Prepared in cooperation with the Federal Emergency Management Agency

Flash Floods of August 10, 2009, in the Villages of Gowanda and Silver Creek, New York

Scientific Investigations Report 2010–5259

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

Cover. Cattaraugus Creek at New York State Thruway, August 10, 2009 (photo courtesy of The Buffalo News, Buffalo, N.Y.)

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Conversion Factors, Datums, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD29) or the North American Vertical Datum of 1988 (NAVD88), as noted.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD83).

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

Abbreviations

EDT	Eastern Daylight Time
EST	Eastern Standard Time
FEMA	Federal Emergency Management Agency
HEC-RAS	Hydrologic Engineering Center River Analysis System
LiDAR	Light Detection And Ranging
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
SPCS	State Plane Coordinate System
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Flash Floods of August 10, 2009, in the Villages of Gowanda and Silver Creek, New York

By Carolyn O. Szabo[1], William F. Coon[1], and Thomas A. Niziol[2]

Abstract

Late during the night of August 9, 2009, two storm systems intersected over western New York and produced torrential rain that caused severe flash flooding during the early morning hours of August 10 in parts of Cattaraugus, Chautauqua, and Erie Counties. Nearly 6 inches of rain fell in 1.5 hours as recorded by a National Weather Service weather observer in Perrysburg, which lies between Gowanda and Silver Creek—the communities that suffered the most damage. This storm intensity had an annual exceedance probability of less than 0.2 percent (recurrence interval greater than 500 years). Although flooding along Cattaraugus Creek occurred elsewhere, Cattaraugus Creek was responsible for very little flooding in Gowanda. Rather the small tributaries, Thatcher Brook and Grannis Brook, caused the flooding in Gowanda, as did Silver Creek and Walnut Creek in the Village of Silver Creek.

Damages from the flooding were widespread. Numerous road culverts were washed out, and more than one-quarter of the roads in Cattaraugus County were damaged. Many people were evacuated or rescued in Gowanda and Silver Creek, and two deaths occurred during the flood in Gowanda. The water supplies of both communities were compromised by damages to village reservoirs and water-transmission infrastructures. Water and mud damage to residential and commercial properties was extensive. The tri-county area was declared a Federal disaster area and more than $45 million in Federal disaster assistance was distributed to more than 1,500 individuals and an estimated 1,100 public projects. The combined total estimate of damages from the flash floods was greater than $90 million.

Over 240 high-water marks were surveyed by the U.S. Geological Survey; a subset of these marks was used to create flood-water-surface profiles for four streams and to delineate the areal extent of flooding in Gowanda and Silver Creek. Flood elevations exceeded previously defined 0.2-percent annual exceedance probability (500-year recurrence interval) elevations by 2 to 4 feet in Gowanda and as much as 6 to 8 feet in Silver Creek. Most of the high-water marks were used in indirect hydraulic computations to estimate peak flows for four streams. The peak flows in Grannis Brook and Thatcher Brook were computed, using the slope-area method, to be 1,400 and 7,600 cubic feet per second, respectively, and peak flow in Silver Creek was computed, using the width-contraction method, to be 19,500 cubic feet per second. The annual exceedance probabilities for flows in these and other basins with small drainage areas that fell almost entirely within the area of heaviest precipitation were less than 0.2 percent (or recurrence intervals greater than 500 years). The peak flow in Cattaraugus Creek at Gowanda was computed, using the slope-area method, to be 33,200 cubic feet per second with an annual exceedance probability of 2.2 percent (recurrence interval of 45 years).

Introduction

Severe thunderstorms during the night of August 9, 2009, caused extensive flooding during the early hours of August 10 across parts of Cattaraugus, Chautauqua, and Erie Counties in western New York (fig. 1). Although many road culverts were washed out and more than one-quarter of the roads in Cattaraugus County were damaged (National Oceanic and Atmospheric Administration, 2010a), the major damages and costs occurred in the residential and commercial sections of villages, such as Gowanda and Silver Creek. The flooding was caused by runoff from torrential rainfall that exceeded the capacity of small streams that flowed through these communities. Many people were evacuated or rescued in both communities, including patients in the Tri-County Memorial Hospital in Gowanda and residents of a creek-side trailer park in Silver Creek, which was destroyed. The water supplies of both communities were compromised by damages to village reservoirs and water-transmission infrastructures. Water depth in the flooded areas was about 1 to 3 ft, enough to fill basements and inundate the first floor of hundreds of homes and businesses. Damages resulted not only from water but also from mud that was carried by the sediment-laden floodwaters.

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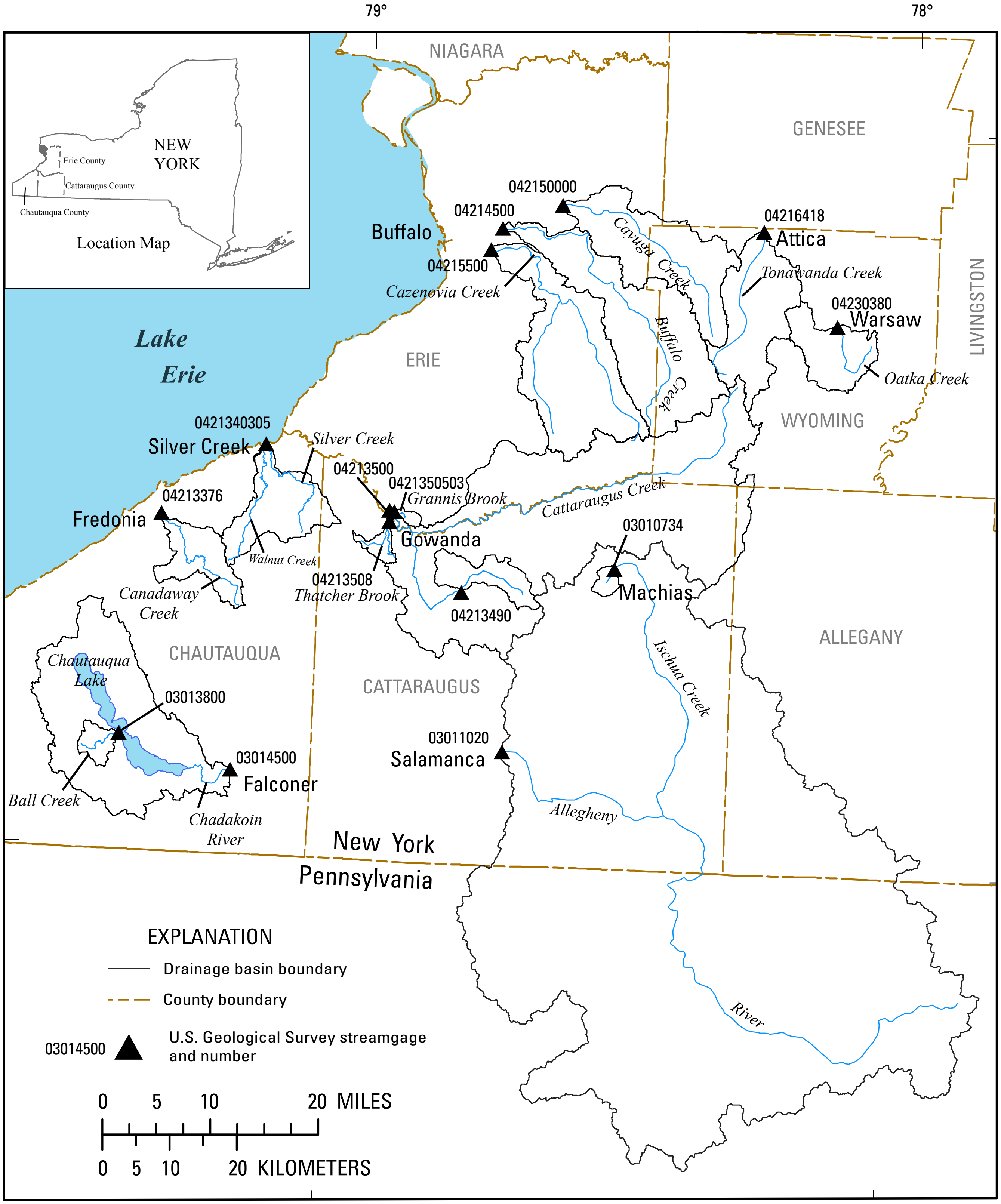

Base from USGS digital data, Zone 18, Universal Transverse Mercator

Figure 1. Locations of study sites and selected U.S. Geological Survey streamgages and associated drainage basins in western New York. (Streamgage names are listed in table 1.)

Two deaths occurred during the flood in Gowanda. One resident suffered a heart attack while emergency responders were delayed by flooded streets. A second resident drowned when he was swept into the rising floodwaters of Thatcher Brook (Fairbanks and others, 2009). The tri-county area was declared a Federal disaster area on September 1, 2009 (Federal Emergency Management Agency, 2009a). More than $45 million in Federal disaster assistance was distributed to fund the recovery efforts of more than 1,500 individuals and an estimated 1,100 public projects (Federal Emergency Management Agency, 2009b). The total cost of damages estimated by emergency managers in the affected counties and municipalities exceeded $90 million (National Oceanic and Atmospheric Administration, 2010a).

In 2009 the U.S. Geological Survey (USGS), in cooperation with the Federal Emergency Management Agency (FEMA), conducted a study to document the meteorological and hydrologic conditions that resulted in the damaging flash floods on August 10, 2009, in western New York. This report presents high-water elevations and maps of the areal extent of flooding that occurred in Gowanda and Silver Creek. Peak flows, estimated by indirect measurement methods for Grannis Brook, Thatcher Brook, and Cattaraugus Creek at or near the Village of Gowanda, and for Silver Creek (downstream from the confluence with Walnut Creek) at the Village of Silver Creek, also are presented. The magnitudes and annual exceedance probabilities (recurrence intervals) of these peak flows are compared with similar data obtained from nearby USGS continuous-record and peak-flow-only streamgages, as well as to data contained in the most recent flood-insurance studies for these communities.

Antecedent Hydrologic Conditions

Rainfall was scattered and varied in intensity during the first 3 days of August 2009. Rain fell across western New York on August 4 and ranged from 0.16 in. in Jamestown, 30 mi southwest of the study area, to 2.69 in. in Colden, northeast of the study area; over an inch of rain was recorded by a National Weather Service (NWS) cooperative weather observer in Perrysburg, which is about 3.5 mi west of Gowanda (National Oceanic and Atmospheric Administration, 2010b; fig. 2). No substantial precipitation fell during the next 3 days, but rain fell on August 8, and over 1 inch of rain fell across the area during the afternoon on August 9, prior to the flood-causing storm. The weather observer in Perrysburg recorded 1.29 in. of rain (National Oceanic and Atmospheric Administration, 2010b) on August 9 between 7:00 a.m. and 10:30 p.m. Eastern Daylight Time (EDT), at which time the observer emptied the rain gauge. Saturated soil conditions existed prior to the intense storm that caused the flooding. Flows in streams that were monitored by the USGS in western New York were generally above average flow levels for August, and at 10:00 p.m. EDT on August 9, just before the major storm event, flows were receding from runoff that had occurred earlier in the day.

