

David R. Vallee and James Notchey  
NOAA/National Weather Service Forecast Office  
Taunton, Massachusetts, 02780

## 1. INTRODUCTION

The Weather Forecast Office (WFO) Hydrologic Forecast System (WHFS) provides an integrated suite of hydrologic software which is used by National Weather Service offices to more efficiently collect, analyze and monitor hydrologic conditions throughout its service area ( NWS 2001). Data are received by satellite and phone communication, decoded, then placed into the hydrologic database for further interrogation and inclusion into daily products, watches and warnings. With the advent of telemetered tide gaging networks along the coast of Rhode Island and Massachusetts, WHFS can be configured to monitor tide data, including observations, astronomical tide forecasts and extra tropical storm surge guidance. These data can then be incorporated into detailed coastal flood watches and warnings, greatly enhancing local coastal flood monitoring and improving the efficiency of product issuance.

## 2. DATA SOURCES

Three types of data sources are presently incorporated into the tide gaging network. These include observations, astronomical tide predictions and storm tide forecasts.

### 2.1 Observed Tide Data

Observed tide elevations are available for Primary and Secondary tide locations in the WFO Taunton, County Warning Area. Primary locations are those associated with National Ocean Service (NOS) gaging platforms. A portion of these platforms provide real-time water surface data. Other platforms, such as those on Narragansett Bay, are part of the Physical Oceanographic Real-Time System (PORTS) and provide real-time water levels, currents, and other oceanographic and meteorological data. National Weather Service (NWS) offices receive the NOS data from the Hydrometeorological Automated Data System (HADS), which is a real-time data acquisition and data distribution system operated by the Office of Hydrologic Development of the National Weather Service. HADS collects the data, encodes the information in the Standard Hydrometeorological Exchange Format (SHEF), then disseminates the information to NWS offices (U.S. DOC 1998).

Secondary tide locations are sites where event-driven tide elevations will be provided from volunteer observers. These observers will phone in tide elevations to the NWS,

by reading installed staff gages at predefined locations along the coastline. These elevation will be entered directly into WHFS for incorporation into event assessment and product issuance. This network of staff gages is under development at the time of this writing.

### 2.2 Astronomical tide predictions

Hourly data sets of astronomical tide predictions, out to 72 hours, are provided by the NOS for all primary stations and encoded in SHEF and disseminated by HADS to WFOs. Astronomical tide predictions for secondary stations are created through a local applications which utilizes a harmonic tide prediction scheme from the Xtide freeware package (Flater 1997) to determine the tide predictions. Additional information on this freeware package can be found at <http://www.flaterco.com/xtide>. These tide predication are then encoded in SHEF and sent to WHFS.

### 2.3 Extra-tropical storm tide forecasts

Storm tide forecasts for primary and secondary stations are generated from extra-tropical storm surge guidance which is produced from the National Centers for Environmental Prediction (NCEP) aviation (AVN) model (Kalnay et al. 1990). AVN based extra-tropical storm surge guidance (Kim et al. 1996) is provided to WFOs by NCEP twice daily following the 00 UTC and 12 UTC model runs and provides hourly tide departures out to 48 hours.

To produce a storm tide forecast, the AVN guidance is manipulated by a locally developed AWIPS application which creates a SHEF message of forecasted storm tide by applying the AVN model storm surge to the astronomical tide predictions for the appropriate tide station.

## 3. STATION LOCATION AND DOCUMENTATION

Twenty-four tide forecast sites have been established in the WFO Taunton County Warning Area. Seven stations, as provided in Table 1, are Primary sites while the remaining stations, as provided in Table 2, are Secondary sites.

Detailed site surveys have been conducted at all NOS sites and the majority of the secondary stations. These surveys included flood stage and flood damage category assessment, the development of impact statements for these critical elevations, and the incorporation of flood elevation histories. All of this information is available to the forecast through the

Hydroview application within WHFS. Table 1 provides a listing of locations and flood stages.

Table 1. List of Primary tide stations.

Name	County	Flood Stage
Boston Harbor, MA	Suffolk	13.5
Nantucket, MA	Nantucket	6.0
Woods Hole, MA	Barnstable	5.5
Newport, RI	Newport	6.5
Fall River, MA	Bristol	n/a
Providence, MA	Providence	7.0
Conimicut Point, RI	Kent	7.0
Quonset Point, RI	Washington	n/a

Table 2. List of Secondary tide stations.

