USACE/NWS/USGS

Fusion Team

Report #2

May 2010 – September 2013

Fusion Team Submission
9/30/2013

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1. Introduction

MISSION STATEMENT:
This report will focus on actions and accomplishments made by the tri-agency (U.S. Army Corps of Engineers (USACE), U.S. Geological Survey (USGS), National Weather Service (NWS)) Fusion Team from May 2010 through September 2013. The team's first report, was submitted May 21, 2010. Background information on the Fusion Team is described in the first report which can be accessed at http://mvs-wc.mvs.usace.army.mil/fusion/fusion.htm. This report will also summarize a 2010 Integrated Water Resources Science and Services (IWRSS) focus group meeting the Fusion Team had with Stakeholders as well as additional actions taken from issues cited since May 2010. It should be noted that while the historic flood of 2011 overtook much of the team's time to report on team activities in 2011, operations during the flood did benefit in a number of ways from actions taken up through that time period and will be mentioned in this report.

2. Overview of 2010-2013 Activities

Shortly after the last report, the Fusion Team held an IWRSS focus group meeting in St. Louis, MO in which various stakeholders were invited to actively participate on ideas that would help them with their work associated with water resources, particularly flood mitigation. One of the objectives of this meeting was to discuss the improvements the Fusion Team had made in the collaboration and communication amongst the three agencies to improve the accuracy and utility of river/rainfall observations and river forecasts since the team formed. Another objective was to collect further input from the stakeholders as to their needs for water information and formulate a plan for continued improvements. This plan later submitted to the NWS Office of Hydrologic Development as a proposed IWRSS demonstration. (Approval and moving forward on the plan is pending future funding.)

For the first objective, the group was provided with an overview of the Fusion Team mission and goals, team actions to date, and referred them to the public Fusion Team Report for more detailed information. For the second objective, the team asked each of the stakeholders to address the following: what information is needed from the three federal agencies whether during normal conditions, droughts, and floods; how do they use rainfall and river forecasts; how do the forecasts impact their operations; what do they need from the agencies for their decision making; and any other suggestions? The stakeholders provided many valuable ideas and suggestions for continued interagency collaboration and communications improvements. A list of these items can be found in Appendix C and D. About a year after the IWRSS focus group meeting, the stakeholders were provided with a status of the action items. The plan is to provide similar updates by way of this annual Fusion Team report.

From this list of all action items since the team's inception, the Fusion Team consolidated the items into several categories. These categories were then ranked and the top 5 items were assigned to an Action Team.

These Action Teams were then left to work on their various actions over the next year. During this time period the Fusion Team held monthly conference calls to discuss action items, action team progress as well as any new issues that may have come up between the agencies.
In September of 2011, the Fusion Team held a meeting in Kansas City to discuss operations and services during the historic 2011 floods along the Mississippi and Missouri Rivers, as well as progress on the ongoing action items. The meeting was attended by the Fusion Team members and a few requested guests within the agencies. Each Fusion Team member presented key issues and lessons learned from the 2011 flooding. Additionally, each of the Action Teams gave updates on their accomplishments over the past year. There were also several other issues/topics discussed at this meeting from which, Action Teams were formed, all of which are described in the following section.

3. IWRSS

About 2009, the National Oceanic and Atmospheric Administration (NOAA) began developing the Integrated Water Resources Sciences and Services (IWRSS) – an innovative partnership of federal agencies with complementary operational missions in water science, observation, prediction and management. Consisting initially of NOAA (NWS), the U.S. Army Corps of Engineers, and the U.S. Geological Survey, the IWRSS consortium envisions a highly collaborative and integrative framework for providing a seamless suite of water resources information across scales ranging from small hill slopes to large watersheds, from droughts to floods, and from historical analyses to long-range predictions.

Since 2008, the Fusion Team has worked collaboratively to refine and improve our processes and products for forecasting. Those efforts have included a number of items such as flood inundation mapping and the metadata gage map that is also being analyzed and addressed under the IWRSS efforts. In early 2013, the Fusion Team contacted the senior leaders of the IWRSS consortium to: 1) determine the areas involving forecasting in which both the Fusion Team and IWRSS were working, 2) identify potential areas of duplication of effort, 3) align the regional (Mississippi Basin) Fusion Team effort with the national IWRSS effort, and 4) ensure future coordination and collaboration between the Fusion Team and IWRSS, where applicable. At that time, the Fusion Team became informed that the IWRSS consortium had a number of sub-teams or action teams in the process of forming to work on specific areas. Two of those action teams, the Flood Inundation Mapping (FIM) and Interoperability and Data Synchronization teams were in the process of forming and developing requirements. The Fusion Team offered to provide the results of their respective efforts in FIM and Data Interoperability to help support the IWRSS actions teams. It was agreed that the Fusion Team would provide a POC to the IWRSS team to keep communications open between IWRSS and the Fusion team and to provide feedback on the progress of the teams. Trent Schade volunteered to be the Fusion Team's POC for the data team and Pedro Restrepo volunteered for the FIM team.

During the June 2013 Fusion Team Annual Meeting, IWRSS provided an update of their efforts to date. Participating by telephone, IWRSS was represented by Jared Bales (USGS) and Thomas Graziano (NWS). They provided overviews of the national Integrated Water Resources Science and Services (IWRSS) activities, discussed how the Fusion team should interact with IWRSS, and pledged to help ensure IWRSS and the Fusion Team were not duplicating effort. Mr. Bales

briefly reviewed the IWRSS sub-teams' and their status. The FIM (Flood Inundation Mapping) team is tasked with developing a process for a seamless and consistent product for mapping for use by all three agencies, a product that will provide the same level of information for stakeholders. The FIM team is completing its requirements document and will begin to move into the implementation phase in the near future. IWRSS also has an Interoperability and Data Synchronization team which will work on developing capabilities to collect, store, and disseminate data to all agencies and stakeholders. The team is currently working on requirements.

Dr. Graziano also discussed IWRSS' stakeholder engagement activities, having held three stakeholder meetings so far with one more to occur this year. The stakeholder engagements were designed to: a) define, document, and prioritize the water resource information and service requirements within the respective basin; b) document the water resource decisions made by stakeholders from a spectrum of service sectors; c) quantify the socioeconomic benefit of addressing these stakeholder requirements and informing these decisions through the provision of new IWRSS information and services; and d) develop a demonstration project plan which enables the IWRSS partners (NOAA, U.S. Army Corps of Engineers [USACE], and U.S. Geological Survey [USGS]) to address these stakeholder requirements through the provision of new information and services. The meeting summaries will be combined into a report which will be available when completed. The Fusion Team indicated that they had held a number of stakeholder engagements since 2008 and would be glad to share the results of those meetings.

After further discussions, the following conclusions were made by the group. With respect to concerns about duplication of effort, the consensus was that this had not/was not occurring. The IWRSS teams are beginning their efforts and the Fusion team will share their knowledge and products to assist them. Dr. Graziano stated there was a critical need for the Fusion Team; where IWRSS is larger in scope and more strategic, the Fusion Team is regional in scope and more tactical, focusing on short term river forecast activities and needs. The Fusion Team and IWRSS will continue to collaborate and communicate periodically (IWRSS will invite Fusion Team members on conference calls) and share information. Fusion team may provide reviews or advice as necessary on IWRSS results and products.

