Missouri River Flood 2011
Vulnerabilities Assessment Report
Volume II-Technical Report

Northwestern Division
US Army Corps of Engineers

October 2012

US Army Corps of Engineers®

ABSTRACT

The duration and magnitude of the 2011 Missouri River runoff event exceeded all other events in the recorded gage history of the river. The thaw of an unusually heavy snowpack coincided with heavy rain throughout the upper and middle portions of the basin. Almost a year's average precipitation fell in 2 weeks in May, in the upper basin. This combination and continuing rainfall raised pool levels at the mainstem reservoirs, reaching record elevations at three reservoirs, and requiring record releases from all six dams from late May through late September. Discharges reached 150,000 cfs cubic feet per second (cfs) at Gavins Point Dam June 1, 2011 and continued through September, peaking at 160,700 cfs June 27. Emergency spillways were operated at all the dams except Oahe, and flood tunnels were used at 3 dams. The inflows exceeded those estimated for the design storm by 20 percent. Total inflow would have exceeded the entire storage capacity of the Corps reservoir system if it had started empty. Flows peaked in the Omaha area at 217,000 cfs. Fortunately for the reach downstream of Gavins Point Dam, the runoff occurred upstream of the dams and had to pass through the dam system, allowing prevention of much greater peak flows in the river (examples include 313,100 cfs at Omaha and 338,000 cfs at Rulo, Nebraska) and prevention of more disastrous damages.

In managing the record runoff of more than 61 Million Acre-Feet in 2011 and record releases from Corps Projects, the Corps flood risk management facilities and actions were effective. The handling of inflow and the releases in preventing even more damage than occurred, but the facilities themselves were damaged but still intact and fully functional. While many key repairs have been accomplished and many more will be complete within a year, other vulnerabilities in facilities and operations will take longer to address. Some have yet to be fully assessed, and others would require large commitments of funds not readily available.

The purpose of this report is to present results of evaluations, assessments, and repairs that have been done, will be done, or still need to be done for facilities and infrastructure that are under Corps of Engineers jurisdiction or responsibility. It is a snapshot in time, as some evaluations and assessments are yet to be completed, but this effort provides an overall picture of immediate and longer term needs to bring flood risk management on the Missouri River to its fullest potential. In the near term, repair of facilities damaged during the flood is our priority effort. Other actions will be necessary to restore many features of reservoir and river corridor infrastructure to their originally designed, or intended, level of function. And in the long term, enhancements can be made subject to feasibility, authority and funding, that will increase the flood risk reduction capability of federal and non-federal infrastructure and related governance in the Missouri basin.

Efforts are underway to Repair-Restore-Enhance the System which are summarized in Vol. I-Summary Report

A summary of information contained in this report is provided in the table below:

Vulnerability Report Section	Salient Feature Addressed	Key Points	Vulnerability/Remaining Work
Economics	Economic Impact to Basin	• Impacted 1+M acres, 10,000+ people, and almost 6,000 structures • Corps Reservoirs and emergency operations prevented nearly $8B in damages	• There is need to update Stage Damage Curves as well as Socioeconomic Data
Reservoirs and Water Management	Reservoir and Dam Infrastructure	• All critical assessments have been completed • Additional funding may be needed to restore system, pending studies	• Ft Peck Plunge pool and Ring Gates continue to be assessed and evaluated • Need to evaluate unlined spillways at Oahe and Pipestem • Some other Miscellaneous measures to restore existing systems • Depending on assessments, some operating restrictions may be implemented
	Water Management	• There are currently no formal operating restrictions on system • Record runoff that flowed into system needed to exit system	• Need to update Water Control Manuals • Implementing the 6 Independent External Panel Recommendations • Restore/maintain all project features to maximize flexibility in system
River Corridor and Conveyance	Floodway and Channel Performance	• Bank stabilization navigation projects, Navigation Channel, Habitat areas, and sedimentation and aggradation issues are being addressed and/or evaluated • Considerable damage did occur in river structures. Most known repairs funded	• Critical and high priority assessments and repairs are being addressed • Several river bends may require attention due to damage or flood determination • Additional studies may be required to fully assess channel condition • Complete the flow corridor study as planned
	Levees	• Critical repairs have been made • Some overtopping and under seepage was issue throughout basin	• Some flow constrictions exist in levee alignment • Repairs are funded but will carry into Fiscal Year 13
Other Considerations	Tribal and Cultural Resources	• Cultural sites were impacted and are being assessed •	• Tribes and others need to remain engaged thru Programmatic Agreement meetings and other partnering meetings
	Communications	• MRJIC worked to communicate and engage local state, and Federal and Tribal interests • MRFTF was a successful joint Federal effort to restore system	• MR Basin Interagency Roundtable(MRBIR) will inherit tasks/initiatives started by MR Flood Task Force (MRFTF)
Shared Responsibilitie s	Flood Risk Management	• Federal Government has little continue over local land uses • Local and some states can help in reducing flood risk and expose	• Federal Government can assist when and if requested • MRBIR will continue the Stakeholder Communications started with MRFTF • To understand FRM, the 8 Authorized Purposes need continued education throughout the basin

Figure 1. Brigadier General Theodore Harrison, Colonel Robert Ruch, Brigadier General John McMahon and Major General William Grisoli speak with South Dakota Governor Dennis Daugaard about flood preparations in Pierre, South Dakota.

TABLE OF CONTENTS

ABSTRACT II
LIST OF FIGURES VI
LIST OF APPENDICES XII
LIST OF ACCRONYMS XIII
1. INTRODUCTION & PURPOSE 1
1.1 INTRODUCTION 1
1.2 REPORT PURPOSE 1
2. BACKGROUND 3
2.1 THE EXISTING SYSTEM 3
2.2 WATER MANAGEMENT IN THE SYSTEM 4
2.3 FLOOD OF 2011 4
2.4 ECONOMICS 5
3. RESERVOIRS AND WATER MANAGEMENT 32
3.1 RESERVOIR AND DAM INFRASTRUCTURE 32
3.2 WATER MANAGEMENT 53
4. RIVER CORRIDOR AND CONVEYANCE 83
4.1 FLOODWAY AND CHANNEL PERFORMANCE 83
4.2 LEVEES 124
5. OTHER CONSIDERATIONS 163
5.1 TRIBAL RELATIONS AND CULTURAL RESOURCES 163
5.2 COMMUNICATIONS 169
5.3 SHARED RESPONSIBILITY 182

LIST OF FIGURES

Figure 1. Brigadier General Theodore Harrison, Colonel Robert Ruch, Brigadier General John McMahon and Major General William Grisoli speak with South Dakota Governor Dennis Daugaard about flood preparations in Pierre, South Dakota. iv

Figure 2. Brigadier General John McMahon speaks with South Dakota Lt. Governor Matt Michels at Dakota Dunes, South Dakota. 2

Figure 3. Potential Flood Area 7

Figure 4. Flooded Area 12

Figure 5. Bismarck, North Dakota Reach 15

Figure 6. Pierre, South Dakota Reach 17

Figure 7. Gavins Point Dam to Omaha Reaches 19

Figure 8. Omaha to Kansas City Reaches 20

Figure 9. Fort Calhoun Nuclear Station (June 25, 2011) 22

Figure 10. Omaha World Herald Photo: The flood-damaged eastbound lane of Interstate I-680, looking west toward the Mormon Bridge from the overpass over I-29. Receding water from the flooded Missouri River revealed flood damage north of Council Bluffs. 24

Figure 11. I-29 North of Omaha and Council Bluffs 25

Figure 12. Hamburg, Iowa in Reach 18 26

Figure 13. Missouri River Basin Federal Dams 34

Figure 14. Rathbun Stilling Basin Overtopping at 3,000 cfs 43

Figure 15. Harlan County Spillway and Stilling Basin 43

Figure 16. Missouri River Basin - Annual Runoff above Sioux City, Iowa 53

Figure 17. System Storage Zones 54

Figure 18. Water Control Calendar of Events 55

Figure 19. Discontinued USGS Streamgages and Stage-Only Gages, 1990-2010 75

Figure 20. Oahe personnel prepare to enter one of the Oahe Dam stilling basin outlet tunnels August 29, 2011. They drove boats one half mile into the tunnels to visually inspect tunnel walls for cracks, spalls or distress in the concrete 82

Figure 21. Components of the river corridor 83

Figure 22. Channel Performance Open River Reach Locations from Ft. Peck to the Mouth 84

Figure 23. Missouri River Basin Major Dams and Reservoirs 86

Figure 24. BSNP Channel with Private Levee System along Right Bank near Indian Cave State Park, Nebraska River Mile 517 Prior to 2011 flood 87

Figure 25. Number of Structures by Priority Level 89

Figure 26. Upper Kansas Bend SWH Chute Inlet at River Miler 546 - Pre Flood 2005. Downstream Flow to Left 90

Figure 27. Upper Kansas Bend SWH Chute Inlet at River Mile 546 (facing downstream) - 2011 Post Flood. Flood Erosion Flanked the Stone Protection at the "V" Structure Along the Downstream Bankline 91

Figure 28. Upper Hamburg Bend Levee Toe Scour Repair Area 93

Figure 29. Revetment Near River Mile 693.5 96

Figure 30. Revetment Near River Mile 679.8 97

Figure 31. Dike Near River Mile 640.2 97

Figure 32. Wolf Creek Bend Revetment Chute Erosion 102

Figure 33. Flanked Dike at River Mile 322.4 on Right Bank. 102

Figure 34. Dike and Revetment Damage at River Mile 250.5 102

Figure 35. Waterway Materials Moved on the Missouri River by Year 106

Figure 36. Kensler's Bend Project at Dakota Dunes along Left Bank River Mile 737 109

Figure 37. Stage Trends on the Missouri River at St. Joseph, Missouri 121

Figure 38. Comparison of 10-Yr Flood Heights for Various Hypothetical River Geometries 121

Figure 39. Missouri River Basin Levee Vulnerability 128

Figure 40. Omaha to L-594 129

Figure 41. L-575 – L-550 130

Figure 42. Union Township – L-471/460 131

Figure 43. L-455 to Wolcott DD 132

Figure 44. L-385 to MO Valley LD 133

Figure 45. Henrietta LD - West Glasgow LD 134

Figure 46. Howard City LD - Tebbets LD 135

Figure 47. Mokane LD - Howard Bend LD 136

Figure 48. NWD Missouri River Levees Impacted in 2011 Flood 140

Figure 49. Omaha - L-594 142

Figure 50. L-575 - L-550 143

Figure 51. Union Township - L-471/460 144

Figure 52. L 455 to MO Valley LD 145

Figure 53. Henrietta LD - West Glasgow LD 146

Figure 54. Howard City LD - Tebbets LD 147

Figure 55. Mokane LD - Howard Bend LD 148

Figure 56. Impacts of Levees on Hydraulic Relationships (Taken from Heine, Pinter, 2012) 153

Figure 57. Velocity Profile of the Missouri River 154
Figure 58. Kansas and Missouri River Remaining Levee Vulnerabilities 157
Figure 59. Corps officials from the Omaha District of the U.S. Army Corps of Engineers meet with members of Responsible River Management at the lower breach of Missouri River Levee Unit L-575 south of Hamburg, Iowa 162
Figure 60. Map of Native American Tribes 163
Figure 61. Flood Risk Management 170
Figure 62. Photo Location Map 184
Figure 63. Fort Peck Lake - Lake Level Comparison - Intake Structure 185
Figure 64. Fort Peck Lake - Lake Level Comparison - Duck Creek Boat Ramp 186
Figure 65. Dams damage/erosion: Fort Peck - Erosion along the spillway plunge pool extending from Fort Peck's spillway in Fort Peck, Montana 187
Figure 66. Levee seepage: Williston - Landside seepage, relief wells needed at Williston Levee, North Dakota 188
Figure 67. Levee boils: Williston - Additional relief wells needed at Williston Levee in North Dakota 188
Figure 68. Lake Sakakawea - Lake Level Comparison - Intake Structure 189
Figure 69. Lake Sakakawea – Charging Eagle Boat Ramp 190
Figure 70. Dams damage/erosion: Garrison - Erosion along the earthen walls extending from Garrison Dam's spillway apron in North Dakota 191
Figure 71. Garrison Spillway damage/erosion: 191
Figure 72. Dams damage/erosion: Garrison - Typical concrete repair from flood in North Dakota. Additional spall repairs needed at most dams 191
Figure 73. Dams damage/erosion: Garrison - Joint separation and seal repairs required at Garrison Dam in North Dakota 192
Figure 74. Dams damage/erosion: Garrison - Erosion along the earthen walls extending from Garrison Dam's spillway apron in North Dakota 192
Figure 75. Dams damage/erosion: Garrison - Downstream camp erosion at Garrison Dam in North Dakota 192
Figure 76. Erosion: Hogue Island, Section 33 Project - Erosion along the Section 33 Project at Hogue Island, North Dakota 193
Figure 77. Dams damage/erosion: Pipestem Dam - Downstream right abutment seepage area at Pipestem Dam in South Dakota 193
Figure 78. Lake Oahe Lake Level Comparison - Intake Structure 194
Figure 79. Lake Oahe Lake Level Comparison - Chantier Boat Ramp in Ft. Pierre, South Dakota 195
Figure 80. Dams damage/erosion: Oahe - Erosion along the earthen walls extending from Oahe's stilling basin outside Fort Pierre, South Dakota 196
Figure 81. Dams damage/erosion: Oahe 196

Figure 82. Dams damage/erosion: Oahe - Erosion at flood tunnel outlet for Oahe outside Fort Pierre, South Dakota (under repair) 196

Figure 83. Dams damage/erosion: Oahe - Flood control tunnel gate roller chain failure at Oahe outside Fort Pierre, South Dakota 197

Figure 84. Dams damage/erosion: Oahe - Outlet works bridge scour at abutment at Oahe, South Dakota 197

Figure 85. Damage/erosion: LaFramboise Island Causeway - City of Pierre waterlines damaged at LaFramboise Island Causeway (Corps) in Pierre, South Dakota 197

Figure 86. Dams damage/erosion: Big Bend Erosion on earthen walls of the project's spillway in South Dakota 198

Figure 87. Dams damage/erosion: Big Bend Erosion on earthen walls of the project's spillway in South Dakota 198

Figure 88. Dams damage/erosion: Big Bend Erosion on earthen walls of the project's spillway in South Dakota 198

Figure 89. Dams damage/erosion: Big Bend - Project's spillway in South Dakota being overtopped during flood 199

Figure 90. Dams damage/erosion: Big Bend – Project's spillway overtopping damage in South Dakota currently under repair 199

Figure 91. Dams damage/erosion: Big Bend – Project's spillway overtopping damage in South Dakota currently under repair 199

Figure 92. Dams damage/erosion: Fort Randall - Sloughing on earthen walls of the project's spillway and regulating tunnels in South Dakota 200

Figure 93. Dams damage/erosions: Fort Randall - Spillway weir spalling 200

Figure 94. Dams damage/erosion: Fort Randall - spillway gate wire hope hoist linkage corrosion 200

Figure 95. Dams damage/erosion: Fort Randall - Spillway wingwall backfill erosion (currently under repair) at Fort Randall in South Dakota 201

Figure 96. Dams damage/erosion: Fort Randall - Downstream spillway wingwall concrete spall at Fort Randall, South Dakota 201

Figure 97. Dams damage/erosion: Gavins Point - Erosion on earthen walls of the project's spillway in South Dakota 202

Figure 98. Dams damage/erosion: Gavins Point - Excess debris led to clogging of water intake at Hydropower Plant (under repair) in South Dakota 202

Figure 99. Dams damage/erosion: Gavins Point - Erosion on earthen walls of the project's spillway in South Dakota (under repair) 202

Figure 100. Levee scouring/erosion: Scour hole between Council Bend chute and MR Levee L624-627 toe in Council Bluffs, Iowa 203

Figure 101. Flood protection project damage: Hickory Street Pump Station - High water mark on interior side of an exterior door at a flood protection project in Omaha, Nebraska 203

Figure 102. Levee scouring/erosion: Typical riverside erosion and vegetation loss at L611-614 near Council Bluffs, Iowa 204

Figure 103. Levee seepage/sandboils: Typical landside seepage and sandboils at L611-614 near Council Bluffs, Iowa 204

Figure 104. Levee breach: Upper breach at L575 205

Figure 105. Levee breach: Upper breach at L575 205

Figure 106. Levee breach: Middle breach at L575 206

Figure 107. Levee breach: Middle breach at L575 206

Figure 108. Levee breach: Middle breach at L575 206

Figure 109. Levee breach: Lower breach at L575 207

Figure 110. Levee breach: Lower breach at L575 207

Figure 111. Levee breach: Upper breach at L550 208

Figure 112. Levee breach: Lower breach at L550 208

Figure 113. Levee scouring/erosion: L536 - Levee erosion – more than 50 percent of the embankment is missing – at MR Levee L536 209

LIST OF TABLES

Table 1. Missouri River Reach Delineation 6
Table 2. Economic Characteristics by Reach for the Potential Flood Area 8
Table 3. Communities within the Missouri River Potential Flood Area by Population 9
Table 4. Key Infrastructure in the Potential Flood Area by Reach 10
Table 5. Population, Structures, and Agriculture within the 2011 Flooded Area by Reach 13
Table 6. Key Infrastructure within the 2011 Flooded Area 21
Table 7. Damages Prevented in Fiscal Year 2011, in Thousands of Dollars (from Stage-Damage Curves) 27
Table 8. Economic Analysis 31
Table 9. Repair-Restore-Enhance 32
Table 10. Scheduled Infrastructure Assessments and Repairs 50
Table 11. Missouri River Water Control Manual Publication Dates 79
Table 12. Channel and Floodway Reach Description 85
Table 13. Preliminary Repair Quantities Needed (tons) by Structure Type and Priority Level 89
Table 14. Omaha District Shallow Water Habitat Construction Sites 92
Table 15. BSNP Structure Repair Summary 96
Table 16. NWO Shoaling Issues 98
Table 17. Structure Damage Repair Quantity Estimates in Kansas City District 99
Table 18. High Priority Structure Damage Repair Quantity Estimates in Kansas City District (Subset of total) 100
Table 19. Kansas City District Shoaling Issues 100
Table 20. Shallow Water Habitat Chutes Damaged by 2011 Flood 101
Table 21. Navigation Structures Repair Estimates 103
Table 22. Levees Having Damage and/or Requiring Assistance 149
Table 23. Top Widths at Constriction Points - Omaha/Council Bluffs to Rulo 152

LIST OF APPENDICES

Appendix Missouri River Flood Photography

LIST OF ACCRONYMS

AG	Advisory Group
AAR	After Action Report
ACE	Annual Chance of Exceedance
AOP	Annual Operating Plan
ARPA	Archeological Resources Protection Act
ARBCON	Atmospheric Resource Board Cooperative Observer Network
AWDN	Automated Weather Data Network
BPU	Board of Public Utilities
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
BNSF	Burlington Northern Santa Fe (Railroad)
BSNP	Missouri River Bank Stabilization and Navigation Project
CAA	Clean Air Act
CWA	Clean Water Act
CPC	Climate Prediction Center
CoCoRaHS	Community Collaborative Rain, Hail, and Snow
CRP	Construction Reference Plane
CNS	Cooper Nuclear Power Station
CURG	Corps user representatives group
CWMS	Corps Water Management system
cfs	Cubic feet per second
DSAP	Dam Safety Assurance Program
DCP	Data Collection Platform
DRGS	Direct Readout Ground Station
DRAA	Disaster Relief Appropriations Act
ESRL	Earth Science Research Laboratory
ESF 15	Emergency Support Function 15
ESA	Endangered Species Act
ER	Engineering Regulation
E	Expected
EA-PRT	External Planning and Response Team
FS	Factor of Safety
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
FCCE	Flood Control and Coastal Emergencies
FOIA	Freedom of Information Act
GIS	Geographic Information System
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HPRCC	High Plains Regional Climate Center
H	Higher-than-normal
HSIP	Homeland Security Infrastructure Program
HSS	Hydraulic Steel Structure
HEC	Hydrologic Engineering Center

HPC	Hydrometeorological Prediction Center
IWRSS	Integrated Water Resources Science and Services
IOP	Interim Operating Plan
LiDAR	Light Detection and Ranging
LWW	Low Use Waterways
L	Lower-than-normal
MLRA	Major Land Resource Area
MAF	Million acre-feet
MRC	Mississippi River Commission
MBRFC	Missouri Basin River Forecast Center
MRAO	Missouri River Area Office
MoRAST	Missouri River Association of States and Tribes
MRAPS	Missouri River Authorized Purposes Study
MRBIR	Missouri River Basin Interagency Roundtable
MRERP	Missouri River Ecosystem Restoration Plan
MRFTF	Missouri River Flood Task Force
MRJIC	Missouri River Joint Information Center
MRPO	Missouri River Project Office
MRRIC	Missouri River Recovery Implementation Committee
MRRP	Missouri River Recovery Program
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote Sensing Center
NPS	National Park Service
NSSC	National Soil Science Center
NSAP	National Standards Assessment Program
NSIP	National Streamflow Information Program
NWCC	National Water and Climate Center
NWS	National Weather Service
NAGPRA	Native American Graves Protection and Repatriation Act
NRCS	Natural Resources Conservation Service
NPPD	Nebraska Public Power District
NDT	Non Destructive Testing
NWD	Northwestern Division
NWK	Kansas City District
NWO	Omaha District
NWD-MRWMD	Northwestern Division-Missouri River Water Management Division
OMB	Office of Management and Budget
OPPD	Omaha Public Power District
O&M	Operations and Maintenance
ORV	Outstanding and remarkable values
P	Precipitation
PED	Pre-construction, Engineering and Design
PI	Periodic Inspections
PICE	Periodic Inspection and Continuing Evaluation

PIR	Project Information Report
PMF	Probable Maximum Flood
PA	Programmatic Agreement
PL	Public Law
RIP	Rehabilitation and Inspection Program
ROV	Remote Operated Vehicle
R,R&R	Repair, rehabilitation and replacement
RCO	Response and Contingency Operations Division
ROW	Right of Way
R&U	Risk and Uncertainty
SWH	Shallow Water Habitat
SWE	Snow water equivalent
SCAN	Soil Climate Analysis Network
SOP	Standard operating procedure
SHPO	State Historic Preservation Officers
SWC	State Water Commission
T	Temperature
IRRM	Interim Risk Reduction Measures
TIGER	Topologically Integrated Geographic Encoding and Referencing (system)
TCPs	Traditional Cultural Properties
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
NASS	National Agricultural Statistics Service
USGS	U.S. Geological Survey
UPRR	Union Pacific Railroad
WCDS	Water control data system
WRDA	Water Resources Development Act
WAPA	Western Area Power Administration

1. Introduction & Purpose

1.1 INTRODUCTION

The U.S. Army Corps of Engineers' (Corps) flood risk management system and processes on the Missouri River are fundamentally intact. The most immediate repairs after the 2011 flood are completed, and other repairs are underway. The Corps remains committed in working with the basin's stakeholders to tackle its flood risk management mission as effectively as possible. The flood exposed or aggravated some vulnerabilities in the Corps' systems which cannot be immediately resolved with existing resources, and this report addresses those vulnerabilities.

The Missouri River Flood of 2011 offered the Corps and others several important lessons. Those lessons included the value of accurate and improved data collection and use; the need for effective communication among all stakeholders before, during and after flood events; the nature and value of resources exposed to flood risk in the Missouri River floodplain; and the value and limitations of existing flood risk management.

Numerous stakeholders and resources were impacted by the flood. Some have felt that a flood such as the 2011 flood should never happen again. Realistically, it would be unsupportable for the Corps to attest to stakeholders, to the public, and to leaders including Congress, that the Corps could prevent floods such as that of 2011 from occurring in the future. The 2011 runoff volume was so huge and unprecedented that the Corps' system, even restored and improved, will not be able to preclude flooding from such an event in the future. Further, the size and reach of the Missouri River basin, regional climate variability, infrastructure limitations, and distributed roles at all levels to manage flood risk, render it impossible to prevent even some lesser flood events and resulting damages. Had downstream rainfall and runoff occurred in 2011 at the same time as the upstream events, impacts would have been even greater; future similar runoff events could occur downstream of the six mainstem dams which prevented much higher peaks in the 2011 event. However, the Corps and others have effectively managed risk from numerous events in the past and can more effectively manage for those events in the years ahead.

1.2 REPORT PURPOSE

This report is authorized and funded under Public Law (PL) 84-99, Flood Control and Coastal Emergencies (FCCE), the scope of which includes disaster preparedness, flood response, post-flood response, and rehabilitation of flood control works threatened or destroyed by flood. Thus, this report describes what is needed to restore the system to constructed functionality. It also suggests system improvements, some of which are already being implemented, aimed toward strengthening the system. It points out gaps between authorized system components and what was appropriated and constructed; for instance, authorized levees that were not constructed upstream of Omaha. The report may also point out where new or revised authorities could have effects on flood risk management. Currently unauthorized flood risk management features or operations could be studied and evaluated in detail, given new specific authority and funding.

Figure 2. Brigadier General John McMahon speaks with South Dakota Lt. Governor Matt Michels at Dakota Dunes, South Dakota.

2. Background

2.1 THE EXISTING SYSTEM

Historically, the Missouri River flooded often. People were aware of the unruly river's flooding history; floodplain residents lived in portable homes and villages. Fort Peck Dam in Montana, the farthest upstream Corps dam, was authorized in 1933 by President Franklin Roosevelt more as a New Deal economic stimulus than as a flood control project. However, development pressure in the floodplain, and resulting flood damages, grew.

Congress passed the Flood Control Act of 1944 to authorize numerous dams across the country; this included the Missouri River Basin Development Project, which combined Corps of Engineers and Bureau of Reclamation plans into one plan, later named the Pick-Sloan Plan after the heads of those two agencies. This authorized five mainstem dams downstream of Ft. Peck Dam, and it authorized operation of all six mainstem dams as part of the Missouri River mainstem reservoir system. This authority and others also resulted in additional tributary and mainstem dams not owned by the Corps, which play a role in flood risk management and are operated by the Corps during flood conditions.

The Missouri River Basin Development Project also included levees throughout the basin including a mainstem levee system from Sioux City, Iowa to the mouth. The actual levee system constructed did not extend upstream of Omaha. This was due to bed degradation below Gavins Point Dam creating a more efficient channel in the upstream reach, reducing levee benefits, and also due to a lack of sponsor support for the reach above Omaha. Overall, there are over 360 miles of levees along the mainstem and floodplain tributaries. Besides federal levees and floodwalls, there are non-federal levees and floodwalls that were allowed into the system over time. The non-federal levees almost invariably have greater overtopping risk, as only 5-year to 10-year levels of protection are needed to qualify for acceptance.

Another important component of the system is the Missouri River Bank Stabilization and Navigation Project (BSNP), and related projects. BSNP was authorized by the Rivers and Harbors Act of 1945; the authorized 9-foot x 300-foot navigation channel was developed over succeeding decades and completed in 1980. This and other authorities over the years built hundreds of miles of bank stabilization works along the entire navigation channel, from upstream of Sioux City, Iowa to the mouth. Over time, the BSNP and related structures have effectively become components of the flood risk management system, as bank stability protects levees and floodwalls.

Still another component is the habitat recovery projects which are an integral part of the BSNP and related water management. These projects are underpinned by the Fish and Wildlife Coordination Act of 1958, the Endangered Species Act of 1972, and the Missouri River Recovery Program (MRRP) authorized by the Water Resources Development Act of 2007. These projects include a number of off-channel chutes and thousands of acres of wetlands, forests, and grasslands.

All these projects together, and more, form a complex multipurpose system which is partly operated and maintained by the Corps and partly operated and maintained by non-federal entities.

2.2 WATER MANAGEMENT IN THE SYSTEM

The 1944 Flood Control Act identified eight purposes for which the Corps' Missouri River mainstem reservoirs should be managed: flood control, water supply, irrigation, navigation, hydropower, fish and wildlife, water quality control and recreation. The Corps is charged with operating the system to balance these eight purposes. The Corps establishes operational guidelines for balancing these purposes in its Missouri River Master Manual. The Master Manual is a water control plan that helps guide how much water should be released, when, and for how long from the six reservoirs for the benefit of the entire Missouri River basin. The Corps is also charged with operating non-Corps reservoirs in the basin during flood conditions.

The Corps most recently revised its Master Manual in 2004 following a 14-year period of public involvement to balance all the competing uses for the Missouri River. Hundreds of alternatives were analyzed and considered during this process. The current Master Manual reflects that input from the public and Tribes throughout the entire basin on how the reservoirs could best be operated to serve all the purposes for which they were authorized and constructed. The Master Manual can be downloaded from the Corps' Missouri River Basin Water Management Division web site (http://www.nwd-mr.usace.army.mil/rcc/) under the "Reports and Publications" section.

Each year an Annual Operating Plan (AOP) is developed to make necessary adjustments to reservoir operations based on current and projected annual conditions. That plan considers key factors related to precipitation in the basin, including amount of water received the previous year, rainfall events, plains snow pack, and mountain snow pack. This annual plan is circulated every fall and public meetings are held throughout the Missouri River basin to gain input from the public and Tribes. Other water control manuals include reservoir regulation manuals for tributary and non-Corps Reservoirs. The most current AOP can be downloaded from the Corps' Missouri River Basin Water Management Division web site (http://www.nwd-mr.usace.army.mil/rcc/) under the "Reports and Publications" section.

2.3 FLOOD OF 2011

The design storm for the Missouri River reservoir system was based on the year 1881, when runoff of 40.0 million acre-feet (MAF) occurred during a 5-month period (March through July). To accommodate this storm, system design included 16.3 MAF of flood control storage with peak releases of 100,000 cubic feet per second (cfs) from Fort Randall Dam. In 2011, runoff during the same March through July period totaled an estimated 48.4 MAF, twice normal levels and more than twenty percent greater than the historic design storm from 130 years earlier. System storage in 2011 crested at 72.8 MAF, just 0.3 MAF below the top of the exclusive flood control zone of 73.1 MAF, using 16.0 MAF of flood control storage with peak releases of 160,000 cfs from Gavins Point Dam. Runoff for all 2011 totaled 61.0 MAF, more than the entire water storage capacity of the system. This record runoff occurred due to historic rainfall over portions of the upper basin coupled with heavy plains and mountain snowpack. Surcharge storage was used in both Fort Peck and Garrison reservoirs, spillways at these two dams were operated for flood control for the first time, and new record pool levels were set at Fort Peck, Oahe, and Fort Randall reservoirs. Record releases were made from all six reservoirs comprising the system.

2.4 ECONOMICS

2.4.1 Missouri river floodplain economic Overview

The Missouri River floodplain is one of extremes, with wide variation in temperatures, rainfall, stream flow, water supply, soils, population density, and business and industrial development. The Missouri River is the longest river system in North America, and its reservoir system is the largest in the United States, with a capacity of 73 MAF People use the Missouri River, its tributaries, groundwater, and river management infrastructure for many different purposes including flood risk management, recreation, navigation, water supply, hydropower, irrigation, water quality and ecosystem services. These uses support economic investment and activity throughout the basin, particularly within and bordering the Missouri River's floodplain. Flooding in 2011 showed many of the vulnerabilities associated with these investments and economic activities. This section provides an overview of the economic characteristics associated with the Missouri River, some of the economic impacts from the 2011 flooding, and a description of the economic vulnerabilities related to Missouri River flooding, even beyond the impacts from 2011.

2.4.1.1 Geographic Extent

The Missouri River extends approximately 2,321 miles from the confluence of the Madison, Gallatin, and Jefferson rivers, near Three Forks, Montana in the Rocky Mountain region, through the Great Plains to the Central Lowlands of Missouri to near St. Louis at its confluence with the Mississippi River. States in the Missouri River floodplain include Iowa, Kansas, Missouri, Montana, Nebraska, North Dakota, South Dakota, and Wyoming. The Missouri River basin drains approximately one sixth of the continental Unites States (529,000 square miles).

The floodplain width is defined as the bluff line on either side of the river. It varies widely in width from just over a mile at its narrowest to over 17 miles at its widest point, with an average of about three miles for the entire reach. Table 1 lists all 28 reaches and Figure 3 displays the entire Missouri River basin and also identifies the potential flood area as extending from bluff to bluff. The stretch of the Missouri River for this assessment extends from Fort Peck Lake headwaters (river mile 1931) to near Washington, Missouri (river mile 66). Due to the large geographic extent of the area, the river has been divided into 28 reaches. These reaches are also based on those delineated in the *Missouri River: Re-Evaluation of Main Stem Flood Control Benefits Report* (USACE, 1955). Since major tributaries have influence on mainstem flooding, many reaches have boundaries beginning and ending at major tributaries. Other reaches are based on major urban centers. The reservoirs are generally treated as their own reaches. These reaches, though altered slightly and interpreted differently over time, are still used today for mainstem stage-damage curves by Northwestern Division's Omaha District (NWO) and Kansas City District (NWK).

Table 1. Missouri River Reach Delineation

Reach	Name	Upstream River Mile	Downstream River Mile
1	Ft. Peck Reservoir	1931	1771
2	Milk River	1771	1761
3	Culbertson	1761	1679
4	Wolf Point	1679	1582
5	Williston	1582	1544
6	Garrison Reservoir	1544	1389
7	Bismarck	1389	1299
8	Oahe Reservoir	1299	1072
9	Pierre	1072	1044
10	Big Bend Reservoir	1044	988
11	Ft. Randall Reservoir	987	880
12	Ft. Randall Dam - Gavins Point Reservoir	880	828
13	Gavins Point Reservoir	828	811
14	Yankton	811	734
15	Sioux City	734	669
16	Decatur	669	635
17	Omaha	635	595
18	Nebraska City	595	542
19	Rulo (Omaha District - NWO)	542	520.5 (Left Bank) 497.3 (Right Bank)
20	Rulo (Kansas City District - NWK)	520.5 (Left Bank) 497.3 (Right Bank)	455
21	St. Joseph	455	367
22	Kansas City	367	349
23	Kansas River	349	313
24	Crooked River	313	250
25	Grand River	250	239
26	Chariton River	239	130
27	Osage River	130	104
28	Gasconade River	104	66

2.4.1.2 Population, Structures, Land and Agriculture in the Potential Flood Area

Data on population, residential and non-residential structures and values, and land area were gathered for each of the 28 reaches. Table 2 displays this data including population, number of structures, structure and content value, and land area within the Missouri River potential flood area. Population data was obtained from 2010 Census shape files available in the Topologically Integrated Geographic Encoding and Referencing (TIGER) system. Residential and non-residential structure data were derived from the Federal Emergency Management Agency (FEMA) Hazus database. Hazus is a nationally-applicable standardized database containing economic data that can be used to estimate potential losses from disasters, such as floods.

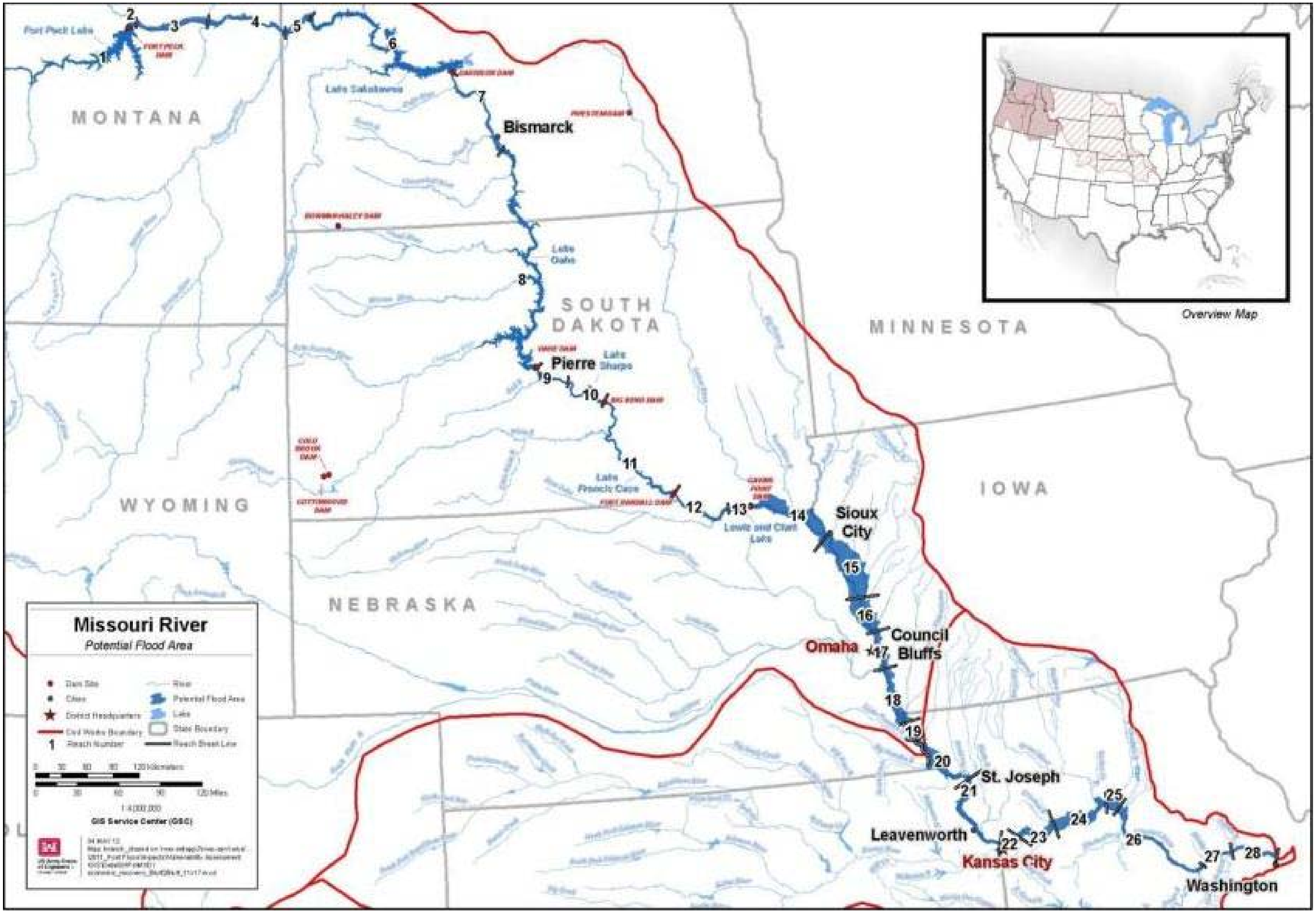

Figure 3. Potential Flood Area

Table 2. Economic Characteristics by Reach for the Potential Flood Area

Reach	Population	Residential Structures	Non-Residential Structures	Total Structure & Content Value ($1,000)	Land Area (Acres)	Agricultural Land Area (Acres)
Ft. Peck Reservoir (1)	22*	39	0	$5,237	71,345	219
Milk River (2)	78	1	0	$51	9,861	4,160
Culbertson (3)	1,404	44	0	$6,848	108,734	42,196
Wolf Point (4)	345	204	1	$21,215	81,848	35,814
Williston (5)	953	1,001	111	$286,638	53,743	16,249
Garrison Reservoir (6)	133*	139	2	$20,208	95,280	263
Bismarck (7)	24,559	10,396	954	$2,777,287	81,660	24,642
Oahe Reservoir (8)	2,239	624	26	$115,888	133,794	8,034
Pierre (9)	6,571	4,033	512	$1,194,325	13,224	1,231
Big Bend Reservoir (10)	489	199	12	$29,962	8,309	1,970
Ft. Randall Reservoir (11)	949	961	126	$240,268	8,232	612
Ft. Randall Dam - Gavins Point Reservoir (12)	507	506	19	$57,024	34,737	9,690
Gavins Point Reservoir (13)	90	231	1	$11,662	3,549	617
Yankton (14)	20,230	10,382	1,073	$2,894,935	281,871	218,195
Sioux City (15)	33,914	14,418	2,010	$4,648,108	438,733	351,076
Decatur (16)	5,416	5,082	474	$952,748	198,960	162,060
Omaha (17)	72,124	24,920	2,871	$10,045,303	82,106	37,063
Nebraska City (18)	3,365	3,361	301	$608,701	163,964	112,501
Rulo (NWO [19])	498	515	26	$53,872	64,716	47,163
Rulo (NWK [20])	1,465	2,028	160	$339,988	149,802	109,817
St. Joseph (21)	16,366	8,602	1,566	$4,895,572	118,250	80,709
Kansas City (22)	5,249	2,893	1,618	$5,977,724	26,858	11,875
Kansas River (23)	2,367	2,212	167	$499,190	91,439	79,066
Crooked River (24)	2,391	1,883	145	$364,873	190,244	165,704
Grand River (25)	127	418	5	$24,821	40,914	33,731
Chariton River (26)	2,923	1,009	144	$330,254	123,960	90,190
Osage River (27)	700	1,104	67	$180,978	29,324	21,297
Gasconade River (28)	575	595	93	$182,854	43,332	33,523
Total	**205,992**	**97,800**	**12,484**	**$36,766,534**	**2,748,789**	**1,699,667**

*Due to inconsistencies in the GIS methodology for determining the Potential Flood Area boundary and the 2011 Flood Area boundary, these two reaches experienced irregularities in the data. For the purposes of this analysis, it was deemed appropriate to count the population in the 2011 Flooded Area in the Potential Flooded Area, as well.
Sources: Population: Topologically Integrated Geographic Encoding and Referencing (TIGER) system shape files, 2010 Census. Structure and Content Data: Hazus 2.0 Database. Federal Emergency Management Agency (FEMA), 2011.
Land and Agricultural Data: USDA/NASS 2010 Cropland Data Layer. U.S. Department of Agriculture (USDA) National Agricultural Statistics Database, 2011.

The structure count estimate is based on 2000 Census data, which is the most up-to-date and readily available data. Regional population centers contain a large portion of the population and structures in the potential flood area. Williston, Bismarck and Mandan, Pierre and Ft. Pierre, Sioux City, Omaha, Council Bluffs, St. Joseph and Kansas City have varying portions of their populations and structures located within the potential flood area, but their higher population densities make them the largest contributors to settlement and development in the floodplain.

Land area and agricultural land area was determined using data obtained from the U.S. Department of Agriculture (USDA)/National Agricultural Statistics Service (NASS) 2010 Cropland Data Layer. Agricultural land makes up 62 percent of the total land area in the floodplain. About 87 percent of agricultural land is used for cultivating corn and soybeans.

2.4.1.3 River Communities in the Potential Flood Area

River communities are primarily those that are located inside the bluffs along the Missouri River. These communities are listed in Table 3. A few communities are located on the bluffs, but still within the Missouri River basin. The majority of the larger cities and communities are located in the lower basin of the Missouri River.

Table 3. Communities within the Missouri River Potential Flood Area by Population

Population	Community
150k+	Omaha, NE; Bellevue, NE; Council Bluffs, IA; Kansas City, MO/KS
50-149k	Bismarck/Mandan, ND; Sioux City, IA; Dakota Dunes, SD; Sergeant Bluff, IA; St. Joseph, MO; Columbia, MO
10-49k	Williston, ND; Pierre/Ft. Pierre, SD; Yankton, SD; Atchison, KS; Leavenworth/Lansing, KS; Jefferson City, MO; Washington, MO
2,500-9,999	Wolf Point, MT; Mobridge, SD; Onawa, IA; Missouri Valley, IA; Blair, NE; Plattsmouth, NE; Nebraska City, NE; Lexington, MO; Boonville, MO

Source: 2010 Census Interactive Population Map, 2010 Census.

2.4.1.4 Key Infrastructure in the Potential Flood Area

Key infrastructure in the Missouri River potential flood area includes energy production, storage, and transmission, emergency response agencies and institutions, other public institutions, entities that care for children or the elderly, key transportation infrastructure, wastewater treatment facilities, and facilities that may pose a significant health and safety threat if severely impacted by flooding (i.e. nuclear facilities). This key infrastructure data was gathered using the 2011 Homeland Security Infrastructure Program (HSIP) Gold database, which contains nationwide foundation level infrastructure information. Table 4 shows the key infrastructure in the Missouri River flood area by reach. Specific categories of infrastructure from the database were aggregated into the general groupings (based on similar attributes) for brevity.

Table 4. Key Infrastructure in the Potential Flood Area by Reach

Reach	Energy Producing Plants & Storage Facilities, Non-Nuclear (Biodiesel, Electricity, Natural gas, etc.)	Nuclear Energy Producing Plants & Storage Facilities	Energy Infrastructure (Generating units, pipelines, oil wells, substations, transmission lines)	Emergency Response (Hospitals, Fire Stations, Emergency Operation Facilities, Red Cross)	Educational, Daycare, Senior Care Facilities (including universities)	Wastewater Treatment Plants	Airports (Public & Base Helipads/ Airports)	Ground Transportation Infrastructure				
								Road			*Railroad*	*Bridges*
								Interstate Miles	*Highway Miles*	*Local Street Miles*	*Miles*	*Road/Railroad*
Ft. Peck Reservoir	1	0	11	0	0	0	0	0	2	15	0	1
Milk River	0	0	6	0	0	0	0	0	6	18	0	0
Culbertson	0	0	19	0	4	0	1	0	30	198	36	15
Wolf Point	0	0	36	0	0	0	0	0	5	110	31	8
Williston	1	0	49	1	3	0	0	0	6	134	23	9
Garrison Reservoir	1	0	28	0	4	0	0	0	4	18	0	2
Bismarck	3	0	56	3	19	0	1	5	2	317	44	36
Oahe Reservoir	0	0	10	4	6	1	1	0	2	93	0	11
Pierre	2	0	24	3	14	0	0	0	23	99	24	17
Big Bend Reservoir	1	0	11	1	1	0	0	0	1	25	0	6
Ft. Randall Reservoir	0	0	6	2	5	0	0	3	3	33	3	11
Ft. Randall Dam - Gavins Point Reservoir	1	0	19	2	4	0	0	0	15	84	10	12
Gavins Point Reservoir	1	0	5	0	2	0	0	0	0	30	0	7
Yankton	0	0	204	8	35	0	3	54	64	881	90	119
Sioux City	4	0	160	23	45	1	7	108	121	1,466	177	226
Decatur	2	1	54	7	8	0	2	59	28	567	73	143
Omaha	7	0	110	12	71	1	3	79	27	637	156	289
Nebraska City	2	0	56	3	1	0	0	88	25	508	97	164
Rulo (NWO)	1	1	11	2	0	0	1	28	7	203	33	47
Rulo (NWK)	1	0	54	2	3	0	2	46	16	485	81	118
St. Joseph	10	0	389	14	15	2	7	8	77	465	229	241
Kansas City	5	0	116	3	5	1	2	13	28	191	176	115
Kansas R.	2	0	30	1	4	0	3	0	33	222	84	70
Crooked R.	0	0	21	3	9	0	3	0	43	472	95	104
Grand R.	0	0	7	0	0	0	0	0	5	96	12	13
Chariton R.	1	0	38	2	1	0	2	4	38	302	114	73
Osage R.	1	0	14	3	2	0	0	0	19	68	32	19
Gasconade R.	0	0	4	2	3	0	3	0	15	121	57	32
Total	**47**	**2**	**1,548**	**101**	**264**	**6**	**41**	**495**	**646**	**7,858**	**1,677**	**1,908**

Source: HSIP Gold Database, 2011.

Two nuclear power plants are located within the floodplain, which poses potential risks to health and safety of nearby populations as a result of flooding. Energy and water treatment facilities located in the floodplain are subject to a risk of disruption in service or operations or high costs if there is a change in supply due to flooding. In smaller communities, these circumstances could also lead to evacuations causing more costs and impacts to the affected population. Transportation industries as well as local populations could also suffer losses due to detours and delays brought about by closed roadways and railroads.

2.4.2 2011 Missouri River Economic Flood Impacts

Using Geographic Information System (GIS) mapping tools and imagery based on where flood waters were located, digitized flood boundaries were developed to reflect the flooded area from the 2011 Missouri River flood event. This 2011 flooded area is displayed in Figure 4. This flooded area boundary is based on GIS integration from three different sources, which were the best available data and sources at the time.

2.4.2.1 Population, Structures, Land and Agriculture within the 2011 Flood Area

This GIS mapping of the flooded area was used as a boundary to extract the population, structures, land and agriculture within this area. While this is not a reflection of actual population, number/value of structures and lands impacted or actual damages incurred, it does depict a general sense of the magnitude of people and property within the flooded area that may have been impacted from the 2011 flooding. Table 5 summarizes this socioeconomic data by reach. It is based on best available data (including nationally standardized data). Hence, there are many uncertainties in the estimates that could be reduced with more precise localized survey data.

Approximately 4.4 percent of the population residing in the floodplain was also located in the 2011 flooded area based on the delineated 2011 flooded boundary area. Nearly the same percentage of residential and non-residential structures is in the flooded area as well. This does not account for the total population impacted in the form of evacuations, lost wages, increased transportation costs, etc. Also, it may not account for structures subject to ground water flooding in basements due to high water tables. Although the economic damages from flooding were not evaluated for this report, it is estimated that over $1.1 billion worth of structures and content value were within the 2011 flooded area and subject to flood damages.

Of the agricultural land within the bluff to bluff area, just over 25 percent of it was subject to Missouri River flooding in 2011. Nearly 40 percent of the total land area was within the 2011 flood impacted area. For some reaches, the percent of the population and property that was affected was much greater than the total average for all reaches. In some flooded areas, entire agricultural production was lost due to flooding. Crop losses and other flooding impacts in a region with a substantial portion of its economy driven by agriculture may have experienced widespread and lasting impacts.

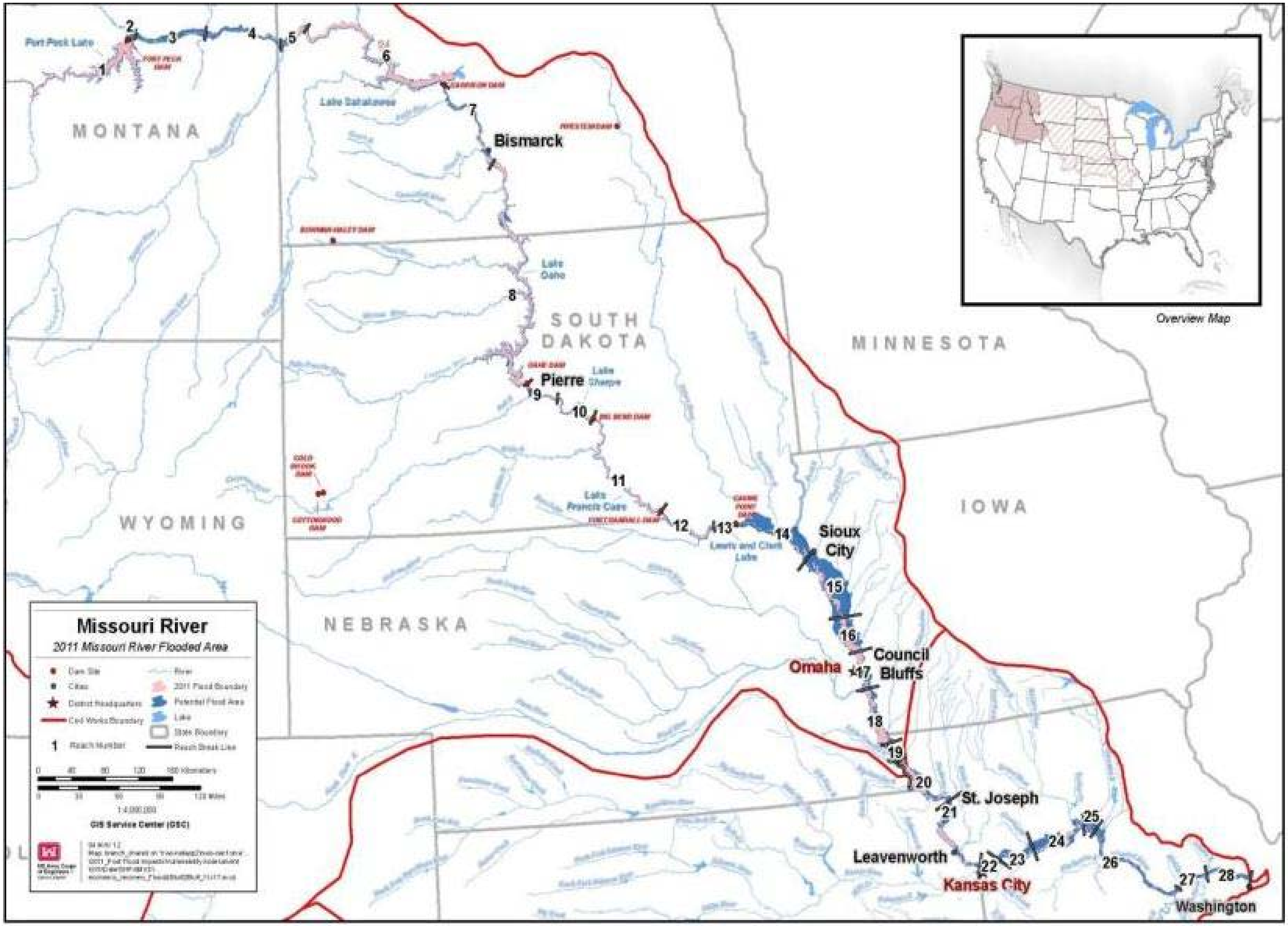

Figure 4. Flooded Area

Table 5. Population, Structures, and Agriculture within the 2011 Flooded Area by Reach

Reach	Population	Residential Structures	Non-Residential Structures	Total Structure & Content Value ($1,000)	Land Area (Acres)	Agricultural Land Area (Acres)
Ft. Peck Reservoir (1)	22	5	0	$590	77,000	120
Milk River (2)	4	1	0	$51	978	28
Culbertson (3)	81	5	0	$806	10,251	2,833
Wolf Point (4)	23	17	0	$2,672	12,535	1,061
Williston (5)	842	188	12	$40,403	35,861	4,847
Garrison Reservoir (6)	133	119	2	$16,840	109,382	753
Bismarck (7)	**2,308**	**603**	**68**	**$175,908**	**24,687**	**5,438**
Oahe Reservoir (8)	192	91	4	$17,480	136,846	1,546
Pierre (9)	**414**	**183**	**11**	**$44,477**	**2,981**	**162**
Big Bend Reservoir (10)	14	5	0	$236	689	18
Ft. Randall Res. (11)	156	135	8	$19,461	12,001	943
Ft. Randall Dam - Gavins Point Reservoir (12)	116	274	9	$28,771	21,623	4,972
Gavins Point Reservoir (13)	12	9	0	$720	515	90
Yankton (14)	**1,136**	**320**	**34**	**$94,269**	**18,375**	**8,652**
Sioux City (15)	**411**	**385**	**44**	**$79,503**	**58,816**	**37,190**
Decatur (16)	**622**	**602**	**30**	**$97,749**	**70,919**	**52,757**
Omaha (17)	**472**	**342**	**58**	**$125,740**	**38,199**	**23,267**
Nebraska City (18)	**797**	**677**	**71**	**$109,911**	**109,720**	**71,471**
Rulo - NWO (19)	**203**	**246**	**9**	**$20,937**	**51,812**	**37,304**
Rulo - NWK (20)	**496**	**808**	**38**	**$106,487**	**98,603**	**69,613**
St. Joseph (21)	**1,159**	**389**	**54**	**$117,446**	**53,808**	**36,350**
Kansas City (22)	3	0	2	$8,233	1,676	1,251
Kansas River (23)	107	110	13	$29,924	21,839	18,551
Crooked River (24)	117	84	6	$13,276	54,817	45,199
Grand River (25)	5	13	0	$1,027	5,445	3,673
Chariton River (26)	270	68	20	$37,481	18,575	10,933
Osage River (27)	23	14	0	$985	2,418	1,040
Gasconade River (28)	36	4	3	$1,208	3,953	2,001
Total (Vulnerable Reaches)	**8,018**	**4,555**	**417**	**$972,427**	**527,920**	**342,204**
Total All Reaches (1-28)	10,174	5,697	496	$1,192,589	1,054,323	442,063

*Bolded reaches indicate high vulnerability reaches within the 2011 flooded area. Many of these reaches experienced significant flooding and required substantial emergency flood fighting to prevent further impacts to areas within each reach. This is further described in Section 2.2.2 "High Vulnerability Reaches."

Sources: Topologically Integrated Geographic Encoding and Referencing (TIGER) system Shapefiles, 2010 Census. HAZUS 2.0 Database. Federal Emergency Management Agency (FEMA), 2011. USDA/NASS: 2010 Cropland Data Layer. U.S. Department of Agriculture (USDA) National Agricultural Statistics Database, 2011.

2.4.2.2 High Vulnerability Reaches

The 2011 flood event identified certain reaches of the river as highly vulnerable to flooding. Factors contributing to their vulnerability include their location relative to the river (and the risk of that location being flooded), as well as the amount of development within the floodplain in these reaches (the potential consequences of significant flooding). Many of these reaches experienced significant flooding and required substantial emergency flood fighting to prevent further impacts to areas within each reach. Additional impacts specific to these reaches are further described below. Aerial photos which display the extent of the 2011 flooding for some of these reaches are also included below.

Bismarck Reach

The Bismarck Reach (Reach 7) lies between Garrison Dam and Lake Oahe and contains the cities of Bismarck, North Dakota and Mandan, North Dakota. This reach has a large population and value of structures and contents located within the 2011 flood boundary. During the 2011 flood event, Bismarck and Mandan required Corps assistance with flood fighting efforts. This included constructing miles of temporary earthen levees and sandbagging to protect critical infrastructure (water treatment facilities on both sides of the river), an elementary school, and many residential areas. According to the 2011 After Action Report (AAR), an estimated $10 million was spent on flood fighting efforts. Figure 5 shows the extent of the 2011 flooding for the Bismarck Reach.

Figure 5. Bismarck, North Dakota Reach

Pierre Reach

The Pierre reach (reach 9), which lies in between Oahe Dam and Lake Sharpe, contains the cities of Pierre, South Dakota and Fort Pierre, South Dakota. Major impacts to the Pierre and Fort Pierre area were avoided through substantial emergency flood fighting efforts, many of which were for protection of water and sewage facilities. According to local officials, the consequences of losing the water and sewage infrastructure could have led to transporting water into the cities by truck, which would have been very costly. According to the 2011 AAR, around four miles of clay levee were constructed on both sides of the river, with estimated costs near $10 million. Figure 6 shows the extent of the 2011 flooding for the Pierre reach.

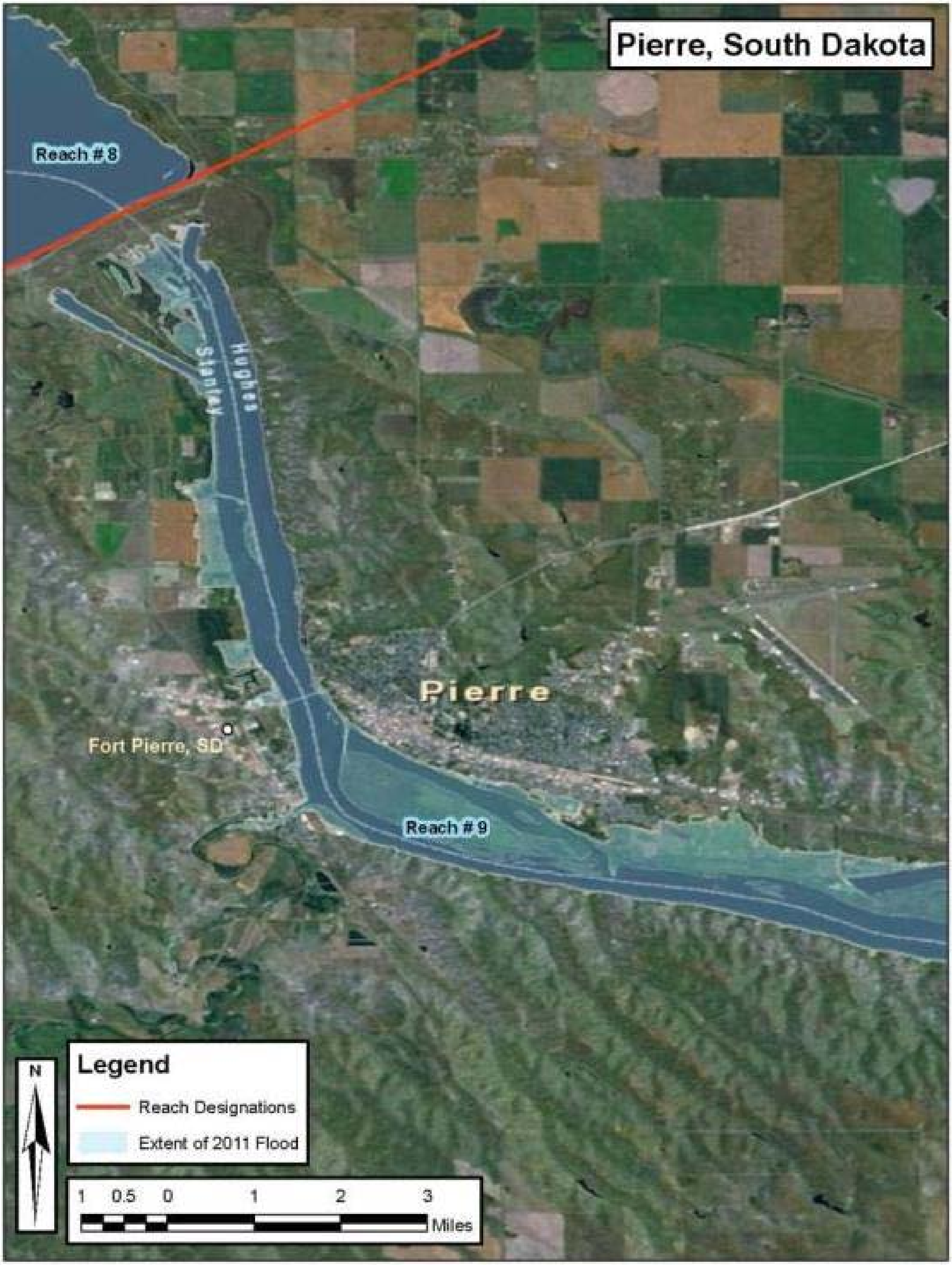

Figure 6. Pierre, South Dakota Reach

Gavins Point Reservoir to Kansas City Reaches

Extensive flood impacts were experienced between Gavins Point Dam, just upstream of Yankton, South Dakota, and Kansas City, Missouri. This stretch of river, approximately 450 river miles long, includes the Yankton through St. Joseph reaches (reaches 14-21) and accounted for significant portions of population, structures, land, and infrastructure impacted during the 2011 flooding. Based on the 2011 flooded area boundary, 52 percent of the population, 63 percent of the value of structures and contents, and 76 percent of agricultural land are within this stretch of river. In the stretch between Rulo, Nebraska and Kansas City, every non-federal levee either breached or overtopped, while federal levees performed as designed. While the federal levees did not breach, several units of the Missouri River Levee system in northwestern Missouri and northeastern Kansas sustained damages requiring expensive repairs.

While this is not a complete list, communities that sustained at least some urban damage included: Dakota Dunes in South Dakota; South Sioux City, Omaha, Decatur, Dakota City, Plattsmouth, Bellevue, Nebraska City and Fort Calhoun in Nebraska; Sioux City, Council Bluffs, Bartlett, and Percival in Iowa; Watson, Phelps City, Big Lake, Fortescue, Lewis and Clark Village, Forest City, St. Joseph, Winthrop, Rushville and Parkville in Missouri; and Elwood, Atchison and Leavenworth in Kansas. Thousands of acres of crops were also inundated in these reaches as well.

Significant portions of key infrastructure impacted are located within this stretch. Key energy-producing facilities such as the Fort Calhoun Nuclear Station (Decatur reach), Nebraska City Unit 2 Coal-Fired Plant (Nebraska City reach), and Cooper Nuclear Station (Rulo - NWO reach) are located in this stretch of river. Based on the 2011 flooded area boundary, most of the transportation infrastructure impacted is located in the eight reaches that make up this stretch of river. Nearly all interstate miles and 75 percent of total miles of road impacted are located in this stretch. Almost 75 percent of railroad miles impacted fall within this stretch, as well.

Much infrastructure required emergency flood protection assistance from the Corps, as well as state and local agencies. Further information on the infrastructure impacted from the 2011 flood, as well as a description of some of the flood fighting activities that took place to prevent or reduce flood damages is provided below. Figures 7 and 8 show the extent of the 2011 flooding for the Gavins Point Dam to Omaha reaches and the Omaha to Kansas City reaches. Table 6 enumerates key infrastructure within the 2011 flooded area by type.

