2.4 Hydrology and Flood History

Introduction

Hydrology is the study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks (groundwater), and in the atmosphere. The *hydrologic cycle* includes all of the ways in which water cycles from the landscape (both underground and in streams and water bodies) to the atmosphere (as water vapor and clouds) and back (as snow, rain and other forms of precipitation) (Figure 2.4.1). Understanding the hydrology of the Schoharie Creek will assist us with making land use decisions in the basin that work within the constraints of the hydrologic cycle and won't exacerbate flooding or cause water quality impairment.

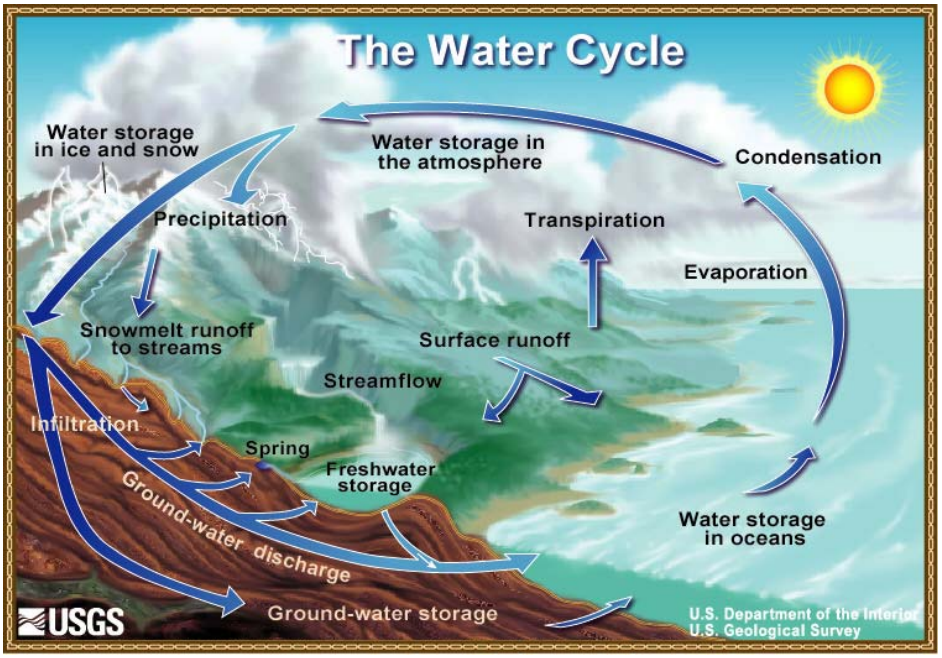

Figure 2.4.1. The Hydrologic (water) Cycle (http://ga.water.usgs.gov/edu/watercyclesummary.html).

Water flowing through the Schoharie Creek reflects the integrated effects of all watershed characteristics that influence the hydrologic cycle. Characteristics include climate of the drainage basin (type and distribution patterns of precipitation and temperature regime), geology and land use/cover (permeable or impermeable surfaces and materials affecting timing and amount of infiltration and runoff, and human-built drainage systems), and vegetation (uptake of water by plants, protection against erosion, and influence on infiltration rates). These factors affect timing and amount of stream flow, referred to as the stream's *hydrologic regime*. For example, a stream with an urbanized watershed where water will run off the hardened surfaces directly into the stream will have higher peak discharges following storms than a watershed, such as the Schoharie Creek, which is predominantly forested and allows a higher percentage of rain water to infiltrate before it reaches the stream, releasing it more slowly over time. Understanding the hydrology of a drainage basin is important to the stream manager because stream flow patterns affect aquatic habitat, flood behavior, recreational use, and water supply and quality.

Schoharie Creek Basics

Encompassing approximately 315 square miles of watershed area, the New York City Watershed portion of the Schoharie Creek is located primarily in Greene County, NY. The stream drains eight Greene County municipalities, not including direct drainage to the reservoir, including large sections of the Towns of Prattsville, Lexington, Jewett, Hunter, Ashland, Windham and the Villages of Hunter and Tannersville. The Schoharie Creek is typical of major streams within the Schoharie watershed in that it is a long, narrow watershed running east to west. This drainage pattern is controlled by the steep topography, formed in large part during the last period of glacial activity. Streams in the Schoharie valley are primarily perennial streams, that is, they flow year-round except in smaller headwater streams or in extreme drought conditions.