4. Fusion Team Meeting Notes – June 25-26, 2013

A USACE/USGS/NWS Fusion Team meeting was held June 25-26, 2013. The team discussed actions taken to date, particularly since the 2011 flood, and where to place their focus the next 1-3 years. The Fusion Team chairman (Chuck Shadie (USACE/Mississippi Valley Division)) arranged for senior leadership from USGS (Jared Bales) and NWS (Thomas Graziano) to provide overviews of the national Integrated Water Resources Science and Services (IWRSS) activities to ensure we were not duplicating effort. No duplication of effort was found. Tom Graziano stated there was a critical need for the Fusion Team; where IWRSS is larger in scope and more strategic, the Fusion Team is regional in scope and more tactical, focusing on short term river forecast activities and needs.

The team reviewed its mission statement and agreed no changes were needed. They next reviewed efforts of the various action teams. Actions to date have dealt with issues surrounding

river forecast accuracy and usability, as well as communication among the agencies and with the public. Increased use of NWS Chat among the agencies in the RFC agency chatrooms was highlighted as a team success story. The team reviewed status of current action subteams and disbanded those that had completed their charge. Those disbanded included the training team, metadata gage team and extranet team. The forecast verification and ratings teams would continue.

The forecast verification team made good progress the past year in reviewing particular events as well as developing a common set of metrics to track forecast trends. This effort of evaluating river forecasts to determine sources of error was slated to continue and team findings would provide the basis for future areas of focus for the Fusion Team. With this refinement of the team's mission, it was suggested to rename the team. In a follow-up meeting with the verification team, it was renamed the Forecast Evaluation and Improvement Team (FEIT (pronounced "fite")).

The ratings team developed a process to coordinate and fine-tune the initial flow value used in USACE and NWS river forecasts at Hermann, MO. After some discussion, it was decided to expand this effort to include Chester, IL, Smithland Dam in Kentucky and Dam 22 near Saverton, MO (ref. FEIT action item, p. 7).

Recent flooding brought to light some confusion in use of the Ensemble QPF Hydrographs compared to the official forecast. A new communication/products action team was formed to address these kinds of issues as well as: ensure Fusion Team developed procedures get to the agencies' field staff, continue cross-agency familiarization, ensure consistent message among the agencies, share critical information such as levee overtoppings, and develop a more thorough explanation of river forecasts and products.

5. Action Teams and Accomplishments

Note: The following appendices provide details on completed and current action items.
Appendix C: Completed Action Items
Appendix D: Current Action Items

a. Forecast Evaluation and Improvement Team

In 2010, a river forecast verification Action Team was formed (now called the Forecast Evaluation and Improvement Team (FEIT)) with a few members from the Fusion Team as well as subject matter experts from USACE and NWS. The main goal of the team was to identify sources of river forecast error in both agencies and address them, if feasible. To attain this goal, the team developed NWS/USACE common performance measures and processes to review forecast accuracy in order to improve NWS-USACE forecasts through collaborated review; and to demonstrate how forecast errors have trended since the 2008 Rainfall-River Forecasting Joint Summit in St. Louis.

The NWS and USACE hydrologists do share information and collaboration is key, however, forecasts may not be identical due to the fact that the agencies use differing models, assumptions, forecasted precipitation, etc. Differences are also partly driven by the fact that USACE and NWS are two different agencies that operate under similar but different missions. It is envisioned that through enhanced collaboration and review of significant events, river forecasts will improve to better meet public needs.

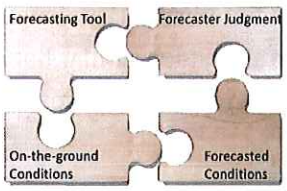
The FEIT has monthly calls to evaluate forecasts as events unfold. Errors and source of errors that can be identified are documented. Certain criteria such as significant impact to the user of river forecasts, determine which events will be scrutinized/evaluated more thoroughly by delving deeper into the data after events occur.

A methodology to delve deeper into the data to determine the source(s) of error was developed. As a start, the metrics focused mainly on the St. Louis forecast for its location near the confluence of the Missouri and upper Mississippi Rivers and its great interest to the navigation industry. Five locations were selected for routine performance evaluation: St. Louis, Lock & Dam 22 and Baton Rouge on the Mississippi River; Valley City on the Illinois River; and Hermann, MO on the Missouri River.

For annual review of performance trends, the team developed a spreadsheet to populate with a common set of data and formulas. It was decided to use data only from the UTC 1200 forecast since that was the one time period when both agencies provided forecasts. The data would include available forecasts prior to the 2008 establishment of the Fusion Team. In this way, the UTC 1200 forecast collaboration as well as other forecast enhancements could possibly be inferred through comparative statistics. Upon review of the datasets, the team agreed to begin with 2005 since prior to that, the data was in formats not easily used by the current NWS verification system. Performance metrics chosen to use include: the Nash-Sutcliffe Efficiency Coefficient (NSE), Hydrologic False Alarm Ratio (HFAR), Probability of Detection (POD), Mean Error (ME) and Mean Absolute Error (MAE).

For the more detailed event studies, all available data would be used in order to best determine the parameters contributing to forecast errors falling in the general categories of forecasting tools, antecedent (on-the-ground) conditions, forecast conditions and forecaster judgment as described below. For those errors that could be scrutinized more closely at the local office, the team members would take recommended actions and bring those to the attention of respective management to work toward resolving/improving. For those error sources beyond the scope of the RFC or District, such as QPF from the Weather Prediction Center or the Weather Forecast Office, the team lead would ensure the issue is moved forward through appropriate channels.

The Pieces to a River Forecast



The Pieces to a River Forecast

1. Forecasting tool used to
   a) Compute local inflows, plains snowmelt, infiltration rates, routed flows
   b) Incorporate forecast precipitation/temperature
   c) Other
2. Forecaster judgment regarding
   a) Assessing current basin conditions , observed precipitation and flows
   b) Running/calibrating forecasting tool to compute local inflows, infiltration rates, route flows, combine hydrographs
   c) Application of 6-hour QPF estimations over x-number of hours
   d) Other
3. On-the-ground conditions regarding
   a) Accuracy of rating curves in estimating river flows
   b) Accuracy/distribution of precipitation gages to determine actual precipitation
   c) Accuracy of radar estimated precipitation
   d) Other
4. Forecasted conditions regarding
   a) Accuracy of location, aerial extent and intensity of QPFs
   b) Accuracy of temperature (snowfall vs. rainfall)
   c) Other

The team developed an event summary spreadsheet to capture the unique attributes of the event and post likely sources of error. In this way, error sources that tended to repeat could be easily identified and addressed to the extent possible. To date, the team has reviewed an event from May 2010 and is in the process of reviewing events in March 2013 and April 15-May 15, 2013. Details of the findings and recommendations for the 2013 event as well as an example event spreadsheet can be found in Appendix E. Following is a short summary of both reviewed events:

May 2010 findings: A particular event in May 2010 of over-forecasting in some areas and under-forecasting in others was reviewed; details regarding specific inputs to the forecast process and possible sources of error are listed in the table below. Generally, error sources fell into the following areas:

- Forecast precipitation was either too much, too little or over the wrong basin
- Inaccurate estimate of soil moisture
- Location of a storm over the basin was not properly taken into account
- Rating curve shifts

- Backwater influence not properly taken into account or handled by the model
- Inability to account for ungaged runoff
- Routing errors
- Modeling errors or assumptions (e.g., uniform forcings, 6-hour timesteps)
- Local flow errors
- Unforecasted regulation changes

Initial Conclusions of May 2010 Event

QPF (under-forecast or misplaced) was cited by several offices as a possible (significant) source of error. Underestimation of soil moisture was also cited by numerous offices and may be the source of error where more runoff occurred than was modeled. At this writing, modeling tributary backwater due to high mainstem flows was beyond the capabilities of either of the agencies, although MBRFC is implementing a HEC-RAS model on the Missouri river that should be able to account for backwater near the mouths of the Grand, Chariton and Kansas Rivers. MVN indicated that modification of the routing method may improve the forecast accuracy. NWD noted that adjusting 6-hour QPF from non-uniform hourly values may improve the forecast accuracy. For those errors that could be scrutinized more closely at the local office, the team members brought those to the attention of respective management to work toward resolving/improving.

