



Flash Flood Services for the Future:

Flash Flood Summit and Focus Group Findings

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Cover: Top and side panel photos courtesy of Ed Clark, National Weather Service. Bottom side panel photo courtesy of Jim Palmer.

ACKNOWLEDGEMENTS

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LIST OF ACRONYMS

AWIPS	Advanced Weather Interactive Processing System
BOC	Baseline operating capability
CWFDP	Centralized Water Forecasting Demonstration Project
DART	Deep-ocean Assessment and Report of Tsunamis
DOT	U.S. Department of Transportation
EM	Emergency manager
EPA	U.S. Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
FFG	Flash flood guidance
FFPI	Flash Flood Potential Index
GFE	Graphical Forecast Editor
GIS	Geographic information system
GUI	Graphical user interface
HWM	High water mark
HWT	Hazardous Weather Testbed
IWRSS	Integrated Water Resources Science and Services
MPE	Multi-Sensor Precipitation Estimation
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NEXRAD	Next generation radar
NFIE	National Flood Interoperability Experiment
NGO	Non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSSL	National Severe Storms Laboratory
NWC	National Water Center
NWS	National Weather Service (NOAA)
OAR	Office of Oceanic and Atmospheric Research

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OHD	Office of Hydrologic Development
QC	Quality control
QPE	Quantitative precipitation estimation
RBC	River Basin Commission
RENCI	Renaissance Computing Institute
RFC	River Forecast Center
SPC	Storm Prediction Center
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
UCAR	University Corporation for Atmospheric Research
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
VIPER	Virginia Interoperability Picture for Emergency Response
WEA	Wireless emergency alert
WFO	Weather Forecast Office
WPC	Weather Prediction Center
WRES	Water Resources Evaluation Service
WRN	Weather-Ready Nation

EXECUTIVE SUMMARY

Flash floods are a critical issue of concern to communities across the United States. A changing climate is complicating decades-old regional assumptions about the frequency and magnitude of flash flood events. In some areas, an aging infrastructure is reducing communities' protection from flooding. Increased development in flood-prone areas is also putting more citizens in harm's way. The combined impact of these factors increases both the scientific and flood management challenges faced by many communities.



Reducing the societal cost of flooding, in terms of both economic losses and tragic fatalities, is a great challenge facing the nation. To effectively prepare for and respond to these flood risks, the National Weather Service (NWS) must document stakeholders' needs, identify service gaps, develop and implement science and technology, and enhance operations to advance flash flood services. Another critical component of flash flood services includes effective communication among warning and response officials, media, and the general public.

On September 9–11, 2014, the NWS convened a two-and-a-half-day Flash Flood Summit to begin refining the vision for the future of U.S. flash flood services. The Summit, held in the newly constructed National Water Center (NWC) in Tuscaloosa, Alabama, brought together 60 representatives from federal and state governments, the private sector, academia, and non-governmental organizations (NGOs).

The objectives of the Summit were to:

- Agree on a shared vision for future flash flood services: hydrologically consistent, end-to-end flash flood services to be implemented through a national water modeling and information services framework.
- Identify priority requirements/functional components to achieve the flash flood services vision.
- Explore the intersection between science and social science requirements to help inform priorities.
- Agree on a path forward to transform flash flood services over the next 10 years.

At the outset of the Summit, the organizers proposed a vision for future flash flood services as a starting point for discussion:

Transform predictive flash flood services for any causative event by establishing an end-to-end, nationally consistent framework that provides:

- *Seamlessly integrated observation and monitoring networks.*
- *High-resolution, hydrologically continuous (from flash flooding to flooding) national water model directly coupled with numerical weather prediction datasets and other forcings.*
- *Objective forecasting and characterization of the urgency, severity, and certainty of flood impacts at the street level.*
- *Actionable information, consistent communication, and decision support services to transform society to become ready, responsive, and resilient to flash flood and flood threats.*

Participants were charged with refining the vision by further defining and developing specific requirements that reflected their knowledge and practical experience, as well as emerging technical, scientific, and social science developments in the area of flash floods. Starting with a very broad vision

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and group brainstorming of all potential needs, the Summit was structured to hone in on the most important needs among the flash flood vision's four primary elements—observation/monitoring, modeling, forecasting/characterization, and communication—and to explore inter-relationships among these elements.

During a series of small breakout group sessions, each building on the work accomplished during prior sessions, participants subscribed to the vision and identified, discussed, and prioritized the most pressing needs/requirements for advancing the vision (Figure 1).

Focus groups were held in:

- Austin, Texas (11/12/14)
- Boulder, Colorado (12/10/14)
- Binghamton, New York (1/14/15)
- Romeoville (Chicago), Illinois (2/18/15)
- Mobile, Alabama (3/2/15)

Following the Summit, NWS convened five focus groups across the country to gain a better understanding of local flash flood needs and to help ground truth and supplement the communications vision developed during the Summit.

Three recommendations emerged from the focus groups that would help advance flash flood communication locally and align with the NWS communications vision.

- **Simplify flash flood messaging.** The current watch/warning/advisory system is confusing to the public, and both emergency managers and broadcast meteorologists expressed difficulty conveying the risk level using this terminology. Rethinking the system in simpler, widely understood terms that convey *actionable* information will likely improve overall understanding and response. NWS should also consider *how* these messages are being disseminated, with an emphasis on including video and/or graphics.
- **Improve modeling capacity to allow for higher resolution products.** While clarification and simplification of the existing watch/warning system is desired, participants also recommended greater specificity on the timing, severity, and location of flash flood risks. Modeling capacity will have to be improved to forecast with greater geographic and temporal specificity (e.g., a less than one-hour time step, identifying specific stream or road intersection impacted). When higher resolution information is eventually available for dissemination, it will need to be distilled into actionable, simple terms for users.
- **Continue to foster and cultivate strong relationships between Weather Forecast Offices (WFOs) and local partners.** Over the years, WFOs and local partners have built valuable relationships based on open data sharing, transparent personal communication, and trust. Every effort must be made to foster and strengthen these relationships so that WFOs can continue to provide the services and information decision-makers need to effectively communicate flash flood risks. These collaborative partnerships provide WFOs with a valuable “boots on the ground” feedback loop for real-time, site-specific conditions, and they help disseminate consistent messages across the affected community before, during, and after flash flood events.

Over the course of the next several years, the NWS will use the vision crafted during the Summit and focus groups to outline a series of near-term, mid-term, and long-term projects and activities to begin implementing the requirements set forth in this report. At the same time, the NWS will establish a *community of practice*—a cadre of interested parties within the NWS, other federal agencies, and research organizations—to cultivate its capabilities in alignment with the vision. This community will serve as the focal group for requirements validation, establish an interdisciplinary approach to design

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and development, and work to integrate other related water resources capacity building activities to transform flash flood information and services.

A number of new initiatives and activities will help create the building blocks for meeting the flash flood vision and its associated requirements. Beginning in 2015, a centralized water forecasting demonstration project with critical data and evaluation services will be established at the NWC. A high-resolution, hydrologically continuous, physically based water model will concurrently be established for testing and evaluation. This testing will include exploring new, geospatially based datasets and services that can better inform stakeholders. Mid-term and longer-term proposals build on these capabilities to provide objectively derived characterizations of flash flooding at the street level.



Flash Flood Summit participants and vision board

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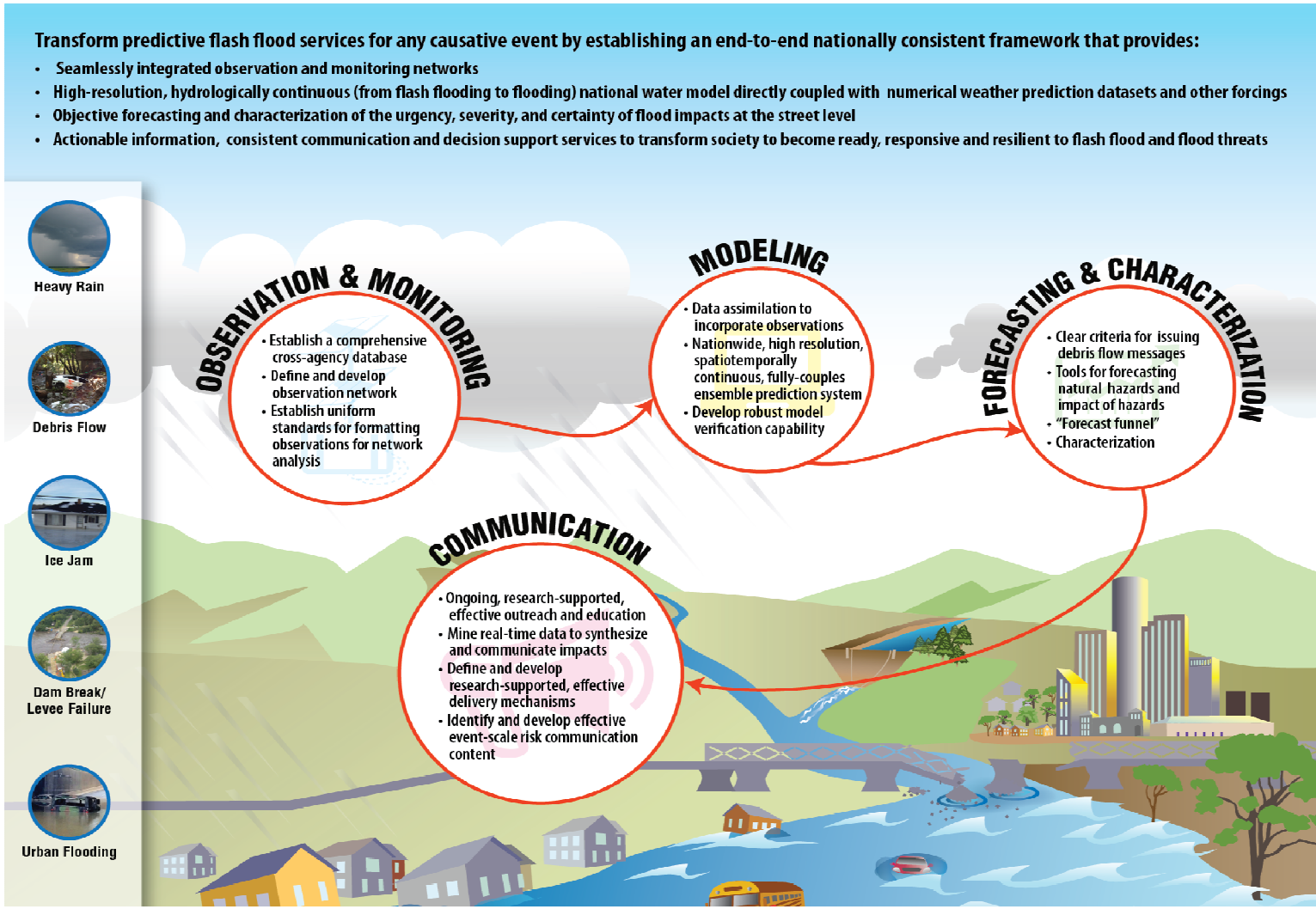


Figure 1. The vision board was used as a guide throughout the Summit to remind participants of the Flash Flood vision’s primary elements and how they are connected (the original vision board can be found in Figure 3). Through several facilitated breakout group sessions, participants identified and narrowed down the priority requirements for each element required to advance the vision. This graphic is a cleaned-up version of the vision board that was populated by Summit participants.

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1.0 BACKGROUND AND INTRODUCTION

On September 9–11, 2014, the NWS convened a two-and-a-half-day Flash Flood Summit at the NWC to develop the vision for the future of U.S. flash flood services. The need for the Summit was clear.

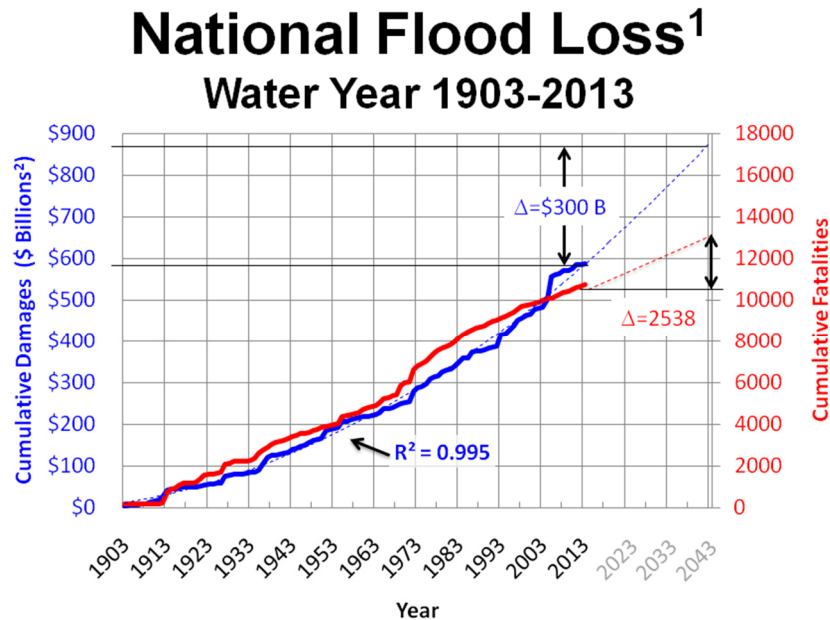
The annual average damage due to flooding has risen in each of the past three decades (costs adjusted for inflation):

- 1981–1990: \$4.7 billion
- 1991–2000: \$7.9 billion
- 2001–2010: \$10.2 billion

Over the next 30 years, the NWS estimates that flash floods will (see Figure 2):

- Cause at least \$300 billion in damages.
- Lead to over 2,500 fatalities.

Despite improvements in forecasting accuracy and advancements in hydrological and atmospheric modeling, many challenges remain in providing timely and actionable information about flash floods. Such challenges include making decisions within a dynamic environment (i.e., continuously changing landscape and climate) and effectively communicating flash flood risk to the public (e.g., the location and severity of flooding expected to occur as well as where it is not expected to occur), so that fatalities and damages are reduced in the future.



¹National Weather Service Hydrologic Information Center (www.nws.noaa.gov/hic/)

²Damages are adjusted for inflation to 2013. Damages are considered to be minimum estimates.

Figure 2. Information presented during Summit keynote by Donald Cline, NWS.

1.1 Summit Objectives and Flash Flood Vision

The Summit brought together an interdisciplinary group of 60 scientists, social scientists, and community leaders from federal and state governments, the private and non-profit sectors, and academia. The group included participants from the National Oceanic and Atmospheric Administration (NOAA) (both NWS and the Office of Oceanic and Atmospheric Research [OAR]), the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), the University Corporation for Atmospheric Research (UCAR), the University of Alabama, and the Alabama Office of Water Resources (for a complete participant list, see Appendix A). The Summit was held in the newly constructed NWC in Tuscaloosa, Alabama, on the campus of the University of Alabama.

Hydrologic, atmospheric, and other scientific expertise were combined with social science expertise so that the vision for flash flood services could benefit from input by both technical and communications perspectives. Social scientists intimately understand the process needed to translate scientific information in ways that effectively communicate flood risks to target audiences and result in the appropriate behavioral responses. This mix of physical and social scientists led to rich discussions and a fuller appreciation of the human dimensions of flash flood services. The workshop design was intended to ensure that strategies for effective communication would be discussed and integrated throughout the Flash Flood Summit deliberations and development of the vision requirements.

The Summit objectives were to:

- Agree on a shared vision for future flash flood services: a hydrologically consistent, end-to-end flash flood services to be implemented through a national water modeling and information services framework.
- Identify priority requirements/functional components to achieve the flash flood services vision.
- Explore the intersection between science and social science requirements to help inform priorities.
- Agree on a path forward to transform flash flood services over the next 10 years.

