The Delaware Coastal Flood Monitoring System user Guide

http://coastal-flood.udel.edu

Developed by the Delaware Environmental Observing System and the Delaware Geological Survey

Last revised: March 2014

The Delaware Coastal Flood Monitoring System User Guide (2013). Published by the Delaware Environmental Observing System and the Delaware Geological Survey. Version 2.0. 20 pages.

The Delaware Coastal Flood Monitoring System (CFMS) project was funded, in part, through grants from the DNREC Delaware Coastal Management Program (DCMP), the Delaware National Estuarine Research Reserve (DNERR), the Delaware Emergency Management Agency (DEMA)m and the National Science Foundation Experimental Program to Stimulate Competitive Research (EPSCoR.)

Table of Contents

I. Introduction

What is the Delaware Coastal Flood Monitoring System?

The Delaware Coastal Flood Monitoring System (CFMS), as it is commonly termed, is a web-based display tool and early warning system designed to provide emergency managers, planners, and others the information on the extent, timing, and severity of upcoming coastal flood conditions. It is comprised of hydrologic 48-hour forecasts along the Delaware Bay/River, a back-end system that determines predicted water levels for each coastal community and sends out any necessary alert notices, real-time water level observations from USGS and NOS tide gages, and a website to display that information.

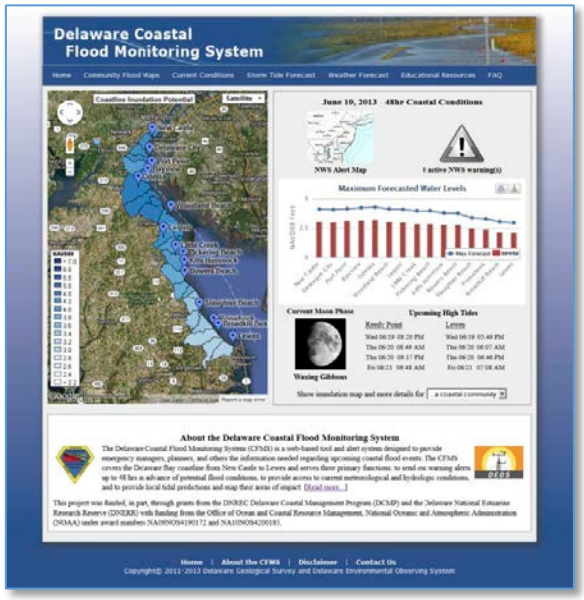

Figure 1.1 Screenshot of CFMS website

The CFMS covers 15 coastal communities along the Delaware Bay/River coastline from the City of New Castle in New Castle County to the City of Lewes in Sussex County, approximately one location for every 3 miles of coastline. Each community has its own web page displaying forecasted water levels, flood maps, and other local information. Emergency personnel can subscribe to received text-based or email alerts if water levels are predicted to increase higher than a custom designated criteria set for their own community.

The CFMS serves three primary objectives:

- to provide emergency and administrative personnel time to prepare for coastal flooding events,
- to provide access to real-time tidal and meteorological conditions, and
- to provide community-based tidal and storm surge predictions, with potential flood inundation maps, road elevation profiles and other local information.

Who is the intended audience of the CFMS?

Although the CFMS website is publicly available and can be viewed by any interested persons, the target audience for the CFMS is state, county, and local emergency management personnel, researchers, planners, and others involved in the preparation and planning for severe coastal flooding events.

Who developed and operates the CFMS?

The Delaware Coastal Flood Monitoring System was initially developed jointly by the Delaware Environmental Observing System (DEOS) and the Delaware Geological Survey (DGS) at the University of Delaware in 2011., with the last website revision released in early 2013. It is currently operated by DEOS and DGS with support from the Delaware Environmental Monitoring and Analysis Center (DEMAC) and DNREC Delaware Coastal Programs.

The Delaware Environmental Observing System is a support tool for decision makers involved with emergency management, natural resource monitoring, transportation, and other activities throughout the State of Delaware. Their primary goal is to provide state agencies and the citizens of Delaware with immediate information about environmental conditions in and around the State. DEOS also archives data for historical environmental studies and research. For more information on DEOS, visit http://www.deos.udel.edu

The Delaware Geological Survey is a science-based, public-service-driven Delaware state agency at the University of Delaware that conducts geologic and hydrologic research, service, and exploration for the benefit of the citizens of the First State. The mission of the DGS is to provide objective earth science information, advice, and service to its stakeholders–the citizens, policy makers, industries, and educational institutions of Delaware. For more information on DGS, visit http://www.dgs.udel.edu

COASTAL STORMS IN DELAWARE'S PAST

In the U.S. Mid-Atlantic and Northeastern states, both tropical systems (such as hurricanes) and extratropical storms (particularly nor'easters) frequently cause significant loss of life, injuries and property damages reaching many billions of dollars. Delaware has been significantly affected by many great storms throughout its modern history, particularly the Hurricane of October 1878, Ash Wednesday Storm in March of 1962, the Mother's Day storm in May of 2008, and most recently Superstorm Sandy in October of 2012.

Due to its geographic location along the US East Coast, low lying elevation, high rates of relative sea level rise, and expanding coastal population, Delaware is becoming increasingly vulnerable to high tides and storm surge. Loss of life and damages to the natural and built-up environment as a result of severe coastal flooding is likely the most significant natural hazard facing Delaware today.

