Section 3. Watershed Inventory and Assessment

3.1 Stony Clove Creek Water Quality Assessment

Linkage between Streams, their Watersheds and the Atmosphere

As described in other sections of this plan, streams and their watersheds are intimately connected to each other through many complex pathways. The character of a stream is shaped by the watershed size, topography, geology, soils, vegetation, and climate. The history of the landscape – both in terms of the natural and sometimes catastrophic events such as glaciers, floods and forest fires, and of human activities such as settlement, logging, and road-building – largely determines the unique character of the stream.

As water travels over the landscape and through the ground, it mobilizes substances in its path. Materials are transported in water either as particles or in dissolved form. Some of these materials, such as minerals, are naturally occurring, while others are waste products deposited by humans and wildlife. Streams also receive contributions from the atmosphere in the form of particles, gases, and dissolved substances carried in rain, snow and even fog. As these different materials move into and through the stream system, they change the environment of the organisms living in and near the streams, from microscopic plants and insects, to fish, to people, to entire ecosystems. For example, nutrients such as phosphorus and nitrogen can stimulate the growth of algae and bacteria in streams. Ultimately, watershed and stream characteristics and their response to influences such as land management and weather determine the structure and productivity of the stream community (e.g., plants, algae, invertebrates, and fish) and control what is exported downstream. The character of the water delivered by the Stony Clove Creek into the Esopus Creek is the result of a dynamic system of interacting physical, chemical, and biological processes – historical and current – unique to its watershed.

What is water quality?

Water quality as a technical term is used to describe the chemical, physical, and biological characteristics of water, usually in relation to its suitability for a particular use. All waters in New York State are given a class and standard designation based on best usage for a given water body (NYS DEC, 1998). For example, Class B fresh surface waters according to state regulations (6 NYCRR Chapter X § 701.7) are best suited for primary (swimming) and secondary (boating) contact recreation and fish propagation and survival. An additional designation indicates that it may support trout populations (t) or trout spawning (ts), and special requirements apply to protect these valuable and sensitive fisheries. This best use classification system is further detailed in Section 2.11. The Management Unit descriptions of the Stony Clove in Section 4 make reference to this best use classification system. (These are not to be confused with Rosgen stream types, which characterize stream channel form, or morphology, rather than water quality (See Section 3.2).

New York State sets water quality standards for a variety of substances that are relevant and applicable to specific use classes (6 NYCRR Part X § 700-706). Standards and guidance values are established to control exposure to toxic and deleterious substances, and substances that have nuisance effects (produce undesirable color, tastes, or odors). Where fish propagation and survival are included in the best use classification, standards and guidance values for aquatic (acute) and aquatic (chronic) types apply. The NYSDEC Technical and Operational Guidance (TOGS 1.1.1) document produced by the Division of Water gives further details on standards and guidance values.

Progressive History of Water Quality Protections

The goal of the Federal Water Pollution Control Act of 1956 was to restore and maintain the integrity of the nation's waters and its later amendments in 1972 became known as the "Clean Water Act." Under the Clean Water Act, pollution is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water. This federal legislation was instrumental in reducing point source pollution (coming from a single source such as a sewage outfall) on a national scale. Once effective controls were in place to reduce point source pollution, attention shifted to non-point source pollution (arising from multiple diffuse sources, such as road runoff, rather than a single point of discharge). The federal Safe Drinking Water Act (SDWA) of 1987 required states further to protect source waters – (streams and reservoirs that feed water supplies), address non-point source pollution, implement water quality standards and address other public health issues related to water quality. SDWA amendments in 1996 further expanded on these protections, and public water suppliers were required to extend protection to the entire watershed area for surface water supplies.

According to the Surface Water Treatment Rule (SWTR 1989; revised 1996), drinking water supply systems using surface waters (including streams, lakes, and reservoirs) must either be filtered, or apply for and receive a filtration waiver from the USEPA. Only those systems able to comply with the stringent source water quality criteria, meet the inactivation (disinfection contact time) requirements, and maintain an effective watershed control program are granted a filtration waiver. In 2002, the EPA granted the New York City Water Supply its most recent Filtration Avoidance Determination (FAD), reflecting the success of many watershed protection programs, achieved through partnerships between the City, federal, state and county agencies, and local stakeholders. Under the 2002 FAD, the City will continue and expand programs that target key potential pollution sources.

http://www.nyc.gov/html/dep/watershed/pdf/finalfad2002.pdf gives the full context of the requirements that must be met by NYCDEP for the Catskill/Delaware portion of the New York City Water Supply.