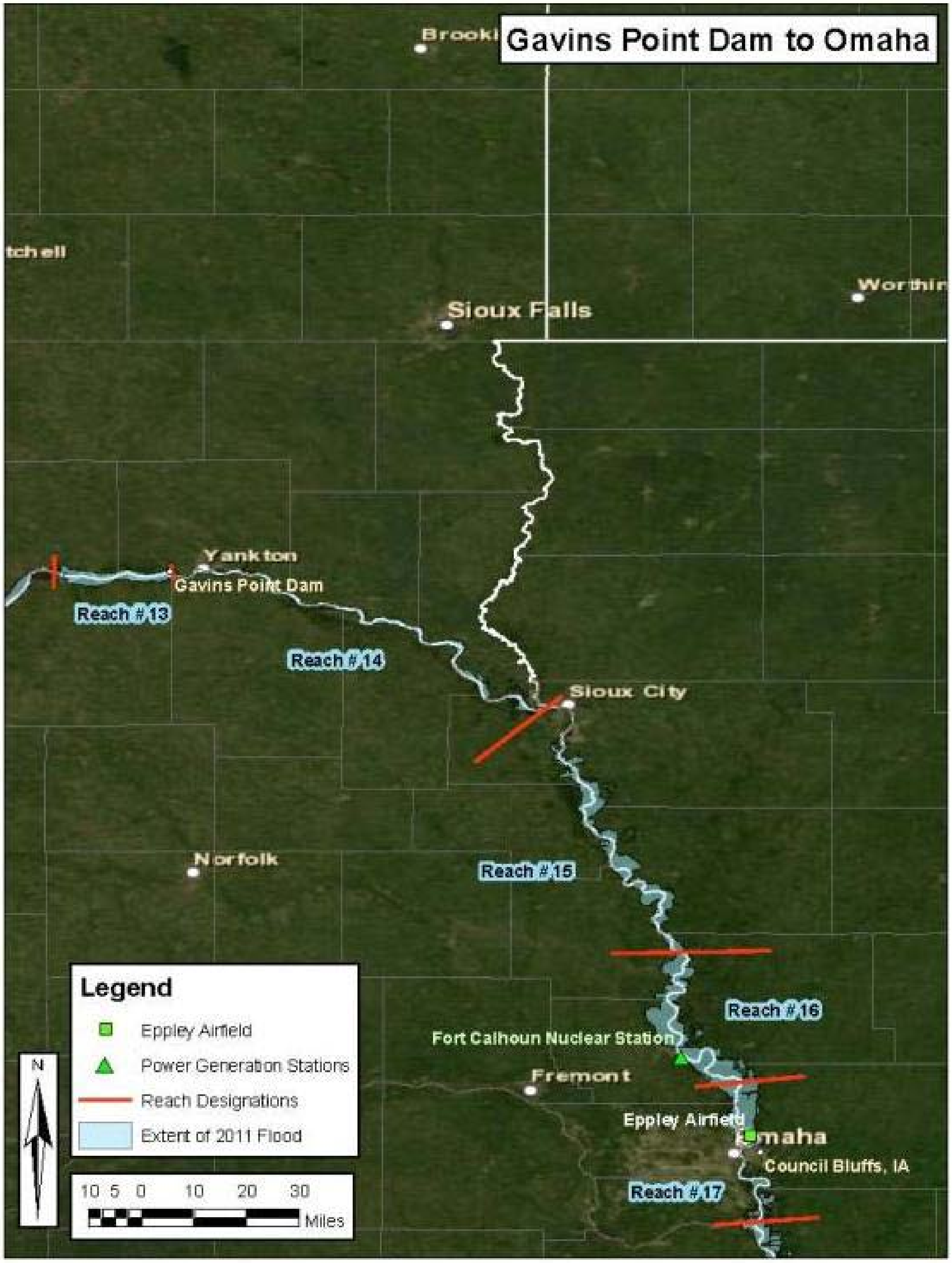

Figure 7. Gavins Point Dam to Omaha Reaches

Figure 8. Omaha to Kansas City Reaches

2.4.2.3 Key Infrastructure within the 2011 Impacted Area

Table 6. Key Infrastructure within the 2011 Flooded Area

Reach	Energy Producing Plants & Storage Facilities, Non-Nuclear (Biodiesel, Electricity, Natural gas, etc.)	Nuclear Energy Producing Plants & Storage Facilities	Energy Infrastructure (Generating units, pipelines, oil wells, substations, transmission lines)	Emergency Response (Hospitals, Fire Stations, Emergency Operation Facilities, Red Cross)	Educational, Daycare, Senior Care Facilities (including universities)	Wastewater Treatment Plants	Airports (Public & Base Helipads/ Airports)	Ground Transportation Infrastructure				
								Road			*Railroad*	*Bridges*
								Interstate Miles	*Highway Miles*	*Local Street Miles*	*Miles*	*Road/Railroad*
Ft. Peck Reservoir (1)	0	0	0	0	0	0	0	0	0	7	0	0
Milk River (2)	0	0	7	0	0	0	0	0	0	1	0	0
Culbertson (3)	0	0	7	0	0	0	0	0	0	6	0	0
Wolf Point (4)	0	0	12	0	0	0	0	0	0	3	0	3
Williston (5)	0	0	39	0	1	0	0	0	4	49	4	1
Garrison Reservoir (6)	0	0	11	0	4	0	0	0	2	31	0	3
Bismarck (7)	**0**	**0**	**20**	**0**	**2**	**0**	**0**	**1**	**0**	**53**	**1**	**3**
Oahe Reservoir (8)	0	0	14	0	0	0	0	0	3	31	2	18
Pierre (9)	**0**	**0**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**13**	**1**	**0**
Big Bend Reservoir (10)	1	0	11	0	0	0	0	0	0	0	0	3
Ft. Randall Reservoir (11)	0	0	6	0	1	0	0	1	1	23	1	7
Ft. Randall Dam - Gavins Point Reservoir (12)	0	0	7	0	0	0	0	0	6	38	4	2
Gavins Point Reservoir (13)	0	0	0	0	0	0	0	0	0	2	0	3
Yankton (14)	**0**	**0**	**145**	**0**	**0**	**0**	**0**	**0**	**1**	**24**	**0**	**4**
Sioux City (15)	**0**	**0**	**74**	**0**	**0**	**0**	**0**	**0**	**1**	**118**	**0**	**18**
Decatur (16)	**1**	**1**	**28**	**0**	**0**	**0**	**0**	**1**	**0**	**135**	**5**	**15**
Omaha (17)	**1**	**0**	**31**	**0**	**0**	**0**	**2**	**32**	**1**	**77**	**20**	**54**
Nebraska City (18)	**0**	**0**	**37**	**1**	**0**	**0**	**0**	**38**	**12**	**267**	**45**	**101**
Rulo (NWO [19])	**0**	**0**	**7**	**0**	**0**	**0**	**0**	**0**	**5**	**139**	**28**	**18**
Rulo (NWK [20])	**1**	**0**	**42**	**0**	**0**	**0**	**1**	**6**	**8**	**251**	**37**	**47**
St. Joseph (21)	**0**	**0**	**154**	**1**	**0**	**0**	**3**	**1**	**6**	**83**	**51**	**46**
Kansas City (22)	0	0	37	0	0	0	0	1	1	1	1	6
Kansas River (23)	0	0	8	0	0	0	0	0	2	25	13	19
Crooked River (24)	0	0	11	0	0	0	2	0	5	90	23	16
Grand River (25)	0	0	5	0	0	0	0	0	0	5	0	1
Chariton River (26)	0	0	30	0	0	0	0	0	1	14	9	11
Osage River (27)	0	0	6	0	0	0	0	0	0	2	2	0
Gasconade River (28)	0	0	4	0	0	0	0	0	1	2	4	3
Total (Critical Reaches)	**3**	**1**	**543**	**2**	**2**	**0**	**6**	**79**	**35**	**1,159**	**187**	**306**
Total All Reaches (1-28)	*4*	*1*	*758*	*2*	*8*	*0*	*8*	*80*	*61*	*1,490*	*252*	*402*

Source: HSIP Gold Database, 2011.

Public Utilities

Key public utility infrastructure was flooded or severely threatened by the 2011 flood in several locations, requiring significant flood fighting efforts to ensure public safety and provide continuing utility service. Across its entire service area, the Omaha Public Power District (OPPD) estimates that the 2011 flood cost the utility provider $100 million to purchase additional power to meet customer power demands and to make repairs necessary to restore power.

Of special significance, the Fort Calhoun Nuclear Generating Station, owned and operated by OPPD, experienced substantial impacts related to the 2011 flooding. The Fort Calhoun Station is located adjacent to the Missouri River between Fort Calhoun and Blair, Nebraska (reach 16) and was surrounded by flood waters from the 2011 flooding (Figure 9). While the nuclear reactor at the plant had been in shut down mode for scheduled refueling, the flooding resulted in the reactor remaining in shut down mode. According to OPPD, the Nuclear Regulatory Commission has placed the Fort Calhoun Station in an extended shutdown due to performance issues related to the flood and other regulatory issues. It was estimated that $36.4 million was spent on flood-fighting and protective measures related to Fort Calhoun Station.

Figure 9. Fort Calhoun Nuclear Station (June 25, 2011)

Cooper Nuclear Power Station (CNS) is a Nebraska Public Power District (NPPD) nuclear plant near Brownville, Nebraska (reach 19) that issued a "Notification of Unusual Event" due to the flooding situation. The river reached a water elevation threshold that required certain emergency management measures be enacted. CNS erected barriers around transformer yards, switch yards, warehouses and support buildings. In addition, CNS constructed plywood and sandbag barriers and openings for non-critical plant structures. CNS submitted $2.4 million to FEMA for reimbursement of costs incurred as part of their emergency flood operations. The state also spent approximately $115,000 in additional labor hours to support the flood fighting effort.

The Nebraska City Coal-Fired Power Plant (OPPD-owned and operated) is located on the Missouri River near Nebraska City, Nebraska (reach 18). During the 2011 flood event, the plant spent $1.3 million monitoring and repairing a levee. OPPD also spent $8.8 million on-site at the plant completing flood protection measures to ensure critical plant infrastructure was protected, including raising a levee and constructing a back-up earthen berm. In addition, OPPD spent $8.0 million raising the rail line into the plant to ensure the coal supply needed to continue plant operation was maintained.

Omaha Eppley Airfield

Eppley Airfield is located in northeastern Omaha, adjacent to the Missouri River (reach 17). It is the largest airport in Nebraska and serves eastern Nebraska, western Iowa, northern Kansas, northern Missouri and South Dakota. According to the Omaha World-Herald, Eppley Airfield serves nearly 4.3 million passengers a year, averaging about 90 daily flights.

During the 2011 flood event, Eppley Airfield remained open, but it required a massive flood-fighting effort. The Omaha World-Herald reported in July 2011 that the airfield estimated $26 million was spent on flood fighting efforts to protect the airfield. The airport installed a line of 70 pumping wells along the perimeter of the airport due to rising groundwater levels, which could have bubbled from the ground and flooded runways and terminals. The pumps were used to pump 100 million gallons of water from the site daily, most of it pumped over levees surrounding the airport and back into the river. Sand berms were built along the base of the existing levees to prevent levee failure. Sandbagging of airport buildings and other pieces of infrastructure deemed critical was also included as part of the flood fighting effort (Omaha World-Herald, June 15, 2011).

Transportation Infrastructure

The 2011 flood event impacted major transportation infrastructure for an extended period during 2011 in multiple states. The flood forced the closing of several Missouri River bridges as well as long stretches of interstates, highway, and roads for weeks or months at a time. Missouri River bridges were closed from northern Missouri to just above Gavins Point, making it impossible at times to cross the river for more than 100 miles between Sioux City, Iowa and Omaha and between Plattsmouth, Nebraska (just south of Omaha) to St. Joseph, Missouri. Millions of dollars were required to repair these roads prior to reopening after the flood waters had receded.

Interstate Highway 29 (I-29) is a major north-south interstate highway in the Midwestern U.S. It extends from Kansas City, Missouri at the junction with I-35 and I-70 to the Canadian border near Pembina, North Dakota, where it connects with Manitoba Highway 75. I-29 suffered significant flood damage and was closed in several locations between St. Joseph, Missouri and the Missouri-Iowa border during the 2011 flood event. This stretch of the interstate serves 10,000 to 15,000 vehicles per day. The stretches of I-29 closures required lengthy detours by thousands of drivers during that time period. Several Missouri highways and county roads in this region were also closed for several weeks, including U.S. 59 in Buchanan County and Routes 111 and 159 in Holt County. Preliminary Missouri Department of Transportation estimates of flood damage to highways and roads in Missouri total $11 million, and most of this total was sustained in the northwestern portion of the state.

Major interstates and highways and portions of I-29 and adjacent interstates were closed in Iowa as well. A local newspaper reported that in total, about 60 miles of interstate roads were closed over three months, forcing truckers, commuters and other travelers to take detours of 100 miles or more (Des Moines Register, September 12, 2011). Iowa Department of Transportation estimates that between 16,000 and 20,000 vehicles travel these roads daily. Sixteen miles of I-29 and I-680 between Crescent, Iowa and Loveland, Iowa were closed for over 100 days; 35 miles of I-29 between U.S. Highway 34/IA 978 and the Missouri state line were closed for over 100 days; and 3.1 miles of Interstate 680 west of Crescent (a major commuter route between western Iowa and eastern Nebraska) were closed for over 100 days and cost $19.2 million to repair prior to reopening (Figures 10 and 11). Some of the other stretches of interstate just required debris removal prior to reopening, costing in the hundreds of thousands of dollars.

Figure 10. Omaha World Herald Photo: The flood-damaged eastbound lane of Interstate I-680, looking west toward the Mormon Bridge from the overpass over I-29. Receding water from the flooded Missouri River revealed flood damage north of Council Bluffs.

Figure 11. I-29 North of Omaha and Council Bluffs

As listed in Table 6, approximately 250 miles of railroad tracks were in the 2011 flood area. Both the Burlington Northern Santa Fe (BNSF) Railroad and Union Pacific Railroad (UPRR) were forced to spend heavily to raise track sections, build temporary berms, and repair damaged tracks. Many railroad shipments were delayed and rerouted through other states. UPRR traffic was interrupted between St. Joseph, Missouri and Kansas City, Missouri during the flood event. BNSF estimated that throughout the summer of 2011, 40 percent of its trains were rerouted and 400 workers were relocated to accommodate the rerouting. In particular, the BNSF Railroad was unable to deliver coal to the Iatan power plant, located between St. Joseph and Kansas City, for several weeks beginning in late June. BNSF estimates spending approximately $300 million to repair and rehabilitate its railroad tracks after the flood event. Amtrak also suspended service on routes through Minnesota, North Dakota and eastern Montana due to the flood. Thousands of hours of work and millions of dollars were required to repair the flooded tracks (Omaha World-Herald, September 1, 2011).

Figure 12 shows the extent of the 2011 flooding for the area around Hamburg, IA south of Omaha/Council Bluffs, and within the Nebraska City reach (reach 18), which is an especially vulnerable reach. The Missouri River can be seen on the left side of the picture and Interstate I-29 can clearly be seen within the flooded area following five levee breaches in L-575 and L-550. Note that at the widest part, the flooded area approaches 17 miles wide in what is an important regional north-south corridor and east-west crossing for interstate and railroad travel and commerce, as well as being some of the most productive agricultural areas in the nation. Cooper Nuclear Power Station is just a few miles south (downstream, on the Nebraska side) of the area shown.

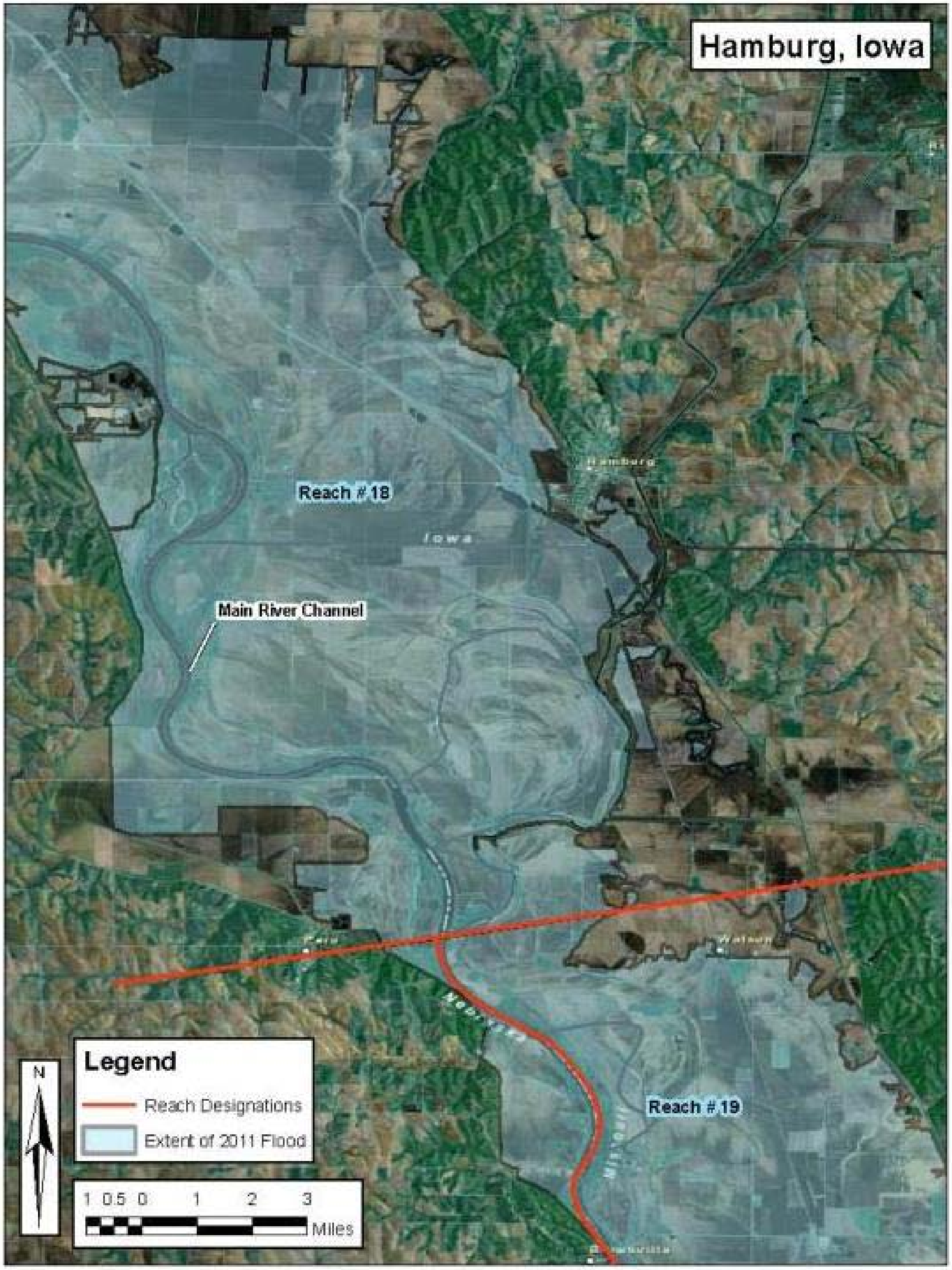

Figure 12. Hamburg, Iowa in Reach 18

2.4.2.4 2011 Flood Damages Prevented

Flood damages prevented represent the difference in damages that would be sustained without flood risk management structures (levees and reservoirs) and emergency operations (such as temporary levees, sandbags, pumps, and technical assistance) versus the damages that were sustained with these structures and measures in place. Using the methods described in Section 2.4.2.5, "Stage-Damage Curves," Omaha and Kansas City Districts calculated fiscal year (FY) 2011 flood damages prevented in their area of responsibility by Corps and Bureau of Reclamation reservoir projects, Corps non-reservoir projects, and Corps-supported emergency operations. Damages prevented along the mainstem reaches and along tributaries were identified by state for each type of project.

Table 7 displays FY 2011 flood damages prevented, calculated for the Missouri River basin. Nearly $8.2 billion in flood damages were prevented in FY 2011 by Corps and Bureau of Reclamation projects in the Omaha and Kansas City Districts combined. Of this total, Corps mainstem dams were responsible for over 67 percent; Bureau of Reclamation and other Corps dams, nearly 5 percent; Corps levees and channel improvement projects, nearly 22 percent; and Corps-supported emergency operations activities, over 6 percent. In FY 2011, over 93 percent of flood damages prevented in the Missouri River basin by reservoir and non-reservoir projects and most of the flood damages prevented by Corps-supported emergency operations activities were along the Missouri River mainstem. For all categories of projects, most of the flood damages prevented were in urban areas.

Table 7. Damages Prevented in Fiscal Year 2011, in Thousands of Dollars (from Stage-Damage Curves)

STATE	Corps Reservoirs		Corps Non-Res. Projects		Emergency Operations		STATE TOTALS
	NWK	NWO	NWK	NWO	NWK	NWO	
CO		$0		$7,799		$0	$7,799
IA	$70	$1,019,239	$0	$918,362	$1,000	$98,400	$2,037,071
KS	$62,407		$20,520		$2,050		$84,977
MN		$0		$0		$0	$0
MO	$3,420,812	$5,555	$63,381	$2,106	$25,200	$0	$3,517,054
MT		$61,533		$10,272		$45,344	$117,149
ND		$397,740		$7,443		$126,438	$531,621
NE	$0	$885,640	$1,164	$730,923	$500	$98,207	$1,716,434
SD		$20,382		$17,608		$96,146	$134,136
WY		$27,438		$1,266		$11,861	$40,565
Subtotal	$3,483,289	$2,417,527	$85,065	$1,695,779	$28,750	$476,396	$8,186,806
Totals:	Reservoirs	$5,900,816	Non-Res.	$1,780,844	Emer. Ops.	$505,146	$8,186,806

NWO data include revisions made to Annual Flood Damage Reduction Report data April 4, 2012.

2.4.2.5 Stage-Damage Curves

Stage-damage curves are tables that show the predicted total damages, in dollars, which would result from various stages of flooding. Stage-damage curves are important because they are used to calculate flood damages that would be sustained for a certain stage, and when cross-referenced to flows and frequency of flows, can be used to estimate average annual flood damages expected. Stage damage curves set the basis for how the Corps operates the reservoirs for flood risk management and are also useful for determining the feasibility of new projects. They enable the identification of vulnerabilities to flooding and the evaluation and comparison for making sound water resources investment decisions.

Stage-damage curves are also used to estimate flood damages prevented by all Corps projects nation-wide, on an annual basis. Projects include dams, levees, channel improvements, and emergency management activities. Flood damages prevented are the difference in flood damages with-project versus without-project. On the Missouri River, flood damages can be prevented by stage reductions due to dam holdouts, by levees, and/or by emergency management activities. Accurate estimates of flood damages prevented and sustained require accurate stage-damage curves.

The Omaha District currently uses 191 stage-damage curves to assess flood damages sustained and prevented by projects each fiscal year. Of these, 13 are for Missouri River mainstem reaches, 107 are for tributary reaches, and 71 are for individual Corps local protection projects. Kansas City District uses 64 stage-damage curves, of which 16 (9 urban and 7 rural) are for mainstem reaches, and 48 are for tributary reaches. For both districts, some Corps projects have no curves, and some (even relatively new projects) have no stream gage, so spreadsheets or feasibility report graphs and tables and/or stage estimates from local observers are used, if available, to estimate damages sustained and prevented.

For Omaha District, the price levels for nearly 88 percent of the damage curves are in 1975 dollars, but the land use data on which the damages are based may have been collected much earlier. These curves include damages for residential, commercial, and public buildings and their contents; crops; rural homes and outbuildings and their contents; and transportation facilities. The remaining 12 percent of the damage curves were developed from post-1975 feasibility reports and contain only the types of damages included in the reports. For Kansas City District, land use data for 11 of the curves are from the 1990s and 53 are from the 1950s. Damage curves from other sources are used to supplement outdated curves and increase accuracy, and all damage curves used are updated to current price levels. These ad hoc improvements have limitations, however, as explained below.

The damage curves along the Missouri River in Volume 6D (Economic Studies) of the Missouri River Master Water Control Manual Review and Update (Master Manual) published in 1994 include curves of urban, agricultural, recreation, and navigation damages for river and reservoir reaches. The land use data on which these curves are based are approximately 20 years old – more recent than most other curves the districts use, but still outdated. Because the Master Manual reach boundaries downstream from Gavins Point Dam within the Omaha District vary by damage category and do not always coincide with Omaha District reach boundaries, some uncertainties are involved in assigning damages obtained from Master Manual curves to Omaha District reaches.

Finally, the range of stages or flows for some of the existing stage-damage curves was not great enough to bracket the unregulated flows that would have occurred in 2011 without dam holdouts. To avoid severely underestimating flood damages prevented, damage curves were extrapolated, but the extrapolations would have been more accurate if they could have been based on updated land use data and actual damages.

In summary, it is clearly evident that the stage-damage curves used for the Omaha and Kansas City Districts would greatly benefit from being updated. These stage-damage curves are key and integral for management and operations of the reservoirs for flood risk management, identifying vulnerabilities to flooding, and making sound water resources investment decisions. Thus, it is essential to have accurate and current stage-damage curves as further described in the next section.

2.4.3 Economic Vulnerabilities and Data Requirements

The ability to accurately estimate economic impacts from flooding is essential to making optimal and defensible investment decisions on development and commerce along the Missouri River and its tributaries as well as management and operation of the basin's reservoirs for flood risk management. Shortcomings in that reporting ability potentially can result in vulnerabilities in the system, including the following:

- Inefficient investment decisions from a national economic development standpoint
- Inability to evaluate (outside of lengthy feasibility studies) economic consequences of alternative river management operations
- Potential wasteful investment in projects that are ineffective relative to alternative courses of action
- Decisions that may threaten public safety or harm the environment
- Loss of credibility with government officials and the public if inaccurate or incomplete data are grossly inconsistent with the realities experienced by flood victims
- Inability to accurately estimate and communicate the residual risks of flooding and managing for future flood risk

Economic impacts are primarily projected from stage–damage curves. These stage-damage curves indicate how much damage to property including homes, businesses, facilities, crops, and infrastructure can be expected at specific locations along the river when a particular river stage is reached. The curves are based on property inventories covering vast areas of flood plain along the Missouri River and its tributaries. For site-specific project studies, stage-damage curves are typically constructed within the study. But for larger river reaches, stage-damage curves have been partially developed and sometimes modified over time, but there is no program and funding for updating them, regularly or otherwise. They are used, despite their shortcomings, for calculations of annual flood damages and flood damages prevented; systemic river analysis, including reservoir operations parameters; dam and levee safety analyses; and other similar purposes, since no other alternatives for data exist.

Existing stage-damage curves used to estimate flood damages have four primary shortcomings:

- Omaha and Kansas City Districts are using outdated damage curves that range from about 20 to over 50 years old. The flood plain property inventories that served as the basis for the curves are long out of date. In general, this results in an underestimation of flooding impacts to property.
- Records regarding the development of the curves are very old and generally difficult or impossible to track down. Consequently, the methodology and procedures used in their development are often unknown. There are uncertainties related to what is or is not included in the very broad generalized and aggregated damage totals indicated by the curves, which makes it very challenging to incrementally improve them based on more current and better information, such as data available from the 2011 flood fight.
- Most of the existing stage-damage curves are truncated at lower levels of inundation than are often seen on the contemporary Missouri River. It is believed that in many cases, especially in the Omaha District reaches, existing stage-damage curves were built on lesser events and do not include the full spatial extent of damages sustained or prevented in the 2011 flood and other recent flood events. For example, the Omaha District database used for flood damages prevented calculations did not include the reaches immediately below Oahe, Big Bend, and Fort Randall

Dams because releases of the 2011 magnitude in these normally non-flood prone reaches were unprecedented.

- Most of the Kansas City District curves include only urban damage in the biggest cities and crop damage. They do not include damages to small towns along the river, damage to rural infrastructure such as roads and railroads and any agricultural damages other than damage to crops.

Inadequate and outdated stage-damage data results in more assumptions, greater uncertainty and potential deviation from actual damages. The absence of stage-damage curves reflecting contemporary land use patterns and full spatial extent of flood plains forces use of either outdated data or more recent but very highly generalized data from national sources such as FEMA's Hazus database. Use of these sources undoubtedly produces incomplete and inaccurate data and analysis that can contribute to a misleading portrayal of potential flood risk and consequences to people and property. Improvements to stage-damage curves are essential for determining the most optimal, efficient and effective methods for managing and reducing flood risk.

2.4.3.1 Resource and Funding Needs

Modernized and improved estimates and reporting of flood damages would greatly reduce the vulnerabilities inherent in decision-making and operations based on misleading data. The ability to address these economic vulnerabilities requires resources and funding support. An appropriate effort to address the known shortcomings in the economic data for both Omaha and Kansas City Districts would include the following tasks:

- Development of updated and comprehensive property inventories, including property depreciated replacement values and elevations, for the floodplain of the Missouri River mainstem. These inventories would use Hazus data as a starting point but would be refined subsequently with more localized data where appropriate including assessor data, surveying and/or ground-truthing.
- Development of updated stage-damage curves based on the updated property inventories. The HEC-FIA software developed by the Corps' Hydrologic Engineering Center provides the state-of-the-art method for single-event flood damage estimation. Up-to-date GIS mapping of stream floodplains would be combined with the new property inventories in the HEC-FIA modeling, and the model would be executed to develop new stage-damage functions for each location on each stream. These new curves could then be compared to previous curves. This exercise would be invaluable in assessing potential consequences using sound and accurate stage-damage curves and would also help determine adequacy of current models, and how to improve them. Updated data and stage-damage curves could indicate areas of risk that may not have been evident using previous data and information. The model also would be useful in analyzing the economic components of alternative river management schemes and would provide a quick means of carrying out economic analyses for reconnaissance studies and other smaller scale analyses, possibly including emergency levee repairs under the PL 84-99 program.
- Investigation of economic impacts associated with the 2011flood event. Investigation of the 2011 flood would begin with the development of accurate flooded area mapping showing the extent and depth of flooding throughout the basin. Using this mapping, investigate physical inundation damage, costs of emergency management operations, and impacts of operational disruptions for the following categories: (1) urban areas, including homes, businesses, and public facilities; (2) rural areas, including farm homes and outbuildings, crops, equipment, livestock, and land; (3) infrastructure and utilities, including roads, railroads, bridges, airports, water and sewer plants, and power plants; (4) hydropower facilities; (5) navigation port facilities; and (6) recreation

facilities. Included also would be a more thorough assessment of public sector emergency costs for items such as sandbagging, traffic operations, relocation assistance, and temporary food and shelter assistance.

The cost for the Missouri River economic analysis for both Omaha and Kansas City Districts is estimated at approximately $2.1 million as summarized in Table 8 below.

Table 8. Economic Analysis

Development of updated property inventories	$708,000
Investigation of economic impacts from 2011 flood event	$494,000
Development of new stage-damage curves incl. HEC-FIA modeling	$898,000
Total	$2,100,000

The categories in the estimate greatly overlap in many areas and the estimate should be taken in its entirety. In addition, this estimate is economics focused and does not include efforts that would be valuable for specific socioeconomic impacts. Additional assessments of value could be included for impacts to Tribes, impacts on regional economies in terms of job and income losses or gains, social impacts such as health and safety concerns, on environmental justice, and on community resilience, and impacts associated with critical facilities impacts. In the absence of those additional assessments, economic impacts alone will help provide information on various probable socioeconomic impacts in a more general sense.

2.4.4 Recommendation

It is recommended that an updated floodplain inventory be acquired and an investigation of 2011 economic impacts be assessed and used to calculate updated stage-damage curves for the Missouri River. This will equip the Corps to respond with far greater nimbleness and accuracy in predicting economic consequences and managing residual risks. More accurate stage-damage curves will allow the Corps and the nation to make better investment decisions, including on proposed improvements to the system and system operations.

3. Reservoirs and Water Management

3.1 RESERVOIR AND DAM INFRASTRUCTURE

The Corps owns and operates an array of infrastructure that includes 6 mainstem dams, 40 tributary dams, other appurtenant structures, and hundreds of miles of bank stabilization and channel projects. During flood conditions, the Corps also manages the water releases from numerous dams owned by the Bureau of Reclamation (BOR) as required by the Flood Control Act.

The preeminent features in flood risk management on the Missouri River are the six mainstem dams (Fort Peck, Garrison, Oahe, Big Bend, Fort Randall and Gavins Point), and appurtenant structures such as the Williston Levees along the Garrison reservoir. The mainstem projects are operated and maintained by the Omaha District, except that the water releases are managed by Northwestern Division's Missouri Basin Water Management Office. The mainstem dams pass normal releases primarily through hydropower generators, but have gated spillways for large releases; four have additional outlet (flood) tunnels (Fort Peck, Garrison, Oahe, and Fort Randall).

Another 40 Corps-owned dams are located along tributary river systems, operated and maintained by the Kansas City and Omaha Districts, which also manage their water releases. Also, the Bureau of Reclamation owns 22 Section 7 tributary dams, for which the Corps manages water releases by during flood conditions. The Missouri River Bank Stabilization and Navigation Project is located in the downstream reach of the river, from Sioux City, Iowa to St. Louis, Missouri; those Corps operated structures are addressed in this report's Floodway and Channel Performance section.

The Corps is characterizing our ongoing and future response actions under the generalized headings: Repair, Restore, and Enhance. Our immediate focus is Repair of the mainstem dam structures as authorized by Congress through both the regular Operations and Maintenance (O&M) funds allocated for each project, and supplemental repair funding provided under the Disaster Relief Appropriations Act (DRAA) of 2012.

Future investments will be required to restore and enhance system operations, dependent on the findings from subsequent risk based studies and engineering evaluations. Implementation of the Restore and Enhance actions are not confirmed at this time, but are documented herein to provide readers with our best understanding of vulnerabilities as of this writing.

Table 9. Repair-Restore-Enhance

Action	Objective	Requirements
Repair	Fix damages caused by 2011 flood ensuring condition and/or functionality are re-established.	Use existing authorities and funding. May require additional funding.
Restore	Renovate system to original design intent and performance criteria to ensure resilience and reliability	Use existing authorities. May require detailed analyses and studies to justify work. Will require additional appropriations
Enhance	Improve system capacity and capability beyond original design to lower risk and improve performance and durability.	May require additional authorities. Will require detailed analyses and studies to justify work. Will require additional appropriations.

3.1.1 2011 Flood and Post-Flood Assessments

The mainstem dams experienced the main impact of the 2011 runoff event. Five of the six dams released discharges that exceeded twice their previous records. Three reservoirs, Fort Peck Lake, Lake Oahe, and Francis Case Lake (Fort Randall Dam) experienced record high pool elevations, as did the Williston Levees. Maximum discharge rates ranged from 65,900 cfs at Fort Peck to 166,000 at Big Bend. Emergency spillways were operated at all the dams except Oahe, and flood tunnels were used at Garrison, Oahe, and Fort Randall.

Omaha District initiated infrastructure assessments after high pools receded. In addition to visual inspections, performance assessments included detailed review of instrumentation data records in accordance with Corps' criteria. Assessments accomplished as of summer 2012 include:

- Spillway and intake gate Hydraulic Steel Structure (HSS) inspections
- Non Destructive Testing (NDT) of spillway and intake gate welds and trunion anchorages
- Cleaning and camera inspections of various subdrain systems and relief wells
- Diver inspections of the Garrison, Fort Randall, and Gavins Point stilling basins
- Geophysical evaluations and coring of the spillway slabs
- Remote Operated Vehicle (ROV) inspections of other stilling basins and intakes
- Hydrographic surveys of reservoir sediment deposition
- Dewatering inspection of the Fort Randall flood tunnels

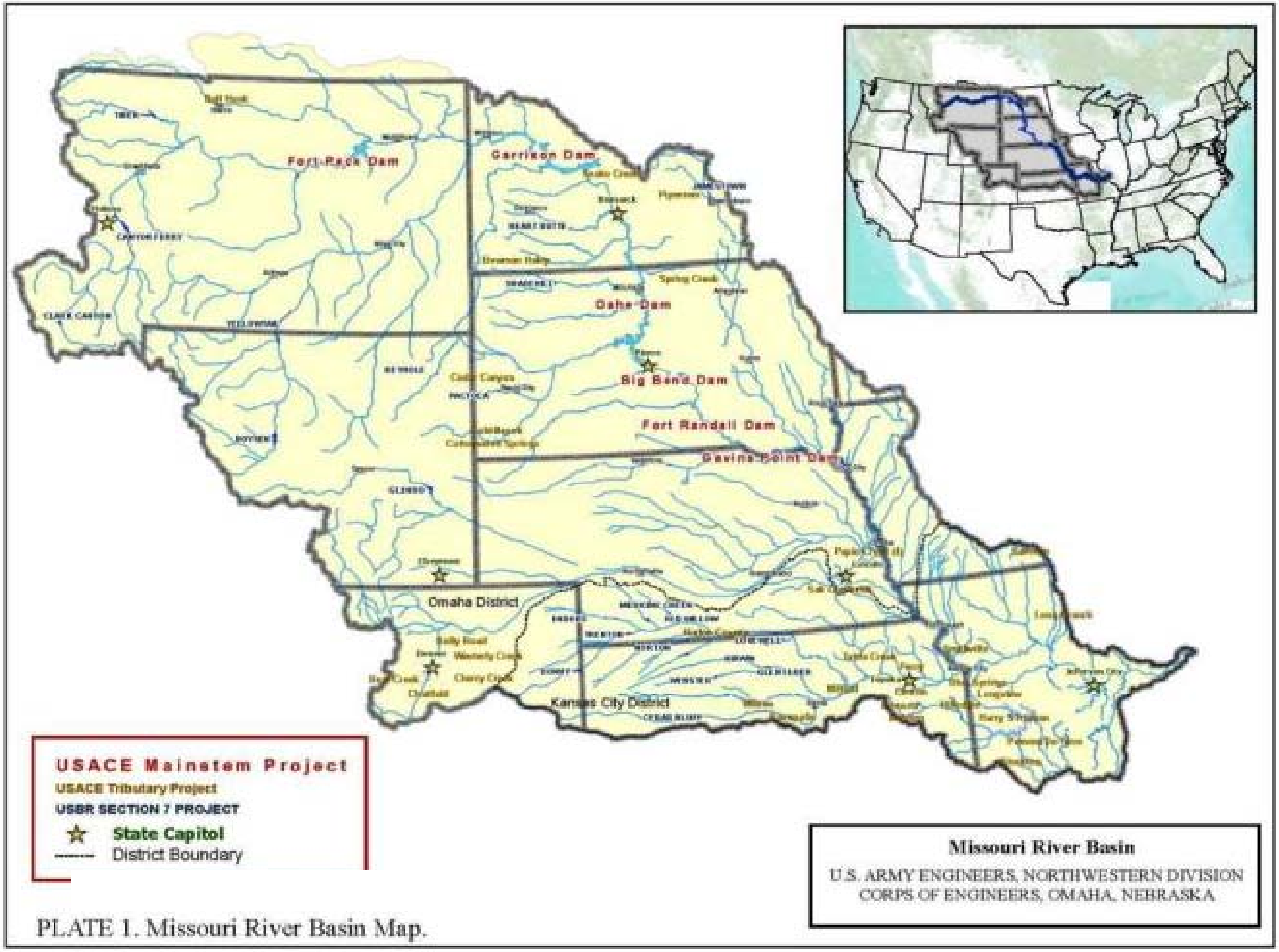

Figure 13. Missouri River Basin Federal Dams

3.1.2 General Mainstem Dam Findings by Feature

The infrastructure system retains sufficient structural integrity for normal operations, which are anticipated throughout 2012 in light of low snowpack and little likelihood of high runoff. However, minor to moderate structural damage is widespread in the system, and spillway issues yet to be confirmed could be very significant. The Corps needs to more fully evaluate risks posed by potentially deficient spillways and other discharge features, in order to make post-2012 operational decisions and to invest appropriately for system reliability. Also, previously held concerns regarding facilities that were not actually involved in the 2011 event have gained renewed importance in light of the 2011 flood.

Numerous repairs are needed to ensure future operational reliability; most repairs are underway and will be completed before the 2013 flood season, using available DRAA funds. Over 100 contracting actions are occurring in 2012, and efforts will continue in 2013 and 2014. These actions reflect our best understanding of needs at this time. Post flood requirements will evolve as the Corps continues to gather information. The following repairs were needed at multiple projects and will be accomplished in the near term.

3.1.2.1 Mainstem Dam Embankments and Abutments

Minor riprap erosion and scarping occurred along the upstream faces of Big Bend and Pipestem dams. Additional riprap will be added to Big Bend dam. Spot re-grading at other dams will be implemented by maintenance staff as needed.

Relief wells did function during the flood to manage underseepage and ensure embankment stability. However, many relief wells had already exceeded their design life and become less responsive to rehabilitative efforts due to the fragility of the wood stave components. Relief wells are essential due to the pervious or semi-pervious foundations beneath the dams. Actions to replace critical relief wells throughout the mainstem system were already underway and remain ongoing. Critical subdrains at the Garrison west terrace gravel area and the Fort Randall toe are being replaced as well.

3.1.2.2 Flood Tunnels, Stilling Basins, and Outlet Tunnels

Overall, these features performed remarkably well, given the long duration of flows and the dramatic fluctuations in discharge volumes. Spillway and flood tunnel gate openings were adjusted several times a day to meet hydropower requirements or support other needs, further stressing components.

Minor concrete spalling has been observed within accessible portions of the tunnels. Remote cameras have been used for initial examination of horizontal outlet works tunnels and stilling basins, where feasible. Visual inspections are now being augmented with sonar and diver inspections. Dewatering was performed at Fort Randall dam to allow a thorough assessment which identified additional repair needs; dewatering is not feasible for the other projects.

Preliminary findings suggest the presence of debris in front of Gavins Point power plant, and within stilling basins where it could cause long term erosion damage. Debris removal will be performed as soon as practicable.

High discharges overtopped retaining walls at a spillway (Big Bend) and at two outlet works (Oahe and Garrison), causing erosion along adjacent pavement and backfilled areas and along downstream channel banks and walkways. Similarly, prolonged use of the Fort Randall spillway pressurized and damaged the wall backfill and drainage system. Existing emergency rock stockpiles were used to arrest erosion during the flood event, with large quantities used at Garrison, Big Bend, and Fort Randall. Efforts to repair the erosion, re-establish wall drains, and replace backfill and pavements are essentially complete.

3.1.2.3 Spillways

Significant efforts are underway to ensure future reliability of the spillways. The number of spillway gate bays ranges from eight (at Big Bend and Oahe) to 28 (at Garrison). Planned restoration actions will include spot painting, and minor repairs (cleaning, seal repair, grinding or repair of welds, install drain holes, etc). Plans are also underway replace select electrical controls. Limited stoplogs are available at each project, so work on the spillway gates is anticipated be implemented on one gate at a time. This means the gate repairs will take more than a year to complete. However, the spillway design capacities are enormous. Temporary loss of one gate bay will not impede operational flexibility except for extreme inflow conditions. In some cases the aged cranes must also be repaired, prior to start of work on the spillway gates.

Concrete coring and ultrasonic testing will be performed at the five spillways utilized in 2011, to verify conditions of the concrete slabs.

3.1.2.4 Access Roads

Some project roads experienced excessive “wear and tear” during the 2011 flood event, attributed to rock hauling operations, and overtopping flows which caused erosion. The failed portion of the Fort Randall spillway access road will be relocated to the east. The Garrison west tailrace access road, which sustained significant damage from hauling during emergency work on the tailrace, will be resurfaced to facilitate access along the west powerhouse and tailrace cut-slopes. Repairs are forecasted to begin in summer 2012. Completion dates have not yet been determined.

3.1.2.5 Recreation Facilities

Numerous Corps-owned recreation facilities were inundated by high reservoir and tailwater conditions. Parking lots, access roads, camping sites, rest room facilities, beaches, boat ramps, and other features sustained damage. Utilities will be re-established, pavements replaced, dead trees removed, grass replanted, etc. Milford Lake on the Republican River experienced a record outbreak of blue-green algae, attributed to sustained high reservoir conditions. Many facilities will not be available for use during the summer of 2012.

3.1.3 Project Specific Findings and Active Mainstem Repairs

This section describes assessment findings for each project. Efforts are underway to conduct repairs which will return the identified structures to pre-flood conditions. Only features requiring unique repair actions are described herein. Table 10 provides a summary of repair activities. As previously discussed, assessments are ongoing and response actions may evolve as additional information becomes available.

3.1.3.1 Fort Peck

There is no unaddressed vulnerability associated with the embankment or abutments. The relief well system is currently functioning; however, the wells have exceeded their design life. Select relief wells are being replaced and the toe drain repaired to improve underseepage control.

3.1.3.1.1 Spillway

The Fort Peck spillway is the primary flood control feature for an enormous reservoir, with a design capacity of over 230,000 cfs. The spillway is critical for release of flood inflows, as the discharge capacity of the powerhouse is only 15,000 cfs and the two outlet works ring gates, with a total design discharge capacity of 45,000 cfs, cannot be used at full capacity due to unrepaired damages incurred during the 1975 flood. This is further described in Section 3.1.4.1 of this report. Testing and evaluation actions are underway to determine the extent of spillway repairs. An operational test is planned for the fall of 2012.

Considerable erosion was observed below the spillway cutoff structure as a result of the 2011 flood. The Fort Peck spillway was constructed with a vertical cutoff wall at the downstream end, in lieu of an energy dissipation structure, such as a stilling basin. This configuration increases the likelihood of erosion damage at the terminus. Also, the downstream spillway chute slabs have experienced considerable foundation movements (heave) over the years, increasing potential for the chute slabs to be displaced during extreme spillway flows. These issues have been studied repeatedly since construction, however, no significant repairs have been made due to prohibitively high cost and the low probability that backward erosion would progress sufficiently to develop into a breach condition.

Ongoing dam safety assessments include:

- Verification for subdrains and the structural adequacy of the spillway slabs. This will include testing of the slab using geophysical methods, limited destructive testing, and installation of new instrumentation.
- Evaluation of the plunge pool.
- Non Destructive Testing (NDT) of spillway gate welds. Cracks have been noted in the welds at five of the sixteen vertical lift gates at Fort Peck. (As a precaution, the Operators will preferentially use the remaining eleven gates if spillway releases are needed prior to decisions on future repairs).

Repairs will be recommended to the spillway based on the outcome these assessments.

Assessments of the spillway gates, chute slabs and plunge pool are ongoing. A spillway flow test is planned for September 2012. Additional repairs may be warranted.

3.1.3.2 Garrison

There is no unaddressed vulnerability associated with the embankment. Assessments of the spillway gates, floor slabs and outlet works flood tunnel gates are ongoing. Additional repairs may be warranted.

3.1.3.2.1 Spillway

This was the first use of the spillway. Early during the releases, a "rooster tail" was observed, indicating an irregular surface which required repairs. Patching efforts were performed at spillway slab, during a coordinated outage.
The original designers successfully planned for a self scouring channel, which expanded from a narrow pilot channel as releases are stepped up. Roadways and recreational facilities were located along the pre-flood pilot channel, which self scoured during use to form an efficient outlet channel. A downstream embankment which contained the plunge pool, known locally as the spillway pond, will be replaced.

The original riprap along the Garrison upstream spillway approach channel banks was removed during the 1975 flood and used to repair the Snake Creek embankment. The exposed bank had eroded continually since that time, and receded significantly during the 2011 flood. Eroded material has deposited at the spillway entrance. Bathometric surveys indicate that the approach channel floor is up to 16 feet above design elevations, prohibiting adequate seating of some stoplogs, engulfing several bubbler nozzles needed for de-icing, and reducing the overall hydraulic efficiency of the spillway. Dredging and repair of the east spillway approach channel cut slope will be done as soon as possible, reservoir permitting. A contract will be awarded this summer to replace the slope protection and properly key into the subgrade.

3.1.3.2.2 Outlet Works (Flood Tunnel) Gates

The flood tunnels at Garrison are operated with tainter gates, rather than roller gates. Each of the three gates require analysis of the trunnion bearing to determine the capacity of the struts, planned for the fall of 2012. Concerns also exist regarding leakage of the hydraulic lubrication system.

3.1.3.2.3 West Terrace Gravel and West Abutment Drainage

Unique native materials at the Garrison right abutment and downstream powerhouse slope area are known as the west terrace gravels. Drainage improvements are needed to manage foundation seepage and support monitoring. Instrumentation data indicates the original drainage features have deteriorated over time, and are not as efficient as desired. Recent camera inspections of these systems indicate significant obstructions and plugged perforations with some minor sediment transport. The west terrace gravel relief wells were partially replaced in 2010.

3.1.3.2.4 Williston Protective Works (Williston Levees)

Record high discharges out of Fort Peck combined with record inflows downstream of Fort Peck and and unusually high Garrison Reservoir elevation produced a new record stage at the Williston Protective Works. Twenty-four hour surveillance of the project was conducted during elevated river stages.

The Williston levee is approximately 8 miles long and relies on a series of berms and an extensive system of relief wells to control underseepage pressures that develop during high river stages. The relief well system is generally in poor condition and proved minimally adequate in controlling these pressures. The underseepage control system failed in the Station 62+00 area, requiring active remediation to control backwards erosion piping and to prevent a potential levee breach.

Extensive underseepage and boil activity were prevalent in several areas of the levee system. Efforts are currently underway to replace wells and add additional wells in areas judged most critical based on surveillance. It is likely that many wells are in need of replacement. Many of the piezometers along the levee have become unreliable and are also in need of replacement. A contract was awarded in March 2012 to evaluate and repair the underseepage system.

The levee is accessible only from either end, and levee access roads are unsuitable for construction equipment. Road conditions and a shortage of local contractors adversely impacted response actions during the flood event. A contract to repair and restore the toe road was awarded in April 2012.

3.1.3.3 Oahe

Vulnerability associated with the embankment and spillway features downstream of the gate structure are outside the scope of the post flood repair authorities, but pose vulnerabilities that merit future actions. Assessments of the spillway gates and outletworks flood tunnel gates are ongoing. Additional repairs may be warranted.

3.1.3.3.1 Outlet works (Flood Tunnels)

Failure of roller chain assemblies on two of the six flood tunnel service gates required utilization of both emergency gates to close off the tunnels. Each tunnel has an average discharge capacity of 18,500 cfs. Loss of flood tunnel gates significantly impacts overall discharge capacity and system operations, as operators strive to avoid use of the Oahe spillway. The roller chains are different at each project. Extra "on the shelf" parts are not available and must be re-manufactured with an estimated lead time of 1 year. Repairs are planned for 2013.

3.1.3.3.2 Spillway Structure

Although the Oahe spillway was not used, its upstream features (approach channel and gate structure) were impacted by the high reservoir levels. Sediment deposition within the upstream approach channel necessitates cleanout in front of the spillway gates in order to place stoplogs, perform necessary inspections and maintenance, and ensure future operability.

3.1.3.4 Big Bend

There is no unaddressed vulnerability associated with the embankment and abutments, with the exception of the riprap repairs previously mentioned. Similar to the other projects, the relief well system is currently functioning; however, the wells have exceeded their design life. Select relief wells are being replaced and the toe drain repaired to improve underseepage control. Assessments of the spillway gates and floor slabs are ongoing. Additional repairs may be warranted.

3.1.3.4.1 Spillway

High releases through the Big Bend spillway combined with high tailwater conditions from the Fort Randall pool (which backs up to Big Bend Dam) caused overtopping of the spillway chute walls. The original designers realized that the chute walls would be overtopped for short duration and believed the resulting damages would not be severe. The tailwater at Big Bend Dam exceeded elevation 1365 for over 2 months during the 2011 high water event and resulted in significant erosion of the chute wall backfill, failure of the pavement slabs on the backside of the wall and damage to the chute wall railing. A contract is currently underway to repair the erosion damage and armor the areas above the wall to protect it during future releases.

3.1.3.5 Fort Randall

There is no unaddressed vulnerability associated with the embankment and abutments. Similar to the other projects, the relief well system is currently functioning; however, the wells have exceeded their design life. Select relief wells are being replaced and the drain collection system is being repaired to improve underseepage control. Efforts are underway to evaluate the integrity of the powerhouse retaining walls and associated drainage systems, and address operability of the structure dampers. Assessments of the spillway gates and floor slabs, as well as the outlet works gates and tunnels, is ongoing. Additional repairs may be warranted.

Similar to Garrison, patching efforts were performed along the slab, during a coordinated outage. Flows were temporarily diverted to the flood tunnels. Patching materials generally held up well. Additional patching will be performed to prepare for the next flood event. Joint seals were damaged, and will also be replaced. However, the joint seals are a perennial problem, and no long term solution has been found to date. Collapse of the left bank sidewalk occurred during operation, but was attributed to spillway flows entering the side wall drains and charging the backfill behind the structure. Repairs have been completed.

3.1.3.6 Gavins Point

There is no unaddressed vulnerability associated with the embankment and abutments. Similar to the other projects, the relief well system is currently functioning; however, the wells have exceeded their design life. Select relief wells are being replaced and the drainage collection system repaired to improve underseepage control.

The Gavins Point spillway is typically used on an annual basis, but it is not typically used for regulation of the reservoir. This spillway is extremely important for system operations, as there are no flood tunnels at Gavins Point dam, which has minimal flood storage in comparison to the upper three reservoirs (Fort Peck, Garrison, and Oahe). Without a functional spillway, discharge capacity may be limited to the powerhouse capacity of 36,000 cfs. The sustained high-volume 2011 releases caused damages to the spillway slab foundation, although the extent is not yet known. DRAA funds are being used to replace vertical drain covers and patch concrete surfaces. However, recent investigations suggest that there are voids beneath the spillway slab. Additional testing and analysis will be completed to determine extent of the additional damages, the risk to the structure, and the temporary and permanent repairs that may be needed. Due to the extended time to complete the additional assessment, any final repairs will have to be addressed with future Flood Repair Supplement funds or budgeted under other appropriations.

3.1.4 Recommended Restoration Items

The section describes repairs that are deferred due to one or more factors and are needed to fully enable mainstem dam operations as intended by the original designers.

3.1.4.1 Fort Peck Outlet Works Ring Gates

Flood control tunnels 3 and 4 at Fort Peck are regulated by cylindrical ring gates that are in very poor condition. Operational problems have been regularly documented and studied since the 1950s. Issues with entrained air, cavitation, gate vibration, violent surging, loud noises, corrosion, and gate icing are prevalent. The gates were last used for flood releases in 1975. No formal operation restrictions have been placed on use of the ring gates, though the upper segments have been welded in place and recommendations are to limit the lift to one foot, which is sufficient to discharge 3,000 cfs. Future use of the ring gates is desirable, to allow greater flexibility in reservoir management.

3.1.4.2 Oahe Spillway

The distance from the spillway gates to the Missouri River is approximately 2 miles. Discharges have never passed through the emergency spillway at the Oahe Project due to risks of backward erosion of the unlined channel. As a result, Water Management takes measure to avoid the use of the Oahe spillway, not due to dam safety concerns, but because extensive repairs would be needed following use of the spillway. Improvements to the Oahe spillway are recommended for operational flexibility during future large flood events. At critical times during the 2011 flood, system releases were within 5,000-7,000 cfs of maxing out the capacity of the available discharge features. Pool elevations were within a few inches from the top of the gates. If a single outlet tunnel or hydropower unit had been unavailable at these times or if inflow spikes had driven the pool higher, it would have been necessary to release through the spillway and incur significant erosion damage.

The spillway design was modified during construction by moving the spillway gates upstream approximately 2 miles, discharging into an unlined spillway channel 334 feet wide and approximately 2 miles long, with the unlined spillway channel discharging into the sides of an unprotected shale ridge in the bluff line and thence into the Missouri River floodplain. A 100-foot wide pilot channel was provided from the bluff line to the Missouri River channel. The construction of the chute, flip bucket (or stilling basin), and discharge channel was deferred until the need for the structures was demonstrated.

Historically, the Oahe reservoir has been in the exclusive flood control zone (above elevation 1,617 feet) nine times since the system was filled in 1967, about one in five years. It is imperative that the Corps evaluate risks and consequences associated with the Oahe spillway, and develop a long-term strategy.

3.1.4.3 Oahe Historic Movement Areas Near Station 61+00

The stability of Station 61+00 area has been evaluated multiple times since evidence of movement was detected during original construction. The latest was when an independent expert panel review was conducted during 2000-2001, in response to high pool conditions and suspected accelerated foundation movements during 1996 and 1997. Past independent panels included internationally-known and respected dam safety professionals. In 2001, a panel concluded that “The dam has sufficient global resistance to operate without restriction to the maximum surcharge pool of El. 1645 ft.” (The maximum pool elevation during 2011 was El. 1,619.7 ft.). However, the 2001 panel also recommended performing further drilling, lab test data and the field performance. New samples of the foundation shales were collected and sent to Virginia Technical University for shear strength testing in 2007 and 2009. Twenty-two vertical relief wells have been installed since 2001, to help relieve pressures in the shale foundation.

3.1.5 Tributary Corps Infrastructure

The Corps is responsible for multiple tributary projects, in addition to the six mainstem dams, with 22 tributary dams in the Omaha District and 18 in the Kansas City District. The applicable District’s offices perform Operational and Water Management activities, the latter in close coordination with the Missouri River Division Water Management staff. Operational concerns exist at several of the tributary dams, and are specified in the following paragraphs. In 2011 multiple tributary projects received large but brief inflows. No Corps tributary dams experienced record pools. Restoration of the identified tributary operational and structural deficiencies is important for overall system management for all authorized operation purposes.

It is important to caveat that our understanding about the performance and reliability of the tributary projects change over time, based on new information or changed conditions. The dams highlighted below reflect our best understanding of tributary deficiencies at this time.

3.1.5.1 Rathbun Dam (Chariton River, Iowa)

Rathbun Lake is located on the Chariton River in southern Iowa. Rathbun dam has a vulnerability related to flood control capacity. Because the Chariton River enters the Missouri River near the downstream end of the Kansas City Watershed, the vulnerabilities at Rathbun are primarily constrained within its own watershed. Multiple repairs to address damages from high pools have been required since 2007. The potential for future repairs due to high pool can be reduced by altering the Water Control Plan.

The project was designed to store the Standard Project Flood which generally correlates with annual exceedance probabilities of 200-year to 1000-year return intervals, but current estimates are that the flood control is filled at about a 30-year event. This is due to combined effects from higher than expected inflows and limited discharge capacity. The annual inflow volume since construction is nearly twice that predicted from historical data at the time the product was designed and constructed in the 1960's. Secondly, the discharges are limited due to downstream channel capacity. The water control manual has seasonal limits on discharges ranging from 800 cfs to 1,500 cfs. A deviation request was processed to increase discharges to 3,000 cfs during the 2010 high pool event. A deviation was also processed in 2011to maintain releases at 1,500 cfs in lieu of the normal 500 cfs seasonal restriction. Revisions to the Water Control Plan are needed to improve evacuation of the flood control storage.

Work on a water control manual update has been initiated in 2012 with O&M funding. During the public meeting on April 14, 2011, there was much interest in the Rathbun Lake water management. It appears the balance of interests in the authorized project purposes has shifted since the reservoir was constructed, and there appears to be strong justification for a revision in the water management manual.

Discharges have also been limited by the stilling basin capacity, which overtops at about 1,800 cfs (about 1/3 of the design discharge). Modifications during the 2010 high pool have mostly alleviated concerns from stilling basin overtopping. Flood supplemental funding was obtained during the 2010 high pool that was used for dam safety modifications in addition to repairing park damages. The most significant modification included placement of riprap scour protection in the outlet channel adjacent to the stilling basin.

Figure 14. Rathbun Stilling Basin Overtopping at 3,000 cfs

3.1.5.2 Harlan County Dam (Republican River Basin, Nebraska)

Harlan County has a pool restriction at elevation 1,962 feet msl (approximately mid-height on the Tainter gates). The pool restriction is a perpetual deviation request that will be renewed until the gates are rehabilitated. The deviation request implemented in 2003 was labeled as an Interim Operating Plan (IOP). The Interim Risk Reduction Measures (IRRM) plan recognized the IOP as an IRRM already implemented. The pool elevation in the IOP was selected to prevent Tainter gate buckling due to overstress resulting from trunnion friction. The IOP modifies the flood control operation of the Tainter gates by reducing the maximum design load of 30.0 feet of water to only 17.5 feet before flood waters are released. This premature release is intended to reduce the likelihood of gate failure for dam safety purposes, but it reduces the project's flood control benefits.

Figure 15. Harlan County Spillway and Stilling Basin

Omaha District completed an analysis of the Harlan County gates in 1999. Consistent with design standards at the time, the original structural design for the Tainter gates did not account for trunnion bearing friction. Other incidental loads that were also neglected include side seal friction, hoist chain wrap-around friction, wave loads, and unbalanced loads if the gate begins to rack. Stick/slip conditions in the bearings have been noted when operating the gates during maintenance and inspections. There are indications that some of the trunnion bushings have rotated relative to the trunnion arms. The evaluation concluded that operation of the gates during a flood could lead to gate failure. Gate failure is defined as the separation of the gate from the dam structure resulting in uncontrolled flow, or the gate becoming inoperable and creating a blockage of flow through the spillway.

During the Kansas City District Dam Safety Committee meeting on December 1, 2011, six gates (Gates 3, 4, 6, 7, 8 and 18) were identified as red tagged and will not be exercised since operating could cause more damage by scrapping grease off the bearing than benefit from promoting grease penetration. During 2010 - 2011, a climbing inspection was completed on all 18 gates. Numerous minor deficiencies were found, including paint corrosion, deficient welds, missing fasteners, and bearing casting defects. More significantly, greasing records showed significant lubrication problems. Gate exercising was last completed on all 18 gates in 1997. Since that time, some gates have been exercised during annual inspections. The current plan is to exercise those gates that take grease during the next fall/winter season that the reservoir level drops below the spillway sill (1943.5). Gate 9 is also suspect since grease is being extruded from the casting. Also, inspections of the sluiceway gates have been discontinued due to un-certifiable hydraulic steel structures for personnel safety.

The recent downgrade in the bearing condition leading to red tagging the gates reinvigorates concerns that were temporarily alleviated by the IOP. It is the District’s opinion that the rule curves cannot be further adjusted to accommodate further restrictions in the gate operations than already accounted for in the IOP.

The present flood control function is somewhat redundant due to Milford Lake and downstream levees that were constructed after Harlan County Dam. The annual flood control benefit attributed to Harlan County is about $1 million/year. Analysis of the dam safety risks has not been completed. However, a previous, uncompleted Dam Safety Assurance Program (DSAP) study concluded the following:

- Under normal loading conditions, bearing seizure would have little consequence due to the redundancy of 18 gates and the sluiceways. Strut arm failure would result in partial loss of pool and inability to regulate downstream flows, causing economic damages attributed mostly to loss of irrigation and potentially some minor downstream agriculture damage.

- Under the spillway design flood, bearing seizure or gates lodged in the spillway would reduce the full discharge capacity, causing potential overtopping of the dam and catastrophic dam failure. There is comparatively low risk associated with this is due to the low likelihood of the extreme loading event.

- Under intermediate flood events (e.g. 100-year to 1000-year events), the risk is subjective depending primarily on the assumed bearing conditions and the correlation of multiple gate failures occurring under the same loading conditions at the same time. Because of the systemic bearing problems, the probability of failure of the gates is strongly correlated (if one gate fails, then it is highly likely that others will fail.

3.1.5.3 Pipestem Dam (James River, North Dakota)

Pipestem Dam on the James River in North Dakota is operated in conjunction with Jamestown Dam, owned by the Bureau of Reclamation, which the Corps operates for flood control. Both reservoirs experienced extreme inflows in 2009, 2010, and 2011. Although the record pool for Pipestem occurred in 2009, the record inflow occurred in 2011. Advanced measures authorized under PL 84-99 allowed installation of temporary levees along the combined downstream channel to protect the City of Jamestown. These emergency measures permitted increasing outlet works discharges sufficiently to prevent use of the uncontrolled emergency spillway at Pipestem.

At the time of design, spillway erosion was not considered a major issue because of the long length of the spillway and because the large width of the spillway would produce relatively low velocities in the spillway channel. Recent evaluations indicate moderate risks associated with the high potential for spillway head cut erosion leading to a breach of the spillway crest and near complete loss of pool under extreme magnitude or duration flow conditions. The major concerns are the presence of highly erodible soils, high spillway discharge exit velocities and updated hydrologic analyses that suggested a more frequent return interval for these critical flow conditions to develop.

The presence of large rocks and boulders creates potential for irregular flow patterns leading to increased erosion effects. These effects were evidenced in 2009 at nearby Cottonwood Dam in LaMoure, North Dakota where minor discharges through a similar earth cut emergency spillway situated in like materials caused periods of aggressive spillway erosion, nearly resulting in an uncontrolled release of the pool.

3.1.5.4 Cherry Creek Dam (South Platte River, CO)

The most significant potential failure mode for this dam is the overtopping of the embankment during an extreme flood. The Probable Maximum Flood (PMF) is expected to result in overtopping depths up to 2.5 feet for 6 to 10 hours. The PMF would occur during summer thunderstorm events without significant warning time. The pool would rise at ten feet per hour. Overtopping flows would initiate a hydraulic jump at the toe of the dam. The embankment materials are erodible and no downstream slope protection exists. Therefore, dam failure would be likely for small overtopping depths occurring for moderate durations. Failure would result in a catastrophic release in excess of 1 million cfs with a depth of 50 feet. Regardless of the frequency return interval of the event that can first cause overtopping, the urban setting and potential for extreme loss of life pose risks that exceed the tolerable risk guidelines. More than 200,000 people in metropolitan Denver, Colorado live in the inundation area downstream of Cherry Creek Dam. The estimated life loss associated with a flood-induced failure of Cherry Creek Dam ranges from about 1,200 to 2,500 lives. Economic damages are estimated at approximately $22 billion.

There are two seepage-related potential failure modes: internal erosion along the outlet works conduit and internal erosion through the foundation. The uncertainty associated with both these seepage-related potential failure modes is moderately high because. Although a cutoff was not constructed to bedrock in the center of the valley and modern practices were not used for the outlet works conduit construction, there is no physical evidence that the seepage-related failure modes would initiate and would progress to failure.

A Dam Safety Modification Study was initiated in 2011 to assess risks and future modification needs.