For more detailed information on past coastal events, refer to the Delaware Coastal Storm Climatology and Damage Report: 1923-2009. (www.deos.udel.edu/coastalstorm/)

II. Getting Started

To launch the Coastal Flood Monitoring System, navigate to http://coastal-flood.udel.edu. The main page of the CFMS offers many features to the user, as detailed below. This page contains two main sections. On the left side of the page is the Maximum Forecasted Water Level map and the right is dedicated to 48 hour Coastal Conditions.

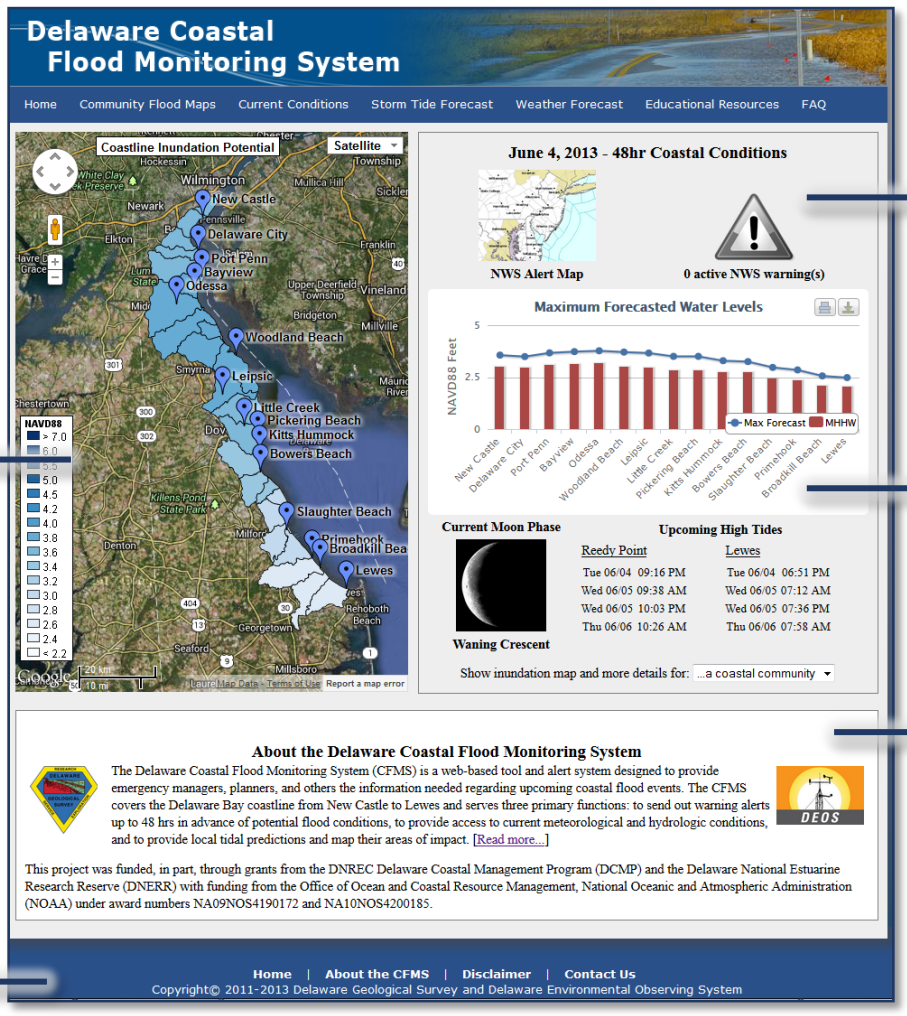

Figure 2.1 Components of the CFMS website home page interface

Maximum Forecasted Water Levels Map

The Maximum Forecasted Water Levels Map shows all of the coastal communities within the CFMS as well as the coastal watersheds. Each watershed is colored according to its maximum predicted coastline inundation potential.

Each community within the CFMS is represented on the map by a blue balloon as shown in Figure 2.2.

Clicking on one of the balloons brings a dialogue window showing maximum predicted water levels data for that specific community, available in NAVD88 feet and Mean Higher High Water (MHHW).

Clicking 'Load flood map' on the pop-up window will load the corresponding community flood map.

The map was built on a Google Maps interface with standard Google Maps tools:

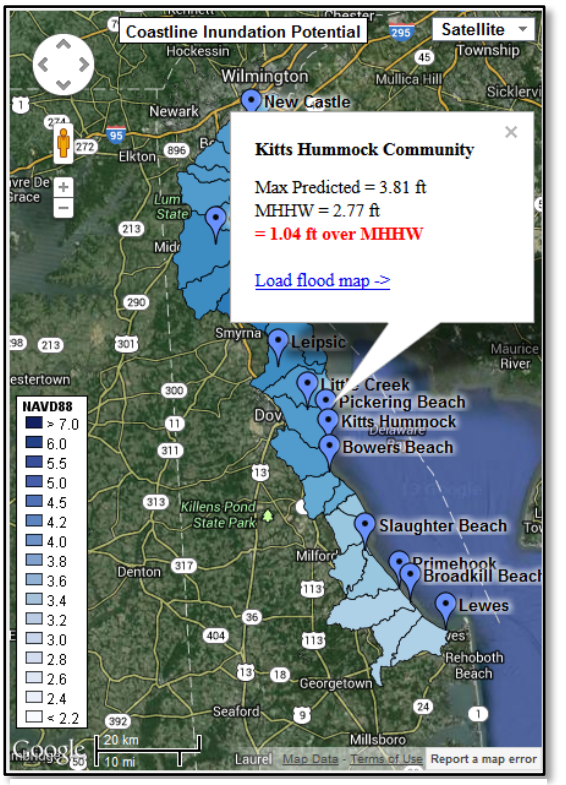

Figure 2.2 Maximum Forecasted Water Levels Map showing Kitts Hummock community

Pan tool: The pan tools enables the map view to move north, south, east, or west. To pan, simply click and hold the left mouse button, then drag the map.

Zooming: Zoom in and out by using the + and - buttons in the top left corner of the map or by using the mouse scroll wheel. To center and zoom in on a location, double click on the desired location on the map.

Map Type: The Maximum Forecasted Water Levels map allows for a number of different basemaps. The default basemap is Satellite. Google Street Map and Open Street Map (OSM) are also available. To change the map type, click on the drop down menu in the upper right portion of the map and select the desired basemap.

For more information on the google maps interface, see their help page at:
https://support.google.com/maps/answer/144352?hl=en&ref_topic=1687350

Maximum Forecasted Water Levels Graph

The Maximum Forecasted Water Levels Graph shows maximum forecasted water levels for each community in both NAVD88 feet and Mean Higher High Water (MHHW). For more information on NAVD88 or MHHW vertical datums, see the Appendix.

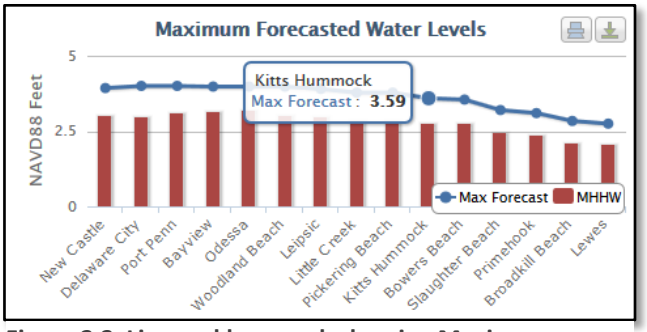

Figure 2.3 Line and bar graph showing Maximum Forecasted Water Levels in NAVD88 feet and MHHW, using example of Kitts Hummock community

Water levels in NAVD88 feet are shown by a blue line graph and water levels in MHHW is shown as a red histogram (bar graph).

Moving the cursor over either the bars in the histogram or the points in the line graph will interactively show appropriate the forecasted water levels at the given location. Figure 2.4 demonstrates this data using the example of the Kitts Hummock community.

The Maximum Forecasted Water Levels Graph can also be downloaded or printed by clicking the appropriate icons at the top right hand corner of the graph panel.

Printing: To print the Maximum Forecasted Water Levels Graph, click on the blue printer icon on the left.

Downloading: To download the Maximum Forecasted Water Levels Graph, click on the green download icon on the right and select the desired download format (pdf, jpeg, pdf, or svg).

Active Alerts

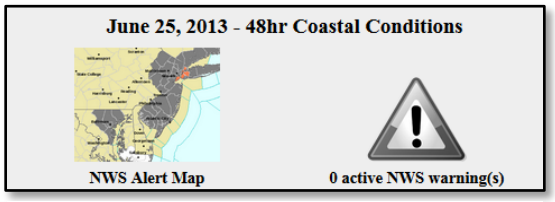

Figure 2.4 Active Alerts panel

The Active Alerts panel show any active alerts from the National Weather Service (NWS).

On the left side of the panel is an NWS Alert Map that can be clicked to navigate to the NWS Forecast Office page for Philadelphia Mount Holly.

The right side of the panel shows any active NWS warnings for the area.

Astronomical Tides

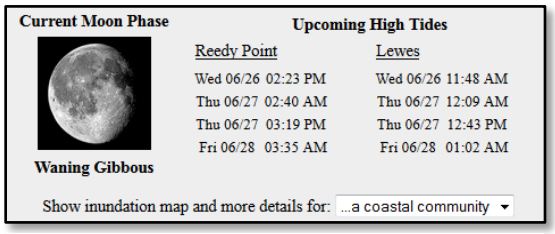

Figure 2.5 Astronomical Tides and Moon panel

The Astronomical Tides panel shows the current moon phase as well as upcoming high tides for Reedy Point and Lewes out to 48 hours. The current moon phase is on the left side of the panel and the upcoming tides are shown on the right.

To find more details about forecasts and current data for a specific community, use the drop down menu next to 'Show inundation map and more details for a coastal community'.

III. Community Maps and Data

The current version of the CFMS includes the coastal communities from the City of New Castle down to the City of Lewes. There were 15 communities identified in this area with approximately one location for every 3 miles of coastline. Figure 3.1 is a map of the region with each community labeled. The CFMS homepage displays the 48-hour maximum forecasted water level for all 15 communities as well as a shaded watershed map displaying the same information.

