Hydrology
Onondaga Creek Fact Sheet

INTRODUCTION

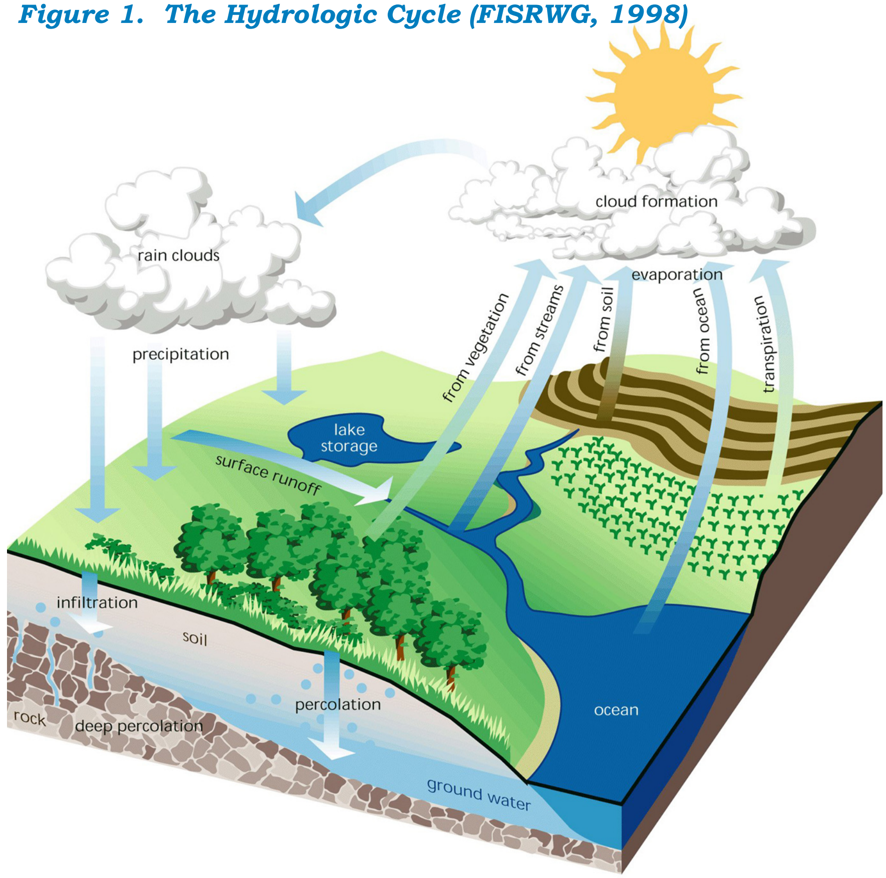
Water flowing in Onondaga Creek could have originated as precipitation within the last few minutes or as centuries-old groundwater. Onondaga Creek collects water from storm runoff, snowmelt, groundwater, and sewers.

Creek hydrodynamics are governed by the hydrologic cycle (Figure 1). Many factors affect water levels and flow rates in a stream: topography, soils and sub-soils, soil saturation, precipitation, water table height, evapotranspiration rates, temperature, and runoff (terms are defined below). Ultimately, weather patterns and land cover (such as forests, crops, lawns, buildings, or pavement) control the quantity and quality of the water in the creek.

Definitions:

- **Precipitation:** rain, sleet, hail, dew, and snow.
- **Evapotranspiration (ET):** sum of evaporation from open water and surfaces, and transpiration from plants.
- **Runoff:** water originating as precipitation, snowmelt, or irrigation water which finds its way into local waterways. Run off is often expressed as the depth to which a drainage area would be covered if all runoff were uniformly distributed over it (USGS glossary).
- **Groundwater recharge:** the precipitation which is not lost via ET or runoff, and thus seeps into groundwater. This replenishes groundwater which is lost as seepage into local waterways.
- **Hydrodynamics:** water movement and the forces it exerts on suspended materials and ground surfaces.

Figure 1. The Hydrologic Cycle (FISRWG, 1998)



Central New York precipitation averages about 40 in/yr, with a range of 27 to 58 inches (Hancock International Airport data, 1951-2004). The rate of evapotranspiration is about 19 in/yr, leaving approximately 20 in/yr for annual runoff (Randall, 1995).

The primary factor controlling runoff is ground cover. Vegetated areas intercept most precipitation, while impervious surfaces (roads, parking lots, roofs) retain almost none.

Typical runoff rates are:[1]

• Forest cover	5%
• Turf (grass) cover	5 – 30%
• Impervious cover	95%

1 Center for Watershed Protection, 2005; Appendix A. Values shown are derived from actual measurements.

Topography controls the speed of water in streams. Water runs down steep slopes faster than shallow slopes. Thus, a stream tends to drain quickly at the headwaters while accumulating water in flatter downstream reaches.