The Schoharie Creek watershed averages approximately 46 inches of precipitation per year in the upper reaches (Hunter), 42" per year in the mid-sections (Lexington) and 38.5" per year near the reservoir (Prattsville). This rainfall often comes in dramatic summer downbursts, remnants of autumn hurricanes, or late winter rain-on-snow events. Average slope of the upper watershed is 22% (watershed elevation drops 22' feet for every 100 feet horizontal distance), 18% in the mid-section and 15% near the reservoir. *Drainage density*, or how much stream length is available to carry water off the landscape per unit area of watershed is slightly lower than average for the Catskills, at $0.0012 m/m^2$. Given the average drainage density, combined with steep mountainous slopes, and high precipitation, the Schoharie system is relatively *flashy*, that is, stream water levels rise and fall quickly in response to storm events. This flashiness is somewhat mitigated by heavy forest cover throughout much of the watershed. Therefore, efforts to protect upland, as well as riparian, forest are important to reduce flooding impacts.

Stream flow Primer

There are two general categories of streamflow: storm flow (also called flood flow) and base flow, between which streams fluctuate over time. Storm flow fills the stream channel in direct response to precipitation (rain or snow) or snowmelt, whereas base flow is primarily groundwater fed and sustains streamflow between storms and during subfreezing or drought periods. A large portion of storm flow is made up of *overland flow*, runoff that occurs over and just below the soil surface during a rain or snowmelt event. This surface runoff appears in the stream relatively quickly and recedes soon after the event. The role of overland flow in the Schoharie watershed is variable, depending upon time of year and severity of storms or snowmelt events. In general, higher streamflows are more common during spring due to rain, snowmelt and combination events, and during hurricane season in the fall. During summer months, actively growing vegetation on the landscape draws vast amounts of water from the soil through *evapotranspiration*. This demand for groundwater by vegetation can significantly delay and reduce the amount of runoff reaching streams during a rain storm. During winter months, precipitation is held in the landscape as snow and ice, so precipitation events do not generally result in significant runoff to streams. However, frozen ground may increase the amount of overland flow resulting from a rain storm if the air temperature is above freezing, particularly in spring on north facing slopes.

Subsurface storm flow, or *interflow*, comes from rain or snow melt that infiltrates the soil and runs down slope through the ground. Infiltrated water can flow rapidly through highly permeable portions of the soil or displace existing water into a channel by “pushing” it from behind. In the Schoharie valley, subsurface flow can occur fairly rapidly along layers of essentially impermeable glacial lake silt/clay deposits. Subsurface storm flow shows up in the stream following overland flow, as stream flow declines back toward base flow conditions.

Base flow consists of water that infiltrates into the ground during and after a rain storm, sustaining streamflow during dry periods and between storm flows. The source of base flow is groundwater that flows through unsaturated and saturated soils and cracks or layers in bedrock or other impermeable layers adjacent to the stream. In this way, streams can sustain flow for weeks or months between precipitation events and through the winter when the ground surface and all precipitation is otherwise frozen. Stable-temperature groundwater inputs keep stream water warmer than the air in winter and cooler than the air in summer – this is what enables fish and other aquatic life to survive in streams year-round.

Hydrologists use a *hydrograph* of a stream, a graph showing amount or depth of flow over time, to analyze flow patterns and trends such as flood frequency or drought cycles. A *stream gage*, a device that primarily measures water level, is necessary to monitor stream discharge and develop a hydrograph. The United States Geological Survey (USGS) maintains a network of stream gages throughout the country, with a number of active gages on the Schoharie Creek and some of its tributaries (Figure 2.4.2).

