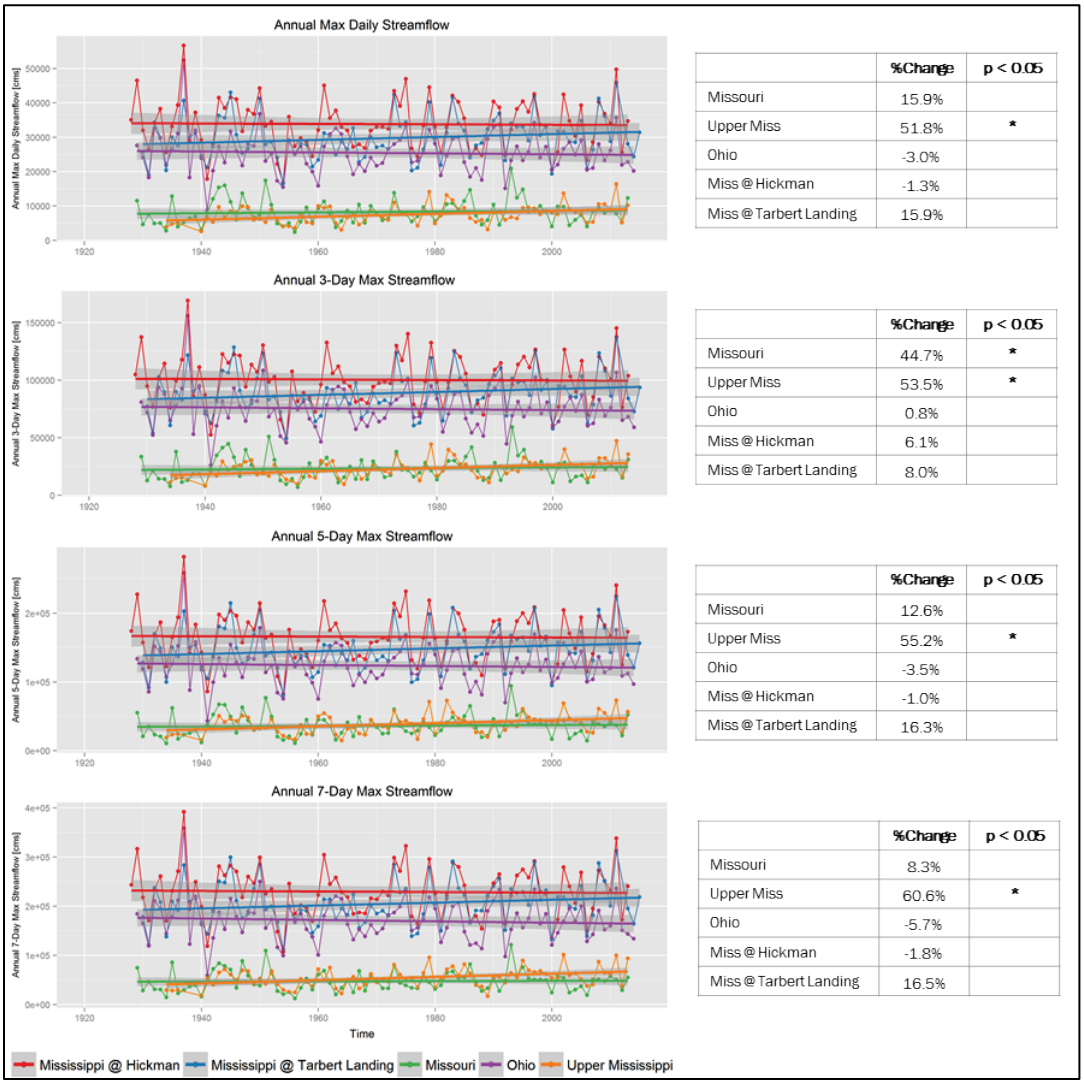
Peak mean daily streamflows from the Upper Mississippi River, measured at Thebes, showed significant increases over the period of record, for all durations (Figure 63). Increases from the other HUC-2s were not deemed statistically significant at the 0.05 level except for the 3-day maximum from the Missouri River Basin, which also increased significantly. The actual increases in the average daily-maximum values emanating from the Upper Mississippi River since 1934 (77 years of record) are the following:

- 1-day: 2,990 m^3/s, (105,000 ft^3/s for one day)
- 3-day: 3,430 m^3/s, (121,000 ft^3/s per day)
- 5-day: 3,300 m^3/s, (117,000 ft^3/s per day)
- 7-day: 3,570 m^3/s, (126,000 ft^3/s per day).

Table 3. Changes and percent contributions in discharge between 1930 and 2014 from the major (HUC-2) index stations as derived from the linear regressions of annual data.

Flow Metric	HUC-2 Basin	Flow in 1930 (m^3/s)	% Contribution in 1930	Flow in 2014 (m^3/s)	% Contribution in 2014	Change in Flow (m^3/s)
Annual.1DayMax.Flows	Missouri River	7,376	17.5%	8,545	20.2%	1,170
	Ohio River	25,633	60.7%	24,864	58.9%	-769
	Upper Mississippi River	5,620	13.3%	8,800	20.8%	3,180
	Total	38,629		42,210		
Annual.Avg.Flows	Missouri River	1,798	15.6%	2,784	17.5%	986
	Ohio River	7,040	61.1%	8,714	54.7%	1,674
	Upper Mississippi River	2,678	23.3%	4,446	27.9%	1,767
	Total	11,516		15,943		
Annual.Flows	Missouri River	656,496	15.6%	1,016,769	17.5%	360,274
	Ohio River	2,571,681	61.1%	3,181,919	54.7%	610,238
	Upper Mississippi River	978,278	23.3%	1,623,329	27.9%	645,052
	Total	4,206,454		5,822,018		
Fall.1DayMax.Flows	Missouri River	3,135	26.8%	4,642	23.1%	1,507
	Ohio River	5,558	47.6%	11,399	56.6%	5,840
	Upper Mississippi River	2,995	25.6%	4,088	20.3%	1,093
	Total	11,689		20,129		
Fall.Flows	Missouri River	111,917	23.6%	210,311	24.2%	98,394
	Ohio River	198,889	42.0%	422,056	48.5%	223,167
	Upper Mississippi River	162,775	34.4%	238,477	27.4%	75,702
	Total	473,580		870,843		
Spring.1DayMax.Flows	Missouri River	5,602	16.4%	7,456	19.0%	1,854
	Ohio River	22,711	66.3%	22,918	58.3%	207
	Upper Mississippi River	5,926	17.3%	8,957	22.8%	3,031
	Total	34,239		39,331		
Spring.Flows	Missouri River	225,152	12.9%	325,184	15.6%	100,032
	Ohio River	1,132,068	64.7%	1,140,648	54.7%	8,581
	Upper Mississippi River	392,174	22.4%	621,321	29.8%	229,147
	Total	1,749,394		2,087,153		
Summer.1DayMax.Flows	Missouri River	5,446	30.8%	6,163	24.7%	717
	Ohio River	8,868	50.1%	11,330	45.5%	2,462
	Upper Mississippi River	3,385	19.1%	7,427	29.8%	4,042
	Total	17,699		24,921		
Summer.Flows	Missouri River	209,517	26.0%	278,508	23.2%	68,991
	Ohio River	349,477	43.4%	480,738	40.1%	131,260
	Upper Mississippi River	245,419	30.5%	440,790	36.7%	195,371
	Total	804,414		1,200,036		
Winter.1DayMax.Flows	Missouri River	2,905	10.9%	4,281	13.0%	1,376
	Ohio River	20,236	76.1%	22,647	68.6%	2,411
	Upper Mississippi River	3,459	13.0%	6,078	18.4%	2,619
	Total	26,599		33,005		
Winter.Flows	Missouri River	88,188	8.2%	176,283	11.2%	88,095
	Ohio River	817,875	76.1%	1,098,349	69.9%	280,474
	Upper Mississippi River	169,118	15.7%	296,800	18.9%	127,682
	Total	1,075,181		1,571,432		

Figure 63. Change in maximum daily streamflow at major index stations.



	%Change	p < 0.05
Missouri	15.9%	
Upper Miss	51.8%	*
Ohio	-3.0%	
Miss @ Hickman	-1.3%	
Miss @ Tarbert Landing	15.9%	

	%Change	p < 0.05
Missouri	44.7%	*
Upper Miss	53.5%	*
Ohio	0.8%	
Miss @ Hickman	6.1%	
Miss @ Tarbert Landing	8.0%	

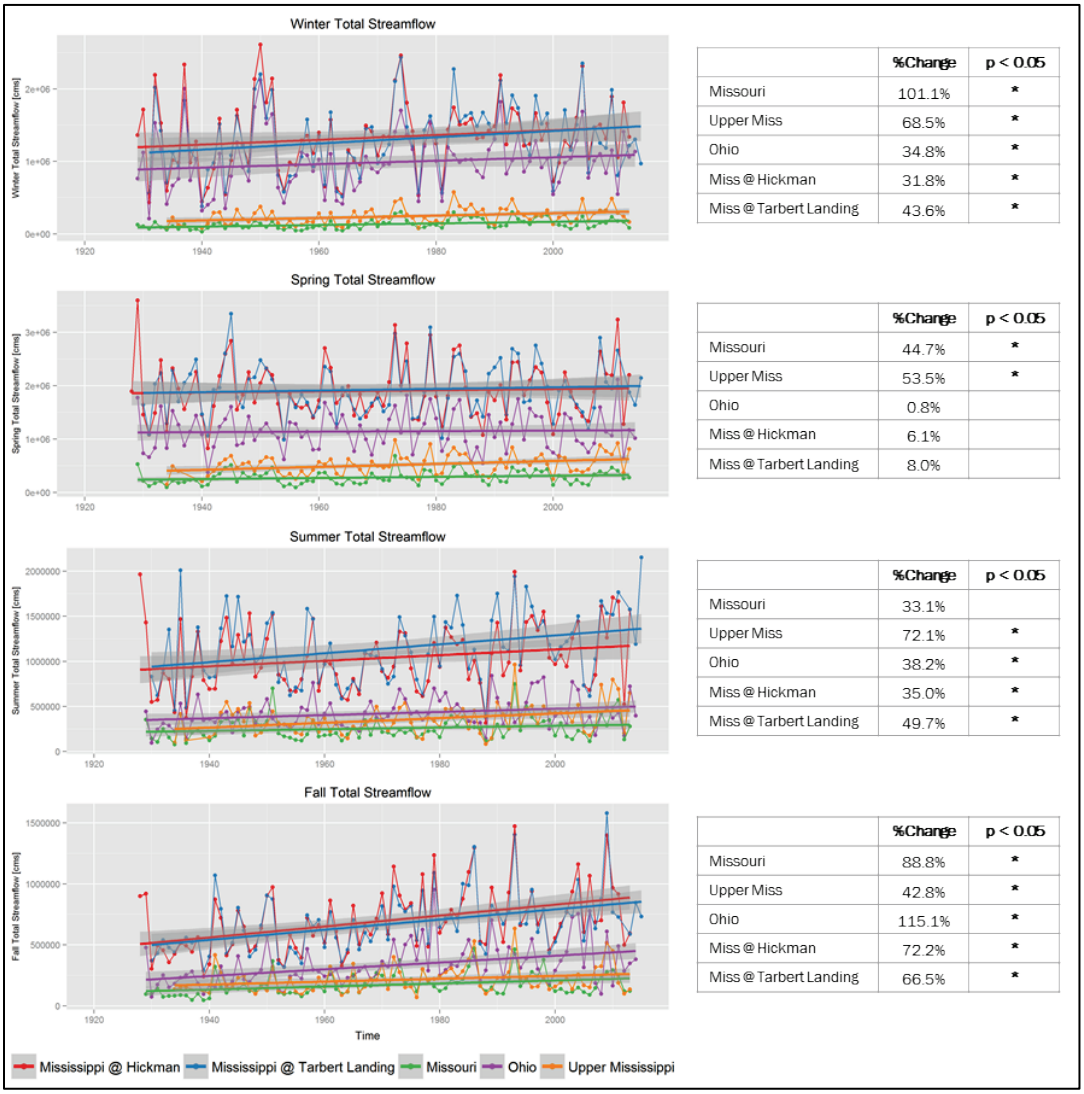
	%Change	p < 0.05
Missouri	12.6%	
Upper Miss	55.2%	*
Ohio	-3.5%	
Miss @ Hickman	-1.0%	
Miss @ Tarbert Landing	16.3%	

	%Change	p < 0.05
Missouri	8.3%	
Upper Miss	60.6%	*
Ohio	-5.7%	
Miss @ Hickman	-1.8%	
Miss @ Tarbert Landing	16.5%	

Seasonal trends

Increases in seasonal streamflows from the Ohio, Upper Mississippi, and Missouri were detected in all seasons, although flows in the Lower Mississippi were found to increase only during the winter, summer, and fall months (Figure 64).

Figure 64. Change in seasonal streamflow at major index stations.



	%Change	p < 0.05
Missouri	101.1%	*
Upper Miss	68.5%	*
Ohio	34.8%	*
Miss @ Hickman	31.8%	*
Miss @ Tarbert Landing	43.6%	*

	%Change	p < 0.05
Missouri	44.7%	*
Upper Miss	53.5%	*
Ohio	0.8%	
Miss @ Hickman	6.1%	
Miss @ Tarbert Landing	8.0%	

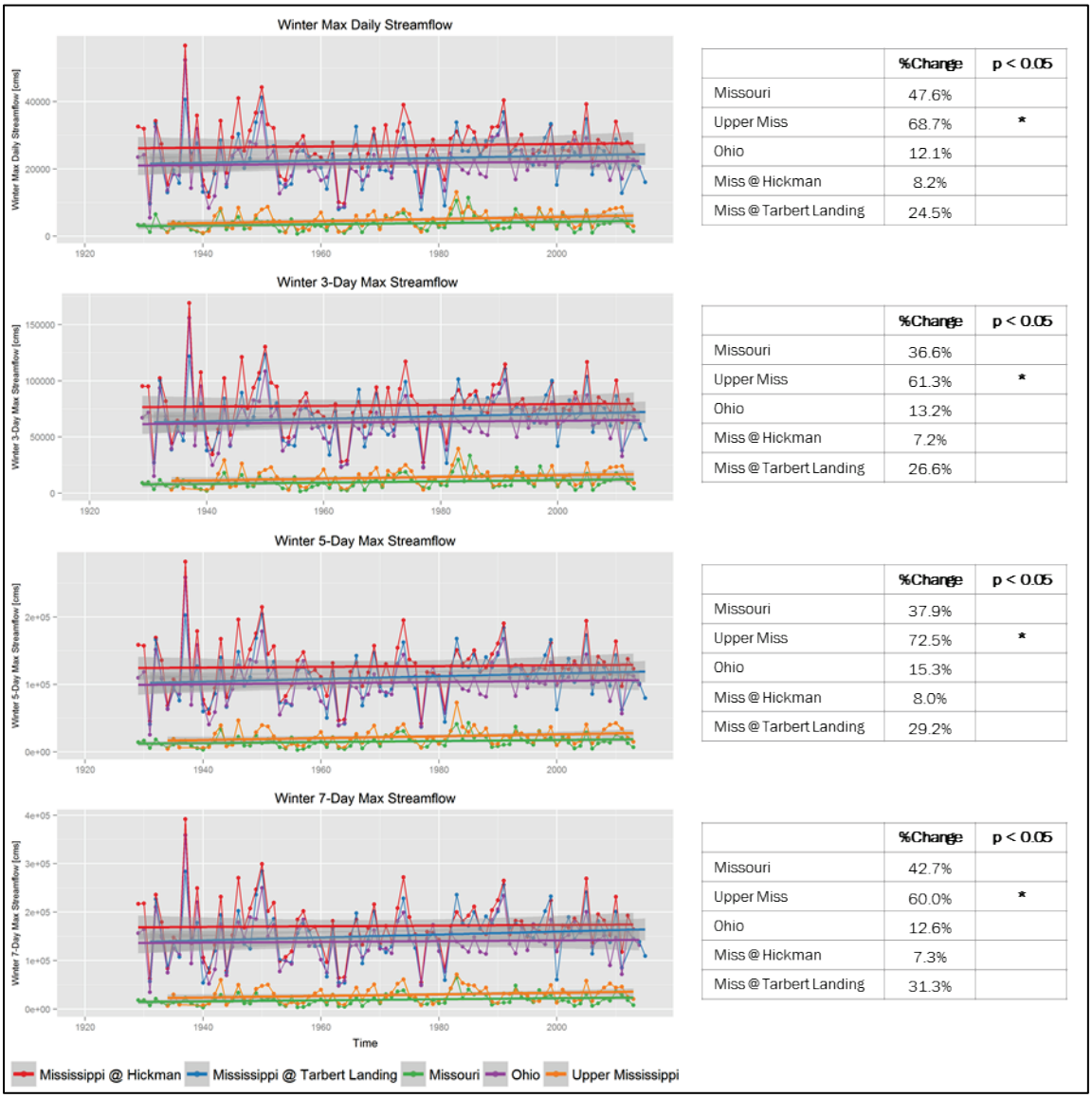
	%Change	p < 0.05
Missouri	33.1%	
Upper Miss	72.1%	*
Ohio	38.2%	*
Miss @ Hickman	35.0%	*
Miss @ Tarbert Landing	49.7%	*

	%Change	p < 0.05
Missouri	88.8%	*
Upper Miss	42.8%	*
Ohio	115.1%	*
Miss @ Hickman	72.2%	*
Miss @ Tarbert Landing	66.5%	*

Peak winter trends

For the period of record, peak winter streamflows at the major index stations were only detected from the Upper Mississippi (Figure 65). Although increases calculated from linear regressions are reported across all of the durations for the other major basins, none are considered to be statistically significant trends at the 0.05 level of probability.

Figure 65. Change in maximum winter streamflows at major index stations.



	%Change	p < 0.05
Missouri	47.6%	
Upper Miss	68.7%	*
Ohio	12.1%	
Miss @ Hickman	8.2%	
Miss @ Tarbert Landing	24.5%	

	%Change	p < 0.05
Missouri	36.6%	
Upper Miss	61.3%	*
Ohio	13.2%	
Miss @ Hickman	7.2%	
Miss @ Tarbert Landing	26.6%	

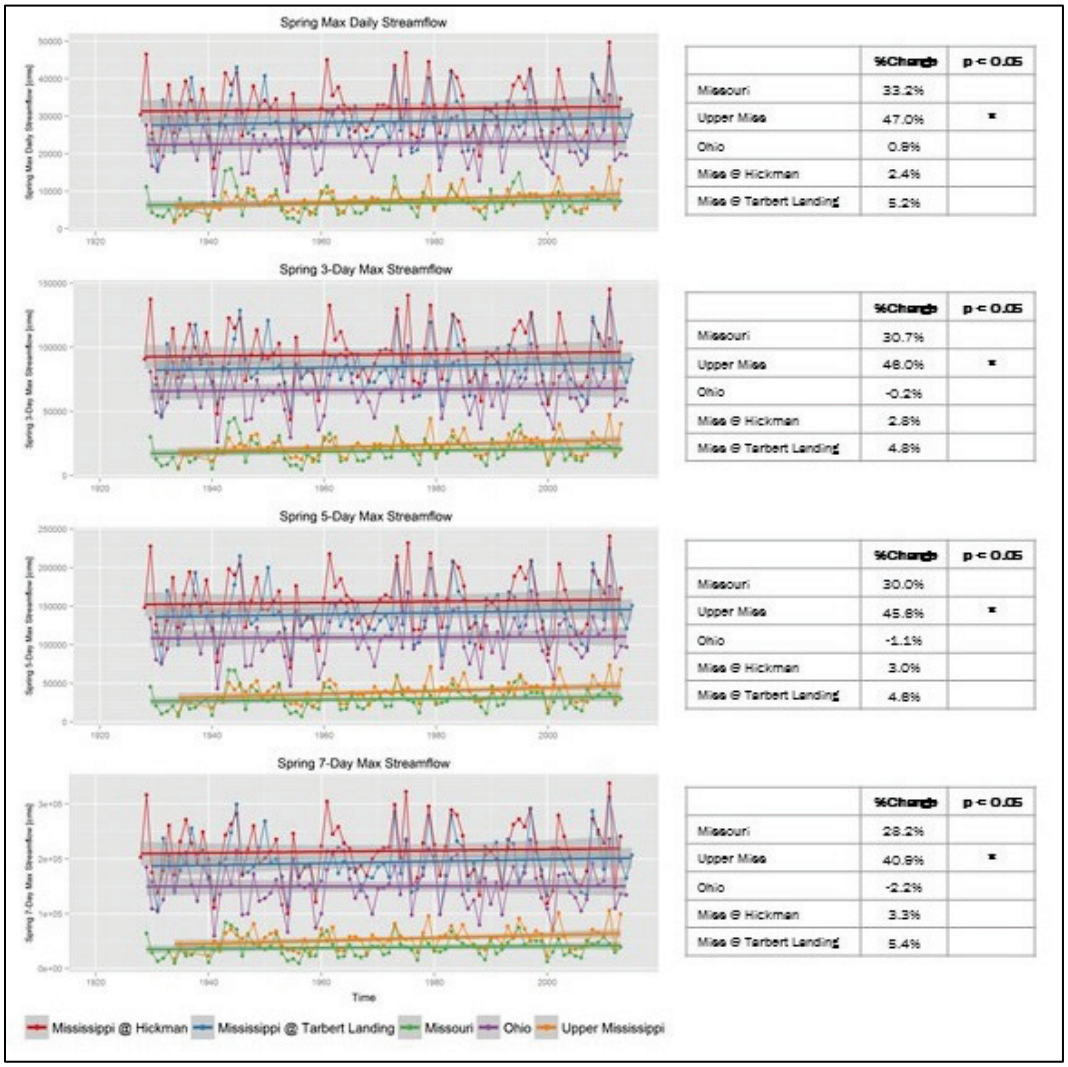
	%Change	p < 0.05
Missouri	37.9%	
Upper Miss	72.5%	*
Ohio	15.3%	
Miss @ Hickman	8.0%	
Miss @ Tarbert Landing	29.2%	

	%Change	p < 0.05
Missouri	42.7%	
Upper Miss	60.0%	*
Ohio	12.6%	
Miss @ Hickman	7.3%	
Miss @ Tarbert Landing	31.3%	

Peak-spring trends

Like wintertime flows, springtime maximum streamflow totals were detected only in the Upper Mississippi over the period of record (Figure 66). All detected trends were positive in the range of 40%–48%.

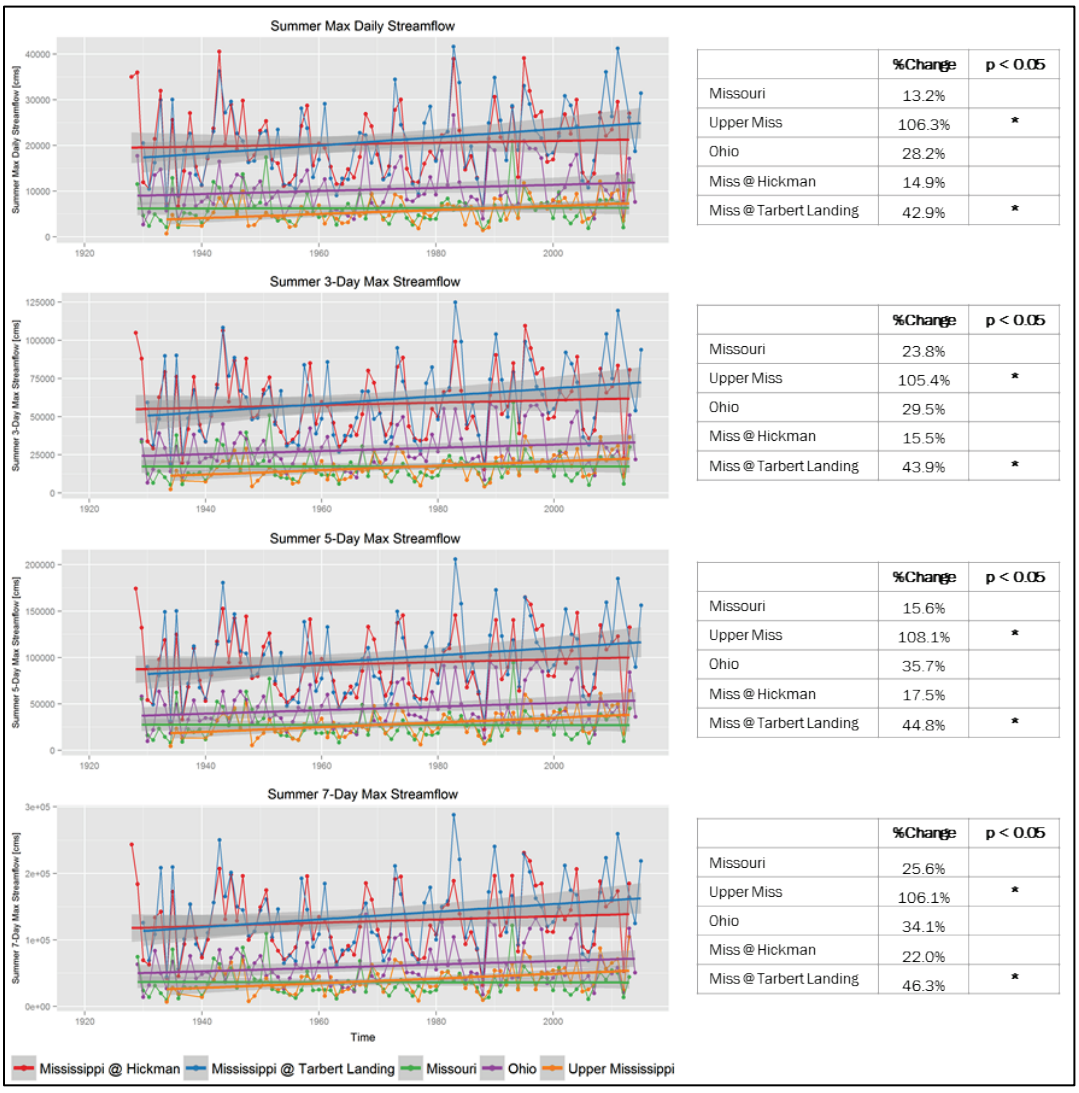
Figure 66. Change in maximum spring streamflows at major index stations.



Peak summer trends

Large increases in summer peak flows (>100%) were identified from the Upper Mississippi, and while flows entering the Lower Mississippi at Hickman, Kentucky, did not increase, peak flows at Tarbert Landing, Louisiana, did show a significant increase (Figure 67). A possible reason for this discrepancy is the apparent decrease in summer peak flows from the Ohio (although not statistically significant). At Thebes, Illinois, the Mississippi River (with inputs from the Missouri) showed significant increases in 3-day, 5-day, and 7-day total summer maximum flows. At the time of this writing, at Thebes, there was ~32,000 m^3/s more streamflow over the course of a week than there was approximately 80 years ago. Again, all of the other basins show increases but are not statistically significant.

Figure 67. Change in maximum summer streamflows at major index stations.



	%Change	p < 0.05
Missouri	13.2%	
Upper Miss	106.3%	*
Ohio	28.2%	
Miss @ Hickman	14.9%	
Miss @ Tarbert Landing	42.9%	*

	%Change	p < 0.05
Missouri	23.8%	
Upper Miss	105.4%	*
Ohio	29.5%	
Miss @ Hickman	15.5%	
Miss @ Tarbert Landing	43.9%	*

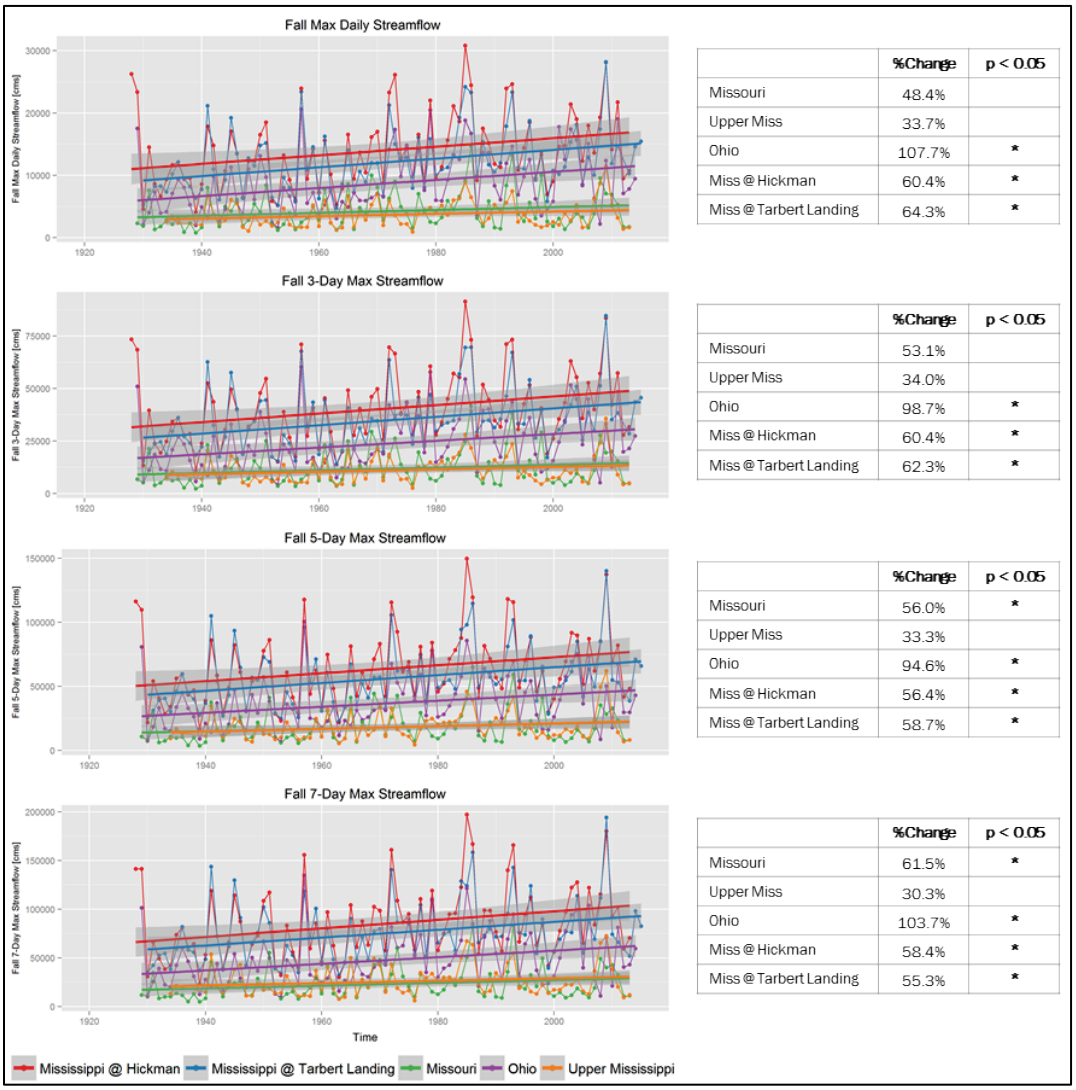
	%Change	p < 0.05
Missouri	15.6%	
Upper Miss	108.1%	*
Ohio	35.7%	
Miss @ Hickman	17.5%	
Miss @ Tarbert Landing	44.8%	*

	%Change	p < 0.05
Missouri	25.6%	
Upper Miss	106.1%	*
Ohio	34.1%	
Miss @ Hickman	22.0%	
Miss @ Tarbert Landing	46.3%	*

Peak fall trends

Over the last 100 years, maximum fall streamflows appear to have increased across most of the Mississippi River Basin (Figure 68) except for the extreme western parts of the basin. These results are in keeping with those previous showing that changes in fall precipitation and streamflows are significant and almost ubiquitous. Flows exiting the Ohio River and along the Mississippi River (at St. Louis, Missouri; 07010000) exhibited increased trends in maximum fall streamflows across all durations analyzed. Downstream at Memphis, Tennessee (07032000), the Mississippi River also showed significant increases in streamflow across all durations, except that the last complete year of record was in 1993.

Figure 68. Change in maximum fall streamflows at major index stations.



	%Change	p < 0.05
Missouri	48.4%	
Upper Miss	33.7%	
Ohio	107.7%	*
Miss @ Hickman	60.4%	*
Miss @ Tarbert Landing	64.3%	*

	%Change	p < 0.05
Missouri	53.1%	
Upper Miss	34.0%	
Ohio	98.7%	*
Miss @ Hickman	60.4%	*
Miss @ Tarbert Landing	62.3%	*

	%Change	p < 0.05
Missouri	56.0%	*
Upper Miss	33.3%	
Ohio	94.6%	*
Miss @ Hickman	56.4%	*
Miss @ Tarbert Landing	58.7%	*

	%Change	p < 0.05
Missouri	61.5%	*
Upper Miss	30.3%	
Ohio	103.7%	*
Miss @ Hickman	58.4%	*
Miss @ Tarbert Landing	55.3%	*

Summary of streamflow trends from index stations results

The most important result from the analysis of the HUC-4 index stations is that discharges from much of the interior part of the basin show important increases in annual streamflow over the past century (from 25% to >100%). Still, some trends of decreasing streamflow for various sub-regions in the upper Missouri and Arkansas River Basins are identified. In the upper parts of the Missouri, Arkansas, Ohio, and Tennessee River Basins, maximum daily and 7-day streamflows emanating from the HUC-4 index stations were observed to decrease significantly, probably as a result of effective flood-control efforts by dam operations.

HUC-4 seasonal distributions are similar to the annual ones with the exception of during the winter, where increases in flow extend well up into the Missouri Basin, reflecting the release of water under ice-covered rivers. Also striking are the large (25% to >100%) widespread increases in discharge during the fall throughout the Mississippi River basin with the exception of the upper parts of the Missouri, Arkansas, and Red Rivers, which showed decreases during this season.

In 1930, the relative contributions to average and total annual flow from the Ohio, Upper Mississippi, and Missouri Rivers were 61%, 23%, and 16%, respectively. By 2014, contributions from these three major suppliers shifted slightly to 55% from the Ohio, 28% from the Upper Mississippi, and 18% from the Missouri. In general, the amount of water being delivered to the LMR has increased over the past century. Total annual and annual average flows have increased at all index stations emanating from the major river basins (or HUC-2s) over the period of record. The actual average increases in mean daily flows from the three main basins to the upstream boundary of the LMR are the following:

- Ohio River: 1,674 m^3/s (23.8%)
- Upper Mississippi River: 1,767 m^3/s (66.0%)
- Missouri River: 986 m^3/s (54.8%).

This comes to an increase in average mean daily flows of approximately 4,427 m^3/s (156,340 ft^3/s). Integrated over an average year and excluding inputs from other smaller tributaries, this brings the average annual increase in flows to the Lower Mississippi to approximately 1.62 million m^3/s (57.1 million ft^3/s).

Peak annual streamflows (expressed as a daily value) from the Upper Mississippi River, measured at Thebes, showed significant increases over the period of record, for all durations:

- 1-day: 2,990 m^3/s, (105,000 ft^3/s)
- 3-day: 3,430 m^3/s, (121,000 ft^3/s)
- 5-day: 3,300 m^3/s, (117,000 ft^3/s)
- 7-day: 3,570 m^3/s, (126,000 ft^3/s).

Increases in seasonal streamflows from the Ohio, Upper Mississippi, and Missouri were detected in all seasons, although flows in the Lower Mississippi were found to increase only during the winter, summer, and fall months.

Peak streamflow from HUC-4s

Peak (instantaneous) streamflow data from the USGS were used to determine the spatial variability for a range of recurrence intervals, ranging from the 1.5-year flow to the 100-year flow. This is not an analysis of change over time but a view of the spatial distribution of peak flows across the basin. To be able to utilize all of the available data within a given sub-region (HUC-4) and to then be able to compare these results with those from other sub-regions, all discharge values were divided by the appropriate drainage area to obtain water yield. The reliability of these estimates of course decreases with increasing recurrence interval. For brevity, only results for the Q1.5 (Figure 69), Q10 (Figure 70), and Q100 (Figure 71) are mapped, although values for other recurrence intervals are provided for each HUC-4 in Appendix I.

Results provide a clear picture of distribution of peak runoff production across the basin. As one would expect, the western, drier part of the basin tends to show the lowest water yields across the range of recurrence intervals with maximum values occurring in the Mississippi Embayment and extending northeast into the lower Ohio. Note that areas within the Mississippi Valley along the lower Mississippi (HUC 0802 and HUC 0805) appear as *islands* of lower water yields in a region of otherwise relatively high yields. This is possibly the result of large-scale pumping of the local aquifers, resulting in depressed streamflow rates. Olsen et al. (1999) examined the relation between climate variability and flood frequency estimates in the Upper Mississippi and Lower Missouri.

Figure 69. Median drainage area-weighted $Q_{1.5}$ by HUC-4.

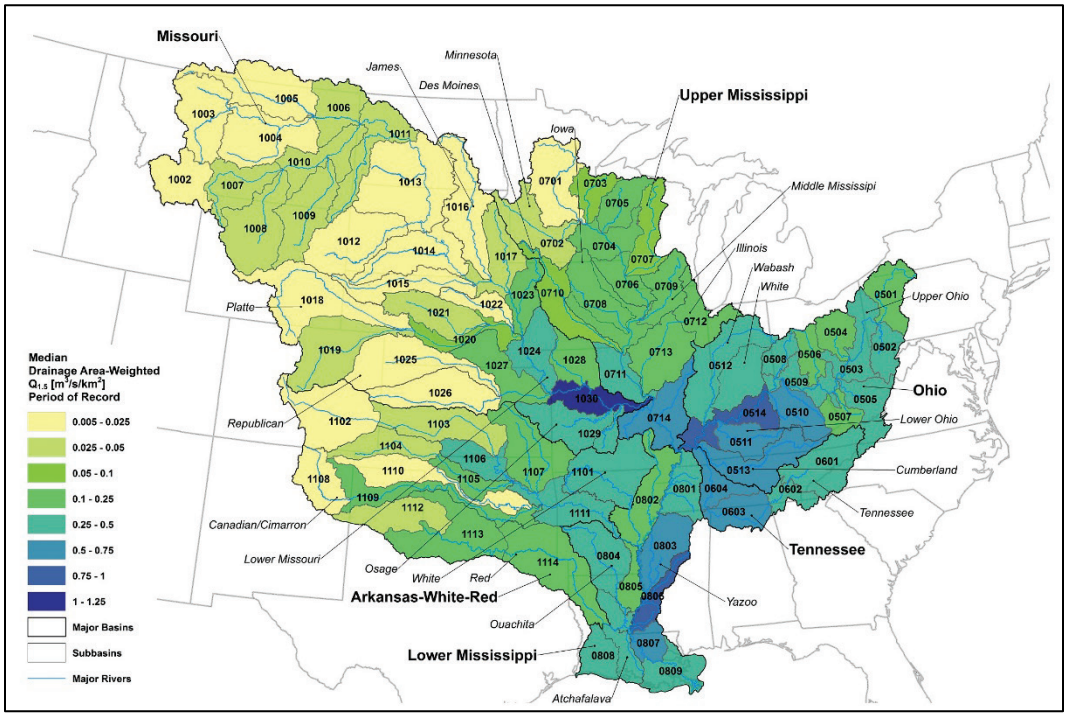


Figure 70. Median drainage area-weighted Q_{10} by HUC-4.

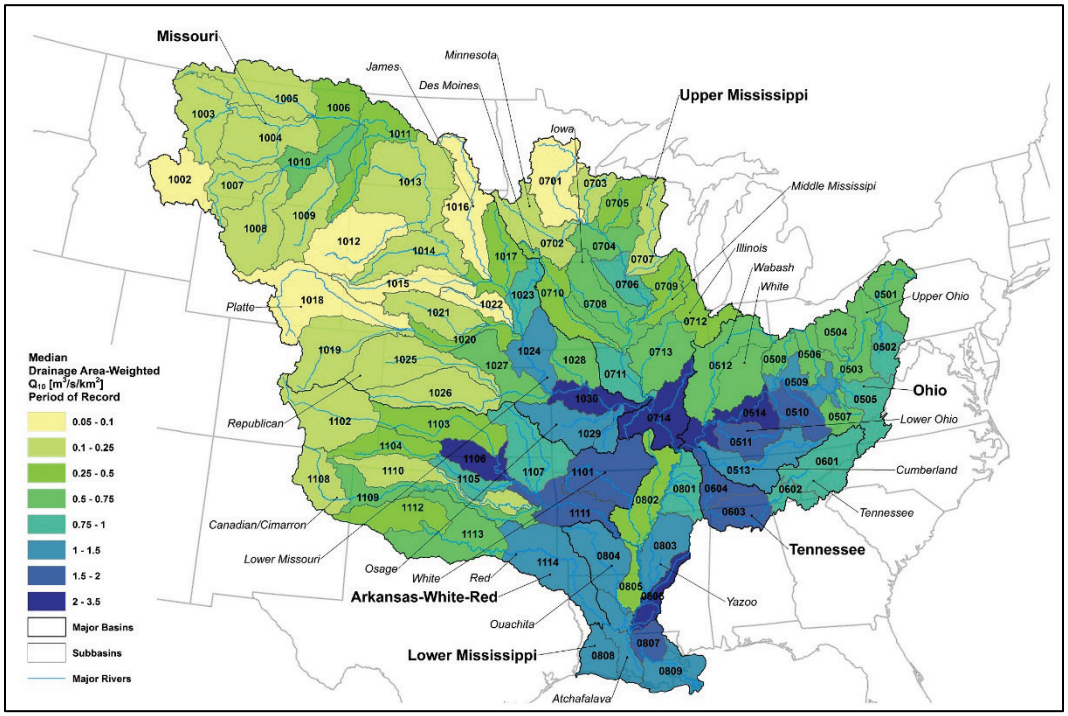
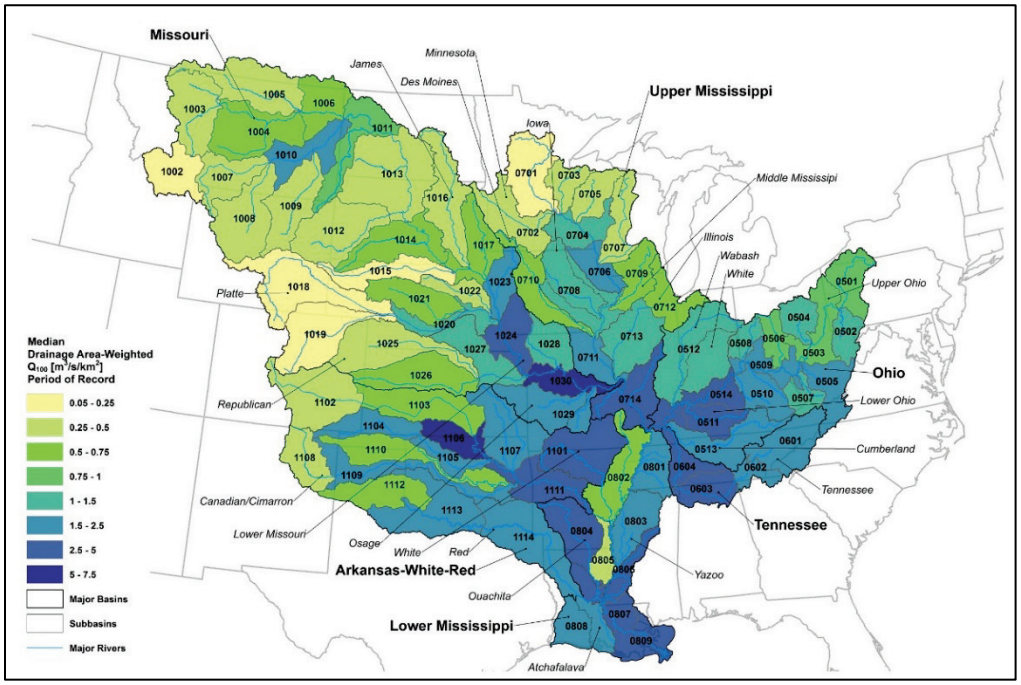


Figure 71. Median drainage area-weighted Q_{100} by HUC-4.



Sediment yield

The primary focus of this investigation has been changes in precipitation and flow, including interpretations of the role of anthropogenic impacts on the latter. Entrainment and transport of sediment from the landscape and through the fluvial system is controlled to a large extent by hydrology, channel hydraulics, and sediment availability. This section provides the results of a basin-wide evaluation of changes in suspended-sediment transport over the past century as well as a comparison of the spatial distribution of current suspended-sediment transport rates. The spatial distribution of values is a function not only of regional difference in hydro-climatic regimes but also to differences in land and water use. Temporal changes within a given sub-region reflect changes in the magnitude and timing of runoff, alterations in land and water use, as well as direct alterations to stream channels and other anthropogenic effects such as dams and flow regulation.

To make comparisons between different-sized rivers, suspended-sediment loads were normalized by dividing by the drainage area of the station to obtain a suspended-sediment yield. This has been expressed in two ways:

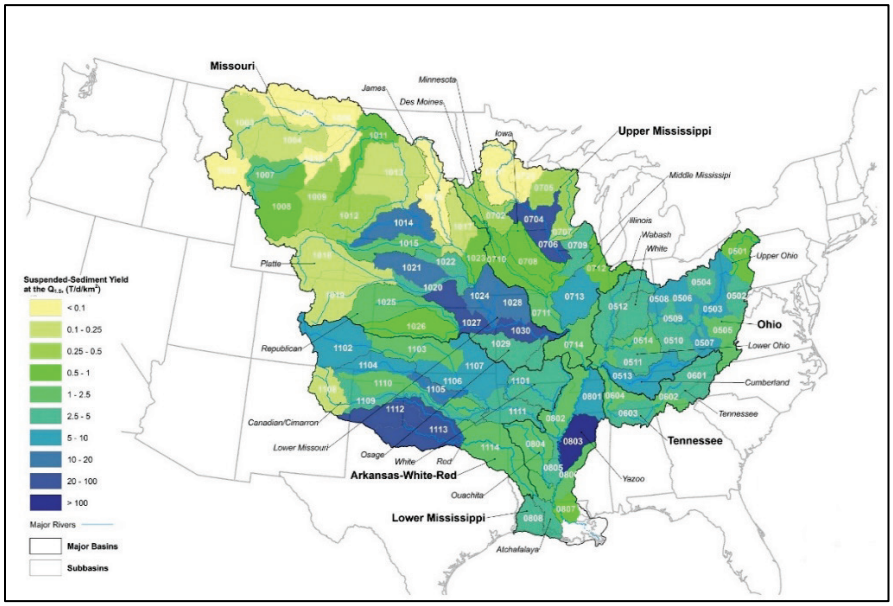
- at the $Q_{1.5}$, often associated with the *effective discharge* as $t/d/km^2$
- and on an average annual basis as $t/y/km^2$.

Values and trends at the *effective* ($Q_{1.5}$) discharge

The long-term, suspended-sediment yield at the $Q_{1.5}$ was calculated for each site using the single sediment-transport rating containing one or more linear segments (in log-log space). Thus, resulting values do not directly account for changes in hydrology or potential shifts in the sediment-transport rating relation, which will be shown later in this report to exhibit important declines in sediment yields. Gages without a corresponding Q1.5 value from flood-frequency analysis were assigned discharge values according to their relation between drainage area and Q1.5 for its associated HUC-4.

The spatial distribution of suspended-sediment yields at the effective discharge is shown in Figure 72. Maximum values occur in the Yazoo Basin (HUC 0803) with suspended-sediment yields of 154 t/d/km^2 at the $Q_{1.5}$. This supports earlier work by Simon et al., (2004) who identified the ecoregion encompassing this basin as having the highest suspended-sediment yields (at the $Q_{1.5}$) in the continental United States. These yields are almost 2.5 times higher than the next largest yielding sub-region, the Lower Missouri (HUC 1030) at 64.1 t/d/km^2. Other high-yielding sub-regions are, in decreasing order, the following: Red River Headwaters (HUC 1112; 59.1 T/d/km^2); two sub-regions from the Upper Mississippi River (HUCs 0706 and 0704; 46.9 and 31.0 t/d/km^2, respectively); the Kansas River (HUC 1027; 28.3 t/d/km^2); and the Red-Washita River (HUC 1113; 20.7 t/d/km^2). A complete list of the median yields by HUC-4 at the Q1.5 is provided in Table J1 in Appendix J.

Figure 72. Median suspended-sediment yield at the $Q_{1.5}$ by sub-region (HUC-4).



Annual variations in suspended-sediment yields are of course related to the inter-annual variations in flow, often making it difficult to detect change over time. To get around this problem, analysis of sediment load or yield at a constant recurrence interval or flow frequency (such as the Q1.5) provides a convenient metric by which to accomplish this. Using the Q1.5 is of further importance because of its implications for channel-forming processes and therefore representing the effective discharge.

Index stations, selected on the basis of their downstream location within each sub-region and the availability of as long a period of record as possible, were used to investigate temporal changes in suspended-sediment yield across the basin. Sediment-transport relations were developed for each decade of sediment sampling and solved for the yield at the Q1.5. In cases where it was appropriate (as with HUC 1111), data from proximal gaging stations on the same river were combined to increase the length of record if they were not separated by an impoundment. Data prior to the 1970s for the Tennessee River Basin could not be obtained from either the USGS or Tennessee Valley Authority but potentially could be accessed in the future from National Archives. The spatial distribution of results from the first and last decades of record is shown in Figure 73 and Figure 74 while a summary of the results is provided in Appendix J. The greatest suspended-sediment loads emanate from the Missouri River Basin, shown as the dark blue regions in Figure 73.

Figure 73. Suspended-sediment load at the $Q_{1.5}$ for the earliest decade of data at sediment index stations (see Table J-2 for dates).

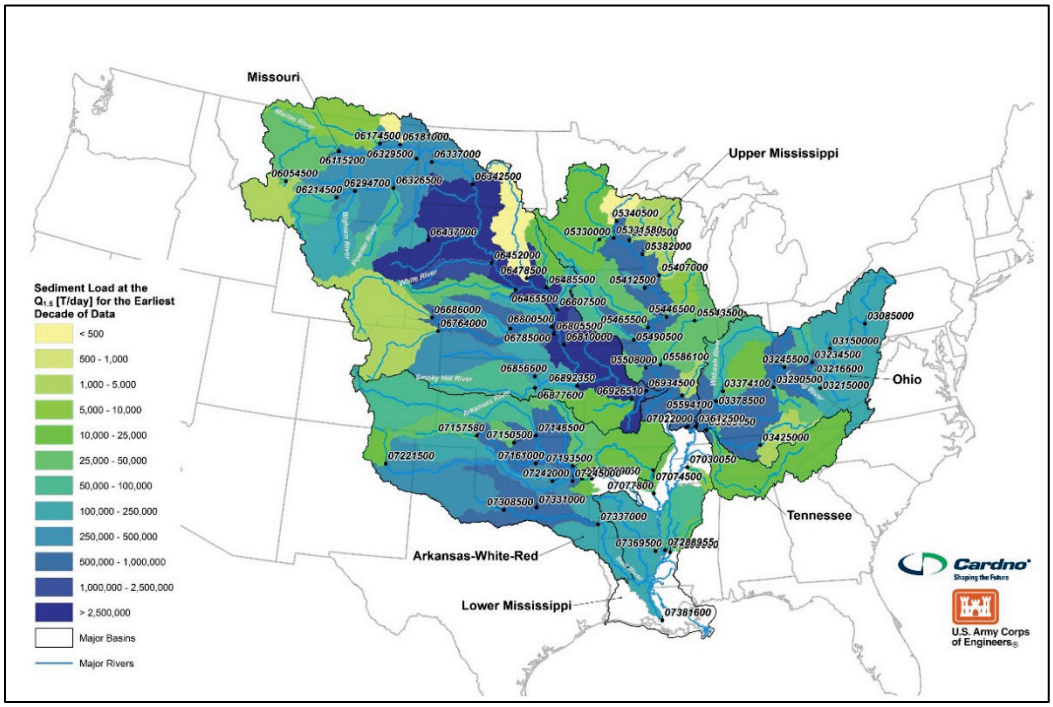
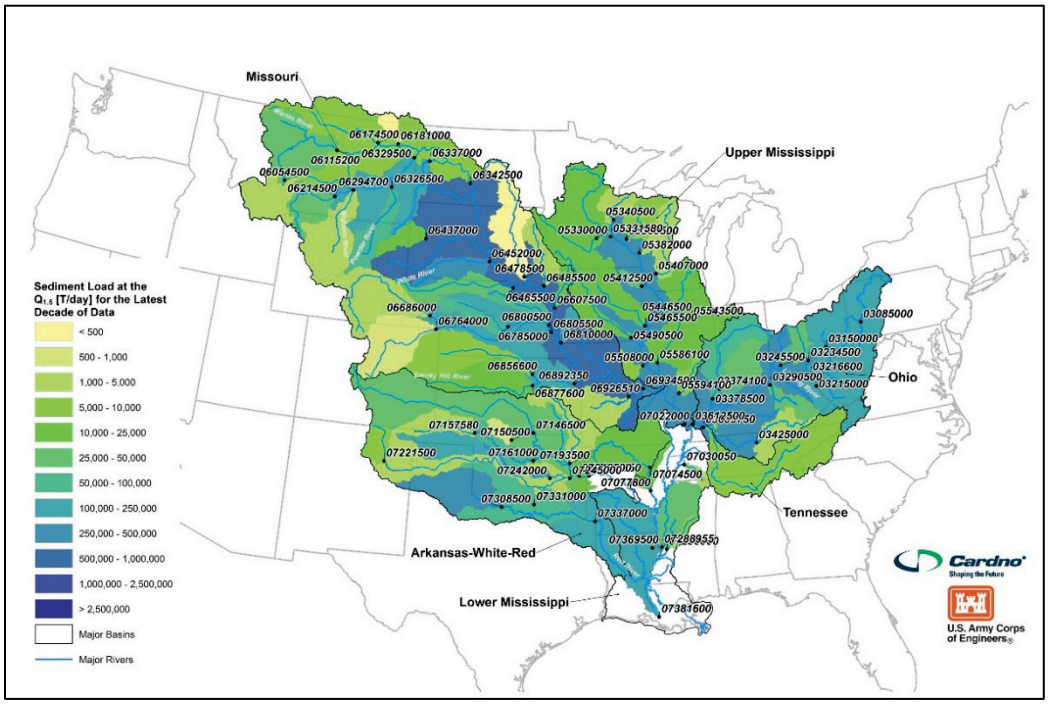


Figure 74. Sediment load at the $Q_{1.5}$ for the latest decade of data at sediment index stations (see Table J-2 for dates).