At the outset of the Summit, the NWS proposed a vision for future flash flood services that would guide the work sessions for the duration of the two-and-a-half days:

National Water Center

- 65,000 square foot facility on the campus of University of Alabama, Tuscaloosa.
- Certified Leadership in Energy and Environmental Design Gold Building.
- Designed specifically for major programmatic functions:
 - Operations Center with Situation Rooms.
 - Geo-Intelligence Laboratory.
 - Collaborative Science and Software Engineering Studio.
 - Systems Proving Ground.

Transform predictive flash flood services for any causative event by establishing an end-to-end, nationally consistent framework that provides:

- *Seamlessly integrated observation and monitoring networks.*
- *High-resolution, hydrologically continuous (from flash flooding to flooding) national water model directly coupled with numerical weather prediction datasets and other forcings.*
- *Objective forecasting and characterization of the urgency, severity, and certainty of flood impacts at the street level.*
- *Actionable information, consistent communication, and decision support services to transform society to become ready, responsive, and resilient to flash flood and flood threats.*

2.0 SUMMIT DESIGN

To achieve the Summit objectives, the NWS presented a flash flood vision statement for validation, vetting, and further development by participants. The vision consisted of four key elements:

- **Observation and monitoring:** methods by which atmospheric and hydrological data are collected.
- **Modeling:** methods by which data are inputted into a variety of models (e.g., landscape, atmospheric circulation, earth system) to help predict precipitation events and precipitation behavior in the landscape.
- **Forecasting and characterization:** model outputs and predictions used to make more precise statements about possible flash flood events and associated hazards.
- **Communication:** methods by which flash flood forecasts are effectively conveyed to emergency responders and the public to elicit appropriate action.

To facilitate the Summit's opening discussion, participants responded to a poll at the time they registered for the Summit. The poll established interests, perspectives, and opinions about current challenges and opportunities associated with flash flood services. Results of the poll are summarized below:

Top priority elements (total votes in parentheses)

- Forecasting and characterization (21)
- Modeling (19)
- Communication (18)
- Observation and monitoring (13)

Major challenges (sample of common answers)

- Communication (at appropriate spatial and temporal scales, with enough lead time, consistent terminology, etc.)
- Forecasting and characterization (precipitation, magnitude, etc.)
- Scaling of practices, consistency across offices (modeling, terminology)

Major opportunities (sample of common answers)

- Growing public awareness (attributable to recent extreme events)

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- Improved modeling (hydrology, climate, etc.)
- Agency/office collaboration (cross-disciplines)
- New methods of communicating with public (social media)
- More accurate data, better mapping capabilities
- Clarifying communication, methods for communication

The NWS used the poll results to gain an understanding of participants’ needs prior to the Summit, to confirm critical elements for moving the flash flood services vision forward, and to identify common themes expressed by participants.

Donald Cline, Acting Director of the NWS Office of Hydrologic Development (OHD), opened the Summit with a keynote presentation introducing the NWS’s challenge of reducing flash flood-related damages and fatalities over the next 30 years. He posed several questions to participants to get them thinking about the types of observation and monitoring, modeling, forecasting and characterization, and communication needs that may be necessary to progress flash flood services forward. The overarching challenge issued to the group was:

“How can we reverse the trend of increasing fatalities and damages over the next 30 years?”

To establish a common understanding of the Summit’s necessity and to elucidate current and emerging issues, a series of presentations (see Table 1) provided the state of the science and emerging technologies and practices from scientific, practical, and social perspectives. These thought-provoking presentations gave participants the context for subsequent discussions, as well as a common starting point of understanding going into breakout group discussions.

Table 1. Summary of Opening Panel Presentations

	Panelists	Panel topics
<i>Panel #1: Physical Science</i>	David Gochis, National Center for Atmospheric Research (NCAR) J.J. Gourley, NOAA/National Severe Storms Laboratory David Maidment, University of Texas at Austin	<ul style="list-style-type: none"> • The feasibility of moving towards forecasting water flow everywhere all the time (beyond point flow forecasts), taking into account the impacts of infrastructure (e.g., dams, levees); improving representations of landscape dynamics; and providing more meaningful risk guidance by creating a probabilistic framework for forecasters/decision-makers, all of which would require significant geospatial data support capable of evolving over time. • Improve flash flood watches and warnings and make them more actionable based on the work conducted under the Hazardous Weather Testbed-Hydrology experiment. • The National Flood Interoperability Experiment (NFIE) will attempt to connect national scale flood modeling with local emergency planning and response.
<i>Panel #2: Practitioner Experience</i>	Leslie Durham, Alabama Office of Water Resources	<ul style="list-style-type: none"> • The importance of moving the public away from reactive behavior to proactive behavior (in the context of recent coastal flash flooding in Alabama, where 1 out of every 4 flood events in the state occur outside FEMA-designated flood areas). • The desire to maximize federal capabilities to provide local solutions, gaining a better understanding of how to

Table 1. Summary of Opening Panel Presentations

	Panelists	Panel topics
	<p>Benjamin Pratt, Susquehanna River Basin Commission</p> <p>Gene Longenecker, FEMA Office of Response & Recovery</p> <p>Mike Sprague, Environmental Emergency Services, Inc.</p> <p>Hector Guerrero, Texas Flash Flood Coalition</p>	<p>maximize the huge opportunities that are available as technologies continue to advance, and the value in understanding where the risk is in each community so that actions can be focused.</p> <ul style="list-style-type: none"> • FEMA looks to Deep-ocean Assessment and Report of Tsunamis (DART) monitoring systems; the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model; and Hazus (hazard loss estimation software), but it can often be difficult for the agency to combine all these sources to provide inundation assessments to local EMs. • In central New York, a three-county NGO provides flood warning service based on its own precipitation and stream gauges and NWS data, but it is grappling with various facets of delivering messages to the public. • The Texas Flash Flood Coalition brings together numerous stakeholders to share best practices and mitigate flash flood impacts. Some examples include a variety of communications and education products (signs, slogans, etc.), an early warning system developed in Austin, and the establishment of alternative routes at low water crossing locations.
Panel #3: Social Science	<p>Rachel Hogan Carr, Nurture Nature Center</p> <p>Julie Demuth, NCAR</p> <p>Laura Myers, University of Alabama, Tuscaloosa</p>	<ul style="list-style-type: none"> • “Focus on Floods” education campaign (Pennsylvania), as well as studies in Delaware River Basin to see whether flooding products (e.g., hydrograph, watches and warnings, flood inundation maps) were being used and understood by the general public. Tried to determine how products could be revised to address confusion. • National Science Foundation (NSF) study looking at flash floods in Boulder, Colorado, and how forecasters, public officials, and media make decisions and perceive the public’s decision-making. Results suggest a need for improved risk management among professionals and improved risk communication with the public, focusing on information at the spatial and temporal scales needed for decision-making. • Studies have shown that out of all weather threats, the public is least concerned about flash flooding. Some issues to consider when communicating with the public include whether 1) environmental cues are being recognized (rain, etc.), 2) watches/warnings/alerts are understood, 3) multiple warning modes should be established, 4) time of day needs to be considered, 5) graphical information is as important as lead time, 6) impact-based messaging may get the public’s attention but not necessarily get them to act.

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After the panel presentations, the vision statement and a key visual—a 10-foot by 4-foot vision board—were unveiled for discussion. The vision board displayed the four main elements of the flash flood services vision and various causative events (Figure 3). Smaller versions of the vision board were also displayed in each of the breakout rooms.

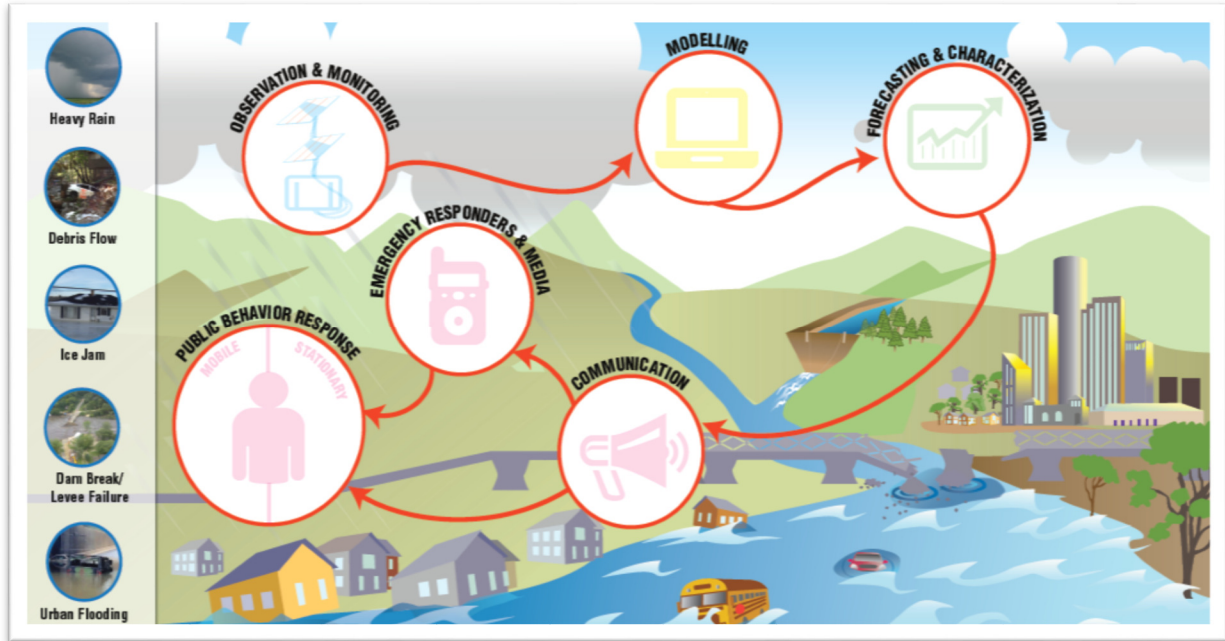


Figure 3. Original vision board.

Participants populated the board and used it interactively throughout the Summit. The four elements of the flash flood services vision served to guide the work sessions, which focused on:

- Identifying requirements for each vision element.
- Prioritizing requirements.
- Identifying each requirement’s status (where it was in the development process and about how much time/effort would be required to implement it).

In the plenary session, the vision board was explained and participants were given the opportunity to discuss the vision statement, the definitions of each element, and the charge to populate the vision board with specific requirements. Participants agreed that the vision board, statement, and elements represented a good working framework that would be “built out” over the course of the workshop.

The first breakout session was held during the afternoon of Day 1 to discuss the flash flood vision’s benefits and challenges. Participants were randomly

Breakout Session Topics

Breakout Session 1: Identify flash flood vision benefits, challenges, and opportunities.

Breakout Session 2: Bin and prioritize ideas to improve flash flood observation, modeling, forecasting, and communications.

Breakout Session 3: Choose top three priorities for each element, define them clearly, and what’s needed to implement them.

Breakout Session 4: Top three priorities are scoped out: who needs to be involved, how long will it take, what level of resources is required?

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assigned to the first breakout group to ensure a mix of expertise. Each breakout group had a facilitator equipped with an on screen worksheet, which was populated in real time during the session so that all ideas were captured accurately. These groups then reconvened in plenary session and reported back on their discussions.

Participants were asked at the conclusion of Day 1 to identify at least four needs (one for each flash flood vision element mentioned previously) and record them on color-coded index cards (Step 1, Figure 4; see Appendix B).

On Day 2, participants (in the same groups as Day 1) brought their index cards into the second breakout session to be prioritized by vision element (Step 2, Figure 4). Working in small sub-groups, 12 requirements for each element were reduced to three or four and were hand-written on post-it notes. The smaller sub-groups reported back to the breakout group, and priorities for each element were discussed.

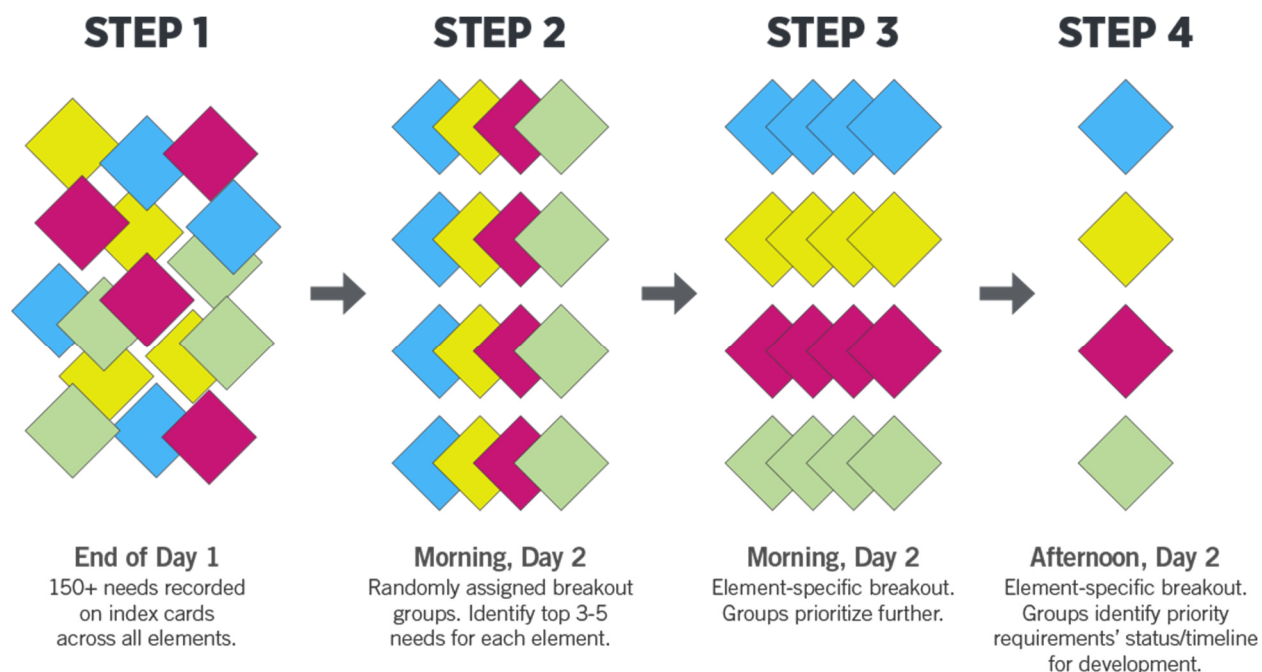


Figure 4. Breakout group process: refining flash flood services vision needs.

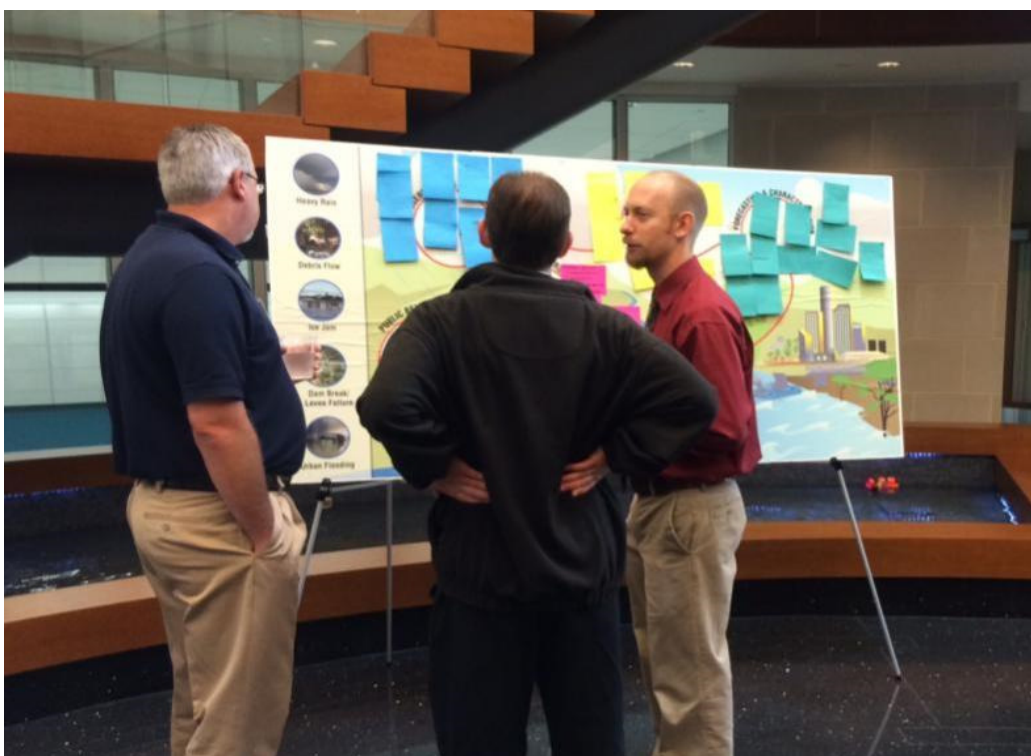
At the conclusion of the session, the post-it notes were then placed onto the large vision board in the rotunda for all Summit participants to see and discuss (see photo below). Approximately 12 requirements were present in each designated element space of the vision board.

