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SUSQUEHANNA RIVER

Biological Stream Assessment

October 1, 2015

STREAM BIOMONITORING UNIT

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BIOLOGICAL STREAM ASSESSMENT

Lower Susquehanna River
Broome and Tioga Counties, New York
Susquehanna River Basin

Survey date: August 8, 2014
Report date: April 1, 2015

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Stream: Lower Susquehanna River

River Basin: Susquehanna River

Reach: Binghamton to Apalachin, NY

Background

The New York State Department of Environmental Conservation (NYSDEC), Stream Biomonitoring Unit (SBU) sampled six sites within a twelve mile reach of the Susquehanna River on August 19, 2014 (Figure 1). This reach extends from Johnson City, one-quarter mile upstream from the Binghamton-Johnson City Joint Sewage Treatment Plant (BJCSTP), to Apalachin approximately 12 miles downstream. The purpose of this survey was to investigate water quality impacts from primary treatment effluent entering the river from the BJCSTP through examining benthic macroinvertebrate communities inhabiting the river.

To characterize water quality based on benthic macroinvertebrate communities, a traveling kick sample was collected from riffle areas at each of the six sites. Methods used are described in the Standard Operating Procedure (NYSDEC, 2014) and summarized in Appendix I. The contents of each sample were field-inspected to determine major groups of organisms present, and then preserved in alcohol for laboratory inspection of 100-specimen subsamples from each site. Biological assessment of water quality was conducted through calculation of benthic macroinvertebrate community metrics including the Biological Assessment Profile (BAP) score for riffle communities.

Macroinvertebrate community parameters used in the determination of water quality included: species richness (Spp), biotic index (HBI), Ephemeroptera, Trichoptera and Plecoptera richness (EPT), percent model affinity (PMA) and nutrient biotic index for phosphorus (NBI-P) (see Appendices II and III). Amount of expected variability of results is stated in Smith and Bode (2004).

Results and Conclusions

1. Results of the biological survey suggest water quality is non-impacted immediately above the BJCTP, moderately to severely impacted at the two sites within a mile downstream of the plant, improved but still slightly impacted conditions five miles downstream, slightly impacted six miles downstream and then finally in Apalachin, eleven miles downstream, benthic community sampling showed non-impacted water quality.

2. User Perception surveys and photographic documentation confirm the non-impacted stream condition just upstream of BJCSTP and the obvious visible degradation of stream condition at sites 0.1 and 1.25 miles downstream from the BJCSTP. These observations also suggest recovery begins at a point approximately 6 miles downstream and appear to confirm the fully recovered, non-impacted biological condition found at the last site in Apalachin approximately 11 miles from the BJCSTP.

3. The results of this survey are similar to findings from multiple site sampling conducted on this reach in 1985; which showed non-impacted conditions above the plant, moderate impact below the plant and benthic community recovery indicated in the sample taken at a point 6.9 miles downstream.

Discussion

The Susquehanna River originates as the outflow of Otsego Lake in Cooperstown, New York. The river is 474 miles long and drains a 27,500 square mile basin that terminates in the Chesapeake Bay at Havre de Grace, Maryland. The total length of the New York portion of the river is 148 miles with a drainage basin of 4,520 square miles. (NYSDEC, http://www.dec.ny.gov/lands/48020.html) This New York portion of the Susquehanna flows from its Otsego Lake source, south-southwest for approximately 80 miles before entering Pennsylvania, where it flows for approximately 15 miles before bending north and re-entering New York State. The river continues in a northwesterly direction toward Binghamton where it bends due west, passes through Binghamton and continues west-southwest for approximately 45 miles before turning south and re-entering Pennsylvania (Figure 1).

Agricultural activity, municipal wastewater discharge and urban storm runoff are the primary source of significant nutrient concentrations to the river reach covered in this survey. The addition of excess nutrients to river systems is known to stimulate excess algae and aquatic plant production which disrupts normal ecosystem function. Decomposition of this biomass overload results in depletion of oxygen levels which may result in fish kills and loss of bio-diversity. Excess algal production also has negative impacts on aesthetics, recreation and water treatment. Water treatment and potentially hazardous disinfection byproducts are of special importance here since many municipalities in the Susquehanna basin utilize the river's water for drinking and irrigation.

The focus of this survey was to determine the effect of the BJCSTP wastewater discharge on Susquehanna River benthic macroinvertebrate communities. In 2011 the BJCSTP experienced two catastrophic events that affected its wastewater treatment capabilities. In May 2011, a portion of the secondary treatment system tanks collapsed. Though the plant was able to maintain secondary treatment through the remaining treatment tanks, it was unable to remove nitrogen. Then in September 2011, floodwaters from Tropical Storm Lee inundated the plant, rendering the remainder of the secondary treatment process tanks inoperable. Since then, the plant has been operating in a chemically enhanced primary treatment (CEPT) mode. This type of treatment uses a process that includes the addition of metal salts, such as ferrous chloride, to encourage aggregation of solids into fast settling flocculent and is capable of removing up to 85% of phosphorus from wastewater (Sandino, 2004). Additionally, the final effluent is disinfected year-round. To assess the impacts of this reduced level of wastewater treatment from the BJCSTP the NYSDEC SBU surveyed six sites, one upstream and five downstream, along a twelve mile reach.

Historically this section of the river has been routinely sampled by the SBU and of particular note is the multiple site assessment survey conducted in 1985. This survey was also intended to determine the effects of effluent discharge from the BJCSTP, albeit without the context of catastrophic facility damage and treatment failure. This survey employed several different sampling methods (ponar, net jab and kick) at generally different locations along the same reach as the 2014 survey, and therefore a site to site quantitative comparison would not be possible. The following is a brief qualitative summary of the 1985 work. Two sites were sampled, 0.1 and 0.8 miles upstream of the treatment plant (Figure 2) and both showed relatively healthy benthic communities containing organisms typical of clean water. It was noted that biomass was high at both sites indicating overall water quality of slight impact due to some nutrient enrichment. The first samples downstream of the BJCSTP were 0.9 to 1.2 miles from where the effluent entered the river. Both pool and riffle samples yielded saprophilic communities that were classified as moderately impacted. The grab sample taken from the pool above the Goudy Station Dam (0.9 miles from discharge) was composed of 99% midges, most of which were pollution tolerant. While it was determined that there was moderate impact to the benthic community there was no indication of a severely impacted sludge bed community. The kick sample taken in a riffle just downstream of the dam, 1.2 miles from discharge (Figure 2b), showed greater diversity of organisms than the pool but was composed of organisms indicating a stressed community dominated by tolerant midges and caddisflies. The species richness at this riffle site was noted to be remarkably high with some clean-water genera of mayflies and stoneflies. It was thus concluded that this moderate impact to the community was organic in nature rather than toxic. At the sample point 3.3 miles downstream of BJCSTP (Figure 2b) the sewage effects were judged to be more apparent. A bottom ponar grab sample of blackened sand was dominated by tolerant midges and worms, with mayflies, caddisflies and stoneflies absent. The water quality at this site was rated as severely impacted. The riffle sample collected at a point 6.9 miles downstream of the discharge (Figure 2c) was comparable to the communities above the discharge and the site was determined to have fully recovered from the effects of the effluent. The sampling conducted at the Apalachin site, 11.2 miles downstream (Figure 2d), showed slight to moderate impact (Bode 1986).

Other historical macroinvertebrate data gathered from the Binghamton to Apalachin reach of the river by the SBU, besides the 1985 survey, include data from routine and intensive sampling conducted in 1973, 1979, 1984, 1991, 1992, 1997, 1998, 2003 and 2008. Much of the sampling conducted in these years occurred at the sites just above the treatment plant and at the furthest downstream Apalachin site. In general, the results of the sampling in these years reflect the upstream of treatment plant, non-impacted condition; and downstream, the recovered and generally non-impacted condition of the benthic community at the Apalachin site (SUSQ-05) (Figure 2d).

The 2014 survey sample for the SUSQ-02B site, 0.75 miles upstream from the plant (Figure 2, Table 1) showed a non-impacted macroinvertebrate community with a BAP score of 8.12 (Figure 4). The assemblage of species was diverse (Table 6) but showed evidence of some nutrient enrichment with the presence of filter feeding Trichoptera; *Ceratopsyche morosa*, *Ceratopsyche slossonae* and *Cheumatopsyche* sp. There were also many Oligochaeta in the sample. The presence of these organisms indicative of nutrient enrichment is reflected in an HBI score of 7.38 and an NBI-P score of 6.12 (Figure 4) that suggest slight impact from nutrient enrichment. The complimentary presence of clean water organisms is seen in the diverse mixture of Ephemeroptera (with the burrowing mayfly, *Anthopotamus* sp. dominating), Coleoptera and Diptera species, yielding high species richness, EPT and PMA scores and thus an assessment of non-impacted water quality (Figure 4). Pollution intolerant stoneflies (Plecoptera: Perlidae) were also observed in the field but were not found in the laboratory sub-sample. Habitat assessment scores indicated an altered habitat due largely to unstable banks, reduced bank vegetation and relatively narrow riparian width (Table 4). Bottom substrate was largely composed of rubble and gravel with a small percentage of sand and silt. This substrate was covered with green algae, indicating some nutrient enrichment.

SUSQ-03, (Figure 2) is the first site downstream (0.1 mile) from the BJCSTP. The sample was collected at a riffle that is formed at the confluence of the outfall tributary, Fuller Hollow Creek. In clear contrast with the upstream location, this site was visibly degraded with dense sewage fungus mats covering all substrate surfaces (Table 1, Figures 3a-c). There was a noxious odor present. In slack water at edges of the riffle and in stagnant pools on the backside of the riffle there were areas of dense anoxic sludge. Fungus flocculent was also evident in the water column.

The benthic community data show negative water quality impact from the treatment plant effluent, with a BAP score of 2.57 barely above the margin between moderate and severe water quality impact (Figure 4). There were high numbers of pollution tolerant midges (Chironomidae) present, with *Polypedilum flavum* and *Phaenopsectra dyari* being the dominant genera in the entire sample, followed by (Oligochaeta) represented by the tolerant taxa *Limnodrilus* sp and Undetermined *Naididae.* Impact source determination indicated municipal and industrial discharge and sewage and animal wastes (Table 2). Habitat assessment scores were positive here but this was most likely due to relatively good bank stability, riffle frequency and bank vegetation. Conductivity at this site (524µmhos) was higher than the other sampling locations which had conductivity values on average of 299 µmhos (Table 5).

At SUSQ-03A, 1.2 miles downstream from the BJCSTP (Figure 2b), the sample was collected from a riffle just below the Goudy Station dam. As with SUSQ-03, there was evidence of sewage effluent. Noxious effluent odor, widespread sewage fungus and algal mats were present. (Table 1 and Figure 3d) The macroinvertebrate community was quite similar to SUSQ-03, but did show some improvement in HBI and PMA scores yielding a BAP of 3.17. Species richness improved slightly (Figure 4). This was due to the presence of tolerant individuals of Crustacea, (*Gammarus* sp.), Mollusca (*Ferrissia* sp. and *Valvatidae)* and Flatworms (Turbellaria) not found at SUSQ-03 (Table 5). Impact source determination indicated municipal/industrial discharge and sewage/animal waste similar to SUSQ-03 (Table 2). Habitat at this site was assessed as slightly altered largely due to narrow riparian width. The dissolved oxygen level was lower at this site than at any of the other sites surveyed (Table 4). This DO sag may be due to an increase in decomposition of organic matter in sediments but more extensive DO sampling would be necessary to confirm.