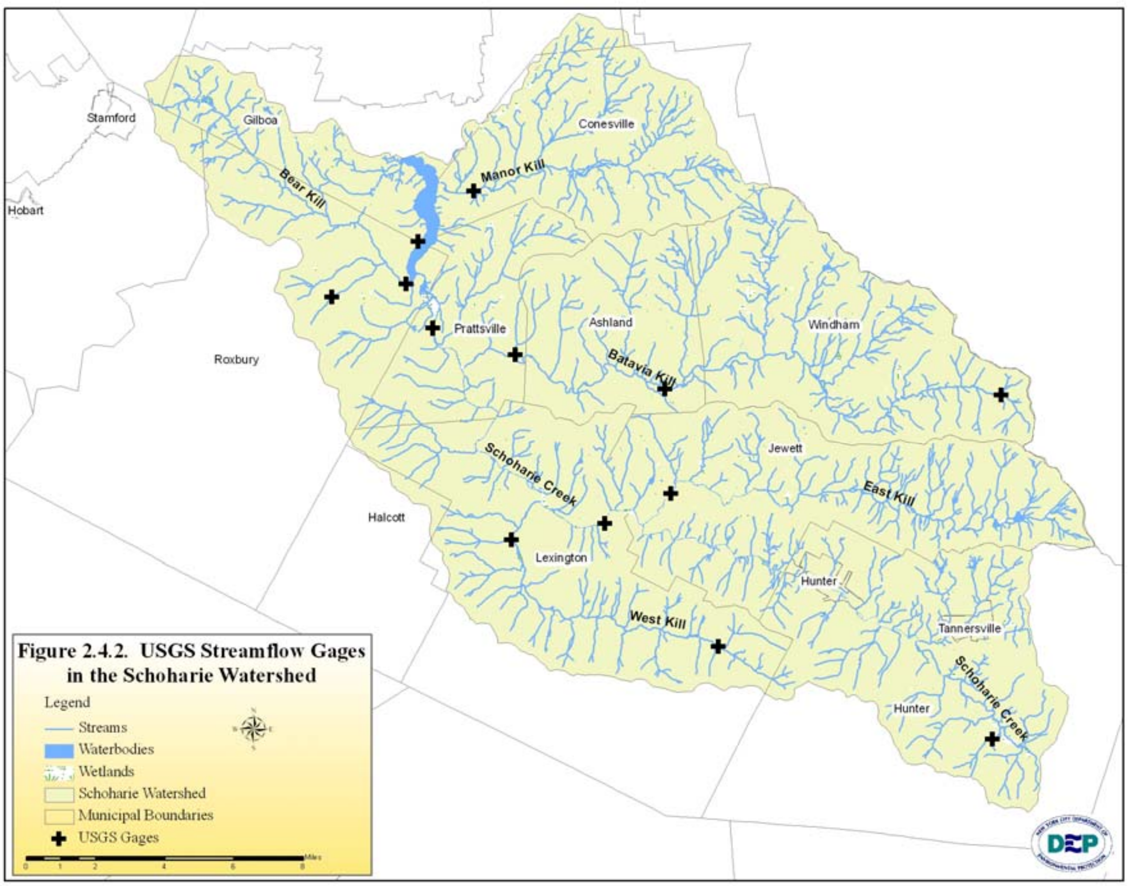

Figure 2.4.2. USGS Streamflow Gages in the Schoharie Watershed

The United States Geological Survey (USGS) maintains two continuously recording stream gages on the Schoharie Creek near Lexington (established 1999, drainage area 96.8 mi^2, USGS ID# 01349705) and Prattsville (established 1902, drainage area 237 mi^2, USGS ID# 01350000). Prior to 1996, a crest stage gage was maintained at Lexington starting in 1929. All gage information is available online at the USGS website: http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01349705 (Lexington) and http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01350000 (Prattsville).

These gages measure the *stage*, or height, of the water surface at a specific location, typically updating the measurement every 15 minutes. By knowing the stage we can calculate the magnitude of the *discharge* (flow), or volume of water flowing by that point, using a relationship developed by USGS called a *rating curve*. Using this rating curve, the magnitude of flow in the Schoharie at the gage location can be determined at any time just by knowing current stage. Flow can also be calculated for any other stage of interest. Additionally, we can use the historic record of constantly changing stage values to construct a picture of stream response to rain storms, snow melt or extended periods of drought, to analyze seasonal patterns or flood characteristics.

