The 2011 Mississippi River Basin Flood: A Perspective on Forecasting, Water Management, and Flood Fight

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Acknowledgement

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THIS ISN'T THE LAZY, ROMANTIC RIVER I REMEMBER...

NEWSPAPER: "MAJOR MISSISSIPPI FLOODING"

Author: Mark Twain

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Mississippi River Watershed
Provide weather, water and climate forecasts and warnings to:
  - Protect life and property
  - Enhance the national economy

River Flood Forecasting is a collaborative effort between many agencies

US Army Corps of Engineers®

USGS
science for a changing world
13 River Forecast Centers issue river guidance
Pre-Event Conditions

- Winter Outlook predicted wetter than average for Ohio & TN Valleys
- Historic snow water equivalents occurred over Upper Miss Valley
- Above normal rainfall in Feb caused elevated streamflow in Ohio Valley
Pre-Event Conditions

• Spring flood Outlook indicated Above Average to High Flood Risk for Mississippi, Ohio, & Tennessee Valleys
• Briefings provided to partners to convey flood risk
• Then it started to “Rain”
Rainfall Overview

[Maps showing rainfall patterns]
Communication/Collaboration

- Continuous forecast coordination between NWS forecasters and USACE decision makers including 100+ scenarios for spillway operations
- Daily coordination with USGS & USACE on real time discharge measurements to help validate and adjust hydraulic models and rating curves
- NWS personnel stationed at USACE Emergency Operations Center
- HEC-RAS collaboration with USACE, NWS, & HEC
USGS Streamgages Active in Water-year 2010, Total 7,845
2,423 Streamgages in the Mississippi River Basin Highlighted
* Installation of 51 Rapid Deployment Gages (RDG)
* 2,331 special streamflow measurements in 15 states, Feb – Aug
* 74 Rating extensions
2011 Major Flood Peaks

- Peak of record
- Ranks 2-5
- Above NWS flood stage
2011 Peaks on the Mississippi River

Annual Peak Discharges by Drainage Area
Specific Years Identified by Colored Circles
Mississippi River Gaging Stations

River Miles (Not to Scale)
Birds Point-New Madrid Floodway

- Main Channel Streamflow
- Inflow and Outflow of Floodway
- Water Level Time Series in Floodway
Ongoing Flood Science and Flood Documentation Efforts for 2011

- U.S. Flood Report to include:
  - Flood peaks
  - Flood probability assessments
  - Water quality studies
  - Sediment/Geomorphology
  - Hydrology Assessments
    - Flood volumes
    - Trends
  - Biologic Impacts
The Mississippi Watershed

- 60% Ohio River
- 40% Upper Mississippi and Missouri Rivers Combined
Ohio Valley Reservoirs

- 78 USACE multi-purpose reservoirs
- 31 TVA multi-purpose reservoirs
- 97 local flood protection projects

Cost of Projects

- $3.6 billion

Damages Prevented

- $35.7 billion
Flood Risk Management

Total LRD Damages prevented: **Over $35.7 B**
Damages prevented 2010 Cumberland River Flood: **$294.6 M**
Damages prevented 2011 Mississippi/Ohio Flood: **$110 B**

**LRD Portfolio of Dams**

- **Navigation Dams** = 58
- **Flood Control Dams** = 79

Average Age = 55 yrs = OM&R $’s

**MSC Comparison of DSACs**

- **DSAC IV Dams**
- **DSAC III Dams**
- **DSAC II Dams**
- **DSAC I Dams**

LRD – 48% DSAC I, 33% DSAC II, 23% DSAC III of USACE dams
LRD Commander assumes direction of LRN Cumberland System and TVA Tennessee System

Flood reduction effects can be achieved all the way to New Orleans
Total 30 Day Rainfall
April 5 to May 5, 2011
Peak Reservoir Utilization
Spring 2011 Floods

- Wettest April in 117 Years across the basin
- Record amount of storage utilized basin-wide
- Stages reduced on entire length of Ohio and lower Mississippi Rivers