Each community has its own web page on the CFMS. It shows a potential flood inundation map centered on that community, with customized forecasted astronomical tides and storm surge, elevation profiles for locally selected roads, conversion factors between common vertical datums for that locations, and more.

Each community also has configurable alerts, which means a user can set a threshold value for any one of these communities and will receive an email or text message alert if a forecasted water level value crosses their threshold. The method for setting up the forecast alerts is online and managed by DEOS, in a similar way to its real-time observation alerts.

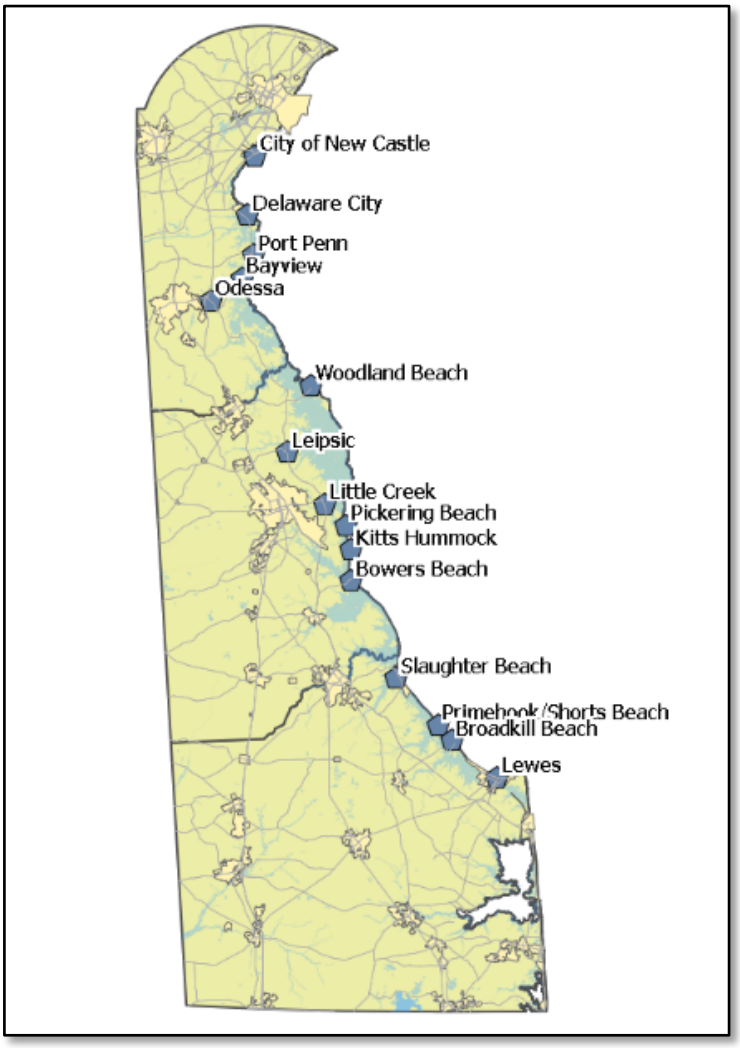

Figure 3.1 Map of the 15 communities included in the current version of the CFMS

Individual communities can be selected a number of ways. On the CFMS main page, the user can click on a specific community on the Maximum Forecasted Water Levels graph or map. Alternatively, users can select the desired community from the drop down menu on the CFMS main page or by navigating to the Community Flood Maps page (Figure 3.2).

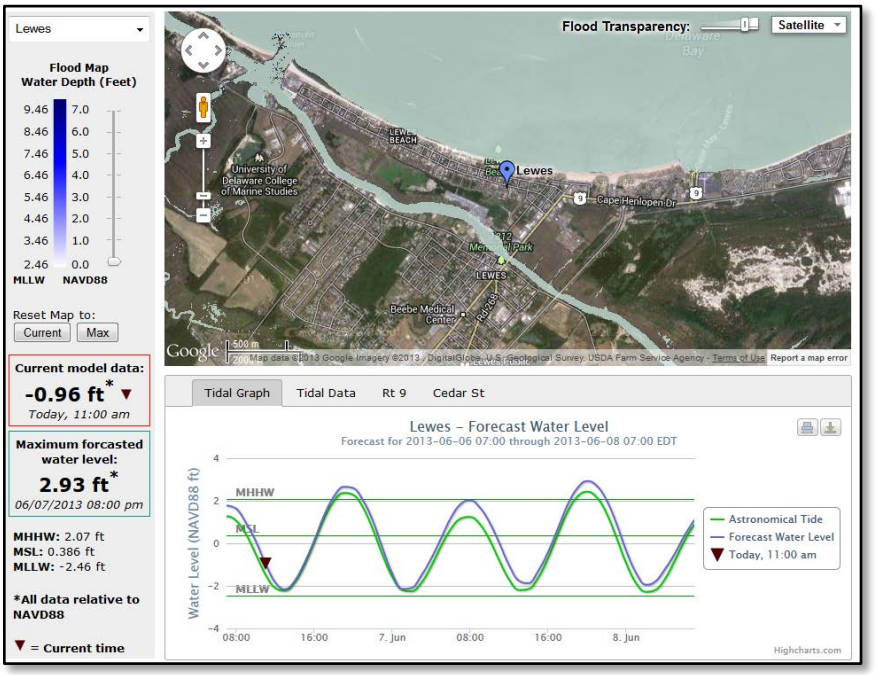

Figure 3.2 Community Maps page interface

On each community flood map page, a variety of information is available. Current model data for any community in both NAVD88 and MHHW is available on the left side of the page. Tidal graphs and data representing maximum forecasted water level data, and a map interface incorporating flood inundation is displayed on the right side of the page.