At survey site location, SUSQ -04A; 6.9 miles below the BJCSTP (Figure 2c), recovery from the effect of the sewage effluent was evident. Sewage fungus and algal mats were not observed at the kick sample site and the noxious odor was no longer detectable. Benthic community metrics showed a measurable improvement compared to SUSQ-03A (Figure 4). Overall water quality was assessed near the threshold between slightly impacted and non-impacted water quality with a BAP score of 7.2. The macroinvertebrate community transitioned to dominance by Ephemeroptera represented by clean water species such as *Maccaffertium mediopunctatum, Leucrocuta* sp. and *Rhithrogena* sp. (Table 5). Data from this site should be considered with the following caveat; the site is in an area that is braided with channels between small islands so that any effluent plume may be diffused or redirected away from the actual sample site (Figure 2c, Table 1). Impact source determination was inconclusive (Table 2). The scoring of physical habitat attributes reflected an altered to moderately altered area of the river impacted by higher sediment deposition, low riffle frequency, and low assessments for bank stability and bank vegetation (Table 3, Figure 5).

Recovery of the biological community and improvement in water quality appears to continue downstream at station SUSQ-04B, 8.9 miles below the BJCSTP (Figure 2c, Table 1). However unlike SUSQ-04A, the kick sample was taken in a section of river that was no longer braided. No plume or other visible evidence of sewage effluent was noted. The BAP score suggested continued recovery of the benthic macroinvertebrate community (BAP 7.47), resulting in a water quality assessment at the threshold between slight and non-impacted (Figure 4). Similar to SUSQ-04A, Ephemeroptera dominate the sample, accounting for 80% of the genera, such dominance resulted in a lower than might be expected species richness value. This is most likely a function of habitat rather than water quality effect. This habitat difference is evident in the low Habitat Model Affinity score (Figure 5) and summarized in the table of physical habitat attribute scores (Table 3). The low values for epifaunal cover, velocity depth regime, sediment deposition and particularly, riffle frequency, may well explain the lower species richness in the sample.

Full recovery of the benthic community to a condition similar to the site upstream of the treatment plant was evident at the last site surveyed, SUSQ-05, 11.9 miles downstream of the BJCSTP (Figure 2e, Table 1). All macroinvertebrate community metrics except NBI-P supported the improvement in water quality to non-impacted (BAP 8.26) at this site (Figure 4). A diverse mixture of clean water indicator species were present. Of particular note is the reappearance of the stoneflies, *Agnetina capitata* and *Paragnetina media*, generally indicative of non-impacted water quality (Table 5). The NBI-P score that shows slightly enriched condition at this point in the river, nearly twelve miles downstream from the BJCSTP, may now be as much attributable to non-point source contributions of nutrients as to any single point source. This phosphorus enrichment likely accounts for the vigorous green algae cover on the substrate at this site. Impact source determination was not warranted with the return to non-impacted condition. Habitat Model affinity scoring shows an altered habitat because of low riffle frequency and low riparian width due to proximity to the highway (Figure 5).

Sewage effluent discharged by the damaged treatment plant is having a dramatic negative impact on water quality within the upper section of this reach of the Susquehanna River. This degradation is measurable over one mile downstream from the plant. Macroinvertebrate communities that were sampled upstream and downstream of the BJCSTP clearly show water quality is non-impacted above the treatment plant and is moderately (bordering on severely) impacted by sewage discharge at points 0.1 mile and 1.0 mile below the plant. The results of the survey suggest benthic macroinvertebrate community and water quality recovery further downstream.

In general the overall result of the 1985 survey were similar to the 2014 survey results. Both surveys documented clear impact from the BJCWTP effluent and a gradient of recovery downstream. In addition, while data gathered from the 2014 survey confirm a recovery gradient, further sampling at additional sites along the reach, especially in the gap between stations 03A and 04A may help to refine this gradient. Follow-up biological surveys may be useful in tracking effectiveness of ongoing effluent mitigation, future reconstruction and eventual installation of tertiary treatment at the BJCSTP. The possible long term effects of toxic sediment deposition and re-suspension in the water column may also warrant investigation.

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Smith, A. J., and R. W. Bode. 2004. Analysis of Variability in New York State Benthic Macroinvertebrate Samples. Division of Water, NewYork State Department of Environmental Conservation, 625 Broadway, Albany, New York, Technical Report, 43 pages.

R.W. Bode. 1986. NYSDEC Technical Report, Susquehanna River Biological Assessment; 1985 Survey

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Figure 1. Overview map, Lower Susquehanna River watershed and 2014 sampling locations.

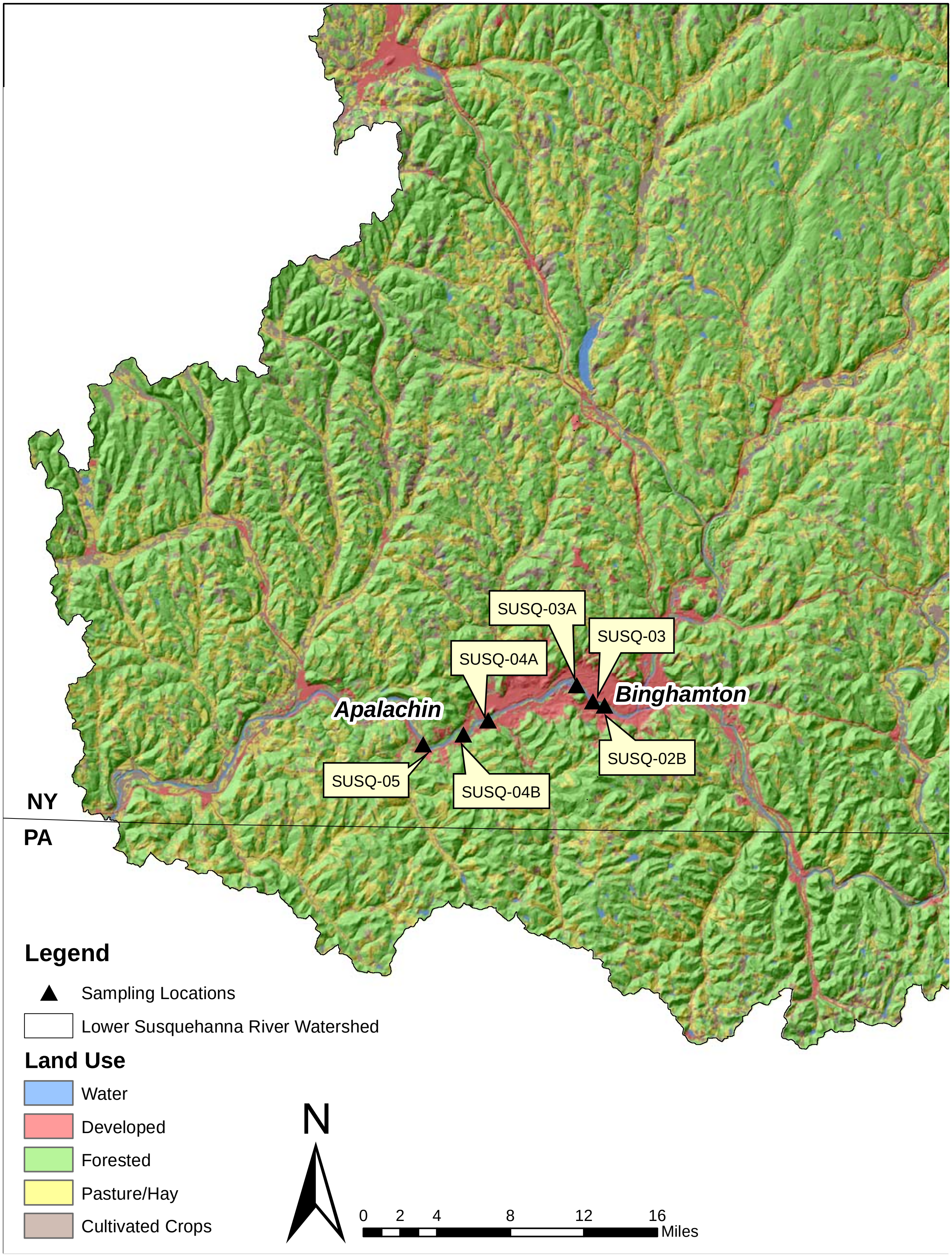


Figure 2. Site location map, Lower Susquehanna River, Stations SUSQ-02B, SUSQ-03 and 1985 Survey Site Locations

