New York State
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Water

Peekskill Hollow Creek

Biological Assessment

2005 Survey

New York State
Department of Environmental Conservation

George E. Pataki, Governor   Denise M. Sheehan, Commissioner

Peekskill Hollow Creek
BIOLOGICAL ASSESSMENT

Lower Hudson River Basin
Putnam and Westchester Counties, New York

Survey date: July 21, 2005
Report date: December 21, 2005

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CONTENTS

Stream: Peekskill Hollow Creek, Putnam and Westchester Counties, New York

Reach: Carmel Township to Van Cortlandtville, New York

Drainage basin: Lower Hudson River

Background:

The Stream Biomonitoring Unit sampled Peekskill Hollow Creek on July 21, 2005. The purpose of the sampling was to assess overall water quality and determine if any long-term effects were present from an oil spill that occurred in February, 2005. One traveling kick sample for macroinvertebrates per sample site was taken in a riffle area at six sites using methods described in the Quality Assurance document (Bode, et al., 2002) and summarized in Appendix 1. The contents of each sample were field-inspected to determine major groups of organisms present, and then preserved in alcohol for laboratory inspection of a 100-specilnen subsample from each site. Macroinvertebrate community parameters used in the determination of water quality included species richness, biotic index, EPT richness, and percent model affinity (see Appendices II and III). Expected variability of results is stated in Smith and Bode (2004). Table 2 provides a listing of sampling sites and Table 3 provides a listing of all macroinvertebrate species collected in the present survey. This is followed by macroinvertebrate data reports, including raw macroinvertebrate data from each site.

Results and Conclusions:

1. Water quality in the Peekskill Hollow Creek was assessed as non-impacted at all sites, indicating very good water quality. No impacts were found that could be attributed to the oil spill.

2. Nutrient enrichment is indicated in the creek, and should be monitored in the future.

Discussion

Peekskill Hollow Creek originates as the outflow of Lake Tibet in the Carmel Township in Putnam County, New York. It flows in a generally southwesterly direction for approximately 17 miles before joining Sprout Creek and then Annsville Creek, which enters the Hudson River at Peekskill. The drainage area is 47.4 square miles. The creek is classified as SC from the mouth to 0.8 miles upstream of the mouth, B from 0.8 miles above the mouth to the dam at Van Cortlandtville, A (TS) from the Van Cortlandtville dam to Tributary 6 south of Lake Peekskill, and C (TS) from Tributary 6 to the source. Peekskill Hollow Creek was previously sampled by the Stream Biomonitoring Unit at Station 6 in 1998, when it was assessed as slightly impacted (Bode et al., 2004).

The present sampling was in response to a spill that occurred on upper Peekskill Hollow Creek on February 18, 2005. Approximately 2500 gallons of home heating oil were released into the creek approximately 1.5 miles upstream of the Taconic State Parkway. The July sampling was conducted to determine recovery from the spill, and to document any remaining long-term effects in the macroinvertebrate communities.

In the present survey, water quality was assessed as non-impacted at all sites, reflecting very good water quality. No impacts were found that could be attributed to the oil spill. Comparison between the site upstream of the spill (Station-I) and the site downstream of the spill (Station-2) was limited somewhat by habitat differences between the sites. Station-1 had a larger proportion of sand in the substrate than Station-2, and the macroinvertebrate community was dominated by midges. The substrate at Station-2 was a heterogeneous mix of rubble, gravel and sand, and the macroinvertebrate community was dominated by clean-water mayflies. Community composition at this site had a very high similarity (91%) to the model community used in Percent Model Affinity analysis (Appendix II). Although a slight oil smell was detected in the substrate at this site, the health of macroinvertebrate community indicated a lack of residual oil impacts.

A new macroinvertebrate measure of nutrient enrichment, the Nutrient Biotic Index (NBI), was recently developed by Smith (2005), and is detailed in Appendix XII. Similar to the Hilsenhoff Biotic Index, it is based on assigned tolerance values for each species on a 0-10 scale, where 0 is low tolerance and 10 is high. Indices were developed for total phosphorus (NBI-P) and nitrate (NBI-N); values for these indices appear in Table 1. Using 6.0 as the lower limit for eutrophic waters, this limit is exceeded at Stations-I, -2, and -4 in Peekskill Hollow Creek. Impact Source Determination (Table 2) also show nutrients to be an influencing factor in the creek. Nutrient enrichment should be a factor of concern in future monitoring of Peekskill Hollow Creek.

Table 1. Peekskill Hollow Creek NBI Values.

	PEEK-01	PEEK-02	PEEK-03	PEEK-04	PEEK-05	PEEK-06
NBI-P	6.10	6.39	5.30	6.14	4.60	5.54
NBI-N	6.57	6.33	5.07	6.06	4.64	5.60

Literature Cited:

Bode, R.W., M.A. Novak, L.E. Abele, D.L. Heitzman and A.J. Smith, 2002, Quality assurance work plan for biological stream monitoring in New York State. New York State Department of Environmental Conservation, Technical Report, 115 pages.

Bode, R.W., M.A. Novak, L.E. Abele, D.L. Heitzman and A.J. Smith, 2004, 30 year trends in water quality of rivers and streams in New York State. New York State Department of Environmental Conservation, Technical Report, 384 pages.

Smith, A.J. and R.W. Bode, 2004, Analysis of variability in New York State benthic macroinvertebrate samples. New York State Department of Environmental Conservation, Technical Report, 43 pages.

Smith, A.J., 2005, Developn1ent of a Nutrient Biotic Index for use with benthic macroinvertebrates. Masters Thesis, SUNY Albany, 70 pages.

Overview of field data

Based on the July 21sampling, Peekskill Hollow Creek at the sites sampled was 2-15 meters wide, 0.1-0.2 meters deep, and had current speeds of 50-120 cm/sec in riffles. Dissolved oxygen was 8.3 - 9.2mg/l, specific conductance was 251-449 µmhos, pH was 6.3-6.9 and the temperature was 19.9 - 24.7°C (68-76 °F). Measurements for each site are found on the field data summary sheets.

Figure 1. Biological Assessment Profile of index values, Peekskill Hollow, 2005. Values are plotted on a normalized scale of water quality. The line connects the mean of the four values for each site, representing species richness, EPT richness, Hilsenhoff Biotic Index, and Percent Model Affinity. See Appendix IV for a more complete explanation.

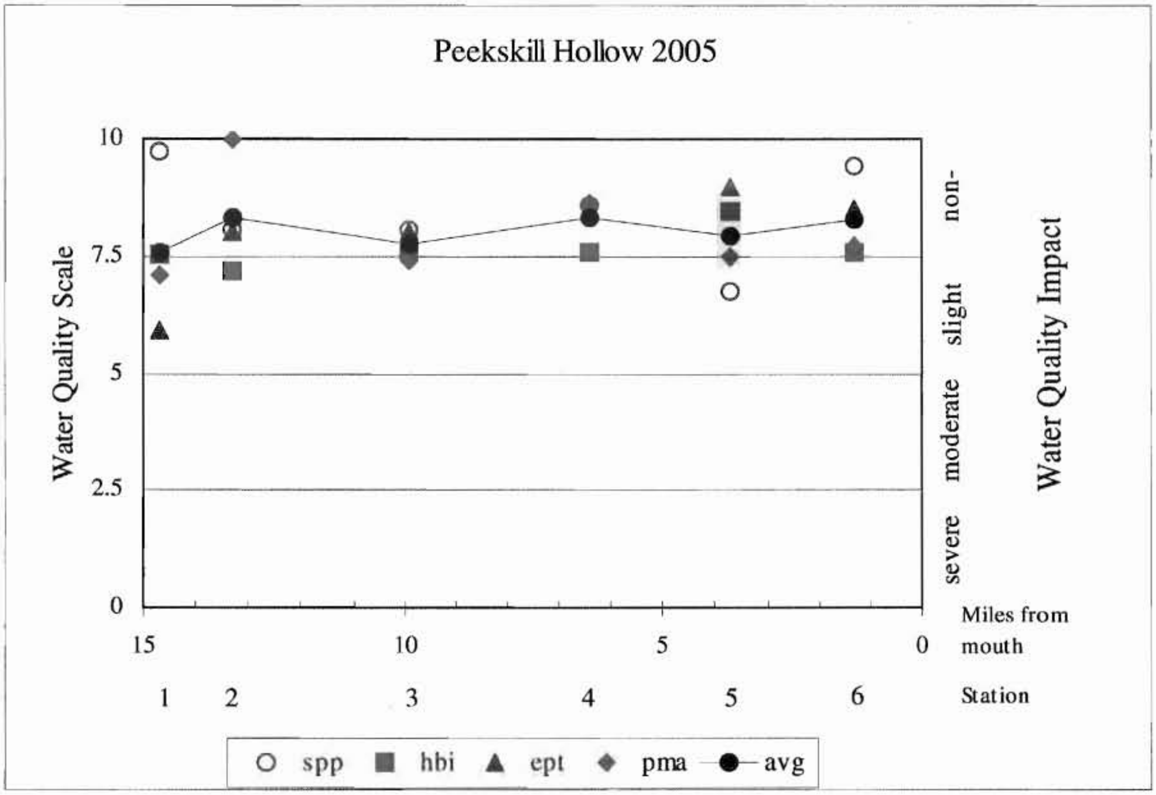
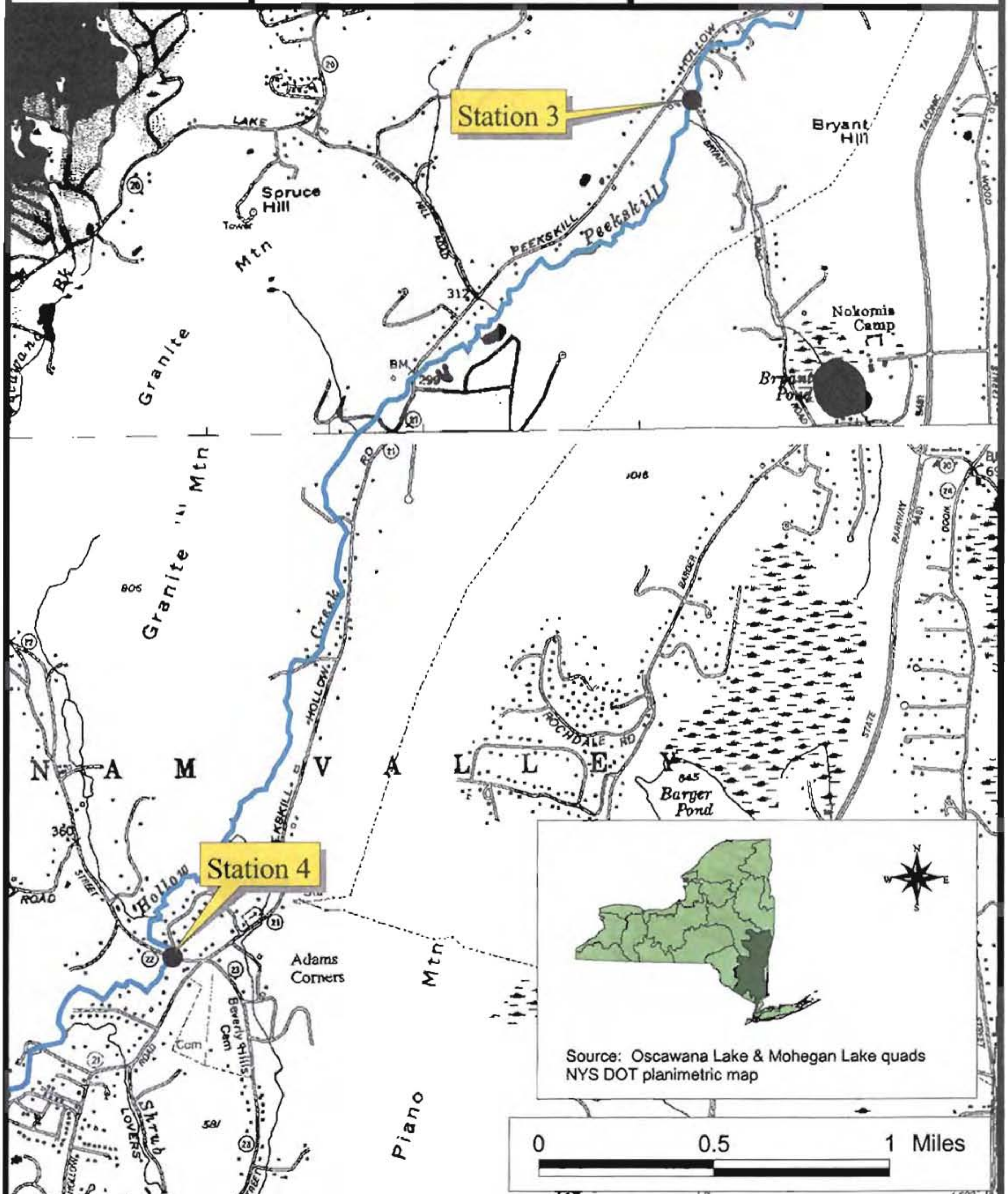