The Schoharie gages have a long enough period of record to prepare a hydrograph covering several years for the stream (Figure 2.4.3). Each spike on the Prattsville gage graph represents a peak in stream flow (and stage) in response to rain storms. Stream level rises (called the "rising limb" of the hydrograph) and falls as the flood recedes (called the "falling (or receding) limb" of the hydrograph). We can analyze long time periods to see seasonal trends or long-term averages for the entire length (period) of gage record. We can see the hydrograph for the gage shows higher flows in fall (hurricane season) compared to winter (water held in ice and snow), and higher flows in spring (snow and ice melt, with rain-on-snow events) compared to summer (drought conditions with vegetation using a lot of water). The highest flows of the year are generally associated with the hurricane season in the fall, followed by winter and spring snowmelt or rain-on-snow events. Overland flow accounts for most of water that causes the sharp peaks in the hydrograph.

Streamflow always rises and peaks following the height of a precipitation event because it takes time for water to hit the ground and run off to the stream (this is known as lag time). Knowing storm timing, we could also calculate *lag time* for Schoharie Creek at the gage location for particular storms or types of storms, and determine how the stream responds to storms both in timing and flood magnitude and recession. Through analysis of the long-term flow and flood records provided by the USGS, the town, its residents and resource managers can begin to better understand the cause/effect of various precipitation amounts on flooding.

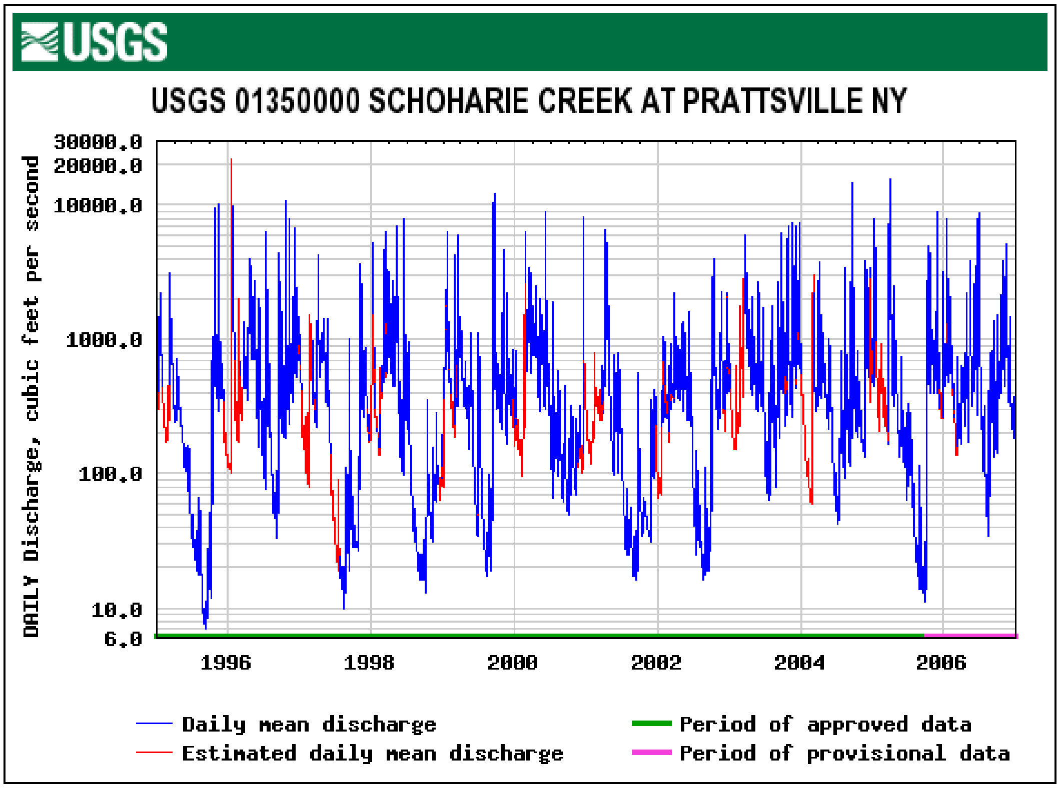

Figure 2.4.3. This hydrograph represents the daily average flow from 12/95 through 12/06.

