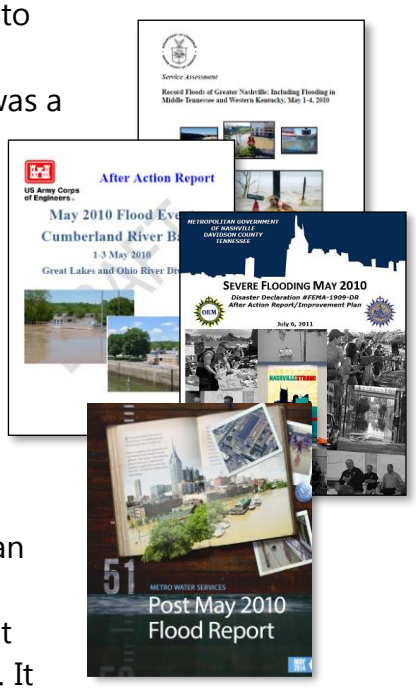
NAI How-to Guide for Flood Warning & Response Case Study: Nashville's SAFE & NERVE Flood Forecasting & Response Tools

In early May 2010, central Tennessee experienced rainfalls from 10-20 inches. The rain and subsequent flooding were greatest in and around greater Nashville, which saw the third highest and highest 24-hour rainfall amounts in 139 years of record keeping. Widespread flooding in the region led to 26 flood-related deaths, 11,000 damaged structures, damage to critical infrastructure and $2 billion in property damage.

Downtown Nashville, May 2010

This flood was unprecedented, but local officials said they needed to prepare for the next one. A variety of departments and agencies prepared after-action reports, and had similar conclusions. There was a need for more and better data, improved coordination and trained personnel. The mayor's Office of Emergency Management's report (p. 135) read:



> "Although the [National Weather Service] broadcast regular flash flood and riverine flood warnings for Davidson County, the sheer magnitude of this event identified the need to create real-time flood forecasting and warning systems for Metro Government."

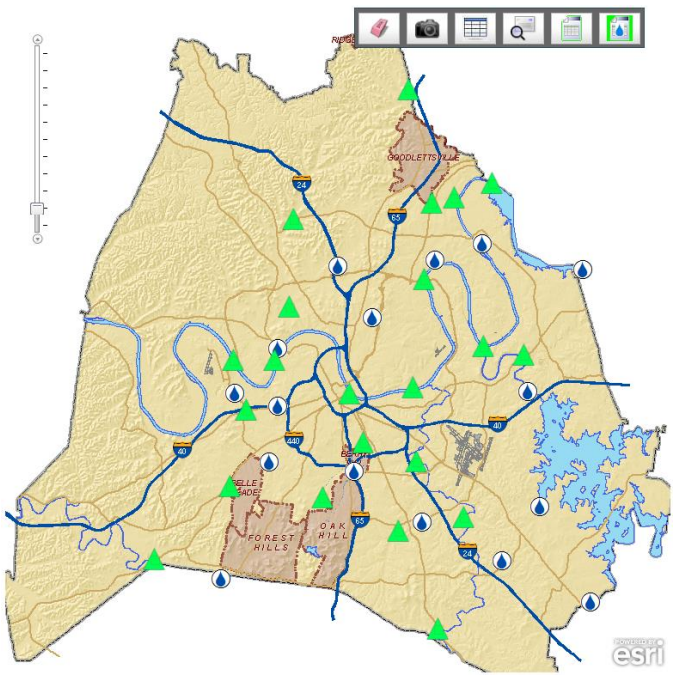
Nashville and Davidson County have a consolidated or metropolitan government. Metro Water Services provides drinking water, wastewater collection and treatment, and stormwater management services to more than 600,000 people in the greater Nashville area. It manages two water treatment plants and three wastewater treatment plants. MWS also houses the stormwater and floodplain management staff.

Flood threat recognition: As the water experts, MWS was the obvious office to manage rain and stream data and develop a better flood warning system. Staff worked with a variety of agencies, including:

→ U.S. Geological Survey for additional river and stream gauges and data,
→ National Weather Service for water and weather forecasting,
→ U.S. Army Corps of Engineers for hydrologic and hydraulic modeling,
→ Mayor's Office of Emergency Management for field data verification,
→ Metro's Planning/GIS and information technology offices, and
→ Several private consulting firms.

The product of this collaboration was a flood forecasting system utilizing GIS tools, numerical models, real-time and forecasted data, communications and coordination between agencies, decision support tools, and targeted response actions. The new tool is called Nashville SAFE or Situational Awareness for Flooding Events.