Table 2. Impact Source Determination, Peekskill Hollow Creek, 2005. Numbers represent similarity to community type models for each impact category. The highest average similarities at each station are shaded. Similarities less than 50% are less conclusive. Highest numbers represent probable type of impact. See Appendix X for further explanation.

	Station					
Community Type	01	02	03	04	05	06
Natural: minimal human impacts	47	59	50	45	55	36
Nutrient enrichment	43	35	53	49	47	48
Toxic: industrial, municipal, or urban run-off	41	38	40	30	34	32
Organic: sewage, animal wastes	31	31	31	29	21	43
Complex: municipal and/or industrial	28	25	38	25	35	40
Siltation	32	35	44	39	30	46
Impoundment	34	30	50	35	37	52

STATION	COMMUNITY TYPE
PEEK-01	Natural, Nutrients
PEEK-02	Natural
PEEK-03	Natural, Nutrients, Impoundment
PEEK-04	Natural, Nutrients
PEEK-05	Natural
PEEK-06	Nutrients, Siltation, Impoundment

Figure 3b	Site Location Map	Peekskill Hollow Creek



stream flow

Figure 3a	Site Location Map	Peekskill Hollow Creek

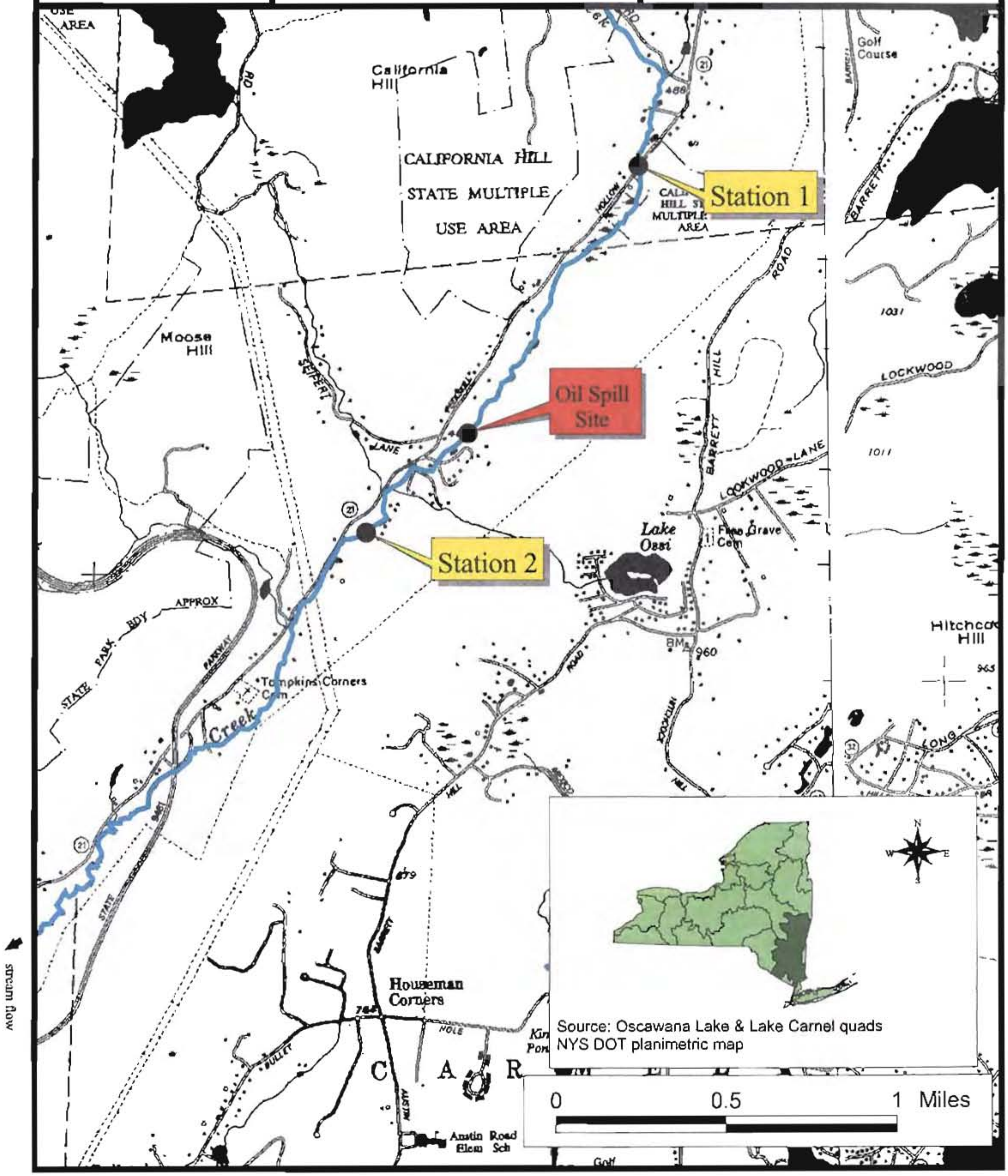


Figure 2	Site Overview Map	Peekskill Hollow Creek

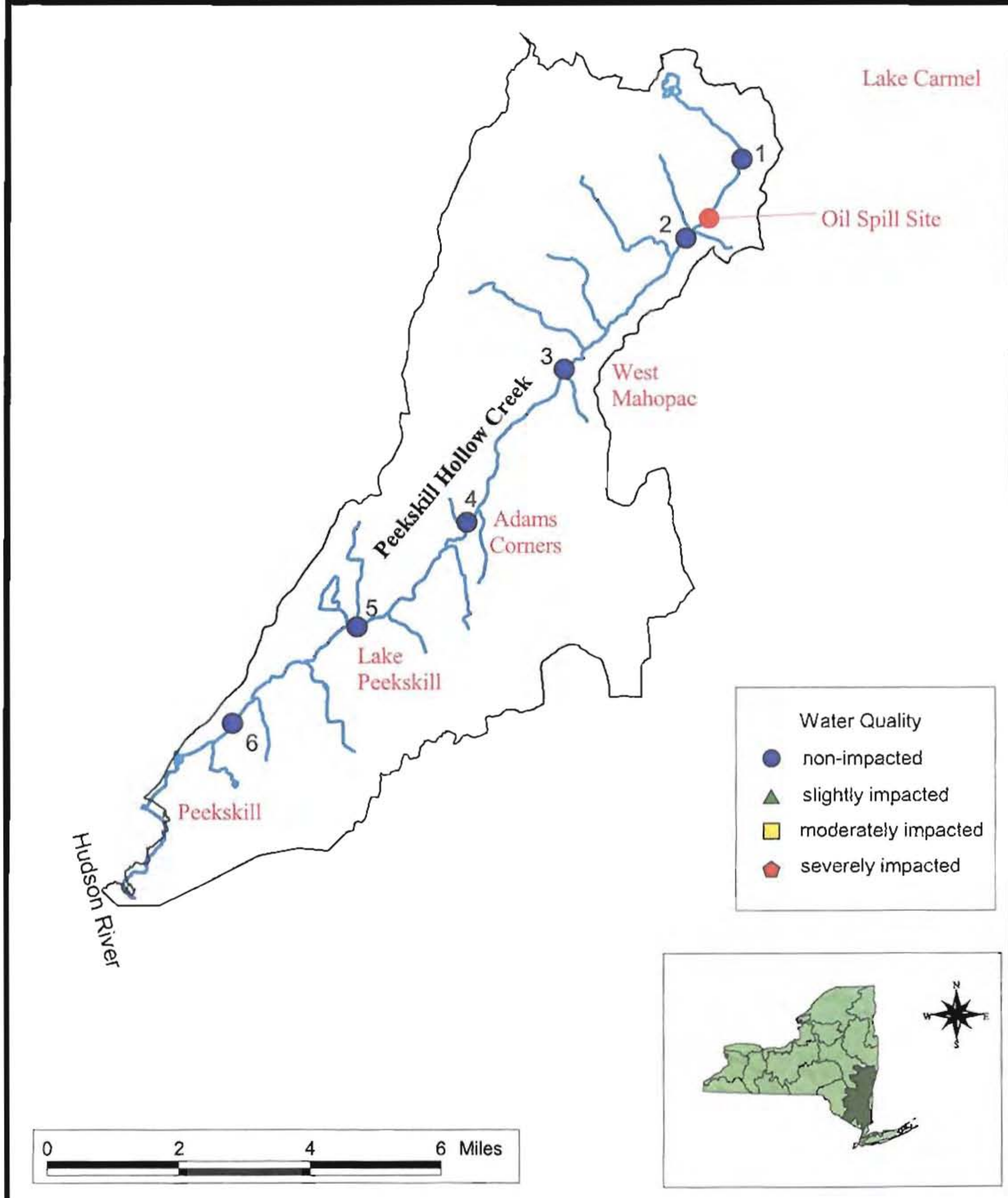


TABLE 3. Station Locations for Peekskill Hollow Creek, Putnam and Westchester Counties, NY

STATION	LOCATION	
PEEK-01	Carmel, NY off Peekskill Hollow Road Above oil spill latitude/longitude: 41°26'04"; 73°45'35" 14.7 river miles above mouth	
PEEK-02	Carmel, NY off Peekskill Hollow Road Below oil spill latitude/longitude: 41°25'08"; 73°46'33" 13.3 river miles above mouth	
PEEK-03	West Mahopac, NY Below Bryant Pond Road bridge latitude/longitude: 41°23'16"; 73°48'47" 9.9 river miles above mouth	[no photograph available]
PEEK-04	Adams Corners, NY Above Church Road bridge latitude/longitude: 41°21'13"; 73°50'31" 6.4 river miles above mouth	
PEEK-05	Putnam Valley, NY Above Oscawana Lake Road bridge latitude/longitude: 41°19'59"; 73°52'29" 3.7 river miles above mouth	[no photograph available]
PEEK-06	Van Cortlandtville, NY Below Pump House Road bridge latitude/longitude: 41°18'50"; 73°54'33" 1.3 river miles above mouth	[no photograph available]

Figure 3c	Site Location Map	Peekskill Hollow Creek

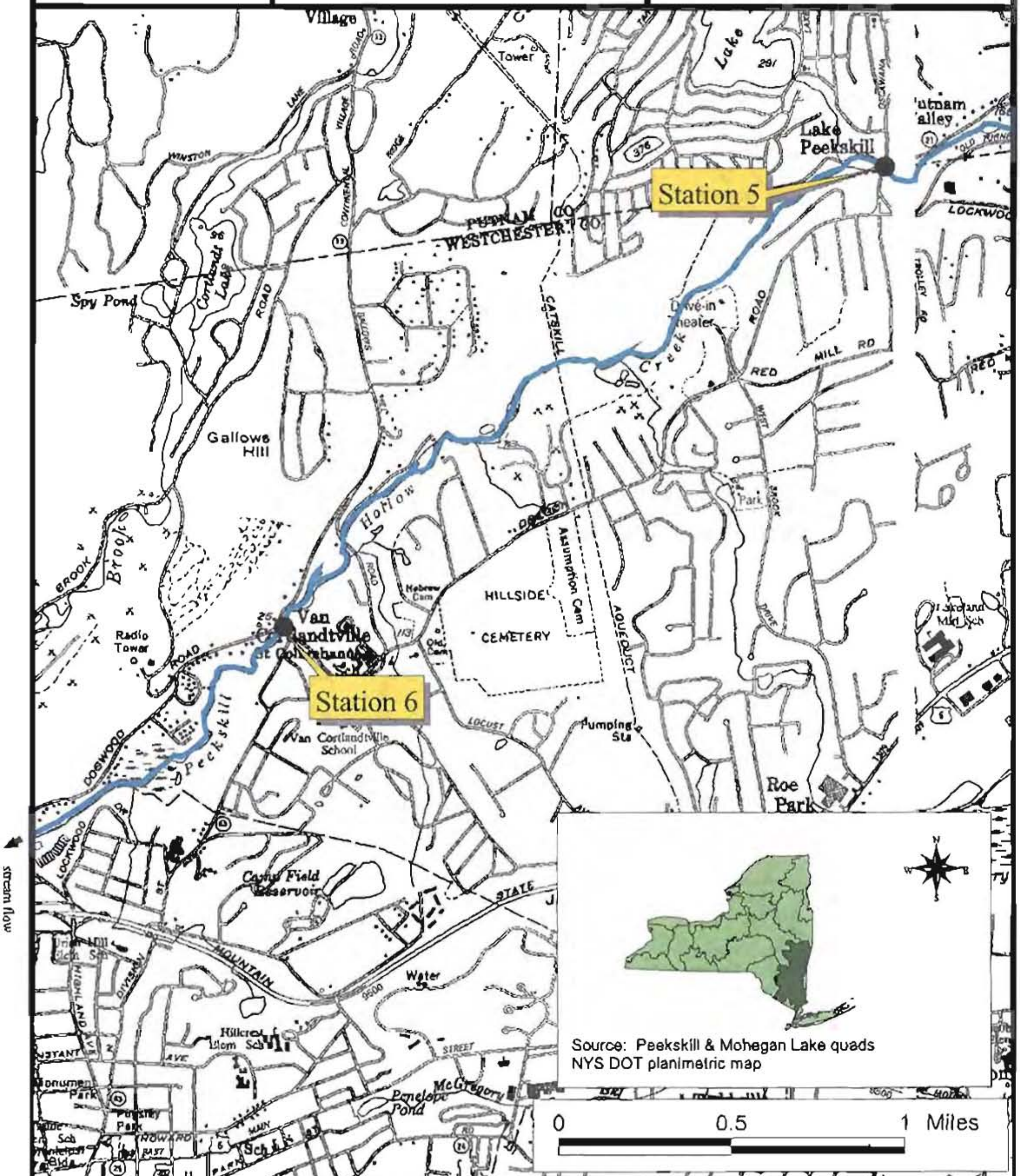


Table 3. Macroinvertebrates collected in Peekskill Hollow Creek, July, 2005

NEMERTEA
- Tetrastemmatidae
  - *Prostoma graecense*

OLIGOCHAETA
- LUMBRICIDA