Results of the comparison between the first and last decades of sediment record disclose large declines in suspended-sediment transport and delivery to the main-stem channels across most of the Mississippi River Basin. Much of this can be attributed to dams, trapping most of the sediment (including the silts and clays) delivered to the impoundments from upstream. Expressed as a percent decrease over the sampling period, the decreases in suspended-sediment yield are shown in Figure 75, and as an absolute value (in tonnes per day at the Q1.5) in Figure 76. The largest reductions in both percentage and amount are along the Missouri River. Meade and Moody (2010) attributed the large decline in sediment loads in the Mississippi River Basin from 1940 to 2007, primarily to the series of major dams along the Missouri River.

Figure 75. Change in suspended-sediment load at the $Q_{1.5}$ at sediment index stations, expressed as a percent. Blank areas represent a lack of index stations.

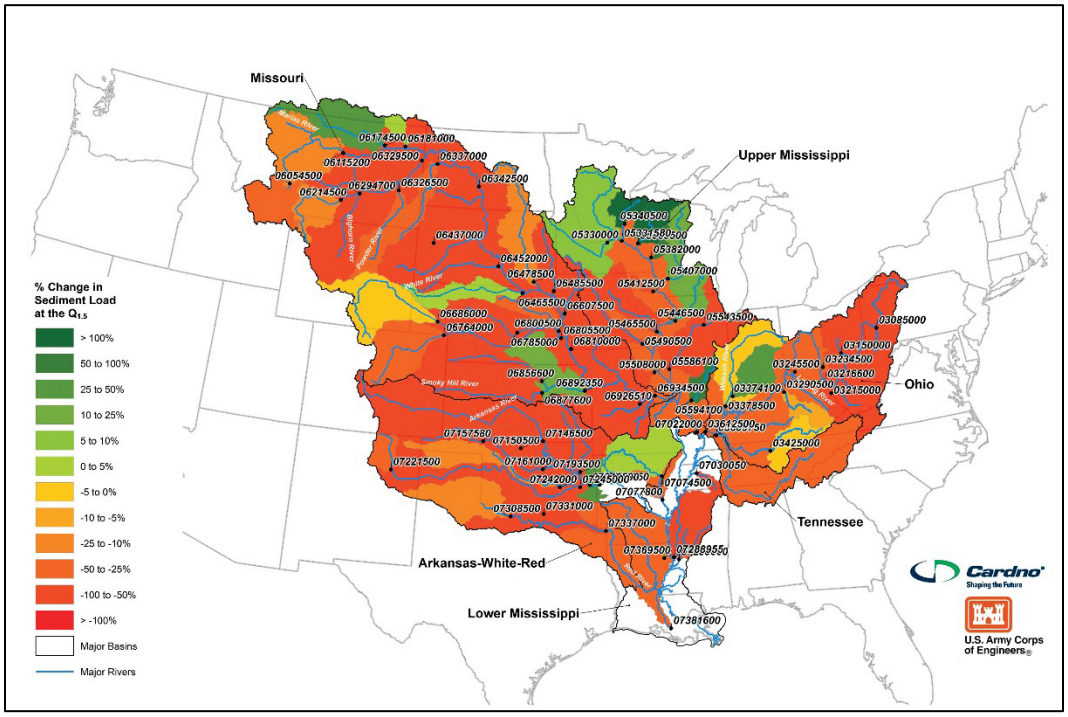
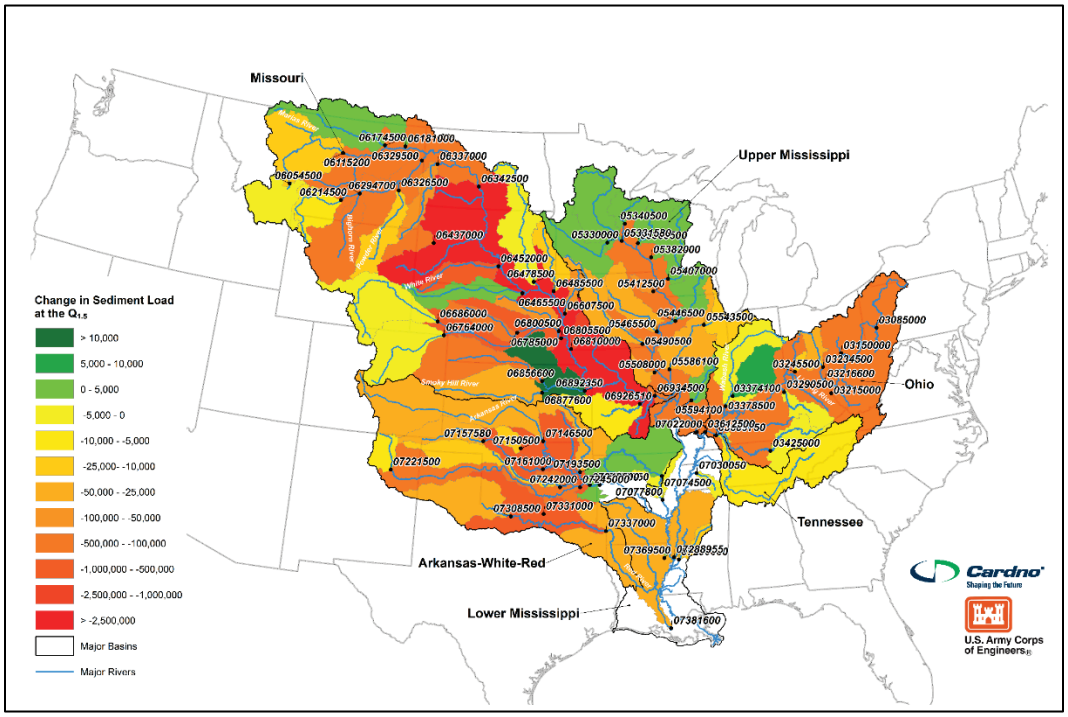


Figure 76. Change in suspended-sediment load at the $Q_{1.5}$ at sediment index stations, Expressed in tonnes per day. Blank areas represent a lack of index stations.



Results from this study show that suspended-sediment loads at the $Q_{1.5}$ have declined from the outlets of all of the major tributaries draining to the LMR. Approximately 5 million fewer tons per day are reaching the LMR (excluding the Atchafalaya River) from its major tributaries at the $Q_{1.5}$:

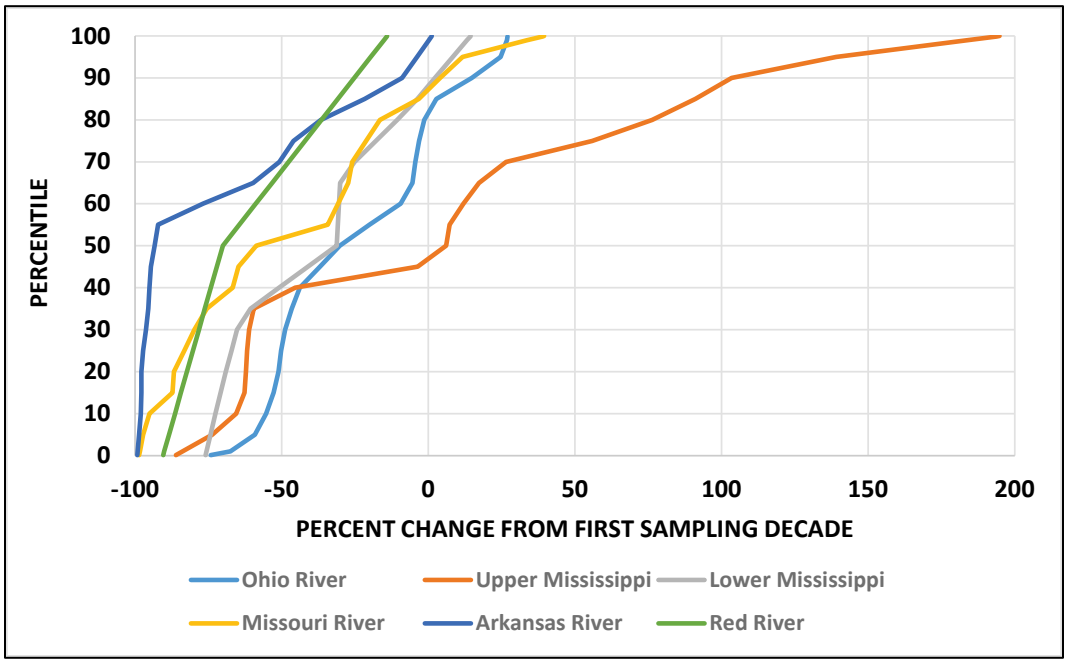
- Ohio River: -48.5% (286,000 t/d)
- Tennessee River: -46.4% (8,380 t/d)
- Upper Mississippi River: -47.3% (446,000 t/d)
- Lower Mississippi (Atchafalaya River): -30.0% (49,600 t/d)
- Missouri River: -86.1% (3,440,000 t/d)
- Arkansas River*: -95.7% (768,000 t/d)
- Red River: -90.5% (775,000 t/d).

**Note that this is not the most downstream site but that data start in the 1940s. These results also assume that the $Q_{1.5}$ has not changed over the period and in fact would probably be even more drastic (with the exception of the Upper Mississippi River) if the current $Q_{1.5}$ were used for the latest period.*

The starting period for each of the major index stations that were used in the comparison is listed in the second table in Appendix J.

Notwithstanding the marked decrease in suspended-sediment loads being delivered to the LMR from its major tributaries during the Q1.5, there are sub-regions that are providing greater loads currently than at the beginning of the sampling periods. These are located in the Upper Mississippi where approximately 50% of the index sites (sub-regions) are showing increases in suspended-sediment yields (Figure 77). This is related to the increase flows throughout much of the region. Approximately 10% of the stations in the Ohio and even the Missouri River Basins are showing increased loads. These in turn could be related to the incision of smaller tributary streams in response to lowering of bed levels of the trunk streams downstream from the major impoundments (Williams and Wolman 1984).

Figure 77. Frequency distribution of changes in suspended-sediment load at the $Q_{1.5}$ from sub-regions at sediment index stations.



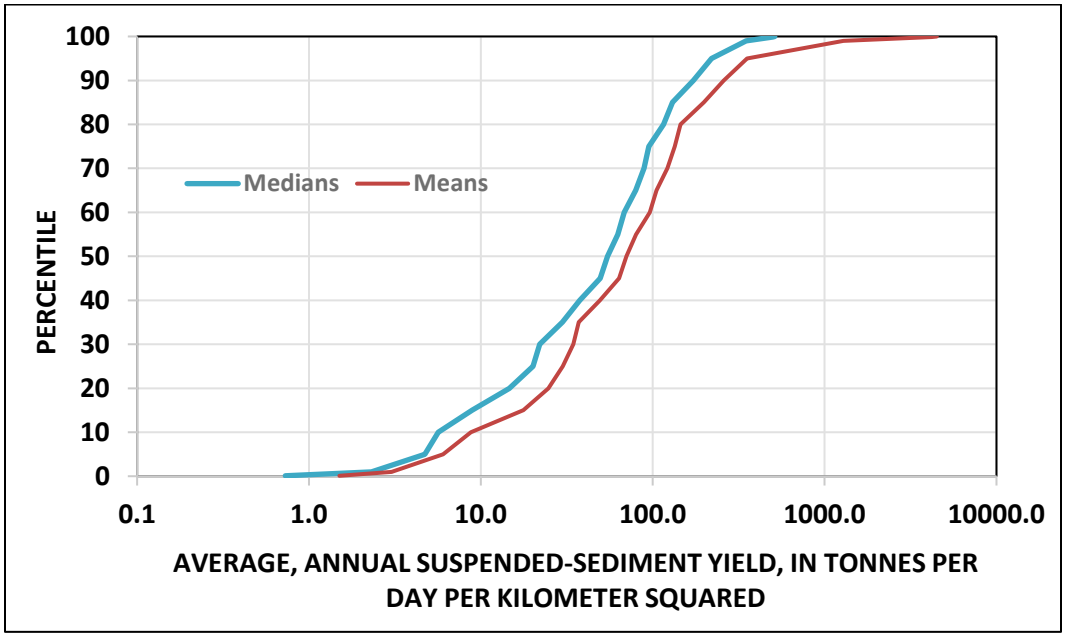
Annual trends

Calculating suspended-sediment transport rates at the $Q_{1.5}$ is a convenient way to compare values over time and space but is difficult to comprehend in real terms. This is because one cannot simply multiply the values in tonnes per day by 365 to obtain average-annual values because a flow of

that magnitude (perhaps bankfull) does not occur every day, but on average, once every 1.5 years. To express sediment-transport results in a way that is conceptually easier to understand, a similar analysis has been conducted using average annual values. In this case, however, the study is at the mercy of the inter-annual variations in discharge that will of course affect calculations and interpretations of changes in average annual values. To accomplish this, data from 970 USGS gages with a sufficient number of discrete sediment samples and mean daily streamflow data were used. Gages used in this analysis have published drainage areas, instantaneous flows associated with each sediment sample, and sampled flows to within at least 25% of the Q1.5 estimated for the site.

Median annual suspended-sediment yields from the sub-regions vary over three orders of magnitude, ranging from 0.6 t/y/km^2 in HUC-1016 (James River) to 514 t/y/km^2 in HUC-1021 (Loup River). The central 50% of the distribution of median values ranges from 20.1 to 95.1 t/y/km^2. Means range over four orders of magnitude (Figure 78).

Figure 78. Frequency distribution of annual suspended-sediment yields for all sub-regions (HUC-4s) in the Mississippi River Basin.



Average annual suspended-sediment yields for each sampling station are displayed in Figure 79 while the median value for each sub-region, in Figure 80. The spatial distribution of results is quite similar to those shown previously for the Q1.5 with the highest values occurring in some of the same sub-regions (i.e., HUC 0803; Yazoo River). Yields greater than

190 t/y/km² are found in several sub-regions of the Missouri Basin's Great Plains including HUC 1021, Loup River; HUC 1028, Chariton-Grand; HUC 1024, Nishnabotna; HUC 1025, Republican, as well as HUC 1113 (Red-Washita) in the Arkansas Basin and HUC 0507, (Big Sandy-Guyandotte) in the Ohio Basin. Areas of the lower Ohio River and Upper Mississippi also have reasonably high average annual-sediment yields. A complete list of the results of median and average annual suspended-sediment yields is provided by HUC-4 in Appendix J. These values represent basin-wide contributions of suspended-sediment across the Mississippi River Basin.

Figure 79. Median annual sediment yield by gage.

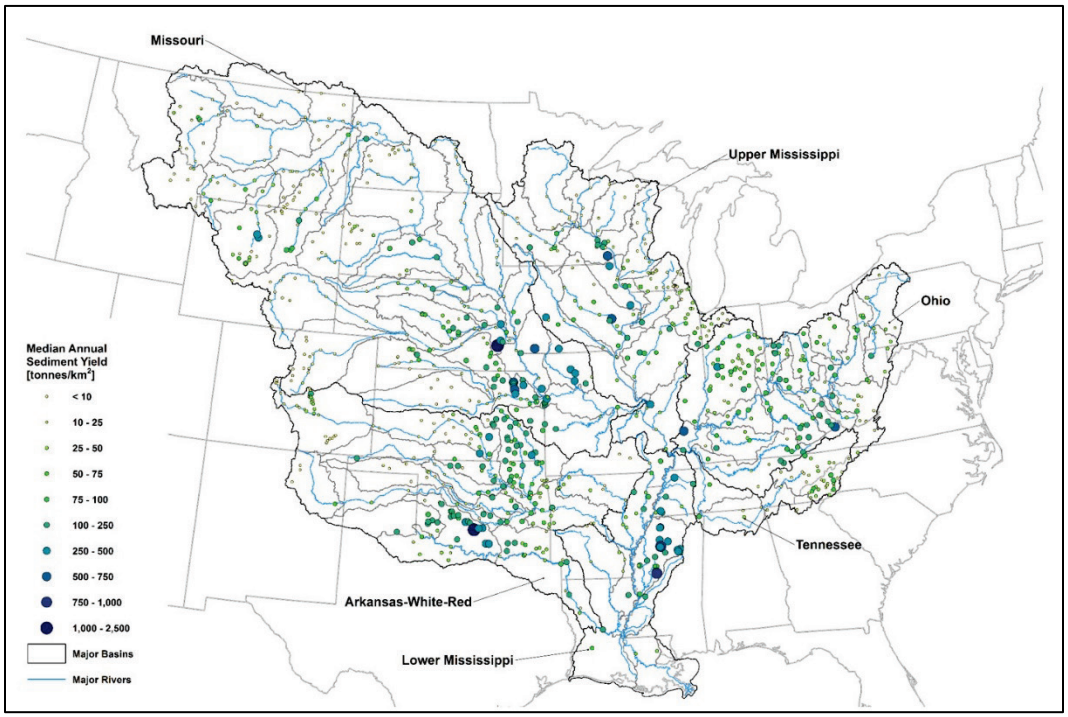
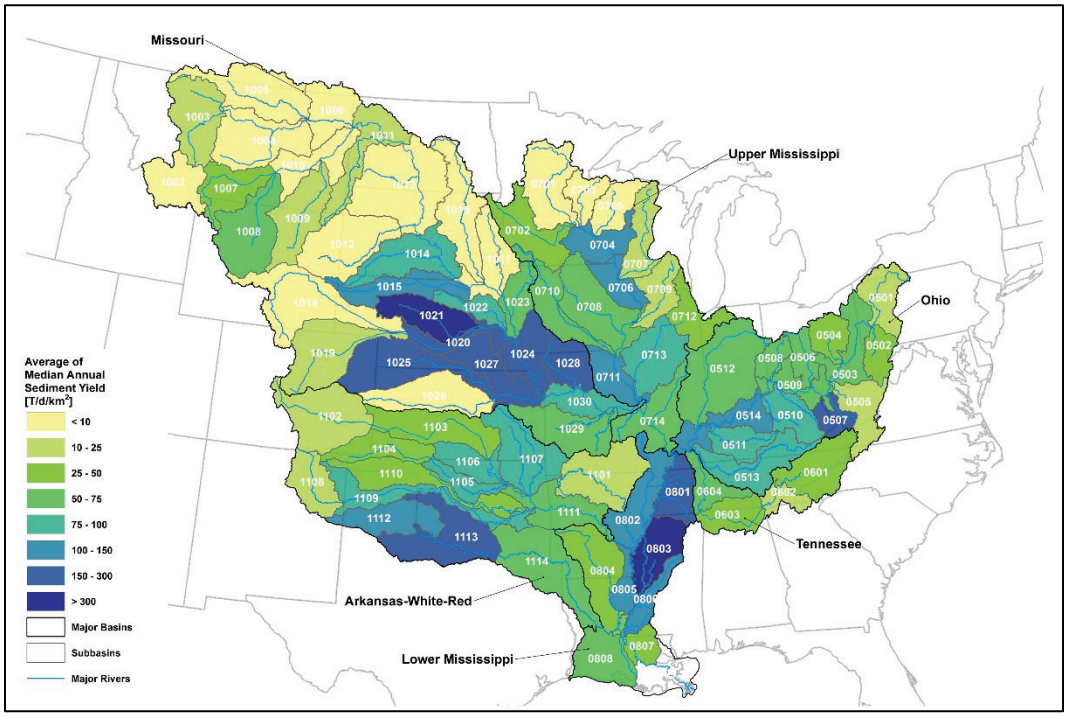


Figure 80. Average annual suspended-sediment yield by HUC-4 from gage medians.



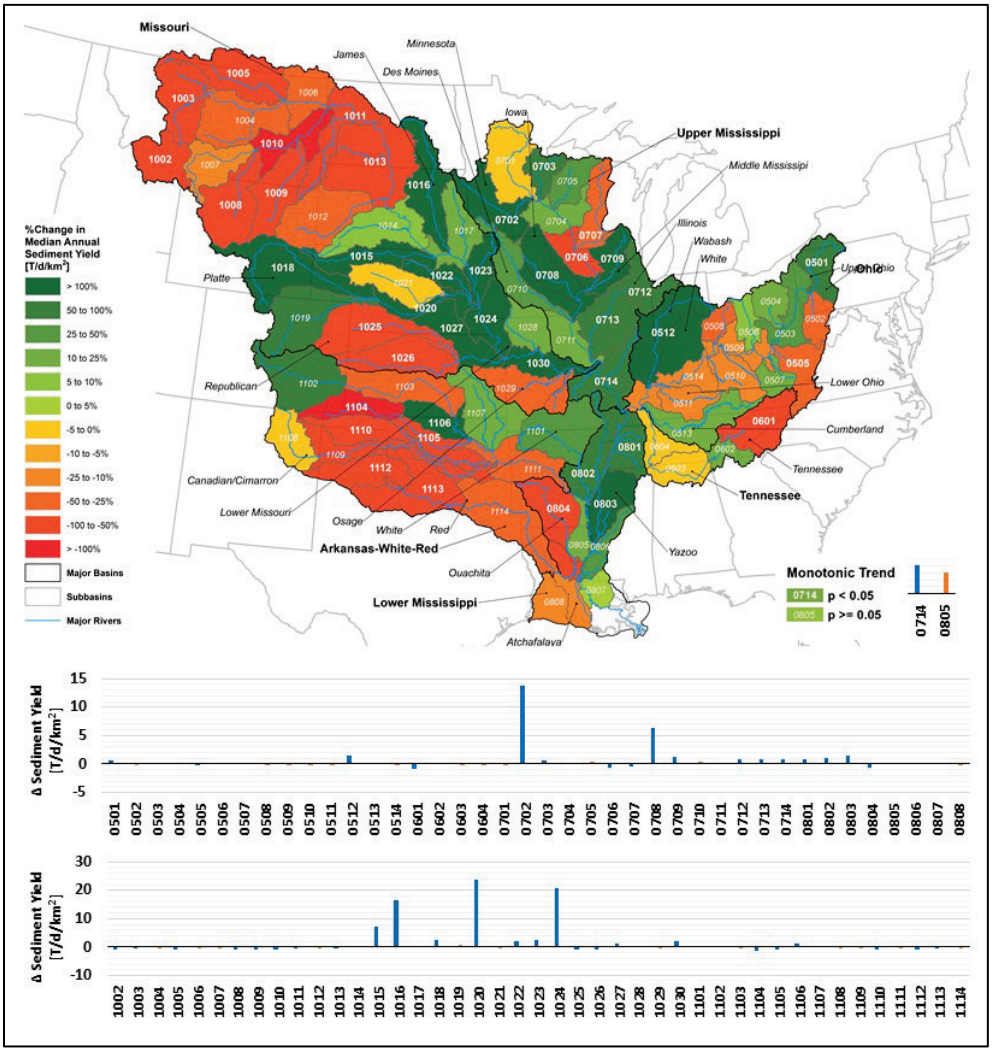
Annual suspended-sediment loads over the periods of sampling and flow record utilize data from all of the stations with sufficient data within each sub-region (HUC-4). Results are, therefore, a measure of changes in sediment production from streams of varying size. On average, the length of record for the HUC-4s is approximately 96 years, reflecting lengthy flow records for at least some of the gages in each HUC-4. In contrast, sediment-yield results reported from the index stations at the $Q_{1.5}$ are a measure of sediment delivery out of the sub-region, discharging from the trunk stream and likely to be largely influenced by dams and flow regulation.

Changes in median annual suspended-sediment yields within each of the sub-regions are shown in Figure 81 and reflect a broad range of hydrologic and anthropogenic changes over the past century. Marked decreases are observed across parts of the Upper Missouri, throughout the Arkansas and in parts of the Upper Ohio and LMR Basins. These decreases are probably the result of land- and water-use practices that result in less water in the channels. In contrast, increases in median annual yields have occurred throughout much of the mid-continent, including the Upper Mississippi and the lower Missouri Basins. Increased suspended-sediment yields reflect the documented increases in water yields in these regions as well as destabilization through incision and widening in response to

anthropogenic disturbances such as lowering of trunk streams and channelization.

Note that although this analysis takes into account long periods of flow record, it utilizes a static sediment-transport rating for each site. Granted that this rating relation represents *average* conditions over the period of flow record for each gage, but it does not account for the rating shifts that have been observed at most of the index stations. The work here found that there was simply not a long enough sampling period at most USGS sediment stations to develop decadal ratings for all stations. A summary of the results for each HUC-4, including the maximum period of flow record and changes in median-annual, suspended-sediment yield is shown in Appendix J.

Figure 81. Changes in median-annual suspended-sediment yields over the period of record by HUC-4.



Trends in annual sediment delivery to the Lower Mississippi from major index stations

To provide an evaluation of how sediment delivery to the LMR has changed over time, sediment-load data from the outlet of the major contributing rivers were considered. To account not only for changes in hydrology, but also for changes in the relation between flow and sediment-transport rates, shifts in the rating relations were included in the analysis. Decadal sediment transport curves were developed for the following major index stations (Table 4):

- Ohio River at Metropolis, Illinois; USGS 06611500
- Missouri River at Hermann, Missouri; USGS 06934500
- Upper Mississippi River represented by loads at the Mississippi River loads at Thebes, Illinois; USGS 0702200, minus loads at the Missouri River at Hermann
- Arkansas River near Sallisaw, Oklahoma; USGS 07246500.

Table 4. Decadal average annual sediment delivery to the Lower Mississippi.

Decade	Average Annual Sediment Load, in millions of tonnes [Mt]				
	Ohio	Missouri	Upper Mississippi	Arkansas	Total
1940s	49.6	360	47.3*	106	616
1950s	58.7α	268	45.1*	57.0	452
1960s	48.4α	259β	43*	24.9	408
1970s	45.3	99.7	9.4	13.2	168
1980s	30.4	40.7	32.6	15.3γ	119
1990s	29.8	83.7	57.2	4.0	175
2000s	31.4	31.2	21.0	3.1	86.6
2010s	20.8	47.8	27.0	2.3	97.9

α Uses 1940s transport curve; β uses 1950s transport curve; γ uses 1970s transport curve.

* Estimated from extrapolation of trend from 1970s–2010s, back to 1940s.

Sediment data for the Ohio River were supplemented by observations at Dam 53 near Grand Chain, Illinois (USGS 03612500). Data for the Arkansas River were supplemented with samples from the station at Ft. Smith, Arkansas (USGS 07249455). Where sediment data were insufficient to develop decadal ratings, ratings from other decades were used as noted in the table. Annual sediment loads were then computed

from daily loads using the associated mean daily streamflow and decadal ratings at each site.

In all cases, suspended-sediment loads from the major contributing streams show drastic monotonic decreases over the period 1940 to present (Table 5; Figure 82). The percent reduction in average-annual, suspended-sediment loads are 61% for the Ohio River, 33% for the Upper Mississippi River, 84% from the Missouri River, and 96% for the Arkansas River. In terms of the actual average annual reduction, the Missouri River by far had the greatest. Approximately 251 million tonnes (Mt) less suspended sediment are being discharged per year to the lower Mississippi today from the Missouri River than in the 1940s. In total, this represents approximately a 300% reduction in average annual suspended-sediment delivery from its major tributaries to the LMR, from approximately 616 Mt/y in 1940 to approximately 98 Mt/y currently (Figure 83).

Numerous other researchers have similarly reported on a large decline in suspended-sediment loads discharged by the Mississippi River to the Gulf of Mexico (Keown et al. 1986; Meade and Moody 2010; Heimann et al. 2011). These reductions in loads have consequences for river stability, protection of hydraulic structures, nutrient transport, and replenishment of coastal wetland areas.

Table 5. Trends in annual sediment delivery to the Lower Mississippi at major index stations using decadal transport curves.

River	$p < 0.05$	Suspended-Sediment Load [Mt/y]		Change in Load	
		Min Year	Max Year	[Mt/y]	%Change
Ohio	*	57.7	22.4	-35.3	-100 to -50%
Missouri	*	299	47.8$^{\alpha}$	-251	-100 to -50%
Upper Mississippi		48.2$^{\beta}$	32.1	-16.1	-50 to -25%
Arkansas	*	55.6	2.3$^{\alpha}$	-53.3	-100 to -50%

$^{\alpha}$ Regression crosses x-axis; decadal average substituted from Table 17.

$^{\beta}$ Regression extended back to 1940s.

Figure 82. Trends in annual sediment delivery to the Lower Mississippi at major index stations using decadal transport curves (see Table 5 for details).

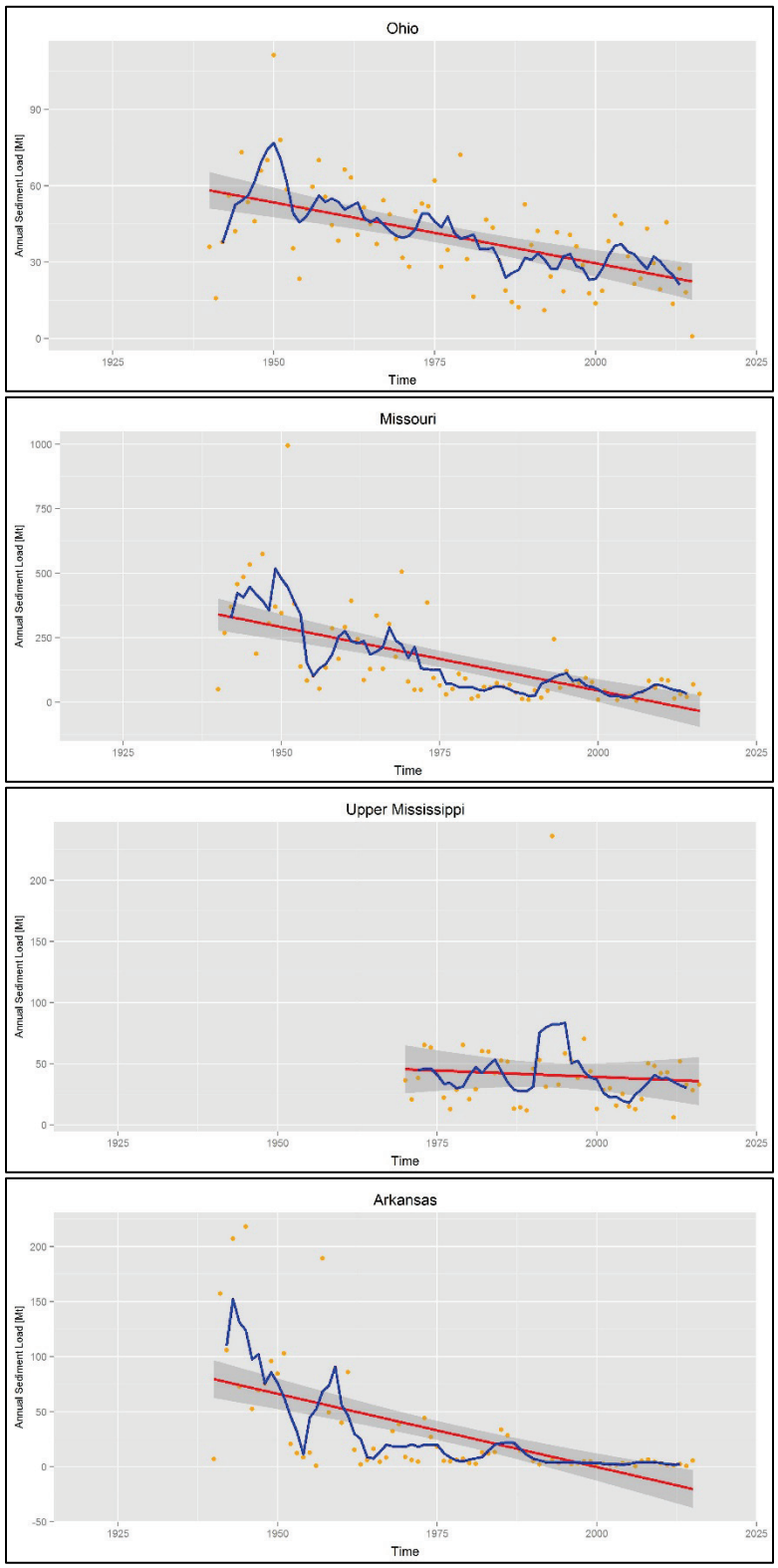
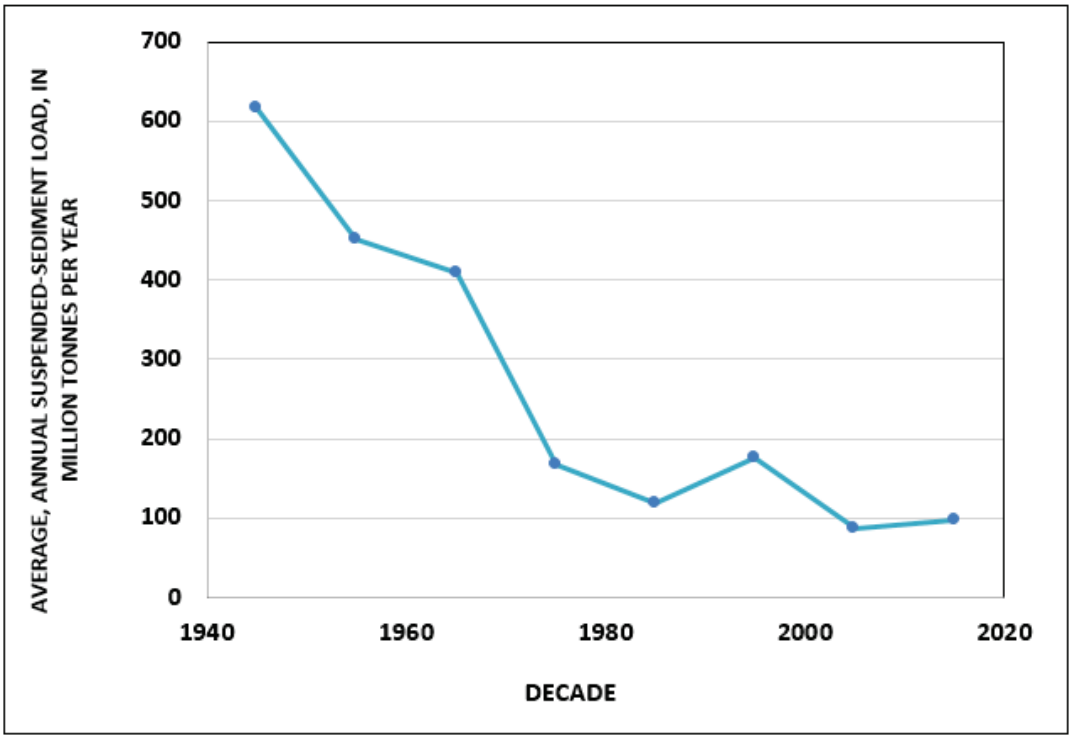


Figure 83. Decline in average annual delivery of suspended-sediment to the LMR.



Summary of sediment-yield results

Suspended-sediment yields were calculated for all stations and all time periods at the $Q_{1.5}$ to represent conditions at the effective discharge. Maximum values occur in the Yazoo Basin (HUC 0803) with suspended-sediment yields of 154 t/d/km^2 and are 2.5 times greater than the next largest yielding region. Other areas of high yields include parts of the Upper Red (HUCS 1112 and 1113), the Kansas and Lower Missouri (HUC 1027 and 1030, respectively), and in two HUCS-4s in Upper Mississippi Rivers (704 and 706). In contrast, low-yielding regions (<0.25 t/d/km^2) occur throughout the upper Missouri, the James River (HUC 1016) and the Mississippi Headwaters.

Index stations were used to establish transport relations by decade to evaluate the change in sediment transport over the period of sampling and to determine the spatial distribution of these changes. Results show that suspended-sediment loads at the $Q_{1.5}$ have declined from the outlets of all of the major tributaries draining to the LMR. Approximately 5 million fewer tons per day are reaching the LMR (excluding the Atchafalaya River) from its major tributaries at the $Q_{1.5}$:

- Ohio River: -48.5% (286,000 t/d)
- Tennessee River: -46.4% (8,380 t/d)
- Upper Mississippi River: -47.3% (446,000 t/d)
- Lower Mississippi (Atchafalaya River): -30.0% (49,600 t/d)
- Missouri River: -86.1% (3,440,000 t/d)
- Arkansas River*: -95.7% (768,000 t/d)
- Red River: -90.5% (775,000 t/d).

Still, there are some sub-regions that are providing greater loads currently than at the beginning of the sampling periods. These are located in the Upper Mississippi basin where approximately 50% of the index sites (sub-regions) are showing increases in suspended-sediment yields.

Using a data set of 970 gages, median annual suspended-sediment yields from the sub-regions were found to vary over three orders of magnitude, ranging from 0.6 t/y/km^2 in HUC-1016 (James River) to 514 t/y/km^2 in HUC-1021 (Loup River). The central 50% of the distribution of median values ranges from 20.1 to 95.1 t/y/km^2. Changes in median annual suspended-sediment yields within each of the sub-regions reflect a broad range of hydrologic and anthropogenic changes over the past century. Marked decreases are observed across large parts of the Upper Missouri, throughout the Arkansas and Red River basins, and in parts of the Upper Ohio and LMR Basins. These decreases are probably the result of land- and water-use practices that result in less water in the channels. In contrast, increases in median annual yields have occurred throughout much of the mid-continent, including the Upper Mississippi and the lower Missouri Basins.

Sediment delivery to the LMR from the HUC-2 basins show drastic monotonic decreases over the period 1940 to present. The percent reduction in average annual suspended-sediment loads are 61% for the Ohio River, 33% for the Upper Mississippi River, 84% from the Missouri River, and 96% for the Arkansas River. Approximately 251 Mt less suspended sediment are discharged per year to the LMR today from the Missouri River than in the 1940s. In total, this represents approximately a 500 Mt/y reduction in average annual suspended-sediment delivery from the major tributaries to the LMR, from approximately 616 Mt/y in 1940 to about 98 Mt/y currently (an 84% reduction).

5 Summary

Altered hydrological conditions in the LMR are a result of changes in precipitation, rainfall-runoff relations, and anthropogenic factors that play a role in the magnitude and frequency of hydrologic events. Numerous studies have shown the significance of climate change and extreme weather events on peak flows, low flows, and flooding, etc. Contributing to shifting hydrologic patterns such as precipitation are human-induced changes to the natural environment such as agriculture, urbanization, channelization, dam construction, etc., that often vary in a spatially systematic way according to regional demands for water. Changing flow regimes also affect suspended-sediment transport rates and channel stability, challenging on-going efforts in flood protection, stream restoration, and water-quality management.

Results of this study show that in general, although most of the Mississippi River Basin is receiving more rainfall than it did 100 years ago, there are vast areas where water yields have decreased significantly, particularly in the western part of the basin and particularly in spring. Precipitation has also shifted temporally such that winter precipitation has significantly decreased in many areas while spring and autumn precipitation has generally increased. Parts of the western basin are experiencing 25% to more than 50% less discharge per unit area than they did 100 years ago. In contrast, the mid-continent is generating considerably more water than it did 100 years ago. In part, this can be attributed to increases in precipitation and a greater influence of hurricane-related rainfall, but the anthropogenic effects cannot not be minimized. The result is that the LMR is receiving more flow from its major HUC-2 tributaries (Ohio, Missouri, and Upper Mississippi Rivers) than at the turn of the twentieth century. Integrating over an average year and excluding inputs from other smaller tributaries bring the average annual increase in flows to the LMR to approximately 1.62 million m^3/s (57.2 million ft^3/s). Average mean daily flow contributions from the Ohio, Upper Mississippi, and Missouri Rivers have changed from 61%, 23%, and 16% in 1930 to 55%, 28%, and 18% in 2014, respectively.

Although the direction of the changes (positive or negative) varies across the basin, these effects are widespread and sizeable in magnitude, indicating that anthropogenic influences have been a major determining factor on changes in streamflow regimes over the past century. The

direction and magnitude of these influences can clearly be sorted by region. While anthropogenic activities have resulted in increases in water yield in the central part of the basin (increases of 50%–100% decreasing eastward to 0%–10%), activities at the basin margins have caused decreases in flow. In the west, decreases of 25%–100% are typical.

Results of this study are in direct contrast with results of McCabe and Wolock (2014) over the same time period. Those authors concluded that precipitation variability accounts for nearly all the variability in observed runoff in the conterminous U.S. based on rainfall-runoff simulations. Similar to the findings of McCabe and Wolock (2014), who determined that streamflow was only weakly correlated to known climate indices, the results of this study show unpredictability of water yields based solely on climate—in this case, precipitation.

Sediment yields were calculated for all stations with available data at the channel-forming discharge ($Q_{1.5}$) and on an annual basis. Results for both the downstream-most stations in each sub-region and for average conditions within each sub-region elucidate current rates of suspended-sediment transport as well as changes over the period of record. Suspended-sediment loads at the outlets of most sub-regions have drastically declined, from the major tributaries at the $Q_{1.5}$, by 30% in the Arkansas, 46%–48% in the Tennessee, Upper Mississippi, and Ohio Basins, and 86% in the Missouri. Similar results were obtained for annual values. Still, increases in sediment yields are found in some sub-regions impacted by increased precipitation and water yields such as the upper Mississippi, and regions bordering the lower and middle Mississippi and Missouri Valleys where channels are responding to the lowering of the trunk streams downstream from dams or because of channelization activities.

The average-annual delivery of suspended sediment to the LMR has declined by approximately 84%, from approximately 616 Mt/y in 1940 to approximately 98 Mt/y, currently. The largest actual decline is from the Missouri River (approximately 250 Mt/y) largely due to the trapping of sediment behind impoundments. Decreases in sediment delivery to these reservoirs are also noted. Other researchers have similarly reported on a large decline in suspended-sediment loads discharged by the Mississippi River to the Gulf of Mexico. These reductions in loads have consequences for river stability, protection of hydraulic structures, nutrient transport, and replenishment of coastal wetland areas.

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Appendix A: GHCND Gages

Table A-1. Timeframe for precipitation analysis by HUC-4.

HUC-4	min Year	max Year	n		HUC-4	min Year	max Year	n
0501	1893	2014	117		1003	1899	2014	114
0502	1896	2014	116		1004	1906	2014	106
0503	1896	2014	117		1005	1912	2014	102
0504	1900	2014	115		1006	1911	2014	90
0505	1902	2014	112		1007	1908	2014	107
0506	1899	2014	116		1008	1913	2014	100
0507	1911	2014	96		1009	1912	2014	82
0508	1900	2014	115		1010	1909	2014	105
0509	1899	2014	115		1011	1911	2014	101
0510	1898	2014	116		1012	1911	2014	104
0511	1897	2014	106		1013	1901	2014	108
0512	1895	2014	120		1014	1904	2014	107
0513	1896	2014	119		1015	1910	2014	99
0514	1895	2014	119		1016	1896	2014	116
0601	1898	2014	117		1017	1899	2014	113
0602	1896	2014	106		1018	1900	2014	107
0603	1898	2014	114		1019	1898	2014	117
0604	1901	2014	110		1020	1902	2014	110
0701	1893	2014	119		1021	1897	2014	114
0702	1896	2014	118		1022	1899	2014	114
0703	1907	2014	79		1023	1897	2014	115
0704	1896	2014	98		1024	1896	2014	118
0705	1905	2014	79		1025	1893	2014	117
0706	1904	2014	96		1026	1900	2014	108
0707	1905	2014	100		1027	1894	2014	120
0708	1895	2014	120		1028	1894	2014	121
0709	1896	2014	115		1029	1897	2014	116
0710	1899	2014	116		1030	1895	2014	118

HUC-4	min Year	max Year	n		HUC-4	min Year	max Year	n
0711	1896	2014	112		1101	1897	2014	116
0712	1900	2014	111		1102	1897	2014	110
0713	1896	2014	117		1103	1901	2014	114
0714	1896	2014	118		1104	1903	2014	107
0801	1906	2014	106		1105	1900	2014	114
0802	1903	2014	108		1106	1910	2014	100
0803	1901	2014	114		1107	1895	2014	116
0804	1901	2014	108		1108	1905	2014	106
0805	1911	2014	102		1109	1907	2014	108
0806	1897	2014	112		1110	1909	2014	105
0807	1898	2014	107		1111	1892	2014	119
0808	1894	2014	115		1112	1908	2014	94
0809	1900	2014	111		1113	1901	2014	111
1002	1907	2014	102		1114	1903	2014	109

Appendix B: USGS Gage Information

Table B-1. Timeframe for water-yield analysis by HUC-4.

HUC-4	Min Year	Max Year	n		HUC-4	Min Year	Max Year	n		HUC-4	Min Year	Max Year	n
0501	1909	2014	106		0711	1923	2014	92		1017	1946	2013	68
0502	1908	2014	107		0712	1916	2015	100		1018	1905	2015	105
0503	1913	2014	102		0713	1909	2014	103		1019	1896	2015	120
0504	1922	2014	93		0714	1909	2014	103		1020	1938	2015	77
0505	1896	2014	113		0801	1930	2015	85		1021	1937	2013	77
0506	1922	2014	93		0802	1927	2015	88		1022	1946	2013	68
0507	1916	2014	87		0803	1909	2015	89		1023	1929	2015	80
0508	1915	2014	100		0804	1929	2015	86		1024	1923	2015	92
0509	1916	2014	87		0805	1939	2012	72		1025	1929	2015	87
0510	1916	2014	91		0806	1939	2015	76		1026	1919	2015	97
0511	1928	2014	81		0807	1941	2015	74		1027	1918	2015	98
0512	1910	2014	102		0808	1923	2015	78		1028	1922	2015	94
0513	1915	2015	101		0809	1909	2014	106		1029	1919	2014	96
0514	1929	2014	86		1002	1895	2014	109		1030	1926	2014	89
0601	1900	2015	116		1003	1903	2015	113		1101	1922	2015	93
0602	1899	2014	116		1004	1908	2013	98		1102	1897	2015	108
0603	1905	2014	98		1005	1904	2013	88		1103	1903	2015	95
0604	1921	2014	94		1006	1910	2015	81		1104	1943	2015	72
0701	1907	2014	108		1007	1908	2014	103		1105	1935	2015	79
0702	1912	2014	84		1008	1907	2015	104		1106	1937	2015	78
0703	1914	2014	101		1009	1920	2013	85		1107	1922	2015	93
0704	1912	2014	93		1010	1939	2013	65		1108	1908	2015	93
0705	1914	2014	101		1011	1905	2012	81		1109	1939	2015	76
0706	1920	2014	89		1012	1930	2014	78		1110	1938	2015	77
0707	1913	2013	101		1013	1909	2014	89		1111	1928	2015	87
0708	1903	2014	112		1014	1932	2013	82		1112	1905	2015	80
0709	1915	2014	100		1015	1939	2013	69		1113	1936	2015	79
0710	1916	2014	99		1016	1944	2013	70		1114	1925	2015	90

Table B-2. Timeframe for precipitation-weighted water yield analysis by HUC-4.

HUC-4	Min Year	Max Year	n	HUC-4	Min Year	Max Year	n	HUC-4	Min Year	Max Year	n
0501	1910	2014	105	0711	1923	2014	92	1017	1946	2013	68
0502	1908	2014	106	0712	1916	2014	99	1018	1905	2013	103
0503	1913	2014	102	0713	1909	2014	103	1019	1898	2014	117
0504	1922	2014	93	0714	1909	2014	103	1020	1938	2013	76
0505	1908	2014	107	0801	1930	2013	84	1021	1937	2013	76
0506	1922	2014	93	0802	1927	2013	87	1022	1946	2013	68
0507	1929	2014	85	0803	1909	2013	88	1023	1929	2013	79
0508	1915	2014	100	0804	1929	2013	85	1024	1923	2014	91
0509	1916	2014	87	0805	1939	2012	72	1025	1929	2014	86
0510	1916	2014	91	0806	1939	2009	69	1026	1919	2014	96
0511	1928	2014	81	0807	1941	2013	73	1027	1918	2014	97
0512	1910	2014	102	0808	1923	2013	77	1028	1922	2014	93
0513	1915	2014	100	0809	1910	2014	105	1029	1919	2014	96
0514	1929	2014	86	1002	1911	2014	94	1030	1926	2014	89
0601	1900	2014	115	1003	1903	2014	112	1101	1922	2013	92
0602	1902	2014	104	1004	1910	2013	96	1102	1897	2013	106
0603	1905	2014	98	1005	1915	2013	82	1103	1903	2013	94
0604	1921	2014	93	1006	1911	2012	75	1104	1943	2013	71
0701	1907	2014	107	1007	1908	2014	103	1105	1935	2013	77
0702	1912	2014	84	1008	1913	2013	98	1106	1937	2013	76
0703	1920	2014	77	1009	1932	2013	75	1107	1922	2013	92
0704	1912	2014	87	1010	1939	2013	65	1108	1908	2013	88
0705	1914	2014	77	1011	1930	2012	79	1109	1939	2013	75
0706	1920	2014	84	1012	1930	2014	78	1110	1938	2013	75
0707	1913	2013	94	1013	1910	2014	88	1111	1928	2013	86
0708	1903	2014	112	1014	1932	2013	82	1112	1938	2013	74
0709	1915	2014	99	1015	1939	2013	69	1113	1936	2013	78
0710	1916	2014	99	1016	1944	2013	70	1114	1925	2013	89

Table B-3. Index stations selected for calculating suspended-sediment yields at the $Q_{1.5}$ for sub-regions.

HUC-4	River	Station	First Decade	Last Decade
0502	Monongahela	03085000	1970	1990
0504	Muskingum	03150000	1970	1990
0506	Scioto	03234500	1960	1990
0507	Big Sandy	03215000	1970	1990
0509	Little Miami	03245500	1970	2000
0509	Ohio	03216600	1970	2010
0510	Kentucky	03290500	1970	1990
0512	Wabash	03378500	1970	2010
0512	White	03374100	1970	2010
0513	Cumberland	03425000	1970	1990
0514	Ohio	03612500	1940	2010
0604	Tennessee	03609750	1970	2010
0701	Mississippi	05331580	1970	2010
0702	Minnesota	05330000	1970	2000
0703	St Croix	05340500	1970	2000
0704	Black	05382000	1960	2000
0705	Chippewa	05369500	1960	1990
0706	Turkey	05412500	1950	2010
0707	Wisconsin	05407000	1970	2000
0708	Iowa	05465500	1970	2010
0709	Rock	05446500	1970	1990
0710	Des Moines	05490500	1970	2010
0711	Salt	05508000	1970	1990
0712	Illinois	05543500	1970	2000
0713	Illinois	05586100	1980	2010
0714	Kaskaskia	05594100	1970	1990
0714	Mississippi	07022000	1970	2010
0801	Hatchie	07030050	1970	2000
0802	White	07077800	1980	2010

HUC-4	River	Station	First Decade	Last Decade
0803	Yazoo	07288955	1970	2010
0805	Tensas	07369500	1970	1990
0806	Big Black	07290000	1970	1990
0808	Lower Atchafalaya	07381600	1970	2010
1003	Missouri	06054500	1970	2000
1004	Missouri	06115200	1970	1990
1005	Milk	06174500	1970	1990
1006	Poplar	06181000	1970	2000
1007	Yellowstone	06214500	1970	2000
1008	Bighorn	06294700	1960	1990
1009	Powder	06326500	1970	2010
1010	Yellowstone	06329500	1970	2010
1011	Little Missouri	06337000	1970	1990
1012	Belle Fourche	06437000	1950	1980
1013	Missouri	06342500	1940	2010
1014	White	06452000	1970	2010
1015	Niobrara	06465500	1970	1990
1016	James	06478500	1970	1990
1017	Big Sioux	06485500	1940	2010
1020	Platte	06805500	1950	2010
1022	Elkhorn	06800500	1940	2010
1023	Little Sioux	06607500	1940	2010
1024	Nishnabotna	06810000	1940	2010
1025	Republican	06856600	1940	2010
1026	Smoky Hill	06877600	1950	1990
1027	Kansas	06892350	1970	2010
1029	Osage	06926510	1970	1990
1030	Missouri	06934500	1940	2010
1101	White	07074500	1970	1990
1103	Arkansas	07146500	1940	2000

HUC-4	River	Station	First Decade	Last Decade
1104	Cimarron	07157580	1930	1980
1105	Cimarron	07161000	1940	1990
1106	Salt Fork Arkansas	07150500	1930	1980
1107	Neosho	07193500	1930	1990
1108	Canadian	07221500	1970	2010
1109	Canadian	07245000	1940	1980
1110	North Canadian	07242000	1940	1990
1111	Arkansas	07246500	1940	2010
1111	Arkansas	07250550	1970	2010
1113	Red	07308500	1970	1990
1113	Washita	07331000	1930	1990
1114	Red	07337000	1930	2010

Appendix C: National Inventory of Dams

Table C-1. Number and size of NID impoundments used in this study.