Tidal Graphs and Tide Data

The Tidal Graph is the default tab when the page is loaded (Figure 3.3). Astronomical tide height data are the green line and the predicted water height data are the blue line. The current data is shown as an inverted triangle on the graph.

A table of the data used to generate the Tidal Graph can be accessed by clicking on the Tidal Data tab, as shown in Figure 3.4.

Moving the cursor along the graph will interactively show the data values of astronomical tides and forecast water levels at that forecasted time.

The map can be changed to show maximum forecasted conditions by selecting to Reset Map to: Max on the left side of the Community Maps page.

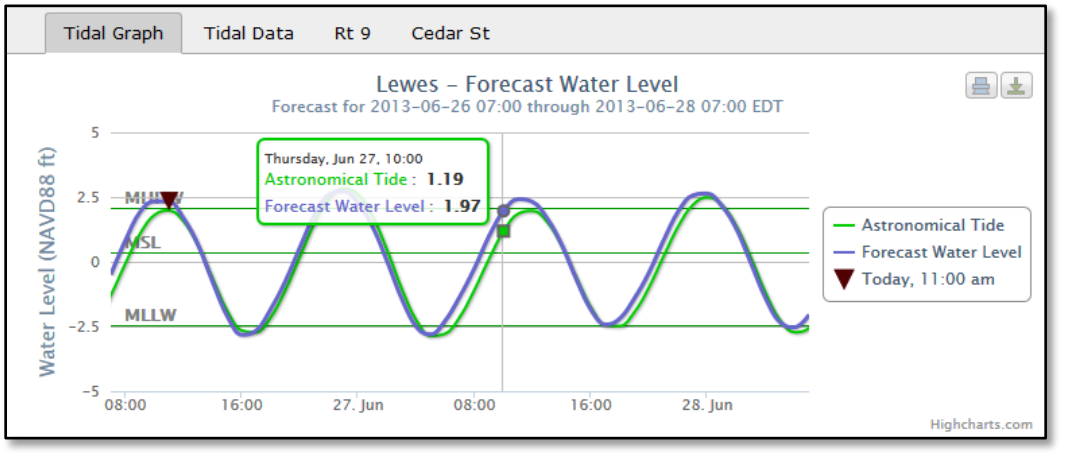

Figure 3.3 Tidal Graph View showing Lewes, DE

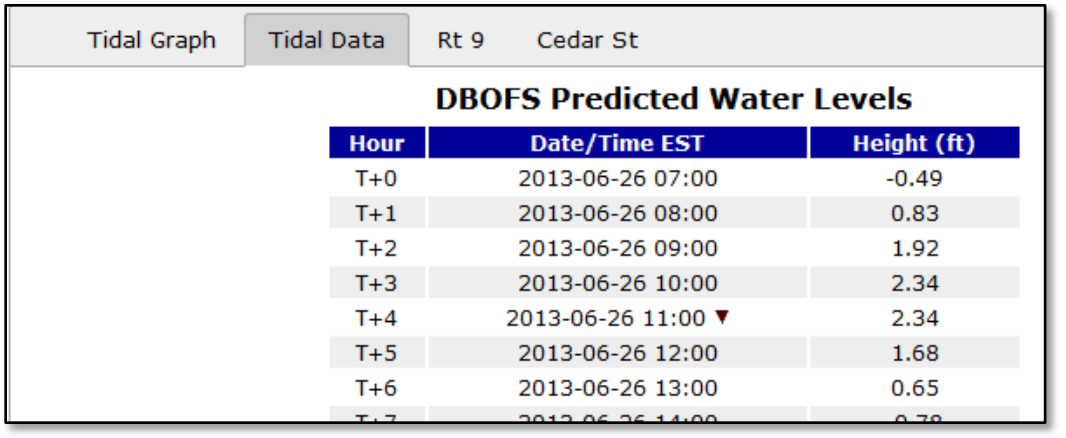

Figure 3.4 Tidal Data view, showing DBOFS Predicted Water Levels

Flood Inundation Map

Flood inundation is shown on the map in shades of blue. The map is built on a Google Maps interface. Predicted water level at the coast was assumed to be constant throughout the study area. This method is termed a single value surface, or "filling the bathtub" model. Elevation values were added to the LIDAR elevation DEM at each grid cell and categorized into one foot increments/layers. Each layer is coded in shades of blue; the higher the number, the deeper the water depth, the darker the shade of blue used. The Flood Map Water Depth menu on the left side of the page can be used to change the map inundation level. Controls for this map interface (zoom in, zoom out, etc.) are part of the Google Maps package.

WHAT IS A BATHTUB MODEL?

Flood inundation maps were created using a "bathtub model". In a bathtub model, water level increases to a constant value, say to 4 feet, and fills the lower land surface uniformly, similar to filling a bathtub. A bathtub model does not take into account hydrologic connectivity, soils, vegetation, infrastructure, or any other related factors that might impact flood extent. However, it does provide insight into low-lying areas highly susceptible to flooding.