Sources of Variability in Water Quality

Streams are highly variable, dynamic systems. The pathways water takes before it enters the stream are key determinants of chemical composition and export of materials from the watershed. The quality of stream water can change dramatically in a matter of hours as, for example, when a thunderstorm washes across the landscape, diluting some local point source pollutants, while increasing the concentration of some non-point source contaminants.

One source of variability is related to the relative contribution of ground water to streams, which changes seasonally and episodically (during storm events). Most streams are dominated by surface water during storms and by groundwater during periods of base flow (such as low summer flows). The balance between groundwater and surface water has profound effects on water chemistry.

Storm runoff is highly variable, affected by the timing, duration, and intensity of storms. Soil moisture and temperature conditions affect the rate and amount of runoff that enters the stream during rain and snow melt events. Surface runoff will be exposed to and pick up different substances than water that sinks into the ground and enters the stream as groundwater. Generally, the maximum runoff, as well as peak nutrient loads, occur during spring. Frozen soils do not allow water to infiltrate, and the biota in the landscape have not yet locked up available nutrients in the new season's growth.

High volumes of surface runoff during storms can flush materials from the watershed into the stream, creating a pulse of nutrients, sediments and other materials. Increased stream velocity and water levels also increase the erosive power and as well as the amount of contact area between the stream and its channel and surrounding floodplain, mobilizing additional materials that are not in contact with the stream during low flows.

Daily variability in light and temperature (diurnal, or day/night cycles) is another source of physical, chemical, and biological variability in streams. The temperature of shallow streams may closely correspond to air temperature, warming during daylight hours. A stream's metabolism also changes in response to light, with photosynthesis and respiration (of aquatic plants and algae) taking place during the day, and respiration alone occurring at night, causing dissolved oxygen (DO) concentrations and pH to fluctuate daily.

Vegetation cover affects temperature both directly (via shading of the stream) and indirectly (through warming of the land surface). Vegetation composition and density also affect the amount of water intercepted and lost to evapotranspiration. Within the stream channel, the placement of stream bank revetment comprised of rock rip-rap can significantly affect local stream temperatures, excluding the establishment of protective trees or shrubs that would shade the stream from the mid-day August heat, and acting as solar storage that prevents the normal cooling that occurs after nightfall.

Considering how dramatically the water quality of streams can change from hour to hour, day to day, or season to season, if we want to characterize water quality adequately, the question of when and how frequently we take our measurements will be critical. The sampling approach for stream water quality assessment will depend on the objectives of the study, but must take into account the natural variability of flowing waters. For example, if the goal was to examine water quality trends over a period of many years, periodic samples collected at a fixed time interval (e.g., monthly) would be suitable. If the goal is to estimate yearly loading of a non-point source contaminant whose concentration increases dramatically with storm flow, sampling of storm events is essential to characterize water quality.

Water Quality Concerns

The quality of stream water is often characterized by physical, chemical, and biological tests that screen for possible contaminants. Additional data on pH, temperature, specific conductivity, and dissolved oxygen are collected at the time of sampling to help with the interpretation of water sample analysis results.

There is no regulatory standard for suspended sediment in New York State. Instead, New York regulates stream turbidity with a narrative standard stating that "no increase that will cause a substantial visible contrast" should occur as a result of a stream disturbance activity. Turbidity in water is a measure of an optical property of water – light scattering and absorption – and is affected by the amount, color, size, and shape of suspended particles. Turbidity is caused by inorganic sediments such as silts or clays, or particulate organic matter such as plankton and detritus. Increases in cloudiness viewed by an observer in the field are assumed to equate with a measure of turbidity using a turbidimeter or nephelometer and expressed in NTU (nephelometric turbidity units). Because of the variable composition of suspended material, no direct relationship between suspended sediments and turbidity exists. Nonetheless, turbidity is important to measure because it is the regulatory standard, and good correlations can be developed for specific streams and flow regimes.