Storm Characteristics

A detailed analysis of the storm that caused the flooding on August 10, 2009, was performed by the National Weather Service office in Buffalo (National Weather Service, 2009). At 8:00 p.m. EDT on August 9, a line of severe thunderstorms located over Lake Ontario was moving south toward western New York (including the city of Buffalo). As the line of storms moved through Buffalo, damaging winds, frequent lightning, and heavy rainfall occurred. Although flows increased in streams, no flooding was reported because the storm was moving rapidly southward. Around 9:30 p.m. EDT, a second line of severe storms developed over Lake Erie and moved eastward over Cattaraugus and Chautauqua Counties. In addition to frequent lightning, this line of storms also produced very heavy rainfall. By 10:00 p.m. EDT the first line of storms intersected the second line and evolved from a wind-damaging weather system into a flash-flood system. The combined storms stalled for a little more than an hour roughly along the southern boundary of Erie County (over an area that included Silver Creek and Gowanda) before weakening and continuing southward to the Pennsylvania border. During the period from 10:30 p.m. on August 9, through midnight EDT on August 10, the weather observer in Perrysburg reported 5.98 in. of rainfall. Radar-derived estimates of rainfall that occurred over the 3-hr period from 9:09 p.m. on August 9 through 12:09 a.m. EDT on August 10, 2009, (fig. 2) showed that rainfall exceeded 4 in. along a line just south of the Erie-Cattaraugus County line. On the basis of the weather observer's "ground-truth" report, the radar-derived precipitation likely underestimated the actual precipitation quantities. The combination of torrential rains and the high-relief topography of the area resulted in extensive flash flooding.

In the areas of the two communities that are the focus of this report, radar-derived estimates of precipitation give daily (not just storm) totals of 7.06 in. for Gowanda and 6.28 in. for Silver Creek (Northeast Regional Climate Center, written instructions for retrieval of site-specific radar-derived precipitation, 2008). The maximum daily total precipitation that was reported by a NWS cooperative weather observer, again the observer from Perrysburg, was 7.27 in. The Northeast Regional Climate Center assigned a recurrence interval for this daily total of 200 to 500 years. The 120-minutes duration, 500-year return-period precipitation quantity for this area is 4.18 in.; therefore, a rainfall of 5.98 in. in 90 min would have a recurrence interval far greater than 500 years or a percent chance of occurring during a given year of less than 0.2 percent (K. Eggleston, Northeast Regional Climate Center, written commun., 2009).

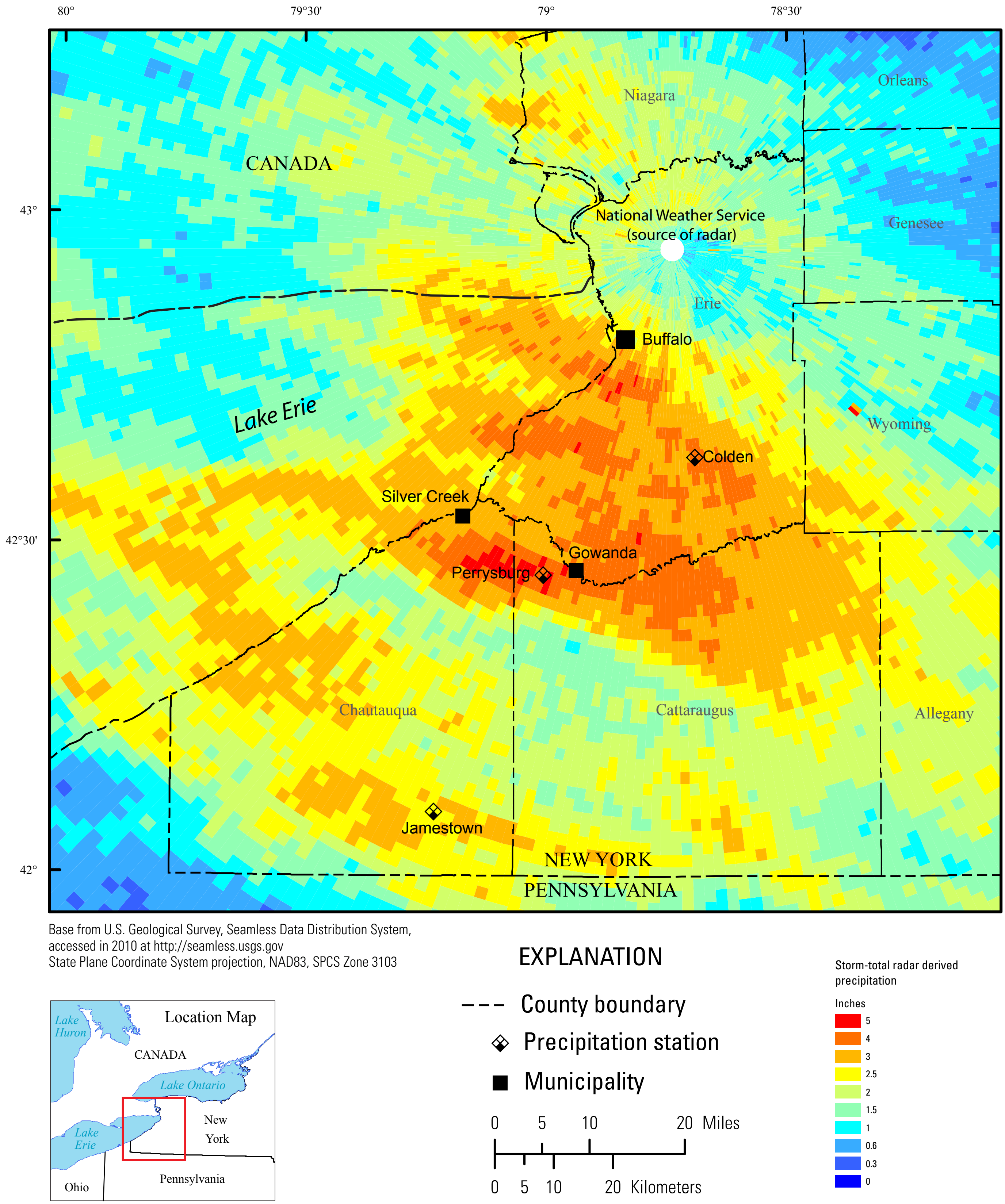

Figure 2. Storm-total radar-derived precipitation in western New York from 9:09 p.m. on August 9, 2009, through 12:09 a.m. Eastern Daylight Time on August 10, 2009. (From the National Weather Service at http://www.wbuf.noaa.gov/svrwx/web_090810_Flashflood/indexflood.html.)

Description of the Floods

Flooding occurred in a relatively small area of western New York, primarily limited to Cattaraugus, Chautauqua, and Erie Counties. These counties were declared disaster areas by both the State and Federal governments. Flooding was primarily due to the under-capacity of small channels to convey the runoff that was generated by the intense precipitation; therefore, the most serious flooding and damages occurred in small stream basins. Outside of developed areas, the major flood damages resulted from the overtopping of roadways and, in many cases, the erosion of road surfaces and complete removal of culverts (fig. 3). In residential and commercial areas, such as Gowanda and Silver Creek, extensive flooding and damage from water and mud occurred (fig. 3). In both of these communities, flooding occurred outside previously defined flood-prone areas and caught many residents by surprise. In addition, the rate at which floodwaters rose was unusually fast and hampered rescue efforts by local emergency responders. Walnut Creek, which joins Silver Creek within the Village of Silver Creek, reportedly rose 3 to 4 ft in 30 min (T. Roche, Silver Creek Police Chief, oral commun., 2009).

In addition to the tremendous amount of runoff that was conveyed in small channels, the flooding in Gowanda was affected by the topographic characteristics of the area. Thatcher Brook and Grannis Brook approach Gowanda through high-relief areas where steep valley sides generally confine high flows. As these streams enter the village and the Cattaraugus Creek floodplain, the gradient decreases substantially, and the confining valley walls disappear. Sheet-flow flooding across the residential and commercial areas of the village occurs whenever water levels exceed the tops of streambanks. Flooding on August 10, 2009, on the north side of Gowanda was exacerbated by a debris-clogged culvert on Grannis Brook. Residents of Gowanda were evacuated to a nearby school. Patients at the Tri-County Memorial Hospital in Gowanda were relocated, campers at Zoar Valley, upstream from Gowanda along Cattaraugus Creek, were rescued by helicopter, and a trailer park in Silver Creek was destroyed (Fairbanks and others, 2009; Thompson, 2009). Reservoirs that supplied water to both communities were overtopped during the floods, and the receding waters left mud, trees, and other debris behind. The water quality of these reservoirs was compromised, and the repairs to the reservoirs and water-supply infrastructures were estimated to take many months to return the reservoirs to their pre-flood functionality (Flynn, 2009).

Cattaraugus Creek at Gowanda (station 04213500) rose 5 ft in 1 hr between 11:35 p.m. and 12:35 a.m. EDT (10:35 to 11:35 p.m. Eastern Standard Time (EST) on August 9) and had an initial peak of 12.88 ft at 1:35 a.m. EDT (12:35 a.m. EST) on August 10 (fig. 4). The creek receded slightly, then rose to its maximum recorded gage height of 13.47 ft at 7:35 a.m. EDT (6:35 a.m. EST) on August 10. The tributaries entering Cattaraugus Creek—Thatcher Brook and Grannis Brook—peaked around 2:00 to 3:00 a.m. EDT on August 10 (Emergency responders, oral commun., 2009). Therefore, tributary inflows were decreasing as Cattaraugus Creek reached its highest stage 5 hours later, and peak flows in Cattaraugus Creek at Gowanda reflected contributions from headwater areas of the basin rather than from nearby tributaries.

Cattaraugus Creek itself was not a source of major flooding in Gowanda compared to the tributaries Thatcher Brook and Grannis Brook, which caused extensive flooding to the south and north of Cattaraugus Creek, respectively. Although flooding along Cattaraugus Creek occurred elsewhere (for example, see report cover photograph), the flows in the creek within the village limits of Gowanda were mostly contained by high banks. The only noted exceptions occurred upstream from the bridge on U.S. Highway 62 (Main Street) at the American Legion (on Legion Drive) on the north bank and at a residence directly across the creek (South Water Street) on the south bank. Both properties likely experienced some flooding from Grannis Brook and Thatcher Brook, respectively, but this flooding would have preceded flooding from Cattaraugus Creek by several hours. Flooding of these two properties occurred because they are at lower elevations than other properties along this reach.