On Day 2 of the Summit, participants attended element-specific groups. Participants chose one of the four groups based on their expertise and interest. In the third breakout session, participants were tasked with taking the 12 or so priority requirements for their specific flash flood vision board element and refining the list further (Step 3, Figure 4). Participants again wrote the new priority requirements on post-it notes and stuck them on the rotunda vision board for all to see.

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In the fourth breakout session, the same groups were tasked with discussing timelines and approaches for moving each need forward (Step 4, Figure 4). By the end of Day 1, over 150 cards were submitted with ideas for improved flash flood services. By the end of Day 2, these needs had been combined, reorganized, prioritized, and fleshed out into three to four top priority requirements that must be developed to advance the flash flood vision (Figure 3).

The last session of the Summit was a plenary discussion of how to move forward with the new vision, including how to best make “the business case” and develop a community of practice. Participants were also asked to provide suggestions for future focus group locations where the vision could continue to be vetted and refined. By the conclusion of the Summit, participants had provided a wealth of information, which will allow NWS to define requirements for the end-to-end national water model, identify research priorities, better understand the communication needs of the public and others, and create a community of practice to advance flash flood services.



Participants gathered in the rotunda to discuss the results of a breakout session posted on the vision board.

3.0 SUMMARY OF SUMMIT OUTCOMES

3.1 Flash Flood Vision: Benefits, Challenges, and Opportunities

Benefits

All of the groups discussed the new flash flood vision’s benefits related to improved modeling and forecasting. Key benefits mentioned across several groups included:

- More accurate and precise hydrologically based products.

Moving from reactive to *proactive* flash flood services with more accurate, precise, and consistent information.

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- Better modeling that includes greater specificity (refined locations, magnitude, etc.) and incorporates all types of forcings.
- Improved forecasting that responds to landscapes and changing climates and integrates observations so that forecasters do not have to check multiple sources.
- Consistency in messaging and products across agencies, which will lead to increased consistency in data management.

Participants noted that improvements in consistency ultimately benefit the public, who are apt to place more trust in flash flood services if they receive consistent information. Several groups mentioned how improvements in modeling (leading to better estimates of timing, duration, and severity) would also contribute to building public trust and compliance with flash flood watches and warnings. Utilizing new mobile communication technologies will allow for customized alerts based on where people are located at the time of a flash flood and provide the safest evacuation route to the user. In the end, improved flash flood services will mean more lives saved.

Challenges

Funding was seen as one of the biggest challenges to achieving the vision. Participants noted that forecasting extreme events and accounting for the complexity of physical processes involved in flash floods is another significant challenge. They also pointed to a lack of consistency in datasets, noting that detailed attributes are often missing, and data is not always synchronized, publically available, or integrated.

In terms of modeling, the size and diversity of the landscape across the entire United States is daunting. Participants also pointed to the overwhelming number of NWS products and the lack of consistency across products; a lack of coordinated roles and responsibilities among agencies (and even within NOAA

Overcome challenges in funding, data and modeling complexities and inconsistencies, and communication.

and NWS) contributes to those inconsistencies. Depending on resources and the experience level of local media and emergency responders, the current watch/warning/advisory paradigm has different levels of effectiveness that are difficult to assess. Participants also identified communications-related challenges, including the ability to reach all members of the public (including those without smartphones) and

getting the public to take warnings seriously (“crying wolf” problem). Throughout the entire Summit, participants discussed the difficulty of issuing an accurate warning that conveys the appropriate action to the public.

Opportunities

Participants discussed the NWS being ready to adjust products and services to potentially simplify the product suite and create greater consistency. If there was a clear, consistent framework for flash flood information, it could allow for addressing behavioral response more proactively. There is an opportunity to use the NWC to integrate extreme precipitation forecasts and land-surface modeling. The NWC could partner with academia to combine their high-resolution models and participation in NOAA Hydrometeorology Testbed activities and other field campaigns. The NFIE could provide a good opportunity to advance/demonstrate capabilities quickly and build upon this success.

The NWC provides the opportunity to physically bring people together across federal agencies and academia to address grand challenges.

Many groups identified the new vision as an opportunity to re-engage the public on new

communications products (e.g., specific locations available using mobile technology) and to learn from other successful marketing campaigns on how to get people to act.

3.2 Prioritized Requirements for Achieving Flash Flood Vision

For the third and fourth work sessions, participants chose to join one of four groups, each representing a vision board element. During the third session, each element-specific group distilled the prioritized requirements that were identified during the second work session. During the final breakout, groups refined the prioritized requirements, if necessary, and then rated each on a scale of 0 to 10, where 0 indicated that the work towards the requirement was in nascent stages, 5 represented planning stages, and 10 meant the requirement was already being undertaken. Questions on timelines and funding level needed to implement the requirements were only addressed if the group had time available. (See Appendix B for full lists of requirements developed and then prioritized.) The following sections summarize the top priorities identified for each of the vision board's four elements.



Participants discuss forecasting during the second breakout group session.

Observation and Monitoring

1. **Observation network:** Define and develop a sustainable observation network to adequately support flash flood monitoring, verification, prediction, and warning. This includes:
 - a. Capability for real-time, high frequency/low latency data transmission.
 - b. Incorporating non-traditional and/or locally managed data sources and new technologies/methodologies when and where appropriate (emerging models will have new needs).
 - c. Filling in the instrumentation and qualitative/situational gaps.
- **Level of development (scale of 0 to 10):** 3 for integration and 5 for infrastructure. Networks are already in place, but they are not specifically for flash flooding; however, they could easily be repurposed. New technologies will take longer to deploy, understand, and develop quality assurance methods (see MesoNET in Lubbock, Texas).
- **Agencies currently involved:** State and local governments, FEMA, the private sector, data providers, River Basin Commissions (RBCs), NWS, NOAA, OAR (has new technologies, including next generation radars [NEXRADs]), USACE, USGS (has temporary gauges for potential dam breaks), and the U.S. Bureau of Reclamation (USBR).
- **Agencies to be involved in future:** NWC becomes the integrator of all available observation networks.
- **Any additional thoughts on timeline and funding needs:** Longer term (> five years), requiring medium amount of funding (for adding sites, maintenance, and building new technologies). These would be sustained costs over time.

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2. **Database:** Establish a comprehensive forecast, situational awareness, and post-event cross-agency database that includes:
 - a. Characterization and interpretation of the event, including links to inundation maps.
 - b. Different data types, seamless time series/timeline, and non-time series (social media, high water marks [HWMs], emergency management circumstances, burn scars, etc.).
 - c. Archiving and verification.
 - **Level of development (scale of 0 to 10):** 2. Some databases are already out there, but they are not coordinated, extensive, consistent, or reliable. Need to connect damage assessment information with the NWS; Annual Flood Loss Report; OHD/Weather Prediction Center (WPC)/National Severe Storms Laboratory (NSSL)/multi-source flash flood experimental database; geographic information system (GIS) database of flash flood events from NWS, USGS streamflow, and public reports; national high water database; E5 hydrologic conditions report by WFOs.
 - **Agencies currently involved:** State and local governments, FEMA, the private sector, data providers, RBCs, NWS, NOAA, OAR (has new technologies, including NEXRADs), USACE, USGS (has temporary gauges for potential dam breaks), and USBR.
 - **Agencies to be involved in future:** NWC could host the database.
 - **Any additional thoughts on timeline and funding needs:** Medium term (two to five years). Hard part is gathering/dedicating people to focus on this; requires medium funding amount.
3. **Standards:** Develop uniform standards across agencies for formatting observations and network analyses that include metadata.
 - **Level of development (scale of 0 to 10):** 6. Already being completed in pockets. The Integrated Water Resources Sciences and Services (IWRSS) Interoperability and Data Synchronization team is working towards the design phase now, so the backbone is in place.
 - **Agencies currently involved:** IWRSS partners and RBCs.
 - **Agencies to be involved in future:** FEMA is on the cusp of participating; community-based systems (municipalities, states, universities).
 - **Any additional thoughts on timeline and funding needs:** Medium term (two to five years). Coordinating all players will take longer to happen; requires low funding amount (depends on how much work is needed to move to the new standards).

Modeling

1. **Data assimilation:** Develop and implement data assimilation methods for distributed hydrologic/hydraulic model applications that incorporate observations of precipitation, streamflow, air temperature, soil moisture/temperature, groundwater, snowpack, river stages, and inundation extent.
 - **Level of development (scale of 0 to 10):**
 - Precipitation: 10
 - Streamflow: 5
 - Soil moisture: 5
 - Air temperature: 10
 - Soil temperature: 5
 - Groundwater: 5

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Snowpack: 10
River stages: 4
Surface inundation: 0
Changes in operating rules: 2

• **Agencies currently involved:**

Data collection: Observational partners, state and local partners (need for sharing of state and local observation and monitoring data).

Methods development: Academia, federal experts, NWS Hydrology Program.

• **Agencies to be involved in future:**

Data collection: Local and private operators.

Methods development: Academia, private-sector engineering.

• **Any additional thoughts on timeline and funding needs:**

Data assimilation: Cost will be high.

Data availability: Two to five years.

Methods/full scale development: Will take more than 5 years.

2. **Model structure:** A nationwide, high-resolution (tens to hundreds of meters) ensemble prediction system that is spatially and temporally continuous and has a fully coupled hill slope/channel. The system will provide scalable, multi-physics, short-term probabilistic forecasts of flood flow, stage, and inundation across dynamic landscapes. It will accommodate:

- a. National and local (very high-resolution) implementations in both ‘standing operations’ and ‘on-demand’ modes.
- b. Earth System dynamics leading to evolving land-cover/land-use characteristics, including human and natural disturbances (e.g., wildfires, population dynamics, channel erosion, landslides, and urbanization).
- c. The built environment’s static and dynamic influences, such as hydraulic infrastructure and water management operations.
- d. Relevant graphical user interface (GUI)-based automation of the prediction workflow (i.e., model configuration, ensemble generation, execution, and post-processing).

• **Level of development (scale of 0 to 10):** 6.

• **Agencies currently involved:** Federal experts (USGS, National Aeronautics and Space Administration [NASA], NOAA, USACE, USBR, FEMA, U.S. Environmental Protection Agency [EPA]), NWS Hydrology Program, academia, and the private sector.

• **Agencies to be involved in future:** WFOs, River Forecast Centers (RFCs).

• **Any additional thoughts on timeline and funding needs:** Developing the model structure will require a high amount of funding and will take approximately two to five years.



Sub-group during second breakout discussing communication priorities.

3. **Model verification capability:** Develop a robust, multivariate model verification framework that is supported by an independent set of observations. These observations will be used to routinely develop quantified evaluation and verification/performance metrics across the suite of water budget variables.
- **Level of development (scale of 0 to 10):** 2.
 - **Agencies currently involved:** NWS Hydrology Program, other federal experts.
 - **Agencies to be involved in future:** More federal experts, academia, emergency response partners, and stakeholders (all levels).
 - **Any additional thoughts on timeline and funding needs:** Developing the model verification capability will require substantial and sustained funding and will take approximately two to five years.

Forecasting and Characterization

1. **Tools:**

- a. Tools for forecasting natural hazards

Continue developing hazard services:

- Advanced Weather Interactive Processing System (AWIPS) 2 GIS services and land surface layers.
- Layering radar and observations with community-provided land surface information.
- Information-centric, AtomicDB, trigger thresholds.

Improved tools: Tools that are more grounded in science for forecasting behavior and the evolution of high-intensity precipitation at time scales ranging from 0 to 48 hours. Output from these tools should provide both probabilistic and deterministic guidance.

Streamlined forecast process: Process to include a weighted ensemble (prediction system and general tools).

- **Level of development (scale of 0 to 10):**

Hazard services: 7

- AWIPS 2 GIS services: 3
- Land surface layers: 1

Improved tools: 1

Streamlined forecast process: 3

- **Agencies currently involved:**

Improved tools: Environmental Modeling Center, academia, National Labs, WFO staff (involved with National Lab work), and Hazardous Weather Testbed (HWT).

Streamlined forecast process: WPC, NSSL, academia, and National Centers for Environmental Prediction (NCEP).

- **Agencies to be involved in future:**

Improved tools: NOAA OAR, NWS Office of Science and Technology Integration, and NWC.

Streamlined forecast process: NWC, RFCs, and WFOs.

- **Any additional thoughts on timeline and funding needs:**

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Hazard services: Medium term; two to five years.

Improved tools: Some are already grant funded (maybe tens of millions).

b. Tools for forecasting hazard impacts

Hazard services: See “Tools for forecasting natural hazards,” above.

Platform: Provides flood inundation risk and impacts characterization by integrating forecasts, observations (gauging, radar, HWM documentation), and other relevant situational awareness layers (burn scars, debris, etc.).

- Focused on communication to forecasters; updated by different agencies.
- Integrated with hazard services.

- **Level of development (scale of 0 to 10):** 2.
- **Agencies currently involved:** University of Oklahoma, NSSL, FEMA, University of Texas at Austin.
- **Agencies to be involved in future:** NWS.
- **Any additional thoughts on timeline and funding needs:** Not discussed.

2. **Characterization:**

- a. By magnitude: Characterize flash flood events by their relative magnitude (such as minor, moderate, and major flash flooding). This must include an understanding of the infrastructure design, channel capacity, and other features (natural and human-made) to transition to impact-based flash flood products.
- b. Thresholds: Establish severity (impact-based) thresholds that are consistent.
- c. Accuracy and uncertainty: Improve weather forecast model accuracy and characterization of uncertainty in predicting location and intensity of rainfall events to increase watch/warning lead-time through multiple-day outlook products (such as Excessive Rainfall Outlooks, and “what-if” scenarios).
- d. Best practices: Develop a set of flash flood forecasting best practices with respect to characterization methods and simplified forecasting terminology.

- **Level of development (scale of 0–10):** 3 (some aspects are currently underway for rivers).
- **Agencies currently involved:** NWS (RFCs and WFOs), USGS, EMs, academia, FEMA, NSSL, and NSF.
- **Agencies to be involved in future:** NWC.
- **Any additional thoughts on timeline and funding needs:** Not discussed.

3. **Debris flow messages:** New flash flood services include clear criteria for issuing debris flow messages based on methodologies currently used in southern California that are restricted to post-fire landscapes. This should be expanded to cover the entire United States and its affiliated territories.

- **Level of development (scale of 0 to 10):** 6.
- **Agencies currently involved:** USGS (lead), Burned Area Emergency Response, U.S. Forest Service, U.S. Department of the Interior, Arizona Geological Survey, Los Angeles County Public Works, California Emergency Management Agency, Oxnard and San Diego WFOs, other WFOs, NWS Pilot Program, and other state geological surveys.
- **Agencies to be involved in future:** State geological surveys, the Urban Drainage District (Denver), USBR, WFOs, NASA, NSF, and academia.

