Floodplain Mapping & Flood Warning Applications in North Carolina

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Summary

Due to North Carolina's diverse terrain and exposure to hurricanes and tropical storms, the risk of flooding is present in all parts of the state. Following unprecedented flooding from Hurricanes Fran and Floyd in the late 1990's the NC General Assembly tasked the division of Emergency Management (NCEM) to improve the flood information and flood warning capabilities for the state. The goal of these programs is to reduce the loss of life and flood-related property damage by providing emergency managers and the public with more timely, detailed, and accurate information. With this goal in mind, NCEM has developed comprehensive databases and applications that use up to date flood maps and near real time stream gage data and forecasting. NCEM has based these applications on ArcGIS Server and ArcIMS technology for the online mapping component of the projects.

The applications are:

1. FMIS (Floodplain Mapping Information System – Online digital flood insurance rate maps (DFIRMS)
2. FIMAN (Flood Inundation Mapping and Alert Network) – Near real time flood inundation maps and flood impacts information and assessment

Introduction

Within the North Carolina Division of Emergency Management, Geospatial & Technology Management Office, the Floodplain Mapping Program (NCFMP) and the Flood Warning Program serve the citizens and emergency managers of North Carolina with two web based applications. The first application is the Floodplain Mapping Information System (FMIS). This application allows users to view and download flooding information using an online interactive map. Several data sets are available for downloading including Digital Flood Insurance Rate Maps (DFIRMs), GIS databases that include the flood zones and other supporting information that were used to create the DFIRMS, elevation and imagery data, and Flood Insurance Study documents. The NCFMP has many users and stakeholders including other state agencies, floodplain administrators, private engineers, city & county planners, realtors, academia, and the general public.

The second application is the Flood Inundation Mapping and Alert Network (FIMAN). This application monitors the near real time status of rain and stream gages for

approximately 300 sensors throughout the state. This application has two components associated with it. The first component, Contrail Web, manages the incoming data that is constantly received from the sensors. Within Contrail Web, alarms can be setup where if a stream reaches a certain level, appropriate individuals in the local area can be notified via text message or e-mail. The second component, FIMAN Maps, takes the data from Contrail to help users visualize the information inside an online mapping viewer. FIMAN Maps also gives users the ability to plan for potential flooding impact by viewing these impacts geographically. FIMAN Maps pulls real time USGS stream data and National Weather Service stream forecast levels. The data from FIMAN Maps is incorporated into the NC State Preparedness and Resource Tracking Application (NC SPARTA), which is monitored 24 hours a day, 7 days a week by NCEM operations staff. The Flood Warning Program tailors to local emergency managers and state agencies responding to flooding related issues. For this reason FIMAN applications require authentication in order for web users to access the applications.

Hurricane Floyd – September, 1999

The NC Floodplain Mapping Program (NCFMP) was created after hurricane Floyd caused over $3.5 billion in damages to the state. Most of the damages were flooding related due to the estimated 15-23 inches of rain that fell across several counties. The Tar River at Tarboro reached 40.9 feet, which was a record high. This is 21 feet above the flood stage of 19 feet. Unfortunately there were 51 human fatalities associated with this storm. 54,000 homes were damaged with 16,674 homes destroyed, and almost $1 billion in agricultural losses alone. At the peak of the flood 18,000 square miles or roughly 1/3 of the land in NC was under water, and much of this land was considered outside of the flood hazard areas at that time.

The limitations of the outdated flood maps made evident after hurricane Floyd when nearly 80% of the people impacted by flooding were not aware they were in a flood-prone area. Hurricane Floyd caused the destruction of 4,117 uninsured/under-insured homes and 16,074 homes in total. Hurricane Floyd revealed flood-hazard data and map limitations in the State. After further research, it was noted that 75% of the State's Flood Insurance Rate Maps (FIRMs) are at least 5 years old and that 55% are at least 10 years old. This prompted the NC General Assembly to commit $23 million to modernize the flood maps across the state. To do this, North Carolina formed a Cooperating Technical State partnership between FEMA and 16 other federal agencies. On September 15, 2000, Federal and local community entities joined North Carolina and FEMA in an agreement to work together to maintain accurate, up-to-date flood hazard data for the State of North Carolina. As part of this agreement, each of the parties agreed to provide input into the development of technical agreements, and where possible commit the appropriate human, technical, financial and information resources. Some of the resources that the State and FEMA need from other Federal agencies include:

- Funding
- Digital elevation data
- Cross-section data for stream channels, bridges, culverts, and coastal transects suitable for engineering modeling
- Base map data (digital orthophoto quadrangles)

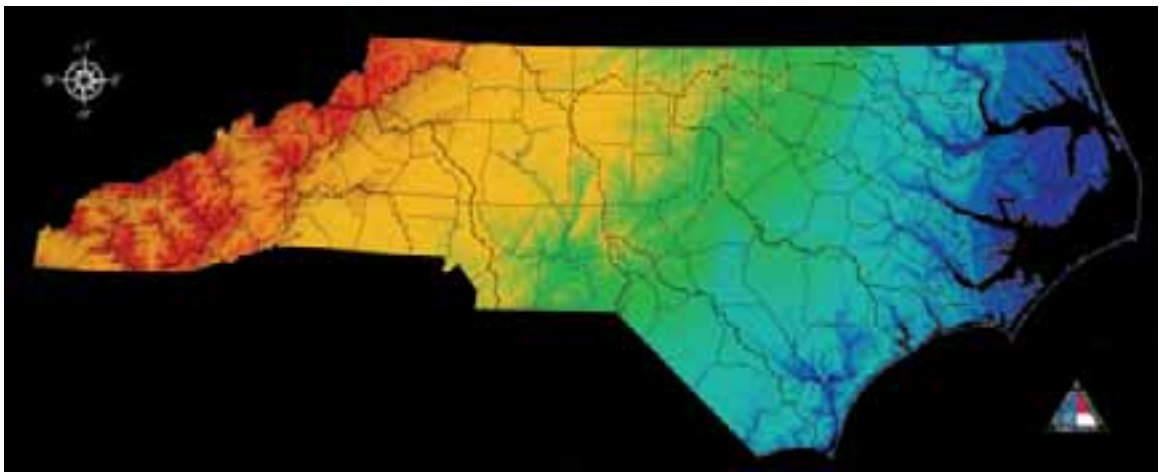
- Data about flood control structures, such as levees, dikes, and dams
- Hydrographic and streamflow data
- Flood hazard data, such as from ongoing or recently completed hazard studies
- Technical guidance on implementation of advanced technologies, such as remote sensing and flood forecasting
- Advice on designing and implementing a state-of-the-art, on-line Information Management System
- Assistance in establishing technical and data standards

Products of the NC Floodplain Mapping Program

Remote Sensing Data

To support improved floodplain delineation NC created one of the largest seamless LiDAR datasets in the world by collecting the elevation data statewide. The Bare Earth LiDAR points allowed for creation of statewide 50 & 20 ft Digital Elevation Models. This updated and accurate elevation data was a critical tool in defining the boundaries of the new flood hazard areas.

Statewide LiDAR Dataset



In addition to the LiDAR elevation data, the NCFMP collected up to date ortho photography from each county in NC. There were 17 counties that did not have ortho photography, so the NCFMP collected this data in cooperation with the NC Geodetic Survey. Once the photography was collected statewide, this imagery could be used to help define the boundaries of the new flood hazard areas by serving as a back drop in the new DFIRMs. Having up to date ortho photography is a high priority for the state due to the wide scope of users.

