SECTION VII

SUMMARY AND CONCLUSIONS

A. MR&T SYSTEM PERFORMANCE/DAMAGES PREVENTED

The performance of the MR&T System during the 2011 Flood is determined by the manner in which it was operated and its physical performance. Its overall effectiveness is measured by the amount of flood damages that were prevented by the flood risk management system (FRMS), or in terms of its percent flood risk reduction. This also relates to the degree of protection afforded by the project.

Section IV described the operation and emergency activities performed during the 2011 Flood and the vulnerabilities the event revealed in system and the way it was operated. Section V described the economic and environmental impacts of the flood and the damages that the System prevented. The following paragraphs and subsections summarize the primary conclusions related to the performance of the System during the 2011 Flood. Recommendations, based on these conclusions, are identified in Section IX.

1. Operations. In general, the System was operated as it was designed to be operated, and the operational plans in place at the start of the event were utilized by decision makers. However, the magnitude of the event tested the System and its individual components like no flood before it and exposed vulnerabilities in many system components and the plans used to operate them. In some cases, operational decisions were required that deviated from pre-flood plans. Details related to those decisions are provided in Section IV and, where appropriate, recommendations for updating plans are provided in Section IX. Additional details related to lessons learned during the flood fight are provided in the After Action Reports in Appendix E, *Communications and Collaboration.*

New technologies presented opportunities to utilize several enhanced tools such as Smartphones, and social media sites (e.g., Facebook and Twitter) that were not fully considered in pre-flood plans. These tools were quickly applied and used successfully to improve internal and external communications during the flood. Properly applied, the enhanced communications tools work well. When they were not applied properly, confusion and frustration resulted and special rules for the proper use of social media were found to be needed. Some other technology related problems encountered in the field included poor cell phone reception in some remote areas, a shortage of phones and radios, difficulty in obtaining them, and the issue that too few people were trained to use some information collection and sharing tools and applications at the beginning of the event.

Overall, the operation of the System was successful and new tools were utilized extensively and effectively during the 2011 Flood. However, there is room for improvement in nearly all areas, particularly in the realm of communications. Internally, some Emergency Managers felt that they could have helped address and minimize some of the more controversial issues if they were in the field directly supporting the District Engineers during the decision making processes. Adapting the pre-flood plans to fully consider new tools and apply the lessons learned during the 2011 Flood will improve operational responses to and preparations for future flood events.

2. Damages. As discussed in Section V, the 2011 Flood affected approximately 119 counties and parishes in portions of seven states. According to damage analyses performed using the HEC-FIA model, damage impacts for the existing 2011 event (as it occurred; i.e., Scenario 1) were estimated to affect 43,358 people, 21,203 residential and nonresidential structures, and 1.2 million acres of agricultural land. Total damages are estimated to be about $2.8 billion. Estimates of the number of inundated structures, the degree of inundation, and the associated dollar damages, provide a profile of the system-wide impacts associated with a given scenario. While the aggregate system-wide estimates are constructed from estimates at the level of the individual structure, definitive attribution of a specific result to an individual structure in the form of inundation, depth of inundation, or dollar damage is not appropriate.

Both Section V of this report and Appendix G, *Economics*, provide greater detail regarding the description of damage results.

3. Results of Flood Damages Prevented. Flood damages prevented by the MR&T Project are based on the difference between the without-project conditions. Based on flood damage estimates, the MR&T System prevented approximately $234 billion in total flood damages during this single event. Without the MR&T Project, approximately 1.46 million residential and commercial structures would have been impacted. With the MR&T Project, this decreases to 21,203.

In comparison, the MR&T System (with reservoirs only, Scenario 2) prevented approximately $11.8 billion in urban and agricultural flood damages during the 2011 Flood, which results to only a 5 percent reduction in total flood damages.

4. Project Effectiveness. Project effectiveness is measured by the amount of flood risk reduced by the project, or in terms of its percent flood risk reduction (FRR). This also relates to the degree of protection (DOP) afforded by the project. The results of project effectiveness from flood damages prevented are displayed in table VII-1for each scenario. Based on the results of the flood damage evaluation, the FRR for Scenarios 1 and 4 resulted in a 98 percent DOP while Scenario 2 (reservoirs only) provided only minimal protection in terms of FRR with a 5 percent DOP.

