3.1 Rondout Creek Water Quality

Introduction

The purpose of this section is to provide a general understanding of water quality in the Rondout Creek. To further this understanding, the authors have included a synopsis of the research that has been conducted in the creek, a general discussion of the various parameters that are routinely monitored and conclusions that can be extrapolated from the various research projects. The following text is meant as an educational primer of Rondout Creek water quality designed to broaden the general understanding of watershed residents. It is not meant to be used in a legal or regulatory context.

Determining whether a stream has good or bad water quality depends largely upon the end user. For example, defining what constitutes good water quality for the supply of drinking water may be different from defining good water quality for maintaining a cold water fishery. The water quality parameters researchers would analyze would differ based upon the different end-users (people versus trout). Overall, the Rondout Creek plays an important role in the delivery of high quality water to the approximately 9 million end-users in New York City and the surrounding region. The high quality of this drinking water is demonstrated by its lack of need of filtration before consumption. Research also indicates that the Rondout Creek supports a healthy aquatic community (Novak et al., 1989; Bode et al., 1995; Arscott et al., 2004).

This good water quality supporting multiple uses can most likely be attributed to the watershed's high percentage of forest cover (see Section 2.7). There have been many studies that demonstrate the effects of land use/land cover on water quality. For example, there has been a vast array of research demonstrating that as land use becomes more urbanized, biotic communities decline in health (Schueler and Holland, 2000; Limburg and Schmidt, 2000; May et al., 2000; Wang et al., 2001; Potter et al. 2005 and Kratzer et al. 2006).

Concentrations of selected chemical constituents, including nitrate, in stream base-flow were strongly affected by the predominant land use in a large Hudson Valley study (Heisig, 2000). The decline of watershed forest cover under 65% percent marked a transition to degraded water quality (Booth, 2000). Based upon these results, it is safe to theorize land use/land cover is a major factor of water quality. Maintaining the land use/land cover conditions that allow for good quality water should be a priority.

Water quality threats in the Rondout basin are more abstract than the classic piped outfall containing pollutants. For example, silt and clay – buried in ice age deposits – are easily eroded into the stream and often, after a major storm, the streams run with a characteristic reddish brown color, which elevates in-stream turbidity. Although temporary, this increase in turbidity can act to degrade fish habitat (Newcombe and Jensen, 1996; Henley et al., 2000; Newcombe, 2003), act as a transport mechanism for other pollutants and *pathogens* (LeChevallier et al., 1981) and cause changes in the operations of the NYC water supply (NYCDEP, 2004). Although a certain percentage of this erosion is natural, disturbances to the steep slopes in the basin and/or other human interventions add to the problem and constitute the percentage of the problem that may be identified and addressed more easily.

The multitude of interventions designed to protect infrastructure (bridges, roads and buildings) along the Rondout Creek can exacerbate the rates of erosion, thus releasing turbidity causing materials into the stream (Fischenich, 2003). In addition, this infrastructure protection is often constructed of rock, or the infrastructure itself of blacktop, and the presence of these surfaces typically means the native vegetation had been removed, possibly adding stress to the stream biota (Sweeney, 1993; Jones III et al., 1999). This Plan offers recommendations for minimizing these efforts in a collaborative effort. The following text will describe many of the water quality parameters of interest and offer a chemical snapshot for the Rondout Creek and its major tributaries.

NYSDEC Stream Classification and Impaired Water Body List

All waters in New York State are given a class and standard designation based on best usage for that water body (NYSDEC, 2004). The New York State DEC stream classification system includes the following designations:

Stream Classifications
Class Best Use
AA Drinking (after disinfection), Bathing and Fishing
A Drinking (after disinfection and approved treatment), Bathing and Fishing
B Bathing and Fishing
C Fishing – Propagation and Survival
D Fishing - Survival
New York Codes, Rules, and Regulations ("NYCRR"), Title 6, Section 701.

Additional designations of "T" or "TS" can be added if a water body has sufficient amounts of dissolved oxygen to support trout (T) and/or trout spawning (TS). Water bodies that are designated as "C (T)" or higher (e.g., "C (TS)", "B", or "A") are collectively referred to as "protected streams," and are subject to additional regulations and require a State permit for disturbance of the bed or banks. Periodically, the DEC publishes the Priority Water bodies List (PWL), which includes a list of water bodies that do not meet their designated "best use" classification. A data sheet that describes the conditions, causes, and sources of water quality degradation for each of the respective listings is also included in the PWL. The PWL is used by the DEC and other agencies as a primary resource for water resources management and funding. In 1998, the Schoharie Reservoir was listed on the PWL for silt and sediment from construction activities and for atmospheric deposition of mercury. Mercury bioaccumulates in the fatty tissue of fish, particularly predatory species, and is passed on to the consumer. In the Schoharie, smallmouth bass over 15" and walleye over 18" should not be eaten; and smallmouth bass under 15" and walleye under 18" should be eaten only once per month (NYSDOH, 2006). Table 1 presents the classifications for the reaches of the Upper Rondout Creek mainstem.

Table 1 NYSDEC designated use classifications for the upper Rondout Creek

461	H-139-14-P 815a portion	Rondout Reservoir	Reservoir area within 1.0 mile from intake.	N-22sw	AA	AA(TS)
462	H-139-14 portion	Rondout Creek	From inlet of Rondout Reservoir (P 815a) to trib. 50.	N-21, N-22sw	A	A(TS)
463	H-139-14 portion	Rondout Creek	From trib. 50 to 0.5 mile above trib. 55.	N-22sw, N-22nw	C	C(TS)
463.1	H-139-14 portion	Rondout Creek	From 0.5 mile above trib. 55 to 0.5 mile below trib. 57.	N-22nw	C	C(T)
463.2	H-139-14 portion	Rondout Creek	From 0.5 mile below trib. 57 to trib. 57a.	N-22nw	C	C(TS)
464	H-139-14 portion	Rondout Creek	From trib. 57a to trib. 58e. (Waters located within forest preserve.)	N-22nw		
465	H-139-14 portion	Rondout Creek	From trib. 58e to source.	N-22nw, N-22ne	B	B(T)

Water Quality Record

In the United States (USEPA, 2005) and New York State (NYSDEC, 2004) nonpoint sources of pollution are the cause of the majority of water quality impairments. In New York State, nonpoint sources of pollution accounted for 90% of impacts on the water quality of rivers and streams and 92% for lakes and reservoirs, including the Rondout (NYSDEC, 2004). There are many ways to measure water quality, from direct laboratory analysis of water samples for various analytes to indirect measures such as aquatic insect surveys as indicators of water quality. Water samples collected from the stream and analyzed for a suite of chemical, biological and physical parameters provide us with a good picture of the constituents that are carried by the Rondout's waters. Between the NYCDEP, USGS, NYSDEC and other researchers the large quantity of these water quality data necessary to draw conclusions is available. Biological indicators, such as fish and macroinvertebrates, are also monitored to determine surface water quality and nonpoint source pollution impacts (Barbour et al., 1999; Murray et al., 2002). For example, biological assessment models have been tested with field data and the results suggested that macroinvertebrate data collected for establishing the degree of water quality impairment can also be used to identify the impairment source with reasonable accuracy (Murray et al., 2002). There is a relatively extensive set of data for both direct and indirect measures on Rondout Creek.

There are several sources for direct water quality measurements for Rondout Creek. The following sources provide the bulk of available information:

- The most extensive and comprehensive set of available data is from NYCDEP as part of its long-term water quality monitoring of the NYC drinking water supply (NYCDEP, 2009).
- The United States Geological Survey (USGS) operates two gaging stations for streamflow in the Rondout Creek Watershed: Rondout Cr above Red Brook at Peekamoose (id # 01364959) (Period of record: 05/01/1996-present (scheduled to be discontinued 03/31/2010)) and Rondout Creek near Lowes Corners (id #01365000) (Period of record: 02/04/1937-present).
- The USGS, under contract to NYC DEP, collected water quality at one location in the Rondout Creek Watershed: Rondout Creek above Red Brook at Peekamoose (1991-2009): http://ny.cf.er.usgs.gov/nyc/unoono.cfm.
- The USGS also collected water quality data near the Rondout Creek near Lowes Corners gage (id #01365000) from 1966 to 1992. The water quality data are available on the USGS website: http://nwis.waterdata.usgs.gov/ny/nwis/qwdata/?site_no=01365000;
- In 2000, Stroud Water Research Center located in Pennsylvania was awarded a Safe Drinking Water Act (SDWA) grant funded by the New York State Department of Environmental Conservation and the USEPA to conduct a six-year study to monitor and evaluate water quality and sources of pollution in the streams, rivers, and reservoirs that provide New York City's (NYC) drinking water. There were two sites in the Rondout Creek watershed included in the study that were variably sampled from 2000-2005. Copies of the final report can be found at: (http://www.stroudcenter.org/research/newyorkproject.htm).
- NYSDEC, Routine Statewide Monitoring Program provides for the routine monitoring of the waters of the State to allow for the determination of the overall quality of waters, trends in water quality, and identification of water quality problems and issues. This monitoring effort is coordinated through the Rotating Integrated Basin Studies (RIBS) Program which typically operates on a 5-year cycle. Contacts for the program staff, which can provide relevant reports, are available at their website: http://www.dec.ny.gov/chemical/30951.html.