Full Flood Pool Used
- Monroe Lake, IN
- Patoka Lake, IN
- Rough River Lake, KY
- Taylorsville Lake, KY

Interim Risk Reduction Measures at critical Dam Safety Action Classification Projects limited flood storage use
**LRD Water Management**

*79 Multi-Purpose Reservoir Projects*

- **LRD Reservoirs**
  - ▲ Reservoir
  - △ Record Pool
  - ○ Flood of Record

- **New Record Stages**
  - Ohio River
    - Smithland
    - Cairo
  - Mississippi River
    - New Madrid
    - Caruthersville
  - Big Muddy River
    - Murphysboro
  - Wabash River
    - Mt. Carmel
  - Patoka River
    - Princeton

- **New Record Pool Levels**
  - Nolin Lake
  - Cave Run Lake
  - Rough River Lake
  - Patoka Lake
  - Taylorsville Lake
  - Monroe Lake
  - Harsha Lake
  - Brookville Lake
  - Kentucky Lake
  - Barkley Lake

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**Total System Flood Storage Capacity Utilized**

- 7-Apr-2011
- 14-Apr-2011
- 21-Apr-2011
- 28-Apr-2011
- 5-May-2011

- Total Percent: 38.9%
24 hours QPF
Bold represents crest stage

Cairo -
65.0ft - Top of Protection
61.7ft - Flood of Record (2011)

Paducah -
63.8ft - Top of Protection
60.5ft - Flood of Record (1937)

NOTE:
Gray Data indicates preliminary data

River System Schematic - Current Status as of 12:00 EDT

Day
Peak | Date
--- | ---
THU | FRI | SAT | SUN | MON | TUE | WED | THU | FRI
--- | --- | --- | --- | --- | --- | --- | --- | ---

Kentucky Dam

CRITICAL STAGES
Cairo -
65.0ft - Top of Protection
61.7ft - Flood of Record (2011)

Paducah -
63.8ft - Top of Protection
60.5ft - Flood of Record (1937)

Nashville District / TVA Forecast Data (Forecasted Rain Included)

Made with @riverbasinmap
Complexities of Water Management

Crests
66.73’ Natural without breach
65.50’ Natural
61.72’ Observed

Cairo Stage
Top of flood pool (375)

Kentucky-Barkley Pool Elevation

Reductions Achieved
KY/BK – 3.25 feet
All LRD/TVA Reservoirs – 3.78 feet
Floodway – 1.23 feet

Increase releases to keep pools steady ahead of crest.
Maintain releases to keep pool on guide curve.

5.01 feet

Natural crest without breach @ 66.73’
Floodway Operation @ 61.72’

A battle of inches!!

Cuts Initiated with Target 61’ at Cairo
Balance releases to maintain pools below 374 ft while reducing flood heights at Paducah.
Birds Point–New Madrid Floodway

- Completed in 1932
- Operated (Levees Breached) in 1937 and 2011
- 133,000 acre floodway – Completely flooded in 2011
- Design Flow of 550,000 cfs
- 2011 Peak Flows of 400,000 cfs
Ohio River Community Model Team

LRD, LRP, LRH, LRL, LRF
ERDC, HEC
OHRFC, LMRF, NCR
ORSANCO
IN, KY, OH, PA, WV
The Mississippi Watershed

- 60% of the Mississippi Watershed is drained by the Ohio River.
- 40% of the Mississippi Watershed is drained by the Upper Mississippi and Missouri Rivers Combined.
Project Purposes

- Flood Control
- Navigation
- Hydropower
- Irrigation
- Water Supply
- Water Quality Control
- Recreation
- Fish and Wildlife
Storage Capacity of Corps Reservoirs

Height Indicates Relative Volume (acre-feet)
- > 10 Mil
- < 10 Mil to > 1 Mil
- < 1 Mil to > 500 K
- < 500 K to > 250 K
- < 250 K to > 100 K
- < 100 K