5. Conclusion. Without the MR&T Project in place (i.e., Scenario 3) total flood damages in the seven-state impacted area would have been over $237 billion. Furthermore, with the Project, as operated during the 2011 Flood event, implementing Scenario 1—the MR&T Project (with minor deviations in the operations of the reservoirs)—provided a 98 percent flood risk reduction. .

Table VII-1. Effectiveness of MR&T Project [1]

		Without MR&T Project (Scenario 3) [2]	With-Project Conditions		
Scenario	**With-MR&T Project Description**	**Total Damages**	**Total Residual Damages**	**Total Damages Prevented Benefits**	**FRR [3]**
1	**As Occurred 2011** (minor deviations in reservoir operations)	$237,152,397,000	$2,863,843,000	$234,288,554,000	98 %
2	**With Reservoirs, But No Levees**	$237,152,397,000	$225,315,506,000	$11,836,891,000	5%
4	**As Designed 2011** (no deviations in reservoir operations in 2011)	$237,152,397,000	$2,863,843,000	$234,288,554,000	98 %

[1] values expressed in 2012 prices

[2] the without-project condition

[3] percent of FRR from project implementation; also referred to as DOP

B. DAMAGES TO THE MR&T SYSTEM

The 2011 Flood was the largest on record for the MR&T System. The MR&T System was designed to pass extreme events with limited damage to its components.

Extreme flood events affect levee systems in predictable ways. Typical problems include overtopping, breaching, erosion of the levee or batture, slope stability, and seepage issues, often resulting in soil boil formation. Damages to levees should be limited to seepage, erosion/scour, and slope protection/paving issues. Overtopping and stability issues should not occur for the PDF or lesser events. A possible exception is when the landside slope becomes saturated from long-term flood events. In addition, levee-floodwall tie-in failures should not occur in a properly designed and constructed FRM component.

Seepage is not detrimental to levee safety unless it moves material through the development of sand boils. Seapage repair measures typically include the addition of berms or relief wells. Seepage repair measures typically include the addition of berms or relief wells.

Prolonged high water and associated velocities often cause increased scour and erosion of levees. As a result, a decreased levee section can become a stability issue during periods of low water. In most cases, scour and erosion repair measures consist of slope paving and protection above the water line and the addition of articulated concrete mattresses (ACM) below the water line.

The damages and deficiencies discussed in this section are based on the 2011 DARs. These reports are summarized in Appendix B, *Levees and Floodwalls*. The performance, damages, and deficiencies identified for each Levee System are discussed by District and summarized in table VII-2.

Table VII-2. Post-Flood Levee System Acceptability Rating By District

District	Number of Systems	Number of Systems Rated Unacceptable (pre-flood)	Number of Systems Rated Unacceptable (post-flood)
MVM	7	1	4
MVK	2	2	2
MVN	6	0	0

During the 2011 Flood, nearly all of the levee/floodwall systems experienced some degree of damage. This is a deterministic indicator that the Systems were not over designed, and emphasizes the need for continued maintenance of all project features. The acceptability rating referenced in table VII-5 is based on criteria used during yearly routine inspections. An “unacceptable” rating occurs when one or more components are rated as unacceptable, preventing the segment or system from performing as designed.

The Channel Improvement Program (CIP) identified a significant number of sites that sustained damage to ACM revetment during the 2011 Flood. ACM revetment damage consisted of upper bank erosion, toe scour, and areas of failure. Of the failure sites, 44 were categorized as critical, meaning that their locations are in close proximity to the mainline levee. Continued or further ACM revetment failure at these locations could compromise the integrity of the mainline levee and navigation channel and increase the cost of repairs.

The CIP has also identified numerous locations on the Mississippi River where dikes sustained damage. The damage generally consisted of structural degradation associated with movement of riprap, flanking, blowouts, expansion of existing notches, and downstream scour of the bankline. If left unrepaired, the

damage presents an increased risk to the integrity of the FRM and navigation systems and ultimately, the cost of repairs.