3.1.6 Tributary Dams Owned by Others

There are also 22 BOR "Section 7" projects in the basin, 11 in each district. These dams have designated flood control storage and are regulated by the Omaha and Kansas City Districts, with oversight of the Water Management Division, when the reservoirs are in the flood control pool. The Water Management Division coordinates the regulation of these Corps and BOR tributary projects with the regulation of the six mainstem dams to meet the regional objectives when needed. Restricted flood operations for the Section 7 projects impacts overall system flood storage and poses potential vulnerabilities.

3.1.6.1 Red Willow Dam

Currently Red Willow Dam on the Republican River is the only known project that cannot provide authorized flood control storage during the 2012 flood season. Storage among the other flood risk mitigation dams in the Republican River basin will be adjusted if necessary, including Corps-owned Harlan County Dam.

Red Willow Dam is undergoing major remedial repairs by the BOR. In October 2009 a sinkhole was discovered on the face of the dam. Subsequent investigations revealed embankment cracking, prompting lowering Hugh Butler Lake. The BOR awarded a contract in September 2011 to conduct extensive modifications.

Repairs to the dam include excavation of the existing embankment and toe drain system; construction of filter/drainage blanket; construction of a two-stage sand filter and coarse sand drain system, including a geotextile membrane; and construction of a downstream stability berm. Modifications will also occur downstream of the spillway and outlet works stilling basins, and limited portions of upstream dam face, and is scheduled for completion in 2013.

3.1.7 Other Corps Infrastructure Vulnerability Considerations

3.1.7.1 Continued O&M Funding

Much of the success of the 2011 flood fight can be attributed to historic investments in dam safety monitoring, inspection and maintenance activities, and an organizational commitment to dam safety.

Reference the following finding from the Independent External Peer Review of the U.S. Army Corps of Engineers (USACE) Dam Safety Program, conducted by the Association of State Dam Safety Officials (ASDO) in 2001:

> "The (ASDSO Peer Review) Team members believe that the true competence of an agency's program rests with that agency's overall execution of their Inspection Program. We believe, and key staff of the Corps does also, that this facet of the program is the keystone of their Dam Safety Program.
>
> "The Corps recognized this fact in the 1960's with the start of the Periodic Inspection and Continuing Evaluation (PICE) of completed Civil Works Structures. Several catastrophic dam failures in the 1970's (Federal and non-Federal) resulted in increased interest and concern by all federal agencies. From the beginning, it was understood that engineers familiar with the design concepts of the dam would carry out the Periodic Inspections (PI). This program had strong support and adequate

> funding well into the 1990's. The Peer Review Team found that budget reductions in the O&M program in recent years has created significant pressures on the funding levels for the Corps Dam Safety Program and most importantly, the PICE program. We noted several instances of postponements of inspections or data gathering, extending dam safety assurance studies, postponing major rehabilitation and major maintenance construction and the postponing of the inspections of Hydraulic Steel Structures and Fracture Critical Members…
>
> "The Peer Review Team did, in fact, find several instances in the Major Subordinate Commands where the PI program has prevented the total or partial failure of a number of projects. We would note that this success could be attributed to qualified and dedicated personnel monitoring and evaluating these projects. Further, inspection reports are a valuable resource that allows the engineer to monitor the dam over a period of time and their continuing performance when evaluated with current state-of-the-art criteria."

Continued commitment to O&M funding allows regular instrumentation and project maintenance, monitoring, training for project personnel, updating Emergency Action Plans, vegetation control, and many other activities that contribute to public safety.

3.1.7.2 Accessible Technical Expertise

Engineers and technicians with knowledge of each dam are invaluable during flood operations. For example, on-site staff performed continual surveillance and transmitted information daily from the project to office engineers. Technical experts in the District were able to evaluate data in a timely manner and take response actions. Skilled people will be needed to respond effectively to future flood events.

3.1.7.3 Trained Operators and Heavy Equipment

Access to heavy equipment and operators from private industry could have been a serious problem in 2011, due to the vast geographical extent of flooding, remote locations of some projects, and competition from the booming oil industry in the upper plains which reduced contractor availability and interest. The ability to access government operators and equipment was instrumental in making prompt emergency repairs. For example, local operators from the BOR conducted intensive emergency erosion repairs along the Garrison outlet works tunnel. Also, trained Corps operators rotated amongst the Missouri River dam projects to assist as needed.

3.1.7.4 Debris and Sediment Control

Many trees within the 2011 flood inundation zone may not survive the long duration flood event. Fallen trees and other residue will present long term debris management challenges, especially when reservoir levels increase. Debris could block and/or damage powerhouse intakes, spillways and outlet works service gates. There is also potential that excessive debris could cause blockages or affect proper gate operations, yielding unintended releases. Similarly, sediment transported from eroded banks and newly exposed surfaces will redeposit, potentially impacting channel conveyance and blocking discharge features. Future monitoring and control will be necessary.

3.1.7.5 Emergency Rock Stockpiles

During the 1980's, the Corps' former Missouri River Division established policies to maintain permanent rock stockpiles at all dams owned by Omaha and Kansas City Districts. Access to rock can be problematic during emergency events and emergency stockpiles greatly speed the response time. Quarries infrequently have desired sizes, quality, and quantities of processed rock on hand, and may not be able to open to produce needed materials during winter conditions. Travel time is also a significant concern. Emergency rock stockpiles were utilized at all six mainstem dams in 2011 and Rathbun Dam in 2010. Depleted stockpiles will be fully replaced in time for the next flood season.

3.1.7.6 Spillway Gate Maintenance

Once repairs are implemented, continued diligence is needed to maintain the gate spillways to preserve future reliability. The following actions are recommended:

- Yearly operational inspection by project personnel.
- Full cycle operational testing requires opening gates through their full operating range yearly, or where dewatering is required, on a maximum cycle of three years.
- Partial opening operational testing requires opening loaded/watered gates at least 1 foot yearly.
- Five-year periodic inspections of spillway gates include project staff support, climbing team contracts, certified weld inspectors, and inspection equipment contracts.

3.1.7.7 Surveillance Plans and Emergency Action Plans

Surveillance plans should be updated to delineate specific areas of interest and identify additional threshold events relating to high tailwater or high discharges that require elevated surveillance.

3.1.7.8 O&M Manual Updates

Post flood repairs to the spillways, outlet works, and other features need to be documented in the project specific O&M manuals to guide future staff on how to operate gates and other features during future large flood events.

3.1.7.9 Water Control Plan Updates

Reference Section 3.2.6 for recommendations regarding mainstem dam operations. Additionally, upgrades for tributary dams should be considered as needed.

3.1.7.10 Localized Tributary Flood Events

For the current 2012 flood season, the greatest risk to flooding is in the lower basin from the unregulated flows below the mainstem dams. Though the flood storage volumes of the tributary dams are small in comparison to the mainstem dams, the tributary dams also provide important flood protection benefits.

3.1.8 Recommendations

The recommended actions described within this section are categorized under the "Repair, Restore, and Enhance" headings. It is important to recognize that as of this writing, many features of our dams have not been fully assessed, and our recommendations may evolve and change as additional information becomes available.

3.1.8.1 Repair Flood-Impacted Corps Infrastructure to Pre-Flood Condition

- Implement the planned repair actions identified in Table 10
- Perform interim repairs for Fort Peck spillway plunge pool erosion until a comprehensive strategy is developed
- Repair other impacted features still undergoing assessment

3.1.8.2 Restore all existing systems to meet original design intent

- Evaluate, design, and build Oahe and Pipestem spillway features to withstand erosion
- Renovate the Fort Peck outlet works ring gates
- Address stability issues at Oahe station 61+00
- Repair the Harlan County Dam spillway gates
- Update water control plans
- Update O&M manuals
- Monitor and control debris and sediment in excess of normal O&M activities

3.1.8.3 Enhance Reservoir Features

At this time there are no specific "Enhance" recommendations for the reservoir containment and release features. Future recommendations to increase performance, lower risk, and improve resiliency may evolve, depending on the outcome of recommended hydrologic studies.

3.1.9 Key Points

- No operational restrictions for the mainstem dams are recommended at this time.
- Several tributary projects currently have reduced flood storage capability, which could impact system operations.
- We remain vulnerable to the unknowns. Assessments are ongoing; additional deficiencies and recommendations for repairs may be revealed following issuance of this report.

Table 10. Scheduled Infrastructure Assessments and Repairs

Completion Scheduled Before Flood Season 2013

PROJECT NAME Name of work	Description of Work	District	Scheduled Contract Award	Scheduled Completion
FT PECK DAM AND LAKE, MT				
Critical Repair Assessments	Critical Repair Assessments. Includes all Spillway Gates, Slab and Stilling Basin. Failure to identify dam safety issues could develop into loss of the structure/dam if not done.	NWO	7/4/2012	4/12/2012
Install Underseepe Control	Install additional under seepage Control Facilities (if required) in Dam Embankment to address Dam safety issues as a result of 2 times record high releases over several month period. Failure to address dam safety issues could develop into loss of the dam.	NWO	9/4/2012	11/30/2012
Rehab and Repair Streamgages	Rehab and repair streamgages	NWO	7/4/2012	10/30/2012
Rehab Relief Wells	Relief Wells & Horizontal Outfalls	NWO	9/4/2012	10/21/2012
Emergency Rock Purchase	Emergency rock purchase	NWO	9/21/2012	3/21/2013
GARRISON DAM, LAKE SAKAKAWEA, ND - Williston Levee				
Build Landside Road for Flood Access	Williston Levee Interim Repairs - Increment I: Provide landside road for site access during flood events.	NWO	7/4/2012	3/21/2013
Install Relief Wells	Increment II - Boils are carrying fines on the Williston levees are occurring requiring additional relief wells, filters to be put in place to ensure integrity of levee. Includes additional under seepage Control Facilities rehab, riprap, and restore levee height. Reconstruction will be required to restore integrity of the levee or this could develop into loss of the levee if not restored.	NWO	8/4/2012	3/21/2013
Install Relief Wells	Williston Levee Interim Repairs -Increment II: Installation of Additional Relief Wells	NWO	9/21/2012	3/21/2013
GARRISON DAM, LAKE SAKAKAWEA, ND				
Critical Repair Assessments	Critical Repair Assessments. Includes all Spillway Gates, Spwy Slab & FC Tunnel Gates. Failure to identify dam safety issues could develop into loss of the structure/dam if not done.	NWO	7/4/2012	4/26/2012
Hydrologic Surveys; Downstream	Hydrologic Surveys	NWO	9/21/2012	2/15/2013
Install Underseepage Control	Install Under seepage Control Facilities in Dam Embankment (if required) to address Dam safety issues as a result of 2 times record high releases over several month period. Rehab critical dam safety instrumentation. Readings from several instruments were suspect during this year's event. Accurate instrumentation is critical to analysis of the integrity of the structures. Failure to address dam safety issues could develop into loss of the dam.	NWO	9/4/2012	11/30/2012
Lake Audubon LiDAR Mapping	Lake Audubon LiDAR mapping and evaluation of need for additional real estate or diking.	NWO	3/30/2012	2/15/2013
Rehab and Repair Streamgages	Rehab and repair streamgages	NWO	7/4/2012	10/30/2012
Rehab West Terrace	West Terrace/Abutment	NWO	9/12/2012	10/21/2012
Surveys of Spillway Channel	Surveys of Garrison Dam Spillway Channel – Spillway releases at Garrison Dam scoured out the pilot channel in the spillway exit channel. Cross-section data needed for validating that design assumptions for width and depth of scour in downstream channel were met. If width and depth of scour were too great, this would have an adverse impact on the ability of Garrison spillway to safely pass flows during future flow events	NWO	3/30/2012	10/21/2012
Weed Control and Treatment	Weed Control and Treatment - Due to newly exposed shoreline and sandbar areas, legally required to control weeds at the project.	NWO	7/4/2012	9/30/2012
Cultural Resource Assessment and Monitoring	Cultural Resource Post Flood Assessments and Monitoring. Includes assessment surveys of potentially impacted sites.	NWO	7/4/2012	3/21/2013
Restore Spillway Channel	Restoration of Spillway approach channel and wall including erosion protection repair to restore full Spillway capacity.	NWO	9/21/2012	3/21/2013
OAHE DAM, LAKE OAHE, SD & ND				
Critical Repair Assessments	Critical Repair Assessments. Includes all Spillway Gates, & FC Tunnel Gates. Failure to identify dam safety issues could develop into loss of the structure/dam if not done.	NWO	3/1/2012	6/4/2012
Install Underseepage Control	Install Under seepage Control Facilities (if required) in Dam Embankment to address Dam safety issues as a result of 2 times record high releases over several month period. Failure to address dam safety issues could develop into loss of the dam.	NWO	9/1/2012	10/30/2012
Interim Repairs on FC Tunnel	FC Tunnel Interim Repairs - Includes Gate Repair & Tunnel Lining Repairs. Roller chain parts and spares are required. Tunnel lining repairs TBD based upon inspection in mid November.	NWO	9/21/2012	9/30/2012
Open river reach below Oahe	Hydrological Surveys	NWO	9/21/2012	2/15/2013
Repair Causeway	Oahe Dam - Pierre Causeway to LaFramboise Island: The Causeway structure was constructed in 1962 to direct flows of the Missouri River to the south side of LaFramboise Island. Approximately 800 feet of the causeway has undergone extensive erosion due to overtopping. The City of Pierre, SD has water wells on the island, and the water lines and associated utilities run through the causeway.	NWO	3/1/2012	10/15/2012
Cultural Resource Impacted Site Repairs	Cultural Resource Post Flood Impacted Site Repairs or Protection of newly discovered sites. Total extent unknown until assessments are completed, includes E&D	NWO	9/21/2012	7/30/2013
Dredge Upstream of Spillway Gates	Dredging on U/S Area of Spillway Gates. Sediment has built up in front of gates, bulkheads placement may not be ensured. Extent will be determined after ERDC data is analyzed. Riprap may be needed to slow sedimentation rates in the bay.	NWO	9/21/2012	3/21/2013
Fort Yates Erosion Control	Fort Yates Erosion Control	NWO	9/21/2012	3/21/2013
BIG BEND DAM, LAKE SHARPE, SD				
Critical Repair Assessments	Critical Repair Assessments. Includes all Spillway Gates, Slab and Stilling Basin. Failure to identify dam safety issues could develop into loss of the structure/dam if not done.	NWO	7/4/2012	4/5/2012
Emergency Rock Purchase	Emergency rock purchase	NWO	7/4/2012	9/30/2012
Repair Boat Ramp and Comfort Station	Repair recreation area boat ramp, roads, comfort stations and utilities that have been negatively impacted by extended Fort Randall record pool elevations that inundated recreation area.	NWO	9/21/2012	11/1/2012
Upstream Dam Embankment Riprap Repair	Upstream dam embankment riprap repair identified during the Dam Safety Assessments	NWO	7/4/2012	11/21/2012
Hydrologic Surveys	Hydrologic Surveys	NWO	9/21/2012	2/15/2013
Cultural Resource Assessment and Monitoring	Cultural Resource Post Flood Assessments and Monitoring. Includes assessment surveys of potentially impacted sites.	NWO	7/4/2012	3/21/2013
Install and Rehab Under seepage	Replacement/Rehabilitation of Dam Safety Instrumentation. Work to be performed by in-house crews and covers open tube piezometers as well as closed system vibrating wire transducers.	NWO	9/21/2012	3/21/2013
Rehab Relief Wells	Relief Wells & Horizontal Outfalls	NWO	9/21/2012	3/21/2013
Spillway Concrete Repairs	Flood Damage Repairs -Spillway Concrete repairs identified by Arcadis assessments	NWO	9/21/2012	3/21/2013
Spillway Compression and Joint Seal	Flood Damage Repairs- Spillway Compression and Joint seal repair identified during the Dam Safety Assessments	NWO	9/21/2012	3/21/2013

Completion Scheduled Before Flood Season 2013				
PROJECT NAME Name of work	**Description of Work**	**District**	**Scheduled Contract Award**	**Scheduled Completion**
FORT RANDALL DAM, LAKE FRANCIS CASE, SD				
Emergency Rock Purchase	Emergency rock purchase	NWO	7/4/2012	9/30/2012
Install Intake Gate Hoist PLC	Install Intake Gate Hoist Programmable Logic Controllers (PLC)	NWO	8/4/2012	11/30/2012
Install Underseepage Controls	Install Under seepage Control Facilities in Dam Embankment to address Dam safety issues as a result of 2 times record high releases over several month period. Failure to address dam safety issues could develop into loss of the dam.	NWO	9/21/2012	11/30/2012
Repair A-Wall Road	"A-Wall" Erosion repair	NWO	9/21/2012	11/30/2012
Spillway Gate Critical Repair Assessment	Critical Repair Assessments. Includes all Spillway Gates, Spwy Slab & FC Tunnel Gates and Tunnels. Failure to identify dam safety issues could develop into loss of the structure/dam if not done.	NWO	7/4/2012	4/19/2012
Cultural Resource Assessment and Monitoring	Cultural Resource Post Flood Assessments and Monitoring. Includes assessment surveys of potentially impacted sites.	NWO	7/4/2012	3/21/2013
Repair Louvers	Install Intake Louvers	NWO	9/21/2012	3/21/2013
Replace Embankment Toe Drains	Replace Left and Right Embankment Toe Drains	NWO	9/21/2012	3/21/2013
Replace Seal Joints	Remove and/or replace twenty-one seal joints between each Spillway chute and slab construction joint. Occurred during spillway flow during high water event. Failure to replace joint seals will result in additional damage during freeze thaw cycles.	NWO	9/21/2012	3/21/2013
GAVINS POINT DAM, LEWIS AND CLARK LAKE, SD				
Critical Repair Assessments	Critical Repair Assessments. Includes all Spillway Gates, Slab and Stilling Basin. Failure to identify dam safety issues could develop into loss of the structure/dam if not done.	NWO	7/4/2012	4/5/2012
Hydro Graphic Surveys	Hydro Graphic Surveys - Missouri River – Necessary for updating existing hydraulic models for any post-flood assessments of flood event and future flooding. Also needed to validate tailwater rating curves at each of the mainstem dams, to ensure continued satisfactory performance of each dam. Channel bathymetry in many reaches are over 30 years old and do not adequately represent current channel conditions.	NWO	9/21/2012	2/15/2013
Install Relief Wells	Relief Wells & Horizontal Outfalls	NWO	9/21/2012	11/30/2012
Install Underseepage Control	Install Under seepage Control Facilities (if required) in Dam Embankment to address Dam safety issues as a result of 2 times record high releases over several month period. Failure to address dam safety issues could develop into loss of the dam.	NWO	9/4/2012	10/30/2012
Restore Spillway Slab	Restore Spillway Slab, Spillway sustained damaged to slab that has to be repaired which could develop into loss of the dam if not restored	NWO	9/21/2012	11/15/2012
Update Spillway Rating Curves	Update Spillway Rating Curves - Data Collection and Analysis - Rating curves for most mainstem dam project hydraulic features have been updated over the past 10 years, but should be reverified.	NWO	8/1/2012	10/21/2012
Velocity Profiles and Transects	Velocity Profiles and Transects-This information is needed to assess impacts to the existing MRRP features and to evaluate the impacts of any recommended changes to the system.	NWO	9/21/2012	11/15/2012
Boat Basin – Santee Rec Area Repair	Repair Boat Basin – Santee Rec Area	NWO	9/21/2012	3/21/2013
Cultural Resource Assessment and Monitoring	Cultural Resource Post Flood Assessments and Monitoring. Includes assessment surveys of potentially impacted sites.	NWO	7/4/2012	3/21/2013
Niobrara River Delta Surveys	Niobrara River Delta Surveys -For assessment of post flood actions relative to the sewage lagoons and well field	NWO	7/4/2012	3/21/2013
Repair Tailrace Erosion Protection	Repair Erosion Protection in Powerhouse Tailrace area.	NWO	9/21/2012	3/21/2013
Training Dike Boat Ramp Repair	Repair Training Dike Boat Ramp	NWO	4/18/2012	3/21/2013
MISSOURI RIVER, SIOUX CITY TO MOUTH, IA, KS, MO & NE				
Assessment of Structures	MRBSP - Assessments of Structures, Sioux City IA to Rulo, NE. Includes over 2500 dikes, revetments, and other BSNP features. Assessments required to determine the extent of repairs. Assessments to occur beginning in Dec after river levels are low to allow proper inspection. Full extent of damage cannot be ascertained until assessments are complete.	NWO	7/4/2012	9/30/2012
Interim Repair on Structures	MRBSP - Increment I. Interim Repairs to damaged structures, including dikes, revetments, and other BSNP features. Performance concerns regarding bank sloughing, head cutting, channel loss and/or channel re-direction and associated negative impacts to levees.	NWO	7/4/2012	11/30/2012
Rehab and Repair Streamgages	Rehab and repair streamgages	NWO	7/4/2012	9/30/2012
Repair chute entrance scour	EXCESSIVE SCOUR NEAR CHUTE ENTRANCE. Due to the flood of 2011 excessive scour occurred on the bank of the Lower Hamburg Bend on the Missouri River near River Mile 550.6 to 553.4. Excessive amounts of water going through chute. Need to repair chute entrance control structure to avoid impacts to navigation.	NWO	4/1/2012	6/5/2012
Repair Levee Toe Scour	EXCESSIVE SCOUR NEAR LEVEE TOE. Due to the flood of 2011 excessive scour occurred on the bank of the Upper Hamburg Bend Chute on the Missouri River near River Mile 554. The scour is threatening the toe of a levee protecting agricultural lands and a power generating facility. Funding is needed to armor the scour area and then fill and compact soil into the void.	NWO	4/1/2012	6/5/2012
Repair Levee Toe Scour	EXCESSIVE SCOUR NEAR LEVEE TOE. Due to the flood of 2011 excessive scour occurred on the bank of the Council Bend Chute on the Missouri River near River Mile 617.5. The scour is threatening the toe of a levee protecting a portion of the City of Council Bluffs. Funding is needed to armor the scour area and then fill and compact soil into the void.	NWO	4/1/2012	6/5/2012
Replace Project Signage	PROJECT SIGNS. Replace project identification signs and boundary signs destroyed during flood event. Includes hardware to install signs.	NWO	7/4/2012	9/30/2012
	BSNP structure survey	NWK	3/1/2012	9/30/2012
	Hydrographic survey of Missouri River	NWK	5/1/2012	12/30/2012

Completion Scheduled Before Flood Season 2013

PROJECT NAME Name of work	Description of Work	District	Scheduled Contract Award	Scheduled Completion
SECTION 33 - MISSOURI RIVER, MULTIPLE STATES				
Assess and Repair Section 33	Assessment and Repairs of Section 33 Stuctures Damaged due to 2011 Flood. Repairs to existing structures and/or sloughing easements may be used.	NWO	9/21/2012	2/25/2013
Other: Rehab and Repair Streamgages	Rehab and repair streamgages	NWO	7/4/2012	9/30/2012
PIPESTEM DAM, NORTH DAKOTA				
Rehab and Repair Streamgages	Rehab and repair streamgages	NWO	7/4/2012	9/30/2012
Rehab Right Abutment Drains	Right Abutment Drains: Drains are required to effectively control seepage pressures in the d/s right abutment area. A drainage system would effectively reduce the seepage and provide access to the area for surveillance and intervention if needed.	NWO	6/18/2012	11/15/2012
Repair Left Upstream Blanket	Left Upstream Blanket Repairs: Riprap on u/s face of dam has been damaged due to high pool levels. Concern is with stability of erosion protection of the the underlying upstream seepage blanket.	NWO	6/18/2012	11/15/2012
OTHER				
Clinton Lake, KS	Revetment damage due to sustained high flows	NWK	6/1/2012	9/30/2012
Harlan County, NE	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work in recreation areas will include but not be limited to repair and/or replace damaged campground roads, picnic tables, playgrounds, camp pads, benches, boat docks, and signs	NWK	6/1/2012	9/30/2012
Harry S. Truman, MO	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work in recreation areas will include but not be limited to repair and/or replace damaged campground roads, picnic tables, playgrounds, camp pads, benches, boat docks, and signs	NWK	6/1/2012	9/30/2012
Kanopolis Lake, KS	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work will include but not be limited to removal of deposited debris on the face of the dam, repair grass kill and erosion along the shoreline, repair damaged access roads, repair the breakwater that protects boat ramps, repair upstream dam rock protection. Work may also include dam safety repairs to damages to outlet channels and transition areas.	NWK	6/1/2012	9/30/2012
Long Branch, MO	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work in recreation areas will include but not be limited to repair and/or replace damaged campground roads, picnic tables, playgrounds, camp pads, benches, boat docks, and signs	NWK	6/1/2012	9/30/2012
Melvern Lake, KS	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work in recreation areas will include but not be limited to repair and/or replace damaged campground roads, picnic tables, playgrounds, camp pads, benches, boat docks, and signs	NWK	6/1/2012	9/30/2012
Milford Lake, KS	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work in recreation areas will include but not be limited to repair and/or replace damaged campground roads, picnic tables, playgrounds, camp pads, benches, boat docks, and signs	NWK	6/1/2012	9/30/2012
Milford Lake, KS	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work will include but not be limited to removal of deposited debris on the face of the dam, repair grass kill and erosion along the shoreline, repair damaged access roads, repair the breakwater that protects boat ramps, repair upstream dam rock protection. Work may also include dam safety repairs to damages to outlet channels and transition areas.	NWK	6/1/2012	9/30/2012
POMME DE TERRE, MO	Replace signs; Replace missing buoys	NWK	5/1/2012	9/30/2012
POMME DE TERRE, MO	Replace two courtesy docks	NWK	5/1/2012	9/30/2012
POMME DE TERRE, MO	Replenish beach sand: Rock for parking lot and camp pad repair: Erosion repair in parks	NWK	5/1/2012	9/30/2012
Rathbun Lake, IA	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work in recreation areas will include but not be limited to repair and/or replace damaged campground roads, picnic tables, playgrounds, camp pads, benches, boat docks, and signs	NWK	6/1/2012	9/30/2012
Smithville Lake, MO	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work will include but not be limited to removal of deposited debris on the face of the dam, repair grass kill and erosion along the shoreline, repair damaged access roads, repair the breakwater that protects boat ramps, repair upstream dam rock protection. Work may also include dam safety repairs to damages to outlet channels and transition areas.	NWK	6/1/2012	9/30/2012
Tuttle Creek Lake, KS	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work in recreation areas will include but not be limited to repair and/or replace damaged campground roads, picnic tables, playgrounds, camp pads, benches, boat docks, and signs	NWK		9/30/2012
Tuttle Creek Lake, KS	Amount needed to clean up and complete repairs following high water and heavy rain in summer 2011. Work will include but not be limited to removal of deposited debris on the face of the dam, repair grass kill and erosion along the shoreline, repair damaged access roads, repair the breakwater that protects boat ramps, repair upstream dam rock protection. Work may also include dam safety repairs to damages to outlet channels and transition areas.	NWK		9/30/2012
Wilson	Repair walkway damage on ADA , fishing docks in Lucas park and courtesy loading dock at the Minooka park east boat ramp; New building skylights	NWK	5/1/2012	9/30/2012
Wilson	Purchase and deliver rock for repair or eroded roads and campsites, roads, and embankment drains	NWK	5/1/2012	9/30/2012

3.2 WATER MANAGEMENT

The Missouri River basin has a drainage area of 529,000 square miles, including about 9,700 square miles located in Canada. The basin spans 10 states, including all of Nebraska; most of Montana, Wyoming, North Dakota, and South Dakota; about half of Kansas and Missouri; and smaller parts of Iowa, Colorado, and Minnesota. The Missouri River is the longest river in North America extending 2,321 miles from Three Forks, Montana to the mouth near St. Louis, Missouri, and 2,619 miles from the utmost source to the mouth.

On average, 23 percent of the annual runoff above Sioux City, Iowa is received in March and April as a result of plains snowmelt augmented by early spring rains. About 50 percent of the annual runoff comes May, June, and July and about 25 percent in March and April as a result of the melt of the mountain snowpack augmented by late spring and summer rains. Runoff varies widely from year to year but averages 24.8 MAF annually above Sioux City. Records dating back to 1898 indicate runoff has varied from a high of 61.0 MAF in 2011 to a low of 10.7 MAF in 1931 as shown in Figure 16. Prior to 2011, the previous record runoff was 49.0 MAF in 1997. The average annual runoff between Sioux City and Hermann, Missouri, the last major gaging station on the Missouri River, is 44.0 MAF.

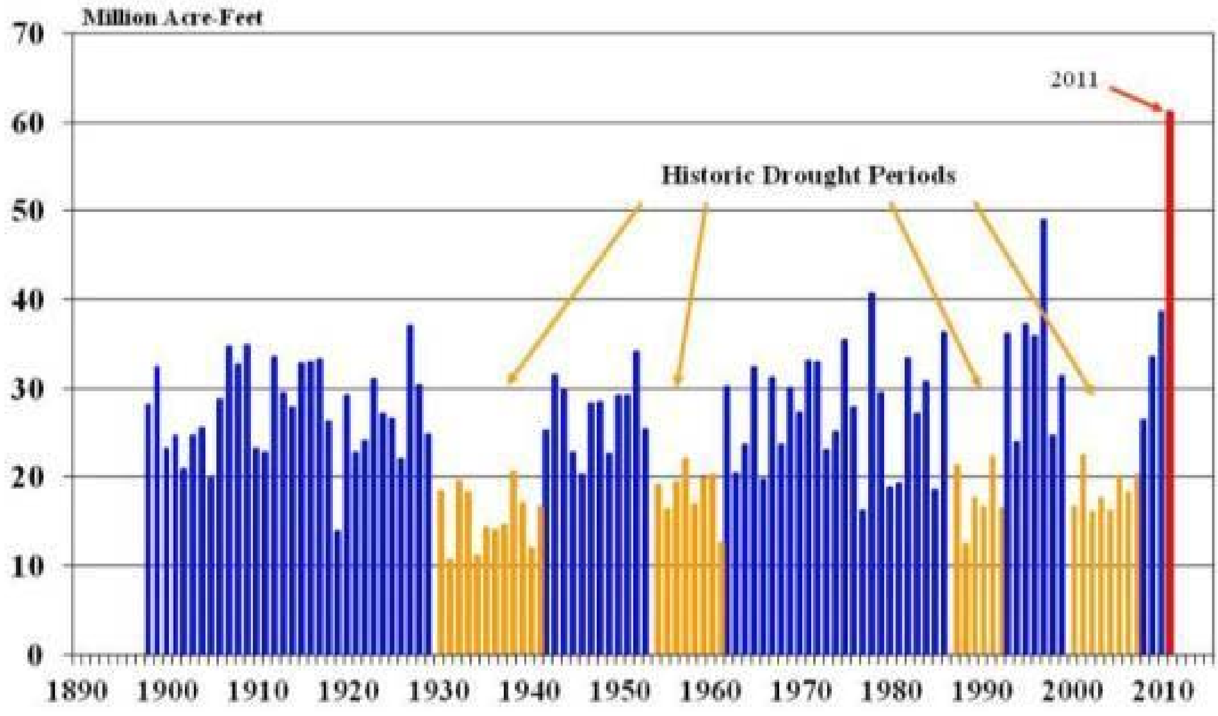

Figure 16. Missouri River Basin - Annual Runoff above Sioux City, Iowa

3.2.1 Reservoir System Description

The combined storage capacity of all six mainstem reservoirs is 73.1 MAF, about three times the annual runoff in the basin above Sioux City, Iowa. This high ratio of storage capacity to runoff lends an unusual degree of flexibility to the regulation of the multipurpose reservoir system. The storage capacity of the system and each reservoir is divided into four unique storage zones for regulation purposes, as shown in Figure 17. The bottom 25 percent of the total storage capacity comprises the permanent pool designed for sediment storage, minimum fisheries, and minimum hydropower heads. The largest zone, comprising 53 percent of the total storage capacity, is the carryover multiple use zone which is designed to serve all project purposes, though at reduced levels, through a severe drought like that of the 1930's. The annual flood control and multiple use zone, occupying 16 percent of the total storage capacity, is the preferred operating zone of the system. Ideally, the system storage is at the base of this zone at the start of the spring runoff season. Spring and summer runoff is captured in this zone reducing flood risk between and below the mainstem dams and then the stored water is metered out through the remainder of the year to serve the other project purposes, returning the reservoirs to the base of this zone by the start of the next runoff season. The top 6 percent of the system storage capacity is the exclusive flood control zone. This zone is used only during extreme floods, and evacuation is initiated as soon as downstream conditions permit.

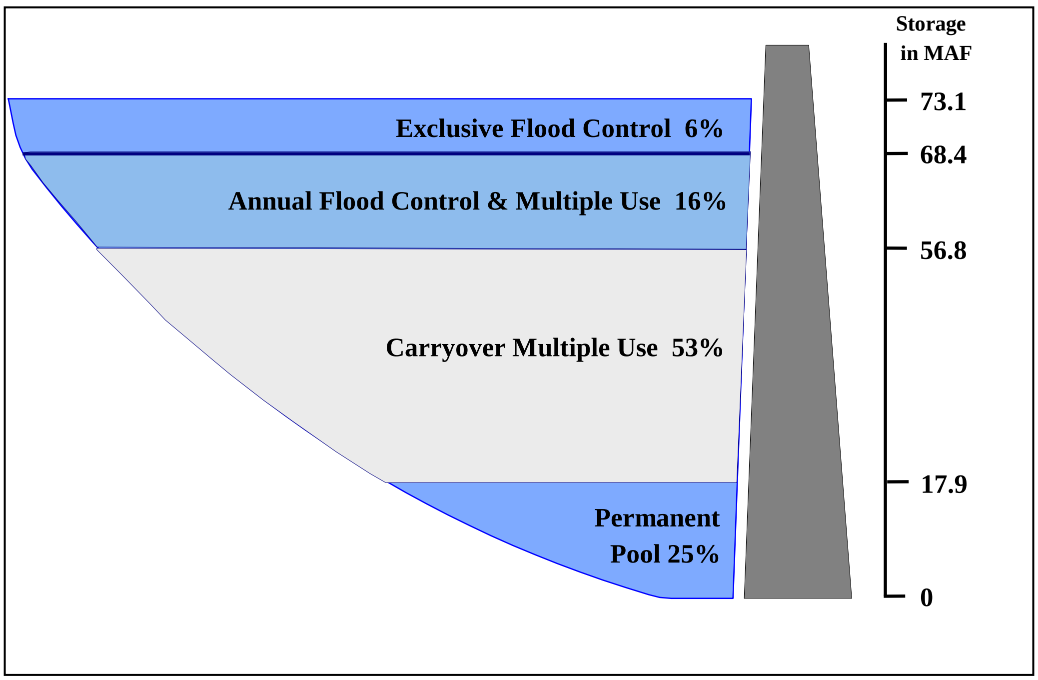

Figure 17. System Storage Zones

3.2.2 Reservoir System Regulation Overview

The system is regulated to serve the eight congressionally authorized purposes of flood control, navigation, hydropower, irrigation, water supply, water quality control, recreation, and fish and wildlife. Flood control is the only authorized project purpose that requires the availability of empty storage space rather than impounded water; all other purposes are supported by storing water in the reservoirs or releasing it to meet downstream needs.

Regulation of the reservoir system is in many ways a repetitive annual cycle. The Water Control Calendar of Events, shown on Figure 18, displays the time sequence of many of the cyclic events driving system regulation. The water control plan is designed to achieve the multipurpose objectives of the system given these cyclical events.

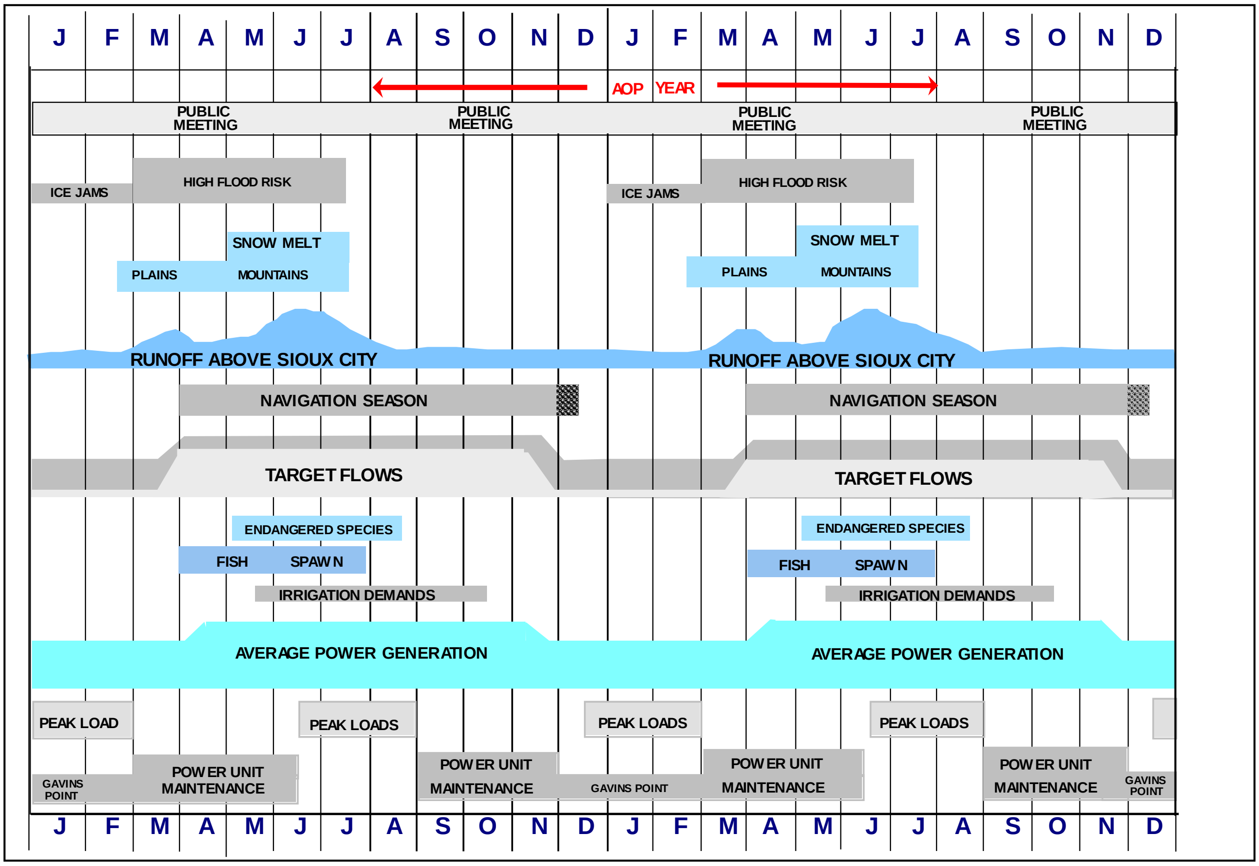

Figure 18. Water Control Calendar of Events

3.2.2.1 Flood Control

The two primary high-risk flood seasons shown in Figure 18 are the plains snowmelt season from late February through April, and the mountain snowmelt period of May through July. Runoff during both of these periods may be augmented by rainfall; this is particularly true in the lower basin where flooding is often the result of heavy rain below the system. The winter ice-jam flood period extends from mid-December through February.

Due to winter release limitations imposed by ice cover on river reaches between and below the mainstem dams, a major portion of the flood control space in the reservoir system must be evacuated prior to winter.

However, high winter releases have been made on occasions when downstream ice conditions permit, or when required for evacuation of water during high runoff years.

3.2.2.2 Hydropower

Since the completion of the power production facilities at the mainstem dams, virtually all project releases have been made through the power plants. Western Area Power Administration (WAPA) markets hydroelectric energy and capacity from the reservoir system. The highest average power generation period extends from mid-April to mid-October. The highest peaking loads occur during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The major maintenance periods for the hydropower facilities extend from March through mid-May and September through November, which normally are the lower demand and off-peak energy periods. The exception is Gavins Point where maintenance is performed after the end of the navigation season when all three generation units are normally not required to provide downstream flow support.

3.2.2.3 Navigation

The Missouri River navigation channel extends for 735 miles from near Sioux City, Iowa (River Mile 732.3) to the mouth (River Mile 0) near St. Louis, Missouri. Navigation on the Missouri River is limited to the normal ice-free season with a full-length season normally extending from April 1st through November 30th at the mouth. During this time releases from the reservoir system are scheduled, in combination with downstream tributary flows, to meet downstream target flows at Sioux City, Omaha, Nebraska City and Kansas City. Winter releases after the close of navigation season are much lower, and vary depending on whether there is a need to conserve or evacuate storage. Winter releases may also be adjusted to avoid problems at water intakes on the lower river during periods of ice formation.

3.2.2.4 Water Supply

Numerous water intakes are located along the Missouri River, both within the reservoirs and below the reservoir system. These intakes are primarily for municipal and industrial water use, thermal power plant cooling including several nuclear power plants, and irrigation. Low reservoir levels and reduced releases during periods of extended drought contribute to water access problems at several of these intakes; however, in all cases the problems have been a matter of restricted access to the river due to issues such as sedimentation obstruction or intake design rather than insufficient water volume.

3.2.2.5 Water Quality

Reservoir release levels necessary to meet downstream water supply purposes generally exceed the minimum release levels necessary to meet minimum downstream water quality requirements. However, low reservoir levels and reduced releases during periods of extended drought contribute to water quality problems in the upper basin, including problems at several Tribal intakes.

3.2.2.6 Irrigation

Although none of the originally envisioned federal irrigation projects have been constructed, numerous irrigators withdraw water directly from the reservoirs and downstream river reaches. While minimum releases established for water quality control and other uses are usually ample to meet the needs of irrigators, low reservoir levels and low river stages make access to the available water supply difficult for these users.

3.2.2.7 Recreation

The six large reservoirs, river reaches between the reservoirs, and the river below the reservoir system provide considerable recreational opportunities, including boating, fishing, hunting, camping, sightseeing, and swimming. Water levels are a key factor in recreational use of the reservoirs and river reaches. The lower three reservoirs, Big Bend, Fort Randall, and Gavins Point, are generally regulated in a consistent manner regardless of basin runoff, because of their limited storage. Pool levels at the upper three reservoirs vary widely in response to runoff conditions, and recreation may be affected by both high and low reservoir levels. Very high or very low reservoir releases may also impact boat access and maneuverability between and below the reservoirs.

3.2.2.8 Fish and Wildlife

Fish production and development in the reservoir system is related to water levels and releases during the spawning period and the availability of appropriate habitat. Minimum release restrictions and pool fluctuations for fish spawning management generally occur from April through June. In addition to fish and wildlife generally, the reservoir system is regulated to provide protection for three species in accordance with the Endangered Species Act (ESA): the endangered interior least tern, the threatened piping plover, and the endangered pallid sturgeon. Gavins Point releases are increased in March and May to provide a bi-modal spring pulse along the lower river, which is designed to benefit the endangered pallid sturgeon. Nesting of the two federally protected bird species, the endangered interior least tern and the threatened piping plover, occurs from early May through mid-August. Releases from Gavins Point are generally increased at the start of the nesting season to a rate that is expected to meet downstream requirements for much of the nesting season. This procedure reduces the need to increase releases as tributary flows decline during the nesting season, which could impact nests on low-lying habitat. Intraday peaking patterns are established at Garrison and Fort Randall to provide a maximum daily stage at nesting sites below those projects.

3.2.2.9 Historic and Cultural Properties

As acknowledged in the 2004 Programmatic Agreement (PA) for the Operation and Management of the Missouri River Main Stem System, wave action and fluctuation in the level of the system reservoir pools result in erosion along the banks of the reservoirs, impacting historic and cultural sites. During periods of extended drought, additional sites become exposed as pool levels decline. The Corps will continue working with the Tribes utilizing 36 CFR Part 800 and the PA to address the exposure of these sites. The objective of a programmatic agreement is to deal "…with the potential adverse effects of complex projects or multiple undertakings…". The PA objective was to collaboratively develop a preservation program that would avoid, minimize, and/or mitigate adverse effects along the system reservoirs.

3.2.3 Operating Restrictions and Considerations

At any given time, features of any of the mainstem dams may be unavailable for use due to normal maintenance or may be restricted due to the prior or potential failure of that component if it were used. Many project features such as hydropower units, outlet tunnels and spillways are routinely inspected and may be taken out of service for a limited time for maintenance and/or repairs. Other features may be taken out of service due to actual or potential failures. These failures do not necessarily represent dam safety risks; however, these restrictions may reduce the operational flexibility for the individual project or the system as a whole and may result in the transfer of risk to other components or projects. In some cases, the use of a particular feature of the dam may not be formally restricted, but its use may be limited while other options exist.

3.2.3.1 Operating Restrictions

Features of a dam that are not available for use are formally documented in correspondence from the Omaha District's Chief of Engineering Division/Dam Safety Officer to the Chief, Missouri River Basin Water Management.

At the time of this report there are no formal operating restrictions in place at the six mainstem dams. In the wake of the 2011 flood event, many post flood inspections have been completed; others are planned or on-going. Some of these inspections have the potential to result in operating restrictions for the projects in the future. For example, a spillway flow test is planned at Fort Peck in September 2012 to evaluate the sub-drainage system under the spillway to determine if it is functioning properly and if there is excessive uplift pressure on the spillway slab. At Gavins Point, voids have been found in the frost blanket under the spillway. Additional tests are planned to determine the magnitude of the issue and potential fixes. These types of issues could result in operating restrictions until repairs are completed.

3.2.3.2 Operating Constraints/Considerations

While there are no formal operating restrictions in place at this time, there are many operational constraints and/or considerations that water managers incorporate into daily reservoir regulation activities. These issues may at times limit operational flexibility and the ability to mitigate other issues, and may result in the transfer of risk from one area to another. Key long-term operating constraints and considerations are detailed in the following paragraphs.

Fort Peck Ring Gates

There are three ways to release water from Fort Peck reservoir: the two power plants, the spillway, and outlet tunnels. During normal operations, releases are passed through the power plants to the extent possible. When releases in excess of power plant capacity are needed, additional releases can be made through the spillway or outlet tunnels. However, during low water years, the reservoir level often falls below the spillway crest, leaving the outlet tunnels as the only non-power generating way to release water. Since 1975 concerns have been raised regarding the operation of the outlet tunnels due to the condition of the ring gates. The primary concern is the potential for damage to the gates or intake structure due to gate vibrations, which could potentially hinder closure of the gates. As a result, the outlet tunnels are only used when absolutely necessary, and at those times the release rate and duration are limited to the extent possible.

Flexibility is very important when operating the reservoir system, especially during long-duration, extreme events like experienced in 2011. If issues had arisen with the Fort Peck spillway in 2011, releases would have been restricted to the power plant capacity of 15,000 cfs without use of the outlet tunnels. The outlet tunnels would have provided an additional 45,000 cfs release capability if they were fully functional. Without the use of the outlet tunnels, releases are restricted to the power plant capacity anytime the reservoir is below the spillway crest, which typically has occurred within the first year or two of a drought. This release restriction could slow the drawdown of the reservoir if a dam safety problem ever arose. In addition, the outlet tunnels are needed to meet minimum flow requirements in the reach immediately downstream of the dam, if both power plants are offline for any reason. Spillway releases cannot meet minimum flow requirements in that reach because those releases enter the river farther downstream.

Fort Peck Spillway Gates

As part of the post flood inspection of the six mainstem dams, cracks were found in welds for 5 of the 16 gates on the spillway gates at Fort Peck. As a result, the Omaha District has issued guidance regarding the use of the spillway gates including the order in which gates should be operated. The guidance does not prohibit use of any of the gates, rather provides a preferred method of operation which is expected to have a minimal impact on operation of the project over the near term. Additional testing will be done in the near future to further evaluate the welds on the spillway gates.

Oahe Spillway

The Oahe spillway consists of a gated structure which releases water into an unlined earth cut spillway channel rather than a concrete spillway chute such as exists at the other five mainstem projects. The distance from the spillway gates to the Missouri River is approximately 2 miles. As a result, Water Management takes measure to avoid the use of the Oahe spillway, not due to dam safety concerns, but because extensive repairs would be needed following use of the spillway. When operational changes are made to avoid using the Oahe spillway, risk is transferred to other mainstem projects. For example, during the 2011 flood event, water was held in the surcharge pools at Fort Peck and Garrison to avoid using the Oahe spillway. If use of the Oahe spillway was not an issue, the gates could have been opened, providing surcharge storage in Oahe and peak releases could have potentially been reduced.

The exclusive flood control zone at Oahe extends from elevation 1617.0 to the top of the gates at 1620.0. Since the reservoir system first filled in 1967, Oahe has been in this zone a total of nine times, and has frequently remained in that zone for extended periods of time. During the 2011 flood, a significant rainfall event in the Oahe drainage basin would have required use of the spillway; the same could be said for other years the reservoir was in the exclusive zone.

Coordination with Western Area Power Administration

During the 2011 flood, the Corps and WAPA faced many challenges. A specific challenge occurred in the early days of the flood when WAPA had difficulty providing “control,” or the ability to meet fluctuating power demands, while the Corps attempted to pass the record volumes of water necessary to meet system regulation needs. For a period of several weeks, the Corps project offices adjusted supplemental releases on nearly an hourly basis in response to changes in power generation (and thus changes in power plant releases) in order to maintain a consistent flow in the downstream channel. Control was provided at either Oahe or Fort Randall. At Oahe, project personnel made supplemental release adjustments at the outlet tunnels, while at Fort Randall they were made at either the outlet tunnels or the spillway. Both of these required additional project personnel be available for changes.

In addition to providing control, daily power demands required additional gate changes during part of flood. Early in the summer, power demands were noticeably lower at night, requiring lower powerhouse releases. Outlet tunnel releases at Garrison were adjusted in the morning and evening as necessary to maintain consistent downstream flows. With Fort Randall and Oahe, the plant that was not controlling was also varied in this day and evening pattern. These adjustments lessened later in the summer as overnight power demands increased and total project releases were reduced.

The outlet tunnels were not designed for frequent operational changes, and the Omaha District's Engineering and Operations Divisions were concerned that operating the tunnels in this manner could result in failure of the gates which could have resulted in dam safety issues. As a result, WAPA worked with other power generators and the Corps to reduce the number of gate changes required while still meeting mission requirements.

Other Operational Considerations

Regulating the mainstem reservoir system to meet the eight congressionally authorized project purposes involves balancing many competing needs throughout the year. At any given time these competing purposes may function as operational restrictions and may limit Water Management's ability to fully meet the requirements of or maximize the benefits provided to other uses of the river.

3.2.4 Operating Strategy for the Coming Year

A drawdown strategy was developed in the wake of the 2011 flood to safely evacuate flood waters from the system, to allow citizens to return to their homes and businesses to begin the recovery process, and to allow inspection, assessment and repair of critical infrastructure including Corps' dams and levees. The key public concern with the drawdown strategy was the decision not to evacuate additional water from the reservoir system to provide additional flood risk mitigation in the coming year.

3.2.4.1 Basis for "Flexible and Aggressive" Approach in 2012

Following Water Management's fall public meetings, the Corps committed to maintain a flexible approach in the operation of the mainstem reservoir system throughout the fall and winter; to evacuate additional water from the system if conditions allowed; and to aggressively evacuate water from the system early in the runoff season if it appeared that 2012 would be another high runoff year. While the most critical repairs were completed prior to the start of the 2012 runoff season, much work remains to be done. The dams and levees remain vulnerable and this vulnerability was part of the rationale for the Corps' commitment to flexible and aggressive operation of the reservoir system.

3.2.4.2 Outlook for the 2012 Runoff Season

A warm, dry fall and winter allowed the evacuation of an additional 700,000 acre-feet of water from the reservoir system prior to the start of the 2012 runoff season. Current conditions in the basin indicate that the risk of snowmelt driven flooding is low, while the risk of rainfall driven flooding is normal.

The current forecast for the Missouri River basin above Sioux City calls for slightly below normal runoff due to lack of plains snowpack, below normal mountain snowpack and generally drier than normal conditions throughout most of the basin. The current reservoir forecast indicates that unless hydrologic conditions in the basin change, the system will likely begin the 2013 runoff season below the base of the annual flood control pool.

3.2.4.3 Use of Annual Operating Plan to Document Operational Strategy

The draft AOP documents a range of potential runoff scenarios and provides an opportunity for the public to comment on the proposed regulation of the reservoir system in the coming year. The draft 2012-2013 AOP, which will be developed in the late summer/early fall of 2012, will incorporate current information regarding the status of the reservoir system, operating restrictions, basin conditions, status of repairs and other data into the proposed operating strategy for the coming year. Stakeholder input can then be used to shape the final strategy for the final AOP. Although operating in accordance with the Master Manual is generally desirable, use of the flexibility within the Manual and deviating from the Manual when appropriate are important options especially in light of the system vulnerability.

3.2.4.4 U.S. Fish and Wildlife Service Coordination on Gavins Point Spring Pulse

Coordination with the U.S. Fish and Wildlife Service is on-going regarding the spring pulse from Gavins Point Dam. While no decisions have been made at this time, the spring pulse is the most controversial issue with regard to regulation of the reservoir system and the path forward may have wide- reaching impacts. The spring pulse is a brief release of additional water in an effort to mimic historic hydrologic conditions that were altered following construction of the dams.

3.2.5 Implementation of Independent Technical Review Panel Recommendations

As part of post-flood assessment efforts, the Corps enlisted the assistance of an Independent Technical Review Panel comprised of experts in meteorology, hydrology, streamflow forecasting and/or reservoir system operations to review, analyze and assess the operation of the six mainstem dams leading up to and during the Flood of 2011.

The panel reviewed and assessed a number of questions, including whether water management decisions made during the Flood of 2011 were appropriate and in alignment with the Missouri River Master Manual, the water control plan that guides the operation of the Missouri River (panel charter is attached). The team also looked at whether the Corps could have prevented or reduced the impact of flooding by taking other management actions leading up to the flood, whether long-term regulation forecasts properly accounted for the runoff into the mainstem system, whether climate change played a role in 2011's record runoff and the role floodplain development played in the operation of the reservoir system prior to and during the 2011 flood event. The panel began its independent review on October 4, 2011 and submitted its final report to the Corps on December 19, 2011.

The panel's report included six recommendations, provided below. All recommendations are currently being implemented in collaboration with other federal, state and local agencies as appropriate. Five of the six recommendations, numbers 2 through 6, were specifically directed at the Water Management Division. Recommendation 1, support for a program of infrastructure enhancement, is being addressed by the Omaha and Kansas City Districts with support from Northwest Division (NWD) Programs Division.

Excerpt from: *Recommendations for Future Management of the Missouri River Mainstem Reservoir system*, December 2011

> *The panel makes the following recommendations:*
>
> *1. Support for a program of infrastructure enhancement to ensure all flood release spillways and tunnels are ready for service and that all levees are in good condition. One of the main functions of the Corps is to maintain the water-resources infrastructure that was constructed in the past. The panel would like to emphasize the importance of adequate funding and direction for a program of infrastructure repair and rehabilitation to ensure that all flood-release spillways and tunnels are ready for service as soon as possible.*

2. Hydrologic studies to update the design flood with new probabilities. The panel recommends re-examining the Missouri River system planning that is based on the entire historical record and adjusting to the recent decades of varying climatic extremes. In addition, the Corps should be given the flexibility to manage the system storage depending on anticipated dry and wet cycles. This modification to the Master Manual procedures might be controversial and require collaborative development with state and federal agencies.

3. A review of the system storage allocations, based upon the 2011 flood event. The unprecedented inflow volume tested the reservoir system more than ever before. The panel recommends a review of the system storage allocations, to include the flood-control storage needed for floods like 2011 or larger. The panel noted that the Corps is already considering a storage allocation study such as this.

4. The panel recommends improved future cooperation and collaboration with the National Weather Service (NWS), and its already-established forecast systems as well as with U.S. Geological Survey (USGS), possibly through the Integrated Water Resources Science and Services (IWRSS) initiative. Coordination meetings should be held with the other agencies that produce water supply forecasts, specifically the NWS and the Natural Resources Conservation Service (NRCS), to help alert the Corps to potential trouble spots. State, local, city officials, and other emergency managers, such as Federal Emergency Management Agency (FEMA) and Sheriff's departments, should be included in these meetings during periods of heightened flood risk. Communication systems for awareness of other agency forecasts and distribution of current conditions, forecasts, and planned releases for the system to all local officials and emergency managers.

5. Studies to enhance data collection, forecasting, and resulting runoff from plains snow. Suggested activities include establishment of additional permanent plains snow measurement stations (using already established snow measurement standards), focused on the development of improved historical record at permanent stations; and research on the effects of prairie soils, geomorphology, and hydrology on snowmelt runoff. Also, the Corps should work to improve collaboration with other groups that collect and analyze snow data, for example, the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network.

6. A decision support system to include real-time status information on tributary reservoirs and inflows and linked to a modern interactive graphic forecast system. In noting the complexity of the communication systems required to manage the mainstem reservoirs, while considering the status of weather, downstream flooding, inflows, and storage in tributary reservoirs, the panel observed that a program of modernization is needed to create an effective decision support system linked to a modern interactive graphic forecast system.

A status report on implementation of the five Water Management recommendations is provided in the following paragraphs.

3.2.5.1 Recommendation #1: Update Hydrologic Studies

The Water Management office prepares technical studies and reports to provide information and guidance used in the regulation of the reservoir system. Some of these are updated on a regular basis and others are updated periodically as new data become available. Much of the information in these studies is used in regulation studies and reports.

Missouri River Mainstem Reservoirs Hydrologic Statistics

This report describes the methodology, assumptions, data used, and results of the statistical analyses of hydrologic data for the Missouri River Mainstem Reservoir system and was most recently updated in February 1999. Results of this analysis include the development of hydrologic statistics consisting of pool and release duration relationships, pool-probability relationships, and release-probability relationships for each of the six mainstem reservoir projects. The relationships are derived from historical records reflecting actual reservoir regulation and from the results of model simulation studies reflecting current regulation criteria over a long-term hydrologic record. Results of these analyses are compared with the previously developed relationships to determine the recommended or adopted pool-probability and release-probability relationships. This report and the relationships in it will be updated with historic data, including information from the 2011 flood event.

This is a high priority report. The Water Management office has enlisted the assistance of personnel from the Omaha District Hydrologic Engineering Branch to update the study. Water Management is funding the study out of its 2012 budget, which is comprised primarily of O&M funds provided by the Omaha and Kansas City Districts. A draft report is currently available and the report will be finalized during 2012.

Missouri River Mainstem Reservoirs Long-Term Runoff Forecasting

The purpose of this report is to describe the methodology, data used, assumptions and results of the analyses to update the runoff forecasting equations for the Missouri River Mainstem Reservoir system. It also contains example applications of the forecasting methodology along with comparisons to previously used forecasting methods. Forecasting methods have been developed to prepare long-term (up to 1 year) runoff forecasts for use in planning annual mainstem reservoir system regulation plans and for setting target releases from the system and individual reservoir projects.

This report was being updated prior to the 2011 runoff event. Since the completion of the report in 1996 (data through 1995), 16 additional years of record have occurred in the Missouri River basin, encompassing the previous runoff year of record in 1997 followed by a 9-year drought from 1999 to 2007. These years of record have added substantial variability to the runoff record as well as a lowering of long-term annual average runoff due to the length of the drought. The report will be revised to include the 2011 runoff.

Two additional analyses, described below, are on-going in support of this effort and will be incorporated into the forecasting methodology if proven effective in increasing the accuracy of long-range runoff forecasts for the Missouri River basin.

Summary of March-April Runoff Relationships to Hydrologic Factors to Consider During the Plains Snowmelt Period

Typically 25 percent of the annual runoff in the Missouri River basin occurs during March and April. The greatest sources of runoff in March and April are plains snowmelt and rainfall runoff, which are influenced by factors including, but not limited to: 1) the depth of accumulated snow water equivalent, 2) soil moisture content, 3) soil frost depth or frozen ground, 4) timing of snowmelt influenced by ambient air temperatures, and 5) rainfall precipitation on snow. The objective of this analysis is to outline the degree of certainty that the factors of accumulated snow water equivalent, antecedent precipitation, soil moisture content, and frost depth, can be used to predict March-April snowmelt. Furthermore, regression equations relating these factors to March-April runoff will be established where there is an acceptable degree of certainty between the variables and runoff. Finally, a general framework for forecasting March-April runoff will be incorporated into the updated Long-Term Runoff Forecasting procedure.

Stochastic Modeling

In response to the independent technical review panel's recommendation, Missouri River Basin Water Management has initiated a preliminary engineering/statistical analysis to evaluate the feasibility of operating the mainstem reservoirs for anticipated wet and dry climatic cycles. The first step is to determine if wet and dry inflow periods can be forecasted with an acceptable degree of certainty.

Preliminary stochastic or time-series flow models are being used to analyze historic reach inflows to the mainstem reservoirs. The models evaluate patterns in historic monthly inflows as a means to develop forecasts of future monthly inflows. These models will be tested against historic inflows to determine the accuracy of forecasting monthly inflows twelve-months in advance.

Updating the Long-Term Runoff Forecasting report and the two associated analyses are high priority items. Work is proceeding by Water Management staff utilizing O&M funds. The report is expected to be finalized during 2012.

Incremental Runoff Below Gavins Point

This report determines incremental flows at key locations for the Missouri River below Gavins Point Dam. Results of this analysis include the development of statistical data for daily and monthly reach inflows for five conditions of statistical significance. In addition, the average monthly flow data for each reach, as well as the summation of reaches at key locations, is sorted and ranked by month and year. This analysis was last done in July 2005. It will be updated to include incremental flows through 2011.

This is a medium priority report. The Water Management office plans to enlist the assistance of personnel from the Columbia River Water Management Division to update the study. Water Management will fund the study utilizing O&M funds. The report is expected to be finalized in late 2012 or early 2013.

Runoff Volumes for Annual Operating Plan Studies

This report provides the monthly reach runoff volumes used for AOP studies. The AOP studies currently utilize statistically derived runoff volumes based on the 109-year historical record of runoff above Sioux City, Iowa extending from 1898 to 2006. The AOP studies are comprised of five runoff levels with statistical significance implied by their titles: upper decile, upper quartile, median, lower quartile, and lower decile. All volumes discussed are adjusted to the 1949 level of water resources development in the Missouri River basin. This analysis will be updated to include recent runoff years including 2011.

This is a high priority study. Work is proceeding by Water Management staff utilizing O&M funds. The report is expected to be finalized in the summer of 2012 and will be incorporated in the reservoir regulation studies included in the draft 2012-2013 AOP.

Missouri River Stage Trends

This report provides an analysis of the observed stage trends along the Missouri River. Trends in river stages are presented for tailwater locations, the navigation channel and headwater locations. Tailwater locations are subject to scour, generally resulting in a lowering of the river stages over time. Headwater locations are subject to sediment deposition, resulting in an increase in river stages over time. Locations along the navigation channel are subject to a variety of factors that can cause increases or decreases in stages over time. This report will be updated to include data through 2011.

This is a high priority report. The Water Management office has enlisted the assistance of personnel from the Omaha District Hydrologic Engineering Branch to update the study. Work is on-going; O&M funds are being used. The report will be finalized during 2012.

Climatic Attribution Study of 2011(Part 1 of 2 reports)

The Corps is working with the National Oceanic and Atmospheric Administration's (NOAA) Earth Science Research Laboratory (ESRL) to scope an Attribution Study for the 2011 Missouri River basin flood.

Methods of climate attribution will be applied to identifying the meteorological processes associated with the 2011 flooding event over the Missouri River basin. The proposed work will provide a report that identifies and explains the causes for the extreme weather and climate conditions over the Missouri River basin in 2011. It will assess the relative contributions of natural or anthropogenic climate change factors for the weather and climate conditions and assess the predictability of those conditions. The physical and related meteorological processes during the 2011 Missouri River basin flooding will be compared with the past (trends, projections, internal cycles of climate variability, and previous extreme flooding in the basin). The contribution of both natural variability (e.g., ENSO [El Niño Southern Oscillation], NAO [North Atlantic Oscillation], PDO [Pacific Decadal Oscillation], and other internal dynamics) and anthropogenic climate change will be explored. The study will assess the context of the 2011 conditions within the longer-term trend observed and projected under influences of anthropogenic climate change.

The proposed rigorous climate attribution effort focused on the 2011 Missouri River basin flooding will provide the basis for a narrative that goes beyond describing what happened, to assess why it happened, is it predictable, and what is the likelihood of it happening in the future. The weather and climate analysis is also intended to provide information that can be used by policy, planning and decision makers in their determinations of how to prepare for and to manage the risk of future flooding in the basin. The NOAA ESRL will enlist the expertise of other climate scientists in this effort.

This is a high priority report. The Water Management office is currently working with the NOAA ESRL on the scope and cost estimate and intends to fund this study utilizing O&M funds. Assuming a current issue with NOAA funding mechanisms can be resolved, a draft report could be provided by the end of 2012 and a final report in early 2013.

Assessment of the Skill and Reliability of Climate Forecasting System (Part 2 of 2 Reports)

In addition to the climate attribution study of the 2011 flood, the Corps is also working with NOAA ESRL to assess the skill and reliability of dynamical predictions of seasonal climate over the Missouri River Basin. The predictions are those derived from both the NOAA operational and the new experimental climate forecast systems (CFS). These data sets, which cover predictions not only for 2011, but importantly also for retrospective periods, will permit us to evaluate performance and capabilities for the 1981-2011 period. We will work in partnership with the team currently addressing the causes of the 2011 Missouri Basin flooding, and propose that this new skill assessment concentrate on key meteorological conditions identified and described as part of the Phase-I activity to understand and explain the climate extremes in the Missouri River Basin during 2011.