Collection of High-Water-Mark Data

Two hundred forty-three high-water elevations in the flooded communities were surveyed by the USGS by differential leveling methods according to guidelines described by Kennedy (1988). A variety of surveying instruments, including an automatic optical level, a digital level, and a total station, were used to measure elevations to an accuracy of at least 0.01 ft. High-water marks are an indication of the water level at the peak stage of a river during a flood event and can be used to delineate a flooded area, compute peak streamflows, or calibrate peak-flow models used in flood-insurance studies. High-water marks are usually determined from mud, seed, or debris lines (or a combination thereof) left behind as the floodwaters receded or from wash lines where fine-grained soils have been eroded or loose vegetative material has been removed. High-water marks generally can be found on trees because seeds and small debris can get caught in the bark, but mud lines are common marks found in developed areas. The accuracy of the high-water marks is subjectively rated by the USGS personnel locating the mark, as outlined in Lumia and others (1986). High-water marks can be rated “excellent” (within 0.02 ft of the “true” high-water mark), “good” (within 0.05 ft), “fair” (within 0.10 ft), or “poor” (greater than 0.10 ft). Typical high-water marks included debris lines (fig. 5A), wash lines on a sloping shale bank (fig. 5B), mud lines (fig. 5C and D), and seed lines or grass on trees (fig. 5E).

The fill above and the edge of the road on the downstream side of a concrete culvert were eroded.

A culvert and road were completely washed away.

Mud and debris covered residential lawns.

Mud-covered belongings from flooded basements were discarded and lined the streets of Gowanda.

Figure 3. Photographs of damage from the floods of August 10, 2009.

During the field activities related to the flooding, which were conducted on August 12-13, August 18-21, September 8-9, and October 19-21, 2009, 155 and 88 high-water marks were located and surveyed within the village limits of Gowanda and Silver Creek, respectively. Many of these marks were used exclusively for estimation of peak flows in the streams that flowed through these communities. A subset of the marks (app. 1) was compiled to create water-surface profiles of the floods along the streams and maps of inundation in each of the flooded communities.

Floodwater-Surface Profiles

High-water marks that were surveyed along Grannis Brook (fig. 6) and Thatcher Brook (fig. 7) in Gowanda, and Walnut Creek (fig. 8) and Silver Creek (fig. 9) in the Village of Silver Creek, were used to create profiles of the water-surface elevations of the flood as it passed through the two communities. The high-water mark locations were picked from a plan drawing of the inundated areas and referenced to street intersections or other landmarks. The profiles were

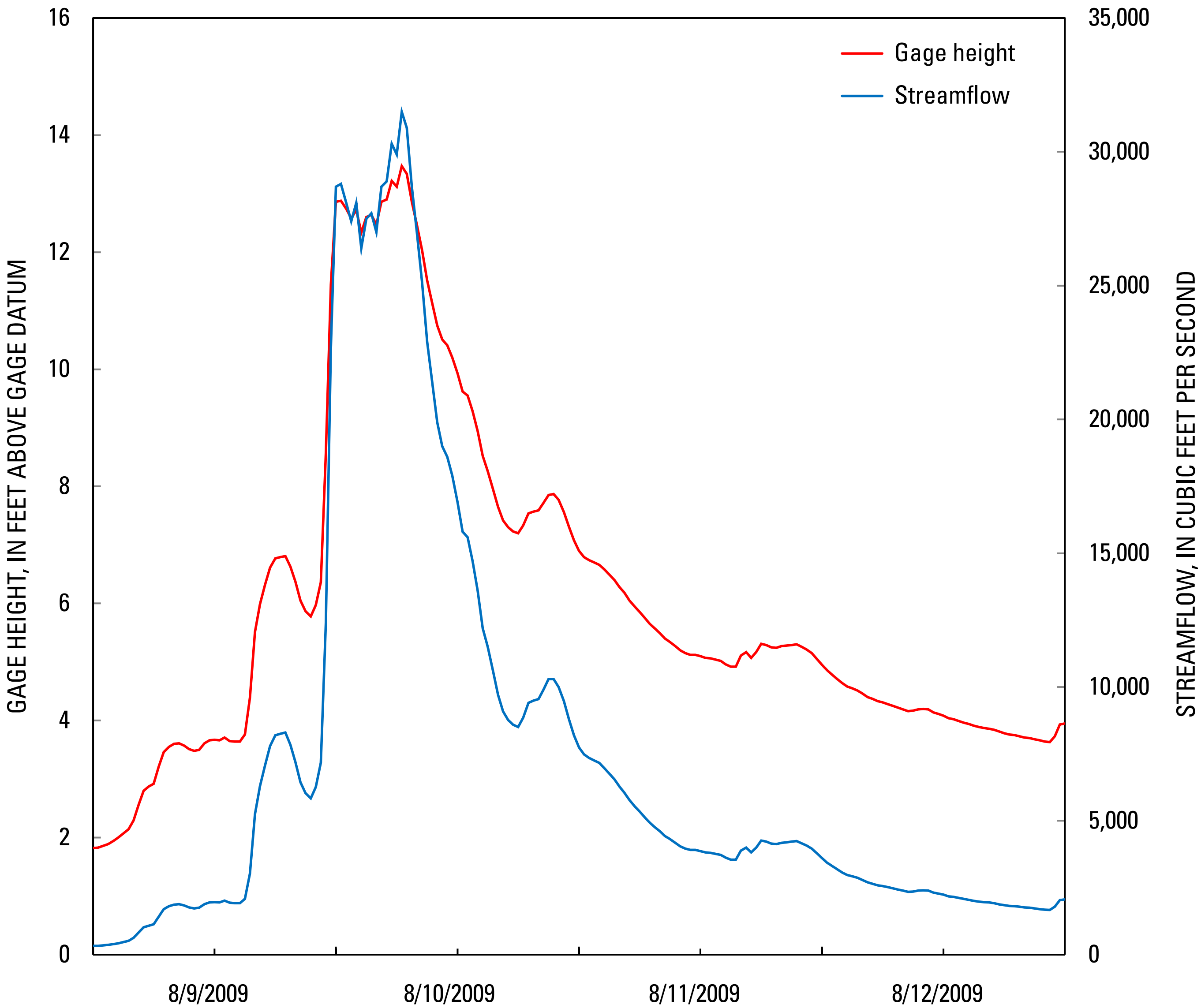

Figure 4. Streamflow and gage-height for Cattaraugus Creek at Gowanda, New York, U.S. Geological Survey station 04213500, August 9-12, 2009.

compared with those from the FEMA 0.2-percent annual exceedance probability (500-year recurrence interval) profiles (Federal Emergency Management Agency, 1983; 2009c). The profiles for Grannis Brook and Thatcher Brook were plotted to the North American Vertical Datum of 1988 (NAVD 88), whereas those for Walnut Creek and Silver Creek were plotted to the National Geodetic Vertical Datum of 1929 (NGVD 29), which are the respective datums used in the most recent FEMA flood-insurance reports. The plots showed that flood levels on August 10 along Grannis Brook were close to, or slightly higher than, the FEMA flood levels, whereas those along Thatcher Brook were 2 to 4 ft higher at some points. The flood levels along Walnut and Silver Creeks were noticeably higher than the FEMA flood levels, at some locations as much as 6 to 8 ft higher.

Areal Extent of Flooding

Floodwater-surface elevations, notes from USGS field personnel, and observations from community leaders and

Figure 5. Examples of representative high-water marks from the floods of August 10, 2009: *(A)* debris line, *(B)* wash line, *(C* and *D)* mud lines, and *(E)* grass on tree.

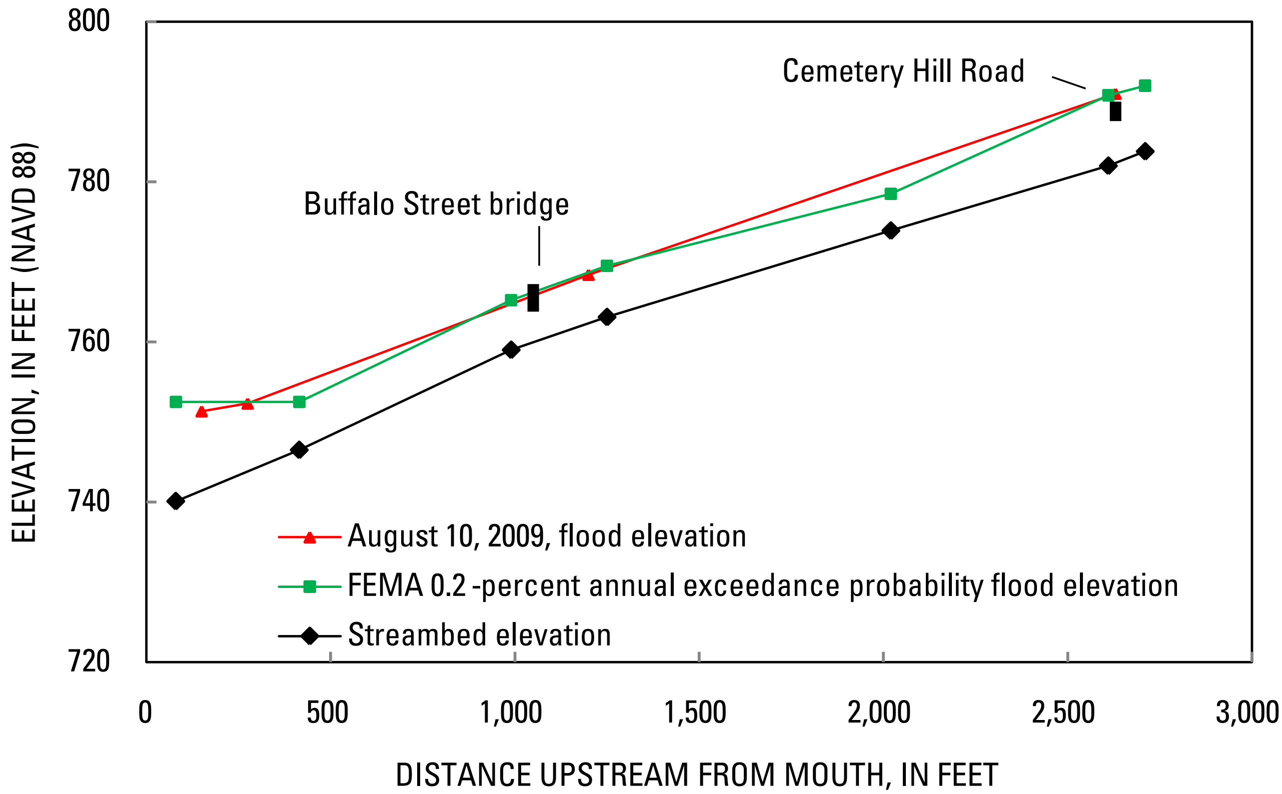

Figure 6. Water-surface elevations for the August 10, 2009, flood and the FEMA 0.2-percent annual exceedance probability flood for Grannis Brook at Gowanda, N.Y.