US Army Corps of Engineers
BUILDING STRONG

Prepared and Produced by the U.S. Army Corps of Engineers Omaha District 2010
Runoff Components

Plains Snowpack
+ rainfall

Mountain Snowpack
+ rainfall

Rainfall

March and April
~ 25% annual runoff

May, June and July
~ 50% annual runoff

March through October

2011 Runoff = 61.0 MAF

Highest runoff since 1898

Previous Record was 49.0 MAF in 1997
Missouri River Mainstem System
Annual Runoff above Sioux City, IA

Historic Drought Periods

Million Acre-Feet

- 34.3 MAF
- 30.3
- 24.4
- 19.3
- 16.2
- 10%
- 25%
- 50%
- 75%
- 90%


2011
2010 – 2011 Mountain Snowpack

Above Fort Peck

Peak (May 2):
141% of normal
Apr 15 peak

Fort Peck to

Peak (May 2):
136% of normal
Apr 15 peak
May 2011 Precipitation

Missouri Basin RFC Pleasant Hill, MO: May, 2011 Monthly Observed Precipitation
Valid at 6/1/2011 1200 UTC - Created 6/2/11 17:40 UTC
Rainfall Comparison for the Missouri River Flood of 2011 (May 1-31, 2011) and Hurricane Irene (Aug 27-29, 2011)

Missouri River Basin above Sioux City

Rainfall (inches):
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 10
- 10 - 12
- 12 - 16
- 16 - 20

0 100 200 400 600 800 1,000 Miles

N
June 2011 Precipitation

NWS Central Region: June, 2011 Monthly Observed Precipitation
Valid at 7/1/2011 1200 UTC - Created 7/2/11 17:40 UTC
July 2011 Precipitation

Missouri Basin RFC Pleasant Hill, MO: July, 2011 Monthly Observed Precipitation
Valid at 8/1/2011 1200 UTC - Created 8/2/11 17:40 UTC
2011 Flood of Record

- Much above average plains snowpack, late-arriving much above normal mountain snowpack and record May rainfall in the upper basin … flood of record.

- Runoff in 2011 was 61.0 million acre-feet (MAF), 247 percent of normal and the highest runoff in 114 years
  - May was the ninth wettest single month on record with 9.3 MAF
  - June was the single wettest month on record with 14.8 MAF of runoff, surpassing the old record of 13.2 MAF set in April 1952.
  - July was the fourth wettest single month on record with 10.2 MAF

- Combined May through July runoff of 34.3 MAF is higher than the total annual runoff in 102 of 113 years in the period of record
  - Estimated 0.2 percent annual exceedance interval
System Tested as Never Before…

- System storage peaked at a record 72.8 MAF on 1 July
  - 16 MAF stored flood waters in mainstem reservoirs
  - Corps and Bureau of Reclamation tributary reservoirs also utilized
- Four mainstem reservoirs utilized exclusive flood control zone
  - Fort Peck, Garrison, Oahe and Fort Randall
- Three mainstem reservoirs set record pool levels
  - Fort Peck, Oahe and Fort Randall
- Two mainstem reservoirs utilized surcharge storage
  - Fort Peck and Garrison
- Spillways at two mainstem dams were operated for the first time
  - Garrison and Big Bend
- Record releases from all mainstem reservoirs
Missouri River Stage Reduction Due to Reservoir Operations

- Culbertson, MT: 1.8 feet
- Bismarck, ND: 5.2 feet
- Yankton, SD: 4.9 feet
- Sioux City, IA: 3.2 feet
- Decatur, NE: 5.3 feet
- Omaha, NE: 3.8 feet
- Nebraska City, NE: 0.7 feet
- Rulo, NE: 1.2 feet
- Kansas City, MO: 6.9 feet
- Boonville, MO: 3.3 feet
- St. Joseph, MO: 3.6 feet
- Waverly, MO: 1.0 feet
- Hermann, MO: 4.0 feet
Missouri River at Sioux City, IA – Actual and Unregulated Flows

