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Flood Recovery Maps for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont, 2014

Scientific Investigations Report 2015–5056

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

Cover. One-percent annual exceedance probability flood boundaries on the White River in the Rochester, Vermont, vicinity.

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SALLY JEWELL, Secretary

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
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)

Datum

Vertical coordinate information is referenced to (1) stage, the height above an arbitrary datum established at a streamgage, and (2) elevation, the height above 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 the distance above the vertical datum.

Flood Recovery Maps for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont, 2014

By Scott A. Olson

Abstract

From August 28 to 29, 2011, Tropical Storm Irene delivered rainfall ranging from about 4 inches to more than 7 inches in the White River Basin. The rainfall resulted in severe flooding throughout the basin and significant damage along the White River and Tweed River. In response to the flooding, the U.S. Geological Survey, in cooperation with the Federal Emergency Management Agency, conducted a new flood study to aid in the flood recovery and restoration. This flood study includes a 20.7-mile reach of the White River from the downstream end at about 2,000 feet downstream from the State Route 107 bridge in the Village of Bethel, Vermont, to the upstream end at about 1,000 feet upstream from the River Brook Drive bridge in the Village of Rochester, Vt., and a 7.9-mile reach of the Tweed River from its mouth in Stockbridge, Vt., to the confluence of the West and South Branches of the Tweed River and continuing upstream on the South Branch Tweed River to the Pittsfield, Vt., town line.

This report presents water-surface elevations determined for the study reaches using the U.S. Army Corps of Engineers one-dimensional step-backwater Hydrologic Engineering Center River Analysis System model, also known as HEC–RAS. The water-surface elevations were determined for floods having a 10-, 4-, 2-, 1-, and 0.2-percent annual exceedance probability (AEP) and for the floodway.

Eighteen high-water marks from Tropical Storm Irene were available along the studied reaches. The discharges in the Tropical Storm Irene HEC–RAS model were adjusted so that the resulting water-surface elevations matched the high-water mark elevations along the study reaches. This allowed for an estimation of the water-surface profile throughout the study area resulting from Tropical Storm Irene. From a comparison of the estimated water-surface profile of Tropical Storm Irene to the water-surface profiles of the 1- and 0.2-percent AEP floods, it was determined that the high-water elevations resulting from Tropical Storm Irene exceeded the estimated 1-percent AEP flood throughout the White River and Tweed River study reaches and exceeded the estimated 0.2-percent AEP flood in 16.7 of the 28.6 study reach miles. The simulated water-surface profiles were then combined with a geographic information system digital elevation model derived from light detection and ranging (lidar) data having a 18.2-centimeter vertical accuracy at the 95-percent confidence level and 1-meter horizontal resolution to delineate the area flooded for each water-surface profile.

Introduction

During August 28–29, 2011, record-breaking rainfall from Tropical Storm Irene resulted in extensive flooding across much of Vermont. In the White River and Tweed River valleys, the flooding resulted in extensive property damage and destruction of transportation corridors. At the White River at West Hartford, Vt., U.S. Geological (USGS) streamgage 01144000,[1] the discharge reached 90,100 cubic feet per second (ft^3/s)—the second largest discharge ever recorded at the streamgage in its 96 years of data collection. The discharge at the streamgage was determined to have an annual exceedance probability (AEP) of 1 to 0.2 percent (Olson and Bent, 2013).

In response to the flooding, President Obama made a presidential declaration of a major disaster (Federal Emergency Management Agency [FEMA]-4022-DR) for the State of Vermont under the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act; 42 U.S.C. §§5121–5207). As an element of addressing the disaster declaration, the USGS, in cooperation with FEMA, has produced a series of flood recovery maps. These maps show the areal extent of flooding from Tropical Storm Irene, as well as estimated flood boundaries, resulting from floods with 10-, 4-, 2-, 1-, and 0.2-percent AEP, and the floodway. The maps cover selected reaches of the White River and the Tweed River. The reaches were selected because of the significant flood damage that occurred and the availability of digital elevation models developed from lidar data. These recovery maps (appendix 1) are for advisory purposes and do not supersede the effective Flood Insurance Rate Maps (FIRMs) (Federal Emergency Management Agency, 2007, 2008).

[1]The White River at West Hartford, Vermont, streamgage is outside the study area and not displayed in figure 1 or appendix 1.

Purpose and Scope

This report describes the development of a series of estimated flood recovery maps for the White River at Bethel, Stockbridge, and Rochester, Vt., and the Tweed River at Stockbridge and Pittsfield,Vt. (fig. 1). The study reaches include a 20.7-mile (mi) reach of the White River from the downstream end at about 2,000 feet (ft) downstream from the State Route 107 Bridge[2] in the Village of Bethel, Vt., to the upstream end at about 1,000 ft upstream from the River Brook Drive bridge in the Village of Rochester,Vt., and a 7.9-mi reach of the Tweed River from its mouth in Stockbridge, Vt., to the confluence of the West and South Branches of the Tweed River and continuing upstream on the South Branch Tweed River to the Pittsfield, Vt., town line. The Tweed River study reach includes the Tweed River and South Branch Tweed River. The flood recovery maps show the effects from the flood of Tropical Storm Irene, as well as flood boundaries resulting from floods with 10-, 4-, 2-, 1-, or 0.2-percent AEP, and the floodway. The purpose of the maps is to provide local government and citizens with the best and most up-to-date information on flood hazards to aid in the rebuilding process.

Study Area Description

The White River and its tributary, the Tweed River, are in the Green Mountains of central Vermont. The drainage basins of both rivers are primarily forested, whereas the valleys often have agricultural and residential uses. Stockbridge, Vt., the location of the confluence of the two rivers, receives 46 inches of rain annually and has a mean annual high temperature of 54 degrees Fahrenheit (°F) and a mean annual low temperature of 31 °F (PRISM Group, 2012a, b, c).

Both rivers drain steep upland areas of relatively high elevations. The drainage area at the downstream end of the White River study reach is 408 square miles (mi^2). The basin has a mean elevation of 1,630 ft above the North American Vertical Datum of 1988 (NAVD 88); 78.7 percent of the basin is above 1,200 ft. The elevation of the river at the downstream end of the study reach is 510 ft, whereas many of the peaks and ridges along the western drainage divide exceed 3,000 ft. The drainage area at the downstream end the Tweed River study reach is 51.0 mi^2. The basin has a mean elevation of 1,830 ft NAVD 88; 88.5 percent of the basin is above 1,200 ft. The elevation at the downstream end of the study reach is 720 ft, whereas the headwaters of the basin exceed 3,000 ft in numerous locations.

The length of the White River study reach is 20.7 miles. The channel changes 312 ft in elevation over its course and has an average slope of 15 feet per mile (ft/mi). The downstream end of the reach is 2,000 ft downstream from the State Route 107 Bridge in the Village of Bethel, Vt., and the reach extends upstream through Stockbridge to about 1,000 ft upstream from the River Brook Drive bridge in the Village of Rochester, Vt. Within the study reach, the river is traversed by 3 state highway bridges, 5 local road bridges, and a concrete weir that was once used by the USGS to measure river discharge. Much of the White River study reach upstream from the confluence with the Tweed River has broad floodplains that serve agricultural purposes. Downstream from the confluence with the Tweed River, the White River has a much more incised channel with narrow or no floodplains until it enters the Town of Bethel and the floodplains once again broaden.

The length of the Tweed River study reach is 7.9 mi. The channel changes 383 ft in elevation over its course and has an average slope of about 49 ft/mi. The study reach extends from the Tweed River mouth, where the river drains into the White River, to the confluence of the West and South Branches of the Tweed River and continues upstream on the South Branch Tweed River to the Leigh Kelly Drive bridge in Pittsfield, Vt. Within the study reach, the river is traversed by 2 state highway bridges, 8 local road bridges, 2 private bridges, and 1 snowmobile trail bridge. The Tweed River has broad floodplains up to the confluence of the West and South Branches of the Tweed. As the study reach continues up the South Branch, the channel gradually steepens and the floodplains narrow until no floodplain exists and the river becomes a mountain stream.

Previous Studies

The Flood Insurance Study (FIS) for Windsor County, Vt. (FEMA, 2007), covers Bethel, Stockbridge, and Rochester, Vt. It is the effective FIS for those towns. The Windsor County FIS is a compilation of town FIS reports. The Bethel and Rochester, Vt., effective FISs were completed by the U.S. Army Corps of Engineers in 1990; Dufresne-Henry, Inc., completed the Stockbridge, Vt., FIS in 1985. The FIS for Rutland County, Vt. (FEMA, 2008), covers Pittsfield, Vt., and is the effective FIS for that town. The effective study for Pittsfield was completed by the U.S. Soil Conservation Service in 1991.

New hydrologic estimates were made and new hydraulic models were developed for this investigation. The results of this study are provided in this report and the flood recovery maps are for advisory purposes for the towns. The results and maps do not supersede the effective FISs or the FIRMs.

Creation of Flood Recovery Maps

Tasks specific to development of the flood recovery maps for the White River and Tweed River study reaches were (1) estimation of flood discharges at the 10-, 4-, 2-, 1-, and 0.2-percent AEPs, (2) collection of topographic and bathymetric data on cross sections and geometric data on structures and bridges along the study reaches,

[2]The State Route 107 bridge and other features and locations not shown in figure 1 can be found in appendix 1.