Measuring flow in a stream Stream flow (a.k.a. "discharge") measurements are typically made at gaging stations operated by the US Geological Survey (USGS). Discharge at each station is calculated by measuring current velocities (ft/s) across the width of the stream, and multiplying by the cross-sectional area (width x depth, ft^2). The resulting volumetric flow is expressed as cubic feet per second (cfs) or cubic meters per second (m^3s^{-1}). After numerous manual measurements over a wide range of flows at a given location (rating curve between stage [depth] and discharge [flow]) can be established. The flow is reported based on automatic recordings of the stream depth ("gage height").

Historically, flows were recorded by the city of Syracuse at Temple Street (1901-1939?) and by the USGS at Atlantic Ave/Ballantyne Ave (1939-1949). Flows in Onondaga Creek are currently recorded continuously at three locations (see Table 1).

Table 1: USGS gaging stations on Onondaga Creek

Name	USGS Number[1]	Drainage area (sq. miles)	Period of record	Gage datum[2] (ft.)
Route 20, near Cardiff	04237962	33.9	Oct.1, 2001 – present	unknown
Dorwin Ave, Syracuse, NY	04239000	88.5	May 16, 1951 – present	414.2
Spencer Street, Syracuse, NY	04240010	110.0	Sept. 1, 1970 – present	362.3

1 Real-time and historical data are available at http://waterdata.usgs.gov/ny/nwis

2 Gage datum is the elevation, in feet above sea-level, of the bottom of the stream channel.

Fluctuations in flow Variation of flow over time is shown in a hydrograph, with time-scales ranging from hours to years. In general, streams which receive primarily surface runoff tend to be highly variable or "flashy." Hard surfaces and artificial drainage systems (e.g. storm sewers) increase "flashiness."

FINDINGS

The Onondaga Creek Watershed

Characteristics

- 114 square miles (301 km^2) Endreny (2004)
- Elevation at headwaters: 1445 ft (587 m) Endreny (2004)
- Elevation at outlet (Onondaga Lake): 363 ft (111 m) Effler (1996)

An exaggerated profile of the creek is shown in Figure 2. Selected tributaries--Hemlock Creek, Kennedy Creek, Rainbow Creek, Fall Creek in Rattlesnake Gulf (R1, R2, R3), and an unnamed tributary in Emerson Gulf are also shown.

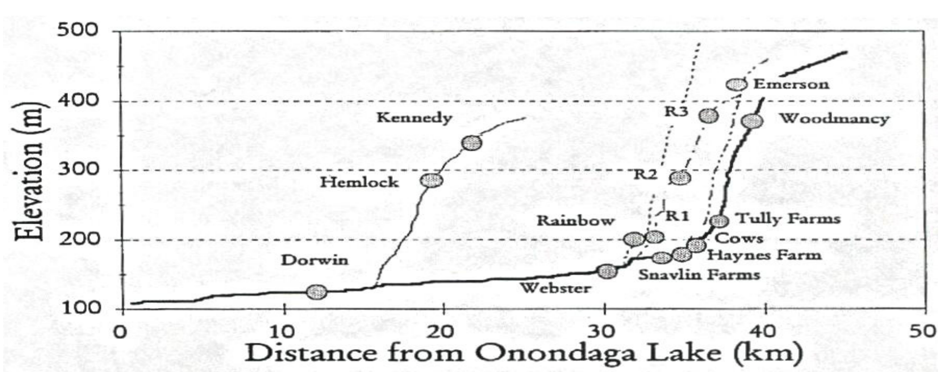


Figure 2. Stream profile of Onondaga Creek and selected tributaries, showing elevation as a function of distance from Onondaga Lake. The vertical exaggeration is approximately 70x. Source: Danehy (1994). Site labels Dorwin, Webster, Tully Farms, and Woodmancy refer to road crossings; Snavlin Farms, Haynes Farm, and Cows are other sampling sites along the mainstem of Onondaga Creek.

Table 2: Precipitation at weather stations in and near the Onondaga Creek watershed

No.	Location	Period of record	annual average precip., in.[1]
1.	Syracuse Hancock Airport, DeWitt, NY	1929 – present (historical data since 1896)	40.0
2.	City of Syracuse Water Deptartment, Skaneateles, NY	1948 – present (historical data since 1893)	41.5
3.	ESF Heiberg Forest, Cortland County, NY	1966 – present	45.8
4.	Mudboil site, Otisco Road, LaFayette, NY	1991 – present	31.9
5.	Route 20 gaging station, near Cardiff, Town of LaFayette, NY	2002 – present	not calculated
6.	Metro. sewage treatment plant, Syracuse, NY	2000 – present	not calculated
7.	SUNY – ESF campus, Syracuse, NY	2000 – present	not calculated

1 Sources: NOAA (2002) and Coon (2006). 1971-2000 data used for computing annual averages at locations 1-3. All available data used for site #4.