Road Elevation Profiles

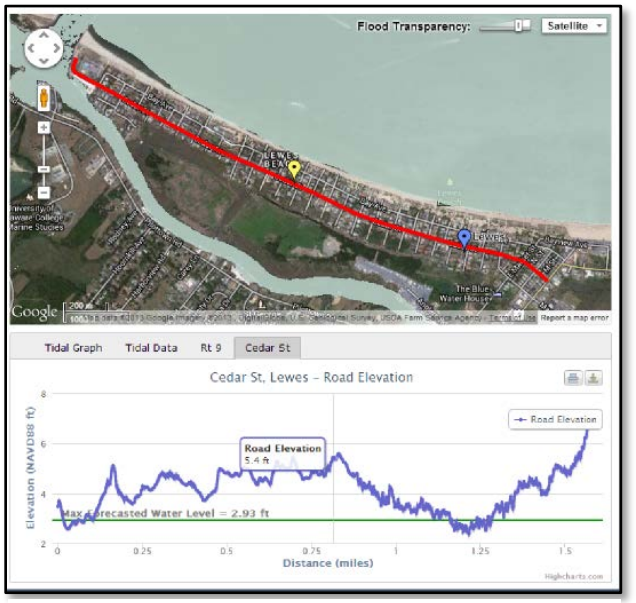

Figure 11. Road elevation profiles showing Cedar St. Lewes

Road elevation profiles are available for major roadways or evacuation routes in the selected community. When a roadway tab is selected, the inundation map will center over the roadway and show the mapped cross section in red. In the road elevation profile the purple line denotes the maximum predicted water level height over the next four days and the green line is the mapped water level height, which can be adjusted by the user with the Flood Map Water Depth bar. Running the cursor along the graph will interactively show the road elevation at that point and also will designate the corresponding location along the road in the map with the yellow balloon.

IV. Real-time Observations & Forecasts

Current Observations Page

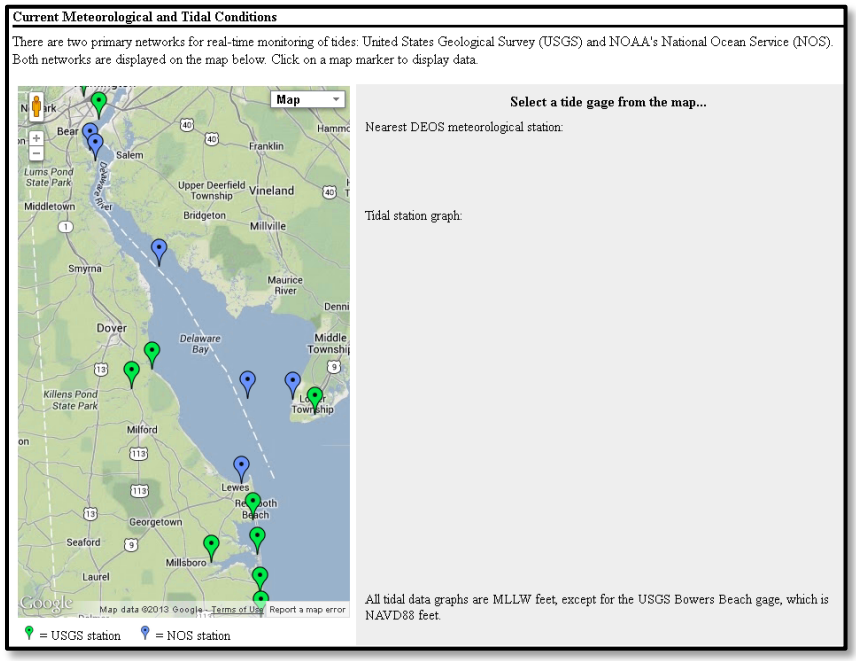

Figure 4.1 Current Observations Page start up interface

The Current Meteorological and Tidal Conditions page offers two networks of data for real-time monitoring of tides: United States Geological Survey (USGS) and NOAA's National Ocean Service (NOS). As shown in Figure 4.1, the page features an interactive google maps interface, with each gage represented by a balloon on the map. The right side of the page will remain gray until a tide gage is selected.

To see current conditions for a gage, click on the desired location balloon. The right side of the page will then display meteorological conditions from the nearest DEOS station to that gage as well as the gage's respective tidal station graph. Tidal data are in MLLW feet, except for the USGS Bowers Beach gage, which is NAVD88 feet. Clicking on the source link under the tidal station graph will bring up the source data website for USGS or NOS.