NYCDEP has a long-term water quality sampling program of streams in the NYC water supply watersheds. Water quality samples are collected at a fixed frequency from a network of sampling sites throughout the watershed. Grab samples are generally collected once a month (twice a month at selected sites). Storm event sampling is also performed at selected sites. While the analyses performed on samples from a specific site vary somewhat based on the objectives for the site, in general, samples are tested for temperature, pH, alkalinity, specific conductivity, dissolved oxygen, turbidity, nutrients, dissolved organic carbon, total organic carbon, chloride, suspended solids (selected sites), major cations (Ca, Mg, Na, K) (analyzed monthly), and total and fecal coliform (most sites). The current monitoring system was re-designed in 2008 and was based on multiple objectives (NYCDEP, 2009), with several sampling sites located in the Rondout Basin. Results are presented in annual water quality monitoring reports (e.g. NYCDEP, 2009). Appendix C lists the current federal drinking water quality standards as determined by the United States Environmental Protection Agency.

Constituents of Rondout Creek Water

The following section provides a summary of the major parameters that are tracked by NYCDEP in the Rondout Creek. Combined, these parameters provide a basic overview of water quality, while potentially allowing for a general understanding of human-induced changes to water quality. The NYCDEP data reported here are annual medians for selected water quality variables. The median is a statistic that expresses the “typical” condition of something. The median is simply the value in the center of a data set, i.e. half of the samples are higher, and half lower. One characteristic of the median is that it is not overly influenced by data from extreme events. It should be noted that values that were reported as “less than” a detection limit, i.e. censored data, were set to one half of the detection limit for the statistical analysis. Also, the results are based on routine grab samples, and do not specifically target extreme events.

Turbidity and Total Suspended Solids

Turbidity, an index of water clarity, is a concern in this watershed for the Safe Drinking Water Act oversight of NYC water supply. The Safe Drinking Water Act and associated regulations are concerned with turbidity levels entering the distribution systems for public water systems; accordingly, from a Safe Drinking Water Act perspective, DEP’s primary concern is the level of turbidity in water leaving the Kensico reservoir (Westchester County). For purposes of drinking water, turbidity is of concern because it has the potential to mask pathogens and interfere with disinfection.

Turbidity is an optical measurement of the light-scattering at 90^{o} caused by particles suspended in water (Figure 1). Turbidity is measured in arbitrary “nephelometric turbidity units” (NTUs) by a “nephelometer”. The higher the NTU value, the lower the water clarity. Turbidity can be influenced not only by the amount of particles in suspension, but also by the shape and size of the particles. There is no single, fixed relationship between turbidity and total suspended solids. Total suspended solids are a measure of suspended solids concentration, expressed as a mass per volume (mg/L) obtained by physically separating the liquid and solid phases by filtration. Further, it is important to note that there is no universal, usable, fixed turbidity/clarity relationship.

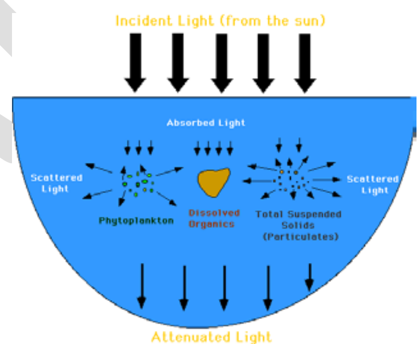

Figure 1 Illustration of light scattering caused by suspended particles in water.

Suspended solids in Catskill streams are predominantly fine sediment. It does not take much of the fine suspended sediment to reduce water clarity. Water clarity can range from clear to an opalescent red-brown following a significant high water event. Sediment gets in the stream primarily from two sources: (1) runoff from the landscape carries fine sediment (silt and clay) into the stream through ditches and culverts; and (2) from entrainment in the stream. Due to the large amount of forested landscape in the Rondout system it is safe to speculate that the main sources of sediment are erosion within the stream channel and banks, and not the landscape. Exposed “clays” that the stream has cut into and the mobilization of fine sediment mixed in the stream bed deposits are the major sources of turbidity at times when turbidity reaches levels of concern for drinking water purposes (NYCDEP, 2006).

However, landscape sources should not be ignored because they may assist in the development of a watershed stewardship ethic, and left untreated may cause further instability within the bed and banks. The regulatory water quality standard for turbidity in New York State is a narrative standard: “no increase that will cause a substantial visible contrast to natural conditions” (NYCRR, Title 6, Section 703.2). There is also a narrative water quality standard for suspended, colloidal, and settleable solids: “None from sewage, industrial wastes or other wastes that will cause deposition or impair the waters for their best usages.” Although there are no numerical standards for turbidity or suspended sediment, these constituents are of concern in streams because the presence of fine-grain sediments such as clay particles suspended in the water column can affect stream biota. These fine sediments can settle on substrates used by colonizing algae and invertebrates and can fill the small spaces between gravel where fish lay their eggs. Transmission of light through the water can be reduced, which can affect stream productivity through decreased photosynthesis. Turbid waters also become warmer as suspended particles absorb heat from sunlight, which can also cause oxygen levels to fall.

Table 2 Annual descriptive statistics for turbidity (NTU) at Rondout Creek near Lowes Corners, 1987-2008. Based on routine grab samples

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987	25	0.2	0.3	0.5	0.5	1.9
1988	26	0.3	0.575	0.7	0.85	4.1
1989	26	0.2	0.5	0.8	1.35	8.8
1990	26	0.3	0.5	0.85	1.775	4.1
1991	27	0.2	0.4	0.7	0.8	3
1992	26	0.1	0.3	0.6	0.83	40
1993	26	0.1	0.2	0.3	0.4	0.7
1994	26	0.1	0.2	0.3	0.5	0.9
1995	25	0.2	0.3	0.3	0.5	1.4
1996	26	0.2	0.4	0.65	1.025	2.3
1997	26	0.2	0.3	0.45	0.525	1.4
1998	25	0.2	0.3	0.4	0.85	180
1999	26	0.2	0.3	0.4	0.6	1.2
2000	25	0.3	0.45	0.8	1.45	4.7
2001	26	0.2	0.375	0.7	1.7	18
2002	24	0.2	0.4	0.4	0.6	2.1
2003	24	0.3	0.7	0.85	1.825	15
2004	24	0.3	0.525	0.75	1.55	12
2005	24	0.2	0.43	0.7	1.8	50
2006	24	0.3	0.4	0.5	0.8	12
2007	24	0.2	0.325	0.6	0.8	4.3
2008	23	0.2	0.3	0.4	0.7	13
Overall	**554**	**0.1**	**0.3**	**0.5**	**0.8**	**180**