The analysis will focus on three areas: 1) evaluate the seasonal forecast skill of the CFS over the Missouri River Basin; 2) analyze the internal and external forcing responsible for this skill, and of the current limits of predictability over Missouri River Basin; and 3) Assess how the seasonal skill of the CFS varies over time, and explain why.

The proposed work will produce a written report that will provide 1) an objective, authoritative assessment of the predictability of the meteorological conditions leading to the flooding in the Missouri River Basin, 2) an appraisal of the skill and reliability of the state-of-the-art NOAA operational climate forecast system to predict these conditions, and 3) a summary of the scientific approach to assess the skill in predicting rapid transitions from multi-year wet years/cycles to dry years/cycles and vice-versa. The information in this report can be used by policy, planning and decision makers in their determinations of how to prepare for and to manage the risk of future flooding in the Missouri River Basin.

This is a high priority report. The Water Management office is currently working with the NOAA ESRL on the scope and cost estimate and intends to fund this study utilizing O&M funds. Assuming a current issue with NOAA funding mechanisms can be resolved, a draft report could be provided in the spring of 2013 and a final report in the summer of 2013.

Hydrologic Statistics on Inflows

In addition to the reports listed above, the Water Management office will update the "Hydrologic Statistics on Inflows" report after these priority studies are complete. The purpose of this report is to describe the methodology, assumptions, data used, and results of the statistical analyses of hydrologic data for the reservoir system. Results of this analysis include the development of hydrologic statistics consisting of inflow volume probability relationships for various durations for each of the six projects. The results of this analysis will be incorporated into the Master Manual as required in Engineering Regulation (ER) 1110-2-8156, Preparation of Water Control Manuals.

The inflow volume probability relationships for various durations will be updated to include daily data through 2011. The data will consist of observed historical and synthetically derived records reflecting regulated and incremental reservoir inflow. This report will also contain a summary of the current reservoir regulation as per the Master Manual and a description of the assumptions used in the long-term computer model simulation studies.

Inflow volume probability relationships are used to define the annual probability of the reservoir inflow reaching or exceeding a certain flow for a variety of durations. For the purpose of this study, the durations were 1-, 3-, 7-, 15-, 30-, 60-, 90-, 120- and 183-day consecutive periods during the greatest inflow. The incremental reservoir inflow is defined as the inflow into the reservoir that is not attributable to the release from the upstream project. This study will examine both the regulated inflow into the reservoir as well as the incremental reservoir inflow.

This is a medium priority study which will be completed once other high priority reports have been completed. The study will be funded with O&M funds and should be completed in 2013.

Releases Needed to Support Navigation

The report, Releases Needed to Support Navigation, will be updated after other high priority studies are complete. The purpose of this report is to document the methodology, assumptions, data, and results of the analysis of mainstem reservoir releases needed to support navigation requirements on the Missouri River. It also provides background information on navigation flow targets, and an analysis of how often each downstream key location serves as the control point for the navigation target.

Missouri River reservoir regulation studies are conducted by Water Management to provide equitable support for authorized purposes including flood control, hydroelectric power, navigation, irrigation, water quality and water supply, recreation, and fish and wildlife including protection of threatened and endangered species. The regulation of the mainstem system considers in-reservoir needs, river flows within the open river reaches between the reservoirs, and downstream river flow requirements. In order to conduct intrasystem operation studies, reasonable estimates of the system (Gavins Point Dam) release requirements must be made, considering the interdependent nature of project releases, flows downstream from individual projects, and reservoir storages.
This is a medium priority study which will be completed once other high priority reports have been completed. The study will be funded with O&M funds and should be completed in 2013.

3.2.5.2 Recommendation #2: Post Flood Analysis of Reservoir Storage

A limited investigation was completed in April 2012 regarding the impact of providing additional flood control storage in the Mainstem Reservoir system; it is available on the Water Management website at: http://www.nwd-mr.usace.army.mil/rcc/. The primary purpose was to examine how additional flood control storage may improve flood risk reduction in the future. The analysis also provided a limited investigation of the impacts of providing additional flood control storage on several congressionally authorized project purposes.

This analysis showed that providing additional flood control storage in the Missouri River Mainstem Reservoir system would enhance flood risk reduction in a repeat of the 2011 flood event. However, due to the tremendous volume of water that must be moved though the system, record releases would be required regardless of the amount of flood control storage provided. If flood control storage were increased by approximately 30 percent, peak release could potentially be reduced from 160,000 cfs to 100,000 cfs. These lower releases would reduce flood risk below the reservoirs, but would not have prevented widespread damages.

The second part of the analysis examined the impact of additional flood control storage on five authorized purposes. Flood control is the only one of these authorized purposes that requires empty space in the reservoirs. This analysis indicates that the other four authorized purposes, which all require water-in-storage to maximize benefits, would experience negative impacts with additional flood control storage.

This analysis showed that increasing the volume of flood control storage in the system would enhance flood risk reduction in a repeat of the 2011 flood event, but would not have prevented record releases from the reservoirs or widespread damages. When analyzed over the 82-year period (1930-2011), despite additional flood control storage, there was no significant increase in average annual flood benefits for any of the alternatives when compared to the No Action alternative. The largest increase in annual flood benefits was less than one percent. When 2011 is considered alone, flood control benefits show a 1.5 to 3 percent increase as flood storage increases. Utilizing the additional flood control storage to reduce flows for long periods in the spring may reduce peak stages during that part of the year, but floods that occur at other times may be aggravated by the higher releases made to evacuate the water stored during that extended low release period.

The lower basin has experienced several years, 2010 being the most recent, when downstream flooding has occurred primarily due to runoff from downstream rainfall events, rather than system releases. Additional flood control storage may reduce flood risks on the lower river during certain runoff events; however, peak downstream flows and maximum stages cannot be reduced in all events. This is due to the difficulty in predicting flood-producing rainfall below the system, including during the late summer and fall evacuation period. The ability to reduce downstream stages depends on the timing of the peak flows and the distance from the control point. Therefore, flood control storage in the system is just a piece of the solution; increasing channel capacity and reducing encroachment in the flood plain are two of many additional methods to effectively reduce flood risk.

This report is not intended to be a complete analysis of impacts and is not intended to be a decision document. It includes a limited investigation of the potential impacts on other authorized purposes for flood risk reduction alternatives. Given the complexity of the system, further studies of economic, environmental, and cultural resource impacts would be required if alternatives to the design regulation are pursued. Additional modeling may also be required to properly assess the coincident flood risk in the lower basin.

3.2.5.3 Recommendation #3: Improved Cooperation/Collaboration

Throughout its history, the Corps' Water Management Division has collaborated with other federal agencies including NOAA, USGS and NRCS which collect and disseminate data necessary for the operation of the mainstem reservoir system, and in return has provided financial support and reservoir information necessary for the other agencies to meet their missions. Examples of coordination include the Cooperative Stream Gaging Program, weather and climate forecasts, snowpack data, and reservoir release forecasts. The Corps has also been an active member of the Fusion Forecasting Team, which is comprised of members from NOAA, the USGS and the Corps. This group is currently working on a joint-agency website that will enable users to access all agencies' critical information via a common starting point. The Water Management office also participates in other collaborative meetings including the Missouri River basin forecaster's meeting and the Mississippi River forecaster's meeting.

Following the flood of 2011, Water Management has increased coordination with NRCS regarding mountain snowpack SNOTEL stations and has incorporated NRCS water supply forecasts into its monthly inflow forecast. Increased coordination with NOAA Central Region and the Climate Prediction Center (CPC) has also taken place regarding use of soil moisture maps and long-term temperature and precipitation outlooks. In addition, the Corps has worked with the Missouri Basin River Forecast Center (MBRFC) regarding reservoir inflow forecasts for the upper three reservoirs.

The Water Management office participates in meetings sponsored by numerous interest groups and non-governmental organizations including the Missouri River Association of States and Tribes (MoRAST), the Missouri River Basin Interagency Roundtable (MRBIR), Missouri River Recovery Implementation Committee (MRRIC), Mid-west Electric Consumers Association, Missouri River Levee and Drainage District, and Missouri-Arkansas River Basin Association, to name a few.

Close coordination is also required with Western Area Power Administration, which markets the hydropower produced by the mainstem dams and the US Fish and Wildlife Service, which has provided a Biological Opinion on the operation of the mainstem reservoir system. Coordination with the BOR, which owns and operates reservoirs throughout the Missouri River basin, is also necessary. There are a total of 22 "Section 7" dams with designated flood control storage that the Corps regulates in coordination with the BOR when they are in the flood control pools.

In the wake of the 2011 flood event, the Missouri River Flood Task Force (MRFTF) was established to facilitate cooperation, coordination and collaboration with partner state and federal agencies. While the MRFTF was transient in nature, the professional relationships gained through the organization have been maintained and fostered.

The Water Management office had made a concerted effort to improve communication with the congressional delegations, media, and stakeholders following the 2011 flood. Since January 2012, the Water Management office has conducted twice monthly coordination calls that include direct input from the NOAA CPC and the MBRFC. The Omaha and Kansas City Districts also provide a status report of on-going repairs on each call.

The Water Management website has been updated to include essential products from the NWS and NRCS as well as additional links to forecasted short-term and long-term runoff and reservoir releases. District websites include associated information for Corps tributary and BOR projects. Postings on the Water Management website also include updated NWS and NRCS water supply forecasts as a comparison to the Corps' monthly inflow forecast.

Finally, the Corps continues its outreach to the public through media interviews and public speaking engagements. Since the conclusion of the 2011 flood, Water Management staff has made presentations at more than 50 meetings and professional conferences throughout the region.

3.2.5.4 Recommendation #4: Enhanced Data Collection, Forecasting and Resulting Runoff from Plains Snowmelt and Other Data/Modeling Improvements

Establishment of Permanent Monitoring system for Plains Snowpack, Frost Depths and Soil Moistures

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. Historically, about 25 percent of the annual runoff in the Missouri River basin above Sioux City, Iowa occurs in March and April, during the time when plains snow is typically melting accompanied by rainfall. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack, existing basin conditions and hydrologic forecasts, which including long-term precipitation outlooks.

The greatest sources of runoff in March and April are plains snowmelt and rainfall runoff, which are influenced by factors including, but not limited to a) the depth of accumulated snow water equivalent, b) soil moisture content, c) soil frost depth or frozen ground, d) timing of snowmelt influenced by ambient air temperatures, and e) rainfall precipitation, sometimes directly on snowpack.

The geographic area above the Missouri River at Sioux City, Iowa is 315,000 square miles. The majority of this area is affected by plains snow. Assessment of current and forecasted basin conditions will logically lead to more accurate runoff forecasts. For those current and forecasted assessments to be as accurate as possible it is critical that the instrumentation, data collection, data reporting, and data analysis be consistent and applicable to the overall purpose. Most importantly, the data must be relevant, timely and geographically comparable. Ascertaining actual and current soil conditions (e.g. moisture, frost depth, infiltration capacity), ground-truthing plains snow liquid content, sometimes referred to as snow water equivalent (SWE), and determining the effects and impacts of the prairie pothole region of the basin in (e.g. eastern North Dakota and South Dakota) as to how it affects surface runoff and baseflow are all critical improving forecasts for March-April runoff.

The Corps has initiated a collaborative effort with a group of experts from NOAA, NRCS, the South Dakota State Climatologist, and the Western Governors Association to develop a proposal to enhance data collection, forecasting, and resulting runoff from plains snow. Suggested activities include: establishment of additional permanent plains snow measurement stations (using already established snow measurement standards), focusing on the development of improved historical record at permanent stations, and researching the effects of prairie soils, geomorphology, and hydrology on snowmelt runoff. Also, the Corps should work to improve collaboration with other groups that collect and analyze snow data, for example, the CoCoRaHS network.

The goal of the proposal is to present a framework for the establishment of an interagency, usable and sustainable network that will enhance the forecasting of runoff during the plains snowmelt period. The proposal, which is summarized in the following paragraphs, is not intended to be a final plan, rather a launching point for additional discussion to include appropriate subject matter experts into developing the final plan.

Proposal Approach

Establishment of the plains snow network in the same manner as the mountain snow network could be established over a period of time. Initially, use of near real-time, on-the-ground snow depth and SWE measurements made manually at regular intervals would provide necessary information in the short-term and also be extremely useful in determining long-term, possibly automated, network needs.

In addition, while the correlation between mountain SWE and May-June-July runoff into the upper two mainstem reservoirs is fairly strong, the correlation of plains SWE and March-April runoff is considered much weaker, due to lack of consistent, historical data and other factors that lead to March-April runoff. The experts all agreed that soil/basin conditions, primarily soil moisture and frost depth, in addition to plains SWE, are key components in determining March-April runoff.

Purpose and Benefit

Increasing the accuracy in forecasting the amount of runoff that will occur in the upper Missouri River basin during the early part of the runoff season (March and April) will allow everyone more time to prepare for the rest of the runoff season. This applies to all runoff conditions – wet, dry or normal.

Benefits would be realized by any federal or state agency that has water management responsibilities, such as USACE, BOR, USDA/NRCS and USGS. In addition, federal and state emergency response agencies would benefit from advance knowledge. At a more local level, state and county emergency and city public works offices, as well as local business owners or homeowners – basically anyone affected by flows, high or low, on major tributaries as well as the Missouri River, would all benefit from this effort.

Definition of March/April Runoff

Missouri River basin runoff during the months of March and April is a result of 1) melting plains snowpack and 2) rainfall that is not lost to soil infiltration or evapotranspiration (e.g. includes evaporation and consumptive use by plants).

March/April Runoff Components

The components used to forecast March and April runoff in the upper Missouri River basin are:

- Assessment of plains snow liquid content or SWE
- Assessment of basin soil conditions, specifically soil moisture and frost depth
- March and April temperature and precipitation forecasts
- Modeling tools to predict runoff that incorporate components #1 through #3

Increasing Accuracy of March/April Runoff Forecast

Logically, the accuracy of the modeling (output) is a direct correlation of the accuracy of the information that is fed into the models (input). Simply put, if the accuracy of components #1 through #3 (plains snow, basin conditions, temperature/precipitation forecasts) is increased, the accuracy of #4 (forecasted runoff) will also increase.

Information regarding what is currently available for each of these four components and what needs to be done is included in the following paragraphs.

Component #1 – Plains Snow: What Is Currently Being Done

Since 2002, NOAA's National Operational Hydrologic Remote Sensing Center (NOHRSC) has produced a daily modeled map of snow and basin conditions of the coterminous U.S. and Alaska (http://www.nohrsc.nws.gov/interactive/html/map.html). The data to produce this map are from a combination of airborne surveys (gamma radiation), satellite observations and on-the-ground field measurements. The daily map is converted to 2-km x 2-km grids by the USACE Cold Regions and Research Engineering Laboratory and provided to various USACE water management offices. The gridded snow map, along with gridded maps of basin conditions, observed and forecasted precipitation and temperature, is used as input into the USACE developed HEC-HMS model to forecast runoff at various locations.

In 2010 the Water Management office established a Missouri River basin Cooperative Plains Snow Survey. The network is comprised of volunteers from federal, state, county and local governments as well as private citizens to collect on-the-ground field measurements. The network was established for regular interval snow depth and SWE measurements to be taken at pre-defined locations. The Corps provided volunteers with the snow tube, digital scale, and instructions. This information is provided to NOHRSC for snow model calibration purposes. Many locations do not currently have volunteers.

The North Dakota State Water Commission has established the Atmospheric Resource Board Cooperative Observer Network (ARBCON). This network has historically reported rainfall during the months of April through September, but has expanded to include snowfall reporting. This information is provided to NOHRSC for snow model calibration purposes. This network still has some shortcomings. While approximately 30 stations in North Dakota are collecting snow depth and/or SWE data in the Missouri River basin, not all measurements are taken at regular intervals or reported to NOHRSC on a near real-time basis (e.g. within 24 hours of measurement).

The CoCoRaHS network consists of thousands of volunteers working together to measure precipitation across the nation. This network works very well for precipitation. However, measurement of SWE is very sparse and sporadic.

Component #1 – Plains Snow: What Needs to be Done

The area of greatest need is on-the-ground SWE measurements, which are used to calibrate the NOHRSC snow model. Ideally, the on-the-ground SWE measurements would 1) be established at pre-defined locations for year-to-year comparisons; and 2) be taken at regular intervals (e.g. every 2 weeks) every year from November through April. While there appears to be an abundance of plains snow observations throughout the basin, it is important to note the difference between snow depth and SWE measurements. The Corps' hydrologic model requires SWE measurements, but regular interval on-the-ground SWE measurements at pre-defined locations are lacking.

Agency personnel/volunteers, who are willing to take SWE measurements at regular intervals at pre-defined locations, need to be identified. In addition, a standard methodology, that may include equipment, needs to be established so that the measurements can be readily received and used by NOHRSC on an on-going, near real-time basis. If snow pillows are used, NRCS National Water and Climate Center (NWCC) expertise should be utilized. Finally, this measurement information needs to be stored in a common database and made accessible to everyone in the basin.

Component #2 – Basin Conditions: What Is Currently Being Done

NOHRSC determines "baseline conditions" each fall via gamma airborne surveys. The top 8 inches of soil moisture at the beginning of the snow season (e.g. initial conditions or antecedent conditions) is determined via these surveys.

The NRCS has established the Soil Climate Analysis Network (SCAN). Various climate and soil data are collected via this network including air temperature, barometric pressure, dew point temperature, ground surface temperature, precipitation, relative humidity, soil temperature, solar radiation, vapor pressure, soil moisture percent, and wind direction, movement and speed. In the four upper Missouri River basin states there are only 10 SCAN sites: seven in Montana and one each in North Dakota, South Dakota and Wyoming.

NOAA's High Plains Regional Climate Center (HPRCC) has established an Automated Weather Data Network (AWDN). Various climate and soil data are collected via this network including air temperature, precipitation, soil temperature (frost depth), relative humidity, solar radiation, wind speed, and potential evapotranspiration. The states of North Dakota and South Dakota have good coverage across each state; however, less than 20 of the South Dakota stations collect soil moisture and none do in North Dakota. There are only two stations in Montana and none in Wyoming in areas that drain into the mainstem reservoir system. Most of the Nebraska AWDN stations collect soil moisture.

Component #2 – Basin Conditions: What Needs to Be Done

Soil moisture and frost depth need to be measured at regular intervals at pre-defined locations.
Soil moisture instrumentation needs to be purchased and installed in predominant soil type areas and then connected to existing AWDN equipment. The same could be done at SCAN sites.

The initial cost of soil moisture instrumentation (probes placed at 10-cm, 25-cm, 50-cm and 100-cm depths) varies, but generally is between $1500 and $2000 per location. Installation involves locating an appropriate location/predominant soil type, digging a hole, installing the probes in the soil and finally connecting the probes to the existing AWDN or SCAN instrumentation. Ideally, soil moisture instrumentation would eventually be located at each AWDN or SCAN site. The NRCS National Soil Science Center (NSSC), state NRCS offices and/or Major Land Resource Area (MLRA) Soil Survey Management offices would all have personnel with appropriate expertise.

The ongoing cost of soil moisture instrumentation would include annual maintenance and eventual replacement (every 10 years or so).

In addition, assessment of basin soil conditions could go beyond moisture and temperature and include assessment of soils themselves, which can indicate infiltration rates, which is part of the input in the runoff models.

Component #3 – Temperature and Precipitation Forecasts: What Is Currently Being Done

NOAA's CPC delivers climate prediction (e.g. precipitation and temperature), monitoring and diagnostic products for timescales from weeks to years. These outlooks indicate the degree of probability of temperature and precipitation being either above normal, normal, or below normal. The information from these outlooks is qualitatively integrated into technical analyses and runoff models.

NOAA's Hydrometeorological Prediction Center (HPC) provides short-term weather (e.g. precipitation) forecasts. These forecasts indicate the location and amount of precipitation forecasted to fall over the next five days. The NWS MBRFC provides this information to the Corps in 6-hour gridded datasets so that it can be quantitatively integrated into real-time runoff models.

Component #3 – Temperature and Precipitation Forecasts: What Needs to be Done

The Corps' HEC-HMS runoff models require a daily forecasted temperature and precipitation for the time period (e.g. through the end of April) and that information needs to be available for all model runs. NOAA would need to provide to USACE, on at least a weekly basis from January through April, a range of expected (E), lower-than-normal (L) and higher-than-normal (H) datasets or ranges of daily (P) precipitation (EP, LP and HP) and (T) temperature (ET, LT, HT) that are needed as input into the real-time snowmelt runoff models.

Component #4 – Modeling Tools: What Is Currently Being Done

The Corps-developed runoff model, HEC-HMS uses as input current plains snow and basin conditions, observed temperature and precipitation and forecasted temperature and precipitation and is state-of-the-art technology. Currently the Water Management office has six sub-basins modeled with HEC-HMS to forecast snowmelt runoff. This is a small portion of the upper basin affected by plains snowmelt.

Component #4 – Modeling Tools: What Needs to be Done

The HEC-HMS modeling effort would need to be expanded to cover the entire area of the basin affected by plains snow. The forecasted temperature and precipitation datasets (EP-ET, EP-LT, EP-HT, LP-ET, LP-LT, LP-HT, HP-ET, HP-LT and HP-HT) would then be input into the models, as well as current plains snow and basin conditions and observed temperature and precipitation, to present nine possible runoff scenarios. These scenarios could then be further reviewed and analyzed to present three runoff scenarios – expected, wetter-than-expected, and drier-than-expected.

Plains Snowpack Summary and Conclusions

Establishment of a basin-wide network that provides plains SWE and basin condition measurements at pre-defined locations taken at regular intervals, as well as forecasted daily temperature and precipitation, will lead to a more accurate March-April runoff forecast. The entire basin will benefit from a more accurate runoff forecast, regardless of wet, dry or normal conditions, in that it will allow all stakeholders to better prepare for the remainder of the runoff season.

The Corps is not a data collection agency, therefore the success of this endeavor will require the involvement of other federal agencies as well as state, county, local and citizen volunteers.

Literature Search of Plains Snow Hydrology Including the Effects of Prairie Soils, Geomorphology and Hydrology on Snowmelt Runoff

A plethora of technical reports have been published that concentrate on the prairie pothole region of the Dakotas and the effects on surface runoff and baseflow. An extensive data call needs to be conducted to collect all pertinent studies and then an even more extensive effort needs to be conducted to filter/correlate scientifically-based and verified results from these reports in such a way that they could be incorporated into the runoff forecast procedure/methodology.

Stream Gaging Network Improvements

Between 1990 and 2010, 387 streamgages in the Missouri River basin that were once in the USGS gaging network were discontinued. A total of 17 additional gaging stations, which formerly had stage-discharge relationships available to associate the river stage with a discharge estimate, have been changed to "stage only" stations and as a result are now less useful in real time water management. A map showing the location of these streamgages and the 81 additional streamgages that were in danger of being cut but are now funded through the National Streamflow Information Program (NSIP) program is shown in Figure 19.

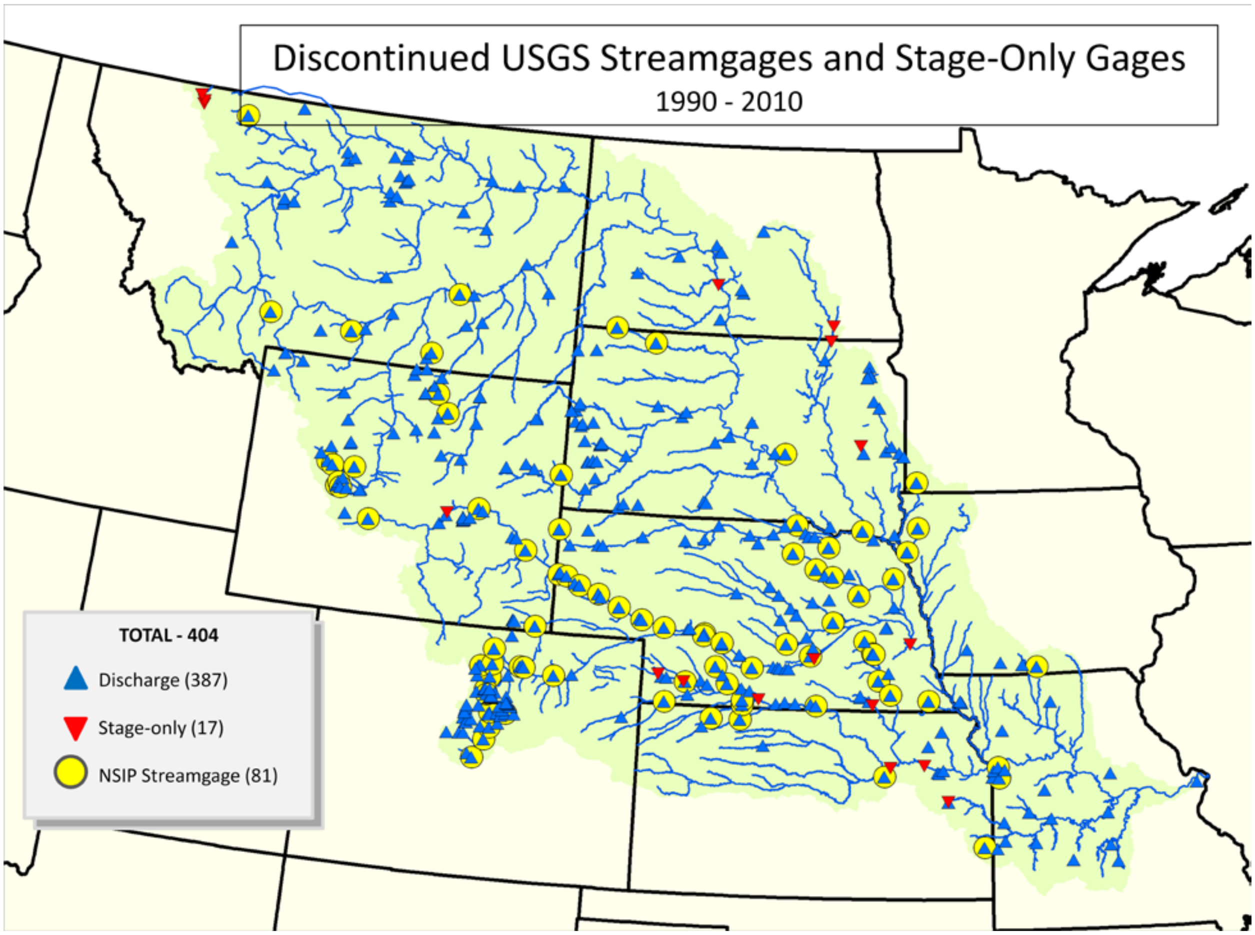

Figure 19. Discontinued USGS Streamgages and Stage-Only Gages, 1990-2010

Some of the numerous issues related to changes in the USGS gaging program are detailed below.

The Corps uses the USGS' rating curves for many Missouri River and tributary locations in the basin. The current rating curves may not cover the full range of stages and discharge likely to occur. This causes delays and holes in the data necessary to run the Missouri River and tributary flow forecast. The USGS takes the base curve and uses that portion of the rating where there is recent measurements to confirm the data on the rating curve. If the river station drops below or rises above the current band of recent data points collected in the field, the new real-time stages will be off the curve and will not have a flow value. Instead of taking data from an older shifted rating curve or even a shifted base curve that incorporates the historical data, the flow is tagged as missing. The Corps needs the USGS rating curves to be extended to cover all the data including record lows and highs where possible.

The Corps has experienced a significant reduction in discharge measurements on the Missouri River due to reduction in Corps funding. This lack of discharge measurement data reduces the accuracy of the Corps' and the NWS' ability to shift Missouri River and tributary flows to match current river and tributary channel flow conditions. The Corps forecasts are used to guide the regulation of the six mainstem reservoirs. Each reduction in Missouri River and tributary flow measurements decreases the accuracy of forecasts used to operate the system for the authorized purposes.

For example, the Missouri River discharge measurements in the lower basin were reduced from FY 2011 to FY 2012 as follows:

Rulo, Nebraska from 42 to 34 per year
St. Joseph, Missouri from 30 to 26 per year
Kansas City, Missouri from 40 to 35 per year
Waverly, Missouri from 30 to 24 per year
Booneville, Missouri from 30 to 24 per year
Hermann, Missouri from 30 to 21 per year

The Corps' Missouri River Water Management and the water management offices in Omaha and Kansas City Districts need sufficient funds to continue to meet the Corps' responsibility in the 40+ year partnership with the USGS in the Stream Gaging Cooperative program. Through this program the USGS has been able to operate and maintain a network of real-time data collection platforms in the Missouri Basin that are used by the Corps and other federal agencies. In addition the USGS' NSIP needs to be fully funded.

The need to "harden" Missouri River basin Data Collection Platform (DCP) gaging houses against flood events became very evident in the 2011 flood. Structure upgrades or relocation to a higher elevation, upgrades to gages and an additional backup gage (radar) to gaging stations would help ensure critical stage and discharge data are collected during the extreme flood events like 2011.

The Corps' Missouri River Water Management office mission requires the ability to support the collection of data through DCPs in the field and receive satellite transmitted data via the Direct Readout Ground Station (DRGS) located in Omaha. The proper software and hardware to screen and analyze real-time data is necessary to develop forecasts and make real-time operational decisions regarding the regulation of the six mainstem dams.

There is also a need for more DCPs in the upper basin. This was especially noted during the 2011 flood when the only DCP on the Judith River was washed out. It is located in the upper reach of the Fort Peck reservoir and is funded by the Bureau of Land Management (BLM). There were no other DCPs on the Judith River to report the high flows headed for Fort Peck. This DCP was used to help calculate observed and forecasted inflows into the Fort Peck reservoir during the Flood of 2011. Another example of a location needing a DCP is the City of Glasgow, Montana, which was flooded from the Milk River last summer. There is no gage at Glasgow. The NWS, which relies on the USGS gaging program to forecast river stages and disseminate flood warnings, requested the USGS to make a measurement on the Milk River; the flow was 30,000 cfs at its peak during the 2011 flood.

There is also a need for seasonal gages operated during the high runoff periods usually spring through early summer in the upper Missouri River basin. Flexibility to fund the USGS' deployment of temporary DCPs could also help the Water Management office continue its flexibility to collect on the ground real-time data necessary for developing forecast of river flows into and out of the mainstem system.

3.2.5.5 Recommendation #5: Decision Support System

Effective reservoir regulation of the system requires accurate real-time data relating to existing and anticipated hydrologic and meteorological conditions within the Missouri River basin. Due to the wide seasonal and areal variations of hydrologic events within this very large basin, it is necessary to integrate a large volume of basic data pertinent to runoff and water supply in order that the reservoir system can be regulated to meet the operational objectives for which it was designed.

Long-range Improvements to Corps Water Management system

A water control data system (WCDS) has been in use since 1978 to serve the data needs of the Water Management office. Data is collected at sites through a variety of sources and integrated into a regional database. This data is then used in short-range and long-range runoff, streamflow, and river-stage forecasting. Runoff forecasts are used as input to computer model simulations so that project release determinations can be optimized to achieve the regulation objectives. The Water Management office continuously monitors the weather conditions occurring throughout the Missouri River basin and the forecasts issued by the National Weather Service. Long-range runoff forecasts are prepared based on estimates of rainfall and snowmelt runoff in the basin. In addition to long-range runoff forecasting, short-term streamflow and river-stage forecasts assist in scheduling system and individual project releases.

Part of the WCDS is the Corps Water Management system (CWMS), the automated information system that supports the water management mission of the Corps. CWMS is a modern graphical software suite that facilitates access to and sharing of water management-related information among district, division, Headquarters, U.S. Army Corps of Engineers (HQUSACE) staff, and staff of cooperating federal, state, and local agencies. It provides tools and information needed to accomplish the water management mission including reservoir and river system status monitoring, flow regulation and decision support. CWMS development is led by the Hydrologic Engineering Center (HEC), an organization within the Institute for Water Resources. HEC is the designated Center of Expertise for the Corps of Engineers in the technical areas of surface and groundwater hydrology, river hydraulics and sediment transport, hydrologic statistics and risk analysis, reservoir system analysis, planning analysis, real-time water control management and a number of other closely associated technical subjects.

CWMS development is an on-going long-term process that includes both software development and system architecture including servers and networking. Direction for CWMS modernization is provided by HEC as the system developer, the program manager, the advisory group (AG) and the Corps user representatives group (CURG). The AG is comprised of senior representatives from each Corps division office, and the CURG group is comprised of representatives from field offices. The Missouri River Basin Water Management office is actively involved in CWMS development and is currently is the process of moving from CWMS version 1.5 to version 2.1.

This is a high priority effort being undertaken in coordination with the Hydrologic Engineering Center, but not directly associated with the flood event. These efforts have been on-going, but there is a big push currently to make the transition to CWMS 2.1 for a variety of reasons. This effort should be complete in 2012 and is being done with O&M funds.

Updates to Legacy Models

The short-range forecast is developed using a system regulation model referred to as the Three-Week Model. The model uses daily input data that is updated on Wednesday of each week or more frequently if needed. The three-week forecast presents inflows, outflows, reservoir pool elevations, and hydropower generation for a 3 to 5-week period for each of the system projects. The study serves as a guide for short-term system modifications and is used to make regulation adjustments within the range normally determined by the long-term monthly studies. This model will be updated to provide a more robust forecasting tool that can easily incorporate National Weather Service inflow forecasts and present alternative regulations. The updated program will include a more modern graphical interface.

Updating Water Management's legacy programs is an important endeavor, but many improvements will be deferred until the higher priority transition to CWMS 2.1 is complete. This effort should be complete in 2013 and is being done with O&M funds. Other legacy programs will be converted as resources allow.

Website Improvements

Improvements will be made to Water Management data dissemination including updates to the website. The Water Management website will be organized to display data in a way that is more user-friendly. Certain text-based products will be enhanced with graphics or data plots. A map-based interface is being developed that will allow users to view different data sets from a variety of sources (including partner agencies) for given locations. In addition, links will be added to various pages so that data from cooperating agencies such as the National Weather Service can more easily be found.

Some improvements have already been made, others will be forthcoming. All NWD websites will migrate to a new web server and format in the near future. Additional improvements will be completed as resources allow.

Reservoir Simulation Models for Educational Purposes

The Water Management office will research cooperative reservoir simulation models to be used for educational purposes. The Missouri River basin is large (529,000 square miles), and the reservoir system has many competing purposes and interests. A model such as this would provide a decision support type tool equipped to evaluate alternative water management strategies. The model would be designed to serve as an educational tool for presentation to the general public and could be used in interactive workshops.

This is a low priority effort and will be completed when other higher priority tasks are completed.

3.2.6 Water Control Manual Updates

The Missouri River Mainstem Reservoir system is regulated in accordance with the Master Manual to serve the eight congressionally authorized project purposes. The Master Manual includes a water control plan that helps guide how the six reservoirs are to be operated as a system including how much water should be released, when, and for how long for the benefit of the entire Missouri River basin. The Corps revised the Master Manual in 2004 following a 14-year period of public involvement to balance all the competing uses for the Missouri River. The current Master Manual reflects the input from the public and Tribes throughout the entire basin on how the reservoirs could best be operated to serve all the purposes for which they were authorized and constructed. Following another public process, the Master Manual was updated again in 2006 to include the technical criteria for the Gavins Point spring pulse for the benefit of the endangered pallid sturgeon.

The 1881 flood served, in large measure, as the signature event for establishing the flood control storage allocations and the associated reservoir release rates. Allocation of sufficient flood control storage (within the combined Exclusive Flood Control and Annual Flood Control and Multiple Use Zones) to control the 1881 flood event established the base of these two flood control zones.

Drought also played a significant role in the design of the reservoir system and the water control plan provided in the Master Manual. The Missouri River mainstem reservoir system is the largest reservoir system in the United States and serving all authorized project purposes during an extended drought like the 1930's was part of the original objectives of the system. This resulted in the construction of the reservoir system with an enormous amount of water normally retained in reservoirs in anticipation of the onset of extended drought. For this reason, the three upper reservoirs are extremely large compared to other Corps reservoirs. The reservoir system was designed to use this stored water during extended drought periods to meet a diminished level of service to all congressionally authorized purposes except flood control.

Any potential adjustments to water control plan or reservoir storage zones for flood control and other authorized purposes must include a detailed analysis on the impacts to other authorized project purposes, the environment including the three listed species that are protected under the Endangered Species Act, and cultural resources. Corps regulations require a public process when changing a water control plan. In addition, consultation with the basin Tribes would also be required, as well as some form of National Environmental Policy Act (NEPA) coverage.

There are six individual manuals in addition to the Master Manual, one for each dam. Each of the individual water control manuals includes detailed information specific to that project, however the individual manuals do not include a water control plan since the reservoirs are operated as a system.

Following the update of the Master Manual in 2006, the Water Management office began a process of updating the individual manuals as time and resources allow. As in all water management offices, updating water control manuals is generally low priority work, and this is particularly true in the Missouri River basin since the water control plan in the Master Manual is current. The water control manual for each dam has been assigned to an engineer in the Water Management office and it is worked on as time allows.

To date, Big Bend has been updated; Fort Peck and Fort Randall have near-final drafts; and varying amounts of work have been done on Garrison, Oahe and Gavins Point. Due to the historic flood event, updates are needed in the three that are in final/near-final form to include the 2011 information. Table 11 provides the publication dates of the latest Missouri River water control manuals.

Table 11. Missouri River Water Control Manual Publication Dates

Project	Publication Date
Missouri River Mainstem Reservoir System Master Manual	2006
Fort Peck	1976
Garrison	1978
Oahe	1978
Big Bend	2007
Fort Randall	1978
Gavins Point	1978

Updates of water control manuals must be done in accordance with ER 1110-2-8156 (Preparation of Water Control Manuals).

3.2.7 Enhancing Future Flood Risk Reduction

As noted in the Post Flood Analysis of Reservoir Storage report, flood control storage in the reservoir system is just a piece of the solution to reduce flood risk in the Missouri River Basin. A holistic approach is needed to ensure a better outcome during the next big flood event. Increasing the carrying capacity of the floodway and reducing encroachment in the flood plain are two of many ways to reduce flood risk. The benefit of approaching flood risk reduction in a more holistic manner is that it provides flexibility to respond to a wide range of flooding situations and the resiliency to recover quickly following an event.

Not all Missouri basins floods are the same: the floods in 1997 and 2011 were huge upper basin floods with large volumes of runoff coming from the melt of the plains and mountain snowpack in addition to rain in the upper basin. The mainstem reservoir system is designed to capture this runoff and release it in a controlled manner over an extended duration. In contrast, typical floods in the lower basin, like those in 2007, 2008, and 2010, are caused by rainfall events below the reservoir system. In this type of event, the releases from the reservoir system can sometimes be lowered to reduce peak stages or shorten the duration of high flows; however there are limits to the ability of the reservoir system to provide benefits. Releases reductions typically take days to reach the area of concern, as much as 10 days from Gavins Point to the mouth of the Missouri River, therefore the effectiveness of the reservoir system is greatly reduced when rainfall occurs too far downstream, or directly over the river rather than over tributary basins.

Absolute flood protection is not possible so the basin needs to plan for future events. Taking a broader view of flood risk reduction would provide benefits in both years with large upper basin runoff like was experienced in 2011, but it also helps reduce damages from localized flood events like ice jams in the upper basin and heavy rains in the lower basin.

The sheer volume of runoff in 2011 ensured a historic flood event regardless of how the reservoir system operated. If the total runoff for the calendar year, 61 MAF, is spread equally across the 365 days of the year, it would result in flows of 84,500 cfs at Sioux City, Iowa each and every day of the year. Prior to 2011 the previous record release from Gavins Point dam was 70,000 cfs. If a more reasonable flow of 30,000 cfs is assumed for the 3 winter months, the remaining 9 months of the year would have flows in excess of 100,000 cfs at Sioux City. While these flows are significantly lower than the actual 160,000 cfs peak release from Gavins Point dam, the high flows would have extended into December delaying the flood recovery, inspection and repairs, and in many areas, the damages would have been catastrophic under either scenario. The river was out of bank in some areas long before releases reached 100,000 cfs and levees failed in others.

Therefore, a comprehensive evaluation of the entire system, including both the reservoir system and the floodways, is necessary to ensure damages like those which occurred in 2011 never happen again. The Corps's Missouri River Authorized Purposes Study (MRAPS), which was defunded several years ago, could have been an avenue to address a wide range of issues including improved flood risk management. In the absence of a comprehensive study such as MRAPS, changes made to the regulation of the reservoir system or to the floodway, will provide only piecemeal benefits to localized issues rather than a wide-ranging plan to reduce flood risk throughout the basin.

3.2.8 Recommendations and Vulnerabilities

In addition to implementing the recommendations of the independent technical review panel, the following Water Management recommendations should be implemented to ensure continued safe and effective operation of the reservoir system to serve the authorized project purposes through the full range of potential hydrologic conditions including droughts and floods.

1. All project features should be maintained, repaired, and/or upgraded to permit unrestricted use to provide maximum operational flexibility of the reservoir system.

2. Real-time operational decisions should continue to be made based on the best available science and should utilize the flexibility provided in the Master Manual to respond to basin conditions. Deviations from the Master Manual should be considered when needed to respond to changed conditions or unforeseen events. Deviation requests should follow established procedures including a full examination of the impacts.

3. The individual water control manuals for the six mainstem reservoirs should be updated. Five of the six individual manuals are more than 30 years old. Documenting the operational history of the projects is important to ensure lessons learned during the historic 2011 flood event, as well as recent drought periods, are incorporated in the future operation of the reservoir system.

Figure 20. Oahe personnel prepare to enter one of the Oahe Dam stilling basin outlet tunnels August 29, 2011. They drove boats one half mile into the tunnels to visually inspect tunnel walls for cracks, spalls or distress in the concrete.

4. River Corridor and Conveyance

The Missouri River corridor and conveyance system is a complex, multipurpose, multicomponent system which is partly operated and maintained by the Corps and partly operated and maintained by non-federal entities. Key components with regard to flood risk management include streambank protection structures and bank stabilization structures from Fort Peck to the mouth and an extensive system of levees constructed from Omaha, Nebraska to the mouth. Referencing Figure 21 below, the streambank protection structures and the bank stabilization structures work to prevent bank erosion and keep the channel from meandering. The levees confine the flow of the river to the floodway, preventing flooding of the adjoining land and nearby structures, and make the channel more reliable for navigation. As such there is interdependence between components and the overall performance of the infrastructure is critical for river corridor and conveyance reliability. This chapter is broken into the following sections; a description and discussion of the Bank Stabilization and Navigation Projects (section 4.1) and then a follow on discussion and description of the levee system along the river (section 4.2)

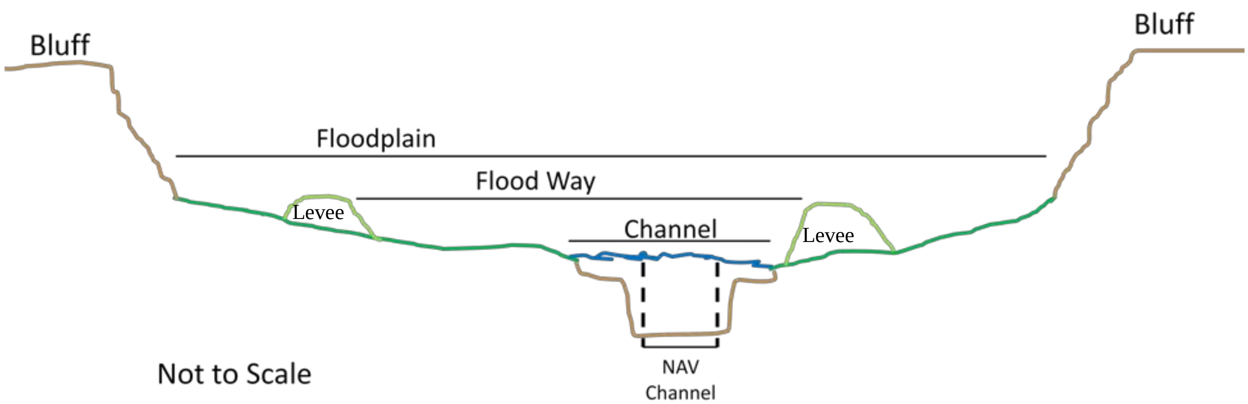

Figure 21. Components of the river corridor

4.1 FLOODWAY AND CHANNEL PERFORMANCE

This section describes how the Corps infrastructure of streambank protection structures, bank stabilization structures and certain aquatic habitat chute control structures in the Missouri River open channel sections from Ft. Peck Dam to the mouth performed during the flood of 2011. Also discussed are the damage assessments conducted and the repair prioritizations and schedules. Included is a discussion of other Channel Performance considerations. Finally, specific recommendations are addressed identifying short and long term Channel Performance vulnerabilities as the river channel projects are being repaired, restored or enhanced. We begin with a description of the reaches.

The Channel Performance river reaches are located between the dams and the headwaters of the reservoirs to Lewis and Clark Lake of Gavins Point Dam, and the channel sections below Gavins Point Dam to the mouth, as shown on Figure 22. The open river reaches from the Ft. Peck Dam to Ponca State Park, Nebraska include several streambank protection authorities. Downstream of Ponca State Park is the

Kensler's Bend Bank Stabilization Project reach and the Missouri River Bank Stabilization and Navigation Project, Sioux City, Iowa to the mouth (BSNP) reach.

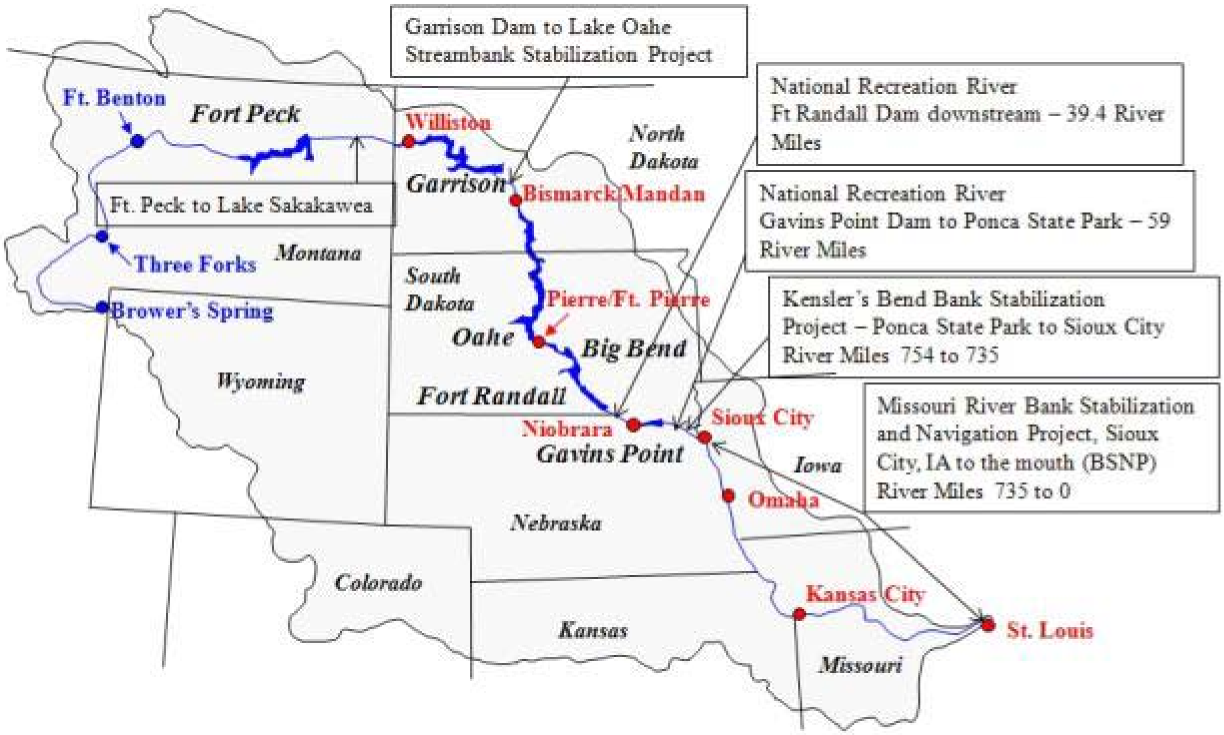

Figure 22. Channel Performance Open River Reach Locations from Ft. Peck to the Mouth

The type of Corps infrastructure, along the open reaches from Ft. Peck Dam to Ponca State Park, are streambank stabilization works constructed of rock and in some cases timber piling. This infrastructure was described earlier in this report. These open reaches are used for recreation, irrigation and water supply.

The next downstream channel open reach below Ponca State Park is the Kensler's Bend Bank Stabilization Project. The Kensler's Bend Project was authorized by the Flood Control Act on August 18, 1941. Project was constructed with timber pilings and rock dikes and revetments. This project is actually a 19 river mile transition project that leads downstream to the BSNP. Its bank stabilization design followed the BSNP design criteria but without the structural encroachment to provide a navigation channel. Designers at the time were preparing for the possibility of a congressionally authorized navigation project all the way to Gavins Point Dam. There is some irrigation in the reach, but the channel is mostly used for recreation.

The BSNP extends from just above the Big Sioux River confluence at Sioux City, Iowa for 735 miles to the mouth with its confluence entering at the Mississippi River just upstream of St. Louis, Missouri and Lock and Dam 27. The project had several River and Harbors Act authorizations beginning with the first authorization of 1912. The River and Harbors Act of 1945 authorized the 9' x minimum of 300' wide navigation channel. The project was constructed with timber piling and rock for its dike and revetment structures. The project was declared completed in 1980. The basin grew up along the BSNP channel taking advantage of its bank stabilization protection. Coal and nuclear powered thermal power plants use cooling water from 21 intake structures for 8 power companies. There are 19 water supply intakes that draw water from the river for public water. There are multiple bridges, overhead and underground pipelines that cross the river. Prior to the flood there were 7 active Marinas supporting 1450 boat slips. Most recreation is along the channel downstream to Plattsmouth, Nebraska (RM 591), but some recreation occurs along its lower reach. The Corps also constructed an extensive levee system from Omaha to the mouth in the vicinity of the channel. There is substantial public and private infrastructure that takes advantage and relies on the BSNP channel remaining along its designed course.

The Fish and Wildlife Service developed a Biological Opinion that calls for specific biological targets that must be met to protect the endangered Pallid Sturgeon, the endangered Least Tern, and threatened Piping Plover. To accomplish that the Corps is acquiring and developing aquatic and terrestrial habitat on individual sites along the entire BSNP reach. To help develop aquatic habitat the Corps has constructed several Shallow Water Habitat (SWH) sites which include side channels called chutes connected to the main river channel. These chutes are constructed through the original BSNP dike and revetment structures. Grade control rock structures called sills control how wide and how deep the chutes will become. The flows diverted through these chutes is no more than 10% which still maintains suitable flows in the main channel to provide a reliable navigation channel.

The BSNP is operated and maintained by the Omaha and Kansas City Districts. NWO is responsible for the project from Sioux City, Iowa to Rulo, Nebraska (RM 734.8 to 498.4) and NWK is responsible for the project from Rulo, Nebraska to the mouth (RM 498.4 to 0.00). NWO also operates and maintains all the open river reaches upstream of Sioux City, Iowa.

Table 12 describes the reaches as to type of floodway and the channel streambank or bank stabilization infrastructure. Streambank stabilization is the bankline protection works to prevent bank erosion. Bank stabilization is the bankline protection works to prevent a channel from meandering and often includes a navigation mission.

Table 12. Channel and Floodway Reach Description

Reach	Floodway	Channel
Ft Peck to Garrison Reservoir Headwaters	Floodplain	Streambank Stabilization
Garrison to Oahe Reservoir Headwaters	Floodplain	Streambank Stabilization
Oahe to Big Bend	All Lake	N/A
Big bend to Ft Randall	All Lake	N/A
Ft Randall to Gavin's Point Reservoir Headwaters	Floodplain	Streambank Stabilization
Gavins Point to Ponca State Park	Floodplain	Streambank Stabilization
Ponca State Park to Sioux City	Floodplain	Bank Stabilization
Sioux City to Omaha	Floodplain	Navigation & Bank Stab.
Omaha to Rulo	Levees – Fed & non Fed	Navigation & Bank Stab.
Rulo to Kansas City	Levees – Fed & non Fed	Navigation & Bank Stab.
Kansas City to St Louis	Levees – Fed & non Fed	Navigation & Bank Stab.

Figure 21 is a map that provides more detail of the Missouri River Basin showing location of the mainstem dams and other tributary dams.

Figure 23 is a map; its region is [207, 250, 1490, 1185].

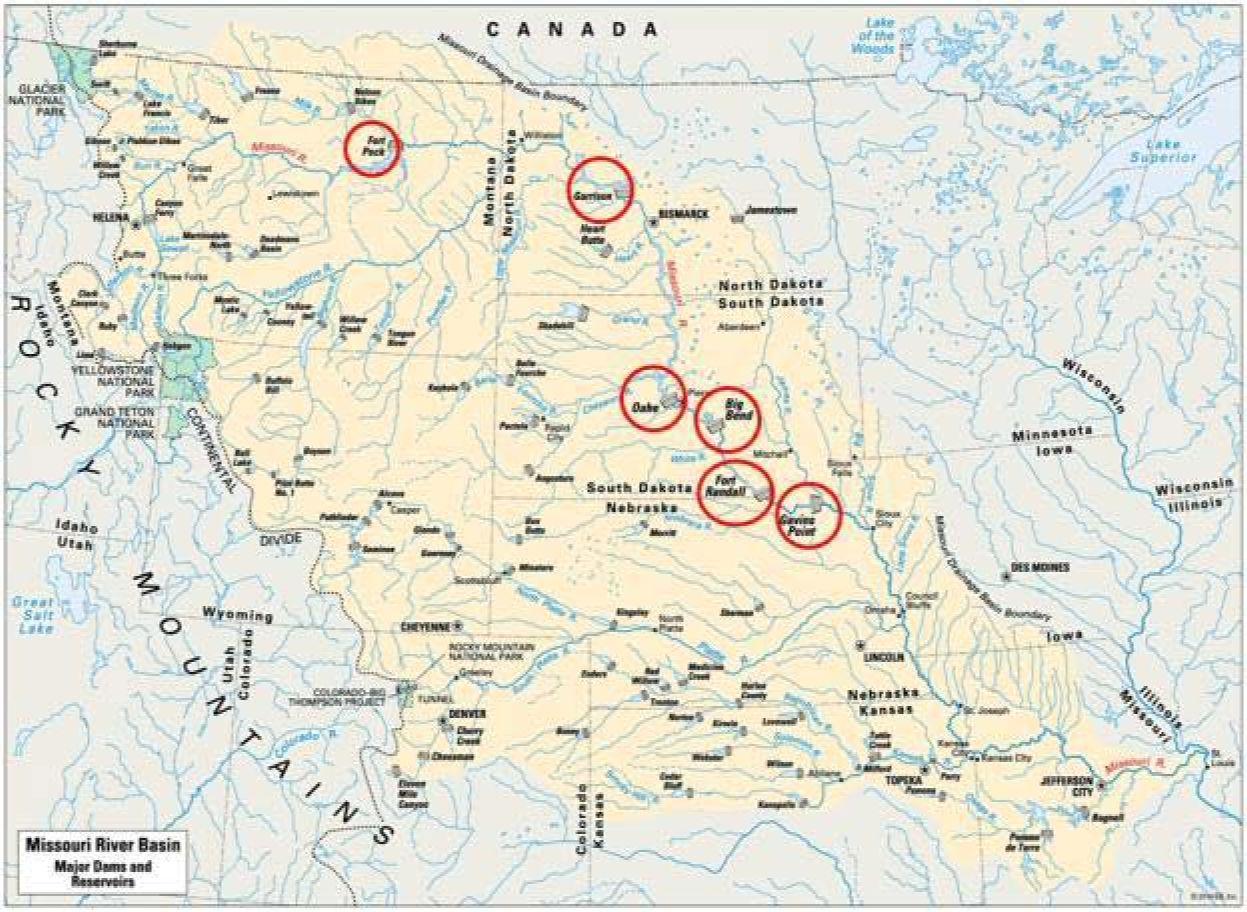

Figure 23. Missouri River Basin Major Dams and Reservoirs

The report as follows is organized by subject with specific discussions by each district. It begins with a discussion of the BSNP infrastructure that is impacted, the damage assessments, and the high priority repairs initiated or planned. The BSNP discussion also includes the channel chute portion of the SWH projects with damage assessments.

Other channel performance considerations are then discussed which include the flood impacts to the Corps BSNP field support offices. BSNP channel bed degradation and aggradation and the interaction of the BSNP with other flood control levee projects are discussed. The federally constructed streambank stabilization projects from Ft. Peck to Ponca State Park are discussed along with headwaters sedimentation and tributary sedimentation. Vulnerabilities after repairs are discussed. Long term vulnerabilities of BSNP budget process and adequate future civil works engineering staffing are identified. Finally recommendations are provided.

4.1.1 BSNP Infrastructure Impacted

The duration and magnitude of the 2011 Missouri River flood event exceeds all other events in the recorded history of the river. The excess energy acting on the river floodplain and Corps projects within this environment was unprecedented. Within the floodplain corridor, the extreme high flood flows tended to travel across bends in the most energy efficient manner. Constructed projects and floodplains in the path of this extreme flow zone were severely impacted. Floodplain material dynamics occurred from the extreme flows traveling linearly down the valley floodplain over the top of the meandering river. Excess flood flow across the bends degraded dikes and revetments at most entry and exit points. Sediment traveled with the flood flows with extreme deposition depths observed throughout the floodplain. Floodplain features and river dynamics that concentrated flows caused excessive scour at many locations. Depending upon location and river dynamics, constructed chutes and backwaters in the floodplain experienced both scour and deposition.

Benefits of the bank stabilization aspect of the BSNP on river stability were significant. With the unprecedented flood volume, prior floods would have indicated that multiple major channel changes and cutoffs would have occurred if not for the BSNP. The BSNP was effective in keeping the main channel within the current alignment and preventing destruction of adjacent infrastructure including roads, railroads, power plants, water intakes, levee and etc. Figure 22 shows a photo of the BSNP prior to the 2011 flood to show its relationship to the floodplain along a private levee system on the right bank. The BSNP channel is designed to be overtopped by flood events, but not allow the main channel to meander. With this design infrastructure such as bridges, intakes and levees along the river have assurances that river main channel meandering will not abandon or cause damage to their location. Of course overtopping flows and flood flows can cause damages, but after these events are over the channel remains consistent. Figure 23 shows a sketch of the relationship of the BSNP within the Missouri River valley.

Figure 24. BSNP Channel with Private Levee System along Right Bank near Indian Cave State Park, Nebraska River Mile 517 Prior to 2011 flood.

4.1.2 Status of BSNP channel assessments

Sustained extreme flows on the Missouri River in 2011 are known to have severely impacted the Missouri River BSNP channel and structures and the MRRP chute control structures. The excess energy acting on the river floodplain and projects within this flow environment were unprecedented.

4.1.2.1 NWO Channel Assessments - BSNP

4.1.2.1.1 Fall 2011 Inspections - BSNP

A series of inspections were conducted starting in fall 2011 to assess river condition as flows decreased. During the period from September to December, six channel inspections were conducted from Sioux City, Iowa, to Rulo, Nebraska over a length of 237 river miles by Omaha District staff. Each inspection required two days with about half the distance traveled in each day.

The primary purpose of the fall 2011 inspections was to evaluate changing channel conditions, identify major damage areas, determine navigation channel condition, and respond to issues and concerns at specific sites.

Field reconnaissance and assessment efforts will continue to evaluate impacts. It is likely that additional impediments to navigation will develop as the channel continues to evolve in the post flood period. Furthermore, it is unlikely that all of the BSNP structure damage attributable to the 2011 flood has been fully indentified.

Information collected from these inspections was used to work with the Coast Guard and the navigation industry to assess risk and accommodate the initial barge trip to Blair, Nebraska in October 2011. The top priority damage areas identified in the inspections were the revetments at Upper Kansas and Upper Hamburg Bends.

4.1.2.1.2 Fall 2011 Repair Actions - BSNP

Preliminary inspection and assessment results have identified 50 to 100 critical priority repair structures and high priority repairs at an additional 300 to 500 structures for Omaha District. Plans and specifications were prepared to start the repairs in the spring of 2012.

The top two priority areas (Kansas Bend – RM 546; Upper Hamburg Bend – RM 556) were the primary repair action areas with rock placed in late fall 2011 by both the Omaha District's Missouri River Project Office (MRPO) and by a contractor. Repairs were initiated in October 2011 when river access allowed construction to start. Repairs were complicated in the fall due to limited access and the damage of rock load out facilities at the quarry. Repair actions were stopped when river levels declined in December 2011.

4.1.2.1.3 Current Assessment - BSNP

The current assessment of the BSNP is being performed with a contractor with heavy involvement by Omaha District Staff. A low water inspection was conducted during the week of January 30, 2012. Inspection was conducted by Omaha District and contractor personnel. The low water inspection relies on using the minimal river levels to allow above water structure inspection and infer structure elevation from the water level. Spot surveys were conducted in March 2012. The draft assessment report was completed in April 2012. BSNP repair priorities were developed using guidelines and engineering judgment to determine critical areas of damage and identify required repairs.

4.1.2.1.4 Future Assessments - BSNP

The post flood assessment activities are still on-going with data collection, field assessments, and repair activities. The extent of BSNP structure damage will not be known for several months. Contracted post flood surveys will not be provided until fall 2012 or later.

Damages in many areas are likely to continue to develop as river structures and the channel continue to respond to the changing river. Bank failures and additional structure failures are likely due to accumulated stress. Channel and bank response will have a recovery period that is unknown during more normal flow regimes.

4.1.2.1.5 NWO Structure Estimated Damage and Repairs

The number of damaged structures and rock repair quantities needed were determined using the best available data. This information is summarized in Figure 25 and Table 13.

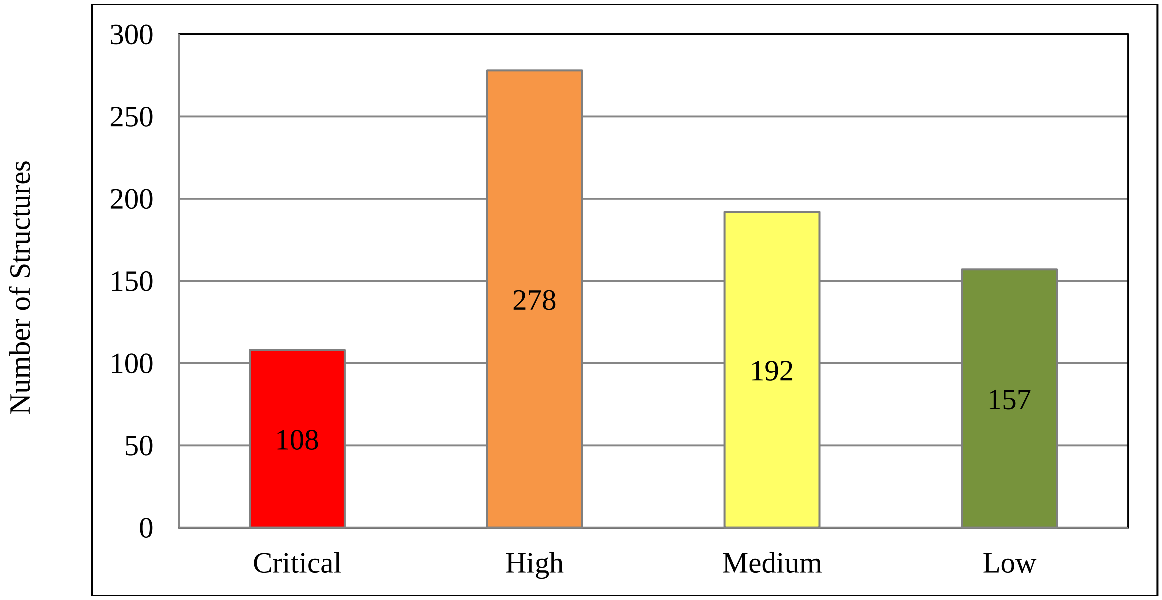

Figure 25. Number of Structures by Priority Level

Table 13. Preliminary Repair Quantities Needed (tons) by Structure Type and Priority Level

Critical	High	Medium	Low	TOTAL
260,000	194,000	32,000	23,000	509,000

4.1.2.2 NWK Channel Assessments - BSNP

Inspections to date have included aerial reconnaissance during the flood event, review of aerial photography, periodic hydrographic surveys of some areas, and preliminary low water inspections during January-February of 2012. While this information is useful to respond to issues and concerns at specific sites and to assess the amount of maintenance needed, prioritized maintenance schedules will not be completed until April 2012. With the extended winter releases from Gavins Point Dam, the river stage remained elevated; and with water surfaces near the Construction Reference Plane (CRP) during preliminary inspections, many structures were not able to be fully assessed during the visual inspection.

4.1.3 Shallow Water Habitat Assessments

NWO and NWK have constructed a number of SWH projects under the MRRP authority. Each district performed early reconnaissance efforts to quickly provide an overview of current conditions. On-going and future study efforts will be used to provide additional information and recommendations. The following figures show some of the typical SWH chute control structure damage. Figure 25 shows a 2005 pre-flood image of Upper Kansas Bend SWH chute inlet and Figure 26 shows the chute inlet with flood damage. SWH assessments discussions that follow will be by district.

