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Flood-Inundation Maps for the Suncook River in Epsom, Pembroke, Allenstown, and Chichester, New Hampshire

Pamphlet to accompany

Scientific Investigations Map 3196

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photograph looking downstream at the Suncook River avulsion channel through the sand pit, Epsom, New Hampshire.

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By Robert H. Flynn, Craig M. Johnston, and Laura Hayes

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

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Flood-Inundation Maps for the Suncook River in Epsom, Pembroke, Allenstown, and Chichester, New Hampshire

By Robert H. Flynn, Craig M. Johnston, and Laura Hayes

Abstract

Digital flood-inundation maps for a 16.5-mile reach of the Suncook River in Epsom, Pembroke, Allenstown, and Chichester, N.H., from the confluence with the Merrimack River to U.S. Geological Survey (USGS) Suncook River streamgage 01089500 at Depot Road in North Chichester, N.H., were created by the USGS in cooperation with the New Hampshire Department of Safety, Division of Homeland Security and Emergency Management. The inundation maps presented in this report depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at the USGS streamgage at Suncook River at North Chichester, N.H. (station 01089500). The current conditions at the USGS streamgage may be obtained on the Internet (*http://waterdata.usgs.gov/nh/nwis/uv/?site_no=01089500&PARAmeter_cd=00065,00060*). The National Weather Service forecasts flood hydrographs at many places that are often collocated with USGS streamgages. Forecasted peak-stage information is available on the Internet at the National Weather Service (NWS) Advanced Hydrologic Prediction Service (AHPS) flood-warning system site (*http://water.weather.gov/ahps/*) and may be used in conjunction with the maps developed in this study to show predicted areas of flood inundation.

These maps along with real-time stream stage data from the USGS Suncook River streamgage (station 01089500) and forecasted stream stage from the NWS will provide emergency management personnel and residents with information that is critical for flood-response activities, such as evacuations, road closures, disaster declarations, and post-flood recovery. The maps, along with current stream-stage data from the USGS Suncook River streamgage and forecasted stream-stage data from the NWS, can be accessed at the USGS Flood Inundation Mapping Science Web site *http://water.usgs.gov/osw/flood_inundation/*.

Introduction

The towns of Epsom, Pembroke, Allenstown, and Chichester, New Hampshire (N.H.), (fig. 1) are rural communities with estimated populations of 4,609, 7,344, 4,957, and 2,583, respectively, in 2009 (New Hampshire Employment Security, Economic and Labor Market Information Bureau, 2010a–d). These towns have experienced severe flooding numerous times, most notably in 1936, 2006, 2007, and 2010. Flooding of the Suncook River and several tributaries (Little Suncook River, Leighton Brook, and Bear Brook) caused damage to property and infrastructure along the river. Flood plains within these towns are moderately developed and contain a mix of residential and commercial structures.

Prior to 2011 town officials relied on several information sources (all of which are available on the Web) to make decisions on how best to alert the public and mitigate flood damages. One source is the Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS) for Epsom, Pembroke, Allenstown, and Chichester, N.H. (U.S. Department of Housing and Urban Development Federal Insurance Administration, 1978a–d). A second source of information is the U.S. Geological Survey (USGS) streamgage, Suncook River at Depot Road in North Chichester, N.H. (station 01089500; table 1). Data on current and historical water levels (stage) are available for this streamgage. A third source is the National Weather Service (NWS) forecasts of flood hydrographs showing peak stage at the USGS streamgage. These forecasts are available through the NWS Advanced Hydrologic Prediction Service (AHPS) site (*http://water.weather.gov/ahps/*). Although USGS current stage and NWS forecast stage information is useful for residents in the immediate vicinity of the streamgage, it is of limited use to residents farther upstream or downstream because the water-surface elevation is not constant along the entire stream channel. Also, FEMA and state emergency management mitigation teams or property owners typically lack information related to the depth of flood waters other than near USGS streamgages or NWS flood-forecast points. To provide information on floods in areas downstream from the USGS streamgage, the USGS, in cooperation with the New Hampshire Department of Safety, Division of Homeland Security and Emergency Management, conducted a study to produce digital flood-inundations maps for a 16.5-mile stretch of the Suncook River. These digital flood-inundation maps show flood-water extent and depth on the land surface and are tied to USGS and NWS flood forecast sites to enable officials to make