The hydrograph of April, 2005 illustrates the effects of a spring storm on top of snow (Figure 2.4.4). The Schoharie rose quickly from the precipitation from a daily average of 411 CFS to 2,290 CFS in 24-hours. The recession took longer than a large summer storm due to the vegetation still being dormant, or just emerging, and the snow pack.

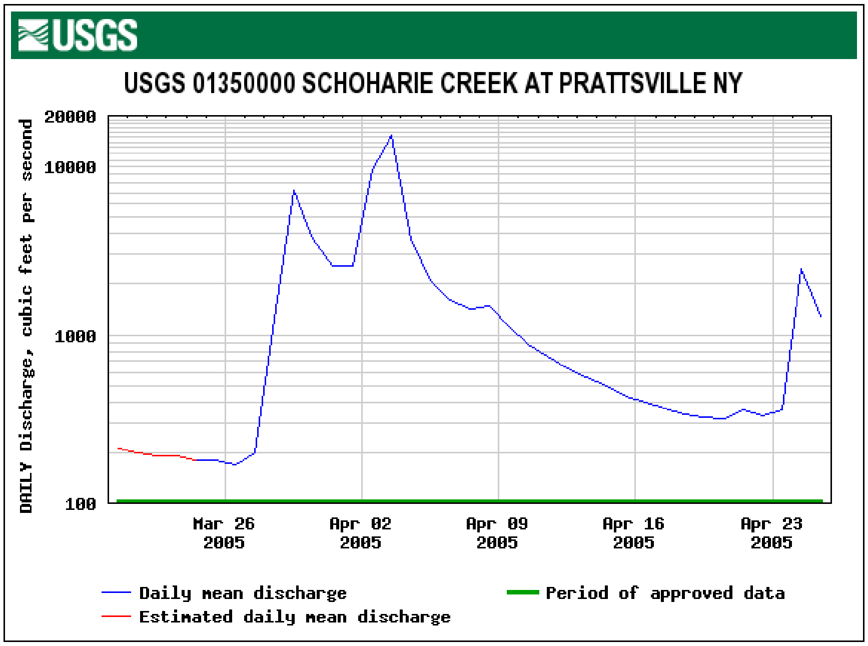

Figure 2.4.4. This hydrograph represents the daily average flow for April, 2005, including a large rain on snow precipitation event.

Schoharie Creek Flood History

As a mountain stream the Schoharie rises quickly as precipitation falls. If enough precipitation falls, the creek will rise to "flood stage". Flood stage for the Schoharie Creek at Prattsville is considered by the National Weather Service to be at 12 feet on the gage, which corresponds to approximately 18,000 cubic feet per second (cfs) (Figure 2.4.5; Table 2.4.1, also available through the USGS website for the Schoharie Creek at Prattsville Gage, referenced above). At 14 feet (roughly 26,000 cfs), the creek begins to overflow onto Main Street (Rte. 23), and by 18 feet (over 45,500 cfs) is considered severe flooding. Flooding in April of 1987, referenced below, peaked at 47,600cfs.

Between 1904 and 2006, the Schoharie Creek at Prattsville has exceeded flood stage 34 times (Figure 2.4.5), or about once in every 3 years. This does not mean that the Creek will exceed flood stage exactly once in 3 years – on the contrary, the record shows that often there will be several years in a row the Creek will flood, and other periods during which the peak flow does not exceed flood stage for several years. Flood cycles tend to follow larger weather patterns such that very wet periods will be high flooding years, and droughty times will see lower flows.