Engineering Products

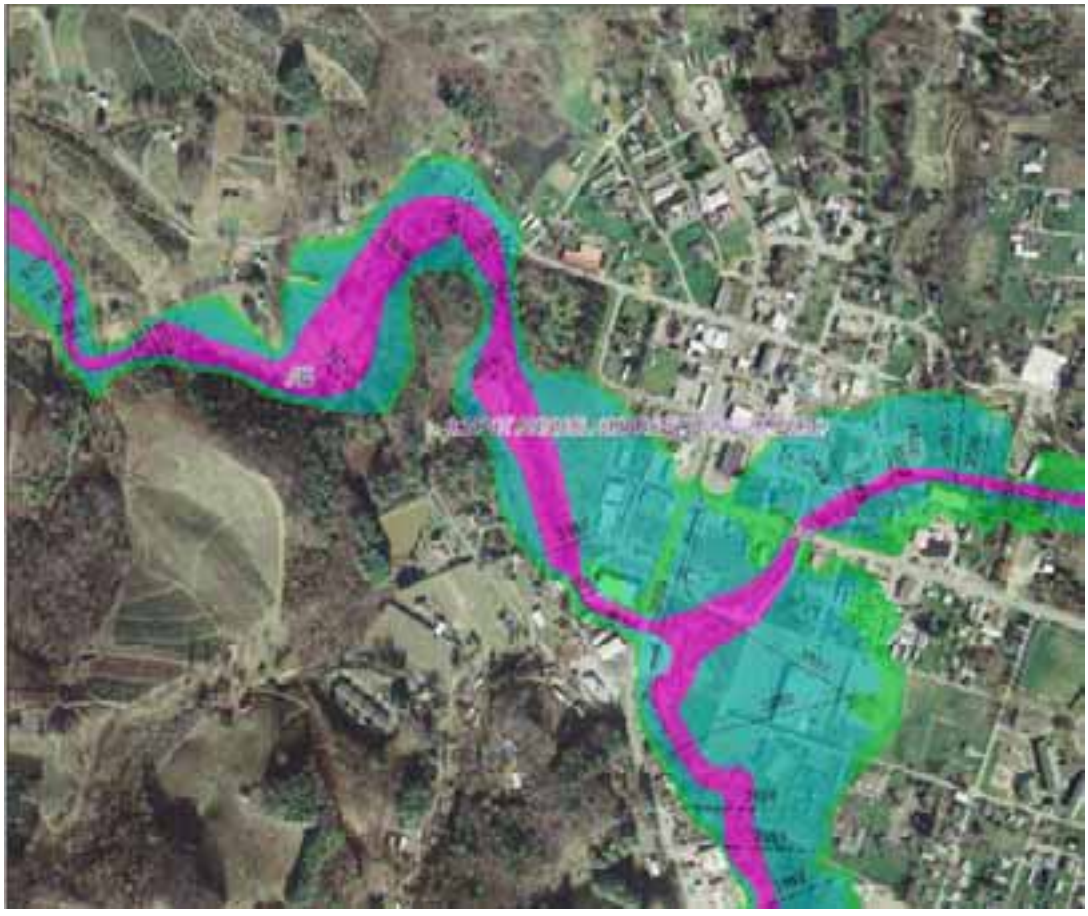
Hydraulic and Hydrologic (H&H) analysis is a core component of defining the boundaries of the new flood hazard areas. The H&H models were generated using the LiDAR bare earth data and a variety of other data sources including field survey. Nearly 30,000 miles of stream were studied or updated in the statewide effort. The modeled

water surface elevations are used with the LiDAR to identify flooding area and expected water surface elevations.

Database Products

The GIS data that is derived from the Hydraulic and Hydrologic analysis, ortho photography, and LiDAR contains the flood hazard boundaries, base flood elevations, and stream centerlines and cross sections, in addition to all supporting base data. This GIS data is used to create the DFIRMs, and can also be used for specific analysis purposes. These DFIRM databases are county-wide, and are submitted to FEMA for review and inclusion in the National Flood Hazard Layer. In addition to the DFIRM geodatabase, an engineering and inventory geodatabase is available that stores the hydraulic and hydrologic data. This E&I data includes modeled stream centerlines and engineering cross sections in addition to detailed inventory data including bridges and culverts. Packaged with the E&I geodatabase are HEC-RAS (Hydrologic Engineering Centers River Analysis System) models that can be used for future stream analysis and studies.