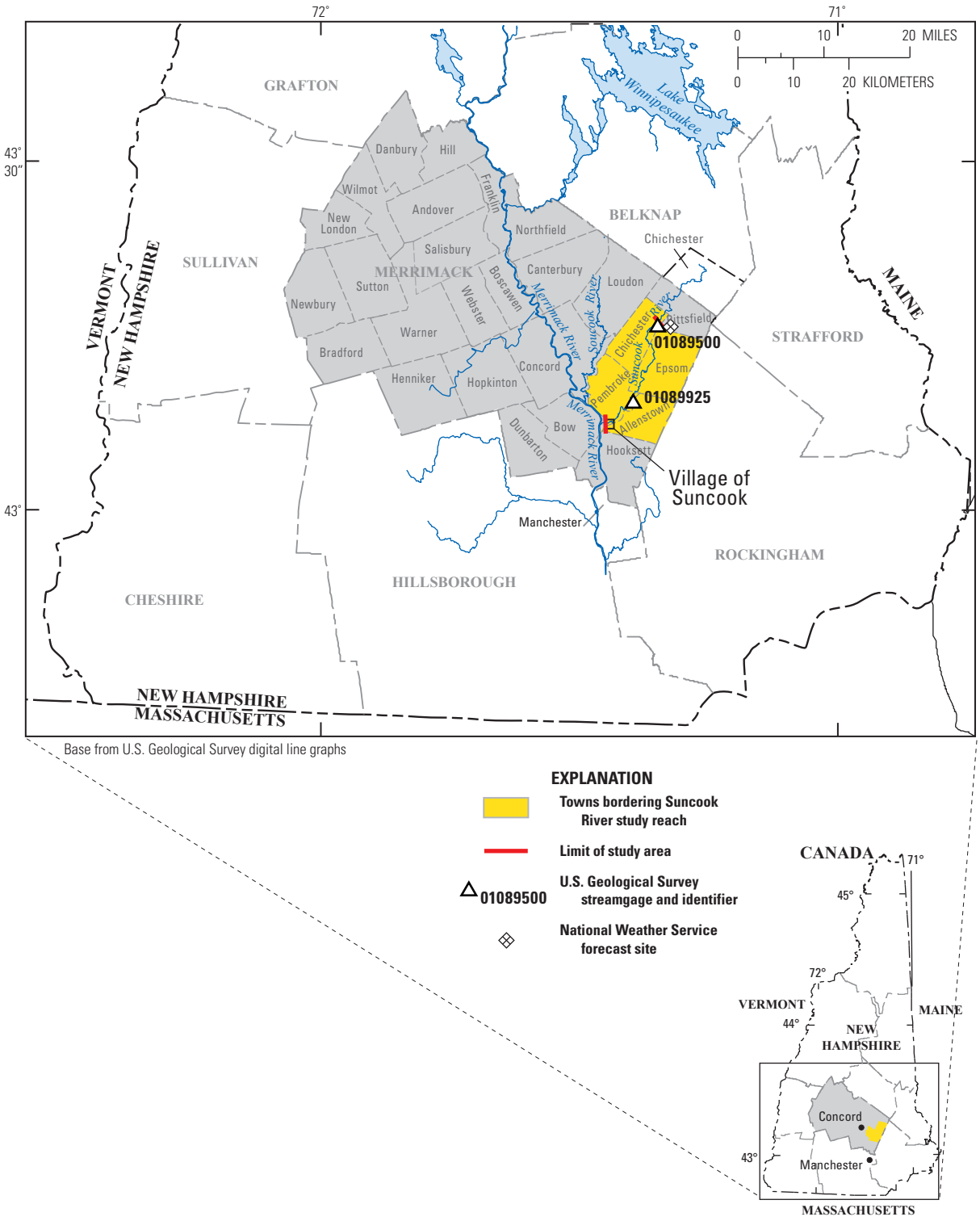

Figure 1. Location of study reach for the Suncook River, National Weather Service forecast site, and U.S. Geological Survey streamgages, Suncook River, New Hampshire.