Climate and Precipitation

Precipitation data are collected at a number of locations near (#1-3 in Table 2) and within (#4-7 in Table 2) the Onondaga Creek watershed.

Long-term (> 30 years) precipitation data for central New York are available from sites #1-3. Annual averages for these sites, listed in Table 2, range from 40-46 inches. In contrast, the Tully Valley (site #4) gets consistently less precipitation through the year (annual average ~32 in). Although precipitation varies between sites, monthly averages, depicted in Figure 3, follow a consistent pattern. In general, precipitation is relatively constant across the seasons, although monthly averages dip in February (1.6-3 in) and crest in June and September (2.8-4.8 in).

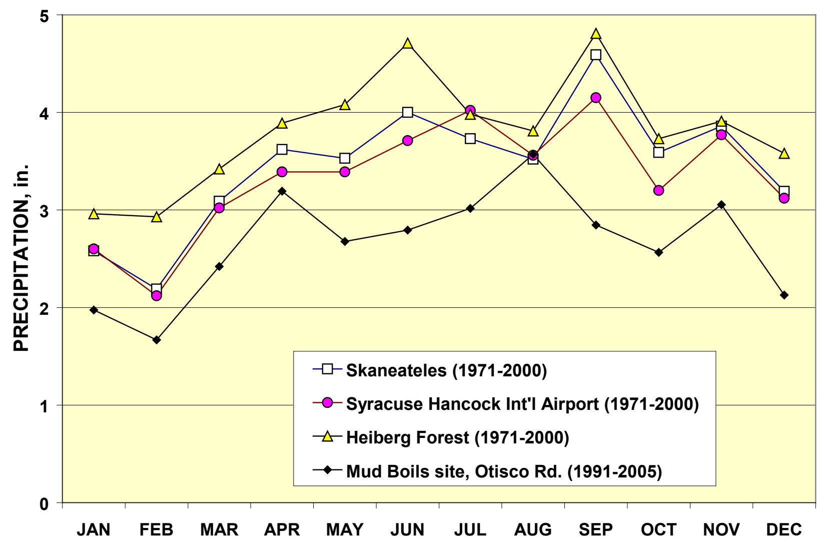


Figure 3: Central New York seasonal trends in precipitation. Sources: NOAA (2002) and Coon (2006)

Storm events An important rainfall parameter is the size of a storm event. Large and intense rains can cause severe erosion, damage to roads and bridges, and flooding. The probability of a large storm occurring is defined by the term "recurrence interval." For example, a two-year storm is one which occurs, on average, once in a two-year period. This term should not be construed as meaning "every two years." One could have three two-year storms landing in one year, followed by five years of no such storms. That would fit the definition, since three storms had occurred in a six-year period.

Table 3 shows how the intensity of rainfall, based on general rainfall patterns, increases as the probability of occurrence decreases. Note that these predictions are based on pre-1964 data. Recent shifts in climate are therefore not taken into account. Climate change models suggest that the eastern U.S. may become wetter and more prone to flooding (Harder, 2005).

Table 3: Central New York rainfall over a 24-hour period, at select recurrence intervals. Note: Values are interpolated from maps in the Rainfall Atlas, TP-40 (National Weather Service, 1964).

Recurrence Interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Number of events in a 100-year interval	50	20	10	~4	~2	~1
Rainfall amount (in)	2.6	3.2	3.8	4.5	4.8	5.2

Stream Flow

Changes in flow throughout the year Figure 4 shows rainfall recorded at the Metropolitan sewage treatment plant (downward peaks) plotted against a year-long hydrograph for Dorwin Ave (upward peaks). The creek's base flow is indicated by the background level between the peaks. From late fall to early summer when vegetation is mostly dormant and the ground may be frozen, base flow was high, and the creek responded rapidly to rain events. The creek's rapidly rising and falling flows are evidenced by tall, narrow peaks. From summer thorough early-mid fall, rainfall was largely intercepted by vegetation, evaporated, or percolated into the ground. Consequently, base flows were low and flow response to rainfall was minimal.