NCFMP DFIRM Database View



Flood Insurance Studies
The Flood Insurance Study is a document that outlines all the data and analysis that was used to create the DFIRMs. Engineering and mapping methods are detailed for each study within the FIS. As part of the FIS, the stream profiles, watershed characteristics, and historic flood elevations are all included.

The Digital Flood Insurance Rate Map is the product that most end users are interested in when trying to determine if a structure is inside or outside of a flood hazard area. This is the legal document that is used when doing a flood determination study and determining the need for flood insurance.

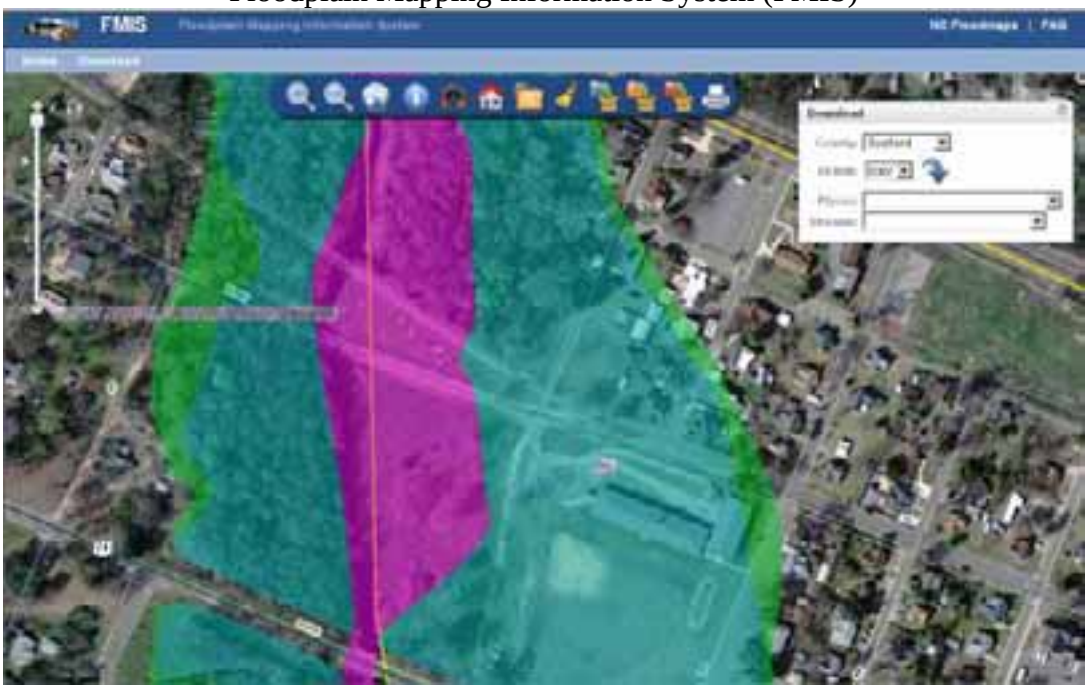
Digital Flood Insurance Rate Map (DFIRM) PDF

The NCFMP has completed the statewide update, and 99 out of the 100 counties have been issued effective DFIRMs. The state's mission requires maps maintain currency so the state is now in the maintenance phase of the project. The continued effort termed Map Maintenance involves going back to the older studies, and applying updated information to generate new DFIRMs. The state currently has 45 counties in the Map Maintenance phase. One of which has currently been issued for preliminary review. Part of the map maintenance effort involves storing and managing the new data as it is created. Updated imagery, GIS data, and DFIRM .pdf files are steadily being maintained by the NCFMP in order to keep the best available data accessible to the NCFMP users and stakeholders.

FMIS Portal

The Floodplain Mapping Information System (FMIS) brings all the DFIRM products mentioned above into one online portal that is freely accessible by the public users (www.ncfloodmaps.com). All data is available for download and most data can be viewed inside the online map viewer. Users can search and query this data using a variety of criteria including address, county, city, stream name, and latitude / longitude coordinates. FMIS was first created with ArcIMS technology, but has since evolved into using ArcGIS Server with the JavaScript API. Data download tools are built into the mapping application for users to have access to available data. Imagery, DFIRM .pdf files, LiDAR, and county wide geodatabases are all available from FMIS.