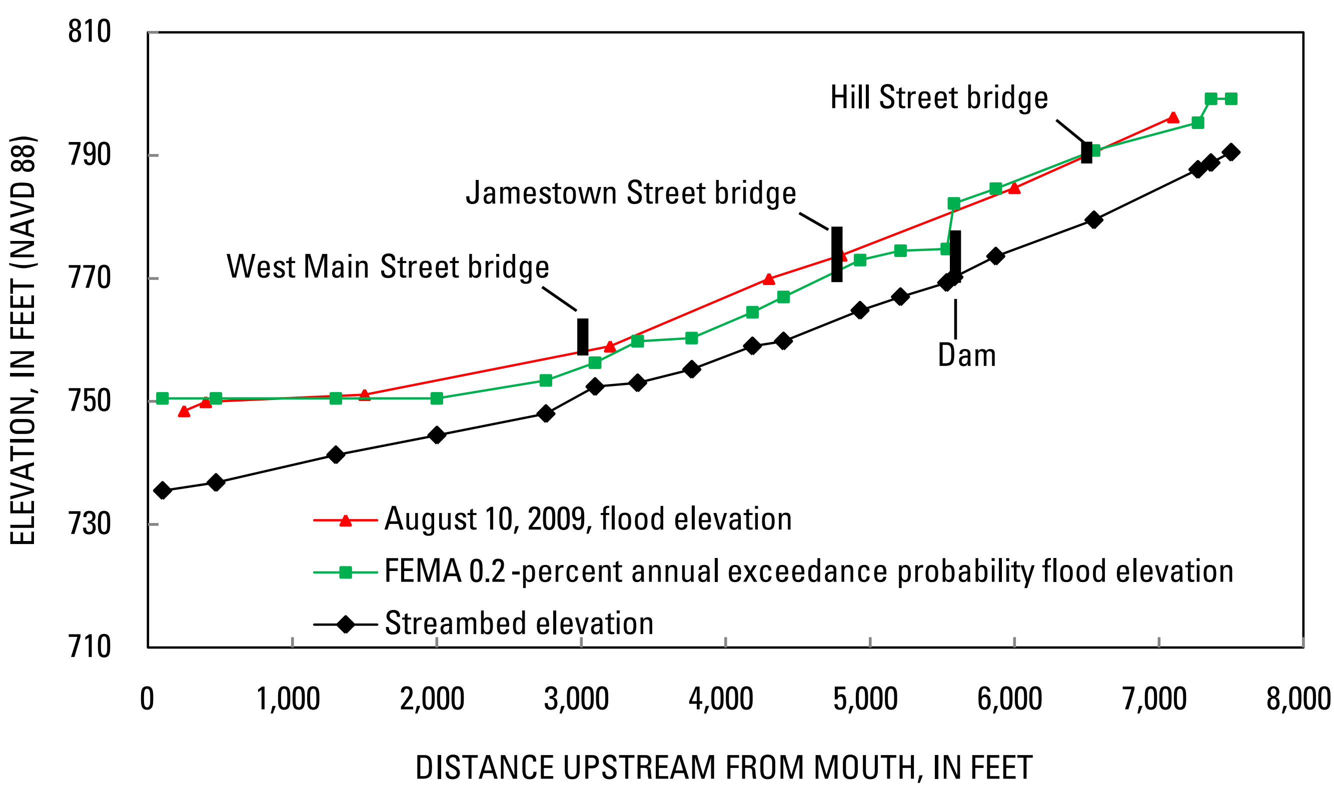

Figure 7. Water-surface elevations for the August 10, 2009, flood and the FEMA 0.2-percent annual exceedance probability flood for Thatcher Brook at Gowanda, N.Y.

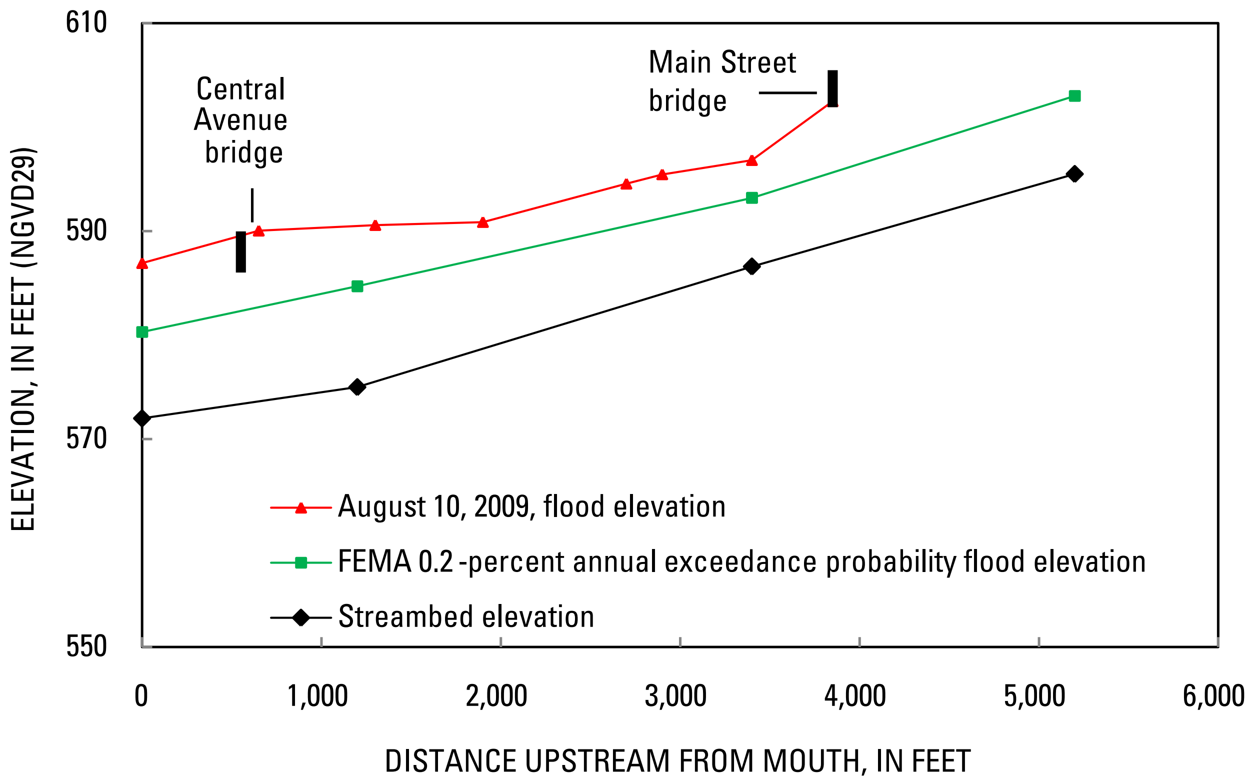

Figure 8. Water-surface elevations for the August 10, 2009, flood and the FEMA 0.2-percent annual exceedance probability flood for Walnut Creek at Silver Creek, N.Y.

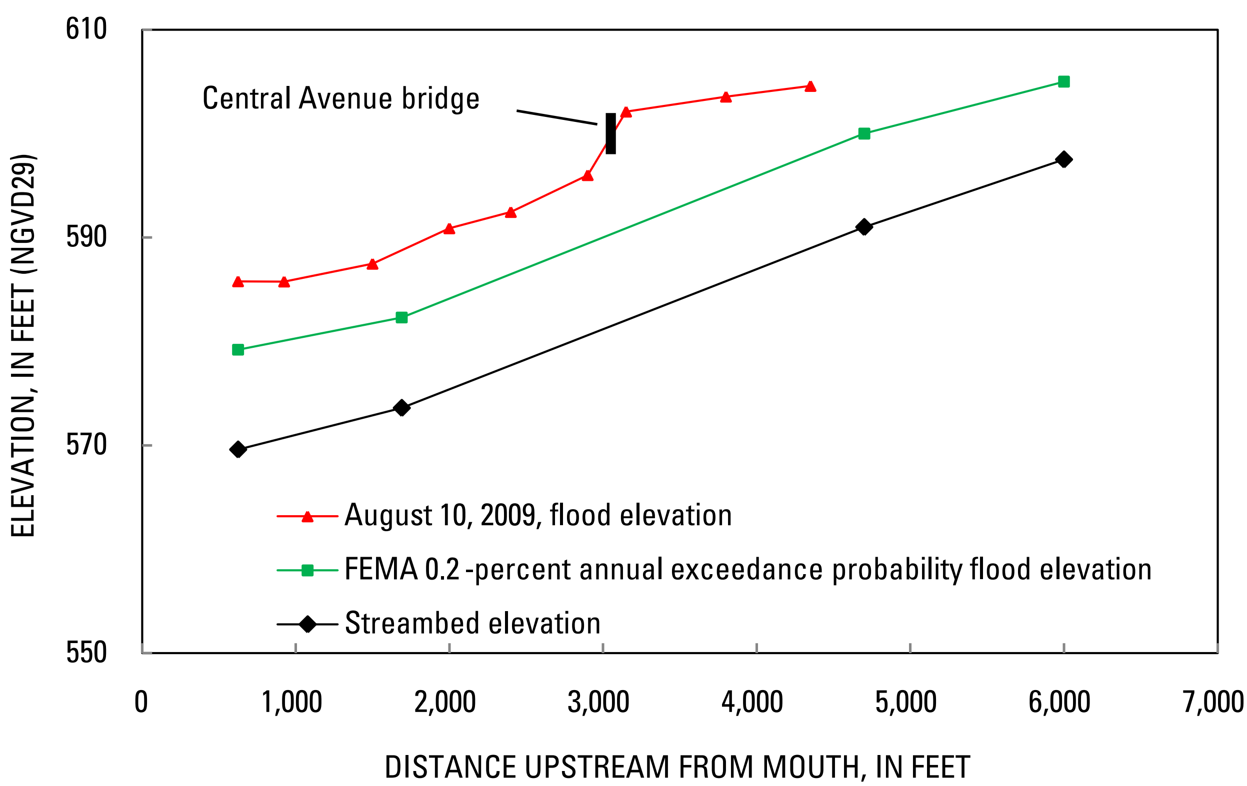

Figure 9. Water-surface elevations for the August 10, 2009, flood and the FEMA 0.2-percent annual exceedance probability flood for Silver Creek at Silver Creek, N.Y.

emergency responders were used, along with a geographic information system, to create maps that showed the areal extent of flooding in Gowanda (fig. 10) and Silver Creek (fig. 11). Calculation of depth of inundation within these delineated areas was not possible because the 30-meter digital elevation data that were available were imprecise, and high-accuracy land-surface elevation data (such as LiDAR) were unavailable. As was done with the presentation of the water-surface-profile plots, the high-water elevations that are presented in these figures are referenced to different datums. Those for the Gowanda area are referenced to NAVD 88, whereas those for the Silver Creek area are referenced to NGVD 29. Again, this was done so that the August 10, 2009, data would be directly comparable to the data presented in the most recent FEMA flood-insurance report for each community.