Based on a holistic view of the 2011 Flood and the performance of the MR&T System, the following additional conclusions may be drawn regarding the system.

- The 2011 Flood was one of the largest on record, particularly in the lower reaches of the Mississippi River.
- Although it was one of the largest floods, much of the extreme rainfall was concentrated resulting in range of interior flooding issues including drought-like conditions on the lower end of the system.
- Flood fighting was a key measure during the flood. The Corps assigned approximately 1000 staff to the flood and spent nearly $60M from March to August while Emergency Operations were underway.
- The flood fighting techniques employed at a tactical level were generally successful in maintaining the integrity of the primary FRM System. An exception is the construction of ring dikes around sand boils and seeps. Some locations reported the throat of the sand boil moving outside the ringed area and requiring re-ringing. This is typically caused by “bleed” channels located too high in the ring dike or missing entirely. The Flood Fight Manuals require updating to provide clearer instructions on ringing sand boils and overall flood fighting terminology and techniques.
- Tie-in issues (floodwall to high ground) have been studied and tested extensively in the aftermath of Hurricane Katrina, and recommendations for tie-in designs are available in the Corps Armoring Manual dated November 2011. As these recommendations are implemented, these types of problems should become less frequent.
- The operation of the MR&T System, as a whole, was adequate to minimize flood impacts. This includes the operation of gates, reservoirs, spillways, and diversions located throughout the System.
- There were 24 reservoirs utilized during the flood with only 5 of them being an MR&T component. The use of the 24 reservoirs ranged from simply monitoring conditions and reporting to normal control to deviation from normal control. Six of the reservoirs reached at least 100% of their flood control storage. Dam safety ratings of reservoirs influences their operation and could impact flood levels in the future.
- No significant breaches occurred in the primary FRM System. Minor breaches occurred in a private spur levee and as part of the operation of the New Madrid Bend Levee.
- Both MVK MR&T System segments were unacceptable (pre-flood), requiring extra diligence during 2011 flood fight operations. An "unacceptable" rating occurs when the condition of one or more components may prevent the system segment from performing as designed.
- One of seven MVM MR&T System segments was unacceptable (pre-flood). This increased to four systems post-flood.
- None of six MVN MR&T System segments were rendered unacceptable (pre or post flood).
- The system contains pre-flood deficiencies of which some were not tested by the flood and remain a risk. An example of such underlying/residual risks relates to the 11 percent of the MR&T System on-going construction efforts that may continue for decades.

C. ENVIRONMENTAL AND CULTURAL RESOURCES

The LMRV covers 36,000 square miles of diverse forest, grasslands, swamps, marshes, productive agricultural land, and some urbanized areas. It includes the Red River Basin, Yazoo River Basin, the Atchafalaya River Basin, and the Mississippi River Delta plain sub-regions. The area is rich in biological diversity and contains some of the most important areas of bottomland hardwoods, forested wetlands, and coastal wetlands in the Nation.

The 2011 Flood's effect on the environmental and cultural resources of the area was largely related to rapid and prolonged inundation of nutrient-rich freshwaters. While much of the inundation would have happened during 2011 with or without a FRMS, in some places the depth or duration of the flooding was influenced by the MR&T system. This resulted in forcing some species to relocate or to move to unsuitable locations, the loss of the young of the year in some mammalian species, the over-freshening and excess nutrients in estuarine areas, and the erosion of cultural resource sites.

Although the Mississippi alluvial plain is ecologically adapted to periodic flooding and inundation, a flood of the magnitude of the 2011 Flood stresses organisms. In addition, in some ways the engineering structures, that protect many areas, concentrate flood waters in other areas beyond what would occur naturally. While many of the effects of such an extraordinary influx of freshwater are unavoidable, there may be a few opportunities to modify operations to minimize environmental and cultural resource damages while still providing a high level of FRM. Section IX includes many recommendations for future efforts and further studies. Perhaps the most underappreciated impact of the operation of the flood control system is the impact on the estuarine system and the oyster industry in Mississippi Sound, Lake Borgne, and Breton Sound, LA. It was estimated that the economic losses to the oyster industry in Mississippi alone in 2011 were approximately $60 million dollars (Appendix F, Section VI). There is also new evidence (Gundersen et al. 2012) that suggests that the nutrient rich river waters may be exacerbating hypoxic areas east of the Mississippi River. Traditionally, routing freshwater floodwaters into Lake Pontchartrain was perceived as the least damaging alternative; perhaps this new information indicates that the Corps should re-examine the order of operation or the extent of operation of various components of the flood control system.