- **Any additional thoughts on timeline and funding needs:**

Phase I: Less than five years, applying criteria to other post-fire landscapes in Colorado, Arizona, and New Mexico; will likely require around \$4 million in funding.

Phase II: Within 10 years, applying criteria to the rest of the western United States in post-fire landscapes; new appropriations of \$8 million would be needed.

Phase III: Ten to 20 years, applying criteria to the rest of the nation; new appropriations of \$30 million would be needed.

4. **Improvements in “forecast funnel”¹:** Create a consistent suite of products leading up to an event similar to how Storm Prediction Center (SPC) approaches probability of tornadoes/severe thunderstorms from day to hours (short-fused watch timeframe). As time and space narrows/focuses in on the event, show probability of event severity (threshold categories), in coordination with the Forecasting a Continuum of Environmental Threats project for modernized watch/warning program in the NWS.

- a. Phase I: Establish consistent messaging (e.g., national maps), continue Flash Flood and Intense Rainfall and HWT-Hydrology experiments, and implement Flooded Locations and Simulated Hydrographs Project and Multi-Radar/Multi-Sensor System products.

- b. Phase II: Establish a process for connecting dots and changing roles and responsibilities.

- **Level of development (scale of 0 to 10):**

Phase I: 5

Phase II: 3

- **Agencies currently involved:** OAR, NSSL, WPC, regional operation centers, RFCs, NCEP, and local meteorologists.

- **Agencies to be involved in future:** NWC.

- **Any additional thoughts on timeline and funding needs:**

Phase I: One to two years; relatively low costs because this is mostly about collaboration and grants are already established for research.

Phase II: Less than five years; relatively low costs because this is mostly about collaboration. New tools could assist collaboration.

¹ A forecast funnel is a process that helps meteorologists make the best forecasts for a specific location days in advance of an event.



Large group discussion in the NWC auditorium.

Communication

1. **Content information:** Identify and develop effective (i.e., precise, relevant, accurate, accessible, useable, timely) event-scale flash flood risk communication content with longer lead times and visualization to mitigate avoidable loss of life and property. This flash flood information should include:
 - a. Impact-based, actionable messages that provide alternative actions.
 - b. More specific hazard-impact locales.
 - c. The urgency, severity, and certainty of a flash flood event.
 - d. The ability to receive feedback and validation, as well as decision support.
- **Level of development (scale of 0 to 10):** 1. Generally in the embryonic stages, but pockets of research/warning systems are underway (e.g., City of Austin flood warning system).
- **Agencies currently involved:** Consultants, academia (University of Iowa, Renaissance Computing Institute [RENCI]), research organizations (NCAR, Natural Hazard Center) and centers (University of Alabama), some localities (e.g., Austin, Boulder, San Antonio—pending), NSF, and the U.S. Department of Homeland Security.
- **Agencies to be involved in future:** State/local emergency management community, broadcast meteorologists/media, the weather enterprise, the American Meteorological Society, the National Weather Association, the Society for Risk Analysis, the American Society of Civil Engineers (ASCE), and Environmental Systems Research Institute (ESRI).

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- **Any additional thoughts on timeline and funding needs:** Four to 10+ years. Overall, estimated high costs; research estimated cost of \$10 million.
- 2. **Effective dissemination:** Enhance and develop research-supported, effective (i.e., precise, accurate, accessible, useable) mechanisms for delivering flash flood risk communication.
 - a. Public
 - Disseminate information flexibly to allow identified audiences to receive varying degrees of uniform information in different formats.
 - NWS flash flood information should reach populations where they are and alert them to specific flash flood impacts relevant to them. Populations may be low-income, technologically disconnected, non-English speaking, etc.
 - National database/website with data displayed in maps and other formats.
 - b. Partners
 - Disseminate information flexibly to allow identified audiences to receive varying degrees of uniform information in different formats.
 - Place more emphasis on local EMs and media; define roles (before, during, and after events) and facilitate collaboration between NWS and locals to help change mindsets to include flash flooding as severe weather/hazard.
 - Enhance partner communication and coordination among organizations.
- **Level of development (scale of 0 to 10):** 1 (overall in the embryonic stage nationwide). There are some level-10 efforts (e.g., NWS using wireless emergency alerts [WEAs], the Integrated Public Alert and Warning System, and iNWS social media to transmit risk communication); some universities are exploring this topic as well).
- **Agencies currently involved:** NWS, U.S. Department of Transportation (DOT), technology providers, World Meteorological Organization, local jurisdictions/EMs, the American Red Cross, Google, WEAs, hazard mapping groups, Iowa Flood Center, FEMA, USGS, the water/weather enterprise, some universities (University of Colorado's Empowering the Public with Information in Crisis, University of Alabama's Center for Advanced Public Safety), and Weather-Ready Nation (WRN).
- **Agencies to be involved in future:** Service organizations; the WRN Ambassadors Program; community groups (Kiwanis Club, etc.); cultural groups; the media; associations representing people with disabilities, the elderly, and other vulnerable populations; faith-based organizations; app providers.
- **Any additional thoughts on timeline and funding needs:** Four to 10+ years; medium cost.
- 3. **Outreach and education:** Provide ongoing, research-supported, comprehensive, and effective education and outreach to convey flash flood risk information developed by NWS and others.
 - a. Public
 - K-12 outreach; education should target the middle/high school level.
 - All socioeconomic groups.
 - Broader marketing campaign.
 - b. Partners

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- Define the roles of partners (water/weather enterprise) in outreach/education.
 - Enhance partner communication and coordination among organizations.
 - Relationships.
 - **Level of development (scale of 0 to 10):** Overall 6 (NWS has an education group but needs more social science). There are some level-10 efforts (NCAR gaps in flash flood risk perception research on longer term risk adjustment; UCAR COMET; Nurture Nature, though focus is on floods—i.e., needs more advocacy from NWS).
 - **Agencies currently involved:** UCAR COMET, NSSL, the Hydrologic Warning Council, the Iowa Flood Center, the American Red Cross, WRN Ambassadors, and many of the agencies mentioned above in priorities #1 and #2.
 - **Agencies to be involved in future:** All organizations mentioned in priorities #1 and #2, as well as schools.
 - **Any additional thoughts on timeline and funding needs:** Four to 10+ years; medium cost.
4. **Communication during events:** Enhance/develop capabilities to process and synthesize (data mining) real-time data, as well as to assimilate, synthesize, and communicate impacts in an event to all customers from traditional and nontraditional sources. Infuse real-time data into information and communications.
- **Level of development (scale of 0 to 10):** 1 (not on a national scale, though some limited tools exist). There are some level-10 efforts (Iowa State University Iowa Environmental Mesonet, Virtual Alabama, Virginia Interoperability Picture for Emergency Response [VIPER] statewide situational awareness systems, University of Texas, NWSChat).
 - **Agencies currently involved:** Forecasters, media, EMs, universities, first responders, citizen-science networks, spotter networks, state Departments of Transportation, and the University of Colorado Empowering the Public with Information in Crisis (EPIC).
 - **Agencies to be involved in future:** Technology providers and ESRI.
 - **Any additional thoughts on timeline and funding needs:** Four to 10+ years, though data mining may be accomplished sooner; medium cost.

3.3 Intersection between Hydrometeorological and Social Sciences

Throughout the Summit, there were important formal and informal discussions about how to effectively communicate flash flood risks. Several social science experts stressed that the social science behind effective communication is not one-size-fits-all, and research is needed to better understand how to improve flash flood communication. The many ideas expressed and questions asked throughout the two days were evidence of a strong interest in incorporating social sciences into the flash flood community of practice. Participants acknowledged that effective communication for improved decision-making is key to moving flash flood services forward in the future. Some specific ideas regarding communication-related challenges and opportunities were discussed at the Summit and are listed below:

- In-vehicle communication systems are a new way to reach people on the road.
- Low-technology strategies should not be overlooked.
- Messages should include telling people what they should do, rather than just what they should not do.
- Schools are great starting points; early education can teach kids how to be “weather wise.”

- Develop a sense of community responsibility.
- Gain the public’s trust.
- Color choice is important, but confusion exists over color use and patterning in some existing federal products.
- High-water marks as reminders of flood levels are emerging in the United States; their utility has yet to be evaluated.
- Mining Tweets during weather events could inform flash flood characterization and products.

In addition to these specific ideas, an overarching suggestion emerged—much can be learned about flash flood risk assessment, communication, and decision-making from the hazards and risk management communities, which are inherently interdisciplinary (e.g., geography, psychology, sociology, communication, public health). Research from these communities should be leveraged and built upon, and efforts should be made to better integrate researchers and practitioners into the weather community.

4.0 GROUND TRUTHING FLASH FLOOD SUMMIT FINDINGS: FLASH FLOOD FOCUS GROUPS

Following the Summit, NWS convened five focus groups across the country to gain a better understanding of local flash flood needs and to help ground truth and supplement the communications vision developed during the Flash Flood Summit (Figure 5; see Appendix D for summary notes from each of the five locations).

Focus groups were held in:

- Austin, Texas (11/12/14)
- Boulder, Colorado (12/10/14)
- Binghamton, New York (1/14/15)
- Romeoville (Chicago), Illinois (2/18/15)
- Mobile, Alabama (3/2/15)

Focus group participants (72 in all) included local officials, EMs, broadcast meteorologists, local NGOs, and community leaders. NWS WFOs also participated and were instrumental in organizing and assembling participants for the meetings. To provide continuity and information sharing between the Summit and the focus groups, at least one participant at each focus group session had also attended the Flash Flood Summit.

The focus group participants were asked four questions:

- How would you characterize your community’s vulnerabilities to flash floods?
- What currently works/doesn’t work in terms of communicating flash flood risks?
- What more can be done?
- What can NWS do to improve communication?

Each community reported facing a variety of challenges unique to their geography. However, three recommendations emerged that would help advance flash flood communication locally and align with the NWS communications vision.

- **Simplify flash flood messaging.** The current watch/warning/advisory system is confusing to the public, and both EMs and broadcast meteorologists expressed difficulty conveying the risk level using this terminology. Rethinking the system in simpler, widely understood terms that convey *actionable* information will likely improve overall understanding and response. NWS should also consider *how* these messages are being disseminated, with an emphasis on including video and/or graphics.

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- **Improve modeling capacity to allow for higher resolution products.** While clarification and simplification of the existing watch/warning system is desired, participants also recommended greater specificity on the timing, severity, and location of flash flood risks. Modeling capacity will have to be improved to forecast with greater geographic and temporal specificity (e.g., a less than one-hour time step, identifying specific stream or road intersection impacted). When higher resolution information is eventually available for dissemination, it will need to be distilled into actionable, simple terms for users.
- **Continue to foster and cultivate strong relationships between WFOs and local partners.** Over the years, WFOs and local partners have built valuable relationships based on open data sharing, transparent personal communication, and trust. Every effort must be made to foster and strengthen these relationships so that WFOs can continue to provide the services and information decision-makers need to effectively communicate flash flood risks. These collaborative partnerships provide WFOs with a valuable “boots on the ground” feedback loop for real-time, site-specific conditions, and they help disseminate consistent messages across the affected community before, during, and after flash flood events.

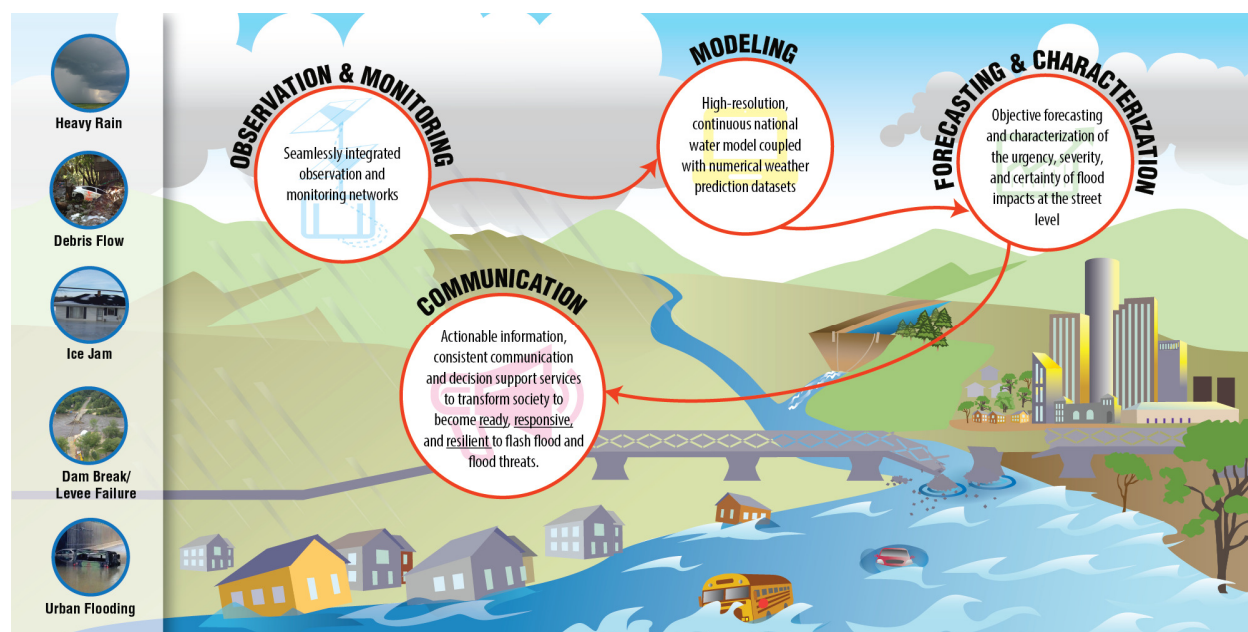


Figure 5. Revised vision board presented at focus groups.

Vulnerabilities

All focus groups agreed that the severity and frequency of flash flood events appear to be getting worse. In Austin, reaching non-English speaking populations is a major concern, and transient and homeless populations are also highly vulnerable during flash flood events. Boulder’s already complex hydrology and dramatic canyon terrain has been exacerbated by burn scars left from recent wildfires; this has reduced flash flood warning lead times to two minutes in some instances. In Binghamton, shallow hydrologic features and sharp changes in terrain, coupled with the lack of creek maintenance on private property, has created some highly

“Alabama has a statewide talk group over public safety radio systems, which allows emergency managers to hear emotion in the WFO’s voice. Text isn’t nearly as effective as hearing the level of urgency in a voice, especially a familiar voice.”

– Mobile, Alabama focus group participant

vulnerable populations. Chicago’s dense lakeshore development and relatively flat and impervious terrain result in fast-moving flood waters that often overwhelm storm drains and flood major roads and highways, cutting off access to businesses and healthcare facilities. Chicago, Binghamton, and Austin all have soil characteristics (shallow or nonexistent topsoil and non-porous clay) that cannot absorb precipitation from high-intensity events. Mobile faces the additional challenge of coastal flooding associated with high tides or storm surge during flash flood events, as well as municipal drainage systems that are unable to handle the large runoff volumes during extreme precipitation events. In Mobile, rainfall amounts associated with one storm are often measured in feet rather than inches. Most communities also mentioned land development in high-risk areas as an issue, as well as other land use changes that impact people’s vulnerability to flash flood events by increasing impervious surfaces. All focus groups reported members of the population who increase their vulnerability to flash floods by not taking warnings seriously or not believing they are truly at risk. In more than one focus group, participants mentioned how the public will respond to warnings for other severe weather events, such as tornadoes, but not flash floods.

What works? What does not work?

Some common themes were identified regarding what works and what does not work in communicating flash flood risks. Communications that focus on mobile phone use—such as phone alert systems, applications (e.g., social media), or mobile-enabled websites—were considered successful and especially important for reaching people driving in their vehicles during a flash flood event. The timing and type of message makes a difference; using visuals/graphics, memorable slogans (“Turn around, don’t drown”), human voices, and pre-event warnings were mentioned as effective strategies. All focus groups cited good communication and positive relationships with WFOs as important before, during, and after events. Participants valued WFO-led pre-event briefings (webinars), and WFOs value, when available, local observational network data to help ground truth radar data.