HUC4	Number of Dams	Total Surface Area [km^2]
501	115	201.2
502	94	95.7
503	210	386.2
504	72	142.2
505	65	77.1
506	66	68.7
507	22	32.3
508	47	63.1
509	80	310.9
510	93	112.5
511	113	175.1
512	221	303.1
513	88	906.1
514	141	440.0
601	85	2218.0
602	25	441.7
603	21	860.7
604	59	686.6
701	122	1336
702	100	249.4
703	79	171.2
704	104	443.8
705	137	432.9
706	67	471.5
707	143	285.1
708	188	551.2
709	68	256.7
710	312	193.1
711	338	504.6
712	37	114.3
713	23	1154
714	47	381.4

HUC4	Number of Dams	Total Surface Area [km²]
801	261	46.6
802	93	193.0
803	392	170.4
804	75	873.9
805	5	30.3
806	49	20.3
807	5	3.4
808	23	67.3
809	2	0.08
1002	19	59.1
1003	32	406.9
1004	43	423.8
1005	93	228.2
1006	11	45.8
1007	9	9.6
1008	100	265.8
1009	23	16.7
1010	22	5.1
1011	51	17.1
1012	65	117.1
1013	158	824.1
1014	58	1828.0
1015	31	26.4
1016	80	79.4
1017	134	731.0
1018	100	611.2
1019	324	223.3
1020	235	88.1
1021	28	63.8
1022	23	5.4
1023	832	40.0
1024	862	102.5
1025	90	213.0
1026	121	400.0
1027	719	190.6
1028	908	147.1

HUC4	Number of Dams	Total Surface Area [km²]
1029	167	457.9
1030	276	33.8
1101	99	2394.0
1102	119	152.9
1103	294	185.7
1104	4	3.2
1105	83	47.7
1106	191	269.5
1107	480	807.0
1108	14	54.9
1109	130	772.6
1110	278	155.0
1111	263	847.3
1112	123	241.1
1113	1300	662.0
1114	345	1750

Appendix D: Average Monthly Evaporation at NID Impoundments

Figure D-1. Average January evaporation from NID impoundments.

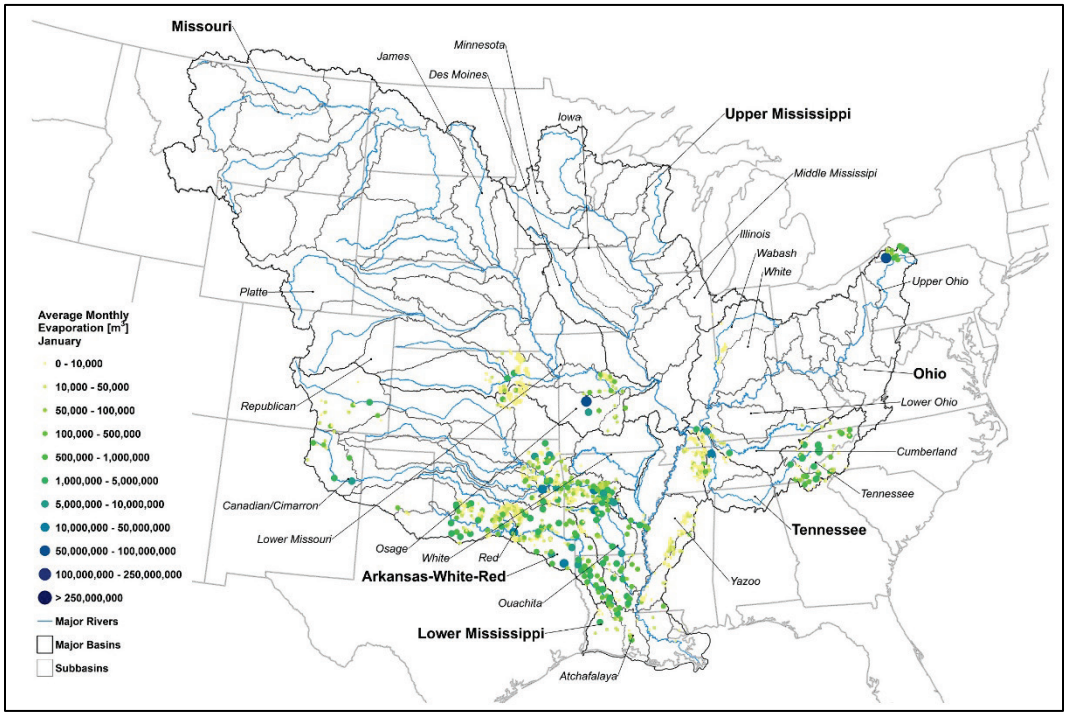


Figure D-2. Average February evaporation from NID impoundments.

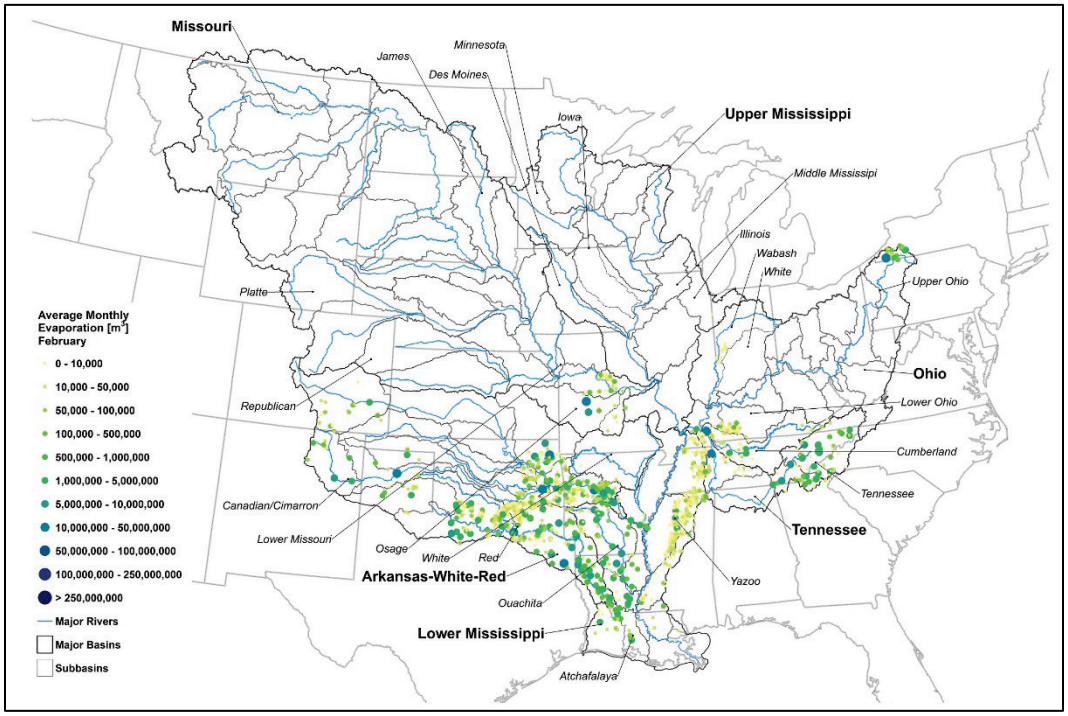


Figure D-3. Average March evaporation from NID impoundments.

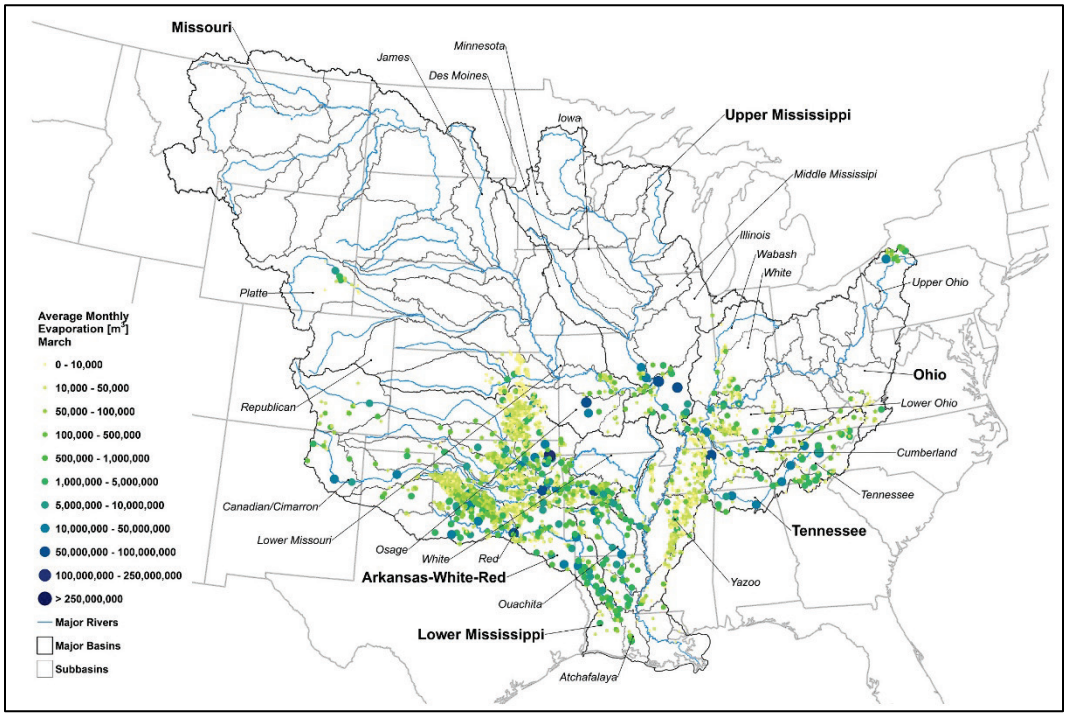


Figure D-4. Average April evaporation from NID impoundments.

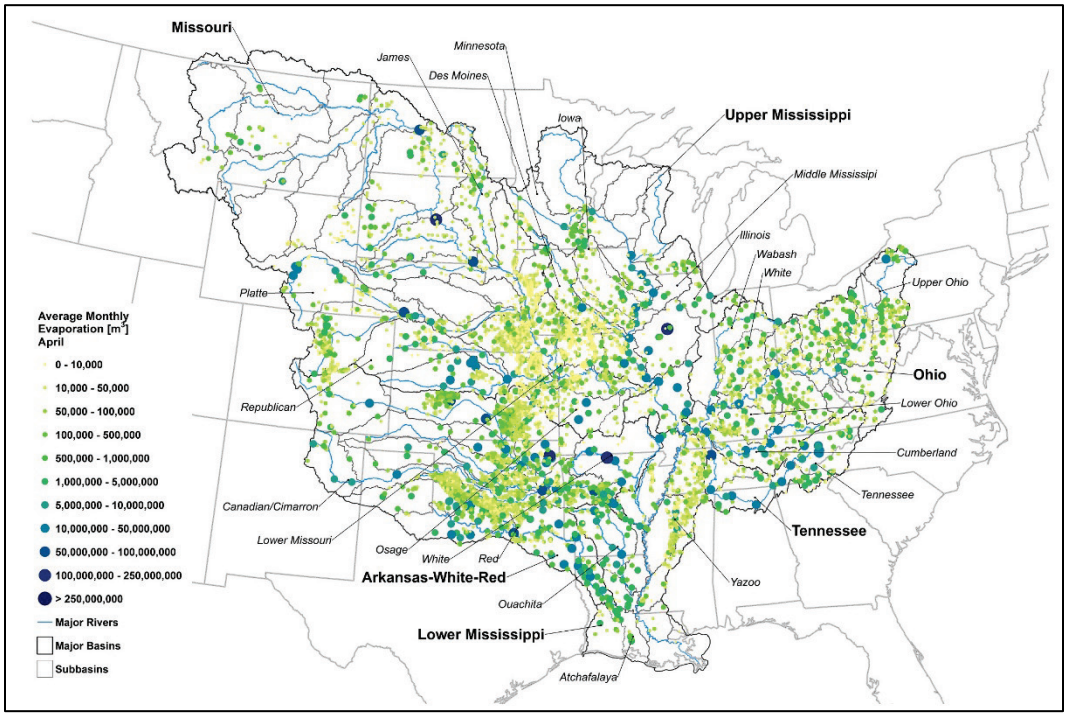


Figure D-5. Average May evaporation from NID impoundments.

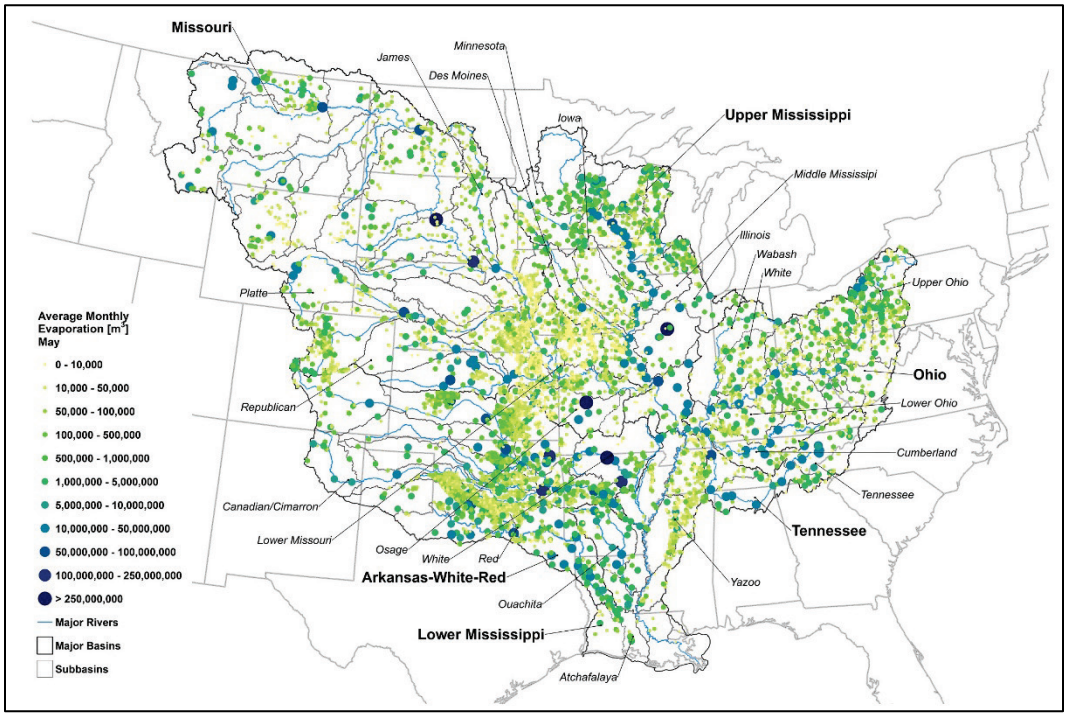


Figure D-6. Average June evaporation from NID impoundments.

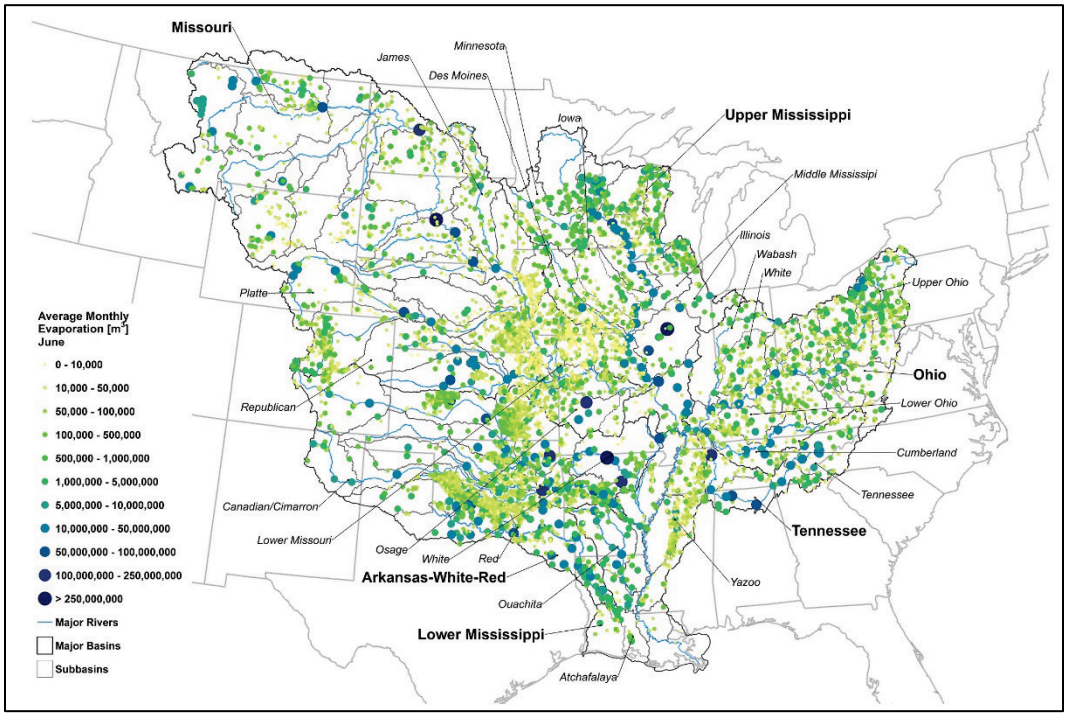


Figure D-7. Average July evaporation from NID impoundments.

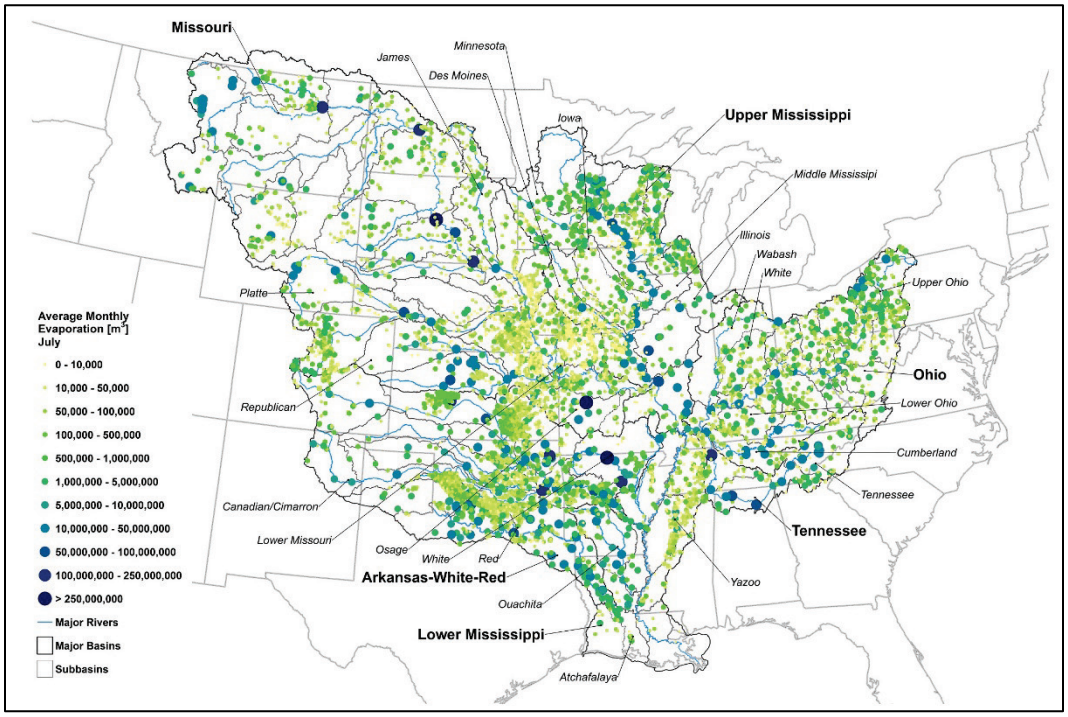


Figure D-8. Average August evaporation from NID impoundments.

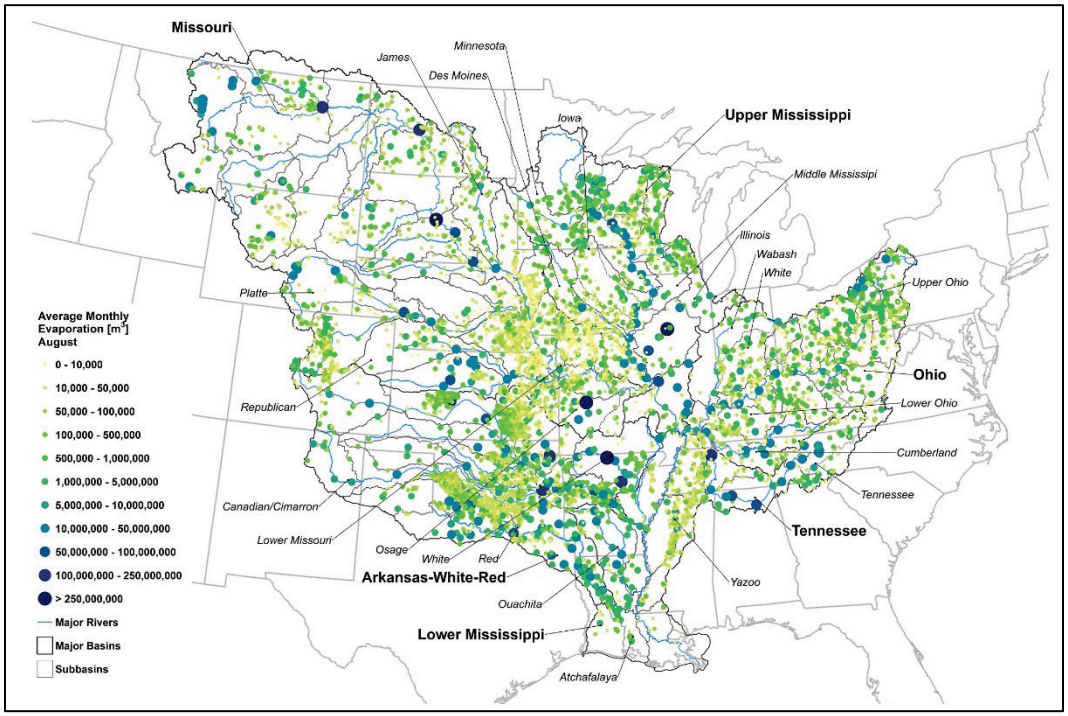


Figure D-9. Average September evaporation from NID impoundments.

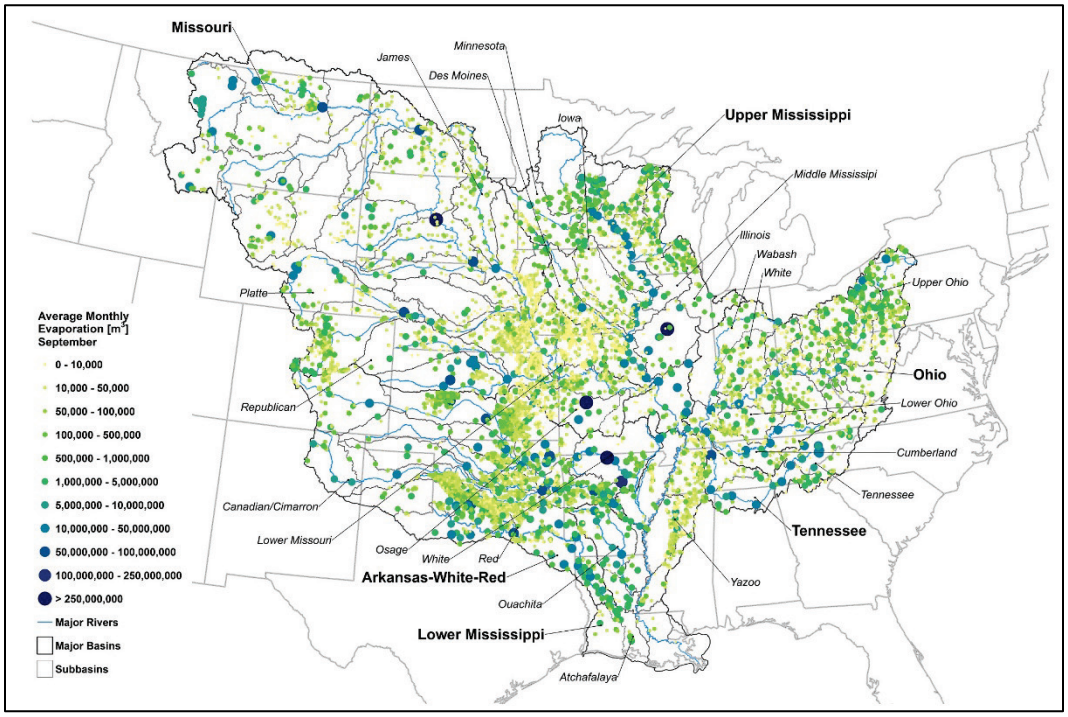


Figure D-10. Average October evaporation from NID impoundments.

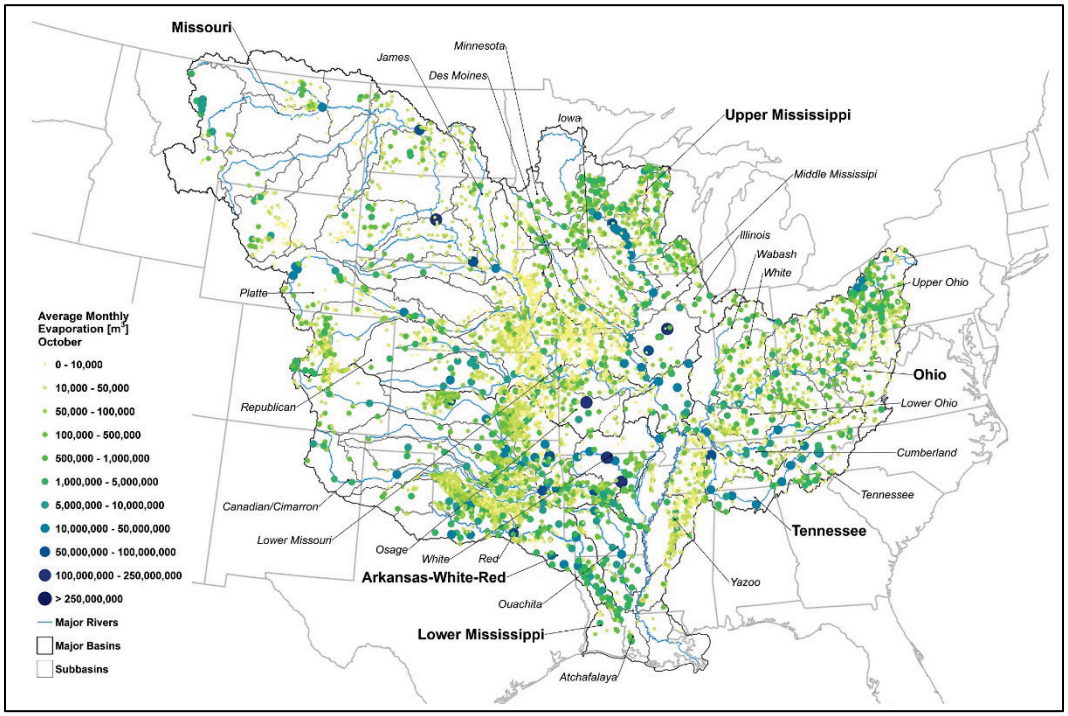


Figure D-11. Average November evaporation from NID impoundments.

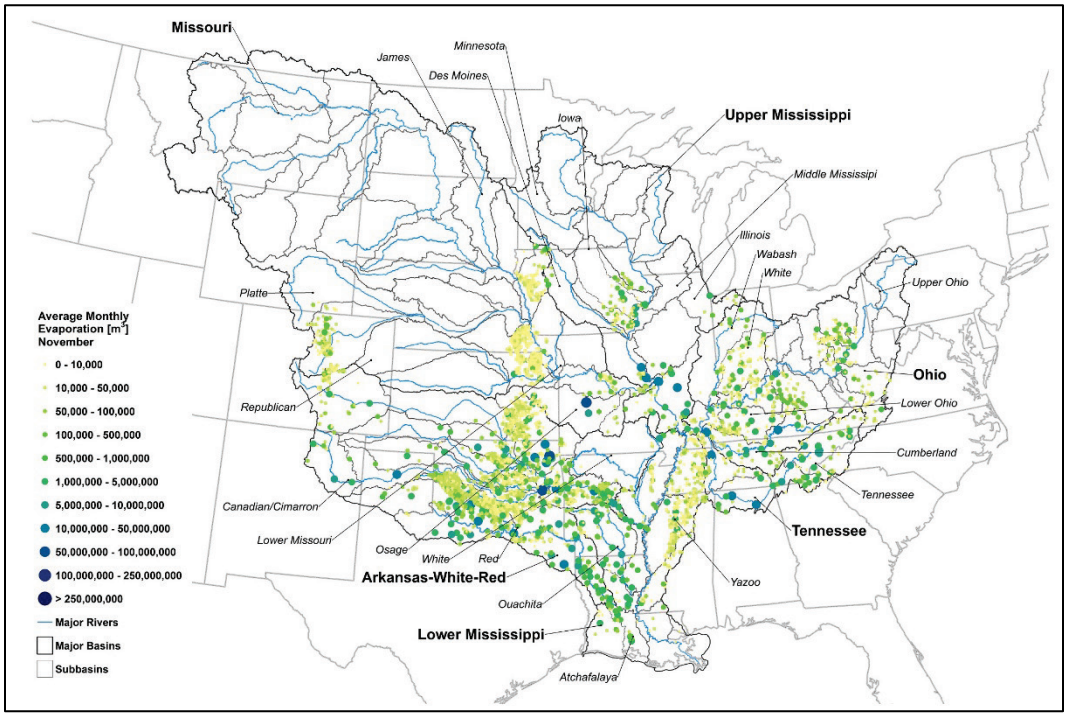
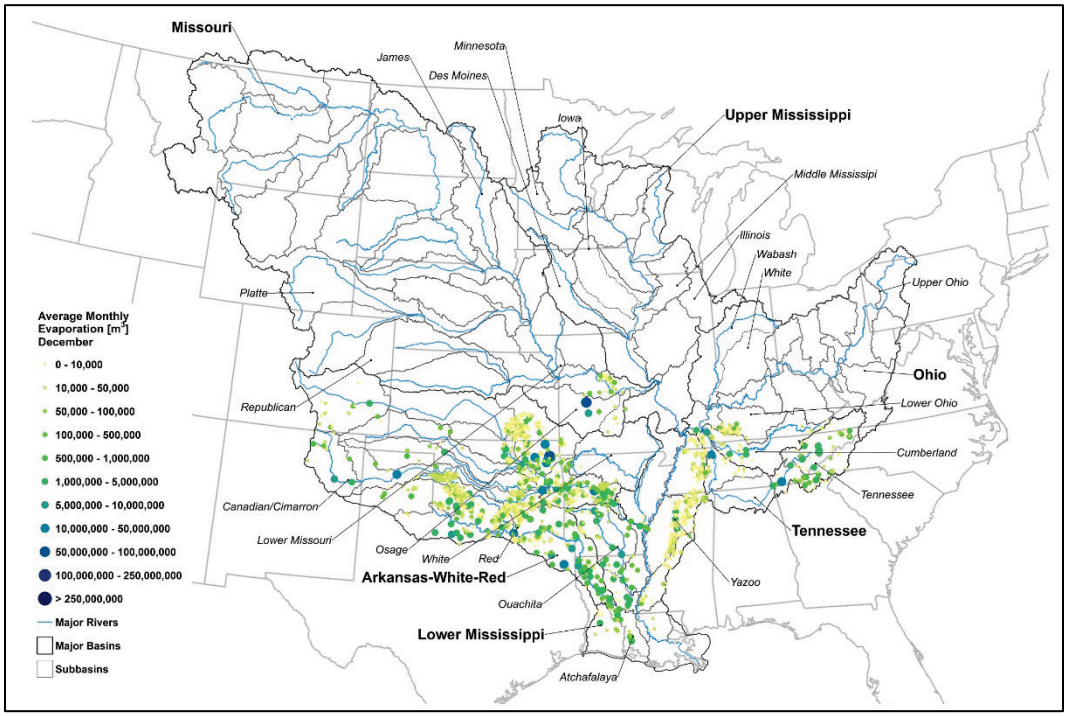


Figure D-12. Average December evaporation from NID impoundments.



Appendix E: Precipitation Trends by HUC-4

Table E-1. Change in annual rainfall by HUC-4.

		Year		Rainfall [mm]		Change in Rainfall	
HUC4	p < 0.05	Min	Max	Min Year	Max Year	[mm]	%Change
0501	*	1893	2014	1032.1	1142.5	110.4	10 to 25%
0502		1896	2014	1127.9	1166.2	38.3	0 to 5%
0503		1896	2014	995.2	1033.0	37.8	0 to 5%
0504		1900	2014	976.1	1013.5	37.4	0 to 5%
0505		1902	2014	1108.4	1082.7	-25.7	-5 to 0%
0506	*	1899	2014	928.4	1014.5	86.1	5 to 10%
0507		1911	2014	1097.3	1158.5	61.2	5 to 10%
0508		1900	2014	943.1	1030.9	87.8	5 to 10%
0509		1899	2014	1018.6	1104.7	86.1	5 to 10%
0510		1898	2014	1117.2	1223.9	106.7	5 to 10%
0511		1897	2014	1187.2	1299.4	112.2	5 to 10%
0512	*	1895	2014	989.4	1076.5	87.0	5 to 10%
0513		1896	2014	1248.1	1345.2	97.0	5 to 10%
0514	*	1895	2014	1075.6	1218.7	143.1	10 to 25%
0601	*	1898	2014	1164.8	1294.6	129.7	10 to 25%
0602		1896	2014	1316.3	1445.1	128.8	5 to 10%
0603	*	1898	2014	1300.8	1472.1	171.3	10 to 25%
0604	*	1901	2014	1238.8	1423.6	184.8	10 to 25%
0701	*	1893	2014	618.2	755.7	137.6	10 to 25%
0702		1896	2014	640.5	695.7	55.2	5 to 10%
0703	*	1907	2014	656.6	823.3	166.7	25 to 50%
0704	*	1896	2014	737.6	853.7	116.1	10 to 25%
0705		1905	2014	770.5	827.4	56.9	5 to 10%
0706	*	1904	2014	777.1	942.2	165.1	10 to 25%
0707		1905	2014	780.3	829.1	48.9	5 to 10%
0708	*	1895	2014	803.5	906.9	103.4	10 to 25%
0709		1896	2014	826.7	912.5	85.7	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0710		1899	2014	782.5	838.3	55.8	5 to 10%
0711		1896	2014	885.8	984.1	98.3	10 to 25%
0712	*	1900	2014	800.3	979.7	179.5	10 to 25%
0713	*	1896	2014	859.2	959.5	100.3	10 to 25%
0714		1896	2014	995.7	1067.2	71.6	5 to 10%
0801	*	1906	2014	1225.1	1393.6	168.5	10 to 25%
0802		1903	2014	1214.6	1221.3	6.7	0 to 5%
0803	*	1901	2014	1264.8	1433.4	168.6	10 to 25%
0804	*	1901	2014	1267.5	1416.1	148.6	10 to 25%
0805		1911	2014	1302.3	1373.9	71.6	5 to 10%
0806	*	1897	2014	1320.0	1491.9	171.9	10 to 25%
0807		1898	2014	1442.3	1607.6	165.4	10 to 25%
0808		1894	2014	1407.9	1555.8	147.8	10 to 25%
0809		1900	2014	1542.4	1592.1	49.8	0 to 5%
1002	*	1907	2014	382.4	305.0	-77.4	-25 to -10%
1003		1899	2014	330.8	316.4	-14.5	-5 to 0%
1004		1906	2014	362.8	372.5	9.7	0 to 5%
1005		1912	2014	309.9	305.7	-4.2	-5 to 0%
1006		1911	2014	316.7	341.3	24.6	5 to 10%
1007	*	1908	2014	346.8	400.3	53.6	10 to 25%
1008		1913	2014	236.3	259.5	23.3	5 to 10%
1009		1912	2014	352.8	362.8	10.0	0 to 5%
1010		1909	2014	326.7	364.4	37.7	10 to 25%
1011		1911	2014	365.2	415.6	50.5	10 to 25%
1012		1911	2014	416.4	433.4	17.0	0 to 5%
1013	*	1901	2014	389.5	449.1	59.6	10 to 25%
1014	*	1904	2014	434.9	507.9	73.0	10 to 25%
1015	*	1910	2014	433.7	525.4	91.7	10 to 25%
1016		1896	2014	505.3	526.8	21.4	0 to 5%
1017		1899	2014	603.2	663.1	59.9	5 to 10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1018		1900	2014	364.7	336.5	-28.2	-10 to -5%
1019		1898	2014	382.9	418.7	35.8	5 to 10%
1020		1902	2014	621.4	693.1	71.8	10 to 25%
1021		1897	2014	586.0	613.3	27.2	0 to 5%
1022		1899	2014	659.2	696.2	37.0	5 to 10%
1023	*	1897	2014	677.2	768.0	90.9	10 to 25%
1024		1896	2014	820.6	847.6	27.0	0 to 5%
1025		1893	2014	524.8	562.0	37.2	5 to 10%
1026		1900	2014	570.3	600.8	30.6	5 to 10%
1027		1894	2014	727.9	791.7	63.9	5 to 10%
1028		1894	2014	866.4	973.6	107.3	10 to 25%
1029		1897	2014	969.6	1046.5	76.9	5 to 10%
1030		1895	2014	947.2	1025.0	77.8	5 to 10%
1101		1897	2014	1142.3	1162.3	20.0	0 to 5%
1102		1897	2014	404.4	336.0	-68.4	-25 to -10%
1103	*	1901	2014	599.9	728.2	128.3	10 to 25%
1104		1903	2014	477.1	429.0	-48.1	-25 to -10%
1105		1900	2014	723.5	808.1	84.6	10 to 25%
1106		1910	2014	752.8	872.6	119.8	10 to 25%
1107		1895	2014	957.8	1026.8	69.0	5 to 10%
1108		1905	2014	394.5	433.5	39.1	5 to 10%
1109	*	1907	2014	470.6	672.7	202.1	25 to 50%
1110		1909	2014	666.5	652.0	-14.6	-5 to 0%
1111	*	1892	2014	1035.1	1234.1	199.0	10 to 25%
1112	*	1908	2014	489.2	618.1	129.0	25 to 50%
1113		1901	2014	674.1	727.4	53.3	5 to 10%
1114	*	1903	2014	1073.6	1305.9	232.3	10 to 25%

Table E-2. Change in maximum annual daily rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501		1893	2014	49.8	53.9	4.1	5 to 10%
0502		1896	2014	53.7	51.7	-2.0	-5 to 0%
0503		1896	2014	50.7	52.0	1.3	0 to 5%
0504		1900	2014	52.2	53.8	1.6	0 to 5%
0505		1902	2014	54.3	56.6	2.3	0 to 5%
0506		1899	2014	52.3	56.6	4.3	5 to 10%
0507		1911	2014	56.2	56.4	0.3	0 to 5%
0508		1900	2014	54.6	61.5	6.9	10 to 25%
0509		1899	2014	58.4	60.3	1.8	0 to 5%
0510	*	1898	2014	58.2	66.8	8.6	10 to 25%
0511	*	1897	2014	66.0	77.0	11.0	10 to 25%
0512		1895	2014	60.8	65.7	4.9	5 to 10%
0513		1896	2014	70.6	73.8	3.2	0 to 5%
0514	*	1895	2014	66.7	74.4	7.7	10 to 25%
0601	*	1898	2014	57.2	69.3	12.1	10 to 25%
0602		1896	2014	68.3	79.9	11.6	10 to 25%
0603	*	1898	2014	72.4	89.3	16.9	10 to 25%
0604	*	1901	2014	69.9	89.0	19.1	25 to 50%
0701	*	1893	2014	52.4	59.6	7.2	10 to 25%
0702	*	1896	2014	50.7	58.6	7.9	10 to 25%
0703		1907	2014	58.7	59.6	0.9	0 to 5%
0704	*	1896	2014	51.5	64.7	13.2	25 to 50%
0705		1905	2014	55.4	59.0	3.6	5 to 10%
0706	*	1904	2014	57.1	66.8	9.8	10 to 25%
0707		1905	2014	57.3	54.0	-3.3	-10 to -5%
0708	*	1895	2014	59.0	65.8	6.9	10 to 25%
0709	*	1896	2014	56.9	64.4	7.5	10 to 25%
0710		1899	2014	60.9	63.9	2.9	0 to 5%
0711		1896	2014	62.3	70.3	8.0	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712	*	1900	2014	51.7	68.5	16.8	25 to 50%
0713		1896	2014	58.7	64.4	5.8	5 to 10%
0714		1896	2014	66.8	70.7	3.9	5 to 10%
0801		1906	2014	77.6	87.2	9.6	10 to 25%
0802		1903	2014	79.6	83.7	4.1	5 to 10%
0803		1901	2014	84.2	92.3	8.2	5 to 10%
0804	*	1901	2014	85.6	99.0	13.3	10 to 25%
0805	*	1911	2014	85.5	100.1	14.7	10 to 25%
0806		1897	2014	95.7	99.3	3.6	0 to 5%
0807	*	1898	2014	93.1	117.5	24.5	25 to 50%
0808	*	1894	2014	97.1	118.3	21.2	10 to 25%
0809	*	1900	2014	97.3	121.3	24.0	10 to 25%
1002		1907	2014	26.2	23.9	-2.3	-10 to -5%
1003		1899	2014	30.5	30.2	-0.3	-5 to 0%
1004		1906	2014	30.8	34.7	4.0	10 to 25%
1005		1912	2014	31.3	33.9	2.6	5 to 10%
1006		1911	2014	33.5	37.0	3.6	10 to 25%
1007		1908	2014	31.6	33.1	1.5	0 to 5%
1008		1913	2014	25.6	26.3	0.7	0 to 5%
1009		1912	2014	32.1	35.3	3.3	10 to 25%
1010		1909	2014	33.3	36.0	2.7	5 to 10%
1011		1911	2014	37.6	40.6	3.0	5 to 10%
1012		1911	2014	38.9	40.4	1.6	0 to 5%
1013		1901	2014	40.4	43.1	2.7	5 to 10%
1014		1904	2014	44.6	46.7	2.1	0 to 5%
1015	*	1910	2014	40.1	48.6	8.5	10 to 25%
1016		1896	2014	47.7	49.0	1.3	0 to 5%
1017		1899	2014	51.7	56.5	4.8	5 to 10%
1018		1900	2014	34.9	32.4	-2.5	-10 to -5%
1019		1898	2014	36.3	38.9	2.6	5 to 10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	53.7	60.3	6.6	10 to 25%
1021		1897	2014	54.6	54.0	-0.6	-5 to 0%
1022	*	1899	2014	54.0	61.8	7.8	10 to 25%
1023		1897	2014	57.0	61.9	4.9	5 to 10%
1024		1896	2014	68.5	65.5	-3.0	-5 to 0%
1025		1893	2014	56.3	51.7	-4.5	-10 to -5%
1026		1900	2014	56.0	58.3	2.2	0 to 5%
1027		1894	2014	64.0	66.1	2.1	0 to 5%
1028	*	1894	2014	62.8	74.7	11.9	10 to 25%
1029		1897	2014	71.4	76.5	5.1	5 to 10%
1030	*	1895	2014	64.4	75.6	11.2	10 to 25%
1101		1897	2014	76.1	78.4	2.3	0 to 5%
1102		1897	2014	40.3	35.6	-4.7	-25 to -10%
1103	*	1901	2014	55.7	65.8	10.1	10 to 25%
1104		1903	2014	54.4	46.1	-8.4	-25 to -10%
1105	*	1900	2014	61.3	77.9	16.6	25 to 50%
1106		1910	2014	76.5	74.4	-2.2	-5 to 0%
1107		1895	2014	75.1	81.1	6.0	5 to 10%
1108		1905	2014	42.2	41.2	-1.0	-5 to 0%
1109	*	1907	2014	55.0	65.9	10.9	10 to 25%
1110		1909	2014	64.9	66.9	2.0	0 to 5%
1111	*	1892	2014	73.7	86.0	12.2	10 to 25%
1112		1908	2014	53.5	63.6	10.0	10 to 25%
1113		1901	2014	68.1	71.8	3.7	5 to 10%
1114		1903	2014	89.1	89.2	0.1	0 to 5%

Table E-3. Change in maximum annual 7-day rainfall total by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501		1893	2014	795.3	857.6	62.3	5 to 10%
0502		1896	2014	841.4	866.6	25.2	0 to 5%
0503		1896	2014	800.7	844.7	44.0	5 to 10%
0504		1900	2014	797.7	861.6	64.0	5 to 10%
0505		1902	2014	857.1	920.9	63.8	5 to 10%
0506		1899	2014	846.2	877.6	31.4	0 to 5%
0507		1911	2014	946.7	915.2	-31.5	-5 to 0%
0508		1900	2014	907.7	936.1	28.4	0 to 5%
0509		1899	2014	908.9	980.2	71.3	5 to 10%
0510		1898	2014	994.7	1062.3	67.5	5 to 10%
0511		1897	2014	1127.2	1211.5	84.3	5 to 10%
0512	*	1895	2014	926.6	1034.7	108.1	10 to 25%
0513		1896	2014	1098.7	1218.9	120.2	10 to 25%
0514		1895	2014	1060.4	1171.7	111.4	10 to 25%
0601	*	1898	2014	939.8	1121.4	181.7	10 to 25%
0602		1896	2014	1174.1	1278.2	104.2	5 to 10%
0603	*	1898	2014	1170.8	1381.6	210.7	10 to 25%
0604	*	1901	2014	1158.8	1380.9	222.1	10 to 25%
0701	*	1893	2014	781.0	918.2	137.2	10 to 25%
0702		1896	2014	780.9	817.8	36.9	0 to 5%
0703		1907	2014	803.1	896.9	93.9	10 to 25%
0704		1896	2014	822.3	939.7	117.4	10 to 25%
0705		1905	2014	838.0	901.4	63.4	5 to 10%
0706	*	1904	2014	871.1	1040.6	169.5	10 to 25%
0707		1905	2014	891.2	829.1	-62.1	-10 to -5%
0708		1895	2014	890.3	965.7	75.4	5 to 10%
0709		1896	2014	882.5	958.9	76.5	5 to 10%
0710		1899	2014	923.4	951.8	28.4	0 to 5%
0711		1896	2014	955.8	1072.8	116.9	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712	*	1900	2014	782.3	1005.3	223.1	25 to 50%
0713		1896	2014	887.0	961.9	74.9	5 to 10%
0714		1896	2014	983.2	1095.5	112.2	10 to 25%
0801		1906	2014	1206.2	1375.4	169.1	10 to 25%
0802		1903	2014	1267.5	1263.2	-4.2	-5 to 0%
0803		1901	2014	1320.8	1415.4	94.6	5 to 10%
0804		1901	2014	1374.9	1515.6	140.7	10 to 25%
0805		1911	2014	1353.6	1493.9	140.4	10 to 25%
0806		1897	2014	1413.9	1561.8	147.9	10 to 25%
0807	*	1898	2014	1324.0	1740.2	416.2	25 to 50%
0808	*	1894	2014	1351.2	1744.2	392.9	25 to 50%
0809	*	1900	2014	1439.4	1774.3	334.9	10 to 25%
1002		1907	2014	444.1	396.5	-47.7	-25 to -10%
1003		1899	2014	483.6	492.1	8.5	0 to 5%
1004		1906	2014	493.4	547.6	54.3	10 to 25%
1005		1912	2014	492.0	476.8	-15.2	-5 to 0%
1006		1911	2014	480.4	553.3	72.9	10 to 25%
1007		1908	2014	463.2	542.2	79.1	10 to 25%
1008		1913	2014	373.1	403.2	30.1	5 to 10%
1009		1912	2014	469.6	526.5	56.9	10 to 25%
1010	*	1909	2014	463.2	560.6	97.3	10 to 25%
1011		1911	2014	562.2	588.4	26.2	0 to 5%
1012		1911	2014	585.8	611.8	26.1	0 to 5%
1013		1901	2014	575.4	642.0	66.5	10 to 25%
1014		1904	2014	616.6	682.5	65.9	10 to 25%
1015		1910	2014	603.4	691.2	87.7	10 to 25%
1016		1896	2014	681.7	713.2	31.5	0 to 5%
1017		1899	2014	805.2	817.2	12.0	0 to 5%
1018		1900	2014	529.4	458.7	-70.7	-25 to -10%
1019		1898	2014	551.2	582.0	30.8	5 to 10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	810.3	860.4	50.1	5 to 10%
1021		1897	2014	805.7	784.6	-21.1	-5 to 0%
1022	*	1899	2014	785.4	916.0	130.5	10 to 25%
1023	*	1897	2014	836.1	951.8	115.8	10 to 25%
1024		1896	2014	1037.7	973.7	-64.1	-10 to -5%
1025		1893	2014	802.7	749.2	-53.5	-10 to -5%
1026		1900	2014	825.0	807.9	-17.1	-5 to 0%
1027		1894	2014	978.5	936.5	-41.9	-5 to 0%
1028		1894	2014	973.3	1106.5	133.2	10 to 25%
1029		1897	2014	1046.1	1210.7	164.7	10 to 25%
1030		1895	2014	983.3	1166.8	183.5	10 to 25%
1101		1897	2014	1129.6	1228.8	99.2	5 to 10%
1102	*	1897	2014	600.4	493.1	-107.3	-25 to -10%
1103	*	1901	2014	820.9	989.7	168.8	10 to 25%
1104		1903	2014	766.2	680.8	-85.4	-25 to -10%
1105		1900	2014	1014.1	1026.5	12.4	0 to 5%
1106		1910	2014	1039.8	1067.5	27.7	0 to 5%
1107		1895	2014	1099.6	1253.1	153.5	10 to 25%
1108		1905	2014	618.9	621.9	3.0	0 to 5%
1109	*	1907	2014	805.7	927.4	121.6	10 to 25%
1110		1909	2014	968.6	958.8	-9.8	-5 to 0%
1111		1892	2014	1184.9	1304.6	119.7	10 to 25%
1112		1908	2014	840.4	923.8	83.5	5 to 10%
1113		1901	2014	1029.1	1027.3	-1.8	-5 to 0%
1114		1903	2014	1307.0	1353.5	46.6	0 to 5%