Figure 5 depicts typical monthly average flows at the three USGS gaging stations along Onondaga Creek. Flow increases from upstream to downstream, as evidenced by the flow increase for every month, beginning at Route 20, to Dorwin Ave, and finally to Spencer Street. Note also that the flow pattern in Figure 4 mimics that in Figure 3. Stream flow is maximum in the spring due to the release of stored water from snow melt, high water table, and saturated soil conditions. Furthermore, vegetation has not yet leafed out, and temperatures are low, so evapotranspiration is minimal. In summer and early fall, exposed leaves provide large surface areas to collect and store water on or within plants. Warm temperatures promote both evaporation and transpiration of water. Hence, runoff is minimal, water tables drop, and stream flow is minimal. As weather turns colder, evaporation diminishes and transpiration shuts down. Thus, moisture accumulates in soil, the water tables rise, and runoff increases. Runoff reaches a maximum in December because temperatures are not consistently below freezing, and less precipitation is stored as snow compared to January and February.

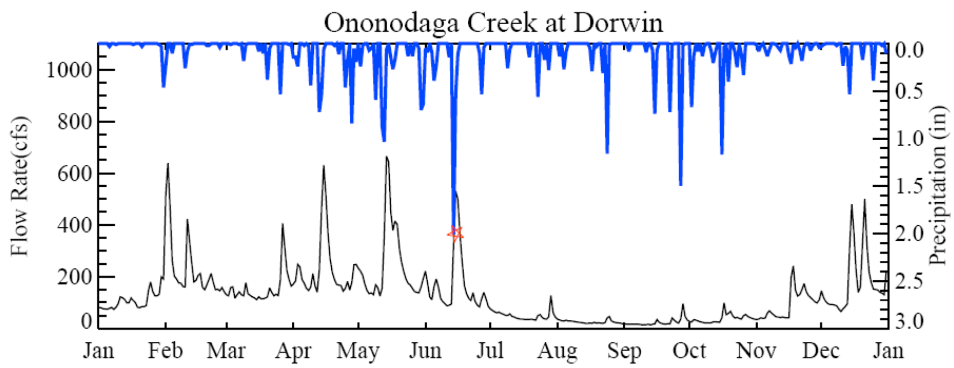


Figure 4: Daily streamflow at Dorwin Ave. (upward scale) and rainfall, as recorded at the Metro sewage treatment plant (downward scale) for calendar year 2002.

Source: Ecologic et al. 2003; Appendix 4

Peak Flows Maximum flows generally occur during storms, but can also be caused by rapid melting of snow on the ground. For example, following a heavy snowfall in March 1993, warm weather caused rapid melting and widespread flooding. The maximum flow during a single year is the peak annual discharge. Annual peaks, as recorded at various gaging stations over the past century, are shown in Figure 6.

The highest flow, 6000 cfs, occurred in 1920, the result of a combination of rain on snow (Amos *et al.*, 1927). Forest cover was at a low point at this time, so there was little vegetation to intercept rainfall (see below). This flood caused considerable property damage (see Flood Control Fact Sheet). Since construction of a flood control dam in 1947-48, the highest flow recorded was just over 4000 cfs at Spencer Street. Stream gage monitoring at the dam show that the dam has reduced peak flows in the city of Syracuse (see Flood Control Fact Sheet). It should be noted that during the period 1925-1980, substantial reforestration occurred in Onondaga County. This would also be expected to substantially reduce peak flows. Other factors, such as increased urbanization and changing weather, make a quantitative comparison of pre- and post-dam conditions nearly impossible.

- varying precipitation amounts,
- increasing temperatures,
- reforestation of rural areas, and
- urban expansion.