Due to the increasing reliance on mobile-based communication, reaching populations without smartphones or internet is a major challenge. A related challenge is reverse 911 alert systems that require landlines, which are becoming less common. There is often a lack of specificity regarding flood intensity levels and georeferences in recognizable, actionable terms (e.g., identifying exact road crossings that are flooded, referring to a creek or stream by a different name than locals call it). Although the safest routes are identified and made available to the public in cities like San Antonio, Texas, the safest routes during an event are not always known. Participants considered some NWS products to be effective, but noted that there has been confusion when river flood warnings are issued as bulk products and then portions of the warning are cancelled, or when a flash flood watch is issued for an area where an ongoing river flood watch/warning is in effect. Overall, all focus group locations agreed that there is general confusion among knowledgeable users and the public on the NWS watch/warning/advisory system.

What more can be done?

When discussing what more can be done, focus group participants offered several recommendations related to enhanced resolution of forecasts (both spatial and temporal), such as characterizing flood severity on a more targeted basis; increasing flash flood updates to an hour or less time step (versus current six-hour); expanding observation networks by funding and integrating local observations like the Community Collaborative Rain, Hail, and Snow Network and other local rainfall gauge networks; and determining what is nationally feasible in response to demands for “street level” forecasts. Thresholds and indices were also mentioned, such as developing a tool that provides watershed-scale rainfall thresholds and including higher resolution versions of flash flood potential. Other suggestions included

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expanding local rain gauge observation networks for real-time information to supplement national networks and to ground truth flash flooding events.



Mobile, Alabama, focus group.

What can NWS do to improve communication?

Focus group participants indicated that NWS needs better graphics and tools (apps, social media, etc.) and some clarification or simplification of the watch/warning/advisory language. Some suggested presenting flash flooding to the public in its historical context (e.g. comparing predicted event to previous event), as well as building awareness through post-event public education and debriefs for local officials and EMs (which would complement the already popular and effective pre-event briefings). Participants also encouraged NWS to convey actionable information in its communications and to engage local officials in tailored trainings (e.g., for floodplain managers). Although most groups discussed the potential value of a national education campaign, some felt it would be more effective to train local leaders to educate the public. All groups conceded that individuals will still make decisions on their own to engage in risky behavior, no matter how well information is disseminated.

5.0 NEXT STEPS

Achieving the vision for transforming flash flood services is a great challenge. The goals and requirements identified by the Flash Flood Summit participants and follow-up focus groups will require concerted and coordinated efforts spanning multiple years (Figure 6). The NWS intends for these efforts to be supported by an interdisciplinary team of subject matter experts from physical sciences, high performance computing, informational science, and social sciences. In the near-term, NWS will focus on the following:

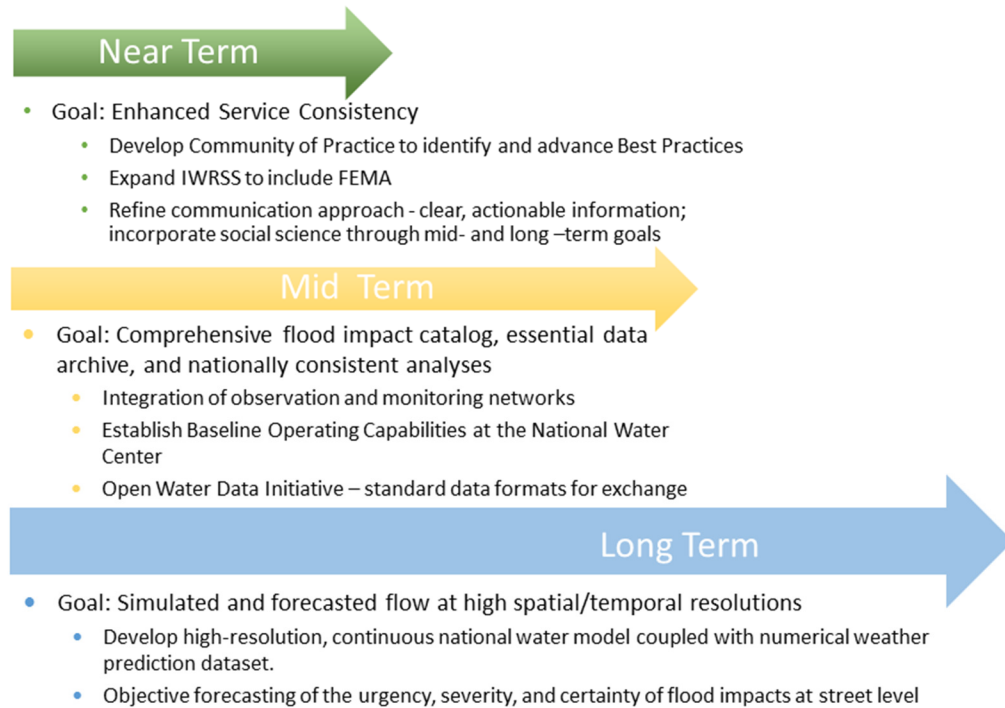


Figure 6. IWRSS timeline

Near Term

Establishing a community of practice. A community of practice will be established to ensure that flash flood requirements developed at the Summit are further vetted/refined, and comprehensive solutions to meet these requirements are integrated with other program areas and baseline capabilities. The community of practice will include partner agencies such as FEMA, USACE, and USGS, as well as members beyond NWS and the federal sector, to leverage agency assets and capabilities and avoid duplication. The community of practice will be expanded beyond the federal sector to ensure that experts from the social science discipline and other partner organizations work with physical and computer scientists to explore solutions and develop vision elements for transformed flash flood services. At the same time, the community must communicate with and inform related programs slated to build foundational water resource services, such as the emerging Open Data movement, the continued progress of IWRSS, and the development of baseline operating capabilities (BOCs) at the NWC.

The community of practice will act as a focal group for continued stakeholder engagement and will continue to validate the requirements proposed by the broader practitioner community. It will also ensure that design and development activities meet the end goal for meaningful and actionable information that allows an individual or organization to take proactive steps toward reducing their flood risk.

The community of practice can be leveraged to define operating principles for emerging enterprise-level capabilities; for example, the information forecasters should communicate as they become more confident in the timing, severity, and impacts of a flash flood event. One such example is the anticipated release of Hazard Services, an internal decision support and software package that will integrate the capabilities of three existing software packages. With Hazard Services, the forecaster can

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include actionable information in existing products by integrating geospatial datasets of potential impacts and analyses within the product issuance tool. The community of practice could help define these datasets and, to the extent that gaps exist, provide recommendations and best practices for acquiring them.

Such a community requires clear and open communication using 21st century techniques, such as collaboration portals and shared workspace. These must be available for both governmental and non-governmental members.

Identifying best practices. The community of practice will identify best practices by reviewing current operational procedures across the NWS. Best practices are programmatic activities that are performed within the current operational paradigm without dependencies on software development or resources. Best practices increase the level of consistency in current product suites spatially (across offices) and temporally (e.g., how do outlooks evolve to watch issuance conditions that may then worsen to warning issuances with continued decision support information provided through statements).

Expanding IWRSS to include FEMA. Under the auspices of the IWRSS consortium, NOAA, USGS, and USACE are working together to leverage agency assets and develop collaborative solutions for addressing flooding and other issues. By December 2014, FEMA will join IWRSS under the IWRSS Memorandum of Understanding. FEMA's role in emergency response and mitigating flood risks will add another set of tools and datasets—including flooding inundation mapping data—to the IWRSS suite of capabilities. FEMA's expected participation in the IWRSS Interoperability and Data Synchronization project will enhance the effort to establish a common operating picture for water resources. This common operating picture is directly tied to the requirements identified during the Summit and complements the existing IWRSS business model.

It is important to recognize that a number of initiatives and opportunities are already beginning to lay the foundation for transformational services that could be developed in the mid to longer term. These include:

Mid Term and Long Term

Establishing BOCs at the NWC. The NWC vision is "Scientific excellence and innovation driving water prediction and decisions for a water resilient nation." Its mission will include collaborative research and development, as well as delivery of state-of-the-science hydrologic analyses, forecast information, data, decision support services, and guidance. With a strong emphasis on partners, the NWC coordinates, integrates, and supports consistent water prediction activities from global to local levels. As NWC BOCs are established, a number of key projects will integrate with, and facilitate the vision for, transformational flash flood services. First, under the Centralized Water Forecasting Demonstration Project (CWFDP), a Water Resources Data Service and Water Resources Evaluation Service (WRES) will be established. The CWFDP facilitates the development of next-generation hydrologic modeling efforts and meets many of the requirements for centralized, observed data collection; it also provides data services to disseminate critical observations and forcings. In addition, the CWFDP will establish an initial high-resolution, hydrologically continuous, modeling framework. As performance and datasets are evaluated using the emerging WRES, output information can be used to prototype and explore new products and services necessary to evolve communication and decision support services. Second, the NWC is uniquely situated to enhance collaboration between the research sectors and IWRSS partners, including close collaboration with social scientists. These collaborations can infuse new science into the design and development process for all aspects of new

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flash flood services, including observation collection, modeling, forecasting, and communication informed by social science research. Finally, the NWC's proposed Social Intelligence Division will help "close the loop" on the research-to-operations and operations-to-research pathway. By establishing capabilities that routinely monitor and gauge the efficacy and response to information services, the federal partners can work to continuously gather requirements for improved science and services.

Participating in the Open Water Data Initiative. At the White House level, efforts are underway to bring federal and state purveyors of water resources information into compliance with the President's May 9, 2013, Executive Order, "Making Open and Machine Readable the New Default for Government Information."² Unlike weather data, critical water budget information, ranging from historical analyses to real-time observations, is held at over 25 federal agencies and numerous state-level organizations. This Open Water Data Initiative will define the standards for water resources information collection, archiving, and dissemination. It will propose a data model through which various unique data can be geospatially and temporally organized. The initiative will also inform and accelerate efforts to meet many of the requirements defined in the observation category of flash flood services, and it will influence the design for modeling, forecasting, and communication approaches. Similarly, the Open Water Data Initiative has implications for national water modeling and forecasting and the NWC. NOAA will play an integral role in this initiative through the Federal Geographic Data Committee and the Advisory Committee on Water Information's Subcommittee on Spatial Water Data.

² <http://www.whitehouse.gov/the-press-office/2013/05/09/executive-order-making-open-and-machine-readable-new-default-government->

APPENDIX A: ATTENDEE LIST

Appendix A: Attendee List

Flash Flood Summit

National Water Center

September 9–11, 2014

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**APPENDIX B: NEEDS/REQUIREMENTS IDENTIFIED
(FIRST ROUND OF INDEX CARDS)**

Appendix B: Needs/Requirements Identified (first round of index cards)

Observation and Monitoring

- Integrated, densely populated, sustainable rainfall gaging.
- Quantitative measurements of multiple hydrologic states need to be QC'd and assimilated in real-time.
 - Includes:
 - River stage and flow
 - Inundation areas
 - Soil moisture and groundwater and snowpack
 - Reservoir and lake levels
- On the ground indicators of actual level of flooding occurring.
- Spatially extensive network of meteorological/hydrological monitoring equipment that collects data at high temporal resolution.
- We develop and maintain a nationally consistent program for observing and archiving flash flood specific locations, impacts, and severity.
- We need a unified database in near real-time of flooding reports from automated and human sources available to local, state, federal, and private entities with an interest in the flash flood enterprise.
- Development of a multi-sensor precipitation estimator that covers all areas across the U.S. and its affiliated territories with at least 5-minute temporal and 1 km spatial resolution.
- Weather forecast offices will collect information in the field to categorize the flash flood hazard into categories (e.g., minor, moderate, and major). Offices will interact with users to define and collect requirements for flash flood sources.
- Verification of debris- flow language in flash flood messages.
- Denser gauge coverage in areas with poor radar coverage
 - With less latency in observation (because it delays process)
 - Minimum density? Minimum temporal?
- Necessary infrastructure to identify increasing risk to facilitate flood warning.
- The ability to interface successfully with observation and monitoring networks built and maintained by different vendors, agencies, etc.
- A comprehensive network of gages and local reporting/observation networks or volunteers on streams and rivers.
- Study a geographically and meteorologically diverse array of flash floods to identify quantifiable measures—beyond point rainfall and point stream readings—that can locate and/or predict flash flood impacts and their severity.

- Observations of forcing need spatial uncertainty along with absolute magnitude.
- Uniform standards across/among agencies. All feds as a minimum.
- High resolution, accurate, forcing data for the conterminous United States, which has been analyzed for bias and uncertainty, so that hydrologic projections can include those metrics too.
- Need for rain gages/monitoring outside of the “usual” locating (e.g., creeks), especially in areas (e.g., bike paths) where the earliest flooding usually occurs...for the forecasters to get the earliest indicators into their WFOs.
- Methodology for “observing” flash floods to support verification, fine-tuning forecast procedures, and enhancing products.
- Comprehensive real-time multisource flash flood monitoring and verification observations.
- Improve soil moisture monitoring.
- FFW hazard impacts (flash flood event) centralized database.
- Establish a baseline that includes realistic requirement of ground-truth stream gage rainfall gage data to support calibration of radar, satellite and models that is a recognized, fully funded and supported requirement within government.
- Integrated remote sensing and in-situ observations at time and space scales of flash flood (can be regionally dependent) observations should be integrated so that cross validation can occur. e.g., urban vs. rural, mountains vs. plains.
- Establishment of a nationwide (perhaps regionally-varying) threshold watershed size to be used as a goal for stream elevation gage placement.
- Establishment of a NEXRAD (next generation radar) beam centerline height maximum, which corresponds to point where radar-rainfall estimates break down. Use as guide in deploying gap-filling radars.
- Creation of “inter-site grids” functionality for MPE program such that QPE grid creation/QC can be more consistent as with forecasts in GFE.
- Multi sensor / satellite imagery observations in near real time to help verify forecasts of areal flooding and flooding between current river forecast points.
- Utilize storm water precipitation network in large cities like Chicago.
- Data, ground-truth or remotely-sensed, needs to be as real-time as possible. Example: Radar-rainfall estimates every volume scan should not arrive 20 or 30 minutes late.
- There is a requirement to consider a new paradigm in USGS streamflow gaging at national level for developing alternative low-cost, less-Cadillac flood hydrograph (stage only, flow as well, and even binary [flow above threshold: yes/no]). A network that directly benefits the modeling or new modeling paradigms. Sophisticated cities often have their flood warning systems—those stay, but this new network idea could contribute to smaller communities very distant from USGS servicing offices for which direct measurement of discharge not possible.
- Observation data for flash flooding should be maintained for public access on a common website hosted by IWRSS co-operators.

- Public reporting of observation data through social media, especially photos and locations, should be maintained on a website co-operated by IWRSS partners.
- System should combine all components QPF, QPE, high-risk areas, in an easy viewable format for situational awareness.
- Need for observations and monitoring on a sufficient spatiotemporal scale to support model input and model verification.
- Make all available precipitation and streamflow data available in a consistent format and on an available platform. Data should be available in “real time” if available, i.e., collected every 5 minutes but only transmitted once per hour. Needs to be transmitted more frequently when needed.
- Flash floods occur on moderate to quite short time scales that are often finer than existing data networks. It is a requirement that agencies be given guidance to up time series density within current technological constraints and then be given vision to push networks to the long-term vision. For example, many/most USGS stream gages on 15-minute intervals but only hourly GOES transmission—can a unified guidance be made to enhance the random transmissions, which are alarm based and not constrained to one-hour windows.
- A nationwide network of sensors would be very important to have in order to improve verification measures, particularly in remote locations where few people may be affected by severe events.
- Monitor levee system health to rapidly model/forecast/communicate levee break flood impacts.
- Expanded availability of soil moisture, land cover, and other data on watershed conditions (and the ability to assimilate into models).
- Provide funding to prevent the contraction of, and to engender the expansion of, the real time USGS stream-gaging network. Alongside this, reinvigorate the bed load and suspended load data collection programs at gaging locations.
- Expand observation (i.e., gauge) network to be able to cover spatial holes.
- Develop threshold and alarm criteria as part of monitoring to better identify locations of intense events.