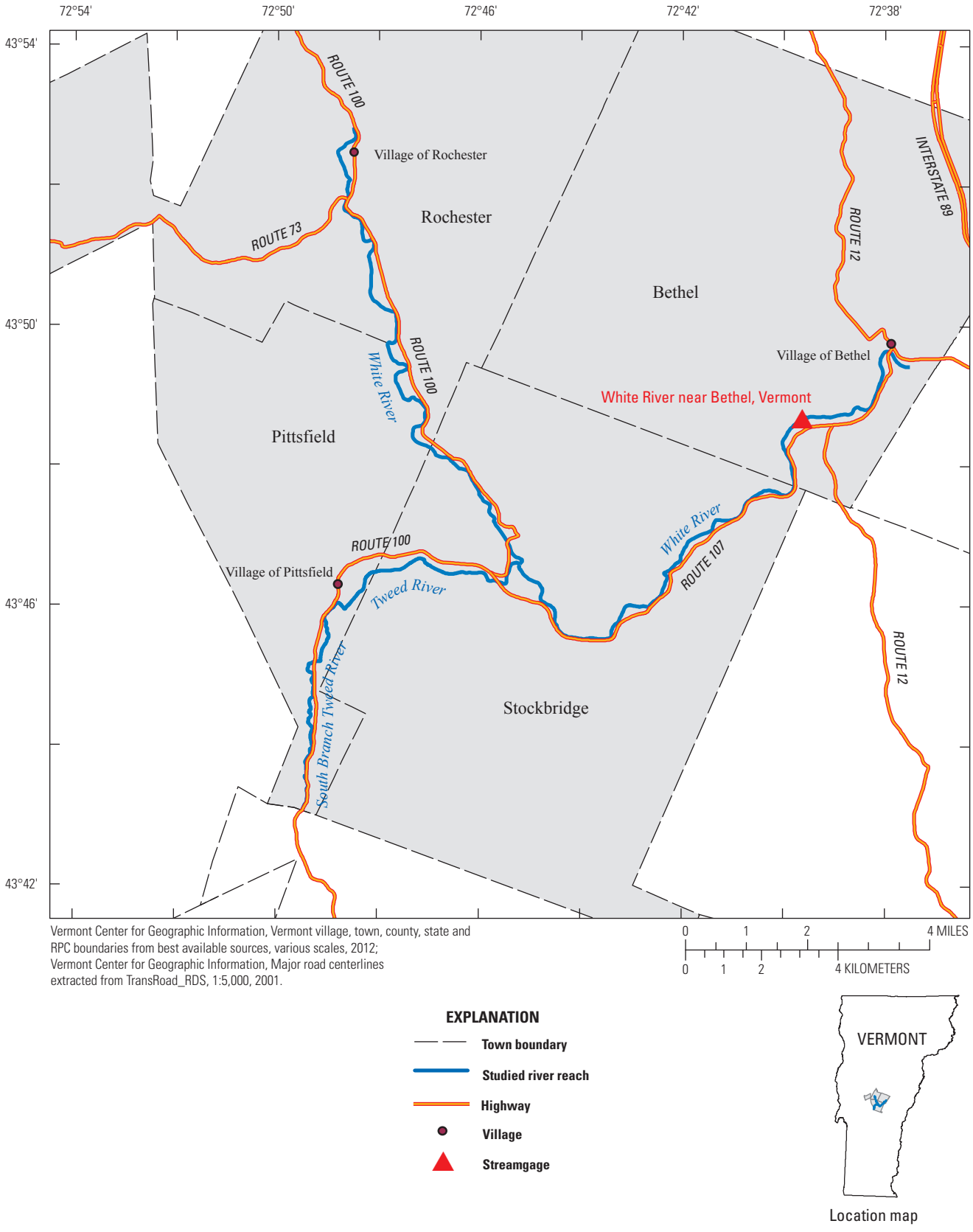

Figure 1. Location of the White and Tweed River study reaches in Bethel, Stockbridge, Pittsfield, and Rochester, Vermont.

(3) development of the hydraulic model for the study reaches and computation of the water-surface profiles for the flood discharges using the U.S. Army Corps of Engineers HEC–RAS computer program (U.S. Army Corps of Engineers, 2010), and (4) production of estimated flood recovery maps at the simulated water-surface profiles using the U.S. Army Corps of Engineers HEC–GeoRAS computer program (U.S. Army Corps of Engineers, 2012) and a geographic information system (GIS).

Estimation of Flood Discharges

Flood discharges at the 10-, 4-, 2-, 1-, and 0.2-percent AEPs were estimated for the White and Tweed Rivers study reaches for use in the HEC–RAS hydraulic model. On the White River, there are two streamgages where discharge has been measured. The first streamgage, 01144000, White River at West Hartford, Vt., is an active, continuously recording USGS streamgage, but it is downstream from the study reach. Streamgage 01144000 has a drainage area of 689 mi^2. The second streamgage, 01142000, White River near Bethel, Vt., is within the White River study reach, but it was discontinued in 1955. It has a drainage area of 240 mi^2. Recent flood frequency analyses were done for both streamgages by Olson (2014).

Weighting the at-site frequency curves with the results of regression equations, as explained in Olson (2014), lowered the discharges in frequency curves at both streamgages. Because weighting with the regression equations provided lower discharge results for the White River at both streamgages, it was decided that the additional regional information provided by the regression equations was not a good solution for these streamgages. Therefore, the at-site frequency curves were used unweighted. The discharges at each of the streamgages were interpolated and extrapolated using a constant linear relation of drainage area to discharge in logarithmic units. The relation took the form $(A_1 / A_2)^x = (Q_1 / Q_2)$, where A_1 and A_2 are the drainage areas of river locations 1 and 2, Q_1 and Q_2 are the flood discharges for a selected AEP at river locations 1 and 2, and x was found by solving the above equation with data from the two White River streamgages. The results are as shown in table 1.

The flood discharge for Tropical Storm Irene was 90,100 ft^3/s at streamgage 01144000, White River at West Hartford, Vt. (Olson and Bent, 2013). Using a trial-and-error technique, it was found that an exponent x equal to 0.510, along with the values for discharge and drainage area of the streamgage, applied to the equation above resulted in discharges that gave water-surface elevations from the hydraulic model that matched the Tropical Storm Irene high-water marks (Medalie and Olson, 2013). These discharges, which were used to simulate the flooding from Tropical Storm Irene, are shown in table 1.

No streamgage data were available for the Tweed River study reach. Extrapolating the White River discharges to

Table 1. Flood discharges used in the hydraulic model for the White River in West Hartford, Bethel, Stockbridge, and Rochester, Vermont.

[mi^2, square miles; ft^3/s, cubic feet per second; VT, Vermont]

Location on White River	Drainage area (mi^2)	Flood discharges (ft^3/s) for indicated annual exceedance probabilities (in percent)					Tropical Storm Irene discharge (ft^3/s)
		10	4	2	1	0.2	
x in $(A_1/A_2)^x = (Q_1/Q_2)$		0.534	0.550	0.561	0.577	0.615	0.510
1,000 feet upstream of River Brook Drive, Rochester, VT	71.4	10,300	13,200	15,800	18,300	25,300	28,400
Upstream of West Branch	79.7	10,900	14,100	16,800	19,500	27,000	30,000
Upstream of Breakneck Brook	130	14,200	18,400	22,000	25,900	36,500	38,500
Upstream of Tweed River	143	14,900	19,400	23,300	27,400	38,800	40,400
Upstream of Stony Brook	199	17,800	23,300	28,000	33,100	47,500	47,800
Upstream of Lilliesville Brook	228	19,200	25,100	30,200	35,800	51,600	51,300
At streamgage 01142000, White River near Bethel, VT	240	19,700	25,800	31,100	36,900	53,300	52,600
Upstream of Third Branch White River	271	21,000	27,600	33,300	39,600	57,400	56,000
Downstream of Third Branch White River	408	26,100	34,600	41,900	50,100	73,900	69,000
At streamgage 01144000, White River at West Hartford, VT	689	34,600	46,100	56,200	67,800	102,000	90,100

the drainage areas of the Tweed River resulted in discharges that were unreasonably large. Therefore, flood discharges for selected annual exceedence probabilities were determined using regression equations developed for rural, unregulated streams in Vermont (Olson, 2014). The resulting discharges are shown in table 2.

No discharge data were available for the Tweed River during Tropical Storm Irene. The discharges for Tropical Storm Irene were estimated by adjusting discharges in the hydraulic model so that the resulting water surface best fit the high-water marks. The discharges closely fit the log-linear drainage area relation $(A_1 / A_2)^x = (Q_1 / Q_2)$ with an x of 1.10. The resulting discharges were determined using this equation for six locations and are shown in table 2.

Topographic and Bathymetric Data

All elevation data used in this study are referenced to NAVD 88; all horizontal data are referenced to the North American Datum of 1983. Cross-section elevation data were obtained from a digital elevation model (DEM) that was derived from lidar data collected during April 2012 by Fugro Earthdata, Inc., of Frederick and Hagerstown, Maryland (Fugro EarthData, Inc., 2012a). The lidar data have a horizontal 18.2-centimeter (0.60-ft) vertical accuracy at the 95-percent confidence level and 1-meter (3.28-ft) horizontal resolution.

The lidar data were collected by Fugro Earthdata, Inc., for the Vermont Agency of Transportation; the lidar data were collected along state highways that were heavily damaged following Tropical Storm Irene. The data were collected in a 1,000-meter-wide corridor that was centered on the highways. A state highway runs along most the study reaches of the White and Tweed Rivers. In two locations, the state highway and the river diverge, and the lidar data do not cover the entire river valley. The first location is an 1,800-ft reach on the Tweed River from 2,410 to 4,210 ft downstream from the confluence of the West and South Branches of the Tweed River. This reach includes cross sections TY, TZ, and TAA as shown in appendix 1. The second location is a 1,485-ft reach on the White River from 1,180 to 2,665 ft downstream from the confluence of the Tweed and White Rivers. This reach includes cross sections WBI and WBJ. In these two reaches, the best available mapping was used for out-of-channel cross-section geometry and delineation of the flood boundaries, which was the 10-meter DEM (USGS, 2004).

Using HEC–GeoRAS—a set of procedures, tools, and utilities for processing geospatial data in ArcGIS—elevation data were extracted from the DEM for 233 cross sections. Because lidar data cannot provide ground elevations below the water surface of a stream, the channel segments of the cross sections were surveyed by USGS field crews from the New England Water Science Center during spring and summer 2013. The cross-sectional bathymetry data were collected by wading or sounding at 202 sections. For these sections, within-channel data were directly merged with the DEM data. For the other cross sections, the DEM data represented the within-channel elevations well because the channel was a steep, pool and riffle type channel.

A differential global positioning system (DGPS) with real-time kinematic (RTK) technology was used to derive horizontal locations and elevations at the surveyed cross sections. Nine determinations of elevations by RTK DGPS at benchmark locations were within 0.06 ft of the known elevations, an error range that exceeds the accuracy of the lidar data.

Table 2. Flood discharges used in the hydraulic model for the Tweed River and South Branch Tweed River in Stockbridge and Pittsfield, Vermont.

[mi², square miles; ft³/s, cubic feet per second]

Location on river	Drainage area (mi²)	Flood discharges (ft³/s) for indicated annual exceedance probabilities (in percent)					Tropical Storm Irene discharge (ft³/s)
		10	4	2	1	0.2	
South Branch Tweed River							
Upstream of Johnson Brook	9.57	936	1,250	1,520	1,820	2,650	2,130
Upstream of Townsend Brook	14.7	1,410	1,870	2,270	2,710	3,930	3,410
Upstream of West Branch Tweed River	22.0	2,040	2,710	3,290	3,910	5,660	5,310
Tweed River							
Upstream of Guernsey Brook	41.1	3,780	5,000	6,050	7,190	10,400	10,600
Upstream of Bartlett Brook	48.1	4,300	5,680	6,860	8,140	11,700	12,600
At mouth	51.0	4,500	5,930	7,160	8,490	12,200	13,400

Geometry of Riverine Structures

Twenty-two riverine structures, consisting of 21 road crossings and a streamgage weir, have the potential to affect water-surface elevations during floods along the stream. Bridge and other riverine structure geometry data were obtained from field surveys conducted by personnel from the USGS New England Water Science Center during the spring and summer 2013.

There are a few exceptions to the use of the field survey data for the structures in the hydraulic model. Although the flood recovery maps represent conditions at the time of the survey, several bridges were damaged during the flooding, and some were replaced. At the time of the survey for this study, three bridges on the White River—the Route 107 bridge in the Village of Bethel, and the Route 73 and River Brook Drive bridges in Rochester—had been replaced. On the Tweed River study reach, four bridges had been repaired or replaced—a private covered bridge, the Route 100 bridge, the Stonewood Crossing bridge, and a private road bridge, all in Pittsfield. To best simulate the flooding that occurred during Tropical Storm Irene, it would be ideal to have the geometry of all the bridges that were in place during the flooding. Unfortunately, pre-flood data were not available for 5 of these 7 structures. The only structure data available were for the Route 107 crossing of the White River in the Village of Bethel and the Route 73 crossing of the White River in Rochester. The Route 107 bridge geometry data were taken from the hydraulic model of the effective Flood Insurance Study model for Bethel (Federal Emergency Management Agency, 2007). The geometry data for the Route 73 bridge in Rochester were provided by the Vermont Agency of Transportation (Nick Wark, written commun., September 11, 2013). The other five structures were included in the Tropical Storm Irene model as surveyed during summer 2013.