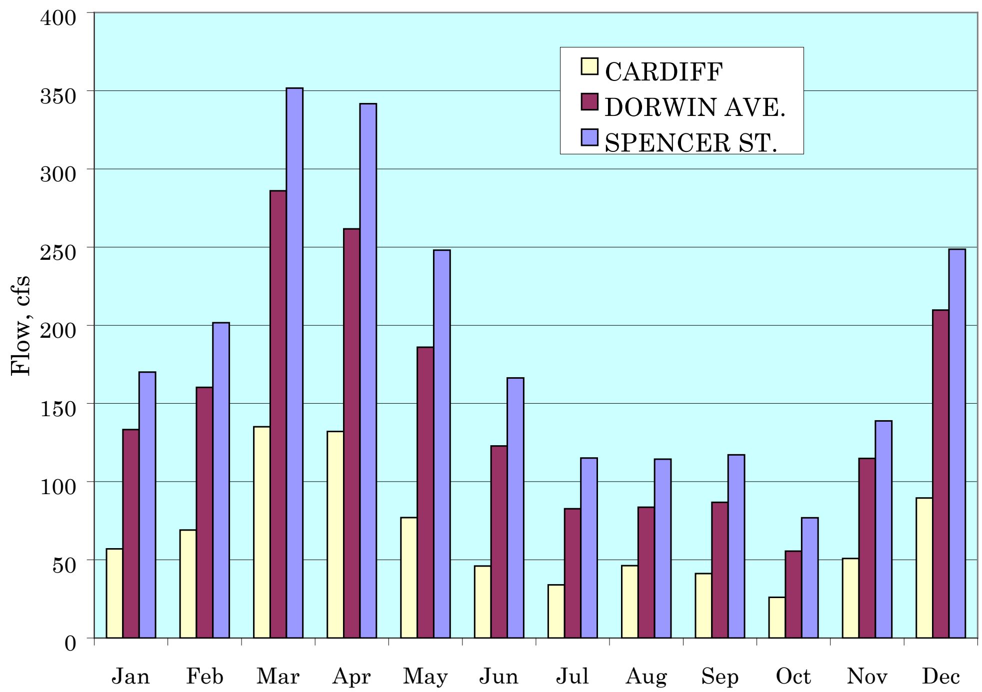


Figure 5: Monthly average stream flows at 3 USGS gaging stations on Onondaga Creek: Cardiff (Route 20), Dorwin Ave, and Spencer Street, for the period Oct. 1, 2001 to Sept. 30, 2004

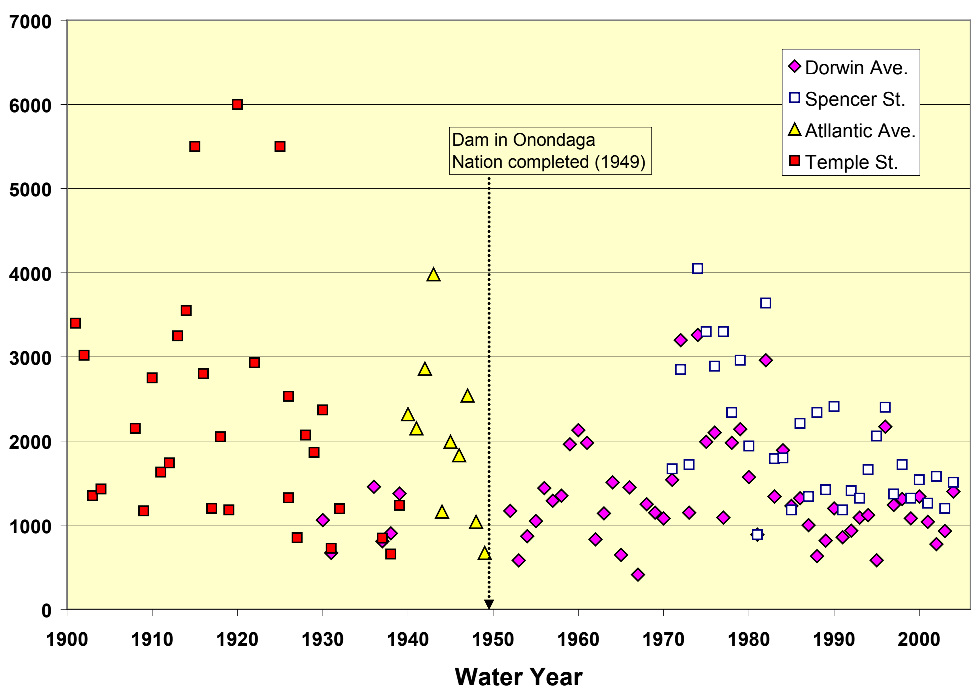


Figure 6: Peak flows observed in Onondaga Creek, at 4 gaging stations, all in Syracuse, NY

Note: The record prior to 1950 may be incomplete due to missing records.
Sources: Amos et al. 1927; USGS on-line data base http://waterdata.usgs.gov/ny/nwis; City of Syracuse, gaging data.

The probability of a high flow occurring can be predicted using statistical analysis (see Table 4). This is similar to prediction of a large rainfall event: historical data are compiled and fit to a probability curve. Extreme events, like 25-year or 100-year peak flows are extrapolated from the historical record. The USGS, which provides official estimates of peak flows, cautioned that the values presented in 1990 (Table 4) were not reliable due to changing conditions in the watershed.

Peak flows are analogous to extreme storms, but they are not synonymous. A 5-year storm event does not directly translate to a 5-year high-flow event. While a storm can be regarded as a relatively random event, there are numerous additional factors which affect the size and duration of a peak flow, including:

- time of year (during warm weather, trees intercept and transpire precipitation),
- prior conditions, such as
  - saturated soils
  - snow cover,
- distance of rainfall from stream outlet, and
- the presence of drainage structures in the storm area.

The 100-year peak flow is of special significance because this is used by the Federal Emergency Management Agency (FEMA) for delineation of flood-prone areas where flood insurance is required. High flows are associated with high water levels and swift currents. Photos of Onondaga Creek at high flows during the past two years are shown in Figures 7 and 8 below.