This GIS-based mapping tool relies on near real-time data provided by more than 20 USGS river and stream gauges. As the rising gauge heights reach the NWS flood categories, the triangles on the map change color to match the flood category and begin to blink, providing a visual indicator of the onset or existence of flood conditions.



Distribution of SAFE's rain and river gauges. Plans are to extend the program to smaller watersheds.

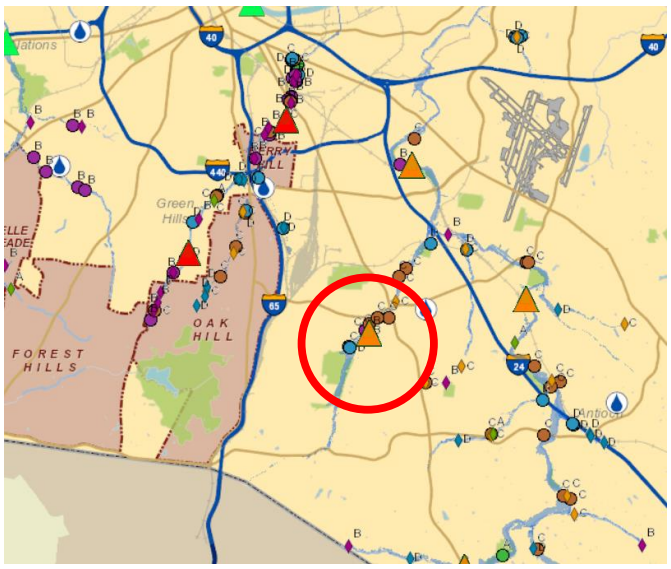
Initially, no special appropriations were needed. In the midst of flood recovery activities, MWS was able to use its existing budget to leverage additional gauges that are cost-shared with USGS. The procedures and software were prepared during normal staff hours by a number of metro departments. Since the flood, there has been continued work to upgrade the capacity to effectively respond to severe weather events.

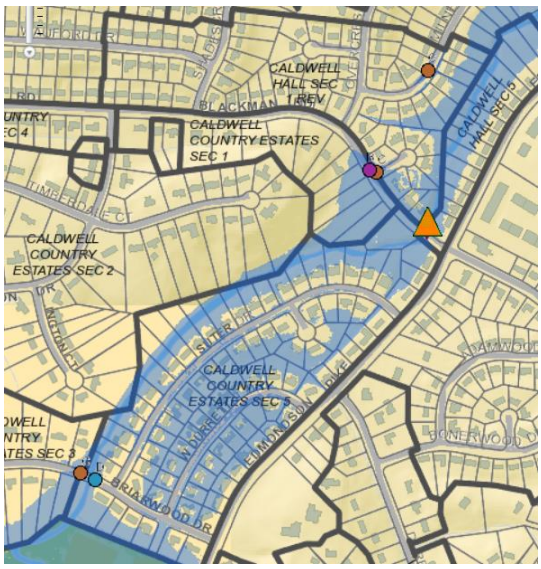
Since 2010, the cost for the development of the Nashville SAFE tool has been about $3.7 million, with the cost shared with the Corps, USGS and Nashville's Metro Planning Department. The annual budget for maintenance is $200,000.

One of the results of the extensive flood modelling has been the creation of new Flood Insurance Rate Maps. More than 300 miles of streams were modeled that had never been mapped. MWS continues to consider additional features that may make SAFE more effective, including the addition of more gauges in the smaller watersheds.

Flood inundation maps: The SAFE tool relies on rain and stream gauge data and newly updated hydraulic and hydrologic models and maps to produce real-time flood inundation maps. An example is on the next page. The SAFE tool can also produce maps showing predicted inundation during severe weather response or for planning and training purposes. Plans are to use Hydrologic Engineering Center Real-time Simulation (HEC-RTS) modelling to grid rainfall data over major basins as a more effective means of forecasting flood events.

Flood response: SAFE includes Watershed Advisory Guides that identify the impacts of different flood levels in the watershed. For each gauge, there are four NWS flood stages coupled with seven additional, more specific, flood levels (A-K).





The screenshot on the left is the Nashville SAFE base map during an activation caused by an extreme rain event. The triangles indicate the location of USGS gauge stations. The normally green-colored triangles have turned orange (indicating "flood stage") and red ("moderate flood stage"). The color of the triangles are the same colors as in the WAG screenshot, below. This happens in real time as the gauge levels rise. The colored icons indicate flooded intersections, roadways and bridges. Expanding the area circled in red shows flooded parcels (map above right).