Floodplain Mapping Information System (FMIS)



As part of the NCFMP Integrated Hazard Research Management the FMIS application is undergoing expansion to include a new layer of risk assessment components. Users will be able to view and query data derived from multiple hazards, DFIRM panels, and buildings.

Flood Inundation Mapping and Alert Network (FIMAN)

The NC Flood Warning Program was developed in conjunction with the NCFMP and focuses on improving the flood warning capabilities of the state. Near real time stream gage and rain data from USGS and NCEM sensors is collected and then made available to web users in a variety of formats. Analysis results that show flooding impact are made available for planning and preparation. The Flood Warning Program leverages the data products from the NCFMP, and provides a near real time monitoring capabilities to web users.

North Carolina Division of Emergency Management has installed a network of over 240 gages that provide real-time stream flow and rainfall data. These sensors, in addition to the existing 85 USGS gages, provide the ability to monitor changes in stream levels throughout the eastern and western parts of the state. The data from a gage is transmitted to an antenna on a communications tower located nearby the gage site. Once the data is received at the tower it is then piped into a Timewave communication device for processing and decoding. The processed data is then transmitted over the internet via the NC State Highway Patrol's connection to the State ITS Eastern Data Center in Raleigh. The National Weather Service also receives this data over the internet at this point.

Gage data is constantly being received at the Eastern Data Center and stored into Contrail Web, a Linux based software package. Contrail Web is designed to manage the data received from the gage sensors. This data is stored inside a set of Linux based MySQL databases. These databases are replicated to a secondary data center located in Western NC. Every 30 minutes a custom windows application updates Contrail Web to include the near real-time stream gage readings from the USGS. With the USGS gages, the gage network has a total of over 500 sensors, including stream and rain gage data. One component of Contrail Web is a web interface that can be used to display sensor data and static maps. In addition, alarms can be set within the application to send alerts for when flooding is occurring or about to occur at specific sites. These alarms can be in the form of e-mails, or cellular text messages. Site specific information can be viewed inside the Contrail Web interface that includes stream stage, flow volume, and precipitation amounts. Availability to detailed site information is a key component of Contrail Web. This data can be exposed for other applications to consume.

Contrail Web – Site Specific Data

FRENCH BROAD RIVER AT ASHEVILLE, NC

Site Information

Name:	FRENCH BROAD RIVER AT ASHEVILLE, NC
Site ID:	03451500
Latitude:	35.6
Longitude:	-82.57
Elevation:	0 feet

Sensors

Sensor	Type	Sensor Id	Reported	Report
Flow Volume	Flow Volume	02_00060	2000 cfs	2010-04-14 09:00:00
Precipitation increment	Rain Increment	17_00045	0 in	2010-04-14 06:00:00
Stage	Stage	03_00065	2.27 ft	2010-04-14 09:00:00

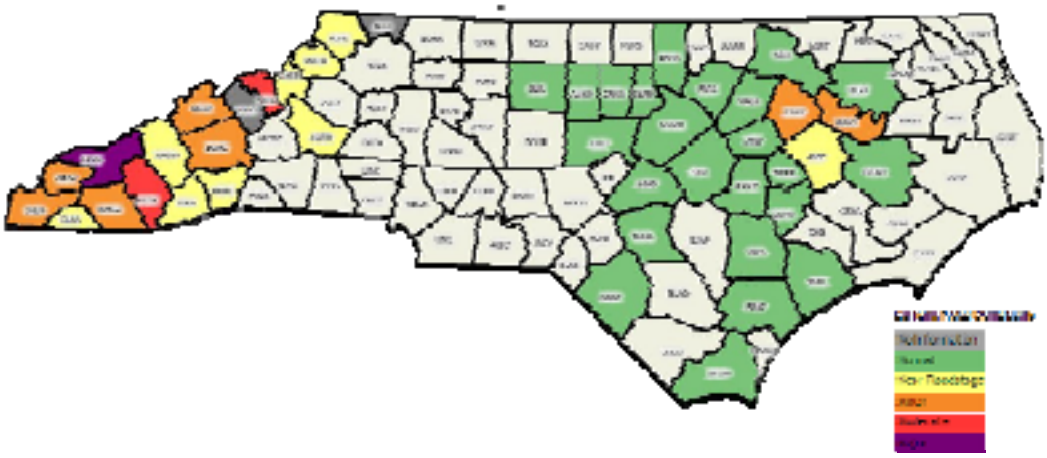
Contrail Web has a basic map component where users can view the status of the sensors in real time. The maps inside Contrail Web are limited, which created a need to develop a second component of the Flood Warning program, FIMAN Maps.