Grannis Brook flooding was exacerbated by the culvert at Cemetery Hill Road, which because of its small size could not convey the flood flows and was partly blocked by debris. Water outside of the channel at this point flowed down East Main Street and Perry Street, through the adjacent residential areas (fig. 10). Floodwaters, up to 3 ft deep, continued through the commercial area along Buffalo Street (U.S. Highway 62) before flowing into Cattaraugus Creek. At the south end of the village, floodwaters in Thatcher Brook had exceeded that channel's capacity to such a degree that water levels just south of the village limit overtopped the western bank on which U.S. Highway 62 is located (fig. 10). Water flowed down U.S. Highway 62 (Jamestown Street) through a railroad underpass, then through a residential area that, for lesser magnitude floods, would have been protected from flooding by the railroad embankment between this neighborhood and the brook. Downstream from the end of the railroad embankment (upstream from Hill Street), the floodwaters on either side of the embankment combined and flowed as sheet flow, in some cases more than 3 ft deep, throughout the village from this point to Cattaraugus Creek.

Floodwaters in Silver Creek upstream from the village limit covered the vegetated floodplains on the insides of meander bends but were confined by the valley walls and caused no destruction of property. Once inside the village limits, however, floodwaters inundated the floodplain areas on which a trailer park and businesses had been built, caused extensive damage, and threatened the lives of residents and emergency responders. A similar situation occurred on Walnut Creek, but most of the damaged properties between Main Street (U.S. Highway 20) and Central Avenue (State Highway 5; fig. 11) were private residences. Water depths in these areas typically ranged from 3 to 5 ft but increased to as much as 8 ft in the area below the confluence of the two creeks, where the railroad embankment that parallels the Lake Erie shoreline caused the floodwater to pond before eventually draining through one of two outlets—Silver Creek or the Jackson Street railroad underpass (about 800 ft to the west; fig. 11).

Magnitudes of Peak Streamflows

In addition to the flood sites on Grannis Brook, Thatcher Brook, and Silver Creek, peak streamflows presented in this report were determined at 12 USGS continuous-record or peak-flow-only streamgages in western New York (table 1). Stage-to-streamflow relations that had been previously defined by streamflow measurements at 11 of these sites were used to assign peak flows to the recorded peak gage heights. Indirect measurements of peak flows were made at four sites, including one continuous-record site where confirmation of the stage-to-streamflow relation was desired and three ungaged sites on streams that were hardest hit by the August 10 floods but for which stage-to-streamflow relations had not been defined. Estimates of the peak flows in Grannis Brook, Thatcher Brook, and Cattaraugus Creek (all in Gowanda) were computed by the slope-area method following procedures described by Dalrymple and Benson (1967). Computations were performed by the USGS Slope-Area Computation program (Fulford, 1994). The estimated peak flows in Grannis Brook, Thatcher Brook, and Cattaraugus Creek were 1,400 ft^3/s, 7,600 ft^3/s, and 33,200 ft^3/s, respectively (table 2).

The computation of the peak flow in Silver Creek was complicated by erratic floodplain flow, a large contraction in flow area caused by a railroad bridge, and bypass flow though a railroad underpass. The peak flow in the main channel was computed using two methods: the open-channel width-contraction (or contracted opening) method (Matthai, 1967) and the critical-depth method (Barnes and Davidian, 1978) with the River Analysis System, HEC-RAS (Brunner, 2008). The results from the two computations agreed within 1 percent. The peak flow through the railroad underpass was computed using the flow-through-culvert method described by Bodhaine (1968) with the USGS Culvert Analysis Program (Fulford, 1998). The computed peak flows in the main and bypass channels of Silver Creek were 19,000 ft^3/s and 520 ft^3/s, respectively (table 2).

Annual Exceedance Probabilities of Peak Streamflows

The annual exceedance probability is the chance that a flood of a given magnitude will be equaled or exceeded in any one year. The reciprocal of the annual exceedance probability is the recurrence interval, expressed in years. For example, a flood that has a 1 in 100 chance of being equaled or exceeded in any one year has an annual exceedance probability of 1 percent and a recurrence interval of 100 years (Holmes and Dinicola, 2010). This flood is commonly referred to as the 100-year flood. Similarly, a 500-year flood has a 0.2-percent chance (or 1 in 500 chance) of being equaled or exceeded in a

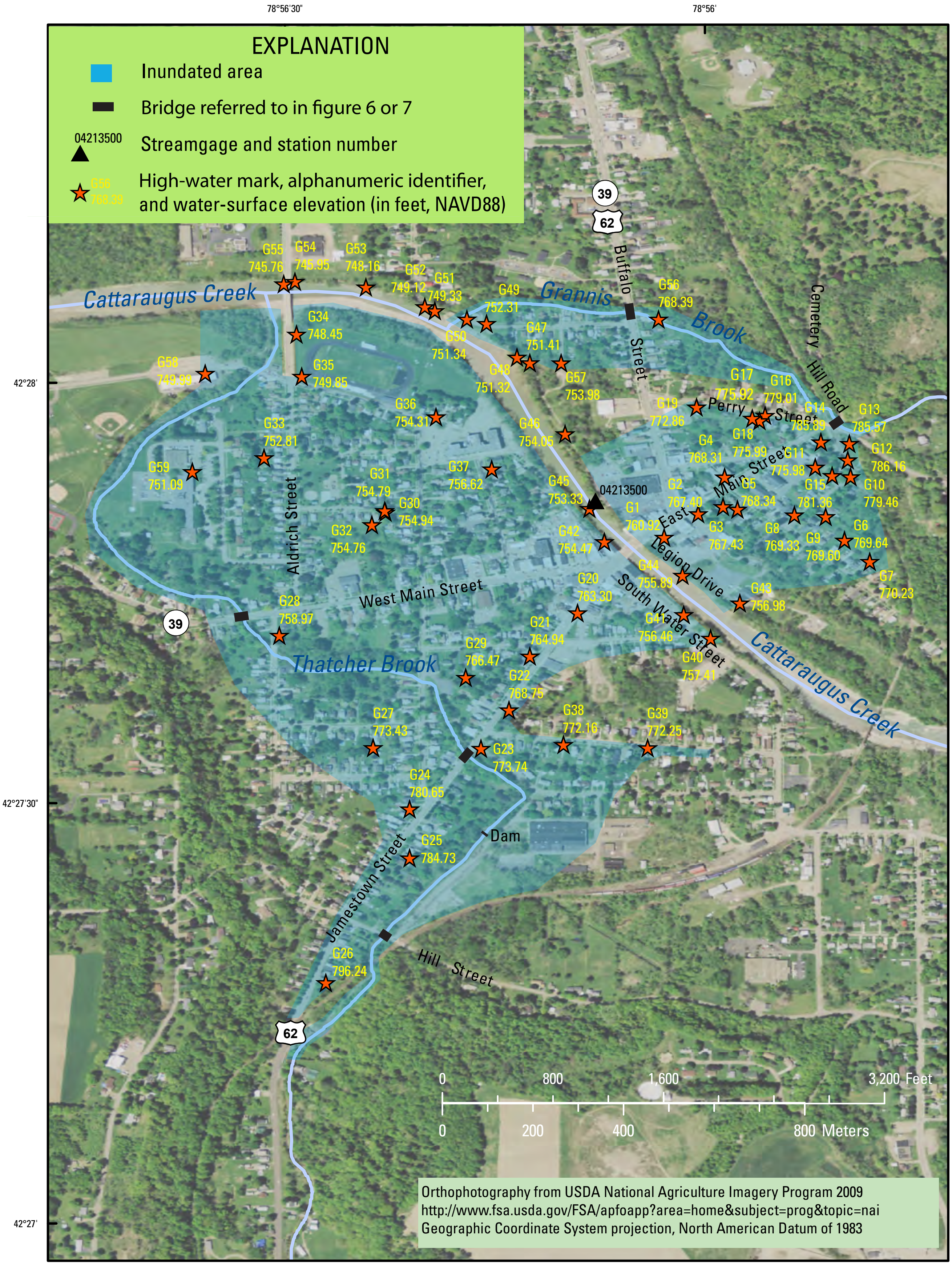

Figure 10. Areal extent and water-surface elevations of flooding in Gowanda, N.Y., August 10, 2009.