Stream biota can be affected when fine-textured sediments such as clay particles are suspended in the water column. These fine sediments can settle on substrates used by colonizing algae and invertebrates (aquatic insects), and can fill the small spaces between gravel where fish lay their eggs, preventing the flow-through of water and oxygen, effectively smothering the eggs. Water transparency and light transmission through the water can be reduced, which can affect stream productivity. Sediment particles also interfere with drinking water disinfection, another negative consequence of increased sediment concentrations carried by streams to drinking water reservoirs.

Engineers who designed and constructed the Ashokan Reservoir in the early 1900s recognized that abundant sediment supply and transport characterize the Catskill system. High sediment loading from the watershed was evidently an issue at the time of the reservoir's construction, because the design of Ashokan Reservoir was adapted to minimize impacts from sediment on the quality of water delivered from the reservoir. The reservoir is divided into two parts, with a settling basin in the western portion where Esopus Creek enters. Gates in a dividing weir allow the transfer of water from the west basin to the east basin after it has sufficiently settled. A wall then diverts water as it enters the east basin to allow fine particles to settle before reaching the intake for the Catskill Aqueduct.

As sediment is transported by the stream, other substances hitch a ride on the sediment particles. Phosphorus, a nutrient, and pathogenic organisms (bacteria, viruses) adsorb, or attach themselves to the fine particles. Besides the repository of nutrients and microbes stored in soil, other sources of undesirable substances include improperly functioning septic tanks, lawn fertilizers, livestock and wildlife. Increases in both phosphorus and nitrogen enrich streams and receiving waters. Resultant excessive algal growth can reduce dissolved oxygen when algae eventually die and decay, affecting fish and other aquatic life. Pathogenic organisms pose a human health threat.

Overview of Water Quality Data for Stony Clove Creek

Extensive monitoring of stream water quality has been conducted for many years in Stony Clove Creek and some of its tributaries. NYCDEP has routinely monitored Stony Clove Creek at a site in Phoenicia for several years. The data examined in this report (1987-2002) covers the period for which NYCDEP has final data (i.e., results have been verified and passed quality control measures) in its computer database. A wide range of physical, chemical, and biological tests were conducted at a frequency that ranged from weekly to monthly, except for trace metals, which were sampled quarterly.

Beginning in 2002, NYCDEP began sampling monthly upstream from Phoenicia town center on NYS Route 214 where the U.S. Geological Survey (USGS) installed a stream gage in December 1996 (USGS 01362380 Stony Clove Creek Near Phoenicia). Additional water quality (“discrete”) samples have been collected since 1999 by USGS at the station described above and at an upstream site on Hollow Tree Brook (Hollow Tree Brook at Lanesville, NY; USGS# 01362342). Water quality sampling has been conducted in Stony Clove Creek by other researchers (USGS, NYSDEC, Stroud Water Research Center, Cornell University), but results discussed here are confined to NYCDEP data (1987-2002; metals data through 2001) and only for the monitoring site in Phoenicia above the confluence with Esopus Creek. Water quality at this site represents the net effect of inputs and processes in the Stony Clove basin as a whole. Additional upstream sites are discussed later in reference to a special turbidity and suspended sediment study.

Stony Clove Creek is designated as a Class B(t) stream for the entire mainstem, from its headwaters at Notch Lake to its confluence with Esopus Creek. Comparisons of stream water sample test results with Class B(t) water quality standards for nutrients (forms of nitrogen and phosphorus) and metals and where possible, exceedences of specific standards are useful for assessing the extent to which stream water quality maintains the state classification (Table 1). Comments at the end of the table include several important points to consider when interpreting this summary of water quality. A strict application of standards was not possible when a different form of the substance analyzed (analyte) was tested (such as the total recoverable form of a metal rather than the dissolved form). The conservative assumption for historical data is that if total metals concentrations are below the standard for the dissolved form, then the standard was not exceeded (dissolved form is only a portion of the total). For the purposes of this overview and summary, standards are reported as a benchmark for comparison. Some general conclusions drawn from 16 years of water quality testing on Stony Clove Creek include:

- No problems with serious public health implications were identified.
- Conditions are generally consistent with standards set for a cold water fishery (including the trout fishery here), at least with regard to pH, temperature, and dissolved oxygen.
- Fecal coliform bacteria were found above benchmarks on rare occasions. This reinforces the need for a common sense approach to proper installation and maintenance of septic systems and the potential benefits of sewage treatment for the town center. These treatment measures, however, do not address any contribution from wildlife or livestock in the watershed.
- Aluminum and other metals concentrations that appear high are likely to have a natural (geologic) source, and conservation measures to reduce sediment entrainment and transport could reduce metals associated with sediment contributions from stream bed and bank or roadside ditch erosion.