April 15-May 15, 2013 findings: In this event, river forecasts from both USACE and NWS were forecast over a critical level (38 ft) at St. Louis, which did not occur; observed levels were lower. Hind-casting analysis indicated that error sources fell into the following areas:

- Forecast precipitation under-forecast for some time periods
- Inaccurate estimate of soil moisture
- Over-simulation of runoff
- Inaccurate rating curves
- Inability to account for runoff in ungaged areas
- Routing errors
- Modeling errors or assumptions (e.g., uniform forcings, 6-hour timesteps)
- Local flow errors

Initial Conclusions of April 15-May 15, 2013 Event
Two sources of error were deemed the most significant:

1. Too much runoff was generated; likely cause was cited as model calibration. MBRFC member took action to bring need for recalibration of lower Missouri River to MBRFC management.
2. Observed flow conditions at Lock & Dam 22 on the Mississippi were found to be unrealistically high. This led to an action item to adjust the L&D 22 rating for USACE MVR (Jim Stiman, lead) with USACE MVS (Russ Errett, POC) assisting by providing some data collected during 2013 at L&D 24.

Additional supporting information can be found in Appendix F.

b. Training (Cross Agency and Public Outreach)

The training team was chartered with the following goals:

- Facilitating training for NWS Chat
- Providing training that would help reduce confusion associated with agency-specific terminology

These goals have been integrated into other activities, and as a result this team will be discontinued. Use of NWS Chat has spread from its initial use in the upper Mississippi River watershed to routine use within all of the Greater Mississippi River watershed basins. Following the major flood events of the past several years, development of training materials has been a priority at the national level. Initial cross training on river forecasting and water management concepts was piloted between the NWS and USACE in the Ohio Basin in 2012, and has led to the ongoing development of a national Water Management basics class within USACE. This effort does not need to be duplicated within the Fusion Team.

c. Extranet Site

The tri-agency Fusion Team extranet site operates like a single agency intranet site in that it is not for public access. It is a Sharepoint site for internal use between the NWS, USACE and USGS so that field offices, USACE Emergency Operations Centers and NWS Regional Operations Centers (ROCs) can share internal information. The site continues to grow and contains useful information for USACE/USGS/NWS field offices, including

- Point of Contact information for each agency
- Multi-agency river gage map with combined information available for each gage
- Flood Playbook
- Process to request extended rating curves
- Process for RFCs to request a USACE or USGS in-house liaison
- Process to request a Rapid Deployment Gage from the USGS
- Methods to estimate flood categories and impacts
- Documents for various action team members to share
- Reports and meeting minutes
- Fusion Team Charter and member list

d. Metadata Gage Map

At the July 2010 meeting, the focus group told the Fusion Team members how the various agency river observation and forecast information was used in their activities, particularly as they related to floods. One message that was stated numerous times was the need to have one website that they could use as a "starting point" where they could then gain access to all the information they needed from each agency. In response to the focus groups need for a website "starting point", an effort was undertaken to develop a web interface that would provide a common starting point to access data and forecasts. Several requirements were listed by the focus group

related to this one website, with the multi-agency river gage map as the initial attempt to address those actions.

Objective:
Develop a website to provide a common starting point to water-interested stakeholders for accessing data and forecasts.

Process:
An Action Team of NWS, USGS, and USACE members was formed to develop this website. The team developed a one-stop-shop webpage. This webpage brings together stream gage/reservoir data and forecasts from the USGS, NWS, USACE and other agencies into one location. The web pages that are maintained by each agency are compiled into this one location and provide the user a portal to available stream gage/reservoir data and forecasts. Gage metadata and the gage operator contact information would also be available in this one-stop-shop page.

Challenges:
- Getting "buy-in" from all three agencies in order to keep the web interface current and relevant at all times.
- Identifying an agency to host the web interface site and develop/maintain the application for agency POC's to add/edit/delete information.
- Develop a process to incorporate data from updated stations into the master station list.
- Develop a consistent protocol for sharing gage metadata.

Summary:
The stakeholders were invited to a webinar that showed a demonstration of the newly created webpage. Unfortunately, none of the stakeholders attended the webinar. However, the NWS, USGS, and USACE Headquarters had representatives participate. The Action Team completed their objective and the future of this webpage is currently in discussions with the Fusion Team and the IWRSS consortium.

e. Flood Inundation Mapping

During the 2011 Mississippi Basin Flood, flood inundation mapping (FIM) was needed to help not only the NWS, USGS, and USACE prepare and respond to the event, but also by other responders from local, state, and federal agencies as well as the general public. Some FIMs were developed by USACE for site specific areas to help responders in response to requests from state and local governments. Generally, these tended to be for either the current forecasted crests of the flood and may have included levee breech analysis for areas where the projected stages had not been experienced before. Following the flood, during one of the Interagency Flood Risk Management teleconferences sponsored by USACE, Mississippi Valley Division, some of the NWS FIM capability was demonstrated and several state officials raised concerns about obtaining gage or other real time data from various Federal sources. FIM is being conducted by USACE, NWS, USGS as well as by other Federal and state agencies, but it appeared that these efforts are not well coordinated. An NWS Service Assessment had listed as an action item that the Fusion Team should take the lead in establishing standards for flood maps issued during

floods. The Fusion Team considered looking into this issue. The goals would be to define the type of FIM that could be provided during and after an extreme event, define the procedures that would be followed to release to responders and the public, ensure the FIM is easily understood in how it relates to the river forecast, and ensure that consistent FIM products would be provided while avoiding duplication of effort by the agencies.

The Fusion Team, however, was aware that a multi-agency national team, associated with IWRSS (Integrated Water Resources Sciences & Services) had been designated to look into these FIM issues. The Fusion Team contacted the IWRSS representatives on their FIM team to learn about their efforts and accomplishments and to ensure that anything that the Fusion team does in response the Service Assessment recommendation is not redundant or at cross purposes with the IWRSS FIM team. At that time (Feb 2013), the FIM team was still drafting the team's requirements document. In June 2013, it was recommended that the Fusion Team provide a POC for the IWRSS FIM team to keep communications open between IWRSS and the Fusion team and to provide feedback on the progress of the teams. Pedro Restrepo (NWS) volunteered to be the Fusion Team's POC for the IWRSS FIM team.