Modeling

- Simplified definition of “flash flooding” that provides a large output from a model, i.e. it is or is not a flash flood—actionable!!
- Balancing complexity of physical processes with need for reductionist approach.
- We need to identify and learn from cities like Austin who are running their own models and using their elaborate rainfall gage networks to warn their citizens of imminent flash flooding.
- We need a Digital elevation model produced via consistent national methodology that covers all U.S. territory at a resolution high enough to resolve characteristics of the built environment and their impact on drainage networks.
- Hydrological models that incorporate geomorphic change.
- Design and provide to the Weather Forecast Office, a tool/model that can be used to forecast for fast responding gaged and ungaged streams and create a hydrograph for these locations.

- Models need to provide spatially and temporally continuous predictions of flow, stage, inundation at scales of 10's to 100's of meters, and timescales of minutes.
- Support an ensemble modeling framework that is grid-based and does not depend on stream flow observations, but can be improved on the basins where they exist.
- Development of a nationwide distributed hydrologic model that has a resolution of ¼ HRAP grid or better.
- Model implementation needs to contain historic event or reforecast capability for skill, reliability, and operational proof of concept.
- Integrated, consistent, high-resolution data sets.
- Improvements on the creation of flash flood guidance (FFG), or even proving its utility.
- Reimagine model output, and design new displays of new fields, parameters, or indices that streamline the forecast process toward making direct predictions of impactful flash floods and their severity.
- Develop modeling platform that is flexible enough to be sensitive to various dominant hydrologic process across the conterminous United States.
- A modern modeling system that can account for the on-the-ground variation of characteristics (i.e., urban streets, crossings) to produce likely impacts from heavy precipitation events.
- Scale of models is precise enough to allow individualized risk and action messages.
- Plug and play models—models that may be provided by different vendors, organizations, etc., but can run in the same platform (i.e., modular).
- Models need to capture all hydrologic and land surface processes relevant for flash flooding. (Example: 2-way coupling between atmosphere and land surface is not necessary at flash flood scale but routing of surface water and representation of soil moisture conditions is important).
- Centralized modeling to produce a national flash flood guidance grid.
- Nationwide, real time implementation of DHM-TF modeling framework.
- Establish consistent database of best-estimate rainfall data and stream gauge data. A “one stop shop” for USGS, USACE, NOAA, other agencies, local alert groups. Data currently too spread out for easy research use.
- Nationwide seamless hydro model that underpins consistent set of water resource products.
- Distributed hydrologic models with associated data assimilation procedures.
- Model output available for user selectable points, or polygons to show forecast information for locations between current river forecasts points on the time scale chosen by user: 15 min, 30 min, 1 hour, 6 hour, etc.
- Modeling supports interactive GIS layers to compare impacts with various observational sources (ground-truth) and hazard impact information (structures, vulnerabilities, etc.)
- Development of GUIs to increase ease of model creation in SSHP and CHPS. Lack of easy development slows progress

- We need to conduct rigorous, objective evaluations of coupled hydrologic and rainfall-forced models in order to predict flash flooding (as opposed to reacting to it).
- A requirement that much of the modeling is not for the support of FEMA flood plains in traditional sense. What is the role of 2-D unsteady models for assessment of “prone” areas to guide emergency responders? How would the quality of the hydraulic modeling be treated in an emergent real time?
- Static inundation data for suites of flood ranges, from normal streamflow up to historical or possible maxima, should be computed prior to flash-flooding and emergency response for all populated stream reaches in the nation and hosted on an interactive mapping website co-operated by IWRSS partners.
- Develop, or provide the funding and resources to develop at the local level, a 2D fully-coupled hydrologic and hydrodynamic model that would provide inundation-based 5-day flood forecasting output at hourly resolution.
- Models need to incorporate the built infrastructure and their operations.
- Geo-spatially identify low-lying, often-flooded areas to identify potential impacts.
- Include all relevant forces including landscape features and changes to them.
- Modeling must be on a sufficiently small spatial and temporal scale such that it provides meaningful information to inform decision making during flash floods. (E.g., digitized low water crossings, flooded bridges, allow for positioning of response/resources, etc.).
- Modeling of small watersheds does not have benefit of long time spans for watershed processes to “smooth” out the response to input. The modeling should be required to accommodate a threshold state for which a watershed initially abstracts and “loads up” prior to a sudden reaction to more input. Small watersheds often act as if valves are closed and then opened. Riverine scale models do not seem to have this as much.
- Improve accuracy of weather models at high-resolution scale to better predict special location of intense events that can cause flash flooding.
- With improved weather forecast model output and availability of high-resolution terrain and soil moisture data, hydrologic and hydrologic models can provide improved flow and stage forecasts.
- Make a high-resolution model available on a consistent platform to all partner agencies. Resolution needs to be high enough to meet all interested parties needs—not so coarse that you can’t make decisions.
- Flash flooding can be caused by factors on a time scale of several to tens of minutes. The modeling framework needs to operate on this small time step.

Forecasting and Characterization

- Development of graphical and text-based flash flood watches and warning that cover a wide spectrum of impacts.
- Using government and academic partners, develop a framework/package that delivers probabilistic, impact-based products on flash flooding.
- Systematic forecasting recognizable across the nation—what is said in one location is said the same way in any other.

- The NWS needs to find a way to improve the forecasting of extreme flash flood events and encourage forecasters and the weather enterprise of their importance.
- A clear warning for “flash flood” that indicates location and severity, i.e., exceedance of FFG by a factor of 2 or 3 (simple).
- Criteria for issuing debris-flow messages.
- Provide the magnitude of the flash flood in a warning (e.g., minor, moderate, or major).
- We need to identify the NWP (or weather model) fields that correspond to flash flood events of different magnitudes at several lead times and describe the theory behind why these fields are important.
- Quantitative stream flow forecasts need to be post-processed using model re-analyses (MOS) to provide final products.
- Streamflow forecasts need to be mapped to available infrastructure design thresholds for improved impacts forecasts.
- Improved forecasting of small, short-lived cells of high-intensity precipitation.
- Location-specific warning with adequate lead-time to respond effectively.
- Clear legends and use of color to communicate urgency (Nature Nurture research findings).
- Flash flood products will not contain spatially inconsistent information that is a function of NWS WFO boundary or local office method of operation.
- No visible political boundaries apparent in watch/warning/advisory/etc. information.
- The forecasting and characterization output must be reproducible to ensure consistency. Document and explain any modifications to the model.
- Assemble the various hydrologic projections in a way that provides the most probable response of the hydrologic system to an event; not just an ensemble average.
- Display tools and/or model fields that connect rainfall forecasts (rate, duration) to maps of flood-prone locations, helping illuminate the likelihood of high impact flash floods.
- Improve forecasting for local flash flood locations in order to decrease size of warning area.
- Quantify forecast uncertainty—probabilistic forecast guidance.
- High quality unbiased ensemble precipitation forecasts.
- Flash flood forecasts that are tied to the underlying land surface (not county boundaries).
- Hazard services application to allow NWS WFO/RFC forecasters to disseminate information centric services instead of current NWS “products.”
- Need to break away from old definitions and structures to develop a spectrum of information from a longer outlook to the more detailed, “this is it, take action now.” Should be more consistent with approach for severe thunderstorm and tornado forecasting. Needs to escalate with threat so that the bells and whistles are only for the truly life-threatening wall of water.
- Forecasts need to reflect uncertainty in both time and space scales that are commensurate with flash flood—this may (may not be) regional requirement.

- Provide NWS field forecasters with better FFW prediction tools in order for them to improve GPRA performance metrics. Predictive tools should include leveraging better GIS capabilities than AWIPS currently offers.
- Establishment of a flash flood severity scale.
- Establishment of a threshold (from scale) of what constitutes flash flooding. Needs to be consistent so model development can be verified to help with characterization. Example: at least 6 inches of water, must be moving.
- NWS needs to simplify the characterization of “flood” and flash flood” products/messages to be simpler and have less volume of products sent out.
- We need to conduct multiple methods of research on the effectiveness of various information sources (i.e., models, observations, etc.) on the forecasters’ decision-making processes during severe events in order to ensure timely and accurate forecasts.
- Improve weather forecast model accuracy and characterization of uncertainty in prediction of location and intensity of rainfall events.
- Outlooks for impactful flood events should be tied/related to longer-term synoptic-scale forecast models (GFS, NAM, etc.) to increase watch/warning lead-time.
- Need a way to characterize and describe flash flood severity or impacts in NWS forecasts.
- Enable or develop a singular application program interface (API)/map-based situational awareness tool that displays radar data (and derivatives), gaging data (stream, rain, tide, etc.), and other relevant layers (burn scars, etc.) in real-time for whole-office forecasting needs.
- Flash flood forecasts and retrospective assessments should not draw too close connections to the risk levels used in design hydrology. For example, the 100-year storm/flood. Flash floods are on spatial scales for which such classification is highly confusing. Neighboring small-scale urban watersheds can produce quite divergent response for anticipated “event” magnitude. I see this as a forecast perspective and not communication although overlap exists.
- Ability to target specific customers.
- Objectively characterize flood risk at street level.
- If the WFO is to continue issuing forecasts, they need a simplistic interface to determine flood risks. They are busy enough with severe weather OR move flood/flash flood warning services to another entity.
- Define impacts and level of risk.
- Forecasts should cater to specific needs of specific users groups—general public needs a different product than emergency responders.
- Public-specific to where they are and what they are doing.
- Emergency responders—just as specific, but over broader area, with more quantitative info to plan operations.

Communication

- Need to communicate the difference between garden variety and extreme events.

- Educate children from school-age on the flash flood hazard.
- The NWS needs to simplify its hydrological product suite (using impacts) that incorporates three levels of flash floods (e.g., minor, moderate, extreme) that is well understood by the public.
- An indication of flash flood that the public has been educated to understand, i.e., it moves cars, houses, trees, rocks and mud.
- We need to enhance the current warning paradigm with point-specific hazard and impact and action information in a way that allows private and governmental partners to offer services to the public where only that warning information necessary to their safety (based on location and time) is displayed to them.
- Conduct a comprehensive study to determine if/how/when local stakeholders respond to flash flood watches and warnings. Modify products and services accordingly.
- Effective communication of inherent and unavoidable uncertainty in predictions/forecasts.
- Using social science surveys, the NWS should find out how the public responded to flash flood warnings during extreme flash flood or rain events.
- Increase the amount of people reached when a flash flood watch or warning is issued to 95%.
- Actionable messages distributed through a variety of sources to reach the most applicable affected population possible.
- Mapping applications are becoming prolific—Requirement: Next generation flood forecast and impact products should be served in scalable mapping applications.
- Forecast products need to communicate flood threshold probabilities.
- Local endorsement of risk messages.
- Risk messages are accompanied by appropriate individual actions, and link to check locally specific status/conditions.
- Consistent framework for presenting actionable, local, impact-based alerts (i.e., messages, whether watch, warning, other product) to vulnerable populations.
- Target the appropriate audience considering associated risk and lead-time.
- The information must be accurate while having a low false alarm rate. It must do no harm relative to current services—it must not be any less accurate than or have a higher false alarm rate than current services.
- Change the NWS mindset and message from “severe weather and flash flooding” to “flash flooding IS severe weather.”
- Develop reporting templates/formats for the various types of end users of flash flood forecasts; public, emergency responders, media, and collaborators.
- Flash flood product dissemination will be flexible to allow specific target audiences, i.e., emergency managers, public officials, TV stations, general public to receive different degrees of complex information, uncertainty, calls to action, etc.
- Emergency Responders and Media: Active collaboration before/during/after the events between NWS and EMS/media. EMS/Media need to help alter the public perception of flash floods by placing

importance on it in advance, branding themselves in the product dissemination, giving NWS info they receive, etc.

- Education of the public about the meaning of forecast products and associated appropriate actions.
- Effective coordination/communication between flood-relevant agencies and offices such that one single authoritative picture of flash flooding emerges.
- Need to work hand-in-hand with our partners (IWT) so that there is a direct connection between our messaging and appropriate community reactions to the messaging. Needs a national structure and direction to assist in building a more consistent framework and approach to this messaging.
- Identify and provide spatially and temporarily precise, accurate information that conveys the information needed for users to effectively assess and respond to flash flood risks. (Note that this is a need/requirement, but I recognize that how we accomplish this is multi-faceted.)
- Graphical maps shows where flood hazards are forecast in animation with ability to view as mobile app that allows users to plot current location.
- Communicate uncertainty and risk in ways that are actionable to different stakeholders. (Public, EMs, ...)
- Provide real-time guidance to users for flash flood risk/impacts.
- Develop (and ensure they're valid!) risk communication messages/interventions (experimental) that "speak to" the individual characteristics people have—e.g., lack of direct experience, optimism bias—to enhance their risk perceptions.
- Flash flood message must alert and direct end user, i.e., make them aware of the hazard and direct them how to clear themselves of that hazard.
- Hazard message should modernize from text-base to graph-base and be geographically specific to user.
- Set goals for frequency of media training in hydro products. Set goals for training items.
- Improve WEA to recognize those traveling to help discriminate times to activate for FFW.
- Improve WEA to consider phone GPS location to discriminate when to activate.
- We need to understand how to be able to reach vulnerable groups (low income, technologically disconnected, non-English speakers, etc.) to convey risk information to them in flash flood threat situations.
- Target public education at middle/high school level.
- Traceable message issue to response.
- Define a successful message. What is success?
- Flash flood messages need to go beyond what to do to avoid flooding (turn around, don't drown) but also provide additional information that says an alternative is/or what to do beyond the initial message.
- Consolidate number and variety of warning and forecast products to simplify messages to the public.
- Incorporate effective color-coding and magnitude or probability of risk based on geographic location.

- Target public education at middle/high school level.
- Message must provide adequate lead-time based on target audience.
- Abandon the distinction between “flash” and flood in message dissemination, and instead develop new styles of messaging that simply contain substantive info on the specific hazard and impacts.
- A flash flood forecast should communicate a specific population’s exposure to potentially damaging flooding in a specific geographic area and characterize the specific consequences and recommended loss abatement and life saving actions.
- Flash floods have a complicating concept of space and extent compared to riverine modeling and risks. Flash floods occur on smaller scales for which joint probability aspects. Two confluence tributaries each as a probability during an “event” to produce perhaps a dangerous response but if the correlation between the tributaries is weak than the probability of an either/or tributary being to blame below a confluence is actually higher than looking at a tributary alone – opportunity to consider when communicating risk or retrospective assessment.
- Location specific flood hazard information provided on in-car navigation.
- Flash flood “warnings” (generic) must be very site-specific so that I know whether it’s relevant to me. Example: intersection-level info.
- NWS products should include specific information about predicted impacts from a flash flood (e.g., closed roads, swift water in specific locations, etc.).
- A geographically defined warning based on geophysical characteristics, not political boundaries. However, all political, social and human impacts can be flushed out from the defined warning using geospatial analysis.

APPENDIX C: NEEDS/REQUIREMENTS PRIORITIZED

Appendix C: Needs/Requirements Prioritized

Observation and Monitoring

Group 1

- Data observations collection and processing:
 - Spatially dense, sustainable gauging network reporting at high temporal timeframe (five minutes).
 - Real-time data assimilation: multi-sensor precipitation streamflow, stage, soil moisture, ground water, snowpack, reservoir, lake.
- Archive and verification:
 - Archive of flash flood event information:
 - Nationally consistent:
 - Location, impacts, severity.
 - Database available to local, state, and federal officials, as well as others with flash flood interests.
- Categorization of flash flood events:
 - Collect information to benchmark flash flood events as minor, moderate, major.