Table E-4. Change in winter rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501		1893	2014	227.8	225.8	-2.1	-5 to 0%
0502		1896	2014	251.7	244.4	-7.2	-5 to 0%
0503		1896	2014	217.4	205.0	-12.4	-10 to -5%
0504		1900	2014	207.1	189.8	-17.3	-10 to -5%
0505		1902	2014	248.3	234.1	-14.1	-10 to -5%
0506		1899	2014	197.1	193.1	-3.9	-5 to 0%
0507		1911	2014	273.3	253.0	-20.3	-10 to -5%
0508		1900	2014	199.5	200.3	0.8	0 to 5%
0509		1899	2014	237.6	228.6	-9.0	-5 to 0%
0510		1898	2014	292.7	265.9	-26.8	-10 to -5%
0511		1897	2014	318.5	312.3	-6.2	-5 to 0%
0512		1895	2014	197.0	200.8	3.8	0 to 5%
0513		1896	2014	342.6	337.4	-5.1	-5 to 0%
0514		1895	2014	256.9	279.0	22.1	5 to 10%
0601		1898	2014	295.2	334.4	39.2	10 to 25%
0602		1896	2014	384.4	387.9	3.5	0 to 5%
0603		1898	2014	383.7	401.5	17.8	0 to 5%
0604		1901	2014	343.4	367.2	23.8	5 to 10%
0701	*	1893	2014	43.3	65.8	22.5	50 to 100%
0702		1896	2014	50.5	57.7	7.2	10 to 25%
0703		1907	2014	61.8	71.9	10.1	10 to 25%
0704		1896	2014	61.8	80.1	18.4	25 to 50%
0705		1905	2014	72.5	76.0	3.5	0 to 5%
0706	*	1904	2014	77.6	109.0	31.5	25 to 50%
0707		1905	2014	75.2	86.8	11.6	10 to 25%
0708		1895	2014	93.7	96.8	3.1	0 to 5%
0709		1896	2014	110.8	117.1	6.3	5 to 10%
0710		1899	2014	79.3	71.5	-7.8	-10 to -5%
0711		1896	2014	117.1	145.4	28.3	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712		1900	2014	129.7	153.9	24.2	10 to 25%
0713	*	1896	2014	120.8	155.9	35.1	25 to 50%
0714		1896	2014	175.7	204.0	28.3	10 to 25%
0801		1906	2014	333.5	356.3	22.8	5 to 10%
0802		1903	2014	314.7	304.0	-10.7	-5 to 0%
0803		1901	2014	373.0	393.0	20.0	5 to 10%
0804		1901	2014	355.5	350.8	-4.7	-5 to 0%
0805		1911	2014	368.3	403.3	35.0	5 to 10%
0806		1897	2014	393.3	412.4	19.1	0 to 5%
0807		1898	2014	413.9	386.7	-27.2	-10 to -5%
0808		1894	2014	398.3	382.8	-15.6	-5 to 0%
0809		1900	2014	340.0	363.8	23.8	5 to 10%
1002	*	1907	2014	51.4	30.6	-20.8	-50 to -25%
1003	*	1899	2014	40.0	29.2	-10.7	-50 to -25%
1004		1906	2014	36.9	34.2	-2.7	-10 to -5%
1005	*	1912	2014	32.7	23.0	-9.7	-50 to -25%
1006		1911	2014	23.8	22.8	-1.0	-5 to 0%
1007		1908	2014	40.9	44.0	3.0	5 to 10%
1008		1913	2014	21.1	24.2	3.1	10 to 25%
1009	*	1912	2014	42.3	30.7	-11.6	-50 to -25%
1010		1909	2014	27.9	30.1	2.2	5 to 10%
1011		1911	2014	30.0	33.7	3.8	10 to 25%
1012		1911	2014	37.1	29.5	-7.6	-25 to -10%
1013		1901	2014	28.7	29.8	1.1	0 to 5%
1014		1904	2014	33.0	34.8	1.7	5 to 10%
1015		1910	2014	34.2	31.5	-2.7	-10 to -5%
1016		1896	2014	36.2	35.5	-0.7	-5 to 0%
1017		1899	2014	51.4	45.8	-5.6	-25 to -10%
1018		1900	2014	35.4	31.3	-4.1	-25 to -10%
1019		1898	2014	36.3	32.6	-3.7	-25 to -10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	48.9	50.7	1.8	0 to 5%
1021		1897	2014	41.3	44.2	2.9	5 to 10%
1022		1899	2014	59.4	48.4	-11.0	-25 to -10%
1023		1897	2014	58.0	55.5	-2.5	-5 to 0%
1024		1896	2014	70.4	74.7	4.3	5 to 10%
1025		1893	2014	37.3	36.3	-1.0	-5 to 0%
1026		1900	2014	44.5	45.0	0.4	0 to 5%
1027		1894	2014	59.1	62.9	3.8	5 to 10%
1028		1894	2014	97.7	100.0	2.3	0 to 5%
1029		1897	2014	117.4	133.0	15.6	10 to 25%
1030		1895	2014	127.4	137.4	10.0	5 to 10%
1101		1897	2014	222.4	249.9	27.6	10 to 25%
1102	*	1897	2014	35.1	24.1	-11.0	-50 to -25%
1103		1901	2014	49.9	64.2	14.3	25 to 50%
1104		1903	2014	33.9	30.5	-3.4	-25 to -10%
1105		1900	2014	78.2	94.1	15.9	10 to 25%
1106		1910	2014	80.6	93.7	13.1	10 to 25%
1107		1895	2014	112.7	114.8	2.1	0 to 5%
1108		1905	2014	27.7	36.4	8.7	25 to 50%
1109	*	1907	2014	36.5	72.6	36.1	50 to 100%
1110		1909	2014	71.8	72.6	0.8	0 to 5%
1111	*	1892	2014	185.2	252.8	67.6	25 to 50%
1112		1908	2014	41.5	62.9	21.4	50 to 100%
1113		1901	2014	84.9	88.3	3.4	0 to 5%
1114		1903	2014	259.1	319.9	60.9	10 to 25%

Table E-5. Change in spring rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501		1893	2014	267.3	285.4	18.1	5 to 10%
0502		1896	2014	288.8	313.7	25.0	5 to 10%
0503		1896	2014	263.9	278.0	14.2	5 to 10%
0504		1900	2014	268.7	275.4	6.7	0 to 5%
0505		1902	2014	281.8	303.9	22.1	5 to 10%
0506		1899	2014	263.4	279.4	16.0	5 to 10%
0507		1911	2014	286.6	320.5	33.9	10 to 25%
0508		1900	2014	270.7	290.2	19.5	5 to 10%
0509		1899	2014	282.6	319.8	37.2	10 to 25%
0510		1898	2014	304.2	344.2	40.0	10 to 25%
0511		1897	2014	332.7	371.1	38.4	10 to 25%
0512		1895	2014	279.5	308.9	29.3	10 to 25%
0513		1896	2014	341.6	372.3	30.7	5 to 10%
0514	*	1895	2014	300.8	362.8	62.0	10 to 25%
0601	*	1898	2014	305.2	351.5	46.3	10 to 25%
0602		1896	2014	376.6	366.8	-9.8	-5 to 0%
0603		1898	2014	363.4	395.2	31.8	5 to 10%
0604		1901	2014	343.2	412.0	68.8	10 to 25%
0701		1893	2014	156.9	189.8	32.9	10 to 25%
0702		1896	2014	162.6	195.5	32.9	10 to 25%
0703		1907	2014	160.9	210.4	49.5	25 to 50%
0704		1896	2014	191.7	224.3	32.6	10 to 25%
0705		1905	2014	181.9	222.1	40.2	10 to 25%
0706		1904	2014	221.0	257.8	36.8	10 to 25%
0707		1905	2014	193.2	209.1	15.9	5 to 10%
0708	*	1895	2014	220.9	264.9	44.0	10 to 25%
0709		1896	2014	226.8	245.0	18.2	5 to 10%
0710	*	1899	2014	202.5	258.2	55.6	25 to 50%
0711		1896	2014	255.1	288.5	33.4	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712		1900	2014	239.0	266.5	27.5	10 to 25%
0713		1896	2014	252.0	276.9	24.9	5 to 10%
0714		1896	2014	289.2	321.0	31.8	10 to 25%
0801		1906	2014	334.2	410.2	76.0	10 to 25%
0802		1903	2014	345.7	380.4	34.7	10 to 25%
0803		1901	2014	378.1	408.3	30.2	5 to 10%
0804		1901	2014	395.6	387.3	-8.3	-5 to 0%
0805		1911	2014	366.9	379.1	12.2	0 to 5%
0806		1897	2014	375.7	401.2	25.5	5 to 10%
0807		1898	2014	365.2	378.3	13.1	0 to 5%
0808		1894	2014	371.3	321.7	-49.5	-25 to -10%
0809		1900	2014	370.6	343.8	-26.8	-10 to -5%
1002		1907	2014	108.1	100.8	-7.3	-10 to -5%
1003		1899	2014	89.1	101.1	12.0	10 to 25%
1004	*	1906	2014	85.7	126.8	41.1	25 to 50%
1005	*	1912	2014	65.4	93.5	28.1	25 to 50%
1006		1911	2014	70.6	88.7	18.1	25 to 50%
1007	*	1908	2014	107.9	141.7	33.9	25 to 50%
1008		1913	2014	76.2	94.9	18.7	10 to 25%
1009		1912	2014	118.9	124.7	5.8	0 to 5%
1010	*	1909	2014	75.2	116.9	41.8	50 to 100%
1011		1911	2014	85.8	116.9	31.1	25 to 50%
1012		1911	2014	127.6	157.0	29.4	10 to 25%
1013		1901	2014	101.1	130.5	29.5	25 to 50%
1014	*	1904	2014	129.7	169.8	40.2	25 to 50%
1015		1910	2014	134.3	169.9	35.5	25 to 50%
1016		1896	2014	153.2	144.3	-8.9	-10 to -5%
1017		1899	2014	163.2	203.7	40.4	10 to 25%
1018		1900	2014	131.7	113.3	-18.4	-25 to -10%
1019		1898	2014	133.2	135.2	2.0	0 to 5%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020	*	1902	2014	164.9	232.0	67.2	25 to 50%
1021		1897	2014	175.8	194.3	18.5	10 to 25%
1022		1899	2014	181.3	224.4	43.1	10 to 25%
1023	*	1897	2014	178.3	232.4	54.1	25 to 50%
1024		1896	2014	217.3	255.9	38.6	10 to 25%
1025		1893	2014	161.2	168.4	7.2	0 to 5%
1026		1900	2014	166.3	183.5	17.1	10 to 25%
1027	*	1894	2014	192.9	242.6	49.7	25 to 50%
1028	*	1894	2014	235.5	287.2	51.8	10 to 25%
1029		1897	2014	273.2	304.1	30.9	10 to 25%
1030		1895	2014	267.9	299.8	32.0	10 to 25%
1101		1897	2014	328.2	340.4	12.2	0 to 5%
1102		1897	2014	119.9	90.6	-29.3	-25 to -10%
1103	*	1901	2014	168.6	216.4	47.8	25 to 50%
1104		1903	2014	137.0	119.5	-17.5	-25 to -10%
1105		1900	2014	219.8	246.1	26.3	10 to 25%
1106		1910	2014	209.7	271.4	61.7	25 to 50%
1107		1895	2014	280.9	305.0	24.1	5 to 10%
1108		1905	2014	87.9	93.8	6.0	5 to 10%
1109	*	1907	2014	128.9	198.4	69.5	50 to 100%
1110		1909	2014	205.2	188.1	-17.1	-10 to -5%
1111		1892	2014	325.8	359.3	33.6	10 to 25%
1112		1908	2014	134.1	180.0	46.0	25 to 50%
1113		1901	2014	217.8	214.1	-3.7	-5 to 0%
1114		1903	2014	349.5	347.2	-2.3	-5 to 0%

Table E-6. Change in summer rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501		1893	2014	303.5	333.2	29.7	5 to 10%
0502		1896	2014	336.6	343.3	6.7	0 to 5%
0503		1896	2014	303.3	295.0	-8.3	-5 to 0%
0504		1900	2014	293.3	307.4	14.1	0 to 5%
0505	*	1902	2014	340.4	298.8	-41.6	-25 to -10%
0506		1899	2014	273.5	292.4	18.9	5 to 10%
0507		1911	2014	322.5	333.3	10.9	0 to 5%
0508		1900	2014	266.2	284.9	18.7	5 to 10%
0509		1899	2014	281.7	307.6	25.9	5 to 10%
0510		1898	2014	305.8	332.1	26.4	5 to 10%
0511		1897	2014	276.1	316.2	40.2	10 to 25%
0512	*	1895	2014	256.3	315.4	59.1	10 to 25%
0513		1896	2014	322.8	316.4	-6.4	-5 to 0%
0514		1895	2014	274.2	286.8	12.6	0 to 5%
0601		1898	2014	348.4	327.6	-20.8	-10 to -5%
0602		1896	2014	346.8	319.7	-27.1	-10 to -5%
0603		1898	2014	322.6	298.3	-24.3	-10 to -5%
0604		1901	2014	293.9	303.4	9.5	0 to 5%
0701		1893	2014	267.7	308.0	40.3	10 to 25%
0702		1896	2014	284.5	272.9	-11.6	-5 to 0%
0703		1907	2014	292.4	315.8	23.5	5 to 10%
0704		1896	2014	295.8	338.8	43.0	10 to 25%
0705		1905	2014	323.2	317.4	-5.8	-5 to 0%
0706	*	1904	2014	273.3	348.1	74.7	25 to 50%
0707		1905	2014	322.2	292.9	-29.2	-10 to -5%
0708	*	1895	2014	273.2	333.4	60.2	10 to 25%
0709		1896	2014	266.7	323.4	56.7	10 to 25%
0710		1899	2014	291.3	314.7	23.4	5 to 10%
0711		1896	2014	274.7	297.7	23.0	5 to 10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712	*	1900	2014	231.3	323.4	92.1	25 to 50%
0713		1896	2014	252.5	291.8	39.3	10 to 25%
0714		1896	2014	271.0	274.8	3.8	0 to 5%
0801		1906	2014	274.1	290.7	16.6	5 to 10%
0802		1903	2014	281.3	242.7	-38.5	-25 to -10%
0803		1901	2014	269.6	279.6	10.0	0 to 5%
0804		1901	2014	285.9	291.2	5.2	0 to 5%
0805		1911	2014	265.4	264.4	-1.0	-5 to 0%
0806		1897	2014	341.5	297.8	-43.7	-25 to -10%
0807		1898	2014	427.8	415.3	-12.5	-5 to 0%
0808		1894	2014	395.3	391.1	-4.2	-5 to 0%
0809		1900	2014	479.1	474.5	-4.6	-5 to 0%
1002		1907	2014	122.8	113.7	-9.1	-10 to -5%
1003		1899	2014	129.2	126.8	-2.3	-5 to 0%
1004		1906	2014	145.3	146.6	1.3	0 to 5%
1005		1912	2014	151.2	125.4	-25.8	-25 to -10%
1006		1911	2014	151.5	163.0	11.5	5 to 10%
1007		1908	2014	113.0	121.0	7.9	5 to 10%
1008		1913	2014	77.2	63.8	-13.4	-25 to -10%
1009		1912	2014	124.6	111.9	-12.7	-25 to -10%
1010		1909	2014	148.3	130.5	-17.7	-25 to -10%
1011		1911	2014	181.7	167.6	-14.1	-10 to -5%
1012		1911	2014	171.1	165.0	-6.1	-5 to 0%
1013		1901	2014	189.0	188.7	-0.3	-5 to 0%
1014		1904	2014	188.9	196.4	7.6	0 to 5%
1015		1910	2014	177.6	213.3	35.6	10 to 25%
1016		1896	2014	226.1	216.3	-9.8	-5 to 0%
1017		1899	2014	264.6	242.6	-22.0	-10 to -5%
1018		1900	2014	123.3	111.0	-12.3	-10 to -5%
1019	*	1898	2014	129.0	161.8	32.8	25 to 50%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	261.2	263.6	2.3	0 to 5%
1021		1897	2014	253.9	238.5	-15.4	-10 to -5%
1022		1899	2014	275.5	259.9	-15.6	-10 to -5%
1023		1897	2014	274.9	293.2	18.3	5 to 10%
1024		1896	2014	316.8	315.2	-1.6	-5 to 0%
1025		1893	2014	218.2	236.5	18.3	5 to 10%
1026		1900	2014	216.7	249.0	32.3	10 to 25%
1027		1894	2014	289.9	298.4	8.6	0 to 5%
1028		1894	2014	308.7	336.0	27.2	5 to 10%
1029		1897	2014	316.0	317.9	2.0	0 to 5%
1030		1895	2014	302.3	308.2	5.9	0 to 5%
1101	*	1897	2014	314.0	247.1	-66.9	-25 to -10%
1102		1897	2014	154.1	156.6	2.4	0 to 5%
1103		1901	2014	232.4	273.9	41.5	10 to 25%
1104		1903	2014	195.3	188.6	-6.7	-5 to 0%
1105		1900	2014	229.2	263.9	34.6	10 to 25%
1106		1910	2014	248.3	287.2	38.9	10 to 25%
1107		1895	2014	297.7	317.1	19.4	5 to 10%
1108		1905	2014	176.7	206.4	29.7	10 to 25%
1109		1907	2014	192.8	223.3	30.5	10 to 25%
1110		1909	2014	196.2	227.6	31.4	10 to 25%
1111		1892	2014	281.9	264.3	-17.6	-10 to -5%
1112		1908	2014	184.6	217.1	32.5	10 to 25%
1113		1901	2014	192.1	213.2	21.1	10 to 25%
1114		1903	2014	238.0	267.0	29.0	10 to 25%

Table E-7. Change in fall rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501	*	1893	2014	212.9	289.7	76.8	25 to 50%
0502	*	1896	2014	207.5	267.0	59.6	25 to 50%
0503	*	1896	2014	192.5	238.8	46.2	10 to 25%
0504	*	1900	2014	188.6	234.3	45.7	10 to 25%
0505		1902	2014	214.1	243.4	29.2	10 to 25%
0506		1899	2014	183.6	220.6	37.0	10 to 25%
0507		1911	2014	206.2	247.3	41.2	10 to 25%
0508		1900	2014	202.2	230.3	28.2	10 to 25%
0509	*	1899	2014	187.7	244.9	57.2	25 to 50%
0510	*	1898	2014	203.1	262.1	58.9	25 to 50%
0511	*	1897	2014	204.0	299.4	95.4	25 to 50%
0512		1895	2014	221.0	252.0	31.0	10 to 25%
0513	*	1896	2014	221.4	298.7	77.3	25 to 50%
0514	*	1895	2014	215.8	279.1	63.2	25 to 50%
0601	*	1898	2014	199.2	280.0	80.8	25 to 50%
0602	*	1896	2014	198.2	331.2	133.0	50 to 100%
0603	*	1898	2014	224.2	322.3	98.1	25 to 50%
0604	*	1901	2014	211.9	326.6	114.7	50 to 100%
0701		1893	2014	141.4	169.4	28.0	10 to 25%
0702		1896	2014	135.4	153.6	18.2	10 to 25%
0703		1907	2014	150.2	201.6	51.4	25 to 50%
0704		1896	2014	170.3	189.2	19.0	10 to 25%
0705		1905	2014	188.7	202.8	14.1	5 to 10%
0706		1904	2014	207.5	198.5	-9.0	-5 to 0%
0707		1905	2014	192.1	217.6	25.5	10 to 25%
0708		1895	2014	196.0	201.9	5.9	0 to 5%
0709		1896	2014	210.0	203.7	-6.4	-5 to 0%
0710		1899	2014	195.5	166.2	-29.4	-25 to -10%
0711		1896	2014	222.4	237.6	15.1	5 to 10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712		1900	2014	197.6	223.2	25.6	10 to 25%
0713		1896	2014	195.7	234.0	38.3	10 to 25%
0714		1896	2014	224.6	262.0	37.4	10 to 25%
0801	*	1906	2014	236.7	313.2	76.5	25 to 50%
0802		1903	2014	240.8	295.6	54.8	10 to 25%
0803	*	1901	2014	205.3	325.9	120.6	50 to 100%
0804	*	1901	2014	205.8	360.3	154.5	50 to 100%
0805	*	1911	2014	216.4	322.1	105.8	25 to 50%
0806	*	1897	2014	187.0	335.6	148.6	50 to 100%
0807	*	1898	2014	237.9	341.4	103.5	25 to 50%
0808	*	1894	2014	235.2	375.0	139.8	50 to 100%
0809		1900	2014	318.1	323.2	5.1	0 to 5%
1002		1907	2014	82.1	67.1	-15.0	-25 to -10%
1003		1899	2014	64.0	57.0	-7.1	-25 to -10%
1004		1906	2014	71.3	63.8	-7.4	-25 to -10%
1005		1912	2014	55.6	50.6	-5.0	-10 to -5%
1006		1911	2014	54.5	58.4	3.9	5 to 10%
1007		1908	2014	85.7	85.3	-0.4	-5 to 0%
1008		1913	2014	54.5	57.4	2.9	5 to 10%
1009		1912	2014	72.6	73.1	0.5	0 to 5%
1010		1909	2014	54.3	71.6	17.3	25 to 50%
1011		1911	2014	59.9	78.0	18.1	25 to 50%
1012		1911	2014	73.1	74.5	1.5	0 to 5%
1013		1901	2014	66.8	74.0	7.3	10 to 25%
1014		1904	2014	70.0	91.4	21.4	25 to 50%
1015		1910	2014	70.1	94.8	24.8	25 to 50%
1016		1896	2014	88.7	109.1	20.4	10 to 25%
1017		1899	2014	117.1	148.3	31.2	25 to 50%
1018		1900	2014	65.1	67.6	2.4	0 to 5%
1019		1898	2014	65.2	79.4	14.2	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	127.4	139.4	12.0	5 to 10%
1021		1897	2014	101.8	123.0	21.3	10 to 25%
1022		1899	2014	124.3	146.9	22.6	10 to 25%
1023		1897	2014	146.6	158.8	12.3	5 to 10%
1024		1896	2014	200.8	183.3	-17.5	-10 to -5%
1025		1893	2014	94.5	98.9	4.3	0 to 5%
1026		1900	2014	117.9	114.0	-3.9	-5 to 0%
1027		1894	2014	155.2	175.8	20.6	10 to 25%
1028		1894	2014	210.1	232.3	22.2	10 to 25%
1029		1897	2014	236.2	267.1	30.9	10 to 25%
1030		1895	2014	226.6	261.9	35.3	10 to 25%
1101	*	1897	2014	232.4	308.2	75.8	25 to 50%
1102		1897	2014	67.0	61.0	-5.9	-10 to -5%
1103		1901	2014	141.3	141.1	-0.3	-5 to 0%
1104		1903	2014	93.1	82.9	-10.1	-25 to -10%
1105		1900	2014	186.9	175.9	-11.0	-10 to -5%
1106		1910	2014	183.8	190.2	6.3	0 to 5%
1107		1895	2014	233.8	257.1	23.3	5 to 10%
1108		1905	2014	77.4	91.7	14.3	10 to 25%
1109	*	1907	2014	100.7	160.6	60.0	50 to 100%
1110		1909	2014	164.6	146.7	-17.9	-25 to -10%
1111	*	1892	2014	221.2	332.2	111.0	50 to 100%
1112		1908	2014	128.4	137.4	9.0	5 to 10%
1113		1901	2014	168.0	187.6	19.6	10 to 25%
1114	*	1903	2014	196.4	340.7	144.4	50 to 100%

Table E-8. Change in maximum daily winter rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501		1893	2014	26.3	27.3	1.0	0 to 5%
0502		1896	2014	31.0	29.0	-2.0	-10 to -5%
0503		1896	2014	26.8	29.3	2.5	5 to 10%
0504		1900	2014	27.1	30.3	3.2	10 to 25%
0505		1902	2014	29.7	34.2	4.6	10 to 25%
0506		1899	2014	27.2	31.3	4.0	10 to 25%
0507		1911	2014	34.1	35.2	1.1	0 to 5%
0508		1900	2014	31.7	33.3	1.5	0 to 5%
0509		1899	2014	34.4	35.1	0.7	0 to 5%
0510		1898	2014	38.8	41.6	2.8	5 to 10%
0511		1897	2014	44.4	51.1	6.7	10 to 25%
0512		1895	2014	34.4	34.2	-0.2	-5 to 0%
0513		1896	2014	51.4	48.9	-2.5	-5 to 0%
0514		1895	2014	43.1	45.8	2.8	5 to 10%
0601	*	1898	2014	37.7	49.9	12.2	25 to 50%
0602		1896	2014	50.1	56.3	6.2	10 to 25%
0603		1898	2014	54.2	62.5	8.3	10 to 25%
0604		1901	2014	48.7	56.8	8.2	10 to 25%
0701	*	1893	2014	10.5	14.1	3.6	25 to 50%
0702		1896	2014	12.9	14.4	1.5	10 to 25%
0703		1907	2014	12.4	15.5	3.1	25 to 50%
0704		1896	2014	15.6	15.3	-0.2	-5 to 0%
0705		1905	2014	16.2	15.8	-0.5	-5 to 0%
0706		1904	2014	17.4	21.6	4.2	10 to 25%
0707		1905	2014	16.1	15.0	-1.1	-10 to -5%
0708		1895	2014	21.3	20.0	-1.4	-10 to -5%
0709		1896	2014	21.9	22.1	0.2	0 to 5%
0710	*	1899	2014	19.6	15.8	-3.7	-25 to -10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0711		1896	2014	25.3	31.4	6.1	10 to 25%
0712		1900	2014	23.0	28.9	6.0	25 to 50%
0713	*	1896	2014	24.3	32.3	8.0	25 to 50%
0714		1896	2014	33.8	38.4	4.5	10 to 25%
0801		1906	2014	56.4	57.2	0.9	0 to 5%
0802		1903	2014	53.9	54.3	0.4	0 to 5%
0803		1901	2014	56.7	58.9	2.2	0 to 5%
0804		1901	2014	55.3	62.4	7.2	10 to 25%
0805		1911	2014	59.6	61.2	1.6	0 to 5%
0806		1897	2014	66.9	62.5	-4.4	-10 to -5%
0807		1898	2014	64.8	68.0	3.3	5 to 10%
0808		1894	2014	66.6	70.3	3.7	5 to 10%
0809		1900	2014	65.3	65.9	0.6	0 to 5%
1002	*	1907	2014	10.0	6.4	-3.5	-50 to -25%
1003	*	1899	2014	9.0	6.3	-2.7	-50 to -25%
1004		1906	2014	7.3	7.7	0.4	0 to 5%
1005	*	1912	2014	7.4	5.3	-2.1	-50 to -25%
1006		1911	2014	5.6	6.2	0.6	10 to 25%
1007		1908	2014	9.5	8.9	-0.6	-10 to -5%
1008		1913	2014	6.4	6.4	0.0	-5 to 0%
1009		1912	2014	8.9	6.8	-2.0	-25 to -10%
1010		1909	2014	7.2	6.4	-0.7	-10 to -5%
1011		1911	2014	7.0	6.9	-0.1	-5 to 0%
1012	*	1911	2014	9.1	6.8	-2.3	-50 to -25%
1013		1901	2014	7.3	7.2	-0.1	-5 to 0%
1014		1904	2014	10.9	8.9	-2.0	-25 to -10%
1015		1910	2014	8.2	9.5	1.3	10 to 25%
1016		1896	2014	10.6	9.6	-0.9	-10 to -5%
1017		1899	2014	12.7	13.3	0.6	0 to 5%
1018	*	1900	2014	9.4	7.0	-2.4	-50 to -25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1019	*	1898	2014	10.0	8.0	-2.0	-25 to -10%
1020		1902	2014	13.5	13.7	0.1	0 to 5%
1021		1897	2014	12.1	12.7	0.5	0 to 5%
1022		1899	2014	16.1	13.8	-2.3	-25 to -10%
1023		1897	2014	16.2	14.7	-1.5	-10 to -5%
1024		1896	2014	19.8	17.8	-2.0	-25 to -10%
1025		1893	2014	12.0	11.4	-0.6	-5 to 0%
1026		1900	2014	14.4	14.1	-0.3	-5 to 0%
1027		1894	2014	17.5	16.7	-0.8	-5 to 0%
1028		1894	2014	23.6	23.4	-0.2	-5 to 0%
1029		1897	2014	27.0	32.2	5.2	10 to 25%
1030		1895	2014	26.1	32.3	6.2	10 to 25%
1101		1897	2014	43.6	48.8	5.2	10 to 25%
1102	*	1897	2014	11.3	7.3	-4.1	-50 to -25%
1103		1901	2014	15.8	18.9	3.1	10 to 25%
1104		1903	2014	13.0	9.8	-3.2	-25 to -10%
1105		1900	2014	23.7	26.7	2.9	10 to 25%
1106		1910	2014	23.7	27.4	3.7	10 to 25%
1107		1895	2014	26.2	30.7	4.5	10 to 25%
1108		1905	2014	10.3	11.1	0.8	5 to 10%
1109	*	1907	2014	12.3	23.8	11.5	50 to 100%
1110		1909	2014	20.6	23.1	2.5	10 to 25%
1111		1892	2014	41.8	48.9	7.1	10 to 25%
1112		1908	2014	14.6	19.7	5.1	25 to 50%
1113		1901	2014	25.5	25.1	-0.4	-5 to 0%
1114		1903	2014	51.4	54.4	3.0	5 to 10%

Table E-9. Change in maximum daily spring rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501	*	1893	2014	29.0	34.2	5.1	10 to 25%
0502		1896	2014	33.3	35.1	1.8	5 to 10%
0503		1896	2014	32.0	33.0	1.0	0 to 5%
0504		1900	2014	35.1	33.7	-1.5	-5 to 0%
0505	*	1902	2014	32.1	39.0	6.9	10 to 25%
0506		1899	2014	36.0	35.5	-0.5	-5 to 0%
0507		1911	2014	34.5	40.2	5.7	10 to 25%
0508		1900	2014	36.7	39.2	2.5	5 to 10%
0509		1899	2014	41.2	39.2	-2.0	-5 to 0%
0510		1898	2014	42.5	43.5	1.0	0 to 5%
0511		1897	2014	46.4	53.3	6.9	10 to 25%
0512		1895	2014	39.6	44.3	4.7	10 to 25%
0513		1896	2014	48.2	51.4	3.2	5 to 10%
0514		1895	2014	44.7	51.9	7.2	10 to 25%
0601	*	1898	2014	40.6	48.4	7.8	10 to 25%
0602		1896	2014	52.3	54.8	2.4	0 to 5%
0603		1898	2014	56.1	59.9	3.8	5 to 10%
0604	*	1901	2014	50.7	62.6	11.9	10 to 25%
0701		1893	2014	29.2	29.3	0.2	0 to 5%
0702		1896	2014	29.0	32.8	3.8	10 to 25%
0703		1907	2014	29.5	34.0	4.5	10 to 25%
0704		1896	2014	31.9	34.6	2.6	5 to 10%
0705		1905	2014	32.9	32.3	-0.6	-5 to 0%
0706	*	1904	2014	32.8	41.6	8.9	25 to 50%
0707		1905	2014	31.9	32.2	0.2	0 to 5%
0708		1895	2014	35.7	40.6	5.0	10 to 25%
0709		1896	2014	34.1	38.5	4.3	10 to 25%
0710		1899	2014	36.8	38.9	2.1	5 to 10%
0711		1896	2014	40.0	44.6	4.5	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712	*	1900	2014	34.2	40.7	6.5	10 to 25%
0713		1896	2014	37.2	42.4	5.2	10 to 25%
0714		1896	2014	42.1	48.0	5.9	10 to 25%
0801		1906	2014	52.9	62.3	9.4	10 to 25%
0802		1903	2014	54.7	59.5	4.8	5 to 10%
0803		1901	2014	60.0	68.1	8.1	10 to 25%
0804		1901	2014	66.3	68.2	1.9	0 to 5%
0805		1911	2014	65.8	69.4	3.6	5 to 10%
0806		1897	2014	70.9	68.1	-2.9	-5 to 0%
0807		1898	2014	67.1	79.8	12.7	10 to 25%
0808		1894	2014	70.4	71.7	1.3	0 to 5%
0809		1900	2014	72.7	75.7	3.0	0 to 5%
1002		1907	2014	18.3	16.9	-1.4	-10 to -5%
1003		1899	2014	17.7	20.8	3.0	10 to 25%
1004	*	1906	2014	18.4	23.8	5.4	25 to 50%
1005	*	1912	2014	15.5	21.5	6.0	25 to 50%
1006		1911	2014	17.1	20.8	3.7	10 to 25%
1007		1908	2014	22.7	24.4	1.7	5 to 10%
1008		1913	2014	17.9	19.9	2.0	10 to 25%
1009		1912	2014	22.5	24.0	1.5	5 to 10%
1010		1909	2014	17.8	23.0	5.2	25 to 50%
1011		1911	2014	19.7	24.7	5.0	25 to 50%
1012		1911	2014	25.8	28.8	3.0	10 to 25%
1013	*	1901	2014	21.4	27.7	6.3	25 to 50%
1014		1904	2014	28.0	31.7	3.7	10 to 25%
1015		1910	2014	27.2	33.3	6.1	10 to 25%
1016		1896	2014	30.1	28.4	-1.6	-10 to -5%
1017		1899	2014	30.2	35.7	5.5	10 to 25%
1018		1900	2014	25.9	21.5	-4.3	-25 to -10%
1019		1898	2014	25.8	26.7	0.9	0 to 5%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	33.2	38.5	5.3	10 to 25%
1021		1897	2014	35.6	35.5	-0.1	-5 to 0%
1022		1899	2014	38.6	36.9	-1.7	-5 to 0%
1023	*	1897	2014	31.7	39.0	7.3	10 to 25%
1024		1896	2014	37.4	42.7	5.3	10 to 25%
1025		1893	2014	33.3	33.2	-0.1	-5 to 0%
1026		1900	2014	32.8	37.0	4.2	10 to 25%
1027		1894	2014	36.8	42.4	5.7	10 to 25%
1028		1894	2014	39.5	42.6	3.0	5 to 10%
1029		1897	2014	44.7	50.8	6.1	10 to 25%
1030		1895	2014	41.2	46.9	5.7	10 to 25%
1101		1897	2014	52.0	54.8	2.8	5 to 10%
1102		1897	2014	25.7	21.4	-4.3	-25 to -10%
1103	*	1901	2014	34.4	43.0	8.5	10 to 25%
1104		1903	2014	33.2	27.3	-6.0	-25 to -10%
1105	*	1900	2014	43.4	54.1	10.7	10 to 25%
1106		1910	2014	43.0	50.8	7.9	10 to 25%
1107		1895	2014	50.5	52.2	1.7	0 to 5%
1108		1905	2014	23.8	24.8	1.0	0 to 5%
1109	*	1907	2014	34.5	43.2	8.7	25 to 50%
1110		1909	2014	45.2	42.1	-3.0	-10 to -5%
1111		1892	2014	54.7	58.6	3.9	5 to 10%
1112		1908	2014	35.3	40.9	5.6	10 to 25%
1113		1901	2014	45.1	48.0	2.9	5 to 10%
1114		1903	2014	61.0	62.0	1.0	0 to 5%

Table E-10. Change in maximum daily summer rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501		1893	2014	43.7	44.7	1.0	0 to 5%
0502		1896	2014	44.1	45.1	1.0	0 to 5%
0503		1896	2014	44.2	44.1	-0.1	-5 to 0%
0504		1900	2014	42.3	46.7	4.5	10 to 25%
0505		1902	2014	46.8	41.9	-4.9	-25 to -10%
0506		1899	2014	41.8	47.0	5.2	10 to 25%
0507		1911	2014	42.4	46.6	4.2	5 to 10%
0508		1900	2014	41.7	48.5	6.7	10 to 25%
0509		1899	2014	43.8	49.3	5.5	10 to 25%
0510		1898	2014	45.3	51.0	5.7	10 to 25%
0511		1897	2014	48.6	51.6	3.0	5 to 10%
0512	*	1895	2014	43.8	51.8	8.0	10 to 25%
0513		1896	2014	47.8	49.7	1.9	0 to 5%
0514		1895	2014	47.6	51.1	3.4	5 to 10%
0601		1898	2014	44.4	46.9	2.4	5 to 10%
0602		1896	2014	46.4	50.7	4.4	5 to 10%
0603		1898	2014	47.8	53.5	5.7	10 to 25%
0604		1901	2014	47.1	53.6	6.4	10 to 25%
0701		1893	2014	46.4	52.5	6.1	10 to 25%
0702		1896	2014	46.2	50.8	4.6	5 to 10%
0703		1907	2014	56.5	49.1	-7.4	-25 to -10%
0704		1896	2014	47.3	55.3	8.0	10 to 25%
0705		1905	2014	52.4	49.2	-3.1	-10 to -5%
0706		1904	2014	51.4	55.0	3.6	5 to 10%
0707		1905	2014	48.7	47.6	-1.1	-5 to 0%
0708		1895	2014	51.1	53.6	2.5	0 to 5%
0709		1896	2014	47.8	53.7	5.9	10 to 25%
0710		1899	2014	49.7	55.6	6.0	10 to 25%
0711		1896	2014	47.2	56.6	9.4	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712	*	1900	2014	44.8	54.5	9.7	10 to 25%
0713		1896	2014	47.3	49.8	2.5	5 to 10%
0714		1896	2014	48.5	51.5	2.9	5 to 10%
0801		1906	2014	51.8	54.9	3.1	5 to 10%
0802		1903	2014	54.2	47.3	-6.8	-25 to -10%
0803		1901	2014	48.0	54.3	6.3	10 to 25%
0804		1901	2014	51.2	57.8	6.6	10 to 25%
0805		1911	2014	48.2	53.9	5.7	10 to 25%
0806		1897	2014	53.2	54.6	1.4	0 to 5%
0807		1898	2014	58.4	60.5	2.2	0 to 5%
0808		1894	2014	60.6	61.8	1.2	0 to 5%
0809		1900	2014	60.8	67.8	7.0	10 to 25%
1002		1907	2014	19.8	20.1	0.3	0 to 5%
1003		1899	2014	24.1	25.4	1.3	5 to 10%
1004		1906	2014	26.6	28.5	1.8	5 to 10%
1005		1912	2014	28.7	27.0	-1.7	-10 to -5%
1006		1911	2014	29.6	31.7	2.2	5 to 10%
1007		1908	2014	22.4	21.8	-0.6	-5 to 0%
1008		1913	2014	19.8	15.3	-4.5	-25 to -10%
1009		1912	2014	27.8	23.7	-4.1	-25 to -10%
1010		1909	2014	29.0	26.1	-2.9	-10 to -5%
1011		1911	2014	35.3	31.9	-3.4	-10 to -5%
1012		1911	2014	31.3	31.3	0.0	0 to 5%
1013		1901	2014	36.2	34.7	-1.5	-5 to 0%
1014		1904	2014	35.1	38.7	3.6	10 to 25%
1015	*	1910	2014	33.2	39.7	6.5	10 to 25%
1016		1896	2014	40.5	42.6	2.1	5 to 10%
1017		1899	2014	45.4	46.9	1.4	0 to 5%
1018		1900	2014	25.4	23.2	-2.3	-10 to -5%
1019		1898	2014	25.5	30.2	4.7	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	46.9	50.6	3.7	5 to 10%
1021		1897	2014	44.5	44.6	0.1	0 to 5%
1022		1899	2014	44.8	53.4	8.6	10 to 25%
1023		1897	2014	48.4	53.3	4.9	10 to 25%
1024		1896	2014	53.4	57.6	4.2	5 to 10%
1025		1893	2014	45.5	43.4	-2.1	-5 to 0%
1026		1900	2014	44.9	48.4	3.5	5 to 10%
1027		1894	2014	53.3	55.1	1.8	0 to 5%
1028		1894	2014	54.4	58.2	3.8	5 to 10%
1029		1897	2014	57.5	57.1	-0.3	-5 to 0%
1030		1895	2014	50.0	58.1	8.1	10 to 25%
1101		1897	2014	53.6	48.9	-4.7	-10 to -5%
1102		1897	2014	30.6	30.3	-0.4	-5 to 0%
1103	*	1901	2014	44.2	53.6	9.4	10 to 25%
1104		1903	2014	40.6	39.7	-0.9	-5 to 0%
1105		1900	2014	48.6	55.6	7.0	10 to 25%
1106		1910	2014	55.5	54.3	-1.2	-5 to 0%
1107		1895	2014	53.6	62.5	8.9	10 to 25%
1108		1905	2014	32.4	34.2	1.7	5 to 10%
1109		1907	2014	43.0	45.4	2.4	5 to 10%
1110		1909	2014	45.1	46.9	1.9	0 to 5%
1111		1892	2014	51.9	53.0	1.1	0 to 5%
1112		1908	2014	43.3	45.1	1.9	0 to 5%
1113		1901	2014	45.3	48.6	3.3	5 to 10%
1114		1903	2014	49.4	57.2	7.8	10 to 25%

Table E-11. Change in maximum daily fall rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501	*	1893	2014	32.3	39.7	7.5	10 to 25%
0502		1896	2014	36.3	36.1	-0.2	-5 to 0%
0503		1896	2014	32.4	34.9	2.5	5 to 10%
0504		1900	2014	31.5	37.5	6.0	10 to 25%
0505		1902	2014	35.8	41.6	5.8	10 to 25%
0506		1899	2014	30.9	37.1	6.2	10 to 25%
0507		1911	2014	36.1	38.1	2.0	5 to 10%
0508		1900	2014	36.8	39.1	2.3	5 to 10%
0509		1899	2014	33.9	41.1	7.2	10 to 25%
0510		1898	2014	38.9	44.2	5.2	10 to 25%
0511	*	1897	2014	41.1	51.9	10.9	25 to 50%
0512		1895	2014	40.6	44.5	3.8	5 to 10%
0513		1896	2014	45.7	49.6	3.9	5 to 10%
0514		1895	2014	41.3	49.2	7.9	10 to 25%
0601	*	1898	2014	36.7	49.4	12.6	25 to 50%
0602	*	1896	2014	40.7	56.2	15.5	25 to 50%
0603	*	1898	2014	42.6	60.3	17.6	25 to 50%
0604	*	1901	2014	42.1	58.8	16.6	25 to 50%
0701		1893	2014	31.5	34.7	3.2	10 to 25%
0702		1896	2014	29.8	33.9	4.1	10 to 25%
0703		1907	2014	33.6	38.5	4.9	10 to 25%
0704		1896	2014	34.9	38.1	3.2	5 to 10%
0705		1905	2014	31.8	39.8	8.0	25 to 50%
0706		1904	2014	40.9	37.9	-3.0	-10 to -5%
0707		1905	2014	39.1	36.5	-2.7	-10 to -5%
0708		1895	2014	40.5	39.1	-1.5	-5 to 0%
0709		1896	2014	41.3	37.9	-3.4	-10 to -5%
0710		1899	2014	41.5	34.6	-6.9	-25 to -10%
0711		1896	2014	44.6	44.1	-0.4	-5 to 0%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712		1900	2014	34.9	41.8	6.9	10 to 25%
0713		1896	2014	38.5	42.2	3.7	5 to 10%
0714		1896	2014	45.1	45.8	0.7	0 to 5%
0801	*	1906	2014	48.4	58.1	9.7	10 to 25%
0802		1903	2014	51.7	56.5	4.8	5 to 10%
0803	*	1901	2014	47.6	64.2	16.6	25 to 50%
0804	*	1901	2014	50.6	72.5	22.0	25 to 50%
0805	*	1911	2014	49.4	69.4	20.0	25 to 50%
0806	*	1897	2014	42.6	72.6	29.9	50 to 100%
0807	*	1898	2014	48.4	79.3	30.9	50 to 100%
0808	*	1894	2014	51.3	83.3	32.1	50 to 100%
0809		1900	2014	65.7	72.5	6.9	10 to 25%
1002		1907	2014	17.4	14.1	-3.3	-25 to -10%
1003		1899	2014	15.9	14.0	-1.9	-25 to -10%
1004		1906	2014	16.9	15.3	-1.6	-10 to -5%
1005		1912	2014	14.9	13.4	-1.5	-10 to -5%
1006		1911	2014	16.6	16.0	-0.6	-5 to 0%
1007		1908	2014	20.3	18.3	-2.0	-10 to -5%
1008		1913	2014	14.3	16.3	2.0	10 to 25%
1009		1912	2014	17.2	17.9	0.7	0 to 5%
1010		1909	2014	15.6	17.8	2.2	10 to 25%
1011		1911	2014	16.2	20.8	4.6	25 to 50%
1012		1911	2014	18.7	19.7	1.0	5 to 10%
1013		1901	2014	18.4	20.6	2.2	10 to 25%
1014		1904	2014	19.9	25.6	5.7	25 to 50%
1015	*	1910	2014	19.1	24.5	5.4	25 to 50%
1016		1896	2014	24.5	27.1	2.6	10 to 25%
1017		1899	2014	28.1	34.8	6.7	10 to 25%
1018		1900	2014	17.9	16.3	-1.6	-10 to -5%
1019		1898	2014	17.8	19.4	1.6	5 to 10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	35.0	31.8	-3.2	-10 to -5%
1021		1897	2014	31.4	29.2	-2.2	-10 to -5%
1022		1899	2014	34.5	34.1	-0.4	-5 to 0%
1023		1897	2014	34.9	34.6	-0.3	-5 to 0%
1024		1896	2014	46.4	39.4	-7.0	-25 to -10%
1025		1893	2014	31.0	25.2	-5.7	-25 to -10%
1026		1900	2014	31.6	32.6	0.9	0 to 5%
1027		1894	2014	39.2	40.3	1.1	0 to 5%
1028		1894	2014	44.8	48.7	4.0	5 to 10%
1029		1897	2014	51.7	51.2	-0.5	-5 to 0%
1030		1895	2014	48.0	49.2	1.3	0 to 5%
1101	*	1897	2014	45.1	59.0	13.9	25 to 50%
1102		1897	2014	18.4	17.5	-0.9	-5 to 0%
1103		1901	2014	35.5	38.7	3.2	5 to 10%
1104		1903	2014	31.3	24.3	-7.1	-25 to -10%
1105		1900	2014	41.7	49.9	8.2	10 to 25%
1106		1910	2014	48.9	46.0	-3.0	-10 to -5%
1107		1895	2014	53.0	54.9	1.9	0 to 5%
1108		1905	2014	21.9	25.5	3.6	10 to 25%
1109	*	1907	2014	30.3	42.8	12.5	25 to 50%
1110		1909	2014	42.0	40.6	-1.3	-5 to 0%
1111	*	1892	2014	47.8	66.2	18.3	25 to 50%
1112		1908	2014	34.4	36.3	1.9	5 to 10%
1113		1901	2014	43.7	49.3	5.5	10 to 25%
1114	*	1903	2014	50.0	68.7	18.7	25 to 50%

Table E-12. Change in maximum 7-day fall rainfall by HUC-4.

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0501		1893	2014	510.5	610.8	100.3	10 to 25%
0502		1896	2014	520.3	572.4	52.1	10 to 25%
0503		1896	2014	486.7	529.2	42.5	5 to 10%
0504		1900	2014	483.1	532.0	48.8	10 to 25%
0505		1902	2014	525.0	623.9	98.9	10 to 25%
0506		1899	2014	471.0	520.4	49.4	10 to 25%
0507		1911	2014	553.2	562.4	9.2	0 to 5%
0508		1900	2014	540.8	560.2	19.4	0 to 5%
0509	*	1899	2014	464.3	617.5	153.1	25 to 50%
0510	*	1898	2014	528.5	661.5	132.9	25 to 50%
0511	*	1897	2014	492.6	823.2	330.6	50 to 100%
0512		1895	2014	636.4	633.4	-3.0	-5 to 0%
0513		1896	2014	631.8	737.2	105.4	10 to 25%
0514		1895	2014	621.5	736.9	115.4	10 to 25%
0601	*	1898	2014	526.2	714.9	188.7	25 to 50%
0602	*	1896	2014	552.8	876.3	323.5	50 to 100%
0603	*	1898	2014	618.2	888.9	270.7	25 to 50%
0604	*	1901	2014	609.1	864.7	255.5	25 to 50%
0701		1893	2014	468.8	533.1	64.3	10 to 25%
0702		1896	2014	428.3	491.4	63.0	10 to 25%
0703		1907	2014	504.7	547.9	43.2	5 to 10%
0704		1896	2014	513.2	561.1	47.9	5 to 10%
0705		1905	2014	502.2	576.5	74.3	10 to 25%
0706		1904	2014	608.2	586.7	-21.5	-5 to 0%
0707		1905	2014	550.9	560.3	9.4	0 to 5%
0708		1895	2014	586.1	584.0	-2.2	-5 to 0%
0709		1896	2014	618.8	582.1	-36.7	-10 to -5%
0710	*	1899	2014	626.4	496.1	-130.3	-25 to -10%
0711		1896	2014	624.3	669.6	45.2	5 to 10%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
0712		1900	2014	526.7	601.9	75.3	10 to 25%
0713		1896	2014	604.7	594.2	-10.5	-5 to 0%
0714		1896	2014	686.3	660.5	-25.8	-5 to 0%
0801	*	1906	2014	698.1	882.7	184.6	25 to 50%
0802		1903	2014	772.3	834.2	61.9	5 to 10%
0803	*	1901	2014	682.0	934.6	252.6	25 to 50%
0804	*	1901	2014	706.4	1106.8	400.4	50 to 100%
0805	*	1911	2014	663.2	1007.4	344.2	50 to 100%
0806	*	1897	2014	549.9	1047.7	497.8	50 to 100%
0807	*	1898	2014	695.0	1142.2	447.2	50 to 100%
0808	*	1894	2014	725.5	1206.7	481.3	50 to 100%
0809		1900	2014	1045.6	998.2	-47.4	-5 to 0%
1002	*	1907	2014	270.2	204.5	-65.7	-25 to -10%
1003		1899	2014	221.5	200.2	-21.3	-10 to -5%
1004		1906	2014	226.6	216.5	-10.2	-5 to 0%
1005		1912	2014	196.6	186.8	-9.8	-5 to 0%
1006		1911	2014	221.2	214.7	-6.4	-5 to 0%
1007		1908	2014	295.3	272.3	-23.1	-10 to -5%
1008		1913	2014	204.5	219.6	15.1	5 to 10%
1009		1912	2014	247.1	253.7	6.7	0 to 5%
1010		1909	2014	203.0	257.9	54.9	25 to 50%
1011		1911	2014	220.8	288.3	67.5	25 to 50%
1012		1911	2014	255.9	277.4	21.5	5 to 10%
1013		1901	2014	231.4	303.9	72.4	25 to 50%
1014	*	1904	2014	247.7	365.8	118.1	25 to 50%
1015		1910	2014	263.4	344.2	80.8	25 to 50%
1016		1896	2014	325.8	394.9	69.1	10 to 25%
1017		1899	2014	404.1	503.9	99.8	10 to 25%
1018		1900	2014	243.3	225.1	-18.3	-10 to -5%
1019		1898	2014	251.7	280.1	28.4	10 to 25%

HUC4	p < 0.05	Year		Rainfall [mm]		Change in Rainfall	
		Min	Max	Min Year	Max Year	[mm]	%Change
1020		1902	2014	513.9	447.5	-66.5	-25 to -10%
1021		1897	2014	433.4	410.6	-22.8	-10 to -5%
1022		1899	2014	463.3	495.1	31.8	5 to 10%
1023		1897	2014	518.7	481.8	-36.9	-10 to -5%
1024		1896	2014	675.2	579.0	-96.2	-25 to -10%
1025		1893	2014	425.9	341.6	-84.3	-25 to -10%
1026		1900	2014	445.2	432.0	-13.2	-5 to 0%
1027		1894	2014	569.1	575.0	5.9	0 to 5%
1028		1894	2014	665.8	738.5	72.7	10 to 25%
1029		1897	2014	755.2	789.9	34.6	0 to 5%
1030		1895	2014	705.7	744.4	38.7	5 to 10%
1101		1897	2014	706.7	893.1	186.4	25 to 50%
1102		1897	2014	271.4	230.8	-40.6	-25 to -10%
1103		1901	2014	518.8	520.4	1.6	0 to 5%
1104		1903	2014	417.3	345.1	-72.2	-25 to -10%
1105		1900	2014	635.0	661.3	26.3	0 to 5%
1106		1910	2014	700.0	669.5	-30.5	-5 to 0%
1107		1895	2014	774.1	816.4	42.3	5 to 10%
1108		1905	2014	325.3	347.8	22.5	5 to 10%
1109	*	1907	2014	422.0	585.5	163.5	25 to 50%
1110		1909	2014	606.3	547.6	-58.7	-10 to -5%
1111	*	1892	2014	672.3	1049.7	377.4	50 to 100%
1112		1908	2014	504.7	519.1	14.4	0 to 5%
1113		1901	2014	631.8	716.6	84.8	10 to 25%
1114	*	1903	2014	722.8	988.4	265.6	25 to 50%

Additional data on rainfall trends by HUC-4 can be found in *PRCP_byHUC4_formatted.xlsx*.

Appendix F: Water Yield Trends by HUC-4

Table F-1. Change in annual water yield by HUC-4.