Because reconstruction continues in Vermont since Tropical Storm Irene, there are two temporary bridges included in the hydraulic model for the flood recovery maps. They are the Route 73 crossing of the White River in Rochester and the Route 100 crossing of the Tweed River in Pittsfield. In an effort to provide the most up-to-date data for the maps, the Vermont Agency of Transportation provided the geometry data for the planned Route 73 bridge in Rochester (Nick Wark, written commun., September 11, 2013). An additional model that included this planned Route 73 bridge was developed, and the data are included with the flood recovery map.

Development of the Hydraulic Model

As stated in section "Topographic and Bathymetric Data," HEC–GeoRAS—a set of procedures, tools, and utilities for processing geospatial data in ArcGIS—elevation data were extracted from the DEM for 233 cross sections. The cross-section data were merged with the surveyed channel data and subsequently were input to the HEC–RAS model. Objects blocking the flow of water, such as buildings, were digitized in a GIS and were converted to HEC–RAS input by the HEC–GeoRAS software. The data for the 22 riverine structures, consisting of 21 road crossings and a streamgage weir, were manually input into the HEC–RAS model.

Hydraulic analyses require the estimation of energy losses that result from frictional resistance exerted by a channel on flow. These energy losses are quantified by the Manning's roughness coefficient (*n*-value). Initial *n*-values were selected on the basis of field observations, field photographs, and high-resolution aerial photographs (Fugro EarthData, Inc., 2012b). The initial *n*-values were adjusted to minimize the differences between simulated and observed water-surface elevations at the Tropical Storm Irene high-water marks. The *n*-values were also adjusted to avert defaults to critical depth by the HEC–RAS model. For the White River study reach, the final channel *n*-values ranged from 0.040 in straight, lower gradient, sand and gravel channels to 0.065 in meandering, steep, cobble to boulder channels. The floodplains had *n*-values ranging from 0.035 on smooth lawns to 0.085 in heavily forested areas. For the Tweed River study reach, the final *n*-values ranged from 0.040 in straight, lower gradient, sand and gravel channels to 0.075 in meandering, steep, boulder channels. The floodplain areas had *n*-values ranging from 0.040 in grassy areas to 0.110 in heavy forest with thick underbrush.

The HEC–RAS analysis for this study was done using the steady-state flow computation option. Subcritical flow regime was assumed for the simulations. Normal depth was used as the starting water surface and was based on an estimated average water-surface slope of 0.00120 for the White River and 0.00394 for the Tweed River from data contained in the effective Flood Insurance Study (Federal Emergency Management Agency, 2007) and from channel survey data. The discharges used in the model were discussed in the section, "Estimation of Flood Discharges."

The water-surface profiles for the 10-, 4-, 2-, 1-, and 0.2-percent AEP and for Tropical Storm Irene used to produce the flood recovery maps in this study were computed by using HEC–RAS, version 4.1.0 (U.S. Army Corps of Engineers, 2010). HEC–RAS is a one-dimensional step-backwater model for simulation of water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options. Differences between surveyed and simulated elevations of high-water marks for Tropical Storm Irene are shown in table 3. Many of the differences exceed 1 foot. However, these differences are for sites near bridges that were replaced following the flood, for sites in reaches with debris issues, or for sites in steep reaches where the high-water mark may be more representative of the energy grade line than the water surface. Two of the high-water marks that have elevations more than 4 ft less than the simulated water surface are likely to be erroneously flagged marks, and little confidence was placed in these marks in the model adjustment process. The results demonstrate that the model is capable of simulating

Table 3. Comparison of simulated water-surface elevations to observed high-water marks at selected locations along the White and Tweed River study reaches for Tropical Storm Irene, August 27–28, 2011.

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

River station (ft)[1]	Surveyed water-surface elevation (ft, NAVD 88)	Simulated water-surface elevation (ft, NAVD 88)	Difference in elevations (ft)
White River			
2,150	536.95	541.67	4.72
2,439	545.67	543.33	-2.34
3,052	546.33	545.31	-1.02
13,174	560.19	560.22	0.03
90,648	792.41	792.80	0.39
99,467	822.77	822.49	-0.28
108,097	835.02	835.06	0.04
108,215	837.05	835.41	-1.64
Tweed River			
3,219	745.55	745.37	-0.18
5,667	753.23	752.78	-0.45
5,906	756.17	756.72	0.55
20,618	839.15	838.62	-0.53
20,754	842.80	840.86	-1.94
22,253	847.06	852.68	5.62
26,919	891.03	890.41	-0.62
30,110	932.03	931.69	-0.34
38,016	1,040.21	1,041.15	0.94
38,742	1,054.86	1,054.87	0.01

[1]River station is referenced to the longitudinal baseline used in the hydraulic model and is measured in feet from the downstream end of the model.

accurate water levels. The resulting water-surface elevations for the 10-, 4-, 2-, 1-, and 0.2-percent AEP and Tropical Storm Irene are in appendix 2. Water-surface elevations determined using the hydraulic model with the new Route 73 bridge are in appendix 3.

A floodway was also determined for the study reaches. A floodway is the channel plus adjacent floodplain areas that must be free of intrusions, such as fill or development, so that the 1-percent AEP flood can be carried without substantial increases in water-surface elevations. The increase allowed in the analysis is 1.00 foot. The floodway was computed by using HEC–RAS, version 4.1.0 (U.S. Army Corps of Engineers, 2010). The results of the floodway analysis, by cross section, are in appendix 4. Results of the floodway analysis modified for the planned new Route 73 bridge are in appendix 5.

Annual Exceedance Probability of Flooding From Tropical Storm Irene

A 20.7-mile reach of the White River was included in this investigation. On the basis of the hydraulic models, Tropical Storm Irene discharge exceeded the 1-percent AEP flood throughout the White River study reach and exceeded the 0.2-percent AEP flood in the upper 12.6 miles of the White River study reach. A 7.9-mile reach of the Tweed River was included in this investigation. Tropical Storm Irene discharge exceeded the 1-percent AEP flood throughout the Tweed River study reach and exceeded the 0.2-percent AEP flood in the lower 4.2 miles of the Tweed River study reach, including the entire reach below the confluence of the South and West Branches of the Tweed River.

Development of Flood Recovery Maps

Flood recovery maps were created in a GIS by combining the water-surface profiles and the DEM data. The DEM data were derived from the same lidar data described in section "Topographic and Bathymetric Data and Geometry of Riverine Structures." Estimated flood-inundation boundaries for each simulated profile were developed with HEC–GeoRAS software (U.S. Army Corps of Engineers, 2012), which 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). Shapefile polygons of the inundated areas for each profile were modified, as required, in the ArcMap application of ArcGIS (Environmental Systems Research Institue, Inc., 2012a) to ensure a hydraulically reasonable transition of the flood boundaries between modeled cross sections.

Any inundated areas that were detached from the main channel were examined to identify subsurface connections with the main river, such as through culverts under roadways. Where such connections existed, the mapped inundated areas were retained in their respective flood recovery maps; otherwise, the erroneously delineated parts of the flood extent were deleted. The flood-inundation areas were overlaid on geo-referenced aerial photographs of the study area (U.S. Department of Agriculture, 2012). A visual comparison was made between the 1-percent AEP flood boundary from the effective FIRM and the 1-percent AEP flood boundary generated in this investigation. The boundaries were comparable, but the boundaries generated in this investigation appear to have greater detail.

The Flood Recovery Mapping is provided in appendix 1. Appendix 1 contains an ArcGIS published map document (.pmf) that can be read using the freeware, ArcReader (Environmental Systems Research Institute, Inc. [ESRI], 2012b). ArcReader version 10.1 can be downloaded from ESRI at http://www.esri.com/software/arcgis/arcreader/. The published map document provides the flood boundaries for the 10-, 4-, 2-, 1-, and 0.2-percent AEP floods, the floodway, and Tropical Storm Irene. It also contains cross sections with identifiers and the base flood-elevation markers. The base flood-elevations markers indicate the elevation of the 1-percent AEP at 2-foot elevation increments along the study reaches. Flood boundaries and the floodway at the Route 73 bridge in Rochester, Vt., that correspond to the planned bridge design are also incorporated into the map document.

Uncertainties and Limitations Regarding Use of Flood Recovery Maps

Although the flood recovery maps represent the boundaries of inundated areas with a distinct line, some uncertainty is associated with these maps. The accuracy of the floodwater extent portrayed on these maps will vary with the accuracy of the DEM used to simulate the land surface. Water-surface elevations computed with the HEC–RAS model were estimated using steady-state hydraulic modeling, assuming unobstructed flow from ice or debris. The hydraulic model reflects the land-cover characteristics, roughness characteristics, channel elevations, and any bridge, dam, or other hydraulic structures existing as of August 2013. Changes to any of these features may change the water-surface profile.

Furthermore, unique meteorological factors (timing and distribution of precipitation) may cause actual streamflows along the modeled reach to vary from those assumed to occur during a flood, which may lead to deviations from the water-surface elevations and flood 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 USGS provides these maps as a reference and emergency planning tool but assumes no legal liability or responsibility resulting from the use of this information.

Summary

A series of digital flood recovery maps for water-surface elevations for floods with a 10-, 4-, 2-, 1-, and 0.2-percent annual exceedance probability (AEP) and for the floodway were developed by the U.S. Geological Survey in cooperation with the Federal Emergency Management Agency for the White River at Bethel, Stockbridge, and Rochester, Vermont, and for the Tweed River at Stockbridge and Pittsfield, Vt. These flood recovery maps include a 20.7-mile reach of the White River from the downstream end at about 2,000 feet downstream from the State Route 107 bridge in the Village of Bethel, Vt., to the upstream end at about 1,000 feet upstream from the River Brook Drive bridge in the Village of Rochester,Vt., and a 7.9-mile reach of the Tweed River from its mouth in Stockbridge, Vt., to the confluence of the West and South Branches of the Tweed River and continuing upstream on the South Branch Tweed River to the Leigh Kelly Drive bridge in Pittsfield, Vt. The maps were developed by 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.

References Cited

Environmental Systems Research Institute, Inc., 2012a, ArcGIS, version 10.1: Redlands, Calif., accessed June 27, 2014, at http://www.esri.com/software/arcgis/.

Environmental Systems Research Institute, Inc., 2012b, ArcGIS, ArcReader version 10.1: Redlands, Calif., accessed October 10, 2014, at http://www.esri.com/software/arcgis/arcreader.

Federal Emergency Management Agency, 2007, Flood insurance study, Windsor County, Vermont (all jurisdictions): Washington, D.C., Federal Emergency Management Agency, 4 v.

Federal Emergency Management Agency, 2008, Flood insurance study, Rutland County, Vermont (all jurisdictions): Washington D.C., Federal Emergency Management Agency, 3 v.