As a result of the coordination with the IWRSS FIM team, the Fusion Team will continue to coordinate and assist the FIM team as necessary. No other actions relative to FIM are currently scheduled for the Fusion Team.

f. Consistency in forecasts displayed on USACE and NWS web pages

Upon realizing the NWS forecasts on the Advanced Hydrologic Prediction Service (AHPS) pages and the Rivergages.com pages were occasionally inconsistent, the team developed a method to ensure the USACE Rivergages.com web site list of NWS forecasts was the same as those displayed on the AHPS page. This entailed USACE accessing a more direct source for the real time data used by the NWS. This team is now disbanded as it completed its action.

g. Rating Curve Consistency

Background:
The USGS is responsible for making river flow measurements and developing and maintaining a station rating curve. That rating curve is used by all three agencies. The rating curve is "shifted" on an ongoing basis, per measurements taken by the USGS. Highly erodible alluvial-bed rivers like the Mississippi and Missouri Rivers result in shifts that can vary significantly throughout the year, up to several feet, especially during and after periods of high flow. The three agencies often show different river gage flows associated with the same stage on their respective web pages, which can be confusing to the public. In addition, large differences in river flow can impact the forecasting process for other NWS and USACE offices (e.g. NCRFC, USACE-MVS).

Objective:
Ensure consistent river gage flow data (rating and shifts) across all agencies.

Process:
An Action Team of NWS, USGS, and USACE members was formed to share information in regards to 1) how the USGS develops the base rating curves and modifies them via shifts and 2) use of those rating curves by the NWS and USACE in their river flow/stage forecasting processes. The team decided to use the Missouri River at Hermann, Missouri streamgaging station (Hermann) as a pilot site. This site was selected because it is the "ending" station in the NWS/USACE (MBRFC/MRBWM) Missouri River forecasts and the "starting" station in the NWS/USACE (NCRFC/MVS) Mississippi River forecasts.

Determinations/Findings:
The USGS takes approximately 22 measurements each year at Hermann.
During the navigation season (March-October), approximately 2-3 discharge measurements per month are taken; during the non-navigation season (November-February), approximately 1 discharge measurement per month is taken.

After each measurement, the USGS field crew classifies the discharge measurement – good, fair, or poor using a qualitative method that considers several factors at the time of the measurement. In general, a discharge measurement rated "good" indicates that the measured discharge is within 5 percent, "fair" is within 8 percent and "poor" is greater than 8 percent of the actual discharge. The USGS field crew emails the results of each discharge measurement, normally within a few hours of completion, to the NWS and USACE. The email would include what the measurement was classified as well as documentation as to how the USGS planned to use the measurement information in shifting the rating curve.

The NWS and USACE correspond via email with each other as well as the USGS as to how they each plan to implement the latest USGS discharge measurement. Both the NWS and USACE experimented with simply adopting the USGS flows at Hermann, but both agencies found that their model results suffered at Hermann. The NWS decided to move away from this approach because it involved arbitrarily adding or subtracting routed flow from upstream. USACE also decided that a more subjective approach, that included upstream station rating curves and modeled ungaged flow, was warranted.

Both forecast agencies continually review and adjust rating curves for all the stations used in their various forecast models based on 1) USGS discharge measurements and ratings, and 2) model results.

Summary:
While river stage can be measured to a finite degree of accuracy (within a fraction of an inch), determination of the corresponding flow cannot. A rating curve is used to **approximate** flows as it relates to river stage. This is especially true in a highly erodible alluvial-bed river such as the Missouri River. Since any USGS discharge measurement rated "good" is believed to be within 2-5% from the actual discharge, the goal is that each agency 1) coordinate their application of the latest USGS measurement to their respective rating curve, 2) with the end goal being that their flows are within an acceptable range (~2-5%) of each other.

h. Communication/Products Team

Work of the Fusion Team since the 2008 flood has resulted in enhanced communication between the three agencies as evidenced in the successes realized during the 2011 flood. However, communication can falter through time as personnel change and as such vigilance to ensure communication is warranted. Additionally, issues have been raised in regards to whether we are now producing additional products that are actually confusing the public and decision makers. The communication/products team is charged with:

1. Assessing the effectiveness of our communication
2. Determining actions needed to enhance communication
3. Assess current products from the agencies for clarity and effectiveness and to determine if these products are being used properly by agency decision makers.
4. Assessing the current suite of public products as to clarity and effectiveness.

The focus of this team is to ensure information provided to the agencies, stakeholders and the public is consistent and as accurate as possible. Expected outputs would be recommended improvements in our communications processes, evaluations of the customers' effective use of these products, and recommendations as to which products should continue to be provided. Initial members on the action team will be: USACE: Brian Astifan and Joan Stemler, NWS: Kevin Low and Jim Noel, and USGS: Bob Holmes (or another USGS employee he may name). This action team should begin periodic conference calls as soon as possible, but not later than Oct 2013.

6. Conclusions and Path Forward

Since the previous Fusion Team Report in May 2010, the Fusion Team has continued to work collaboratively to identify issues within our respective agencies' processes which contribute to uncertainty and inaccuracies in developing forecasts. Several of the action teams have and continue to work to resolve these issues with respect to forecasting errors and rating curve differences between the agencies. In addition, the Fusion Team has developed products such as the metadata gage maps to improve communications not only between agencies but also with stakeholders and local and state agencies. Many of the benefits of these actions as well as previous efforts paid dividends as the agencies responded to the 2011 floods, 2012-13 drought, and 2013 floods in the Mississippi watershed. Improved communications and collaboration between the agencies provided improved forecast products during these events.

Future activities of the Fusion Team will continue to focus on three areas. First, continuous improvement of forecasting products to provide the best, scientifically-based forecasting products to the Nation. Second, ensuring the forecasting products are communicated consistently to stakeholders and customers to provide utility and effectiveness as they use these products. Lastly, work regionally (within the Mississippi watershed) and Nationally with other groups and agencies such as IWRSS to coordinate similar efforts, provide lessons learned, avoid duplication, and continue to provide consistent forecasting products.

7. References

The 2010 Annual Report can be found at the following website:
http://mvs-wc.mvs.usace.army.mil/fusion/fusion.htm

This Report No. 2 of the USACE/NWS/USGS Fusion Team has been reviewed and approved by the Team's members. As required under the Team Charter, the undersigned Fusion Team Chairman and Advisory Committee will provide this report to their respective Senior Agency Authorities. In addition, as noted earlier, this report will be posted to the Fusion Team website.

Chairman, Fusion Team:

Charles E. Shadie, P.E., D.WRE
Chief, Watershed Division
Mississippi Valley Division
US Army Corps of Engineers

Advisory Committee:

Noreen O. Schwein
National Hydrologic Services Policy Leader
Hydrologic Services Branch, Office of Climate, Water and Weather Services
National Weather Service

Robert R. Holmes, Jr., PhD, P.E., D.WRE
National Flood Hazard Coordinator
U.S. Geological Survey

David R. Busse, P.E.
Chief, Engineering & Construction Division
US Army Corps of Engineers, St. Louis District

APPENDIX A

USACE/NWS/USGS Mission Statements

USACE Mission Statement

The USACE Mission is to provide vital public engineering services in peace and war to strengthen our Nations security, energize the economy, and reduce risks from disasters.

In support of the USACE Mission, the Mississippi Valley Division's mission statement is to serve the Mississippi Valley Region by managing the watersheds and developing collaborative engineering solutions that will reduce risks through the reduction of flood damage potential, maintain and enhance navigation, and protect/restore/enhance environmental ecosystems; while being prepared to respond to Regional and National emergencies.

USGS Mission Statements

The Water Mission Area (WMA) is one of seven science mission areas of the U. S. Geological Survey (USGS). The WMA mission is to collect and disseminate reliable, impartial, and timely information that is needed to understand the Nation's water resources.