Number of Days above Flood Stage

Unregulated: ~ 100
Actual: ~ 80

Flood Stage = 30 ft (~ 122,000 cfs)
Independent External Review Panel

- Panel members from NRCS, USGS, NWS and Colorado State University

- “The panel found no evidence that Corps personnel were attempting to do anything other than to operate the system using the best available methods and to minimize the overall negative consequences. The flood in 2011 was a record-breaking event with unprecedented levels of runoff that could not be predicted in advance, and the Corps responded well to a difficult test of historic dimensions.”

(page 84, Summary and Conclusions)
Independent External Review Panel

• Panel Recommendations

1. Support a program of infrastructure enhancement.
2. Update hydrologic studies to include 2011.
4. Improved cooperation/collaboration with NWS, USGS and NRCS.
5. Studies to enhance data collection and forecasting (especially plains snow).
6. Implement modern interactive, graphics decision support system.
The Mississippi Watershed

Flow Contribution to Lower Mississippi River
April/May 2011 Flooding
White & Arkansas Rivers

- Major flooding occurred on the White and Arkansas Rivers in the Southwestern Division.
- Rainfall totals of 20 - 30 inches were common during the 2-month period.
- Record flooding occurred in many locations and record pool levels were set at several White River Lakes in the Little Rock District.
- Four of the Little Rock District lakes on the White River system required multiple surcharge operations.

Table Rock Dam, Missouri
Pool of Record: 935.47 ft
Record Release: 69,000 cfs
Water Management

- By early to mid May, the Mississippi River crest was approaching the confluence with the White and Arkansas Rivers.

- SWD and its Districts began looking for ways to reduce flows entering the Mississippi River and thereby reduce the flows and stages at critical locations downstream.

- The lakes in Little Rock District had full to above full flood control pools and they could not reduce releases from those lakes.
Water Management

- However, Tulsa District’s system of lakes which release water into the Arkansas River had available storage capacity.

- SWD and Tulsa District initiated a deviation to reduce flows on the Arkansas River at Van Buren, Arkansas from 150,000 cfs to 100,000 cfs during 3 - 14 May.

- This deviation was effective in reducing flows on the lower Arkansas River during the period just prior to and during the passage of the flood crest on the Mississippi River, reducing the maximum crest.
The Mississippi Watershed

Flow Contribution to Lower Mississippi River

60% Ohio River

40% Upper Mississippi and Missouri Rivers Combined
2011 Flood Facts

- 2011 Flood – Set stage and flow records over much of the Lower Mississippi River Basin
- Some groups have suggested that the current MR&T project has overly confined the river, not giving adequate “Room for the River” during major floods with the potential for devastating consequences if the system is overtopped or fails
- Operated 3 of 4 floodways and 0 of 4 backwater areas
- During the 2011 flood, 6.35 million acres were flooded while 1.5 million acres of floodways and backwater areas were not used
- The 2011 flood produced approximately 80 – 85% of the flows of the MR&T’s project design flood while the MR&T project is only 87% complete
• Flooded 26,000 square miles
• 600,000 homeless
• More than 250 people killed
• Economic damages ~$1 billion
Mississippi River & Tributaries
“An Integrated System”

- **Levees** – “backbone of flood protection”
- **Tributary Basin Improvements** – “completing the task”
- **Channel Stabilization** – “tickling the River for navigation & flood control”
- **Floodways** – “overflow relief”
MR&T Project & 2011 Flood Facts

- MR&T Project Authorized following the 1927 Flood when a “Levees Only” policy was in effect
- Designed for a Project Design Flood (PDF) – Extreme Event w/Reasonable Chance of Occurrence
- 2011 Flood Exceeded 1927 and/or 1937 floods but was only about 80-85% of PDF
- MR&T Project contained the 2011 Flood despite being only 89% Complete while:
  - No MR&T Levees failed or were overtopped
  - Used 3 of 4 Floodways during the 2011 Flood,
  - Backwater Areas’ Flooding Limited to Interior Flooding Although Came Close to Using Yazoo BW Area
- MR&T System still had/will have more “Room for the River” for events up to the PDF
## 2011 Mississippi & Atchafalaya STAGES