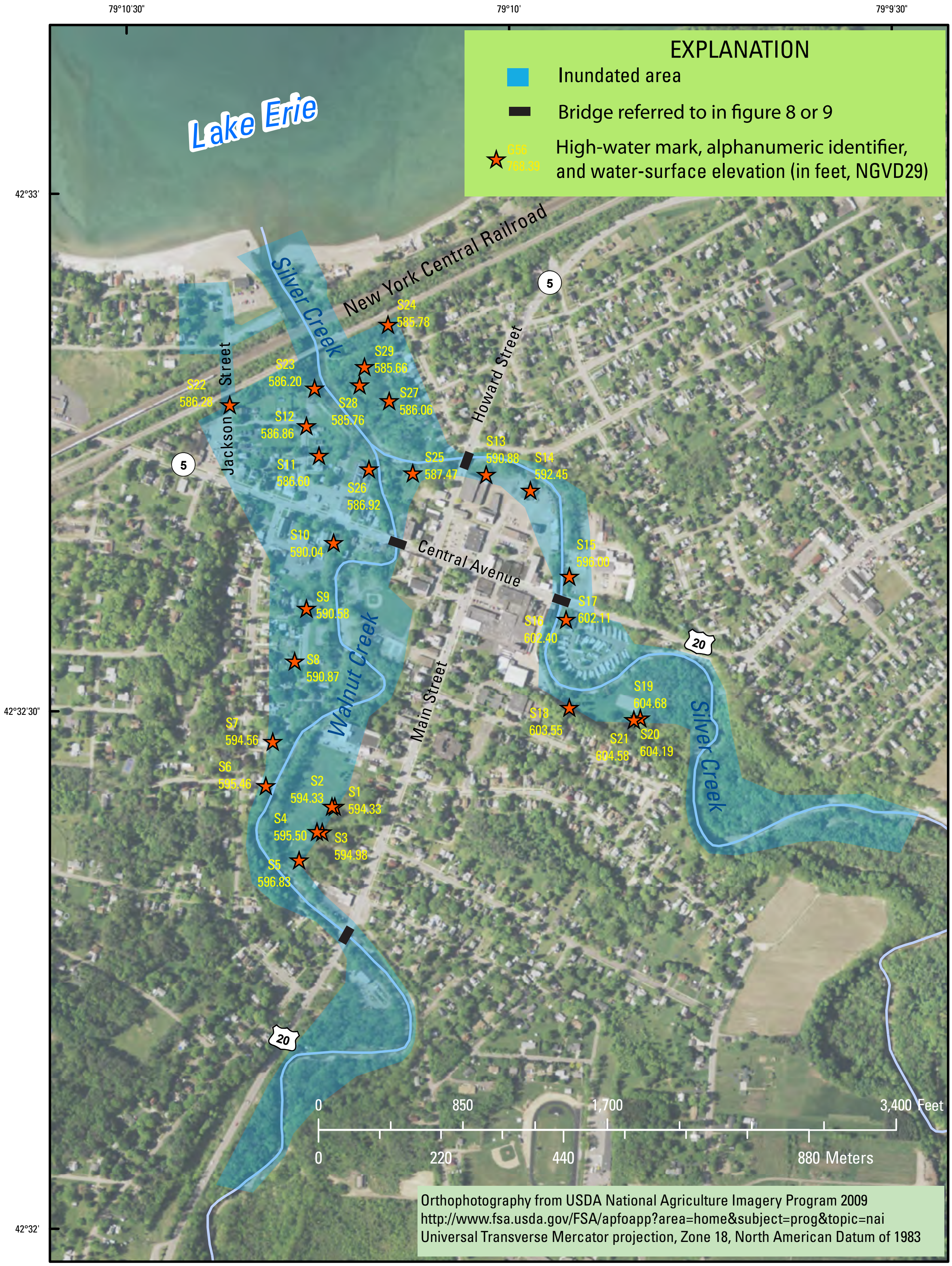

Figure 11. Areal extent and water-surface elevations of flooding in Silver Creek, N.Y., August 10, 2009.

Table 1. Historic peak flows, and peak flows and associated annual exceedance probabilities for the floods of August 10, 2009, at selected U.S. Geological Survey streamgages in western New York.

[Station locations are shown in figure 1. mi^2, square miles; ft^3/s, cubic feet per second; $ft^3/s/mi^2$, cubic feet per second per square mile; E, estimated; >, greater than; <, less than; --, no data]

				Maximum prior to flood of August 10, 2009		Flood of August 10, 2009			
Station number	Station name	Drainage area (mi^2)	Period of annual peak flow record (water years)	Date of peak	Peak flow (ft^3/s)	Peak flow (ft^3/s)	Peak yield ($ft^3/s/mi^2$)	Annual exceedance probability[1] (percent)	Recurrence interval[1] (years)
03010734	Ischua Creek tributary near Machias	5.12	1978–81, 83–2008	Sept. 14, 1979	570	329	64.2	25	4
03011020	Allegheny River at Salamanca	1,608	1904–2008	June 23, 1972	73,000	17,900	11.1	80	1.25
03013800	Ball Creek at Stow	9.58	1974–2008	Sept. 14, 1979	2,000	E 300	31.3	> 100	< 1
03014500	Chadakoin River at Falconer	194	1935–2008	Sept. 14, 1979	2,250	1,340	6.91	50	2
04213376	Canadaway Creek at Fredonia	32.9	1979, 86–2008	Aug. 7, 1979	12,000	E 1,500	45.6	67	1.5
0421340305	Silver Creek at mouth at Silver Creek	51.8	None	--	--	19,500	376	[2] < 0.2	[2] > 500
04213490	South Branch Cattaraugus Creek near Otto	25.1	1963–99	Sept. 14, 1979	4,350	E 7,400	295	< 0.2	> 500
04213500	Cattaraugus Creek at Gowanda	436	1940–2008	Mar. 7, 1956	34,600	33,200	76.1	2.2	45
0421350503	Grannis Brook at Gowanda	[3]2.48	None	--	--	1,400	564	[2,4] < 0.2	[2,4] > 500
04213508	Thatcher Brook at Gowanda	[3]6.49	1986	Aug. 1, 1986	3,100	7,600	1,170	[2] < 0.2	[2] > 500
04214500	Buffalo Creek at Gardenville	142	1937, 39–2008	June, 1937	16,000	5,590	39.4	67	1.5
04215000	Cayuga Creek near Lancaster	96.4	1937, 39–68, 1972–2008	June, 1937	18,000	4,890	50.7	50	2
04215500	Cazenovia Creek at Ebenezer	135	1941–2008	Sept. 9, 2004	14,700	13,400	99.2	2.5	40
04216418	Tonawanda Creek at Attica	76.9	1972, 78–2008	July 8, 1998	9,400	3,030	39.4	40	2.5
04230380	Oatka Creek at Warsaw	39.1	1964–2008	July 8, 1998	4,110	1,450	37.1	50	2

[1] From Lumia and others (2006), unless otherwise specified.

[2] From table 3.

[3] Drainage area at peak-flow measurement site not at the mouth of the stream.

[4] From values estimated from a plot of peak discharges and drainage areas in Federal Emergency Management Agency (2009c), the Grannis Brook peak would have an annual exceedance probability of 2.8 percent (recurrence interval of 35 years); however this probability was deemed to be unreasonably high when the peak flow was compared to those estimated for other nearby small basins.

Table 2. Peak flows computed for the floods of August 10, 2009, at sites in Gowanda and Silver Creek, New York.

[Site locations are shown in figure 1. mi^2, square miles; ft^3/s, cubic feet per second; --, no data]

Community	Stream	Drainage area[1] (mi^2)	Number of high-water marks: Surveyed	Number of high-water marks: Included in final maps and tables[2]	Type of indirect measurement of flow	Peak flow (ft^3/s)
Silver Creek	Walnut Creek	26.3	12	12	(3)	--
	Silver Creek	51.8	76	17	Width contraction	[4]19,500
Gowanda	Cattaraugus Creek	436	49	16	Slope area	33,200
	Grannis Brook	2.48	47	21	Slope area	1,400
	Thatcher Brook	6.49	59	22	Slope area	7,600

[1] Drainage area at discharge measurement site.

[2] See appendix 1 for list of high-water marks.

[3] The Silver Creek indirect measurement was made downstream from the confluence of Silver and Walnut Creeks and, therefore, is a measure of the combined flows in both streams.

[4] Includes 520 ft^3/s bypass flow through Jackson Street railroad underpass.

given year. The estimates of annual exceedance probabilities, which are statistically derived and based on peak flows measured or recorded on a particular stream, can be improved as the peak-flow record is extended. On streams where flow records are unavailable, regression equations (based on long-term peak-flow records from streams with similar basin characteristics) can be used to estimate flows with particular annual exceedance probabilities. Regression equations to estimate peak flows on rural, unregulated streams in six hydrologic regions in New York were developed by Lumia and others (2006) and are included in the program StreamStats (U.S. Geological Survey, 2010). The basin characteristics, which were deemed significant in estimating peak flows in the southwestern hydrologic region of New York that includes the study area, are drainage area, the main-channel slope, and mean annual precipitation.

Annual exceedance probabilities for peak flows at the indirect-measurement sites were compiled from available sources (table 3). Those for Grannis Brook, Thatcher Brook, and Cattaraugus Creek at Gowanda were obtained from the FEMA flood-insurance report for Erie County (Federal Emergency Management Agency, 2009c), and those for Silver Creek were obtained from the flood-insurance report for the Village of Silver Creek (Federal Emergency Management Agency, 1983). For comparison, peak flows for given annual exceedance probabilities were computed using StreamStats (U.S. Geological Survey, 2010) and also are presented in table 3.

The peak flow in Cattaraugus Creek at Gowanda had an annual exceedance probability of 2.2 percent (45-year recurrence interval; table 1). The peak flows in Thatcher Brook and Silver Creek had annual exceedance probabilities less than 0.2 percent (recurrence intervals greater than 500 years). The annual exceedance probability of the peak flow in Grannis Brook was uncertain. On the basis of the FEMA flood-insurance report (Federal Emergency Management Agency, 2009c), the peak flow had an annual exceedance probability of 2.8 percent (35-year recurrence interval), which was incongruent when compared with the annual exceedance probabilities of the flows at other sites with small drainage areas that fell almost entirely within the area of heaviest precipitation. From StreamStats estimates (U.S. Geological Survey, 2010), the annual exceedance probability for the Grannis Brook peak was 0.2 percent (500-year recurrence interval; table 3), which agrees with the results for the other small-basin sites. Given the relative magnitude and flooding extent of the peak flow in Grannis Brook compared to those in Thatcher Brook and Silver Creek, an annual exceedance probability of 0.2 percent is reasonable and is presented in table 1 to quantify this peak flow.

Peak flows that occurred on August 10, 2009, and their annual exceedance probabilities were compiled for other USGS continuous-record and peak-flow-only streamgages in western New York (fig. 1; table 1). These data indicate that high flows occurred throughout western New York, but severe flooding was limited to the area that received the most intensive rainfall, as shown in figure 2. Only the site on South Branch Cattaraugus Creek near Otto (a discontinued peak-flow-only USGS streamgage) experienced a flood of a magnitude similar to the hard-hit areas of Gowanda and Silver Creek (less than 0.2 percent chance of exceedance). Cazenovia Creek at Ebenezer (near Buffalo) had a flow with a 2.5-percent

Table 3. Peak flows for indicated annual exceedance probabilities for selected streams in Gowanda and Silver Creek, New York.

[Site locations are shown in figure 1. mi^2, square miles; ft^3/s, cubic feet per second; --, no data]

Stream and location	Drainage area (mi^2)	Peak flows (ft^3/s) for indicated annual exceedance probabilities				
		10-percent	4-percent	2-percent	1-percent	0.2-percent
Silver Creek at mouth at Silver Creek[1]	51.8	4,450	--	6,100	7,000	9,000
Cattaraugus Creek at Gowanda[2]	436	26,800	--	36,800	41,500	52,000
Grannis Brook at mouth at Gowanda[2]	[3] 2.68	1,040	--	1,600	1,740	2,050
Thatcher Brook at mouth at Gowanda[2]	[3] 7.38	1,650	--	2,400	2,700	3,100
		Peak flows (ft^3/s) for indicated annual exceedance probabilities computed using StreamStats[4]				
		10-percent	4-percent	2-percent	1-percent	0.2-percent
Silver Creek at mouth at Silver Creek		5,200	6,880	8,320	9,790	13,600
Cattaraugus Creek at Gowanda[5]		24,400	29,900	34,200	38,700	50,000
Grannis Brook at mouth at Gowanda		518	690	840	992	1,390
Thatcher Brook at mouth at Gowanda		1,360	1,820	2,230	2,640	3,730

[1] Federal Emergency Management Agency (1983).