The FIMAN Maps web mapping application is the visualization and planning tool that incorporates the stream gage data with supporting GIS layers. Tools within this custom web application include viewing the status of flooding statewide, visualizing flooding impact for specific gage sites, and accessing forecasted flood information from the National Weather Service. There are three main components in FIMAN Maps:

1. Current Conditions
2. Forecasted Conditions
3. What-if Conditions

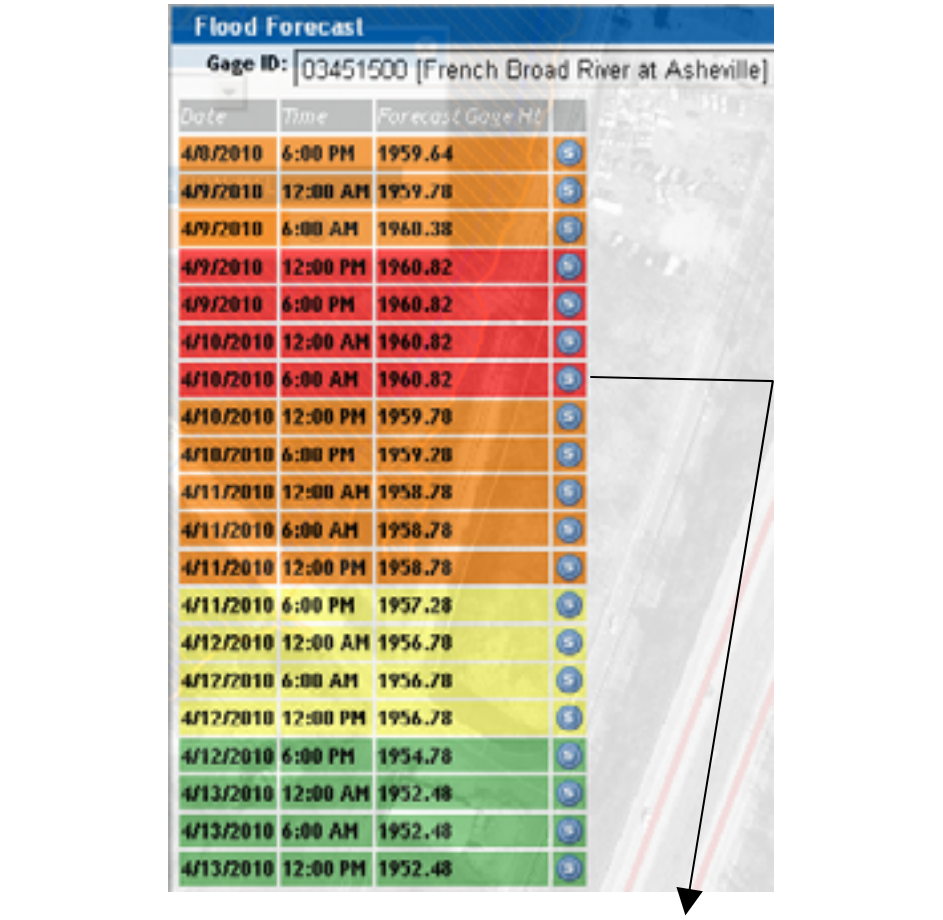
Current Conditions:
The statewide status map within the FIMAN Maps web application gives web users a quick status update by county. The counties in this map are color coded based on the level of flooding. This status map is interactive, and if the user clicks on a county, the application will zoom to the extent of the county, allowing the user to get access to site specific data. Overlaying the flood impact polygons with imagery is a quick way to see which structures are at the most risk for flooding. Known flood impacts are also available that describes detailed information on how the various flooding levels affect that specific area.