Figure 26. Upper Kansas Bend SWH Chute Inlet at River Miler 546 - Pre Flood 2005. Downstream Flow to Left

Figure 27. Upper Kansas Bend SWH Chute Inlet at River Mile 546 (facing downstream) - 2011 Post Flood. Flood Erosion Flanked the Stone Protection at the "V" Structure Along the Downstream Bankline

4.1.3.1 NWO Shallow Water Habitat Assessments

A total of 33 off-channel chute and backwater projects have been constructed in Omaha District between Ponca, Nebraska (RM 754) and Rulo, Nebraska (RM 498). Other constructed sites, including the mitigation projects and in-channel construction projects, are not addressed by this reconnaissance. All Omaha District chute and backwater sites are listed in Table 14.

Table 14. Omaha District Shallow Water Habitat Construction Sites

Site No.	Off Channel Projects	RM DS	RM US	Year	Length	State	SWH 2010 Acres[1]
1	Ponca State Park Backwater	753		2004		NE	70
2	Glovers Pt Backwater	711.5		2005		Tribal	28.6
3	Glovers Point Chute	711.2	713.4	2005	11,100	Tribal	15
4	Hole In the Rock Backwater	706		2006		Tribal	5
5	Blackbird-Tieville-Decatur Flow Thru	688	698	2006		IA	7
6	Middle Decatur Chute	687.4	688.2	2009	4,640	NE	20
7	Lower Decatur Revet. Lower	685.7	687.3	2008	8,200	NE	7
8	Lower Decatur Chute	684.9	687.3	2008	2,400	NE	9
9	Louisville Bend Backwater	682	685	1995		IA	60
10	Fawn Island Chute	673.3	674.1	2010	2,979	IA	9
11	Three Rivers Revet. Lowering	669.4	670	2010	2,810	NE	12
12	Bullard Bend Backwater	663		2009		NE	25
13	Soldier Bend Backwater	660.4		2004		IA	26.8
14	Tyson Backwater	653.2		2009		IA	63.9
15	California Bend, IA, Chute	649.5	650.1	1999	4,000	IA	11.6
16	California Bend (IA) Backwater	649.5		2004		IA	16.3
17	California Bend, NE, Chute	648.5	650.1	2003	9,230	NE	36
18	Lower Calhoun Chute	637.1	637.6	2009	2,750	NE	9
19	Boyer Backwater	634.2		2010		NE	43
20	Boyer Chute	633.7	637.8	1994	16,760	IA	56
21	Council Bend Chute	616.8	617.8	2007	5,630	IA	18
22	Plattsmouth Lake Connect. Backwater	592.8	593.8	2005		NE	25
23	Plattsmouth Backwater Phase 2	592.3		2008		NE	25
24	Plattsmouth Chute	592.1	594.5	2005	12,070	NE	90
25	Tobacco Island Chute	586.3	588.4	2002	15,450	NE	23
26	Upper Hamburg Chute	552.2	555.9	1996	15,950	NE	97
27	Lower Hamburg Backwater	552		2005		MO	7
28	Lower Hamburg Chute	550.6	553.4	2005	13,200	MO	34
29	Kansas Bend Chute	544.5	546.4	2005	9,150	NE	23
30	Nishnabotna Chute	542.4	543.3	2005	5,780	NE	19
31	Langdon Bend Backwater	529		2000		NE	10
32	Deroin Bend Chute	516.4	520.5	2002	18,140	MO	85
33	Rush Bottoms Chute	499	502	2008	8,400	MO	12
	[1] - Refers to the shallow water habitat acres as determined in a 2010 evaluation. This is pre-2011 high flow acres.						

Inspection of the SWH chutes and backwaters were conducted in the period from November to December 2011. Due to time and access constraints, it was not possible to visit all sites. Conditions at these sites were assessed with available aerial photos from the post flood period. Different metrics were recorded during the reconnaissance including items such as erosion, deposition, and flow measurements. Data collected during the field reconnaissance will be used to make informed decisions regarding the future sustainability of the projects along with any recommendations for future efforts.

Inspection indicates that SWH has been lost in many constructed projects and gained in others. This also applies to the overall river corridor. However, much of the new habitat in the river corridor does not appear to be sustainable and will likely experience sediment deposition and habitat reductions during normal flow years.

Habitat and channel conditions are known to be dynamic. Further changes are expected in 2012 as the river begins to adjust back to more normal flow rates.

Chute projects at Glovers Point, Middle Decatur, Lower Decatur, California Bend (IA), Lower Calhoun, and Plattsmouth all experienced severe deposition such that sustainability is in question. These chutes will be monitored during the 2012 flow season to determine if deposited materials can be eroded to restore these areas to the pre-flood function.

Chutes at Fawn Island, Council Bend, Upper Hamburg, Lower Hamburg, Kansas Bend, and Deroin Bend all experienced erosion. Chute alignment and the impacts of erosion are concerns at these sites, and data collection, planning, and evaluation to identify any needed repair projects is underway.

Fawn Island chute erosion has severely impacted the bank line with progression toward a private residence. Remedial action to protect the residence is on the critical priority list of repairs, and a long-term solution will be developed.

Chutes at Council Bend and Upper Hamburg Bend have eroded scour holes approaching the levee toe. See Figure 27 for levee toe scour repair activities at Upper Hamburg Bend.

Figure 28. Upper Hamburg Bend Levee Toe Scour Repair Area

Concerns have been raised regarding the impact of constructed chutes on adjacent federal levees. Studies conducted prior to the flood indicated that SWH projects can add conveyance area and reduce flood levels. A case study is proposed at Hamburg Bend to evaluate numerous factors including chute interaction with the Lower Hamburg Bend levee failure, levee toe erosion at Upper Hamburg Bend, chute impacts to seepage, and the role of chutes with respect to flood levels. Study scoping has been initiated to perform case studies at critical locations to evaluate these and other issues. These studies will be conducted jointly with Kansas City District and completed in FY 2013.

Backwater sedimentation was expected during high flows due to floodplain inundation. Although no backwaters were filled, excavation is likely required to optimize habitat function in several areas. Backwaters with varying degrees of deposition (Ponca, Glovers Point, Hole-in-the-Rock, Louisville, Bullard, Soldier, Tyson, California (IA), Boyer, Plattsmouth/Goose Lake, and Langdon Bend) will be monitored to determine any required remedial actions. Most backwaters have a sediment bar at the river connection which has reduced connectivity. Excavation at most backwaters will probably be required to some extent to restore lost habitat acres, optimize function, and restore river connectivity.

None of the mitigation site pump stations upstream of Omaha are functional following the flood. Assessments are being performed by a contractor and results are expected in June 2012. Due to mitigation area floodplain deposition, the mitigation area goals and need for pump replacement will be evaluated.

4.1.3.2 NWK Shallow Water Habitat Assessments

Assessments are under way through similar methods and schedules as was done for the BSNP. However additional multidimensional modeling has been initiated at Wolf Creek: RM 478-482 near levee L-497 to assist with answering questions related to SWH and adjacent levee and channel performance. Nearly all SWH sites were altered during the 2011 flood, and the path forward will depend on the results of the detailed assessments.

Additional information to include hydrographic surveys and LiDAR (Light Detection and Ranging) may be collected to allow for pre- and post-flood comparisons; however, much of the post flood data would not be collected until late 2012 or 2013. Ad hoc surveys will continue through 2012 with in-house crews as time permits and as specific needs arise. These smaller surveys will improve the assessment of the channel performance through 2012 and 2013. However, a more complete assessment with the full hydro survey and LiDAR will likely not be available until 2014.

4.1.3.3 SWH Project Inspection Guidelines / Repair Priority

Project impacts were evaluated to develop a subjective repair priority based on the impacts to other authorized purposes such as flood control and navigation. A secondary evaluation was also conducted to assess impacts to habitat with the primary criteria consisting of long term sustainability followed by meeting shallow water depth and velocity objectives. In addition to these general guidelines, engineering judgment is necessary to determine critical areas of damage and whether repair is required.

The following list was used during the inspection as a general guideline for prioritizing repair of MRRP projects and structures:

- Impacts to flood control, navigation, and adjacent infrastructure / property
- Assessment of current and future risk to project performance

- Type and location of structure
- SWH/Environmental consequences (favorable and adverse)

4.1.4 Summary of Preliminary BSNP Channel Assessment Findings

Overall, the Missouri River floodplain corridor was impacted tremendously. Wide areas of scour and deposition occurred within the floodplain corridor.

4.1.4.1 NWO Preliminary BSNP Channel Assessment Findings

4.1.4.1.1 General BSNP Assessment Findings

The duration and magnitude of the 2011 Missouri River flood event exceeds all other events in the recorded gage history of the river. The excess energy acting on the river floodplain and projects within this environment were unprecedented. Within the floodplain corridor, the extreme high flood flows tended to travel across bends in the most energy efficient manner. Constructed projects and floodplains in the path of this extreme flow zone were severely impacted:

- Floodplain material dynamics occurred from the rivers extreme flows traveling linearly down the valley floodplain over the top of the meandering river
- Excess flood flow across the bends degraded dikes and revetments at most entry and exit points
- Sediment traveled with the flood flows, with extreme deposition depths observed throughout the floodplain
- Floodplain features and river dynamics that concentrated flows caused excessive scour at many locations
- Depending upon location and river dynamics, constructed chutes and backwaters in the floodplain experienced both scour and deposition

Ongoing and future study efforts will be used to provide additional information and further evaluate repair actions and recommendations.

4.1.4.1.2 BSNP Structure Damage

Significant observations from the inspection are as follows:

- Most channel areas appeared to adjust as the flows were reduced; the required 9-foot navigation depth was available through December downstream of Blair, Nebraska (RM 648) to Rulo, Nebraska (RM 498). However, Gavins Point Dam flow releases were above normal.

- Lower Decatur Bend (RM 687) shows serious problems with a widened channel area, as flow has flanked the revetment and sediment has deposited within the navigation channel. October inspections showed 8-foot depths in the proper channel. The Coast Guard reported even less depth in November. Aerial photos in January illustrate the sandbar in the navigation channel. Presently, there are no known barge trips scheduled that far upstream. Structure repair is required prior to providing navigation channel depth and width.

- Shallow spots in the Boyer (RM 637) and Upper Hamburg (RM 556) areas remained above 8-9 feet throughout the fall 2011 reconnaissance period. The Hamburg Bend crossing appears to have lost a few feet of depth since August, but still was at least 9-feet in late October. Upper Kansas Bend was steady around 11-feet through mid-September, but may have lost two- or three-feet of depth later in the fall. The field reconnaissance on October 4, 2011 showed at least one high spot with water depth less than 8-feet.

- The fall 2011 field inspections resulted in the identification of numerous damage areas. Repair activities were conducted on the most critical of these in fall 2011; stone was placed at Upper Hamburg and Kansas Bend to facilitate barge traffic to Blair, Nebraska (RM 648) in the fall of 2011.

- January 2012 low water inspections occurred and subsequent surveys were identified.

Table 15 provides a summary of the BSNP structure repairs with a comparison to recent history.

Table 15. BSNP Structure Repair Summary

Reach	Length (miles)	Year	Number Structures	Total Structure Length (ft)	Rock Total (tons)
Ponca to Rulo, NE	252	2012	735	TBD	509,000
		3 Year Avg.	70	19,000	51,000
Note: 2012 values include all priority level damages based on current information. 3 Year historic average is from scheduled maintenance 2008 – 2010 provided for comparison purposes.					

Examples of the typical damage that occurred at BSNP structures within NWO are shown in Figures 28 through 30.

RM 693.58 to 693.48

Revetment (Right Bank)

Damage: Bank failure.

Repair Dimensions: Approximately 410 ft long and 6 ft high.

Figure 29. Revetment Near River Mile 693.5

Figure 30. Revetment Near River Mile 679.8

RM 679.81 to 679.79

Revetment (Left Bank)

Damage: Revetment rock degraded.

Repair Dimensions: Approximately 100 ft long and 7 ft high.

Figure 31. Dike Near River Mile 640.2

RM 640.19

Dike (Left Bank)

Damage: Dike degraded.

Repair Dimensions: Approximately 200 ft long and 4 ft high.

4.1.4.1.3 BNP Shoaling Issues

Table 16 identifies locations of shoaling, a brief assessment of the problem, and the current status.

Table 16. NWO Shoaling Issues

River Mile	Description	Impacts
687	Lower Decatur Bend structure degradation and over widened channel. A repair project is under design and will be a top construction priority.	Navigation channel depth and width not met
637	Boyer Bend transient shoaling problem. This area has been a chronic issue over the past several years and was exacerbated by the 2011 flood. This area will be monitored in spring 2012.	Possible navigation channel concern, not an issue in April 2012
550-556	Upper and Lower Hamburg Bend chutes both experienced extreme erosion with significant channel deepening. Consequently, the diversion of water from the main channel has resulted in main channel shoaling. Repair projects for each chute are currently in the design process and will be a top construction priority.	Possible navigation channel concern, not an issue in April 2012
546	Kansas Bend revetment degradation downstream of the chute entrance led to massive land erosion, cutting a new flow path to the chute, and is now bypassing the structure.	Possible navigation channel concern, not an issue in April 2012

4.1.4.1.4 Shallow Water Habitat

Inspection indicates that SWH habitat has been lost in many constructed projects and gained in others. This also applies to the overall river corridor. However, much of the new habitat does not appear to be sustainable and will likely experience deposition during normal flow years. Most projects have altered habitat compared to pre-flood conditions. Monitoring is recommended in 2012 to assess long term habitat impacts. Corrective repair actions to restore connectivity and critical areas to maintain optimum habitat function are likely needed. Habitat and channel conditions are known to be dynamic. Further changes are expected in 2012 as the river begins to adjust back to more normal flow rates.

4.1.4.1.5 Shallow Water Habitat Chutes

Chute projects at Glovers Point, Middle Decatur, Lower Decatur, California Bend (IA), Lower Calhoun, and Plattsmouth all experienced deposition such that long-term sustainability is in question. These chutes will be monitored during the 2012 flow season to determine if natural channel flows erodes deposited materials to restore the pre-flood chute condition. Chute dynamic action with erosion and deposition of materials has occurred during previous flood events.

Chutes at Fawn Island, Council Bend, Upper Hamburg, Lower Hamburg, Kansas Bend, and Deroin Bend all experienced erosion. Chute alignment and the impacts of erosion are concerns at these sites, and data collection, planning, and evaluation of the need for repair projects is underway.

Chute erosion damage usually consisted of degradation of the entrance control structure, flanking of internal control structures, and both chute widening and deepening.

Measured chute/river flow ratios are useful to assess chute geometry changes as a result of the event. Results indicate that Upper Hamburg, Lower Hamburg, and Deroin Bend all increased in flow considerably. These projects also have noted BSNP structure concerns with planned construction repair projects.

Fawn Island chute erosion has severely impacted a private residence, with near failure of the home. Chutes at Council Bend and Upper Hamburg have eroded scour holes approaching the levee toe. These projects have planned repair projects to repair scour and reduce flood risk.

4.1.4.1.6 Shallow Water Habitat Backwaters

Backwater sedimentation was expected during high flows due to floodplain inundation. Although no backwaters were filled, excavation is likely required to optimize habitat function in several areas. Backwaters with varying degrees of deposition (Ponca, Glovers Point, Hole-in-the-Rock, Louisville, Bullard, Soldier, Tyson, California (IA), Boyer, Plattsmouth/Goose Lake, and Langdon Bend) will be monitored to determine any required remedial actions. Most backwaters have a sediment bar at the river connection which has reduced connectivity. Excavation at most backwaters will probably be required to some extent to restore lost habitat acres, optimize function, and restore river connectivity.

4.1.4.2 NWK Preliminary BSNP Channel Assessment Findings

4.1.4.2.1 BSNP Structure Damage

Although structure damage during 2011 was extensive, the project performed quite well in preventing meander migrations and channel avulsions, meaning that the river returned to the project alignment (1960 river mileage) when flood waters receded. Prior to the BSNP, the Missouri River eroded an estimated average of 9,100 acres per year in the meander belt (USACE, 1981). Preliminary assessments of BSNP structures indicate the 2011 damage to be two to four times the average annual damage. From Rulo to the mouth the damages assessed to date do not materially threaten the function of the navigation project for the coming navigation season. However, the damage to the project, degraded dikes and revetments that are both too low and in some cases shortened, is extensive and the present risk of further damage from "normal" runoff is high, which could lead to navigation problem areas. This risk will remain high until the control structures can be fully repaired. Table 17 presents rough estimates of stone quantity by 100 mile reaches required to repair structures to acceptable levels. Table 18 contains a subset of quantities associated with high priority repairs required by reach. High priority repairs are those that, left unrepaired, have the greatest likelihood of jeopardizing the integrity of the BSNP – threatening both the sustainability of the navigation channel through shoaling, standouts, reduced depth, and wandering thalweg – as well as reduced bank stability which could impact adjacent land and infrastructure.

Table 17. Structure Damage Repair Quantity Estimates in Kansas City District

River Reach	Estimated Number of Structures	Estimated Stone Quantity
RM 0 – 100	75	140,000 Tons
RM 100 – 200	75	120,000 Tons
RM 200 – 300	100	175,000 Tons
RM 300 – 400	50	80,000 Tons
RM 400 – 498	100	165,000 Tons
Total	400	680,000 Tons

Table 18. High Priority Structure Damage Repair Quantity Estimates in Kansas City District (Subset of total)

River Reach	Estimated Number of Structures	Estimated Stone Quantity
RM 0 – 100	10	35,000 Tons
RM 100 – 200	10	23,000 Tons
RM 200 – 300	40	75,000 Tons
RM 300 – 400	20	39,000 Tons
RM 400 – 498	20	28,000 Tons
Total	100	200,000 Tons

4.1.4.2.2 Shoaling Issues

Shoaling issues existed in isolated locations before the 2011 flood. Flood damage also created additional shoaling areas. These have the potential to impact navigation early in the navigation season. It is anticipated, however, that most shoaling issues will be rectified by functioning BSNP structures with time. Given the stresses placed on the system by the extended high flows during the 2011 flood, some structure modifications or additions may be needed. These actions, if needed, will be executed as a high priority to facilitate full navigation capacity of the river. Table 17 identifies locations of shoaling, a brief assessment of the problem and the current status. In these areas, efforts are already underway to construct or modify BSNP structures to mitigate the shoaling problems.

Table 19. Kansas City District Shoaling Issues

River Mile	Description	Impacts and Actions
133	Shoaling in the cross over.	Navigation impeded following flood. Modifications completed to resolve concern. A channel inspection in March 2012 showed no impact to navigation.
212-214	Shoaling in bend.	Navigation impeded. Control structure is currently under construction and further river structure modifications are scheduled.
180	Shoaling in bend.	Navigation not impacted but could be a concern at lower stages. New control structure will be designed and built in adjacent chute, and increased monitoring will determine if more immediate action is needed.

4.1.4.2.3 Shallow Water Habitat

In general, preliminary assessments indicate that SWH was both created and destroyed during the flood depending on localized channel dynamics. Nearly all SWH sites were altered during the flood and the path forward will depend on the results of the detailed assessments. Where the flood created SWH, maintenance activities will be conducted in an adaptive management mode to ensure the continued availability of the SWH. In areas where SWH was destroyed, rehabilitation activities will be completed in a way that minimizes future maintenance needs. In any case, several of the SWH features and control structures were severely damaged during the 2011 flood and will require significant repairs in order to remain functional.

4.1.4.2.4 Shallow Water Habitat Chutes

Table 20 contains a listing of SWH chutes that experienced damage during the 2011 flood and the nature of the damage experienced.

Table 20. Shallow Water Habitat Chutes Damaged by 2011 Flood

Chute Name	River Mile		Post 2011 Flood Status	Estimate Stone Quantity
	DS	US		
Wolf Creek	477	481	Erosion of approx. 250 ft observed on the landward bank of the revetment chute and two bank notches just downstream of the revetment chute (RM 480.3 to 481). Dike and revetment maintenance is needed in this area. Downstream bank notches did not appear to experience significant erosion or deposition.	20,000 Tons
Worthwine Island	456	460	Possible erosion issue behind revetment chute near RM 459. May need bank stabilization on left bank of revetment chute/chute complex. Control structures in chute appear to have performed well and are still functioning as designed.	20,000 Tons
Benedictine Bottoms	424	428.3	May need some repairs to revetment at revetment chute.	10,000 Tons
Jameson Island	213	-	Navigation problem reported downstream of chute entrance ~ Oct 2011. The flood accelerated chute development, providing naturally varying/high quality habitat prior to completion of the flow control structure. This structure was constructed fall 2011 to limit flow in chute. Last recon (March 2012) indicated the channel dimensions were present; however additional recon and structure maintenance is planned.	30,000 Tons (MRRP FY11 funded contract for chute control structure, was planned pre-flood)
Diana Bend Revetment Chutes	185.4	187.3	Possible erosion issue behind revetment chute.	10,000 Tons
Tadpole Island Chute (Overton Bottoms South)	178.1	180.5	Chute flow control structure flanked and degraded. Constricted navigation channel reported downstream of chute entrance. Repair of control structure scheduled for summer 2012 or sooner if monitoring indicates. Chute has deepened, scoured, and widened, associated with high water.	40,000 Tons
Smokey Waters	131	133.3	Revetment at chute entrance near RM 133.3 was degraded and allowing too much water into chute. Chute closed off to +5 CRP fall 2011. Bank notches downstream of chute did not experience significant erosion or deposition.	20,000 Tons

Examples of typical damage that occurred at BSNP structures within NWK are shown in Figures 31-33.

RM 478.0

Revetment (Right Bank)

Damage: Chute Erosion

Figure 32. Wolf Creek Bend Revetment Chute Erosion

RM 322.4

Revetment (Right Bank)

Damage: Flanked Dike

Figure 33. Flanked Dike at River Mile 322.4 on Right Bank.

RM 250.5

Dike & Revetment (Right Bank)

Damage: Dike and Revetment

Figure 34. Dike and Revetment Damage at River Mile 250.5

4.1.5 High Priority BSNP Repairs

4.1.5.1 NWO High Priority BSNP Repairs

4.1.5.1.1 Provide Full Service Navigation

Based on reconnaissance to date, repairs are required at Kansas Bend (RM 546), Upper and Lower Hamburg Bend (RM 550 – 556), and Lower Decatur Bend (RM 687) to maintain full service navigation in 2012. Repairs will be performed in priority of navigation channel use and severity of impact. Many other damaged dikes and revetments have been identified. Field reconnaissance and assessment efforts will continue to evaluate impacts. It is likely that additional impediments to navigation will develop as the channel continues to evolve in the post flood period. Preliminary inspection and assessment results have identified 50 to 100 high priority repair structures. Repair actions follow:

- Omaha District used in-house and contractor staff to start repairs at Kansas (RM 546) and Upper Hamburg (RM 556) bends in October 2011.
- Repair actions were complicated by river access and quarry load out facilities after the flood.
- Repairs stopped when river levels dropped in December 2011.
- 2012 repair actions will start as soon as it is feasible with rising river levels to allow floating plant construction access.
- Repairs will be conducted according to priority. Impacts to flood control, the navigation channel, and adjacent infrastructure are top priority.
- Repair contracts have been awarded at Council Bend (RM 617) and Upper Hamburg Bend (RM 556) to address chute erosion near the levee toe.

4.1.5.1.2 Decrease Risk of Additional Damages

Numerous additional priority structures have been identified through the ongoing assessment as needing repairs. Preliminary results indicate that there are between 300 and 500 of these structures. Table 21 contains a preliminary estimate of the cost of those repairs and the length of construction activities to complete repairs.

Table 21. Navigation Structures Repair Estimates

Structure Reach	Cost	Duration of Construction
Sioux City to Rulo (RM 750 to 498)	$20 to $30 M	2 to 4 Years

4.1.5.1.3 SWH Repairs

Repair priorities for MRRP projects will first focus on impacts to other purposes like flood control, navigation, and adjacent properties and infrastructure.

Habitat impacts will continue to be evaluated and a priority list developed to address critical areas. The function for some areas is likely altered to the point that significant project redesign is needed.

4.1.5.1.4 NWO Schedule for Repairs

In-House

The production of a schedule for repairs and the nature of the resources required are pending the completion of reconnaissance efforts. The MRPO will be utilized to the greatest extent possible. Based on staffing and equipment levels, a reasonable maximum rock quantity that can be placed by the project office is in the range of 40,000 to 60,000 tons. Placement rate varies considerably depending on river levels and barge distance from the river load out rock quarry.

Contract

The production of a schedule for repairs and the nature of the resources required are pending the completion of reconnaissance efforts. Contract capability will be used to meet repair priorities. At this time, multiple contracts for repairs are anticipated with an initial contract award date of June 2012 targeted.

Future Repairs

On-going and future study efforts will be used to provide additional information and further evaluate repair actions and recommendations.

4.1.5.2 NWK High Priority BSNP Repairs

4.1.5.2.1 Provide Full Service Navigation

Based on reconnaissance to date, no immediate repairs are required to maintain full service navigation from the mouth to Rulo, Nebraska in 2012. However, at areas that have historically had recurring issues, such as river reach from RM 212-218, Cote Sans Dessein Bend at RM 133, Berger Bend at RM 90, Augusta Bend at RM 56, Cul De Sac Bend at RM 25 and Brickhouse Bend at RM 10, increased monitoring will be conducted, and any needed repairs will be given high priority in order to assure navigation access to the upstream reaches of the river.

4.1.5.2.2 Decrease Risk of Additional Damages

Damaged structures that are left unrepaired tend to deteriorate at an accelerated rate, leading to greater impacts to navigation and significantly higher repair costs. The greatest risk of additional damages is associated with river control structures that have experienced excessive erosion. Preliminary assessments to date indicate that approximately 100 of the estimated 400 total structures needing repair fall in this category from Rulo to the mouth. Adaptive modifications are needed to mitigate excessive risks at these sites.

However, often more critical than individual severely damaged structures, are reaches with successive structures that are all moderately damaged. Because this can lead to more extensive navigation problems if not addressed early, repair work will be scheduled on a reach basis rather than on an individual structure basis. Additionally, chutes that have eroded excessively due to prolonged high flows or due to compromised grade control structures are at risk of diverting too much water from the navigation channel and will need to be adaptively modified as well.

4.1.5.2.3 Bring Project Back to Pre-flood Performance Level

The actions required to return the BSNP back to pre-flood performance are approximately two to four times greater than in a typical year and the maintenance required to prevent further near term BSNP degradation is currently being assessed. In most cases SWH habit features are functioning to effectively support SWH creation. In some cases this development has progressed more rapidly than anticipated or beyond the limit originally envisioned, so many structures within SWH projects are in need of maintenance to limit flows diverted from the navigation channel. The adaptive actions required at each SWH site is are under assessment. If funded at or near capability in FY 2013 and beyond, total repair could take between 3 and 6 years, depending on availability of rock and contractors capable of performing the work, as well as the rate at which future damages due to normal wear and tear on the structures occur.

4.1.5.2.4 Schedule for Repairs

In-House

The production of a schedule for repairs and the nature of the resources required are pending the completion of reconnaissance efforts. Current plans are to engage in-house labor crews to supplement contract efforts to expedite high priority actions. Depending on channel conditions and haul distances, the Kansas City hired labor crews are planning on placing up to 50,000 to 100,000 tons of riprap within Kansas City reach of the Missouri River.

Contract

The production of a schedule for repairs and the nature of the resources required are pending the completion of reconnaissance efforts. Current contracts will be employed to meet 2012 needs. Additional contracting actions are being initiated to create capacity to meet anticipated needs. Maintenance contract awards are anticipated in the fourth quarter of FY 2012 and will likely extend for several years to accommodate the timeframe for post-flood repairs.

4.1.5.3 NWO & NWK Waterway Materials Historic Comparison

As stated in the District Assessment Findings, the estimated stone tonnage of waterway materials for structure damage repairs for NWO is 509,000 tons and NWK is 680,000 tons. The total is 1,189,000 tons. Figure 34 shows this tonnage transported on the river and placed equally over the years 2012-2014 in comparison to the historic waterway materials tonnage transported on the Missouri River since 1935. The comparison helps to understand the damage repair stone placement effort to the historic work during BSNP construction and O&M prior to 1980 and project O&M after the BSNP was completed in 1980.

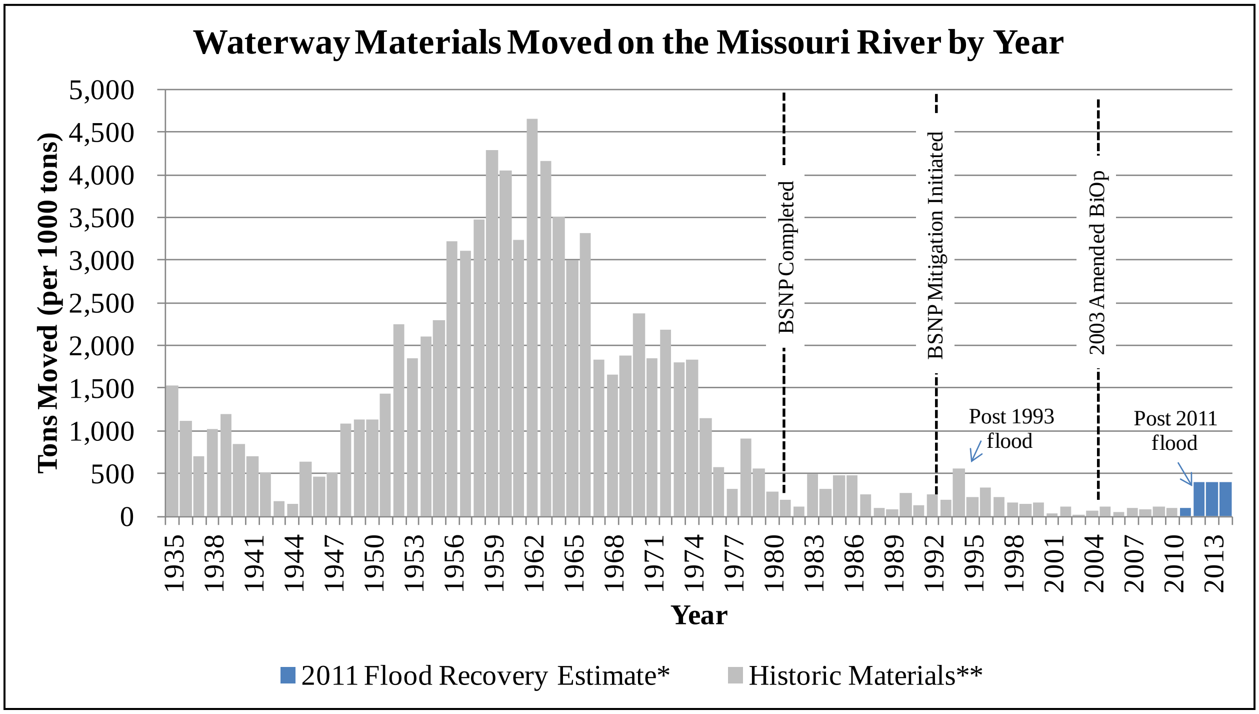

Figure 35. Waterway Materials Moved on the Missouri River by Year

4.1.6 Other Channel Performance Considerations

4.1.6.1 BSNP Support Facilities Impacted by Flooding

4.1.6.1.1 NWO Missouri River Project Office

Since 1939, NWO has had a river mooring facility with off channel harbor and support buildings located in north Omaha along the Missouri River at RM 627. As a support and repair facility for the BSNP and the mainstem dams, it provided machine shop services, welding, fabrication and the floating plant services. In 1988 the facility was reorganized into a field office responsible for the O&M of the BSNP, four dams in Omaha, Nebraska, 10 dams in Lincoln, Nebraska and staff support of the District inspection of completed works program. The project was purposely located along the river to provide effective fleet and support access for maintaining the BSNP. There are several buildings and the Omaha District shares the site with the U.S. Coast Guard that has an office building and mooring for the buoy tender *Gasconade*. The MRPO facilities and grounds were flooded in 1943, 1952 and 2011.

There was sufficient notification to remove everything from the grounds, shop buildings and the office. The office was protected with a porta dam surrounding the building. The other buildings were not protected as is the norm. In the office a dehumidifier was placed that was powered by a portable gas generator. The Coast Guard remained in the flooded area on its cutter *Gasconade* and monitored and filled the gas to the portable generator for the dehumidifier. The Corps' floating plant remained moored and lashed in placed in the moorings. The flood brought 3 ½ to 4 feet of water into the buildings but no flood water entered the office. The MRPO staff moved to an off-site location which only temporarily interrupted mission work. This office provides critical flood support operations for NWO.

Presently, the MRPO staff has cleaned out the buildings from the flood sediment and they are now in the process of other post flood repairs to bring the building up to standards, such as electrical wiring replacement. Several small contracts have been allowed to continue with the needed repairs. The staff has returned to the office, and the floating plant staff began working in early April 2012.

The risks associated with the location of the MRPO along the river are well understood. The location is ideal for servicing the BSNP and at the same time supporting the local dams and other mission requirements for which the office is responsible.

There are no additional vulnerabilities for the MRPO to support its defined mission.

4.1.6.1.2 NWK Missouri River Area Office

The Missouri River Area Office (MRAO) has its main support office and maintenance buildings along the Missouri River at RM 328.6. The flooding did not damage this location. The MRAO also has a repair station and moorings at Gasconade (RM 104) and office and storage buildings at Glasgow, Missouri (RM 226.3) along the river. Gasconade did not incur any flood damages. Some minor damages were experienced at the support facility at Glasgow due to high water, including paint damage, grass kill, and damage to a retaining wall. These issues have been addressed; no follow-up action is needed, and no additional vulnerabilities have resulted.

4.1.6.2 Channel Bed Degradation and Aggradation

4.1.6.2.1 Missouri River Upstream of Rulo, Nebraska (NWO)

Stage trend evaluation indicated that degradation reaches experienced drops of 3 to 5 feet on average with the worst case at Ponca, Nebraska, (RM 752) of 7 to 8 feet. Past history indicates that the channel will continue to adjust over the next several years and recover some of the decline. The Omaha District has updated the tail water rating curves at Garrison, Oahe, Fort Randall and Gavins Point dams. Northwestern Division-Missouri River Water Management Division (NWD-MRWMD) is updating the Missouri River Stage Trends Study which will be completed in the summer of 2012.

Aggradation reaches also experienced change. Post-flood conditions in these areas are less defined and will take several more years to identify if new areas are affected by aggraded reservoir pool conditions.

In general, impacts in aggradation reaches include increased water surface elevations, increased bank/shoreline erosion rates, higher groundwater levels, lost recreational opportunities, and impacts on water supply intakes.

Sediment deposition in the aggradation reaches will impact future flood elevations. Original real estate take lines were expanded to account for this, but in many areas the original government boundary has proven to be insufficient. The Corps is obligated to remedy the problem in the least costly manner. The remedy that the Corps has employed to date has been to obtain additional real estate in the form of fee title and flowage easements, as this alternative costs less and is more reliable than structural fixes.

4.1.6.2.2 Missouri River Downstream of Rulo, Nebraska (NWK)

Some reaches of the lower Missouri River have been experiencing long-term degradation of the river bed. While not exclusively a flood issue or risk, there is a need to better understand the impacts in a dynamic river system such as the Missouri. Should the bed elevation trend continue downward in the areas impacted, the structures in the vicinity of the degradation will become more susceptible to damage during the temporary bed scouring that occurs during high water. The Kansas City District is currently conducting a feasibility study to look at the cause, effects, and possible solutions to bed degradation on the lower Missouri River (below Rulo) with a focus on the more highly degraded Kansas City reach.

4.1.6.3 Interaction of the BSNP with Flood Control Projects (Levees)

The river control structures that comprise the BSNP are not maintained to their original design elevations. Due to accretion, channel development, and budgetary constraints, the Corps determined that structures did not need to be maintained at the original design elevation in order to maintain the project purposes of bank stabilization and navigation.

Therefore, in 1987 the Corps adopted new maintenance guidelines that lowered the maintenance elevation of nearly all structures, some as much as five feet.

At that time no consideration was given to the impacts on flood control projects (levees). A study is planned to determine if the present maintenance practices can contribute to stress on the adjacent levees. This study is planned for FY 2013 and is subject to availability of funding.

The stabilization of the river has created a very efficient main channel. However, periodic flooding has lead to accretion on the flood plain between the main channel and the levee. A study will be completed to assess the amount of flood plain accretion that resulted from the recent flood events and impacts to water surface levels. This study will cover the river from Sioux City, Iowa to Kansas City, Missouri, and is scheduled for completion in the winter of 2013.

4.1.6.4 Kensler’s Bend Bank Stabilization Project – River Mile 754-735

As stated previously the Kensler’s Bend Bank Stabilization Project is a 19 river mile project upstream of the BSNP to provide a transition channel. There are approximately 150 bank stabilization structures constructed for this project. This project performed extremely well during the 2011 flood. Substantial rock stabilization structures with the aid of river bed degradation allowed this project to handle the flood with little damage. The structure damage assessment conducted by NWO completed in May 2012 identified only 9 damaged structures. There was 1 structure that was considered critically damaged. There were 6 with high damage, 1 with medium damage and 1 with low damage. All the work will be included in the BSNP contract for the upper BSNP/Kensler’s Bend reach scheduled for June 2012. Critical damage will be repaired first. The project with the slight damage is considered not vulnerable and there will be no additional recommendations for consideration.

Figure 36. Kensler's Bend Project at Dakota Dunes along Left Bank River Mile 737

4.1.6.5 Federally Constructed Streambank Stabilization Projects Ft. Peck to Ponca State Park

4.1.6.5.1 Background

Streambank stabilization in the open water reaches below and between the mainstem dams is not part of the Pick-Sloan Plan. The open water reaches are: Fort Peck Dam to Lake Sakakawea (Williston, North Dakota), Garrison Dam to Lake Oahe (Bismarck, North Dakota), Oahe Dam to Lake Sharpe (Pierre, South Dakota), Fort Randall Dam to Lewis and Clark Lake (Niobrara, Nebraska), and Gavins Point Dam to Ponca State Park, Nebraska. Compared to the pre-dam condition, the operation of the mainstem projects has reduced the average annual bank erosion rates in all of the open water reaches below the dams.

However, in the pre-dam river, larger flood events would rebuild flood plains, and over time there would be a no-net-loss of high bank land. The post-dam river does not experience the historic natural flood hydrograph, and the dams trap the necessary sediment to rebuild the flood plain. This results in general channel widening and a net loss of historic high banks.

4.1.6.5.2 History

The Corps has constructed streambank stabilization projects in all of the open water reaches. The following authorities have allowed the Corps to construct streambank stabilization projects:

- Along the Ft. Peck to Lake Sakakawea reach the Corps constructed a streambank stabilization project in 1984 for the Bureau of Indian Affairs (BIA). This was authorized and funded under a special congressional authority to allow federal to federal transfer of funds between the Corps and the BIA. A bank stabilization project was constructed for the Fort Peck Indian Reservation irrigation water intake structure at Frazer/Wolf Point, Montana. After completion the Corps turned project responsibility over to local irrigation district for operations and maintenance. The Corps continues inspections under the inspection of completed projects program.

- Flood Control Acts of 1963 and 1968: Under this authority, more commonly known as the Garrison to Oahe Project, the Corps constructed six streambank stabilization projects in the reach between Garrison Dam and Lake Oahe. This construction took place from 1965 to 1975 and stabilized approximately 28.5 miles of bank line. These projects were turned over to the local sponsor, the North Dakota State Water Commission (SWC), for operations and maintenance. In most cases the SWC signed subsequent agreements with local water boards.

- Water Resources Development Act of 1974: Section 32 of WRDA 1974 authorized a national erosion control demonstration program aimed at promoting lower cost erosion control techniques.

From 1978 through 1982 the Omaha District constructed 29 separate projects on the Missouri River from Garrison Dam to Ponca State Park. The total length of protection is approximately 51.5 miles of bank. The breakdown by state is as follows: North Dakota - 18 projects, 26.2 miles; South Dakota - five projects, 12.8 miles; and Nebraska - 6 projects, 15.5 miles. All of these projects were turned over to the local sponsors (SWC in North Dakota, counties in South Dakota, Natural Resource Districts in Nebraska) for O&M. The Omaha District also constructed two Section 32 projects on the lower Yellowstone River.

- Section 33 of the Water Resources Development Act of 1988: Referred to as the Section 33 Program, this authority applies to the open water reaches of the Missouri River (non-reservoir) from Fort Peck Dam in Montana to Ponca State Park in Nebraska. The Section 33 authority allows the Corps to stabilize eroding Missouri River banks, or purchase a sloughing easement on affected property, whichever is least expensive. Section 33 also provides the authority for the Corps to maintain existing federally constructed streambank stabilization projects within the project reach. The authority is limited to no more than $3 million per fiscal year and is subject to the availability of funds. To date the Corps has constructed three projects under this authority. Two projects were demonstrations of bio-stabilization techniques in McCone County, Montana and the other involved erosion control and river training structures to ensure adequate stabilization and flow depths for the Buford-Trenton Irrigation District intake in McKenzie County, North Dakota. The Omaha District purchased one sloughing easement in Nebraska under this authority and used this authority to complete maintenance activities in the Garrison to Oahe reach in 1994 and 1995 and also in the Fort Randall reach in 1996.

- Wild and Scenic Rivers Act of 1978 (Recreational River): This act authorized the Missouri National Recreational River from Gavins Point Dam to Ponca State Park. This legislation contained authority to construct streambank stabilization and made the Corps and the National Park Service co-managers. Through congressional ads, the Omaha District has on several occasions used funds under this authority to maintain the Section 32 projects in this reach. Two projects have been constructed using this authority. One is a very short revetment to protect an eagle nesting site near St. Helena, Nebraska, and the other is a revetment along the right bank to protect the boat ramp and camping area at Ponca State Park.

- Title VII and Title IX: These authorities allow the Corps to construct projects to alleviate sedimentation related problems along the Missouri River in the states of North Dakota and South Dakota. Relative to streambank stabilization, these authorities are limited to protection of cultural, historic, and environmental resources. To date, no projects have been constructed under either of these authorities.

- Work for Others: Working for the Bureau of Indian Affairs (BIA), in 1984 the Omaha District constructed a streambank stabilization project at the Frazer-Wolf Point irrigation intake in the Fort Peck reach. This project was to ensure that the thalweg of the river remained in front of the intake. This project was turned over to the local irrigation district for O&M.

4.1.6.5.3 Issues

The issues relative to streambank erosion/stabilization are discussed below.

The Omaha District has received $3 million in funds under the Section 33 authority in FY 2012 for structure repairs within the open water reaches above Ponca, Nebraska. An inspection was done at Hogue Island near Bismarck, North Dakota in February 2012 and the Gavins Point structures were inspected in March 2012. Additional inspections were completed and are detailed below. Inspections for the remainder of structure reaches will occur over the next several months. Repair plans are under way for Hogue Island at an estimated cost of $1 – 1.5 million. Damage priorities will be determined on the basis of the inspection and coordination efforts. Damage repairs at selected projects will use the remainder of the available repair funds.

- Fort Peck Reach. In the reach below Fort Peck there is concern for general farm/ranch land loss, however, the greatest concern is over the loss of irrigation pump/intake sites. Loss of these facilities for a season can be devastating to individual operators and long-term loss can devalue the land by as much as 80 percent. Resource agencies like the U.S. Fish and Wildlife Service and state game and fish agencies are generally opposed to systematic or wide spread bank stabilization due to endangered species concerns. The structures in this reach have not been inspected. However, based on the information received from the landowners and local governments, the most pressing issue is the re-establishment of the irrigation intake sites that were damaged by the 2011 flood. In June 2012 Corps will be conducting a field reconnaissance of the Frazer/Wolf Point bank stabilization project with the BIA to provide any flood related technical assistance.

- Garrison Reach. In this reach, the SWC and the county water boards, as well as the landowners, contend that Section 33 and Title VII provide the Corps with the authority to stabilize eroding banks, and that because the river is regulated by the Corps it is the Corps' responsibility to provide streambank stabilization. These agencies and landowners argue that economic justification should not be required, and that if such justification is required the entire Pick-Sloan benefits should be brought to the table, not just the value of the affected land. They also contend that Section 33 has relieved the local sponsors from their O&M obligations. The Corps, through consultation with counsel, has determined that Section 33 has not relieved the local sponsors of their O&M responsibilities. Resource agencies at all levels strongly oppose stabilization due to: (1) the presence of least terns and piping plovers, (2) the extensive stabilization that already exists, and (3) the fact that stabilization usually is followed by development. The streambank stabilization projects in this reach of the river sustained significant damage during the 2011 flood, but performed very well compared to the design criteria, with only one major structural loss (Hogue Island). The Omaha District is moving forward with a repair contract for Hogue Island ($1-1.5 million). NWO is in the process of assessing two requests for assistance (sloughing easements) in this reach. These requests will also be prioritized along with all other structural damage to determine how the remainder of the FY 2012 Section 33 funds will be spent.

- Oahe Reach. The only erosion issues in this reach are associated with Oahe Dam and are being addressed through the O&M program.

- Fort Randall Reach. There are a number of actively eroding banklines in this reach, and the Omaha District has evaluated a number of sites under the Section 33 Program. To date the Corps has not been able to economically justify streambank stabilization, and there has been no interest in selling sloughing easements. Resource agencies are opposed to any additional streambank stabilization due to the presence of the least tern and piping plover. Part of this reach of the river is also a designated National Recreational River under the Wild and Scenic Rivers Act, and the National Park Service (NPS) is opposed to additional stabilization as the agency feels it is in conflict with the outstanding and remarkable values (ORV) for which the reach was designated. The two federally constructed (Section 32) projects in this reach have been inspected. The inspection was completed in March 2012. This damage will be prioritized with the rest of the Section 33 repair work.

- Gavins Point to Ponca Reach. There are a number of actively eroding banklines in this reach, and the Omaha District has evaluated a number of sites under the Section 33 Program. To date the Corps has not been able to economically justify streambank stabilization. The resource agencies and the NPS all oppose additional bank stabilization. The resource agencies' concerns center around habitats of endangered species (terns, plovers, and pallid sturgeon). The NPS is opposed to additional stabilization as it feels it is in conflict with the ORV for which the reach was designated as a National Recreation River.

The landowners and the Missouri River Bank Stabilization Association feel that the designation itself requires/authorizes bank stabilization. In addition to the nine Section 32 projects, the Corps has constructed a project to protect the Ponca State Park boat ramp and camping area using this authority (2000 and 2007), and the Lewis and Clark Rural Water District (working with the Corps' Engineer Research and Development Center) constructed a bio-stabilization project to protect its well field in 2007. Most of the projects in this reach have been inspected. While the projects performed well during the 2011 flood, there is extensive damage. A number of structures are completely destroyed. All damages will be prioritized with the damages from other reaches. All repairs will have to be coordinated with the NPS.

4.1.6.5.4 Summary

- The 2011 flood severely damaged a number of streambank stabilization projects. The Corps has the authority (Section 33) to repair this damage.

- Section 33 is limited to $3,000,000 per fiscal year. While the total cost to repair damaged projects and process sloughing easement requests is not known at this time, it is safe to assume that the total cost will exceed the existing $3,000,000 funding allotment. At $3,000,000 per year, is it likely to take 3-5 years to complete this work.

- The other existing authorities (Title VII, Title IX and Wild and Scenic River Act) are narrow in scope and will require extensive planning efforts, making them impractical in repairing flood damages.

4.1.6.6 Headwaters Sedimentation – Missouri River Mainstem Reservoirs

4.1.6.6.1 Background

Although only approximately five percent of the total storage capacity in the Missouri River system has been lost to sediment deposition, over 90 percent of the losses are in the multipurpose/carryover and permanent zones. The multipurpose/carryover zone is where the reservoirs are operated nearly all of the time, making problems associated with sedimentation disproportionately larger than the actual loss of gross storage. Sedimentation in the reservoir headwaters on the mainstem of the Missouri River leads to increased bank/shoreline erosion, legal claims concerning boundary lines, increased open water and ice-effected flooding or ground water problems, lost recreational opportunities, and negative impacts on water supply. Sedimentation in the headwater areas can impact or restrain the day-to-day operations of the mainstem projects. The NWD-MRWMD has altered operations to mitigate some effects associated with sedimentation in the headwaters area of the reservoirs.

4.1.6.6.2 Issues

The issues relative to sedimentation in the headwater areas of the mainstem reservoirs are discussed below.

- Increased Flooding. As sediment deposits in the main channel, the base elevation of the river rises and channel capacity decreases. This leads to increased frequency and sometimes increased severity of both open water and ice-affected flooding. Original real estate take lines were expanded to account for this, but in many areas the original government boundary has proven to be insufficient. The Corps is obligated to remedy the problem in the least costly manner. On a short-term basis the Corps can alter flows from the upstream reservoir to alleviate some flooding. An example of this would be an increase or decrease in flows in response to an ice jam. Long-term, the Corps' remedy to date has been to obtain additional real estate in the form of fee title and flowage easements, as this alternative costs less and is more reliable than structural fixes such as levees or channelization and allows the Corps added flexibility in meeting authorized purposes.

- Williston, North Dakota (Garrison). Sedimentation in the Williston area is causing increased water surface elevations in and upstream of the Williston area. This has caused the Corps to increase the government boundary through both fee title and flowage easements. This increase in water surface elevations may also be impacting the capacity of the Williston levee. The Corps is completing a cursory assessment to determine if more detailed analysis is warranted. At this time the sediment deposition does not affect the operations of the mainstem system.

- Bismarck/Mandan Area, North Dakota (Oahe). The headwaters of Lake Oahe are just south of the Bismarck/Mandan area. To date the Federal Government has not increased the project boundary to account for any additional flooding. Initial data suggest that the high pools and high flows during the summer of 2011 has caused at least a temporary change in the sediment deposition patterns in the upper end of Lake Oahe. The long and short-term impact that this deposition has had on channel capacity/flood potential is being assessed. Loss of channel capacity can exacerbate ice affected flooding. Under certain scenarios discharges from Garrison Dam may be reduced in order to provide some relief from ice affected flooding.

- Pierre/Ft Pierre, South Dakota (Big Bend). Sediments from the Bad River discharge into the Missouri River just upstream of the Lake Sharpe headwaters, causing a loss of channel capacity just downstream of the Pierre/Ft. Pierre area. This loss of channel capacity, coupled with severely cold weather can cause rapid advancement of the ice cover and initiate low elevation flooding in the communities of Pierre and Ft. Pierre. When these conditions exist, discharges from Oahe Dam are reduced to the minimum necessary for continued operations. In most cases this minimizes the flooding, but not always. To alleviate flooding impact Congress authorized and funded the Corps to flood-proof or buy out flood prone property and infrastructure up to $35 million. This program was completed in 2007. However, the original authority and appropriation fell well short of the need. The cost estimate to complete the buyout/flood proofing project is $50 million. The 2011 flood does not appear to have altered the deposition patterns in this area.

- Niobrara, Nebraska (Gavins Point). The Niobrara River and the Missouri River converge at the mouth of the Niobrara River, at Niobrara, Nebraska. The sand bed channel of the Niobrara River delivers more than half of the sediment input to the Missouri River in this reach. The Niobrara River delta extends approximately 10 miles up the Niobrara, and has resulted in a backwater effect on the Missouri that has increased river stages nearly 10 miles above the confluence on the Missouri River. Niobrara State Park was moved from the banks of the Niobrara River to a high nearby bluff due to increased flooding in the 1980's. The Omaha District has increased the project boundary through multiple fee title and flowage easement actions, and additional real estate actions are pending. During the 2011 flood, severe flooding occurred on the Missouri, inundating a housing community at Lazy River Acres, a few miles above the mouth of the Niobrara, as well as flooding the old Niobrara town site, inundating the sewage lagoons, and limiting access on multiple state and county roads. The flooding resulted in lowering of the river bed due to the high flows. Nearby gages experienced stage lowering from one to three feet.

- Increased Bank/Shoreline Erosion. As stated above, sediment deposition leads to decreased channel capacity. When this is combined with high flows and/or high pools the result can be increased and sometimes rapid erosion of the bank/shoreline. This process can be very dynamic with erosion/deposition areas changing on an annual and sometimes seasonal basis. Erosion leads to general channel widening which further decreases conveyance and increases flooding potential (see above). Erosion in the headwater areas has not threatened private property to date. The NWD-MRWMD does not alter operations to lessen/avoid erosion.

- Increased Groundwater Levels. Due to the raised base elevation of the river bed, there is an associated increase in the base elevation of the local ground water table. This can damage crop land and local infrastructure such as roads and bridges, cause water quality issues with domestic wells, and compromise septic systems. If homes are located in these areas, higher ground water levels can impact the integrity of the foundation material or lead to wet basements. The NWD-MRWMD does not alter operations to lessen/avoid adverse groundwater impacts. Similar to flooding, the remedy that has been employed by the Omaha District is to obtain additional real estate interests.

- Williston, North Dakota (Garrison). Higher groundwater elevations have impacted groundwater elevations upstream of Williston. To address this, the Omaha District has used the O&M authority to purchase ground water flowage easements on a number of properties upstream of the original project takeline. In addition, Congress authorized and funded the Corps to purchase groundwater flowage easements on over 9,000 acres of land in the Buford-Trenton Irrigation District. This project was completed in 2008.

- Niobrara, Nebraska (Gavins Point). Sediment deposition at the mouth of the Niobrara River has resulted in increased river stages and subsequent increases in local groundwater stages. Significant acres of cropland around the confluence have been transformed from row crop to forage grasses, and finally to cattail wetlands due to groundwater.

The increased groundwater stage was the primary driver in the relocation of the Village of Niobrara in the 1970's and Niobrara State Park in the 1980's. Some remaining infrastructure located in the old Niobrara town site is monitored for groundwater impacts. The relocation effort was completed in 1976. Mitigation efforts after that time would be considered a new claim against the Government; contrary to commonly held belief in the area, there is not a "second phase" of the relocation that would move the schools and associated facilities under the original real estate action.

- Lost Recreational Opportunities. There are population centers located near the headwater areas of four of the mainstem reservoirs. The dynamic nature of alluvial processes (see erosion above) makes access from the headwater areas into the main reservoir unreliable and sometimes non-existent. Relocating these facilities is very expensive and in some cases not practical, leading to permanent lost access for recreation. Because sedimentation was a known factor when these facilities were originally constructed, the Corps does not generally compensate owners/operators for lost revenue or increased cost due to sedimentation impacts, nor does the NWD-MRWMD alter operations to lessen/avoid adverse impacts to recreation.

- Impacts on Water Supply. There are only a few water intakes in the headwaters areas. These are municipal intakes at Fort Yates, North Dakota, Springfield, South Dakota, and Niobrara, Nebraska. An additional concern for water supply is contaminated sediments that can occur naturally or from agricultural run-off or mining operations. Because sedimentation was a known factor when these facilities were originally constructed, the Corps does not generally compensate owners/operators for increased cost due to sedimentation impacts, nor does the NWD-MRWMD alter operations to lessen/avoid adverse impacts to these intakes.

- Funding/Authority. The only authority available to address sedimentation impacts on the tributary arms of the mainstem reservoirs is the O&M Program. Some claims wait years to be settled due to the lack of funds in the O&M Program.

4.1.6.6.3 Effects of the 2011 Flood on Tributary Sedimentation

While the prolonged record or near record pool levels and flows on the mainstem reservoirs likely caused increased deposition in the headwater areas, it is unlikely that this will impact long-term trends. This will be verified through subsequent surveys.

4.1.6.7 Tributary Sedimentation – Missouri River Mainstem Reservoirs

4.1.6.7.1 Background

Although only approximately five percent of the total storage capacity in the Missouri River system has been lost to sediment deposition, over 90 percent of the losses are in the multipurpose/carryover and permanent zones.

The multipurpose/carryover zone is where the reservoirs are operated nearly all of the time, making problems associated with sedimentation disproportionately larger than the actual loss of gross storage. Sedimentation in the tributary arms of the mainstem reservoirs leads to increased bank/shoreline erosion, legal claims concerning boundary lines, increased open water and ice-affected flooding or ground water problems, lost recreational opportunities, and negative impacts on water supply. Sedimentation in the tributary arms does not impact or restrain the day-to-day operations of the mainstem projects. The NWD-MRWMD does not alter operations to mitigate effects of sedimentation on the tributary arms.

4.1.6.7.2 Issues

The issues relative to sedimentation in the tributary arms of the mainstem reservoirs are discussed below.

- Increased Flooding. As sediment deposits in the tributary arms, the base elevation of the stream rises and channel capacity decreases. This leads to increased frequency and sometimes increased severity of both open water and ice-affected flooding. The larger tributaries along the western side of the reservoirs are more impacted. Original real estate take lines were expanded to account for this, but in many areas the original government boundary has proven to be insufficient. The Corps is obligated to remedy the problem in the least costly manner. The remedy that the Corps has employed to date has been to obtain additional real estate in the form of fee title and flowage easements, as this alternative costs less and is more reliable than structural fixes such as levees or channelization.

- Increased Bank/Shoreline Erosion. As stated above, sediment deposition leads to decreased channel capacity. When this is combined with high flow events on the tributary stream the result can be increased and sometimes rapid erosion of the bank/shoreline. In many areas, the erosion has reached or exceeded the government boundary. As with flooding, the Corps is obligated to remedy the problem in the least costly manner. The remedy that the Corps has employed to date has been to obtain additional real estate in the form of fee title and slough/erosion easements.

- Increased Groundwater Levels. Due to the raised base elevation of the tributary streams, there is an associated increase in the base elevation of the local ground water table. This can damage crop land and local infrastructure such as roads and bridges, cause water quality issues with domestic wells, and compromise septic systems. If homes are located close to the tributary streams, higher ground water levels can impact the integrity of the foundation material or lead to wet basements. Similar to the previously discussed issues, the remedy that has been employed by the Omaha District is to obtain additional real estate interests.

- Lost Recreational Opportunities. The larger tributary arms offer advantages for development of recreational facilities such as boat ramps and marinas. Tributary embayments are generally less susceptible to large wind/wave attack and are usually closer to public roads, making them more accessible to the public.

Unlike the mainstem of the Missouri River, where the sediment yield has been greatly reduced, most tributaries still have their pre-development sediment loads. This combined with the backwater effect from the pool and the relatively small amount of storage in the tributary arms cause sedimentation impacts to be realized much sooner in the tributary arms than on the mainstem of the Missouri River. Relocating these facilities is very expensive and in some case not practical leading to lost access for recreation. Because sedimentation was a known factor when these facilities were originally constructed, the Corps does not generally compensate owners/operators for lost revenue or increased cost due to sedimentation impacts.

- Impacts on Water Supply. Many water users (municipal, agricultural, industrial) have located their intakes in tributary arms for the same reasons that recreational facilities are located in tributary arms. Similar to recreational facilities, the impacts of sedimentation are realized sooner in the tributary arms than in the main reservoir. An additional concern for water supply is contaminated sediments that can occur naturally or from agricultural run-off or mining operations. Because, sedimentation is a known factor when these facilities are originally constructed, the Corps does not generally compensate owners/operators for increased cost due to sedimentation impacts.

- Funding/Authority. The only authority available to address sedimentation impacts on the tributary arms of the mainstem reservoirs is the O&M Program. Some claims wait years to be settled due to the lack of funds in the O&M Program.

4.1.6.7.3 Effects of the 2011 Flood on Tributary Sedimentation

While the prolonged record or near-record pool levels on the mainstem reservoirs likely caused localized increases in tributary arm sediment deposition, it is unlikely that this will impact long-term trends. The Omaha District does not plan to specifically assess tributary sedimentation changes from the 2011 flood, but rather look at the entire mainstem reservoir system.

4.1.7 BSNP and SWH Infrastructure Vulnerabilities After Repairs

Due to the extreme amount of damage, repairs to the BSNP will likely require two to three years. During this period, the risk of additional damage to adjacent facilities is increased. Navigation channel reliability is also reduced during this period. Public safety and boater hazards are likely increased due to channel changes and structure failures. The lack of vegetation has considerably reduced floodplain and bank stability, with increased failure risk in the near term. Many MRRP SWH projects have been altered considerably. The sustainability of these projects is likely reduced with consequences to habitat quality and extent. Sediment deposition within the aggradation reach of each dam has aggravated impact areas with risks due to increased flood elevations, increased bank / shoreline erosion rates, and similar impacts related to rising stages.

4.1.8 Long Term Vulnerabilities

4.1.8.1 BSNP Budget Process

4.1.8.1.1 BSNP O&M Budget Navigation Business Line History

Before FY 1995 the cost codes allowed for the BSNP navigation O&M costs and bank stabilization O&M costs were accounted for under separate COEMIS cost codes (1980's Corps of Engineers Management Information System and precursor to CEFMS initiated in 1998). The bank stabilization cost code was written with a non-navigation bias and was not normally associated with navigation channels. NWD (formally Missouri River Division - MRD at the time) used these two cost codes for the BSNP and established a 46% Navigation - 54% Bank Stabilization split for the O&M work done on the channel from Sioux City, Iowa to the mouth. For the Omaha District channel from Sioux City, Iowa to Rulo, Nebraska the split was calculated to be as much as 30% Navigation -70% Bank Stabilization, but the prior percentages were eventually used for the whole BSNP system.

When the new baseline budget cost code system was established during 1995 there was a great emphasis on reducing the number of cost codes and consolidating similar work. As a result the cost code for bank stabilization was rewritten to restrict that work to prevent sloughing of non-navigation channels. Maintenance of dikes and revetments for navigation channels was placed in a navigation cost code even though some of the structure repair work may be for bank stabilization to keep the river in place.

In FY 1999 as a part of the 1993 Government Performance and Results Act, all agencies were required to establish budgets aligned to business functions. For the O&M budget the Corps chose Navigation, Flood Damage Reduction, Hydropower, Environmental Stewardship and Recreation. New cost codes (Work Category Codes) were established that only cover these five business functions. Bank Stabilization, Water Supply, etc. were not included. Bank stabilization work not associated with a river that has a navigation authority is budgeted for under the flood damage reduction function. Bank stabilization associated with a river that has a navigation project is budgeted for under the navigation business function. This is how the BSNP is presently identified in the O&M Budget.

4.1.8.1.2 BSNP Categorized as Low Use Waterway

Identifing the BSNP within the Navigation Business line worked fairly well until the FY 2002 Budget EC required that navigation projects with certain tonnage or ton-mile metrics were categorized as either Waterways or Low Use Waterways (LWW). Navigation projects with less than 1 million tons or less than 1 billion ton miles were identified as LWW. It was not until the prepartation of the President's FY 2012 O&M budget that the Corps used the navigation projects with LWW designations to identify budget reductions to meet Office of Management and Budget (OMB) guidance. OMB in MEMO M-10-19 required non-security agencies FY 2012 budget submittal to be 5 percent less than FY 2011. OMB memo M-10-20 directed each agency to propose five low performing programs for elimination or reduction by 50%. For the Navigation Business line the Corps identified USACE programs for the 50 percent reduction; low use defined coastal project with less than 1 million tons of commercial cargo and inland waterways under 1 billion ton miles.

The FY 2011 budget for Low Use Waterway projects was $140.2 million. The FY 2012 President's Budget for Low Use Waterways was $76 million. This impacted 121 navigation project O&M budgets either eliminating funding or greatly reducing it. The BSNP navigation funding was reduced by 50 percent. The Great 2011 Missouri River Flood has delayed the total impacts of this budgetary dilemma. Congress has funded the routine O&M fully and has provided supplemental repair funding under the Disaster Relief Apropriations Act (DRAA). However the BSNP is still a LWW and with the seriously challenged national economy it is expected that future O&M funding will be greatly reduced.

4.1.8.1.3 BSNP as a Multipurpose Project

The BSNP is actually an expanded multipurpose project. Originally authorized as a Bank Stabilization project and a Navigation Project it has matured via later legislation and physical dynamics to include an Environmental Stewardship mission and a levee and infrastructure protection project. Because the BSNP exists as a stable infrastructure, this has allowed the public to construct bridges, water intakes, marinas etc along its channel. Levees have been constructed from Omaha, Nebraska to the mouth along its channel and near its bankline with the knowledge that the river will not meander to cause harm or distruction of these systems. The BSNP could be also catergorized as a Flood Damage Reduction project.

4.1.8.1.4 BSNP Budgetary Vulnerability

Because the BSNP is catergorized as a navigation LWW project, the navigation channel and all the infrastructure, land, SWH and other systems built along the river are vulnerable if full routine O&M funding is not provided.

4.1.8.2 Maintaining High Quality Civil Works Infrastructure Engineering Expertise

4.1.8.2.1 General

The Congressional Budget Office released a study on January 30, 2012 comparing the compensation of federal and private-sector employees. Although other federal employees faired well, it was those employees with professional degrees or doctorates that were behind. As stated in the report the higher one's degree, the lower the salary and benefits compared to one's educational peers. A high school graduate earned 36 percent more compensation than an equivalent private sector worker. A college graduate earned roughly the same salary, but made about 46 percent more in benefits. If an individual had a professional degree or doctorate, he or she made an average of 18 percent less in compensation.

Congress and the President have voted to freeze federal salaries since 2011 for two years and are proposing to extend that further into the future. Federal benefits are also being looked at to reduce federal costs in these very challenging economic times.

Congress is also considering various hiring restricitions on agencies. If restrictions are placed on the hiring of new Corps staff, this may impact the Corps' ability to replace retiring engineers. The engineering talent pool that is available to the Corps could in the future thin out in favor of the private sector. If a trend develops the Corps may be faced with difficult times in attracting and retaining highly qualified engineers to build and maintain the nation's Civil Works infrastructure.

4.1.8.2.2 Engineering Expertise Vulnerability

The Corps must be viligant in understanding the competition for engineering talent and develop processes to help attract and retain engineering expertise. Not doing so will leave the infrastructure the Corps builds and maintains vulnerable.