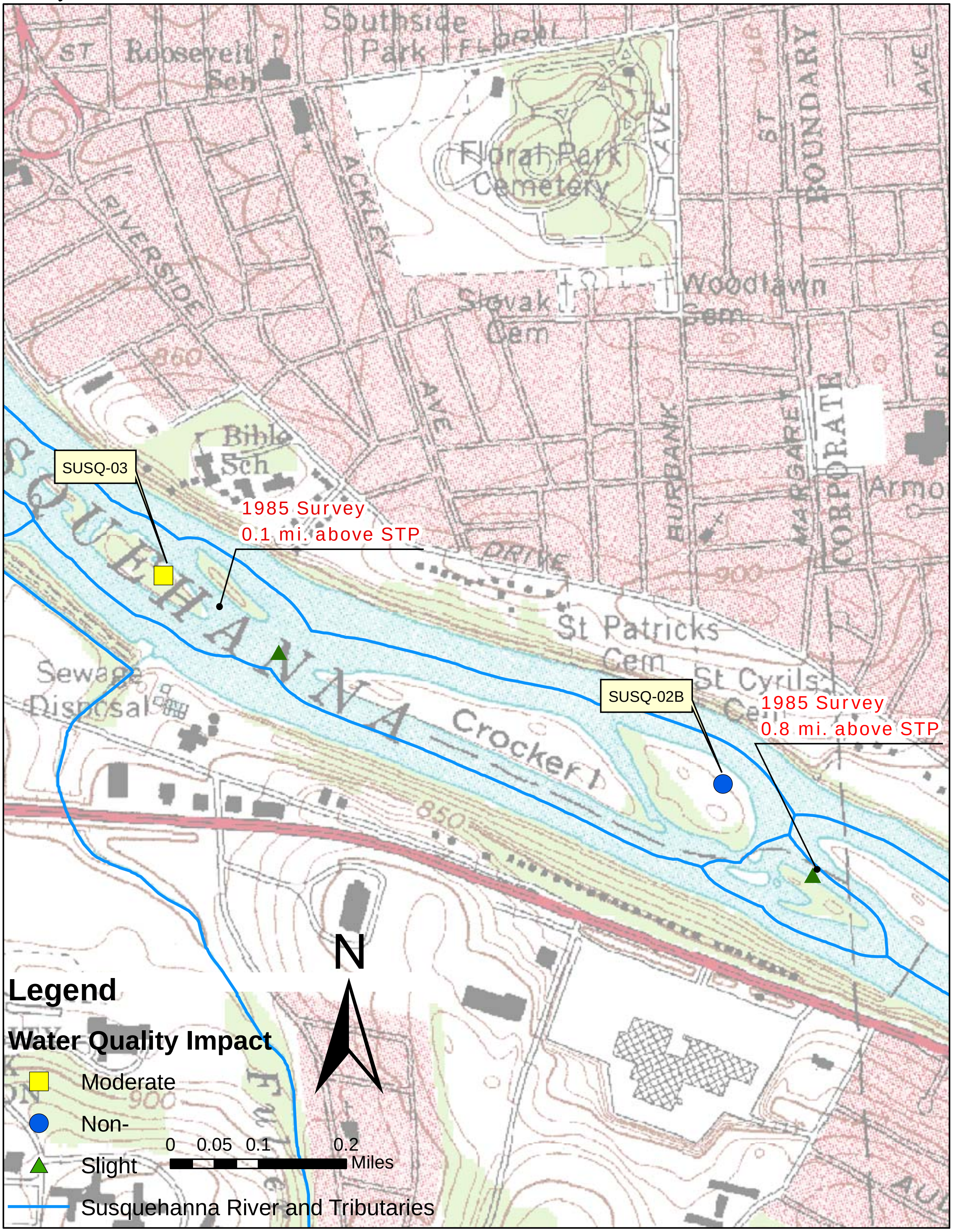


Figure 2b. Site location map, Lower Susquehanna River, Station SUSQ-03A, 1985 Sample Sites

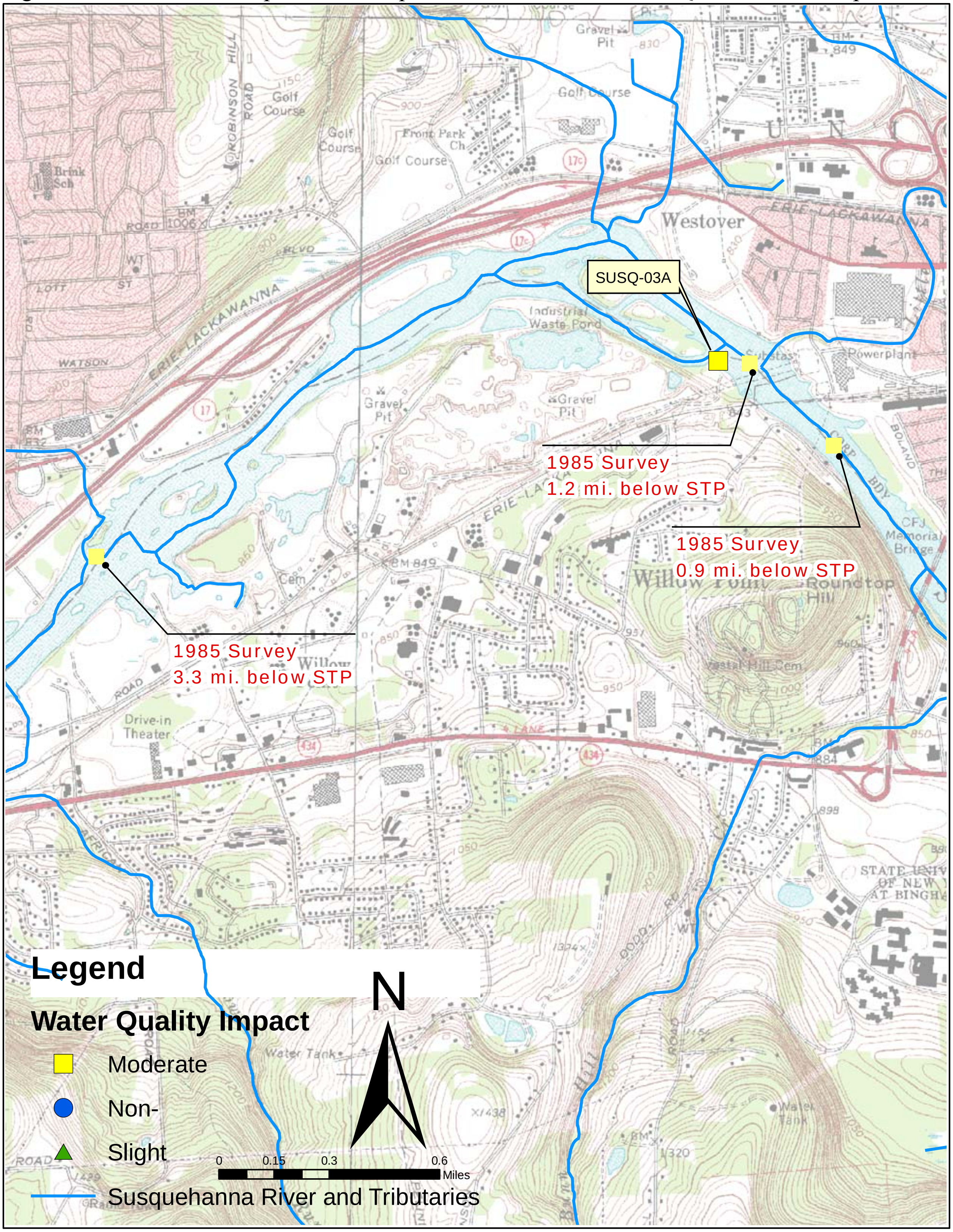


Figure 2c. Site location map, Lower Susquehanna River, Stations SUSQ- 04A, SUSQ-04B, 1985 Survey site locations

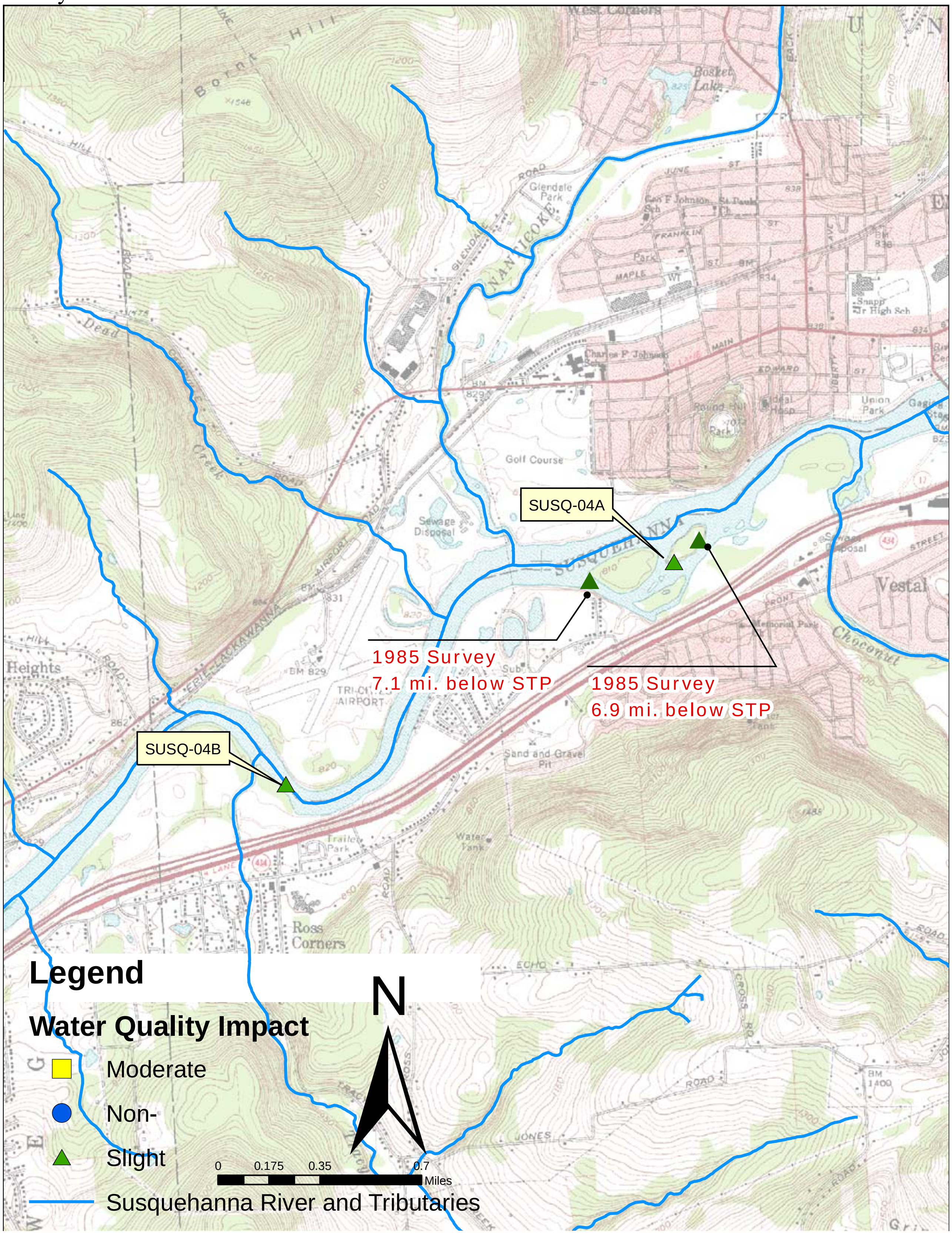


Figure 2d. Site Location Map, Lower Susquehanna River, Station SUSQ-05 and 1985 Survey Site.