<table>
<thead>
<tr>
<th>Station</th>
<th>Flood Stage</th>
<th>2011 Crest Stage</th>
<th>2011 Crest</th>
<th>Record Stage</th>
<th>Record Year</th>
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<tbody>
<tr>
<td>Cairo, IL</td>
<td>40.0</td>
<td>61.72***</td>
<td>2 May</td>
<td>59.51</td>
<td>1937</td>
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<tr>
<td>New Madrid, MO</td>
<td>34.0</td>
<td>48.35</td>
<td>6 May</td>
<td>47.97</td>
<td>1937</td>
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<td>Caruthersville, MO</td>
<td>32.0</td>
<td>47.61</td>
<td>7 May</td>
<td>46.00</td>
<td>1937</td>
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<td>Memphis, TN</td>
<td>34.0</td>
<td>47.87</td>
<td>10 May</td>
<td>48.70</td>
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<td>Helena, AR</td>
<td>44.0</td>
<td>56.59</td>
<td>12 May</td>
<td>60.21</td>
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<td>Arkansas City, AR</td>
<td>37.0</td>
<td>53.14</td>
<td>16 May</td>
<td>59.20</td>
<td>1927</td>
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<td>Greenville, MS</td>
<td>48.0</td>
<td>64.22</td>
<td>17 May</td>
<td>65.4****</td>
<td>1927</td>
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<td>Vicksburg, MS</td>
<td>43.0</td>
<td>57.1</td>
<td>19 May</td>
<td>56.20*</td>
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<td>Natchez, MS</td>
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<td>Red River Lndg, LA</td>
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<td>63.09</td>
<td>21 May</td>
<td>61.61</td>
<td>1997</td>
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<td>Baton Rouge, LA</td>
<td>35.0</td>
<td>45.01</td>
<td>18 May</td>
<td>47.28</td>
<td>1927</td>
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<td>New Orleans, LA</td>
<td>17.0**</td>
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<td>1922</td>
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<td>Simmesport, LA</td>
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<td>23 May</td>
<td>59.13</td>
<td>1927</td>
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<td>Butte LaRose, LA</td>
<td>25.0</td>
<td>23.14</td>
<td>26 May</td>
<td>27.28</td>
<td>1973</td>
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<td>Morgan City, LA</td>
<td>4.0</td>
<td>10.35</td>
<td>29 May</td>
<td>10.53</td>
<td>1973</td>
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</tbody>
</table>

**New Record Stage**

*62.2’ If Levees Held   **Levees Protect New Orleans to 20.0’ Stage  
***NWS Crest of 63.0’ on 5 May w/o BPNM Operation – Actual Stage of 59.7’ on 5 May 2011 w/BPNM Operation  
****Adjusted to Current Gage Location - Prior to 1940 stages were taken at City Front or Warfield Point  

Note: With Morganza Operation, Baton Rouge to N. Orleans crests occur prior to upstream locations and remain steady during these floodway operations.