4.1.9 Recommendations

4.1.9.1 Recommended Changes to Operating Procedures for BSNP

No changes to the current reservoir operating procedures are recommended as a result of the channel performance evaluation. However, it should be noted that excessively high or low Missouri River flows may hamper repair activities.

4.1.9.2 Current BSNP Surveillance Plans and Recommended Changes

4.1.9.2.1 In-House Forces

Current surveillance plans are to perform an initial reconnaissance in late March or early April for the BSNP as river and weather conditions allow. The primary purpose of this assessment will be to identify additional damaged structures, navigation impacted areas, bank stability issues, and flood control impacts. Inspections will be on the river unless identified issues warrant helicopter use. Inspection will be conducted using Corps staff.

4.1.9.2.2 Industry and River Users

Navigation industry, Coast Guard, recreational boaters, and private landowners also provide valuable information regarding channel condition. Standard procedures have established communication formats that will continue to be used.

4.1.9.3 Recommended Future Modifications to Improve Operations

4.1.9.3.1 General

At this time there are no systemic recommended modifications to improve operation. As stated above, repairs will be made in an adaptive management mode which will lead to site-specific modifications. However, with the recognition that levees, bridges, and other infrastructure along the river can restrict channel and floodplain capacity during flood flows, it is recommended that additional efforts be made to assess what the impact is and how best to mitigate for it.

4.1.9.3.2 Flow Corridor Assessment

The ability of habitat projects to provide flood benefits has been a topic covered in numerous newspaper articles and discussions during flood events occurring in 2007 to 2011. Potential benefits from habitat projects can occur either through increased flood storage and reduced flood heights downstream of habitat sites, or through increased channel conveyance and reduced flood heights adjacent to and upstream of habitat sites. In 2008, the Corps and federal agency partners initiated a pilot study to test the concept of what effect, if any, habitat projects being implemented as part of the MRRP, such as river widening to create SWH, or levee setbacks to allow for floodplain connectivity, have on flood heights. Existing hydraulic models were selected for use between Boonville, Missouri and Jefferson City, Missouri, a reach with a significant amount of public land and also a location where previous habitat projects had been credited in the media with reduced flood heights. Hypothetical changes to river geometry were tested for relative change compared to what the river looked like in 1992, prior to the MRRP and also prior to the 1993 flood which dramatically altered levees in the area. Additionally, existing habitat projects in the reach were modeled and compared to the “1992” conditions to test potential effects to river stages during the 2007 flood event. General questions addressed by the pilot study include:

- Did habitat restorations raise or lower river stages? Can we spend habitat funding more wisely in the future, obtaining flood benefits through restoration?

- Stages at low flows are decreasing, but larger flows are getting higher. Is this a concern? If so, can this trend be addressed through habitat projects?

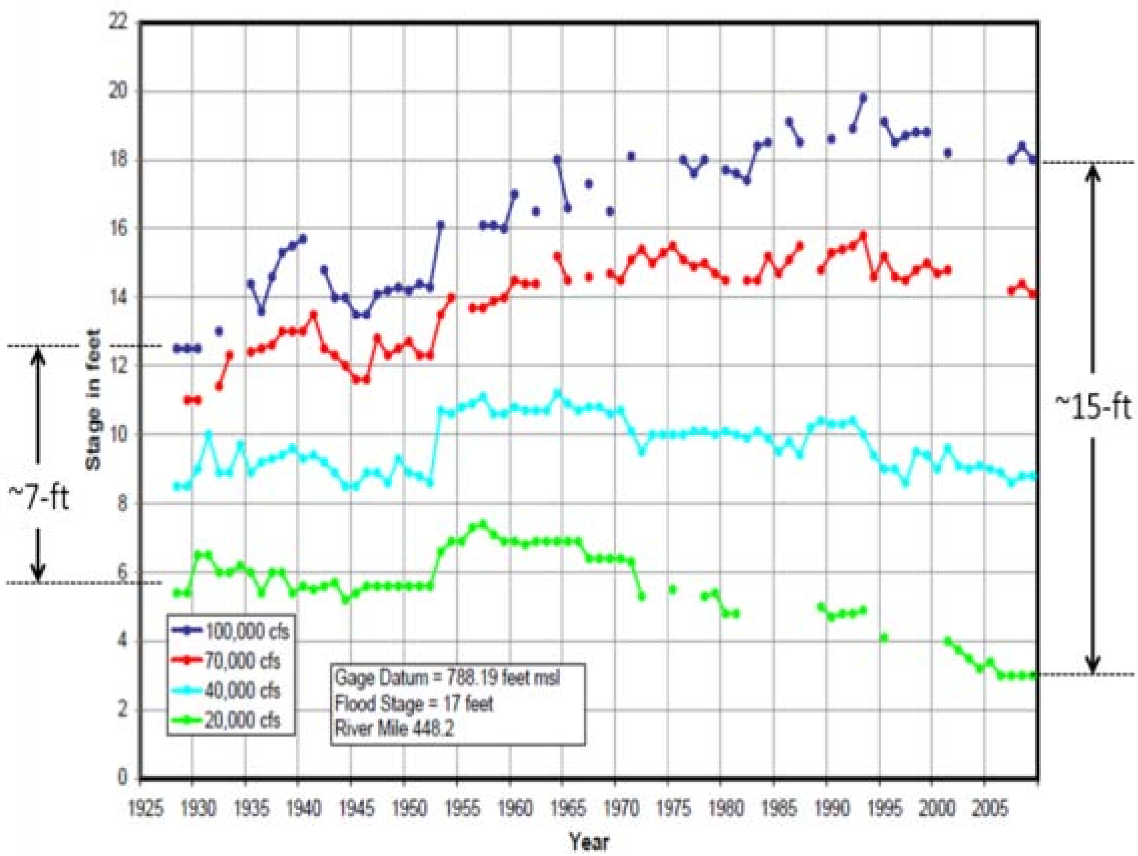

Figure 37. Stage Trends on the Missouri River at St. Joseph, Missouri

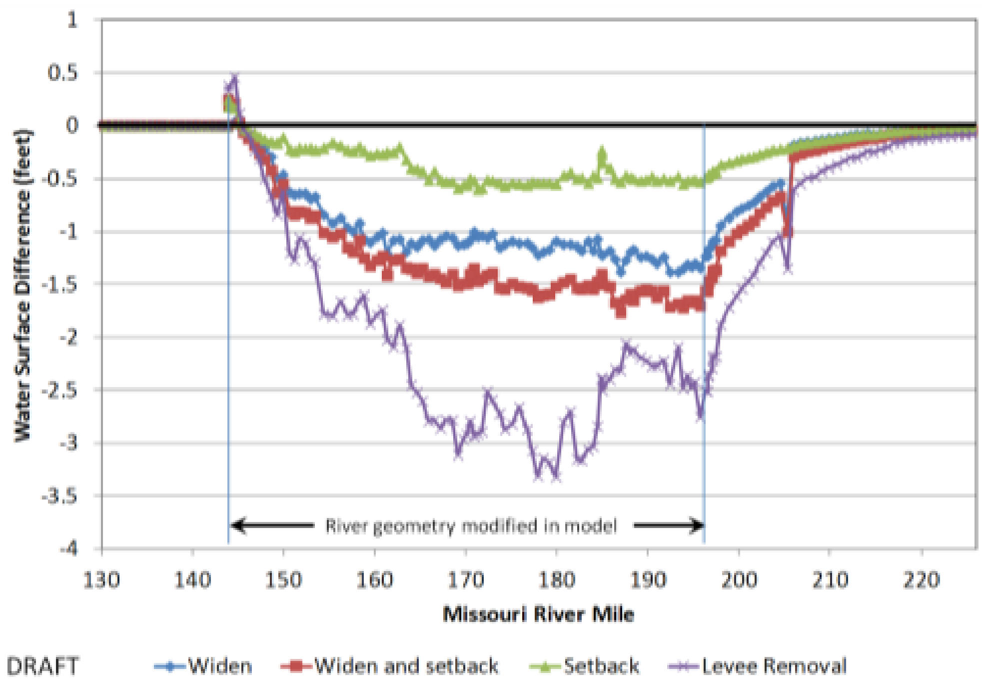

Figure 38. Comparison of 10-Yr Flood Heights for Various Hypothetical River Geometries

Results varied depending on flow magnitude, type and amount of action, etc, but in general, river widening and levee setbacks showed promise to reduce flood levels, and as a result, potential to reduce the frequency of levee overtopping (see Figures 36 and 37). However, while some flood storage was observed, ability to reduce river levels downstream of the projects due to the added flood storage appeared to be minor for simulation of the 2007 flood and existing completed habitat projects. With the concept tested, and in light of approximately 16 levee overtops and or breaches in 2011, several questions remain:

- Within existing public lands, what is the maximum feasible reduction in flood heights that could be achieved while creating desired habitat for native species through additional river widening and/or levee setback scenarios? Would these changes improve levee performance to include reduced scour potential of levee toes, decreased seepage rates, and or reduced frequency of levee overtopping?

- Given the constraints of a willing seller program to obtain habitat sites, is it feasible to identify "pinch points" on the system and place a higher priority on acquiring habitat sites that could provide greater benefits?

- Considering potential land cover changes, such as potential for sediment deposition in the floodplain, and/or potential development of floodplain forest, would flood levels remain reduced over time? If not, how long will the created flood benefits remain viable?

- Could flood storage be designed into existing levee cells, and or better coordinated through structure operations and/or prescribed breaching to reduce flood damages?

- What effect would levee setback and or river widening actions have on viability of other project purposes, such as commercial navigation?

To answer these questions, the Corps is proposing a continuation of modeling in the pilot reach located between Boonville, Missouri and Jefferson City, Missouri and initiation of models between Council Bluffs, Iowa and St. Joseph, Missouri, another reach where significant public lands are available. These two modeling efforts will first focus on potential benefits through creation of habitat on existing public lands, and also identify habitat sites that could provide greater habitat benefits in the future, in the event willing sellers would become available. Additionally, in partnership with the National Weather Service, the Corps is developing unsteady flow models that will soon improve flood forecast capabilities, and would eventually allow scenarios to be modeled to determine best practices for exercising floodplain storage and/or floodways to minimize and/or reduce flood heights.

4.1.9.3.3 Shallow Water Habitat Project Levee Impact Assessment

Concerns have been raised regarding the impact of constructed chutes on the safety of adjacent federal levees.

A case study is proposed at Hamburg Bend to evaluate numerous factors including chute interaction with the Lower Hamburg Bend levee failure, levee toe erosion at Upper Hamburg Bend, chute impacts to seepage, and the role of chutes with respect to flood levels and floodplain flow velocity.

4.1.9.4 Complete Flood Damage Repairs to BSNP and SWH

Continue to repair the flood damaged BSNP river control structures and the SWH control structures to pre-flood conditions as rapidly as possible, understanding logistically it may take 2-3 years to complete. Priority repair processes will greatly reduce the level of vulnerabilities until the project repairs are complete.

4.1.9.5 Recommended Mitigative Strategies for Future Vulnerabilities

4.1.9.5.1 BSNP O&M Funding LWW Issue

The NWD, NWO and NWK leadership should look at how the BSNP budgetary Low Use Waterway navigation designation impacts the routine O&M Budget and begin to develop processes to fully fund the BSNP O&M Program as a multipurpose project.

4.1.9.5.2 Maintaining Engineering Excellence

NWD, NWO and NWK leadership should develop strategies to attract and retain the future engineers to select the Corps Civil Works program as a career. Private sector competition for engineering talent and less than attractive governmental pay and restrictive hiring processes could reduce the Corps' ability to suitably build, operate and maintain the public's civil works infrastructure.

4.2 LEVEES

4.2.1 Levee System and Floodplain Development History

The Missouri River downstream from Omaha, Nebraska and Council Bluffs, Iowa primarily consists of a navigation project with stabilized banks, an engineered channel, and a system of agricultural levees protecting vast acres of farmland. These levees were constructed between the mid-1940's and the early 1980's. The following sections describe the history of the levee systems, significant flood events, vulnerabilities from the 2011 flood and relevant studies as well as channel performance and impacts. In general there have been a number of flood events, which are regularly followed by assessments, studies, and reports. The following sections also demonstrate that there has also been an evolution in levee design concepts and appropriate methods of addressing flood risk.

4.2.1.1 Levee System Design and Construction

The Missouri River Agricultural Levees, Sioux City, Iowa to St. Louis were authorized by the Flood Control Act, approved 22 December 1944. The project consisted of earth-filled levees with two-feet of freeboard above the design flood. Minimum width of the leveed river was set by the Flood Control Act at 3,000 feet from Sioux City to the mouth of the Kansas River. In addition, a 1,000 foot setback of the levee from the established bank line was typically recommended. Design discharges were set as 250,000 cfs at Omaha and 295,000 cfs at Nebraska City. While much of the system does maintain these minimum floodway widths numerous locations along the river exist with widths less than the 3,000 feet minimum, especially at bridge constrictions where widths commonly vary from 1,200 feet to 1,600 feet, and reach as low as 1,090 feet.

It should be noted that while a "floodway" width of 3,000 feet was recommended, this usage of the term "floodway" predates the modern concept of a floodway as defined by the FEMA. The modern concept of a floodway is largely defined by the National Flood Insurance Program (NFIP) and is the area required to convey the base flood event without increasing the water surface elevation of that flood more than one foot at any point (Title 44Code of Federal Regulations 60.3). The current levee system has a much more significant impact on flood elevations. A review of peak flow stage events at Nebraska City shows an increase of greater than 4 feet as a result of encroachments and accretion into the natural floodplain. At the time of the levees design, induced stage effects and the effects of rating curve shifts were not studied (Missouri River Levee System; Phase II General Design Memorandum, November 1975).

It is outside of the scope of this report to determine what a modern floodway width would be for this specific reach of the Missouri River. Studies completed by the Nebraska Game and Parks evaluated the historic channel alignment and floodplain extents along the Missouri River prior to channelization and levee construction (A Sustainable Middle Missouri River Concept, 2009). Nebraska Game and Parks identified erodible corridor widths of 5,300 feet to 7,000 feet, which would likely serve as a starting point for levee alignments based on geotechnical concerns. From a hydrologic standpoint the Platte River provides an example, where non-levee portions of the river provide floodway top widths in excess of 5,000 feet to as high as 14,000 feet. From these values it can be estimated that a modern floodway would provide widths of approximately 5,000 feet to 9,000 feet.

4.2.1.2 1952 Flood, 1956 Benefits Re-Evaluation, and the 1962 System Restudy

The first major test for the Missouri River Levee Systems came in 1952. At this time many of the levee systems had not been constructed. The 1952 event resulted in a discharge of 396,000 cfs with a record stage of 40.2 feet at Omaha, Nebraska. In the stretch of agricultural levees downstream of Omaha and Council Bluffs, Iowa, levee systems L-575, L-550, and L-536, breached. The 1952 flood caused an estimated $179 million dollars in damages along the entire Missouri Valley from the Dakotas to St. Louis. The 1952 event remains the flood of record for Omaha.

Following the 1952 flood, two studies were conducted to re-evaluate the economic feasibility of construction of the previously authorized levee projects; the Main Stem Flood Control Benefits Re-evaluation (dated 1956), and Missouri River Agricultural Levee Restudy Program (dated 1962). These studies had the objective to determine which levee units, or groups of physically interrelated levee units would provide benefits equal to or in excess of their costs.

4.2.1.3 The 1968 National Flood Insurance Program, Environmental Protection, and the 1975 Phase II General Design Memorandum

Between the 1952 flood and the 1986 flood, two major legislative processes impacted the modern concept of floodplain management and flood risk. First, the National Flood Insurance Program (NFIP) was created by Congress through the National Flood Insurance Act of 1968. Second, the environmental movement gained momentum in the 1960's and 1970's, focusing the Nation's attention on how to better protect and restore its natural resources.

The NFIP enabled property owners in participating communities to purchase flood insurance protection from the government. NFIP also promoted the concept of a floodway and a floodplain fringe. It recognized that the construction of encroachments including levees, embankments, and structures in the floodplain had adverse impacts on flood stages and it established regulations to limit these impacts. Over time, standards for levees also evolved, changing the requirements for levees beyond those originally incorporated in many levee system designs.

During the 1960's and 1970's appreciation for, and concern over the environment gained momentum leading ultimately to the development of environmental legislation. This included the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), the Clean Water Act (CWA), and the Clean Air Act (CAA). One of the most significant effects of NEPA was to set up procedural requirements for all federal government agencies to ensure that environmental impacts were factored into the decision-making process for federal undertakings, such as decisions related to floodplain development. The ESA focused on limiting habitat destruction in order to protect imperiled species from extinction as a result of unregulated economic growth and development. Likewise, CWA and CAA (among dozens of other laws passed in the 1970's), provided new protections for specific natural resources that were increasingly being impacted as a result of high levels of development.

In a sense, the Missouri River Levee System Phase II General Design Memorandum, dated November 1975, incorporated concepts from both the NFIP and the new environmental laws into policy applicable to the river system. This memorandum identified the effects of induced stages, the effects of rating curve shifts, and environmental and social well-being considerations for the Missouri River Levee System.

4.2.1.4 1984 Flood, 1986 Adequacy Study, and the 1990 System Re-Evaluation

Large areas of the Missouri River Basin received intermittent heavy rainstorms during the months of May and June of 1984 that led to flooding in June. While damage to the levee systems from this event was anticipated to occur, loading of the levees exceeded what was expected. Due to this, a 1986 study evaluated the adequacy of Missouri River Levee System. This system adequacy study identified that many of the levee systems could not meet their authorized design loading. The study investigated "upgrading" the levees (i.e.: raising the elevation), to provide their authorized capacity and was determined to be economically unfeasible. No non-structural alternatives were considered in this study. The Missouri River Levee System Reevaluation of 1990 completed a similar analysis. This evaluation of structural levee raises identified benefit to cost ratios of between 0.1 - 0.4 for most levee systems.

4.2.1.5 The 1993 Flood, the 1994 Galloway Report, and the 1995 Floodplain Management Assessment

An unusual combination and sequence of hydro-meteorological events occurred in the spring and summer of 1993 which culminated in the widespread Midwest flood event known as The Great Flood of 1993. The flooding occurred as a result of a previous wet fall, normal to above-normal snow accumulation, rapid spring snowmelt accompanied by heavy spring and early summer rainfall.

The flood was among the most costly and devastating to ever occur in the United States, with $15 billion in damages, much of which occurred below the Omaha District. During this event Levee System L-550 on the Missouri River breached.

Following the 1993 flood event, the Interagency Floodplain Management Review Committee was tasked to delineate the major causes and consequences of the 1993 Midwest flood. The Committee also evaluated the performance of existing floodplain management and related watershed management programs which resulted in the publication of *Sharing the Challenge: Floodplain Management into the 21st Century*, commonly referred to as the Galloway Report. Some of the conclusions from the Galloway Report are:

- The need to consider both structural and nonstructural means to mitigate flood damages
- Human activity throughout the basin has caused significant loss of habitat
- Levees can cause problems in some critical reaches by backing water up on other levees or lowlands
- Many levees are poorly sited and will fail again in the future

The Floodplain Management Assessment of the Upper Mississippi and Lower Missouri River of 1995 was a congressionally authorized study completed in response to the Midwest Flood of 1993. This study focused on providing a comparison of impacts and costs associated with a wide array of alternative policies, programs, and structural and nonstructural measures. The report emphasized preparing the system for even larger floods in the future.

4.2.1.6 2010 Flood

The 2010 Missouri River flood event was the result of Missouri River tributary runoff. This flood is most notable for the damages it caused to the flood protection infrastructure. The levee systems located along the Missouri River were notably tested during the 2010 event, but did not fail. Minor to moderate damage was experienced primarily along the river, and to flood protection systems

4.2.1.7 2011 Missouri River Flood Event

The 2011 flood was triggered by record snowfall in the Rocky Mountains of Montana and Wyoming along with near record spring rainfall in central and eastern Montana. According to the National Weather Service, in the second half of the month of May 2011, almost a year's worth of rain fell over the upper Missouri River Basin. Extremely heavy rainfall in conjunction with record snowpack in the Rocky Mountains contributed to this flood event. All six major USACE reservoirs located along the Missouri River released record amounts of water to prevent overflow which led to flooding that threatened numerous communities, critical facilities, and major infrastructure along the river from Montana to Missouri.

At the time of this assessment, significant efforts to repair federal levees located along the Missouri River in preparation of flood season were ongoing. ER 500-1-1 provides the policies for the Civil Emergency Management Program under the authorities of the PL 84-99 program.

4.2.1.8 Vulnerabilities

As discussed above, the current alignment of the Missouri River Levee System is based primarily on designs developed in the 1940’s and early 1950’s. Like most levee systems of that era the overriding design goal was to maximize the size of the protected area behind the levee, in order to provide protection to agricultural activities, residential, commercial and agricultural structures and infrastructure. By maximizing the amount of protected area (increasing agricultural potential), and maintaining levee alignments in relatively straight lines along the banks of the river, it was thought that the best benefit to cost could be obtained. In the 1940’s and 1950’s, the concept of maximizing the protected area was well received. National floodplain management programs were decades away from being initiated, and loss of fish and wildlife habitat was a secondary concern. This approach resulted in poorly aligned levee systems, systems that were often located too close to the river, resulting in negative hydrologic impacts, negative environmental impacts, and increased concerns over integrity of the levee systems.

4.2.2 Missouri River Levee System

The system of levees on the Missouri River is extensive from Omaha, Nebraska to the Missouri River confluence with the Mississippi River at St. Louis, Missouri, with levees on one or both banks for nearly this entire reach. The system is diverse; levees are located in rural and agricultural settings as well as in heavily populated urban settings such as Omaha, Nebraska, Council Bluffs, Iowa, St Joseph, Missouri, and Kansas City, Missouri. The inventory includes both federally authorized and constructed levees that are operated by non-federal sponsors, and non-federal levees which were constructed and are operated by non-federal sponsors.

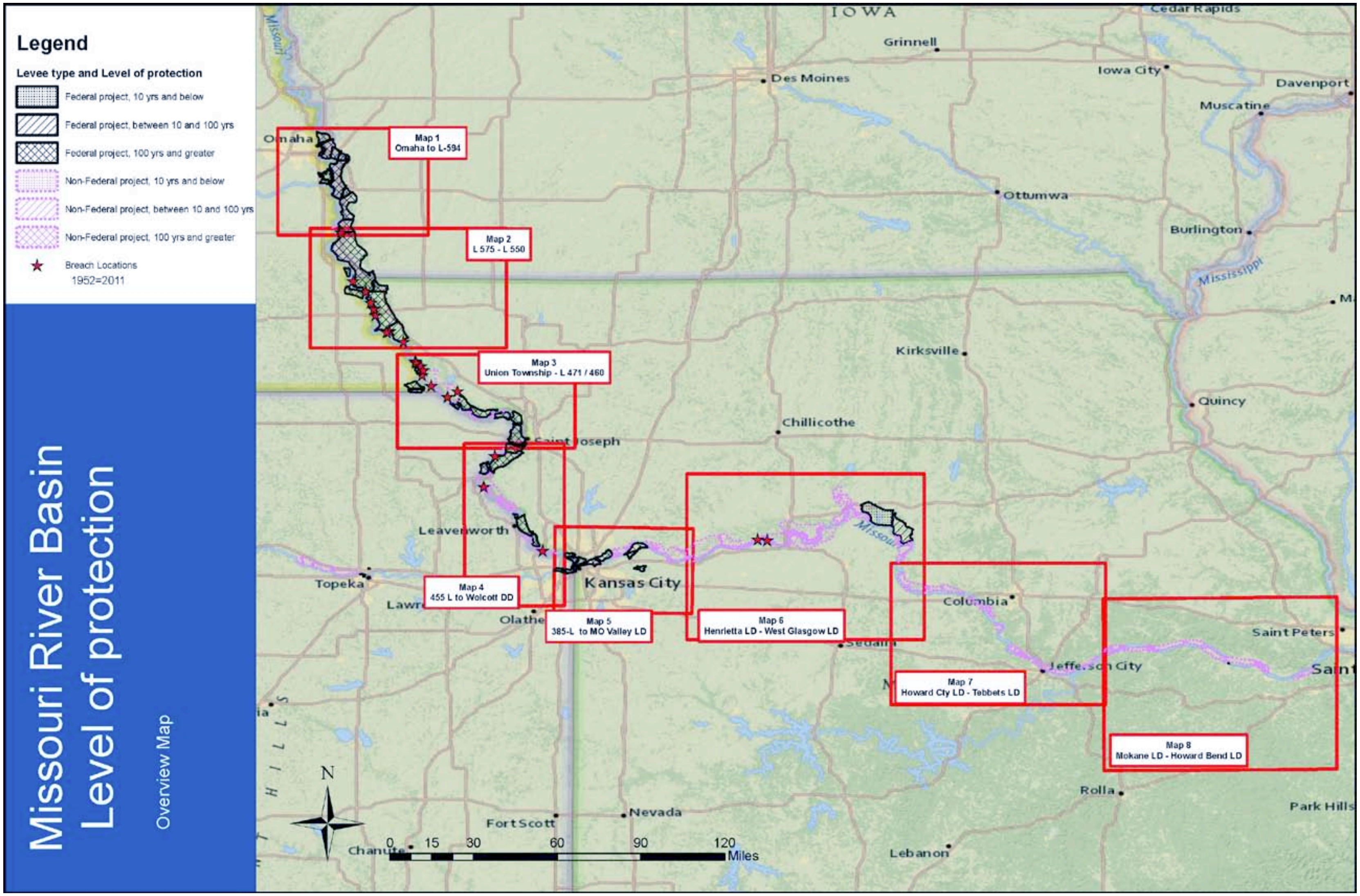

Figure 39. Missouri River Basin Levee Vulnerability

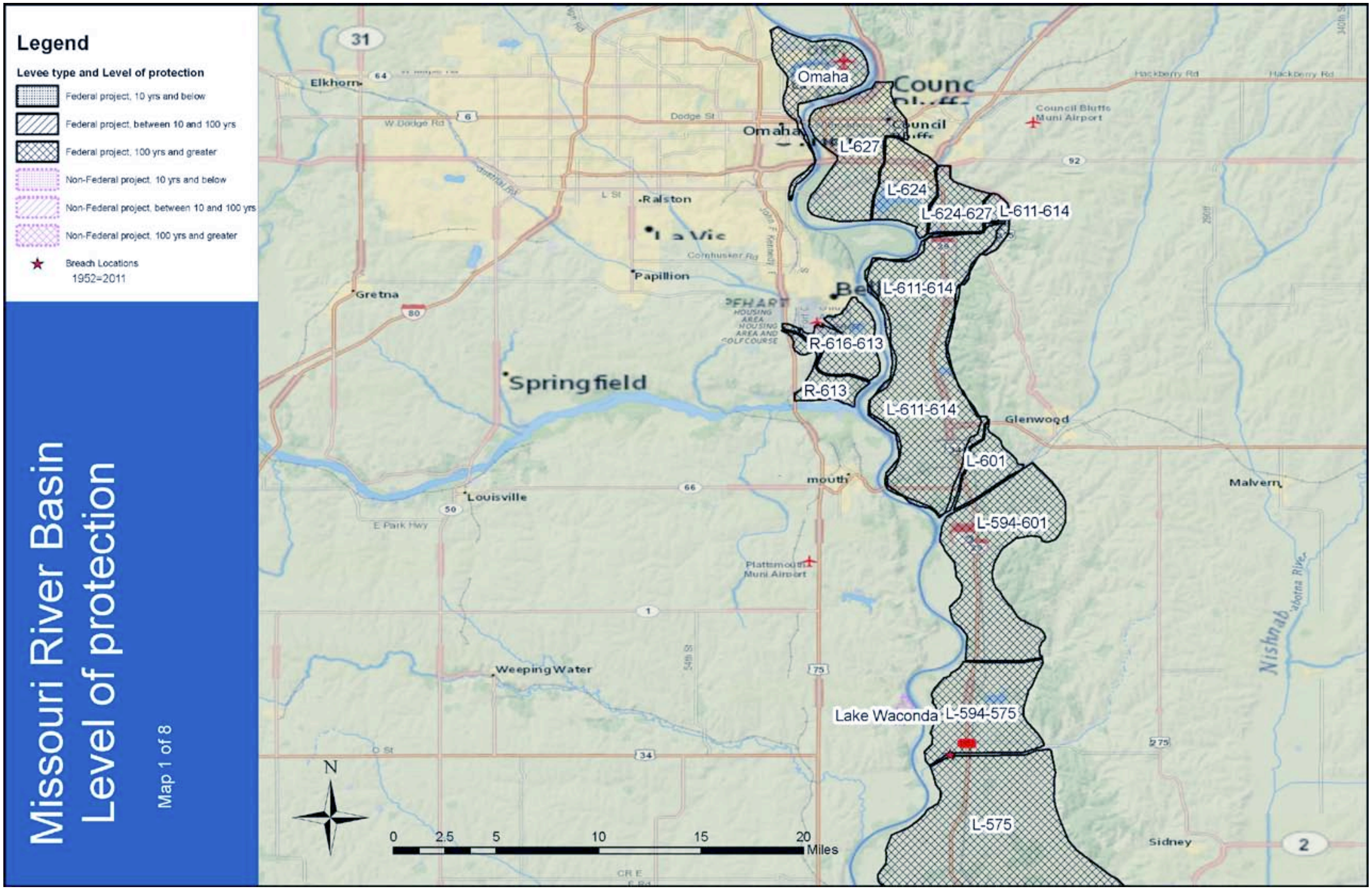

Figure 40. Omaha to L-594

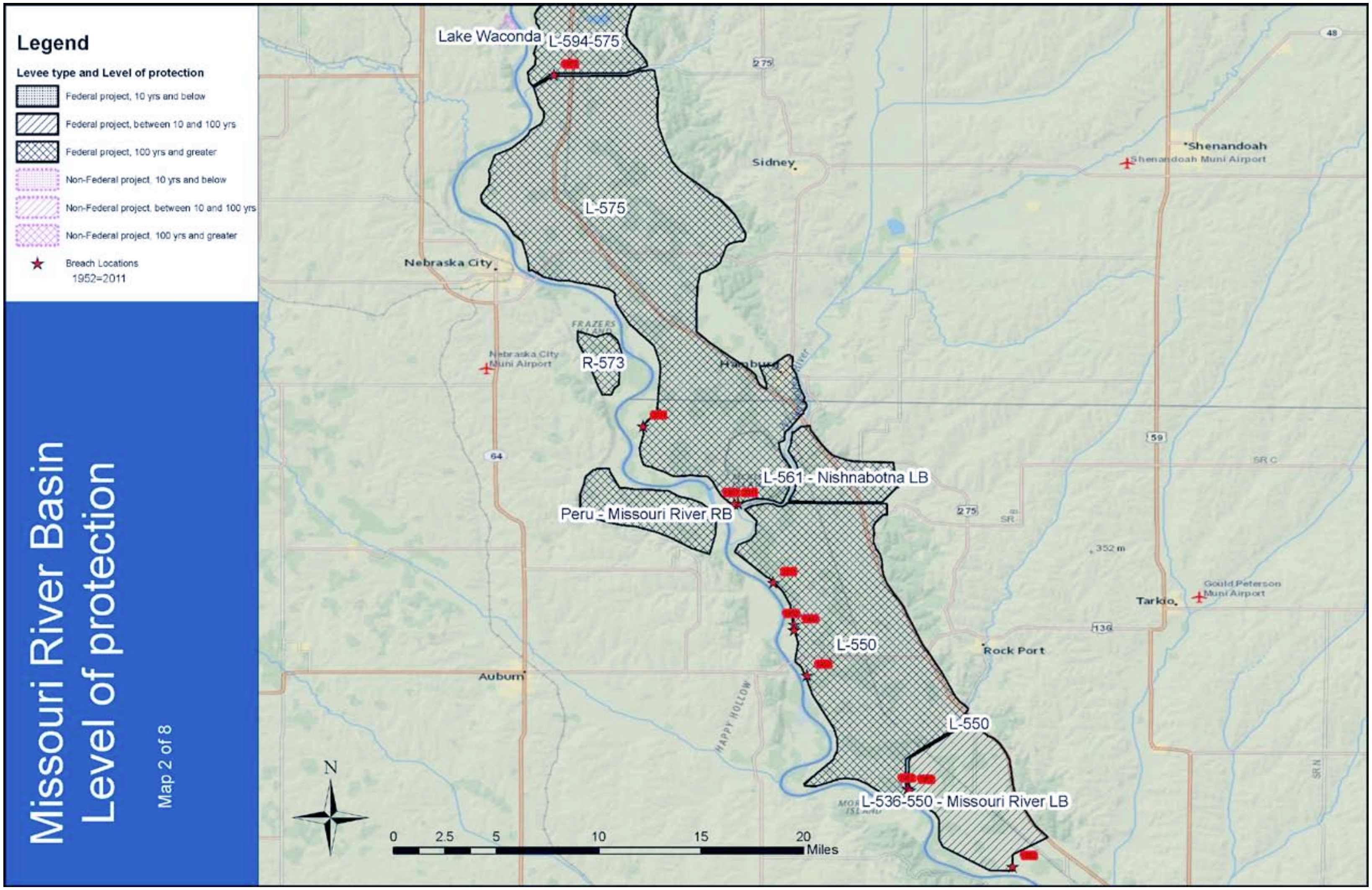

Figure 41. L-575 – L-550

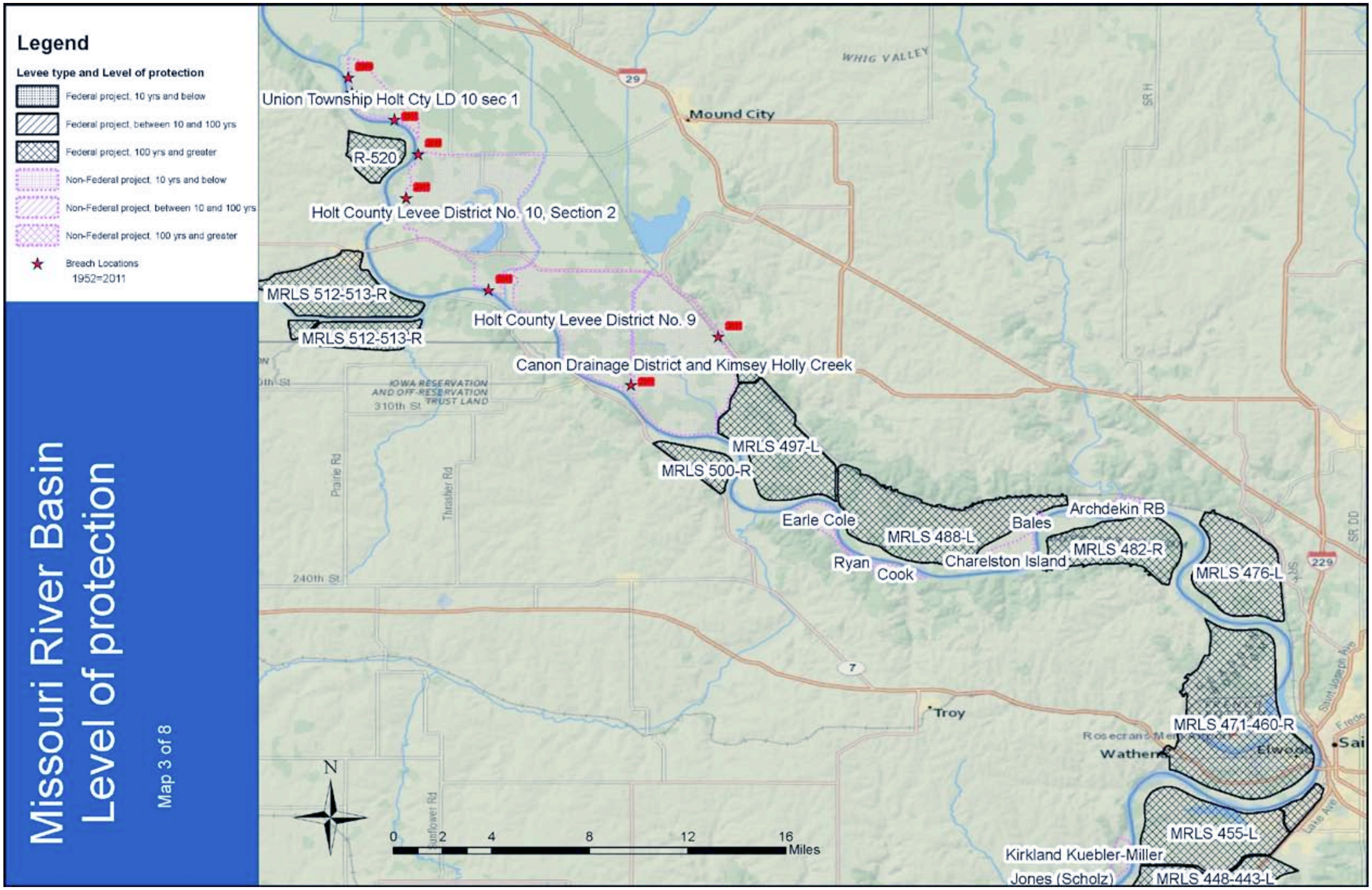

Figure 42. Union Township – L-471/460

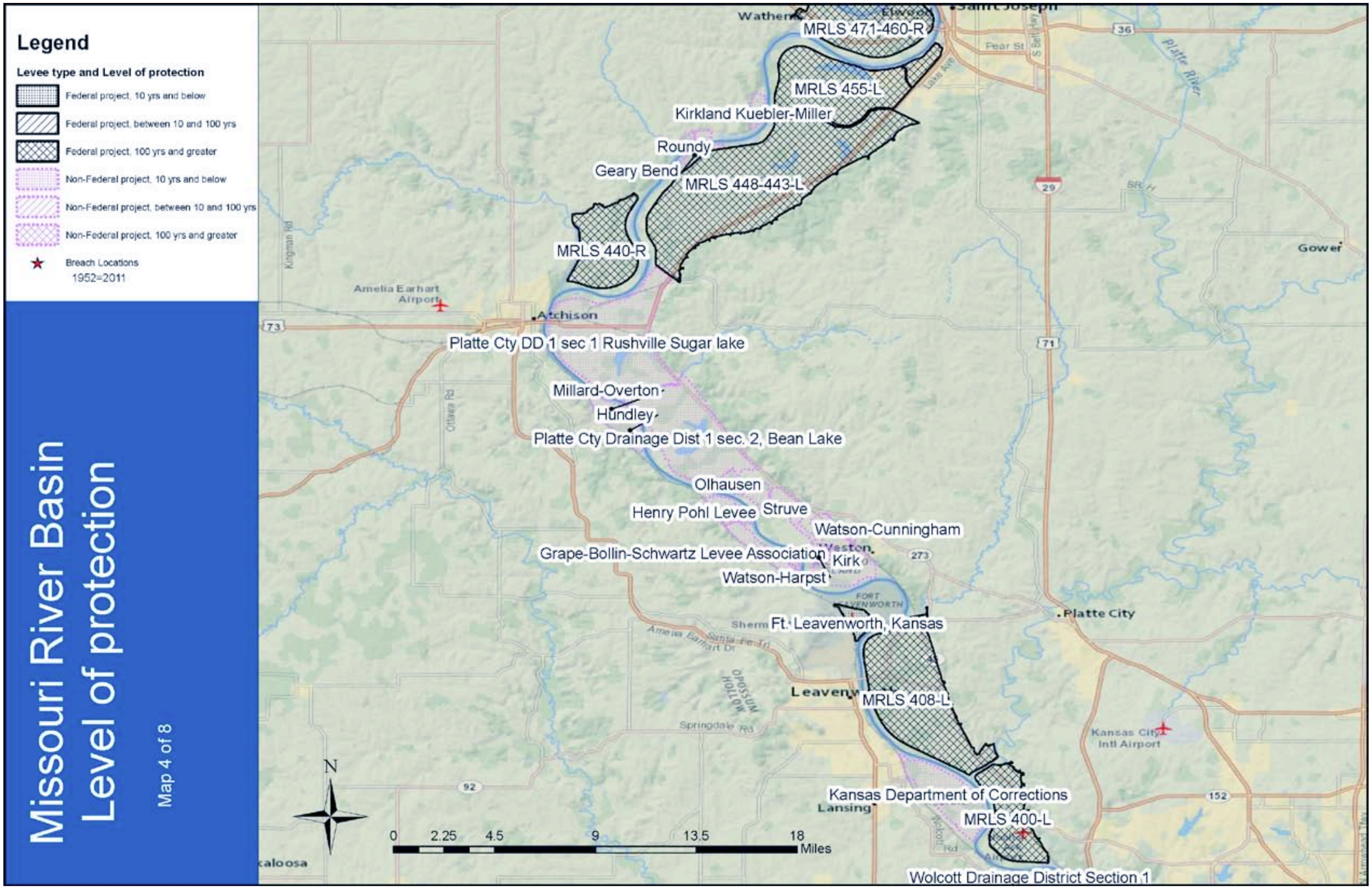

Figure 43. L-455 to Wolcott DD

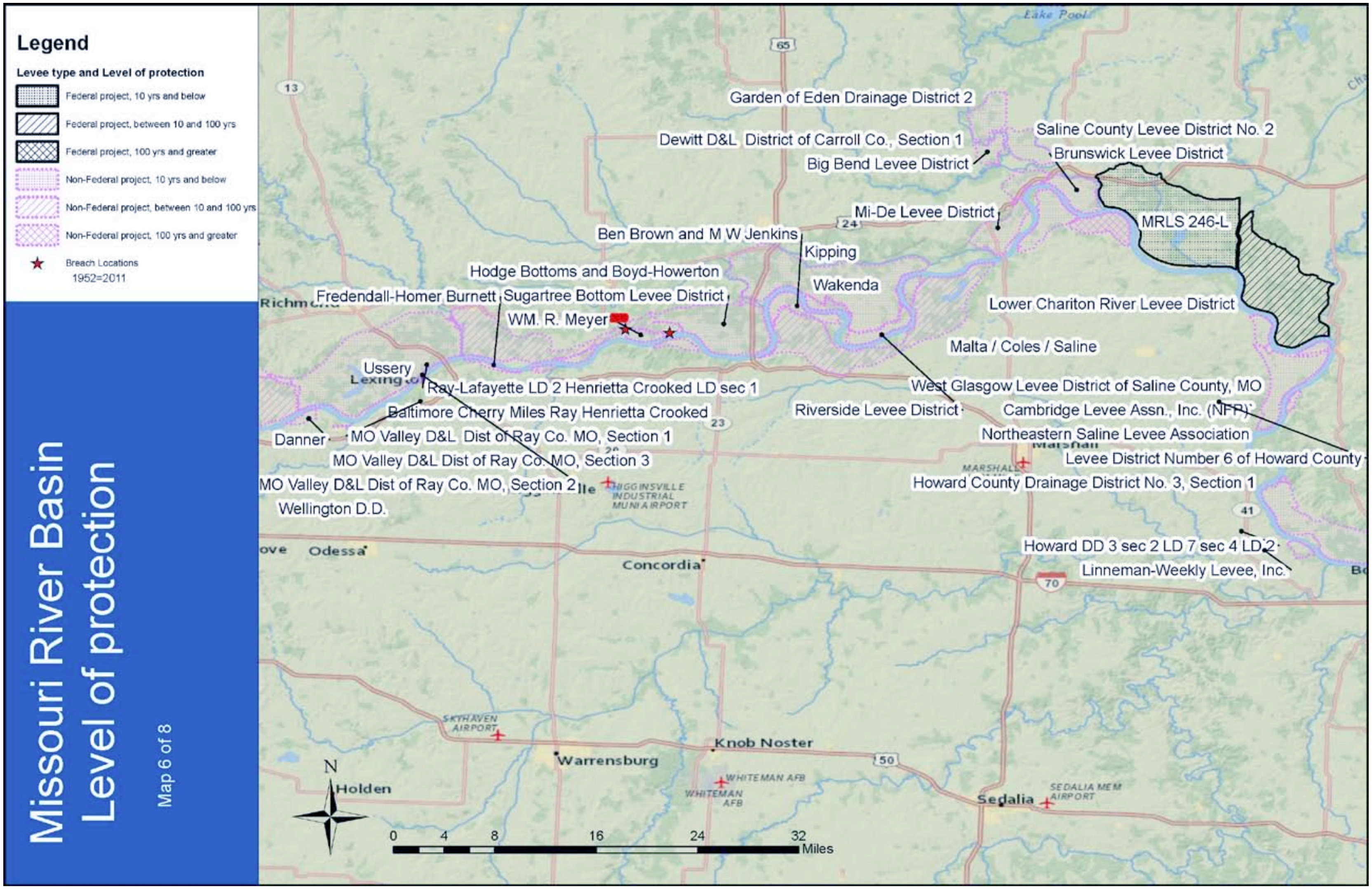

Figure 44. L-385 to MO Valley LD

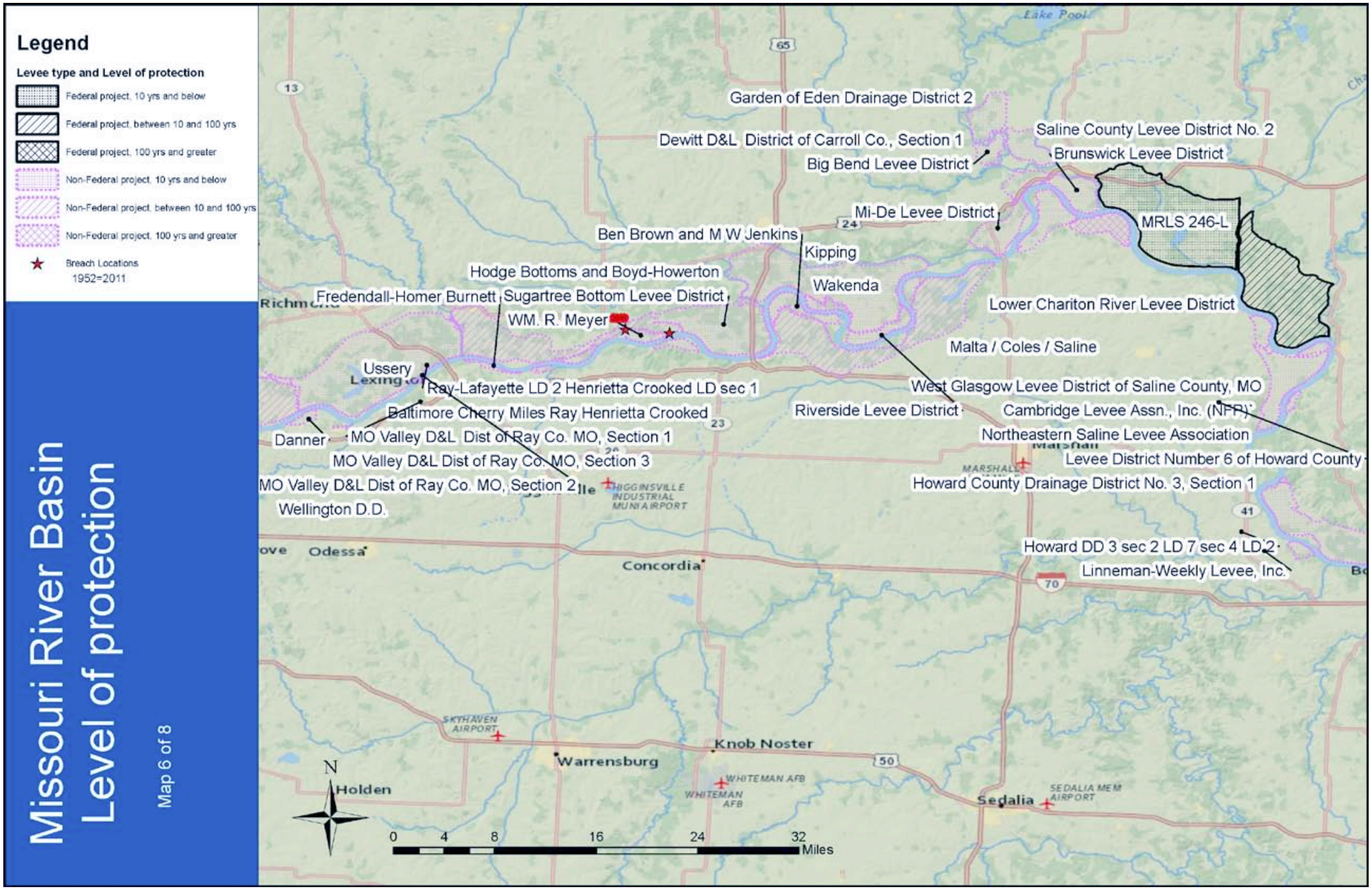

Figure 45. Henrietta LD - West Glasgow LD

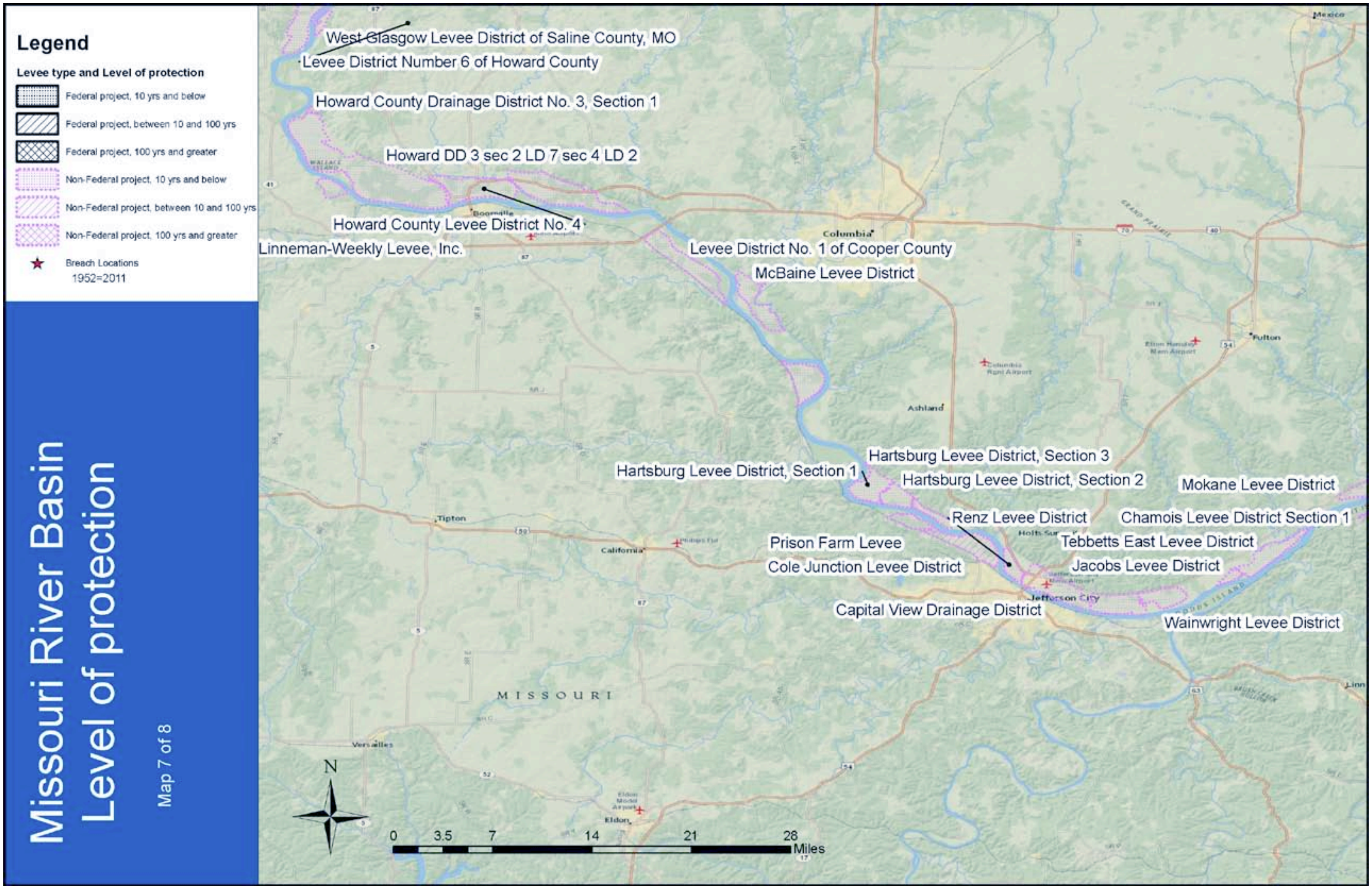

Figure 46. Howard City LD - Tebbets LD

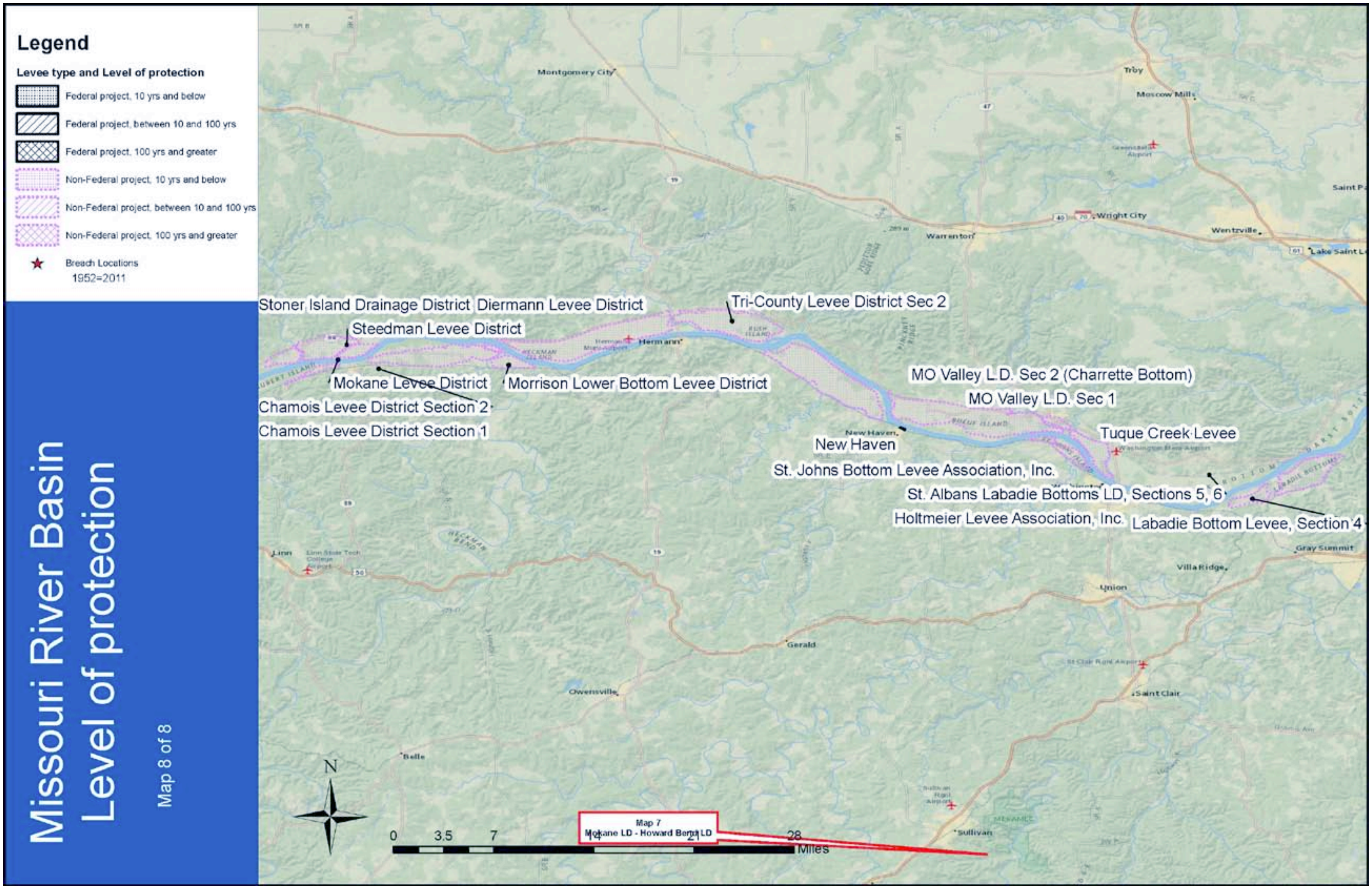

Figure 47. Mokane LD - Howard Bend LD

The federal levees are more robust in general, and were designed and constructed to Corps standards in place at the time of original construction. The non-federal levees were not necessarily constructed to Corps standards and had little if any detailed subsurface investigation or detailed design activities in advance of construction. The frequency at which the existing Missouri River levees overtop varies widely. In general, the federal levees were designed based upon an authorized discharge and currently overtop at a 100-year (1% annual chance of exceedance) frequency or greater events. The non-federal levees are significantly lower in profile than the federal levees and most overtop at 50-year (2% annual chance of exceedance) frequency events or less. The constructed Missouri River levee system therefore has obvious inherent vulnerabilities associated with inconsistent design standards and widely varying overtopping stages.

4.2.2.1 Omaha District (NWO) Levees

The NWO area of responsibility includes Missouri River levees upstream of Rulo, Nebraska. The Missouri River levee portfolio in the NWO area of responsibility includes 25 levee systems totaling approximately 253 miles. All are federally authorized with one exception, the Wa Con Da levee system.

4.2.2.2 Kansas City District (NWK) Levees

The NWK area of responsibility includes Missouri River levees from Rulo, Nebraska downstream to near the mouth at St Charles, Missouri. The Missouri River levee portfolio in the NWK area of responsibility includes 106 levee systems totaling approximately 917 miles. The Missouri River levees in NWK are a mix of both federally authorized (23 levee systems) and non-federal levees (83 levee systems).

4.2.3 Missouri River Levees Impacted by the 2011 Flood Event

Beginning May 26 and extending through October 16, 2011, the Missouri River experienced severe flooding. This flooding caused moderate to extensive damage to many of the levees within the basin that are currently active in the PL 84-99 Rehabilitation and Inspection Program (RIP). NWK and NWO identified and classified repair activities required to restore system reliability using a qualitative risk assessment process. This process considered the likelihood of a particular flood event occurring at any particular time, how the damaged levee would perform during the flood event, and the severity of the consequences if the damaged project was to fail during the flood event. For each damaged levee, the districts also identified and described potential failure modes based on an evaluation of the project's vulnerabilities. Lastly, the districts identified the likely consequences of inundation of the leveed area for each damaged levee if inundation were to occur.

Damaged levees were ranked in terms of risk, with risk being a function of both likelihood of inundation during subsequent flood events and the consequences of inundation. Life safety was the primary factor in consequence ranking, but damage to critical infrastructure and environmental impacts were also considered.

4.2.3.1 Discussion of Levee Performance/Vulnerabilities

4.2.3.1.1 Performance Monitoring

It is well established that the 2011 flood was unprecedented, and the 147 days the levees were loaded is months beyond the envisioned flood duration used in design of the federal levees. The flood also was unique in that it was predicted sufficiently in advance to allow both NWO and NWK to plan levee surveillance activities to obtain valuable levee performance data throughout the event. In addition to sponsor monitoring and flood fight efforts, districts used a combination of aerial reconnaissance coupled with boots on-the-ground performance monitoring by trained levee engineers, to identify performance areas of concern and to obtain valuable performance data useful in predicting levee performance under increasing loads. This is considered a best practice and will be repeated in future events as performance data of the levees under load are critical in developing rehabilitation designs, communicating inundation risks to sponsors, stakeholders and the public, and in scoping system-wide flood risk management improvements. Performance data is also important in that it advances Corps of Engineers methodology development related to base failure rates for various performance concerns for levees.

4.2.3.1.2 Vulnerabilities Resulting from 2011 Flood Damage

Damages to Missouri River levees from 2011 flooding revealed significant vulnerabilities that will remain until damaged levees are repaired. The damages of greatest concern with regard to levee performance are erosion, seepage, and slope stability. Each of these damage types can be influenced by secondary indicators. For example, seepage and piping could be influenced by levee vegetation (roots), corroded culverts, encroachments, inoperable relief wells, and animal burrows. Erosion of the riverside blanket can be a precursor to seepage issues or embankment stability issues.

Erosion

Erosion damage was widespread. The duration of the 2011 event was a key contributing factor to the erosion damages incurred. Many levees which performed satisfactorily or had minor erosion damage in the recent 2007, 2008, and 2010 flood events sustained heavy erosion damage in 2011. Highly erodible silts in the native blanket material, levee/foundation geometry and alignment, and river velocity were also factors impacting levee performance relative to erosion that were magnified by the long duration event. Lastly, activities such as revetment notching and chute construction as part of shallow water habitat restoration may have impacted the erosion performance and will be evaluated further. This issue is addressed elsewhere in this report.

Seepage

Nearly all levees loaded during the 2011 event exhibited significant underseepage which ponded landward of the levees, leading to partial inundation of the leveed area. Sand boils developed at many of these levees as well, with severity ranging from isolated pin boils to massive boils and/or boil fields requiring significant flood fight actions including emergency berm construction and emergency relief well installations to contain. These problems were often located at the end of seepage berms and in landward drainage ditches. Both districts also experienced significant damages to pump stations and appurtenant infrastructure, requiring emergency actions to prevent levee failures. The duration of the event was again a contributing factor relative to seepage performance. Further, erosion of the riverward blanket in some locations resulted in entrance conditions more critical than assumed for design. This condition contributed negatively to the seepage performance in several locations where significant riverside scour occurred.

Stability

Embankment slope stability issues were not as widespread as the seepage and erosion issues, but did occur on multiple levees. In general where embankment sloughing or slope failures occurred, the issues were either erosion induced instabilities affecting the riverward levee slope or related to concentrated embankment or foundation seepage affecting the landside slope.

4.2.3.1.3 Design Capacity

Design capacity is an important factor because it sets the conditions for maximum water surface that can be passed without inundating the leveed area. Design capacity for federally authorized projects was often originally set at the maximum flood of record, with some additional freeboard to account for hydrology and hydraulic uncertainty and settlement. Design capacity is also an economic decision.

Non-federal levee design capacity varies widely. PL 84-99 accepts in the RIP non-federally constructed, locally maintained levees and floodwalls that provide a minimum of a 10-year level of protection with 2-feet of freeboard to an urban area, or a minimum of a 5-year level of protection with 1 foot of freeboard to an agricultural area.

Most of the levees that were overtopped during the 2011 flood also ultimately breached due to overtopping. This included a total of 11 non-federal levees in the Kansas City District. None of these levees had appurtenant resiliency features such as a flattened landside slope or designed overtopping sections to resist the landward erosion caused by overtopping of the magnitude and duration experienced in this event. This is considered a significant long term vulnerability of the Missouri River levees.

The levees in Figure 40 provide risk management downstream of the last mainstem dam (Gavins Point). The extensive area impacted by the flood event contained numerous federal and nonfederal levees, with 75 levees damaged - stretching 500 miles on the Missouri River from Mile 623 to Mile 120.

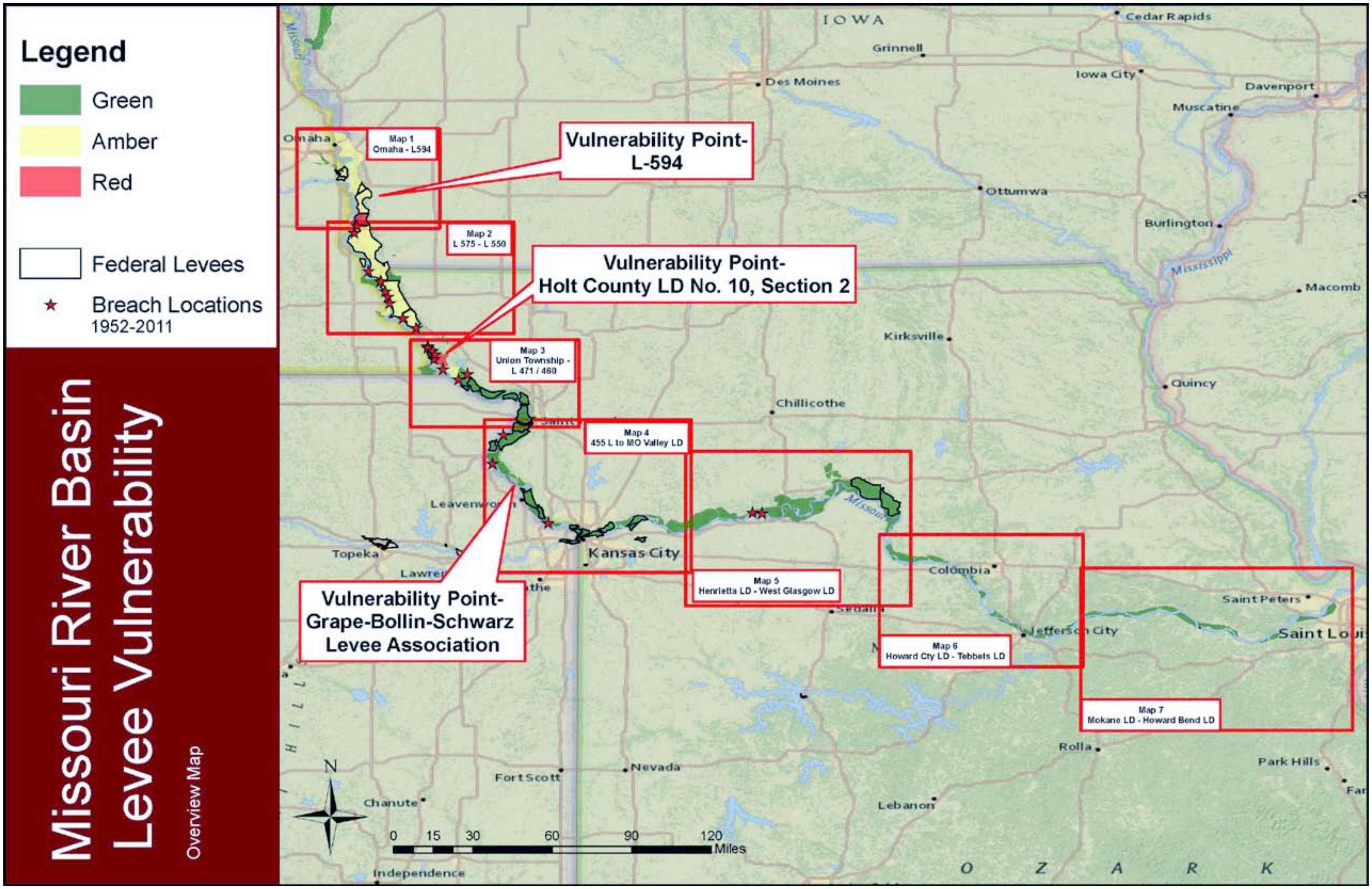

Figure 48. NWD Missouri River Levees Impacted in 2011 Flood

The following seven figures illustrate Missouri River levee-protected areas from north to south.