The primary water quality concern in Stony Clove Creek is sediment from eroding stream channels, banks, roadside ditches and uplands resulting in high turbidity. Stony Clove was added to the NYSDEC Lower Hudson Basin Priority Waterbody List (PWL Water Quality Impacted Segments, Table A.12a, 2000) because it is "known to be stressed by silt/sediment from streambank erosion." Furthermore, downstream receiving waters (Esopus Creek and Ashokan Reservoir) have appeared on the NYS 303(d) list of Impaired Waters Requiring a Total Maximum Daily Load (TMDL) for silt/sediment. Also associated with high suspended sediment concentrations are concerns over nutrients (particularly phosphorus) and pathogens attached to soil and fine sediment particles. Stony Clove Creek water samples are screened for pathogens through routine monitoring of indicator bacteria. A separate monitoring program exists for specific pathogens known to have human health impacts (Giardia and Cryptosporidium).

A summary of key water quality variables shows how Stony Clove Creek compares with other streams in the Esopus drainage for turbidity, total phosphorus, and fecal coliform bacteria (Fig. 1). Based on concentrations from discrete (grab) samples, the median value is among the highest of the six streams shown. A peak in 1996 shows a spike in turbidity along with a pulse of nutrients and fecal coliform bacteria that occurred when a heavy rain fell on snow covered frozen soils, resulting in rapid runoff and high stream flow. Another peak in 1999 shows the effects of high runoff from Hurricane Floyd.