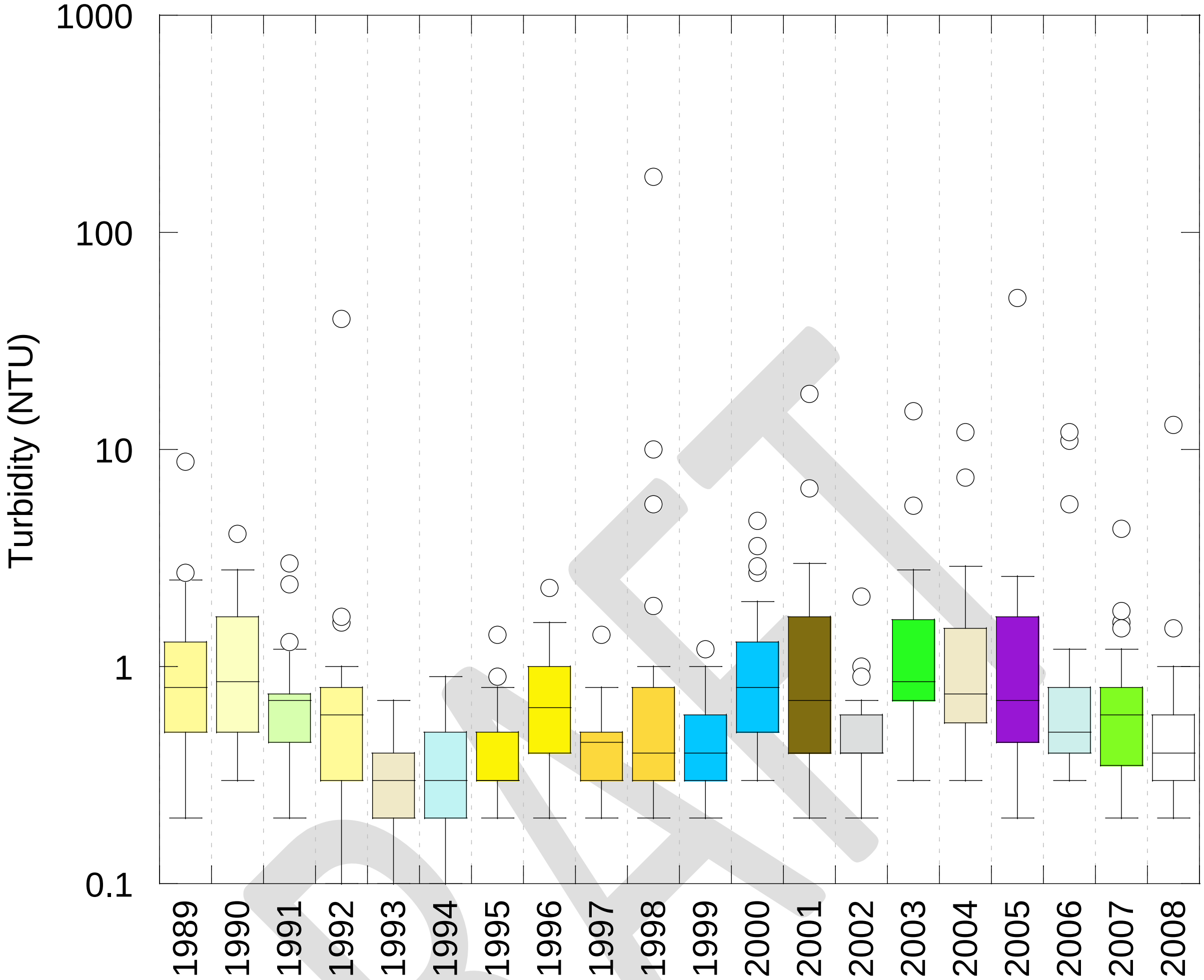

Figure 2 Boxplot of turbidity (NTU) data at Rondout Creek by year, 1989-2008

The median turbidity value for Rondout Creek near Lowes Corners based on data from 1987-2008 is 0.50 NTU. The data from the routine grab samples from 1989-2008 are displayed using a boxplot in the figure and the table provides the annual descriptive statistics. While Rondout Creek usually has fairly low turbidity values, storms can cause these numbers to increase by four orders of magnitude. For example, samples collected during storm events have had turbidities as high as 1600 NTU. Likewise the median value for total suspended solids is 0.55 mg/l, but during storm events has reached almost 3,000 mg/l.

Table 3 Annual descriptive statistics for total suspended solids (mg/l) at Rondout Creek near Lowes Corners, 1989, 2001-2008

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1989	9	0.2	0.2	0.8	4.8	8
2001	1	<0.4	*	0.2	*	0.2
2002	23	<0.4	0.2	0.6	1	3.2
2003	24	4	0.5	0.95	1.575	21.8
2004	24	0.3	0.5	0.8	1.775	20.3
2005	24	<0.3	0.4	0.6	1.05	51.8
2006	24	<0.3	0.2	0.4	0.6	13.8
2007	24	<0.3	0.2	0.3	0.675	3.5
2008	23	<0.3	0.2	0.3	0.6	22.5
Overall	**176**	**<0.3**	**0.3**	**0.55**	**1**	**51.8**

In the case of Catskill stream turbidity, both hydrology (storm events) and geology are important determining factors. Table 4 on the next page illustrates the wide range of annual median turbidity values across different basins in the Catskills. While the Neversink reports a similar average annual median between 1987 – 2008 of 0.4NTU, other mainstem streams result in turbidity levels as 2.5 and 2.8NTU. The hydrology and geology are natural factors that cannot be effectively managed. Therefore, management efforts should be focused on preventing further human-induced water quality degradation through implementation of best management practices designed to reduce/minimize sediment impacts. These efforts should be both direct (e.g. planting a riparian buffer) and indirect (e.g. reducing stormwater inputs and/or properly installing new infrastructure so it doesn't destabilize the stream).

Table 4 Annual median turbidity (NTU) values for selected inflow sites to West of Hudson Reservoirs, 1987-2008

	Rondout Creek at Lowes Corners (Rondout Inflow)		Neversink River at Claryville (Neversink Inflow)		West Branch Delaware River at Beerston (Cannonsville Inflow)		East Branch Delaware River at Margaretville (Pepacton Inflow)		Schoharie Creek at Prattsville (Schoharie Inflow)		Esopus Creek at Allaben (upstream of Shandaken Portal)		Esopus Creek at Boiceville (Ashokan Inflow)	
Year	N	Median	N	Median	N	Median	N	Median	N	Median	N	Median	N	Median
1987	25	0.5	26	0.5	26	1.1	10	0.8	50	3.6	50	5.1	50	7
1988	26	0.7	26	0.65	25	3	25	1.4	49	3.2	49	2.5	49	4.1
1989	26	0.8	27	1	26	2.65	26	2.35	52	2.3	50	2.3	134	3.75
1990	26	0.85	26	0.6	25	3.2	26	2.6	51	2.6	57	2	112	2.5
1991	27	0.7	27	0.5	25	3.6	27	2.1	51	2.1	50	1.4	206	2.2
1992	26	0.6	26	0.5	26	2	25	1.5	43	1.9	45	1	247	2.5
1993	26	0.3	26	0.2	26	1.65	26	1.6	25	1.6	25	1.6	249	2.9
1994	26	0.3	26	0.3	25	1.8	25	1.3	22	2.95	25	2.1	265	3.8
1995	25	0.3	25	0.3	24	2.6	25	2	22	1.95	24	1.4	273	2.9
1996	26	0.65	26	0.55	26	3.05	26	2.8	19	19	24	5.85	300	22
1997	26	0.45	26	0.4	25	3.8	26	1.9	20	3.7	24	1.5	266	4.8
1998	25	0.4	25	0.4	26	1.95	25	1.4	22	2.8	21	1.6	251	5.3
1999	26	0.4	26	0.4	25	2.9	26	1.4	23	5.1	23	2.3	251	9.6
2000	25	0.8	25	0.4	25	2.4	25	1.5	23	8.5	22	1.6	252	8.8
2001	26	0.7	26	0.4	25	1.9	26	1.3	18	2.6	24	2.8	251	9
2002	24	0.4	24	0.4	24	2.6	23	1.7	24	2.5	23	1.5	127	4.9
2003	24	0.85	24	0.5	24	2.45	17	1.7	20	3.45	24	1.65	71	4.6
2004	24	0.75	24	0.4	24	2.55	24	1.65	24	3.4	24	2.45	62	4.3
2005	24	0.7	24	0.45	24	2.3	24	1.6	21	5.1	23	5.9	65	23
2006	24	0.5	24	0.4	24	2.9	24	1.5	24	4.15	25	6.8	53	14
2007	24	0.6	24	0.5	24	2.8	24	1.8	24	2.6	24	3	54	4.35
2008	23	0.4	23	0.4	21	2.7	22	1.65	23	2.1	23	2	48	4.5
Overall	**554**	**0.5**	**556**	**0.4**	**545**	**2.5**	**527**	**1.7**	**650**	**2.8**	**679**	**2**	**3636**	**5**

Pathogens

NYCDEP monitors for pathogens, specifically giardia and cryptosporidium, in a large number of Catskill mountain streams. Specifically, NYCDEP's Pathogen Program monitors fourteen sampling location sites within the Schoharie Creek Watershed (Figure 3.1.7), twelve stream locations and two waste water treatment plants (WWTP) for, among other water quality parameters, protozoa; *Cryptosporidium spp.* oocysts and *Giardia spp*. cysts. While there are no regulatory thresholds for these protozoa in surface waters, NYCDEP maintains a monitoring program for them due to their potential negative effects on public health. These protozoa are of concern to public health for two reasons: 1) if consumed, certain strains of these protozoa can cause disease in humans, and 2) the presence of these protozoa indicates that the water has been contaminated with fecal matter (animal or human) and; therefore, may be carrying other pathogens that have the potential to cause disease in humans.