  - Undetermined Lumbricina
- LUMBRICULIDA
  - Lumbriculidae
    - Undetermined Lumbriculidae
- TUBIFICIDA
  - Tubificidae
    - *Aulodrilus pluriseta*
    - *Limnodrilus hoffmeisteri*
  - Naididae
    - *Stylaria lacustris*

MOLLUSCA
- PELECYPODA
  - Sphaeriidae
    - *Pisidium* sp.

ARTHROPODA
- INSECTA
  - EPHEMEROPTERA
    - Isonychiidae
      - *Isonychia bicolor*
    - Baetidae
      - *Acentrella sp.*
      - *Baetis flavistriga*
      - *Baetis intercalaris*
      - *Baetis tricaudatus*
    - Heptageniidae
      - *Stenonema sp.*
    - Ephemerellidae
      - *Ephemerella sp.*
      - *Serratella sp.*
    - Leptohyphidae
      - *Tricorythodes sp.*
  - PLECOPTERA
    - Leuctridae
      - Undetermined Leuctridae
    - Perlidae
      - *Acroneuria abnormis*
      - *Acroneuria sp.*
      - *Paragnetina media*
    - Perlodidae
      - *Isoperla sp.*
    - Peltoperlidae
      - *Tallaperla sp.*
  - ODONATA
    - Gomphidae
      - *Ophiogomphus sp.*
    - Aeschnidae
      - *Boyeria sp.*
      - *Cordulegaster sp.*
  - COLEOPTERA
    - Hydrophilidae
      - *Hydrobius sp.*
    - Psephenidae
      - *Ectopria nervosa*
    - Elmidae
      - *Dubiraphia vittata*
      - *Optioservus fastiditus*
      - *Optioservus trivittatus*
      - *Optioservus sp.*
      - *Oulimnius latiusculus*
      - *Stenelmis crenata*
  - MEGALOPTERA
    - Corydalidae
      - *Nigronia serricornis*
    - Sialidae
      - *Sialis sp.*
  - TRICHOPTERA
    - Polycentropodidae
      - Undetermined Polycentropodidae
    - Philopotamidae
      - *Chimarra aterrima?*
      - *Dolophilodes sp.*
    - Hydropsychidae
      - *Cheumatopsyche sp.*
      - *Hydropsyche betteni*
      - *Hydropsyche bronta*
      - *Hydropsyche morosa*
      - *Hydropsyche sparna*
      - *Potamyia sp.*
    - Rhyacophilidae
      - *Rhyacophila fuscula*
    - Glossosomatidae
      - *Glossosoma sp.*
    - Hydroptilidae
      - *Leucotrichia sp.*
    - Limnephilidae
      - Undetermined Limnephilidae
    - Lepidostomatidae
      - *Lepidostoma sp.*
  - DIPTERA
    - Tipulidae
      - *Antocha sp.*
      - *Tipula sp.*
      - *Pseudolimnophila sp.*
    - Ceratopogonidae
      - Undetermined Ceratopogonidae
    - Simuliidae
      - *Simulium tuberosum*
    - Tabanidae
      - Undetermined Tabanidae
    - Athericidae
      - *Atherix sp.*

Empididae

Hemerodromia sp.