Table 1. Description of U.S. Geological Survey streamgage, Suncook River at Depot Road, North Chichester, New Hampshire.

[mi^2, square miles; ft, feet]

Station name	Station number	Drainage area (mi^2)	Latitude	Longitude	Period of record	Maximum recorded elevation (stage) at gage (ft above gage datum) and date
Suncook River at Depot Road in North Chichester, N.H.	01089500	154.4	N 43°15'24"	W 71°22'12"	May 1918 to September 1920, June 1921 to November 1927, November 1928 to September 1970, November 2007 to 2011	15.97 ft on April 17, 2007

timely operational and public safety decisions during floods. The flood-inundation maps show estimated flood-inundated areas overlaid on high-resolution, georeferenced, aerial photographs of the study area for each of the water-surface profiles generated by the HEC-RAS hydraulic model.

Purpose and Scope

The purpose of this report is to describe the development of flood-inundation maps for the Suncook River at Epsom, Pembroke, Allenstown, and Chichester, N.H. The maps and other flood information are available on the USGS Flood Inundation Mapping Science Web site. Internet users can select estimated inundation maps that correspond closely to (1) current stages at the USGS streamgage, (2) the NWS forecasted peak stage, and (3) other desired stream stages.

The scope of the study was limited to the Suncook River between its confluence with the Merrimack River and the USGS streamgage 01089500 at Suncook River at Depot Road in North Chichester, N.H. Tasks specific to development of the maps were the (1) collection of topographic/bathymetric data and geometric data (for structures/bridges) throughout the study reach, (2) determination of energy-loss factors (roughness coefficients) in the stream channel and flood plain and collection of steady-flow data, (3) computation of water-surface profiles using the U.S. Army Corps of Engineers HEC–RAS computer model, (4) production of flood-inundation maps at various stream stages using the U.S. Army Corps of Engineers HEC–GeoRas computer program and a geographic information system (ArcGIS), and (5) development by USGS of a Web interface that links to USGS real-time streamgage information and NWS forecasted peak stage to facilitate the display of user-selected flood-inundation maps on the Internet.

Maps were produced for water levels referenced to the water-surface elevation (stage) at the USGS streamgage at Suncook River at Depot Road in North Chichester, N.H.; the water-surface elevations ranged from the NWS-determined "flood stage" of 7.0 ft to the water-surface elevation (stage) of the 0.2-percent annual exceedance probability flow at 18.0 ft, at the Suncook River streamgage.

Suncook River at N.H. 28, near Suncook, N.H., streamgage number 01089925 was installed in August of 2011. This streamgage records stage only, and data from this streamgage were not used in this study. The location of streamgage on the figures and map sheets is for informational purposes only.

Study Area Description

The Suncook River is in south-central New Hampshire in the New England physiographic province, New England Upland physiographic section. The drainage areas range from 154.4 mi^2 for the Suncook River at the North Chichester streamgage to 255.7 mi^2 for the study reach downstream extent at the Suncook River confluence with the Merrimack River. The river's headwaters originate in Belknap County, south of Lake Winnipesaukee, and the river flows in a generally southward direction for approximately 39 miles. There are three major tributaries to the Suncook River in the study area: Bear Brook, Little Suncook River, and Leighton Brook. The basin terrain is moderately hilly. The study reach is approximately 16.5 mi long and has an average top-of-bank channel width of about 282 ft and an average channel slope of 9.1 ft/mi. Although the land contiguous to the study reach is primarily forest or cropland, the basin is being developed with new houses and commercial businesses. The cumulative population for the four towns in the study area has increased 7.83 percent to 19,493 between 2000 and 2009 (New Hampshire Employment Security, Economic and Labor Market Information Bureau, 2009a–d). Population and land-use information for each of the towns in the study area are presented in table 2. Along the study reach, there are five major roads, seven bridges, and six dams that cross the channel and the adjacent flood plain.