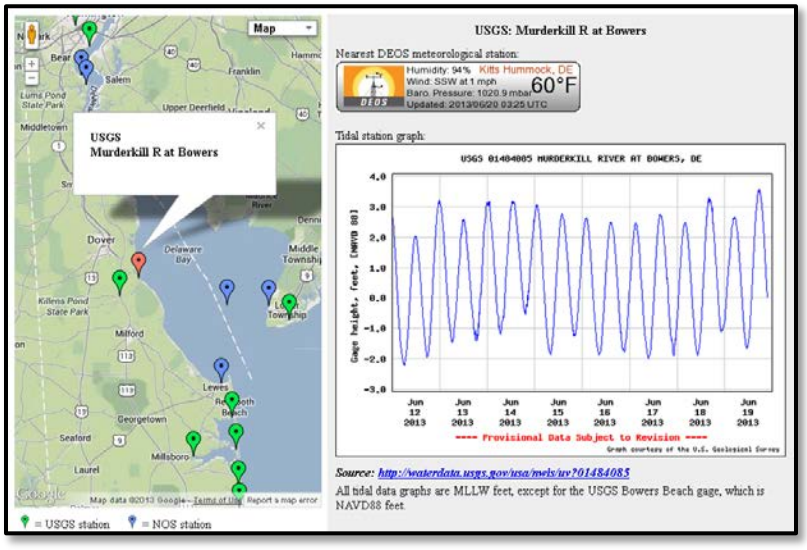

Figure 4.2 Current observations showing Murderkill River at Bowers, DE

Weather Forecast Page

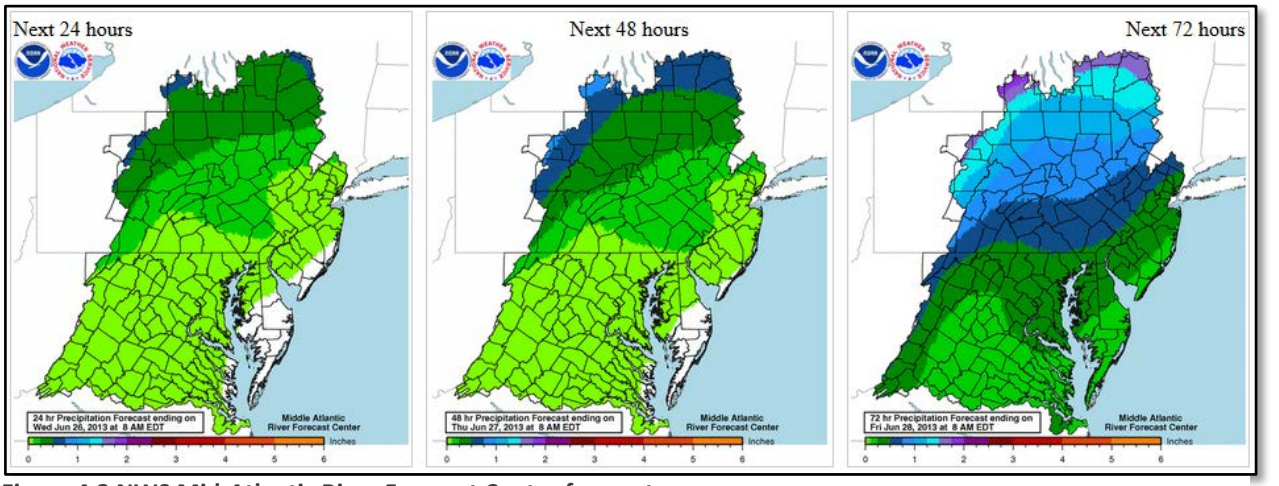

Figure 4.3 NWS Mid-Atlantic River Forecast Center forecasts

The weather forecast page offers precipitation and wind forecasts from the National Weather Service (NWS) as well as links to additional NWS forecasts and resources. As shown in Figure 4.3, precipitation forecasts are available from the NWS Mid-Atlantic River Forecast Center (MARFC) for the next 72 hours in the Delaware region. Wind speed, direction, and gusts are from the NWS's National Digital Forecast Database (NDFD).

Marine/Tide Forecast Page

The Storm Tide Forecast page has links and real-time graphs for hydrodynamic models that produce tidal/storm surge forecast guidance for the Delaware Bay region. These systems run operationally several times per day and output hourly predictions on water levels, temperature, waves, and winds.

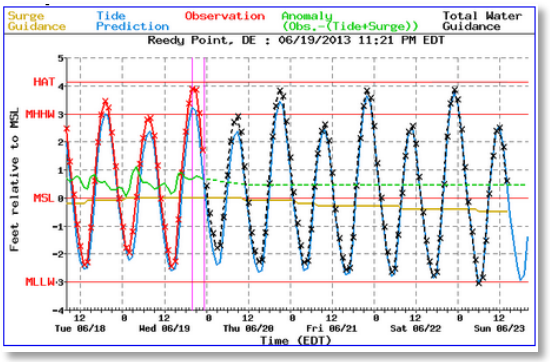

Figure 4.4 ET-Surge model tide+surge forecast for Reedy Point, Delaware

The National Weather Service (NWS) runs an operational extratropical storm surge model called ET-SURGE (also known as the ETSS model.) This model was developed by the NWS's Meteorological Development Laboratory (MDL) and is a variation on the NWS's Sea, Lake and Overland Surges from Hurricanes (SLOSH) model. ET Surge runs operationally four times daily out to 96 hours at a relatively coarse spatial resolution. Station forecasts are used by NWS and other organizations. ET-SURGE should be considered as model guidance only and not be used for tropical systems.

V. Alerts

The DEOS Alerts System is a system of event-driven triggers that can send emails and notify cell phones when an extreme weather or hydrologic event occurs or, in the case of the CFMS, predicted to occur. Forecast alerts associated with the CFMS are intended to let emergency managers know they need to begin monitoring on predicted tide forecasts, tide gages, and possibly begin preparations for coastal flooding.