Fugro EarthData, Inc., 2012a, VTrans_DEM: Montpelier, Vt., Vermont Agency of Transportation, accessed January 7, 2015, at http://vcgi.vermont.gov/warehouse/products/ALL-LDR_MIX_LIDAR_STATE_ALL.

Fugro EarthData, Inc., 2012b, VTrans_Ortho: Montpelier, Vt., Vermont Agency of Transportation data.

Medalie, Laura, and Olson, S.A., 2013, High-water marks from flooding in Lake Champlain from April through June 2011 and Tropical Storm Irene in August 2011 in Vermont: U.S. Geological Survey Data Series 763, 11 p., accessed July 14, 2014, at http://pubs.usgs.gov/ds/763/.

Olson, S.A., 2014, Estimation of flood discharges at selected annual exceedance probabilities for unregulated, rural streams in Vermont, *with a section on* Vermont regional skew regression, by Veilleux, A.G.: U.S. Geological Survey Scientific Investigations Report 2014–5078, 27 p. plus appendixes, accessed July 7, 2014, at http:/dx.doi.org/10.3133/sir20145078.

Olson, S.A., and Bent, G.C., 2013, Annual exceedance probabilities of the peak discharges of 2011 at streamgages in Vermont and selected streamgages in New Hampshire, western Massachusetts, and northeastern New York: U.S. Geological Survey Scientific Investigations Report 2013–5187, 17 p., accessed July 7, 2014, at http://dx.doi.org/10.3133/sir20135187.

PRISM Group, Oregon State University, 2012a, United States average monthly or annual precipitation, 1981–2010, 30 arc-second normal, created July 10, 2012: Corvallis, Oreg., Oregon State University, accessed September 16, 2013, at http://www.prism.oregonstate.edu/.

PRISM Group, Oregon State University, 2012b, United States average monthly or annual maximum temperature, 1981–2010, 4 km grid cell resolution, created July 10, 2012: Corvallis, Oreg., Oregon State University, accessed September 16, 2013, at http://www.prism.oregonstate.edu/.

PRISM Group, Oregon State University, 2012c, United States average monthly or annual minimum temperature, 1981–2010, 4 km grid cell resolution, created July 10, 2012: Corvallis, Oreg., Oregon State University, accessed September 16, 2013, at http://www.prism.oregonstate.edu/.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2010, HEC–RAS river analysis system, user's manual, version 4.1: U.S. Army Corps of Engineers [variously paged].

U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2012, HEC–GeoRAS, GIS tools for support of HEC–RAS using ArcGIS 10, user's manual, version 10: U.S. Army Corps of Engineers [variously paged].

U.S. Department of Agriculture, 2012, National Agriculture Imagery Program, 1:40,000 scale: U.S. Department of Agriculture, accessed July 7, 2014, at http://vcgi.vermont.gov/.

U.S. Geological Survey, 2004, National elevation dataset, 1 arc-second: U.S. Geological Survey, accessed October 18, 2013, at http://ned.usgs.gov/.

Appendix 1. Flood Recovery Maps at Selected Annual Exceedance Probabilities for the White and Tweed Rivers in Bethel, Stockbridge, Pittsfield, and Rochester, Vermont

[Available separately for download at http://pubs.usgs.gov/sir/2015/5056/.]

Appendix 2. Water-Surface Elevations for Selected Annual Exceedance Probabilites for the White River in Bethel, Stockbridge, and Rochester, Vermont, and Tweed River in Stockbridge and Pittsfield, Vermont

Table 2–1. Water-surface elevations for selected annual exceedence probabilities for the White River in Bethel, Stockbridge, and Rochester, Vermont, and Tweed River in Stockbridge and Pittsfield, Vermont.

[Cross sections with identifiers are shown in appendix 5. ft, feet; NAVD 88, North American Vertical Datum of 1988; %, percent; VT, Vermont]

Cross-section indentifier	River station (ft)	Minimum channel elevation (ft, NAVD 88)	Water-surface elevation for selected annual exceedence probabilities (ft, NAVD 88)					Water-surface elevation estimated for Tropical Storm Irene (ft, NAVD 88)
			10%	4%	2%	1%	0.20%	
White River								
WA	162.7	510.24	527.56	530.28	532.35	534.42	539.65	538.64
WB	1,046.1	511.84	528.81	531.55	533.63	535.70	541.07	540.03
WC	2,080.2	514.83	530.91	533.46	535.48	537.51	542.63	541.64
	2,338.1	Route 12 Bridge, Bethel, VT						
WD	2,660.9	515.98	533.93	536.52	538.58	540.27	546.16	[a]545.22
WE	3,710.9	520.67	534.90	537.20	539.10	540.78	546.39	[a]545.47
WF	5,270.2	523.49	537.89	539.69	541.24	542.73	547.68	[a]546.91
WG	5,819.8	524.18	539.20	540.91	542.12	543.43	547.99	[a]547.27
WH	7,379.3	529.13	542.39	544.00	545.22	546.32	549.88	[a]549.40
WI	8,383.4	530.91	544.31	545.70	546.80	547.87	551.00	[a]550.70
WJ	9,748.3	535.76	547.11	548.28	549.22	550.17	553.06	[a]552.82
WK	10,734.6	536.98	549.66	550.80	551.63	552.40	554.53	554.35
WL	11,958.9	537.99	552.20	553.78	554.87	555.98	558.43	558.26
WM	13,374.2	538.26	554.60	556.20	557.29	558.29	560.66	560.54
WN	14,123.2	537.86	556.27	558.07	559.33	560.43	562.84	562.74
	14,366.7	Abandoned Streamgage Weir, Bethel, VT						
WO	14,583.6	540.75	557.36	559.22	560.52	561.70	564.40	564.28
WP	15,514.8	542.68	559.20	561.29	562.74	564.01	566.72	566.62
WQ	16,395.3	544.32	560.77	562.94	564.49	565.96	569.22	569.10
WR	17,273.2	547.01	562.86	565.07	566.69	568.24	571.73	571.61
WS	18,229.7	549.84	564.47	566.41	567.87	569.32	572.58	572.47
WT	18,929.9	548.00	566.36	568.29	569.76	571.25	574.87	574.75
WU	19,907.7	556.27	570.32	572.59	574.21	575.68	578.64	578.53
WV	20,660.1	562.86	572.85	574.87	576.39	577.66	580.20	580.11
WW	21,453.2	563.88	577.93	579.76	581.21	582.59	585.85	585.73
WX	22,134.4	565.78	581.46	583.68	585.40	587.11	590.79	590.66
WY	22,881.4	571.10	584.12	585.99	587.52	589.09	592.58	592.46
WZ	23,842.4	574.67	586.98	588.49	589.66	590.90	593.94	593.83
WAA	25,153.4	580.45	592.81	594.54	595.81	597.05	600.03	599.92
WAB	25,622.9	580.28	594.05	595.75	597.02	598.24	601.11	601.00
WAC	26,601.5	584.22	596.76	598.66	600.11	601.51	604.55	604.44
WAD	27,341.3	585.00	599.46	600.82	601.98	603.12	605.91	605.82
WAE	28,431.5	594.00	604.34	605.33	606.08	606.86	608.91	608.86
WAF	29,123.3	595.87	606.63	607.81	608.71	609.57	611.63	611.59
WAG	30,322.4	598.46	610.83	612.28	613.35	614.48	616.88	616.84
WAH	31,098.9	602.99	614.17	615.23	616.00	616.79	618.83	618.79
WAI	32,208.0	610.73	620.90	621.77	622.40	623.04	624.60	624.57
WAJ	33,084.0	615.45	625.78	626.80	627.59	628.36	630.32	630.29
WAK	33,614.0	617.91	628.92	629.96	630.75	631.52	633.57	633.54
WAL	34,207.3	614.27	631.35	632.51	633.33	634.02	635.17	635.16

Table 2–1. Water-surface elevations for selected annual exceedence probabilities for the White River in Bethel, Stockbridge, and Rochester, Vermont, and Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; NAVD 88, North American Vertical Datum of 1988; %, percent; VT, Vermont]

Cross-section indentifier	River station (ft)	Minimum channel elevation (ft, NAVD 88)	Water-surface elevation for selected annual exceedence probabilities (ft, NAVD 88)					Water-surface elevation estimated for Tropical Storm Irene (ft, NAVD 88)
			10%	4%	2%	1%	0.20%	
White River—Continued								
	34,386.7	Bridge Street Bridge, Stockbridge, VT						
WAM	34,544.5	613.03	634.07	636.11	637.76	639.49	643.95	643.85
WAN	35,540.3	625.03	636.90	638.99	640.61	642.28	646.50	646.42
WAO	36,235.1	627.43	641.21	643.14	644.65	646.21	650.10	650.02
WAP	37,540.0	631.96	649.10	651.18	652.80	654.45	658.53	658.46
WAQ	38,127.6	638.22	652.36	654.47	656.13	657.83	662.11	662.03
WAR	39,358.9	649.05	658.36	659.65	660.71	661.92	665.32	665.25
WAS	39,731.5	649.64	662.63	663.82	664.61	665.46	667.79	667.74
WAT	40,937.2	657.12	669.05	670.71	671.95	673.20	676.33	676.29
WAU	41,537.2	659.51	671.38	672.73	673.71	674.69	677.12	677.11
WAV	42,592.2	667.09	677.74	679.35	680.61	681.86	684.86	684.94
WAW	43,184.4	670.34	681.24	682.83	684.07	685.32	688.37	688.43
WAX	44,378.8	671.03	686.55	688.31	689.66	691.03	694.45	694.52
WAY	44,902.5	671.33	688.31	690.18	691.59	692.98	696.39	696.46
	45,169.4	Blackmer Boulevard Bridge, Stockbridge, VT						
WAZ	45,377.7	667.59	691.94	694.62	696.67	698.73	703.11	708.81
WBA	46,920.0	678.71	695.23	697.85	699.90	701.96	706.67	710.76
WBB	47,999.7	682.19	697.36	699.78	701.69	703.65	708.23	711.62
WBC	49,333.0	684.32	700.98	703.32	705.15	707.01	711.32	713.47
WBD	50,363.7	686.98	704.85	707.41	709.37	711.31	715.92	717.04
WBE	51,148.5	694.82	706.92	709.37	711.31	713.21	717.83	718.70
WBF	51,669.3	695.24	708.52	710.65	712.43	714.26	718.80	719.56
WBG	52,583.0	697.84	712.15	713.93	715.24	716.53	720.00	720.49
WBH	53,827.1	704.92	716.82	718.78	720.30	721.82	725.57	725.74
WBI	55,404.0	708.69	721.33	723.19	724.64	726.07	729.60	729.70
WBJ	56,215.9	708.43	723.63	725.37	726.71	728.04	731.34	731.42
WBK	57,195.9	709.78	727.79	729.93	731.55	733.16	737.02	737.09
WBL	58,381.6	717.32	729.58	731.68	733.34	735.02	739.21	739.30
WBM	59,190.1	717.45	729.96	731.90	733.50	735.13	739.27	739.36
WBN	60,094.9	719.06	731.51	732.90	734.24	735.71	739.62	739.73
	60,248.2	Route 100 Bridge, Stockbridge, VT						
WBO	60,446.0	720.14	733.33	735.42	736.64	738.21	741.24	741.44
WBP	62,003.0	721.06	736.20	737.63	738.61	739.71	742.33	742.55
WBQ	62,859.1	724.38	737.50	739.14	740.19	741.28	743.94	744.23
WBR	63,649.9	725.92	737.97	739.53	740.56	741.64	744.27	744.57
WBS	64,894.5	727.17	739.10	740.43	741.40	742.40	744.90	745.19
WBT	66,003.0	729.10	740.78	742.01	742.94	743.88	746.26	746.55
WBU	66,762.6	729.07	742.00	743.15	744.01	744.85	746.95	747.21
WBV	67,964.9	730.68	744.11	745.52	746.57	747.59	750.07	750.39
WBW	68,729.2	731.89	745.13	746.62	747.75	748.84	751.50	751.84
WBX	69,530.0	732.19	745.54	746.87	747.85	748.79	751.06	751.35
WBY	70,204.6	735.60	747.10	748.59	749.73	750.86	753.67	754.03
WBZ	71,272.1	736.94	748.03	749.28	750.31	751.35	754.03	754.38
WCA	72,045.5	737.43	748.88	749.93	750.77	751.65	754.11	754.46