The Flood of 2011 occurred just 3 years after the previous 2008 opening of the Bonnet Carre Spillway, providing a unique opportunity to convene an environmental interagency team in 2011 that was largely composed of the same people who participated in the 2008 event. The dynamics in 2011 were much better, generating many recommendations for codifying the interagency process for future generations. Additionally, the scouring of cultural resources sites in the BPNM Floodway underscores the importance of early coordination with cultural resources personnel.

D. REPAIRS AND MEASURES FOR THE MR&T SYSTEM

The MR&T System experienced a wide range of levee-related issues from slope instability to seepage and sand boils due to the 2011 Flood. Resulting structural damages were assessed by teams who prepared documents identifying the location, nature, and extent of damages. The teams also identified appropriate repair alternatives and estimated preliminary repair costs. Theses assessments utilized a DAR format to keep the data gathering and supporting information consistent. Forty-four separate DARs were developed to ensure that all levee reaches, structures and navigational river miles affected by this event were inspected and thoroughly documented. Through the assessment effort a FRAGO critical repair classification system was used to classify the degree of risk and consequences associated with each of the damaged areas. Using this classification system, MR&T repair projects were classified as either "critical" or "non-critical" and appropriately sequenced for construction.

During the 2011 Flood, nearly all of the levee/floodwall systems experienced some degree of damage. Repair efforts are moving forward and include seepage repair measures such as berms or relief wells. Scour and erosion repair measures are another common type of repair effort being advanced and these primarily consist of slope paving and protection above the water line and the addition of (ACM) below the water line. Repairs to the BPNM mainline levees are also proceeding and include restoration of the fuseplug levee components.

Damages to the MR&T floodways as a result of the 2011 Flood primarily consisted of scour below spillways, sedimentation in inflow and outflow channels, wave wash erosion, and loss of some monitoring equipment. Scoured areas are being repaired through appropriate techniques of filling and compaction. Sedimentation and wave wash erosion areas are also being addressed to restore areas to pre-flood conditions and assure the proper operation of the floodways in the future.

During the Flood, many Mississippi River basin reservoirs were utilized to attenuate the flood crests and reduce overall impacts. The only MR&T reservoir that experienced flood damages was Wappapello Lake. Repairs are moving forward on the damaged reservoir features including the exit channel, spillway, roads, and utilities. Currently the overall project is still able to function as intended and is not in danger of failing.

The channel improvement program (CIP) has identified a significant number of sites that sustained damage to ACM revetment during the 2011 Flood. Revetment damage consists of upper bank erosion, toe scour and areas of ACM failure. Repairs consist of restoring the bank to the previous configuration, adding a layer of ACM to an existing revetment, replacing damaged revetment and restoring upper bank paving to the previous configuration. Continued or further revetment failure at these locations could result in a threat to the integrity of the mainline levee and navigation channel and increased cost of repairs.

The CIP has also identified numerous locations on the Mississippi River where dikes sustained damage. This damage consists of removal of riprap, flanking, blowouts, expansion of existing notches, downstream scour pockets in the bankline and overall structure degradation. Repairs consist of restoring the damaged dikes to the pre-flood configuration, in most cases. Consideration is being given to leaving a notch in damaged sections of some dikes to capture environmental benefits when it does not compromise the structure or its performance. If left unrepaired, this damage will progress over time, presenting an increased threat to the integrity of the FRMS and navigation systems and increased cost of repairs.