		Year		Water Yield [m³/s/km²]		Change in Water Yield	
c	p < 0.05	Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501		1909	2014	6.63	7.32	0.69	10 to 25%
0502		1908	2014	7.76	7.53	-0.23	-5 to 0%
0503		1913	2014	4.46	4.88	0.42	5 to 10%
0504	*	1922	2014	3.69	4.67	0.99	25 to 50%
0505		1896	2014	5.87	5.88	0.01	0 to 5%
0506	*	1922	2014	3.17	4.28	1.11	25 to 50%
0507		1916	2014	4.40	5.03	0.63	10 to 25%
0508		1915	2014	3.49	4.37	0.88	25 to 50%
0509	*	1916	2014	4.01	4.99	0.97	10 to 25%
0510		1916	2014	5.08	5.72	0.64	10 to 25%
0511		1928	2014	6.29	7.49	1.20	10 to 25%
0512	*	1910	2014	3.11	4.73	1.62	50 to 100%
0513		1915	2015	6.86	6.54	-0.32	-5 to 0%
0514	*	1929	2014	4.61	6.00	1.39	25 to 50%
0601		1900	2015	7.62	7.42	-0.20	-5 to 0%
0602	*	1899	2014	9.33	7.54	-1.79	-25 to -10%
0603		1905	2014	6.58	7.13	0.55	5 to 10%
0604		1921	2014	6.22	6.62	0.40	5 to 10%
0701	*	1907	2014	1.00	2.06	1.06	> 100%
0702	*	1912	2014	0.00	1.35	1.35	> 100%
0703	*	1914	2014	2.61	3.22	0.61	10 to 25%
0704	*	1912	2014	1.67	2.87	1.19	50 to 100%
0705		1914	2014	3.44	3.35	-0.09	-5 to 0%
0706	*	1920	2014	1.94	3.28	1.34	50 to 100%
0707		1913	2013	3.60	3.06	-0.54	-25 to -10%
0708	*	1903	2014	1.60	3.12	1.52	50 to 100%
0709	*	1915	2014	2.23	2.99	0.76	25 to 50%

c	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0710	*	1916	2014	0.97	2.61	1.65	> 100%
0711		1923	2014	2.32	3.15	0.83	25 to 50%
0712	*	1916	2015	2.47	4.40	1.94	50 to 100%
0713	*	1909	2014	2.18	3.38	1.20	50 to 100%
0714		1909	2014	2.77	3.56	0.80	25 to 50%
0801		1930	2015	5.32	6.15	0.83	10 to 25%
0802		1927	2015	4.15	5.36	1.22	25 to 50%
0803		1909	2015	4.91	6.02	1.11	10 to 25%
0804		1929	2015	5.18	5.31	0.14	0 to 5%
0805	*	1939	2012	5.06	1.88	-3.19	-100 to -50%
0806		1939	2015	5.49	5.63	0.13	0 to 5%
0807		1941	2015	6.39	6.28	-0.12	-5 to 0%
0808		1923	2015	6.58	5.46	-1.12	-25 to -10%
0809							
1002	*	1895	2014	1.44	2.15	0.72	25 to 50%
1003	*	1903	2015	1.65	1.11	-0.54	-50 to -25%
1004	*	1908	2013	0.89	0.15	-0.74	-100 to -50%
1005		1904	2013	0.16	0.17	0.00	0 to 5%
1006		1910	2015	0.31	0.27	-0.04	-25 to -10%
1007		1908	2014	3.88	3.81	-0.07	-5 to 0%
1008		1907	2015	1.87	1.62	-0.25	-25 to -10%
1009	*	1920	2013	1.59	0.55	-1.04	-100 to -50%
1010		1939	2013	0.65	0.38	-0.27	-50 to -25%
1011	*	1905	2012	0.37	0.15	-0.22	-100 to -50%
1012	*	1930	2014	0.06	0.42	0.36	> 100%
1013		1909	2014	0.25	0.24	-0.01	-10 to -5%
1014		1932	2013	0.20	0.27	0.07	25 to 50%
1015	*	1939	2013	0.30	0.54	0.24	50 to 100%
1016	*	1944	2013	0.02	0.29	0.27	> 100%
1017	*	1946	2013	0.30	0.77	0.47	> 100%

c	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1018		1905	2015	0.77	0.63	-0.13	-25 to -10%
1019	*	1896	2015	1.38	0.38	-1.01	-100 to -50%
1020	*	1938	2015	0.08	0.69	0.61	> 100%
1021		1937	2013	2.49	2.80	0.31	10 to 25%
1022		1946	2013	0.77	1.14	0.37	25 to 50%
1023	*	1929	2015	0.56	1.76	1.20	> 100%
1024	*	1923	2015	0.99	2.46	1.47	> 100%
1025	*	1929	2015	0.23	0.04	-0.20	-100 to -50%
1026	*	1919	2015	0.21	0.08	-0.14	-100 to -50%
1027	*	1918	2015	0.41	1.06	0.66	> 100%
1028	*	1922	2015	1.91	3.03	1.12	50 to 100%
1029		1919	2014	2.72	3.25	0.53	10 to 25%
1030	*	1926	2014	0.38	4.12	3.74	> 100%
1101		1922	2015	3.95	4.81	0.86	10 to 25%
1102		1897	2015	0.63	0.35	-0.27	-50 to -25%
1103		1903	2015	0.12	0.17	0.06	25 to 50%
1104	*	1943	2015	0.09	0.00	-0.09	-100 to -50%
1105		1935	2015	0.39	0.40	0.01	0 to 5%
1106	*	1937	2015	0.47	0.85	0.38	50 to 100%
1107	*	1922	2015	1.80	3.07	1.27	50 to 100%
1108		1908	2015	0.21	0.17	-0.05	-25 to -10%
1109		1939	2015	0.45	0.26	-0.20	-50 to -25%
1110	*	1938	2015	0.12	0.07	-0.05	-50 to -25%
1111	*	1928	2015	2.72	5.07	2.34	50 to 100%
1112	*	1905	2015	0.35	0.14	-0.21	-100 to -50%
1113		1936	2015	0.40	0.54	0.14	25 to 50%
1114		1925	2015	3.43	3.86	0.44	10 to 25%

Table F-2. Change in maximum annual daily water yield by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501	*	1909	2014	0.190	0.159	-0.031	-25 to -10%
0502		1908	2014	0.270	0.215	-0.055	-25 to -10%
0503	*	1913	2014	0.186	0.144	-0.042	-25 to -10%
0504	*	1922	2014	0.085	0.121	0.035	25 to 50%
0505		1896	2014	0.179	0.187	0.008	0 to 5%
0506		1922	2014	0.166	0.136	-0.030	-25 to -10%
0507		1916	2014	0.234	0.165	-0.069	-50 to -25%
0508		1915	2014	0.145	0.155	0.010	5 to 10%
0509		1916	2014	0.221	0.245	0.024	10 to 25%
0510	*	1916	2014	0.192	0.265	0.073	25 to 50%
0511		1928	2014	0.244	0.207	-0.037	-25 to -10%
0512	*	1910	2014	0.100	0.191	0.092	50 to 100%
0513		1915	2015	0.293	0.353	0.060	10 to 25%
0514	*	1929	2014	0.167	0.429	0.262	> 100%
0601		1900	2015	0.184	0.214	0.030	10 to 25%
0602		1899	2014	0.231	0.176	-0.055	-25 to -10%
0603	*	1905	2014	0.182	0.404	0.222	> 100%
0604	*	1921	2014	0.238	0.338	0.099	25 to 50%
0701	*	1907	2014	0.011	0.021	0.010	50 to 100%
0702	*	1912	2014	0.004	0.034	0.030	> 100%
0703	*	1914	2014	0.032	0.046	0.015	25 to 50%
0704		1912	2014	0.063	0.066	0.004	5 to 10%
0705		1914	2014	0.060	0.061	0.001	0 to 5%
0706		1920	2014	0.125	0.105	-0.020	-25 to -10%
0707		1913	2013	0.062	0.063	0.002	0 to 5%
0708	*	1903	2014	0.030	0.101	0.070	> 100%
0709		1915	2014	0.052	0.055	0.003	5 to 10%
0710	*	1916	2014	0.024	0.069	0.045	> 100%
0711	*	1923	2014	0.149	0.241	0.092	50 to 100%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	0.029	0.153	0.124	> 100%
0713	*	1909	2014	0.070	0.129	0.059	50 to 100%
0714	*	1909	2014	0.076	0.265	0.189	> 100%
0801		1930	2015	0.200	0.237	0.037	10 to 25%
0802	*	1927	2015	0.075	0.120	0.045	50 to 100%
0803	*	1909	2015	0.130	0.327	0.197	> 100%
0804		1929	2015	0.216	0.197	-0.019	-10 to -5%
0805		1939	2012	0.085	0.065	-0.020	-25 to -10%
0806		1939	2015	0.325	0.361	0.036	10 to 25%
0807		1941	2015	0.277	0.397	0.120	25 to 50%
0808		1923	2015	0.224	0.164	-0.059	-50 to -25%
0809							
1002	*	1895	2014	0.020	0.026	0.006	25 to 50%
1003	*	1903	2015	0.033	0.012	-0.021	-100 to -50%
1004	*	1908	2013	0.016	0.004	-0.012	-100 to -50%
1005		1904	2013	0.009	0.007	-0.002	-25 to -10%
1006	*	1910	2015	0.006	0.002	-0.003	-100 to -50%
1007		1908	2014	0.072	0.060	-0.012	-25 to -10%
1008	*	1907	2015	0.043	0.025	-0.018	-50 to -25%
1009	*	1920	2013	0.038	0.010	-0.028	-100 to -50%
1010		1939	2013	0.010	0.007	-0.003	-50 to -25%
1011		1905	2012	0.020	0.012	-0.008	-50 to -25%
1012		1930	2014	0.007	0.008	0.002	25 to 50%
1013		1909	2014	0.023	0.015	-0.008	-50 to -25%
1014		1932	2013	0.008	0.009	0.001	10 to 25%
1015	*	1939	2013	0.005	0.008	0.004	50 to 100%
1016	*	1944	2013	0.002	0.008	0.006	> 100%
1017	*	1946	2013	0.014	0.029	0.015	> 100%
1018	*	1905	2015	0.020	0.009	-0.010	-100 to -50%
1019	*	1896	2015	0.024	0.012	-0.012	-100 to -50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	0.000	0.040	0.040	> 100%
1021		1937	2013	0.035	0.039	0.004	10 to 25%
1022		1946	2013	0.027	0.030	0.003	10 to 25%
1023		1929	2015	0.043	0.051	0.008	10 to 25%
1024		1923	2015	0.084	0.116	0.033	25 to 50%
1025	*	1929	2015	0.008	0.001	-0.007	-100 to -50%
1026	*	1919	2015	0.013	0.003	-0.010	-100 to -50%
1027	*	1918	2015	0.016	0.064	0.047	> 100%
1028		1922	2015	0.115	0.149	0.035	25 to 50%
1029		1919	2014	0.134	0.178	0.044	25 to 50%
1030	*	1926	2014	0.017	0.335	0.318	> 100%
1101		1922	2015	0.143	0.204	0.061	25 to 50%
1102	*	1897	2015	0.017	0.009	-0.008	-50 to -25%
1103	*	1903	2015	0.006	0.010	0.004	50 to 100%
1104	*	1943	2015	0.012	-0.001	-0.013	> -100%
1105		1935	2015	0.036	0.025	-0.011	-50 to -25%
1106		1937	2015	0.041	0.045	0.004	10 to 25%
1107	*	1922	2015	0.095	0.149	0.054	50 to 100%
1108	*	1908	2015	0.012	0.005	-0.008	-100 to -50%
1109	*	1939	2015	0.030	0.006	-0.024	-100 to -50%
1110	*	1938	2015	0.011	0.002	-0.009	-100 to -50%
1111	*	1928	2015	0.097	0.331	0.234	> 100%
1112	*	1905	2015	0.052	0.009	-0.043	-100 to -50%
1113		1936	2015	0.039	0.025	-0.014	-50 to -25%
1114		1925	2015	0.159	0.169	0.010	5 to 10%

Table F-3. Change in maximum annual 7-day water yield totals by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501		1909	2014	0.681	0.592	-0.089	-25 to -10%
0502		1908	2014	0.743	0.655	-0.088	-25 to -10%
0503	*	1913	2014	0.550	0.427	-0.123	-25 to -10%
0504		1922	2014	0.380	0.404	0.023	5 to 10%
0505		1896	2014	0.528	0.542	0.014	0 to 5%
0506		1922	2014	0.503	0.474	-0.029	-10 to -5%
0507		1916	2014	0.632	0.466	-0.165	-50 to -25%
0508		1915	2014	0.449	0.491	0.042	5 to 10%
0509		1916	2014	0.570	0.622	0.052	5 to 10%
0510		1916	2014	0.710	0.632	-0.078	-25 to -10%
0511		1928	2014	0.847	0.639	-0.209	-25 to -10%
0512	*	1910	2014	0.437	0.566	0.128	25 to 50%
0513		1915	2015	0.856	0.807	-0.049	-10 to -5%
0514	*	1929	2014	0.639	0.845	0.206	25 to 50%
0601		1900	2015	0.573	0.594	0.020	0 to 5%
0602		1899	2014	0.663	0.543	-0.120	-25 to -10%
0603		1905	2014	0.738	0.899	0.161	10 to 25%
0604		1921	2014	0.753	0.851	0.097	10 to 25%
0701	*	1907	2014	0.066	0.129	0.063	50 to 100%
0702	*	1912	2014	0.015	0.163	0.148	> 100%
0703	*	1914	2014	0.186	0.247	0.061	25 to 50%
0704		1912	2014	0.192	0.231	0.040	10 to 25%
0705		1914	2014	0.284	0.260	-0.024	-10 to -5%
0706		1920	2014	0.296	0.298	0.002	0 to 5%
0707	*	1913	2013	0.297	0.230	-0.067	-25 to -10%
0708	*	1903	2014	0.152	0.340	0.188	> 100%
0709		1915	2014	0.226	0.213	-0.013	-10 to -5%
0710	*	1916	2014	0.125	0.272	0.147	> 100%
0711		1923	2014	0.413	0.570	0.157	25 to 50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	0.196	0.465	0.270	> 100%
0713	*	1909	2014	0.284	0.418	0.135	25 to 50%
0714	*	1909	2014	0.352	0.582	0.229	50 to 100%
0801		1930	2015	0.768	0.764	-0.004	-5 to 0%
0802		1927	2015	0.437	0.553	0.116	25 to 50%
0803		1909	2015	0.567	0.727	0.160	25 to 50%
0804		1929	2015	0.732	0.626	-0.105	-25 to -10%
0805	*	1939	2012	0.481	0.284	-0.197	-50 to -25%
0806		1939	2015	0.777	0.861	0.085	10 to 25%
0807		1941	2015	0.782	1.087	0.305	25 to 50%
0808		1923	2015	0.759	0.732	-0.027	-5 to 0%
0809							
1002		1895	2014	0.124	0.150	0.026	10 to 25%
1003	*	1903	2015	0.166	0.064	-0.103	-100 to -50%
1004	*	1908	2013	0.084	0.018	-0.067	-100 to -50%
1005		1904	2013	0.037	0.026	-0.011	-50 to -25%
1006	*	1910	2015	0.031	0.011	-0.020	-100 to -50%
1007		1908	2014	0.412	0.364	-0.047	-25 to -10%
1008	*	1907	2015	0.228	0.132	-0.096	-50 to -25%
1009	*	1920	2013	0.187	0.052	-0.136	-100 to -50%
1010		1939	2013	0.057	0.037	-0.020	-50 to -25%
1011		1905	2012	0.078	0.043	-0.035	-50 to -25%
1012		1930	2014	0.017	0.037	0.020	> 100%
1013		1909	2014	0.079	0.048	-0.032	-50 to -25%
1014		1932	2013	0.030	0.032	0.002	5 to 10%
1015	*	1939	2013	0.020	0.037	0.017	50 to 100%
1016	*	1944	2013	0.009	0.040	0.031	> 100%
1017	*	1946	2013	0.056	0.111	0.055	50 to 100%
1018	*	1905	2015	0.100	0.051	-0.048	-50 to -25%
1019	*	1896	2015	0.137	0.042	-0.094	-100 to -50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	0.009	0.087	0.078	> 100%
1021		1937	2013	0.124	0.146	0.022	10 to 25%
1022		1946	2013	0.105	0.104	-0.001	-5 to 0%
1023		1929	2015	0.117	0.178	0.061	50 to 100%
1024	*	1923	2015	0.190	0.319	0.129	50 to 100%
1025	*	1929	2015	0.023	0.004	-0.019	-100 to -50%
1026	*	1919	2015	0.038	0.008	-0.030	-100 to -50%
1027	*	1918	2015	0.058	0.200	0.142	> 100%
1028		1922	2015	0.381	0.428	0.047	10 to 25%
1029		1919	2014	0.392	0.478	0.085	10 to 25%
1030	*	1926	2014	0.065	0.682	0.617	> 100%
1101		1922	2015	0.402	0.479	0.077	10 to 25%
1102	*	1897	2015	0.069	0.029	-0.041	-100 to -50%
1103		1903	2015	0.020	0.029	0.009	25 to 50%
1104	*	1943	2015	0.020	-0.001	-0.021	> -100%
1105		1935	2015	0.082	0.061	-0.021	-50 to -25%
1106		1937	2015	0.096	0.125	0.030	25 to 50%
1107		1922	2015	0.342	0.436	0.094	25 to 50%
1108	*	1908	2015	0.042	0.017	-0.025	-100 to -50%
1109	*	1939	2015	0.084	0.027	-0.056	-100 to -50%
1110	*	1938	2015	0.024	0.006	-0.017	-100 to -50%
1111	*	1928	2015	0.367	0.725	0.359	50 to 100%
1112	*	1905	2015	0.093	0.023	-0.070	-100 to -50%
1113		1936	2015	0.088	0.083	-0.005	-10 to -5%
1114		1925	2015	0.558	0.581	0.023	0 to 5%

Table F-4. Change in winter water yield by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501		1909	2014	2.09	2.35	0.26	10 to 25%
0502		1908	2014	2.90	2.65	-0.26	-10 to -5%
0503		1913	2014	1.55	1.66	0.11	5 to 10%
0504		1922	2014	1.16	1.48	0.32	25 to 50%
0505		1896	2014	2.03	1.96	-0.07	-5 to 0%
0506		1922	2014	1.06	1.37	0.31	25 to 50%
0507		1916	2014	1.85	1.61	-0.25	-25 to -10%
0508		1915	2014	1.03	1.37	0.33	25 to 50%
0509		1916	2014	1.48	1.73	0.26	10 to 25%
0510		1916	2014	2.09	2.10	0.01	0 to 5%
0511		1928	2014	2.38	2.89	0.51	10 to 25%
0512		1910	2014	0.94	1.44	0.50	50 to 100%
0513		1915	2015	2.97	2.52	-0.45	-25 to -10%
0514		1929	2014	1.69	2.12	0.43	25 to 50%
0601		1900	2015	2.36	2.53	0.16	5 to 10%
0602		1899	2014	2.78	2.55	-0.23	-10 to -5%
0603		1905	2014	2.50	3.07	0.56	10 to 25%
0604		1921	2014	2.44	2.63	0.19	5 to 10%
0701	*	1907	2014	0.11	0.27	0.16	> 100%
0702	*	1912	2014	-0.01	0.08	0.09	> 100%
0703		1914	2014	0.37	0.42	0.04	10 to 25%
0704	*	1912	2014	0.22	0.35	0.12	50 to 100%
0705		1914	2014	0.47	0.56	0.08	10 to 25%
0706		1920	2014	0.36	0.48	0.12	25 to 50%
0707		1913	2013	0.50	0.54	0.04	5 to 10%
0708		1903	2014	0.24	0.35	0.11	25 to 50%
0709		1915	2014	0.49	0.62	0.13	25 to 50%
0710		1916	2014	0.10	0.21	0.10	50 to 100%
0711		1923	2014	0.44	0.62	0.18	25 to 50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	0.65	1.03	0.39	50 to 100%
0713		1909	2014	0.53	0.79	0.26	50 to 100%
0714		1909	2014	0.62	1.01	0.39	50 to 100%
0801		1930	2015	2.19	2.01	-0.18	-10 to -5%
0802		1927	2015	1.30	1.75	0.45	25 to 50%
0803		1909	2015	1.57	2.32	0.75	25 to 50%
0804		1929	2015	2.04	1.86	-0.18	-10 to -5%
0805	*	1939	2012	1.74	0.77	-0.96	-100 to -50%
0806		1939	2015	1.90	2.33	0.43	10 to 25%
0807		1941	2015	2.30	2.26	-0.04	-5 to 0%
0808		1923	2015	2.36	2.37	0.01	0 to 5%
0809	*						
1002	*	1895	2014	0.16	0.26	0.10	50 to 100%
1003		1903	2015	0.15	0.16	0.01	0 to 5%
1004	*	1908	2013	0.06	0.02	-0.04	-100 to -50%
1005	*	1904	2013	0.00	0.01	0.00	> 100%
1006	*	1910	2015	0.01	0.06	0.05	> 100%
1007		1908	2014	0.24	0.26	0.01	0 to 5%
1008		1907	2015	0.12	0.14	0.02	10 to 25%
1009	*	1920	2013	0.11	0.06	-0.05	-50 to -25%
1010		1939	2013	0.07	0.06	-0.01	-25 to -10%
1011		1905	2012	0.01	0.01	0.00	10 to 25%
1012	*	1930	2014	-0.01	0.05	0.06	> 100%
1013	*	1909	2014	0.00	0.01	0.01	> 100%
1014	*	1932	2013	0.01	0.03	0.02	> 100%
1015	*	1939	2013	0.05	0.12	0.07	> 100%
1016	*	1944	2013	0.00	0.01	0.01	> 100%
1017	*	1946	2013	0.01	0.04	0.03	> 100%
1018	*	1905	2015	0.04	0.05	0.01	25 to 50%
1019		1896	2015	0.06	0.06	0.00	-5 to 0%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	0.01	0.11	0.10	> 100%
1021		1937	2013	0.61	0.68	0.08	10 to 25%
1022	*	1946	2013	0.09	0.19	0.10	> 100%
1023	*	1929	2015	0.04	0.20	0.16	> 100%
1024	*	1923	2015	0.13	0.26	0.13	50 to 100%
1025	*	1929	2015	0.03	0.01	-0.03	-100 to -50%
1026		1919	2015	0.01	0.01	0.00	-25 to -10%
1027	*	1918	2015	0.04	0.10	0.06	> 100%
1028		1922	2015	0.28	0.38	0.09	25 to 50%
1029		1919	2014	0.54	0.62	0.08	10 to 25%
1030	*	1926	2014	0.05	0.58	0.53	> 100%
1101		1922	2015	1.05	1.24	0.19	10 to 25%
1102	*	1897	2015	0.06	0.03	-0.03	-100 to -50%
1103	*	1903	2015	0.01	0.02	0.01	50 to 100%
1104	*	1943	2015	0.01	0.00	-0.01	> -100%
1105	*	1935	2015	0.02	0.05	0.03	> 100%
1106	*	1937	2015	0.03	0.11	0.08	> 100%
1107	*	1922	2015	0.18	0.45	0.27	> 100%
1108	*	1908	2015	0.02	0.01	-0.01	-100 to -50%
1109		1939	2015	0.04	0.03	-0.01	-25 to -10%
1110		1938	2015	0.01	0.01	0.00	25 to 50%
1111	*	1928	2015	0.78	1.28	0.51	50 to 100%
1112	*	1905	2015	0.01	0.03	0.02	> 100%
1113		1936	2015	0.03	0.05	0.02	50 to 100%
1114		1925	2015	1.12	1.29	0.16	10 to 25%

Table F-5. Change in spring water yield by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501		1909	2014	3.04	2.64	-0.40	-25 to -10%
0502		1908	2014	2.90	2.93	0.03	0 to 5%
0503		1913	2014	1.93	1.83	-0.10	-10 to -5%
0504		1922	2014	1.56	1.76	0.21	10 to 25%
0505		1896	2014	2.14	2.38	0.24	10 to 25%
0506		1922	2014	1.32	1.66	0.34	25 to 50%
0507		1916	2014	1.94	2.12	0.17	5 to 10%
0508		1915	2014	1.35	1.67	0.32	10 to 25%
0509		1916	2014	1.63	2.08	0.45	25 to 50%
0510		1916	2014	2.12	2.26	0.14	5 to 10%
0511		1928	2014	2.59	2.56	-0.03	-5 to 0%
0512	*	1910	2014	1.25	1.84	0.59	25 to 50%
0513		1915	2015	2.59	2.43	-0.16	-10 to -5%
0514		1929	2014	2.07	2.20	0.13	5 to 10%
0601		1900	2015	2.60	2.59	-0.02	-5 to 0%
0602	*	1899	2014	3.26	2.17	-1.08	-50 to -25%
0603		1905	2014	2.53	2.39	-0.13	-10 to -5%
0604		1921	2014	2.37	2.22	-0.14	-10 to -5%
0701	*	1907	2014	0.35	0.80	0.45	> 100%
0702	*	1912	2014	0.06	0.68	0.62	> 100%
0703		1914	2014	1.06	1.29	0.23	10 to 25%
0704	*	1912	2014	0.74	1.04	0.30	25 to 50%
0705		1914	2014	1.29	1.21	-0.08	-10 to -5%
0706	*	1920	2014	0.77	1.17	0.40	50 to 100%
0707	*	1913	2013	1.47	1.06	-0.41	-50 to -25%
0708	*	1903	2014	0.65	1.30	0.65	> 100%
0709		1915	2014	0.90	1.10	0.21	10 to 25%
0710	*	1916	2014	0.46	1.08	0.62	> 100%
0711	*	1923	2014	0.76	1.38	0.62	50 to 100%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	1.18	1.65	0.47	25 to 50%
0713	*	1909	2014	0.90	1.43	0.53	50 to 100%
0714		1909	2014	1.14	1.49	0.34	25 to 50%
0801		1930	2015	1.81	2.21	0.39	10 to 25%
0802		1927	2015	1.83	1.97	0.14	5 to 10%
0803		1909	2015	2.02	1.92	-0.10	-10 to -5%
0804		1929	2015	2.20	1.96	-0.24	-25 to -10%
0805	*	1939	2012	2.09	0.39	-1.70	-100 to -50%
0806		1939	2015	2.12	1.92	-0.20	-10 to -5%
0807		1941	2015	2.31	1.75	-0.56	-25 to -10%
0808		1923	2015	2.28	1.51	-0.78	-50 to -25%
0809							
1002	*	1895	2014	0.50	0.68	0.18	25 to 50%
1003	*	1903	2015	0.62	0.28	-0.35	-100 to -50%
1004	*	1908	2013	0.34	0.05	-0.29	-100 to -50%
1005		1904	2013	0.09	0.06	-0.03	-50 to -25%
1006		1910	2015	0.11	0.08	-0.03	-50 to -25%
1007		1908	2014	0.84	0.79	-0.04	-10 to -5%
1008		1907	2015	0.39	0.38	-0.01	-5 to 0%
1009	*	1920	2013	0.53	0.16	-0.37	-100 to -50%
1010		1939	2013	0.19	0.13	-0.06	-50 to -25%
1011		1905	2012	0.15	0.13	-0.03	-25 to -10%
1012	*	1930	2014	0.03	0.15	0.12	> 100%
1013		1909	2014	0.15	0.14	0.00	-5 to 0%
1014		1932	2013	0.09	0.14	0.05	50 to 100%
1015	*	1939	2013	0.13	0.20	0.07	50 to 100%
1016	*	1944	2013	0.03	0.12	0.09	> 100%
1017	*	1946	2013	0.17	0.43	0.27	> 100%
1018		1905	2015	0.29	0.23	-0.07	-25 to -10%
1019	*	1896	2015	0.34	0.13	-0.21	-100 to -50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	0.01	0.26	0.24	> 100%
1021		1937	2013	0.77	0.86	0.10	10 to 25%
1022		1946	2013	0.29	0.44	0.16	50 to 100%
1023	*	1929	2015	0.25	0.60	0.36	> 100%
1024	*	1923	2015	0.29	0.91	0.62	> 100%
1025	*	1929	2015	0.07	0.01	-0.06	-100 to -50%
1026	*	1919	2015	0.04	0.02	-0.02	-50 to -25%
1027	*	1918	2015	0.11	0.34	0.23	> 100%
1028	*	1922	2015	0.62	1.32	0.70	> 100%
1029		1919	2014	1.11	1.29	0.19	10 to 25%
1030	*	1926	2014	0.09	1.52	1.43	> 100%
1101		1922	2015	1.64	1.86	0.22	10 to 25%
1102		1897	2015	0.14	0.11	-0.03	-25 to -10%
1103	*	1903	2015	0.02	0.05	0.03	> 100%
1104	*	1943	2015	0.02	0.00	-0.02	-100 to -50%
1105		1935	2015	0.13	0.15	0.02	10 to 25%
1106		1937	2015	0.17	0.31	0.14	50 to 100%
1107	*	1922	2015	0.66	1.25	0.60	50 to 100%
1108		1908	2015	0.07	0.04	-0.03	-50 to -25%
1109	*	1939	2015	0.18	0.07	-0.11	-100 to -50%
1110		1938	2015	0.03	0.03	-0.01	-50 to -25%
1111	*	1928	2015	1.20	1.94	0.74	50 to 100%
1112		1905	2015	0.11	0.05	-0.05	-50 to -25%
1113		1936	2015	0.15	0.15	0.00	0 to 5%
1114		1925	2015	1.64	1.40	-0.25	-25 to -10%

Table F-6. Change in summer water yield by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501	*	1909	2014	0.54	0.96	0.42	50 to 100%
0502		1908	2014	1.00	0.93	-0.06	-10 to -5%
0503	*	1913	2014	0.38	0.72	0.33	50 to 100%
0504	*	1922	2014	0.45	0.74	0.29	50 to 100%
0505		1896	2014	0.92	0.79	-0.12	-25 to -10%
0506	*	1922	2014	0.31	0.69	0.38	> 100%
0507	*	1916	2014	0.32	0.67	0.35	> 100%
0508		1915	2014	0.47	0.76	0.29	50 to 100%
0509		1916	2014	0.44	0.60	0.16	25 to 50%
0510		1916	2014	0.51	0.58	0.08	10 to 25%
0511		1928	2014	0.63	0.79	0.17	25 to 50%
0512	*	1910	2014	0.36	0.76	0.39	> 100%
0513		1915	2015	0.65	0.64	-0.02	-5 to 0%
0514		1929	2014	0.43	0.64	0.21	25 to 50%
0601	*	1900	2015	1.48	1.12	-0.35	-25 to -10%
0602	*	1899	2014	1.86	1.28	-0.58	-50 to -25%
0603		1905	2014	0.77	0.54	-0.23	-50 to -25%
0604		1921	2014	0.66	0.67	0.01	0 to 5%
0701	*	1907	2014	0.28	0.53	0.25	50 to 100%
0702	*	1912	2014	-0.03	0.39	0.43	> 100%
0703		1914	2014	0.61	0.76	0.15	25 to 50%
0704	*	1912	2014	0.35	0.75	0.40	> 100%
0705		1914	2014	0.79	0.72	-0.08	-10 to -5%
0706	*	1920	2014	0.41	0.86	0.44	> 100%
0707	*	1913	2013	0.83	0.63	-0.21	-25 to -10%
0708	*	1903	2014	0.37	0.89	0.52	> 100%
0709	*	1915	2014	0.36	0.72	0.36	50 to 100%
0710	*	1916	2014	0.25	0.89	0.65	> 100%
0711		1923	2014	0.55	0.54	-0.01	-5 to 0%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	0.28	0.96	0.68	> 100%
0713	*	1909	2014	0.40	0.65	0.25	50 to 100%
0714		1909	2014	0.42	0.50	0.08	10 to 25%
0801		1930	2015	0.56	0.74	0.18	25 to 50%
0802		1927	2015	0.49	0.55	0.05	10 to 25%
0803		1909	2015	0.56	0.56	0.00	-5 to 0%
0804		1929	2015	0.36	0.49	0.13	25 to 50%
0805		1939	2012	0.36	0.31	-0.05	-25 to -10%
0806		1939	2015	0.58	0.45	-0.13	-25 to -10%
0807		1941	2015	0.81	0.69	-0.12	-25 to -10%
0808		1923	2015	0.75	0.50	-0.25	-50 to -25%
0809							
1002	*	1895	2014	0.53	0.81	0.28	50 to 100%
1003	*	1903	2015	0.67	0.35	-0.32	-50 to -25%
1004	*	1908	2013	0.31	0.08	-0.22	-100 to -50%
1005		1904	2013	0.03	0.05	0.02	50 to 100%
1006		1910	2015	0.06	0.07	0.02	25 to 50%
1007		1908	2014	2.25	2.09	-0.16	-10 to -5%
1008	*	1907	2015	1.12	0.65	-0.47	-50 to -25%
1009	*	1920	2013	0.68	0.23	-0.45	-100 to -50%
1010		1939	2013	0.28	0.14	-0.14	-50 to -25%
1011	*	1905	2012	0.13	0.00	-0.13	-100 to -50%
1012	*	1930	2014	0.03	0.12	0.10	> 100%
1013		1909	2014	0.06	0.04	-0.02	-50 to -25%
1014		1932	2013	0.06	0.06	0.00	5 to 10%
1015	*	1939	2013	0.06	0.12	0.06	50 to 100%
1016	*	1944	2013	-0.01	0.09	0.10	> 100%
1017	*	1946	2013	0.07	0.19	0.12	> 100%
1018		1905	2015	0.34	0.20	-0.14	-50 to -25%
1019	*	1896	2015	0.76	0.07	-0.69	-100 to -50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	0.02	0.20	0.18	> 100%
1021		1937	2013	0.53	0.58	0.05	5 to 10%
1022		1946	2013	0.21	0.29	0.07	25 to 50%
1023	*	1929	2015	0.19	0.50	0.31	> 100%
1024	*	1923	2015	0.32	0.67	0.35	> 100%
1025	*	1929	2015	0.08	0.01	-0.07	-100 to -50%
1026	*	1919	2015	0.09	0.02	-0.07	-100 to -50%
1027	*	1918	2015	0.15	0.34	0.19	> 100%
1028		1922	2015	0.52	0.75	0.23	25 to 50%
1029		1919	2014	0.54	0.58	0.04	5 to 10%
1030	*	1926	2014	0.14	0.81	0.67	> 100%
1101		1922	2015	0.65	0.61	-0.04	-10 to -5%
1102	*	1897	2015	0.31	0.09	-0.22	-100 to -50%
1103		1903	2015	0.04	0.05	0.01	10 to 25%
1104	*	1943	2015	0.04	0.00	-0.04	> -100%
1105		1935	2015	0.10	0.09	-0.01	-10 to -5%
1106		1937	2015	0.13	0.22	0.09	50 to 100%
1107		1922	2015	0.46	0.69	0.23	25 to 50%
1108	*	1908	2015	0.09	0.05	-0.04	-50 to -25%
1109	*	1939	2015	0.11	0.05	-0.06	-100 to -50%
1110	*	1938	2015	0.04	0.02	-0.02	-100 to -50%
1111		1928	2015	0.26	0.46	0.20	50 to 100%
1112	*	1905	2015	0.12	0.02	-0.10	-100 to -50%
1113		1936	2015	0.12	0.09	-0.03	-50 to -25%
1114		1925	2015	0.32	0.36	0.04	10 to 25%

Table F-7. Change in fall water yield by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501	*	1909	2014	0.75	1.17	0.41	50 to 100%
0502		1908	2014	0.81	0.99	0.18	10 to 25%
0503	*	1913	2014	0.37	0.60	0.23	50 to 100%
0504	*	1922	2014	0.25	0.51	0.26	> 100%
0505		1896	2014	0.67	0.79	0.12	10 to 25%
0506	*	1922	2014	0.10	0.41	0.31	> 100%
0507	*	1916	2014	0.15	0.54	0.39	> 100%
0508		1915	2014	0.30	0.41	0.11	25 to 50%
0509	*	1916	2014	0.16	0.52	0.37	> 100%
0510	*	1916	2014	0.18	0.60	0.42	> 100%
0511	*	1928	2014	0.32	1.06	0.74	> 100%
0512		1910	2014	0.26	0.42	0.15	50 to 100%
0513		1915	2015	0.46	0.73	0.27	50 to 100%
0514	*	1929	2014	0.23	0.63	0.40	> 100%
0601		1900	2015	1.01	1.12	0.11	10 to 25%
0602		1899	2014	1.15	1.29	0.14	10 to 25%
0603		1905	2014	0.51	0.76	0.25	25 to 50%
0604		1921	2014	0.52	0.78	0.26	25 to 50%
0701	*	1907	2014	0.22	0.36	0.14	50 to 100%
0702	*	1912	2014	-0.01	0.11	0.12	> 100%
0703		1914	2014	0.49	0.63	0.14	25 to 50%
0704	*	1912	2014	0.25	0.51	0.25	50 to 100%
0705		1914	2014	0.64	0.71	0.07	10 to 25%
0706	*	1920	2014	0.29	0.51	0.22	50 to 100%
0707		1913	2013	0.68	0.62	-0.07	-10 to -5%
0708		1903	2014	0.28	0.32	0.04	10 to 25%
0709		1915	2014	0.36	0.52	0.16	25 to 50%
0710		1916	2014	0.14	0.26	0.12	50 to 100%
0711		1923	2014	0.32	0.36	0.03	10 to 25%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	0.29	0.68	0.39	> 100%
0713		1909	2014	0.20	0.24	0.03	10 to 25%
0714		1909	2014	0.25	0.33	0.08	25 to 50%
0801	*	1930	2015	0.42	0.74	0.32	50 to 100%
0802	*	1927	2015	0.30	0.58	0.28	50 to 100%
0803	*	1909	2015	0.27	0.73	0.45	> 100%
0804		1929	2015	0.34	0.49	0.15	25 to 50%
0805		1939	2012	0.23	0.30	0.07	25 to 50%
0806		1939	2015	0.39	0.52	0.13	25 to 50%
0807		1941	2015	0.68	0.85	0.17	25 to 50%
0808		1923	2015	0.59	0.78	0.19	25 to 50%
0809	*						
1002	*	1895	2014	0.24	0.31	0.07	25 to 50%
1003		1903	2015	0.21	0.19	-0.02	-10 to -5%
1004	*	1908	2013	0.08	0.02	-0.06	-100 to -50%
1005	*	1904	2013	0.01	0.01	0.01	> 100%
1006		1910	2015	0.05	0.05	-0.01	-25 to -10%
1007		1908	2014	0.46	0.39	-0.07	-25 to -10%
1008		1907	2015	0.23	0.22	-0.01	-10 to -5%
1009	*	1920	2013	0.15	0.09	-0.06	-50 to -25%
1010		1939	2013	0.10	0.05	-0.05	-50 to -25%
1011	*	1905	2012	0.01	0.00	-0.01	-100 to -50%
1012	*	1930	2014	-0.01	0.06	0.07	> 100%
1013	*	1909	2014	0.01	0.01	0.01	> 100%
1014		1932	2013	0.01	0.02	0.01	50 to 100%
1015	*	1939	2013	0.05	0.09	0.04	50 to 100%
1016	*	1944	2013	-0.01	0.03	0.04	> 100%
1017	*	1946	2013	0.01	0.08	0.06	> 100%
1018		1905	2015	0.07	0.06	-0.01	-25 to -10%
1019	*	1896	2015	0.13	0.06	-0.07	-100 to -50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	0.01	0.10	0.09	> 100%
1021		1937	2013	0.54	0.63	0.10	10 to 25%
1022	*	1946	2013	0.08	0.15	0.08	> 100%
1023	*	1929	2015	0.05	0.22	0.17	> 100%
1024		1923	2015	0.12	0.26	0.14	> 100%
1025	*	1929	2015	0.03	0.00	-0.03	-100 to -50%
1026	*	1919	2015	0.03	0.01	-0.02	-100 to -50%
1027		1918	2015	0.07	0.10	0.03	25 to 50%
1028		1922	2015	0.26	0.35	0.10	25 to 50%
1029		1919	2014	0.39	0.36	-0.02	-10 to -5%
1030	*	1926	2014	0.06	0.47	0.41	> 100%
1101		1922	2015	0.54	0.59	0.06	10 to 25%
1102		1897	2015	0.08	0.06	-0.03	-50 to -25%
1103		1903	2015	0.02	0.02	0.00	-5 to 0%
1104	*	1943	2015	0.01	0.00	-0.01	-100 to -50%
1105		1935	2015	0.05	0.06	0.01	10 to 25%
1106		1937	2015	0.09	0.11	0.02	10 to 25%
1107		1922	2015	0.32	0.31	-0.01	-5 to 0%
1108		1908	2015	0.03	0.03	0.00	-5 to 0%
1109		1939	2015	0.04	0.02	-0.02	-100 to -50%
1110		1938	2015	0.01	0.01	0.00	-10 to -5%
1111	*	1928	2015	0.18	0.58	0.40	> 100%
1112		1905	2015	0.04	0.02	-0.02	-100 to -50%
1113		1936	2015	0.06	0.08	0.02	25 to 50%
1114		1925	2015	0.20	0.38	0.18	50 to 100%

Table F-8. Change in maximum daily spring water yield by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501	*	1909	2014	0.162	0.110	-0.052	-50 to -25%
0502		1908	2014	0.178	0.170	-0.008	-5 to 0%
0503	*	1913	2014	0.143	0.096	-0.047	-50 to -25%
0504		1922	2014	0.069	0.082	0.013	10 to 25%
0505		1896	2014	0.116	0.141	0.025	10 to 25%
0506		1922	2014	0.112	0.098	-0.014	-25 to -10%
0507		1916	2014	0.161	0.138	-0.023	-25 to -10%
0508		1915	2014	0.105	0.099	-0.005	-5 to 0%
0509		1916	2014	0.155	0.171	0.016	10 to 25%
0510		1916	2014	0.130	0.188	0.058	25 to 50%
0511		1928	2014	0.161	0.163	0.002	0 to 5%
0512	*	1910	2014	0.073	0.124	0.051	50 to 100%
0513	*	1915	2015	0.165	0.246	0.081	25 to 50%
0514	*	1929	2014	0.126	0.283	0.157	> 100%
0601		1900	2015	0.115	0.135	0.020	10 to 25%
0602		1899	2014	0.140	0.112	-0.027	-25 to -10%
0603	*	1905	2014	0.129	0.258	0.129	50 to 100%
0604	*	1921	2014	0.144	0.229	0.085	50 to 100%
0701	*	1907	2014	0.010	0.019	0.009	50 to 100%
0702	*	1912	2014	0.006	0.025	0.019	> 100%
0703	*	1914	2014	0.028	0.040	0.012	25 to 50%
0704		1912	2014	0.053	0.045	-0.007	-25 to -10%
0705		1914	2014	0.052	0.051	-0.001	-5 to 0%
0706		1920	2014	0.078	0.065	-0.013	-25 to -10%
0707		1913	2013	0.053	0.049	-0.004	-10 to -5%
0708	*	1903	2014	0.022	0.069	0.047	> 100%
0709		1915	2014	0.038	0.038	0.000	-5 to 0%
0710	*	1916	2014	0.017	0.048	0.031	> 100%
0711	*	1923	2014	0.090	0.155	0.065	50 to 100%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	0.032	0.099	0.067	> 100%
0713	*	1909	2014	0.047	0.080	0.033	50 to 100%
0714	*	1909	2014	0.063	0.160	0.097	> 100%
0801	*	1930	2015	0.113	0.176	0.063	50 to 100%
0802	*	1927	2015	0.056	0.090	0.033	50 to 100%
0803	*	1909	2015	0.098	0.225	0.128	> 100%
0804		1929	2015	0.158	0.110	-0.048	-50 to -25%
0805	*	1939	2012	0.069	0.046	-0.023	-50 to -25%
0806		1939	2015	0.244	0.186	-0.058	-25 to -10%
0807		1941	2015	0.246	0.229	-0.017	-10 to -5%
0808	*	1923	2015	0.153	0.076	-0.077	-100 to -50%
0809	*						
1002		1895	2014	0.015	0.020	0.004	25 to 50%
1003	*	1903	2015	0.025	0.008	-0.017	-100 to -50%
1004	*	1908	2013	0.013	0.002	-0.010	-100 to -50%
1005		1904	2013	0.008	0.005	-0.003	-50 to -25%
1006	*	1910	2015	0.004	0.002	-0.002	-100 to -50%
1007		1908	2014	0.044	0.037	-0.007	-25 to -10%
1008		1907	2015	0.020	0.015	-0.005	-25 to -10%
1009	*	1920	2013	0.025	0.009	-0.016	-100 to -50%
1010		1939	2013	0.007	0.005	-0.002	-25 to -10%
1011		1905	2012	0.016	0.012	-0.004	-25 to -10%
1012		1930	2014	0.003	0.006	0.003	50 to 100%
1013		1909	2014	0.016	0.014	-0.002	-25 to -10%
1014		1932	2013	0.006	0.007	0.001	10 to 25%
1015		1939	2013	0.004	0.007	0.003	50 to 100%
1016	*	1944	2013	0.002	0.006	0.004	> 100%
1017		1946	2013	0.012	0.024	0.012	> 100%
1018	*	1905	2015	0.014	0.007	-0.008	-100 to -50%
1019	*	1896	2015	0.015	0.007	-0.009	-100 to -50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	-0.001	0.020	0.021	> 100%
1021		1937	2013	0.022	0.027	0.005	10 to 25%
1022		1946	2013	0.015	0.020	0.005	25 to 50%
1023		1929	2015	0.022	0.030	0.008	25 to 50%
1024	*	1923	2015	0.038	0.071	0.033	50 to 100%
1025	*	1929	2015	0.003	0.000	-0.003	-100 to -50%
1026	*	1919	2015	0.004	0.001	-0.002	-100 to -50%
1027	*	1918	2015	0.007	0.037	0.030	> 100%
1028	*	1922	2015	0.062	0.110	0.049	50 to 100%
1029		1919	2014	0.086	0.108	0.022	25 to 50%
1030	*	1926	2014	0.000	0.181	0.181	> 100%
1101		1922	2015	0.102	0.117	0.015	10 to 25%
1102	*	1897	2015	0.008	0.004	-0.003	-50 to -25%
1103		1903	2015	0.002	0.004	0.002	50 to 100%
1104	*	1943	2015	0.001	0.000	-0.001	-100 to -50%
1105		1935	2015	0.020	0.017	-0.002	-25 to -10%
1106		1937	2015	0.020	0.024	0.004	10 to 25%
1107	*	1922	2015	0.056	0.094	0.038	50 to 100%
1108		1908	2015	0.004	0.002	-0.002	-50 to -25%
1109	*	1939	2015	0.021	0.004	-0.017	-100 to -50%
1110	*	1938	2015	0.004	0.001	-0.003	-100 to -50%
1111	*	1928	2015	0.077	0.193	0.116	> 100%
1112	*	1905	2015	0.022	0.004	-0.017	-100 to -50%
1113		1936	2015	0.019	0.014	-0.005	-50 to -25%
1114		1925	2015	0.107	0.115	0.008	5 to 10%

Table F-9. Change in maximum daily summer water yield by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501		1909	2014	0.042	0.052	0.010	10 to 25%
0502		1908	2014	0.095	0.074	-0.021	-25 to -10%
0503		1913	2014	0.036	0.052	0.015	25 to 50%
0504	*	1922	2014	0.026	0.051	0.025	50 to 100%
0505		1896	2014	0.055	0.050	-0.005	-10 to -5%
0506		1922	2014	0.034	0.061	0.027	50 to 100%
0507		1916	2014	0.035	0.043	0.008	10 to 25%
0508		1915	2014	0.038	0.058	0.020	50 to 100%
0509		1916	2014	0.047	0.069	0.022	25 to 50%
0510		1916	2014	0.056	0.053	-0.002	-5 to 0%
0511		1928	2014	0.048	0.052	0.003	5 to 10%
0512	*	1910	2014	0.025	0.060	0.035	> 100%
0513		1915	2015	0.045	0.054	0.009	10 to 25%
0514	*	1929	2014	0.027	0.104	0.077	> 100%
0601		1900	2015	0.059	0.050	-0.009	-25 to -10%
0602	*	1899	2014	0.061	0.037	-0.023	-50 to -25%
0603		1905	2014	0.039	0.041	0.002	5 to 10%
0604		1921	2014	0.032	0.036	0.004	10 to 25%
0701	*	1907	2014	0.006	0.013	0.007	> 100%
0702	*	1912	2014	-0.001	0.018	0.019	> 100%
0703		1914	2014	0.017	0.025	0.008	25 to 50%
0704		1912	2014	0.022	0.030	0.008	25 to 50%
0705		1914	2014	0.033	0.024	-0.009	-50 to -25%
0706		1920	2014	0.046	0.048	0.001	0 to 5%
0707		1913	2013	0.030	0.025	-0.004	-25 to -10%
0708	*	1903	2014	0.013	0.056	0.043	> 100%
0709	*	1915	2014	0.013	0.028	0.015	> 100%
0710	*	1916	2014	0.016	0.042	0.026	> 100%
0711		1923	2014	0.088	0.088	0.001	0 to 5%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	0.007	0.074	0.067	> 100%
0713	*	1909	2014	0.028	0.050	0.021	50 to 100%
0714	*	1909	2014	0.025	0.058	0.034	> 100%
0801		1930	2015	0.042	0.052	0.009	10 to 25%
0802	*	1927	2015	0.017	0.030	0.014	50 to 100%
0803	*	1909	2015	0.026	0.052	0.026	50 to 100%
0804		1929	2015	0.024	0.034	0.010	25 to 50%
0805		1939	2012	0.021	0.021	0.000	-5 to 0%
0806		1939	2015	0.043	0.044	0.001	0 to 5%
0807		1941	2015	0.054	0.062	0.008	10 to 25%
0808		1923	2015	0.046	0.024	-0.023	-50 to -25%
0809	*						
1002	*	1895	2014	0.017	0.023	0.006	25 to 50%
1003	*	1903	2015	0.024	0.011	-0.014	-100 to -50%
1004	*	1908	2013	0.012	0.003	-0.009	-100 to -50%
1005		1904	2013	0.002	0.003	0.001	25 to 50%
1006		1910	2015	0.002	0.002	-0.001	-50 to -25%
1007		1908	2014	0.069	0.057	-0.012	-25 to -10%
1008	*	1907	2015	0.042	0.020	-0.022	-100 to -50%
1009	*	1920	2013	0.033	0.007	-0.027	-100 to -50%
1010		1939	2013	0.009	0.005	-0.003	-50 to -25%
1011	*	1905	2012	0.011	0.001	-0.009	-100 to -50%
1012		1930	2014	0.004	0.005	0.001	10 to 25%
1013	*	1909	2014	0.006	0.003	-0.004	-100 to -50%
1014		1932	2013	0.004	0.004	-0.001	-25 to -10%
1015	*	1939	2013	0.002	0.004	0.002	50 to 100%
1016	*	1944	2013	0.000	0.002	0.002	> 100%
1017	*	1946	2013	0.004	0.011	0.007	> 100%
1018	*	1905	2015	0.014	0.007	-0.008	-100 to -50%
1019	*	1896	2015	0.021	0.007	-0.014	-100 to -50%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	0.002	0.017	0.014	> 100%
1021		1937	2013	0.027	0.026	-0.002	-10 to -5%
1022		1946	2013	0.018	0.019	0.001	5 to 10%
1023		1929	2015	0.023	0.026	0.003	10 to 25%
1024		1923	2015	0.053	0.062	0.010	10 to 25%
1025	*	1929	2015	0.007	0.000	-0.006	-100 to -50%
1026	*	1919	2015	0.009	0.001	-0.008	-100 to -50%
1027	*	1918	2015	0.013	0.039	0.026	> 100%
1028		1922	2015	0.079	0.077	-0.002	-5 to 0%
1029		1919	2014	0.054	0.053	-0.001	-5 to 0%
1030	*	1926	2014	0.002	0.152	0.150	> 100%
1101		1922	2015	0.030	0.023	-0.007	-25 to -10%
1102	*	1897	2015	0.015	0.006	-0.009	-100 to -50%
1103		1903	2015	0.004	0.006	0.002	25 to 50%
1104	*	1943	2015	0.009	-0.001	-0.010	> -100%
1105		1935	2015	0.015	0.009	-0.006	-50 to -25%
1106		1937	2015	0.020	0.021	0.001	5 to 10%
1107		1922	2015	0.052	0.052	0.000	-5 to 0%
1108	*	1908	2015	0.008	0.003	-0.005	-100 to -50%
1109	*	1939	2015	0.013	0.003	-0.010	-100 to -50%
1110	*	1938	2015	0.006	0.000	-0.006	-100 to -50%
1111		1928	2015	0.024	0.048	0.024	> 100%
1112	*	1905	2015	0.027	0.003	-0.024	-100 to -50%
1113	*	1936	2015	0.017	0.008	-0.009	-100 to -50%
1114		1925	2015	0.031	0.034	0.003	5 to 10%

Table F-10. Change in maximum daily fall water yield by HUC-4.