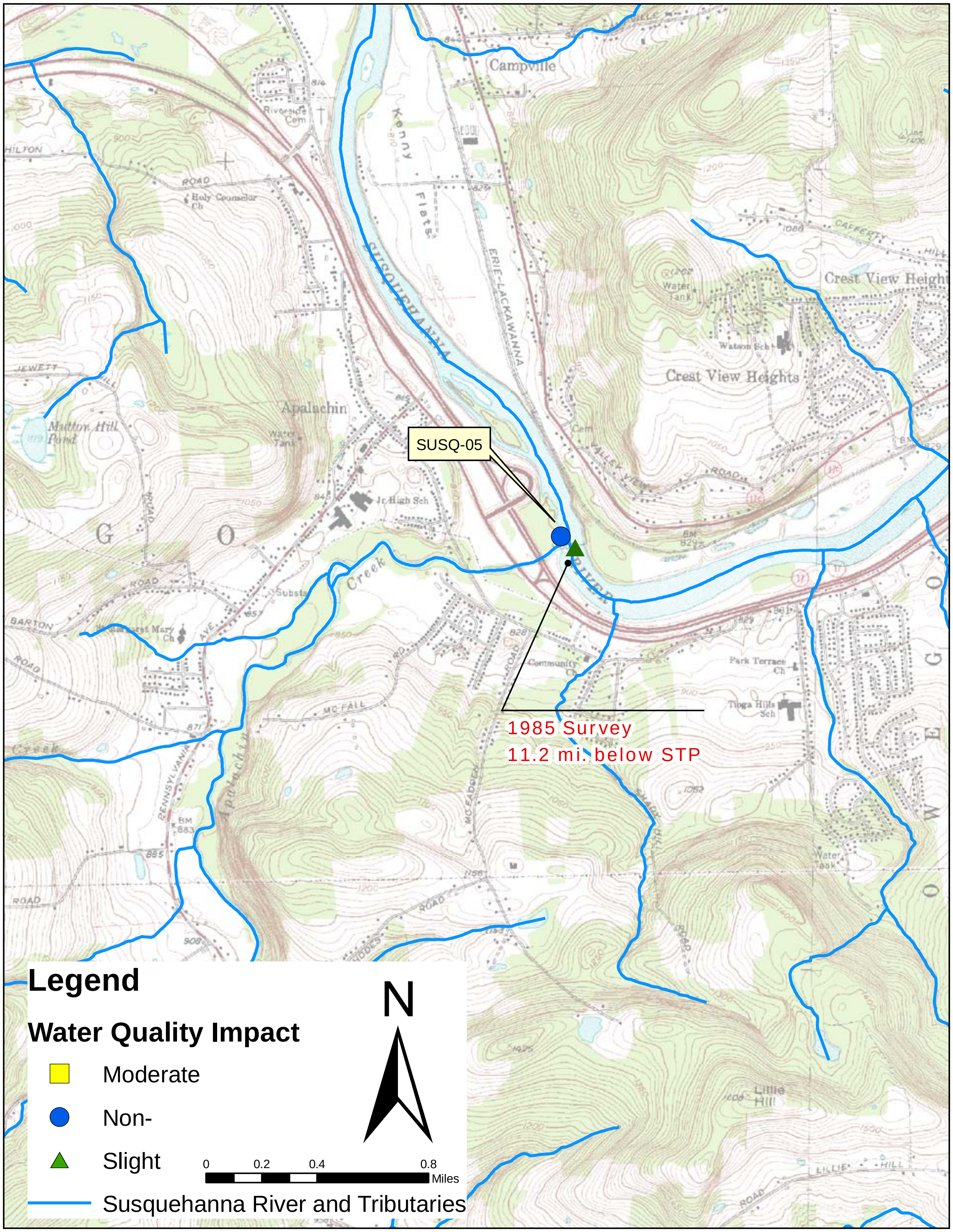


Table 1. Survey locations on Lower Susquehanna R. 2014

SUSQ-02B	Johnson City, NY		
	0.75 miles upstream of BJCSTP		
	Latitude:	42.093942	
	Longitude:	-75.947967	

SUSQ-03	Johnson City, NY		
	0.1 mile below BJCSTP		
	Latitude:	42.098848	
	Longitude:	-75.962625	
	*note outfall plume.		

SUSQ-03A	Johnson City, NY		
	1.2 miles below BJCSTP		
	Latitude:	42.111700	
	Longitude:	-75.980700	
	*note algal mats in foreground		

SUSQ-04A	Vestal, NY		
	6.9 miles below BJCSTP		
	Latitude:	42.08347	
	Longitude:	-76.074200	

Table 1 Cont'd. Survey locations on Lower Susquehanna River

SUSQ-04B	Vestal, NY 8.9 miles below BJCSTP Latitude: Longitude:	 42.072688 -76.100503
SUSQ-05	Apalachin, NY 11.9 miles below BJCSTP Latitude: Longitude:	 42.06417 -76.142500

Figures 3a and 3b. Photographic detail of substrate.

Figure 3a. Sewage fungus mat covering substrate - Station SUSQ-03; 0.1 mile downstream from Binghamton -Johnson City Sewage Treatment Plant

Figure 3b. Anoxic sludge -SUSQ-03

Figures 3c and 3d. Photographic detail of water column and substrate.

Figure 3c. Fungus flocculent in water column – SUSQ-03

Figure 3d. Algal growth on substrate at Station SUSQ-03A, 1.2 miles below BJCSTP

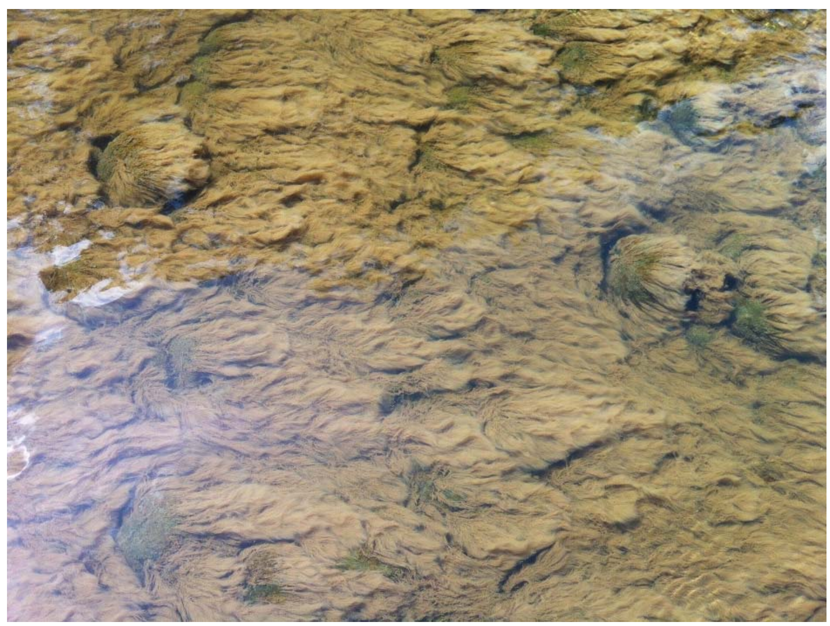


Figure 4. Biological Assessment Profile (BAP) of index values, Lower Susquehanna River, Binghamton –Johnson City to Apalachin 2014. Values are plotted on a normalized scale of water quality. The BAP represents the mean of the five values for each site, representing species richness (Spp), Ephemeroptera, Plecoptera, Trichoptera richness (EPT), Hilsenhoff's Biotic Index (HBI), Percent Model Affinity (PMA), and the Nutrient Biotic Index for phosphorus (NBI-P). See Appendix IV for a more complete explanation.

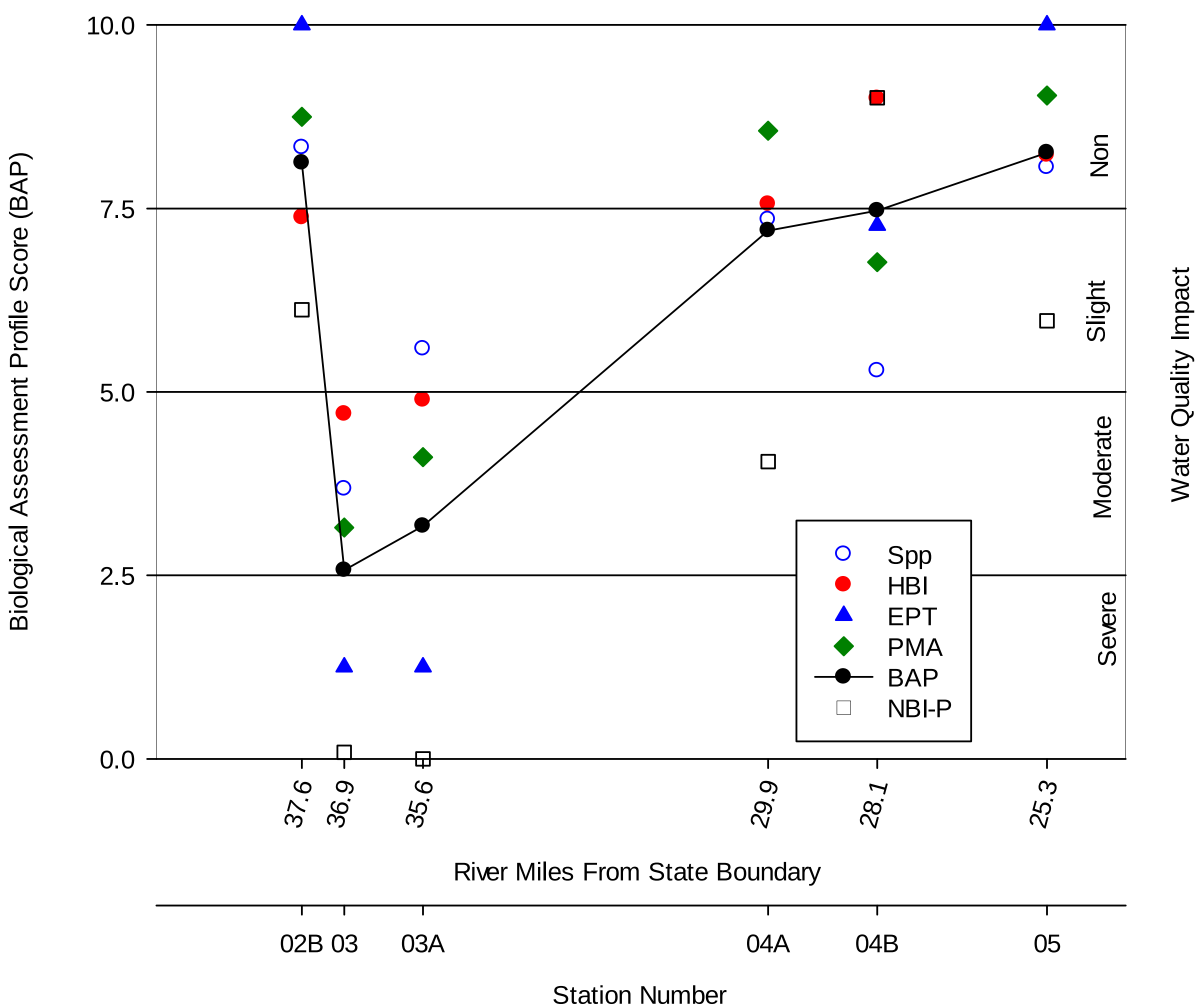


Table 2. Summary of Impact Source Determination (ISD) results for Lower Susquehanna River, 2014, impacted sites. Category abbreviations are Mun./Ind.= Municipal/Industrial sources, Non-point = Non-point source nutrient runoff, Sew./An. Wastes = Sewage effluent and animal waste sources. Further detail on ISD is found in Appendix X. Shaded values represent ≥50% similarity to ISD model communities indicating a significant result. Values ≤50% represent inconclusive results.

Station	Mun./Ind.	Non-point	Sew./An. Wastes	Siltation	Toxic
SUSQ-03	52	35	55	49	37
SUSQ-03A	54	36	52	40	40
SUSQ-04A	30	31	29	46	24
SUSQ-04B	20	23	22	37	16

Figure 5. Habitat assessment scores for each sampling location on Lower Susquehanna River, 2014.