There are currently 15 locations between the City of New Castle and the City of Lewes for which you can set forecast alerts. Each subscriber sets a critical predicted water level for notification. If that level is reached at any time within the 48 hour forecast, an alert is sent via text and/or email. Alerts describe location, flood potential, timing, and provide a link to the system web portal.

To sign up to receive email or text alerts, please email us at coastal-flood@udel.edu.

VI. Disclaimer

The Delaware Coastal Flood Monitoring System (CFMS) website displays forecasted water level data for several locations in Delaware. **These data are for planning purposes only.** The user assumes the entire risk related to use of this data. The CFMS presents data as is provided by automated, operational models, as described below.

- Predicted water levels at the coastline are generated by the Delaware Bay Operational Forecast System (DBOFS), a physically-based hydrodynamic model that utilizes current meteorological forecasts. DBOFS data should be considered as modeled, forecast guidance only and is not guaranteed by the University of Delaware, Delaware Environmental Observing System or Delaware Geological Survey.
- Flood inundation maps on the CFMS website are purely computer-generated, produced by projecting the DBOFS predictions at the coast inland to each community. This is termed a "bathtub model" and based solely on a constant water level surface and land surface elevation DEM. No human intervention is performed to refine or qualify the coastline forecast values or the inland inundation maps.
- Current Conditions tidal data are obtained directly from the USGS and NOS real-time tidal gages. The CFMS site reports the latest observation and graphical display from each station. Per NOAA and USGS, these are considered preliminary data and should not be considered final until officially approved.
- Current Conditions meteorological data are obtained directly from the latest reading from the nearest DEOS meteorological station. A disclaimer on the DEOS data can be found at http://www.deos.udel.edu/disclaimer.html.

The authors, the University of Delaware, Delaware Environmental Observing System, and Delaware Geological Survey, disclaim any and all warranties, whether express or implied, including (without limitation) any implied warranties of merchantability or fitness for a particular purpose. In no event will DGS, DEOS or UD be liable to the user or to any third party for any direct, indirect, incidental, consequential, special or exemplary damages or lost profit resulting from any use or misuse of this data.

Appendix

Delaware Bay Operational Forecast Model (DBOFS)

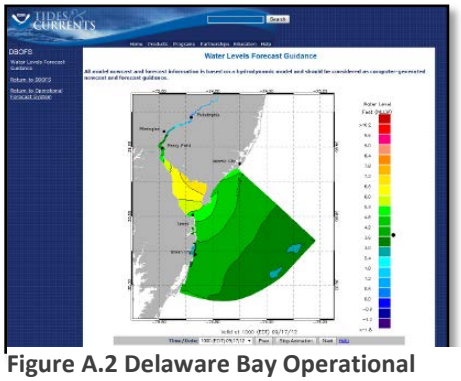

Figure A.2 Delaware Bay Operational Forecast System Forecasts

Coastal forecasts are made by the Delaware Bay Operational Forecast System (DBOFS), a numerical hydrodynamic forecast system developed by NOAA/National Ocean Service's Coast Survey Development Laboratory (CSDL) Marine Modeling and Analysis Programs. It is based on the Regional Ocean Modeling System (ROMS) as its core ocean circulation model and the North American Mesoscale (NAM) model for meteorological input. Model runs are performed every 6 hours. Forecasts are made for each hour out to 48 hrs in advance. The spatial resolution of the DBOFS model varies from 100 m (near the upper Delaware River) up to 3 km (in the near-shore Atlantic Ocean). Predictions along the coastline are imported into the CFMS, and used to generated the flood inundation maps.

Digital Elevation Model

Land-based elevation (topographic) datasets were produced for Delaware from airborne LiDAR. Sussex County LiDAR was collected in 2005 through a contract with the U.S. Geological Survey and NASA using NASA's Experimental Advanced Airborne Research Lidar (EAARL) system. New Castle and Kent Counties were collected in 2007 through a contract with Sanborn as part of their orthophotography acquisition. In 2009, DNREC Coastal Programs compiled all mass point data for the 3 counties and sent them to NOAA Coastal Services Center for re-processing as a statewide 2-meter grid. Accuracy of the original mass points meets or exceeds FEMA Accuracy standard for use in flood mapping and remapping work. In New Castle and Kent Counties, RMSE is 18.5 cm for well-defined points, and 37.5 cm for heavily vegetated areas. In Sussex County, the RMSE is 15 cm.

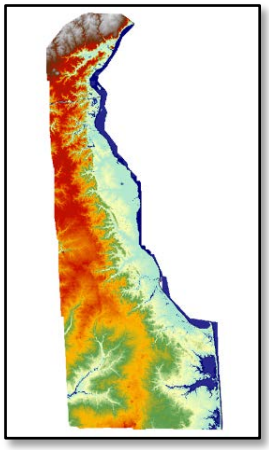

Figure A.1 Shaded DEM for Delaware

The Delaware Coastal Flood Monitoring System is maintained jointly by the Delaware Geological Survey and the Delaware Environmental Observing System at the University of Delaware, with support from the Delaware Environmental Monitoring and Analysis Center and the Delaware Department of Natural Resources (DNREC) Delaware Coastal Programs.