DEP's monitoring data has shown the presence of these (oo)cysts in ambient water, and during high flow conditions related to runoff events; however concentrations have been at low levels. In any event, since certain strains have the potential to cause disease in humans, determining their source, transport properties, and fate are of utmost importance to DEP. DEP maintains a surveillance program designed to narrow down source locations and trends of (oo)cysts throughout New York City's water supply watersheds. Additional tools used by DEP to ultimately assess the public health risk associated with these protozoa in the watershed include: 1) PCR (polymerase chain reaction) source tracking to identify anthropogenic (human) and autochthonous (natural) sources, 2) landuse/landcover which also indirectly identifies potential human sources such as failing septic systems and wildlife sources, 3) and watershed physiographic characteristics such as percent area of contribution to a site, slope and elevation which may affect transport and fate.

Protozoan pathogen sampling was conducted by DEP at site RDOA, on Rondout Creek from 2002-2008. The results based on 67 and 68 samples for *Cryptosporidium* and *Giardia*, respectively, indicate very low mean and median *Cryptosporidium* and *Giardia* (oo)cyst concentrations based on 50-L samples (Table X.X).

The samples were analyzed following USEPA Method 1623, the nationally accepted method for enumerating protozoan pathogens. Similar to data at other sites in the NYC watershed, *Giardia* concentrations were higher than *Cryptosporidium*. The maximum results obtained for *Cryptosporidium* and *Giardia* were 2 oocysts and 43 cysts, respectively, which is low compared to results of some other sites within the West-of-Hudson wathershed (DEP, 2008).

Table 5 Basic statistics for protozoan pathogen sampling at site RDOA on Rondout Creek

	Cryptosporidium•50L^{-1}	*Giardia*•50L^{-1}
# of samples	68	67
Mean	0.32	5.87
Median	0	4
Max	2	43

Temperature
Water temperature is one of the most important variables in aquatic ecology. Temperature affects movement of molecules, fluid dynamics, and metabolic rates of organisms as well as a host of other processes. In addition to having its own potential "toxic" effect (i.e. when temperature is too high), temperature affects the solubility and, in turn, the toxicity of many other parameters. Generally the solubility of solids increases with increasing temperature, while gases tend to be more soluble in cold water (i.e. available O_2 to fish).

In densely wooded areas where the majority of the streambed is shaded, heat transferred from the air and groundwater inputs drive in-stream temperature dynamics. However, in areas that aren't shaded the water temperatures can rise much more quickly due to the direct exposure to the sun's radiation. Rock and blacktop also hold heat and can transfer the heat to the water (like hot coals in a grill). Annual fluctuation of temperature in a stream may drive many biological processes, for example, the emergence of aquatic insects and spawning of fish. Even at a given air temperature, stream temperature may be variable over short distances depending on plant cover, stream flow dynamics, stream depth and groundwater inflow. Water temperatures exceeding 77° Fahrenheit cannot be tolerated by brook trout, and they prefer water temperatures less than 68° Fahrenheit (TU, 2006).

The annual median water temperature of Rondout Creek from 1987 to 2008 was 8.0°C (46.4°F). The annual median temperature ranged from 6.5°C (43.7°F) (1988) to 11.0°C (51.8°F) (1990).

Phosphorus
Phosphorus is a nutrient essential to plant growth. In aquatic ecosystems phosphorus occurs primarily in the form of organic phosphorus. Organic phosphorus is bound in plant and animal tissue and is unavailable for plant uptake. Phosphate (PO_4^{3-}) is a form that is available and needed by plants. Plants assimilate phosphate from the surrounding water and convert it to organic phosphorus. In freshwater ecosystems phosphate tends to be the nutrient that is least available for plant growth. Consequently, phosphate is often the limiting factor, and small additions to surface waters can result in large amounts of plant growth and eutrophication.

Phosphate binds to soil particles, which act to slow its transport. The soil-attached phosphate will often settle out in standing water (ponds/lakes/reservoirs), which once disturbed and resuspended, or due to anoxic conditions, can lead to excessive vegetation growth. The most likely sources of phosphate inputs include animal wastes, human wastes, fertilizer, detergents, disturbed land, road salts (anticaking agent), and storm water runoff. Based upon the average concentrations found in water samples from 85 sites across the United States in relatively undeveloped watersheds, the median concentrations of total phosphorus (P) and orthophosphate were 0.022 and 0.010 mg/L respectively (Clark et al., 2000). In general, any concentration over 0.05 mg/L of phosphate will likely have an impact on surface waters (Behar, 1996). However, in many streams and lakes concentrations of phosphate as low as 0.01 mg/L can have a significant impact on water resources by causing a proliferation of aquatic vegetation and phytoplankton. In order to control eutrophication, the USEPA recommended limiting phosphate concentrations to 0.05 mg/L in waters that drain to lakes, ponds and reservoirs, and 0.1 mg/L in free flowing rivers and streams (USEPA, 1996). DEP considers the 0.05 mg/L as a guidance value for streams. However, the critical guidance value for the Rondout Reservoir is 0.015 mg/L (NYCDEP, 2009).

The median total phosphorus concentration (1987-2008) for Rondout Creek was 0.006 mg/l. However, during storm events total phosphorus concentration greater than 1 mg/l have been observed.

Table 6 Basic statistics for phosphorous (as PO_4) sampling at site RDOA on Rondout Creek (in µg/L)

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987	19	<10	5	12	16	27
1988	26	<10	7.5	9	15.75	48
1989	25	6	8	13	17.5	77
1990	26	2	4	6	9	15
1991	27	<2	3	4	7	24
1992	26	<2	4	4.5	6	98
1993	26	3	5.75	7	9	14
1994	26	2	4	5	7	101
1995	25	3	3	5	6	9
1996	26	<2	4	5	6	31
1997	26	2	3	5	5	7
1998	25	<2	3	4	7	123
1999	26	<3	4	5	6	24
2000	24	<3	5	7	9.75	13
2001	26	<2	5	7	8	152
2002	22	2	3	5	7	8
2003	24	<3	4	6	7	77
2004	24	<3	4	5.5	7	25
2005	23	<3	4	6	8	140
2006	23	<3	3	5	6	21
2007	24	<3	4	5	7	13
2008	22	<3	3	6	7.25	25
Overall	**541**	**<2**	**4**	**6**	**8**	**151**

Nitrogen

Nitrogen is found in various forms in ecosystems including organic forms, nitrate (NO_3^-), nitrite (NO_2^-) and ammonium (NH_4^+). The majority of nitrogen is in the form of a gas (N_2), which makes up approximately 80% of our air. It is converted into inorganic forms by some types of terrestrial plants (legumes) with nitrogen-fixing bacteria, lightning and microbes in the water and soil. Nitrate, the most mobile form of nitrogen, can either be assimilated by vegetation to make protein, leached into groundwater or surface water, or converted to nitrogen gas in the process of denitrification (Welsch et al. 1995). Nitrites, ammonia and ammonium are intermediate forms of nitrogen in aquatic systems and are quickly removed from the system by being converted to another form of nitrogen (NO_3^- or N_2) (Behar, 1996). Ammonium is released into the system during animal or plant decomposition or when animals excrete their wastes. Through the process of nitrification, ammonium is oxidized to nitrates by nitrifying bacteria. Nitrate concentrations in water can serve as an indicator of sewage or fertilizer in surface or ground water.

Based upon average concentrations found in water samples from 85 sites across the United States in relatively undeveloped watersheds, the median concentrations of nitrate/nitrogen and total nitrogen were 0.087 and 0.26 mg/L respectively (Clark et al., 2000). Due to land uses and atmospheric deposition, the undeveloped watershed concentrations (below 0.087 mg/L) of in-stream NO_3^- rarely occur in the Hudson Valley and Rondout basin. Major sources of nitrate (most mobile form of nitrogen) in streams are municipal and industrial wastewater discharges and agricultural and urban runoff. Deposition from the atmosphere of the nitrogenous material in automobile exhaust and industrial emissions are also a source (Smith et al., 1991).

Nitrate in excessive amounts can accelerate eutrophication of surface waters, and can present a human health concern in drinking water. Any water that contains nitrate concentrations of 44 mg/L (equivalent to 10 mg/L nitrate-nitrogen for EPA and NYSDOH standards) or higher has the potential to cause methemoglobinemia, or "blue baby" disease in children, and the excess nitrate can indicate serious residential or agricultural contaminants (McCasland et al., 1998). Although the human health standard for nitrate consumption has little correlation with stream health, high levels of nitrate in both surface and ground water typically indicate widespread nonpoint source pollution.