Chironomidae

Thienemannimyia gr. spp.
Diamesa sp.
Pagastia orthogonia
Cardiocladius obscurus
Cricotopus trifascia gr.
Heterotrissocladius sp.
Orthocladius nr. dentifer
Parakiefferiella sp.
Parametriocnemus lundbecki
Rheocricotopus robacki
Tvetenia bavarica gr.
Tvetenia vitracies
Microtendipes pedellus gr.
Microtendipes rydalensis gr.
Paratendipes albimanus
Polypedilum aviceps
Polypedilum fallax gr.
Polypedilum flavum
Polypedilum illinoense
Polypedilum tuberculum
Micropsectra dives gr.
Micropsectra polita
Rheotanytarsus exiguus gr.
Rheotanytarsus pellucidus
Tanytarsus guerlus gr.

Macroinvertebrate Data Reports: Raw Data

STREAM SITE:	Peekskill Hollow Creek	PEEK-01	
LOCATION:	Carmel Township, NY	off Peekskill Hollow Road	
DATE:	12 July 2005		
SAMPLE TYPE:	Kick sample		
SUBSAMPLE:	100 organisms		
ANNELIDA			
OLIGOCHAETA			
LUMBRICULIDA	Lumbriculidae	Undetermined Lumbriculidae	2
TUBIFICIDA	Tubificidae	*Aulodrilus pluriseta*	2
		Limnodrilus hoffmeisteri	5
MOLLUSCA			
PELECYPODA	Sphaeriidae	*Pisidium sp.*	1
ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Baetidae	*Baetis intercalaris*	5
PLECOPTERA	Leuctridae	Undetermined Leuctridae	12
	Perlidae	*Acroneuria sp.*	3
ODONATA	Gomphidae	*Ophiogomphus sp.*	1
	Aeschnidae	*Cordulegaster sp.*	1
COLEOPTERA	Hydrophilidae	*Hydrobius sp.*	3
	Elmidae	*Optioservus sp.*	4
		Stenelmis crenata	1
MEGALOPTERA	Corydalidae	*Nigronia serricornis*	2
TRICHOPTERA	Philopotamidae	*Dolophilodes sp.*	2
	Hydropsychidae	*Cheumatopsyche sp.*	14
	Limnephilidae	Undetermined Limnephilidae	1
	Lepidostomatidae	*Lepidostoma sp.*	1
DIPTERA	Ceratopogonidae	Undetermined Ceratopogonidae	2
	Tabanidae	Undetermined Tabanidae	1
	Empididae	*Hemerodromia sp.*	1
	Chironomidae	*Thienemannimyia gr. spp.*	13
		Pagastia orthogonia	1
		Heterotrissocladius sp.	1
		Parakiefferiella sp.	1
		Parametriocnemus lundbecki	4
		Tvetenia bavarica gr.	2
		Microtendipes pedellus gr.	1
		Polypedilum aviceps	5
		Polypedilum fallax gr.	1
		Polypedilum illinoense	1
		Polypedilum tuberculum	1
		Micropsectra polita	2
		Rheotanytarsus exiguus gr.	2
		Tanytarsus guerlus gr.	1
SPECIES RICHNESS:	34 (very good)		
BIOTIC INDEX:	4.45 (very good)		
EPT RICHNESS:	7 (good)		
MODEL AFFINITY:	62 (good)		
ASSESSMENT:	non-impacted (7.57)		

DESCRIPTION: The habitat at this site included much sand and gravel, but the macroinvertebrate community was diverse and well-balanced. Based on the metrics, water quality was assessed as non-impacted.

Macroinvertebrate Data Reports: Raw Data

STREAM SITE:	Peekskill Hollow Creek	PEEK-02	
LOCATION:	Tompkins Corners, NY	Peekskill Hollow Road	
DATE:	12 July 2005		
SAMPLE TYPE:	Kick sample		
SUBSAMPLE:	100 organisms		
ANNELIDA			
OLIGOCHAETA			
LUMBRICIDA		Undetermined Lumbricina	2
LUMBRICULIDA	Lumbriculidae	Undetermined Lumbriculidae	5
TUBIFICIDA	Tubificidae	*Limnodrilus hoffmeisteri*	3
ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Baetidae	*Baetis intercalaris*	32
		Baetis tricaudatus	5
	Heptageniidae	*Stenonema sp.*	2
	Ephemerellidae	*Serratella sp.*	1
PLECOPTERA	Perlodidae	*Isoperla sp.*	1
	Peltoperlidae	*Tallaperla sp.*	4
ODONATA	Gomphidae	*Ophiogomphus sp.*	1
	Aeschnidae	*Boyeria sp.*	1
COLEOPTERA	Elmidae	*Optioservus sp.*	1
TRICHOPTERA	Hydropsychidae	*Hydropsyche betteni*	1
		Hydropsyche sparna	6
		Potamyia sp.	1
	Rhyacophilidae	*Rhyacophila fuscula*	1
	Lepidostomatidae	*Lepidostoma sp.*	1
DIPTERA	Tipulidae	*Tipula sp.*	1
		Pseudolimnophila sp.	1
	Ceratopogonidae	Undetermined Ceratopogonidae	1
	Athericidae	*Atherix sp.*	6
	Chironomidae	*Thienemannimyia gr. spp.*	7
		Diamesa sp.	4
		Pagastia orthogonia	1
		Parametriocnemus lundbecki	4
		Polypedilum aviceps	4
		Micropsectra dives gr.	1
		Rheotanytarsus pellucidus	2
SPECIES RICHNESS:	28 (very good)		
BIOTIC INDEX:	4.74 (good)		
EPT RICHNESS:	11 (very good)		
MODEL AFFINITY:	91 (very good)		
ASSESSMENT:	non-impacted (8.32)		

DESCRIPTION: This site was approximately 0.5 miles downstream of the oil spill. A faint oil smell was released when the kick sample was taken, although no oil was visible. The macroinvertebrate community was well-balanced and diverse, and metrics clearly indicated non-impacted water quality. No biological indications of oil effects were present.

STREAM SITE:	Peekskill Hollow Creek	PEEK-03	
LOCATION:	West Mahopac, NY	below Bryant Pond Road	
DATE:	12 July 2005		
SAMPLE TYPE:	Kick sample		
SUBSAMPLE:	100 organisms		
NEMERTEA	Tetrastemmatidae	*Prostoma graecense*	2
ANNELIDA			
OLIGOCHAETA			
TUBIFICIDA	Naididae	*Stylaria lacustris*	1
MOLLUSCA			
PELECYPODA			
	Sphaeriidae	*Pisidium sp.*	1
ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Isonychiidae	*Isonychia bicolor*	15
	Baetidae	*Acentrella sp.*	1
		Baetis intercalaris	5
PLECOPTERA	Perlidae	*Acroneuria abnormis*	4
COLEOPTERA	Elmidae	*Oulimnius latiusculus*	1
		Optioservus trivittatus	1
TRICHOPTERA	Polycentropodidae	Undetermined Polycentropodidae	1
	Philopotamidae	*Chimarra aterrima?*	10
	Hydropsychidae	*Cheumatopsyche sp.*	2
		Hydropsyche betteni	2
		Hydropsyche bronta	19
		Hydropsyche sparna	7
	Rhyacophilidae	*Rhyacophila fuscula*	2
DIPTERA	Tipulidae	*Antocha sp.*	2
	Simuliidae	*Simulium tuberosum*	1
	Chironomidae	*Thienemannimyia gr. spp.*	2
		Diamesa sp.	2
		Cardiocladius obscurus	1
		Orthocladius nr. dentifer	2
		Parametriocnemus lundbecki	1
		Rheocricotopus robacki	1
		Tvetenia bavarica gr.	1
		Tvetenia vitracies	5
		Microtendipes rydalensis gr.	1
		Polypedilum aviceps	7

SPECIES RICHNESS:	28 (very good)
BIOTIC INDEX:	4.41(very good)
EPT RICHNESS:	11 (very good)
MODEL AFFINITY:	64 (good)
ASSESSMENT:	non-impacted (7.77)

DESCRIPTION: The kick sample was taken approximately 150 meters downstream of the Bryant Pond Road bridge near West Mahopac, accessed through soccer fields. The riffle had excellent habitat, and the macroinvertebrate fauna contained many mayflies, stoneflies, caddisflies, beetles and hellgrammites. Water quality was clearly indicated as non-impacted.