Table 2–1. Water-surface elevations for selected annual exceedence probabilities for the White River in Bethel, Stockbridge, and Rochester, Vermont, and Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; NAVD 88, North American Vertical Datum of 1988; %, percent; VT, Vermont]

Cross-section indentifier	River station (ft)	Minimum channel elevation (ft, NAVD 88)	Water-surface elevation for selected annual exceedence probabilities (ft, NAVD 88)					Water-surface elevation estimated for Tropical Storm Irene (ft, NAVD 88)
			10%	4%	2%	1%	0.20%	
White River—Continued								
WCB	72,857.2	739.60	751.39	752.61	753.47	754.30	756.23	756.46
WCC	73,316.1	741.11	753.21	754.74	755.83	756.85	758.75	758.98
WCD	74,978.0	746.56	757.34	758.68	759.71	760.40	762.13	762.35
WCE	75,838.5	748.79	759.06	760.08	760.89	761.56	763.20	763.42
WCF	76,883.6	749.93	761.91	763.08	763.87	764.56	766.16	766.36
WCG	77,756.2	749.93	763.12	764.28	765.06	765.74	767.36	767.56
WCH	79,171.7	751.80	766.72	768.00	768.90	769.79	771.83	772.08
WCI	80,006.3	756.92	768.56	770.11	771.27	772.43	775.29	775.66
WCJ	81,084.3	755.84	771.15	772.73	773.92	775.04	777.69	778.03
WCK	82,177.8	765.88	775.50	777.30	778.73	780.03	783.14	783.53
WCL	83,205.9	764.53	778.86	780.37	781.63	782.86	785.96	786.37
WCM	83,689.3	766.90	779.22	780.66	781.88	783.10	786.20	786.61
WCN	84,934.1	768.14	780.56	781.77	782.81	783.87	786.73	787.14
WCO	85,500.3	769.40	780.97	782.10	783.09	784.11	786.90	787.31
WCP	87,066.9	771.98	782.54	783.39	784.13	784.96	787.36	787.74
WCQ	88,108.9	774.25	784.59	785.53	786.27	787.06	789.25	789.62
WCR	89,193.4	775.82	785.61	786.40	787.06	787.76	789.76	790.11
WCS	90,430.2	777.85	787.79	788.51	788.84	789.31	790.68	790.99
	90,793.6	Liberty Hill Road Bridge, Rochester, VT						
WCT	91,069.4	778.74	792.16	793.51	794.78	795.09	795.98	796.21
WCU	92,596.5	784.22	793.84	795.04	795.86	796.32	797.45	797.68
WCV	93,698.8	784.81	795.90	796.74	797.39	797.95	799.22	799.45
WCW	95,416.5	787.43	798.76	799.79	800.60	801.43	803.11	803.40
WCX	96,152.6	788.58	799.86	801.00	801.90	802.81	804.78	805.13
WCY	97,333.4	790.68	802.20	803.04	803.74	804.48	806.28	806.62
WCZ	98,577.8	795.80	805.21	806.06	806.67	807.29	808.82	809.09
WDA	99,224.9	794.23	809.11	810.18	810.94	811.67	813.31	813.57
	99,327.5	State Garage Road Bridge, Rochester, VT						
WDB	99,466.8	797.28	811.56	813.33	814.90	816.75	822.21	822.49
WDC	100,388.2	800.66	815.02	816.87	818.39	819.87	823.64	823.95
WDD	101,102.7	805.48	817.11	818.71	819.91	821.02	824.20	824.52
WDE	101,877.9	805.84	817.44	818.85	819.98	821.03	824.13	824.43
	101,991.7	Route 73 Bridge, Rochester, VT (Temporary Structure)						
WDF	102,206.0	805.94	819.72	821.25	822.70	824.06	827.96	[b]832.45
WDG	103,340.7	810.96	822.02	823.29	824.41	825.55	828.93	[b]832.89
WDH	104,059.3	813.88	824.81	825.93	826.78	827.64	830.28	[b]833.47
WDI	104,247.9	810.79	825.26	826.31	827.13	827.95	830.46	[b]833.54
WDJ	105,584.0	815.00	826.49	827.58	828.41	829.23	831.66	[b]834.15
WDK	106,136.2	815.85	826.99	828.07	828.89	829.71	832.04	[b]834.34
WDL	106,983.8	817.42	827.39	828.41	829.21	829.99	832.25	[b]834.46
WDM	108,075.9	819.88	829.73	830.42	830.99	831.58	833.34	[b]835.06
	108,175.3	River Brook Drive Bridge, Rochester, VT						
WDN	108,255.4	819.85	830.63	831.35	831.93	832.49	834.09	[b]835.58
WDO	109,156.2	821.50	832.23	832.99	833.56	834.07	835.28	[b]836.09

Table 2–1. Water-surface elevations for selected annual exceedence probabilities for the White River in Bethel, Stockbridge, and Rochester, Vermont, and Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; NAVD 88, North American Vertical Datum of 1988; %, percent; VT, Vermont]

Cross-section indentifier	River station (ft)	Minimum channel elevation (ft, NAVD 88)	Water-surface elevation for selected annual exceedence probabilities (ft, NAVD 88)					Water-surface elevation estimated for Tropical Storm Irene (ft, NAVD 88)
			10%	4%	2%	1%	0.20%	
Tweed River								
TA	680.3	721.06	[c]729.12	[c]731.24	[c]732.89	[c]734.56	[c]738.66	739.38
TB	1,197.1	720.00	729.20	[c]731.24	[c]732.89	[c]734.56	[c]738.66	739.93
TC	1,734.9	724.97	731.10	732.11	732.89	[c]734.56	[c]738.66	740.29
TD	2,345.3	730.87	737.51	738.27	738.85	739.36	740.62	742.02
TE	3,113.3	730.25	740.45	741.29	741.87	742.41	743.57	743.77
	3,292.3	Route 107 Bridge, Stockbridge, VT						
TF	3,530.0	731.43	741.74	742.86	743.58	744.43	747.34	747.69
TG	4,392.2	736.78	744.41	745.18	745.76	746.25	748.03	748.28
TH	5,104.6	740.98	747.89	748.56	749.05	749.55	750.66	750.88
TI	5,762.3	742.03	750.37	750.99	751.45	751.91	752.88	753.10
	5,852.9	South Hill Road Bridge, Stockbridge, VT						
TJ	5,905.6	743.18	752.38	753.34	753.92	754.53	755.65	756.72
TK	7,156.5	748.33	754.69	755.48	755.95	756.42	757.55	757.93
TL	7,890.0	751.21	758.96	759.52	760.07	760.45	761.53	761.74
TM	8,811.4	755.91	763.25	764.00	764.38	764.84	765.89	766.11
TN	9,850.4	759.02	766.59	767.36	768.01	768.63	770.38	770.63
TO	10,376.2	761.52	768.69	769.44	770.02	770.60	772.30	772.56
TP	10,812.2	766.69	771.84	772.32	772.68	773.04	774.07	774.31
TQ	11,403.6	768.08	774.63	775.24	775.70	776.14	777.10	777.31
TR	12,443.2	770.37	778.90	780.04	780.77	781.47	783.14	783.56
TS	13,029.2	776.28	783.15	784.38	785.14	785.81	787.07	787.29
TT	13,642.1	780.51	787.70	788.65	789.27	789.80	790.60	790.78
TU	14,410.6	782.87	790.95	791.67	792.21	792.74	794.20	794.54
TV	14,961.6	787.73	793.86	794.70	795.36	795.98	797.55	797.87
TW	15,453.5	790.13	795.87	796.41	796.67	797.22	798.59	798.79
TX	15,807.7	792.59	799.15	799.90	800.50	800.77	801.44	801.44
TY	16,140.3	793.93	800.29	801.13	801.70	802.14	803.07	803.12
TZ	16,607.6	795.60	803.45	804.19	804.72	805.22	806.40	806.45
TAA	17,462.7	804.04	809.38	809.99	810.47	810.90	811.91	811.97
TAB	18,282.1	814.27	817.99	818.40	818.71	819.06	819.88	819.93
TAC	18,618.8	814.04	819.48	820.02	820.43	820.83	821.79	821.85
TAD	19,102.6	815.80	821.53	822.20	822.73	823.25	824.47	824.53
TAE	19,676.6	816.63	826.63	827.49	827.94	828.36	829.33	829.40
	19,718.8	Snomobile Trail Bridge, Pittsfield, VT						
TAF	19,769.2	818.27	827.55	828.96	829.75	830.23	830.70	[d]830.69
TAG	20,329.8	824.80	832.70	832.71	833.14	833.54	834.55	[d]834.73
TAH	20,632.9	828.35	835.69	836.72	837.18	837.57	838.50	[d]838.79
	20,682.5	Paramenter Place Bridge, Pittsfield, VT						
TAI	20,720.3	829.43	836.71	838.86	839.30	839.56	840.55	[d]840.76
TAJ	21,126.8	833.07	838.78	839.74	840.23	840.64	841.68	[d]841.91
TAK	21,351.5	835.56	840.98	841.49	841.84	842.15	842.86	[d]842.92
TAL	21,635.0	838.94	843.41	843.84	844.16	844.46	845.21	[d]845.01
TAM	21,989.4	838.06	845.66	846.31	846.79	847.24	848.19	[d]848.08

Table 2–1. Water-surface elevations for selected annual exceedence probabilities for the White River in Bethel, Stockbridge, and Rochester, Vermont, and Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; NAVD 88, North American Vertical Datum of 1988; %, percent; VT, Vermont]