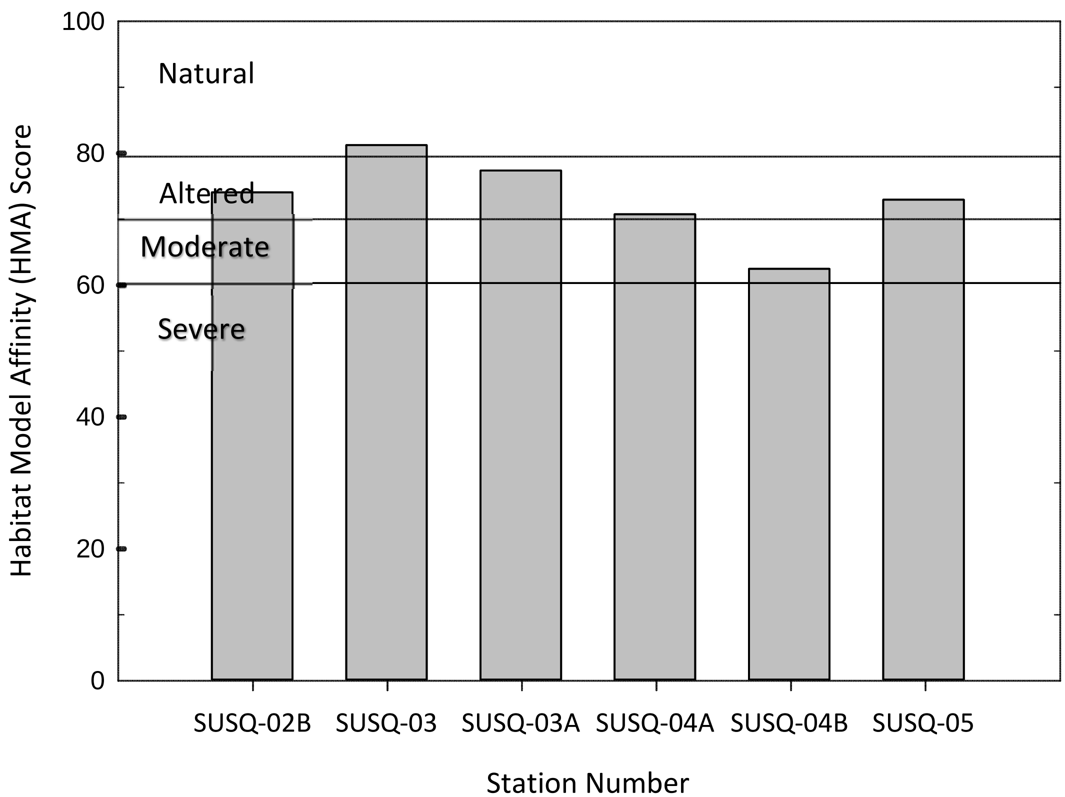


Table 3. Summary of habitat assessment attribute scores* used in calculating the Habitat Model Affinity (Figure 4) at locations on the Lower Susquehanna River, 2014.

Station	Epi. Cover	Embed.	Vel/Dep Reg.	Sed. Dep.	Flow Satus	Chan. Alt.	Rif. Freq.	Bank Stab.	Bank Veg.	Rip. Width
SUSQ-02B	14	14	19	12	19	15	15	9	8	9
SUSQ-03	16	16	18	10	19	16	18	13	13	8
SUSQ-03A	12	12	18	15	19	15	18	13	10	8
SUSQ-04A	16	16	15	9	19	18	7	8	8	12
SUSQ-04B	8	14	9	6	18	17	1	14	14	12
SUSQ-05	13	15	15	12	19	16	6	12	14	10

* The following attributes are ranked on a scale from 0 (poor) - 20 (optimal). Epi. Cover = Epifaunal substrate cover, Embed. = Embeddedness, Vel/Dep Reg. = Velocity Depth Regime, Sed. Dep. = Sediment Deposition, Flow Status = Channel Flow Status, Chan. Alt. = Channel Alteration, Rif. Freq. = Riffle Frequency, Bank Stab. = Bank Stability, Bank Veg. = Bank Vegetative Cover, Rip. Width = Riparian Corridor Width. Values of 10 or below are highlighted to identify those parameters ranked as marginal or poor.

Table 4. Summary of stream physical attributes measured at each sampling location on Lower Susquehanna River, Binghamton –Johnson City STP to Apalachin reach, 2014.

Station	Depth (m)	Width (m)	Current (cm/sec)	Embed. (%)	Temp. (°C)	Conduct. (µmhos)	pH	DO (mg/L)	DO Sat. (%)
SUSQ-02B	0.2	60	77	25	20	302	8.3	9.5	106
SUSQ-03	0.35	60	120	30	21	524	7.2	9.8	110
SUSQ-03A	0.25	80	70	40	22	319	7.7	8.2	93
SUSQ-04A	0.4	60	30	25	20	306	7.7	9.4	103
SUSQ-04B	0.3	60	20	30	21	310	7.8	9.3	104
SUSQ-05	0.2	80	70	30	25	261	8.5	13	162

Table 5. Macroinvertebrate species collected in Lower Susquehanna River, 2014.

Genus Species	Location – Station/River Mile					
	SUSQ-02B 37.6	SUSQ-03 36.9	SUSQ-03A 35.6	SUSQ-04A 29.9	SUSQ-04B 28.1	SUSQ-05 25.3
AMPHIPODA			1	8	4	
Gammarus sp.			1	8	4	
BASOMMATOPHORA			2			
Ferrissia sp.			2			
COLEOPTERA	14	10	5	12	7	24
Dineutus sp.				1		
Optioservus sp.		1				
Optioservus trivittatus	4			5	2	7
Psephenus herricki				1		
Stenelmis crenata	2				1	
Stenelmis sp.	8	9	5	5	4	17
DIPTERA	21	66	76	9	1	7
Antocha sp.	1		1			
Cardiocladius obscurus	2	5	2			1
Chironomus sp.		3	6	1		
Cricotopus bicinctus	4	11	14			
Cricotopus sp.	6					1
Cricotopus tremulus gr.		1				
Cricotopus trifascia gr.						1
Cricotopus vierriensis	4	3		1		
Cryptochironomus fulvus gr.			1			
Microtendipes pedellus gr.				4		
Orthocladius dubitatus	2					
Phaenopsectra dyari		21	17			
Polypedilum aviceps			1			
Polypedilum flavum	2	21	29	1	1	1
Polypedilum illinoense			1			
Rheotanytarsus exiguus gr.						1
Thienemannimyia gr. spp.		1	3	1		
Tvetenia sp.				1		
Tvetenia vitracies			1			2
EPHEMEROPTERA	26			39	80	44
Acentrella sp.	2				1	
Acerpenna sp.				2		
Anthopotamus sp.	13			1		
Baetis intercalaris	1			3	1	2
Caenis sp.						1
Isonychia sp.	2			6	18	14
Leucrocuta sp.	3			13	33	15
Maccaffertium mediopunctatum	1			9	12	2
Maccaffertium sp.	1					5
Maccaffertium terminatum				1	3	3
Plauditus sp.	2					2
Rhithrogena sp.	1			1		

Genus Species	Location – Station/River Mile					
	SUSQ-02B 37.6	SUSQ-03 36.9	SUSQ-03A 35.6	SUSQ-04A 29.9	SUSQ-04B 28.1	SUSQ-05 25.3
Stenacron sp.				1	5	
Undetermined *Caenidae*					1	
Undetermined *Heptageniidae*				2	6	
HOPLONEMERTEA			1			
Undetermined Nemertea			1			
LUMBRICULIDA	15					1
Undetermined Lumbriculidae	15					1
MEGALOPTERA					1	1
Nigronia serricornis						1
Sialis sp.					1	
MESOGASTROPODA			2			
Undetermined Valvatidae			2			
ODONATA				1		
Argia sp.				1		
PLECOPTERA						2
Agnetina capitata						1
Paragnetina media						1
RHYNCHOBDELLIDA						1
Undetermined Hirudinea						1
TRICHOPTERA	19	1	6	6	2	10
Ceraclea sp.	2					1
Ceratopsyche morosa	3					
Ceratopsyche slossonae	3					
Cheumatopsyche sp.	4		6	5	2	4
Chimarra obscura	1					1
Glossosoma sp.	4					
Hydropsyche phalerata	1					1
Hydropsyche sp.		1				
Protoptila sp.						3
Undetermined Hydropsychidae	1					
Undetermined Leptoceridae				1		
TRICLADIDA	5		1		1	1
Undetermined Turbellaria	5		1		1	1
TUBIFICIDA		21	6	1	2	
Limnodrilus sp.		1				
Undet. Tubificidae w/o cap. setae			1		2	
Undetermined Enchytraeidae				1		
Undetermined Naididae		20	5			
VENEROIDEA		2		24	2	9
Undetermined Pisidiidae		2		24	2	9

Appendix I. Biological Methods for Kick Sampling

A. Rationale: The use of the standardized kick sampling method provides a biological assessment technique that lends itself to rapid assessments of stream water quality.

B. Site Selection: Sampling sites are selected based on these criteria: (1) The sampling location should be a riffle with a substrate of rubble, gravel and sand; depth should be one meter or less, and current speed should be at least 0.4 meter per second. (2) The site should have comparable current speed, substrate type, embeddedness, and canopy cover to both upstream and downstream sites to the degree possible. (3) Sites are chosen to have a safe and convenient access.

C. Sampling: Macroinvertebrates are sampled using the standardized traveling kick method. An aquatic net is positioned in the water at arms' length downstream and the stream bottom is disturbed by foot, so that organisms are dislodged and carried into the net. Sampling is continued for a specified time and distance in the stream. Rapid assessment sampling specifies sampling for five minutes over a distance of five meters. The contents of the net are emptied into a pan of stream water. The contents are then examined, and the major groups of organisms are recorded, usually on the ordinal level (e.g., stoneflies, mayflies, caddisflies). Larger rocks, sticks, and plants may be removed from the sample if organisms are first removed from them. The contents of the pan are poured into a U.S. No. 30 sieve and transferred to a quart jar. The sample is then preserved by adding 95% ethyl alcohol.

D. Sample Sorting and Subsampling: In the laboratory, the sample is rinsed with tap water in a U.S. No. 40 standard sieve to remove any fine particles left in the residues from field sieving. The sample is transferred to an enamel pan and distributed homogeneously over the bottom of the pan. A small amount of the sample is randomly removed with a spatula, rinsed with water, and placed in a petri dish. This portion is examined under a dissecting stereomicroscope and 100 organisms are randomly removed from the debris. As they are removed, they are sorted into major groups, placed in vials containing 70 percent alcohol, and counted. The total number of organisms in the sample is estimated by weighing the residue from the picked subsample and determining its proportion of the total sample weight.

E. Organism Identification: All organisms are identified to the species level whenever possible. Chironomids and oligochaetes are slide-mounted and viewed through a compound microscope; most other organisms are identified as whole specimens using a dissecting stereomicroscope. The number of individuals in each species and the total number of individuals in the subsample are recorded on a data sheet. All organisms from the subsample are archived (either slide-mounted or preserved in alcohol). If the results of the identification process are ambiguous, suspected of being spurious, or do not yield a clear water quality assessment, additional subsampling may be required.