Macroinvertebrate Data Reports: Raw Data

STREAM SITE:	Peekskill Hollow Creek	PEEK-04
LOCATION:	Adams Corners, NY	above Church Road
DATE:	12 July 2005	
SAMPLE TYPE:	Kick sample	
SUBSAMPLE:	100 organisms	

NEMERTEA	Tetrastemmatidae	*Prostoma graecense*	1
ANNELIDA			
OLIGOCHAETA			
LUMBRICULIDA	Lumbriculidae	Undetermined Lumbriculidae	10
ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Isonychiidae	*Isonychia bicolor*	4
	Baetidae	*Baetis flavistriga*	2
		Baetis intercalaris	2
	Heptageniidae	*Stenonema sp.*	1
	Ephemerellidae	*Ephemerella sp.*	4
	Leptohyphidae	*Tricorythodes sp.*	4
PLECOPTERA	Perlidae	*Acroneuria sp.*	3
		Paragnetina media	1
ODONATA	Aeschnidae	*Boyeria sp.*	2
COLEOPTERA	Psephenidae	*Ectopria nervosa*	1
	Elmidae	*Dubiraphia vittata*	2
		Optioservus fastiditus	9
MEGALOPTERA	Corydalidae	*Nigronia serricornis*	11
TRICHOPTERA	Philopotamidae	*Dolophilodes sp.*	1
	Hydropsychidae	*Cheumatopsyche sp.*	3
		Hydropsyche betteni	4
		Hydropsyche bronta	8
DIPTERA	Tipulidae	*Antocha sp.*	2
	Athericidae	*Atherix sp.*	2
	Chironomidae	*Thienemannimyia gr. spp.*	1
		Parametriocnemus lundbecki	1
		Tvetenia vitracies	1
		Paratendipes albimanus	1
		Polypedilum aviceps	5
		Microtendipes pedellus gr.	2
		Rheotanytarsus exiguus gr.	10
		Rheotanytarsus pellucidus	1
		Tanytarsus guerlus gr.	1

SPECIES RICHNESS:	30 (very good)
BIOTIC INDEX:	4.41 (very good)
EPT RICHNESS:	12 (very good)
MODEL AFFINITY:	76 (very good)
ASSESSMENT:	non-impacted (8.34)

DESCRIPTION: The kick sample was taken just above the Church Street bridge at Adams Corners, in a suburban residential setting. The habitat was adequate and all four community metrics were within the range of non-impacted water quality.

STREAM SITE:	Peekskill Hollow Creek PEEK-05
LOCATION:	Putnam Valley, NY above Oscawana Lake Road
DATE:	12 July 2005
SAMPLE TYPE:	Kick sample
SUBSAMPLE:	100 organisms

ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Isonychiidae	*Isonychia bicolor*	2
	Baetidae	*Acentrella sp.*	8
PLECOPTERA	Perlidae	*Acroneuria abnormis*	14
		Paragnetina media	4
COLEOPTERA	Elmidae	*Optioservus sp.*	1
MEGALOPTERA	Corydalidae	*Nigronia serricornis*	1
TRICHOPTERA	Philopotamidae	*Chimarra aterrima?*	6
		Dolophilodes sp.	5
	Hydropsychidae	*Cheumatopsyche sp.*	6
		Hydropsyche betteni	1
		Hydropsyche bronta	1
		Hydropsyche morosa	4
		Hydropsyche sparna	1
	Glossosomatidae	*Glossosoma sp.*	1
	Hydroptilidae	*Leucotrichia sp.*	1
DIPTERA	Tipulidae	*Antocha sp.*	2
	Simuliidae	*Simulium tuberosum*	3
	Chironomidae	*Diamesa sp.*	2
		Cardiocladius obscurus	4
		Cricotopus trifascia gr.	2
		Orthocladius nr. dentifer	1
		Parametriocnemus lundbecki	2
		Polypedilum aviceps	27
		Rheotanytarsus exiguus gr.	1

SPECIES RICHNESS:	24 (good)
BIOTIC INDEX:	3.53 (very good)
EPT RICHNESS:	13 (very good)
MODEL AFFINITY:	65 (very good)
ASSESSMENT:	non-impacted (7.94)

DESCRIPTION: This site was in a business district, although the immediate stream habitat was adequate. A 2-foot dam was 50 meters upstream of the riffle. The macroinvertebrate community was dominated by midges, caddisflies, and stoneflies. The Percent Model Affinity value at this site was adjusted from 52 to 65, due to the high numbers of stoneflies. Such an adjustment is prescribed when low PMA values are caused by high numbers of intolerant organisms (see Novak and Bode, 1992). The adjustment by a factor of +13 reflects the number of stoneflies exceeding the model. Based on the four metrics, water quality was assessed as non-impacted.

Macroinvertebrate Data Reports: Raw Data

STREAM SITE:	Peekskill Hollow Creek	PEEK-06	
LOCATION:	Van Cortlandtville, NY	below Pump House Road	
DATE:	12 July 2005		
SAMPLE TYPE:	Kick sample		
SUBSAMPLE:	100 organisms		
NEMERTEA	Tetrastemmatidae	*Prostoma graecense*	2
OLIGOCHAETA			
LUMBRICIDA		Undetermined Lumbricina	4
LUMBRICULIDA	Lumbriculidae	Undetermined Lumbriculidae	4
ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Isonychiidae	*Isonychia bicolor*	2
	Baetidae	*Acentrella sp.*	2
	Ephemerellidae	*Ephemerella sp.*	2
PLECOPTERA	Perlidae	*Acroneuria sp.*	8
		Paragnetina media	1
COLEOPTERA	Psephenidae	*Psephenus herricki*	1
	Elmidae	*Oulimnius latiusculus*	7
		Stenelmis sp.	2
MEGALOPTERA	Corydalidae	*Nigronia serricornis*	2
	Sialidae	*Sialis sp.*	1
TRICHOPTERA	Philopotamidae	*Chimarra aterrima?*	2
	Hydropsychidae	*Cheumatopsyche sp.*	12
		Hydropsyche betteni	2
		Hydropsyche bronta	8
		Hydropsyche sparna	9
	Rhyacophilidae	*Rhyacophila fuscula*	1
	Lepidostomatidae	*Lepidostoma sp.*	2
DIPTERA	Tipulidae	*Antocha sp.*	2
	Simuliidae	*Simulium tuberosum*	1
	Athericidae	*Atherix sp.*	1
	Empididae	*Hemerodromia sp.*	1
	Chironomidae	*Thienemannimyia gr. spp.*	1
		Pagastia orthogonia	1
		Parametriocnemus lundbecki	3
		Tvetenia vitracies	3
		Phaenopsectra dyari?	1
		Polypedilum aviceps	5
		Polypedilum flavum	5
		Rheotanytarsus exiguus gr.	1
		Rheotanytarsus pellucidus	1

SPECIES RICHNESS:	33 (very good)
BIOTIC INDEX:	4.42 (very good)
EPT RICHNESS:	12 (very good)
MODEL AFFINITY:	66 (very good)
ASSESSMENT:	non-impacted (8.30)

DESCRIPTION: The sampling site was 80 meters downstream of the Pump House Road bridge. The macroinvertebrate community included mayflies, stoneflies, caddisflies, hellgrammites, and dragonflies. All four metrics were within the range of non-impacted water quality.

FIELD DATA SUMMARY

STREAM NAME: Peekskill Hollow Creek	**DATE SAMPLED: 7/21/2005**			
REACH: Carmel to Van Cortlandtville				
FIELD PERSONNEL INVOLVED: Bode, Novak				
STATION	01	02	03	04
ARRIVAL TIME AT STATION	10:30 AM	11:30 AM	12:05 PM	1:40 PM
LOCATION	Carmel Above oil spill	Carmel Below oil spill	West Mahopac	Adams Corners
PHYSICAL CHARACTERISTICS				
Width (meters)	2.0	4.0	6.0	6.0
Depth (meters)	0.1	0.1	0.1	0.2
Current speed (cm per sec.)	50	80	80	70
Substrate (%)				
Rock (>25.4 cm, or bedrock)		10	10	10
Rubble (6.35 – 25.4 cm)	30	30	40	30
Gravel (0.2 – 6.35 cm)	20	20	10	20
Sand (0.06 – 2.0 mm)	40	20	20	20
Silt (0.004 – 0.06 mm)	10	20	20	20
Embeddedness (%)	40	40	40	30
CHEMICAL MEASUREMENTS				
Temperature (° C)	19.9	21.0	22.5	22.0
Specific Conductance (umhos)	251	262	335	350
Dissolved Oxygen (mg/l)	8.3	9.2	8.8	8.3
pH	6.3	6.5	6.6	6.4
BIOLOGICAL ATTRIBUTES				
Canopy (%)	70	50	50	60
Aquatic Vegetation				
algae – suspended				
algae – attached, filamentous			x	
algae – diatoms		x		
macrophytes or moss				
Occurrence of Macroinvertebrates				
Ephemeroptera (mayflies)	x	x	x	x
Plecoptera (stoneflies)	x	x	x	x
Trichoptera (caddisflies)		x	x	x
Coleoptera (beetles)	x		x	
Megaloptera (dobsonflies, alderflies)			x	x
Odonata (dragonflies, damselflies)	x			x
Chironomidae (midges)		x		x
Simuliidae (black flies)				
Decapoda (crayfish)				x
Gammaridae (scuds)				
Mollusca (snails, clams)				
Oligochaeta (worms)				
Other				
FAUNAL CONDITION	Very good	Very good	Very good	Very good