22 March 2012
# Historical Flows

<table>
<thead>
<tr>
<th>Station</th>
<th>PDF 5/</th>
<th>2011</th>
<th>% of PDF</th>
<th>1937 6/</th>
<th>1927 6/</th>
<th>1973</th>
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<td>2,360,000</td>
<td>2,100,000</td>
<td>88%</td>
<td>2,010,000</td>
<td>1,626,000</td>
<td>1,536,000</td>
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<td>Memphis, TN</td>
<td>2,410,000</td>
<td>2,213,000</td>
<td>91%</td>
<td>2,020,000</td>
<td>N/A</td>
<td>1,633,000</td>
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<td>Helena, AR</td>
<td>2,490,000</td>
<td>2,130,000</td>
<td>85%</td>
<td>1,968,000</td>
<td>1,756,000</td>
<td>1,627,000</td>
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<td>Arkansas City, AR</td>
<td>2,890,000</td>
<td>2,293,000</td>
<td>79%</td>
<td>2,159,000</td>
<td>1,712,000</td>
<td>1,879,000</td>
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<td>Vicksburg, MS</td>
<td>2,710,000</td>
<td>2,320,000</td>
<td>85%</td>
<td>2,060,000</td>
<td>1,806,000</td>
<td>1,962,000</td>
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<td>Natchez, MS</td>
<td>2,720,000</td>
<td>2,260,000</td>
<td>83%</td>
<td>2,046,000</td>
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<td>Red River Landing, LA</td>
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<td>1,641,000</td>
<td>78%</td>
<td>1,467,000</td>
<td>1,461,000</td>
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<td>Baton Rouge, LA</td>
<td>1,500,000</td>
<td>1,436,000</td>
<td>95%</td>
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<td>1,381,000</td>
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<td>N. Orleans, LA</td>
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<td>1,230,000</td>
<td>98%</td>
<td>1,342,000</td>
<td>1,360,000</td>
<td>1,248,000</td>
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<td>Morgan City, LA 7/</td>
<td>920,000</td>
<td>512,000</td>
<td>55%</td>
<td>493,000</td>
<td>741,000</td>
<td>692,000</td>
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<td>Wax Lake Outlet, LA 7/</td>
<td>580,000</td>
<td>323,000</td>
<td>55%</td>
<td>N/A</td>
<td>N/A</td>
<td>292,000</td>
</tr>
</tbody>
</table>

C - Peak Discharge, Provisional
1/ Discharge Range at Hickman, KY
2/ Total Confluence Flow of 1,936,000 cfs measured at approximate mile 950.8 at 1400 CDT 5/02/2011 near Wickliffe, KY, prior to operation of Birds Point-New Madrid
3/ Peak Flow Measured 4 May 2011 = 1,730,000 cfs at Hickman plus 370,000 cfs flow through Birds Point-New Madrid Floodway
4/ Includes flow through Birds Point-New Madrid Floodway
5/ Project Design Flood (PDF) provides design flows for MR&T project. Prior to 2011 Flood, MR&T Project was 89% complete.

2011 Flood Flows ~ 80-85% of MR&T PDF Flows.

6/ Reference - "Annual Maximum, Minimum, and Mean Discharges of the Mississippi River and Its Outlets and Tributaries to 1963"
7/ Wax Lake Outlet was constructed from 1937-1942. Prior to that, Lower Atchafalaya River was the major outlet.
8/ New Orleans Mean Daily Flow Measured at Belle Chasse in 2011, Readings at this site are tidally influenced. An instantaneous measurement of 1,320,000 cfs was made on 17 May 2011

Revised 27 Jan 2012
Flooded Areas

1927 Flood vs 2011 Flood

1927 Flood = 16.8M acres

2011 Flood = 6.35M acres

Over 10M acres not flooded in 2011
Room for the River Concept

- **1927 Flood**
  - Flooded 26,000 square miles = 16,800,000 acres
  - Levees only policy – No floodways or backwater areas

- **2011 Flood**
  - Flooded 9,900 square miles = 6,350,000 acres
  - Flooded 38% of area flooded by 1927 Flood
  - MR&T project includes levees and floodways and backwater areas to *Make Room for the River*

- **Floodways and Backwater Areas**
  - Total acreage of floodways = 366,000 acres
    - Total used during 2011 Flood = 212,000 acres
  - Total acreage of backwater areas = 1,652,000 acres
    - Total used during 2011 Flood = 335,000 acres (interior flooding)
  - Over 1.5 million acres of floodways and backwater areas were not inundated during the 2011 Flood
  - While the 2011 Flood is not as large as the Project Design Flood, there is still *Room for Larger Floods*
Questions?