- NWO Levees – Figures 49 and 50 through L536 and R550
- NWK Levees – Figure 51 – Union Township through Figure 55

Green, amber, and red designations represent the flood vulnerability of the areas protected by the levees as of the printing of this report.

- Green **-** Levee will be substantially whole on that date for flood season. No breaches or significant scour concerns, riverside or landside. No significant seepage concerns. Levee is fully capable of meeting its designed purposes.
- Amber **-** Levee is substantially whole with a critical section that has been returned to design height; levee is flood fightable; or the temporary measure from last year is still in place. No breaches; major scouring addressed; (This will be a subjective call made by the district, so all aspects of what the district deems as being critical repair may not be listed here.)
- Red **-** Levee has breaches or major scouring such that the levee will not provide flood protection; it is not flood fightable.

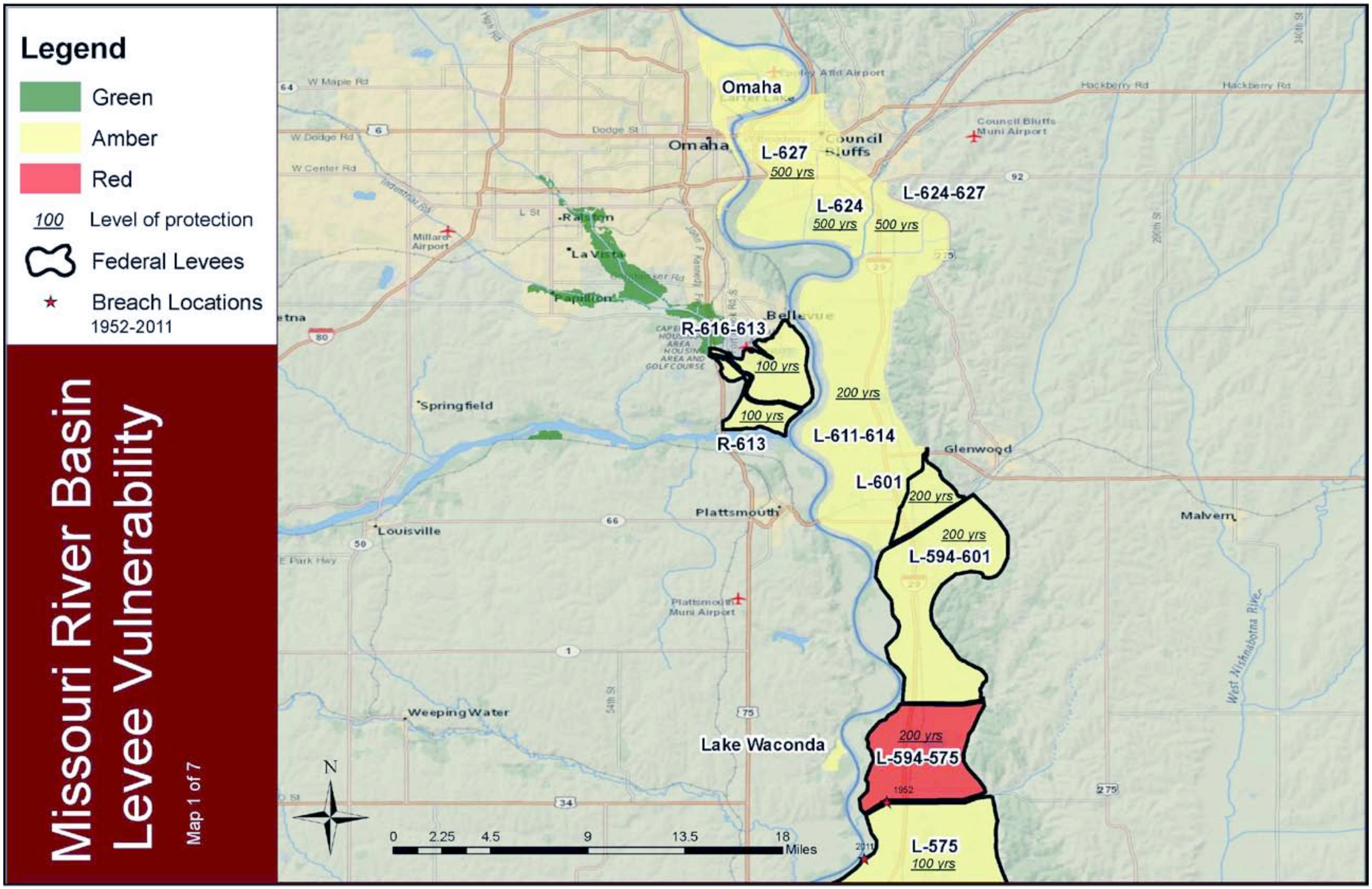

Figure 49. Omaha - L-594

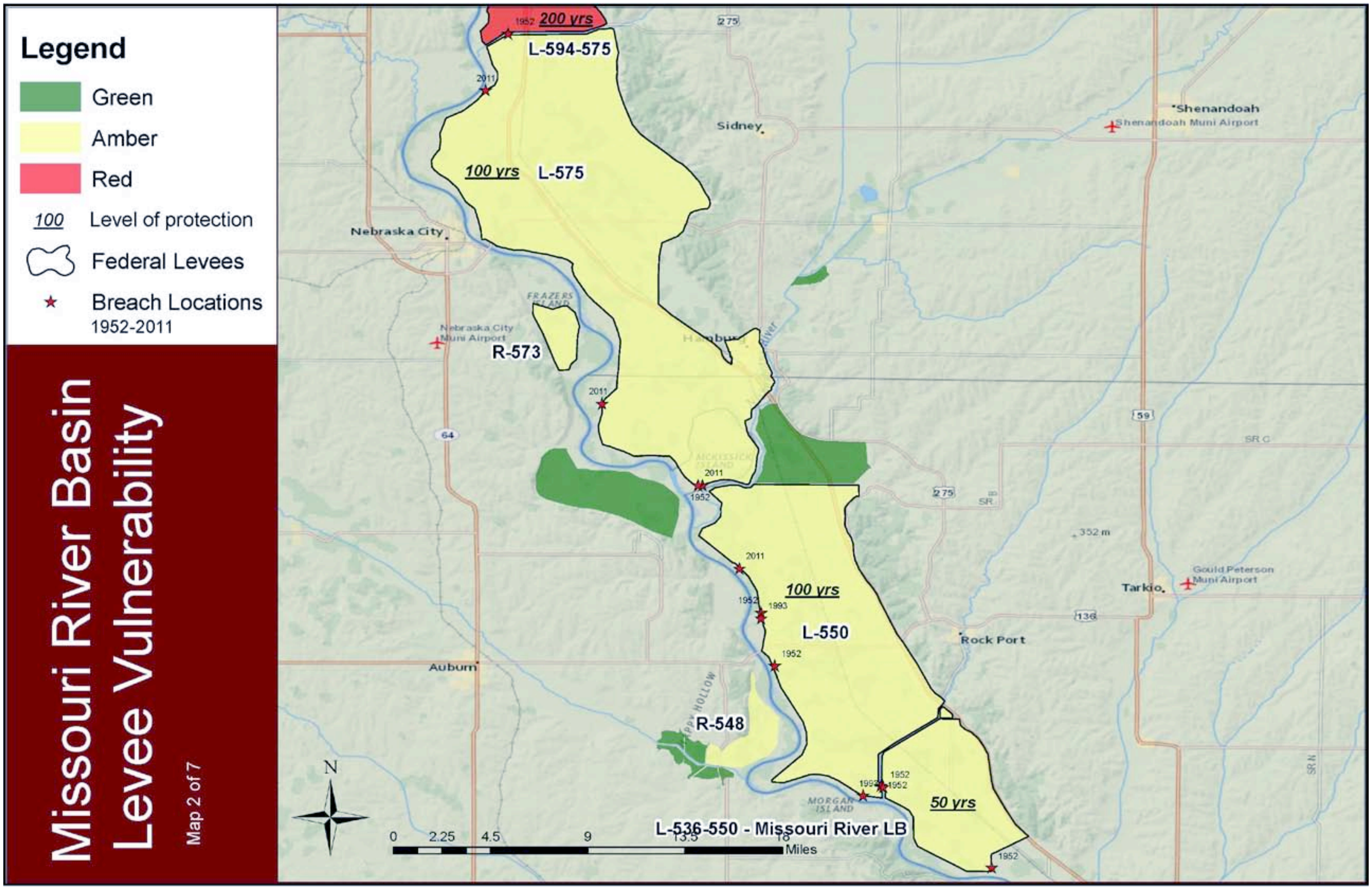

Figure 50. L-575 - L-550

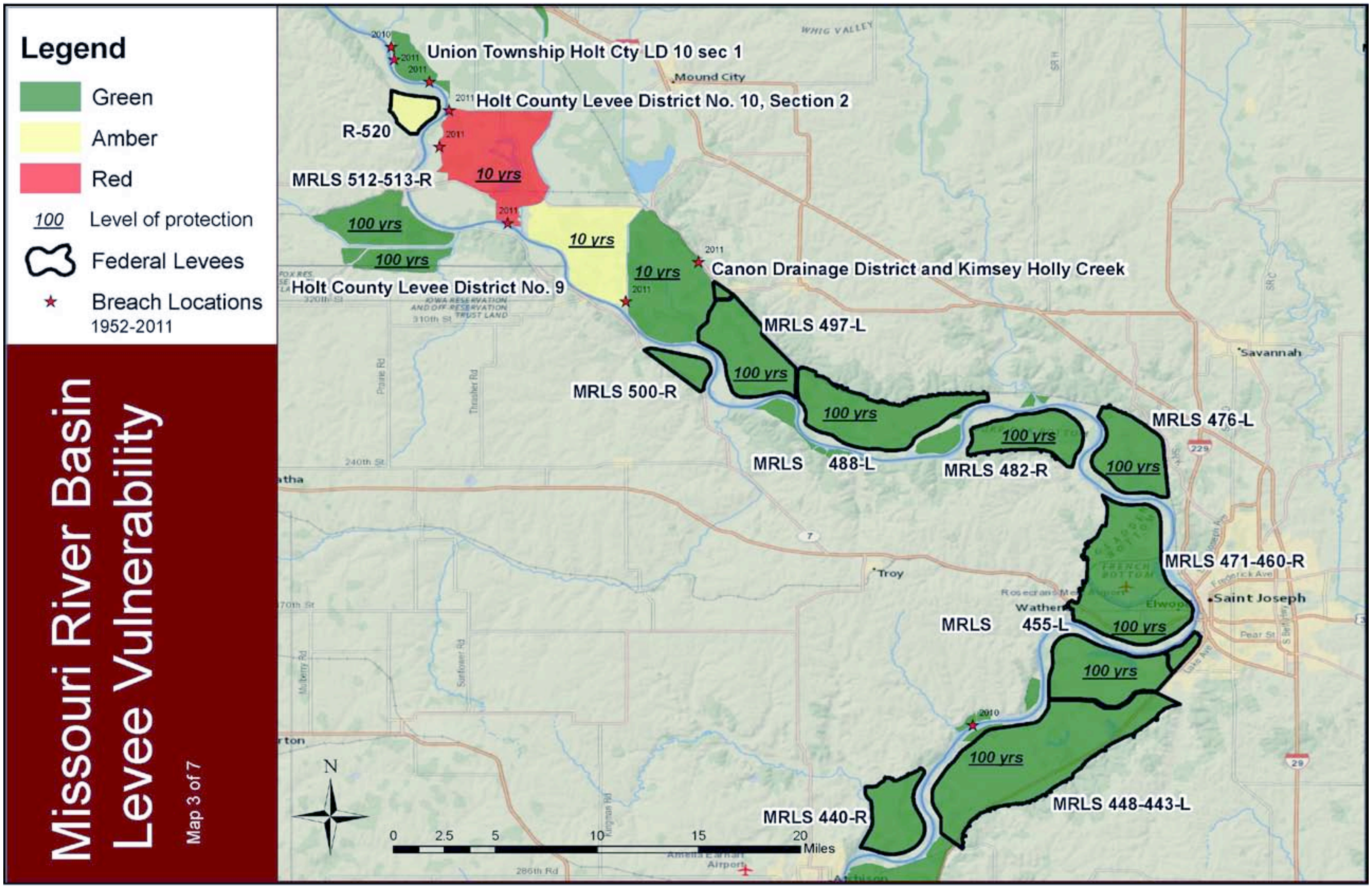

Figure 51. Union Township - L-471/460

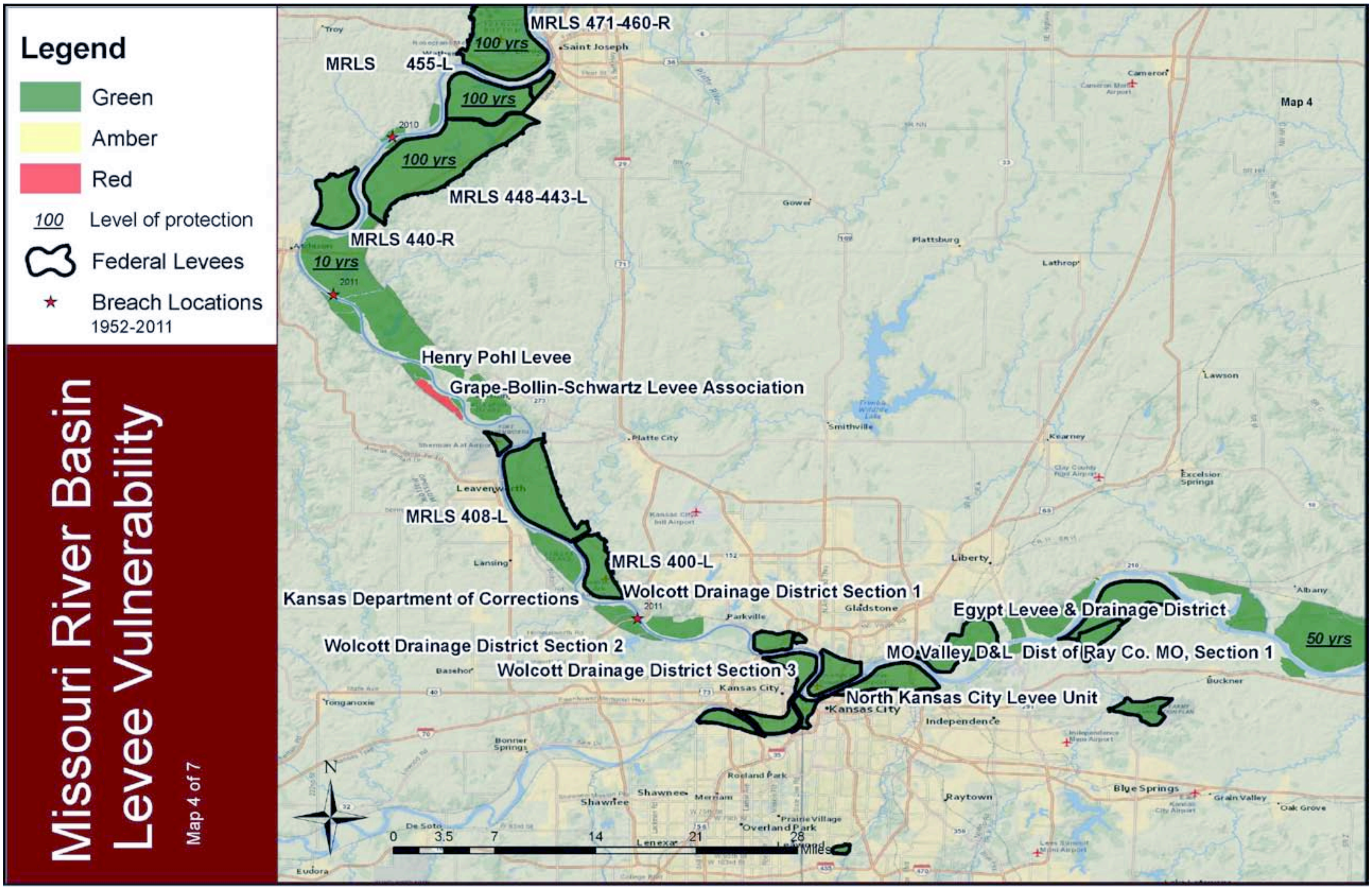

Figure 52. L 455 to MO Valley LD

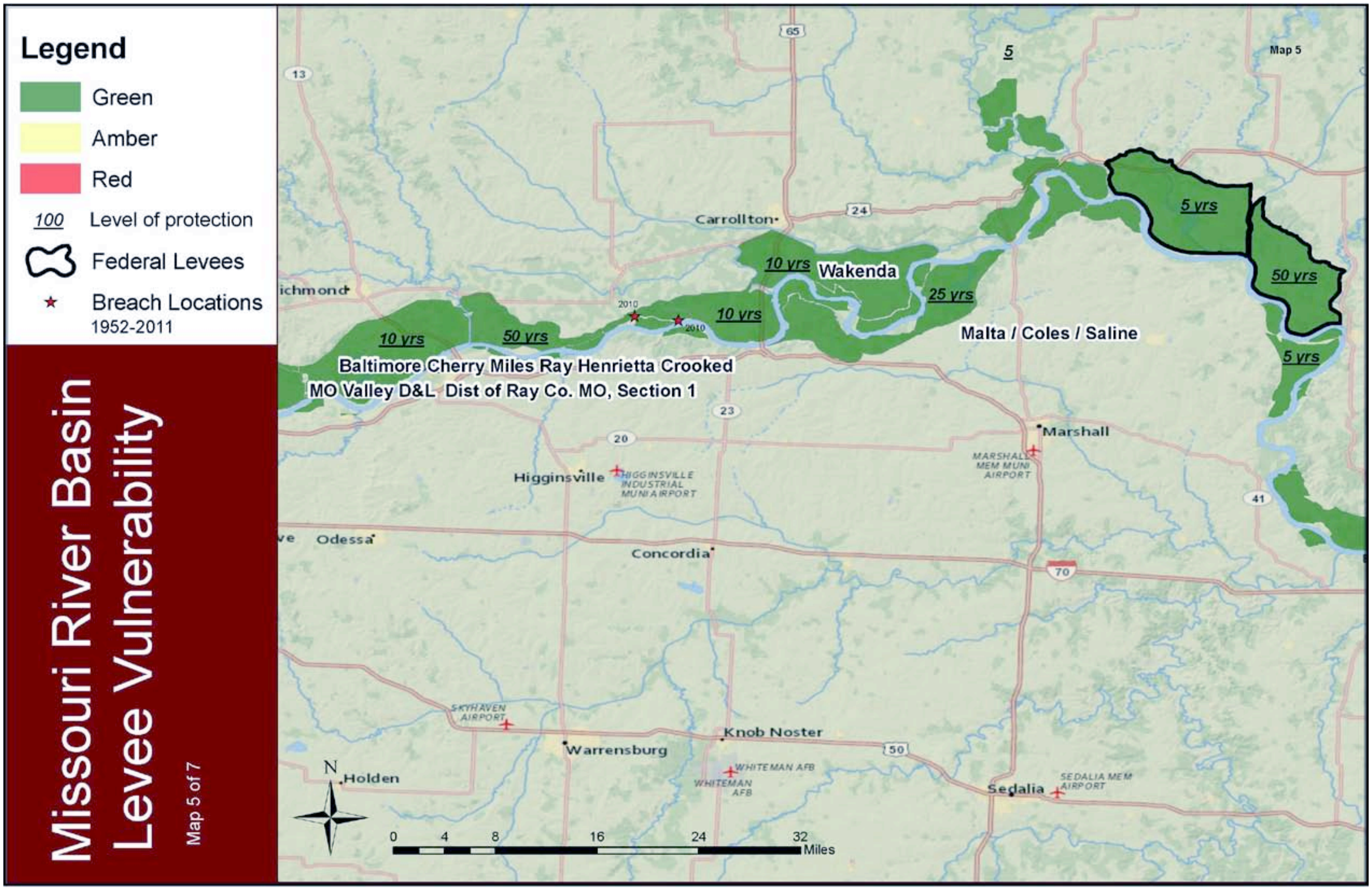

Figure 53. Henrietta LD - West Glasgow LD

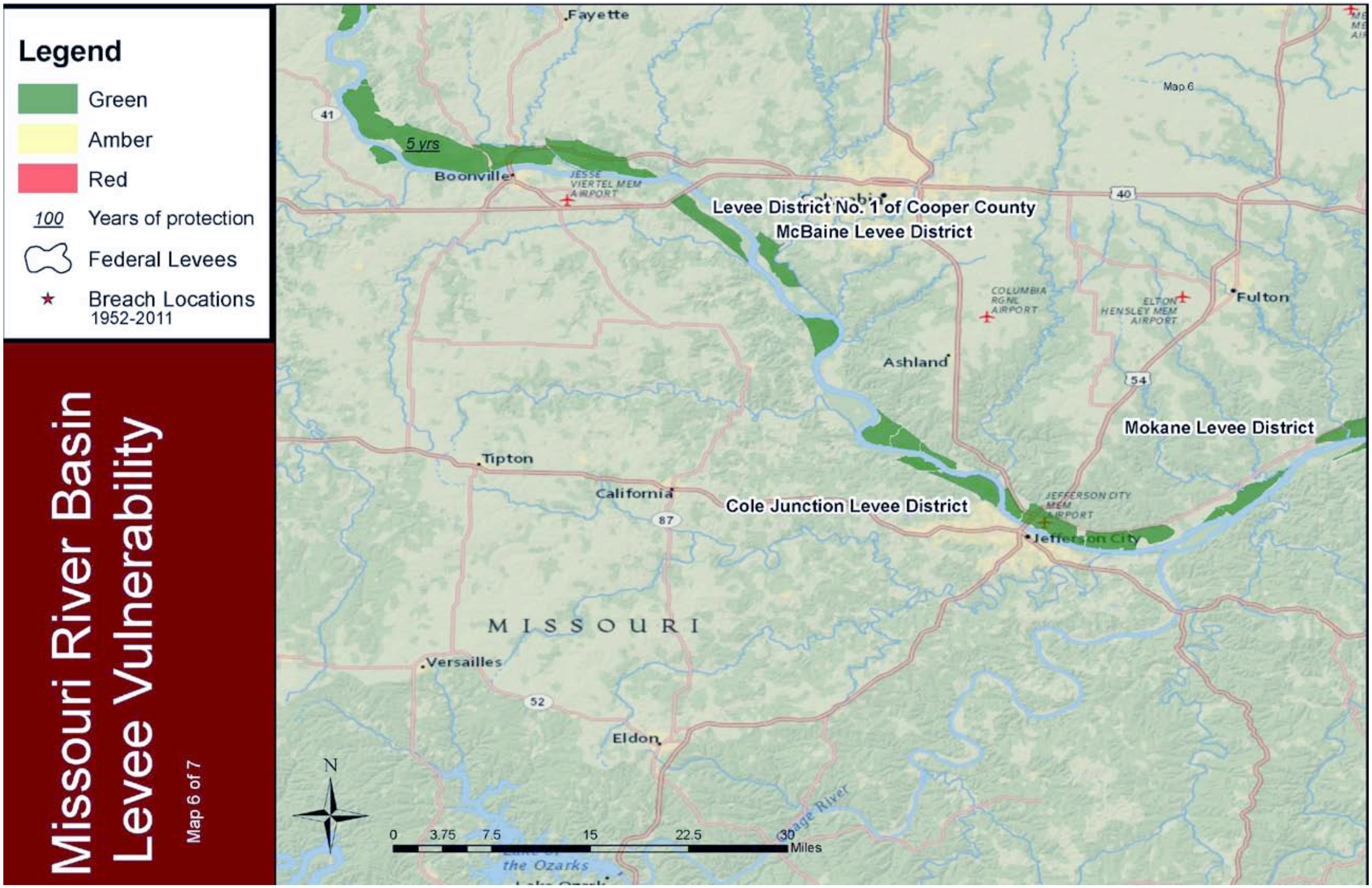

Figure 54. Howard City LD - Tebbets LD

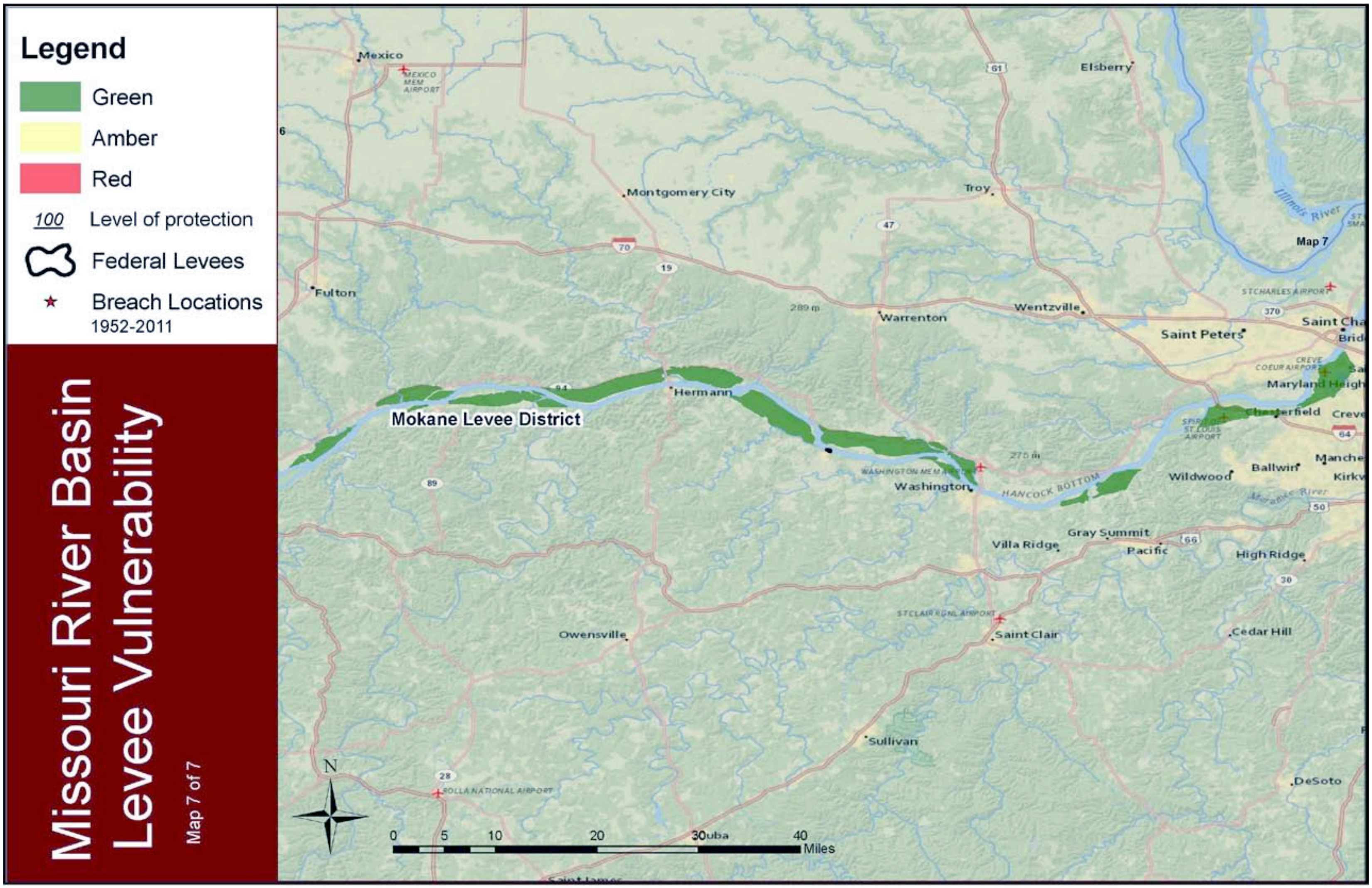

Figure 55. Mokane LD - Howard Bend LD

Table 22 lists over 60 levees which were damaged or require assistance.

Table 22. Levees Having Damage and/or Requiring Assistance

District	Project Type	Project Name	MR Mile Markers	State	City	PL84-99 Rehab	Direct Flood Asst	Technical Asst
NWO	Federal	MR Levee Unit R 627 (Omaha FPP)	623.5-611.7	NE	Omaha	Yes	Yes	Yes
NWO	Federal	MR Levee Unit L 624-627	619.6-605.8	IA	Council Bluffs	Yes	Yes	Yes
NWO	Federal	MR Levee Unit L 611-614	605.5-587.9	IA	Council Bluffs	Yes	Yes	Yes
NWO	Federal	MR Levee Unit R 616	601.7-596.6	NE	Bellevue	Yes	Yes	Yes
NWO	Federal	MR Levee Unit R 613	596.6-595.8	NE	Bellevue	Yes		Yes
NWO	Federal	MR Levee Unit L 601	587.7-580.3	IA	Pacific Junction	Yes	Yes	Yes
NWO	Federal	MR Levee Unit L 594	580.3-573.6	IA	Bartlett	Yes		Yes
NWO	Non-Federal	Lake Waconda	577.6-575.8	NE	Cass County	Yes		Yes
NWO	Federal	MR Levee Unit L575	573.6-543.7	MO/NE/IA	Percival	Yes	Yes	Yes
NWO	Federal	MR Levee Unit R 562	548.9-541.5	NE	Peru	Yes		Yes
NWO	Federal	MR Levee Unit R 573	557	NE	South of NE City	Yes		Yes
NWO	Federal	Ditch 6, Hamburg	552	IA	Hamburg	Yes	Yes	Yes
NWO	Federal	MR Levee Unit L 550	543.5-522.2	MO	Rockport	Yes	Yes	Yes
NWO	Federal	MR Levee Unit R 548	534.4-528.3	NE	Brownville	Yes		Yes
NWO	Federal	MR Levee Unit L 536	522.2-515.7	MO	Rockport	Yes	Yes	Yes
NWK	Non-Federal	Union Township Levee District	507.6 to 504.0	MO	Big Lake	Yes	Yes	Yes
NWO	Federal	MR Levee Unit R 520	505.5-501	NE	Rulo	Yes		Yes
NWK	Non-Federal	Holt County Levee District No. 10, Section 2	502.7 - 492.0	MO	Big Lake	Yes	Yes	Yes
NWK	Federal	MRLS 500-R	501.8 -496.8	KS	Doniphan	Yes		Yes
NWK	Federal	MRLS 512-513-R	497.3 - 495.0	NE	Rulo	Yes		Yes
NWK	Non-Federal	Holt County Levee District No. 9	491.8 - 486.2	MO	Fortescue	Yes		Yes
NWK	Non-Federal	Canon Drainage District of Holt County	486.2 - 482.8	MO	Forest City	Yes		Yes
NWK	Federal	MRLS 497-L	483.0 - 476.0	MO	Forest City	Yes	Yes	Yes
NWK	Federal	Kimsey Holly Levee District	482.8	MO	Forest City	Yes		Yes
NWK	Federal	MRLS 488-L	476.0 - 465.0	MO	Forbes	Yes	Yes	Yes
NWK	Federal	MRLS 482-R	467.0 - 458.0	KS	Doniphan	Yes		Yes
NWK	Federal	MRLS 476-L	461.0 - 455.0	MO	Amazonia	Yes		Yes
NWK	Federal	MRLS 471-460-R	456.6 - 441.7	MO / KS	Elwood / St. Joseph	Yes	Yes	Yes

District	Project Type	Project Name	MR Mile Markers	State	City	PL84-99 Rehab	Direct Flood Asst	Tech-nical Asst
NWK	Federal	MRLS 455-L	447.3 - 437.3	MO	St. Joseph	Yes	Yes	Yes
NWK	Federal	MRLS 448-443	438.0 - 428.0	MO	Halls	Yes	Yes	Yes
NWK	Non-Federal	Rushville-Sugar Lake	428.0 - 418.2	MO	Rushville-Sugar Lake	Yes		Yes
NWK	Non-Federal	Bean Lake Levee Association	418.2 - 411.3	MO	Bean Lake/Iatan	Yes	Yes	Yes
NWK	Non-Federal	Henry Pohl Levee	412.3 - 409.9	KS	Atchison	Yes		Yes
NWK	Non-Federal	Grape-Bollin-Schwartz Levee Association	409.9 - 406.2	KS	Leavenworth	Yes		Yes
NWK	Federal	MRLS 408-L	401.3 - 391.2	MO	Farley	Yes		Yes
NWK	Federal	MRLS 440-R	401.3 - 391.2	KS	Atchison	Yes		Yes
NWK	Non-Federal	Kansas Department of Corrections	394.0 - 388.0	KS	Leaven-worth	Yes		Yes
NWK	Federal	MRLS 400-L	391.2 - 384.8	MO	Waldron	Yes	Yes	Yes
NWK	Non-Federal	Wolcott Drainage District Section 1	386.4 - 383.7	KS	Wyan-dotte	Yes		Yes
NWK	Non-Federal	Wolcott Drainage District Section 2	386.4 - 383.7	KS	Wyan-dotte	Yes		Yes
NWK	Non-Federal	Wolcott Drainage District Section 3	382.3 - 381.3	KS	Wyandotte	Yes		Yes
NWK	Federal	North Kansas City	366.0	MO	North Kansas City	Yes	Yes	Yes
NWK	Non-Federal	Tri-County of Ray, Clay, Jackson District	341.5 - 337.0	MO	Clay	Yes		
NWK	Non-Federal	Egypt Levee & Drainage District	337.0 - 334.2	MO	Ray	Yes		
NWK	Non-Federal	MO Valley D&L Dist of Ray Co. MO, Section 1	333.8 - 326.2	MO	Orrick	Yes		
NWK	Non-Federal	Henrietta-Crooked River L&D District, Sec 1	313.8 - 311.8	MO	Henrietta	Yes		
NWK	Non-Federal	Henrietta-Crooked River L&D District, Sec 2	313.8 - 311.8	MO	Hardin	Yes		
NWK	Non-Federal	Ray County Levee & Drainage District	311.8 - 307.0	MO	Hardin	Yes		
NWK	Non-Federal	Miles Point Drainage District	307.0 - 304.2	MO	Norborne	Yes		Yes
NWK	Non-Federal	Cherry Valley Levee District	304.2 - 302.5	MO	Norborne	Yes		
NWK	Non-Federal	Baltimore Bend Levee	302.5 - 300.0	MO	Norborne	Yes		
NWK	Non-Federal	Belcher-Lozier Levee District	300.0 - 298.2	MO	Norborne	Yes		
NWK	Non-Federal	Sugartree Bottom Levee District	298.5 - 288.5	MO	Widespot	Yes		
NWK	Non-Federal	Saline Lafayette Drainage District	292.9 - 278.2	MO	Waverly	Yes		
NWK	Non-Federal	Wakenda (Farmers & Root)	288.0 - 282.5	MO	Wakenda	Yes		
NWK	Non-Federal	Malta Bend Levee District	277.0 - 273.5	MO	Saline	Yes		
NWK	Non-Federal	Teteseau Bend Levee Dist	273.5 - 263.2	MO	Grand Pass	Yes		Yes

District	Project Type	Project Name	MR Mile Markers	State	City	PL84-99 Rehab	Direct Flood Asst	Tech-nical Asst
NWK	Non-Federal	Miami Levee District No. 1	261.8 - 251.7	MO	Saline	Yes		
NWK	Non-Federal	Saline County Levee -No. 2	251.8 - 246.0	MO	Saline	Yes		
NWK	Federal	Lower Chariton	238.7 - 227.5	MO	Glasgow	Yes		
NWK	Non-Federal	Cambridge Levee Assoc	235.4 - 231.0	MO	Cambridge	Yes	Yes	Yes
NWK	Non-Federal	Levee District No. 1 of Cooper County	185.0 - 177.5	MO	Woolridge	Yes		Yes
NWK	Non-Federal	McBaine Levee District	179 - 175	MO	Huntsdale	Yes		
NWK	Non-Federal	Cole Junction	152 - 145.8	MO	Jefferson City	Yes		
NWK	Non-Federal	Mokane Levee District	121.4 - 120.7	MO	Mokane	Yes		

4.2.3.2 Recurring Problems

The following sections describe some of the recurring problems associated with the current levee alignments along the Missouri River. This section of the report is followed by an opportunities section where the unique opportunities associated with a levee setback levee are described.

Flood risk is a combination of the probability that damages will occur and the consequences of those damages. Levees provide a structural method of mitigating this risk. Levee safety encompasses many concepts related to the ability of a levee system to provide this mitigation.

In summary, the lands located closest to the river are naturally lower in elevation and are comprised of less suitable levee foundation soil types. By locating levees in these areas, flood conveyance results in increased velocity, leading to increased hydraulic loading and erosion. Increased hydraulic loading and erosion causes increased geotechnical concerns due to the less stable soil type near the river, and the need for greater levee heights to compensate for the lower ground elevations near the river and higher stages form encroachment of the floodway. In addition, these physiological conditions lead to increased levee damage due to the more frequent hydraulic loading and associated erosion, requiring more frequent and extensive O&M activities, as well as more extensive repair, rehabilitation and replacement (R,R&R) costs after a major flood event. These same low lying lands provide the greatest habitat potential and when disconnected from the river represent significant negative habitat impacts.

4.2.3.2.1 Flood Risk and Levee Safety - Hydrologic Conditions

Hydraulic constrictions are locations where an insufficient amount of flood conveyance exists. This limited conveyance leads to increased velocities, the potential for scour, and increased flood stages.

4.2.3.2.2 Hydraulic Constrictions and Resulting Problems

The April 1946 Missouri River Levees (Sioux City, Iowa to the Mouth); Definite Project Report, indicated through extensive investigations that “minimum floodway width between agricultural levees, based on the results of preliminary studies, prepared floodway widths between levees which would vary from a minimum of 3,000 feet from Sioux City, Iowa, to Kansas City, Missouri, and 5,000 feet from Kansas City to the mouth."

Further investigation during this assessment resulted in identifying numerous locations where the levee to levee floodway width or the levee to natural high bluff floodway width was significantly smaller than recommended in the 1944 Flood Control Act.

Table 23 illustrates the extent of pinch points and flow constrictions between Omaha/Council Bluffs and Rulo. It should be noted that at locations which have less width than the authorized 3,000 feet, a new floodway assessment would result in widths greater than 3,000 feet (estimated between 5,000 feet and 9,000 feet for the river reach between Omaha and Rulo). This table illustrates that numerous constriction points exist, specifically in the levee to natural high bluff conditions, and at bridges. A modern levee design would result in a more efficient hydrologic system, both along the levees and at bridge crossings.

Table 23. Top Widths at Constriction Points - Omaha/Council Bluffs to Rulo

Federal Levee System	Levee to Levee (feet)	Levee to Bluff (feet)	Width at Bridge (feet)
R-520		34,390	
L-536		3,280	
L-550	3,170	2,730	1,770
R-548	3,170		
R-562	3,780		
L-575	3,780	3,140	1,090
R-573	4,960		
L-594	4,090	2,780	
Lake Waconda	4,091		
L-601		3,010	
L-611-614	2,910	2,390	1,260
R-613	2,950		
R-616	2,910		2,500
L-624		10,510	
L-627	2,760		1,180
Omaha	3,000	2,890	1,180

By locating levees too near the river, hydrologic conditions are adversely impacted. The construction of a levee removes flow area available for the passage of flood waters. The areas located closest to the river generally provide the deepest flow areas and as such the most conveyance. In response, velocities increase and water surface elevations increase to obtain more flow area. Figure 56, taken from Heini and Pinter 2012, shows the typical response of hydrologic conditions resulting from the construction of a levee. For cross sections upstream or adjacent to a levee, this figure shows increased stages resulting from levee construction during high flow events.

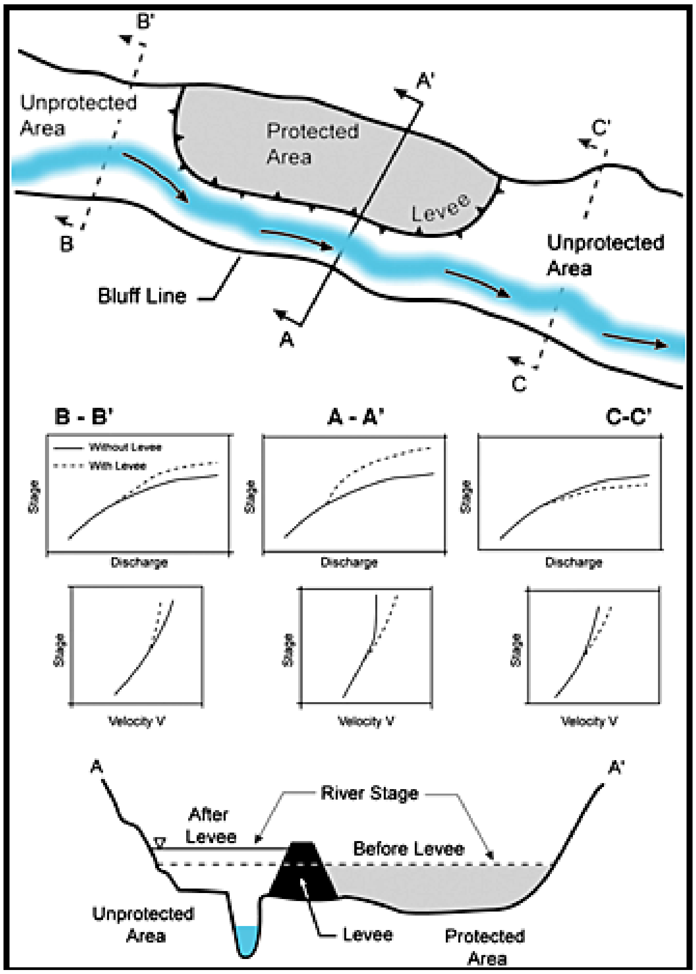

Figure 56. Impacts of Levees on Hydraulic Relationships (Taken from Heine, Pinter, 2012)

A plot of velocities along the Missouri River can be used to identify a number of locations with constrictions, or "pinch points". Figure 57 shows the velocities modeled in the 100-year flood event from Rulo to Bellevue, Nebraska. This figure identifies the relationship between manmade constrictions such as bridges and levees and high velocity locations.

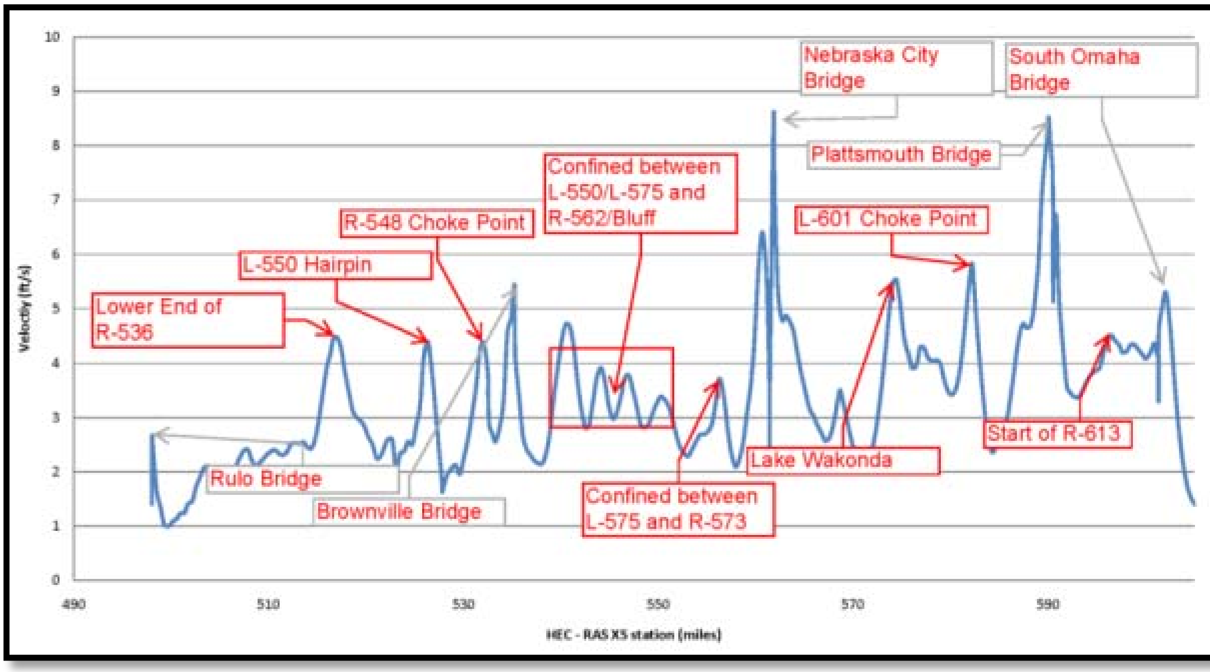

Figure 57. Velocity Profile of the Missouri River

Induced stages, or increased water surface elevations are the result of decreased conveyance and increased velocities. The construction of the Missouri River Levee System along with roadway and railroad embankments have contributed to increased flood stages (5+ feet), well in excess of 1 foot allowed by modern standards. These increased stages lead to increased frequency of overtopping of levee systems, as well as to higher hydrostatic forces, increased seepage, and ultimately higher risk of failure prior to overtopping. In addition to vulnerabilities to Missouri River levees revealed by damages from the 2011 flood event, various other vulnerabilities have been identified that have the potential to impact multiple levees or the entire Missouri River levee system.

4.2.4 Repair

4.2.4.1 Status of Rehab Activities (as of May 18, 2012)

Projects	NWO	NWK	Totals
Approved PIRs	19	47	66
Awarded Contract	11	19	30
Physically Complete		3	3
Total Rehab Projects	19	48	67

4.2.4.2 Levee Rehabilitation Considerations

ER 500-1-1 outlines the comprehensive requirements, intent and limitations of rehabilitation activities. Both districts complied with these requirements in the determination of what projects were going to be repaired and which ones were not. Key principles of ER 500-1-1 include:

- Levees must have been active in the RIP at the time of the flood event;
- Rehabilitation activities are to repair damage to a levee caused by the flood event;
- Damages attributed to negligent sponsor maintenance are not eligible for repair; and
- Repairs are intended to restore the levee to the pre-flood condition.

4.2.4.2.1 Rehabilitation Planning

The nature of levee rehabilitation often requires significant engineering judgment particularly in regard to what is considered flood damage, what would be considered a betterment, what is the appropriate level of investigative effort and design effort to develop rehabilitation plans, and what is the appropriate repair criteria. Pursuant to these concerns, NWK and NWO engineering staff participated in a meeting near the end of the flood event to develop similar design goals for levee rehabilitation. The reasons for developing similar design goals included limited funding available for rehabilitation and consistency for non-federal levee sponsors within NWD. The highest priority topics identified by both districts included repair of underseepage damage and repair of drainage structure/gatewells. The consensus approach and criteria for these items are outlined below.

Underseepage

A decision matrix for identifying areas for rehabilitation was established. The goal was to identify a series of key points that each district could use to determine areas that need rehabilitation. Engineering judgment will be necessary as each levee is evaluated. Justification for rehabilitation (or lack of rehabilitation) will be based on the following criteria:

- Levee loading when boil activity first occurred
- Magnitude of boil activity – small pin boils, large boil field, single boil, etc
- Location of boil activity – distance from toe, local features (ex - ditch), geological features (ex - channel meander).
- Level of response necessary during flood event to prevent levee failure
- Anticipated performance during future floods of equal or greater magnitude

Lack of concise, current USACE underseepage design criteria necessitated the development of criteria for rehabilitation. Minimum underseepage design criteria were established after a discussion of each district's current local practice.

Current NWO local practice for design and rehabilitation is Underseepage Factor of Safety (FS) = 1.6 at levee or seepage berm toe. Permanent Right of Way (ROW) is required for seepage berms, and farming is not allowed on long berms. If FS = 1.6 cannot be achieved within available ROW, wells are used at seepage berm toes.

Current NWK local practice for design is Underseepage FS = 1.6 at levee toe, graduated FS at berm toe depending on berm width (decrease of 0.1 per 100 feet of berm width). Current NWK local practice for design for rehabilitation is minimum of original design criteria but increased depending on field adjustments. Temporary ROW required for underseepage berms, and farming is allowed on long berms.

NWD minimum underseepage rehabilitation criteria were established as FS = 1.3 at levee toe and 1.0 at berm toe. Justification for higher criteria should be based on consequence of failure, level of risk, and specific features at each levee.

Drainage Structure/Gatewell

Standard criteria for drainage structure/gatewell rehabilitation were established after a discussion of each district's current local practice.

Current NWO local practice – Replace pipes using current criteria if there is any damage.
Current NWK local practice – In situ repairs if possible (flexible gaskets, liners, etc), otherwise replace using current criteria.

The NWD Standard Rehabilitation Criteria is: If the structure can be repaired/lined and there is no evidence significant material movement has occurred, the structure should be repaired. If the structure cannot be confidently repaired and/or there is evidence of significant material movement, the structure should be replaced using current criteria.

4.2.5 Restore

4.2.5.1 Vulnerabilities Previously Identified at Specific Systems

The federal levee system of the lower basin has shown vulnerabilities to flood events since the 1993 flood event. Flood events within the lower basins, including the 2011 event, has exposed vulnerabilities within federal levee system for over 20 years. Vulnerabilities of federal levees providing flood risk management along the major metropolitan areas of the Missouri mainstem and its Kansas River tributary have the potential to impact over $22 billion in economic infrastructure, as well as, the working environment and residences of nearly 200 thousand individuals within the metropolitan areas. Four major levee systems within the lower basin of the Missouri River and tributary continue to show vulnerability to major flood events; MRLS 455 and R460- 471, Kansas City's Levee system, Topeka Levee system, and Manhattan levees. These federal levees do not meet authorized design levels due to infrastructure weakness and/or low levee heights resulting in potential for undermining the integrity of the levee system through underseepage, flood walls failure, and overtopping of levees during high water events. These levee systems continue to fail to meet their authorized design levels and remain problematic vulnerabilities within the basin flood protection system. Of the four levee systems, two levee systems have units in the feasibility study phase (Kansas City Levees and Manhattan Levees) with the other two levees in design or have recently initiated construction contracts. These metropolitan areas and their high value regional and national economic structure remain high priority vulnerabilities due to underfunding for completion of study, design and construction. Restoration of the authorized levels of protection should remain a high priority to stakeholders of the basin.

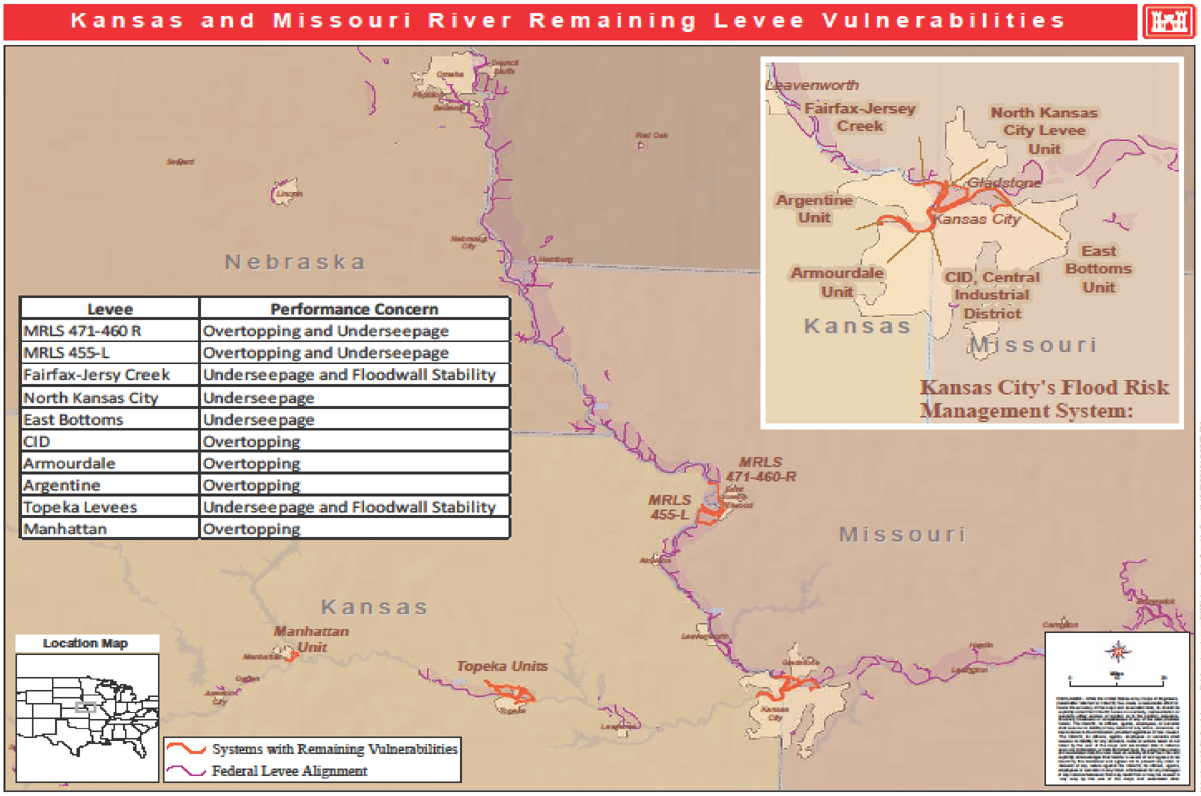

Figure 58. Kansas and Missouri River Remaining Levee Vulnerabilities

The following paragraphs provide more information on remaining vulnerabilities at specific levee systems.

4.2.5.1.1 Kansas City's Flood Risk Management System: East Bottoms

Underseepage control is needed near the confluence of the Missouri and Blue Rivers along the Blue River tieback segment. The geotechnical Risk and Uncertainty (R&U) analysis is corroborated by observations during the 1993 flood event. Approximate annual chance of exceedance (ACE) is 0.001 (1000-year levee). Population at risk is 17,489 during the day and 6,638 at night. Levee failure would inundate 712 structures and cause $3.4 billion in damages. Critical infrastructure includes: KCPL Power Plant, KCMO Wastewater Treatment Plant, major railroad infrastructure, and industries with potentially environmentally damaging materials stored on site. Pre-construction, Engineering and Design (PED) is scheduled to begin in FY 12 and last for 2-3 years. Start of construction could possibly begin in FY 15.

4.2.5.1.2 Kansas City's Flood Risk Management System: North Kansas City, Lower Segment

Underseepage control improvements are identified at two areas: Harlem and National Starch. The geotechnical R&U analysis is corroborated by observations during the 1993 flood event and from documents associated with mid-1950's construction efforts which essentially state that additional underseepage control measures may be needed if verified by future flood performance observations. Approximate ACE is 0.0013 (750-yr levee). Population at risk is 29,688 during the day and 10,948 at night. Levee failure would inundate 1,927 structures and cause $2.0 billion in damages. Critical infrastructure includes: downtown Kansas City Airport; railroad yards, and downtown North Kansas City. Current and planned construction activities for the installation of relief wells to address underseepage issues should be complete by the end of FY 13.

4.2.5.1.3 Kansas City's Flood Risk Management System: Fairfax-Jersey Creek

Underseepage control and increased floodwall pile capacities are needed at the floodwall along Board of Public Utilities (BPU) Power Plant. Analysis of flood loading to top of wall indicates unacceptable probability of failure due to overstressed foundation elements. Reconstruction of the sheet-pile wall along Kansas City, Kansas Municipal Wharf is necessary based on geotechnical risk analysis and overall existing wall conditions. Analysis suggests failure of sheet-pile wall under flood conditions would lead to progressive scour and ultimate failure of floodwall atop levee. Population at risk is 8,944 during the day and 2,236 at night. Levee failure would inundate 347 structures and cause $2.6 billion in damages. Critical infrastructure includes: KCKS BPU Power Station, major railroad infrastructure; General Motors Fairfax Assembly Plant, and multiple industries with potentially environmentally damaging materials stored on site. These projects are currently in design, and a possible construction start could occur in FY 13. Construction is expected to last two years.

4.2.5.1.4 Kansas City's Flood Risk Management System: Lower Kansas River Units

Analysis of overtopping risk shows that three levee systems (Argentine, Armourdale, and Central Industrial District) along both sides of the lower Kansas River do not meet the authorized 390,000 cfs conveyance target. This indicates a need for an increase in the existing overtopping protection along all three units. In addition to the need for decreasing the overtopping risk, analysis of geotechnical and structural risks indicate the need for some limited measures to improve underseepage control and a significant need for measures to reduce structural and uplift risk at three major pump stations. Design activities are scheduled to begin in FY14 and last two to three years. Start of construction is unknown, but will require congressional authorization in a Water Resources Development Act (WRDA) bill.

4.2.5.1.5 Missouri River Levee System R471-460

Analysis of overtopping risk shows that this unit does not achieve the authorized conveyance target. Over ten miles of the unit requires a raise, with a maximum raise between 3 and 3.5 feet. Population at risk is 1,546 during the day and 1,633 at night. Levee failure would inundate 751 structures and cause $0.3billion in damages. Critical infrastructure includes: Rosecrans Airport (primary St. Joseph airport), the base for the 139th Airlift Wing of the Missouri Air National Guard; US-36 highway; and multiple industries with potentially environmentally damaging materials stored on site. Design activities are underway. Start of construction could occur in FY13 if funding is available. Construction will take several years.

4.2.5.1.6 Missouri River Levee System L-455

Analysis of overtopping risk shows that this unit does not achieve the authorized conveyance target. A portion of the unit requires a raise of about one foot. Additionally, several drainage structures will require a raise and the existing underseepage control system will require an expansion. The population at risk is 5,106 during the day and 3,920 at night. Levee failure would inundate 1,470 structures and cause $0.6

billion in damages. Critical infrastructure includes: KCPL Power Plant; St. Joseph Wastewater Treatment Plant; and an elementary school. Design activities are underway. Start of construction could occur in FY13 if funding is available. Construction will take several years.

4.2.5.1.7 Topeka Levees

The existing system of 6 levee units provides local flood risk management for the metropolitan area of Topeka, Kansas. Analysis of overtopping risk shows that levee height is sufficient, but there is a risk of levee failure on some units at less than the design flood due to structural and geotechnical concerns. The levee units which require modification include the South Topeka Unit, Waterworks Unit, Oakland Unit, and North Topeka Unit. Proposed improvements include underseepage controls, floodwall replacement, and replacement of floodwall gatewells and sluice gates. Design activities are underway and construction could occur in FY14 if funding is available. Construction will take several years.

4.2.5.1.8 Manhattan Levee

The City of Manhattan, Kansas and an unincorporated area of Pottawatomie County, Kansas are protected from Big Blue and Kansas River flooding by the Manhattan Levee. Level of protection is a major concern based on observations from the Flood of 1993 that indicated the levee does not provide the authorized level of protection. The area protected by the levee includes more than 1,500 homes and more than 500 businesses and public facilities, including a regional shopping mall and numerous other commercial and industrial facilities estimated at more than $800 million in value. This project is currently in the Feasibility Study phase with an Alternative Formulation Briefing anticipated for late FY13.

4.2.5.2 Non-Federal Levees with Little Resiliency to Overtopping

Most non-federal levees have an annual chance of exceedance for incipient overtopping of 0.04 or greater (i.e., they are 25-year levees or less). For comparison, most federal levees are 100-year to 500-year levees. Non-federal levees are also not constructed with any specific features that would provide resiliency to overtopping. The result is that these levees typically breach when overtopped. The impacts of levee breaches, including scouring of the foundation and deposition of sediment across areas landward of the levee alignment, are much worse than the impacts of overtopping alone. The vulnerability of overtopping-induced breaches at many non-federal levees could be improved with the addition of special features that would improve levee performance during overtopping conditions. Such features could include specially designed overtopping reaches, armoring of the landside slopes, or the installation of more erosion-resistant levee vegetation.

4.2.5.3 Missouri River Bank Stabilization and Navigation Project

The Missouri River Bank Stabilization and Navigation Project (BSNP) spans over 700 miles of the Missouri River from Sioux City, Iowa to the mouth, located near St. Louis, Missouri. The existing BSNP maintains a channel that is 9-feet deep and 300-feet wide. Features of the BSNP consist mainly of rock revetments and dikes that restrict lateral movement of the river channel and maintain a self-scouring navigation channel. The BSNP positively affects levees by controlling the meandering of the river and preventing excessive riverbank erosion. O&M activities on the BSNP are critical to ensuring the continued performance of the project. Damages to the BSNP from 2011 flooding are estimated to cost about $30 million and will take between four and six years to repair. Adequate future O&M funding is critical to ensure the continued performance of the BSNP project and the benefits that it offers to Missouri River levees.

4.2.5.4 Funding for Levee Safety Program

The Levee Safety Program is an effective and established program ideal for identifying and managing vulnerabilities to Missouri River levees. The intent of the program is to regularly assess, communicate, and manage the risks to people, property, and the environment from inundation that may result from breach, overtopping, or malfunction of components of levee systems. Funding continues to be a challenge for levee safety program activities but is critical to ensure that the levee safety program can continue to be successfully executed.

4.2.6 Other Vulnerability Considerations

4.2.6.1 Ice Jams

A discussion on ice jams is included in the Upper Mississippi River System Flow Frequency Study, Hydrology and Hydraulics Appendix F Missouri River, November 2003. The flood history within the Missouri River basin provides documentation of numerous impacts of ice causing much higher stages than would normally occur for an open water condition. Refer to the flood history section of that report for a detailed discussion of ice impacts. The hydrologic analysis evaluated the requirement for an ice affected flow. The hydraulic analysis does not include any adjustment for ice. Typically, flood events in the early spring will include floating ice with the potential for ice jams to occur. Installation of the mainstem dams has altered the frequency of spring floods and the accompanying ice jams. However, extreme flood events in the upper reaches of the Missouri River may include ice conditions.

4.2.6.2 Pick-Sloan vs. Actual Levee Assignments

- Levees upstream of Omaha, Nebraska identified in the Pick Sloan Plan were never constructed.
- Nearly all levees between Omaha, Nebraska and Rulo, Nebraska are federally authorized and were constructed in accordance with the Pick-Sloan Plan.
- The lone exception is the Waconda levee which was non-federally constructed.
- Downstream from Rulo, the constructed levees deviate significantly from the Pick Sloan plan, with the majority of levees in this reach of the river being non-federal levees. The non-federal levees were not constructed according to Pick-Sloan. In many cases the levee location is approximately as planned, but the incipient overtopping event is much less than envisioned in the Pick-Sloan Plan.
- Levee's alignments in many cases also constrict the flow. Setback alignments should be evaluated with sponsors and constructed where feasible.

4.2.7 Recommendations

- Complete rehab to repair damage to Missouri River levees from the 2011 Missouri River flood event. (Short term)
- Complete improvements proposed in Section 216 studies to restore projects to authorized capacity. (Long term)
- Continue with on-going Levee Safety Program activities including inspections and risk screenings to facilitate communication of risks, the development of Interim Risk Reduction

Measures (IRRMs) and the development of long term corrective actions as required. (Long and Short term)

- Work with locals to pursue building resiliency into low profile levees that overtop at events greater than 50-year frequency. (Long term)
- Work with locals to remove constrictions/install setback levees where possible to open up the floodway. (Long term)

A more risk based approach, adherence to new levee safety regulations, and habitat impacts would indicate that if the Missouri River levees were aligned today, they would likely be different. Levee setbacks, which are associated with the National Standards Assessment Program (NSAP) process, provide an opportunity to modify the existing alignment to be more in-tune with modern levee design approaches.

Figure 59. Corps officials from the Omaha District of the U.S. Army Corps of Engineers meet with members of Responsible River Management at the lower breach of Missouri River Levee Unit L-575 south of Hamburg, Iowa

5. Other Considerations

5.1 TRIBAL RELATIONS AND CULTURAL RESOURCES

5.1.1 Tribal Relations

5.1.1.1 Background

The Flood Control Act of 1944 authorized the Corps to construct five mainstem dams on the Missouri River. As the mainstem projects were developed, a little more than 339,000 acres of reservation land were taken from seven tribes. The land that was taken and subsequently inundated was the most fertile and wooded bottom land that the tribes had and was considered the most productive agricultural, hunting, and collecting land. Ultimately, over 1,000 tribal families were affected and required to relocate. The community infrastructure for each of the seven affected tribes was impacted as well and required relocation. Additionally, tribal economies and cultural resources were significantly damaged and the associated effects are still felt in the present day tribal communities.