USGS actively promotes the use of this information by decision makers to –

- Minimize loss of life and property as a result of water-related natural hazards, such as floods, droughts, and land movement.
- Effectively manage groundwater and surface-water resources for domestic, agricultural, commercial, industrial, recreational, and ecological uses.
- Protect and enhance water resources for human health, aquatic health, and environmental quality.
- Contribute to the wise physical and economical development of our Nation's resources for the benefit of present and future generations.

NWS Mission Statement

Provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy.

APPENDIX B

Fusion Team Members

Senior Agency Authorities

USACE	Brigadier General Peter A. DeLuca Commander U.S. Army Corps of Engineers Mississippi Valley Division
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USGS	Robert R. Mason, Jr. Acting Chief, Office of Surface Water USGS Headquarters

Chairman

USACE	Charles E. Shadie, P.E. Chief, Watershed Division USACE Mississippi Valley Division

Advisory Committee

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NOAA/NWS	Noreen O. Schwein, Hydrologic Services Branch, Office of Climate, Water and Weather Services
USGS	Robert R. Holmes, Office of Surface Water

Technical Members

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Appendix C - Fusion Team Completed Action Items

Item #	Action	Status	Date Complete
1	Hold MVR/RIAC meeting.		10/7/08
2	Ensure Chester & Cape Girardeau MVS forecasts are sent to LMRFC.		11/1/08
3	Ensure 22 TW/Illinois/Missouri flows used by MVS are sent to NCRFC.		11/1/08
6	Develop a cross training schedule to allow NWS/USACE to spend time with the towing industry in order to learn how their product is used.	At June 2013 meeting, cross-agency familiarization was deemed more appropriate than training. The training action team was discontinued; cross-agency familiarization became an objective of the Products/Communication Action Team.	6/26/13
7	Develop tri-agency coordinated meeting list.		1/26/09
8	Collate a list of critical "check points" along major rivers for which rating curves need to be extended prior to next flood event. A "check point" is defined as a point that is critical in modeling; typically in larger water sheds.	Ref. spreadsheet: all critical gages for ratings one sheet.xls	11/1/09
9	Develop plan to get critical rating table extensions in a timely manner during specific events.	Ref. spreadsheet: *all critical gages for ratings one sheet.xls*	2/1/09
10	Develop process to coordinate requests for real-time rating extensions.		2/1/09
11	Investigate tri-agency use of NWS Chat; expand use for enhanced coordination.	Upper Mississippi and Missouri basin test completed	2/4/10
12	Share forecasts from Lower three Districts (MVM, MVK, MVN) and LRD (Ohio) with NWS	Ref. #38	2/1/09
13	Develop and implement plan to deal with draw down curve corrections.	Ref #28	2/27/09

Item #	Action	Status	Date Complete
14	Explore feasibility of co-development of HEC-RAS river forecast models.	Ref. #39	2/4/09
15	Develop common template for Action Items.		12/17/10
16	Draft Flood Event Playbook to enable water resource agencies to better coordinate, collaborate, and communicate inter-/intra-agency activities during high impact water resource events (floods, droughts, spills, dam failures, etc).	First draft presented 6/23/09	3/30/10
17	Review and update Flood Event Playbook on annual basis and conduct annual Tri-agency Flood Exercise	Regional Flood Risk Management Team (RFRMT) conducted a tabletop flood exercise, Feb 2011; Fusion Team participated.	Annually
19	Develop procedure to deploy USACE Liaison to RFC during a major flood.	Further actions in 40 and 45	1/16/09
20	Develop procedure to deploy USGS Liaison to RFC during a major flood.	Further actions in 41 and 46	3/26/09
21	Create 24/7 secured POC list for COE/NWS/USGS personnel.	POC list posted to tri-agency collaboration site.	1/25/12
24	Produce No Rain/Navigation Forecast (or Zero QPF/ River Forecast Minimum product)		7/7/09
26	Establish policy for dealing with gage height differences due to USGS draw-down curves or other procedures	Complete for draw down curves; an action team will address other, similar corrections (Ref. #49)	2/27/09
28	Develop plan and needed items that could be funded through ARRA (e.g., LIDAR, HEC-RAS development)	Funds were not available.	9/30/09
31	Present initial Fusion Team actions from Summit I to navigation industry at Inland Waterway Conference.		March 2009
34	Pursue USACE approval for USACE staff to use NWSchat (Ref. #11)		11/17/09

Item #	Action	Status	Date Complete
35	USACE lower districts develop SHEF formatted forecast and deliver to LMRFC. (Ref #12)		3/1/09
37	Select pool of candidates to be Corps Liaison to RFC during a major flood. (Ref. #20)		3/1/09
38	Select pool of candidates to be USGS Liaison to RFC during a major flood. (Ref. #21)		3/1/09
39	Develop Fusion Team web site		8/26/09
40	Demonstrate how forecasts have improved since the 2008 Summit.	The FEIT developed a process to review significant events to find sources of error and document on a spreadsheet. Findings will be provided to the Fusion Team for action as appropriate. The FEIT also developed common metrics to show forecast trends on an annual basis.	8/28/12
41	Draft Fusion Team Report	Second draft completed 10/23/09; third draft 2/8/10; fourth draft 2/21/10	5/18/10
42	Create a list of supplies and procedures to make USACE deployment quick and efficient. Laptop needs to have air card, NWS Chat connection, cell phone, e-mail access, etc. (Ref. #20)		1/19/11
43	Create a list of supplies and procedures to make USGS deployment quick and efficient. Laptop needs to have air card, NWS Chat connection, cell phone, e-mail access, etc. (Ref. #21)		3/1/10
45	Get permission to use Pidgin client for NWS Chat operations. Determine tri-agency naming conventions for handles (names). Conduct follow-on chat test. (Ref. #11)		3/9/10
47	Create internal web page for tri-agency staff.		4/1/2010

Item #	Action	Status	Date Complete
48	Evaluate impact levels at specific forecast points such as St. Louis.	Compile POD, FAR and MAE metrics for impact levels at specific locations; begin with St. Louis. Methodology is in place to review performance metrics by location.	8/28/12
49	Develop Team Charter with ground rules.		5/7/10
50	Address IT security issues between agencies to achieve better interoperability. Share data such as national levees database and Corps Maps.	RFCs have access to the national levees database. Interoperability will be tested via IWRSS team and/or through continued enhancement to tri-agency sharing of data.	10/25/10
51	Create an inventory of gages with ownership and/or maintenance responsibility and determine optimum way to assist emergency management in reporting gage problems.	USGS/USACE/NWS/USBR gage data information can be found at http://www.nwd-mr.usace.army.mil/rcc/nwo/gagemap/gagemap11.html	6/20/12
53	Determine whether or not there is a need for updated flood flow frequency curves on navigable rivers.	After discussion among USACE districts in the Upper Mississippi basin, it was suggested to update on a 20-year cycle. Last update was 1998.	Sept 2013
57	Provide information to emergency managers on regulation plans, deviations from those plans, and flood impacts as a result of those deviations.	USACE provides regulation plans to the public via the internet, public meetings, press releases, etc. Regulation plan changes can be requested and it is best to make such a request through a governing body such as a city or state.	9/22/11
60	Determine delivery method of observation and forecast information so that coordinating partners get the information at the same time.	This issue will be tackled by the IWRSS Consortium and was closed for the Fusion Team.	11/9/12