FIELD DATA SUMMARY				
STREAM NAME: Peekskill Hollow Creek		DATE SAMPLED: 7/21/2005		
REACH: Carmel to Van Cortlandtville				
FIELD PERSONNEL INVOLVED: Bode, Novak				
STATION	05	06		
ARRIVAL TIME AT STATION	2:20 PM	2:50 PM		
LOCATION	Putnam Valley	Van Cortlandtville		
PHYSICAL CHARACTERISTICS				
Width (meters)	15	15		
Depth (meters)	0.2	0.2		
Current speed (cm per sec.)	120	80		
Substrate (%)				
Rock (>25.4 cm, or bedrock)	10	10		
Rubble (6.35 – 25.4 cm)	40	30		
Gravel (0.2 – 6.35 cm)	20	20		
Sand (0.06 – 2.0 mm)	20	20		
Silt (0.004 – 0.06 mm)	10	20		
Embeddedness (%)	30	40		
CHEMICAL MEASUREMENTS				
Temperature (°C)	23.6	24.7		
Specific Conductance (umhos)	440	449		
Dissolved Oxygen (mg/l)	8.4	8.5		
pH	6.9	6.9		
BIOLOGICAL ATTRIBUTES				
Canopy (%)	50	80		
Aquatic Vegetation				
algae – suspended				
algae – attached, filamentous	x			
algae – diatoms	x			
macrophytes or moss				
Occurrence of Macroinvertebrates				
Ephemeroptera (mayflies)	x	x		
Plecoptera (stoneflies)	x	x		
Trichoptera (caddisflies)	x	x		
Coleoptera (beetles)				
Megaloptera (dobsonflies, alderflies)		x		
Odonata (dragonflies, damselflies)		x		
Chironomidae (midges)				
Simuliidae (black flies)				
Decapoda (crayfish)	x			
Gammaridae (scuds)				
Mollusca (snails, clams)				
Oligochaeta (worms)				
Other	x			
FAUNAL CONDITION	Very good	Very good		

LABORATORY DATA SUMMARY

STREAM NAME: Peekskill Hollow Creek		**DRAINAGE: 13**		
DATE SAMPLED: 7/21/2005		**COUNTY: Putnam & Westchester**		
SAMPLING METHOD: Travelling Kick				
STATION	01	02	03	04
LOCATION	Carmel Above oil spill	Carmel Below oil spill	West Mahopac	Adams Corners
DOMINANT SPECIES/%CONTRIBUTION/TOLERANCE/COMMON NAME				
1.	Cheumatopsyche sp.	Baetis intercalaris	Hydropsyche bronta	Nigronia serricornis
	14 %	32 %	19 %	11%
	facultative	intolerant	facultative	intolerant
	caddisfly	mayfly	caddisfly	odonata
2.	Thienemannimyia gr. spp.	Thienemannimyia gr. spp.	Isonychia bicolor	Undetermined Lumbriculidae
Intolerant = not tolerant of poor	13 %	7 %	15%	10%
water quality	facultative	facultative	intolerant	facultative
	midge	midge	mayfly	worm
3.	Undetermined Leuctridae	Hydropsyche sparna	Chimarra aterrima?	Rheotanytarsus exiguus gr.
Facultative = occurring over a	12 %	6 %	10 %	10%
wide range of water quality	intolerant	facultative	intolerant	facultative
	stone fly	caddisfly	caddisfly	midge
4.	Limnodrilus hoffmeisteri	Atherix sp.	Hydropsyche sparna	Optioservus fastiditus
Tolerant = tolerant of poor	5 %	6%	7 %	9%
water quality	intolerant	intolerant	facultative	intolerant
	worm	crane fly	caddisfly	beetle
5.	Baetis intercalaris	Undetermined Lumbriculidae	Polypedilum aviceps	Hydropsyche bronta
	5 %	5%	7 %	8 %
	intolerant	facultative	facultative	facultative
	mayfly	worm	midge	caddisfly
% CONTRIBUTION OF MAJOR GROUPS (NUMBER OF TAXA IN PARENTHESES)				
Chironomidae (midges)	36.0 (14.0)	38.0 (5.0)	23.0 (10.0)	23.0 (9.0)
Trichoptera (caddisflies)	18.0 (4.0)	19.0 (3.0)	43.0 (7.0)	16.0 (4.0)
Ephemeroptera (mayflies)	5.0 (1.0)	13.0 (2.0)	21.0 (3.0)	17.0 (6.0)
Plecoptera (stoneflies)	15.0 (2.0)	0.0 (0.0)	4.0 (1.0)	4.0 (2.0)
Coleoptera (beetles)	8.0 (3.0)	10.0 (1.0)	2.0 (2.0)	12.0 (3.0)
Oligochaeta (worms)	9.0 (3.0)	1.0 (1.0)	1.0 (1.0)	10.0 (1.0)
Mollusca (clams and snails)	1.0 (1.0)	0.0 (0.0)	1.0 (1.0)	0.0 (0.0)
Crustacea (crayfish, scuds, sowbugs)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Other insects (odonates, diptera)	8.0 (6.0)	19.0 (4.0)	3.0 (2.0)	17.0 (4.0)
Other (Nemertea, Platyhelminthes)	0.0 (0.0)	0.0 (0.0)	2.0 (1.0)	1.0 (1.0)
SPECIES RICHNESS	34	28	28	30
BIOTIC INDEX	4.45	4.74	4.41	4.41
EPT RICHNESS	7	11	11	12
PERCENT MODEL AFFINITY	62	91	64	76
FIELD ASSESSMENT	Very good	Very good	Very good	Very good
OVERALL ASSESSMENT	Non-impacted	Non-impacted	Non-impacted	Non-impacted

LABORATORY DATA SUMMARY

STREAM NAME: Peekskill Hollow Creek		**DRAINAGE: 13**		
DATE SAMPLED: 7/21/2005		**COUNTY: Putnam & Westchester**		
SAMPLING METHOD: Travelling Kick				
STATION	05	06		
LOCATION	Putnam Valley	Van Cortlandtville		
DOMINANT SPECIES/%CONTRIBUTION/TOLERANCE/COMMON NAME				
1.	Polypedilum aviceps	Cheumatopsyche sp.		
	27 %	12 %		
	facultative	facultative		
	midge	caddisfly		
2.	Acroneuria abnormis	Hydropsyche sparna		
Intolerant = not tolerant of poor	14 %	9 %		
water quality	intolerant	facultative		
	stonefly	caddisfly		
3.	Acentrella sp.	Acroneuria sp.		
Facultative = occurring over a	8 %	8%		
wide range of water quality	intolerant	intolerant		
	mayfly	stonefly		
4.	Chimarra aterrima?	Hydropsyche bronta		
Tolerant = tolerant of poor	6 %	8 %		
water quality	intolerant	facultative		
	caddisfly	caddisfly		
5.	Cheumatopsyche sp.	Oulimnius latiusculus		
	6 %	7%		
	facultative	intolerant		
	caddisfly	beetle		
% CONTRIBUTION OF MAJOR GROUPS (NUMBER OF TAXA IN PARENTHESES)				
Chironomidae (midges)	39.0 (7.0)	21.0 (9.0)		
Trichoptera (caddisflies)	26.0 (9.0)	36.0 (7.0)		
Ephemeroptera (mayflies)	10.0 (2.0)	6.0 (3.0)		
Plecoptera (stoneflies)	18.0 (2.0)	9.0 (2.0)		
Coleoptera (beetles)	1.0 (1.0)	10.0 (3.0)		
Oligochaeta (worms)	0.0 (0.0)	8.0 (2.0)		
Mollusca (clams and snails)	0.0 (0.0)	0.0 (0.0)		
Crustacea (crayfish, scuds, sowbugs)	0.0 (0.0)	0.0 (0.0)		
Other insects (odonates, diptera)	6.0 (3.0)	8.0 (6.0)		
Other (Nemertea, Platyhelminthes)	0.0 (0.0)	2.0 (1.0)		
SPECIES RICHNESS	24	33		
BIOTIC INDEX	3.53	4.42		
EPT RICHNESS	13	12		
PERCENT MODEL AFFINITY	65	66		
FIELD ASSESSMENT	Very good	Very good		
OVERALL ASSESSMENT	Non-impacted	Non-impacted		

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 meters 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 the dislodged organisms are carried into the net. Sampling is continued for a specified time and for a specified distance in the stream. Rapid assessment sampling specifies sampling five minutes for a distance of five meters. The net contents 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 stereo microscope 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 is 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.

MACROINVERTEBRATE COMMUNITY PARAMETERS

1. Species richness is the total number of species or taxa found in the 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; less than 11, severely impacted.

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

3. Hilsnhoff Biotic index is a measure of the tolerance of the organisms in the 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 purposes of characterizing species' tolerance, intolerant = 0-4, facultative = 5-7, and tolerant = 8-10. 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 the Quality Assurance document (Bode et al., 1996). Ranges for the levels of impact are: 0-4.50, non-impacted; 4.5 1-6.50, slightly impacted; 6.5 1-8.50, moderately impacted; and 8.51 - 10.00, severely impacted.

4. Percent Model Affinity is a measure of similarity to a model non-impacted community based on percent abundance in seven major macroinvertebrate groups (Novak and Bode, 1992). Percent 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.

Bode, R.W., M.A. Novak, and L.E. Abele. 1996. Quality assurance work plan for biological stream monitoring in New York State. NY S DEC technical report, 89 pp.

Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist 20(1): 31-39.

Lenat, D. R. 1987. Water quality assessment using a new qualitative collection method for freshwater benthic macroinvertebrates. North Carolina DEM Tech. Report. 12 pp.

Novak, M.A., and R. W. Bode. 1992. Percent model affinity: a new measure of macroinvertebrate community composition. J. N. Am. Benthol. Soc. 11(1):80-85.

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 Macroinvertebrate Community Parameters Appendix*). 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-organism 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. 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.