FIMAN Statewide Status Map



The statewide status map uses an ArcSDE / SQL Server Spatial View. The data that makes up the view is updated every 30 minutes so that the map shows near real time status. A custom windows application updates the view by accessing the data in Contrail and populates the necessary data tables in the ArcSDE / SQL Server.

Forecast Conditions:
At most sites for which the NWS issues a flood forecast, inundation maps are displayed for each forecasted time interval. The maps can assist in the preparation and the response to the impacts at that gage site by emergency managers. Gages at reservoir dam sites and navigational locks and dams are not mapped.


Flood Forecast
Gage ID: 03451500 [French Broad River at Asheville]
Date Time Forecast Gage Ht
4/8/2010 6:00 PM 1959.64
4/9/2010 12:00 AM 1959.78
4/9/2010 6:00 AM 1960.38
4/9/2010 12:00 PM 1960.82
4/9/2010 6:00 PM 1960.82
4/10/2010 12:00 AM 1960.82
4/10/2010 6:00 AM 1960.82
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4/13/2010 12:00 AM 1952.48
4/13/2010 6:00 AM 1952.48
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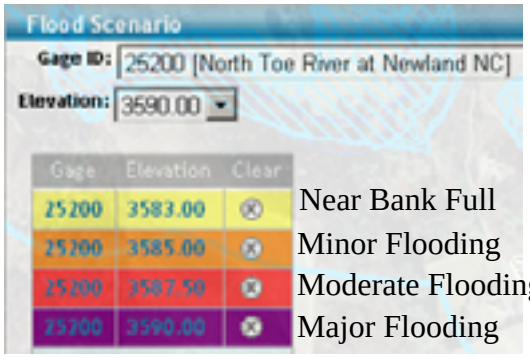
What-if Flood Scenario Mapping

The third component of FIMAN Maps is the Scenario Module. This function allows the user to examine the "what-if" impacts of flooding at a site by being able access the map polygons for each one-half foot rise in water from bank full to flood of record. This tool is particularly useful for developing response and recovery plans and procedures well ahead of an actual flood.