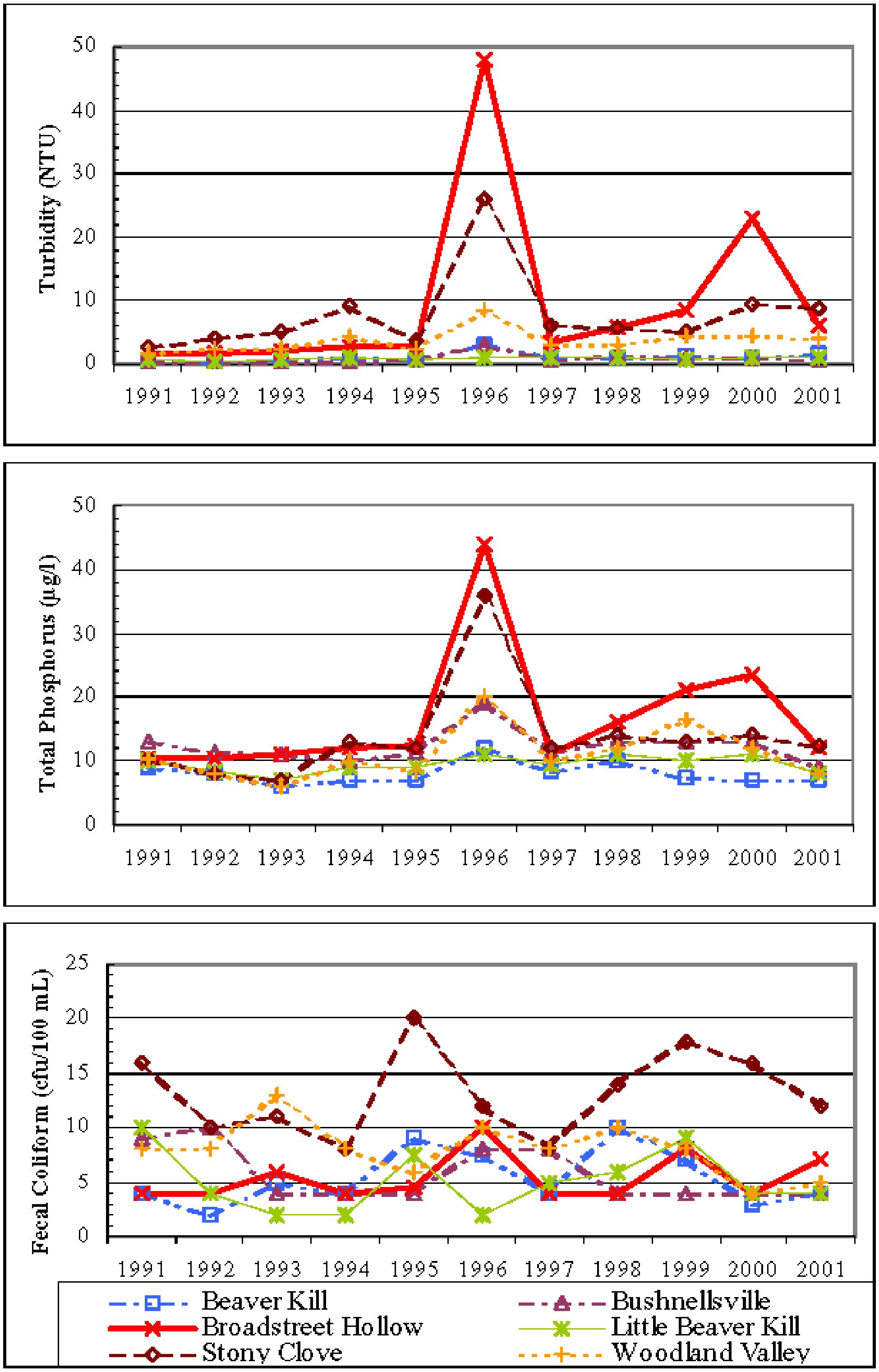

Figure 1 Annual medians for selected water quality analytes (turbidity, total phosphorus, and fecal coliform) for several Catskill streams in the Ashokan basin, 1991-2001.

An intensive study of turbidity and suspended sediment sources was done by NYCDEP from 1993-1997. Each sampling point in this study represented a tributary input to the Stony Clove, or a specific reach on the main stem that received materials locally from the channel and banks and from upstream and watershed sources. This study focused on acute problems generated by storm events. Sites were monitored more frequently (daily after a rain event), and multiple sites were used to characterize sediments contributed by specific reaches and tributaries. Multiple events were monitored during Spring and Fall runoff periods, to capture the range of variability and recovery of the stream to pre-storm turbidity levels and sediment concentrations. Sampling captured storms of varying length and intensity and differing antecedent (pre-storm) conditions.

While turbidity differs markedly between the upstream and downstream sampling stations of a failing streambank in Chichester (Fig. 2 & 3), no significant change in flow accounts for this increase. The apparent high suspended sediment loading from the failing streambank persists over the time period of the study (1994 - 1997), although differences in turbidity are evident during storm events of different magnitudes. The highest peak in turbidity during the study period was recorded after a rain event with snow cover and frozen soils in January 1996 (Fig. 2).

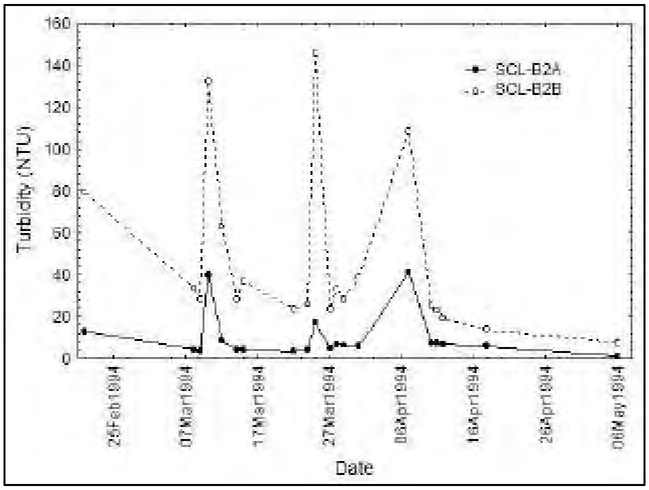

Figure 2 Turbidity readings above and below a large bank failure on the Stony Clove Creek in Chichester, February to May 1994.