Previous Studies

The current FISs for Epsom, Pembroke, Allenstown, and Chichester (U.S. Department of Housing and Urban Development Federal Insurance Administration,1978a–d) were completed by Hamilton Engineering Associates, Inc., and Anderson-Nichols and Co. in 1977 and 1978, respectively. Those studies provided information on the 0.2-, 1-, 2-, and 10-percent annual exceedance probability water-surface profiles and associated flood-plain maps for the Suncook River, Little Suncook River, and Sanders Brook. Estimates of the peak discharges for the 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent annual exceedance probability floods along the Suncook River were described in Flood Study of the Suncook River in Epsom, Pembroke, and Allenstown, New Hampshire, 2009 (Flynn, 2010). Estimates of the peak discharge with a 1-percent annual exceedance probability along the Suncook River are shown in table 3. The peak discharge with a 1-percent annual exceedance probability at the Suncook River streamgage (9,820 ft^3/s) corresponds to an elevation of 15.34 ft referenced to the gage datum.

Constructing Water-Surface Profiles

The water-surface profiles used to produce the flood-inundation maps in this study were computed using HEC–RAS, version 4.1.0 (U.S. Army Corps of Engineers, 2010). HEC–RAS is a one-dimensional step-backwater model used

Table 2. Miscellaneous town information along study reach, Suncook River, New Hampshire.

[Data from the New Hampshire Employment Security, Economic and Labor Market Information Bureau (2009a–d); mi^2, square miles; %, percent]

Characteristic	Town			
	Epsom	Pembroke	Allenstown	Chichester
Land area (mi^2)	34.5	22.6	20.5	21.2
2009 Population density	133.6	324.9	241.8	121.8
2009 Residential land (%)	85.6	78.3	82.5	85.6
2009 Commercial land (%)	12.6	15.9	14.3	13.0
2009 Public utilities and other land use (%)	1.8	5.8	3.2	1.4
2000 Population	4,051	6,917	4,854	2,259
2009 Population	4,609	7,344	4,957	2,583
2000–2009 Population percent increase	13.8	6.2	2.1	14.3

Table 3. 1.0-Percent annual exceedance probability peak-discharge estimates, drainage areas, and percentage of total discharge for selected locations on the Suncook River, New Hampshire.

[Data from Flynn (2010); mi^2, square miles; ft^3/s, cubic feet per second]

Location on Suncook River	Drainage area (mi^2)	Estimated peak discharge (ft^3/s)	Percentage of total discharge
At Suncook River streamgage 01089500	154.4	9,820	62
At U.S. Route 4	161.2	10,200	65
Downstream from Little Suncook River	200.9	12,600	80
At Short falls Road bridge	210.1	13,100	83
Upstream from Bear Brook	219.3	13,700	87
Downstream from Bear Brook	236.4	14,700	93
At U.S. Route 28 bridge (site of new USGS streamgage 01089925)	240.1	14,900	94
At U.S. Route 3 bridge	255.2	15,700	99
At confluence with Merrimack River	255.7	15,800	100

to simulate water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options. The HEC—RAS analysis for this study was completed using the steady-state flow computation option.

Hydrologic and Steady-Flow Data

The hydrologic network in the study area consists of one streamgage (fig. 1; table 1). USGS streamgage 01089500, Suncook River at Depot Road in North Chichester, Merrimack County, was active from 1919 to 1920, 1922 to 1927, 1929 to 1970. In November of 2007, the Suncook River streamgage was reactivated. The water level (stage) is measured continuously at the streamgage, and a continuous record of streamflow is computed. All water-surface elevations are referenced to gage datum and to North American Vertical Datum of 1988 (NAVD 88). The gage is equipped with a satellite radio transmitter that allows data to be transmitted routinely to the Internet within an hour of collection.

Steady-flow data consist of flow regime, boundary conditions (normal depth and streamgage rating-curve values), and peak discharge. The steady-flow data for the study reach were determined for the Suncook River streamgage 01089500 using discharge values with known stages obtained from streamflow measurements and stage-discharge relations (Flynn, 2010). In addition, after the flood of April 16–18, 2007, high-water-mark data were collected at the then inoperative streamgage site and downstream to the Suncook River's confluence with the Merrimack River (Flynn, 2010 and 2008). These high-water-mark data were used for HEC–RAS model calibration.