Cross-section indentifier	River station (ft)	Minimum channel elevation (ft, NAVD 88)	Water-surface elevation for selected annual exceedence probabilities (ft, NAVD 88)					Water-surface elevation estimated for Tropical Storm Irene (ft, NAVD 88)
			10%	4%	2%	1%	0.20%	
Tweed River—Continued								
	22,037.5	Covered Bridge (Private), Pittsfield, VT						
TAN	22,110.8	837.96	846.72	847.98	849.09	851.37	852.65	852.41
TAO	22,267.8	839.31	847.21	848.42	849.48	851.59	852.98	852.72
	22,360.7	Tweed River Drive Bridge, Pittsfield, VT						
TAP	22,449.8	841.67	848.63	849.59	850.62	852.34	853.77	853.52
TAQ	22,964.7	847.57	853.15	853.51	853.69	853.85	854.85	854.65
TAR	23,478.9	853.31	857.19	857.50	857.81	858.10	858.15	858.11
TAS	24,387.6	858.83	863.83	864.34	864.66	864.98	866.56	866.37
TAT	24,866.1	862.30	867.21	867.86	868.40	868.91	869.88	869.73
TAU	25,341.0	866.57	872.58	873.29	873.77	874.13	874.96	874.80
TAV	25,930.4	870.34	876.22	876.98	877.52	878.08	879.29	879.08
TAW	26,680.5	877.46	882.90	883.58	884.10	884.58	885.65	885.45
	26,769.2	Route 100 Bridge, Pittsfield, VT (Temporary Structure)						
TAX	26,883.3	880.02	886.06	887.03	887.78	888.56	890.55	890.13
TAY	27,560.7	889.76	893.01	893.26	893.67	894.10	895.18	894.91
TAZ	28,018.4	894.42	899.55	900.20	900.60	901.00	901.93	901.78
TBA	28,645.7	900.85	906.63	906.97	907.35	907.67	908.77	908.61
TBB	29,049.6	908.47	913.34	914.04	914.52	914.91	915.90	915.71
TBC	29,466.3	912.17	917.59	918.05	918.41	918.80	919.53	919.31
TBD	30,030.2	918.47	923.60	924.53	925.16	925.73	926.77	926.29
	30,063.9	Bakers Road Bridge, Pittsfield, VT						
TBE	30,109.5	919.49	927.29	930.12	930.58	931.09	932.08	931.69
TBF	30,420.9	926.18	928.94	930.40	930.90	931.42	932.53	932.07
TBG	30,887.2	932.05	934.92	935.44	935.59	935.75	936.10	935.89
TBH	31,222.5	933.07	938.79	938.90	939.16	939.41	939.92	939.72
TBI	31,558.9	937.30	940.27	940.72	941.00	941.27	941.92	941.66
TBJ	31,992.3	940.88	943.96	944.35	944.70	945.05	945.90	945.55
TBK	32,569.5	948.46	952.38	952.82	953.16	953.48	953.72	953.71
TBL	33,063.3	955.74	959.43	959.94	960.32	960.73	961.35	960.87
TBM	33,549.2	962.89	965.71	966.08	966.38	966.66	967.77	967.57
TBN	33,851.3	965.42	969.86	970.33	970.67	971.02	971.82	971.44
	33,919.7	Stonewood Crossing Bridge, Pittsfield, VT						
TBO	33,987.0	967.22	971.61	972.10	972.50	972.77	973.52	973.22
TBP	34,322.5	971.39	974.84	975.41	975.80	976.28	977.11	976.78
TBQ	34,766.2	976.64	981.97	982.52	982.94	983.28	984.07	983.76
TBR	35,175.3	981.86	986.67	987.38	987.84	988.34	989.19	988.86
TBS	35,466.7	989.76	992.90	993.37	993.70	993.97	994.86	994.43
TBT	35,665.3	993.54	996.65	996.98	997.23	997.52	998.09	997.70
	35,719.8	Private Drive Bridge, Pittsfield, VT						
TBU	35,768.7	994.00	998.51	999.16	999.69	999.94	1,001.84	1,000.43
TBV	35,985.8	997.90	1,001.31	1,001.86	1,002.29	1,002.67	1,003.61	1,003.06
TBW	36,320.7	1,004.17	1,008.30	1,008.75	1,008.97	1,009.26	1,009.97	1,009.53

Table 2–1. Water-surface elevations for selected annual exceedence probabilities for the White River in Bethel, Stockbridge, and Rochester, Vermont, and Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; NAVD 88, North American Vertical Datum of 1988; %, percent; VT, Vermont]

Cross-section indentifier	River station (ft)	Minimum channel elevation (ft, NAVD 88)	Water-surface elevation for selected annual exceedence probabilities (ft, NAVD 88)					Water-surface elevation estimated for Tropical Storm Irene (ft, NAVD 88)
			10%	4%	2%	1%	0.20%	
Tweed River—Continued								
TBX	36,704.8	1,010.11	1,013.10	1,013.46	1,013.63	1,013.85	1,014.31	1,014.04
TBY	37,044.7	1,015.35	1,018.93	1,019.39	1,019.85	1,020.25	1,021.25	1,020.64
TBZ	37,456.6	1,026.15	1,028.71	1,029.11	1,029.35	1,029.68	1,030.43	1,029.99
TCA	37,853.5	1,028.41	1,034.92	1,035.78	1,036.25	1,036.66	1,037.63	1,037.05
	37,885.1	Fellows Lane Bridge, Pittsfield, VT						
TCB	37,938.5	1,030.77	1,036.42	1,037.62	1,038.51	1,039.46	1,041.27	1,040.38
TCC	38,166.3	1,037.11	1,040.56	1,041.12	1,041.58	1,042.07	1,043.30	1,042.78
TCD	38,407.2	1,040.09	1,046.23	1,046.91	1,047.40	1,047.89	1,048.51	1,048.02
	38,435.7	Hadley Lane Bridge, Pittsfield, VT						
TCE	38,464.3	1,041.44	1,049.42	1,049.90	1,050.28	1,050.75	1,051.76	1,051.27
TCF	38,956.8	1,053.71	1,056.54	1,056.88	1,057.13	1,057.40	1,058.07	1,057.66
TCG	39,270.5	1,056.79	1,062.58	1,063.32	1,063.88	1,064.43	1,065.71	1,064.94
TCH	39,893.2	1,065.49	1,069.79	1,070.53	1,071.09	1,071.65	1,072.97	1,072.19
TCI	40,419.1	1,074.05	1,078.60	1,079.04	1,079.27	1,079.55	1,080.20	1,079.82
TCJ	40,841.6	1,081.89	1,086.84	1,087.53	1,087.88	1,088.24	1,089.04	1,088.56
TCK	41,303.3	1,095.80	1,100.22	1,100.90	1,101.39	1,101.91	1,103.37	1,102.42
TCL	41,636.3	1,099.44	1,106.88	1,107.70	1,108.19	1,108.66	1,109.42	1,109.08
	41,667.9	Leigh Kelly Drive Bridge, Pittsfield, VT						
TCM	41,697.0	1,099.80	1,107.78	1,108.59	1,109.08	1,109.56	1,110.53	1,109.99
TCN	41,745.8	1,103.58	1,108.37	1,109.11	1,109.62	1,110.08	1,111.00	1,110.48
Tweed River Bypass								
BA	70.3	827.36	830.90	831.70	832.03	832.32	833.09	833.10
BB	173.7	836.61	836.86	837.39	837.56	837.70	837.98	837.96
BC	261.9	835.63	837.14	838.03	838.37	838.67	839.29	839.19
BD	379.3	838.91	839.32	839.93	840.24	840.52	841.19	841.08

[a]With Route 12 bridge geometry as it existed prior to Tropical Storm Irene.

[b]With Route 73 bridge geometry as it existed prior to Tropical Storm Irene.

[c]Backwater from White River.

[d]Peak water-surface without bypass diversion.

Appendix 3. Water-Surface Elevations for Selected Annual Exceedence Probabilities for the White River Modified for the Planned Route 73 Bridge in Rochester, Vermont

Table 3–1. Water-surface elevations for selected annual exceedance probabilities for the White River modified for the planned Route 73 bridge in Rochester, Vermont.

[Cross sections with identifiers are shown in appendix 5. NAVD 88, North American Vertical Datum of 1988; ft, feet; VT, Vermont; --, no change in water-surface elevation resulting from planned geometry of new Route 73 bridge]

Cross-section indentifier	River station (ft)	Minimum channel elevation (ft, NAVD 88)	Water-surface elevation for selected annual exceedence probabilities (ft, NAVD 88)				
			10%	4%	2%	1%	0.20%
	99,327.5	State Garage Road Bridge, Rochester, VT					
WDB	99,466.8	797.28	--	--	--	--	--
WDC	100,388.2	800.66	--	--	--	--	--
WDD	101,102.7	805.48	--	--	--	--	--
WDE	101,877.9	805.84	--	--	--	--	--
	101,991.7	Route 73 Bridge, Rochester, VT (Planned Structure)					
WDF	102,206.0	805.94	819.32	821.16	822.49	825.52	827.92
WDG	103,340.7	810.96	821.75	823.07	824.15	826.40	828.83
WDH	104,059.3	813.88	824.80	825.90	826.72	828.05	830.22
WDI	104,247.9	810.79	825.25	826.29	827.08	828.31	830.41
WDJ	105,584.0	815.00	826.49	827.56	828.38	829.47	831.63
WDK	106,136.2	815.85	--	828.06	828.87	829.92	832.02
WDL	106,983.8	817.42	--	828.40	829.19	830.17	832.22
WDM	108,075.9	819.88	--	--	--	831.64	833.33
	108,175.3	River Brook Drive Bridge, Rochester, VT					

Appendix 4. Results of the Floodway Analysis for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont

Table 4–1. Results of the floodway analysis for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont.

[Cross sections with identifiers are shown in appendix 5. ft, feet; ft², square feet; ft/s, feet per second; NAVD 88, North American Vertical Datum of 1988]

Cross-section indentifier	River station (ft)	Floodway			Water-surface elevation		
		Width (ft)	Section area (ft²)	Mean velocity (ft/s)	Without floodway (ft, NAVD 88)	With floodway (ft, NAVD 88)	Increase (ft)
White River							
WA	162.7	286.9	5,665	8.84	534.42	534.78	0.36
WB	1,046.1	329.6	6,048	8.28	535.70	536.10	0.39
WC	2,080.2	345.5	5,624	8.91	537.51	537.86	0.35
	2,338.1	Route 12 Bridge, Bethel, VT					
WD	2,660.9	570.0	9,380	5.34	540.27	540.63	0.36
WE	3,710.9	445.0	6,022	6.58	540.78	541.44	0.66
WF	5,270.2	660.0	6,400	6.19	542.73	543.62	0.89
WG	5,819.8	620.0	6,246	6.34	543.43	544.44	1.00
WH	7,379.3	571.3	5,776	6.86	546.32	547.02	0.70
WI	8,383.4	510.0	5,796	6.83	547.87	548.40	0.53
WJ	9,748.3	930.0	6,975	5.68	550.17	551.17	1.00
WK	10,734.6	475.7	4,690	8.44	552.40	553.04	0.64
WL	11,958.9	510.0	5,097	7.24	555.98	556.22	0.24
WM	13,374.2	290.0	4,055	9.10	558.29	559.26	0.97
WN	14,123.2	215.0	3,655	10.10	560.43	561.11	0.68
	14,366.7	Abandoned Streamgage Weir, Bethel, VT					
WO	14,583.6	240.0	3,607	10.23	561.70	562.65	0.96
WP	15,514.8	196.0	3,740	9.87	564.01	564.72	0.71
WQ	16,395.3	205.0	3,775	9.77	565.96	566.62	0.66
WR	17,273.2	313.0	5,216	7.07	568.24	568.93	0.69
WS	18,229.7	231.0	3,677	10.04	569.32	570.08	0.76
WT	18,929.9	170.3	2,841	12.99	571.25	571.59	0.34
WU	19,907.7	252.0	4,138	8.92	575.68	576.35	0.67
WV	20,660.1	242.7	3,089	11.95	577.66	578.20	0.54
WW	21,453.2	197.6	2,705	13.64	582.59	582.63	0.04
WX	22,134.4	331.9	4,351	8.48	587.11	587.13	0.02
WY	22,881.4	380.2	5,108	7.22	589.09	589.49	0.40
WZ	23,842.4	231.0	3,104	11.89	590.90	591.33	0.44
WAA	25,153.4	364.7	4,373	8.44	597.05	597.41	0.36
WAB	25,622.9	253.3	3,623	10.18	598.24	598.47	0.23
WAC	26,601.5	452.0	4,325	8.28	601.51	601.68	0.17
WAD	27,341.3	540.0	4,599	7.78	603.12	603.82	0.70
WAE	28,431.5	552.1	5,012	7.14	606.86	607.85	0.99
WAF	29,123.3	277.0	3,364	10.64	609.57	609.83	0.26
WAG	30,322.4	670.0	5,740	6.24	614.48	614.77	0.30
WAH	31,098.9	685.0	4,465	8.02	616.79	617.04	0.25
WAI	32,208.0	531.3	4,309	8.31	623.04	623.99	0.95
WAJ	33,084.0	637.8	4,136	8.65	628.36	629.17	0.81
WAK	33,614.0	555.0	4,487	7.98	631.52	632.53	1.00
WAL	34,207.3	217.8	2,570	13.93	634.02	634.75	0.73