Name	County	Flood Stage
Newburyport, MA	Essex	n/a
Glocester, MA	Essex	10
Marblehead, MA	Essex	11.5
Scituate, MA	Plymouth	10.0
Plymouth, MA	Plymouth	12
Provincetown, MA	Barnstable	11
Sandwich, MA	Barnstable	11
ChathamOuter Harbor, MA	Barnstable	8
Vineyard Haven, MA	Dukes	5.5
Hyannis Port, MA	Barnstable	7
Onset, MA	Plymouth	9.5
Mattapoisett, MA	Plymouth	7.5
New Beford, MA	Bristol	9
Conimicut Point, RI	Kent	7.0
Quonset Point, RI	Washington	n/a
Point Judith, RI	Washington	8.7
Watch Hill	Washington	n/a
Block Island	Washington	6.6

#### 4. OVERVIEW OF COASTAL FLOOD OPERATIONS

Forecasters routinely monitor the coastal flood situations through the use of time series analyses provided in the Hydroview application. Examples of these time series are available at [http://www.nws.noaa.gov/er/box/coastal\\_flood.htm](http://www.nws.noaa.gov/er/box/coastal_flood.htm), under the Papers and Studies section, for this preprint article. When the situation warrants, the forecaster can place WHFS into coastal flood mode, through a pull down menu option. Vallee and Notchey (2001) describe this methodology in detail. The River Product Composer (Riverpro) is utilized to compose detailed coastal flood watches and warnings as appropriate. These products provide text and tabular forecast information along with impact statements for impacted areas along the coastline.

Proper configuration to the statement section templates is extremely important. Examples of output are provided in the following figures.

#### 4.1 Coastal Flood Watch

Coastal Flood Watches (Figure 1) are issued when the threat of coastal flooding exists within the next 36 hours. NWS products provide an overview of the threat and possible impact while also presenting the expected tide forecasts for selected locations.

Figure 1. Example of a coastal flood watch statement issued by Riverpro.

COASTAL FLOOD WATCH  
NATIONAL WEATHER SERVICE TAUNTON, MA  
500 PM EDT WED OCT 3 2001

...COASTAL FLOOD WATCH FOR EAST COASTAL MASSACHUSETTS FOR THURSDAY AFTERNOON AND EVENING...

MODERATE COASTAL FLOODING WITH TIDES OF 2 TO 3 FEET ABOVE NORMAL IS POSSIBLE DURING THE LATE THURSDAY AFTERNOON AND EARLY EVENING TIDE CYCLE ALONG THE EAST COAST OF MASSACHUSETTS FROM THE MERRIMACK RIVER TO CHATHAM. THE COMBINATION OF A LARGE HIGH PRESSURE SYSTEM OVER QUEBEC AND A SLOW MOVING OCEAN STORM 600 MILES EAST OF CAPE COD WILL CONTINUE TO PRODUCE GALE FORCE NORTHEAST WINDS THROUGH THURSDAY EVENING. ASTRONOMICAL TIDES ARE RUNNING HIGH DUE TO THE FULL MOON. THE ADDED EFFECT OF THE PROLONGED GALE FORCE ONSHORE FLOW WILL RESULT IN A 2 TO 3 FOOT STORM SURGE LATE THURSDAY AFTERNOON. SHOULD THIS OCCUR...MODERATE COASTAL FLOODING WOULD RESULT.

FOR BOSTON HARBOR...HIGH TIDE WILL OCCUR NEAR 5 PM. A HIGH TIDE OF 14.5 FEET MLLW IS POSSIBLE. AT TIDE ELEVATIONS OF 14.5 FEET...SIGNIFICANT COASTAL ROAD AND RESIDENTIAL FLOODING IS LIKELY FROM THE NORTH SHORE SOUTHWARD TO PLYMOUTH. ROAD CLOSURES ARE LIKELY AND RESIDENTS SHOULD BE PREPARED TO EVACUATE FOR SEVERAL HOURS SHOULD FLOODING OCCUR.

&&  
OTHER CRITICAL STORM TIDE FORECASTS INCLUDE THE FOLLOWING LOCATIONS. ALL ELEVATIONS ARE IN FEET, MEAN LOWER LOW WATER AND TIME OF HIGH TIDE IS ROUNDED TO THE NEAREST HOUR.

SITE	FLOOD STAGE	TIME OF HIGH TIDE	FORECAST STORM TIDE
MARBLEHEAD	12.8	5 PM	14.2
GLOCESTER	14.0	5 PM	15.8
SCITUATE	11.5	4 PM	13.5
PLYMOUTH	10.8	4 PM	13.0

ALL COASTAL RESIDENTS SHOULD MONITOR THE LATEST FORECASTS AND POSSIBLE WARNINGS THROUGH NOAA WEATHER RADIO OR YOUR LOCAL MEDIA OUTLETS.

## 4.2 Coastal Flood Warning

Coastal Flood Warnings (Figure 2) are issued when the threat of coastal flooding exists within the next 24 hours. NWS products provide an overview of the threat and possible impact while also presenting the expected tide forecasts for selected locations.

Figure 2. Example of a Coastal Flood Warning

COASTAL FLOOD WARNING  
NATIONAL WEATHER SERVICE TAUNTON, MA  
500 AM EDT THU OCT 4 2001

...COASTAL FLOOD WATCH FOR EAST COASTAL MASSACHUSETTS FOR THURSDAY AFTERNOON AND EVENING...