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0501		1909	2014	0.054	0.062	0.008	10 to 25%
0502		1908	2014	0.079	0.071	-0.007	-10 to -5%
0503		1913	2014	0.031	0.036	0.006	10 to 25%
0504	*	1922	2014	0.014	0.033	0.019	> 100%
0505		1896	2014	0.063	0.053	-0.010	-25 to -10%
0506	*	1922	2014	0.012	0.032	0.020	> 100%
0507		1916	2014	0.019	0.041	0.022	> 100%
0508		1915	2014	0.018	0.029	0.011	50 to 100%
0509		1916	2014	0.025	0.057	0.032	> 100%
0510	*	1916	2014	0.025	0.058	0.033	> 100%
0511	*	1928	2014	0.029	0.063	0.034	> 100%
0512		1910	2014	0.020	0.035	0.015	50 to 100%
0513	*	1915	2015	0.043	0.087	0.043	50 to 100%
0514	*	1929	2014	0.009	0.106	0.097	> 100%
0601	*	1900	2015	0.047	0.072	0.024	50 to 100%
0602		1899	2014	0.049	0.055	0.006	10 to 25%
0603	*	1905	2014	0.029	0.078	0.049	> 100%
0604	*	1921	2014	0.030	0.069	0.039	> 100%
0701	*	1907	2014	0.003	0.008	0.004	> 100%
0702	*	1912	2014	0.000	0.004	0.004	> 100%
0703	*	1914	2014	0.010	0.016	0.006	50 to 100%
0704	*	1912	2014	0.007	0.015	0.008	> 100%
0705		1914	2014	0.018	0.022	0.005	25 to 50%
0706		1920	2014	0.017	0.015	-0.002	-25 to -10%
0707		1913	2013	0.018	0.019	0.001	5 to 10%
0708		1903	2014	0.009	0.015	0.006	50 to 100%
0709		1915	2014	0.010	0.015	0.004	25 to 50%
0710		1916	2014	0.006	0.011	0.004	50 to 100%
0711		1923	2014	0.048	0.060	0.012	10 to 25%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
0712	*	1916	2015	0.005	0.043	0.038	> 100%
0713		1909	2014	0.013	0.017	0.004	25 to 50%
0714	*	1909	2014	0.014	0.043	0.028	> 100%
0801	*	1930	2015	0.034	0.063	0.030	50 to 100%
0802	*	1927	2015	0.010	0.038	0.028	> 100%
0803	*	1909	2015	0.002	0.073	0.071	> 100%
0804	*	1929	2015	0.021	0.041	0.021	> 100%
0805	*	1939	2012	0.011	0.028	0.017	> 100%
0806		1939	2015	0.042	0.068	0.027	50 to 100%
0807		1941	2015	0.058	0.106	0.048	50 to 100%
0808		1923	2015	0.042	0.062	0.019	25 to 50%
0809	*						
1002	*	1895	2014	0.004	0.006	0.002	50 to 100%
1003	*	1903	2015	0.004	0.003	-0.001	-50 to -25%
1004	*	1908	2013	0.002	0.001	-0.001	-100 to -50%
1005		1904	2013	0.000	0.000	0.000	0 to 5%
1006		1910	2015	0.001	0.001	0.000	-50 to -25%
1007		1908	2014	0.009	0.008	-0.001	-25 to -10%
1008		1907	2015	0.005	0.004	0.000	-25 to -10%
1009	*	1920	2013	0.003	0.002	-0.001	-50 to -25%
1010		1939	2013	0.002	0.001	-0.001	-100 to -50%
1011	*	1905	2012	0.001	0.000	-0.001	-100 to -50%
1012	*	1930	2014	0.000	0.001	0.001	> 100%
1013	*	1909	2014	0.000	0.000	0.000	> 100%
1014		1932	2013	0.001	0.001	0.000	50 to 100%
1015	*	1939	2013	0.001	0.002	0.001	50 to 100%
1016	*	1944	2013	0.000	0.001	0.001	> 100%
1017	*	1946	2013	0.000	0.002	0.002	> 100%
1018		1905	2015	0.002	0.002	0.000	-10 to -5%
1019	*	1896	2015	0.004	0.002	-0.001	-50 to -25%

HUC4	p < 0.05	Year		Water Yield [m³/s/km²]		Change in Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²]	%Change
1020	*	1938	2015	0.000	0.004	0.003	> 100%
1021		1937	2013	0.013	0.014	0.002	10 to 25%
1022		1946	2013	0.002	0.004	0.002	50 to 100%
1023		1929	2015	0.003	0.006	0.003	50 to 100%
1024		1923	2015	0.018	0.017	-0.001	-5 to 0%
1025	*	1929	2015	0.002	0.000	-0.002	> -100%
1026	*	1919	2015	0.003	0.000	-0.003	-100 to -50%
1027		1918	2015	0.005	0.010	0.005	> 100%
1028		1922	2015	0.037	0.045	0.007	10 to 25%
1029		1919	2014	0.038	0.041	0.003	5 to 10%
1030	*	1926	2014	0.004	0.077	0.072	> 100%
1101		1922	2015	0.023	0.050	0.027	> 100%
1102		1897	2015	0.003	0.002	-0.001	-50 to -25%
1103		1903	2015	0.002	0.001	-0.001	-50 to -25%
1104	*	1943	2015	0.001	0.000	-0.001	> -100%
1105		1935	2015	0.010	0.008	-0.002	-25 to -10%
1106		1937	2015	0.013	0.013	0.001	0 to 5%
1107		1922	2015	0.038	0.033	-0.005	-25 to -10%
1108		1908	2015	0.002	0.001	-0.001	-50 to -25%
1109	*	1939	2015	0.007	0.002	-0.004	-100 to -50%
1110		1938	2015	0.001	0.001	-0.001	-100 to -50%
1111	*	1928	2015	0.012	0.083	0.071	> 100%
1112		1905	2015	0.009	0.002	-0.007	-100 to -50%
1113		1936	2015	0.009	0.007	-0.002	-25 to -10%
1114		1925	2015	0.018	0.036	0.018	> 100%

Additional data on water yield trends by HUC-4 can be found in *WYield_byHUC4_formatted.xlsx*.

Appendix G: Precipitation-Weighted Water Yield Trends by HUC-4

Table G-1. Change in annual precipitation-weighted water yield by HUC-4.

		Year		Precipitation-Weighted Water Yield [m3/s/km2/100 mm]		Change in Precipitation-Weighted Water Yield	
HUC4	p < 0.05	Min	Max	Min Year	Max Year	[m3/s/km2/100 mm]	%Change
0501		1910	2014	0.640	0.639	-0.002	-5 to 0%
0502		1908	2014	0.664	0.656	-0.009	-5 to 0%
0503		1913	2014	0.454	0.470	0.016	0 to 5%
0504	*	1922	2014	0.389	0.454	0.065	10 to 25%
0505		1908	2014	0.524	0.548	0.024	0 to 5%
0506	*	1922	2014	0.344	0.422	0.078	10 to 25%
0507		1929	2014	0.406	0.428	0.022	5 to 10%
0508		1915	2014	0.362	0.424	0.062	10 to 25%
0509		1916	2014	0.393	0.451	0.059	10 to 25%
0510		1916	2014	0.463	0.456	-0.008	-5 to 0%
0511		1928	2014	0.549	0.559	0.010	0 to 5%
0512	*	1910	2014	0.317	0.437	0.120	25 to 50%
0513		1915	2014	0.538	0.485	-0.053	-10 to -5%
0514		1929	2014	0.437	0.469	0.032	5 to 10%
0601		1900	2014	0.636	0.567	-0.069	-25 to -10%
0602	*	1902	2014	0.645	0.532	-0.113	-25 to -10%
0603		1905	2014	0.497	0.486	-0.012	-5 to 0%
0604		1921	2014	0.483	0.461	-0.021	-5 to 0%
0701	*	1907	2014	0.169	0.268	0.099	50 to 100%
0702	*	1912	2014	0.003	0.190	0.187	> 100%
0703		1920	2014	0.390	0.392	0.002	0 to 5%
0704	*	1912	2014	0.248	0.332	0.083	25 to 50%
0705		1914	2014	0.451	0.409	-0.042	-10 to -5%
0706	*	1920	2014	0.245	0.351	0.106	25 to 50%
0707	*	1913	2013	0.455	0.371	-0.084	-25 to -10%
0708	*	1903	2014	0.200	0.343	0.143	50 to 100%
0709	*	1915	2014	0.271	0.330	0.060	10 to 25%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m3/s/km2/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m3/s/km2/100 mm]	%Change
0710	*	1916	2014	0.132	0.306	0.173	> 100%
0711		1923	2014	0.244	0.321	0.077	25 to 50%
0712	*	1916	2014	0.300	0.453	0.153	50 to 100%
0713	*	1909	2014	0.247	0.355	0.108	25 to 50%
0714		1909	2014	0.277	0.328	0.051	10 to 25%
0801		1930	2013	0.420	0.430	0.010	0 to 5%
0802		1927	2013	0.348	0.409	0.062	10 to 25%
0803		1909	2013	0.385	0.412	0.026	5 to 10%
0804		1929	2013	0.390	0.366	-0.024	-10 to -5%
0805	*	1939	2012	0.375	0.130	-0.245	-100 to -50%
0806		1939	2009	0.390	0.389	-0.001	-5 to 0%
0807		1941	2013	0.416	0.379	-0.037	-10 to -5%
0808		1923	2013	0.445	0.343	-0.103	-25 to -10%
0809							
1002	*	1911	2014	0.265	0.771	0.506	> 100%
1003	*	1903	2014	0.538	0.343	-0.195	-50 to -25%
1004	*	1910	2013	0.235	0.044	-0.191	-100 to -50%
1005		1915	2013	0.053	0.054	0.001	0 to 5%
1006		1911	2012	0.105	0.070	-0.035	-50 to -25%
1007		1908	2014	1.147	0.958	-0.190	-25 to -10%
1008		1913	2013	0.701	0.675	-0.026	-5 to 0%
1009	*	1932	2013	0.522	0.106	-0.416	-100 to -50%
1010	*	1939	2013	0.205	0.096	-0.109	-100 to -50%
1011	*	1930	2012	0.080	0.036	-0.044	-100 to -50%
1012	*	1930	2014	0.017	0.094	0.077	> 100%
1013		1910	2014	0.061	0.051	-0.010	-25 to -10%
1014		1932	2013	0.048	0.051	0.003	5 to 10%
1015	*	1939	2013	0.064	0.108	0.044	50 to 100%
1016	*	1944	2013	0.007	0.048	0.041	> 100%
1017	*	1946	2013	0.047	0.112	0.065	> 100%
1018		1905	2013	0.208	0.190	-0.018	-10 to -5%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m3/s/km2/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m3/s/km2/100 mm]	%Change
1019	*	1898	2014	0.322	0.085	-0.237	-100 to -50%
1020	*	1938	2013	0.013	0.099	0.086	> 100%
1021		1937	2013	0.468	0.429	-0.039	-10 to -5%
1022		1946	2013	0.113	0.161	0.048	25 to 50%
1023	*	1929	2013	0.085	0.221	0.136	> 100%
1024	*	1923	2014	0.122	0.273	0.152	> 100%
1025	*	1929	2014	0.045	0.006	-0.039	-100 to -50%
1026	*	1919	2014	0.036	0.012	-0.024	-100 to -50%
1027	*	1918	2014	0.058	0.127	0.068	> 100%
1028		1922	2014	0.212	0.295	0.083	25 to 50%
1029		1919	2014	0.283	0.301	0.017	5 to 10%
1030	*	1926	2014	0.050	0.388	0.338	> 100%
1101		1922	2013	0.349	0.396	0.047	10 to 25%
1102		1897	2013	0.155	0.104	-0.051	-50 to -25%
1103		1903	2013	0.018	0.024	0.006	25 to 50%
1104	*	1943	2013	0.021	0.001	-0.020	-100 to -50%
1105		1935	2013	0.049	0.046	-0.003	-10 to -5%
1106	*	1937	2013	0.057	0.098	0.041	50 to 100%
1107	*	1922	2013	0.181	0.288	0.107	50 to 100%
1108	*	1908	2013	0.060	0.037	-0.023	-50 to -25%
1109	*	1939	2013	0.084	0.030	-0.054	-100 to -50%
1110	*	1938	2013	0.017	0.010	-0.007	-50 to -25%
1111	*	1928	2013	0.243	0.391	0.148	50 to 100%
1112	*	1938	2013	0.044	0.025	-0.019	-50 to -25%
1113		1936	2013	0.059	0.068	0.008	10 to 25%
1114		1925	2013	0.296	0.284	-0.012	-5 to 0%

Table G-2. Change in maximum annual daily precipitation-weighted water yield by HUC-4.

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [$m^3/s/km^2/100$ mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[$m^3/s/km^2/100$ mm]	%Change
0501	*	1910	2014	0.369	0.295	-0.075	-25 to -10%
0502		1908	2014	0.506	0.418	-0.088	-25 to -10%
0503	*	1913	2014	0.371	0.270	-0.101	-50 to -25%
0504		1922	2014	0.156	0.223	0.067	25 to 50%
0505		1908	2014	0.318	0.337	0.018	5 to 10%
0506		1922	2014	0.316	0.240	-0.077	-25 to -10%
0507	*	1929	2014	0.414	0.292	-0.122	-50 to -25%
0508		1915	2014	0.266	0.257	-0.009	-5 to 0%
0509		1916	2014	0.403	0.386	-0.017	-5 to 0%
0510		1916	2014	0.338	0.386	0.048	10 to 25%
0511	*	1928	2014	0.371	0.260	-0.111	-50 to -25%
0512	*	1910	2014	0.170	0.285	0.116	50 to 100%
0513		1915	2014	0.420	0.472	0.052	10 to 25%
0514	*	1929	2014	0.256	0.575	0.319	> 100%
0601		1900	2014	0.316	0.310	-0.006	-5 to 0%
0602		1902	2014	0.279	0.224	-0.055	-25 to -10%
0603	*	1905	2014	0.242	0.460	0.217	50 to 100%
0604		1921	2014	0.342	0.359	0.017	5 to 10%
0701	*	1907	2014	0.024	0.035	0.012	25 to 50%
0702	*	1912	2014	0.010	0.056	0.046	> 100%
0703		1920	2014	0.066	0.075	0.009	10 to 25%
0704		1912	2014	0.130	0.101	-0.029	-25 to -10%
0705		1914	2014	0.119	0.105	-0.014	-25 to -10%
0706	*	1920	2014	0.216	0.152	-0.065	-50 to -25%
0707		1913	2013	0.108	0.113	0.005	0 to 5%
0708	*	1903	2014	0.050	0.157	0.107	> 100%
0709		1915	2014	0.089	0.082	-0.008	-10 to -5%
0710	*	1916	2014	0.042	0.104	0.062	> 100%
0711	*	1923	2014	0.227	0.336	0.109	25 to 50%
0712	*	1916	2014	0.051	0.243	0.192	> 100%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
0713	*	1909	2014	0.113	0.202	0.089	50 to 100%
0714	*	1909	2014	0.116	0.376	0.260	> 100%
0801		1930	2013	0.244	0.276	0.032	10 to 25%
0802	*	1927	2013	0.097	0.136	0.038	25 to 50%
0803	*	1909	2013	0.150	0.373	0.223	> 100%
0804		1929	2013	0.231	0.198	-0.032	-25 to -10%
0805	*	1939	2012	0.095	0.065	-0.031	-50 to -25%
0806		1939	2009	0.301	0.403	0.102	25 to 50%
0807		1941	2013	0.279	0.324	0.045	10 to 25%
0808		1923	2013	0.205	0.141	-0.064	-50 to -25%
0809							
1002	*	1911	2014	0.063	0.121	0.058	50 to 100%
1003	*	1903	2014	0.112	0.039	-0.072	-100 to -50%
1004	*	1910	2013	0.049	0.014	-0.035	-100 to -50%
1005		1915	2013	0.027	0.021	-0.006	-25 to -10%
1006	*	1911	2012	0.018	0.006	-0.013	-100 to -50%
1007		1908	2014	0.235	0.190	-0.045	-25 to -10%
1008		1913	2013	0.152	0.101	-0.051	-50 to -25%
1009	*	1932	2013	0.130	0.020	-0.110	-100 to -50%
1010	*	1939	2013	0.033	0.020	-0.013	-50 to -25%
1011		1930	2012	0.049	0.029	-0.020	-50 to -25%
1012		1930	2014	0.017	0.018	0.001	5 to 10%
1013		1910	2014	0.053	0.033	-0.021	-50 to -25%
1014		1932	2013	0.019	0.018	-0.001	-5 to 0%
1015	*	1939	2013	0.010	0.018	0.008	50 to 100%
1016	*	1944	2013	0.004	0.015	0.010	> 100%
1017		1946	2013	0.027	0.050	0.023	50 to 100%
1018	*	1905	2013	0.056	0.027	-0.028	-100 to -50%
1019	*	1898	2014	0.061	0.028	-0.033	-100 to -50%
1020	*	1938	2013	0.003	0.060	0.057	> 100%
1021		1937	2013	0.069	0.067	-0.002	-5 to 0%
1022		1946	2013	0.044	0.047	0.003	5 to 10%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [$m^3/s/km^2/100$ mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[$m^3/s/km^2/100$ mm]	%Change
1023		1929	2013	0.068	0.084	0.016	10 to 25%
1024		1923	2014	0.126	0.168	0.043	25 to 50%
1025	*	1929	2014	0.017	0.001	-0.015	-100 to -50%
1026	*	1919	2014	0.022	0.005	-0.016	-100 to -50%
1027	*	1918	2014	0.027	0.091	0.063	> 100%
1028		1922	2014	0.174	0.194	0.020	10 to 25%
1029		1919	2014	0.177	0.235	0.058	25 to 50%
1030	*	1926	2014	0.033	0.448	0.415	> 100%
1101		1922	2013	0.189	0.244	0.055	25 to 50%
1102	*	1897	2013	0.044	0.024	-0.020	-50 to -25%
1103		1903	2013	0.010	0.015	0.005	25 to 50%
1104	*	1943	2013	0.026	-0.003	-0.029	> -100%
1105	*	1935	2013	0.053	0.028	-0.025	-50 to -25%
1106		1937	2013	0.052	0.056	0.004	5 to 10%
1107		1922	2013	0.126	0.174	0.048	25 to 50%
1108	*	1908	2013	0.031	0.013	-0.019	-100 to -50%
1109	*	1939	2013	0.051	0.007	-0.044	-100 to -50%
1110	*	1938	2013	0.016	0.002	-0.014	-100 to -50%
1111	*	1928	2013	0.115	0.387	0.272	> 100%
1112	*	1938	2013	0.068	0.012	-0.056	-100 to -50%
1113	*	1936	2013	0.058	0.031	-0.027	-50 to -25%
1114		1925	2013	0.187	0.182	-0.005	-5 to 0%

Table G-3. Change in winter precipitation-weighted water yield by HUC-4.

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
0501		1910	2014	0.929	1.041	0.113	10 to 25%
0502		1908	2014	1.109	1.093	-0.016	-5 to 0%
0503		1913	2014	0.733	0.797	0.064	5 to 10%
0504		1922	2014	0.587	0.750	0.163	25 to 50%
0505		1908	2014	0.821	0.821	0.000	-5 to 0%
0506		1922	2014	0.548	0.705	0.157	25 to 50%
0507		1929	2014	0.680	0.627	-0.053	-10 to -5%
0508		1915	2014	0.554	0.656	0.102	10 to 25%
0509		1916	2014	0.649	0.738	0.089	10 to 25%
0510		1916	2014	0.735	0.781	0.045	5 to 10%
0511		1928	2014	0.805	0.878	0.073	5 to 10%
0512	*	1910	2014	0.480	0.686	0.207	25 to 50%
0513		1915	2014	0.828	0.750	-0.077	-10 to -5%
0514		1929	2014	0.642	0.740	0.098	10 to 25%
0601		1900	2014	0.780	0.783	0.004	0 to 5%
0602		1902	2014	0.599	0.729	0.130	10 to 25%
0603		1905	2014	0.656	0.752	0.096	10 to 25%
0604		1921	2014	0.632	0.735	0.103	10 to 25%
0701	*	1907	2014	0.283	0.459	0.177	50 to 100%
0702	*	1912	2014	-0.028	0.157	0.185	> 100%
0703		1920	2014	0.721	0.572	-0.149	-25 to -10%
0704		1912	2014	0.413	0.465	0.053	10 to 25%
0705		1914	2014	0.763	0.784	0.021	0 to 5%
0706		1920	2014	0.455	0.482	0.026	5 to 10%
0707		1913	2013	0.736	0.664	-0.072	-10 to -5%
0708		1903	2014	0.243	0.372	0.129	50 to 100%
0709		1915	2014	0.471	0.526	0.055	10 to 25%
0710		1916	2014	0.151	0.269	0.117	50 to 100%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
0711		1923	2014	0.351	0.400	0.048	10 to 25%
0712	*	1916	2014	0.497	0.683	0.186	25 to 50%
0713		1909	2014	0.410	0.499	0.088	10 to 25%
0714		1909	2014	0.365	0.466	0.101	25 to 50%
0801		1930	2013	0.575	0.586	0.011	0 to 5%
0802	*	1927	2013	0.409	0.569	0.159	25 to 50%
0803	*	1909	2013	0.394	0.587	0.193	25 to 50%
0804		1929	2013	0.511	0.528	0.018	0 to 5%
0805	*	1939	2012	0.456	0.186	-0.270	-100 to -50%
0806		1939	2009	0.475	0.545	0.070	10 to 25%
0807		1941	2013	0.590	0.532	-0.059	-10 to -5%
0808		1923	2013	0.598	0.587	-0.011	-5 to 0%
0809							
1002	*	1911	2014	0.147	0.987	0.840	> 100%
1003	*	1903	2014	0.403	0.596	0.194	25 to 50%
1004	*	1910	2013	0.168	0.078	-0.091	-100 to -50%
1005	*	1915	2013	0.015	0.042	0.027	> 100%
1006	*	1911	2012	0.050	0.273	0.224	> 100%
1007		1908	2014	0.622	0.637	0.015	0 to 5%
1008		1913	2013	0.584	0.634	0.051	5 to 10%
1009	*	1932	2013	0.298	0.170	-0.128	-50 to -25%
1010		1939	2013	0.277	0.220	-0.057	-25 to -10%
1011		1930	2012	0.020	0.016	-0.003	-25 to -10%
1012	*	1930	2014	-0.021	0.142	0.163	> 100%
1013	*	1910	2014	0.009	0.032	0.023	> 100%
1014	*	1932	2013	0.039	0.112	0.073	> 100%
1015	*	1939	2013	0.200	0.405	0.205	> 100%
1016	*	1944	2013	-0.004	0.025	0.029	> 100%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
1017	*	1946	2013	0.026	0.087	0.061	> 100%
1018	*	1905	2013	0.127	0.179	0.052	25 to 50%
1019		1898	2014	0.175	0.171	-0.004	-5 to 0%
1020	*	1938	2013	0.035	0.217	0.182	> 100%
1021		1937	2013	1.514	1.742	0.228	10 to 25%
1022	*	1946	2013	0.184	0.388	0.204	> 100%
1023	*	1929	2013	0.058	0.368	0.310	> 100%
1024		1923	2014	0.217	0.332	0.115	50 to 100%
1025	*	1929	2014	0.100	0.021	-0.079	-100 to -50%
1026		1919	2014	0.038	0.028	-0.010	-50 to -25%
1027	*	1918	2014	0.078	0.181	0.103	> 100%
1028		1922	2014	0.291	0.362	0.071	10 to 25%
1029		1919	2014	0.514	0.417	-0.097	-25 to -10%
1030	*	1926	2014	0.059	0.392	0.333	> 100%
1101		1922	2013	0.430	0.522	0.092	10 to 25%
1102		1897	2013	0.190	0.152	-0.038	-25 to -10%
1103		1903	2013	0.024	0.033	0.009	25 to 50%
1104	*	1943	2013	0.043	-0.001	-0.044	> -100%
1105	*	1935	2013	0.027	0.067	0.040	> 100%
1106	*	1937	2013	0.032	0.150	0.117	> 100%
1107	*	1922	2013	0.164	0.372	0.208	> 100%
1108	*	1908	2013	0.064	0.026	-0.039	-100 to -50%
1109		1939	2013	0.088	0.051	-0.037	-50 to -25%
1110		1938	2013	0.016	0.023	0.007	25 to 50%
1111		1928	2013	0.350	0.522	0.171	25 to 50%
1112	*	1938	2013	0.021	0.074	0.053	> 100%
1113	*	1936	2013	0.030	0.090	0.060	> 100%
1114		1925	2013	0.363	0.391	0.028	5 to 10%

Table G-4. Change in spring precipitation-weighted water yield by HUC-4.

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
0501	*	1910	2014	1.099	0.929	-0.170	-25 to -10%
0502		1908	2014	0.994	0.911	-0.083	-10 to -5%
0503		1913	2014	0.710	0.653	-0.056	-10 to -5%
0504		1922	2014	0.584	0.636	0.051	5 to 10%
0505		1908	2014	0.732	0.794	0.061	5 to 10%
0506		1922	2014	0.495	0.587	0.092	10 to 25%
0507		1929	2014	0.685	0.641	-0.045	-10 to -5%
0508		1915	2014	0.493	0.562	0.069	10 to 25%
0509		1916	2014	0.571	0.636	0.064	10 to 25%
0510		1916	2014	0.695	0.635	-0.060	-10 to -5%
0511	*	1928	2014	0.813	0.624	-0.189	-25 to -10%
0512	*	1910	2014	0.468	0.575	0.106	10 to 25%
0513	*	1915	2014	0.767	0.632	-0.135	-25 to -10%
0514		1929	2014	0.646	0.615	-0.031	-5 to 0%
0601	*	1900	2014	0.829	0.743	-0.086	-25 to -10%
0602	*	1902	2014	0.831	0.596	-0.235	-50 to -25%
0603		1905	2014	0.672	0.605	-0.067	-10 to -5%
0604		1921	2014	0.654	0.539	-0.114	-25 to -10%
0701	*	1907	2014	0.262	0.438	0.176	50 to 100%
0702	*	1912	2014	0.037	0.362	0.325	> 100%
0703		1920	2014	0.646	0.646	0.000	-5 to 0%
0704		1912	2014	0.423	0.482	0.059	10 to 25%
0705		1914	2014	0.716	0.552	-0.164	-25 to -10%
0706		1920	2014	0.359	0.462	0.103	25 to 50%
0707	*	1913	2013	0.739	0.527	-0.212	-50 to -25%
0708	*	1903	2014	0.301	0.484	0.183	50 to 100%
0709		1915	2014	0.425	0.464	0.039	5 to 10%
0710	*	1916	2014	0.242	0.397	0.155	50 to 100%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
0711	*	1923	2014	0.299	0.460	0.161	50 to 100%
0712	*	1916	2014	0.477	0.647	0.170	25 to 50%
0713	*	1909	2014	0.362	0.497	0.135	25 to 50%
0714		1909	2014	0.388	0.438	0.050	10 to 25%
0801		1930	2013	0.529	0.521	-0.008	-5 to 0%
0802		1927	2013	0.508	0.509	0.000	0 to 5%
0803		1909	2013	0.550	0.450	-0.100	-25 to -10%
0804		1929	2013	0.561	0.474	-0.087	-25 to -10%
0805	*	1939	2012	0.539	0.110	-0.429	-100 to -50%
0806		1939	2009	0.527	0.517	-0.009	-5 to 0%
0807		1941	2013	0.546	0.503	-0.044	-10 to -5%
0808		1923	2013	0.572	0.476	-0.096	-25 to -10%
0809	*						
1002	*	1911	2014	0.367	0.753	0.386	> 100%
1003	*	1903	2014	0.710	0.268	-0.442	-100 to -50%
1004	*	1910	2013	0.352	0.025	-0.327	-100 to -50%
1005		1915	2013	0.134	0.077	-0.058	-50 to -25%
1006		1911	2012	0.160	0.089	-0.071	-50 to -25%
1007	*	1908	2014	0.839	0.580	-0.259	-50 to -25%
1008		1913	2013	0.524	0.426	-0.098	-25 to -10%
1009	*	1932	2013	0.511	0.093	-0.418	-100 to -50%
1010	*	1939	2013	0.236	0.096	-0.139	-100 to -50%
1011		1930	2012	0.155	0.099	-0.056	-50 to -25%
1012	*	1930	2014	0.030	0.093	0.063	> 100%
1013		1910	2014	0.149	0.104	-0.045	-50 to -25%
1014		1932	2013	0.066	0.079	0.014	10 to 25%
1015		1939	2013	0.088	0.124	0.036	25 to 50%
1016	*	1944	2013	0.027	0.078	0.050	> 100%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
1017		1946	2013	0.093	0.196	0.104	> 100%
1018		1905	2013	0.240	0.194	-0.045	-25 to -10%
1019	*	1898	2014	0.242	0.098	-0.144	-100 to -50%
1020	*	1938	2013	0.012	0.113	0.100	> 100%
1021		1937	2013	0.503	0.426	-0.078	-25 to -10%
1022		1946	2013	0.156	0.193	0.037	10 to 25%
1023	*	1929	2013	0.136	0.271	0.135	50 to 100%
1024	*	1923	2014	0.139	0.330	0.191	> 100%
1025	*	1929	2014	0.043	0.004	-0.039	-100 to -50%
1026	*	1919	2014	0.025	0.014	-0.011	-50 to -25%
1027	*	1918	2014	0.058	0.137	0.079	> 100%
1028	*	1922	2014	0.269	0.429	0.160	50 to 100%
1029		1919	2014	0.402	0.402	-0.001	-5 to 0%
1030	*	1926	2014	0.057	0.492	0.436	> 100%
1101		1922	2013	0.496	0.531	0.035	5 to 10%
1102		1897	2013	0.125	0.117	-0.007	-10 to -5%
1103		1903	2013	0.012	0.024	0.012	> 100%
1104	*	1943	2013	0.015	0.001	-0.014	-100 to -50%
1105		1935	2013	0.052	0.054	0.002	0 to 5%
1106	*	1937	2013	0.064	0.112	0.047	50 to 100%
1107	*	1922	2013	0.211	0.383	0.172	50 to 100%
1108		1908	2013	0.072	0.041	-0.031	-50 to -25%
1109	*	1939	2013	0.116	0.026	-0.090	-100 to -50%
1110		1938	2013	0.015	0.014	-0.001	-10 to -5%
1111	*	1928	2013	0.358	0.510	0.151	25 to 50%
1112		1938	2013	0.042	0.033	-0.009	-25 to -10%
1113		1936	2013	0.064	0.060	-0.004	-10 to -5%
1114		1925	2013	0.459	0.390	-0.069	-25 to -10%

Table G-5. Change in summer precipitation-weighted water yield by HUC-4.

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
0501	*	1910	2014	0.191	0.277	0.086	25 to 50%
0502		1908	2014	0.273	0.270	-0.003	-5 to 0%
0503	*	1913	2014	0.130	0.237	0.107	50 to 100%
0504	*	1922	2014	0.155	0.232	0.078	50 to 100%
0505		1908	2014	0.256	0.265	0.009	0 to 5%
0506	*	1922	2014	0.110	0.222	0.112	> 100%
0507	*	1929	2014	0.101	0.196	0.095	50 to 100%
0508	*	1915	2014	0.171	0.256	0.086	50 to 100%
0509		1916	2014	0.146	0.190	0.044	25 to 50%
0510		1916	2014	0.154	0.162	0.009	5 to 10%
0511		1928	2014	0.213	0.236	0.022	10 to 25%
0512	*	1910	2014	0.141	0.240	0.099	50 to 100%
0513		1915	2014	0.202	0.188	-0.014	-10 to -5%
0514		1929	2014	0.160	0.213	0.053	25 to 50%
0601		1900	2014	0.430	0.348	-0.082	-25 to -10%
0602		1902	2014	0.511	0.420	-0.091	-25 to -10%
0603	*	1905	2014	0.256	0.174	-0.081	-50 to -25%
0604		1921	2014	0.235	0.214	-0.020	-10 to -5%
0701	*	1907	2014	0.115	0.168	0.053	25 to 50%
0702	*	1912	2014	-0.019	0.148	0.167	> 100%
0703		1920	2014	0.215	0.240	0.025	10 to 25%
0704	*	1912	2014	0.133	0.222	0.089	50 to 100%
0705		1914	2014	0.246	0.231	-0.015	-10 to -5%
0706	*	1920	2014	0.143	0.257	0.114	50 to 100%
0707		1913	2013	0.259	0.217	-0.042	-25 to -10%
0708	*	1903	2014	0.136	0.274	0.139	> 100%
0709	*	1915	2014	0.136	0.223	0.087	50 to 100%
0710	*	1916	2014	0.086	0.285	0.198	> 100%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
0711		1923	2014	0.164	0.186	0.022	10 to 25%
0712	*	1916	2014	0.127	0.294	0.167	> 100%
0713		1909	2014	0.154	0.221	0.067	25 to 50%
0714		1909	2014	0.153	0.173	0.020	10 to 25%
0801		1930	2013	0.209	0.251	0.042	10 to 25%
0802		1927	2013	0.199	0.212	0.013	5 to 10%
0803		1909	2013	0.225	0.202	-0.023	-25 to -10%
0804		1929	2013	0.125	0.159	0.033	25 to 50%
0805		1939	2012	0.139	0.118	-0.021	-25 to -10%
0806		1939	2009	0.195	0.159	-0.036	-25 to -10%
0807		1941	2013	0.206	0.163	-0.043	-25 to -10%
0808	*	1923	2013	0.217	0.121	-0.096	-50 to -25%
0809	*						
1002	*	1911	2014	0.291	0.827	0.536	> 100%
1003	*	1903	2014	0.524	0.282	-0.243	-50 to -25%
1004	*	1910	2013	0.187	0.067	-0.119	-100 to -50%
1005	*	1915	2013	0.022	0.043	0.021	50 to 100%
1006		1911	2012	0.041	0.042	0.000	0 to 5%
1007		1908	2014	2.026	1.847	-0.179	-10 to -5%
1008		1913	2013	1.280	1.249	-0.030	-5 to 0%
1009	*	1932	2013	0.637	0.156	-0.482	-100 to -50%
1010		1939	2013	0.193	0.123	-0.070	-50 to -25%
1011	*	1930	2012	0.045	0.005	-0.040	-100 to -50%
1012	*	1930	2014	0.014	0.075	0.062	> 100%
1013		1910	2014	0.026	0.019	-0.008	-50 to -25%
1014		1932	2013	0.031	0.028	-0.002	-10 to -5%
1015	*	1939	2013	0.031	0.063	0.032	> 100%
1016	*	1944	2013	-0.002	0.038	0.039	> 100%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
1017	*	1946	2013	0.024	0.082	0.058	> 100%
1018		1905	2013	0.250	0.195	-0.054	-25 to -10%
1019	*	1898	2014	0.523	0.028	-0.495	-100 to -50%
1020	*	1938	2013	0.004	0.079	0.074	> 100%
1021		1937	2013	0.231	0.239	0.009	0 to 5%
1022		1946	2013	0.076	0.108	0.032	25 to 50%
1023	*	1929	2013	0.057	0.182	0.125	> 100%
1024	*	1923	2014	0.093	0.208	0.115	> 100%
1025	*	1929	2014	0.037	0.003	-0.035	-100 to -50%
1026	*	1919	2014	0.040	0.006	-0.034	-100 to -50%
1027	*	1918	2014	0.054	0.105	0.051	50 to 100%
1028		1922	2014	0.151	0.209	0.058	25 to 50%
1029		1919	2014	0.166	0.174	0.008	0 to 5%
1030	*	1926	2014	0.048	0.248	0.200	> 100%
1101		1922	2013	0.238	0.234	-0.004	-5 to 0%
1102	*	1897	2013	0.173	0.068	-0.105	-100 to -50%
1103		1903	2013	0.020	0.019	-0.001	-10 to -5%
1104	*	1943	2013	0.021	-0.002	-0.023	> -100%
1105		1935	2013	0.042	0.032	-0.010	-25 to -10%
1106		1937	2013	0.048	0.072	0.024	25 to 50%
1107		1922	2013	0.151	0.192	0.041	25 to 50%
1108	*	1908	2013	0.054	0.023	-0.031	-100 to -50%
1109	*	1939	2013	0.052	0.020	-0.031	-100 to -50%
1110	*	1938	2013	0.017	0.009	-0.008	-50 to -25%
1111		1928	2013	0.095	0.153	0.059	50 to 100%
1112	*	1938	2013	0.042	0.012	-0.030	-100 to -50%
1113		1936	2013	0.068	0.043	-0.025	-50 to -25%
1114		1925	2013	0.125	0.115	-0.011	-10 to -5%

Table G-6. Change in fall precipitation-weighted water yield by HUC-4.

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [m³/s/km²/100 mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[m³/s/km²/100 mm]	%Change
0501		1910	2014	0.325	0.393	0.068	10 to 25%
0502		1908	2014	0.354	0.366	0.011	0 to 5%
0503	*	1913	2014	0.163	0.260	0.097	50 to 100%
0504	*	1922	2014	0.130	0.230	0.100	50 to 100%
0505		1908	2014	0.296	0.329	0.033	10 to 25%
0506	*	1922	2014	0.057	0.193	0.135	> 100%
0507	*	1929	2014	0.083	0.215	0.132	> 100%
0508		1915	2014	0.136	0.179	0.043	25 to 50%
0509	*	1916	2014	0.074	0.208	0.135	> 100%
0510	*	1916	2014	0.090	0.208	0.118	> 100%
0511	*	1928	2014	0.132	0.351	0.219	> 100%
0512		1910	2014	0.110	0.165	0.055	50 to 100%
0513		1915	2014	0.173	0.226	0.053	25 to 50%
0514	*	1929	2014	0.096	0.210	0.114	> 100%
0601		1900	2014	0.486	0.398	-0.088	-25 to -10%
0602	*	1902	2014	0.536	0.398	-0.138	-50 to -25%
0603		1905	2014	0.218	0.223	0.005	0 to 5%
0604		1921	2014	0.219	0.245	0.026	10 to 25%
0701		1907	2014	0.176	0.209	0.034	10 to 25%
0702	*	1912	2014	-0.005	0.073	0.078	> 100%
0703		1920	2014	0.328	0.329	0.001	0 to 5%
0704	*	1912	2014	0.189	0.269	0.081	25 to 50%
0705		1914	2014	0.410	0.355	-0.055	-25 to -10%
0706	*	1920	2014	0.143	0.258	0.115	50 to 100%
0707		1913	2013	0.353	0.293	-0.060	-25 to -10%
0708		1903	2014	0.135	0.141	0.007	0 to 5%
0709	*	1915	2014	0.154	0.255	0.101	50 to 100%
0710	*	1916	2014	0.074	0.133	0.059	50 to 100%
0711		1923	2014	0.122	0.128	0.006	5 to 10%
0712	*	1916	2014	0.132	0.295	0.163	> 100%
0713		1909	2014	0.086	0.105	0.019	10 to 25%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [$m^3/s/km^2/100$ mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[$m^3/s/km^2/100$ mm]	%Change
0714		1909	2014	0.105	0.118	0.013	10 to 25%
0801	*	1930	2013	0.175	0.247	0.072	25 to 50%
0802	*	1927	2013	0.112	0.189	0.077	50 to 100%
0803	*	1909	2013	0.132	0.225	0.094	50 to 100%
0804		1929	2013	0.127	0.128	0.001	0 to 5%
0805		1939	2012	0.086	0.085	0.000	-5 to 0%
0806		1939	2009	0.168	0.163	-0.005	-5 to 0%
0807		1941	2013	0.249	0.223	-0.026	-25 to -10%
0808		1923	2013	0.226	0.180	-0.046	-25 to -10%
0809	*						
1002	*	1911	2014	0.205	0.547	0.342	> 100%
1003		1903	2014	0.347	0.364	0.017	0 to 5%
1004	*	1910	2013	0.112	0.040	-0.072	-100 to -50%
1005	*	1915	2013	0.011	0.025	0.013	> 100%
1006		1911	2012	0.116	0.069	-0.047	-50 to -25%
1007		1908	2014	0.606	0.476	-0.130	-25 to -10%
1008		1913	2013	0.415	0.431	0.016	0 to 5%
1009	*	1932	2013	0.282	0.085	-0.197	-100 to -50%
1010	*	1939	2013	0.218	0.060	-0.158	-100 to -50%
1011	*	1930	2012	0.018	0.006	-0.012	-100 to -50%
1012	*	1930	2014	-0.001	0.083	0.084	> 100%
1013	*	1910	2014	0.008	0.016	0.008	> 100%
1014		1932	2013	0.027	0.024	-0.003	-25 to -10%
1015		1939	2013	0.067	0.099	0.032	25 to 50%
1016	*	1944	2013	-0.005	0.023	0.027	> 100%
1017	*	1946	2013	0.015	0.049	0.034	> 100%
1018		1905	2013	0.115	0.098	-0.017	-25 to -10%
1019	*	1898	2014	0.192	0.076	-0.116	-100 to -50%
1020	*	1938	2013	0.008	0.066	0.058	> 100%
1021		1937	2013	0.565	0.512	-0.053	-10 to -5%
1022		1946	2013	0.074	0.100	0.026	25 to 50%
1023	*	1929	2013	0.051	0.134	0.083	> 100%

HUC4	p < 0.05	Year		Precipitation-Weighted Water Yield [$m^3/s/km^2/100$ mm]		Change in Precipitation-Weighted Water Yield	
		Min	Max	Min Year	Max Year	[$m^3/s/km^2/100$ mm]	%Change
1024	*	1923	2014	0.063	0.134	0.071	> 100%
1025	*	1929	2014	0.038	0.004	-0.034	-100 to -50%
1026	*	1919	2014	0.025	0.006	-0.019	-100 to -50%
1027		1918	2014	0.044	0.058	0.014	25 to 50%
1028		1922	2014	0.108	0.137	0.029	25 to 50%
1029		1919	2014	0.147	0.122	-0.025	-25 to -10%
1030	*	1926	2014	0.022	0.188	0.166	> 100%
1101		1922	2013	0.207	0.186	-0.022	-25 to -10%
1102		1897	2013	0.116	0.098	-0.018	-25 to -10%
1103		1903	2013	0.014	0.014	0.000	0 to 5%
1104	*	1943	2013	0.016	0.000	-0.016	> -100%
1105		1935	2013	0.032	0.032	0.000	-5 to 0%
1106		1937	2013	0.045	0.056	0.010	10 to 25%
1107		1922	2013	0.112	0.117	0.004	0 to 5%
1108		1908	2013	0.044	0.029	-0.015	-50 to -25%
1109	*	1939	2013	0.038	0.011	-0.027	-100 to -50%
1110		1938	2013	0.008	0.007	-0.001	-25 to -10%
1111	*	1928	2013	0.065	0.160	0.095	> 100%
1112		1938	2013	0.017	0.017	0.000	-5 to 0%
1113		1936	2013	0.031	0.039	0.008	25 to 50%
1114		1925	2013	0.082	0.093	0.012	10 to 25%

Appendix H: Stream flow Trends at Index Stations

Table H-1. Change in annual streamflow at index stations with significant trends.

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
03025500	Allegheny	0501	1915	2013	101,931	119,675	17,744	10 to 25%
03031500	Allegheny	0501	1933	2013	129,318	155,379	26,061	10 to 25%
03144500	Muskingum	0504	1922	2014	59,749	77,465	17,716	25 to 50%
03150000	Muskingum	0504	1922	2014	70,042	93,834	23,792	25 to 50%
03193000	Kanawha	0505	1878	2012	137,361	118,673	-18,688	-25 to -10%
03221000	Scioto	0506	1922	2013	6,935	10,555	3,620	50 to 100%
03227500	Scioto	0506	1921	2013	12,392	18,398	6,007	25 to 50%
03231500	Scioto	0506	1921	2014	31,894	43,590	11,695	25 to 50%
03234500	Scioto	0506	1931	2014	42,479	57,702	15,223	25 to 50%
03215000	Big Sandy	0507	1940	1975	35,913	56,825	20,913	50 to 100%
03270500	Great Miami	0508	1914	2013	21,187	27,694	6,507	25 to 50%
03274000	Great Miami	0508	1928	2013	28,522	43,535	15,013	50 to 100%
03315500	Green	0511	1938	1992	72,858	97,397	24,539	25 to 50%
03325000	Wabash	0512	1924	2013	14,101	18,927	4,826	25 to 50%
03327500	Wabash	0512	1944	2013	21,486	30,947	9,461	25 to 50%
03329000	Wabash	0512	1924	2013	29,950	43,067	13,117	25 to 50%
03335500	Wabash	0512	1924	2013	58,347	82,844	24,497	25 to 50%
03336000	Wabash	0512	1940	2013	66,245	97,160	30,915	25 to 50%
03340500	Wabash	0512	1928	2013	85,691	130,399	44,708	50 to 100%
03341500	Wabash	0512	1928	2013	95,046	140,938	45,891	25 to 50%
03342000	Wabash	0512	1939	2013	102,490	159,764	57,274	50 to 100%
03343000	Wabash	0512	1930	1993	101,445	151,548	50,103	25 to 50%
03347000	White	0512	1932	2013	1,752	2,942	1,189	50 to 100%
03348000	White	0512	1933	2012	3,109	5,476	2,367	50 to 100%
03351000	White	0512	1930	2013	9,242	15,481	6,239	50 to 100%
03353000	White	0512	1905	2013	9,639	19,639	10,000	> 100%
03354000	White	0512	1931	2014	18,817	33,272	14,456	50 to 100%
03377500	Wabash	0512	1928	2013	242,686	359,139	116,453	25 to 50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
03384500	Ohio	0514	1941	1979	1,608,535	3,102,104	1,493,570	50 to 100%
03611500	Ohio	0514	1929	2014	2,564,416	3,181,919	617,503	10 to 25%
03568000	Tennessee	0602	1875	2007	408,441	348,245	-60,196	-25 to -10%
03571850	Tennessee	0603	1931	1986	336,055	445,923	109,868	25 to 50%
05220500	Mississippi	0701	1931	1989	15,082	27,832	12,750	50 to 100%
05261000	Mississippi	0701	1988	1999	32,486	80,126	47,641	> 100%
05267000	Mississippi	0701	1925	2014	34,092	66,848	32,756	50 to 100%
05288500	Mississippi	0701	1932	2013	63,964	108,447	44,483	50 to 100%
05331000	Mississippi	0701	1901	2015	73,673	174,291	100,618	> 100%
05292000	Minnesota	0702	1939	2013	682	2,348	1,667	> 100%
05301000	Minnesota	0702	1943	2013	5,017	11,033	6,016	> 100%
05311000	Minnesota	0702	1910	2013	1,767	15,503	13,736	> 100%
05325000	Minnesota	0702	1905	2013	9,918	58,757	48,839	> 100%
05330000	Minnesota	0702	1935	2013	23,207	70,836	47,630	> 100%
05339500	St. Croix	0703	1924	1960	25,871	49,247	23,376	50 to 100%
05340500	St. Croix	0703	1904	2013	34,433	53,910	19,477	50 to 100%
05344500	Mississippi	0704	1929	2015	128,004	260,135	132,131	> 100%
05378500	Mississippi	0704	1929	2011	218,444	395,649	177,206	50 to 100%
05383500	Mississippi	0704	1931	1954	172,644	414,764	242,120	> 100%
05389500	Mississippi	0706	1937	2012	312,650	467,239	154,589	25 to 50%
05391000	Wisconsin	0707	1937	2013	8,098	5,351	-2,746	-50 to -25%
05401500	Wisconsin	0707	1903	1949	76,292	42,099	-34,193	-50 to -25%
05449500	Iowa	0708	1941	2014	1,512	3,616	2,104	> 100%
05451500	Iowa	0708	1915	2014	5,744	12,560	6,816	> 100%
05454500	Iowa	0708	1904	2013	12,300	26,172	13,872	> 100%
05465500	Iowa	0708	1915	2013	51,050	110,342	59,292	> 100%
05474500	Mississippi	0708	1879	2013	574,571	808,343	233,771	25 to 50%
05425500	Rock	0709	1932	2013	3,323	7,716	4,394	> 100%
05430500	Rock	0709	1915	2013	15,517	25,582	10,065	50 to 100%
05437500	Rock	0709	1904	2013	33,597	53,390	19,792	50 to 100%
05443500	Rock	0709	1915	2014	47,350	75,869	28,519	50 to 100%
05446500	Rock	0709	1940	2013	48,023	91,622	43,600	50 to 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
05476000	Des Moines	0710	1936	2013	1,925	5,837	3,913	> 100%
05480500	Des Moines	0710	1914	2014	9,872	24,844	14,971	> 100%
05482000	Des Moines	0710	1916	2014	15,280	39,624	24,343	> 100%
05485500	Des Moines	0710	1941	2014	34,125	68,628	34,503	> 100%
05488500	Des Moines	0710	1921	2013	30,515	86,431	55,916	> 100%
05489500	Des Moines	0710	1918	2013	35,567	90,869	55,302	> 100%
05490500	Des Moines	0710	1904	2013	37,330	93,321	55,991	> 100%
05587450	Mississippi	0711	1934	2014	871,739	1,435,799	564,060	50 to 100%
05587500	Mississippi	0711	1934	1986	806,815	1,362,921	556,106	50 to 100%
05568500	Illinois	0713	1940	2014	139,255	186,449	47,194	25 to 50%
05585500	Illinois	0713	1939	1988	192,304	263,310	71,005	25 to 50%
05586100	Illinois	0713	1939	2015	197,873	282,791	84,918	25 to 50%
07010000	Mississippi	0714	1863	2013	1,683,305	2,121,470	438,165	25 to 50%
07020500	Mississippi	0714	1943	2014	1,846,101	2,455,265	609,163	25 to 50%
07022000	Mississippi	0714	1934	2014	1,705,695	2,628,655	922,960	50 to 100%
07026000	Obion	0801	1930	1990	22,904	33,992	11,089	25 to 50%
07032000	Mississippi	0801	1934	1993	4,294,336	5,794,688	1,500,352	25 to 50%
07047800	St. Francis	0802	1931	2009	30,697	19,896	-10,801	-50 to -25%
07287000	Yazoo	0803	1908	1979	78,259	122,134	43,876	50 to 100%
06054500	Missouri	1003	1911	2014	61,449	45,750	-15,699	-50 to -25%
06090800	Missouri	1003	1891	2014	85,874	69,995	-15,879	-25 to -10%
06099500	Marias	1003	1903	2015	10,407	7,348	-3,059	-50 to -25%
06115000	Missouri	1004	1935	1967	68,936	111,376	42,441	50 to 100%
06120500	Musselshell	1004	1908	2012	1,911	1,143	-768	-50 to -25%
06126500	Musselshell	1004	1947	2012	2,289	1,251	-1,038	-50 to -25%
06140500	Milk	1005	1900	2013	3,005	4,740	1,735	50 to 100%
06172000	Milk	1005	1915	1986	8,035	2,401	-5,633	-100 to -50%
06307830	Tongue	1009	1974	2005	4,835	1,769	-3,066	-100 to -50%
06327500	Yellowstone	1010	1898	2013	158,132	104,038	-54,094	-50 to -25%
06329500	Yellowstone	1010	1911	2012	153,137	104,248	-48,889	-50 to -25%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06400500	Cheyenne	1012	1915	1971	3,590	713	-2,877	-100 to -50%
06401500	Cheyenne	1012	1946	1977	1,222	31	-1,190	-100 to -50%
06338490	Missouri	1013	1970	2008	272,060	153,332	-118,727	-50 to -25%
06454000	Niobrara	1015	1956	1993	48	27	-21	-50 to -25%
06454100	Niobrara	1015	1958	1990	159	120	-39	-25 to -10%
06454500	Niobrara	1015	1947	1993	350	241	-109	-50 to -25%
06455500	Niobrara	1015	1947	1990	305	209	-96	-50 to -25%
06457500	Niobrara	1015	1930	1990	1,445	1,045	-400	-50 to -25%
06461500	Niobrara	1015	1946	2012	8,368	7,572	-796	-10 to -5%
06462000	Niobrara	1015	1953	1982	9,944	7,720	-2,224	-25 to -10%
06465000	Niobrara	1015	1928	2001	12,807	17,588	4,781	25 to 50%
06465500	Niobrara	1015	1939	2012	13,223	20,492	7,269	50 to 100%
06468170	James	1016	1969	2013	107	1,230	1,123	> 100%
06470000	James	1016	1929	2013	-119	1,969	2,088	> 100%
06470500	James	1016	1951	2013	203	3,304	3,101	> 100%
06470878	James	1016	1982	2013	1,374	5,507	4,133	> 100%
06471000	James	1016	1946	2013	239	3,538	3,299	> 100%
06472000	James	1016	1951	2013	614	4,686	4,072	> 100%
06473000	James	1016	1946	2013	296	5,411	5,115	> 100%
06475000	James	1016	1951	2013	553	5,926	5,373	> 100%
06476000	James	1016	1944	2013	763	7,749	6,986	> 100%
06477000	James	1016	1951	2013	709	9,883	9,174	> 100%
06478500	James	1016	1929	2012	968	10,618	9,650	> 100%
06479438	Big Sioux	1017	1973	2013	209	616	407	> 100%
06480000	Big Sioux	1017	1954	2013	956	4,554	3,598	> 100%
06481000	Big Sioux	1017	1949	2013	1,870	6,262	4,392	> 100%
06482020	Big Sioux	1017	1972	2013	4,014	9,328	5,314	> 100%
06485500	Big Sioux	1017	1929	2013	5,021	19,742	14,722	> 100%
06627000	North Platte	1018	1904	1969	14,823	8,873	-5,951	-50 to -25%
06636000	North Platte	1018	1914	1958	19,914	9,767	-10,147	-100 to -50%
06641000	North Platte	1018	1906	1960	20,854	11,224	-9,630	-50 to -25%
06656000	North Platte	1018	1903	1997	22,213	13,884	-8,329	-50 to -25%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06657000	North Platte	1018	1916	2013	8,148	3,625	-4,523	-100 to -50%
06674500	North Platte	1018	1930	2013	7,582	5,472	-2,110	-50 to -25%
06696000	South Platte	1019	1930	1997	547	1,117	570	> 100%
06711565	South Platte	1019	1984	2013	3,299	1,429	-1,870	-100 to -50%
06714215	South Platte	1019	1983	2013	3,258	800	-2,458	-100 to -50%
06720500	South Platte	1019	1927	2006	2,617	5,217	2,600	50 to 100%
06754000	South Platte	1019	1902	2006	6,599	10,059	3,460	50 to 100%
06766000	Platte	1020	1940	1990	3,536	6,708	3,172	50 to 100%
06805500	Platte	1020	1954	2012	52,489	91,704	39,215	50 to 100%
06775500	Middle Loup	1021	1946	2013	3,857	5,085	1,228	25 to 50%
06793000	Loup	1021	1930	2012	4,976	9,622	4,646	50 to 100%
06794500	Loup	1021	1935	1977	12,657	5,266	-7,391	-100 to -50%
06799350	Elkhorn	1022	1973	2012	7,763	13,424	5,662	50 to 100%
06800500	Elkhorn	1022	1929	2012	7,338	20,585	13,247	> 100%
06607500	Little Sioux	1023	1943	2013	3,212	21,827	18,614	> 100%
06610000	Missouri	1023	1929	2013	276,766	379,344	102,578	25 to 50%
06807000	Missouri	1024	1930	2013	331,042	450,442	119,400	25 to 50%
06818000	Missouri	1024	1929	2013	358,087	524,878	166,791	25 to 50%
06824500	Republican	1025	1948	1993	1,111	592	-519	-50 to -25%
06828500	Republican	1025	1951	2015	1,560	230	-1,330	-100 to -50%
06829500	Republican	1025	1947	1992	1,492	-100	-1,592	> -100%
06837000	Republican	1025	1955	2013	2,200	222	-1,978	-100 to -50%
06843500	Republican	1025	1946	2012	4,040	565	-3,475	-100 to -50%
06844500	Republican	1025	1948	2014	3,865	577	-3,289	-100 to -50%
06849500	Republican	1025	1953	2005	3,207	773	-2,434	-100 to -50%
06853020	Republican	1025	1985	2007	2,037	706	-1,332	-100 to -50%
06853500	Republican	1025	1933	2015	7,566	818	-6,748	-100 to -50%
06854500	Republican	1025	1920	1971	7,766	4,823	-2,943	-50 to -25%
06856000	Republican	1025	1947	2013	8,348	2,735	-5,613	-100 to -50%
06856600	Republican	1025	1918	2015	11,630	5,742	-5,889	-100 to -50%
06860000	Smoky Hill	1026	1940	2014	238	-19	-257	> -100%
06861000	Smoky Hill	1026	1951	2013	428	12	-416	-100 to -50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06862000	Smoky Hill	1026	1954	1980	119	-19	-138	> -100%
06864050	Smoky Hill	1026	1940	2010	1,989	713	-1,276	-100 to -50%
06865500	Smoky Hill	1026	1941	2014	3,400	1,351	-2,049	-100 to -50%
06866500	Smoky Hill	1026	1924	2013	4,258	2,537	-1,721	-50 to -25%
06893000	Missouri	1030	1929	2013	439,745	628,389	188,644	25 to 50%
07086000	Arkansas	1102	1911	2006	3,471	4,457	986	25 to 50%
07099500	Arkansas	1102	1895	1974	7,996	6,010	-1,986	-25 to -10%
07133000	Arkansas	1102	1914	2015	1,720	774	-946	-100 to -50%
07138000	Arkansas	1103	1903	2015	4,017	994	-3,023	-100 to -50%
07139000	Arkansas	1103	1923	2015	1,704	453	-1,251	-100 to -50%
07139500	Arkansas	1103	1903	2001	3,327	-120	-3,447	> -100%
07140000	Arkansas	1103	1945	2008	1,960	-124	-2,084	> -100%
07140500	Arkansas	1103	1923	1939	3,681	188	-3,493	-100 to -50%
07141300	Arkansas	1103	1941	2015	3,697	-36	-3,733	> -100%
07146500	Arkansas	1103	1903	2015	13,810	23,119	9,309	50 to 100%
07154500	Cimarron	1104	1951	2015	205	23	-182	-100 to -50%
07156900	Cimarron	1104	1966	2015	784	172	-612	-100 to -50%
07157950	Cimarron	1105	1961	2012	1,573	358	-1,215	-100 to -50%
07158000	Cimarron	1105	1938	2015	3,609	1,312	-2,297	-100 to -50%
07152500	Arkansas	1106	1926	2015	38,959	69,249	30,290	50 to 100%
07170500	Verdigris	1107	1896	2015	11,531	22,975	11,444	50 to 100%
07176000	Verdigris	1107	1936	2015	31,593	52,436	20,843	50 to 100%
07183000	Neosho	1107	1896	2015	11,708	22,517	10,809	50 to 100%
07211500	Canadian	1108	1940	2015	659	347	-312	-50 to -25%
07221500	Canadian	1108	1913	2015	2,252	677	-1,575	-100 to -50%
07224500	Canadian	1108	1937	1971	1,189	-223	-1,412	> -100%
07227000	Canadian	1108	1912	2012	2,700	-352	-3,052	> -100%
07227500	Canadian	1109	1939	2015	3,006	650	-2,356	-100 to -50%
07228000	Canadian	1109	1939	2015	2,849	61	-2,788	-100 to -50%
07237500	North Canadian	1110	1939	2015	1,960	524	-1,436	-100 to -50%
07239000	North Canadian	1110	1938	2002	2,054	788	-1,265	-100 to -50%
07164500	Arkansas	1111	1926	2015	57,449	95,619	38,171	50 to 100%

Table H-2. Change in maximum annual daily streamflow at index stations with significant trends.