The Rondout Creek had a median nitrate-nitrite as nitrogen concentration of 0.251 mg/l (1988-2008) with annual medians ranging from 0.132 mg/l (1998) to 0.485 mg/l (1989).

Table 7 Basic statistics for nitrogen (as NO_3) sampling at site RDOA on Rondout Creek (in mg/L)

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1988	13	0.22	0.29	0.4	0.51	0.61
1989	26	0.13	0.4275	0.485	0.6025	1.02
1990	26	0.18	0.3575	0.45	0.705	1.01
1991	27	0.29	0.32	0.38	0.55	0.67
1992	26	0.06	0.18	0.265	0.3225	0.49
1993	26	0.12	0.2075	0.255	0.3325	0.73
1994	26	0.074	0.1455	0.184	0.2638	0.582
1995	24	0.162	0.2043	0.2465	0.2745	0.354
1996	26	0.106	0.179	0.2165	0.292	0.449
1997	26	0.137	0.1883	0.2525	0.307	0.451
1998	25	0.026	0.0985	0.132	0.1815	0.266
1999	26	0.084	0.1177	0.1605	0.1957	0.316
2000	25	0.05	0.1125	0.15	0.2305	0.259
2001	26	0.151	0.256	0.3	0.37	0.75
2002	24	0.139	0.1865	0.228	0.3777	0.446
2003	24	0.025	0.1328	0.18	0.2562	0.442
2004	24	0.156	0.2003	0.319	0.3968	0.796
2005	23	0.173	0.225	0.272	0.318	0.38
2006	24	0.115	0.171	0.231	0.263	0.468
2007	24	0.186	0.253	0.3015	0.37	0.76
2008	21	0.025	0.1205	0.15	0.1995	0.362
Overall	**512**	**0.025**	**0.1745**	**0.251**	**0.34925**	**1.02**

Fecal Coliform

Fecal coliform bacteria are used as an indicator of possible sewage contamination because they are commonly found in human and animal feces. Although coliform bacteria are generally not harmful themselves, they indicate the possible presence of pathogenic bacteria, viruses, and protozoa that also live in the digestive tract. Therefore, the greater the numbers of fecal coliform bacteria colonies present the greater the human health risk for other pathogens. In addition to the human health risk, excess fecal coliform bacteria can cause increased oxygen demand, cloudy water, and unpleasant odors. Common sources of fecal coliform bacteria in waterways include poorly functioning sewage treatment plants, onsite septic systems, domestic and wild animal manure, and storm water runoff.

Testing for all bacteria, viruses and protozoa is very costly and time consuming. Therefore it is common practice to test for fecal coliform bacteria as an indicator of pathogens. The New York State Department of Health standard for contact recreation (swimming) is as follows: the fecal coliform bacteria density should not exceed 200 colonies per 100 ml, based on a logarithmic mean from a series of five or more samples over a thirty day period.

Although not comparable to the Department of Health standard, annual median values from the Rondout Creek near Lowes Corners for the period of record ranged from 2 CFU/100ml in 2006 to 14 in 1994 and 1996. The median value for the period form 1987-2008 was 6 CFU/100 ml.

Table 8 Basic statistics for fecal coliform sampling at site RDOA on Rondout Creek (as colonies/0.1L)

Year	N	Minimum	25^{th} Percentile	Median	75^{th} Percentile	Maximum
1987	25	<2	3	8	22	70
1988	23	<1	2	6	18	196
1989	21	<1	1	6	16	380
1990	25	<2	2.5	10	16	48
1991	25	<2	3	8	18	148
1992	25	<1	2	12	26	60
1993	26	<2	2	5	16	228
1994	26	1	3.75	14	23.25	134
1995	25	1	4	8	16.5	94
1996	26	<1	2	14	19	45
1997	26	<1	2	5	18.5	46
1998	25	<1	3	8	45	800
1999	26	<2	1	4	12	54
2000	25	<1	2	6	16	40
2001	26	<2	3.5	10	18.3	570
2002	24	<1	2	4.5	9.5	30
2003	24	<1	1.25	7	24.75	76
2004	24	<1	1	5	19	66
2005	24	<1	1	3.5	17.25	69
2006	24	<1	1	2	8	72
2007	24	<1	2	4	9.75	120
2008	23	<1	1	4	21	70
Overall	**542**	**<1**	**2**	**6**	**16**	**800**

Specific Conductivity

Specific conductivity describes the ability of water to conduct an electric current, and is an index of the concentration of chemical ions in solution. An ion is an atom of an element that has gained or lost an electron which will create a negative or positive state. High conductivity is created by the presence of anions such as chloride, nitrate, sulfate, and phosphate or cations such as sodium, magnesium, calcium, iron, and aluminum. The natural conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Conductivity is often used to compare different streams because it is a cheap and easy measurement that can indicate when and where a site is being influenced by a source of contamination. Often when wastewater treatment plant effluent constitutes the majority of flow in a stream, it can be seen in water quality data due to its higher conductivity signature. Road salting practices can also impact conductivity.

Studies of inland fresh waters indicated that streams supporting good mixed fisheries had a conductivity range between 150 to 500 µmhos/cm (USEPA, 1997). The Rondout Creek near Lowes Corners had a relatively low annual median conductivity, ranging from 27-38.5 µmhos/cm with an overall median for 1987-2008 of 32 µmhos/cm. The major contributor of the annual medians most likely reflects the geologic contribution to the total.

Table 9 Basic statistics for conductivity testing at site RDOA on Rondout Creek in µmhos/cm

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987	25	20	24	27	36.5	44
1988	26	25	28	30	35.5	46
1989	26	23	30.75	34.5	38.25	49
1990	26	24	29.75	33.5	38.25	44
1991	27	23	29	33	40	44
1992	26	24	26.75	33.5	37	50
1993	26	25	33.75	38.5	44.25	53
1994	26	25	30.75	34	36	37
1995	25	29	32.5	35	38	43
1996	26	22	26.75	28.5	31	35
1997	25	24	27.5	31	35.5	40
1998	24	21	26.5	30	32.75	39
1999	25	26	29	31	35.5	42
2000	24	23	28	29	31	33
2001	24	26	30	34	39	44
2002	24	26	30.25	33.5	39.25	48
2003	24	22	28	33.5	37.75	41
2004	21	26	28.5	32	35	38
2005	23	23	30	35	39	52
2006	23	24	28	31	36	43
2007	24	25	31.25	36.5	42	44
2008	23	24	28	31	37	40
Overall	**543**	**20**	**29**	**32**	**37**	**53**

Dissolved Oxygen

Dissolved oxygen refers to oxygen gas (O_2) molecules in the water. The molecules are naturally consumed and produced in aquatic systems, and necessary for almost all aquatic organisms. If dissolved oxygen levels fall below a certain threshold, biologic integrity will be compromised. For example, on a scale of 0 to 14 mg/L, a concentration of 7 mg/L to 11 mg/L is ideal for most stream fish (Behar, 1996). Dissolved oxygen can be measured as the concentration of milligrams O_2 per liter (mg/L) or as percent saturation of O_2. Percent saturation is the amount of oxygen in a liter of water relative to the total amount of oxygen the water can hold at a given temperature. In cold water systems, a percent saturation of 60% to 79% is acceptable for most stream animals (Behar, 1996).

The New York State regulations for a stream designating as supporting trout spawning states that the DO should not be less than 7.0 mg/L from other than natural conditions. Data from 1991 to 2008 indicated that the annual median DO for the Rondout Creek ranged from about 10.7 to 12 mg/L and may dip down into the 9 mg/L range during hot summer months. Dissolved oxygen concentrations may dip below 9 mg/L, particularly in the mornings of the summer months, but that level of analysis was outside the scope of this plan.