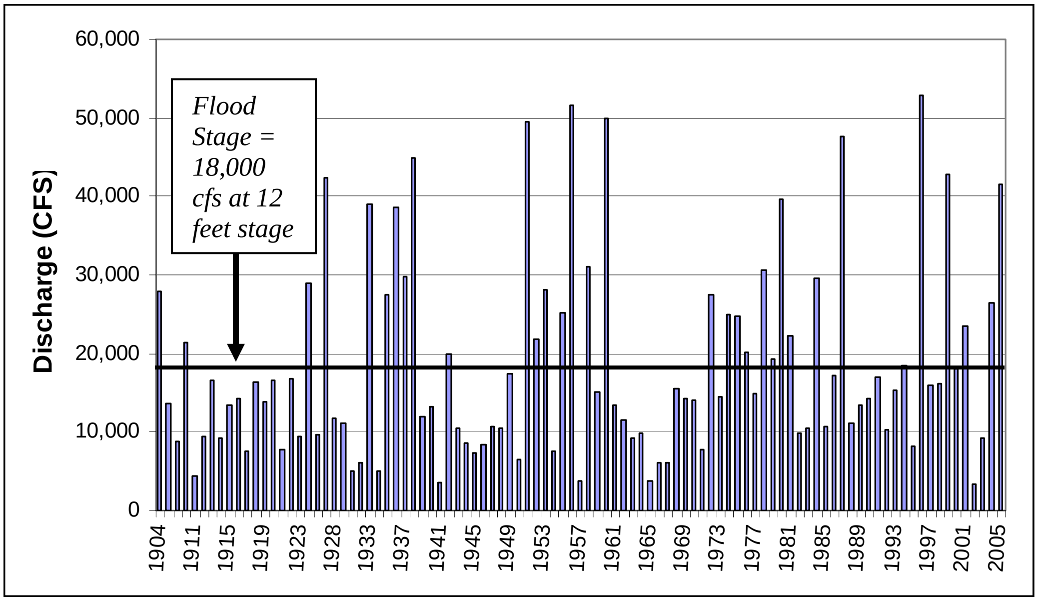

Figure 2.4.5. Annual peak flows for the period 1904 through 2006.

Table 2.4.1. Flood stage descriptions for USGS Gage Schoharie Creek at Prattsville, NY, as provided by the National Weather Service.

01350000
Schoharie Creek At Prattsville, NY
Datum of gage is 1,131.57 feet above mean sea level (NGVD of 1929)

(Flood-description information provided by the National Weather Service)

Elevation, Feet above mean sea level	Feet above datum	
1,151.07	19.5	Disastrous flooding Jan 1978 and Mar 1979 ice jams lower portion of village inundated with 3 ft of water.
1,149.57	18	Severe flooding (Apr 1987) with about two to three feet of water on properties in the village alongside the creek.
1,147.57	16	Water begins to overflow onto Greene Co. Route 7 north of Route 23 bridge downstream.
1,145.57	14	Begins to overflow onto Main Street (NYS Route 23)
1,143.57	12	**FLOOD STAGE…**Overflows into lowlands bankfull.
1,134.57	3	Normal low water.

The peak flow in any given year is not necessarily a significant/damaging storm event, but could represent a dramatic increase in flow, particularly if following drought. To put this in perspective, the flood of record (the highest flood ever documented since beginning to record floods at the gage in 1904) in1996 pushed the Schoharie Creek to its highest stage at 19.4' (peak flow of 52,800 cfs) reaching its 100 year flood stage and representing "disastrous" flooding from Table 2.4.1. The flood of 1996 was caused by unusually warm weather events during the winter which melted large amounts of snow very rapidly. North facing slopes of the Schoharie valley receive little sun exposure compared to south facing slopes. As a result, half of the valley retains a snow pack well into the spring when rain on snow events can cause dramatic spring flooding. Tropical storms and hurricanes in the late summer and early fall also trigger flooding in the valley. Prior to the flood of 1996, the Creek hadn't reached flood stage since November, 1993, when it just topped flood stage at 18,400 cfs, and before that the Creek hadn't reached flood stage since severe flooding in April 1987 (see Table above).

After the flood of 1996 $15.2 million of federal and state funding was distributed amongst 377 municipalities to help repair damage. The Federal Emergency Management Agency (FEMA) estimated that approximately $102 million worth of damage had occurred state wide during the flood (New York State, 1996). The 1996 flood also inspired the town of Gilboa to embark on a 1.5 million dollar project to purchase and demolish several homes which were located in the floodplain and to relocate Stryker Road. The flooding in 2000 was much less than 1996 (stage height 12.1'/18,000 cfs, just at flood stage), but still brought comparable damage statewide, with $12.7 million being released to 206 municipalities across NY, with Greene County receiving $176,596.23.