[2] Values estimated from figure 5, a plot of peak discharges and drainage areas, in Federal Emergency Management Agency (2009c).

[3] Drainage area at the mouth of the stream (Wagner and Dixson, 1985).

[4] U.S. Geological Survey (2010).

[5] Values are same as those presented by Lumia and others (2006).

annual exceedance probability (40-year recurrence interval). Other sites distant from the intensive precipitation area had flows with annual exceedance probabilities equal to or greater than 25 percent (recurrence intervals equal to or less than 4 years).

Summary

A severe thunderstorm struck western New York, south of Buffalo, during the night of August 9, 2009, and caused flash flooding during the early morning of August 10 in parts of Cattaraugus, Chautauqua, and Erie Counties. Nearly 6 inches of rain fell in 1.5 hours as recorded by a National Weather Service observer in Perrysburg, which lies between Gowanda and Silver Creek, the communities that suffered the most damage. The rainfall intensity of this storm had less than a 0.2-percent chance of occurring during a given year (that is, it exceeded the 500-year storm event) and reportedly caused water levels in Walnut Creek in the Village of Silver Creek to rise 3 to 4 feet in 30 minutes. Numerous road culverts were washed out, and more than one-quarter of the roads in Cattaraugus County were damaged. Many people were evacuated or rescued in both communities, including patients in the Tri-County Memorial Hospital in Gowanda and residents of a creek-side trailer park in Silver Creek, which was destroyed. The water supplies of both communities were compromised by damages to village reservoirs and water-transmission infrastructures. Water and mud damage to residential and commercial properties was extensive. Two deaths occurred during the flood in Gowanda. One resident suffered a heart attack while emergency responders were delayed by floodwaters. A second resident drowned when he fell into Thatcher Brook after the floodwaters had undercut the land on which he was standing. The tri-county area was declared a Federal disaster area, and more than $45 million in Federal assistance was distributed to more than 1,500 individuals and an estimated 1,100 public projects. The total cost of damages estimated by emergency managers in the affected counties and municipalities exceeded $90 million.

Peak flows in small basins, such as Grannis Brook, Thatcher Brook, and Silver Creek, occurred between 2:00 and 3:00 a.m. EDT on August 10, 2009, and were the cause of the severe flooding and associated damages in the Villages of Gowanda and Silver Creek. The peak flow in Cattaraugus Creek at Gowanda, which was not a cause of major flooding in this community, occurred about 5 hours after the small tributaries had peaked.

Over 240 high-water marks were surveyed by the U.S. Geological Survey; a subset of these marks was used to create floodwater-surface profiles for four streams and to delineate the areal extent of flooding in Gowanda and Silver Creek. Flood elevations exceeded previously defined Federal Emergency Management Agency (FEMA) 0.2-percent annual exceedance probability (500-year recurrence interval) elevations by 2 to 4 feet in Gowanda and as much as 6 to 8 ft in Silver Creek. Most of the high-water marks were used in indirect hydraulic computations to estimate peak flows for four streams. The peak flows in Grannis Brook and Thatcher Brook were computed, using the slope-area method, to be 1,400 and 7,600 cubic feet per second, respectively, and peak flow in Silver Creek was computed, using the width-contraction method, to be 19,500 cubic feet per second. The annual exceedance probabilities for flows in these and other basins with small drainage areas that fell almost entirely within the area of heaviest precipitation were less than 0.2 percent (or recurrence intervals greater than 500 years). The peak flow in Cattaraugus Creek at Gowanda was computed, using the slope-area method, to be 33,200 cubic feet per second and had an annual exceedance probability of 2.2 percent (recurrence interval of 45 years).

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The authors thank the many residents of the flooded communities for their descriptions of the flood and their cooperation in helping field crews locate high-water marks. Timothy Roche, Chief of Police, Silver Creek, provided valuable information regarding the flood in Silver Creek, as well as photographs of flood damage in the village. Ralph Crawford, Silver Creek Highway Superintendent, and Michael Hutchinson, Gowanda Superintendent of Public Works, provided feedback on the delineation of the inundated areas in their respective communities.

References Cited

Barnes, H.H., and Davidian, J., 1978, Indirect methods, *in* Herschy, R.W., ed., Hydrometry–principles and practices: New York, Wiley, p. 189-190.

Bodhaine, G.L., 1968, Measurement of peak discharge at culverts by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A3, 60 p.

Brunner, G.W., 2008, HEC-RAS, River analysis system user's manual, version 4.0: U.S. Army Corps of Engineers, Hydrologic Engineering Center, report CPD-68, 733 p.

Dalrymple, Tate, and Benson, M.A., 1967, Measurement of peak discharge by the slope-area method: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A2, 12 p.

Fairbanks, Phil, Michel, Lou, and Binkley, Collin, 2009, Creek goes on rampage: The Buffalo News Newspaper, August 11, 2009, p. 1-2.

Federal Emergency Management Agency, 1983, Flood insurance study, Village of Silver Creek, Chautauqua County, New York: Federal Emergency Management Agency, 18 p.

Federal Emergency Management Agency, 2009a, President declares major disaster for New York: Federal Emergency Management Agency, accessed July 29, 2010, at http://www.fema.gov/news/newsrelease.fema?id=49434.

Federal Emergency Management Agency, 2009b, Combined disaster assistance to western New York will top $45 million: Federal Emergency Management Agency, accessed July 29, 2010, at http://www.fema.gov/news/newsrelease.fema?id=49960.

Federal Emergency Management Agency, 2009c, Flood insurance study, Erie County, New York (all jurisdictions), Volume 1 of 5: Federal Emergency Management Agency, accessed February 10, 2010, at New York – Mapping Status, *http://www.rampp-team.com/ny.htm*.

Flynn, Lisa, 2009, Gowanda water supply dwindling: WIVB.com, accessed April 20, 2010, at http://www.wivb.com/dpp/news/gowanda_water_supply_dwindling_090811.

Fulford, J.M., 1994, User's guide to SAC, a computer program for computing discharge by slope-area method: U.S. Geological Survey Open-File Report 94–360, 31 p.

Fulford, J.M., 1998, User's guide to the U.S. Geological Survey culvert analysis program, version 97-08: U.S. Geological Survey Water-resources Investigations Report 98–4166, 70 p.

Holmes, R.R., Jr., and Dinicola, Karen, 2010, 100-year flood—It's all about chance: U.S. Geological Survey General Information Product 106, 1 p., accessed April 19, 2010, at http://pubs.usgs.gov/gip/106/pdf/100-year-flood_041210web.pdf.

Kennedy, E.J., 1988, Levels at streamflow gaging stations: U.S. Geological Survey Open-File Report 88–710, 38 p.

Lumia, Richard, Burke, P.M., and Johnston, W.H., 1986, Flooding of December 29, 1984 through January 2, 1985, in northern New York State, with flood profiles of the Black and Salmon Rivers: U.S. Geological Survey Water-Resources Investigations Report 86–4191, 53 p.

Lumia, Richard, Freehafer, D.A., and Smith, M.J., 2006, Magnitude and frequency of floods in New York: U.S. Geological Survey Scientific Investigations Report 2006–5112, 152 p.

Matthai, H.F., 1967, Measurement of peak discharge at width contractions by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A4, 44 p.

National Oceanic and Atmospheric Administration, 2010a, Storm data and unusual weather phenomena, August 2009, Volume 51, Number 8: National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, N.C., accessed September 7, 2010, at http://www.ncdc.noaa.gov/oa/mpp.

National Oceanic and Atmospheric Administration, 2010b, Satellite and Information Service, Climate Data Center, accessed April 19, 2010, at *http://www7.ncdc.noaa.gov/CDO/cdo*.

National Weather Service, 2009, Flash flood event in southern Erie, northern Chautauqua and northern Cattaraugus Counties, accessed October 15, 2009, at http://www.wbuf.noaa.gov/svrwx/web_090810_Flashflood/indexflood.html.

Thompson, Carolyn, 2009, Two die in Gowanda: ObserverToday.com, accessed August 14, 2009, at http://www.observertoday.com/page/content.detail/id/527609.html.

Wagner, L.A., and Dixson, H.L., 1985, Drainage areas of New York streams, by river basins–a stream gazetteer, data through 1984: U.S. Geological Survey Open-File Report 81–1055, 359 p.

U.S. Geological Survey, 2010, New York StreamStats: U.S. Geological Survey, accessed May 28, 2010, at http://streamstatsags.cr.usgs.gov/ny_ss/default.aspx?stabbr=ny&dt=12737674080151.

Appendix 1. High-water marks in the Villages of Gowanda and Silver Creek, N.Y., for the flash floods of August 10, 2009

Appendix 1. High-water marks in the Villages of Gowanda and Silver Creek, New York, for flash floods of August 10, 2009.

[High-water marks shown in figures 10 and 11. Mark numbers in **bold** type are those high-water marks used to create water-surface profile figures 6-9. Latitude and longitude are in degrees, minutes, and seconds. ft, feet; NGVD29, National Geodetic Vertical Datum of 1929; NAVD88, North American Vertical Datum of 1988]

Mark number	Latitude	Longitude	Elevation, ft NGVD29	Elevation, ft NAVD88	Distance, ft above ground	Quality	Description	Address
Grannis Brook								
G1	42 27 49.0	78 56 02.9	761.37	760.92	0.4	Good	Mud line on side of building	
G2	42 27 50.7	78 56 00.5	767.85	767.40	0.6	Fair	Mud line on fence	
G3	42 27 51.2	78 55 58.7	767.88	767.43	0.8	Good	Mud line on steps of front porch	
G4	42 27 53.3	78 55 58.6	768.76	768.31	1.2	Good	Mud line on basement window	
G5	42 27 51.0	78 55 57.7	768.79	768.34	1.3	Excellent	Mud line on inside garage wall	
G6	42 27 48.8	78 55 50.0	770.09	769.64	2.5	Good	Mud line on side of barn	
G7	42 27 47.3	78 55 48.2	770.68	770.23	0.5	Fair	Debris line on small bush	
G8	42 27 50.6	78 55 53.6	769.78	769.33	1.1	Excellent	Mud line on Church window frame	
G9	42 27 50.5	78 55 51.4	770.05	769.60	1.3	Excellent	Mud line on side of garage	
G10	42 27 53.3	78 55 49.6	779.91	779.46	1.4	Good	Mud line on back door	46 Park Street
G11	42 27 53.4	78 55 50.9	776.43	775.98	1.4	Good	Mud line transposed from inside garage	
G12	42 27 54.5	78 55 49.8	786.61	786.16	2.6	Excellent	Mud line on wooden shed	
G13	42 27 55.7	78 55 49.7	786.02	785.57	0.0	Fair	Debris line on ground	
G14	42 27 55.8	78 55 51.7	786.34	785.89	3.0	Fair	Seed line on tree	
G15	42 27 54.0	78 55 52.1	781.81	781.36	2.2	Good	Mud line transposed from inside barn	
G16	42 27 57.7	78 55 55.7	779.46	779.01	1.6	Not noted	Debris on telephone pole	61 Perry Street
G17	42 27 57.3	78 55 56.1	776.37	775.92	0.9	Fair	Debris line in lattice below porch	61 Perry Street
G18	42 27 57.5	78 55 56.6	776.44	775.99	0.9	Good	Mud line on inside of front door	55 Perry Street
G19	42 27 58.3	78 56 00.6	773.31	772.86	0.0	Good	Debris line on ground	27 Perry Street
G49	42 28 04.3	78 56 15.6	752.76	752.31	1.0	Fair	Grass in fence rail	Union Street
G50	42 28 04.6	78 56 17.0	751.79	751.34	0.5	Fair	Grass in tree	Union Street
G56	42 28 04.6	78 56 03.3	768.84	768.39	0.8	Good	Mud line on shed behind house	133 Buffalo Street
G57	42 28 01.5	78 56 10.3	754.43	753.98	1.4	Good	Mud line on shed behind house	30 Union Street
Thatcher Brook								
G20	42 27 43.6	78 56 09.1	763.75	763.30	2.5	Fair	Seed line in bushes	Front of Burger King
G21	42 27 40.5	78 56 12.5	765.39	764.94	2.2	Good	Mud line on Church door	
G22	42 27 36.7	78 56 14.0	769.20	768.75	0.0	Good	Debris line in front yard	118 Jamestown Street