Group 2

- Define the elements of an observing network:
 - Radar.
 - Stream gauge.
 - Precipitation gauge.
- Define a minimum:
 - Density.
 - Temporal resolution.
 - Appropriate latency.
 - Reporting frequency.
- To support modeling and verification needs:
 - QC.
- This observation network needs to:
 - Include bias info.
 - Include uncertainty in space and magnitude.
- Have uniform standards across agencies:

- Formatting observations for use CONUS-wide.

Group 3

- Establish standards for ideal observation network density. For example:
 - Maximum threshold watershed size for stream gauge.
 - Maximum threshold distance between rain gauges.
 - Maximum threshold NEXRAD beam height to determine location of beam-fill radars.
 - Soil moisture sensors.
- Establish flash flood impact database. Use in model verification, case studies, and assessments. Example:
 - Similar to SPC’s Severe Weather GIS.
 - Database would be national in scope and have consistent standards for what constitutes flash floods.
- Enhance existing tools to increased consistency between WFO/RFC boundaries. Seamless observation product CONUS-wide. Example:
 - Inter-site coordination grids for MPE precipitation QC, similar to GFE.
- Establish observational database from all relevant agencies. Create “one stop shop” for rainfall, stream gauge, soil moisture data, etc.

Group 4

- There is a need for truly real-time data at high frequency of measurement and transmission that are available almost immediately in consistent formats in a central national database.
- Expand data diversity to include other information that can inform modeling (e.g., soil moisture, land cover) or emergency management (e.g., levee conditions).
- Develop new technologies or methods for monitoring that can provide data at lesser expense or greater resolution.
- Add data to fill spatial gaps in existing networks.

Modeling

Group 1

- Model structures:
 - Ensemble.
 - High-resolution (c/km, minutes).
 - Applies to ungauged basins.
 - National consistency.
- Model forcing:

- Gridded High-Resolution Precipitation Nowcaster.
- Local gauge/radar/stream gauge networks.
- Application to urban basis/built environment.
- Earth system dynamics:
 - Consider land surface changes.
 - Precipitation pattern/intensity changes.
 - Wildfire.
 - Infrastructure/population changes.

Group 2

- Get models to identify when a flash flood is going to happen and how severe it is going to be.
 - Employ new parameters/metrics beyond precipitation and streamflow.
- Define requirements for evaluating fidelity of the output.
 - Define flexibility modeling framework that allows for modular (plug and play) application of various modeling platforms and datasets.
 - Account for dominant land cover, climate processes, etc.
- Appropriate scale of models, consistent across all platforms.

Group 3

- Nationwide:
 - High spatial and temporal resolution distributed model:
 - Able to produce a variety of geospatial products (FFG, return period, flow) at various time resolutions.
 - Model should capture flash flood relevant processes.
- GUI-based tools for developing flash flood models.
- Model forcing:
 - High-quality, unbiased ensemble precipitation forecasts.
- Support probabilistic products (e.g., ensemble-based).

Group 4

- The model should be operationally viable 2-D, coupled hydrologic and hydraulic to develop static or dynamic inundation maps at a scale on the order of meters and with an hourly (or less) timestamp.
- The model must be able to incorporate all aspects of the built environment, including dynamics of infrastructure and its operation with natural terrain.

- The model must be able to be evaluated and vetted retrospectively and post-event at a meaningful scale (on the order of meters). This relies on new paradigm data collection and observations.

Forecasting and Characterization

Group 1

- Characterize flash flood events by their relative magnitude (such as minor, moderate, and major flash flooding). This needs to include an understanding of infrastructure design, channel capacity, and other features (natural and human-made) to transition to impact-based flash flood products.
- Forecasting flash floods: We need better tools for forecasting the behavior and evolution of high-intensity precipitation at time scales from zero to 48 hours. Output from these tools should provide both probabilistic and deterministic guidance.
- Forecasting and characterization: We need to ensure that new flash flood services include clear criteria for issuing debris flow messages based on methodologies currently used in southern California. This should be expanded to cover the entire United States and its affiliated territories.

Group 2

- Actionable, location-specific information:
 - Adequate lead time and duration.
 - Uniform and spatially consistent.
 - Severity/intensity.
- Mainstream process to include a forecast-weighted ensemble rather than average (ensemble).
- For the user: provide useable and clear information to trigger needed action and dissemination.
- Establish flood severity thresholds (three to five categories):
 - 0 to 6 hours: secondary road closures.
 - 6 to 12 hours: primary road closures.
 - < 1 hour: flash flood emergency, evacuations.

Group 3

- Uncertainty WPC/NWC:
 - SPC-like flash flood outlook/watch (days to hours showing increasing probabilities and more specific spatially) with probability of severity thresholds.
 - As focus narrows down, severity probability (threshold categories).
- Forecast uncertainty: Create a consistent suite of products leading up to an event similar to how SPC approaches probability of tornadoes/severe thunderstorms from days to hours (short-fused watch timeframe). As time and space narrows/focuses in on the event, show probability of event severity (threshold categories).
- Tools: Hazard services, AWIPS 2 GIS services, land surface layers:

- Layer radar and observations with land surface info.
- Information-centric ATOMIC database, trigger thresholds.
- Characterization: Establish severity thresholds (impact-based). Need to be consistent.

Group 4

- Develop a single website that provides objective flood inundation risk and impacts characterization by integrating forecast observation (gauging, radar, HWM) and other relevant situational awareness layers (burn scars, debris, etc.).
- Develop a set of flash flood forecasting best practices with respect to characterization methods and simplified forecasting terminology.
- Improve weather forecast model accuracy and uncertainty characterization in predicting location and intensity of rainfall events to increase watch/warning lead time through multiple-day outlook products (such as convective outlooks and what-if scenarios).

Communication

Group 1

- Research: Conduct comprehensive study to determine how individuals/stakeholders respond to flash flood watches and warnings.
 - Surveys.
 - Focus groups.
 - Interviews.
- Outreach and education: Undergo/conduct a comprehensive education and outreach campaign to describe the new suite of products and services.
 - K-12 outreach.
 - Stakeholders, which also includes media, EMs, and WFOs/RFCs.
 - Broader marketing campaign.
- Product modification: Based on the comprehensive social science research, develop/modify products and services accordingly.
 - Impact-based/actionable messages.
 - Includes more specifics/hazard impact/locale.

Group 2

- Put more emphasis on local EMs and media, define roles (before, during, and after events), and facilitate collaboration between NWS and locals to help change the mindset to include flash flooding as severe weather/hazard.
- Disseminate information flexibly to allow identified audiences to receive different degrees of uniform information in different formats.

- Identify audiences by risk and lead time to reduce the false-alarm rate.

Group 3

- Develop effective (precise, accurate, accessible, usable/useful) event-scale risk communication content.
- Enhance partner communication and coordination among organizations.
- Enhance/develop capabilities to synthesize and communicate impacts in an event.
- Enhance and develop effective (precise, accurate, accessible, usable/useful) mechanisms for delivering risk communication.
- Develop education/“long term” risk communication.

Group 4

- Location specific: NWS flash flood information should reach populations where they are and alert them to specific flash flood impacts relevant to them. Populations may be low-income, technologically disconnected, non-English speaking, etc.
- Decisions/response/verification: ability to receive feedback and validation of flash flood information and decision support.
- Education/outreach: Flash flood outreach must include all socioeconomic groups; education should target middle/high school level.
- Message format/type: relevant and timely flash flood information with longer lead time and visualization.
 - Modernize current product suite.
 - Provide alternative actions.
 - Communicate urgency, severity, certainty.
 - National database/website with data displayed in maps and other formats suitable for public consumption and use.

APPENDIX D: SUMMARY NOTES FROM FLASH FLOOD FOCUS GROUPS

Appendix D: Summary Notes from Flash Flood Focus Groups

HIGHLIGHTS FROM FLASH FLOOD FOCUS GROUP NOVEMBER 12, 2014

AUSTIN, TEXAS

List of Attendees

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¹ Participated as an observer.

* Also attended the Flash Flood Summit

VULNERABILITY CHARACTERISTICS

Flash flood vulnerability in Austin is high due to following factors:

- About 100 people are moving into this area every day, and they are unfamiliar with the terrain and the history of flooding. New Austin residents may not know the difference between conventional floods and flash floods. In general, people don't know their geography.

- Vulnerable populations also include non-English speaking populations, travelers, the homeless, and those without internet access. Most deaths have been travelers and homeless people. (Homeless people often seek shelter under bridges, where flash flooding can be severe.)
- There is no single instruction for how people should respond during a flash flood event—response depends on whether individuals are mobile and whether they should shelter in place or evacuate. Site-specific instructions are not possible.

WHAT WORKS/DOESN'T WORK?

Examples of what works:

- Atxfloods.com is a helpful, visual website—visuals can often communicate better than words. It has color-coded, street level data for flash flood awareness. Open water crossings are green on the website's map, and closed crossings are red. Information about road conditions is important because 75 percent of flash flood deaths in Austin occur on roads. Atxfloods.com is a smartphone-enabled website, and broadcast meteorologists also view it on their programs to communicate visual information from the website to the public. It links to every social media outlet and helps people become aware of low water crossings even when flash flooding is not occurring. Residents also get a message from the website if their watershed is experiencing a potential flooding problem (based on the address they submit when they sign up for the alert system).
- San Antonio has a "safe route" program to communicate to drivers. Austin mainly uses broadcast media to communicate to drivers. Some counties are adopting a system that uses the location of your cell phone to send you a warning message. Participants agreed that the **smartphone is the future of flash flood warnings**. One participant noted that he would like to have Siri tell him if there is a flood hazard nearby while he is driving.
- **The "turn around, don't drown" slogan is effective.**
- NWSChat is very helpful for local officials.
- There is also an app that uses a Geofence to warn individuals about flooding in their area. The app is called "First Call", named after the "First Call" emergency notification system. It is unclear how the system works with different carriers. In other words, the footprint associated with areas that receive warnings may vary. The warnings through Verizon work off of individual towers—the tower footprint determines who will get the emergency message.

WHAT MORE CAN BE DONE?

- Need to do more for **recommending appropriate action** (e.g., evacuate ahead of time; turn around, don't drown; lift valuables off the floor; go to the second floor; go to the roof/attic and wait for rescue).
- Need to characterize the severity of each flood event on a geographic basis. The message for the public cannot be "everybody evacuate." The message must be tailored to different areas.
- The flash flood warning product from NWS has become like the severe thunderstorm warning, which had to change from ¾-inch to 1-inch hail because the public was not listening to the frequent warnings. There was discussion but no uniform agreement on the value of urban and small stream flood watches (particularly the text warnings). Participants noted that the iNWS has an email that shows the affected area. Typically, the only graphic is the box with the area of interest. The computer system will put the graphic warning onto the screen of the TV broadcaster and the

warning will then turn into a crawl. This is not useful for site-specific information; the warning needs to be translated to street level.

- What is realistic? Maybe shift away from the idea that we are going to tell every individual exactly what they need, and remember that there is responsibility both ways. Sometimes, we need to simply say, “It is going to rain hard. We don’t know exactly where or exactly how much. If you live along a flood-prone creek, keep an eye on it.”

WHAT CAN NWS DO TO INCREASE EFFECTIVENESS?

- NWS should have a national app.
- Make sure NWS gets the stream names right as they are known in the community, and make sure the NOAA weather radio is conveying **actionable information**.
- One participant commented that the NWS shape file is corrupt in many ways.
- Questions about the future of radio:
 - Participants expressed doubt that NWS will continue to support weather radio in 10 years.
 - The robotic voices on the NWS radio broadcasts are hard to understand.
- Follow-on statements to flash flood warnings that are issued as an official product would be helpful. Otherwise, broadcasters have to manually update their crawl.
- The Lower Colorado River Authority and USGS are the standard for gauges, but all information should be in one place.
- Provide historical context (e.g., “might be the heaviest rain since...”).
- With social media, it would be helpful to get all #tags lumped into the same event (e.g., “#ATXflood”).
- People need to have flood preparedness plans ahead of time. Maybe engage neighborhoods/ neighborhood leaders to come up with a plan. If they know their neighbors are doing it, they will do it; it is the idea of being part of a community.

HIGHLIGHTS FROM FLASH FLOOD FOCUS GROUP DECEMBER 10, 2014

BOULDER, COLORADO

List of Attendees

Name	Organization	Email
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* Also attended the Flash Flood Summit

VULNERABILITY CHARACTERISTICS

Flash flood vulnerability in Boulder is high due to following factors:

- The terrain in this region lends itself to a complicated hydrology and vulnerable community. From the narrow, steep drainages in canyons to the large contributing area at canyon outflows to the plains, residents in the Boulder area live in close proximity to risk.
- Since 2010, the number of significant flash flood events has increased due to an increase in areas burned by wildfires (burn scars).
- Nearby communities may be confused or annoyed when they receive warnings that should instead be targeted to specific residences.
- There is little time for EMs to “spin up” warnings, so constant and advanced situational awareness is a key issue. Communities may have a lead time of anywhere from two minutes for those adjacent to a burn scar to around 40 minutes for those closer to the canyon watershed outlet before peak flow occurs.

WHAT WORKS/DOESN'T WORK?

Examples of what works:

- Pre-scripted reverse 911 messages, which can be deployed in areas defined by a targeted polygon, such as communities downstream of a burn scar area.
- For populations with limited mobility who might be unable to take action during an event, EMs issue “drive out now” warnings to inform these populations in the hours ahead.
- The emphasis on educating canyon residents about their flood risk and how to identify warning signs to be able to take appropriate action quickly.
- Thresholds that have been established for how much rain over what period may cause debris flows in burned areas.
- EMs transitioning from action information to situational awareness during flash flood events.
- The hydrology discussion of WFO BOU is useful in bridging the gap between modeling and communications by using simplified, non-technical language.
- The very close and productive relationship between EMs and their local WFO.

Examples of what needs improvement:

- There are challenges in communication with populations who lack cell phones or internet access. Particularly vulnerable populations include the handicapped, elderly, and those without transportation. There may be residents who live “off the grid” by choice, and who would prefer not to receive communication as a general matter.
- WEAs are often broadcast, but they are limited in the amount of information they are able to present and can be transmitted to areas outside of the target warning, creating confusion and distrust.
- There is limited understanding of soil saturation contributing to slumping and landslides. For instance, participants indicated that LiDAR could help contribute to pre-flood awareness, indicating changes in land surface that might be used to identify “hotspots” where intense rainfall may cause slumping. Landslide early warnings and messaging should be developed.
- Confusion and disorganized response might arise when flooding occurs due to overwhelmed infrastructure, such as retention ponds or paved lots far from stream channels (outside of typical floodplain areas).
- Develop a tool that provides watershed-scale rainfall thresholds. This could be used by agencies and dam owners to monitor flash flooding potential that might require emergency actions.
- NWS’s watch/warning system.

WHAT MORE CAN BE DONE?

- Participants questioned the feasibility of “street level” forecasts in the context of the national flash flood vision for forecasting, especially given changing river channels. This could increase risk. Other participants mentioned that they rely on EMs for street level information and that identifying trouble spots and risk areas in street infrastructure is best based on information from local government.

- Must understand what people are thinking and meet their needs, instead of approaching people with the idea that their behavior should change and presupposing what they think (social science approach).
- Need consistent communication for “just-in-time” preparedness. In the moment, people often turn to websites or social media to guide their actions, but there is no national level guidance for communicating through these channels. Need to decrease focus on the last emergency and instead increase preparation through situational awareness. NWS can provide information, but some people will choose risky behavior.
- If an event does not occur according to the way it was forecast, there is a need to subsequently explain “how weather works” so communities might understand not only what to do the next time, but why broadcast meteorologists and EMs reacted in the manner they did.
- The state of Colorado is working on a pilot to map erosion zones, which may be useful in raising awareness of flood hazards other than inundation.
- The group proposed a Boulder area media summit before the traditional flood season to begin outlining a format to strengthen the connection between EMs and broadcast meteorologists.