At each SAFE Action Level (A-K), the guide has a list of what happens, as in the example below. The WAGs contain inundation mapping, flood profile data, and myriad watershed-specific impact assessments performed at the 11 Action Levels. Because the guides have so much detailed information, MWS is moving to replace their three-ring binders with thumb drives.

Watershed Action Level Summary
Mill Creek Near Woodbine

River Mile	6.32		SAFE
Datum El.	432.5	(ft)	Action
Flow (cfs)	Elev (ft)	Stage (ft)	Level
	458.6	26.1	K
	457.5	25.1	J
	456.4	24.0	I
	455.3	22.8	H
	454.2	21.7	G
	452.9	20.4	F
	451.7	19.3	E
	450.3	17.8	D
	448.9	16.4	C
	446.8	14.3	B
	443.1	10.6	A

National Weather Service Flood Categories

Stage (ft)	Elev (ft)	Flood Categories
21	453.5	Major Flood Stage
17	449.5	Moderate Flood Stage
14	446.5	Flood Stage
12	444.5	Action Stage

Historical Crests

21.4	453.9	5/1/2010
20.6	453.1	5/4/1979
16.9	449.4	2/14/1989
16.2	448.7	5/5/2003
15.8	448.3	3/12/1975

Action Level E
Mobile homes off Elm Hill Pk west of Massn
Storage areas for distribution terminal, 705
307 Wimpole Dr between Lawndale Dr and
308 Wimpole Dr between Lawndale Dr and
316-320 Wimpole Dr between Lawndale Dr

Action Level F
Drummond Dr between Wildview Dr loop
741-749 Massman Dr between Elmhill Pk a
306 Wimpole Dr between Lawndale Dr and
324-334 Wimpole Dr between Lawndale Dr

Action Level G
809-813 Carlyle Pl cul-de-sac, near Drumm
E Thompson Ln between Currey Rd and Ol
100 Glenmont Dr and 2701 Glenrose Ave ir
Mashburn Rd and adjacent homes between
301-313 Wimpole Dr & 1001-1041 Murfrees

Screenshot from the Watershed Advisory Guide for Mill Creek.
The inundation maps for Action Levels B, F and K at this gauge are on the next page.

Inundation maps for Action Levels B, F and K at the Mill Creek gauge near Woodbine.

MWS staff can prepare flood simulations for various action levels, either during a flood or for planning and training purposes.

Legend

- Action Level B
- Action Level F
- Action Level K
- 12 — Miles from mouth of stream
- USGS Stream Gauge
- 7 — Bridge/Culvert - numbered upstream to downstream per stream
- 28D — Inundated Street - letter indicates first scenario to overtop
- C3 — Confluence - numbered upstream to downstream per stream
- Building in FEMA Floodway

Not only does SAFE provide real-time flood-level information at a gauge, the tools in the program help predict when the stream will rise to higher levels and when it will crest. Information on the timing and impacts at the different levels can be printed at MWS' station in the Emergency Operations Center and be delivered to the appropriate departments (fire, police and emergency operations) at other desks in the EOC.

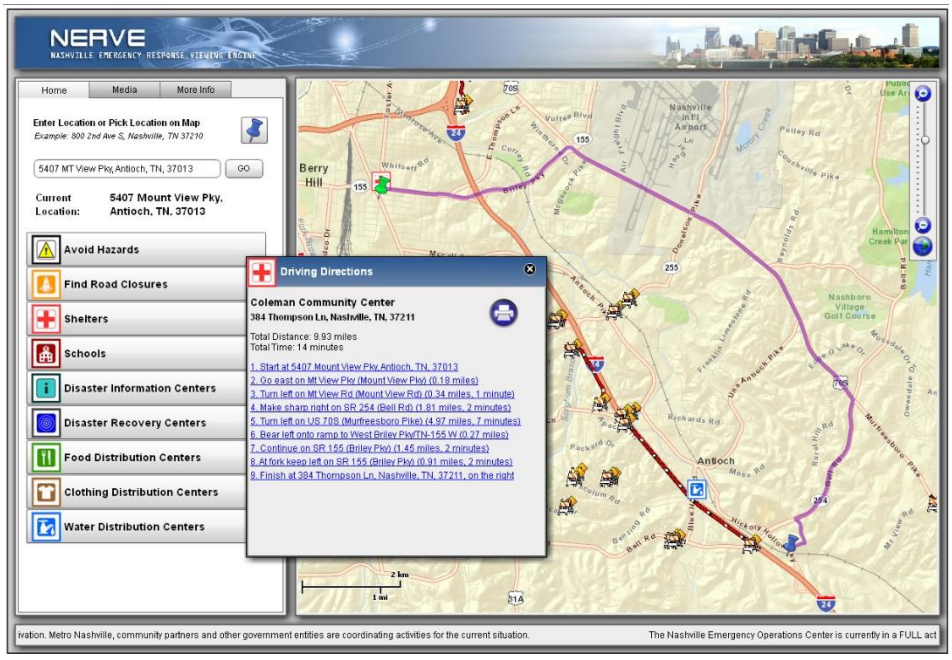
Another SAFE tool feature is a sandbagging calculator based on the Corps' recommended methods. While MWS generally discourages sandbagging, if there is a request to sandbag a property, staff provides them with a handout that calculates the time, labor and materials