Table 4: Flood frequency distribution for Onondaga Creek

Sources USGS (1990) and Higgins (2005)

	Dorwin Ave (cfs)		Spencer St. (cfs)
	USGS1	Higgins[2]	USGS[1]
Frequency / Years of data:	1952-1988	1952-2004	1971-1988
2-yr	1360	1250	2250
5-yr	1980	1800	3100
10-yr	2380	2190	3600
25-yr	2880	2700	4160
50-yr	3250	3100	4540
100 -yr	3600	3510	4890

1 USGS, letter from J.B. Campbell, USGS Water Resources Div., Ithaca NY to Thomas Dussing, Calocerinos & Spina (Jan. 17, 1990). USGS cautioned that the data did not meet the assumptions necessary for a valid statistical analysis due to "extensive …urbanization and the construction of a reservoir that appreciably alters flood flows."

2 Higgins (2005), p. 20; Table 6.

Figure 7. Onondaga Creek at pedestrian bridge upstream of Spencer Street on July 12, 2006, about 1pm.

Note: Flow ~1100 cfs, and depth = 5.7 ft. The peak flow occurred at 5 pm with a flow of 2230 cfs (a 2-year flood).

Figure 8. Creek at Dorwin Ave gage station, April 5, 2005

Note: Average flow on this date was 1090 cfs. Gage height was approx. 4.3 ft.

Short-term changes Stream flow changes quickly in Onondaga Creek, as illustrated by the three hydrographs shown in Figure 9. These hydrographs reflect a moderate rainstorm on July10th – July11th and a large rainstorm on July 12th, 2006.

Anatomy of a rain event: the July 10-11, 2006 rain storm at Cardiff

- At Otisco Road (mud boil area), it begins raining about 10pm on July 10th. 0.48 inch falls during the first hour; another 0.06 inch during the next two hours. Total = 0.54 inch
- Creek starts rising almost immediately.
  - Base flow = 31 cfs
  - First increase (0.7 cfs) noted at 10:30pm
  - Maximum flow (54 cfs) at 4:15-4:45 am, July11th
  - Returns to almost base flow (32 cfs) by 2 am, July 12th
- Total volume discharged (above base flow) = 710,000 cubic feet.
- It is difficult to know how much rain fell across the watershed upstream of Route 20 without analyzing meteorological radar data.[2] As a crude estimate, one could assume 0.54 inch fell across the whole drainage area. On this basis, about 42 million cubic feet of rain fell during this one storm, of which <2% was observed in the creek at Route 20.

General observations: July 10 - 11 and July 12 storms

- Stream flow at Spencer is very "spiky." This is due to the urban character of the watershed; in particular the presence of CSOs (Combined Sewer Overflows) and storm sewers which empty into the creek
- Stream flow at Dorwin exhibits a normal hydrograph under moderate flow conditions (first storm), but shows the influence of the upstream dam during the second storm. Flow does not return to pre-storm conditions for an extended period of time because water is stored behind the dam. This effect is also seen at Spencer St. Dorwin does not show sharp spikes since it is upstream of nearly all urban drainage.
- Stream flow at Cardiff (Route 20) exhibits normal hydrographs during both storms.