Table 4–1. Results of the floodway analysis for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; ft², square feet; ft/s, feet per second; NAVD 88, North American Vertical Datum of 1988]

Cross-section indentifier	River station (ft)	Floodway			Water-surface elevation		
		Width (ft)	Section area (ft²)	Mean velocity (ft/s)	Without floodway (ft, NAVD 88)	With floodway (ft, NAVD 88)	Increase (ft)
White River—Continued							
	34,386.7	Bridge Street Bridge, Stockbridge, VT					
WAM	34,544.5	233.4	3,922	9.13	639.49	639.62	0.13
WAN	35,540.3	210.0	2,972	12.05	642.28	642.41	0.13
WAO	36,235.1	181.4	2,707	13.23	646.21	646.24	0.04
WAP	37,540.0	203.6	2,959	12.10	654.45	654.45	0.00
WAQ	38,127.6	318.2	4,405	8.13	657.83	657.83	0.00
WAR	39,358.9	302.8	2,643	13.55	661.92	661.92	0.00
WAS	39,731.5	250.9	2,534	14.13	665.46	665.46	0.00
WAT	40,937.2	474.5	4,275	7.74	673.20	673.20	0.00
WAU	41,537.2	246.9	2,666	12.41	674.69	674.70	0.02
WAV	42,592.2	248.3	2,935	11.28	681.86	681.86	0.00
WAW	43,184.4	225.6	2,853	11.60	685.32	685.32	0.00
WAX	44,378.8	225.5	3,211	10.31	691.03	691.03	0.00
WAY	44,902.5	210.7	3,441	9.62	692.98	693.06	0.09
	45,169.4	Blackmer Boulevard, Stockbridge, VT					
WAZ	45,377.7	201.2	3,872	8.55	698.73	698.76	0.02
WBA	46,920.0	278.7	4,826	6.86	701.96	701.97	0.01
WBB	47,999.7	211.9	3,848	8.60	703.65	703.65	0.00
WBC	49,333.0	177.7	2,998	11.04	707.01	707.13	0.12
WBD	50,363.7	218.8	3,942	8.40	711.31	711.36	0.05
WBE	51,148.5	282.2	4,234	7.82	713.21	713.22	0.00
WBF	51,669.3	233.0	3,476	9.52	714.26	714.26	0.00
WBG	52,583.0	192.4	2,956	11.20	716.53	717.31	0.78
WBH	53,827.1	280.6	3,829	8.65	721.82	722.10	0.28
WBI	55,404.0	312.5	4,164	7.95	726.07	726.20	0.12
WBJ	56,215.9	199.1	2,787	11.88	728.04	728.09	0.04
WBK	57,195.9	230.1	3,844	8.61	733.16	733.16	0.00
WBL	58,381.6	1,204.0	13,204	2.08	735.02	735.04	0.03
WBM	59,190.1	1,031.3	9,527	2.88	735.13	735.17	0.04
WBN	60,094.9	748.6	5,488	4.99	735.71	735.73	0.02
	60,248.2	Route 100 Bridge, Stockbridge, VT					
WBO	60,446.0	690.0	6,025	4.55	738.21	738.20	0.00
WBP	62,003.0	265.0	3,303	8.30	739.71	739.73	0.02
WBQ	62,859.1	531.5	6,443	4.25	741.28	741.54	0.26
WBR	63,649.9	629.4	6,646	4.12	741.64	742.26	0.62
WBS	64,894.5	497.2	5,260	5.21	742.40	743.38	0.98
WBT	66,003.0	475.0	4,433	6.18	743.88	744.78	0.90
WBU	66,762.6	374.7	3,741	7.32	744.85	745.85	1.00

Table 4–1. Results of the floodway analysis for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; ft², square feet; ft/s, feet per second; NAVD 88, North American Vertical Datum of 1988]

Cross-section indentifier	River station (ft)	Floodway			Water-surface elevation		
		Width (ft)	Section area (ft²)	Mean velocity (ft/s)	Without floodway (ft, NAVD 88)	With floodway (ft, NAVD 88)	Increase (ft)
White River—Continued							
WBV	67,964.9	373.9	4,037	6.79	747.59	748.02	0.43
WBW	68,729.2	610.2	6,287	4.36	748.84	749.47	0.64
WBX	69,530.0	275.0	3,270	8.38	748.79	749.78	1.00
WBY	70,204.6	692.5	6,395	4.28	750.86	751.62	0.76
WBZ	71,272.1	730.0	6,825	4.01	751.35	752.32	0.97
WCA	72,045.5	579.3	3,777	7.25	751.65	752.63	0.98
WCB	72,857.2	295.5	2,502	10.95	754.30	754.37	0.07
WCC	73,316.1	322.1	3,295	8.32	756.85	756.95	0.10
WCD	74,978.0	490.0	4,391	6.24	760.40	761.07	0.66
WCE	75,838.5	439.2	3,494	7.84	761.56	762.55	0.99
WCF	76,883.6	660.0	5,477	5.00	764.56	765.27	0.71
WCG	77,756.2	465.0	3,439	7.97	765.74	766.01	0.27
WCH	79,171.7	212.2	3,067	8.93	769.79	770.78	0.99
WCI	80,006.3	260.5	3,202	8.56	772.43	772.93	0.49
WCJ	81,084.3	165.8	2,247	12.19	775.04	775.30	0.27
WCK	82,177.8	251.2	2,758	9.94	780.03	780.08	0.05
WCL	83,205.9	447.0	4,940	5.24	782.86	783.20	0.34
WCM	83,689.3	606.6	4,507	5.75	783.10	783.47	0.37
WCN	84,934.1	813.1	7,699	3.36	783.87	784.81	0.94
WCO	85,500.3	880.2	7,702	3.36	784.11	785.08	0.97
WCP	87,066.9	474.9	4,051	6.39	784.96	785.87	0.91
WCQ	88,108.9	667.8	5,572	4.65	787.06	787.74	0.67
WCR	89,193.4	945.0	6,581	3.94	787.76	788.75	0.99
WCS	90,430.2	440.0	2,988	8.67	789.31	790.04	0.73
	90,793.6	Liberty Hill Road Bridge, Rochester, VT					
WCT	91,069.4	657.8	6,051	4.28	795.09	795.73	0.64
WCU	92,596.5	660.0	4,989	5.19	796.32	797.16	0.84
WCV	93,698.8	560.0	4,277	6.06	797.95	798.95	1.00
WCW	95,416.5	297.6	3,675	7.05	801.43	801.98	0.56
WCX	96,152.6	875.0	6,455	4.01	802.81	803.44	0.63
WCY	97,333.4	690.0	5,328	4.86	804.48	804.93	0.45
WCZ	98,577.8	458.0	3,352	7.73	807.29	808.23	0.94
WDA	99,224.9	243.3	2,569	10.08	811.67	812.67	1.00
	99,327.5	State Garage Road, Rochester, VT					
WDB	99,466.8	184.3	2,733	9.48	816.75	816.74	0.00
WDC	100,388.2	945.3	5,381	4.81	819.87	820.08	0.21
WDD	101,102.7	894.9	8,438	2.31	821.02	821.20	0.18
WDE	101,877.9	345.5	2,921	6.68	821.03	821.20	0.16

Table 4–1. Results of the floodway analysis for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; ft², square feet; ft/s, feet per second; NAVD 88, North American Vertical Datum of 1988]

Cross-section indentifier	River station (ft)	Floodway			Water-surface elevation		
		Width (ft)	Section area (ft²)	Mean velocity (ft/s)	Without floodway (ft, NAVD 88)	With floodway (ft, NAVD 88)	Increase (ft)
White River—Continued							
	101,991.7	Route 73 Bridge, Rochester, VT (Temporary Structure)					
WDF	102,206.0	348.0	3,635	5.36	824.06	824.06	0.00
WDG	103,340.7	290.0	2,715	7.18	825.55	825.67	0.12
WDH	104,059.3	430.0	3,281	5.94	827.64	828.24	0.60
WDI	104,247.9	390.0	4,353	4.48	827.95	828.89	0.94
WDJ	105,584.0	504.0	4,713	4.14	829.23	830.24	1.00
WDK	106,136.2	639.4	6,024	3.24	829.71	830.67	0.96
WDL	106,983.8	629.1	4,533	4.30	829.99	830.94	0.95
WDM	108,075.9	499.8	3,267	5.97	831.58	832.45	0.88
	108,175.3	River Brook Drive, Rochester, VT					
WDN	108,255.4	580.0	4,185	4.66	832.49	833.47	0.98
WDO	109,156.2	243.5	2,234	8.19	834.07	834.76	0.69
Tweed River							
TA	680.3	300.4	1,552	5.47	729.86	730.04	0.18
TB	1,197.1	137.0	1,181	7.19	731.42	731.60	0.17
TC	1,734.9	142.1	913	9.30	733.62	733.77	0.15
TD	2,345.3	372.7	1,551	5.47	739.36	740.00	0.64
TE	3,113.3	127.8	1,208	7.03	742.41	743.40	0.99
	3,292.3	Route 107 Bridge, Stockbridge, VT					
TF	3,530.0	215.0	1,442	5.89	744.43	745.00	0.58
TG	4,392.2	315.0	1,576	5.17	746.25	747.15	0.89
TH	5,104.6	260.0	1,279	6.36	749.55	749.79	0.25
TI	5,762.3	356.9	1,262	6.45	751.91	752.83	0.92
	5,852.9	South Hill Road Bridge, Stockbridge, VT					
TJ	5,905.6	332.8	1,860	4.38	754.53	755.02	0.49
TK	7,156.5	288.3	1,378	5.91	756.42	757.41	0.99
TL	7,890.0	189.5	812	10.03	760.45	760.44	0.00
TM	8,811.4	244.4	1,395	5.83	764.84	765.81	0.97
TN	9,850.4	245.1	1,602	5.08	768.63	769.08	0.45
TO	10,376.2	462.1	1,988	4.09	770.60	770.89	0.29
TP	10,812.2	421.1	1,621	5.02	773.04	773.31	0.26
TQ	11,403.6	155.0	926	8.79	776.14	776.13	0.00
TR	12,443.2	108.0	899	9.06	781.47	781.83	0.36
TS	13,029.2	107.7	730	11.14	785.81	785.93	0.12
TT	13,642.1	149.7	1,201	6.78	789.80	790.66	0.86
TU	14,410.6	162.7	1,178	6.91	792.74	793.73	0.99
TV	14,961.6	326.6	1,909	3.77	795.98	796.44	0.46
TW	15,453.5	312.5	1,029	6.99	797.22	797.87	0.65
TX	15,807.7	300.0	1,455	4.94	800.77	801.16	0.38