MODERATE COASTAL FLOODING WITH TIDES OF 2 TO 3 FEET ABOVE NORMAL IS EXPECTED AROUND THE TIME OF HIGH TIDE LATER THIS AFTERNOON. INTERESTS ALONG THE EAST COAST OF MASSACHUSETTS SHOULD TAKE ACTION THIS MORNING TO PROTECT PROPERTY.

THE COMBINATION OF A LARGE HIGH PRESSURE SYSTEM OVER QUEBEC AND A SLOW MOVING OCEAN STORM 600 MILES EAST OF CAPE COD WILL CONTINUE TO PRODUCE GALE FORCE NORTHEAST WINDS THROUGH THIS EVENING. ASTRONOMICAL TIDES ARE RUNNING HIGH DUE TO THE FULL MOON. THE ADDED EFFECT OF THE PROLONGED GALE FORCE ONSHORE FLOW WILL RESULT IN A 2 TO 3 FOOT STORM SURGE LATE THIS AFTERNOON AND EVENING.

FOR BOSTON HARBOR...HIGH TIDE WILL OCCUR NEAR 5 PM. A HIGH TIDE OF 14.5 FEET MLLW IS EXPECTED. AT TIDE ELEVATIONS OF 14.5 FEET...SIGNIFICANT COASTAL ROAD AND RESIDENTIAL FLOODING IS LIKELY FROM THE NORTH SHORE SOUTHWARD TO PLYMOUTH. ROAD CLOSURES ARE LIKELY AND RESIDENTS SHOULD BE PREPARED TO EVACUATE FOR SEVERAL HOURS SHOULD FLOODING OCCUR.

&&

OTHER CRITICAL STORM TIDE FORECASTS INCLUDE THE FOLLOWING LOCATIONS. ALL ELEVATIONS ARE IN FEET, MEAN LOWER LOW WATER AND TIME OF HIGH TIDE IS ROUNDED TO THE NEAREST HOUR.

SITE	FLOOD STAGE	TIME OF HIGH TIDE	FORECAST STORM TIDE
MARBLEHEAD	12.8	5 PM	14.2
GLOCESTER	14.0	5 PM	15.8
SCITUATE	11.5	4 PM	13.5
PLYMOUTH	10.8	4 PM	13.0

ALL COASTAL RESIDENTS SHOULD MONITOR THE LATEST STATEMENTS REGARDING THIS COASTAL FLOOD EVENT.

## 5. LIMITATIONS

The tide observations and forecasts are only available at hourly intervals. Therefore, the basic product structure produces times of high tide to the nearest hour. While this is adequate for river flooding, this may not always be optimum for coastal flooding. Products can contain more detailed timing references but some manual intervention through WHFS is required. The user can add or modify any tide data, observed or forecasted, within WHFS. Then the desired products can be composed using the modified information.

## 6. SUMMARY

The Weather Forecast Office (WFO) Hydrologic Forecast System (WHFS) provides an integrated suite of hydrologic software which is used by National Weather

Service offices to more efficiently collect, analyze and monitor hydrologic conditions throughout its service area. Through the incorporation of available tide gage data, this application can be configured to assist coastal offices in the monitoring of coastal flood events and in the more efficient preparation of detailed coastal flood watches, warnings and statements.

## 7. ACKNOWLEDGMENTS

The authors would like to thank Mr. Robert Thompson, Meteorologist-in-Charge, National Weather Service, Taunton, MA for his overwhelming support and enthusiasm for this project. The authors also sincerely thank Dave Henry, Senior Forecaster, National Weather Service, Taunton, MA for his creativity in producing the tide predictions for the list of secondary stations incorporated into the local coastal flood network.

## 8. REFERENCES

Flater, D., 1997: XTIDE - Harmonic tide clock and tide predictor, Version 1.6.1, 26 pp.

National Weather Service, 2001: WHFS - WFO Hydrologic Forecast System Revision 3.0, Operational User's Guide and Training Manual, *National Weather Service Office of Hydrology*, Silver Spring, MD, 120 pp.

Kalnay, E., M. Kanamitsu, and W. E. Baker, 1990: Global numerical weather prediction at the National Meteorological Center. *Bull. Amer. Meteor. Soc.*, 71, 1410-1428.

Kim, S. C., J. Chen, and W. A. Shaffer, 1996: An operational forecast model for extratropical storm surges along the U. S. east coast. *Preprints, Conf. on Oceanic and Atmospheric Prediction*, Atlanta, GA, Amer. Meteor. Soc. 281-286.

U.S. Department of Commerce, March 1, 1998: Standard Hydrometeorological Exchange Format, Version 1.3, *Weather Service Hydrology Handbook No. 1*, NOAA/NWS, 65 pp.

Vallee, D. R., and J. Notchey, 2001: "Event-Driven" hydrologic service backup utilizing the WFO Hydrologic Forecast System, *Eastern Region AWIPS Technical Note No. 4.3-34*, 7 pp.