WHAT CAN NWS DO TO INCREASE EFFECTIVENESS?

- Participants suggested that the NWC could develop a daily matrix for thresholds and risk using known dam design criteria.
- Any national model should account for unique flash flooding features in the western United States, rather than being solely based on riverine and coastal flooding; it should also include the USGS landslides program.
- Develop policies, procedures, and outreach programs (including for information distributed via social media) to elicit behaviors that get people to respond in life-protecting ways.
- Be careful about implying that future risk is low via terms like “anomaly” or a “500-year flood.”
- Continuously define “watch” vs. “warning” for laypeople who do not encounter the terms every day to minimize confusion when these terms are used; or, reconsider these terms altogether.
- Develop a national campaign for (all) weather hazards and early childhood education (e.g., fire mantra “stop, drop, and roll”) and/or encourage residents to make a preparedness plan.
- Increase number and scope of social science studies to avoid reliability problems in past studies. While there are obvious areas for improvement, many issues need more investigation before operational recommendations can be made, and it is valuable to understand how diverse populations may react differently.
- Relationships built between the WFO and the EMs are needed for effective communication.

HIGHLIGHTS FROM FLASH FLOOD FOCUS GROUP JANUARY 14, 2015

BINGHAMTON, NEW YORK

List of Attendees

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* Also attended the Flash Flood Summit

VULNERABILITY CHARACTERISTICS

- The area terrain (sharp changes in elevation, shallow hydrologic features), combined with soil characteristics (shallow topsoil, clay underneath) and high-intensity rain events common to the region, results in frequent flooding. Scouring alters hydrology and impacts infrastructure (bridges, highways). Debris flows can also block waterways and alter flow.
- Historically, municipalities were established in valley locations and in close proximity to rivers for transportation and other economic reasons. Today, development continues in the floodplain due to weak or non-existent municipal zoning. Flooded country roads and highways leads to isolation of small, rural communities during precipitation events.
- Historic floodplain management practices in the area have been ineffective and often exacerbate flooding; e.g., dredging naturally shallow streams. Residents mismanage their property by using “common sense” or “folklore” techniques (i.e., if it floods, let’s make it deeper).
- Property owners sometimes lack the means to maintain creeks on their own property, and when flooding happens, they look to municipalities for assistance. Farmers have been known to change stream directions and manipulate flow without realizing upstream actions impact downstream flooding.

WHAT WORKS/DOESN’T WORK?

Examples of what works:

- Participants noted that the back and forth communication with NWS is good in the area, especially where users are well-versed and have local meteorological data to share. For example, the Steuben County monitoring system's gauges help calibrate radar provided by NWS.
- Participants felt the Flash Flood Potential Index (FFPI) developed by many NWS offices should be promoted and used as a communication tool to illustrate risk to planners and zoning officials. NWS Chat was highly recommended by EMs for submitting and monitoring flash flood reports. Certain language and terms used by NWS, such as "Flash Flood Emergency," is clear and useful. Existing Decision Support initiatives (Powerpoint briefings) were found to be useful for planning and communicating threats.
- Some NWS customers have developed their own specialized warning systems. For example, DOT has a bridge monitoring program. Enhanced monitoring systems deployed by local entities (e.g., Steuben County) help to better communicate flood problems at the local level.
- The free "NY Alert" notification system has "reverse 911" capability and is capable of sending notifications to cell phones and email.
- A public TV/radio live briefing system, which will be available directly to the commercial markets, is currently in development in the area. An agreement will be established that allows EMs to break into programming for live briefings related to emergencies.

Examples of what needs improvement:

- Must simplify NWS definitions/terms and change NWS's approach to messaging. Too many flood-related products and bulletins leads to confusion among the public, educated partners, and users.
- While NY Alert has been helpful in spreading emergency messages, the system is limited by the need for participants to register for the service (e.g., in some counties, only 10 percent of residents are registered). Any 911 callback systems are limited to landlines and Voice over Internet Protocol systems from major providers.
- The Emergency Alert System is antiquated and hard to deal with, and media must often retool these bulletins to make them more digestible. Alerts are too lengthy and not easily compatible with emerging social media technology. TV media need products to be simplified and follow the "copy friendly" method to effectively communicate threats.
- Flash flood products need to reference smaller warning areas and contain more specifics in terms of geographical detail; e.g., waterbodies or road intersections identified by name (although there are issues with smaller creeks being unnamed). River warnings are issued as bulk products that create confusion when a warning is cancelled at one point along the river, but still remains in effect at other gauges. Participants suggested highlighting updates in flood products on the Web page.

WHAT MORE CAN BE DONE?

- Local planning boards and zoning boards need help in developing emergency plans by identifying high-risk areas. A higher resolution version of the FFPI was mentioned as having tremendous potential to assist communities in Binghamton.
- Some interest in flash flood model availability, which is limited due to the existence of over 3,000 streams and creeks in the area and very few gauges.

- Resources are always a problem for smaller communities, but they have seen the value of local flood warning systems, such as the one used in Steuben County: “Local monitoring networks would be ideal.”

WHAT CAN NWS DO TO INCREASE EFFECTIVENESS?

- There is a good understanding of the threat from river flooding, but not small streams and creeks. There will always be some members of the public who will not leave their properties, regardless of the communication method. However, there should at least be attempts to educate everyone and help them understand the dangers.
- Engagement and education will be critical to implementing the communications vision and will require NWS engaging local officials, including floodplain managers, with trainings tailored to their needs. It might be a good practice for the NWS to use scenario formats (i.e., scenario of storm event) to direct the public outreach sessions and to walk attendees through the process. This could work in a “train-the-trainer” format since people are not willing to leave their community for education unless it is incentivized.
- NWS products and language must be simplified and clarified. Participants suggested that some of the issues with language could perhaps be resolved by modifying the existing categories to clarify differences, such as the distinction between “advisory” and “watch.” The level of the emergency should be classified, if possible; e.g., category A, B, C, D. If changing the language is not possible, it would be helpful to develop a cheat sheet with terminology (like what fire departments use for flammables).
- Would be helpful if cell towers could be accessed during events to ensure that everyone with a cell phone is contacted, rather than relying on reverse 911 and landlines.

HIGHLIGHTS FROM FLASH FLOOD FOCUS GROUP FEBRUARY 18, 2015

ROMEOVILLE, ILLINOIS

List of Attendees

Name	Organization	Email
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* Also attended the Flash Flood Summit

VULNERABILITY CHARACTERISTICS

Flash flood vulnerability in the Chicago area is high due to the following factors:

- The terrain in this region is relatively flat and lends itself to hydrology creating flash flooding challenges. Large areas are covered with poorly drained soils (clay), pavement, and wetlands. Development is concentrated along the lakeshore into which many of the tributaries drain, meaning that residents in the Chicago region live in close proximity to risk. Storm drain capacity is often exceeded and major highways such as Lakeshore Drive have been closed due to flooding.
- The geographic footprint of flash flooding is growing. The number of flash flooding events has increased over the past six years, and areas that used to be low-risk are now high-risk. As counties undertake flood control projects, impacts spill over to downstream areas.

- There is a mindset among the public that water does not pose a risk. They see wind (tornadoes), snow, and other weather hazards as a risk, but not flooding. The public often believes that “it’s not going to happen to me,” or “I’m not in danger.”
- Commercial facilities, as well as people in vehicles and residences, are at risk. Healthcare facilities are at a particularly high risk because access to them is blocked. Hospitals and healthcare facilities have been evacuated in the past. Communicating hazards to these commercial/institutional at-risk sectors adds a new challenge to flood risk communication.

WHAT WORKS/DOESN'T WORK?

Examples of what works:

- Some counties use an index that associates a certain amount of rainfall with predicted flood levels to enable prediction of when flooding may occur during an event.
- Use of social media and media monitoring as effective tools to communicate flash flood risks to the public and emergency responders.
- Collaboration among NWS, localities, and the media.
- NWS Chat is used by the media, allowing the transfer of valuable real-time information that can be communicated to the public quickly.
- Close relationship between EMs and their local WFO, which allows for “ground truthing” of the NWS models and observations through real-time reports coming in from the EMs.
- Mass notification tools such as Everbridge, which delivers preset notifications to designated populations.

Examples of what needs improvement:

- Understanding among community of differences between “watch,” “warning,” and “advisory,” and what actions to take during a flash flood event depending on the risk level and where it is occurring.
- Communication to the public that floods are a risk that needs to be taken seriously as lives can be lost and property damaged.
- More public outreach and education.

WHAT MORE CAN BE DONE?

- Enhance frequency and special variability of forecasts. The current six-hour time step for forecasts is not useful during flash flood events since they happen so quickly. If it is not an hour or less, the forecast does not really help. Also, flash flooding occurs in small areas, so enhanced geographic resolution of the forecast would be very helpful.
- A system that would allow NWS to collect and disseminate real-time information on flood conditions and risk would help the public and responders better assess risk and mitigate damage.
- Community education and outreach about the risks flooding poses and what they can do to be prepared. Participants acknowledged that it is impossible to reach every person; some people just do not take in the message. For example, a driver ignored a police vehicle blocking a flooded roadway and had to be rescued.

WHAT CAN NWS DO TO INCREASE EFFECTIVENESS?

- Public education and outreach to change the mindset, “it’s not going to happen to me” and “I’m not in danger.”
- Reduce the number of messages the public receives to enhance effectiveness. Participants stated that there are too many messages disseminated to the public from too many sources, which results in people ignoring them. Participants suggested a system in which information is fed from districts and counties to the NWS, and then disseminated by NWS and the media to the public. The public trusts NWS and the media.
- Post-event debriefs among NWS, intermediaries, EMs, and other stakeholders to discuss events and lessons learned.
- If a forecasted event does not occur, must explain “how weather works” so communities understand what to do next time and why broadcast meteorologists and EMs reacted in the manner they did. This will enhance the weather community’s credibility in the eyes of the public.
- Better communication tools and graphics. Participants specifically noted that the current text alerts are not helpful and better graphical representations of risks are needed. Risk polygons, such as those used by the Weather Underground, are necessary. Broadcast meteorologists have very little time to communicate risks, and better graphics that are frequently updated would be very helpful.
- In advance of the “flash flood season,” there needs to be a broad-based “campaign” to raise awareness of the hazards. The campaign needs to be personalized so people can envision it happening to them.

HIGHLIGHTS FROM FLASH FLOOD FOCUS GROUP MARCH 2, 2015

MOBILE, ALABAMA

List of Attendees

Name	Organization	Email
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* Also attended the Flash Flood Summit

VULNERABILITY CHARACTERISTICS

Flash flood vulnerability in Mobile is high due to the following factors:

- The Northern Gulf region is always vulnerable to the threat of flash floods, often from pop-up thunderstorms during the summer “parking” over one area, but flooding from heavy rains can occur at any time of year.
- While there are some locations that might be considered more flash flood-prone than others, sometimes flooding occurs where it is least expected due to human influences on the landscape:
 - Land use changes due to development.
 - The inability of municipal drainage systems to handle large volumes of water.
 - The lack of maintenance to keep drainage systems clear of debris (often from past storms).

- An additional complication for the Mobile area occurs when coastal flooding is involved; for example, when flash flooding occurs during high tide or storm surge.
- In many cases, public vulnerability comes from people thinking, “It won’t happen to me.”

WHAT WORKS/DOESN'T WORK?

Examples of what works:

- Social media has worked well, and EMs have received lots of positive feedback that this is how people are getting their information. However, information dissemination on just one platform is insufficient; there is a need to overlap methods to capture all demographics.
- The local WFO holds webinars with local EMs before events that are predicted to be significant. This allows EMs to call in their stakeholders, such as school systems and Departments of Transportation, and allows everyone to see the same information and understand the worst-case scenario.
- The state of Alabama has a statewide talk group over public safety radio systems, which allows EMs to hear audio directly from the WFO staff, as well as the emotion in their voices. Hearing this audio is important because it informs how EMs perceive the message being communicated. Text messages are not nearly as effective as hearing urgency in a voice, especially a familiar voice.
- NWSChat is a widely used tool because it allows users to hear from many sources; EMs monitor conditions along typical damage paths to increase their confidence in future local impacts.
- The ability of EMs to pass along information about flooding severity to the NWS and ask that the NWS elevate a flash flood warning to a flash flood emergency.
- A one-on-one relationship between local officials/broadcast meteorologists and their local WFO is key.

Examples of what needs improvement:

- Updating information on Web pages is time-consuming, and participants felt that it was more common for people to get information from frequently updated apps instead of from Web pages.
- Landline phones are becoming less common in the Northern Gulf region, and reverse 911 calls to these phones are not guaranteed to be effective in delivering their intended message.
- Confusion may arise between flash flood and river flood products, especially if a flash flood watch is issued when there is already an ongoing river flood watch or warning. The message “**flooding is flooding**” was a mantra for the meeting. Comments suggested that NWS's hydrologic product suite is too complicated. It will always be necessary to distinguish flash flooding and areal flooding from main-stem river flooding, but there is a need for overall simplification to ensure that the message is clear and straightforward enough *to elicit an appropriate public response to NWS flood products*.
- Broadcast meteorologists noted that although science is enabling longer lead times prior to an event, long lead times may also cause confusion when the current weather does not match the communicated threat.

WHAT MORE CAN BE DONE?

- Participants suggested expanding the observation network by integrating local observations, such as the Community Collaborative Rain, Hail & Snow Network, into a national network to help reflect local differences in precipitation.
- Media find themselves chasing rather than predicting the flood. They rely on hearing accident reports on scanners, looking at radar for highest rainfall rates and totals, and browsing reports on social media, among other methods. This ground truthing is a critical piece in verifying flash flooding events. Getting feedback through social media is common; however, more information is being shared than can be reviewed.
- There is a need for careful communication when characterizing flooding events at the street level to avoid misinterpretation of where flooding is forecasted to take place.
- There is a need for outreach beyond educational campaigns. A local example is the purchasing and programming of NOAA Weather Radios for families in need.
- While social science research is important, participants recognize that research can be overcome by events and would prefer to have the NWS debut services knowing they will evolve and not be caught up in “getting it right” before something goes public.

WHAT CAN NWS DO TO INCREASE EFFECTIVENESS?

- Participants suggested that forecasters add a statement of confidence level to existing webinars to help EMs communicate risk and share presentation audio.
- Improved communication from the NWS to the media would include mixed case bulletins. Media would also like more pictures and video to help grab attention more quickly.
- NWS could reduce lead times on flash flood watches, issuing them only when they go into effect.
- Education campaigns might most effectively capture the public’s attention immediately after a big event. As clean-up is ongoing, it could be a good time to educate the public on maintenance issues that can undermine drainage systems and worsen flooding.
- Flash flooding education might also be incorporated into existing outreach campaigns at home improvement stores, if materials focusing on flash flooding could be made available.
- There is a need for more data sharing among media, emergency management agencies, and the NWS beyond verification of damages and losses to get a complete picture for mitigation plans after the fact.
- Strengthen partnerships among EMs, media, and NWS by using school visits to educate children on flash flooding along with other hazards, such as tornadoes.
- Broadcast meteorologists are no longer able to do as much public service outreach, and catchy messaging about flash flooding needs to stick in people’s minds.
- Radio stations should bolster messaging, especially if they do not issue emergency alerts.
- There is an opportunity to engage the private sector to improve messaging networks, specifically through in-vehicle navigation systems or services. The communication of safe routes to avoid flooding is an issue that could be more widely addressed by the private sector.

- Participants acknowledged that while flash floods seem like an obvious hazard and there are many ways for people to get information, the problem comes down to individuals making decisions to engage in risky behavior.