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
03016000	Allegheny	0501	1942	2013	1,311	564	-747	-100 to -50%
03025500	Allegheny	0501	1915	2013	2,179	1,295	-883	-50 to -25%
03031500	Allegheny	0501	1933	2013	2,675	1,927	-748	-50 to -25%
03036500	Allegheny	0501	1905	2013	3,682	2,075	-1,607	-50 to -25%
03049500	Allegheny	0501	1939	2013	3,628	2,298	-1,329	-50 to -25%
03075070	Monongahela	0502	1934	2013	2,495	1,892	-603	-25 to -10%
03086000	Ohio	0503	1934	2014	6,107	4,234	-1,873	-50 to -25%
03144500	Muskingum	0504	1922	2014	1,050	639	-411	-50 to -25%
03150000	Muskingum	0504	1922	2014	1,429	872	-556	-50 to -25%
03193000	Kanawha	0505	1878	2012	3,464	2,064	-1,400	-50 to -25%
03231500	Scioto	0506	1921	2014	1,219	771	-448	-50 to -25%
03234500	Scioto	0506	1931	2014	1,317	963	-354	-50 to -25%
03282000	Kentucky	0510	1926	2013	1,776	984	-792	-50 to -25%
03284000	Kentucky	0510	1908	2013	1,734	1,317	-417	-25 to -10%
03320000	Green	0511	1931	2013	1,647	1,236	-411	-25 to -10%
03325000	Wabash	0512	1924	2013	616	219	-397	-100 to -50%
03327500	Wabash	0512	1944	2013	678	299	-379	-100 to -50%
03329000	Wabash	0512	1924	2013	1,055	598	-457	-50 to -25%
03353000	White	0512	1905	2013	354	591	237	50 to 100%
03414000	Cumberland	0513	1940	1991	1,878	414	-1,464	-100 to -50%
03417500	Cumberland	0513	1923	1990	2,738	688	-2,050	-100 to -50%
03425000	Cumberland	0513	1923	1990	3,719	1,481	-2,238	-100 to -50%
03426310	Cumberland	0513	1932	2006	2,927	2,078	-849	-50 to -25%
03426500	Cumberland	0513	1932	1981	3,188	2,049	-1,139	-50 to -25%
03431500	Cumberland	0513	1893	2013	3,525	2,605	-921	-50 to -25%
03497000	Tennessee	0601	1900	1981	2,994	734	-2,260	-100 to -50%
03566000	Hiwassee	0602	1900	2013	1,056	518	-538	-100 to -50%
03568000	Tennessee	0602	1875	2007	6,664	3,009	-3,655	-100 to -50%
05261000	Mississippi	0701	1988	1999	282	643	362	> 100%
05267000	Mississippi	0701	1925	2014	343	579	236	50 to 100%
05288500	Mississippi	0701	1932	2013	730	1,014	284	25 to 50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
05331000	Mississippi	0701	1901	2015	803	1,663	860	> 100%
05292000	Minnesota	0702	1939	2013	6	65	59	> 100%
05311000	Minnesota	0702	1910	2013	50	211	161	> 100%
05325000	Minnesota	0702	1905	2013	263	801	537	> 100%
05330000	Minnesota	0702	1935	2013	399	883	484	> 100%
05333500	St. Croix	0703	1915	2013	121	150	29	10 to 25%
05336000	St. Croix	0703	1924	2009	269	387	118	25 to 50%
05339500	St. Croix	0703	1924	1960	351	830	479	> 100%
05340500	St. Croix	0703	1904	2013	523	788	264	50 to 100%
05344500	Mississippi	0704	1929	2015	1,426	2,414	988	50 to 100%
05378500	Mississippi	0704	1929	2011	2,131	3,346	1,215	50 to 100%
05383500	Mississippi	0704	1931	1954	1,506	4,137	2,631	> 100%
05391000	Wisconsin	0707	1937	2013	57	30	-27	-50 to -25%
05401500	Wisconsin	0707	1903	1949	1,405	654	-751	-100 to -50%
05407000	Wisconsin	0707	1914	2013	1,206	921	-285	-25 to -10%
05474500	Mississippi	0708	1879	2013	4,636	5,989	1,353	25 to 50%
05425500	Rock	0709	1932	2013	52	74	22	25 to 50%
05480500	Des Moines	0710	1914	2014	228	423	194	50 to 100%
05481300	Des Moines	0710	1968	2014	358	739	381	> 100%
05587450	Mississippi	0711	1934	2014	6,992	9,641	2,648	25 to 50%
05587500	Mississippi	0711	1934	1986	6,413	9,701	3,288	50 to 100%
05543500	Illinois	0712	1920	2013	1,008	1,792	785	50 to 100%
05568500	Illinois	0713	1940	2014	1,190	1,629	439	25 to 50%
05586100	Illinois	0713	1939	2015	1,634	2,257	622	25 to 50%
05592000	Kaskaskia	0714	1909	2014	305	76	-230	-100 to -50%
05593000	Kaskaskia	0714	1909	2014	470	211	-258	-100 to -50%
07026000	Obion	0801	1930	1990	592	1,041	449	50 to 100%
07047902	St. Francis	0802	1936	1974	560	945	385	50 to 100%
07287000	Yazoo	0803	1908	1979	886	665	-221	-25 to -10%
06065500	Missouri	1003	1923	2013	383	292	-91	-25 to -10%
06066500	Missouri	1003	1946	2013	482	270	-212	-50 to -25%
06090800	Missouri	1003	1891	2014	945	445	-500	-100 to -50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06101500	Marias	1003	1946	2014	84	47	-37	-50 to -25%
06109500	Missouri	1004	1936	2013	796	547	-249	-50 to -25%
06120500	Musselshell	1004	1908	2012	38	23	-15	-50 to -25%
06172000	Milk	1005	1915	1986	302	69	-233	-100 to -50%
06174500	Milk	1005	1940	2012	231	118	-113	-50 to -25%
06132000	Missouri	1006	1935	2015	625	261	-364	-100 to -50%
06177000	Missouri	1006	1929	2015	744	313	-431	-100 to -50%
06185500	Missouri	1006	1942	2013	718	359	-358	-50 to -25%
06279500	Bighorn	1008	1930	2015	406	172	-234	-100 to -50%
06294500	Bighorn	1008	1946	2013	433	165	-268	-100 to -50%
06326500	Powder	1009	1939	2013	257	96	-160	-100 to -50%
06309000	Yellowstone	1010	1929	2015	1,592	1,212	-379	-25 to -10%
06329500	Yellowstone	1010	1911	2012	2,400	1,101	-1,298	-100 to -50%
06386500	Cheyenne	1012	1949	2013	74	25	-49	-100 to -50%
06395000	Cheyenne	1012	1947	2013	70	25	-45	-100 to -50%
06338490	Missouri	1013	1970	2008	1,070	577	-493	-50 to -25%
06342500	Missouri	1013	1929	2012	2,304	440	-1,864	-100 to -50%
06440000	Missouri	1014	1934	1964	4,154	1,119	-3,035	-100 to -50%
06454500	Niobrara	1015	1947	1993	4	2	-3	-100 to -50%
06457500	Niobrara	1015	1930	1990	30	8	-21	-100 to -50%
06461500	Niobrara	1015	1946	2012	53	38	-14	-50 to -25%
06462000	Niobrara	1015	1953	1982	62	44	-18	-50 to -25%
06472000	James	1016	1951	2013	12	41	29	> 100%
06473000	James	1016	1946	2013	11	50	39	> 100%
06475000	James	1016	1951	2013	18	67	49	> 100%
06476000	James	1016	1944	2013	40	98	58	> 100%
06477000	James	1016	1951	2013	34	119	85	> 100%
06478500	James	1016	1929	2012	37	161	123	> 100%
06467500	Missouri	1017	1931	1994	3,173	491	-2,682	-100 to -50%
06627000	North Platte	1018	1904	1969	283	156	-127	-50 to -25%
06636000	North Platte	1018	1914	1958	369	71	-298	-100 to -50%
06641000	North Platte	1018	1906	1960	212	146	-66	-50 to -25%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06642000	North Platte	1018	1905	1997	206	77	-128	-100 to -50%
06652800	North Platte	1018	1958	2013	186	226	40	10 to 25%
06656000	North Platte	1018	1903	1997	245	132	-113	-50 to -25%
06657000	North Platte	1018	1916	2013	134	52	-82	-100 to -50%
06707500	South Platte	1019	1899	2006	49	28	-20	-50 to -25%
06720500	South Platte	1019	1927	2006	65	114	50	50 to 100%
06721000	South Platte	1019	1930	2013	59	124	65	> 100%
06754000	South Platte	1019	1902	2006	128	207	79	50 to 100%
06766000	Platte	1020	1940	1990	75	145	70	50 to 100%
06775500	Middle Loup	1021	1946	2013	17	19	2	10 to 25%
06794500	Loup	1021	1935	1977	500	280	-220	-50 to -25%
06800500	Elkhorn	1022	1929	2012	260	501	240	50 to 100%
06486000	Missouri	1023	1929	2013	2,916	890	-2,026	-100 to -50%
06607500	Little Sioux	1023	1943	2013	151	388	237	> 100%
06610000	Missouri	1023	1929	2013	2,935	1,518	-1,417	-50 to -25%
06824500	Republican	1025	1948	1993	33	3	-30	-100 to -50%
06828500	Republican	1025	1951	2015	51	-1	-52	> -100%
06829500	Republican	1025	1947	1992	39	-3	-41	> -100%
06837000	Republican	1025	1955	2013	50	-3	-53	> -100%
06843500	Republican	1025	1946	2012	103	-9	-111	> -100%
06844500	Republican	1025	1948	2014	100	8	-92	-100 to -50%
06849500	Republican	1025	1953	2005	48	15	-33	-100 to -50%
06853020	Republican	1025	1985	2007	109	35	-74	-100 to -50%
06853500	Republican	1025	1933	2015	251	36	-215	-100 to -50%
06854500	Republican	1025	1920	1971	257	139	-118	-50 to -25%
06856000	Republican	1025	1947	2013	264	109	-156	-100 to -50%
06860000	Smoky Hill	1026	1940	2014	34	5	-29	-100 to -50%
06861000	Smoky Hill	1026	1951	2013	77	-2	-79	> -100%
06862000	Smoky Hill	1026	1954	1980	8	-1	-9	> -100%
06864050	Smoky Hill	1026	1940	2010	188	64	-124	-100 to -50%
06865500	Smoky Hill	1026	1941	2014	85	22	-62	-100 to -50%
06926000	Osage	1029	1926	2013	2,083	1,271	-812	-50 to -25%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
07055000	White	1101	1929	1979	1,906	241	-1,665	-100 to -50%
07061000	White	1101	1938	2012	3,411	2,021	-1,390	-50 to -25%
07074500	White	1101	1928	2013	3,100	1,840	-1,260	-50 to -25%
07086000	Arkansas	1102	1911	2006	47	63	16	25 to 50%
07099500	Arkansas	1102	1895	1974	137	87	-50	-50 to -25%
07123000	Arkansas	1102	1913	2006	152	67	-85	-100 to -50%
07124000	Arkansas	1102	1940	2015	100	36	-64	-100 to -50%
07133000	Arkansas	1102	1914	2015	137	-2	-138	> -100%
07138000	Arkansas	1103	1903	2015	225	-20	-245	> -100%
07139000	Arkansas	1103	1923	2015	112	-4	-116	> -100%
07139500	Arkansas	1103	1903	2001	101	-12	-113	> -100%
07140000	Arkansas	1103	1945	2008	37	1	-37	-100 to -50%
07141300	Arkansas	1103	1941	2015	143	18	-125	-100 to -50%
07146500	Arkansas	1103	1903	2015	490	836	346	50 to 100%
07154500	Cimarron	1104	1951	2015	49	12	-37	-100 to -50%
07156900	Cimarron	1104	1966	2015	26	-1	-27	> -100%
07157950	Cimarron	1105	1961	2012	98	14	-84	-100 to -50%
07158000	Cimarron	1105	1938	2015	378	53	-324	-100 to -50%
07176000	Verdigris	1107	1936	2015	1,006	585	-421	-50 to -25%
07178600	Verdigris	1107	1945	1969	1,479	604	-875	-100 to -50%
07211500	Canadian	1108	1940	2015	76	13	-63	-100 to -50%
07221500	Canadian	1108	1913	2015	199	24	-175	-100 to -50%
07224500	Canadian	1108	1937	1971	175	-45	-220	> -100%
07227000	Canadian	1108	1912	2012	319	-60	-379	> -100%
07227500	Canadian	1109	1939	2015	343	36	-307	-100 to -50%
07228000	Canadian	1109	1939	2015	377	-64	-441	> -100%
07228500	Canadian	1109	1945	2015	512	180	-331	-100 to -50%
07231500	Canadian	1109	1906	2015	1,566	754	-812	-100 to -50%
07245000	Canadian	1109	1939	2015	2,163	514	-1,650	-100 to -50%
07237500	North Canadian	1110	1939	2015	138	-19	-157	> -100%
07239000	North Canadian	1110	1938	2002	94	-8	-101	> -100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
07246500	Arkansas	1111	1948	1969	8,478	1,689	-6,790	-100 to -50%
07250500	Arkansas	1111	1928	1969	7,818	4,295	-3,524	-50 to -25%
07258000	Arkansas	1111	1938	2013	7,702	2,668	-5,034	-100 to -50%
07337000	Red	1114	1937	2015	2,707	1,709	-997	-50 to -25%

Table H-3. Change in winter streamflow at index stations with significant trends.

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
03025500	Allegheny	0501	1915	2013	29,972	40,497	10,525	25 to 50%
03031500	Allegheny	0501	1933	2013	38,522	52,061	13,539	25 to 50%
03234500	Scioto	0506	1931	2014	11,641	19,192	7,551	50 to 100%
03336000	Wabash	0512	1940	2013	16,767	29,259	12,493	50 to 100%
03342000	Wabash	0512	1939	2013	24,799	46,629	21,829	50 to 100%
03347000	White	0512	1932	2013	547	938	391	50 to 100%
03348000	White	0512	1933	2012	873	1,744	871	50 to 100%
03353000	White	0512	1905	2013	2,477	6,068	3,591	> 100%
03384500	Ohio	0514	1941	1979	500,296	1,183,225	682,929	> 100%
03611500	Ohio	0514	1929	2014	814,536	1,098,349	283,813	25 to 50%
03568000	Tennessee	0602	1875	2007	138,989	113,508	-25,481	-25 to -10%
05211000	Mississippi	0701	1884	2013	1,135	4,452	3,317	> 100%
05220500	Mississippi	0701	1931	1989	2,326	5,944	3,619	> 100%
05261000	Mississippi	0701	1988	1999	4,832	12,871	8,039	> 100%
05267000	Mississippi	0701	1925	2014	4,521	10,308	5,787	> 100%
05288500	Mississippi	0701	1932	2013	7,514	15,314	7,800	> 100%
05331000	Mississippi	0701	1901	2015	6,646	19,145	12,499	> 100%
05292000	Minnesota	0702	1939	2013	24	94	71	> 100%
05301000	Minnesota	0702	1943	2013	172	894	722	> 100%
05311000	Minnesota	0702	1910	2013	-24	1,097	1,121	> 100%
05325000	Minnesota	0702	1905	2013	85	3,805	3,721	> 100%
05330000	Minnesota	0702	1935	2013	917	5,255	4,338	> 100%
05333500	St Croix	0703	1915	2013	2,166	2,584	418	10 to 25%
05339500	St Croix	0703	1924	1960	3,556	5,684	2,128	50 to 100%
05340500	St Croix	0703	1904	2013	4,256	7,055	2,799	50 to 100%
05344500	Mississippi	0704	1929	2015	15,309	30,508	15,199	50 to 100%
05378500	Mississippi	0704	1929	2011	28,508	54,230	25,722	50 to 100%
05383500	Mississippi	0704	1931	1954	28,283	43,885	15,603	50 to 100%
05389500	Mississippi	0706	1937	2012	37,817	68,199	30,382	50 to 100%
05391000	Wisconsin	0707	1937	2013	2,177	1,794	-384	-25 to -10%
05407000	Wisconsin	0707	1914	2013	13,732	18,403	4,671	25 to 50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
05420500	Mississippi	0708	1874	2013	56,864	82,054	25,191	25 to 50%
05449500	Iowa	0708	1941	2014	109	264	155	> 100%
05454500	Iowa	0708	1904	2013	1,810	3,527	1,717	50 to 100%
05465500	Iowa	0708	1915	2013	7,566	13,745	6,179	50 to 100%
05474500	Mississippi	0708	1879	2013	65,594	131,939	66,344	> 100%
05425500	Rock	0709	1932	2013	481	1,244	763	> 100%
05430500	Rock	0709	1915	2013	2,620	4,981	2,361	50 to 100%
05437500	Rock	0709	1904	2013	5,344	11,284	5,940	> 100%
05446500	Rock	0709	1940	2013	9,451	19,315	9,864	> 100%
05476000	Des Moines	0710	1936	2013	32	311	279	> 100%
05488500	Des Moines	0710	1921	2013	3,353	8,273	4,920	> 100%
05489500	Des Moines	0710	1918	2013	3,586	8,953	5,366	> 100%
05490500	Des Moines	0710	1904	2013	3,533	9,442	5,909	> 100%
05587450	Mississippi	0711	1934	2014	148,310	232,495	84,186	50 to 100%
05587500	Mississippi	0711	1934	1986	135,046	219,532	84,486	50 to 100%
05568500	Illinois	0713	1940	2014	30,676	45,801	15,125	25 to 50%
05592000	Kaskaskia	0714	1909	2014	1,344	3,900	2,556	> 100%
05592500	Kaskaskia	0714	1909	2014	3,053	6,546	3,493	> 100%
05593000	Kaskaskia	0714	1909	2014	2,679	9,637	6,958	> 100%
07010000	Mississippi	0714	1863	2013	217,969	368,045	150,077	50 to 100%
07020500	Mississippi	0714	1943	2014	292,422	425,139	132,717	25 to 50%
07022000	Mississippi	0714	1934	2014	269,048	460,108	191,060	50 to 100%
07032000	Mississippi	0801	1934	1993	945,742	1,676,660	730,919	50 to 100%
06090300	Missouri	1003	1957	2014	17,253	13,959	-3,294	-25 to -10%
06090800	Missouri	1003	1891	2014	9,944	16,744	6,800	50 to 100%
06101500	Marias	1003	1946	2014	602	1,479	877	> 100%
06109500	Missouri	1004	1936	2013	14,088	18,026	3,938	25 to 50%
06115000	Missouri	1004	1935	1967	9,401	20,952	11,550	> 100%
06115200	Missouri	1004	1935	2012	14,912	19,247	4,335	25 to 50%
06126500	Musselshell	1004	1947	2012	218	125	-93	-50 to -25%
06132000	Missouri	1006	1935	2015	14,414	30,062	15,648	> 100%
06177000	Missouri	1006	1929	2015	12,648	30,516	17,868	> 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06274300	Bighorn	1008	1984	2013	3,504	2,130	-1,374	-50 to -25%
06294700	Bighorn	1008	1946	1980	5,361	10,541	5,180	50 to 100%
06298000	Tongue	1009	1919	2013	153	132	-20	-25 to -10%
06307500	Tongue	1009	1940	2014	490	396	-94	-25 to -10%
06307616	Tongue	1009	1980	2012	533	340	-194	-50 to -25%
06307830	Tongue	1009	1974	2005	633	269	-364	-100 to -50%
06309000	Yellowstone	1010	1929	2015	11,858	17,135	5,277	25 to 50%
06327500	Yellowstone	1010	1898	2013	11,911	14,019	2,108	10 to 25%
06329500	Yellowstone	1010	1911	2012	13,304	17,051	3,747	25 to 50%
06395000	Cheyenne	1012	1947	2013	25	55	29	> 100%
06401500	Cheyenne	1012	1946	1977	126	-25	-151	> -100%
06438500	Cheyenne	1012	1951	2012	263	840	577	> 100%
06338490	Missouri	1013	1970	2008	71,580	41,685	-29,895	-50 to -25%
06342500	Missouri	1013	1929	2012	24,804	67,158	42,354	> 100%
06350000	Cannonball	1013	1951	2015	8	16	8	50 to 100%
06354000	Cannonball	1013	1935	2012	26	71	45	> 100%
06440000	Missouri	1014	1934	1964	16,763	32,404	15,641	50 to 100%
06452000	White	1014	1929	2012	169	518	350	> 100%
06454000	Niobrara	1015	1956	1993	10	5	-5	-50 to -25%
06454100	Niobrara	1015	1958	1990	49	32	-17	-50 to -25%
06454500	Niobrara	1015	1947	1993	114	56	-58	-100 to -50%
06455500	Niobrara	1015	1947	1990	3	2	-1	-50 to -25%
06457500	Niobrara	1015	1930	1990	348	267	-81	-25 to -10%
06465000	Niobrara	1015	1928	2001	2,674	4,111	1,437	50 to 100%
06465500	Niobrara	1015	1939	2012	2,807	4,928	2,121	50 to 100%
06468170	James	1016	1969	2013	0	7	7	> 100%
06470000	James	1016	1929	2013	1	31	30	> 100%
06470500	James	1016	1951	2013	11	104	93	> 100%
06470878	James	1016	1982	2013	38	201	162	> 100%
06471000	James	1016	1946	2013	-15	147	162	> 100%
06472000	James	1016	1951	2013	8	254	247	> 100%
06473000	James	1016	1946	2013	-34	248	282	> 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06475000	James	1016	1951	2013	-30	318	348	> 100%
06476000	James	1016	1944	2013	-57	403	460	> 100%
06477000	James	1016	1951	2013	-53	476	529	> 100%
06478500	James	1016	1929	2012	-43	547	590	> 100%
06467500	Missouri	1017	1931	1994	19,159	48,501	29,342	> 100%
06479438	Big Sioux	1017	1973	2013	4	17	14	> 100%
06479500	Big Sioux	1017	1946	2013	2	9	7	> 100%
06479525	Big Sioux	1017	1977	2013	23	72	49	> 100%
06480000	Big Sioux	1017	1954	2013	2	266	264	> 100%
06481000	Big Sioux	1017	1949	2013	8	382	374	> 100%
06482020	Big Sioux	1017	1972	2013	193	509	316	> 100%
06485500	Big Sioux	1017	1929	2013	177	1,715	1,538	> 100%
06620000	North Platte	1018	1916	2015	197	274	77	25 to 50%
06630000	North Platte	1018	1940	2013	726	1,013	287	25 to 50%
06641000	North Platte	1018	1906	1960	521	-16	-538	> -100%
06642000	North Platte	1018	1905	1997	-938	2,387	3,325	> 100%
06652000	North Platte	1018	1959	2013	2,868	1,511	-1,357	-50 to -25%
06656000	North Platte	1018	1903	1997	1,033	-194	-1,227	> -100%
06657000	North Platte	1018	1916	2013	301	-74	-375	> -100%
06674500	North Platte	1018	1930	2013	1,203	348	-855	-100 to -50%
06679500	North Platte	1018	1931	1997	1,709	1,143	-566	-50 to -25%
06682000	North Platte	1018	1924	1990	2,837	1,664	-1,172	-50 to -25%
06684500	North Platte	1018	1931	1990	3,112	2,470	-642	-25 to -10%
06686000	North Platte	1018	1932	1997	3,496	2,602	-894	-50 to -25%
06690500	North Platte	1018	1943	1991	23	4	-19	-100 to -50%
06696000	South Platte	1019	1930	1997	1	139	138	> 100%
06701500	South Platte	1019	1925	2006	47	237	190	> 100%
06707500	South Platte	1019	1899	2006	194	448	253	> 100%
06711565	South Platte	1019	1984	2013	232	138	-94	-50 to -25%
06714215	South Platte	1019	1983	2013	263	5	-258	-100 to -50%
06720500	South Platte	1019	1927	2006	168	847	678	> 100%
06754000	South Platte	1019	1902	2006	1,305	1,969	665	50 to 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06758500	South Platte	1019	1953	2006	793	1,740	947	> 100%
06765000	South Platte	1019	1940	1969	576	-99	-676	> -100%
06805500	Platte	1020	1954	2012	9,791	19,802	10,011	> 100%
06775500	Middle Loup	1021	1946	2013	962	1,222	260	25 to 50%
06793000	Loup	1021	1930	2012	1,249	4,253	3,005	> 100%
06797500	Elkhorn	1022	1948	2013	151	276	124	50 to 100%
06799000	Elkhorn	1022	1946	2013	720	1,067	347	25 to 50%
06799350	Elkhorn	1022	1973	2012	1,372	2,365	993	50 to 100%
06800500	Elkhorn	1022	1929	2012	840	3,351	2,511	> 100%
06486000	Missouri	1023	1929	2013	23,952	55,317	31,366	> 100%
06607500	Little Sioux	1023	1943	2013	109	2,517	2,408	> 100%
06610000	Missouri	1023	1929	2013	21,959	64,230	42,270	> 100%
06807000	Missouri	1024	1930	2013	32,120	78,906	46,787	> 100%
06813500	Missouri	1024	1950	2014	47,464	83,656	36,191	50 to 100%
06818000	Missouri	1024	1929	2013	35,009	89,135	54,126	> 100%
06824500	Republican	1025	1948	1993	290	200	-90	-50 to -25%
06828500	Republican	1025	1951	2015	368	110	-259	-100 to -50%
06829500	Republican	1025	1947	1992	258	-71	-329	> -100%
06837000	Republican	1025	1955	2013	399	104	-295	-100 to -50%
06843500	Republican	1025	1946	2012	752	127	-625	-100 to -50%
06844500	Republican	1025	1948	2014	745	180	-565	-100 to -50%
06849500	Republican	1025	1953	2005	105	9	-95	-100 to -50%
06853020	Republican	1025	1985	2007	368	75	-293	-100 to -50%
06853500	Republican	1025	1933	2015	1,058	191	-867	-100 to -50%
06854500	Republican	1025	1920	1971	1,376	583	-793	-100 to -50%
06856000	Republican	1025	1947	2013	1,043	424	-620	-100 to -50%
06856600	Republican	1025	1918	2015	1,435	677	-758	-100 to -50%
06860000	Smoky Hill	1026	1940	2014	16	-2	-17	> -100%
06861000	Smoky Hill	1026	1951	2013	22	4	-18	-100 to -50%
06862000	Smoky Hill	1026	1954	1980	7	-1	-8	> -100%
06887500	Kansas	1027	1920	2013	3,949	7,303	3,353	50 to 100%
06889000	Kansas	1027	1919	2015	4,495	7,837	3,342	50 to 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06892350	Kansas	1027	1918	2013	5,394	10,681	5,287	50 to 100%
06893000	Missouri	1030	1929	2013	44,176	103,172	58,996	> 100%
06895500	Missouri	1030	1929	2013	44,517	108,475	63,958	> 100%
06909000	Missouri	1030	1926	2013	59,434	123,245	63,811	> 100%
06934500	Missouri	1030	1929	2013	87,139	175,234	88,095	> 100%
07081200	Arkansas	1102	1968	2015	35	46	11	25 to 50%
07086000	Arkansas	1102	1911	2006	129	381	252	> 100%
07093700	Arkansas	1102	1962	2006	757	1,081	323	25 to 50%
07096000	Arkansas	1102	1890	2012	788	1,014	226	25 to 50%
07097000	Arkansas	1102	1940	2006	739	1,053	313	25 to 50%
07099500	Arkansas	1102	1895	1974	936	660	-275	-50 to -25%
07109500	Arkansas	1102	1940	2015	1,247	767	-480	-50 to -25%
07123000	Arkansas	1102	1913	2006	108	290	182	> 100%
07124000	Arkansas	1102	1940	2015	164	378	214	> 100%
07130500	Arkansas	1102	1939	2015	17	4	-13	-100 to -50%
07133000	Arkansas	1102	1914	2015	180	9	-171	-100 to -50%
07138000	Arkansas	1103	1903	2015	413	256	-157	-50 to -25%
07139500	Arkansas	1103	1903	2001	503	164	-339	-100 to -50%
07140000	Arkansas	1103	1945	2008	519	-84	-603	> -100%
07141300	Arkansas	1103	1941	2015	597	-73	-669	> -100%
07146500	Arkansas	1103	1903	2015	1,508	3,092	1,585	> 100%
07154500	Cimarron	1104	1951	2015	6	2	-4	-100 to -50%
07156900	Cimarron	1104	1966	2015	198	53	-145	-100 to -50%
07157950	Cimarron	1105	1961	2012	305	114	-191	-100 to -50%
07160000	Cimarron	1105	1938	2015	528	1,878	1,350	> 100%
07161000	Cimarron	1105	1940	1989	562	1,545	983	> 100%
07152500	Arkansas	1106	1926	2015	3,490	8,914	5,424	> 100%
07224500	Canadian	1108	1937	1971	37	2	-34	-100 to -50%
07227000	Canadian	1108	1912	2012	51	-1	-52	> -100%
07228500	Canadian	1109	1945	2015	266	652	385	> 100%
07242000	North Canadian	1110	1938	2015	579	1,701	1,121	> 100%
07164500	Arkansas	1111	1926	2015	5,225	11,473	6,248	> 100%

Table H-4. Change in spring streamflow at index stations with significant trends.

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
03016000	Allegheny	0501	1942	2013	32,666	18,793	-13,873	-50 to -25%
03025500	Allegheny	0501	1915	2013	48,445	39,093	-9,352	-25 to -10%
03031500	Allegheny	0501	1933	2013	64,243	48,259	-15,984	-25 to -10%
03036500	Allegheny	0501	1905	2013	75,670	57,747	-17,923	-25 to -10%
03049500	Allegheny	0501	1939	2013	95,956	66,832	-29,124	-50 to -25%
03274000	Great Miami	0508	1928	2013	11,889	16,584	4,695	25 to 50%
03351000	White	0512	1930	2013	4,041	5,709	1,669	25 to 50%
03497000	Tennessee	0601	1900	1981	53,929	22,900	-31,029	-100 to -50%
03566000	Hiwassee	0602	1900	2013	19,933	9,008	-10,925	-100 to -50%
03568000	Tennessee	0602	1875	2007	159,774	66,213	-93,562	-100 to -50%
03589500	Tennessee	0603	1895	2002	210,867	129,398	-81,469	-50 to -25%
03609500	Tennessee	0604	1890	1983	277,932	191,014	-86,918	-50 to -25%
05211000	Mississippi	0701	1884	2013	1,694	3,654	1,960	> 100%
05220500	Mississippi	0701	1931	1989	5,359	8,764	3,405	50 to 100%
05267000	Mississippi	0701	1925	2014	12,803	24,868	12,066	50 to 100%
05288500	Mississippi	0701	1932	2013	26,377	41,829	15,452	50 to 100%
05331000	Mississippi	0701	1901	2015	30,198	72,671	42,473	> 100%
05311000	Minnesota	0702	1910	2013	1,041	7,781	6,740	> 100%
05325000	Minnesota	0702	1905	2013	5,949	26,970	21,021	> 100%
05330000	Minnesota	0702	1935	2013	12,220	31,793	19,574	> 100%
05339500	St. Croix	0703	1924	1960	11,973	19,338	7,365	50 to 100%
05340500	St. Croix	0703	1904	2013	14,731	22,405	7,675	50 to 100%
05344500	Mississippi	0704	1929	2015	57,386	99,884	42,498	50 to 100%
05378500	Mississippi	0704	1929	2011	92,619	151,686	59,067	50 to 100%
05383500	Mississippi	0704	1931	1954	69,177	173,199	104,022	> 100%
05356000	Chippewa	0705	1913	2014	1,278	1,795	517	25 to 50%
05389500	Mississippi	0706	1937	2012	129,050	178,699	49,649	25 to 50%
05391000	Wisconsin	0707	1937	2013	1,724	1,183	-541	-50 to -25%
05400760	Wisconsin	0707	1915	2014	23,083	18,006	-5,077	-25 to -10%
05401500	Wisconsin	0707	1903	1949	30,172	17,539	-12,633	-50 to -25%
05449500	Iowa	0708	1941	2014	687	1,547	860	> 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
05451500	Iowa	0708	1915	2014	2,559	5,334	2,774	> 100%
05454500	Iowa	0708	1904	2013	5,414	10,242	4,828	50 to 100%
05465500	Iowa	0708	1915	2013	21,985	43,422	21,437	50 to 100%
05474500	Mississippi	0708	1879	2013	225,573	317,114	91,541	25 to 50%
05425500	Rock	0709	1932	2013	1,934	3,556	1,622	50 to 100%
05430500	Rock	0709	1915	2013	7,486	10,177	2,691	25 to 50%
05443500	Rock	0709	1915	2014	19,334	27,416	8,082	25 to 50%
05446500	Rock	0709	1940	2013	20,934	32,208	11,274	50 to 100%
05476000	Des Moines	0710	1936	2013	1,151	2,713	1,562	> 100%
05480500	Des Moines	0710	1914	2014	4,926	10,968	6,043	> 100%
05482000	Des Moines	0710	1916	2014	7,582	16,431	8,849	> 100%
05488500	Des Moines	0710	1921	2013	13,479	34,315	20,836	> 100%
05489500	Des Moines	0710	1918	2013	15,887	36,154	20,268	> 100%
05490500	Des Moines	0710	1904	2013	17,708	36,584	18,875	> 100%
05587450	Mississippi	0711	1934	2014	366,122	537,750	171,628	25 to 50%
05587500	Mississippi	0711	1934	1986	333,729	539,466	205,737	50 to 100%
07010000	Mississippi	0714	1863	2013	596,455	783,715	187,261	25 to 50%
07022000	Mississippi	0714	1934	2014	644,099	935,470	291,371	25 to 50%
07047800	St. Francis	0802	1931	2009	12,232	6,074	-6,158	-100 to -50%
07288955	Yazoo	0803	1996	2012	73,397	28,936	-44,461	-100 to -50%
07291000	Homochitto	0806	1939	2015	1,136	720	-416	-50 to -25%
06090800	Missouri	1003	1891	2014	27,983	19,621	-8,362	-50 to -25%
06099500	Marias	1003	1903	2015	4,390	3,079	-1,312	-50 to -25%
06101500	Marias	1003	1946	2014	2,684	1,345	-1,339	-50 to -25%
06120500	Musselshell	1004	1908	2012	811	312	-499	-100 to -50%
06126500	Musselshell	1004	1947	2012	799	279	-520	-100 to -50%
06172000	Milk	1005	1915	1986	4,525	1,131	-3,394	-100 to -50%
06174500	Milk	1005	1940	2012	4,286	2,007	-2,279	-100 to -50%
06186500	Yellowstone	1007	1927	2015	1,647	2,095	448	25 to 50%
06191500	Yellowstone	1007	1890	2014	5,990	8,737	2,748	25 to 50%
06192500	Yellowstone	1007	1898	2013	7,624	9,869	2,245	25 to 50%
06279500	BIGHORN	1008	1930	2015	6,618	4,648	-1,970	-50 to -25%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06294500	Bighorn	1008	1946	2013	11,221	7,545	-3,675	-50 to -25%
06307830	Tongue	1009	1974	2005	1,364	501	-863	-100 to -50%
06329500	Yellowstone	1010	1911	2012	38,659	27,847	-10,813	-50 to -25%
06401500	Cheyenne	1012	1946	1977	281	22	-260	-100 to -50%
06338490	Missouri	1013	1970	2008	62,530	35,999	-26,531	-50 to -25%
06342500	Missouri	1013	1929	2012	66,129	49,493	-16,636	-50 to -25%
06454000	Niobrara	1015	1956	1993	16	10	-7	-50 to -25%
06454500	Niobrara	1015	1947	1993	124	97	-27	-25 to -10%
06455500	Niobrara	1015	1947	1990	5	2	-3	-100 to -50%
06457500	Niobrara	1015	1930	1990	450	316	-133	-50 to -25%
06462000	Niobrara	1015	1953	1982	3,012	2,293	-719	-25 to -10%
06465000	Niobrara	1015	1928	2001	4,258	6,082	1,824	25 to 50%
06470000	James	1016	1929	2013	132	658	526	> 100%
06470500	James	1016	1951	2013	255	1,281	1,026	> 100%
06471000	James	1016	1946	2013	398	1,252	853	> 100%
06472000	James	1016	1951	2013	380	1,367	987	> 100%
06473000	James	1016	1946	2013	439	1,992	1,554	> 100%
06475000	James	1016	1951	2013	565	2,331	1,767	> 100%
06477000	James	1016	1951	2013	908	3,718	2,810	> 100%
06478500	James	1016	1929	2012	1,074	4,965	3,891	> 100%
06480000	Big Sioux	1017	1954	2013	621	2,650	2,029	> 100%
06481000	Big Sioux	1017	1949	2013	1,253	3,342	2,089	> 100%
06485500	Big Sioux	1017	1929	2013	2,904	9,688	6,785	> 100%
06627000	North Platte	1018	1904	1969	5,924	3,351	-2,572	-50 to -25%
06636000	North Platte	1018	1914	1958	8,608	2,955	-5,653	-100 to -50%
06642000	North Platte	1018	1905	1997	660	3,327	2,667	> 100%
06656000	North Platte	1018	1903	1997	5,377	1,735	-3,641	-100 to -50%
06657000	North Platte	1018	1916	2013	2,014	414	-1,600	-100 to -50%
06674500	North Platte	1018	1930	2013	1,649	795	-855	-100 to -50%
06696000	South Platte	1019	1930	1997	130	232	103	50 to 100%
06701500	South Platte	1019	1925	2006	249	473	224	50 to 100%
06714215	South Platte	1019	1983	2013	1,353	156	-1,197	-100 to -50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06720500	South Platte	1019	1927	2006	800	1,458	658	50 to 100%
06765000	South Platte	1019	1940	1969	863	61	-802	-100 to -50%
06805500	Platte	1020	1954	2012	21,376	29,548	8,172	25 to 50%
06775500	Middle Loup	1021	1946	2013	1,046	1,365	319	25 to 50%
06794500	Loup	1021	1935	1977	5,088	1,446	-3,642	-100 to -50%
06800500	Elkhorn	1022	1929	2012	2,793	7,604	4,812	> 100%
06607500	Little Sioux	1023	1943	2013	1,575	8,755	7,180	> 100%
06824500	Republican	1025	1948	1993	368	232	-136	-50 to -25%
06828500	Republican	1025	1951	2015	632	114	-517	-100 to -50%
06829500	Republican	1025	1947	1992	549	-97	-645	> -100%
06837000	Republican	1025	1955	2013	556	93	-463	-100 to -50%
06843500	Republican	1025	1946	2012	1,197	133	-1,064	-100 to -50%
06844500	Republican	1025	1948	2014	1,312	268	-1,044	-100 to -50%
06849500	Republican	1025	1953	2005	550	68	-482	-100 to -50%
06853500	Republican	1025	1933	2015	2,126	421	-1,705	-100 to -50%
06854500	Republican	1025	1920	1971	2,720	1,185	-1,536	-100 to -50%
06856000	Republican	1025	1947	2013	2,247	1,056	-1,191	-100 to -50%
06856600	Republican	1025	1918	2015	3,155	1,918	-1,237	-50 to -25%
06857100	Republican	1025	1964	2014	2,632	1,110	-1,522	-100 to -50%
06860000	Smoky Hill	1026	1940	2014	41	-2	-43	> -100%
06861000	Smoky Hill	1026	1951	2013	69	8	-61	-100 to -50%
06862000	Smoky Hill	1026	1954	1980	9	-2	-11	> -100%
06897500	Grand	1028	1922	2013	2,244	7,886	5,642	> 100%
06902000	Grand	1028	1925	2013	9,203	25,076	15,872	> 100%
06934500	Missouri	1030	1929	2013	223,961	323,993	100,032	25 to 50%
07086000	Arkansas	1102	1911	2006	762	1,038	277	25 to 50%
07096000	Arkansas	1102	1890	2012	1,771	1,359	-412	-25 to -10%
07099500	Arkansas	1102	1895	1974	1,733	1,095	-638	-50 to -25%
07124000	Arkansas	1102	1940	2015	197	395	198	> 100%
07138000	Arkansas	1103	1903	2015	706	307	-399	-100 to -50%
07139500	Arkansas	1103	1903	2001	574	169	-405	-100 to -50%
07140000	Arkansas	1103	1945	2008	539	-39	-579	> -100%

Station	River	HUC4	Year		Streamflow [m^3/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m^3/s]	%Change
07141300	Arkansas	1103	1941	2015	808	50	-758	-100 to -50%
07146500	Arkansas	1103	1903	2015	3,566	7,762	4,197	> 100%
07154500	Cimarron	1104	1951	2015	12	3	-9	-100 to -50%
07156900	Cimarron	1104	1966	2015	201	67	-133	-100 to -50%
07158000	Cimarron	1105	1938	2015	1,184	546	-638	-100 to -50%
07152500	Arkansas	1106	1926	2015	13,129	24,360	11,232	50 to 100%
07183000	Neosho	1107	1896	2015	4,170	7,637	3,468	50 to 100%
07183500	Neosho	1107	1922	2015	6,617	12,028	5,411	50 to 100%
07224500	Canadian	1108	1937	1971	62	-3	-64	> -100%
07227000	Canadian	1108	1912	2012	256	-33	-288	> -100%
07227500	Canadian	1109	1939	2015	501	60	-440	-100 to -50%
07239000	North Canadian	1110	1938	2002	697	182	-515	-100 to -50%

Table H-5. Change in summer streamflow at index stations with significant trends.

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
Station	River	HUC4	Min	Max	Min Year	Max Year	[m3/s]	%Change
03025500	Allegheny	0501	1915	2013	9,804	15,370	5,566	50 to 100%
03031500	Allegheny	0501	1933	2013	13,605	21,038	7,432	50 to 100%
03036500	Allegheny	0501	1905	2013	15,148	22,985	7,837	50 to 100%
03151000	Ohio	0503	1941	1967	81,657	36,519	-45,138	-100 to -50%
03150000	Muskingum	0504	1922	2014	9,115	15,350	6,234	50 to 100%
03221000	Scioto	0506	1922	2013	718	1,545	827	> 100%
03227500	Scioto	0506	1921	2013	1,179	3,171	1,993	> 100%
03231500	Scioto	0506	1921	2014	3,394	8,009	4,614	> 100%
03234500	Scioto	0506	1931	2014	5,222	9,868	4,645	50 to 100%
03271500	Great Miami	0508	1919	1994	2,584	5,232	2,648	> 100%
03274000	Great Miami	0508	1928	2013	3,967	7,504	3,536	50 to 100%
03206000	Ohio	0509	1935	1967	140,789	54,132	-86,657	-100 to -50%
03325000	Wabash	0512	1924	2013	1,524	3,048	1,524	> 100%
03329000	Wabash	0512	1924	2013	3,671	7,467	3,797	> 100%
03335500	Wabash	0512	1924	2013	7,774	15,992	8,218	> 100%
03336000	Wabash	0512	1940	2013	10,529	19,010	8,480	50 to 100%
03340500	Wabash	0512	1928	2013	13,229	25,432	12,203	50 to 100%
03341500	Wabash	0512	1928	2013	15,101	28,083	12,982	50 to 100%
03342000	Wabash	0512	1939	2013	17,773	32,390	14,616	50 to 100%
03343000	Wabash	0512	1930	1993	16,297	29,523	13,226	50 to 100%
03347000	White	0512	1932	2013	206	466	260	> 100%
03348000	White	0512	1933	2012	464	897	434	50 to 100%
03351000	White	0512	1930	2013	1,163	2,575	1,412	> 100%
03353000	White	0512	1905	2013	1,110	3,149	2,039	> 100%
03354000	White	0512	1931	2014	2,332	5,829	3,497	> 100%
03377500	Wabash	0512	1928	2013	36,466	67,712	31,245	50 to 100%
03414000	Cumberland	0513	1940	1991	9,757	23,331	13,574	> 100%
03417500	Cumberland	0513	1923	1990	8,687	29,656	20,969	> 100%
03425000	Cumberland	0513	1923	1990	15,253	35,738	20,485	> 100%
03426310	Cumberland	0513	1932	2006	21,142	38,634	17,492	50 to 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
03426500	Cumberland	0513	1932	1981	17,365	37,041	19,676	> 100%
03611500	Ohio	0514	1929	2014	347,915	480,738	132,823	25 to 50%
03497000	Tennessee	0601	1900	1981	22,502	35,065	12,563	50 to 100%
03568000	Tennessee	0602	1875	2007	61,965	78,883	16,918	25 to 50%
03571850	Tennessee	0603	1931	1986	48,871	101,993	53,122	> 100%
03575500	Tennessee	0603	1925	1994	63,969	91,662	27,693	25 to 50%
03589500	Tennessee	0603	1895	2002	74,831	97,792	22,962	25 to 50%
03593500	Tennessee	0604	1931	2004	78,801	109,967	31,166	25 to 50%
03609500	Tennessee	0604	1890	1983	87,185	111,884	24,699	25 to 50%
05220500	Mississippi	0701	1931	1989	3,571	6,877	3,306	50 to 100%
05261000	Mississippi	0701	1988	1999	6,603	19,657	13,053	> 100%
05267000	Mississippi	0701	1925	2014	8,341	18,111	9,770	> 100%
05288500	Mississippi	0701	1932	2013	15,759	30,208	14,449	50 to 100%
05331000	Mississippi	0701	1901	2015	21,373	49,936	28,564	> 100%
05311000	Minnesota	0702	1910	2013	618	4,235	3,617	> 100%
05325000	Minnesota	0702	1905	2013	3,144	17,980	14,837	> 100%
05330000	Minnesota	0702	1935	2013	6,616	22,311	15,695	> 100%
05339500	St. Croix	0703	1924	1960	4,810	13,627	8,817	> 100%
05340500	St. Croix	0703	1904	2013	8,066	12,746	4,680	50 to 100%
05344500	Mississippi	0704	1929	2015	30,231	76,086	45,855	> 100%
05378500	Mississippi	0704	1929	2011	56,442	104,002	47,560	50 to 100%
05383500	Mississippi	0704	1931	1954	34,789	125,894	91,105	> 100%
05389500	Mississippi	0706	1937	2012	82,544	126,923	44,380	50 to 100%
05391000	Wisconsin	0707	1937	2013	2,132	1,128	-1,004	-50 to -25%
05401500	Wisconsin	0707	1903	1949	17,925	9,263	-8,662	-50 to -25%
05449500	Iowa	0708	1941	2014	441	1,193	752	> 100%
05451500	Iowa	0708	1915	2014	1,254	4,332	3,078	> 100%
05453100	Iowa	0708	1957	2014	3,685	9,069	5,384	> 100%
05454500	Iowa	0708	1904	2013	2,373	9,111	6,739	> 100%
05455700	Iowa	0708	1957	2013	6,240	13,083	6,844	> 100%
05465500	Iowa	0708	1915	2013	10,818	35,257	24,439	> 100%
05425500	Rock	0709	1932	2013	484	1,461	977	> 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
05427570	Rock	0709	1976	2010	2,204	5,747	3,542	> 100%
05430500	Rock	0709	1915	2013	2,568	5,131	2,563	50 to 100%
05437500	Rock	0709	1904	2013	6,063	12,226	6,163	> 100%
05443500	Rock	0709	1915	2014	7,501	19,406	11,905	> 100%
05446500	Rock	0709	1940	2013	9,120	22,745	13,624	> 100%
05476000	Des Moines	0710	1936	2013	527	1,964	1,436	> 100%
05476750	Des Moines	0710	1965	2014	1,724	5,234	3,510	> 100%
05480500	Des Moines	0710	1914	2014	2,769	8,610	5,841	> 100%
05481300	Des Moines	0710	1968	2014	6,303	14,115	7,812	> 100%
05481500	Des Moines	0710	1921	1967	2,990	6,624	3,634	> 100%
05482000	Des Moines	0710	1916	2014	3,808	16,062	12,254	> 100%
05485500	Des Moines	0710	1941	2014	10,844	25,211	14,367	> 100%
05488500	Des Moines	0710	1921	2013	6,503	34,725	28,221	> 100%
05489500	Des Moines	0710	1918	2013	8,494	35,305	26,811	> 100%
05490500	Des Moines	0710	1904	2013	8,333	35,563	27,229	> 100%
05587450	Mississippi	0711	1934	2014	213,238	407,536	194,298	50 to 100%
05568500	Illinois	0713	1940	2014	29,607	43,029	13,422	25 to 50%
05586100	Illinois	0713	1939	2015	43,784	70,487	26,704	50 to 100%
07022000	Mississippi	0714	1934	2014	468,886	726,904	258,019	50 to 100%
07026000	Obion	0801	1930	1990	2,585	4,632	2,047	50 to 100%
07287000	Yazoo	0803	1908	1979	9,035	26,339	17,304	> 100%
07360000	Ouachita	0804	1930	1976	1,234	6,256	5,022	> 100%
07362000	Ouachita	0804	1929	2015	3,915	14,690	10,775	> 100%
06054500	Missouri	1003	1911	2014	21,801	13,840	-7,961	-50 to -25%
06090800	Missouri	1003	1891	2014	34,054	20,158	-13,896	-50 to -25%
06099500	Marias	1003	1903	2015	3,940	2,680	-1,260	-50 to -25%
06140500	Milk	1005	1900	2013	862	2,859	1,997	> 100%
06279500	Bighorn	1008	1930	2015	10,749	6,352	-4,398	-50 to -25%
06294500	Bighorn	1008	1946	2013	15,031	9,621	-5,410	-50 to -25%
06327500	Yellowstone	1010	1898	2013	89,546	46,383	-43,163	-50 to -25%
06329500	Yellowstone	1010	1911	2012	77,729	42,075	-35,655	-50 to -25%
06386500	Cheyenne	1012	1949	2013	382	48	-334	-100 to -50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06395000	Cheyenne	1012	1947	2013	479	97	-383	-100 to -50%
06401500	Cheyenne	1012	1946	1977	480	96	-384	-100 to -50%
06423500	Cheyenne	1012	1929	2013	1,659	705	-954	-100 to -50%
06338490	Missouri	1013	1970	2008	70,916	44,498	-26,418	-50 to -25%
06342500	Missouri	1013	1929	2012	85,499	51,438	-34,061	-50 to -25%
06440000	Missouri	1014	1934	1964	105,406	62,552	-42,854	-50 to -25%
06446000	White	1014	1944	2013	183	98	-85	-50 to -25%
06454000	Niobrara	1015	1956	1993	10	6	-3	-50 to -25%
06457500	Niobrara	1015	1930	1990	316	221	-95	-50 to -25%
06461500	Niobrara	1015	1946	2012	1,929	1,560	-369	-25 to -10%
06462000	Niobrara	1015	1953	1982	2,257	1,528	-729	-50 to -25%
06465500	Niobrara	1015	1939	2012	2,307	4,797	2,490	> 100%
06468170	James	1016	1969	2013	4	159	155	> 100%
06470000	James	1016	1929	2013	-169	777	946	> 100%
06470500	James	1016	1951	2013	-74	1,363	1,437	> 100%
06470878	James	1016	1982	2013	134	2,462	2,328	> 100%
06471000	James	1016	1946	2013	-75	1,400	1,475	> 100%
06472000	James	1016	1951	2013	130	2,374	2,244	> 100%
06473000	James	1016	1946	2013	51	2,172	2,121	> 100%
06475000	James	1016	1951	2013	58	2,337	2,279	> 100%
06476000	James	1016	1944	2013	126	2,764	2,638	> 100%
06477000	James	1016	1951	2013	14	3,350	3,337	> 100%
06478500	James	1016	1929	2012	88	3,573	3,485	> 100%
06467500	Missouri	1017	1931	1994	101,955	77,985	-23,970	-25 to -10%
06480000	Big Sioux	1017	1954	2013	209	1,322	1,113	> 100%
06481000	Big Sioux	1017	1949	2013	434	1,703	1,268	> 100%
06482020	Big Sioux	1017	1972	2013	949	2,433	1,484	> 100%
06485500	Big Sioux	1017	1929	2013	1,297	5,678	4,382	> 100%
06627000	North Platte	1018	1904	1969	6,887	3,838	-3,049	-50 to -25%
06636000	North Platte	1018	1914	1958	9,641	2,386	-7,255	-100 to -50%
06641000	North Platte	1018	1906	1960	13,284	8,563	-4,722	-50 to -25%
06642000	North Platte	1018	1905	1997	11,262	4,830	-6,431	-100 to -50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06690500	North Platte	1018	1943	1991	2,277	3,358	1,081	25 to 50%
06691000	North Platte	1018	1937	1990	1,219	2,855	1,636	> 100%
06714215	South Platte	1019	1983	2013	1,155	427	-728	-100 to -50%
06720500	South Platte	1019	1927	2006	1,266	1,927	661	50 to 100%
06754000	South Platte	1019	1902	2006	1,922	2,966	1,043	50 to 100%
06766000	Platte	1020	1940	1990	1,273	3,193	1,920	> 100%
06775500	Middle Loup	1021	1946	2013	908	1,264	356	25 to 50%
06794500	Loup	1021	1935	1977	3,343	414	-2,929	-100 to -50%
06799350	Elkhorn	1022	1973	2012	1,565	4,068	2,503	> 100%
06800500	Elkhorn	1022	1929	2012	2,335	5,897	3,562	> 100%
06607500	Little Sioux	1023	1943	2013	980	7,084	6,104	> 100%
06828500	Republican	1025	1951	2015	297	3	-294	-100 to -50%
06829500	Republican	1025	1947	1992	462	117	-345	-100 to -50%
06837000	Republican	1025	1955	2013	640	75	-565	-100 to -50%
06843500	Republican	1025	1946	2012	1,221	328	-893	-100 to -50%
06844500	Republican	1025	1948	2014	927	128	-798	-100 to -50%
06849500	Republican	1025	1953	2005	1,622	679	-943	-100 to -50%
06853020	Republican	1025	1985	2007	591	148	-443	-100 to -50%
06853500	Republican	1025	1933	2015	2,827	42	-2,785	-100 to -50%
06856000	Republican	1025	1947	2013	2,987	864	-2,124	-100 to -50%
06856600	Republican	1025	1918	2015	4,470	1,992	-2,479	-100 to -50%
06860000	Smoky Hill	1026	1940	2014	106	0.17	-106	-100 to -50%
06861000	Smoky Hill	1026	1951	2013	226	0.17	-225	-100 to -50%
06862000	Smoky Hill	1026	1954	1980	43	-5	-49	> -100%
06864050	Smoky Hill	1026	1940	2010	847	256	-591	-100 to -50%
06864500	Smoky Hill	1026	1896	2014	1,087	632	-455	-50 to -25%
06865500	Smoky Hill	1026	1941	2014	1,310	612	-698	-100 to -50%
07055000	White	1101	1929	1979	7,770	17,000	9,230	> 100%
07060500	White	1101	1940	2015	16,617	29,451	12,834	50 to 100%
07061000	White	1101	1938	2012	19,011	31,185	12,174	50 to 100%
07138000	Arkansas	1103	1903	2015	1,549	446	-1,103	-100 to -50%
07139000	Arkansas	1103	1923	2015	636	159	-477	-100 to -50%

Station	River	HUC4	Year		Streamflow [m^3/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m^3/s]	%Change
07139500	Arkansas	1103	1903	2001	1,212	-168	-1,381	> -100%
07140000	Arkansas	1103	1945	2008	403	-11	-414	> -100%
07141300	Arkansas	1103	1941	2015	1,266	54	-1,212	-100 to -50%
07154500	Cimarron	1104	1951	2015	133	11	-122	-100 to -50%
07156900	Cimarron	1104	1966	2015	172	34	-139	-100 to -50%
07157950	Cimarron	1105	1961	2012	455	33	-422	-100 to -50%
07158000	Cimarron	1105	1938	2015	1,165	278	-887	-100 to -50%
07176000	Verdigris	1107	1936	2015	6,496	15,035	8,539	> 100%
07183000	Neosho	1107	1896	2015	2,967	8,078	5,111	> 100%
07211500	Canadian	1108	1940	2015	311	112	-199	-100 to -50%
07221500	Canadian	1108	1913	2015	1,136	225	-911	-100 to -50%
07224500	Canadian	1108	1937	1971	564	-114	-678	> -100%
07227000	Canadian	1108	1912	2012	1,458	-211	-1,669	> -100%
07227500	Canadian	1109	1939	2015	1,585	265	-1,320	-100 to -50%
07228000	Canadian	1109	1939	2015	1,161	-183	-1,345	> -100%
07237500	North Canadian	1110	1939	2015	708	65	-643	-100 to -50%
07239000	North Canadian	1110	1938	2002	706	220	-486	-100 to -50%

Table H-6. Change in fall streamflow at index stations with significant trends.