Topographic/Bathymetric Data

Channel cross sections were developed from USGS field surveys that were conducted in the summer of 2008. These cross sections, which provide detailed valley and channel elevation data, were obtained using a total station surveying instrument with elevations determined using closed level-loop surveying techniques from either a known reference datum or from a reference datum established using a Leica System 1200 Global Positioning System (GPS) with a 3-millimeter (mm; 0.01-ft) horizontal accuracy and 10-mm (0.03-ft) vertical accuracy in static mode (Leica Geosystems, 2008). In addition, some cross-sectional data were collected between the Short Falls Road bridge and the Buck Street dam using a GPS in conjunction with an Acoustic Doppler Current Profiler (ADCP) (Flynn, 2008).

Various man-made drainage structures (bridges, culverts, roadway embankments, and dams) along the stream affect or have the potential to affect water-surface elevations during floods. To properly account for these features in the HEC–RAS model, structural dimensions for seven bridges and six dams were measured and surveyed in the field concurrently with the stream-channel surveys.

Energy Loss Factors

Field observations were used to select initial (pre-calibration) Manning's roughness coefficients ("n" values) for energy (friction) loss calculations. The final Manning's n values used ranged from 0.02 to 0.09 for the main channel and 0.02 to 0.12 for the overbank areas modeled.

Model Calibration and Performance

The HEC-RAS hydraulic model was calibrated to the most current stage-discharge relation at the Suncook River streamgage and to high-water marks from the flood of April 16–18, 2007 (table 4). The estimated peak discharge from high-water mark data for the April 16–18, 2007, flood was 10,600 ft^3/s (Flynn, 2008) with an annual exceedance probability of 0.2- to 1-percent and an estimated stage at the streamgage of 15.97 ft, local datum (344.75 ft, NAVD 88). The estimated peak discharge from high-water marks for the flood of May 13–16, 2006, is 7,600 ft^3/s (Olson, 2007), the annual exceedance probability is 2 to 4 percent, and the estimated stage at the streamgage is 13.55 ft, local datum (342.33 ft, NAVD 88). The mean absolute difference between the field-measured high-water marks (HWM) of the May 2007 flood, which are rated as "good," and simulated water levels at the same locations (as modeled in HEC–RAS) is 0.36 ft (4.3 in.). Discrepancies between the model output and the field-collected HWM data are due to model assumptions and (or) interpretation of the location of the HWM in the field.

Development of Water-Surface Profiles

Profiles were developed for 10 stages from the NWS "flood stage" of 7 ft to the 0.2-percent annual exceedance probability water-surface elevation (stage) of 18 ft, as referenced to the Suncook River streamgage (station 01089500). These 10 water-surface profile flood stages are 7, 9, 11, 12, 13, 14, 15, 16, 17, and 18 feet. Discharges for profiles of all 10 stages from the NWS "flood stage" of 7 ft to 18 ft, as referenced to the Suncook River streamgage (station 01089500), at locations downstream from the streamgage are presented in table 5. Discharges for the 1- and 0.2-percent annual exceedance probability flood profiles are presented in Flynn (2010).

Inundation Mapping

Flood-inundation maps were created in a geographic information system (GIS) by combining the water-surface profiles and digital-elevation (DEM) model data. The DEM data were derived from 1-meter (3.28-ft) horizontal resolution Light Detection and Ranging (LiDAR) data (available for the downstream half of the study reach) with a vertical accuracy

Table 4. Comparison of hydraulic-model output and surveyed high-water mark elevations from the flood of April 16–18, 2007, Suncook River, New Hampshire.