Near Bank Full

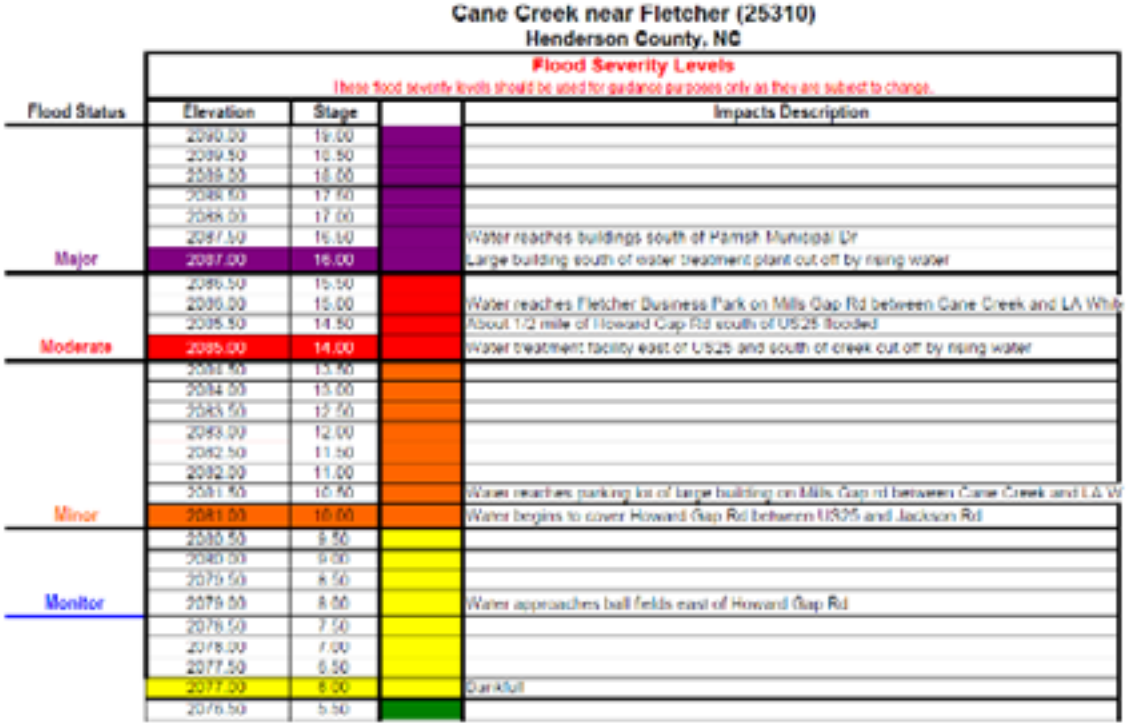
Minor Flooding

Moderate Flooding

Major Flooding

The key aspect of FIMAN Maps is that it helps to visualize the impacts of flooding before and during an event. Roads, bridges, building and critical facilities that may be impacted can be identified. For the many sites that are not NWS forecast sites, flood stage and flood impacts have been established using FIMAN Maps in collaboration with local emergency managers. This has added a new level of understanding to the impacts of flooding. This improved awareness of the potential risks can help attain the overall goal of the program – to reduce the loss of lives and impact to property from flooding. NCEM has created flood impact statements for specific sites throughout the state.

Flood Impact Statement



Cane Creek near Fletcher (25310)
Henderson County, NC

Flood Severity Levels
These flood severity levels should be used for guidance purposes only as they are subject to change.

Flood Status	Elevation	Stage		Impacts Description
	2090.00	19.00		
	2089.50	18.50		
	2089.00	18.00		
	2088.50	17.50		
	2088.00	17.00		
	2087.50	16.50		Water reaches buildings south of Hamsh Municipal Dr
Major	2087.00	16.00		Large building south of water treatment plant cut off by rising water
	2086.50	15.50		
	2086.00	15.00		Water reaches Fletcher Business Park on Mills Gap Rd between Cane Creek and LA Whi
	2085.50	14.50		About 1/2 mile of Howard Gap Rd south of US25 flooded
Moderate	2085.00	14.00		Water treatment facility east of US25 and south of creek cut off by rising water
	2084.50	13.50		
	2084.00	13.00		
	2083.50	12.50		
	2083.00	12.00		
	2082.50	11.50		
	2082.00	11.00		
	2081.50	10.50		Water reaches parking lot of large building on Mills Gap rd between Cane Creek and LA W
Minor	2081.00	10.00		Water begins to cover Howard Gap Rd between US25 and Jackson Rd
	2080.50	9.50		
	2080.00	9.00		
	2079.50	8.50		
Monitor	2079.00	8.00		Water approaches ball fields east of Howard Gap Rd
	2078.50	7.50		
	2078.00	7.00		
	2077.50	6.50		
	2077.00	6.00		Dam Roll
	2076.50	5.50		

The current conditions data within FIMAN Maps is currently integrated into the NC SPARTA system. SPARTA is the core operating set of solutions that NCEM and emergency managers throughout the state rely on during all categories of events. The current conditions statewide map is incorporated into the SPARTA map viewer so that users can obtain a statewide status. The SPARTA map viewer is directly linked to the FIMAN Maps viewer, so that a SPARTA user can have access to that information.

Conclusion

North Carolina is unique in that there are a wide range of flooding types and risk that pose a constant threat to the life and property. NCEM has responded to this threat by making the best available data accessible to the people who need it. The FMIS and FIMAN applications were developed with this goal in mind. The use of ArcGIS technology has enabled NCEM to build these comprehensive web mapping applications that serve a variety of users.