Item #	Action	Status	Date Complete
61	Eliminate need to go to numerous agency websites and having to know which ones to surf.	This issue will be tackled by the IWRSS Consortium and was closed for the Fusion Team.	6/26/13
65	NWS provide an historical observed data link on the AHPS page pointing to USGS historical data.	Historical data is available on the AHPS page under **Other Data Sources:** U.S. Geological Survey (USGS) Data and Site Info for Agency	6/5/12
66	Consider having USACE/USGS link to NWS pages go directly to the NWS hydrograph	To ensure the data is consistent with that on the NWS pages, USACE took the action (67) to ingest the data that populates the NWS hydrograph pages	9/22/11
67	USACE pursue using XML data for NWS forecasts instead of text products (e.g., RVD, RVF)	USACE decoded xml code from xml product sent over NOAA Port. This ensures rivergages.com has latest NWS public forecast.	5/15/12
70	Communicate information regarding development method of rating; provide confidence level or error estimate.	Currently communicated through rating depot, NWS Chat or other modes of communication. The action is now with NWS-USGS HQ	11/9/12
72	Investigate methods to include 30 days of QPF in long-term ensemble forecasts/outlooks. If possible, provide confidence limits.	The NWS RFCs in the Mississippi Valley (NC, MB, OH and LMRFC) developed a 28-day contingency forecast with 16 days of QPF (most available from models)	7/30/12
73	Investigate USACE/USGS/NWS current methods of developing inundation mapping with goal to standardize and avoid duplication of effort.	This item will be addressed by an IWRSS team and will not be pursued by the Fusion Team.	9/30/12

Appendix D - Fusion Team Current Action Items

Item #	Action	Status	Date Complete
4	Develop cross training for river forecasters.	Annual forecaster workshops with agency reviews will continue until further notice.	Ongoing
5	Develop a plan to cross-train NWS RFC/USACE personnel on USGS discharge methods and data processing techniques.	Evaluation of pilot and follow-up training was completed in March 2010. Training will be fine-tuned for other RFCs.	Ongoing
17	Review and update Flood Event Playbook on annual basis and conduct annual Tri-agency Flood Exercise	Regional Flood Risk Management Team (RFRMT) conducted a tabletop flood exercise, Feb 2011; Fusion Team participated.	Annually
18	Conduct training session between USGS and Corps to review official USGS measurement techniques and procedures.	USGS staff have presented discharge measurement techniques at numerous interagency meetings and workshops since 2009.	Ongoing
22	Evaluate recession hydrographs.	Evaluate recessions on an event basis. This will be part of ongoing review by the Forecast Evaluation and Improvement Team (FEIT)	Ongoing
23	Reduce the number of coordination briefings among federal agencies during high impact flood events.	Based on feedback from partners, will address "consolidation" through efficiencies in the presentations (e.g., common format of information, same agenda order with each call) and audience.	Ongoing
25	Develop a river stage forecast evaluation process as it relates to the navigation industry.	Representative from the navigation industry resigned from the team. FEIT can address through evaluation summaries suitable for public.	Ongoing
27	Follow up meeting with navigation industry to discuss due outs	Completed at meetings with navigation in 2009.	Ongoing
29	Set date and agenda for River Forecasters Workshop		Ongoing

Item #	Action	Status	Date Complete
30	Develop and implement plan to make concurrent discharge measurements above 1,000,000 cfs using the standard current meter and Doppler techniques.	Additional discussions and plans will be made with appropriate personnel from the USGS and COE.	Ongoing
32	Evaluate pilot and follow-up of cross training for NWS RFC/USACE personnel on USGS discharge methods and data processing techniques. Share process with other USGS/NWS/USACE offices in Mississippi Valley. (Ref #5)	Training continues through various tri-agency meetings and workshops.	Ongoing
33	Evaluate effectiveness of NWS/USACE cross training with the towing industry in order to learn how the NWS/USACE products and services are used. (Ref #6)	Representative from the navigation industry resigned from the team. Item postponed until further notice.	TBD
36	Assign team to coordinate HEC-RAS model development for a portion of the upper Mississippi. (Ref. #15)	USACE team members were selected. Work is ongoing. As of Aug 2013, NCRFC is conducting a recalibration project of the Mississippi (below LD22) and Illinois RAS model using 2013 data.	Ongoing
44	Request USACE districts in Mississippi River basin provide 14-day release schedules to NWS RFCs in support of zero-QPF navigation forecast.	LRD and NWD provide the reservoir release information to LMRFC and MBRFC respectively. NCRFC receives 14-day schedules from MVR and has requested them from MVS and MVP.	Ongoing

Item #	Action	Status	Date Complete
46	Ensure consistent river gage flow data (ratings and shifts) across all agencies.	After a fairly exhaustive effort and analysis as well comparison of USACE/USGS/NWS missions, the 3 agencies concluded it was not always possible given current technical limitations to be exactly equal w.r.t. flow. Decision was made to accept a tolerance level of 2%, similar to the USGS's method of rating a "good" flow measurement to be within 2-5% from the current rating curve. This effort will be expanded to include L&D22, Chester, IL, and Smithland Dam in Kentucky.	Ongoing
52	Establish procedure for USACE and NWS to coordinate flood impact information.	MVS implemented procedure. NWS Eastern and Central Regions provided training to the field on establishing flood impacts.	Ongoing
54	Look into options for enhancing NWS Chat: combine RFC agency chatrooms, develop better filtering capabilities that would be more agency and topic oriented so minimal monitoring is needed.	Filtering requirements were submitted. In early CY12, NWS Chat was updated to create a 2-way chatroom that combines all open chatrooms. Other requirements pending. NWS rep keep Fusion team apprised.	Ongoing
55	Address QPF discrepancies on NWS home pages	Suggestions were submitted to the Weather Prediction Center (WPC, formally HPC); many enhancements made. NWS office web pages (AHPS) will also have a significant QPF update in FY14.	Ongoing

Item #	Action	Status	Date Complete
56	NWS and USACE need to ensure they understand each others technical terms and operational procedures.	Action assigned to newly formed Products/ Communication Action Team	Ongoing
58	Create a flow chart showing the forecast operations and coordination of USACE, NWS and USGS.	Action assigned to newly formed Products/ Communication Action Team	Ongoing
59	Create a spreadsheet, or similar, that shows the parameters used in river forecasts and where Emergency Managers can find estimates of current parameters (e.g., rainfall, soil moisture, amount of rainfall held in soil, runoff).	NWS is tackling this for observed and forecast precipitation (QPF). The capability for stakeholders to go to the AHPS web pages to view the QPF used to generate hydrologic forecasts is expected to be implemented in FY14.	Ongoing
62	Develop training or help pages for the public to better understand how to use our products.	Action assigned to newly formed Products/ Communication Action Team	Ongoing
63	Pursue getting reservoir forecasts and impacts to FEMA.	Completed in 2011 for the Missouri River	Ongoing
64	Consider holding an annual webinar on how to find flood information from USACE/USGS/NWS web pages.	Action assigned to newly formed Products/ Communication Action Team	Ongoing
68	USGS develop policy concerning river gage maximum operating levels	USGS goal is to have it operational (i.e., accepting and distributing threshold data to USGS web pages) by the 2014 flood season.	
69	Communicate flood frequencies to public in easily understood manner.	NWS policy was established August 17, 2009 following an outreach project completed by Bob Holmes for USGS. Outreach on the topic continues.	Ongoing
71	Determine extent of inconsistent datums or estimated elevations that can result in inaccurate impact information.	The Datum Conversion Workgroup with members from USGS/USACE/NOAA (NWS, NOS, NGS)) will be submitting a plan for conversion of all streamgage datums to NAVD88.	Ongoing