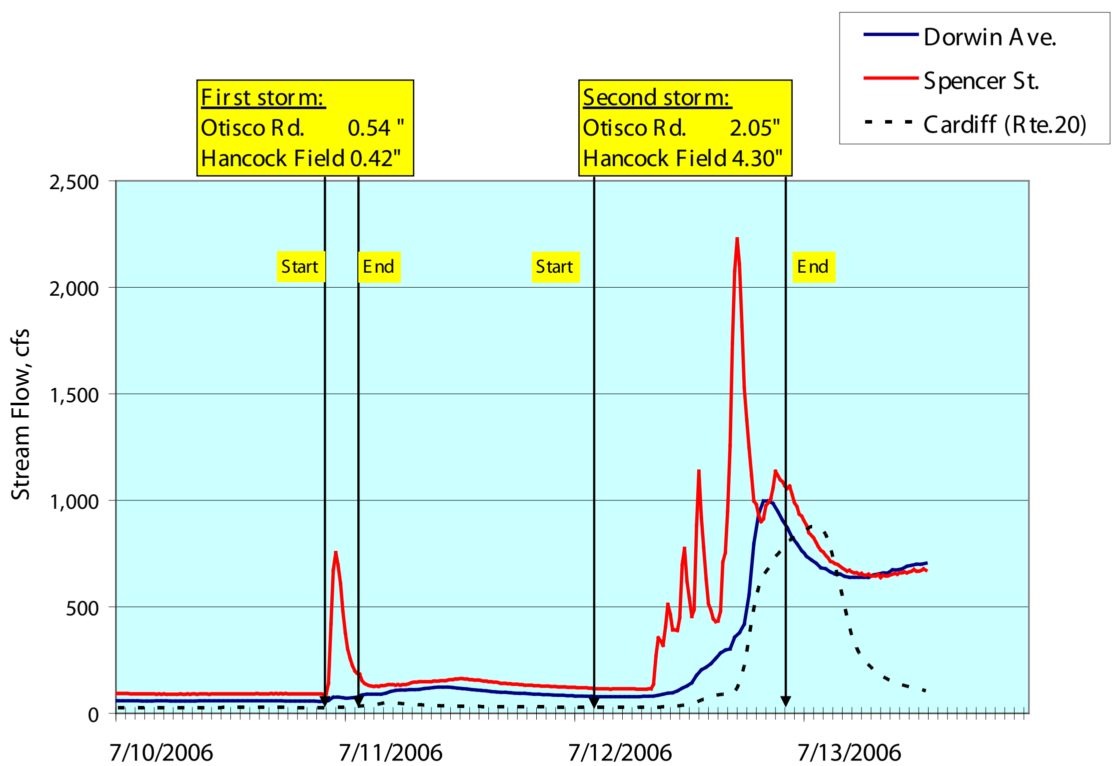


Figure 9. Hydrographs from Onondaga Creek at Cardiff, Dorwin Ave, and Spencer Street

Source: USGS web site for stream flow data: http://nwis.waterdata.usgs.gov/ny/nwis/

2 Radar data from the NEXRAD station in Binghamton, NY can be used to track precipitation over the Onondaga Creek watershed. However, this requires performing a considerable amount of data analysis.

Human Interventions That Affect Hydrology

Land use Originally, the Onondaga Creek watershed was almost completely forested. Based on surveys done in the 1790s of the Central New York Military Tract, Marks and Gardescu (1992) conclude that over 97% of the area was forested. Clearing for European farms, settlements and the salt industry commenced in the early 1800s (Nyland *et al.*, 1986; Sly, 1991). Nyland *et al.* (1986) compiled a series of historical sources to conclude that, by 1855, only 23% of Onondaga County was covered by forest. Deforestation continued such that, by 1925, forest cover was reduced to 9%, dipping to a low of 8% in 1930. Nyland *et al.* attributed the clearing of land cover in the early 1900s to expansion of grazing pasture for dairy farms. Since 1930 forest cover has increased, reaching 40% of land area in Onondaga County by 1980 (Nyland *et al.*, 1986).

Much of the city of Syracuse—in particular downtown and the Onondaga Creek valley—was historically a wetland. Subsequently, it was drained and transformed into an urban landscape with many impervious surfaces. Hence, runoff rates are high in the northern part of the watershed. Current land usage in the watershed is, from south to north:

- mixed (deciduous and evergreen) forest,
- fruit orchards and other agricultural lands, and
- residential, commercial, and industrial usages.

As a result, the quantity of water produced per unit land area increases dramatically as one moves from south to north through the watershed.

Sewers and drainage In rural areas, drainage tiles were once commonly used to drain agricultural lands. They are now only occasionally used where drainage is difficult. Drainage tiles help promote the movement of rainfall to the creek, once it percolates through the overlying soils.

The northern portion of the watershed, including Nedrow, other parts of the Town of Onondaga, and Syracuse, are drained with a complex set of sewer systems. These consist of:

- separated sewers (Town of Onondaga, including Nedrow, and Syracuse south of Ballantyne Ave) Storm water is conveyed directly to Onondaga Creek.
- combined sewers (Syracuse north of Ballantyne Ave) Storm water is combined with wastewater. During small rain events, all water is conveyed to the Metro sewage treatment plant. During medium and large rain events, a fraction of the combined sewage (which is mostly storm water) spills into the creek.

During rain events in the northern part of the watershed, storm water is quickly discharged to the creek, causing sharp spikes in creek flow downstream. When precipitation exceeds 0.20-0.5 in/hr (6-20 mm/hr), CSOs are triggered, quickly discharging additional storm water and sewage into the creek (S. Martin, pers. comm.). This was shown previously in the hydrograph for the Spencer Street gaging station during the two rain events in July 2006 (see Figure 9).

Channelization The lower 8 miles of Onondaga Creek has been completely re-channelized, extending from its mouth at Onondaga Lake, through Syracuse, to the northern boundary of the Onondaga Nation (Calocerinos & Spina, 1990; USGS maps). In addition, the course of the creek up and down-stream of the flood control dam has been heavily altered (see Flood Control fact sheet). Physically, the creek channel has been altered from a relatively shallow, meandering one to one which is much straighter and deeper (incised). While this has had little effect on the hydrology of the upper, rural, parts of the watershed, it has significant effects on the downstream sections. These impacts include:

- possibility of flooding is greatly reduced,
- the passage of water downstream is accelerated, and
- water currents are faster.