Table 10 Basic statistics fordissolved oxygen testing at site RDOA on Rondout Creek in mg/L

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1991	27	9.1	10	11.7	13.8	16.6
1992	26	9.4	10.55	12	13.6	15.2
1993	27	9.1	10.4	11.9	13.5	15.7
1994	26	9.6	10.475	12	13.625	14.9
1995	25	9.5	10.4	12	13.05	14.8
1996	24	9.3	10.1	11.45	12.525	13.6
1997	25	9.2	9.5	10.7	12.85	13.9
1998	24	8.8	9.525	10.9	12.725	13.9
1999	23	9.4	10.4	12	13	14.6
2000	24	10	10.3	11.2	12.475	14.2
2001	24	8.9	9.9	11.55	13.25	14.9
2002	24	9.4	10.225	11.95	13.5	15.2
2003	24	10.1	10.6	11.65	13.8	15
2004	21	9.3	10.35	11.5	13.45	17.1
2005	22	8.7	9.25	11.7	13.225	14
2006	23	9.1	10.1	11.3	12.8	13.7
2007	24	9.3	10.725	12	14.3	19.1
2008	22	9.2	10.4	11.2	13.275	15.9
Overall	**435**	**8.7**	**10.2**	**11.6**	**13.1**	**19.1**

Sulfur

Sulfur in natural waters is essential in the life processes of plants and animals. Although the largest Earth fraction of sulfur occurs in reduced form in igneous and metamorphic rock, there is significant sulfur in sedimentary rock as well. When sulfide minerals undergo weathering in contact with oxygenated water, the sulfur is oxidized to yield stable sulfate ions that become mobile in solution. Another major source of sulfate in the environment is the combustion of coal, petroleum and other industrial processes such as smelting of sulfide ores. Atmospheric deposition both as dry particulates and entrained in precipitation can cause acid rain that can alter stream chemistry. Sulfate is highly mobile and often ends up in our local streams, lakes and reservoirs. Sulfate is classified under the EPA secondary maximum contaminant level (SMCL) standards. The SMCL for sulfate in drinking water is 250 milligrams per liter (mg/l). Sulfate was not monitored by DEP until 1993. Since that time, annual median concentrations found in the Rondout Creek varied from 4.8 to 6.7. Sulfate values basinwide have dropped since 1993 (see figure), have remained at a lower level, possibly due to reduced sulfur emissions throughout the US.

Table 11 Basic statistics for sulfate testing at site RDOA on Rondout Creek in mg/L

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1993	25	5.8	6.395	6.7	7.21	8.03
1994	25	5.65	6.095	6.52	6.805	7.92
1995	25	5.89	6.17	6.42	6.785	7.42
1996	20	5.25	6.2325	6.345	6.5275	7.03
1997	11	5.83	6.06	6.35	6.46	6.9
1998	11	5.58	5.82	6.27	6.66	7.28
1999	12	4.97	5.827	6.295	7.03	8.04
2000	12	4.64	6.13	6.445	6.553	6.88
2001	12	5.22	5.71	6.1	6.493	7.22
2002	12	5.12	5.515	5.795	6.183	6.61
2003	11	4.87	5.44	5.55	5.82	6.54
2004	12	4.89	5.095	5.29	5.86	6.02
2005	13	4.47	5.095	5.27	5.65	5.72
2006	12	4.79	5.042	5.365	5.673	5.99
2007	12	4	4.51	4.82	5.093	5.4
2008	13	3.8	4.7	4.8	4.97	5.3
Overall	**238**	**3.8**	**5.49**	**6.105**	**6.5425**	**8.04**

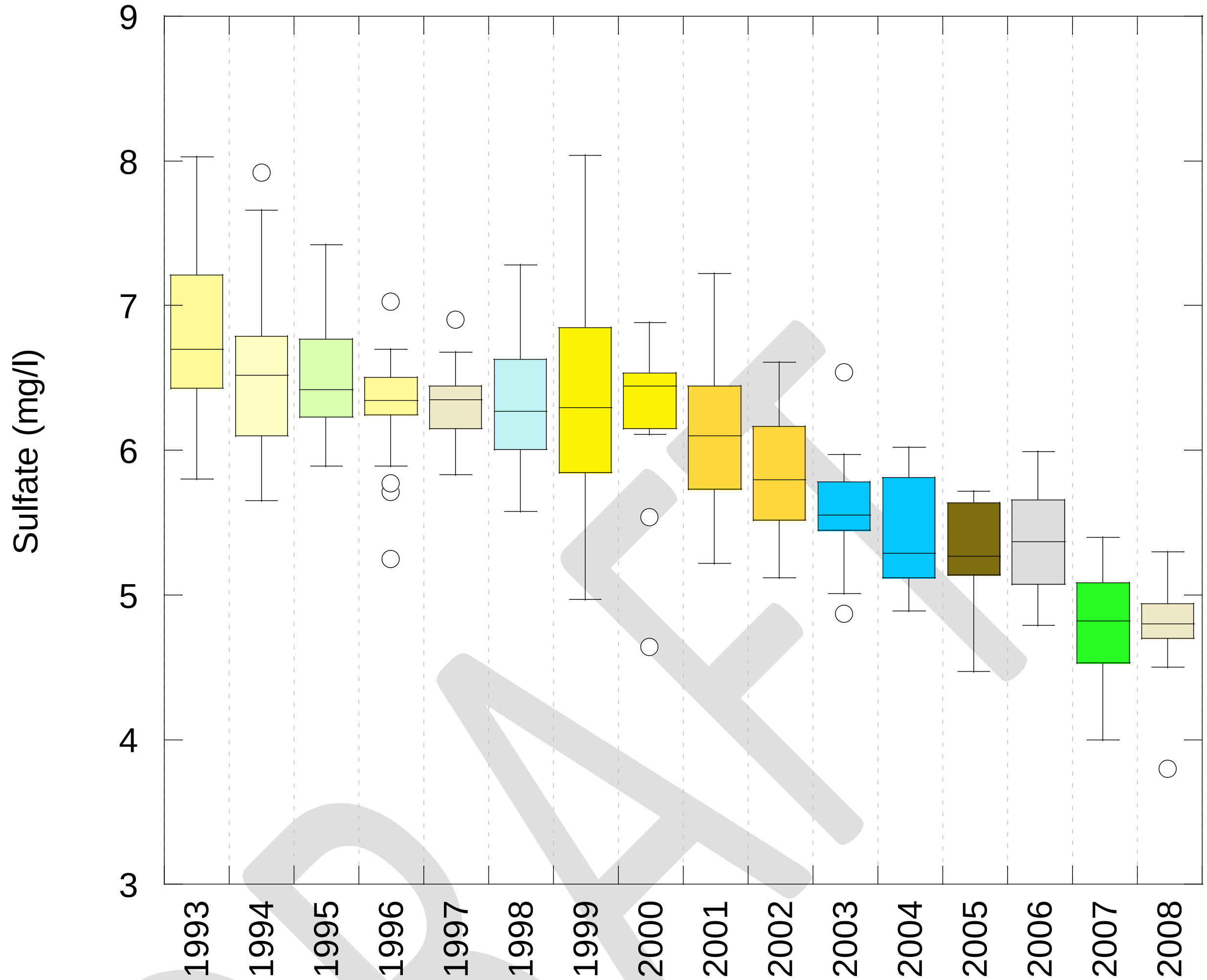

Figure 3 Boxplot of sulfate (mg/l) data at Rondout Creek by year, 1993-2008

pH

For optimal growth, most species of aquatic organisms require a pH in the range of 6.5 to 8.0, and variance outside of this range can stress or kill organisms. Due to the acidity of rainfall in the northeast, maintaining this range is of concern. According to the NYSDEC (2004a), average pH of rainfall in New York ranges from 4.0 to 4.5.

Annual (1987-2008) median pH values for the period of record for the Rondout Creek near Lowes Corners ranged from 6.28 to 7.05. The annual medians were generally slightly acidic, with annual medians being too coarse to differentiate between seasons and flow regimes.

Table 12 Basic statistics for pH testing at site RDOA on Rondout Creek

Year	N	Minimum	25^{th} Percentile	Median	75^{th} Percentile	Maximum
1987	25	5.72	6.05	6.28	6.525	6.86
1988	26	6.38	6.5975	6.7	6.7925	7.07
1989	26	6.22	6.655	6.75	6.925	7.17
1990	26	5.9	6.1625	6.325	6.4925	7.85
1991	27	6.32	6.8	6.93	7.15	7.34
1992	26	6.5	6.8975	7.045	7.215	8
1993	27	6.4	6.85	6.99	7.14	7.33
1994	25	5.64	6.855	6.96	7.105	7.44
1995	24	6.44	6.7175	6.825	7.08	7.29
1996	24	6.01	6.3425	6.48	6.77	7.03
1997	25	6.2	6.435	6.49	6.625	6.99
1998	23	5.94	6.4	6.53	6.73	6.91
1999	24	6.22	6.4475	6.605	6.84	7.05
2000	23	6.6	6.68	6.81	6.87	7.09
2001	26	6.23	6.6225	6.815	7.005	7.21
2002	24	6.09	6.3625	6.555	6.78	6.97
2003	22	5.85	6.3575	6.61	6.7	6.96
2004	22	5.91	6.4725	6.745	6.94	7.31
2005	21	6.32	6.52	6.65	6.81	7.1
2006	23	6.22	6.48	6.68	6.75	7.39
2007	23	6.29	6.59	6.79	6.99	7.22
2008	23	5.96	6.52	6.7	6.85	7.23
Overall	**535**	**5.64**	**6.49**	**6.72**	**6.91**	**8**

Chloride

Chlorides are salts resulting from the combination of chlorine gas with a metal. Chlorine as a gas is highly toxic, but in combination with a metal such as sodium it becomes useful to plants and animals. Small amounts of chlorides are required for normal cell function in plants and animals. Common chlorides include sodium chloride (NaCl), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$). Chlorides can get into surface water from several sources including geologic formations containing chlorides, agricultural runoff, industrial wastewater, effluent from wastewater treatment plants, and the salting of roads. Excess chloride can contaminate fresh water streams and lakes, negatively affecting aquatic communities.