APPENDIX E

List of Acronyms

AHPS – Advanced Hydrologic Prediction Service

FEIT – Forecast Evaluation and Improvement Team

FIM – Flood Inundation Mapping

HEC-RAS - Hydrologic Engineering Centers River Analysis System

HFAR – Hydrologic False Alarm Ratio

IWRSS – Integrated Water Resources Science and Services

L&D 22 – Lock and Dam No. 22

MAE – Mean Absolute Error

MBRFC – Missouri Basin River Forecast Center (NWS)

MRBWM – Missouri River Basin Water Management

ME – Mean Error

MVN – Mississippi Valley New Orleans District (USACE)

MVR – Mississippi Valley Rock Island District (USACE)

MVS – Mississippi Valley St. Louis District (USACE)

NCRFC – North Central River Forecast Center (NWS)

NOAA – National Oceanic and Atmospheric Administration

NSE – Nash-Sutcliffe Efficiency coefficient

NWD – North West Division (USACE)

NWS – National Weather Service

POC – Point of Contact

POD – Probability of Detection

ROC – Regional Operations Center (NWS)

RFC – River Forecast Center (NWS)

SWE – Snow Water Equivalent

USACE – United States Army Corps of Engineers

USGS – United States Geological Survey

UTC – Coordinated Universal Time

QPE – Quantitative Precipitation Estimation

QPF – Quantitative Precipitation Forecast

QTF – Quantitative Temperature Forecast

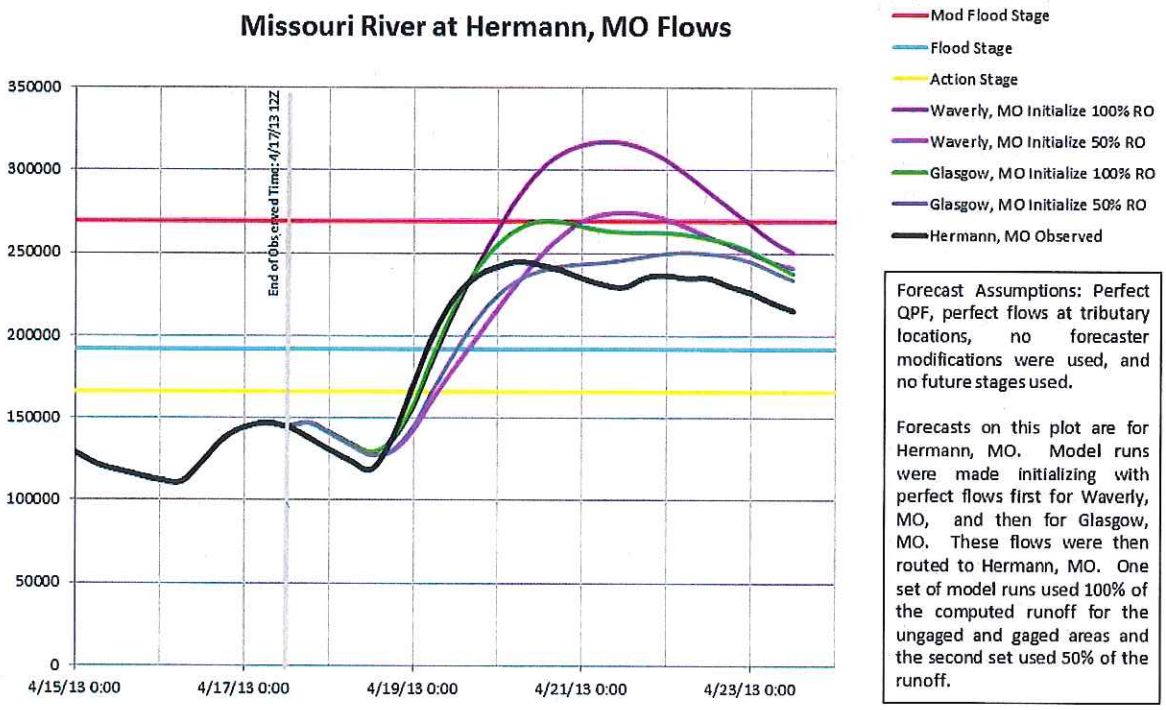
WFO – Weather Forecast Office (NWS)

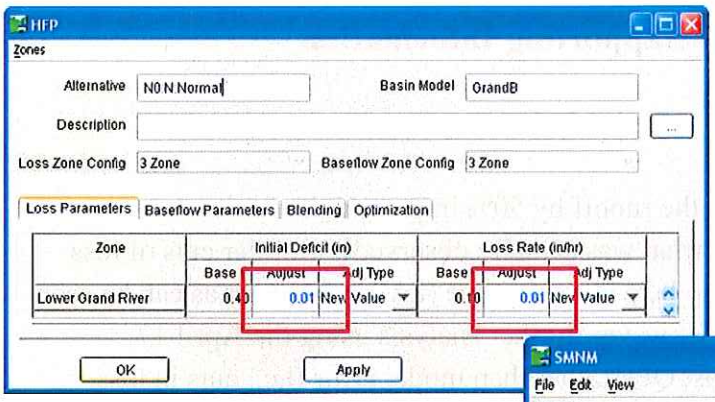
Z-R – Relationship between radar reflectivity (Z) and rainfall rate (R)

Appendix F – FEIT Supporting Information

April 15-May 15 Review

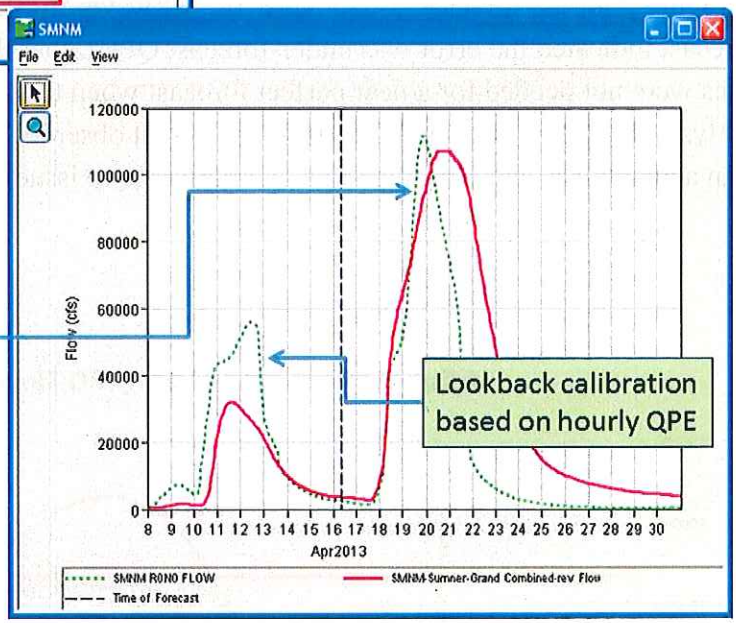
Figure 1 from MBRFC indicates that cutting the runoff by 50% improved the forecast at Hermann (i.e., lowered crests to be closer to what was actually observed). Similar cuts of loss rates in the model used by USACE/NWD also helped to improve (lower) the crest as can be seen in Figure 2 for the forecast issued April 16. However, further analysis using the April 17 forecast indicated the error was under-forecast QPF rather than model error (i.e., cuts in loss rates were not needed for a near perfect forecast when the QPF was accurate). USACE/MVS analysis (Figure 3) indicated that using the actual observed flow values still resulted in higher than actual crests and attributed this to a rating curve issue at Lock and Dam 22.



