WRITTEN TESTIMONY OF MR. GARY M. CARTER DIRECTOR, HYDROLOGIC DEVELOPMENT NATIONAL WEATHER SERVICE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

HEARING ON LESSONS FROM THE 2010 TENNESSEE FLOOD

BEFORE THE SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT COMMITTEE ON APPROPRIATIONS UNITED STATES SENATE

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Thank you, Mr. Chairman and Members of the Committee, for this opportunity to testify about the devastating flood that occurred in the Nashville, Tennessee area on May 1-3, 2010. I am Gary Carter, Director of Hydrologic Development in the National Weather Service (NWS). The National Weather Service is a line office of the National Oceanic and Atmospheric Administration (NOAA), within the Department of Commerce (DOC).

I will provide a brief overview of the event and describe the actions we have already put in place to enhance communications during similar situations in the future. I will also discuss our plans to lead and leverage an interagency federal partnership to deliver more useful information to enable emergency managers and local officials to save lives and protect property during high impact flood events.

WEATHER CONDITIONS

A record-breaking rain and flood event occurred in the middle of Tennessee from May 1-3, 2010. Across the Cumberland and Tennessee Valleys, 26 people lost their lives, eleven of which were in the Nashville area. Damage estimates associated with this event are near \$2 billion. A very slow moving frontal boundary interacted with a very moist, warm airmass moving north from the Gulf of Mexico, which resulted in repeated heavy rainfall over central and western Kentucky and much of the western half of Tennessee. Widespread thunderstorms produced torrential rain and severe weather throughout the region on Saturday. After a break in precipitation Saturday night, another series of storms produced torrential rain over nearly the same area on Sunday. Record breaking rainfall occurred in Tennessee on Saturday May 1 and Sunday May 2. Rainfall amounts across western and middle Tennessee totaled 10-15 inches, with areas to the south and west of greater Nashville, along the Interstate 40 corridor, reaching 18-20 inches (Figure 1).





Figure 1. 48 Hour total rainfall ending 7:00 a.m. EDT Monday, May 3, 2010

As measured at Nashville International Airport, Saturday May 1 was the third wettest 24hour period on record for that area. More notably, the next day, Sunday, proved to be the city's rainiest day since records began in 1871. The resulting 2-day total of 13.57 inches nearly doubled the previous 2-day rainfall record of 6.88 inches. Most of this record breaking rainfall occurred in only a 36-hour period. The likelihood of a 48-hour storm of this magnitude occurring in this region is less than 0.1 percent in any given year. This was a very rare event.

This record-breaking precipitation resulted in catastrophic flooding. Flash flooding in middle Tennessee including the Nashville area occurred Saturday, while unprecedented flooding along the Cumberland River, which flows through metropolitan Nashville, occurred on Sunday May 2 and Monday May 3. The Cumberland River at Nashville rose to a flood stage of 51.86 feet at 6:00 p.m. May 3. The flood stage (the stream stage at which a flowing body of water threatens lives, property, or commerce) of the Cumberland River at that location is 40 feet, and the major flood stage (the stream stage at which extensive inundation of structures and roads is expected and significant evacuations of people and/or transfer of property to higher elevations are necessary) is 45 feet. The flood of record for the regulated system at Nashville was 47.64 feet in 1975. The Cumberland River at Nashville last exceeded its 40-foot flood stage 26 years ago when it hit 45.3 feet on May 9, 1984, also exceeding its major flood stage.

NOAA NWS SERVICES

Hydrologic forecasts provided by the NWS are a coordinated effort between national scientific centers, regional river forecast centers, and local weather forecast offices. The national Hydrometeorological Prediction Center provides forecasts of rainfall amounts out to 5 days into the future. This information is used by each of the thirteen regional

River Forecast Centers. Generally, River Forecast Center areas of responsibility are delineated along natural river drainages. Each river center runs regionally tailored models to provide river and stream forecasts. As part of the forecast process, River Forecast Centers work with partner agencies that control dams and reservoirs to incorporate projected dam releases into the river forecasts. NWS rainfall forecasts and river level forecasts represent the current state of the science.

A number of NWS offices were involved in providing services for this event. Specifically for the Cumberland River and Nashville Metropolitan area, river and streamflow forecasts were provided by the Ohio River Forecast Center (OHRFC). The OHRFC is responsible for a large area that includes fast, moderate, and slow responding rivers with over 100 dams and reservoirs managed in different ways by the U.S. Army Corps of Engineers (USACE) as well as state and local organizations. The Nashville Weather Forecast Office (WFO) provided flood related watches and warnings in addition to severe and hazardous weather information associated with the event.

The weather pattern favorable for producing locally heavy rainfall in the Cumberland and Tennessee Valleys was recognized early on by NWS forecasters. As early as Tuesday, April 27, forecasters highlighted the threat of heavy rain for the upcoming weekend in their Hazardous Weather Outlook. On April 29, a Flood Potential Outlook was issued emphasizing the likelihood of heavy rain for the weekend. Additionally, OHRFC identified the possibility of streams and rivers exceeding flood stages. A Flash Flood Watch for the Nashville area was issued on the afternoon of April 30. Meanwhile, other WFOs issued Flash Flood Watches for adjacent portions of Tennessee and Kentucky.

Heavy rainfall began on Saturday May 1. In the morning, the Nashville WFO issued an Areal Flood Advisory, which included Greater Nashville, then upgraded the Advisory to an Areal Flood Warning that afternoon covering a large area of middle Tennessee. The NWS provided streamflow forecasts indicating major flooding for locations in the Ohio River Valley and the Cumberland Valley. NWS updated the river level forecasts and issued a Flood Warning for the Cumberland River at Nashville at 9:50 a.m. Sunday May 2. Over the next two days, NWS and USACE worked closely to continue to provide updated forecasts during this unprecedented event. Through repeated coordination between NWS and USACE, NWS continued to update the river forecasts and warnings using the latest release information from USACE dams.