E. RECOVERY STRATEGY AND TIMELINE

The MR&T System recovery effort is moving forward through a combination of immediate, critical, and non-critical repair projects to fully restore the System to pre-2011 Flood conditions. These projects include repairs to Mississippi River levees, channel structures, shoaled areas, floodways, and other flood damage reduction structures located throughout the river valley. The MR&T recovery strategy is focused on repairing critical high risk damages first. After these damages are addressed, work will then shift to less critical items and proceed until the MR&T System is fully restored back to pre-2011 Flood conditions. As work moves forward, the Corps will also seek to maintain a balance of system risks and not cause undue risks to individual damaged areas within the MR&T.

“Immediate Need Repairs” were self-funded and initiated and late 2011 to address 29 high risk damaged areas within the valley at a cost of $170 million. After passage of the Consolidated Appropriations Act in December 2011 which provided $802 million in supplemental funding for the MR&T repairs and receipt of additional funding from two other sources ($35 million FCCE, and $153 million Operation & Maintenance), the Corps was able to proceed with implementing 118 “Critical Repair” projects needed to restore and

prepare the System for the next high water event. The supplemental funding would also fund just over 100 of the 302 "Non-Critical Repair" projects that were identified and ranked through the MR&T damage assessment process. Completion of these repair efforts will reduce the current elevated flood risks to the System and restore the MR&T to pre-2011 Flood conditions. The remaining "Non-Critical Repair" projects will be addressed as funds from the annual O&M budget allow.

MR&T repair projects are moving forward, and most of these efforts will be completed in 2012 and 2013 (figure VII-1). Completion of several "Critical Repair" projects will extend into later years (i.e., 9 in 2015 and 1 in 2016) primarily due to the magnitude of the required repairs and duration of the construction efforts. Approximately 25 of the "Non-Critical" repairs were not scheduled at the time of this writing and therefore are not included in figure VII-1.

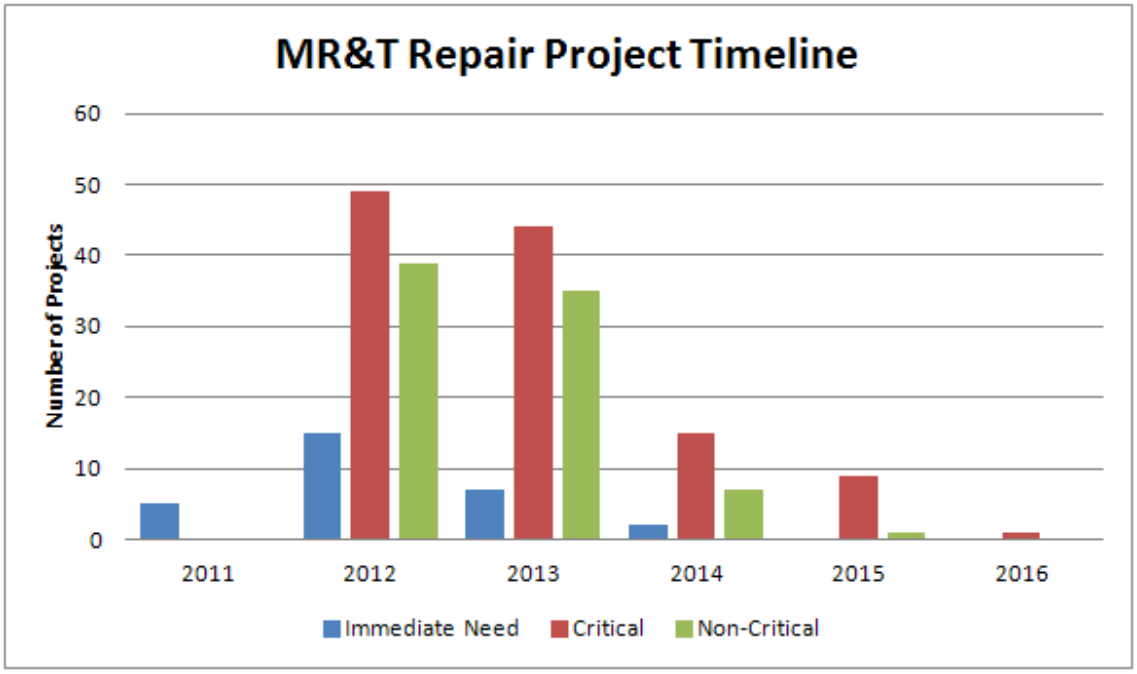

Figure VII-1. Timeline of MR&T Repair Project Completion

The strategy and timeline of MR&T repairs may change as a result of the lessons learned and the recommendations captured through this post-flood effort. Additional studies are also underway that may further improve repair efforts and modify construction schedules. Restoration of the MR&T System will continue with a focus on timely and informed progress towards completion.