[NAVD 88, North American Vertical Datum of 1988; mi, mile; ft, feet]

River station (mi)	Latitude (N, decimal degrees)	Longitude (W, decimal degrees)	High-water mark elevation (ft, NAVD88)	Simulated water-surface elevation (ft, NAVD88)	Elevation difference (ft)
16.44	43.25667	71.3700	344.37	344.5	0.13
13.30	43.22705	71.35659	337.08	337.4	0.32
9.81	43.20235	71.38183	309.22	309.29	0.07
9.76	43.20207	71.383	308.06	308.31	0.25
9.32	43.19566	71.38341	307.5	307.37	-0.13
8.56	43.18979	71.38192	305.53	305.45	-0.08
7.05	43.17599	71.39454	302.81	302.74	-0.07
6.81	43.17284	71.39644	302.03	302.24	0.21
6.67	43.17179	71.39785	301.71	301.74	0.03
6.10	43.16594	71.40455	300.82	301.26	0.44
5.68	43.16063	71.40569	299.22	300.59	1.37
5.50	43.15884	71.4063	296.54	295.42	-1.12
3.55	43.14331	71.42523	292.41	292.44	0.03
2.35	43.1366	71.43085	291.04	291.57	0.53

of 0.001 meter (0.03 in), obtained from U.S. National Geospatial-Intelligence Agency (2011), in combination with 1- and 4-ft contour-interval data created from aerial photogrammetry collected in May 2007 (Eastern Topographics, 2007) and in April 2008 (Eastern Topographics, 2008). The 1-ft contour-interval data (Eastern Topographics, 2007) were created for the reach of the Suncook River from U.S. Route 4 to approximately 0.25 mi downstream from the Short Falls Road bridge. These 1-ft contour-interval data extend 660 ft on either side of this reach. The 4-ft contour-interval data (Eastern Topographics, 2008) were created for the reach of the Suncook River from the Short Falls Road bridge downstream to the confluence with the Merrimack River and from the U.S. Route 4 bridge upstream to the Suncook River streamgage. These 4-ft contour-interval data extend 1,000 ft on either side of the Suncook River. In flood-inundation areas beyond the extent of the available LiDAR and 1- and 4-ft contour-interval data, 10-ft contour interval USGS 15-minute quadrangle topographic Digital Raster Graphics (DRG) produced at a scale of 1:24,000 and referenced to the horizontal datum of North American Datum of 1983 (NAD 83) and the vertical datum of National Geodetic Vertical Datum of 1929 (NGVD 29) (U.S. Geological Survey, 1967a-b, 1968) were used to delineate the extent of flooding. The horizontal accuracy of the DRGs is half of the contour interval (±5 ft). The base maps for the delineation of the flood-inundation areas were created using black and white aerial photographic imagery collected by Eastern Topographics (2007) in May 2007 (post-avulsion; Flynn, 2008) along the Suncook River and 1-ft-resolution color aerial photographic imagery of southeastern New Hampshire (New Hampshire Department of Transportation, 2006) collected for the New Hampshire Department of Transportation (NHDOT) in May 2005 (pre-avulsion) for areas outside the extent of the Eastern Topographics (2007) imagery.

Estimated flood-inundation boundaries for each simulated profile were developed with HEC–GeoRAS software (U.S. Army Corps of Engineers, 2009). HEC–GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS by using a graphical user interface (Whitehead and Ostheimer, 2009). The interface allows the preparation of geometric data for import into HEC–RAS and processes simulation results exported from HEC–RAS (U.S. Army Corps of Engineers, 2010). The HEC–GeoRAS results were then modified to ensure a hydraulically reasonable transition of the boundary between modeled cross sections relative to the contour data for the land surface (Whitehead and Ostheimer, 2009). Based on least accurate data set of the 4-ft contour interval, the resulting inundation maps have a vertical accuracy of about 0.2 ft (2.4 in).

The inundation maps depict estimates of the areal extent of flooding corresponding to selected water levels (stages) at the USGS Suncook River streamgage. The areal extent of flooding corresponding to selected stages at the streamgage was, in some areas, beyond the available LiDAR or 1- and 4-ft contour-interval data. Therefore, the aerial extent of flooding in these locations was determined using USGS 15-minute quadrangle topographic Digital Raster Graphics (DRG) maps.