Another way to look at flooding magnitudes and patterns is through analysis of flood frequency distributions. This shows flood magnitude for various degrees of probability or likelihood, or in other words, how likely each size flood is likely to occur in any one year, or over a period of years. So for example, each year it is possible but not likely we will see a large flood and almost a certainty we will see a small one. This value is actually calculated as a percent likelihood, but is most often converted to a number of years as above in discussing the event of January, 1996, as the "100 year flood". This number of years is called the "recurrence interval" (RI) or "return period" of an event of certain size. For example, the flood with 20% chance of occurring or being exceeded in any single year corresponds to what is commonly referred to as a "5-year flood" (each of these values is the inverse of the other - just divide 1 by % probability to get RI in years, or divide 1 by RI in years to get % probability). This simply means that on average, for the period of record (the very long term), this magnitude flood will occur about once every 5 years. This probability is purely statistical; probability remains the same year to year over time for a particular size flood to occur, though the actual distribution of flood events in time is not regular; many years may go by without a certain magnitude flood, or it may occur several times in a single year. As another interesting characteristic of flood frequency distributions, the 5-year flood may not occur the "right" number of times in a certain period of record. For example, we might expect to see about 2 "5-year floods" for every 10 years of record, but any particular 10 year period may contain greater or fewer of this size flood.

The length of gaging records in New York is typically short, on the order of less than 30 years, compared to long-term history. 200-300 years might give a better picture of how often the range of floods may occur. Therefore, its somewhat difficult to assign probability to the floods we do see, particularly if we are in a particularly wet or dry period. A lot of research has gone into the actual distribution of flood events over time, so we can take as little as 10 years of record and generalize out to much longer periods, 100 or 200 years or longer.

Floods recorded at the Schoharie Creek gage that exceed a 5-year recurrence interval provide an example of distribution of medium to large floods over a longer time period, particularly if compared with two gages in a nearby watershed (Table 2.4.2).

Table 2.4.2. Flood Flows at Three Gages that Exceed Five Year Recurrence Intervals (Flood frequency statistics based on recorded peak flows through 1997. Esopus Creek at Allaben, NY: 5 yr RI flood:~6,500 cfs 10 yr RI flood: ~9,500 cfs Bushnellsville Creek at Shandaken, NY 5 yr RI flood:~800 cfs 10 yr RI flood: ~1,000 cfs Schoharie Creek at Prattsville, NY: 5 yr RI flood: ~24,000 cfs, 10 yr RI flood: ~33,000 cfs.).

Esopus Creek at Allaben, NY	
Date	***Flood Discharge (cfs)***
3/30/51	*20,000*
7/28/69	*7,870*
3/21/80	*15,900*
2/20/81	*6,540*
4/5/84	*8,470*
4/4/87	*16,100*

1/19/96	*15,000*
9/18/04	*6,700*
4/02/05	*20,400*
Bushnellsville Creek at Shandaken, NY	
Date	***Flood Discharge (cfs)***
11/25/50	*1,350*
10/15/55	*1,830*
3/21/80	*845*
4/5/84	*896*
4/4/87	*1,000*
1/19/96	*996*
9/18/04	*No data available*
4/02/05	*No data available*
Schoharie Creek at Prattsville, NY	
Date	***Flood Discharge (cfs)***
Sep. 30, 1924	*29,000*
Nov. 16, 1926	*42,300*
Aug. 24, 1933	*39,000*
Mar. 03, 1934	*50,002*
Jul. 08, 1935	*27,400*
Mar. 18, 1936	*38,500*
Feb. 22, 1937	*29,800*
Sep. 21, 1938	*45,000*
Nov. 25, 1950	*49,500*
Dec. 11, 1952	*28,200*
Aug. 13, 1955	*25,100*
Oct. 16, 1955	*51,600*
Dec. 21, 1957	*31,000*
Sep. 12, 1960	*49,900*
Jun. 22, 1972	*27,400*
Dec. 21, 1973	*24,900*
Dec. 08, 1974	*24,800*
Jan. 09, 1978	*30,600*
Mar. 21, 1980	*39,600*
Apr. 05, 1984	*29,500*
Apr. 04, 1987	*47,600*
Jan. 19, 1996	*52,800*
Sep. 16, 1999	*42,800*
Sep. 18, 2004	*26,500*
Apr. 2, 2005	*42,500*

However, recurrence interval can be misleading – it is a common misperception that a five year flood should occur exactly once every five years. But we know this isn't true – for example, on the Schoharie Creek in the 1930s, there were significant floods six years in a row, with two greater than the 25-year event – the size flood for which most NYS and county bridges are designed. By contrast, there were no such events during the entire decade of the 1940s.