Appendix II. Macroinvertebrate Community Parameters

1. Species Richness: the total number of species or taxa found in a sample. For subsamples of 100-organisms each that are taken from kick samples, expected ranges in most New York State streams are: greater than 26, non-impacted; 19-26, slightly impacted; 11-18, moderately impacted, and less than 11, severely impacted.

2. EPT Richness: the total number of species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) found in an average 100-organisms subsample. These are considered to be clean-water organisms, and their presence is generally correlated with good water quality (Lenat, 1987). Expected assessment ranges from most New York State streams are: greater than 10, non-impacted; 6-10, slightly impacted; 2-5, moderately impacted, and 0-1, severely impacted.

3. Hilsenhoff Biotic Index: a measure of the tolerance of organisms in a sample to organic pollution (sewage effluent, animal wastes) and low dissolved oxygen levels. It is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals. On a 0-10 scale, tolerance values range from intolerant (0) to tolerant (10). For the purpose of characterizing species' tolerance, intolerant = 0-4, facultative = 5-7, and tolerant = 8-10. Tolerance values are listed in Hilsenhoff (1987). Additional values are assigned by the NYS Stream Biomonitoring Unit. The most recent values for each species are listed in Quality Assurance document, Bode et al. (2002). Impact ranges are: 0-4.50, non-impacted; 4.51-6.50, slightly impacted; 6.51-8.50, moderately impacted, and 8.51-10.00, severely impacted.

4. Percent Model Affinity: a measure of similarity to a model, non-impacted community based on percent abundance in seven major macroinvertebrate groups (Novak and Bode, 1992). Percentage abundances in the model community are: 40% Ephemeroptera; 5% Plecoptera; 10% Trichoptera; 10% Coleoptera; 20% Chironomidae; 5% Oligochaeta; and 10% Other. Impact ranges are: greater than 64, non-impacted; 50-64, slightly impacted; 35-49, moderately impacted, and less than 35, severely impacted.

5. Nutrient Biotic Index: a measure of stream nutrient enrichment identified by macroinvertebrate taxa. It is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals with assigned tolerance values. Tolerance values ranging from intolerant (0) to tolerant (10) are based on nutrient optima for Total Phosphorus (listed in Smith, 2005). Impact ranges are: 0-5.00, non-impacted; 5.01-6.00, slightly impacted; 6.01-7.00, moderately impacted, and 7.01-10.00, severely impacted.

Appendix III. Levels of Water Quality Impact in Streams

The description of overall stream water quality based on biological parameters uses a four-tiered system of classification. Level of impact is assessed for each individual parameter and then combined for all parameters to form a consensus determination. Four parameters are used: species richness, EPT richness, biotic index, and percent model affinity (see Appendix II). The consensus is based on the determination of the majority of the parameters. Since parameters measure different aspects of the macroinvertebrate community, they cannot be expected to always form unanimous assessments. The assessment ranges given for each parameter are based on subsamples of 100-organisms each that are taken from macroinvertebrate riffle kick samples. These assessments also apply to most multiplate samples, with the exception of percent model affinity.

1. *Non-impacted*: Indices reflect very good water quality. The macroinvertebrate community is diverse, usually with at least 27 species in riffle habitats. Mayflies, stoneflies, and caddisflies are well represented; EPT richness is greater than 10. The biotic index value is 4.50 or less. Percent model affinity is greater than 64. Nutrient Biotic Index is 5.00 or less. Water quality should not be limiting to fish survival or propagation. This level of water quality includes both pristine habitats and those receiving discharges which minimally alter the biota.

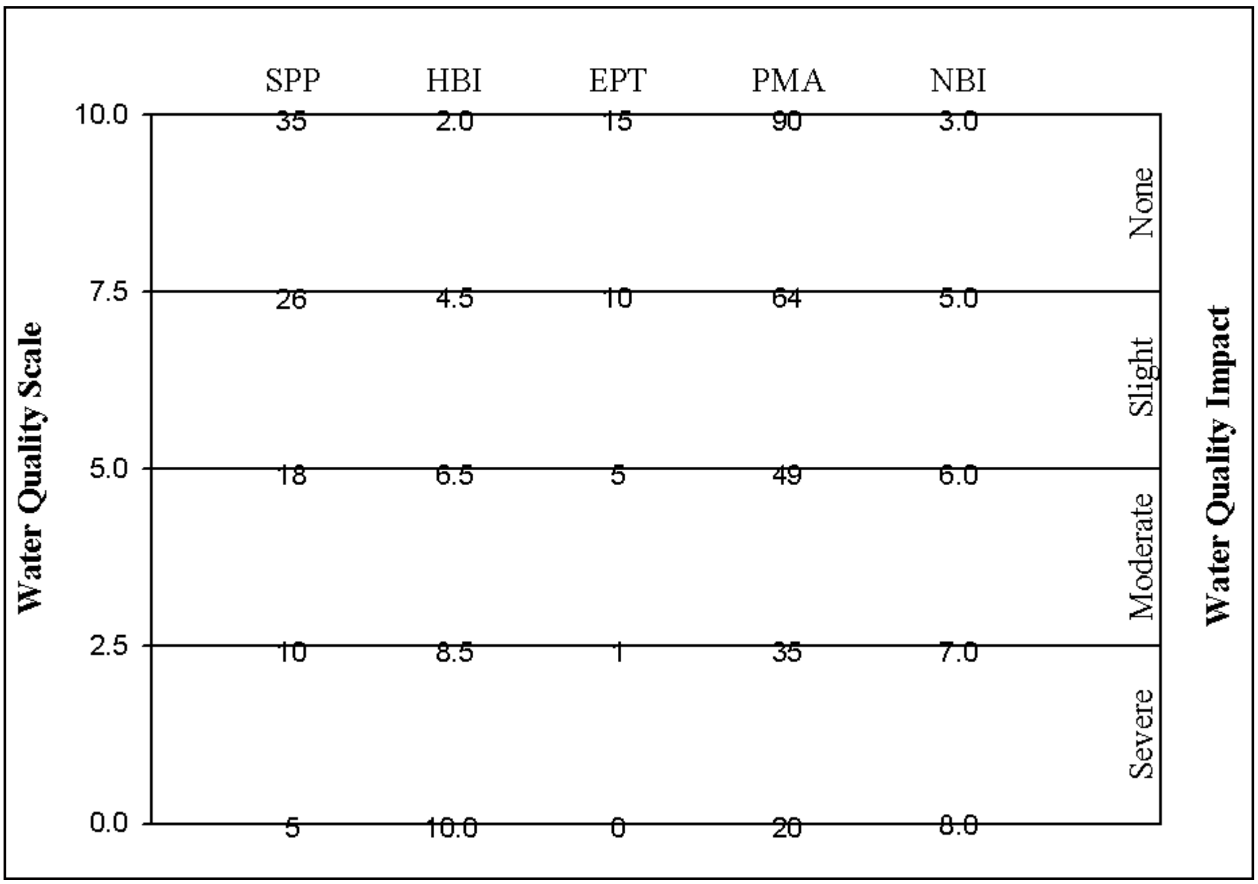
2. *Slightly impacted*: Indices reflect good water quality. The macroinvertebrate community is slightly but significantly altered from the pristine state. Species richness is usually 19-26. Mayflies and stoneflies may be restricted, with EPT richness values of 6-10. The biotic index value is 4.51-6.50. Percent model affinity is 50-64. Nutrient Biotic Index is 5.01-6.00. Water quality is usually not limiting to fish survival, but may be limiting to fish propagation.

3. *Moderately impacted*: Indices reflect poor water quality. The macroinvertebrate community is altered to a large degree from the pristine state. Species richness is usually 11-18 species. Mayflies and stoneflies are rare or absent, and caddisflies are often restricted; the EPT richness is 2-5. The biotic index value is 6.51-8.50. Percent model affinity is 35-49. Nutrient Biotic Index is 6.01-7.00. Water quality often is limiting to fish propagation, but usually not to fish survival.

4. *Severely impacted*: Indices reflect very poor water quality. The macroinvertebrate community is limited to a few tolerant species. Species richness is 10 or fewer. Mayflies, stoneflies and caddisflies are rare or absent; EPT richness is 0-1. The biotic index value is greater than 8.50. Percent model affinity is less than 35. Nutrient Biotic Index is greater than 7.00. The dominant species are almost all tolerant, and are usually midges and worms. Often, 1-2 species are very abundant. Water quality is often limiting to both fish propagation and fish survival.

Appendix IV-A. Biological Assessment Profile: Conversion of Index Values to a 10-Scale

The Biological Assessment Profile (BAP) of index values, developed by Phil O'Brien, Division of Water, NYSDEC, is a method of plotting biological index values on a common scale of water quality impact. Values from the five indices -- species richness (SPP), EPT richness (EPT), Hilsenhoff Biotic Index (HBI), Percent Model Affinity (PMA), and Nutrient Biotic Index (NBI)-- defined in Appendix II are converted to a common 0-10 scale using the formulae in the Quality Assurance document (Bode, et al., 2002), and as shown in the figure below.



Appendix IV-B. Biological Assessment Profile: Plotting Values

To plot survey data:
1. Position each site on the x-axis according to miles or tenths of a mile upstream of the mouth.
2. Plot the values of the four indices for each site as indicated by the common scale.
3. Calculate the mean of the four values and plot the result. This represents the assessed impact for each site.

Example data:

	Station 1		Station 2	
	metric value	10-scale value	metric value	10-scale value
Species richness	20	5.59	33	9.44
Hilsenhoff Biotic Index	5.00	7.40	4.00	8.00
EPT richness	9	6.80	13	9.00
Percent Model Affinity	55	5.97	65	7.60
Nutrient Biotic Index	6.0	5.0	6.0	5.0
Average		6.152 (slight)		7.8 (non-)