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
03016000	Allegheny	0501	1942	2013	7,467	14,356	6,890	50 to 100%
03025500	Allegheny	0501	1915	2013	10,772	20,884	10,112	50 to 100%
03031500	Allegheny	0501	1933	2013	11,641	28,197	16,555	> 100%
03049500	Allegheny	0501	1939	2013	18,404	37,846	19,442	> 100%
03086000	Ohio	0503	1934	2014	31,637	58,057	26,420	50 to 100%
03140500	Muskingum	0504	1937	2014	3,477	7,034	3,557	> 100%
03144500	Muskingum	0504	1922	2014	3,966	8,326	4,359	> 100%
03150000	Muskingum	0504	1922	2014	4,681	10,334	5,653	> 100%
03221000	Scioto	0506	1922	2013	230	838	608	> 100%
03227500	Scioto	0506	1921	2013	474	1,811	1,337	> 100%
03231500	Scioto	0506	1921	2014	1,386	4,553	3,167	> 100%
03234500	Scioto	0506	1931	2014	1,892	6,027	4,135	> 100%
03204000	Guyandotte	0507	1916	1994	321	1,628	1,307	> 100%
03215000	Big Sandy	0507	1940	1975	1,078	4,998	3,920	> 100%
03274000	Great Miami	0508	1928	2013	2,030	4,455	2,425	> 100%
03253500	Licking	0510	1916	2013	1,076	4,396	3,320	> 100%
03282000	Kentucky	0510	1926	2013	2,139	3,865	1,726	50 to 100%
03287000	Kentucky	0510	1926	2013	3,437	6,980	3,543	> 100%
03315500	Green	0511	1938	1992	2,608	15,156	12,549	> 100%
03316500	Green	0511	1940	2013	5,533	14,226	8,693	> 100%
03320000	Green	0511	1931	2013	4,917	18,053	13,136	> 100%
03325000	Wabash	0512	1924	2013	765	2,436	1,671	> 100%
03327500	Wabash	0512	1944	2013	1,470	4,396	2,926	> 100%
03329000	Wabash	0512	1924	2013	2,189	5,343	3,154	> 100%
03335500	Wabash	0512	1924	2013	5,531	9,577	4,046	50 to 100%
03336000	Wabash	0512	1940	2013	6,560	11,195	4,635	50 to 100%
03340500	Wabash	0512	1928	2013	7,458	13,584	6,125	50 to 100%
03341500	Wabash	0512	1928	2013	8,506	14,723	6,217	50 to 100%
03342000	Wabash	0512	1939	2013	9,498	16,649	7,151	50 to 100%
03343000	Wabash	0512	1930	1993	8,040	18,615	10,575	> 100%
03347000	White	0512	1932	2013	111	296	185	> 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
03348000	White	0512	1933	2012	266	521	255	50 to 100%
03351000	White	0512	1930	2013	733	1,504	771	> 100%
03353000	White	0512	1905	2013	694	1,798	1,104	> 100%
03354000	White	0512	1931	2014	1,628	3,479	1,851	> 100%
03377500	Wabash	0512	1928	2013	19,298	36,773	17,475	50 to 100%
03414000	Cumberland	0513	1940	1991	6,618	15,377	8,758	> 100%
03417500	Cumberland	0513	1923	1990	4,973	20,701	15,728	> 100%
03425000	Cumberland	0513	1923	1990	8,118	28,797	20,679	> 100%
03426310	Cumberland	0513	1932	2006	12,375	31,083	18,708	> 100%
03426500	Cumberland	0513	1932	1981	7,297	31,934	24,637	> 100%
03431500	Cumberland	0513	1893	2013	10,015	25,831	15,816	> 100%
03294500	Ohio	0514	1929	2013	78,093	155,708	77,615	50 to 100%
03384500	Ohio	0514	1941	1979	75,722	540,285	464,563	> 100%
03611500	Ohio	0514	1929	2014	196,232	422,056	225,823	> 100%
03497000	Tennesee	0601	1900	1981	12,244	35,296	23,052	> 100%
03566000	Hiwassee	0602	1900	2013	6,069	10,378	4,309	50 to 100%
03568000	Tennesee	0602	1875	2007	36,271	85,591	49,320	> 100%
03571850	Tennesee	0603	1931	1986	51,493	97,218	45,725	50 to 100%
03575500	Tennesee	0603	1925	1994	60,551	89,890	29,339	25 to 50%
03589500	Tennesee	0603	1895	2002	37,898	112,948	75,050	> 100%
03593500	Tennesee	0604	1931	2004	70,096	110,204	40,109	50 to 100%
03609500	Tennesee	0604	1890	1983	44,527	112,958	68,431	> 100%
05211000	Mississippi	0701	1884	2013	4,163	2,952	-1,211	-50 to -25%
05220500	Mississippi	0701	1931	1989	2,859	6,762	3,903	> 100%
05261000	Mississippi	0701	1988	1999	6,878	15,957	9,079	> 100%
05267000	Mississippi	0701	1925	2014	7,129	12,654	5,526	50 to 100%
05288500	Mississippi	0701	1932	2013	11,120	20,444	9,324	50 to 100%
05331000	Mississippi	0701	1901	2015	13,889	26,881	12,992	50 to 100%
05292000	Minnesota	0702	1939	2013	3	160	157	> 100%
05301000	Minnesota	0702	1943	2013	166	1,051	885	> 100%
05311000	Minnesota	0702	1910	2013	99	1,496	1,397	> 100%
05325000	Minnesota	0702	1905	2013	852	6,078	5,225	> 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
05330000	Minnesota	0702	1935	2013	2,240	8,439	6,198	> 100%
05339500	St Crois	0703	1924	1960	4,826	8,210	3,384	50 to 100%
05340500	St Crois	0703	1904	2013	5,948	10,817	4,869	50 to 100%
05344500	Mississippi	0704	1929	2015	21,155	46,673	25,518	> 100%
05378500	Mississippi	0704	1929	2011	36,326	77,096	40,770	> 100%
05383500	Mississippi	0704	1931	1954	31,492	61,236	29,744	50 to 100%
05389500	Mississippi	0706	1937	2012	58,784	88,683	29,898	50 to 100%
05391000	Wisconsin	0707	1937	2013	1,821	1,285	-536	-50 to -25%
05401500	Wisconsin	0707	1903	1949	16,564	7,412	-9,152	-100 to -50%
05425500	Rock	0709	1932	2013	327	973	646	> 100%
05430500	Rock	0709	1915	2013	2,425	4,395	1,970	50 to 100%
05437500	Rock	0709	1904	2013	4,809	9,847	5,038	> 100%
05443500	Rock	0709	1915	2014	7,653	13,189	5,536	50 to 100%
05446500	Rock	0709	1940	2013	8,392	15,432	7,040	50 to 100%
05476000	Des Moines	0710	1936	2013	144	481	336	> 100%
05587450	Mississippi	0711	1934	2014	135,252	233,282	98,030	50 to 100%
05587500	Mississippi	0711	1934	1986	103,354	249,812	146,458	> 100%
05543500	Illinois	0712	1920	2013	23,930	14,723	-9,207	-50 to -25%
05558300	Illinois	0713	1982	2013	29,868	19,504	-10,364	-50 to -25%
05568500	Illinois	0713	1940	2014	19,501	28,302	8,801	25 to 50%
05585500	Illinois	0713	1939	1988	21,719	34,884	13,166	50 to 100%
05586100	Illinois	0713	1939	2015	24,285	35,159	10,874	25 to 50%
07010000	Mississippi	0714	1863	2013	234,864	385,149	150,285	50 to 100%
07020500	Mississippi	0714	1943	2014	299,691	444,179	144,488	25 to 50%
07022000	Mississippi	0714	1934	2014	289,709	457,580	167,871	50 to 100%
07026000	Obion	0801	1930	1990	1,745	4,449	2,704	> 100%
07026040	Obion	0801	1930	2012	2,149	4,298	2,149	50 to 100%
07026300	Obion	0801	1956	1984	1,571	4,042	2,470	> 100%
07032000	Mississippi	0801	1934	1993	462,376	923,696	461,320	50 to 100%
07047902	St. Francis	0802	1936	1974	3,432	8,504	5,072	> 100%
07047970	Mississippi	0802	1929	1976	460,458	769,031	308,572	50 to 100%
07077800	White	0802	1929	1980	22,500	42,676	20,176	50 to 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
07265450	Mississippi	0803	1929	1979	484,687	966,747	482,060	50 to 100%
07287000	Yazoo	0803	1908	1979	-1,309	22,805	24,114	> 100%
07360000	Ouachita	0804	1930	1976	2,331	6,775	4,444	> 100%
07362000	Ouachita	0804	1929	2015	4,839	10,146	5,307	> 100%
07290000	Big Black	0806	1937	2015	1,274	3,418	2,144	> 100%
07291000	Homochitto	0806	1939	2015	183	328	145	50 to 100%
06090800	Missouri	1003	1891	2014	12,201	14,345	2,144	10 to 25%
06099500	Marias	1003	1903	2015	1,074	704	-370	-50 to -25%
06115000	Missouri	1004	1935	1967	11,298	19,604	8,306	50 to 100%
06127500	Musselshell	1004	1946	1978	104	337	233	> 100%
06132000	Missouri	1006	1935	2015	29,780	16,874	-12,906	-50 to -25%
06185500	Missouri	1006	1942	2013	35,736	14,289	-21,447	-100 to -50%
06307500	Tongue	1009	1940	2014	855	529	-325	-50 to -25%
06401500	Cheyenne	1012	1946	1977	48	-10	-58	> -100%
06423500	Cheyenne	1012	1929	2013	267	422	155	50 to 100%
06338490	Missouri	1013	1970	2008	60,256	32,391	-27,864	-50 to -25%
06446000	White	1014	1944	2013	52	27	-25	-50 to -25%
06454000	Niobrara	1015	1956	1993	8	5	-3	-50 to -25%
06455500	Niobrara	1015	1947	1990	44	4	-40	-100 to -50%
06457500	Niobrara	1015	1930	1990	299	234	-65	-25 to -10%
06461500	Niobrara	1015	1946	2012	1,997	1,440	-556	-50 to -25%
06462000	Niobrara	1015	1953	1982	2,296	1,666	-631	-50 to -25%
06465000	Niobrara	1015	1928	2001	2,818	3,595	776	25 to 50%
06465500	Niobrara	1015	1939	2012	2,917	4,101	1,185	25 to 50%
06468170	James	1016	1969	2013	-1	23	25	> 100%
06470000	James	1016	1929	2013	-50	216	267	> 100%
06470500	James	1016	1951	2013	-10	417	427	> 100%
06471000	James	1016	1946	2013	-104	676	781	> 100%
06472000	James	1016	1951	2013	-114	1,125	1,239	> 100%
06473000	James	1016	1946	2013	-225	1,110	1,336	> 100%
06475000	James	1016	1951	2013	-181	1,116	1,297	> 100%
06476000	James	1016	1944	2013	-278	1,270	1,548	> 100%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06477000	James	1016	1951	2013	-256	1,405	1,661	> 100%
06478500	James	1016	1929	2012	-175	1,087	1,261	> 100%
06467500	Missouri	1017	1931	1994	42,504	98,736	56,231	> 100%
06479438	Big Sioux	1017	1973	2013	5	51	46	> 100%
06479500	Big Sioux	1017	1946	2013	3	26	23	> 100%
06480000	Big Sioux	1017	1954	2013	8	563	555	> 100%
06481000	Big Sioux	1017	1949	2013	36	721	685	> 100%
06485500	Big Sioux	1017	1929	2013	299	2,202	1,903	> 100%
06627000	North Platte	1018	1904	1969	1,015	745	-271	-50 to -25%
06641000	North Platte	1018	1906	1960	3,204	877	-2,327	-100 to -50%
06642000	North Platte	1018	1905	1997	723	3,152	2,429	> 100%
06652000	North Platte	1018	1959	2013	3,832	2,022	-1,811	-50 to -25%
06652800	North Platte	1018	1958	2013	2,675	1,059	-1,616	-100 to -50%
06656000	North Platte	1018	1903	1997	3,313	2,362	-951	-50 to -25%
06657000	North Platte	1018	1916	2013	922	231	-690	-100 to -50%
06674500	North Platte	1018	1930	2013	1,555	1,054	-501	-50 to -25%
06679500	North Platte	1018	1931	1997	1,457	1,795	338	10 to 25%
06696000	South Platte	1019	1930	1997	75	218	143	> 100%
06701500	South Platte	1019	1925	2006	257	438	181	50 to 100%
06707500	South Platte	1019	1899	2006	529	768	240	25 to 50%
06711565	South Platte	1019	1984	2013	342	203	-139	-50 to -25%
06720500	South Platte	1019	1927	2006	236	918	682	> 100%
06754000	South Platte	1019	1902	2006	996	2,035	1,039	> 100%
06758500	South Platte	1019	1953	2006	808	1,330	522	50 to 100%
06759500	South Platte	1019	1944	2014	517	1,028	511	50 to 100%
06805500	Platte	1020	1954	2012	8,256	17,433	9,177	> 100%
06775500	Middle Loup	1021	1946	2013	933	1,236	303	25 to 50%
06793000	Loup	1021	1930	2012	286	1,112	827	> 100%
06794500	Loup	1021	1935	1977	1,286	555	-731	-100 to -50%
06799350	Elkhorn	1022	1973	2012	946	1,947	1,001	> 100%
06800500	Elkhorn	1022	1929	2012	885	2,683	1,798	> 100%
06486000	Missouri	1023	1929	2013	62,806	93,716	30,910	25 to 50%

Station	River	HUC4	Year		Streamflow [m³/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m³/s]	%Change
06607500	Little Sioux	1023	1943	2013	453	2,397	1,944	> 100%
06610000	Missouri	1023	1929	2013	50,456	111,898	61,441	> 100%
06807000	Missouri	1024	1930	2013	61,517	122,933	61,416	50 to 100%
06818000	Missouri	1024	1929	2013	65,264	137,485	72,221	> 100%
06824500	Republican	1025	1948	1993	189	109.71	-79	-50 to -25%
06828500	Republican	1025	1951	2015	178	26.30	-152	-100 to -50%
06829500	Republican	1025	1947	1992	101	-22	-123	> -100%
06837000	Republican	1025	1955	2013	375	25	-351	-100 to -50%
06843500	Republican	1025	1946	2012	495	62	-433	-100 to -50%
06844500	Republican	1025	1948	2014	458	85	-373	-100 to -50%
06849500	Republican	1025	1953	2005	169	1.07	-168	-100 to -50%
06853020	Republican	1025	1985	2007	310	42	-268	-100 to -50%
06853500	Republican	1025	1933	2015	834	165	-669	-100 to -50%
06856000	Republican	1025	1947	2013	1,129	450	-679	-100 to -50%
06856600	Republican	1025	1918	2015	1,686	818	-868	-100 to -50%
06857100	Republican	1025	1964	2014	1,623	689	-934	-100 to -50%
06860000	Smoky Hill	1026	1940	2014	13	0.21	-13	-100 to -50%
06861000	Smoky Hill	1026	1951	2013	27	4	-23	-100 to -50%
06862000	Smoky Hill	1026	1954	1980	27	-7	-33	> -100%
06864050	Smoky Hill	1026	1940	2010	244	99	-145	-100 to -50%
06865500	Smoky Hill	1026	1941	2014	554	249	-306	-100 to -50%
06866500	Smoky Hill	1026	1924	2013	761	439	-322	-50 to -25%
06870200	Smoky Hill	1026	1963	2006	1,032	530	-501	-50 to -25%
06893000	Missouri	1030	1929	2013	81,129	157,732	76,603	50 to 100%
06895500	Missouri	1030	1929	2013	79,966	156,429	76,463	50 to 100%
06909000	Missouri	1030	1926	2013	97,070	174,698	77,628	50 to 100%
06934500	Missouri	1030	1929	2013	110,745	209,139	98,394	50 to 100%
07055000	White	1101	1929	1979	4,447	11,718	7,271	> 100%
07099500	Arkansas	1102	1895	1974	1,082	733	-349	-50 to -25%
07124000	Arkansas	1102	1940	2015	143	307	164	> 100%
07139500	Arkansas	1103	1903	2001	225	131	-94	-50 to -25%
07140000	Arkansas	1103	1945	2008	300	-26	-327	> -100%

Station	River	HUC4	Year		Streamflow [m^3/s]		Change in Streamflow	
			Min	Max	Min Year	Max Year	[m^3/s]	%Change
07141300	Arkansas	1103	1941	2015	587	-52	-639	> -100%
07156900	Cimarron	1104	1966	2015	162	38	-123	-100 to -50%
07157950	Cimarron	1105	1961	2012	323	-21	-344	> -100%
07158000	Cimarron	1105	1938	2015	545	147	-398	-100 to -50%
07211500	Canadian	1108	1940	2015	82	30	-52	-100 to -50%
07221500	Canadian	1108	1913	2015	274	132	-143	-100 to -50%
07224500	Canadian	1108	1937	1971	130	-21	-151	> -100%
07227000	Canadian	1108	1912	2012	326	21	-306	-100 to -50%
07228000	Canadian	1109	1939	2015	274	41	-233	-100 to -50%
07237500	North Canadian	1110	1939	2015	195	48	-147	-100 to -50%
07242000	North Canadian	1110	1938	2015	817	1,581	764	50 to 100%

Appendix I: Peak Streamflow Analysis by HUC-4

Table I-1. Median drainage area-weighted peak discharge (water yield) ($m^3/s/km^2$) by HUC-4 for all recurrence intervals.

HUC-4	n	$Q_{1.5}$	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
0501	88	0.220	0.403	0.500	0.640	0.746	0.843
0502	85	0.329	0.600	0.767	0.951	1.107	1.261
0503	120	0.275	0.461	0.566	0.715	0.831	0.951
0504	83	0.212	0.430	0.561	0.784	0.906	1.105
0505	108	0.322	0.628	0.862	1.203	1.424	1.668
0506	60	0.223	0.420	0.535	0.685	0.772	0.935
0507	43	0.217	0.471	0.636	0.837	0.952	1.199
0508	56	0.297	0.466	0.545	0.700	0.856	1.014
0509	87	0.437	0.858	1.063	1.399	1.785	2.062
0510	92	0.563	1.180	1.516	1.923	2.200	2.438
0511	56	0.625	1.252	1.579	2.108	2.635	3.133
0512	253	0.271	0.540	0.684	0.829	0.947	1.097
0513	147	0.611	1.168	1.445	1.938	2.168	2.453
0514	100	0.944	1.835	2.186	2.559	2.871	3.269
0601	240	0.337	0.701	0.863	1.188	1.442	1.720
0602	55	0.374	0.738	0.939	1.198	1.416	1.645
0603	70	0.569	1.195	1.566	2.087	2.482	2.990
0604	70	0.625	1.367	1.686	2.327	2.813	3.274
0701	80	0.024	0.050	0.063	0.078	0.092	0.108
0702	78	0.044	0.142	0.190	0.283	0.355	0.413
0703	28	0.062	0.143	0.180	0.227	0.261	0.294
0704	80	0.119	0.396	0.570	0.834	1.058	1.287
0705	52	0.118	0.224	0.282	0.331	0.374	0.412
0706	64	0.222	0.653	0.962	1.447	1.868	2.396
0707	75	0.081	0.192	0.245	0.334	0.391	0.454
0708	151	0.151	0.405	0.563	0.806	0.962	1.119
0709	95	0.102	0.225	0.297	0.385	0.464	0.516

HUC-4	n	$Q_{1.5}$	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
0710	75	0.092	0.279	0.344	0.489	0.601	0.715
0711	62	0.329	0.739	0.950	1.234	1.397	1.556
0712	192	0.163	0.309	0.387	0.475	0.534	0.587
0713	92	0.176	0.430	0.575	0.810	1.011	1.164
0714	124	0.644	1.632	2.117	2.701	3.140	3.528
0801	73	0.399	0.769	0.962	1.227	1.442	1.672
0802	73	0.165	0.309	0.367	0.480	0.529	0.564
0803	90	0.652	1.139	1.382	1.684	1.948	2.233
0804	133	0.370	1.037	1.433	1.868	2.391	2.983
0805	17	0.125	0.226	0.267	0.313	0.343	0.370
0806	49	0.965	1.873	2.293	2.778	3.105	3.622
0807	58	0.502	1.347	1.727	2.362	2.726	3.279
0808	55	0.335	0.839	1.172	1.387	1.837	2.361
0809	7	0.433	0.976	1.402	2.092	2.700	3.388
1002	79	0.022	0.044	0.053	0.066	0.075	0.083
1003	106	0.024	0.092	0.159	0.259	0.352	0.474
1004	81	0.023	0.107	0.224	0.412	0.535	0.723
1005	69	0.018	0.098	0.155	0.268	0.350	0.430
1006	47	0.026	0.135	0.273	0.421	0.514	0.605
1007	60	0.044	0.102	0.150	0.200	0.235	0.298
1008	141	0.036	0.102	0.138	0.184	0.218	0.265
1009	106	0.035	0.125	0.170	0.234	0.291	0.349
1010	55	0.043	0.283	0.540	0.955	1.575	2.159
1011	43	0.031	0.143	0.252	0.509	0.726	0.922
1012	138	0.009	0.055	0.095	0.199	0.320	0.446
1013	116	0.017	0.106	0.180	0.297	0.363	0.437
1014	71	0.013	0.103	0.200	0.357	0.525	0.746
1015	44	0.008	0.029	0.051	0.084	0.120	0.167
1016	77	0.005	0.047	0.087	0.168	0.242	0.340
1017	93	0.037	0.161	0.268	0.463	0.585	0.741
1018	146	0.024	0.060	0.089	0.118	0.154	0.183

HUC-4	n	$Q_{1.5}$	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
1019	160	0.028	0.079	0.111	0.151	0.185	0.215
1020	65	0.052	0.199	0.313	0.538	0.933	1.144
1021	45	0.040	0.152	0.201	0.281	0.381	0.528
1022	18	0.018	0.055	0.084	0.140	0.202	0.253
1023	65	0.200	0.619	0.909	1.290	1.820	2.110
1024	63	0.347	1.155	1.483	1.995	2.687	3.175
1025	100	0.009	0.054	0.106	0.206	0.316	0.419
1026	71	0.013	0.086	0.160	0.301	0.473	0.712
1027	87	0.163	0.482	0.661	0.991	1.261	1.493
1028	60	0.218	0.486	0.627	0.809	0.974	1.054
1029	110	0.335	0.897	1.178	1.675	2.032	2.442
1030	75	1.147	2.530	3.193	4.076	4.703	5.370
1101	143	0.482	1.204	1.602	2.318	2.811	3.416
1102	131	0.020	0.090	0.130	0.203	0.265	0.313
1103	77	0.040	0.171	0.256	0.384	0.494	0.615
1104	22	0.036	0.215	0.411	0.709	1.106	1.607
1105	24	0.100	0.483	0.783	1.222	1.577	2.150
1106	26	0.315	2.091	3.409	5.032	6.114	7.184
1107	114	0.190	0.653	0.958	1.392	1.696	1.975
1108	46	0.022	0.084	0.143	0.231	0.332	0.441
1109	29	0.101	0.455	0.654	1.055	1.484	1.972
1110	43	0.014	0.096	0.156	0.328	0.481	0.699
1111	110	0.495	1.431	1.841	2.594	3.150	3.769
1112	32	0.039	0.182	0.274	0.401	0.512	0.650
1113	97	0.107	0.381	0.543	1.014	1.299	1.563
1114	147	0.236	0.819	1.134	1.547	1.838	2.203

Appendix J: Suspended-Sediment Yields

Table J-1. Median suspended-sediment yield at the $Q_{1.5}$ for each HUC-4 along with the number of gages and standard error.

HUC-4	# Stations	Median	Std. Error	HUC-4	# Stations	Median	Std. Error
0501	13	1.13	0.71	1003	9	0.04	0.12
0502	22	2.52	2.2	1004	18	0.1	0.2
0503	20	3.74	4.59	1005	9	0.11	0.38
0504	8	3.21	1.51	1006	7	0.08	0.03
0505	25	1.84	9.74	1007	10	0.03	0.4
0506	7	5.89	0.97	1008	12	1.22	36.7
0507	36	6.85	271	1009	28	1.02	9.7
0508	16	6.76	2.63	1010	35	0.28	69.5
0509	12	6.34	2.24	1011	12	0.09	0.12
0510	19	3.59	3.56	1012	11	0.5	0.77
0511	8	4.58	1.48	1013	30	0.33	1.3
0512	62	4.91	1.89	1014	39	0.25	0.17
0513	34	4.6	11.1	1015	7	13.8	3.3
0514	18	4.45	21.7	1016	10	1.32	1.28
0601	53	4.15	16.3	1017	10	0.01	0
0602	9	1.73	1.14	1018	13	0.19	0.06
0603	9	2.76	1.1	1019	25	0.14	1.25
0604	8	2.2	8.03	1020	30	0.19	1.87
0701	11	0.08	0.03	1021	12	3.4	12.9
0702	15	0.32	1.22	1022	22	11.4	3.11
0703	13	0.1	1.23	1023	8	4.75	17.5
0704	12	31	21	1024	4	0.86	27.9
0705	6	0.28	2.32	1025	7	19.7	115
0706	12	46.9	13.5	1026	18	1.89	299
0707	23	0.76	8.03	1027	12	0.56	0.53
0708	22	0.96	36.5	1028	42	28.3	34.5
0709	43	2.36	1.39	1029	10	14.3	3.85

HUC-4	# Stations	Median	Std. Error
0710	7	0.62	3.7
0711	4	7.21	10.1
0712	36	0.77	1.75
0713	19	7.34	1.82
0714	11	1.53	367
0801	20	17.1	26.1
0802	16	1.01	0.52
0803	27	154	210
0804	10	1.26	0.38
0805	1	3.19	NA
0806	2	45.1	43
0807	3	1.16	2.88
0808	5	2.66	1.06
0809			
1002	1	0.77	NA

HUC-4	# Stations	Median	Std. Error
1030	11	1.83	11.9
1101	18	64.1	31.8
1102	21	2.43	1.16
1103	48	5.62	1685
1104	27	1.67	0.75
1105	7	2.93	24.8
1106	8	16.1	5.6
1107	9	4.89	6.54
1108	67	5.73	3.53
1109	8	0.33	8.53
1110	17	4.55	4.23
1111	22	1.77	6.71
1112	50	2.99	2.44
1113	16	59.1	103
1114	34	20.7	82

Table J-2. Suspended-sediment load at the $Q_{1.5}$ showing changes between the first and latest decades of data collection at sediment index stations. Shaded rows denote the downstream-most stations for each region (HUC-2).

HUC-4	Station	River	1st decade	Last Decade	Load at Q1.5		Difference	
					1st	Last	T/d	%change
0502	03085000	Monongahela	1970	1990	28,687	12,264	-16,423	-100 to -50%
0504	03150000	Muskingum	1970	1990	22,683	5,477	-17,206	-100 to -50%
0506	03234500	Scioto	1960	1990	59,048	29,774	-29,274	-50 to -25%
0507	03215000	Big Sandy	1970	1990	65,699	36,435	-29,264	-50 to -25%
0509	03216600	Little Miami	1970	2010	243,309	117,651	-125,658	-100 to -50%
0509	03245500	Ohio	1970	2000	83,674	59,060	-24,614	-50 to -25%
0510	03290500	Kentucky	1970	1990	35,249	33,148	-2,101	-10 to -5%
0512	03374100	Wabash	1970	2010	19,720	25,053	5,333	25 to 50%
0512	03378500	White	1970	2010	54,862	54,860	-2	-5 to 0%
0513	03425000	Cumberland	1970	1990	4,723	4,535	-188	-5 to 0%
0514	03612500	Ohio	1940	2010	588,919	303,106	-285,813	-50 to -25%
0604	03609750	Tennessee	1970	2010	18,038	9,661	-8,377	-50 to -25%
0701	05331580	Mississippi	1970	2010	14,468	15,334	866	5 to 10%
0702	05330000	Minnesota	1970	2000	10,458	11,101	643	5 to 10%
0703	05340500	St Croix	1970	2000	374	1,103	729	> 100%
0704	05382000	Black	1960	2000	1,705	3,241	1,536	50 to 100%
0705	05369500	Chippewa	1960	1990	3,362	7,031	3,669	> 100%
0706	05412500	Turkey	1950	2010	105,508	34,894	-70,614	-100 to -50%
0707	05407000	Wisconsin	1970	2000	3,862	4,712	850	10 to 25%
0708	05465500	Iowa	1970	2010	42,547	16,564	-25,983	-100 to -50%
0709	05446500	Rock	1970	1990	9,159	10,393	1,234	10 to 25%
0710	05490500	Des Moines	1970	2010	53,223	20,215	-33,008	-100 to -50%
0711	05508000	Salt	1970	1990	39,651	5,410	-34,241	-100 to -50%
0712	05543500	Illinois	1970	2000	32,431	12,183	-20,248	-100 to -50%
0713	05586100	Illinois	1980	2010	45,486	18,998	-26,488	-100 to -50%
0714	05594100	Kaskaskia	1970	1990	4,532	7,576	3,044	50 to 100%
0714	07022000	Mississippi	1970	2010	943,146	497,039	-446,107	-50 to -25%
0801	07030050	Hatchie	1970	2000	5,530	1,328	-4,202	-100 to -50%
0802	07077800	White	1980	2010	15,085	10,373	-4,712	-50 to -25%
0803	07288955	Yazoo	1970	2010	72,397	26,110	-46,287	-100 to -50%

HUC-4	Station	River	1st decade	Last Decade	Load at Q1.5		Difference	
					1st	Last	T/d	%change
0805	07369500	Tensas	1970	1990	2,657	3,040	383	10 to 25%
0806	07290000	Big Black	1970	1990	18,274	5,425	-12,849	-100 to -50%
0808	07381600	Lower Atchafalaya	1970	2010	165,236	115,676	-49,560	-50 to -25%
1003	06054500	Missouri	1970	2000	4,972	3,644	-1,328	-50 to -25%
1004	06115200	Missouri	1970	1990	47,563	35,810	-11,753	-25 to -10%
1005	06174500	Milk	1970	1990	5,613	7,834	2,221	25 to 50%
1006	06181000	Poplar	1970	2000	398	416	18	0 to 5%
1007	06214500	Yellowstone	1970	2000	53,763	45,352	-8,411	-25 to -10%
1008	06294700	Bighorn	1960	1990	130,709	1,703	-129,006	-100 to -50%
1009	06326500	Powder	1970	2010	80,281	58,084	-22,197	-50 to -25%
1010	06329500	Yellowstone	1970	2010	309,387	127,930	-181,457	-100 to -50%
1011	06337000	Little Missouri	1970	1990	253,685	173,695	-79,990	-50 to -25%
1012	06437000	Belle Fourche	1950	1980	187,706	24,104	-163,602	-100 to -50%
1013	06342500	Missouri	1940	2010	253,823	6,826	-246,997	-100 to -50%
1014	06452000	White	1970	2010	1,253,268	256,564	-996,704	-100 to -50%
1015	06465500	Niobrara	1970	1990	41,144	41,979	835	0 to 5%
1016	06478500	James	1970	1990	472	388	-84	-25 to -10%
1017	06485500	Big Sioux	1940	2010	16,729	3,334	-13,395	-100 to -50%
1018	06686000	Platte	1970	1990	3,380	3,187	-193	-5 to 0%
1019	06764000	Platte	1970	1990	1,739	960	-779	-50 to -25%
1020	06805500	Platte	1950	2010	866,411	226,904	-639,507	-100 to -50%
1021	06785000	Loup	1940	1990	170,197	60,360	-109,837	-100 to -50%
1022	06800500	Elkhorn	1940	2010	148,185	96,975	-51,210	-50 to -25%
1023	06607500	Little Sioux	1940	2010	84,367	10,688	-73,679	-100 to -50%
1024	06810000	Nishnabotna	1940	2010	1,286,971	176,457	-1,110,514	-100 to -50%
1025	06856600	Republican	1940	2010	308,184	9,144	-299,040	-100 to -50%
1026	06877600	Smoky Hill	1950	1990	69,431	24,472	-44,959	-100 to -50%
1027	06892350	Kansas	1970	2010	148,497	167,007	18,510	10 to 25%
1029	06926510	Osage	1970	1990	12,339	4,329	-8,010	-100 to -50%
1030	06934500	Missouri	1940	2010	4,000,376	556,987	-3,443,389	-100 to -50%
1101	07074500	White	1970	1990	10,585	10,709	124	0 to 5%
1103	07146500	Arkansas	1940	2000	89,665	41,215	-48,450	-100 to -50%

HUC-4	Station	River	1st decade	Last Decade	Load at Q1.5		Difference	
					1st	Last	T/d	%change
1104	07157580	Cimarron	1930	1980	49,014	1,078	-47,936	-100 to -50%
1105	07161000	Cimarron	1940	1990	759,245	60,520	-698,725	-100 to -50%
1106	07150500	Salt Fork Arkansas	1930	1980	25,432	523	-24,909	-100 to -50%
1107	07193500	Neosho	1930	1990	37,298	1,964	-35,334	-100 to -50%
1108	07221500	Canadian	1970	2010	13,021	7,381	-5,640	-50 to -25%
1109	07245000	Canadian	1940	1980	388,584	2,899	-385,685	-100 to -50%
1110	07242000	North Canadian	1940	1990	192,606	173,303	-19,303	-25 to -10%
1111	07246500	Arkansas	1940	2010	802,722	34,847	-767,875	-100 to -50%
1111	07250550	Arkansas	1970	2010	17,270	22,088	4,818	25 to 50%
1113	07308500	Red	1970	1990	332,712	285,961	-46,751	-25 to -10%
1113	07331000	Washita	1930	1990	1,399,169	418,235	-980,934	-100 to -50%
1114	07337000	Red	1930	2010	856,235	81,535	-774,700	-100 to -50%

Table J-3. Median and average annual suspended-sediment loads by HUC-4.

HUC-4	# Stations	Avg # Flow Years	Avg of Median Sediment Yield	Avg of Mean Sediment Yield
			t/y/km²	
0501	7	55.0	17.7	20.2
0502	14	33.5	39.8	41.4
0503	13	52.0	53.2	58.9
0504	6	48.2	46.3	51.2
0505	14	42.5	21.3	27.0
0506	7	55.9	62.6	70.4
0507	14	34.1	272	291
0508	12	66.0	68.1	79.9
0509	9	54.1	57.8	70.0
0510	12	61.2	82.3	98.6
0511	5	67.2	94.2	132
0512	48	48.9	57.4	65.7
0513	15	53.1	85.4	4527
0514	10	50.4	131	136
0601	40	59.4	29.9	37.8
0602	3	45.3	15.9	19.1
0603	5	23.0	29.0	29.8
0604	1	78.0	51.8	58.2
0701	9	45.4	4.7	5.5
0702	15	60.0	30.4	40.3
0703	10	37.3	3.5	3.4
0704	10	33.8	148	182
0705	6	35.8	7.0	7.4
0706	8	60.8	116	231
0707	21	37.5	11.4	35.0
0708	21	64.7	67.9	92.1
0709	36	30.4	19.6	23.2

HUC-4	# Stations	Avg # Flow Years	Avg of Median Sediment Yield	Avg of Mean Sediment Yield
			t/y/km²	
0710	7	62.0	63.0	105
0711	3	37.3	120	123
0712	30	56.9	34.2	35.6
0713	15	44.9	78.3	105
0714	9	66.2	73	96
0801	9	38.3	182	200
0802	13	41.2	129	132
0803	22	14.4	313	357
0804	9	32.4	26.4	29.8
0805	1	78.0	127	145
0806	1	79.0	112	117
0807	2	41.5	32.7	32.3
0808	1	71.0	50.0	64.3
1002	8	60.6	5.1	6.6
1003	17	44.3	21.1	28.7
1004	5	67.2	9.0	22.6
1005	5	35.8	2.7	4.1
1006	9	38.0	3.0	6.1
1007	11	58.7	29.5	33.9
1008	22	45.0	54.6	99.3
1009	29	32.9	20.7	67.7
1010	11	27.0	8.9	11.6
1011	9	16.2	22.4	32.2
1012	25	28.8	7.6	35.2
1013	32	25.1	7.1	13.7
1014	7	43.1	89.5	126
1015	10	38.0	115	138
1016	10	50.8	0.6	1.3

HUC-4	# Stations	Avg # Flow Years	Avg of Median Sediment Yield	Avg of Mean Sediment Yield
			t/y/km²	
1017	6	50.5	5.1	8.0
1018	22	37.1	4.9	6.0
1019	23	43.3	12.3	17.1
1020	12	48.7	171	261
1021	18	29.4	514	572
1022	7	47.6	93.7	250
1023	4	79.8	65.6	141
1024	6	65.0	211	290
1025	18	46.3	198	390
1026	11	76.9	5.3	15.7
1027	37	42.1	172	239
1028	8	40.9	256	318
1029	7	37.6	74.8	89.3
1030	11	30.4	88.8	105
1101	11	51.2	21.0	35.0
1102	33	32.6	17.4	40.7
1103	26	57.8	49.8	73.6
1104	4	25.8	38.5	55.2
1105	5	51.2	92.5	121
1106	8	62.4	96.0	148
1107	53	41.8	86.7	120
1108	4	73.3	13.8	30.1
1109	16	39.1	98.7	146
1110	18	46.1	39.8	77.1
1111	36	30.3	68.9	80.8
1112	8	43.6	136	196
1113	27	47.2	220	390
1114	24	48.1	55.3	70.9

Table J-4. Summary of changes in median annual suspended-sediment yields within each HUC-4 for the period of record.

HUC-4	p < 0.05	Year			Suspended-Sediment Yield [t/y/km²]		Change in Yield	
		Min	Max	n	Min Year	Max Year	[t/y/km²]	%Change
0501	*	1914	2015	102	13.3	22.9	9.5	50 to 100%
0502		1899	2015	107	49.0	34.4	-14.6	-50 to -25%
0503		1912	2015	104	40.5	51.5	11.0	25 to 50%
0504		1922	2015	94	43.3	51.2	7.9	10 to 25%
0505	*	1878	2015	138	11.6	8.3	-3.3	-50 to -25%
0506		1922	2015	94	61.4	67.3	5.9	5 to 10%
0507		1929	2015	87	117.7	136.3	18.6	10 to 25%
0508		1915	2015	101	92.6	64.2	-28.4	-50 to -25%
0509		1916	2015	97	67.3	51.6	-15.7	-25 to -10%
0510		1908	2015	108	97.3	73.5	-23.8	-25 to -10%
0511		1916	2014	94	85.4	70.6	-14.9	-25 to -10%
0512	*	1904	2015	108	26.3	62.8	36.6	> 100%
0513		1908	2015	103	53.2	63.2	10.0	10 to 25%
0514		1929	2015	87	90.4	78.8	-11.6	-25 to -10%
0601	*	1896	2015	120	66.3	14.6	-51.7	-100 to -50%
0602		1914	2014	101	18.2	22.3	4.1	10 to 25%
0603		1931	2015	73	22.6	21.7	-0.9	-5 to 0%
0604		1926	2015	78	57.1	54.8	-2.3	-5 to 0%
0701		1901	2015	113	3.5	3.4	-0.1	-5 to 0%
0702	*	1905	2015	95	1.7	24.7	23.0	> 100%
0703	*	1902	2015	108	1.2	1.9	0.7	50 to 100%
0704		1910	2015	94	42.7	53.3	10.5	10 to 25%
0705		1929	2015	87	8.4	12.2	3.7	25 to 50%
0706	*	1914	2015	102	236.2	62.8	-173.4	-100 to -50%
0707	*	1914	2015	102	9.7	5.7	-4.0	-50 to -25%
0708	*	1874	2015	142	7.1	51.5	44.4	> 100%
0709	*	1914	2015	102	11.0	25.3	14.3	> 100%
0710		1904	2015	106	17.9	26.0	8.1	25 to 50%
0711		1923	2015	93	43.2	47.5	4.4	10 to 25%

HUC-4	p < 0.05	Year			Suspended-Sediment Yield [t/y/km^2]		Change in Yield	
		Min	Max	n	Min Year	Max Year	[t/y/km^2]	%Change
0712	*	1915	2015	101	17.5	32.0	14.4	50 to 100%
0713	*	1909	2015	104	40.3	73.9	33.6	50 to 100%
0714	*	1863	2015	153	19.5	33.7	14.2	50 to 100%
0801	*	1930	2015	86	64.2	118.4	54.2	50 to 100%
0802	*	1928	2015	88	45.4	88.3	42.9	50 to 100%
0803	*	1936	2015	78	101.8	247.3	145.5	> 100%
0804	*	1929	2015	87	43.0	12.4	-30.6	-100 to -50%
0805		1937	2015	78	126.7	156.7	30.0	10 to 25%
0806		1937	2015	79	99.1	124.9	25.7	25 to 50%
0807		1939	2015	76	33.7	35.2	1.5	0 to 5%
0808		1940	2012	71	65.2	50.4	-14.8	-25 to -10%
0809								
1002	*	1890	2015	113	6.7	1.8	-4.8	-100 to -50%
1003	*	1891	2015	125	9.7	4.2	-5.6	-100 to -50%
1004		1931	2015	82	10.6	6.3	-4.2	-50 to -25%
1005	*	1940	2015	76	8.2	2.0	-6.2	-100 to -50%
1006		1909	2015	97	1.3	1.0	-0.4	-50 to -25%
1007		1890	2015	118	37.4	29.1	-8.3	-25 to -10%
1008	*	1913	2015	98	106.7	0.4	-106.3	-100 to -50%
1009	*	1916	2015	95	24.3	5.4	-18.9	-100 to -50%
1010	*	1911	2015	102	94.0	-9.9	-103.9	> -100%
1011	*	1929	2014	86	11.7	5.7	-6.0	-100 to -50%
1012		1930	2015	82	11.4	8.2	-3.2	-50 to -25%
1013	*	1929	2015	87	12.2	5.6	-6.6	-100 to -50%
1014		1929	2014	86	91.8	97.7	6.0	5 to 10%
1015	*	1930	2014	72	11.9	95.9	84.0	> 100%
1016	*	1929	2014	86	0.1	1.4	1.3	> 100%
1017		1929	2014	86	5.6	6.7	1.1	10 to 25%
1018	*	1905	2015	103	1.5	5.1	3.6	> 100%
1019		1885	2015	131	2.3	4.2	1.9	50 to 100%

HUC-4	p < 0.05	Year			Suspended-Sediment Yield [t/y/km^2]		Change in Yield	
		Min	Max	n	Min Year	Max Year	[t/y/km^2]	%Change
1020	*	1931	2015	85	2.5	61.3	58.8	> 100%
1021		1929	2013	85	259.8	254.3	-5.5	-5 to 0%
1022	*	1929	2013	85	50.6	149.6	98.9	> 100%
1023	*	1919	2015	92	14.9	50.9	36.0	> 100%
1024	*	1921	2015	88	11.9	258.8	247.0	> 100%
1025	*	1918	2015	98	40.1	2.4	-37.7	-100 to -50%
1026	*	1896	2015	107	13.4	3.4	-10.1	-100 to -50%
1027	*	1911	2015	102	36.2	85.5	49.3	> 100%
1028		1925	2015	91	280.5	328.5	48.0	10 to 25%
1029		1940	2015	76	127.4	77.0	-50.4	-50 to -25%
1030	*	1929	2015	87	31.0	96.0	65.0	> 100%
1101		1922	2015	94	18.0	22.6	4.6	25 to 50%
1102		1890	2015	125	7.4	11.8	4.3	50 to 100%
1103		1903	2015	97	18.1	10.3	-7.9	-50 to -25%
1104	*	1906	2015	74	44.8	-7.5	-52.3	> -100%
1105	*	1938	2015	78	135.3	38.8	-96.5	-100 to -50%
1106	*	1926	2015	90	46.3	98.8	52.5	> 100%
1107		1896	2015	104	79.4	88.4	9.0	10 to 25%
1108		1907	2015	92	2.7	2.6	-0.1	-5 to 0%
1109		1906	2015	78	202.9	99.6	-103.4	-100 to -50%
1110	*	1903	2015	83	31.7	2.9	-28.9	-100 to -50%
1111		1926	2015	90	44.9	32.5	-12.4	-50 to -25%
1112	*	1904	2015	82	229.0	37.9	-191.1	-100 to -50%
1113	*	1903	2015	92	231.0	108.9	-122.2	-100 to -50%
1114		1906	2015	97	61.7	40.7	-21.0	-50 to -25%

Unit Conversion Factors

Multiply	By	To Obtain
cubic meter per second	35.3147	cubic feet per second
cubic meter per second	22.83	million gallons per day
kilometers	0.62137	miles
meters	3.281	feet
millimeters	0.03937	inches
square kilometers	0.38610	square miles
square kilometers	247.1	acres
tonnes	2,204.6	pounds (mass)

Acronyms and Abbreviations

GHCND	Global Historical Climatology Network-Daily
HUC	hydrologic unit code
IBTrACS	International Best Track Archive for Climate Stewardship
LMR	Lower Mississippi River
MVD	Mississippi Valley Division
NID	National Inventory of Dams
NOAA	National Oceanic Atmospheric Administration
NRCS	Natural Resources Conservation Service
PRCP	precipitation
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

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14. ABSTRACT

Since about 1900, widespread changes in hydrology across the Mississippi River Basin have occurred, resulting in important changes in the delivery of water and sediment to the Lower Mississippi River (LMR). This is due to a combination of natural and anthropogenic factors. There have been increases in annual precipitation and 1- to 7-day totals over large parts of the basin. Changes in seasonal distributions were also identified, as were increases in hurricane-related rainfall.

Streamflow to the LMR has increased significantly over the past 100 years. Median water yields have increased across most of the mid-continent and decreased in the western-most parts of the Missouri and Arkansas River basins. Suspended-sediment loads to the LMR have dramatically declined. The Lower Mississippi River is receiving about 500 million tonnes per year less suspended sediment today than in the 1940s (616 Mt/y to 98 Mt/y).

Human impacts on hydrology and sediment transport throughout the basin are important. In the mid-continent, water yield per unit precipitation showed increases, but markedly decreased in the western parts of the basin. Decreases can be attributed to the construction of thousands of dams, associated flow regulation, withdrawals for agriculture, and to a lesser extent, the increased evaporation behind impoundments.

15. SUBJECT TERMS
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