Table 5. Stream stages (elevations) with corresponding estimated discharges at selected locations on the Suncook River, New Hampshire, for 10 flood-inundation HEC–RAS water-surface profiles.

[NAVD88, North American Vertical Datum of 1988; mi^2, square miles; ft^3/s, cubic feet per second]

Location	Drainage area (mi^2)	Stage, in feet above gage datum (elevation, in feet, NAVD 88)									
		7.00 (335.78)	9.00 (337.78)	11.00 (339.78)	12.00 (340.78)	13.00 (341.78)	14.00 (342.78)	15.00 (343.78)	16.00 (344.78)	17.00 (345.78)	18.00 (346.78)
		Discharge (ft^3)									
USGS Suncook River Streamgage 01089500	154.4	1,240	1,960	3,380	4,600	5,900	7,300	9,000	10,600	12,800	15,300
At U.S. Route 4	161.2	1,290	2,040	3,520	4,790	6,140	7,600	9,370	11,040	13,330	15,930
Downstream of Little Suncook River	200.9	1,590	2,510	4,330	5,890	7,560	9,350	11,530	13,580	16,390	19,600
At Short Falls Road	210.1	1,660	2,620	4,510	6,150	7,880	9,750	12,020	14,160	17,100	20,440
Upstream of Bear Brook	219.3	1,730	2,730	4,700	6,400	8,210	10,150	12,520	14,740	17,800	21,280
Downstream of Bear Brook	236.4	1,850	2,930	5,040	6,870	8,810	10,890	13,430	15,820	19,100	22,830
At U.S. Route 28 bridge (site of new USGS streamgage 01089925)	240.1	1,880	2,970	5,120	6,970	8,930	11,050	13,630	16,050	19,380	23,170
At U.S. Route 3 bridge	255.2	1,990	3,140	5,420	7,380	9,460	11,710	14,430	17,000	20,530	24,540
At mouth of Suncook River	255.7	1,990	3,150	5,430	7,390	9,480	11,730	14,460	17,030	20,570	24,580

Availability of Suncook River, New Hampshire, Flood-Inundation Maps

A USGS Flood Inundation Mapping Science World Wide Web portal (*http://water.usgs.gov/osw/flood_inundation/*) has been established by the USGS to provide estimated flood-inundation information to the public. These maps show the aerial extent of flooding, as well as inundation area depth of flooding, and are available in several commonly used electronic file formats that can be downloaded from that portal. Each stream reach displayed on the Web site contains links to National Water Information System graphs of the current stage and the streamflow at USGS Suncook River streamgage to which the inundation maps are referenced. A link also is provided to the NWS Advanced Hydrologic Prediction Service (AHPS) site (*http:/water.weather.gov/ahps/*) so that the user can obtain information on forecasted peak stage. The estimated flood-inundation maps are displayed in sufficient detail to note the extent of flooding with respect to individual structures so that preparations for flooding and decisions for emergency response can be performed efficiently.

Disclaimer for Flood-Inundation Maps

Inundated areas shown should not be used for navigation, regulatory, permitting, or other legal purposes. The USGS provides these maps "as-is" for a quick reference, emergency planning tool but assumes no legal liability or responsibility resulting from the use of this information.

Uncertainty Associated with Inundation Maps

Although the flood-inundation maps represent the boundaries of inundated areas with a distinct line, some uncertainty is associated with these maps. The flood boundaries shown were estimated based on water stages (water-surface elevations) and streamflows at USGS Suncook River streamgage 01089500. Water-surface elevations along the stream reach were estimated by steady-state hydraulic modeling, assuming unobstructed flow, and using discharges and hydrologic conditions anticipated at USGS streamgage 01089500. The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing as of July 2011. Since these flood-inundation maps were prepared, the Buck Street dams (Sheets 1–20) have been removed (October 2011). Flood-inundation areas and elevations on these maps in the vicinity of the dams may not now reflect current conditions. Unique meteorological factors (timing and distribution of precipitation) may cause actual discharges along the modeled reach to vary from those values assumed during a flood, which may lead to deviations in the water-surface elevations and inundation boundaries shown. Additional areas may be flooded due to unanticipated conditions such as changes in the streambed elevation or roughness, backwater into major tributaries along a main stem river, or backwater from localized debris or ice jams. The accuracy of the floodwater extent portrayed on these maps will vary with the accuracy of the digital elevation model used to simulate the land surface. Elevation data were generated from aerial photogrammetry and LiDAR, and as such, the below-water-surface elevations are approximations; therefore, flood-inundation map depths in the river channel may not be accurate.