Appendix V. Water Quality Assessment Criteria

Non-Navigable Flowing Waters

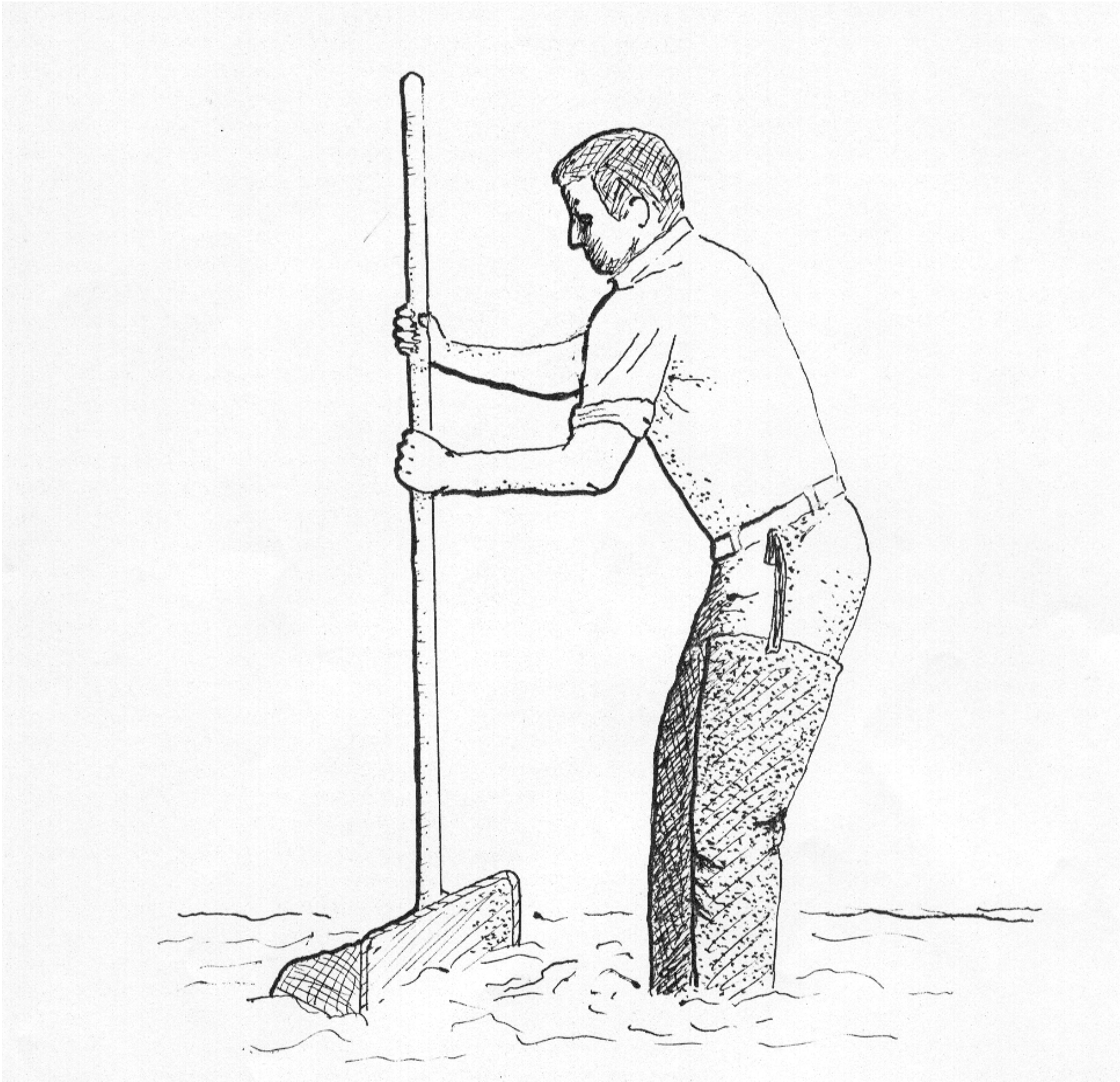
	Species Richness	Hilsenhoff Biotic Index	EPT Value	Percent Model Affinity*	Nutrient Biotic Index
Non-Impacted	>26	0.00-4.50	>10	>64	<5.00
Slightly Impacted	19-26	4.51-6.50	6-10	50-64	5.01-6.00
Moderately Impacted	11-18	6.51-8.50	2-5	35-49	6.01-7.00
Severely Impacted	0-10	8.51-10.00	0-1	<35	>7.01

* Percent model affinity criteria used for traveling kick samples but not for multiplate samples.

Navigable Flowing Waters

	Species Richness	Hilsenhoff Biotic Index	EPT Richness	Species Diversity
Non-Impacted	>21	0.00-7.00	>5	>3.00
Slightly Impacted	17-21	7.01-8.00	4-5	2.51-3.00
Moderately Impacted	12-16	8.01-9.00	2-3	2.01-2.50
Severely Impacted	0-11	9.01-10.00	0-1	0.00-2.00

Appendix VI. The Traveling Kick Sample



Rocks and sediment in a riffle are dislodged by foot upstream of a net. Dislodged organisms are

←current

carried by the current into the net. Sampling continues for five minutes, as the sampler gradually moves downstream to cover a distance of five meters

Appendix VII-A. Aquatic Macroinvertebrates Usually Indicative of Good Water Quality

Mayfly nymphs are often the most numerous organisms found in clean streams. They are sensitive to most types of pollution, including low dissolved oxygen (less than 5 ppm), chlorine, ammonia, metals, pesticides, and acidity. Most mayflies are found clinging to the undersides of rocks.

MAYFLIES

Stonefly nymphs are mostly limited to cool, well-oxygenated streams. They are sensitive to most of the same pollutants as mayflies, except acidity. They are usually much less numerous than mayflies. The presence of even a few stoneflies in a stream suggests that good water quality has been maintained for several months.

STONEFLIES

Caddisfly larvae often build a portable case of sand, stones, sticks, or other debris. Many caddisfly larvae are sensitive to pollution, although a few are tolerant. One family spins nets to catch drifting plankton, and is often numerous in nutrient-enriched stream segments.

CADDISFLIES

The most common beetles in streams are riffle beetles (adult and larva pictured) and water pennies (not shown). Most of these require a swift current and an adequate supply of oxygen, and are generally considered clean-water indicators.

BEETLES

Appendix VII-B. Aquatic Macroinvertebrates Usually Indicative of Poor Water Quality

Midges are the most common aquatic flies. The larvae occur in almost any aquatic situation. Many species are very tolerant to pollution. Large, red midge larvae called "bloodworms" indicate organic enrichment. Other midge larvae filter plankton, indicating nutrient enrichment when numerous.

MIDGES

Black fly larvae have specialized structures for filtering plankton and bacteria from the water, and require a strong current. Some species are tolerant of organic enrichment and toxic contaminants, while others are intolerant of pollutants.

BLACK FLIES

The segmented worms include the leeches and the small aquatic worms. The latter are usually unnoticed. They burrow in the substrate and feed on bacteria in the sediment. They can thrive under conditions of severe pollution and very low oxygen levels, and are thus valuable pollution indicators. Many leeches are also tolerant of poor water quality.

more common, though

WORMS

Aquatic sowbugs are crustaceans that are often numerous in situations of high organic content and low oxygen levels. They are classic indicators of sewage pollution, and can also thrive in toxic situations.

Digital images by Larry Abele, New York State Department of Environmental Conservation, Stream Biomonitoring Unit.

SOWBUGS

Appendix VIII. The Rationale of Biological Monitoring

Biological monitoring refers to the use of resident benthic macroinvertebrate communities as indicators of water quality. Macroinvertebrates are larger-than-microscopic invertebrate animals that inhabit aquatic habitats; freshwater forms are primarily aquatic insects, worms, clams, snails, and crustaceans.

Concept:
Nearly all streams are inhabited by a community of benthic macroinvertebrates. The species comprising the community each occupy a distinct niche defined and limited by a set of environmental requirements. The composition of the macroinvertebrate community is thus determined by many factors, including habitat, food source, flow regime, temperature, and water quality. The community is presumed to be controlled primarily by water quality if the other factors are determined to be constant or optimal. Community components which can change with water quality include species richness, diversity, balance, abundance, and presence/absence of tolerant or intolerant species. Various indices or metrics are used to measure these community changes. Assessments of water quality are based on metric values of the community, compared to expected metric values.

Advantages:
The primary advantages to using macroinvertebrates as water quality indicators are that they:

- are sensitive to environmental impacts
- are less mobile than fish, and thus cannot avoid discharges
- can indicate effects of spills, intermittent discharges, and lapses in treatment
- are indicators of overall, integrated water quality, including synergistic effects
- are abundant in most streams and are relatively easy and inexpensive to sample
- are able to detect non-chemical impacts to the habitat, e.g. siltation or thermal changes
- are vital components of the aquatic ecosystem and important as a food source for fish
- are more readily perceived by the public as tangible indicators of water quality
- can often provide an on-site estimate of water quality
- can often be used to identify specific stresses or sources of impairment
- can be preserved and archived for decades, allowing for direct comparison of specimens
- bioaccumulate many contaminants, so that analysis of their tissues is a good monitor of toxic substances in the aquatic food chain

Limitations:
Biological monitoring is not intended to replace chemical sampling, toxicity testing, or fish surveys. Each of these measurements provides information not contained in the others. Similarly, assessments based on biological sampling should not be taken as being representative of chemical sampling. Some substances may be present in levels exceeding ambient water quality criteria, yet have no apparent adverse community impact.

Appendix IX. Glossary

Anthropogenic: caused by human actions

Assessment: a diagnosis or evaluation of water quality

Benthos: organisms occurring on or in the bottom substrate of a waterbody

Bioaccumulate: accumulate contaminants in the tissues of an organism

Biomonitoring: the use of biological indicators to measure water quality

Community: a group of populations of organisms interacting in a habitat

Drainage basin: an area in which all water drains to a particular waterbody; watershed

Electrofishing: sampling fish by using electric currents to temporarily immobilize them, allowing capture

EPT richness: the number of taxa of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) in a sample or subsample

Eutrophic: high nutrient levels normally leading to excessive biological productivity

Facultative: occurring over a wide range of water quality; neither tolerant nor intolerant of poor water quality

Fauna: the animal life of a particular habitat

Impact: a change in the physical, chemical, or biological condition of a waterbody

Impairment: a detrimental effect caused by an impact

Index: a number, metric, or parameter derived from sample data used as a measure of water quality

Intolerant: unable to survive poor water quality

Longitudinal trends: upstream-downstream changes in water quality in a river or stream

Macroinvertebrate: a larger-than-microscopic invertebrate animal that lives at least part of its life in aquatic habitats

Mesotrophic: intermediate nutrient levels (between oligotrophic and eutrophic) normally leading to moderate biological productivity

Multiplate: multiple-plate sampler, a type of artificial substrate sampler of aquatic macroinvertebrates

Non Chironomidae/Oligochaeta (NCO) richness: the number of taxa neither belonging to the family Chironomidae nor the subclass Oligochaeta in a sample or subsample

Oligotrophic: low nutrient levels normally leading to unproductive biological conditions

Organism: a living individual

PAHs: Polycyclic Aromatic Hydrocarbons, a class of organic compounds that are often toxic or carcinogenic.

Rapid bioassessment: a biological diagnosis of water quality using field and laboratory analysis designed to allow assessment of water quality in a short turn-around time; usually involves kick sampling and laboratory subsampling of the sample

Riffle: wadeable stretch of stream usually with a rubble bottom and sufficient current to have the water surface broken by the flow; rapids

Species richness: the number of macroinvertebrate taxa in a sample or subsample

Station: a sampling site on a waterbody

Survey: a set of samplings conducted in succession along a stretch of stream

Synergistic effect: an effect produced by the combination of two factors that is greater than the sum of the two factors

Tolerant: able to survive poor water quality

Trophic: referring to productivity

Appendix X. Impact Source Determination Methods and Community Models

Definition: Impact Source Determination (ISD) is the procedure for identifying types of impacts that exert deleterious effects on a waterbody. While the analysis of benthic macroinvertebrate communities has been shown to be an effective means of determining severity of water quality impacts, it has been less effective in determining what kind of pollution is causing the impact. ISD uses community types or models to ascertain the primary factor influencing the fauna.