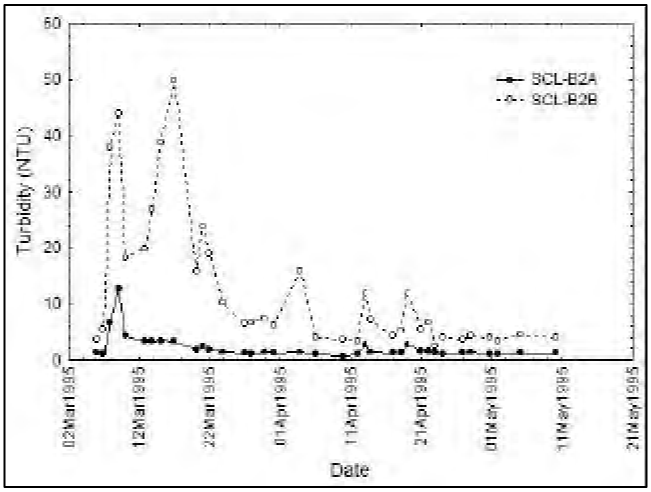

Figure 3 Turbidity readings above and below a large bank failure on the Stony Clove Creek in Chichester, March to May 1995.

Table 1. Stony Clove Creek summary of fixed frequency monitoring water sample analyses by NYCDEP from 1987 through 2002 (storm events and special studies not included).

Analyte	**Total samples**	**NYS Class B (t) Standard**	**Number of exceedences**	**% of exceedences**	**minimum***	**average***	**maximum***	**standard deviation**	**Comments**
INDICATOR VARIABLES									
Dissolved Oxygen (mg/L)	304	6 min daily average	0	0	6.7	11.87	20.0	2.016	A minimum of 6 mg/L is best for cold water fish species.
pH	485	6.5 - 8.5	5	1.0	6.5	7.38	9.5	0.365	Standard is optimum range for aquatic life.
Turbidity (NTU)	502	---	---	---	0.70	12.31	250	22.004	Optical property indicating light absorption &scattering of water.
Suspended Solids (mg/L)	174	---	---	---	-0.40	10.35	164	19.573	Concentrations highest during storm events.
Volatile Suspended Solids (mg/L)	15	---	---	---	-0.50	0.03	1.30	0.611	The organic portion of suspended solids arising from plant and animal materials (living and dead).
Fecal coliform bacteria (cfu/100ml)	483	200 minimum 5 samples/mo	7	not enough samples monthly to apply standard	<1	29	1200	81.05	Indicator of fecal contamination from warm-blooded animals.
NUTRIENTS									
Ammonia-N (mg/L)	288	(pH & temp. dependent)	0	0	-0.40	0.0141	0.10	0.021	Sources: natural and wastewater
Nitrate-N (mg/L)	71	10(A)	0	0	-0.10	0.273	0.61	0.143	Class A standard stated.
Total Phosphorus (Fg/L)	328	---	---	---	-6.0	17.41	105	16.326	Sources: natural and wastewater
Soluble Reactive Phosphorus (Fg/L)	213	---	---	---	-5.0	2.56	20.0	6.081	Form most utilized by plants and algae.

Analyte	Total samples	NYS Class B(t) Standard	Number of exceedences	% of exceedences	minimum	average	maximum	standard deviation	Comments
METALS (total)									
Aluminum (Fg/L)	158	100(ionic)	---	---	-5.0	355.4	11,260	1127.9	Standard applies to ionic form, not the total shown so comparison is not valid.
Copper (Fg/L)	165	200 (A)	0	0	-5.0	1.88	220	6.086	Hardness calculation required; class A type H(W) stated
Iron (mg/L)	165	0.300	43	26	-.03	0.35	9.8	0.849	Standard converted to mg/L
Lead	56	50(A)	0	0	-10.0	-3.25	6.0	2.785	Hardness calculation required; class A type H(W) stated
Magnesium (mg/L)	165	NS	---	---	0.45	0.99	2.59	0.214	
Manganese (mg/L)	164	NS	---	---	-0.01	0.014	0.40	0.049	Standard converted to mg/L
Arsenic (Fg/L)	55	150(dis)	0	0	-5.0	-3.35	3.00	1.838	more stringent chronic level stated & applies to dissolved form
Barium (Fg/L)	56	NS	---	---	-100	12.06	100	24.22	
Cadmium (Fg/L)	56	5 (A)	0	0	-5.0	-1.31	0.50	1.752	Hardness calculation required; class A type H(W) stated
Chromium (Fg/L)	56	50	0	0	-10.0	-2.34	6.0	2.065	Hardness calculation required; class A type H(W) stated
Mercury (Fg/L)	35	0.77(dis)	0	0	-0.20	-0.197	-0.10	--	Not detected in any samples
Selenium (Fg/L)	53	4.6(dis)	4	7.5	-5.0	-3.23	7.0	2.805	Naturally occurring in soils; standard applies to dissolved form
Silica (mg/L)	214	NS	---	---	-1.0	2.81	4.0	0.474	Essential nutrient for diatoms
Silver (Fg/L)	56	50(ionic)	0	0	-10.0	-2.57	-1.0	--	Not detected in any samples