Concentrations of chloride of approximately 140 mg/L should be protective of freshwater organisms for short-term exposure; concentrations less than 35 mg/L are likely protective during long-term exposures (Environment Canada, 2001). Overall, approximately 5 percent of species would experience effects from chronic exposure to concentrations of chloride of 210 mg/L, while 10 percent of species would be affected at concentrations of 240 mg/L (Environment Canada, 2001). According to the United States Environmental Protection Agency, biota on average should not be affected if the four-day average concentration of chloride does not exceed 230 mg/L more than once every three years (USEPA, 2005a). Biotic impacts would be minimal if the one-hour average chloride concentration did not exceed 860 mg/L more than once every three years (USEPA, 2005a). The major sources of chloride in the Rondout watershed are most likely geology and road salting. The annual median chloride concentrations are low across the board, ranging from2.75 mg/l to 4.3 mg/l. Annual medians are too coarse to tease out specific contributors. However, it is appears the annual chloride concentrations have been increasing (see figure), although it is a relatively small increase.

Table 13 Basic statistics for chloride testing at site RDOA on Rondout Creek in mg/L

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987	25	1.5	2	2.75	4	5
1988	25	1.5	2.25	2.75	3	4.25
1989	22	2	2.438	3.75	4.813	5.5
1990	26	1.57	2.07	2.74	3.175	4.29
1991	27	1.42	2.07	2.29	3.51	4.77
1992	26	1.35	1.968	2.18	2.6	4.6
1993	26	1.65	2.178	2.965	4.535	5.1
1994	26	1.42	1.77	2.27	2.505	2.79
1995	25	1.59	2.225	2.73	3.355	4.02
1996	26	<1	1.525	2.225	2.743	3.37
1997	26	1.59	2.077	2.37	2.968	4.49
1998	25	<1	1.99	2.19	2.645	4.69
1999	26	1.92	2.268	2.6	3.598	4.7
2000	14	<2	1.645	2.24	2.545	2.77
2001	12	<0.6	2.025	3.475	4.6	6.35
2002	11	1.4	2.35	3.32	4.12	5.5
2003	11	1.94	2.05	3.55	5.09	6.07
2004	12	1.89	2.162	3.2	4.303	4.61
2005	13	<0.5	2.455	3.57	4.74	5.32
2006	12	1.74	2.54	3.555	4.902	5.75
2007	12	<0.5	2.183	4.05	5.405	6.69
2008	15	2.6	4	4.3	4.8	5.6
Overall	**443**	**<0.5**	**2.11**	**2.6**	**3.66**	**6.69**

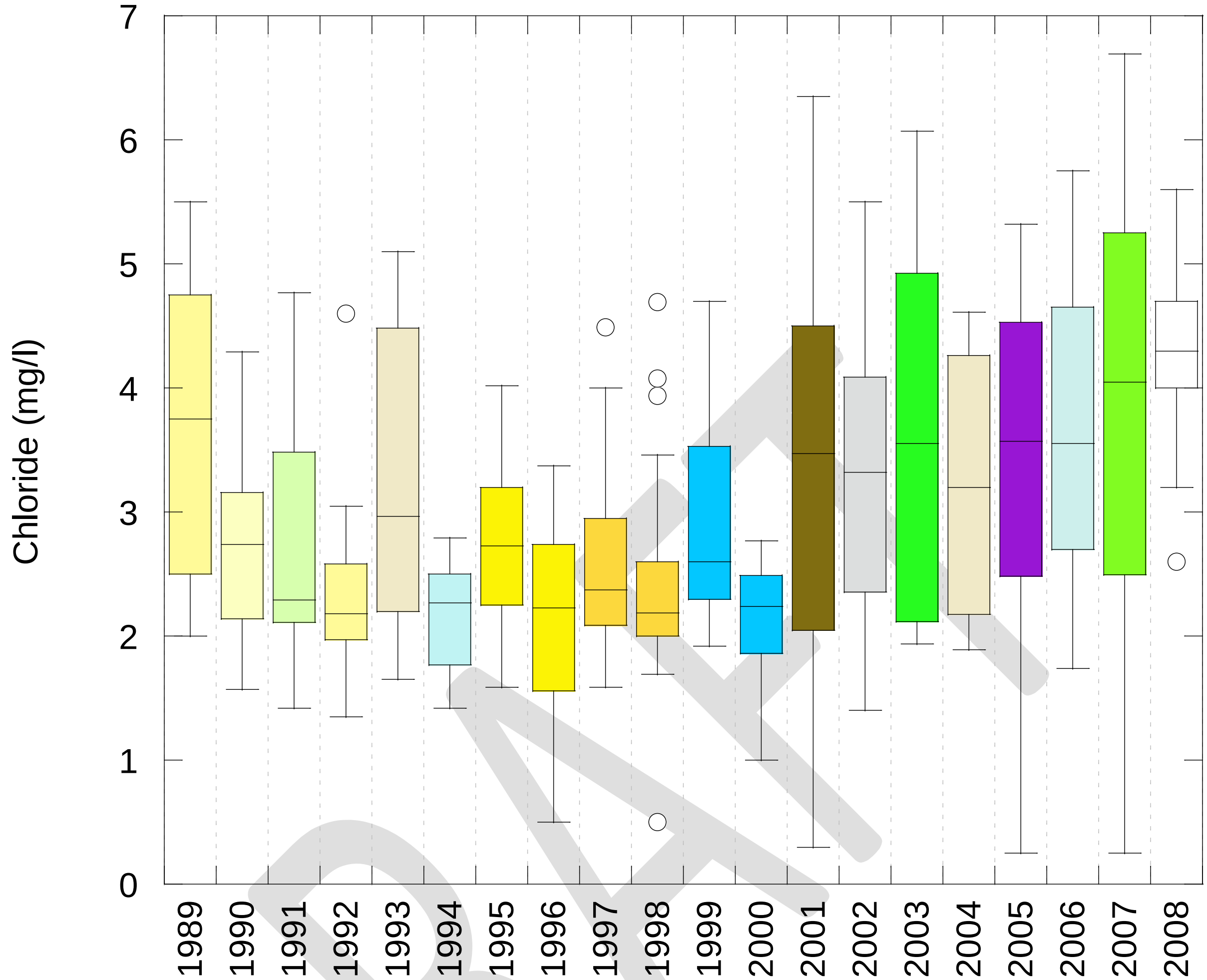

Figure 4 Boxplot of Chloride (mg/l) data at Rondout Creek by year, 1989-2008

Biomonitoring

Benthic macroinvertebrates (BMI) can be simply defined as animals without backbones that are larger than 1 millimeter and live at least a portion of their life cycles in or on the bottom of a body of water. In freshwater systems these animals may live on rocks, logs, sediments, debris, and aquatic plants during their various life stages. A few common examples of BMIs include crustaceans such as crayfish, mollusks such as clams and snails, aquatic worms, and the immature forms of aquatic insects such as stonefly, caddisfly and mayfly nymphs.

BMIs function at the lower levels of the aquatic food chain, with many feeding on algae, detritus, and bacteria. Some shred and eat leaves and other organic matter that enters the water, and others are predators. Because of their abundance and position in the aquatic food chain, BMIs play a critical role in the natural flow of energy and nutrients through the aquatic system (Covich et al., 1997). For example, Sweeney (1993) demonstrated in a second order stream, that leaf litter and woody debris were primarily consumed in the forested woodlot where the debris originated. Also, as benthos die, they decay, leaving behind nutrients that are reused by aquatic plants and other animals in the food chain. Insects fill the roles of predators, parasites, herbivores, saprophages, and pollinators, among others, which indicate the pervasive ecological and economic importance of this group of animals in both aquatic and terrestrial ecosystems (Rosenberg et al., 1986).