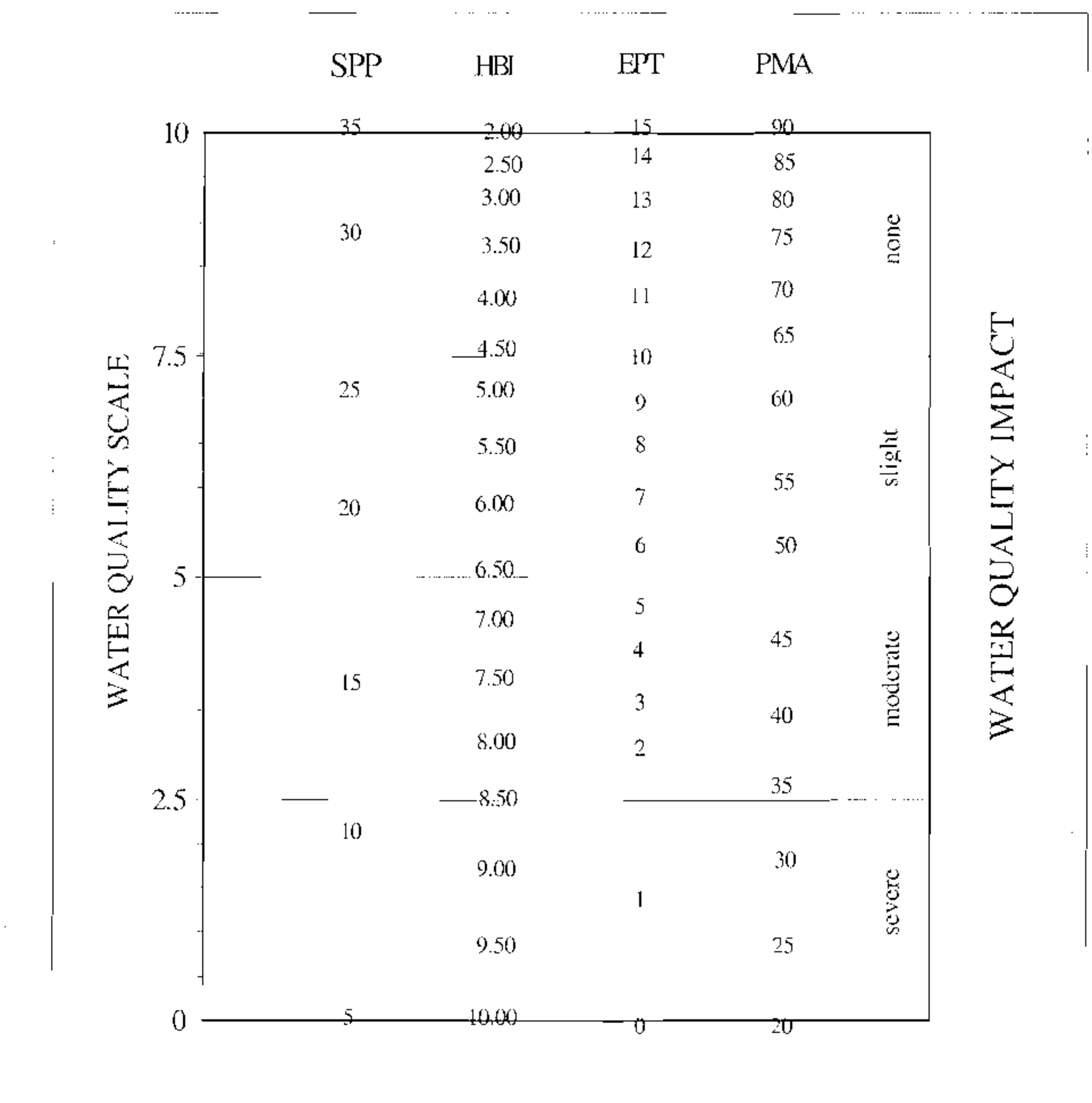
2. *Slightly impacted* Indices reflect good water quality. The macroinvertebrate community is slightly but significantly altered from the pristine state. Species richness usually is 19-26. Mayflies and stoneflies may be restricted, with EPT richness values of 6-10. The biotic index value is 4.51-6.50. Percent model affinity is 50-64. 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 usually is 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. The percent model affinity value is 35-49. 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 less. 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. 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.

Biological Assessment Profile: Conversion of Index values to Common 10-Scale

The Biological Assessment Profile 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 four indices, defined in the Macroinvertebrate Community Parameter Appendix, 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.



Biological Assessment Profile: Plotting Values

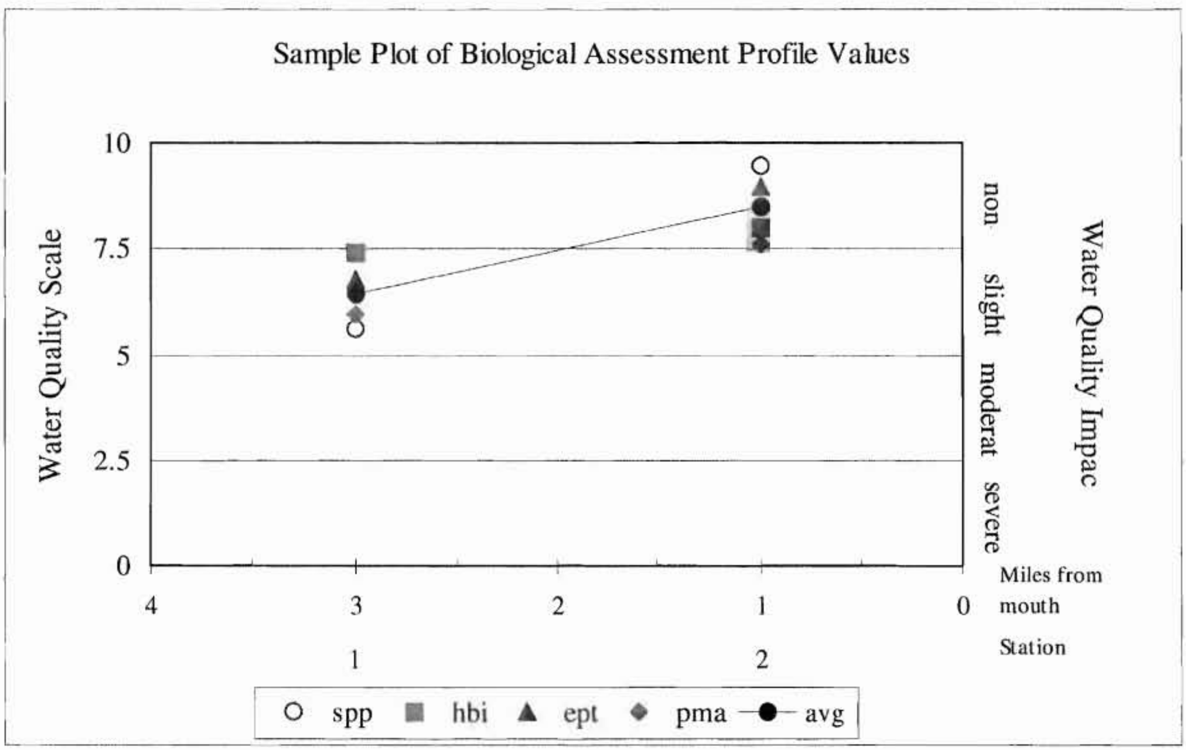
To plot survey data:

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
Average		6.44 (slight)		8.51 (non-)

Table IV-B. Sample Plot of Biological Assessment Profile values



Water Quality Assessment Criteria

Water Quality Assessment Criteria for Non-Navigable Flowing Waters

	Species Richness	Hilsenhoff Biotic Index	EPT Richness	Percent Model Affinity#	Species Diversity*
Non-Impacted	>26	0.00-4.50	>10	>64	>4
Slightly Impacted	19-26	4.51-6.50	6-10	50-64	3.01-4.00
Moderately Impacted	11-18	6.51-8.50	2-5	35-49	2.01-3.00
Severely Impacted	0-10	8.51-10.00	0-1	<35	0.00-2.00

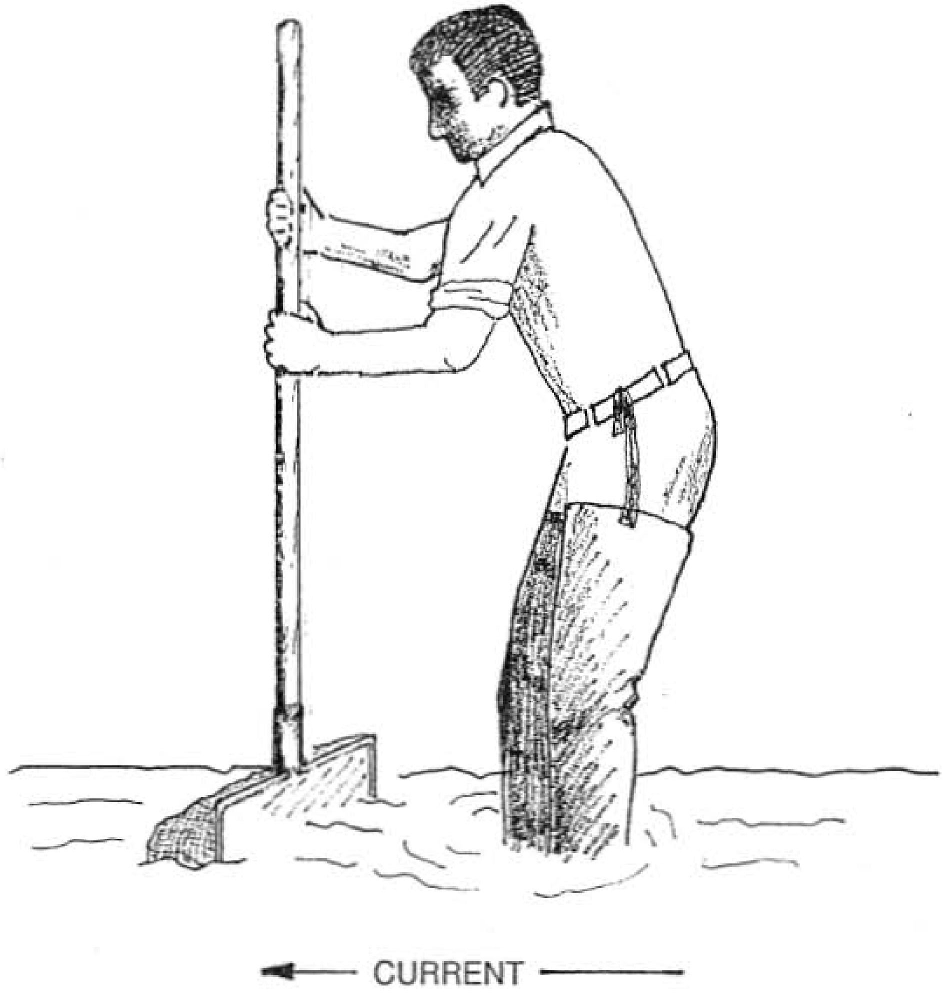
Percent model affinity criteria are used for traveling kick samples but not for multiplate samples.
* Diversity criteria are used for multiplate samples but not for traveling kick samples.