Flooding occurs in response to excessive runoff associated with spring snowmelt, summer thunderstorms, fall hurricanes, and winter rain-on-snow events. Five of the seven major floods recorded at the Esopus Creek at Allaben station occurred in late winter/early spring and are presumably associated with major snowmelt events from either spring thaw or rain-on-snow events. The largest recorded flood is a spring runoff event. A summer flood in 1969 and the flood of January 1996 are the two other large floods recorded at the gage. Three of the six major floods recorded at the Bushnellsville gage occurred during the spring and are coincident with three of the Esopus events, showing some comparison can be made between nearby streams. Conversely, weather in the Catskills can produce localized historically significant flood events such that a peak event may not be recorded at each gage for the same time period or storm event. Significantly, we can see that 10 of 25 events at Schoharie Creek occurred during hurricane season (late summer to late fall), 13 occurred during winter and spring, and only 2 occurred during summer. The January 1996 flood was approximately a 10-year recurrence interval flood on the Bushnellsville Creek, less than a 40 year event at Esopus Creek, and the “flood of record” at the Schoharie Creek. This shows that between-stream comparisons are not always perfect. This is especially so with summer thunderstorms, where highly localized storm cells can produce 10 or more inches of rain in one watershed, and only a few inches in an adjacent watershed for the same storm. Summer peaks shown in Table 2.4.2 do not overlap between any of the three sites.

From review of available data we can generalize that most bankfull (low-level flooding) and greater events will occur in late winter/spring as the result of thaws and major rain-on-snow events. This is in large part due to landscape storage of available water as snow and ice, reduced infiltration capacity if the ground is still frozen (or partially so), and minimal evapotranspiration from vegetation, which would otherwise route moisture back into the atmosphere. Other major floods can be expected during hurricane and tropical storm season in the late summer and fall, particularly as vegetation enters the dormant season and demand for water in the landscape drops off.

The 1990s were generally a time of moderate flood events in the vicinity of the Schoharie, with the exception of the winter flood of January 19, 1996, which was similar in scale to April 1987. Tropical Storm Floyd flooding (September 1999) was typical of tropical storm events and the sometimes uneven distribution of precipitation associated with those storms. While flooding in Esopus drainages was typically less than a 5-year event, several drainages in bordering Schoharie system had over a foot of precipitation in 24 hours with flooding that exceeded the 10-year event discharge.

The years 2000 – 2002 were characterized by droughty conditions with intervening wet conditions. High water events were typically limited to bankfull (or smaller) events. 2003 was an unusually wet year, with several larger than bankfull events occurring during the summer. Predicting precisely when the next 5-year (or greater) flood will occur in the Schoharie is impossible – the probability for a large flood, or a flood of any particular size, is the same each year – though weather and storm patterns can be used to anticipate conditions for a few months out, and seasonal patterns are generally reliable. The last really large flood was in April, 2005, but the probability is high that, when the next flood occurs, late winter/early spring during snowmelt/rainy season will be prime time.

Implications of Schoharie Creek Flooding

The unique hydrology of the Schoharie Creek has consequences for how the stream corridor should be managed. Flood history and dynamics play a large role in determining the shape, or morphology, of stream channels and the hazards associated with land uses on the banks and in the floodplain. For example, applications for stream disturbance permits (from NYS DEC) typically increase following floods as landowners and municipalities attempt to repair damage caused by flooding. If we want to minimize their impact on property, infrastructure and other damages or inconvenience, it is critical that we understand and plan for flooding behavior. Historically, this “planning” has emphasized attempts to constrain and control stream channels, rather than working with processes we can measure and, to some extent, predict. The results are often costly and sometimes catastrophic, such as when berms or levees fail or bridges wash out. These “control” approaches typically result in ongoing maintenance costs that can draw valuable community resources away from other projects. With a better understanding of stream and floodplain processes, we can reduce these costs.