If this series of flood-inundation maps will be used in conjunction with National Weather Service (NWS) river forecasts, the user needs to be aware of additional uncertainties that may be inherent or factored into NWS forecast procedures. The NWS uses forecast models to estimate the quantity and timing of water flowing through selected stream reaches in the United States. These forecast models (1) estimate the amount of runoff generated by precipitation or snowmelt, (2) simulate the movement of floodwater as it proceeds downstream, and (3) predict the flow and stage (water-surface elevation) for the stream at a given location (AHPS forecast point) throughout the forecast period (every 6 hours and 3 to 5 days out in many locations). For more information on AHPS forecasts, please see *http://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf*.

Summary

A series of flood-inundation maps were developed using estimated flood profiles for a 16.5-mile reach of the Suncook River between its confluence with the Merrimack River and the USGS streamgage at Suncook River at Depot Road in North Chichester, N.H. The study was conducted by the USGS in cooperation with the New Hampshire Department of Safety, Division of Homeland Security and Emergency Management. These maps, available at a USGS Web portal, in conjunction with the real-time stage data from the USGS streamgage at Suncook River (station 01089500) and National Weather Service flood-stage forecasts, can help to guide the general public in taking individual safety precautions and provide city officials with a tool to efficiently manage emergency flood operations and flood-mitigation efforts.

In this study, inundation maps were computed for the Suncook River study reach using the U.S. Army Corps of Engineers HEC–RAS and HEC–GeoRAS programs to compute water-surface profiles and to delineate estimated flood-inundation areas for selected stream stages. The model was calibrated using the most current stage-discharge relations at the Suncook River at North Chichester, N.H., streamgage and documented high-water marks from the flood of May 2007. The hydraulic model was then used to determine 10 water-surface profiles for flood stages at 7, 9, 11, 12, 13, 14, 15, 16, 17, and 18 feet, referenced to the Suncook River streamgage datum and ranging from less than bankfull flow (the flow associated with the incipient elevation on the bank where flooding begins which is approximately the 50-percent annual exceedance probability) to the 0.2-percent annual exceedance

probability flood which is greater than the highest recorded water level at the streamgage. The water-surface elevations for the 1- and 0.2-percent annual exceedance probabilities (also referred to as the 100- and 500-year recurrence interval floods) are 15.34 ft and 18 ft, respectively, at the streamgage.

The simulated water-surface profiles were combined with a geographic information system digital elevation model (DEM) to create inundation area maps. The DEM was derived from Light Detection and Ranging (LiDAR) data having a 0.03-ft vertical and less than 3.28-ft horizontal resolution in conjunction with 1-ft and 4-ft contour-interval aerial photogrammetric data having a ±0.2-ft vertical and ±0.2-ft horizontal accuracy (Eastern Topographics, 2007 and 2008) in order to delineate the flooded areas for each profile. Flood-inundation maps were developed showing the estimated flood-inundation areas overlaid on high-resolution, georeferenced, aerial photographs of the study area for the stream stages of 7 ft to 18 ft, local datum, at the Suncook River streamgage. The estimated inundation areas were shaded to give a general indication of depth of water at any point. In flood-inundation areas beyond the extent of the available LiDAR and 1-ft and 4-ft contour-interval data, 10-ft contour-interval USGS 15-minute quadrangle topographic Digital Raster Graphics (DRG) produced at a scale of 1:24,000 and referenced to the horizontal datum North American Datum of 1983 (NAD 83) and the vertical datum National Geodetic Vertical Datum of 1929 (NGVD 29) were used to delineate the extent of flooding. The horizontal accuracy of the Digital Raster Graphics is half of the contour interval (±5 ft).

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