At 4:00 p.m. Sunday May 2, NWS revised river level forecasts and warnings based on the latest observed rainfall and to reflect the latest release information from Old Hickory Dam. Forecasts called for a crest of 48 feet for the Cumberland River at Nashville – eight feet above flood stage and three feet above major flood stage. Following a subsequent discussion between NWS and USACE that same evening, and based on the latest information provided by USACE, the river level forecast was raised to 50.3 feet. Later Sunday night, forecasters monitoring the river levels noticed that it was higher than anticipated. After further coordination with the USACE and confirming a higher release rate from the dam, the forecast river level was raised to 51.5 feet. The Cumberland River

crested at 51.86 feet at 6:00 pm Monday May 3 (Figure 2). The NWS forecast of 51.5 feet was issued 14 hours before the river crested.



Figure 2. Observed (blue) and predicted (green) level of the Cumberland River at Nashville.

COMMUNICATION CHALLENGES

Although the devastating flooding of Nashville could not have been prevented, the federal partners understand it is necessary to improve our communications during these dangerous and life threatening events. If the USACE had not controlled the water releases from their projects, the resulting devastation would have been much worse. Although NWS forecasts and warnings were issued and updated throughout the event; the forecast for the Cumberland River at Nashville was raised several times during the event. As a result, emergency managers, city officials, and the public were unable to comprehend the potential severity of the event until it was well underway. In particular, the devastating levels and extent of the flood inundation was not conveyed in a clear and effective manner.

Recognizing the need for improved coordination and communication, the NWS, the USACE, and the U.S. Geological Survey (USGS) have conducted preliminary reviews and have met several times to develop improved lines of information flow. As one example, a Tri-Agency Fusion team which was created in 2008 to address Upper

Mississippi River flooding has been expanded in response to this event. The Fusion team will ensure the primary actions from these assessments are implemented during the next year.

While the NWS has a vigorous outreach and education program spearheaded by the local Warning Coordination Meteorologist, clearly more can be done to ensure the public is informed about flood and weather impacts, and to ensure the NWS communicates flood impacts in a clear and effective manner. Flood inundation maps are required for emergency managers and local officials to assess risk and make appropriate decisions. NWS is working to expand the development of model-based GIS inundation map products in the United States, which would greatly enhance the ability of emergency responders by allowing a graphical depiction of the potential extent of the flood.

Another idea for improvement is for the USACE and NWS to work together to take advantage of tools currently in use or under development at NWS to prepare project inflow forecasts based on the latest predicted rainfall amounts. The hydrology modeling will be performed by NWS and provided to the USACE for evaluation. The early stages of such collaboration are currently in place, with NWS providing a daily update of inflows to Cumberland River at the Wolf Creek Dam in Russell County, Kentucky, and the Caney Fork River at the Center Hill Dam in DeKalb County, Tennessee.

NATIONAL INTEGRATED WATER RESOURCES SCIENCE AND SERVICES

Many regions of our Nation are experiencing critical problems associated with too much, too little, and poor quality water. These challenges, combined with increased demand, aging water infrastructure and the uncertainties of future climate, pose what is now considered to be one of the greatest threats to our society in the 21st century. Water resource issues profoundly affect our Nation's economy, policies, and regulatory frameworks. To address the growing water challenges and guide critical decisions, NOAA is leading an interagency consortium called Integrated Water Resources Science and Services (IWRSS) to develop and deliver the new and improved information needed by stakeholders and decision makers. The USGS and USACE are core partners in this endeavor. Since no single agency has all of the capabilities and resources needed to tackle these complex issues, IWRSS provides the paradigm needed to facilitate working together in new ways based on the following three pillars outlined below.

The technical pillar of IWRSS is a common operating framework, enabled by making our key systems interoperable, synchronizing data exchange, and implementing spatial visualization tools. These same technical advances will enable one-stop shopping by state and local water managers for federal water information, which is a critical need nationwide.

The second pillar involves the identification and implementation of advanced water science and technology. Across NOAA, other federal agencies, and academia, there is a wealth of relevant scientific research to support water resources information needs; what is missing is an integrative framework to move these science advances into operational

production. The IWRSS strategy calls for the formation of a national water support center to perform the necessary integration of research and technology, and to serve as a proving ground to test new capabilities before delivery to regional and national operations.

The third pillar involves the human dimension; the IWRSS strategy identifies the social science and stakeholder interactions necessary to provide the information and tools to make a difference in water resources decision-making.

The goal of IWRSS is to integrate services and service delivery through more effective communications, improved river and flood forecasts and mapping, and new "summit-to-sea" water resources forecast information. Such an integrated system, will foster better communication and provide the common operating picture required to mitigate the death and destruction caused by major floods.

CONCLUSION

The flooding catastrophe in Nashville resulted from the alignment of many unfortunate circumstances. The enormity of unprecedented two-day rainfall amounts, changing river levels, and lack of public awareness of the potential impacts of the forecast river levels (due in large part to the fact that city residents have not experienced a significant flood in over 25 years), were all contributing factors. NOAA will continue working with our partners in USACE and USGS to improve our coordination and communication of potential flooding situations and to deliver enhanced flood services. In particular, an IWRSS team will be formed to identify long-term options for developing and delivering forecasted flood area inundation maps. Another team will be formed to optimize system interoperability and data synchronization among NWS, USACE, and USGS.

I thank the Committee for the opportunity to speak about this challenge and will answer any questions you may have.