Biological assessments have been used by many states to evaluate the effectiveness of water quality programs, particularly for nonpoint source impact determinations (USEPA, 2002). For example, biological assessment models have been tested with field data and the results suggested that macroinvertebrate data collected for establishing the degree of water quality impairment can also be used to identify the impairment source with reasonable accuracy (Murray et al., 2002). In addition, it has been suggested that the percentage of chironomids in samples may be a useful index of heavy metal pollution (Winner et al., 1980). Furthermore, the Ohio EPA employs biological response signatures, based on biological, chemical, physical, bioassay, pollution source, and watershed characteristic, that consist of key response components of the biological data that consistently indicate one type of impact over another (Yoder, 1991). In New York State, the first recorded biological monitoring effort dates from 1926-1939, but the regulatory role of stream biomonitoring did not begin in New York until after the passage of the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act). The primary objective of New York State's program was to evaluate the relative biological health of the state's streams and rivers through the collection and analysis of macroinvertebrate communities (Bode et al, 2002).

Biological monitoring appears to be an attractive methodology for documenting water quality for several reasons. First, the community collected at a given site reflects the water quality at that site over several weeks, months, or years. The alternative methodology of grabbing a water sample reflects the water quality at the instant the sample is collected (i.e. a snap shot image). Second, the community-based approach focuses on the biological integrity of the water body, and not a limited number of chemical parameters. Third, samples can be preserved in reference collections for future application; this provides a convenient routine of summer collection and winter analysis. Finally, biological assessments tend to be much more cost effective than chemical analysis. Table 3.1.9 lists the rationale for biomonitoring in New York State (Bode et al, 2002).

Rationale for the analysis of macroinvertebrate communities to determine water quality of streams and rivers in New York State (Bode et. al., 2002:
1. BMIs are sensitive to environmental impacts;
2. BMIs are less mobile than fish, and thus can avoid discharges;
3. They can indicate the effects of spills, intermittent discharges, and lapses in treatment;
4. They are indicators of overall, integrated water quality, including synergistic effects and substances lower than detectable limits;
5. They are abundant in most streams, and are relatively easy and inexpensive to sample;
6. They are able to detect non-chemical impacts to the habitat, such as siltation or thermal change;
7. They are readily perceived by the public as tangible indicators of water quality;
8. They can often provide an on-site estimate of water quality;
9. They bioaccumulate many contaminants to concentrations that analysis of their tissues is a good monitor of toxic substances in the aquatic food chain;
10. They provide a suitable endpoint to water quality objectives.

Standardized protocols for benthic macroinvertebrate monitoring were developed in the mid-1980s due to the need for cost-effective habitat and biological survey techniques (Plafkin et al., 1989). The primary driver of the development was limited economic resources available to states with miles of unassessed streams. It was also recognized that it was crucial to collect, compile, analyze, and interpret environmental data rapidly to facilitate management decisions and resulting actions for control and/or mitigation of impairment. Therefore, the conceptual principles of rapid bioassessment protocols (RBPs) were as follows: cost-effective, yet scientifically valid procedures; provisions for multiple site investigations in a field season; quick turn-around of results for management decisions, easily translated to management and the public; and environmentally benign procedures (Barbour et al. 1999). Finally, in order to save time, it was recognized that a certain degree of accuracy would need to be sacrificed, and a field-based assessment would be necessary (Hilsenhoff, 1988). Therefore, a family based assessment was developed that could be calculated in the field by professionals (Hilsenhoff, 1988). This field based assessment allows professionals to focus their time and efforts on the more in-depth analysis of areas that indicated degradation in the rapid field assessment.

In the 2004 NYS DEC issued a report entitled *30 Year Trends in Water Quality of Rivers and Streams in New York State Based on Macroinvertebrate Data 1972-2002*. Based on the biomonitoring data Rondout Creek was assessed as non-impacted for most of its length. Reaches of the creek above Peekamoose were found to be slightly impacted due to acid effects. This finding of a slight impact from acidity was similar to previous unpublished DEC studies. The macroinvertebrate community of these upper reaches was dominated by acid-tolerant midges and stoneflies. The impacts from acid effects were not observed a few miles downstream where non-impacted conditions were reported at Bull Run. Also, it was noted that the assessment of nonimpacted water quality at Sundown represented an apparent improvement from slightly impacted conditions documented at the site in 1991 and 1992.

Biomonitoring protocols have been used by DEP to assess the biological integrity of Rondout Creek's benthic macroinvertebrate community at the stream's headwaters and at a site just above Rondout Reservoir (Table 14). The results are similar to those obtained by the NYS DEC, as discussed above. At the downstream site, non-impaired conditions prevailed in all but one of the six years sampling was performed, the exception occurring in the most recent year of sampling (2006), when the site was rated slightly impaired. Results from that year should be viewed with caution, however, because the number of organisms in the 2006 subsample was substantially lower than the minimum number specified in the protocols. This probably had the effect of depressing the scores for total taxa and EPT, leading to an artificially low assessment.

The headwater site was assessed as slightly impaired in 2005 and 2006 – the two years it was sampled, but that assessment too may be misleading. Low community indices at headwater sites is not uncommon, and this can lead to erroneous assessments of impacted water quality (Bode et al. 2002). When this occurs, Bode et al. (2002) prescribe upward adjustment of the site's assessment by one category, which in this case would result in non-impaired assessments for both years.

The results at Sugarloaf Brook, the one tributary to Rondout Creek where biomonitoring has been conducted, are equivocal. Despite two successive slightly impaired assessments (2006 & 2007), the site consistently had high numbers of mayfly, stonefly, and caddisfly taxa; these groups are among the most sensitive benthic macroinvertebrates. Indeed, these groups were numerically dominant in all samples. Within each sample, however, one of these groups vastly outnumbered the rest, producing low scores for the total taxa and percent model affinity metrics; this in turn led to the slightly impaired assessments cited above. Results of impact source determination analysis were inconclusive. Further monitoring of this stream may help resolve some of these uncertainties.

Table 14 Results of biomonitoring in the Rondout Creek watershed above the Rondout Reservoir

Year	Above Rondout Reservoir	Rondout headwaters	Sugarloaf Brook
2001	Non-impaired	No sampling done	No sampling done
2002	Non-impaired	No sampling done	No sampling done
2003	Non-impaired	No sampling done	No sampling done
2004	Non-impaired	No sampling done	No sampling done
2005	Non-impaired	Slightly impaired^	No sampling done
2006	Slightly impaired*	Slightly impaired^	Slightly impaired#
2007	No sampling done	No sampling done	Slightly impaired#

* The result may have been artificially depressed by the low number of organisms collected in the 2006 subsample.
^ Upward adjustment of categories is recommended for headwater sites due to low community indices commonly found in the watershed setting.
#Despite high number of mayfly, stonefly & caddisfly taxa, one group greatly outnumbered the rest, producing low scores for total taxa and percent model affinity metrics.

Stream Management Implications

Determining whether a stream has good or bad water quality often depends largely upon the end user. For the purposes of the NYC water supply, the Rondout watershed supplies good quality water with the exception of the time period following large storms in which in-stream turbidity and suspended solids are high. Streams in the Catskills have moved large amounts of suspended sediment during storms for thousands of years; and will continue to do so for thousands of years until all the glacial lake sediment and glacial till have been removed from the stream network. That being said, watershed landowners do have direct influence over land uses in the watershed and there are other, more local reasons for watershed protections measures to be implemented. For example, protecting and enhancing the fishery could also benefit the economy and aesthetic values of the region. Proper watershed management can also assist in protecting infrastructure, reducing flood damages and help to develop a stream stewardship ethic. Taken together, all these benefits can increase the quality of life of watershed residents, while providing high quality drinking water to the residents of New York City into the future.

In 2001, approximately 98% of the Rondout basin was forested. However, this is somewhat deceptive since much of the developed land is adjacent to the stream, particularly roads. Future development in the stream corridor, with a resulting increase in impervious surface, may increase runoff and impair water quality. Therefore, management efforts should be focused on preventing further human-induced degradation through implementation of best management practices designed to reduce/minimize impacts. These efforts should be both direct measures such as remediating failing septic systems and upgrading sewer treatment plants (point sources of pollution); and indirect measures such as reducing stormwater inputs, properly installing new infrastructure and planting riparian buffers. In areas where existing infrastructure is acting to destabilize the stream, or is threatened by erosion, stabilization techniques incorporating natural channel design should be employed. Reforesting the banks of the Rondout Creek and its tributaries, coupled with the protection of cold groundwater seeps, may help to lower summer water temperatures and enhance the fishery.

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