Table 4–1. Results of the floodway analysis for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; ft², square feet; ft/s, feet per second; NAVD 88, North American Vertical Datum of 1988]

Cross-section indentifier	River station (ft)	Floodway			Water-surface elevation		
		Width (ft)	Section area (ft²)	Mean velocity (ft/s)	Without floodway (ft, NAVD 88)	With floodway (ft, NAVD 88)	Increase (ft)
Tweed River—Continued							
TY	16,140.3	157.8	860	8.36	802.14	802.19	0.04
TZ	16,607.6	143.0	1,021	7.04	805.22	805.95	0.73
TAA	17,462.7	212.1	911	7.90	810.90	811.90	1.00
TAB	18,282.1	229.2	1,093	6.58	819.06	820.06	1.00
TAC	18,618.8	220.6	1,120	6.42	820.83	821.68	0.85
TAD	19,102.6	146.9	778	9.24	823.25	824.04	0.79
TAE	19,676.6	320.0	1,209	5.64	828.36	828.71	0.35
	19,718.8	Snowmobile Trail Bridge, Pittsfield, VT					
TAF	19,769.2	475.0	1,987	3.43	830.23	830.33	0.10
TAG	20,329.8	237.5	797	8.56	833.54	833.53	0.00
TAH	20,632.9	270.0	818	4.33	837.57	837.57	0.00
	20,682.5	Paramenter Place Bridge, Pittsfield, VT					
TAI	20,720.3	243.1	1,065	3.32	839.56	839.57	0.01
TAJ	21,126.8	369.6	816	4.34	840.64	840.64	0.00
TAK	21,351.5	292.2	725	5.39	842.15	842.24	0.08
TAL	21,635.0	102.7	426	9.17	844.46	844.93	0.46
TAM	21,989.4	74.5	574	6.82	847.24	848.04	0.80
	22,037.5	Covered Bridge (Private), Pittsfield, VT					
TAN	22,110.8	62.0	685	5.71	851.37	851.89	0.52
TAO	22,267.8	134.0	978	4.00	851.59	852.37	0.78
	22,360.7	Tweed River Drive, Pittsfield, VT					
TAP	22,449.8	216.0	1,257	3.11	852.34	853.33	0.98
TAQ	22,964.7	240.0	662	5.91	853.85	854.48	0.63
TAR	23,478.9	256.0	880	4.44	858.10	859.10	1.00
TAS	24,387.6	113.8	564	6.93	864.98	865.24	0.26
TAT	24,866.1	112.2	546	7.16	868.91	869.92	1.00
TAU	25,341.0	98.3	541	7.23	874.13	874.15	0.02
TAV	25,930.4	97.6	559	6.99	878.08	878.48	0.40
TAW	26,680.5	80.7	438	8.94	884.58	884.87	0.29
	26,769.2	Route 100 Bridge, Pittsfield, VT (Temporary Structure)					
TAX	26,883.3	165.0	838	4.67	888.56	888.63	0.08
TAY	27,560.7	83.7	335	11.68	894.10	894.91	0.82
TAZ	28,018.4	162.0	784	4.99	901.00	901.76	0.76
TBA	28,645.7	110.5	391	9.99	907.67	907.73	0.06
TBB	29,049.6	187.0	663	5.90	914.91	915.00	0.08
TBC	29,466.3	87.6	420	6.45	918.80	918.83	0.03
TBD	30,030.2	64.6	322	9.57	925.73	925.77	0.04

Table 4–1. Results of the floodway analysis for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; ft², square feet; ft/s, feet per second; NAVD 88, North American Vertical Datum of 1988]

Cross-section indentifier	River station (ft)	Floodway			Water-surface elevation		
		Width (ft)	Section area (ft²)	Mean velocity (ft/s)	Without floodway (ft, NAVD 88)	With floodway (ft, NAVD 88)	Increase (ft)
Tweed River—Continued							
	30,063.9	Bakers Road Bridge, Pittsfield, VT					
TBE	30,109.5	123.0	978	2.77	931.09	931.56	0.47
TBF	30,420.9	158.0	743	3.65	931.42	931.95	0.53
TBG	30,887.2	204.0	397	6.82	935.75	935.94	0.19
TBH	31,222.5	371.4	977	2.78	939.41	939.66	0.25
TBI	31,558.9	178.0	552	4.91	941.27	941.28	0.01
TBJ	31,992.3	210.3	632	4.29	945.05	945.04	0.00
TBK	32,569.5	146.6	347	7.80	953.48	953.48	0.00
TBL	33,063.3	137.5	562	4.83	960.73	960.85	0.12
TBM	33,549.2	108.4	310	8.73	966.66	966.76	0.10
TBN	33,851.3	182.0	634	4.27	971.02	971.37	0.34
	33,919.7	Stonewood Crossing Bridge, Pittsfield, VT					
TBO	33,987.0	281.1	1,076	2.52	972.77	973.76	0.99
TBP	34,322.5	102.0	292	9.30	976.28	976.39	0.10
TBQ	34,766.2	66.8	358	7.58	983.28	983.74	0.45
TBR	35,175.3	62.0	300	9.03	988.34	988.58	0.23
TBS	35,466.7	71.9	221	8.24	993.97	994.46	0.49
TBT	35,665.3	105.0	336	5.41	997.52	998.52	1.00
	35,719.8	Private Drive Bridge, Pittsfield, VT					
TBU	35,768.7	73.0	339	5.37	999.94	1,000.63	0.69
TBV	35,985.8	65.2	188	9.70	1,002.67	1,002.67	0.00
TBW	36,320.7	249.1	488	3.73	1,009.26	1,009.26	0.00
TBX	36,704.8	105.9	248	7.35	1,013.85	1,013.85	0.00
TBY	37,044.7	86.3	277	6.58	1,020.25	1,020.25	0.00
TBZ	37,456.6	82.1	204	8.94	1,029.68	1,029.68	0.00
TCA	37,853.5	53.7	273	6.66	1,036.66	1,036.84	0.18
	37,885.1	Fellows Lane Bridge, Pittsfield, VT					
TCB	37,938.5	84.6	472	3.85	1,039.46	1,039.47	0.01
TCC	38,166.3	78.9	195	9.31	1,042.07	1,042.07	0.00
TCD	38,407.2	62.3	242	7.52	1,047.89	1,047.89	0.00
	38,435.7	Hadley Lane Bridge, Pittsfield, VT					
TCE	38,464.3	140.2	390	4.67	1,050.75	1,050.75	0.00
TCF	38,956.8	76.8	222	8.21	1,057.40	1,057.83	0.42
TCG	39,270.5	51.8	281	6.48	1,064.43	1,064.62	0.19
TCH	39,893.2	76.2	328	5.54	1,071.65	1,071.65	0.00
TCI	40,419.1	50.0	210	8.65	1,079.55	1,079.96	0.41
TCJ	40,841.6	64.9	281	6.48	1,088.24	1,088.65	0.41
TCK	41,303.3	46.5	168	10.85	1,101.91	1,101.91	0.00
TCL	41,636.3	39.0	274	6.64	1,108.66	1,109.20	0.54

Table 4–1. Results of the floodway analysis for the White River in Bethel, Stockbridge, and Rochester, Vermont, and the Tweed River in Stockbridge and Pittsfield, Vermont.—Continued

[Cross sections with identifiers are shown in appendix 5. ft, feet; ft², square feet; ft/s, feet per second; NAVD 88, North American Vertical Datum of 1988]

Cross-section indentifier	River station (ft)	Floodway			Water-surface elevation		
		Width (ft)	Section area (ft²)	Mean velocity (ft/s)	Without floodway (ft, NAVD 88)	With floodway (ft, NAVD 88)	Increase (ft)
Tweed River—Continued							
	41,667.9	Leigh Kelley Drive Bridge, Pittsfield, VT					
TCM	41,697.0	56.0	329	5.53	1,109.56	1,110.52	0.97
TCN	41,745.8	69.0	289	6.30	1,110.08	1,110.85	0.77
		Tweed River Bypass					
BA	70.3	52.9	173	2.14	832.32	832.57	0.25
BB	173.7	77.3	68.8	5.38	837.70	837.79	0.09
BC	261.9	80.0	227	1.63	838.67	839.08	0.42
BD	379.3	50.1	59.5	6.22	840.52	840.54	0.02

[a]With Route 12 bridge geometry as it existed prior to Tropical Storm Irene.

[b]With Route 73 bridge geometry as it existed prior to Tropical Storm Irene.

[c]Backwater from White River.

[d]Peak water-surface without bypass diversion.

Appendix 5. Results of the Floodway Analysis for the White River Modified for the Planned Route 73 Bridge in Rochester, Vermont

Table 5–1. Results of the floodway analysis for the White River modified for the planned Route 73 bridge in Rochester, Vermont.

[Cross sections with identifiers are shown in appendix 5. ft, feet; ft², square feet; ft/s, feet per second; NAVD 88, North American Vertical Datum of 1988; VT, Vermont]

Cross-section indentifier	River station (ft)	Floodway			Water-surface elevation		
		Width (ft)	Section area (ft²)	Mean velocity (ft/s)	Without floodway (ft, NAVD 88)	With floodway (ft, NAVD 88)	Increase (ft)
	99,327.5	State Garage Road, Rochester, VT					
WDB	99,466.8	184.3	2,733	9.48	816.75	816.74	0.00
WDC	100,388.2	495.5	4,038	6.41	819.87	820.13	0.26
WDD	101,102.7	510.6	5,978	3.26	821.02	821.67	0.65
WDE	101,877.9	306.7	2,932	6.65	821.03	821.92	0.89
	101,991.7	Route 73 Bridge, Rochester, VT (Planned Structure)					
WDF	102,206.0	343.0	4,102	4.75	825.52	825.53	0.01
WDG	103,340.7	265.0	2,785	7.00	826.40	826.44	0.04
WDH	104,059.3	430.0	3,464	5.63	828.05	828.66	0.62
WDI	104,247.9	390.0	4,482	4.35	828.31	829.22	0.91
WDJ	105,584.0	504.3	4,826	4.04	829.47	830.46	0.99
WDK	106,136.2	639.9	6,149	3.17	829.92	830.86	0.95
WDL	106,983.8	630.0	4,644	4.20	830.17	831.11	0.94
WDM	108,075.9	500.0	3,306	5.90	831.64	832.53	0.89
	108,175.3	River Brook Drive, Rochester, VT					

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