Comments on Stony Clove Creek summary of fixed frequency monitoring water sample analyses by NYCDEP from 1987 through 2002 (Table 1):

In most cases, the standards presented here are used as a benchmark value for comparison, since the available sample results may not be expressed in the same form given in the NYSDEC standards. Some important notes of explanation for the interpretation of these results follow.

1. Negative values in minimum, average, and maximum columns indicate test results below the analytical laboratory detection limit. Detection limits vary by analyte and may change over time for any given analyte. The actual detection limits were used in these calculations, with the exception of fecal coliform counts, where samples below the detection limit were set equal to zero.

2. Metals analyzed by NYCDEP from 1987 through 2001 are included here. The method used for that period is for the total recoverable form of the element (rather than a full acid digestion). It is assumed that if these concentrations do not exceed a standard based on the dissolved fraction, that they met the standard. For several metals (copper, lead, cadmium, and chromium) the sample concentrations must be corrected for hardness to make a valid comparison with standards. This hardness calculation was not made here. Sometimes the Class A standard is stated instead (A). Dis=dissolved form; Ionic=ionic form only.

3. NYSDEC standards for coliform bacteria are based on an examination of a minimum of 5 samples per month. An insufficient number of samples was collected on a monthly basis to meet this criterion.

4. There is no Class B standard for nitrate, but the Class A standard was used here to show that no samples exceeded a more stringent standard.

5. Dissolved oxygen maximum indicates oxygen supersaturation for one sample in 2002. Field equipment met quality assurance standards on that date.

DEP Stream Biomonitoring Results from Stony Clove

DWQC's Water Quality Impact Assessment group collected stream benthic macroinvertebrate (aquatic insects living in and around the streambed) biomonitoring samples from Stony Clove in 1997, 1998, 1999 and 2000 at routine Hydrology sampling site SCL (Biomonitoring site #217). At the request of Stream Management Program staff, an additional site was located on Stony Clove at the downstream end of a reach with a stretch of failing bank (Biomonitoring site #225). All samples were collected in accordance with the biomonitoring program's Quality Assurance Project Plan (QAPP), whose procedures nearly duplicate the sampling and collection methods of the DEC's Stream Biomonitoring Unit. A 5-minute kick net sample of the macrobenthos is collected in riffle habitat, and a randomly-generated subsample of approximately 100 organisms is sent to a contractor for identification, to the genus and species levels, and enumeration. Four metric scores derived from the taxa lists from each sample are calculated, normalized, and averaged to derive a final water quality score for the site, ranging from 0-10. Scores at or above

7.5 are categorized as "non-impaired" and are considered to correspond with excellent water quality. All samples discussed below passed internal Drinking Water Quality Control (DWQC) Quality Assurance protocols.

Normalized biomonitoring metric scores and final Water Quality scores currently in DEP's record for Stony Clove indicate excellent water quality with 6 out of 7 scores well above 7.5 (Table 2). The single low score—at site 225 in 2000—is attributable to low species richness and percent model affinity scores, which in turn appears to be primarily a function of the dominance of two mayfly taxa in the sample that year (63% of the total). Mayflies are sensitive organisms generally indicative of good water quality, and one of the two taxa, comprising one-third of the total number of organisms in the sample, is considered extremely sensitive. Thus, the low 2000 score at site 225 is probably more of a reflection of a recent hatch of these taxa, or some similar, localized phenomenon, than of suboptimal water quality.