F. IMPACTS OF CONSTRAINTS

The damages to the MR&T System will be repaired and the deficiencies and vulnerabilities in its flood fight plans will be addressed as MVD recovers the System. The System will be restored to a pre-flood condition and in some cases be a better system. A challenge such as the 2011 Flood reveals strengths and more importantly weaknesses of designs, construction, plans and processes. For example, the flood confirmed that underseepage is a major issue and will impact the plans for completion of MR&T levee construction. The restored system will undoubtedly be stronger after all issues are addressed through recovery; however, there are constraints that preclude the execution of a perfectly efficient and timely construction project. Such

constraints are common in Corps projects and include real estate actions, funding limitations, borrow pit acquisitions, land acquisition, environmental/cultural mitigation, design time, stakeholder/partner engagement, etc. Although these constraints are shared with many Corps' projects, the MR&T System was damaged to the extent that it presented unacceptable levels of risks to lives and livelihoods that rely on the FRMS.

Prior to the passage of the Consolidated Appropriations Act 2012, PL 112-74 (December 2011), the Corps recognized the urgency to self fund 29 projects in high risk areas within the valley at cost of about $170 million. The severity of damages and associated risks the 29 areas posed made them a priority for the Corps to quickly accomplish the repairs by pulling funding from other ongoing Corps projects from across the Nation.

The process of prioritization and self funding proved to be very difficult, and inefficient. Identifying where to draw the line for these initial projects required balancing the severity the life safety risks with the level of funding that could be found within the Corps' budgets. A significant effort was invested in explaining to stakeholders and the public why certain projects were funded and others would be put on hold until funding was available. The process of identifying and pulling existing Corps funding from other Districts throughout the country was also difficult. Evaluating the financial status of thousands of projects required a significant effort. This process was made even more difficult because transferring funds from other Corps projects caused work stoppages and completion delays (requiring communication of these impacts with cost-share partners and stakeholders) and other inefficiencies. No time frame could be provided as to when or even if the funds would be returned to those projects.

The passage of the Consolidated Appropriations Act 2012, PL 112-74 provided $802 million in supplemental funding to be used towards MR&T repairs. This funding along with funding from other sources ($170 million self-financed, $35 million FCCE, and $153 million Operation & Maintenance) allowed for completion of all MR&T critical repairs as quickly as possible within the constraints explained above. Project management will be monitoring construction projects for key schedule drivers and other project delivery issues. Information related to residual risk from unfinished repairs will be shared with internal and external emergency managers to better inform flood fight teams and river communities as they prepare for future flood seasons.

G. RESIDUAL RISKS

The MR&T System will not be without risk after all repairs of 2011 damages are complete. Many of these residual risks relate to the 11 percent of the MR&T System that is not yet complete due to on-going construction efforts that may continue for decades. The incomplete portions of the MR&T System increase the chances of overtopping as well as underseepage-driven stability problems. Pre-flood deficiencies on 3.1 miles of floodwalls on the lower Atchafalaya present risks until they are addressed since they are not planned to be repaired as part of the 2011 flood repairs. Risks will also remain in the MR&T System due to the inability to address channel improvement needs over the next several years while 2011 damage repairs continue. The channel improvement flood-related repair construction is primarily accomplished by mat laying crew and equipment. This unique resource dedicated to flood-related repairs will likely be unable to accomplish baseline channel improvement construction projects/tasks during the period of repair. The assignment of unique resources to flood repairs potentially leaves baseline work untouched, thus allowing these residual risks to remain in the System. Another example of residual and increasing risk is development in floodway lands, which increase the economic consequences of the risk equation. These residual risks can be incrementally addressed through continued funding, design, and management of the MR&T System. Effective communication, awareness, and planning will be key to best managing the MR&T System residual risks in the future.