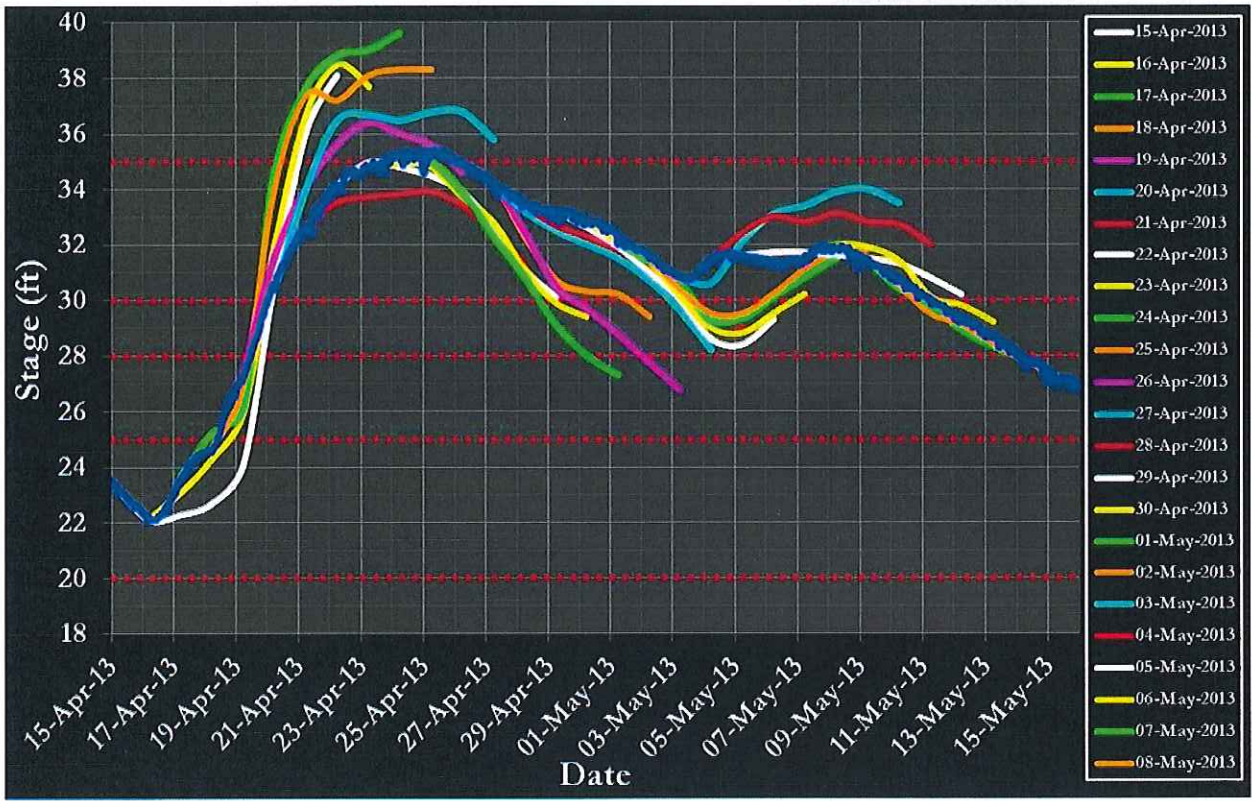


April 16th Forecast

Use of 20-20-60 ... 60-20-20 QPF distribution helped match peak (not volume) .... But in order to match observed, the initial and constant loss rates were lowered to levels that are not consistent with original calibration ... 0.10" and 0.10"/hr (Upper Grand and Thompson) and 0.01" and 0.01"/hr (Lower Grand). Why? Appears that the QPF was under-estimated.



Corrected for OBS UM, IL, & MO



FEIT Event Summary Spreadsheet example

Event Date May 8-21, 2010						
Possible Sources of Error	**NCRFC**	**MBRFC**	**MVR**	**NWD**	**MVS**	**MVN**
Forcings						
Forecast Precipitation (QPF)	Forecasts used only 24 hours of QPF and it was a multi-day rain event.	Forecasts used only 24 hours of QPF and it was a multi-day rain event	Under forecasted flows at L&D 22. Forecasts used only 24 hours of QPF and it was a multi-day rain event. Heavy May 12 QPF over Illinois Basin missed most of the basin leading to over-forecasted flows at Valley City for May 12 forecast.	Day 3 QPF (May 13) was not accurate (actual about twice of forecast).	Forecasts of local flow within the districts is based upon water on the ground and since there was 3 days of rainfall, local flow was under estimated for the first 3-4 days of forecasts.	Too little QPF; 24-48 hours of QPF (typically) from upstream used for 10-day forecasts so forecast bias is low.
Estimated Observed Precipitation (QPE)		Over or under-estimated of observed precipitation (e.g., incorrect Z-R in use of WFO).				
Forecast Temperatures (QTF)						
Observed Temperatures						

Possible Sources of Error	NCRFC	MBRFC	MVR	NWD	MVS	MVN
Antecedent Conditions						
Soil Moisture		Sometimes too wet and sometimes too dry based on run-time modifications made by various forecasters.		Nearly saturated grounds could have contributed to greater runoff than forecast.		
Snow Water Equivalent (SWE)						
Unspecified						
Gages						
Rating Curve						
Rating Shifts		Several locations had ratings shifted during event based on log entries.				
Backwater Influence		Possible backwater from Missouri River on the Grand River.				
Gage Observation Issue						
Ice Effects						
Unspecified						

Possible Sources Of Error	NCRFC	MBRFC	MVR	NWD	MVS	MVN
Model Assumptions						
Local Runoff		Ungaged areas unit hydrographs may be "too fat"; runoff was overestimated.	Accounting for ungaged runoff is an issue during all storm events.	Observed runoff greater than forecast.		
Uniform Conditions Over the Basin		Downstream/upstream storm over some of the runoff zones, shape timing of several unit hydrographs modified based on run-time modifications made by various forecasters.				
State of Precipitation (solid or liquid)						
Evapotranspiration					Regardless of the day 1 forecast from the Upper Miss, Illinois, or Missouri Rivers, the first day forecast for St. Louis seems to be largely dependent upon forecaster judgment with the MVS routing model.	Lag & K routing used: lag and attenuation are dynamic and values are not known precisely, therefore, tend to be sources of error.
Routing						
Calibration						
Unspecified						

Possible Sources of Error	NCRFC	MBRFC	MVR	NWD	MVS	MVN
Forecaster Judgment/Assumptions						
Storm Placement Within Basin		Downstream/upstream storm over some of the runoffs, shape, timing of several unit hydrographs modified based on run-time modifications made by various forecasters.				
Timing		Timing of several unit hydrographs modified.				
Unspecified					Local error possible.	
Other						
Unforecasted Regulation Changes						
Levee failure/overtopping						
Dam failure/overtopping						
Hydraulic Modeling						