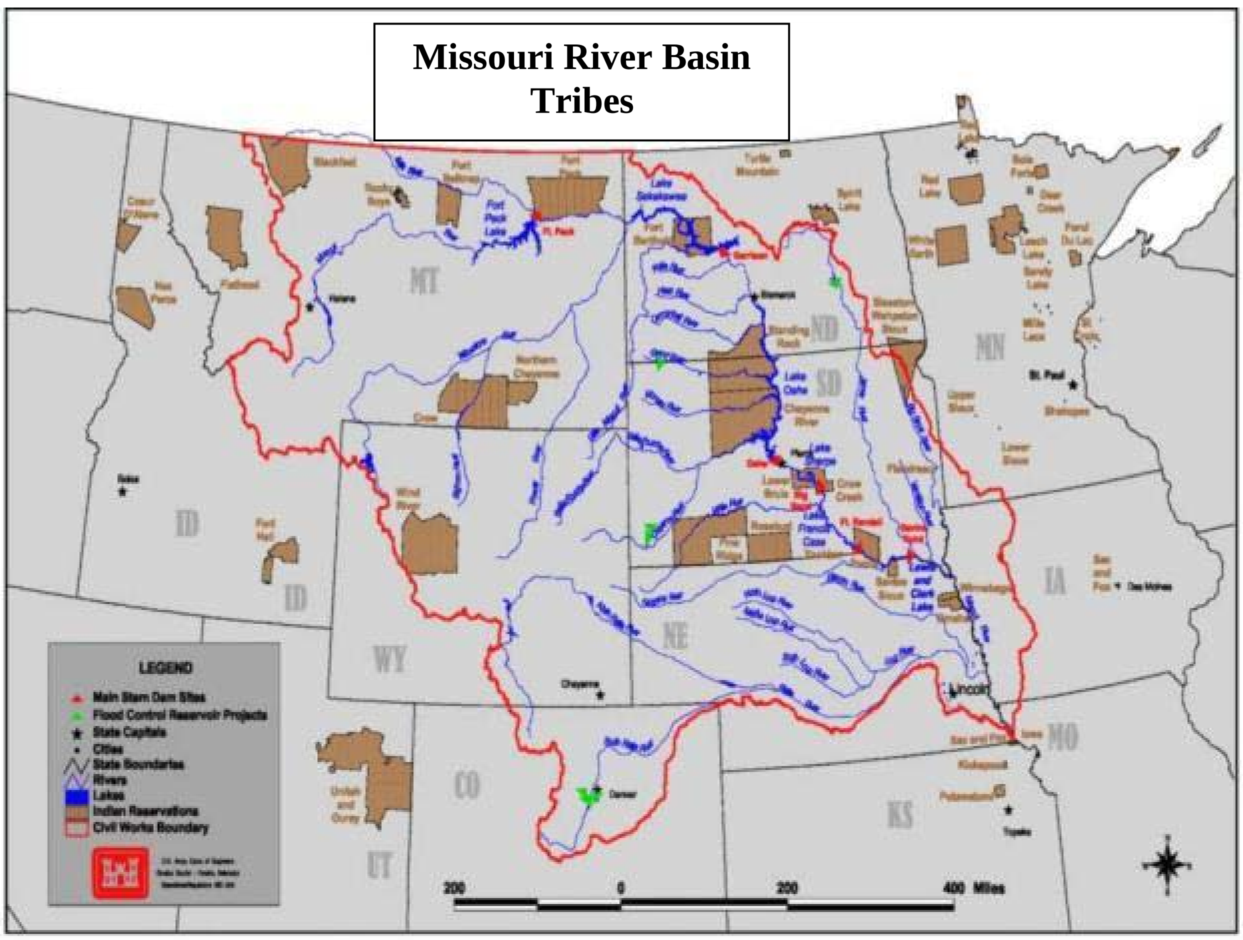

Figure 60. Map of Native American Tribes

5.1.1.2 Why Include Tribes?

The United States has a unique legal and political relationship with Native American tribal governments, established through and confirmed by the Constitution of the United States, treaties, statutes, executive orders, and judicial decisions. The Missouri River basin is home to 29 Native American Tribes (Figure 67). The federal government is required to honor its obligations and meet its trust responsibility to these tribes. This includes representing the best interests of the tribes, their resources, and their members. In general, trust responsibility includes a federal obligation to:

- Consult with tribal governments prior to taking actions that may affect tribal interests or trust resources.
  - Tribal "trust resources" include land, air, water, vegetation, wildlife, and fisheries.
- Respect "reserved rights."
- Protect, preserve, and perpetuate Native American cultural, subsistence, and religious sites on land managed or held in trust by the federal government.

As the Corps works to address the myriad of questions, concerns, and system repairs resulting from the 2011 flood they will need to remain cognizant of the unique relationships and responsibility the Federal Government has to the basin's tribes. Relationships will need to be established or maintained where all federally recognized tribes are acknowledged as sovereign entities and will be treated with respect. The trust responsibility to these tribes will be honored and fulfilled through tribal partnerships and by addressing tribal concerns regarding trust resources, treaty rights, and reserved rights. A government-to-government relationship will be maintained with tribes in which sufficiently early pre-decisional consultation is an integral part of the planning and implementation process.

5.1.1.3 Challenges

Tribal relationships are good, but the Corps' shared history with the tribes is difficult to overcome. The tribes attribute poor water quality; increased trespassing and theft or damage to cultural resources; artificial sediment deposits that impact water infrastructure; harmed fisheries; damaged riparian habitat; and increased recreational traffic and its associated impacts to the operation of the Missouri River system. The Missouri River basin is large which requires the commitment of significant resources for minimal engagement. This is difficult because the Tribes are spread throughout the basin and are mostly located in remote rural areas that are difficult to reach at times. The Tribes also have limited resources and staffing making travel throughout the basin for multiple meetings cost prohibitive. Lastly, tribes have significant issues and concerns related to Missouri River tributaries. With the loss of the Missouri River Ecosystem Restoration Plan (MRERP), the Tribes feel they have lost their opportunity to discuss their specific issues. Therefore, they feel disenfranchised and believe that what they have to say is not considered important or valued.

There are significant challenges that lay ahead. However, the next section focuses on the Corps' trust responsibility to protect tribal cultural resources and sites of cultural and religious significance to Tribes from erosion, encroachment, looting and vandalism. There are over 8,691 miles of shoreline under Corps management, which contain approximately 11,200 archaeological and sacred sites. Unfortunately, the level of funding needed to meet the Corps' obligation far exceeds the amount of funding that is available creating one system vulnerability.

5.1.2 Cultural Resources

5.1.2.1 Background

The Corps is responsible for compliance with the National Historic Preservation Act (NHPA). Section 106 of the NHPA requires the Corps to take into account the effects of its undertakings and regulated actions on historic properties (sites listed on or eligible for listing on the National Register of Historic Places). For federally-owned land, Section 110 of the act requires federal agencies to establish a program to preserve, protect, identify, evaluate, and nominate historic properties under their jurisdiction or control, including traditional cultural properties (TCPs) and historic properties to which Native American Tribes attach religious and cultural significance, in consultation with others.

Under NHPA obligations, the Corps is required to coordinate and consult on cultural resource matters with State Historic Preservation Officers (SHPO), Tribes, and other interested parties. In addition, the Corps is required to meet its tribal trust obligations, protect trust resources, and obtain Tribal views of trust and treaty responsibilities or actions related to the Corps, in accordance with provisions of treaties, laws and Executive Orders, as well as principles lodged in the Constitution of the United States. Impacts to cultural sites managed by the Corps greatly affect the Corps' relationships with Tribes. Omaha and Kansas City Districts have always encouraged and fostered relations with our Tribal partners. The Omaha District has engaged in extensive outreach and Tribal consultation since the signing of the Programmatic Agreement for the Operation and Management of the Missouri River Main Stem system in 2004. Tribes have expressed deep concern over damages to cultural resource sites caused by the recent flooding and related repair activities and have demanded that the Corps provide the required due diligence in identifying and protecting these sites.

5.1.2.2 Cultural Resource Implementation

Kansas City and Omaha Districts are required to comply with preservation laws.

The Kansas City District complies with Section 106 of the NHPA for all Corps undertakings and regulated projects. Corps owned lands in the lower basin, primarily lands acquired under the Missouri River Mitigation Project, also require stewardship as required by Section 110 of the NHPA. In addition, the Kansas City District is required to follow the same mandated Tribal consultation practices as outlined in the 2004 Programmatic Agreement mentioned below.

In 2004, the Omaha District embarked on the development of a programmatic agreement (PA) in coordination with multiple Tribes, SHPO, federal agencies, and interested parties in the development of a mutually acceptable NHPA procedure. This process took approximately two years to complete and resulted in a collaborative document signed in 2004 by 29 signatories including: HQUSACE, NWD, NWO, Advisory Council on Historic Preservation, SHPO/Tribal Historic Preservation Office, Tribes, and Bureau of Indian Affairs. Tribes or agencies that chose not to sign the PA in 2004 follow the PA process. Government-to-government consultation will be conducted with any Tribe or agency upon their request.

During the development of the 2004 PA, NWD Commander General Fastabend made a commitment of $3 million annually for cultural resource activities in the Omaha District and estimated a $77 million backlog of mainstem system historic preservation needs. Utilizing the Consumer Price Index for inflation, the Omaha District estimates that in 2012 the historic preservation backlog is approximately $92 million. Annual funding since 2004 has helped address and/or resolved numerous preservation issues; however continuous impacts, such as erosion and looting, as well as the rising cost of material and services continue to escalate program costs.

Since the signing of the PA and the funding commitment, the Omaha District has been working with the signatory parties to implement the agreement. Collaboratively, the group has been able to complete a Five Year Program Plan, six mainstem Cultural Resource Management Plans, a Monitoring and Enforcement Plan, and an Education Program Plan. Additionally, site mitigation is a critical component of the program; the District has successfully mitigated/stabilized several sites.

Since 2004 the Omaha District has accomplished:

- Over 760 federal activity/undertaking requests
- Approximately 900,000 acres have been inventoried (several projects are 100% complete)
- Approximately 85 sites have been tested and evaluated for national register eligibility
- On average, 40% of cultural resource sites are monitored each year
- Several felony convictions and one misdemeanor conviction for Archeological Resources Protection Act (ARPA) violations have been prosecuted by the U.S. Fish and Wildlife Service and the Omaha District
- Approximately 28 of 5,000 sites have been mitigated or protected from adverse affects.

Cultural Resource Preservation is important to the Omaha District and the signatories. The Omaha District believes the PA has the essential elements to implement the concept of shared stewardship. It is essential for the Omaha District to continue to work closely with Tribal governments, state agencies, other federal agencies, and the public in the development and implementation of the program.

5.1.2.3 Cultural Resource Funding

In the Missouri River floodplain, the Kansas City District receives cultural resource funds for activities covered by Section 106 of the NHPA. As for Corps-owned land, there is currently no funding for such management activities. The Kansas City District will require funding to develop and implement historic management plans for these Corps-owned lands.

Omaha District and Northwestern Division aggressively pursue several sources of funding to support the cultural resources program and meet the $3 million commitment made by General Fastabend. Competing priorities within the Corps’ budget has made fulfilling the program commitment challenging. However, since 2004, the Omaha District has met and in some years, exceeded the commitment. Budget constraints and competing needs will continue to pose challenges to the Northwestern Division and the Omaha District.

Omaha District Cultural Resource Program received FY12 Disaster Relief Appropriations Act (DRAA) funding, which will provide a total of $8 million for the program. Program activities will include: bank stabilizations, post flood archeological assessments, TCP surveys and routine monitoring.

In FY13 Omaha District requested $6.5 million of DRAA funds; FY13 funding will continue archeological assessments and bank stabilizations. Individual assessments will be submitted monthly, the final overall assessment being completed in 2013. This report will be a bench mark for future cultural resource activities. FY13 and FY14 funds are critical to the program; funding shortage could result in non-compliance with cultural preservation laws but also failure to meet the Omaha District 2004 PA funding commitment.

5.1.2.4 Missouri River Basin Vulnerabilities

Fluctuating water levels, channel currents, and inundation of fragile soils leads to erosion, resulting in sloughing of banks that may contain historic properties and burials. Eroded banks and shoreline can severely impact irreplaceable cultural resources and human remains. Additionally, exposed artifacts are susceptible to several negative impacts such as illegal looting and vandalism.

- Exposure of artifacts and human remains – The greatest vulnerability to cultural resources is exposure and loss. Fluctuating water levels and channel currents can expose artifacts and human remains. NHPA, ARPA, and the Native American Graves Protection and Repatriation Act (NAGPRA) protect these irreplaceable resources. In the event cultural resources are exposed (artifact or human remains), the District Archeologist should be notified. Upon inspection, the District Archeologist may be required to contact several entities, including, but not limited to: Tribal Liaison, Tribes, SHPOs, Tribal Cultural Preservation Offices, and law enforcement.

  Conditions conducive to artifact and human remains exposure/damage:
  - Sloughing of saturated soils.
  - Shoreline and banks stripped of soil and aggregate exposing previously buried cultural resources.
  - Levee breaches impacting cultural resources and burials far from the river channel.
  - Sterilized (no vegetation) soils are highly erodible and can quickly uncover cultural resources and burials.

- Looting – NHPA and ARPA require federal agencies to preserve and protect historic properties. The destruction, vandalism, or disturbance of sites or artifacts is a loss to the nation. Tribes feel that looting of sites is a cultural travesty; a personal attack on them as individuals and as a Tribal Nation.

5.1.2.5 Preventative Measures

Sites are often exposed to elements such as erosion, looting, and vandalism; so complete preservation is difficult and often impossible. Forces impacting sites can shift through time. Active monitoring and preservation planning are essential to long-term site protection. The routine monitoring of historic properties is recommended in order to determine the nature and extent of adverse effects. The development of protective measures and technologies based on these observations is crucial to eliminate or reduce these impacts.

Preventative measures for the FY12 runoff season include:

- Repetitive Monitoring of Sites – Monitoring serves several useful purposes in archaeological resource management. Monitoring is an information-gathering tool to collect visual information about a site's physical condition. Since site conditions can change very quickly, repetitive monitoring is necessary to ensure site conditions have not deteriorated.

- Archaeological Surveys – Current archaeological surveys provide detailed information on site conditions and identify new or previously unknown sites. Surveys are valuable tools for prediction of potential cultural resource emergencies.

- Post Flood Event Archaeological Site Assessments – Individual site assessments will provide a detailed analysis of how sites were impacted, as well as recommendations on mitigation. Due to the large number of sites in the Omaha District, an intensive assessment process is necessary. This assessment will provide an overview and detailed analysis of the damages incurred. Omaha District will contract with the South Dakota Archeological Research Center. Additionally, Omaha and Kansas City staff archaeologists are also performing an intensive investigation of impacted sites.

- Site Stabilization – Bank stabilization has been successfully implemented to protect archaeological sites adjacent to the Missouri River Mainstem Lakes. Bank stabilization measures used by the Omaha District have included conventional rock riprap and experimental vegetative bank stabilization. Typically Tribes have supported the use of bank stabilization practices as a treatment method for erosion impacts. Omaha District will stabilize approximately 15 new sites which will minimize further damage.

- Outreach to Tribes, SHPOs, and Other Concerned Parties – Tribal Trust responsibilities and the NHPA require federal agencies to consult with Tribes, SHPOs, and other concerned parties. Effective communication and cohesive explanation of Corps authorities is critical to sustaining positive relations.

- Consultation – Official consultation will be conducted on all undertakings and any decision documents.

- Looting – Public education and outreach to law enforcement agencies will increase awareness of the destructiveness of illegal looting. The Omaha District has a toll-free number [1-866-NOSWIPE (667-9473)] to call to report looting/vandalism. This number is a direct line to the U.S. Fish and Wildlife Service Special Agent who can investigate and prosecute looters.

5.1.3 Recommendations

The following recommendations will assist in the FY13 and FY14 cultural resource management and also preparation for a similar flood event**.**

1. Continue partnering and outreach to Tribes and SHPOs. Establish periodic meetings for distribution of current information and sharing of Tribal and SHPO concerns. Encourage participation in PA meetings and structure agendas to encourage group dialogue. Participate in Tribal Events and Conferences, i.e. Great Plains Tribal Leaders Conference and National Congress of American Indians.
2. Continue documentation of consultation process.
3. Continue or enhance monitoring effort, specifically with Tribal partners.
4. Update Cultural Resource Management Plans, as necessary in consultation with Tribes.
5. Ensure all lands managed by the Corps have a current archaeological survey.
6. Continue or increase bank stabilization projects.
7. Ensure all flood response personnel are knowledgeable about cultural resource procedures.
8. Ensure all flood response personnel are knowledgeable about procedures involving the discovery of human remains.
9. Continue or enhance outreach to law enforcement officials regarding looting.

5.2 COMMUNICATIONS

Faced with the most significant hydrological event for the basin in more than 100 years of record keeping, three key challenges were identified with respect to communication of the Corps' role, emergency response efforts, and improving the awareness of those who live throughout the basin. They are:

- Basin wide, there is a fundamental lack of understanding of the complexity of the Missouri River mainstem system, its design and limitations. Because of this limited awareness, there was a general lack of understanding of the Federal Government's ability to minimize flood damages during extreme natural events as well as local and individual roles and responsibilities with respect to flood damage reduction and preparation.
- Ongoing challenges faced by the Corps to routinely address the diverse audiences across the entire basin, including Tribal nations, especially during an emergency event.
- Challenge of managing complex interagency coordination during a flood event and the complexity of maintaining multi-agency (internal and external) awareness during normal operations.

Despite these challenges, the division has adopted numerous best practices following lessons learned from the 2011 flood and incorporated them in new communication standard operating practices and other tools in the 'communications toolbox'. Recommendations from an independent external panel review are being incorporated into the methodology for runoff predictions and improved agency and local stakeholder communication practices continue throughout the basin. These will be discussed in more depth below.

5.2.1 First Challenge – Instilling Awareness, Understanding, and Confidence Throughout the Basin

There is a lot of complexity to the operation of the Missouri River and the balance the Corps must maintain for the eight purposes authorized by Congress and realized in the Master Manual and annual operating plan. In addition, flood events throughout basin can be varied and unique, depending on the source, location, duration, contributing non-regulated factors as well as consequent contributions by the Corps' system.

Developing an understanding within the basin on this system, what it does and more importantly, what it does not provide regarding flood risk reduction is sometimes a Herculean task. During extreme events such as the 2011 flood, emotion associated with loss of property helps fuel paranoia, rumor and exacerbates the word-of-mouth misunderstanding of Corps operations.

To address this challenge, the division has maintained a very proactive engagement posture with opinion leaders, special interest groups, and local agencies throughout the basin to keep the conversation going. Ultimately it is this populace who has the ability to affect the operations and guidance the Corps receives for its management.

The Corps must leverage every possible media outlet and opinion leader to help the agency communicate more effectively and efficiently to increase the awareness of everyone's role in mitigating the risk associated with life along the basin. Improved awareness and understanding of individual insurance, understanding and enforcement of local zoning restrictions for development within the floodplain, and overall state, local and individual preparation for significant events and other natural disasters combines to share the responsibility for responsible flood risk management.

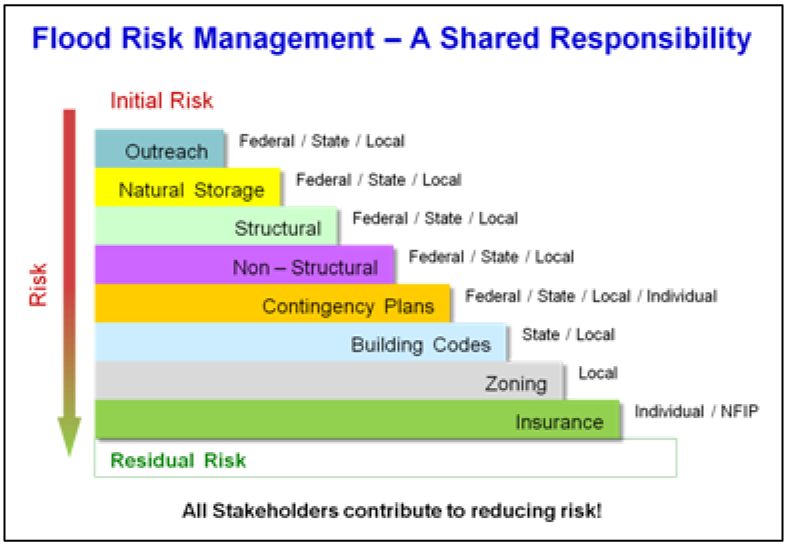

Figure 61. Flood Risk Management

Entering the 2012 runoff season, the effort has benefited from unusually warm and dry conditions throughout the basin. Regardless, the Corps' efforts for proactive communications and engagements with stakeholders throughout the basin continue. In addition to emergency-related events, and in addition to the normal operations of Corps engagements with agencies that have a role in the river operation, there must be a continued effort to maximize every opportunity to help educate the broader public.

Section 5.2.1.1 includes a summary of engagements, not all-inclusive, at all levels since the summer of 2011 flood event into current operations.

5.2.1.1 Events and Engagements

- During the 2011 flood and during the drawdown, several dozen community organization speaker requests were facilitated by the Omaha and Kansas City Districts. Mostly Rotary Club, Kiwanis, (etc) type presentations, this continued effort to explain the event while audience members were fresh helped develop a better understanding of what occurred.
- Missouri River Basin Interagency Roundtable (MRBIR) and Missouri River Recovery Implementation Committee (MRRIC) Meetings (ongoing)
- Missouri River Flood Task Force (MRFTF) meetings and workgroup coordination (Oct 2011-May 2012)
- "Open House" listening sessions in Omaha and throughout basin (NWD Omaha, Fall 2011)
- BIA/GPTCA/USACE Tribal water Management Summit (BG McMahon, COL Robert Ruch and members of the Corps staff attended and presented, Sept 27-28, 2011)
- Sioux Falls Rotary Club (COL Robert Ruch, November 21, 2011)
- St. Joseph, Mo., Public Meeting, (BG McMahon and COL Hofmann, November 2011)
- BG McMahon testimony to Congress (multiple)
- Cattleman's Association in Nashville (Erik Blechinger, February 3, 2012)
- Greater Kansas City Engineers Week Luncheon, (BG McMahon , February 18, 2012)
- MLDAA Meeting (ASA-CW, February 2012)

- Mo Navigator's Meeting (COL Tipton, February 2012)
- Division and district Congressional office visits (March 2012)
- American Water Resources Association Conference in New Orleans on the subject of GIS applications used during the 2011 Missouri River Flood. (COL Ruch was the Keynote Speaker , March 26, 20120)
- Water Protection Network (BG McMahon, March 2012)
- Society of American Military Engineers, St. Louis, MO. (COL Tony Hofmann, April 11, 2012)
- Ribbon Cutting events on major projects
- SD Hydrologist
- Responsible River Management Meeting (BG McMahon)
- Tribal visits by districts throughout basin (Multiple)
- Visits to Dams by Sen. Blunt/Hoeven May 29-30, 2012

In addition to those specific events, as mentioned above, as part of normal operations the Missouri River Reservoir Control Center has resumed regular basin-wide coordination calls, to include the media, in effort to maintain awareness and increase the general understanding of the basin operations as they relate to current projections and weather forecasts. Other flood-related efforts that continue include:

- Continued use of social media and 'push' messaging
- Spring Annual Operation Plan meetings throughout Basin (April 16-20)
- Media embed with NWD staff on mainstem design and vulnerabilities
- Follow-on vulnerability interview w/Chiefs of Operations and Engineering for Omaha (Schenk/ Bertino)

5.2.1.2 Recommendation

Unique to the other vulnerabilities identified in this report, the Communications challenge is not hindered by a lack of authorization or authority to the Corps, but the complexity, diversity and geographical displacement of those with roles and responsibilities throughout the Basin.

Communications is a contact sport. Gaining the attention of the audience is always in competition with whatever is news at the time. It must become part of the Department of Army and the Corps' DNA to proactively engage, discuss, accept criticism but return with corrections to that criticism, if we are to truly affect the discussion through not only the Missouri River basin but in Corps water management in general.

Candor must be our guide and we must not shy away from even the most hostile audience. At all levels of the Army we must continue to ensure sound engineering decisions, in an environment greatly affected by politics and emotions of the moment, are able to be defended and fairly scrutinized.

The bottom line: We must reach out and touch every segment of our affected audiences, stakeholders and partners if we are to increase everyone's awareness and understanding about the system's design, capability, limitation and operation, and each person's individual risk and responsibility.

5.2.2 Second Challenge – Communicating the 2011 Flood – Marshalling Limited Resources for a Major Event

Communication of the complexity and diversity of the Missouri River, the shared responsibilities of those who live and work within the basin, and its management, during typical years, in addition to extreme years and floods, has always been a complicated task for the Corps. On a routine basis, this is accomplished through local public affairs staffs and as part of regional programs with partnerships developed throughout the basin.

Prior to the peak releases, existing public affairs assets within the Omaha and Kansas City Districts initiated a crisis communications and public outreach campaign to warn communities along the basin that unprecedented reservoir releases were imminent and inevitable. Communication efforts continued throughout the summer to keep communities from Montana to Missouri informed about the Corps' water management and emergency response efforts.

On May 30, 2011 (in order to ensure timely and coordinated release of accurate information to the public), NWD established the Missouri River Joint Information Center (MRJIC), a single point of communications for the release of information.

The center was located in Omaha, Nebraska and staffed with personnel from Northwestern Division, Omaha and Kansas City Districts for crisis communications. From its inception, the MRJIC faced a myriad of challenges. The first challenge, simply, was timing. On the heels of significant flooding in the Mississippi Valley and tornadoes in both Tuscaloosa, Alabama and Joplin, Missouri, the Missouri River Flood of 2011 came at a point when the emergency response public affairs community of the Corps was taxed to its upper limits.

Talent was drawn from the best public affairs assets in the two impacted districts. Public affairs assets from outside the district who were not supporting other emergencies and rehired annuitants were also utilized during the flood. In the absence of available senior public affairs leadership in the region or from the Corps' headquarters, the division special assistant on Missouri River programs was brought in to lead the JIC effort.

Senior public affairs specialists worked with the chief to identify the needs of the organization and balance those against the assets available.

The second challenge was the scale of the problem. The Flood of 2011 did not impact just one community or geographic area. The Flood of 2011 extended along approximately 1,771 miles of the Missouri River, not including affected tributaries. With flat lands further south in the basin, overland flooding could stretch for miles and imperil communities not usually impacted by the Missouri River. Despite the great expanse of land impacted, information could travel faster than the water in the river. Be it a tidbit, rumor, or speculation, if it was uttered in Bismarck, North Dakota, it was the hot topic in St. Joseph, Missouri the following day. This meant messaging had to be thorough, clear and communicated across the Missouri River Basin nearly simultaneously. Hence, rumor control had to be addressed as a basin-wide problem and not specific to a particular town. That said, the need to communicate generically did not abate the need for highly detailed, specific information up and down the river. For as much as everyone might want to know what the latest release at Gavins Point might be, so, too, did they want to know how that information translated to their specific portion of the river. This created another logistical challenge that had to be addressed and coordinated across several disciplines and groups in the Corps, including the MRJIC.

A third challenge existed in the protracted nature of the flooding. A flash flood or fire or other disaster tends to be a moment in time that quickly passes and allows the rebuilding and healing process for communities and people to begin. Not so with the Missouri River Flood. High water arrived in communities beginning in early June and remaining until September. This created a number of paradigms. First, people couldn't move past the pain and emotional anguish caused by the loss of a home or business in the flood. There was no quick resolution to their dilemma. This created an environment that further heightened anxiety and resentment from a specific portion of the public. A different segment of the impacted public watched their homes or businesses survive the initial surge of high waters only to lose them later from rising groundwater issues, levee breaches or substantial erosion to the Missouri River's banks, while others simply could not get to their businesses due to closed roads and other infrastructure.

The demands of dealing with a concerned public and media over a lengthy period of time took its toll on members of the team. Most members worked a minimum of 12 hour days, 7 days a week. Later in the flood as the natural disaster stabilized, that work rotation eased to 6 days a week with overlap on the weekends.

The Corps' Flood Control and Coastal Emergency (FCCE) Fund paid for the staff members that traveled to Omaha to augment the center. Staff members had been previously trained on how to respond and fill emergency response roles via the Corps' External Planning and Response Team (EA-PRT) for Emergency Support Function 15. The training was developed based on guidelines outlined in FEMA's IS-250 Emergency Support Function 15 (ESF 15) External Affairs Training: A New Approach to Emergency Communication and Information Distribution. Staff members rotated in and out of the MRJIC on assignments that lasted between two and three or more weeks. Several staff members fulfilled multiple rotations, returning home for a week or two and then back to the MRJIC for continuity purposes.

The Corps' rehired annuitants program, which allows the organization to rehire previous employees, currently retired, to assist with mission essential tasks, was employed to bring on two former chiefs of public affairs. Already familiar with Corps processes and the Corps' approach to risk and crisis communications, the staff was able to get up-to-speed and assist in needed areas rapidly.

The center was divided into two cells, a call center for the general public to contact with questions and a media relations cell for the media to contact for responses to query, fact verification and interview requests.

The strategic communications plan was developed as a 5-Phase Approach to the flood event. Phase I detailed the establishment of the MRJIC. Phase II included communications needs, efforts and tools required to effectively respond to peak releases. Phase III addressed the drawdown of peak releases and sustained normal releases at normal levels. Phase IV covered the post flood inspection, and Phase V provided communications guidance for winter releases. The plan included overarching key messages and talking points for use by the Northwestern Division, Omaha and Kansas City District commanders and staff.

The Northwestern Division declared the official end of the Missouri River Flood of 2011on October 17, 2011. After action reports and an evaluation of strategic communications goals indicated that the strategic communications plan achieved the desired goals initially identified. Those goals were to 1) gain and maintain public trust and confidence 2) clearly communicate to the public the cause/prompt for historic reservoir releases 3) educate the public about the Missouri River Reservoir system's design, the Corps' regulation of the system and the Corps' adherence to the Missouri River Master Manual 4) monitor and measure public perception of reservoir regulation and emergency response efforts, and 5) manage and mitigate flood-related rumors.

After reservoir storages throughout the basin peaked and releases could be reduced, the MRJIC began to drawdown. The MRJIC officially closed September 30. Daily tasks were reabsorbed into the appropriate district offices and the public affairs offices continued to keep communities informed via news release, stakeholder contact, and continued outreach efforts such as speaking to civic organizations and upon request by governors and congressional representatives.

5.2.2.1 MRJIC Daily Operations

To address the complicated nature of the communications challenge, the MRJIC utilized several existing and new tools to help corral the multiple audiences, efforts and interests.

5.2.2.1.2 Call Center – Inundation Maps

The initial vehicle created by MRJIC to inform and respond to stakeholder interest within the Missouri River Basin was the establishment of a Call Center, web site and email to engage the general public and media. The MRJIC web site contained sectionalized geospatial maps along the basin and demonstrated the expected inundation in levee protected and non-protected areas under the then expected 150,000 cfs release that would be realized (later raised to 160,000 in most areas). Within the establishment of the MRJIC, the Corps responded, on average, to about 100 public and 30 media queries per day during the first few weeks of operation (several hundred a day during the initial formation), including requests for live and pre-recorded radio and on-camera interviews. In many cases the discussions were focused on helping the caller read and understand the vast amount of information that was placed online and occasional changes to those projections.

Throughout the flood event, MRJIC was contacted regularly by local, regional and national media, regularly working with reporters from the New York Times, Wall Street Journal, Washington Post, CNN Online, Reuters and Dow Jones. One international print publication, the Enoch Times, contacted the center for information related to the safety of the Fort Calhoun Nuclear Power Plant located in Blair, Nebraska and the Cooper Nuclear Power Plant located in Brownville, Nebraska.

As part of the standard operating procedures in the MRJIC, each public affairs staff member assigned to answering phones was required to complete a media query form to determine the name of the reporter, news station, email address and phone number, whether the request was for facts or an interview, the type of interview, specific questions being asked, and the reporter’s deadline. If the public affairs professional was able to use key messages and talking points to immediately respond, the query was handled during the initial phone call. In other cases, the public affairs professional promised a call back and placed the form in a queue for response by the reporter’s deadline or the end of the day. The goal was to meet all requests by deadline where possible. The MRJIC worked diligently to meet all requests for information, deadlines, and to provide access where requested to the media.

5.2.2.1.3 Daily Congressional Delegation (CODEL) Calls

Prior to the start of the emergency response mission, the Omaha District’s Facebook site had 300 followers. The district launched its social media presence in the fall of 2010 after research to determine how and where congressional audiences, state and local governments, private businesses, special Missouri River basin interest groups, recreationists and private landowners including farmers and ranchers were getting their information and whether those groups appeared to be making use of social media. Special consideration was given to how social media could be used to reach audiences in the event of a crisis.

With the establishment of MRJIC, an additional MRJIC Facebook site was created. It was advertised in email signature blocks, news releases, bulletins, and press kits along with the existing Kansas City District site and the Corps' social media sites. Call center staff advertised it with each contact and the media were frequently reminded to remind their audiences about how they could find and track the Corps on Facebook, and follow the Corps on Twitter. By early August, the number of social media followers on the Omaha District Facebook page swelled to more than 8,000. All combined, the two district and MRJIC Facebook sites had more than 15,000 followers.

Local news and radio stations shared the information and posted it on their web sites. Local and county emergency management officials did the same. The toll-free phone number was shared as well. Three Facebook sites (one for Omaha District, one for Kansas City District and one for the region) were staffed, monitored and updated throughout each day with the latest information available.

Regular informal analysis was conducted to determine which status updates appeared to receive higher than normal responses, as well as when visitor numbers peaked and decreased and by what percentage and which topics seemed to merit additional explanation or more clearly developed messages.

The Corps produced videos to help educate the public about emergency response measures and the Corps' role and to explain the circumstances surrounding the Flood of 2011 and how it developed. In all, 40 videos were produced with 31 being posted to the Omaha District's YouTube Channel. B-roll footage was also captured for documentary purposes and uploaded to Defense Video and Imagery Distribution System (DVIDS) for use by the media.

Hundreds of photographs taken by public affairs specialists coordinating media interviews or visiting the sites of projects to write articles for internal and external publication and documentary purposes were also uploaded to the Corps' FLICKR site for use by the public and the media.

5.2.2.1.4 Concentrated, Broad, and Niche Media Focus

Daily updates on current conditions and construction activity were posted to social media sites and regular news releases were distributed to help feed communities' and the media's insatiable appetite for information.

More than 110 news releases were distributed from the time the Corps learned it would reach unchartered territory with its reservoir releases through the end of the flood fight. Each news release was written in alignment with the overall strategic communications plan. Topics included levee breaches, contracts awarded for advances measures put into place for flood risk reduction, dam inspections and the gradual drawdown strategy of reservoir releases to name a few. Additional public affairs guidance was used to help ensure news releases were aligned with appropriate command message information. Examples of media engagement include the following:

- Hard copies of a monthly news release that addressed on-the-ground weather conditions, the current forecast and the Corps' planned water release schedule were made to approximately 750 stakeholders including Governor and Congressional offices, private business owners, farmers, ranchers, mayors' offices, state officials, local emergency managers and homeowners.

- News articles were written daily for pitching and potential placement in external publications that had been researched to determine whether identified targeted publics could be potentially reached to help get the message out and tell the Corps' story.

- Article ideas were also pitched to the media, a number of which were pursued and covered. One example was the comparison of the amount of water that came through the east coast during Hurricane Irene to the idea that the Flood of 2011 was a kind of inland hurricane in the amount of precipitation that was experienced as a result of the heavy rains in Montana and the Dakotas. The idea was to help the public understand the amount of water that had come through the region in order to help manage perception. With emotions running high due to the devastation caused by flooding, it was difficult for the public to understand how and why the Corps lost its flexibility in managing the reservoirs due to the amount of runoff coming into the system. The MRJIC staff took advantage of strong media relationships to pitch the article idea and provided a graphic comparison to the Wall Street Journal, Lincoln Journal Star and the Omaha World-Herald. All three outlets used the comparison and graphics in subsequent articles.

- The team even developed a special series titled: "Five Flood Facts," that was distributed to media outlets throughout the region. Each week, a separate topic was covered in an effort to facilitate expanded responsiveness to the public, provide an enhanced awareness of the flood's origin and its ongoing impacts, and answers to all manners of ongoing factors spawned by the flood event. Media outlets and radio stations throughout the basin made use of the information.

By the end of August, the database tally of media contacts totaled 800. By the time the MRJIC closed Sept. 30, 2011, that number swelled to more than 900 contacts.

5.2.2.1.5 Managing Media Scrutiny

On June 10, 2011 Gannet Corporation submitted a Freedom of Information Act (FOIA) request demanding access to emails from the Chief of Water Management, Jody Farhat, and other key leaders in the Corps prior to and during the management of the flood event. Another request from the Great Plains Examiner followed June 16 and another from the Associated Press on June 20. The Corps' Office of Counsel complied with the requests, reviewing information for security purposes, redacting information that could not be released due to the Privacy Act or potential Operational Security violations. More than 3,000 emails were provided to comply with the FOIA requests. Later, the MRJIC voluntarily offered the CD to other members of the media, including the Omaha World-Herald.

Media were frequently escorted in and out of the MRJIC and the Emergency Operation Centers located in both Omaha and Kansas City Districts. Guided tours were setup upon request for congressional members, and the Corps extended an open invitation to media members to tour the MRJIC, conduct interviews with staff and capture video footage. Media members were also invited into the MRJIC to take part in the daily call-in press conference.

5.2.2.1.6 Support to Speaker Requests and Expanded Use of Video Products

Subject matter experts and public affairs specialists attended and presented at public meetings, town hall meetings and upon request to civic organizations when time and availability allowed. Key members of leadership, including the Omaha and Kansas City District Commanders, Chief of Emergency Management and Chief of Water Management made themselves readily available for print, radio and broadcast media interviews. Both commanders kept a daily one-hour block of time open on their calendars each afternoon specifically for handling interviews.

Each time an on-camera interview was conducted, the DVIDS TV Eyes team was contacted for a copy of the clip for analysis purposes to gauge whether key messages showed up in broadcasts, if so, how many and the tone of the broadcasts. The analysis helped with the critique of the interviewee and to determine whether messages needed updating or polishing.

5.2.2.1.7 Coordinating with External Stakeholders and Agencies

With so many various agencies involved and impacted, the team developed special email distribution lists to ensure coordination and the sharing of information with sister agencies such as FEMA, the USGS, and the National Weather Service. Special lists were also included in the Corps' media distribution system to ensure public information officers from other agencies were aware when the Corps distributed news releases. The Corps encouraged wide distribution of all news releases and many agencies reposted information on their web sites and in their own social media communications efforts. Upon special request to partake in conference calls with public information officers in local communities, the team accommodated when possible.

A staged live press conference area was also setup to conduct impromptu press conferences when necessary. The Nuclear Regulatory Commission borrowed the area to hold a press conference to reassure the media of the safety of two nuclear power plants impacted by flooding during the event.

As the communication of the flood fight transitioned from response to preparations for recovery, a detailed draw-down strategy was developed to safely evacuate water from the reservoir and levees system to allow residents to return to their homes, farms and business. This plan also balanced minimization to erosion and expedited the ability to inspect and repair the federal system. The MRJIC was the staff element responsible for the development of the plan.

5.2.2.2 Recommendations

In normal operational times, the Corps is limited in the size and depth of its communication teams and assets located in public affairs. Unlike a Fortune 500 company, with the challenge to maintain affordability to its customers and with funding of these assets under general and administrative expenses, there is a constant struggle to maintain leanness in this area. The current process in place to quickly augment these normal staffs under extreme events is the growing development of the EA-PRT and standardization of the tools, processes and training they fall under.

The Corps' FCCE Fund paid for labor, travel, printing and other costs associated with the MRJIC. The total cost of fighting the Missouri River Flood of 2011 cost American taxpayers approximately $71 million. The cost for communicating with targeted publics during the emergency response mission came to $723,300, just one percent of the total cost of the flood fight. The Corps invests in, develops and makes use of its own in-house talent to streamline costs for communications where possible. In-house video production is an example of where costs were streamlined during the Missouri River Flood of 2011. A private sector estimate for the cost of producing one 6-minute video came to $21,745. While some of the videos produced by the Corps to help educate the public were longer than six minutes, the estimate was used as a baseline and multiplied by the 40 videos produced during the flood fight. The calculation determined that the Corps saved about $869,800 on video production.

In addition, NWD has generated a MRJIC standard operating procedure (SOP) to codify and detail the steps to standardize the development of a MRJIC and this SOP is being shared with the USACE-wide PRT to help integrate into that training. Part of that SOP includes annual assessments of in-house staff and capability as well as verifying key media tools, agency points of contact and other audience information to ensure that network is identified and current in advance of potential emergency operations.

Development of uniformity of materials from the operational side of the Corps efforts, used as communication tools for outside audiences (i.e. inundation maps), would benefit the external perception of continuity and coordination of the federal effort. An investment in more interactive web-based models, toolkits and multi-media assets would continue to explain the complexity of not only the emergency response mission, but the 'normal-year' balance of managing the eight authorized purposes of the mainstem system.

On June 7, 2012, NWD's MRJIC received the Silver Anvil Award from the Public Relations Society of America, their highest honor, for government crisis communications. Regardless of the success of the summer 2011 MRJIC effort, continued focus on support to this EA-PRT concept, development of best practices and procedures, investment in the latest visual information tools, video equipment and capacity, and maintenance of a cadre of on-call capability is the best solution to balance the requirement for quick emergency communication capability with limited annual federal resources.

5.2.3 Third Challenge – Post Flood Communication Efforts – Coordinating Multi-Agency Roles and Responsibilities

Almost as broad and challenging as reaching a media and public audience across a 1,771-mile reach of the Missouri River basin is the coordination of the federal, state and local agencies involved with operations and management of issues along that river during normal and emergency events.

During the course of the flood, much of the coordination of multiple Tribal and state road departments, local county emergency management efforts, state and national officials and others were coordinated as part of the MRJIC daily call and coordinated meetings and briefings over the course of the summer. During the emergency, the common focus and motivation to share information, awareness and diffuse rumor or confusion was a shared concern. Maintaining this level of open and candid discourse is a vulnerability to the operations once the waters recede.

During typical operation years, the balance of managing the eight authorized purposes of the river and addressing the changing and volatile political interests annually is part of current coordinated efforts of current Corps efforts. Examples include the MRBIR, composed of executives of federal agencies with activities in the basin, and MRRIC, a basin-wide collaborative forum both focused to bringing together various stakeholders and develop a shared vision and comprehensive plan for Missouri River recovery.

5.2.3.1 Development of the Missouri River Flood Task Force

Even before the summer floodwaters receded, the Corps began the task of developing a post-flood task force to coordinate the multiple efforts which would be required to recover from the most significant flood event in the basin in modern times. As part of the post-flood communications and process review process, the Corps initiated the development of the MRFTF following similar models used for other Missouri River programs/projects. Invitation letters to stakeholders and other federal and state agencies were sent during August and September of 2011.

The MRFTF was established to provide a temporary forum for coordination, collaboration and cooperation among the federal officials and designated officers of state, local and Tribal governments within the states of Nebraska, Montana, Iowa, South Dakota, North Dakota, Wyoming, Kansas and Missouri. The mission of the Task Force was to complete initial repairs of the federal levee system by March 1, 2012 and to conduct long-term recovery activities in response to the Missouri River Basin flood of 2011 to address floodplain management challenges and keep comprehensive flood risk management as a top priority. The Task Force is chartered to seize the opportunity to shape the future of the floodplain, and to set conditions for success for all involved by streamlining governmental processes, accelerating necessary assessments, identification of shared responsibility, coordination, and permitting requirements, and by applying agile and critical thinking to the problem set. These coordinated efforts will ensure timely progress and yield the intended results on the ground in the immediate future, and lead to a comprehensive recovery plan to achieve long-term flood risk management.

The inaugural MRFTF meeting was held October 2011 as a video teleconference with the existing Missouri River Basin Interagency Roundtable. More than seventy attended representing federal agencies, states, Tribes, local cities and utilities, private industry and special interest groups, among others. The MRFTF developed eight working groups focused on Levee Repair, Agricultural impacts, Tribal Support, Regulatory and Permitting concerns, Communications, Floodplain Management, River Management, Hydropower and Navigation.

Over the course of the winter in virtual and two other face-to-face gatherings, the work groups focused on specific tasks to recover the system from the 2011 event as well as discuss best paths forward in the coordination and communication of efforts along the river. The final face-to-face meeting occurred in May 2012 in Omaha, Nebraska.

The current assumption in the transition of the continuing tasks of the MRFTF will be absorbed into the above-mentioned ongoing Missouri River-related partnerships (MRBIR) as well as into improved coordination with other outreach teams such as the silver Jackets Program ongoing throughout most of the states a throughout the basin. Clarity on this transition is still being developed at the time of the writing of this report.

5.2.3.2 Independent External Technical Review

As part of post-flood assessment efforts, the Corps enlisted the assistance of experts in meteorology, hydrology, streamflow forecasting, and reservoir system operations to review, analyze, and assess the Corps' operation of the six mainstem dams along the Missouri River leading up to, and during the Flood of 2011. The review panel members were:

- Bill Lawrence, Meteorologist/Hydrologist in charge for the Arkansas-Red Basin River Forecast Center, National Weather Service
- Darwin Ockerman, Hydrologist, U.S. Geological Survey
- Cara McCarthy, Senior Forecast Hydrologist, Natural Resources Conservation Service National Water and Climate Center
- Neil Grigg, PhD, Professor of Civil Engineering, Colorado State University

The panel reviewed and assessed a number of questions, including whether water management decisions made during the Flood of 2011 were appropriate and in alignment with the Missouri River Master Manual, the water control plan that guides the operation of the Missouri River. The team also looked at whether the Corps could have prevented or reduced the impact of flooding by taking other management actions leading up to the flood, whether long-term regulation forecasts properly accounted for the runoff into the mainstem system, whether climate change played a role in this year's record runoff and the role floodplain development played in the operation of the reservoir system prior to and during this year's flood event.

In short, the independent review help verify the operational decisions by the Corps through the 2011 flood fight were sound but did highlight that future modeling and decisions should include updated information of recent hydrological events which would potentially impact current models and decision points. With respect to communications, the report emphasized the need for improved and sustained coordination and communication with agencies along the basin as well as continuance of the dedicated coordination by the Corps as demonstrated during the flood event.

Currently, the Missouri River reservoir team members are part of the Fusion Forecasting team which includes representation by the Corps, USGA, and NOAA to provide alignment and timely sharing of information and forecast data. Since the flood of 2011, regular face-to-face meetings with agencies and stakeholders throughout the basin have been well attended and the continued improvement of that coordination and communication is reflected in the nature of those discussions.

Similar to the daily stakeholder call held during the 2011 flood, the Missouri River Reservoir Control Center hosts a twice-monthly stakeholder conference call to ensure awareness and two-way communication with federal, state, and Tribal agencies throughout the basin, as well as media monitoring the Missouri River operations. These calls include direct input from the National Weather Service and are recorded and available online through the USACE web site.

Working with other agencies, online tools, web sites and social media sites are constantly being improved and fed with the most current runoff and predictions to ensure timely awareness in the event conditions become severe.

Communicating information to the public is a team effort. USACE is engaged with Tribal, federal and state leaders to support their efforts to ensure coordination and awareness of state emergency operations and preparation.

5.2.3.3 Internal Agency Coordination

In addition to the use of the Institute for Water Resources to help coordinate the development and transition of the MRFTF efforts and the development of the Northwestern Division Missouri River Joint Information Center Standard Operating Procedure, NWD has taken a deliberate step in rehearsing, planning, and coordinating internal planning and preparation for improved agency coordination during an emergency event in the Missouri River basin, located on the far eastern border of the division.

The Division Response and Contingency Operations Division (RCO) conducted a Missouri River Runoff "Kickoff" process that coordinated operations, recovery, planning, emergency and communication efforts throughout the basin in a similar fashion that it does normally with the more local Columbia River Basin. This heightened sense of awareness for the Portland-located main division office will help improve the Corps' regional response to future events.

Also, following the 2011 event, as a member of the Mississippi River Commission due to the Corps' contribution to the combined flows into the Mississippi River, the Northwestern Division has focused its engagement on coordination and awareness of the Missouri River impacts with the coordinated management of the runoff throughout the Midwest.

The Mississippi River Commission (MRC) was established by an act of Congress on June 28, 1879. Congress charged the MRC with the mission to develop plans to improve the condition of the Mississippi River, foster navigation, promote commerce, and prevent destructive floods-perhaps the most difficult and complex engineering problem ever undertaken by the federal government up to that take.

During its spring High water trip, the special assistant to Missouri River Operations, Erik Blechinger, and the Division Deputy Commander, Colonel Robert Tipton, participated in listening sessions throughout the lower reach of the Missouri River. A similar northern reach program is planned for this fall during the low water trip in August.

5.2.3.4 Recommendation

As the basin moves further away from the recent memory of the 2011 event, and the normal struggle for special interests along the basin begins to retake footing, it is imperative to maintain the contacts, coordination and awareness among all the partners, state, federal and private, to ensure that balance is maintained with respect to the awareness of impacts to flood control prevention. Everyone has a role, and more importantly, a responsibility.

Our recommendation is to continue the successful efforts that were demonstrated during the flood to maintain that momentum for future years. Integration of the partnerships and communication efforts into the Silver Jackets program, and a deliberate methodology to maintain the various communication teams associated with the Missouri River related programs will also greatly contribute to the awareness for future significant events.

The Army's continuing dialogue must include motivation and assistance to help educate the public along the Missouri River of their role to mitigate the risks associated with living close and within the flood plain. State and local assistance in controlling encroachment, enforcement of development restrictions and education along this issue must also be encouraged as part of the national dialogue.

5.2.4 Moving Ahead, Applying What We Have Learned

The collaborative efforts by the Corps and other partners throughout the basin, and the individual stakeholders have continued long after the flood waters receeded in 2011 and will do so long after the last repairs are made throughout the system. By incorporating the recommendations by the independent external panel review and continuing the improved, and more effective, dialogue the 2011 flood spawned, the entire basin is in a much improved posture for future events. But we still have a long way to go.

The Missouri River Basin Reservoir Control Center has continued the practice of routine (bi-weekly through the runoff season) to inform federal, state, local, individual and media representatives throughout the basin.

The partnerships and teams developed under the Missouri River Flood Task Force have evolved into working groups of other panels and teams to ensure this network of experts and their mutual awareness continues. The on-line toolbox, existing as the MRFTF web presence, has been migrated into the standard division external web presence, with the assistance of our partners in the Institute of Water Resources, and is available for any potential reactivation of the MRFTF, if conditions warranted.

The Northwestern Division has codified its MRJIC operations in to a new Standard Operating Procedure which is slated to be annually updated to include current contacts of agency points of contacts throughout the basin, as well as continue to adopt best practices and tools developed by communicators across the Corps.

Lastly, this report, and our ongoing dialogue with the members of Congress is part of what be our determined focus to keep this important conversation of the 'shared responsibility' ongoing. The vulnerabilities and challenges identified in this report did not develop overnight and it will take a deliberate, ongoing effort to ultimately bring the individual awareness, public policies, as well as physical infrastructure to a sufficient level in order to provide the level of comfort and certainty that those who live throughout the Missouri River basin demand, and deserve.

5.3 SHARED RESPONSIBILITY

Flood risk management is a shared public and private effort. The Corps stands ready to implement the charge given it to reduce flood risk; and with the recommendations herein, to do it as well and better than it has been done to date. Other federal agencies will assist in that effort as their authorities allow. State and local governments play key roles that support flood risk reduction, in guiding and regulating land use, and in emergency preparedness and response. Various organizations have roles educating the public regarding floodplain management and educating government as to local needs. Private corporations and individuals have a role in making sound decisions regarding land use and investments in locations where flooding is a risk. With all parties collaborating to optimize systems, increase awareness, and reduce exposure, future Missouri River floods will have less potential to significantly impact the nation's wellbeing and security. This report describes what the Corps proposes be done to restore its flood risk management system and to improve system performance and resilience to the degree feasible.

Once restored or improved per the recommendations herein, the system will provide much the same level of flood risk management as before the 2011 event. The Corps' system, processes and commitment are robust; they have prevented large amounts of damage in the past, and they will continue to do so in the future. Within all constraints, it remains the Corps' commitment, working with others, to manage and maintain the authorized system of dams, levees, channel and banks with the goal to minimize flood risk to the maximum extent possible.

Appendix
Missouri River Flood Photography

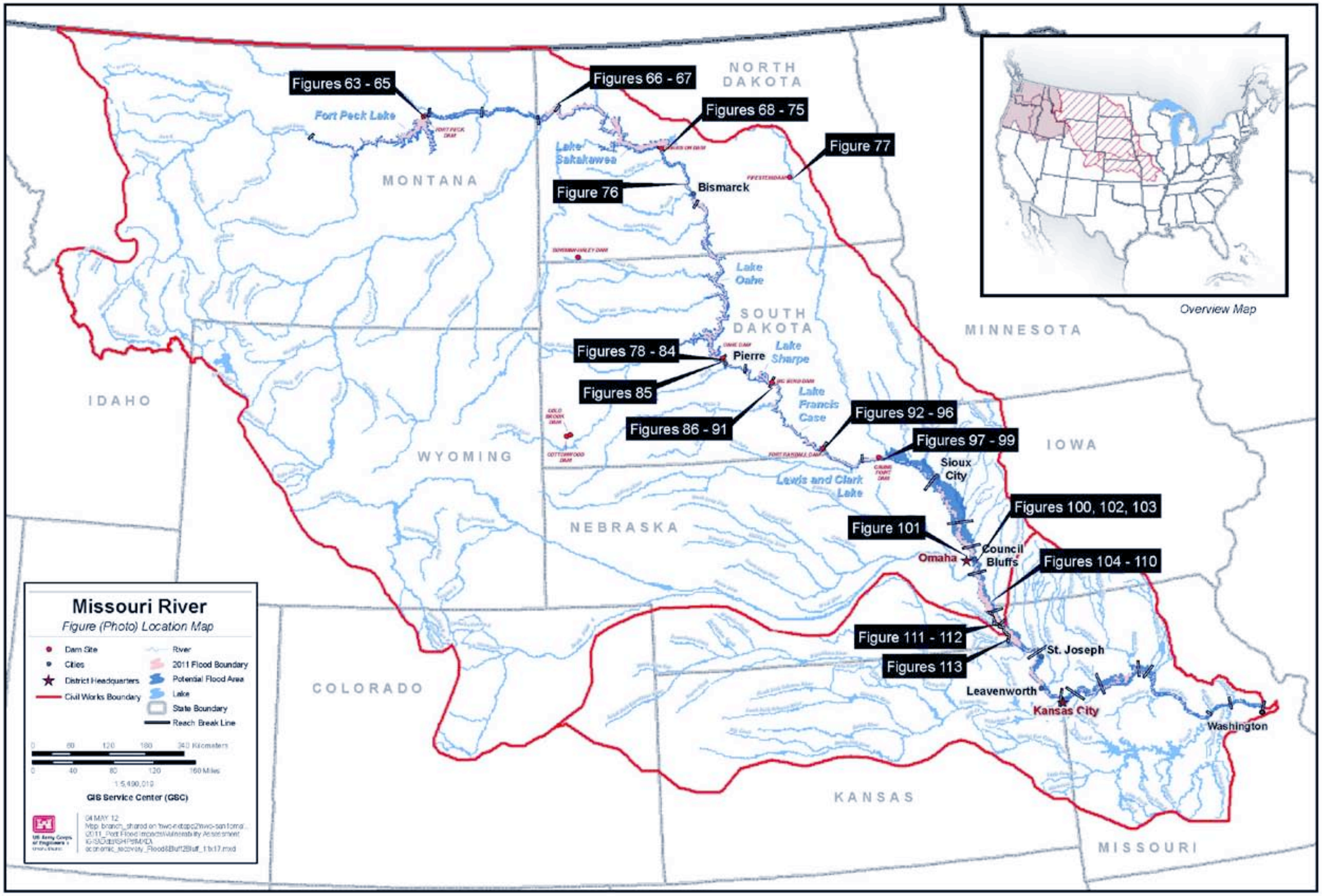

Figure 62. Photo Location Map

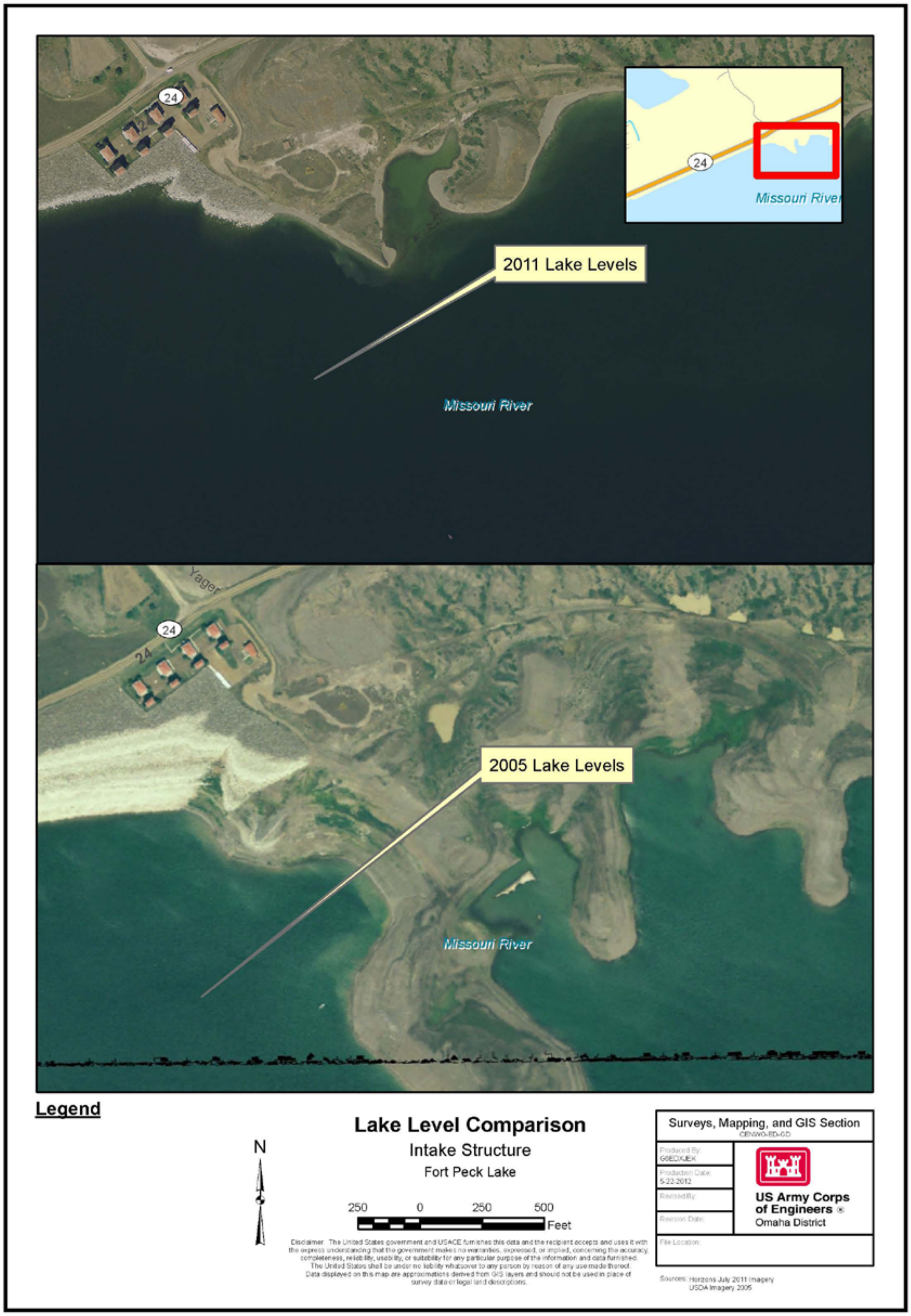

Figure 63. Fort Peck Lake - Lake Level Comparison - Intake Structure

Figure 64. Fort Peck Lake - Lake Level Comparison - Duck Creek Boat Ramp

Figure 65. Dams damage/erosion: Fort Peck - Erosion along the spillway plunge pool extending from Fort Peck's spillway in Fort Peck, Montana

Figure 66. Levee seepage: Williston - Landside seepage, relief wells needed at Williston Levee, North Dakota

Figure 67. Levee boils: Williston - Additional relief wells needed at Williston Levee in North Dakota

Figure 68. Lake Sakakawea - Lake Level Comparison - Intake Structure

Figure 69. Lake Sakakawea – Charging Eagle Boat Ramp

Figure 70. Dams damage/erosion: Garrison - Erosion along the earthen walls extending from Garrison Dam's spillway apron in North Dakota

Figure 71. Garrison Spillway damage/erosion:

Figure 72. Dams damage/erosion: Garrison - Typical concrete repair from flood in North Dakota. Additional spall repairs needed at most dams.

Figure 73. Dams damage/erosion: Garrison - Joint separation and seal repairs required at Garrison Dam in North Dakota

Figure 74. Dams damage/erosion: Garrison - Erosion along the earthen walls extending from Garrison Dam's spillway apron in North Dakota

Figure 75. Dams damage/erosion: Garrison - Downstream camp erosion at Garrison Dam in North Dakota

Figure 76. Erosion: Hogue Island, Section 33 Project - Erosion along the Section 33 Project at Hogue Island, North Dakota

Figure 77. Dams damage/erosion: Pipestem Dam - Downstream right abutment seepage area at Pipestem Dam in South Dakota

Figure 78. Lake Oahe Lake Level Comparison - Intake Structure

Figure 79. Lake Oahe Lake Level Comparison - Chantier Boat Ramp in Ft. Pierre, South Dakota

Figure 80. Dams damage/erosion: Oahe - Erosion along the earthen walls extending from Oahe's stilling basin outside Fort Pierre, South Dakota

Figure 81. Dams damage/erosion: Oahe

Figure 82. Dams damage/erosion: Oahe - Erosion at flood tunnel outlet for Oahe outside Fort Pierre, South Dakota (under repair)

Figure 83. Dams damage/erosion: Oahe - Flood control tunnel gate roller chain failure at Oahe outside Fort Pierre, South Dakota

Figure 84. Dams damage/erosion: Oahe - Outlet works bridge scour at abutment at Oahe, South Dakota

Figure 85. Damage/erosion: LaFramboise Island Causeway - City of Pierre waterlines damaged at LaFramboise Island Causeway (Corps) in Pierre, South Dakota


Figure 86. Dams damage/erosion: Big Bend Erosion on earthen walls of the project's spillway in South Dakota


Figure 87. Dams damage/erosion: Big Bend Erosion on earthen walls of the project's spillway in South Dakota


Figure 88. Dams damage/erosion: Big Bend Erosion on earthen walls of the project's spillway in South Dakota

Figure 89. Dams damage/erosion: Big Bend - Project's spillway in South Dakota being overtopped during flood

Figure 90. Dams damage/erosion: Big Bend – Project's spillway overtopping damage in South Dakota currently under repair

Figure 91. Dams damage/erosion: Big Bend – Project's spillway overtopping damage in South Dakota currently under repair

Figure 92. Dams damage/erosion: Fort Randall - Sloughing on earthen walls of the project's spillway and regulating tunnels in South Dakota

Figure 93. Dams damage/erosions: Fort Randall - Spillway weir spalling

Figure 94. Dams damage/erosion: Fort Randall - spillway gate wire hope hoist linkage corrosion

Figure 95. Dams damage/erosion: Fort Randall - Spillway wingwall backfill erosion (currently under repair) at Fort Randall in South Dakota

Figure 96. Dams damage/erosion: Fort Randall - Downstream spillway wingwall concrete spall at Fort Randall, South Dakota

Figure 97. Dams damage/erosion: Gavins Point - Erosion on earthen walls of the project's spillway in South Dakota

Figure 98. Dams damage/erosion: Gavins Point - Excess debris led to clogging of water intake at Hydropower Plant (under repair) in South Dakota

Figure 99. Dams damage/erosion: Gavins Point - Erosion on earthen walls of the project's spillway in South Dakota (under repair)

Figure 100. Levee scouring/erosion: Scour hole between Council Bend chute and MR Levee L624-627 toe in Council Bluffs, Iowa

Figure 101. Flood protection project damage: Hickory Street Pump Station - High water mark on interior side of an exterior door at a flood protection project in Omaha, Nebraska

Figure 102. Levee scouring/erosion: Typical riverside erosion and vegetation loss at L611-614 near Council Bluffs, Iowa

Figure 103. Levee seepage/sandboils: Typical landside seepage and sandboils at L611-614 near Council Bluffs, Iowa

Figure 104. Levee breach: Upper breach at L575

Figure 105. Levee breach: Upper breach at L575

Levee breach of L575 on Missouri River seen as waters have receded significantly.

Figure 106. Levee breach: Middle breach at L575

Figure 107. Levee breach: Middle breach at L575

Figure 108. Levee breach: Middle breach at L575

The middle levee breach of L575 on Missouri River seen as waters have receded significantly.

Figure 109. Levee breach: Lower breach at L575

Figure 110. Levee breach: Lower breach at L575

The lower levee breach of L575 on Missouri River seen as waters have receded significantly.

Figure 111. Levee breach: Upper breach at L550

The upper levee breach of L550 on Missouri River seen as waters have receded significantly

Figure 112. Levee breach: Lower breach at L550

The lower levee breach of L550 on Missouri River seen as waters have receded significantly.

Figure 113. Levee scouring/erosion: L536 - Levee erosion – more than 50 percent of the embankment is missing – at MR Levee L536