Appendix 1. High-water marks in the Villages of Gowanda and Silver Creek, New York, for flash floods of August 10, 2009—Continued

[High-water marks shown in figures 10 and 11. Mark numbers in **bold** type are those high-water marks used to create water-surface profile figures 6-9. Latitude and longitude are in degrees, minutes, and seconds. ft, feet; NGVD29, National Geodetic Vertical Datum of 1929; NAVD88, North American Vertical Datum of 1988]

Mark number	Latitude	Longitude	Elevation, ft NGVD29	Elevation, ft NAVD88	Distance, ft above ground	Quality	Description	Address
				Thatcher Brook—Continued				
G23	42 27 33.9	78 56 16.0	774.19	773.74	2.8	Excellent	Mud line on inside garage wall	Corner Jamestown & Torrance Streets
G24	42 27 29.6	78 56 21.1	781.10	780.65	1.4	Good	Mud line on playground set	Jamestown Street near South Chapel Street
G25	42 27 26.1	78 56 21.1	785.18	784.73	3.0	Good	Mud line on carport leg	220 Jamestown Street
G26	42 27 17.2	78 56 27.1	796.69	796.24	2.2	Good	Mud line on garage door frame	336 Jamestown Street
G27	42 27 34.0	78 56 23.7	773.88	773.43	1.2	Good	Mud line on swimming pool filter	24 Orchard Place
G28	42 27 42.0	78 56 30.4	759.42	758.97	2.4	Excellent	Mud line on shed	184 West Main Street
G29	42 27 39.0	78 56 17.1	766.92	766.47	3.6	Excellent	Mud line on shed	Behind Lutheran Church
G30	42 27 50.8	78 56 22.8	755.39	754.94	2.2	Not noted	Mud line on house	18 St. Johns Street
G31	42 27 50.9	78 56 22.9	755.24	754.79	2.1	Not noted	Mud line on house	20 St. Johns Street
G32	42 27 49.9	78 56 23.8	755.21	754.76	2.1	Not noted	Mud line on garage	24 St. Johns Street
G33	42 27 54.7	78 56 31.5	753.26	752.81	2.0	Excellent	Mud line on garage	106 Aldrich Street
G34	42 28 03.5	78 56 29.2	748.90	748.45	0.0	Fair	Debris line on ground	East road embankment of Aldrich Street
G35	42 28 00.5	78 56 28.8	750.30	749.85	1.5	Fair	Debris line in chain-link fence	School athletic field
G36	42 27 57.6	78 56 19.2	754.76	754.31	0.8	Not noted	Debris line below front door	House between 135 and 149 North Water Street
G37	42 27 53.9	78 56 15.2	757.07	756.62	0.5	Excellent	Mud line on foundation	St. Mary’s Episcopal Church
G38	42 27 34.2	78 56 10.1	772.61	772.16	0.0	Good	Mud line on ground	Chestnut Street
G39	42 27 34.0	78 56 04.1	772.70	772.25	0.0	Fair	Mud line on ground	Chestnut Street
G58	42 28 02.7	78 56 36.0	750.44	749.99	1.1	Good	Mud line inside bus garage	North Water Street
G59	42 27 54.3	78 56 38.6	751.54	751.09	1.5	Good	Mud line on window	Tri-County Memorial Hospital
				Cattaraugus Creek				
G40	42 27 41.8	78 55 59.6	757.86	757.41	0.0	Good	Debris line	72 South Water Street
G41	42 27 43.5	78 56 01.5	756.91	756.46	0.0	Good	Debris line	
G42	42 27 48.7	78 56 07.2	754.92	754.47	0.0	Good	Seed/debris line	

Appendix 1. High-water marks in the Villages of Gowanda and Silver Creek, New York, for flash floods of August 10, 2009—Continued

[High-water marks shown in figures 10 and 11. Mark numbers in **bold** type are those high-water marks used to create water-surface profile figures 6-9. Latitude and longitude are in degrees, minutes, and seconds. ft, feet; NGVD29, National Geodetic Vertical Datum of 1929; NAVD88, North American Vertical Datum of 1988]

Mark number	Latitude	Longitude	Elevation, ft NGVD29	Elevation, ft NAVD88	Distance, ft above ground	Quality	Description	Address
Cattaraugus Creek—Continued								
G43	42 27 44.3	78 55 57.5	757.43	756.98	0.5	Good	Mud line on door	American Legion
G44	42 27 46.3	78 56 01.6	756.34	755.89	0.0	Good	Seed line	
G45	42 27 51.5	78 56 07.8	753.78	753.33	0.0	Good	Wash line	
G46	42 27 56.4	78 56 10.0	754.50	754.05	1.0	Poor	Mud line on tree	In village park
G47	42 28 01.5	78 56 12.5	751.86	751.41	0.0	Good	Debris line on ground	In village park
G48	42 28 01.9	78 56 13.4	751.77	751.32	1.5	Good	Seed line on tree	In village park
G51	42 28 05.2	78 56 19.3	749.78	749.33	0.0	Good	Debris line	Seneca Street
G52	42 28 05.5	78 56 20.0	749.57	749.12	0.0	Good	Debris line	Seneca Street
G53	42 28 06.9	78 56 24.2	748.61	748.16	0.0	Good	Seed line	
G54	42 28 07.3	78 56 29.3	746.40	745.95	0.0	Fair	Debris line	East side of Aldrich Street
G55	42 28 07.1	78 56 30.1	746.21	745.76	0.0	Good	Seed line	West side of Aldrich Street
Walnut Creek								
S1	42 32 25.3	79 10 10.2	594.33	593.88	0.0	Good	Fine debris line	
S2	42 32 25.3	79 10 10.4	594.33	593.88	0.0	Good	Fine debris line	
S3	42 32 23.8	79 10 11.1	594.98	594.53	0.0	Good	Fine debris line	
S4	42 32 23.8	79 10 11.5	595.50	595.05	0.0	Fair	Fine debris line	
S5	42 32 22.1	79 10 12.8	596.83	596.38	1.0	Fair	Silt line on tree	
S6	42 32 26.3	79 10 15.7	595.46	595.01	1.0	Fair	Silt line	
S7	42 32 28.9	79 10 15.3	594.56	594.11	1.3	Fair	Silt line on fence	
S8	42 32 33.6	79 10 13.9	590.87	590.42	3.0	Poor	Silt line on house	
S9	42 32 36.7	79 10 13.2	590.58	590.13	4.1	Fair	Debris line on house	
S10	42 32 40.6	79 10 11.3	590.04	589.59	5.4	Good	Mud line on house	
S11	42 32 45.6	79 10 12.8	586.60	586.15	4.5	Good	Mud line on fence	
S12	42 32 47.3	79 10 13.9	586.86	586.41	6.0	Fair	Mud line on phone pole	
Silver Creek								
S13	42 32 45.0	79 09 59.6	590.88	590.43	1.5	Fair	Mud line on metal shed	
S14	42 32 44.2	79 09 56.1	592.45	592.00	6.0	Excellent	Mud line	Inside Department of Public Works building

Appendix 1. High-water marks in the Villages of Gowanda and Silver Creek, New York, for flash floods of August 10, 2009—Continued

[High-water marks shown in figures 10 and 11. Mark numbers in **bold** type are those high-water marks used to create water-surface profile figures 6-9. Latitude and longitude are in degrees, minutes, and seconds. ft, feet; NGVD29, National Geodetic Vertical Datum of 1929; NAVD88, North American Vertical Datum of 1988]

Mark number	Latitude	Longitude	Elevation, ft NGVD29	Elevation, ft NAVD88	Distance, ft above ground	Quality	Description	Address
					Silver Creek—Continued			
S15	42 32 39.3	79 09 52.7	596.00	595.55	0.0	Poor	Debris line	
S16	42 32 36.8	79 09 52.8	602.40	601.95	4.5	Fair	Mud line	Same coordinates as S17
S17	42 32 36.8	79 09 52.8	602.11	601.66	4.5	Good	Mud line	
S18	42 32 31.7	79 09 52.2	603.55	603.10	5.5	Good	Mud line on house	
S19	42 32 31.2	79 09 47.1	604.68	604.23	0.0	Poor	Seed line	
S20	42 32 31.3	79 09 46.6	604.19	603.74	1.8	Fair	Seed line on tree	
S21	42 32 31.2	79 09 47.1	604.58	604.13	0.0	Fair	Seed line in grass	Same coordinates as S19
S22	42 32 48.3	79 10 20.0	586.28	585.83	3.0	Good	Mud line on tree	11 Jackson Street
S23	42 32 49.5	79 10 13.4	586.20	585.75	5.0	Good	Seed line on tree	
S24	42 32 53.4	79 10 07.9	585.78	585.33	0.0	Poor	Mud line	On railroad embankment
S25	42 32 45.6	79 10 05.6	587.47	587.02	3.0	Good	Mud line on garage	
S26	42 32 45.0	79 10 08.8	586.92	586.47	2.5	Good	Mud line on shed	Behind wastewater-treatment plant
S27	42 32 49.0	79 10 07.5	586.06	585.61	7.4	Good	Seed line on tree	
S28	42 32 49.8	79 10 09.9	585.76	585.31	6.5	Good	Seed line on tree	
S29	42 32 50.9	79 10 09.6	585.66	585.21	8.0	Good	Seed line on tree	

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