Water Quality Assessment Criteria for 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.

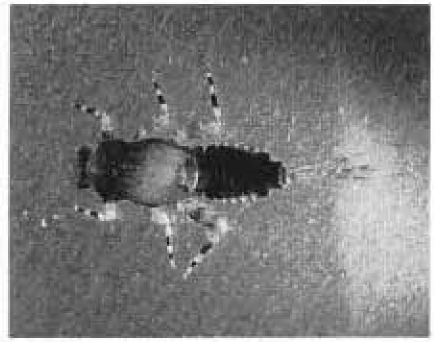
THE TRAVELING KICK SAMPLE



Rocks and sediment in the stream riffle are dislodged by foot upstream of a net; dislodged organisms are carried by the current in the net. Sampling is continued for a specified time, gradually moving downstream to cover a specified distance.

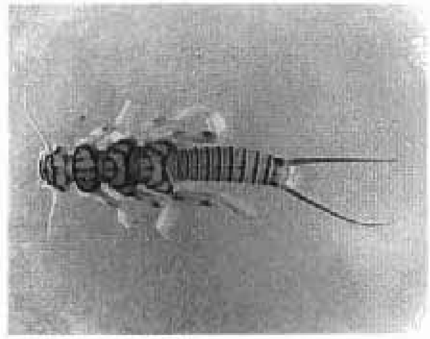
AQUATIC MACROINVERTEBRATES THAT USUALLY INDICATE GOOD WATER QUALITY

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.



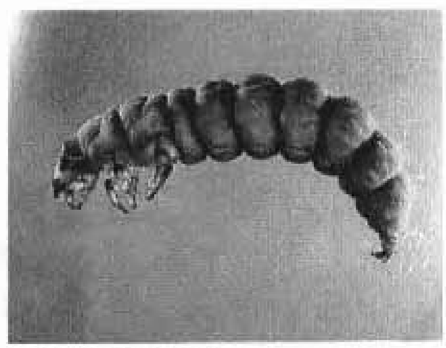
MAYFLIES

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

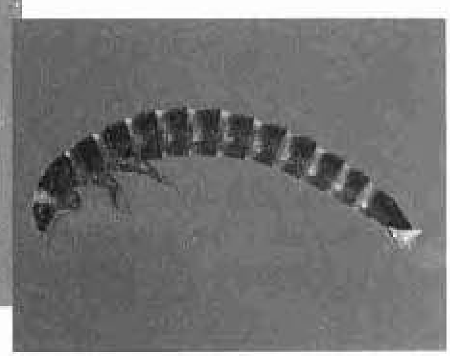
Caddisfly larvae often build a portable case of sand, stones, sticks, or other debris. Many caddisfly larvae are sensitive to pollution, although a few are tolerant. One family spins nets to catch drifting plankton, and is often numerous in nutrient-enriched stream segments.



CADDISFLIES

The most common beetles in streams are riffle beetles and water pennies. Most of these require a swift current and an adequate supply of oxygen, and are generally considered clean-water indicators.

BEETLES

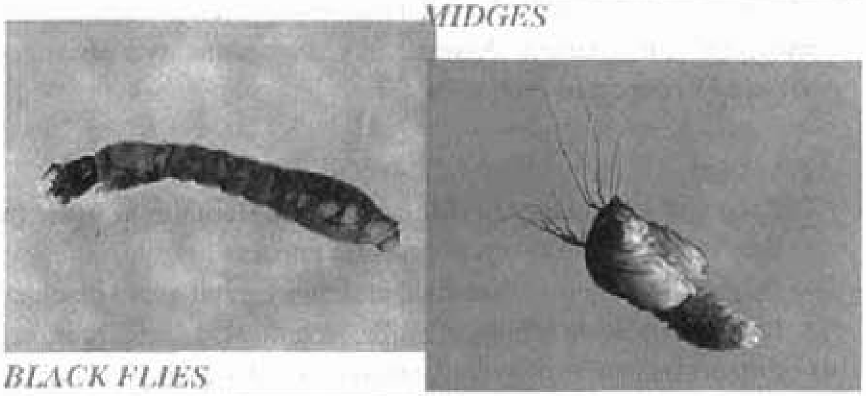


AQUATIC MACROINVERTEBRATES THAT USUALLY INDICATE POOR WATER QUALITY

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.

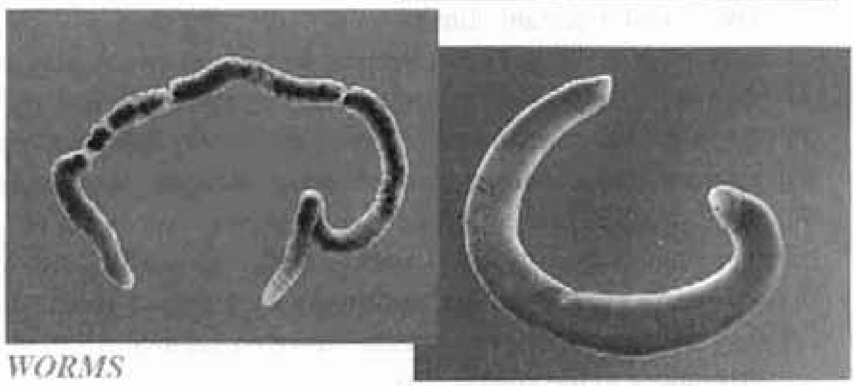
MIDGES

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.



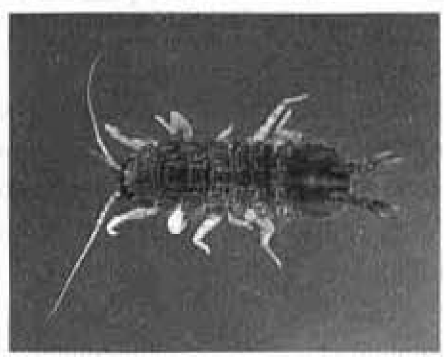
BLACK FLIES

The segmented worms include the leeches and the small aquatic earthworms. The latter are more common, though 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.



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.



SOWBUGS

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

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:

1) they are sensitive to environmental impacts
2) they are less mobile than fish, and thus cannot avoid discharges
3) they can indicate 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, e.g. siltation or thermal changes
7) they are vital components of the aquatic ecosystem and important as a food source for fish
8) they are more readily perceived by the public as tangible indicators of water quality
9) they can often provide ail on-site estimate of water quality
10) they can often be used to identify specific stresses or sources of impairment
11) they can be preserved and archived for decades, allowing for direct comparison of specimens
12) they 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.

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

EPT richness: the number of species of mayflies (**E**phemeroptera), stoneflies (**P**lecoptera), and caddisflies (**Tr**ichoptera) in a sample or subsample

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

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

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 time; usually involves kick sampling and laboratory subsampling of the sample

Riffle: wadeable stretch of stream usually having a rubble bottom and sufficient current to break the water surface; rapids

Species richness: the number of macroinvertebrate species 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

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, impoundment, and natural. 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, or may indicate "natural," lacking an impact. 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.

Impact Source Determination Models

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

Impact Source Determination 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

Impact Source Determination Models

	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

Impact Source Determination Models

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

Impact Source Determination Models

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

METHODS FOR CALCULATION OF THE NUTRIENT BIOTIC INDEX

Definition: The Nutrient Biotic Index (Smith, 2005) is a diagnostic measure of stream nutrient enrichment identified by macroinvertebrate taxa. The frequency of occurrences of taxa at varying nutrient concentrations allowed the identification of taxon-specific nutrient optima using a method of weighted averaging. The establishment of nutrient optima is possible based on the observation that most species exhibit unimodal response curves in relation to environmental variables (Jongrnan et al. 1987). The assignment of tolerance values to taxa based on their nutrient optimum provided the ability to reduce macroinvertebrate community data to a linear scale of eutrophication from oligotrophic to eutrophic. Two tolerance values were assigned to each taxon, one for total phosphorus, and one for nitrate (listed in Smith, 2005). This provides the ability to calculate two different nutrient biotic indices, one for total phosphorus (NBI-P) and one for nitrate (NBI-N). Study of the indices indicate better performance by the NBI-P, with strong correlations to stream nutrient status assessment based on diatom information.

Calculation of the NBI-P and NBI-N: Calculation of the indices [2] follows the approach of Hilsenhoff (1987).

$$NBI\ Score_{(TP\ or\ NO3^-)} = \sum (a \times b) / c$$

Where ***a*** is equal to the number of individuals for each taxon, ***b*** is the taxon's tolerance value, and ***c*** is the total number of individuals in the sample (for which tolerance values have been assigned).

Classification of NBI Scores NBI scores have been placed on a scale of eutrophication with provisional boundaries between stream trophic status.

Index	Oligotrophic	Mesotrophic	Eutrophic
NBI-P	< 5.0	> 5.0 – 6.5	> 6.0
NBI-N	< 4.5	> 4.5 – 6.0	> 6.0

References:

Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist 20(1): 31-39.

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