A Wilcoxon Rank Sum test of the scores from the two sites found no significant difference in the central tendencies of the Water Quality scores or the individual metric scores at a=0. An analysis of the percent similarity of the taxonomic assemblages between the two sites in 1999 found approximately 90% similarity between the two sites at the ordinal level. This suggests that the habitat and associated biota of the two sites are comparable. DEP sampling at site 225 was discontinued after the USGS began its monitoring of Stream Management Program sites.

Table 2 Normalized metric and water quality scores from biomonitoring samples collected on Stony Clove. n=number of replicate samples; results shown are average if n=2.

Site	Year	n	Species richness	EPT richness	Biotic Index	Percent Model Affinity	Water Quality Score
217	1997	2	9.2	10	8.3	9.2	9.2
217	1998	1	8.6	10	8.6	8.0	8.8
217	1999	1	8.3	10	8.3	8.3	8.7
225	1999	2	8.1	10	8.8	8.2	8.8
225	2000	1	4.3	9	8.6	6.7	7.1

Stream restoration and water quality improvement

One aim of stream restoration at the reach scale is to reduce turbidity and suspended sediment loads from unstable areas where erosion from the stream channel can be reduced. Sediment load is a product of flow and sediment concentration. Sediment concentration is a function of how much sediment the stream can pick up by bank or bed erosion, or by inputs from runoff sources. Changes in channel form made during restoration projects will affect flow velocities and erosive power, two factors influencing how much bed and bank erosion occurs. Consequently, the amount of material contributed by the channel, banks, and floodplain is expected to change as a result of these changes. A generalized net result is lower peak amounts of sediment, slower rise and less time to recovery (Figure 4). The net result for aquatic life and water use include reduced sedimentation of feeding or breeding areas for fish and insects, and potentially lower concentrations of pathogens adhering to sediment particles.

Possible benefits from restoration of stream reaches include reducing the contributions of sediment for that particular reach. This could produce a positive effect for aquatic life and recreation at a local scale, and potentially improve water quality downstream.

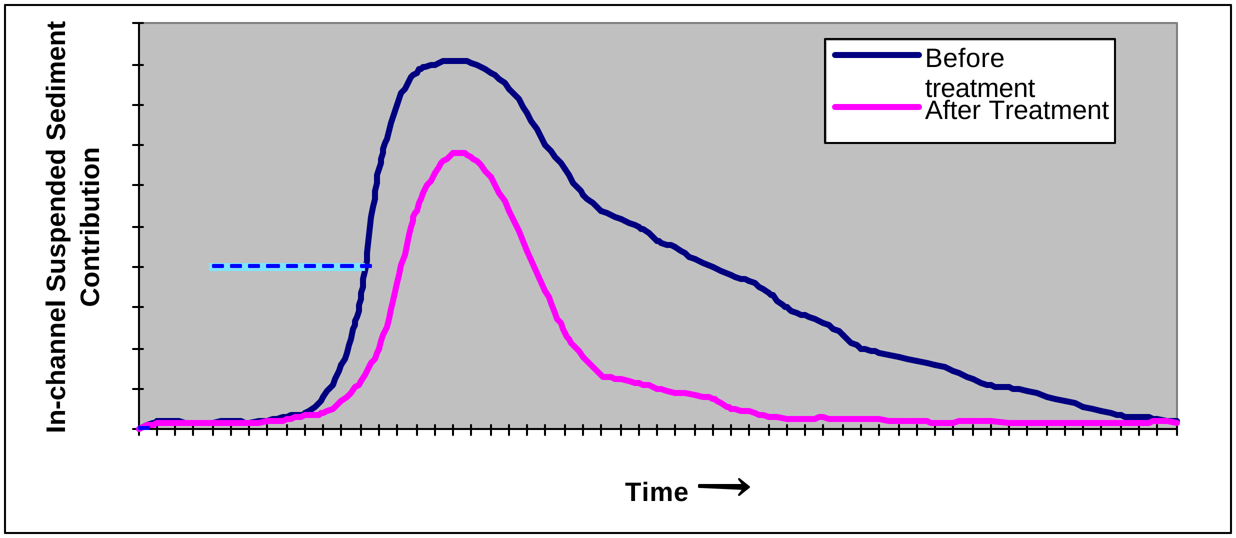

Figure 4 Generalized response of sediment contribution from a project reach, as a result of restoration to stable channel morphology