needed. Given the short warning times in many of Nashville's watersheds, this action usually results in the request being dropped.

MWS has designated experienced staff to serve as watershed advisors. They analyze current and predicted stream conditions and make recommendations to emergency managers during a flood. Job Action Sheets that specify procedures and standards of practice were prepared. These help the advisors get a full understanding of the data so they can interpret it in real time while collaborating with the other agencies. Watershed advisors routinely attend training sessions and conduct table-top exercises to remain well-versed in the tool's features.

NERVE: NERVE is the Nashville Emergency Response Viewing Engine, the next logical step after SAFE was developed. It helps the public and emergency responders. NERVE is a one-stop, online interactive mapping site with real-time data related to emergencies. It can be used for any emergency, not just floods. NERVE also includes a media center, where press releases related to the emergency are posted, and links to other sites containing emergency or important information.

The home screen tells the user if there are any emergencies happening and whether the EOC is activated. The user enters an address and can choose from a menu of nearby hazardous areas, shelters, closed roads, etc. One can select a destination and NERVE will provide directions to it that avoids closed roads and bridges (below).



Critical facilities: MWS owns and operates numerous pump stations and treatment plants, many of which were flooded in 2010. For most of them, MWS included mitigation measures during repairs, which included:

→ Installing concrete walls or curbs (right),
→ Raising electrical panels, ductwork and machinery,
→ Replacing damaged pumps with submersible pumps,
→ Protecting openings with watertight, pressure-rated doors or stop planks,
→ Elevation of an access road,
→ Construction of berms for low level floods and a 9-foot-high sheet pile floodwall at a deeper flood-prone site,
→ Floodgates at building openings and driveways, and
→ Moving an operation to high ground and repurposing the building to be a wet-floodproofed storage area.

Curbs around wells and pits can be an inexpensive mitigation measure.

Some measures were funded with FEMA Public Assistance mitigation funds.

Flood action plans have also been prepared to specify when a gate is closed or a machine is turned off. Sometimes the best action is to shut down and leave. Shutting down is very important to protect a treatment plant (if something is left running, electrical shorts can destroy equipment). The completed modifications to one water treatment plant were estimated to cut the time needed to restart the plant from 30 days to 15.

Reconstruction: In the days following the flood, the permitting departments were faced with permitting more than 4,000 flood-damaged buildings. The workload quickly increased from 40 permits per day to 280. Staff from other MWS offices were trained on processing the simpler applications and MWS put a contractor to work doing in depth damage field estimates using the "rapid evaluation" technique. A triage approach divided all permit applications into three categories:

1. Building flooded, but not in the SFHA. Mitigation encouraged, but not required. Permit issued.
2. Building in the SFHA, less than 40% damaged. Mitigation encouraged, but not required. Permit issued.
3. Building in the SFHA, more than 40% damaged. This scenario necessitated an accurate contractor's estimate, often accompanied by an appraisal of the value of the structure. If determined the structure was substantially damaged, the applicant was required to bring it into compliance with the floodplain ordinance. With a commitment to repair in accordance with the floodplain ordinance, there was no limit to the amount an applicant could spend to repair the flood-damaged structure.

If the building was substantially damaged, MWS' substantial damage letter was used to obtain funding support through the NFIP's Increased Cost of Compliance Coverage.

Since the 2010 flood, metro has consolidated all permit counters into a one-stop permit shop. The first step in the permit flow is a check by MWS to see if the project is in the SFHA. If so, MWS identifies what needs to be done before the project goes to Codes Administration. The certificate of occupancy must wait on MWS' approval of the finished construction Elevation Certificate.