Development of methods: The method found to be most useful in differentiating impacts in New York State streams was the use of community types based on composition by family and genus. It may be seen as an elaboration of Percent Model Affinity (Novak and Bode, 1992), which is based on class and order. A large database of macroinvertebrate data was required to develop ISD methods. The database included several sites known or presumed to be impacted by specific impact types. The impact types were mostly known by chemical data or land use. These sites were grouped into the following general categories: agricultural nonpoint, toxic-stressed, sewage (domestic municipal), sewage/toxic, siltation, and impoundment. Each group initially contained 20 sites. Cluster analysis was then performed within each group, using percent similarity at the family or genus level. Within each group, four clusters were identified. Each cluster was usually composed of 4-5 sites with high biological similarity. From each cluster, a hypothetical model was then formed to represent a model cluster community type; sites within the cluster had at least 50 percent similarity to this model. These community type models formed the basis for ISD (see tables following). The method was tested by calculating percent similarity to all the models and determining which model was the most similar to the test site. Some models were initially adjusted to achieve maximum representation of the impact type. New models are developed when similar communities are recognized from several streams.

Use of the ISD methods: Impact Source Determination is based on similarity to existing models of community types (see tables following). The model that exhibits the highest similarity to the test data denotes the likely impact source type. In the graphic representation of ISD, only the highest similarity of each source type is identified. If no model exhibits a similarity to the test data of greater than 50 percent, the determination is inconclusive. The determination of impact source type is used in conjunction with assessment of severity of water quality impact to provide an overall assessment of water quality.

Limitations: These methods were developed for data derived from subsamples of 100-organisms each that are taken from traveling kick samples of New York State streams. Application of these methods for data derived from other sampling methods, habitats, or geographical areas would likely require modification of the models.

NONPOINT NUTRIENTS, PESTICIDES

	A	B	C	D	E	F	G	H	I	J
PLATYHELMINTHES	-	-	-	-	-	-	-	-	-	-
OLIGOCHAETA	-	-	-	5	-	-	-	-	-	15
HIRUDINEA	-	-	-	-	-	-	-	-	-	-
GASTROPODA	-	-	-	-	-	-	-	-	-	-
SPHAERIIDAE	-	-	-	5	-	-	-	-	-	-
ASELLIDAE	-	-	-	-	-	-	-	-	-	-
GAMMARIDAE	-	-	-	5	-	-	-	-	-	-
Isonychia	-	-	-	-	-	-	-	5	-	-
BAETIDAE	5	15	20	5	20	10	10	5	10	5
HEPTAGENIIDAE	-	-	-	-	5	5	5	5	-	5
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE	-	-	-	-	-	-	-	5	-	-
Caenis/Tricorythodes	-	-	-	-	5	-	-	5	-	5
PLECOPTERA	-	-	-	-	-	-	-	-	-	-
Psephenus	5	-	-	5	-	5	5	-	-	-
Optioservus	10	-	-	5	-	-	15	5	-	5
Promoresia	-	-	-	-	-	-	-	-	-	-
Stenelmis	15	15	-	10	15	5	25	5	10	5
PHILOPOTAMIDAE	15	5	10	5	-	25	5	-	-	-
HYDROPSYCHIDAE	15	15	15	25	10	35	20	45	20	10
HELICOPSYCHIDAE/ BRACHYCENTRIDAE/ RHYACOPHILIDAE	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE	5	-	15	5	5	-	-	-	40	-
Simulium vittatum	-	-	-	-	-	-	-	-	5	-
EMPIDIDAE	-	-	-	-	-	-	-	-	-	-
TIPULIDAE	-	-	-	-	-	-	-	-	-	5
CHIRONOMIDAE										
Tanypodinae	-	-	-	-	-	-	5	-	-	5
Cardiocladius	-	-	-	-	-	-	-	-	-	-
Cricotopus/ Orthocladius	10	15	10	5	-	-	-	-	5	5
Eukiefferiella/ Tvetenia	-	15	10	5	-	-	-	-	5	-
Parametriocnemus	-	-	-	-	-	-	-	-	-	-
Microtendipes	-	-	-	-	-	-	-	-	-	20
Polypedilum aviceps	-	-	-	-	-	-	-	-	-	-
Polypedilum (all others)	10	10	10	10	20	10	5	10	5	5
Tanytarsini	10	10	10	5	20	5	5	10	-	10
TOTAL	100	100	100	100	100	100	100	100	100	100

ISD Models (cont'd)

	MUNICIPAL/INDUSTRIAL								TOXIC					
	A	B	C	D	E	F	G	H	A	B	C	D	E	F
PLATYHELMINTHES	-	40	-	-	-	5	-	-	-	-	-	-	5	-
OLIGOCHAETA	20	20	70	10	-	20	-	-	-	10	20	5	5	15
HIRUDINEA	-	5	-	-	-	-	-	-	-	-	-	-	-	-
GASTROPODA	-	-	-	-	-	5	-	-	-	5	-	-	-	5
SPHAERIIDAE	-	5	-	-	-	-	-	-	-	-	-	-	-	-
ASELLIDAE	10	5	10	10	15	5	-	-	10	10	-	20	10	5
GAMMARIDAE	40	-	-	-	15	-	5	5	5	-	-	-	5	5
Isonychia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BAETIDAE	5	-	-	-	5	-	10	10	15	10	20	-	-	5
HEPTAGENIIDAE	5	-	-	-	-	-	-	-	-	-	-	-	-	-
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caenis/Tricorythodes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PLECOPTERA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psephenus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Optioservus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Promoresia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenelmis	5	-	-	10	5	-	5	5	10	15	-	40	35	5
PHILOPOTAMIDAE	-	-	-	-	-	-	-	40	10	-	-	-	-	-
HYDROPSYCHIDAE	10	-	-	50	20	-	40	20	20	10	15	10	35	10
HELICOPSYCHIDAE/														
BRACHYCENTRIDAE/														
RHYACOPHILIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simulium vittatum	-	-	-	-	-	-	20	10	-	20	-	-	-	5
EMPIDIDAE	-	5	-	-	-	-	-	-	-	-	-	-	-	-
CHIRONOMIDAE														
Tanypodinae	-	10	-	-	5	15	-	-	5	10	-	-	-	25
Cardiocladius	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cricotopus/														
Orthocladius	5	10	20	-	5	10	5	5	15	10	25	10	5	10
Eukiefferiella/														
Tvetenia	-	-	-	-	-	-	-	-	-	-	20	10	-	-
Parametriocnemus	-	-	-	-	-	-	-	-	-	-	-	5	-	-
Chironomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum aviceps	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum (all others)	-	-	-	10	20	40	10	5	10	-	-	-	-	5
Tanytarsini	-	-	-	10	10	-	5	-	-	-	-	-	-	5
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100

ISD Models (cont'd)

	SEWAGE EFFLUENT, ANIMAL WASTES									
	A	B	C	D	E	F	G	H	I	J
PLATYHELMINTHES	-	-	-	-	-	-	-	-	-	-
OLIGOCHAETA	5	35	15	10	10	35	40	10	20	15
HIRUDINEA	-	-	-	-	-	-	-	-	-	-
GASTROPODA	-	-	-	-	-	-	-	-	-	-
SPHAERIIDAE	-	-	-	10	-	-	-	-	-	-
ASELLIDAE	5	10	-	10	10	10	10	50	-	5
GAMMARIDAE	-	-	-	-	-	10	-	10	-	-
Isonychia	-	-	-	-	-	-	-	-	-	-
BAETIDAE	-	10	10	5	-	-	-	-	5	-
HEPTAGENIIDAE	10	10	10	-	-	-	-	-	-	-
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE	-	-	-	-	-	-	-	-	5	-
Caenis/Tricorythodes	-	-	-	-	-	-	-	-	-	-
PLECOPTERA	-	-	-	-	-	-	-	-	-	-
Psephenus	-	-	-	-	-	-	-	-	-	-
Optioservus	-	-	-	-	-	-	-	-	5	-
Promoresia	-	-	-	-	-	-	-	-	-	-
Stenelmis	15	-	10	10	-	-	-	-	-	-
PHILOPOTAMIDAE	-	-	-	-	-	-	-	-	-	-
HYDROPSYCHIDAE	45	-	10	10	10	-	-	10	5	-
HELICOPSYCHIDAE/ BRACHYCENTRIDAE/ RHYACOPHILIDAE	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE	-	-	-	-	-	-	-	-	-	-
Simulium vittatum	-	-	-	25	10	35	-	-	5	5
EMPIDIDAE	-	-	-	-	-	-	-	-	-	-
CHIRONOMIDAE										
Tanypodinae	-	5	-	-	-	-	-	-	5	5
Cardiocladius	-	-	-	-	-	-	-	-	-	-
Cricotopus/ Orthocladius	-	10	15	-	-	10	10	-	5	5
Eukiefferiella/ Tvetenia	-	-	10	-	-	-	-	-	-	-
Parametriocnemus	-	-	-	-	-	-	-	-	-	-
Chironomus	-	-	-	-	-	-	10	-	-	60
Polypedilum aviceps	-	-	-	-	-	-	-	-	-	-
Polypedilum (all others)	10	10	10	10	60	-	30	10	5	5
Tanytarsini	10	10	10	10	-	-	-	10	40	-
TOTAL	100	100	100	100	100	100	100	100	100	100

ISD Models (cont'd)

	SILTATION				
	A	B	C	D	E
PLATYHELMINTHES	-	-	-	-	-
OLIGOCHAETA	5	-	20	10	5
HIRUDINEA	-	-	-	-	-
GASTROPODA	-	-	-	-	-
SPHAERIIDAE	-	-	-	5	-
ASELLIDAE	-	-	-	-	-
GAMMARIDAE	-	-	-	10	-
Isonychia	-	-	-	-	-
BAETIDAE	-	10	20	5	-
HEPTAGENIIDAE	5	10	-	20	5
LEPTOPHLEBIIDAE	-	-	-	-	-
EPHEMERELLIDAE	-	-	-	-	-
Caenis/Tricorythodes	5	20	10	5	15
PLECOPTERA	-	-	-	-	-
Psephenus	-	-	-	-	-
Optioservus	5	10	-	-	-
Promoresia	-	-	-	-	-
Stenelmis	5	10	10	5	20
PHILOPOTAMIDAE	-	-	-	-	-
HYDROPSYCHIDAE	25	10	-	20	30
HELICOPSYCHIDAE/ BRACHYCENTRIDAE/ RHYACOPHILIDAE	-	-	-	-	-
SIMULIIDAE	5	10	-	-	5
EMPIDIDAE	-	-	-	-	-
CHIRONOMIDAE					
Tanypodinae	-	-	-	-	-
Cardiocladius	-	-	-	-	-
Cricotopus/ Orthocladius	25	-	10	5	5
Eukiefferiella/ Tvetenia	-	-	10	-	5
Parametriocnemus	-	-	-	-	-
Chironomus	-	-	-	-	-
Polypedilum aviceps	-	-	-	-	-
Polypedilum (all others)	10	10	10	5	5
Tanytarsini	10	10	10	10	5
TOTAL	100	100	100	100	100