As a result, water flow through Syracuse is more like that of an open pipe than a natural stream. There are few, if any, opportunities for deposition of suspended sediment. Also, peaks in the hydrograph continue downstream with little change since there are no areas for water to spread out, such as in a natural floodplain or wetlands. The danger of drowning in the creek is greatly increased due to the strong currents and narrow channel.

Dams The flood control dam on the Onondaga Nation (see Flood Control fact sheet) acts a regulating valve on stream flow. The dam contains an underflow pipe which limits flow downstream. Water starts backing up behind the dam at a flow of ~250 cfs (7 m^3/s). As the water depth behind the dam builds, the flow through the pipe increases to a maximum of 1,270 cfs (36 m^3/s)[3]. This effectively reduces peak flows which could emerge from the Tully Valley and West Branch, such that the hydrograph is "flattened" and spread out over a longer time period. As a consequence, the area upstream of the dam, up to 860 acres (2.43 km^2) of forested lands largely in the Onondaga territory, is subject to flooding.

The drainage area above the dam is 67.7 square miles, which represents 61% of the entire watershed. Much of this area is either forested or agricultural, so runoff rates are much lower than for the downstream areas.

IMPLICATIONS

Land use has an enormous impact on the amount of runoff reaching the creek. Forested watersheds produce about one-tenth as much runoff as urban watersheds. Agricultural and suburbanized areas also produce more runoff than forests. Therefore, control of runoff, and consequently flooding, can be reduced through land-use practices and zoning laws that emphasize maintenance of existing forest canopy, planting trees, limits to urban sprawl, and best management practices on farms.

The speed that water reaches the creek depends on a variety of factors, some of which are under human control:

Factor	Effect
planting and maintaining existing vegetation	slows runoff
impervious surfaces	accelerates runoff
removal of drainage tiles	slows runoff
stormwater and CSO detention	slows runoff
sewer separation (without detention)	accelerates runoff

Peak flows, which are the cause of flooding, are controlled by the combination of runoff speed and volume. Peak flow, with the attendant risk of flooding, drowning, increased pollutant loads, and ecological impacts, can be reduced by

- reforestation,
- use of pervious rather than impervious surfaces,
- limiting urban and suburban development,
- maintaining or constructing wetlands,
- eliminating use of drainage tiles, and
- storm water detention.

By judicious selection of those factors which decrease runoff, potential for downstream flooding can be reduced. In particular, the detention of stormwater and combined sewage in Syracuse would be very effective in reducing the sharp peak flows which are seen at Spencer Street. Retention and detention methods include in-line storage, such as the Erie Blvd. Storage System, constructed wetlands, and rain barrels. Green strategies which eliminate storm water by evaporating or precolating runoff include green roofs, rain gardens, urban trees, and permeable pavement (Stoner, Kloss and Calarusse, 2006).

The flood control dam and downstream channelization effectively reduces flooding in Nedrow and Syracuse, but increases flooding upstream of the dam. Also, the dam and the Dorwin drop structure act as barriers for upstream movement of fish (see Fish and Aquatic Habitat Fact Sheets). Artificial stream channels have negative impacts on stream ecology, due to loss of natural habitat diversity and increased water velocity (FISWRG, 1998).

3 The dam also has an overflow weir which would come into use only after the 18,200 acre-feet (22.5 million m^3) reservoir behind the dam was filled to capacity. This has never happened since the dam opened in 1949.

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Sources of Data

NOAA, National Climatic Data Center

1. Annual precipitation at Hancock airport
2. Monthly precipitation at Hancock airport
3. Monthly precipitation, temperature climate normals (1971-2001) for

a. Syracuse Hancock Airport, in the Town of DeWitt

b. City of Syracuse Water Department, in Skaneateles

c. ESF Heiberg Forest, in Tully

USGS

1. Daily precipitation at
    - a. Otisco Road (1991-2005)
    - b. Route 20 (2002-2005)
2. Average daily discharge at
    - a. Near Cardiff (2002-2005
    - b. Dorwin Ave (1951-2006)
    - c. Atlantic Ave (1940-49)
    - d. Spencer Street (1970-2006)
3. Annual and monthly mean streamflow –
    - a. Near Cardiff (2002-2005)
    - b. Dorwin Ave (1951-2004)
    - c. Spencer Street (1970-2004)
4. Instantaneous streamflow

    Can be downloaded from USGS NWIS site

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The Onondaga Lake Partnership (OLP) sponsors the Onondaga Creek Revitalization Plan project with funds from the U.S. Environmental Protection Agency. Visit www.onlakepartners.org for more information about the OLP.

This fact sheet and additional information about the Onondaga Creek Revitalization Plan project can be found on the World Wide Web at www.esf.edu/onondagacreek/.