U.S. Department of the Interior
U.S. Geological Survey

Surface-Water Quality, Oneida Reservation and Vicinity, Wisconsin, 1997–98

Water-Resources Investigations Report 00–4179

Prepared in cooperation with the
Oneida Tribe of Indians of Wisconsin

USGS
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By Morgan A. Schmidt, Kevin D. Richards, and Barbara C. Scudder

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Middleton, Wisconsin
2000

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To Obtain
foot (ft)	0.3048	meter
square mile (mi^2)	2.59	square kilometer
liter (L)	.2642	gallon
milligram (mg)	.000002205	pound
cubic foot per second (ft^3/s)	.02832	cubic meter per second

Temperature, in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$°F = [1.8(°C)] + 32.$$

Abbreviated water-quality units: Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Other Abbreviations Used in this Report:

EPT	Ephemeroptera, Plecoptera, Trichoptera
GLEAS	Great Lakes Environmental Assessment Score
HA	Health Advisory
HBI	Hilsenhoff Biotic Index
MCL	Maximum Contaminant Level
MDL	Minimum Detection Limit
MRL	Method Reporting Level
MTV	Mean Tolerance Value
NAWQA	National Water-Quality Assessment Program
SMCL	Secondary Maximum Contaminant Level
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

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Abstract

Streamwater samples were collected at 19 sites in the vicinity of the Oneida Tribe of Indians of Wisconsin Reservation. Samples were collected during 5 sampling periods in 1997–98. Field measurements were made and samples were analyzed for nutrients, suspended sediment, major ions, and pesticides.

Physical characteristics and human activity influence surface-water quality in the study area. Predominant land use in a drainage basin, specifically agricultural land use, appears to be a strong influence on surface-water quality. Other important influences on surface-water quality in the Oneida Reservation area include point-source contamination, size of the drainage basin, presence of clayey surficial deposits, and the timing and flow conditions during sampling.

Concentrations of total phosphorus and of dissolved nitrite plus nitrate nitrogen often exceeded U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels (MCL's). Concentrations of nutrients were highest at sites with greater than 80 percent agricultural land use in the drainage basin.

Sodium and manganese were the major ions that most often exceeded USEPA water-quality criteria. The highest concentrations of sodium and chloride were detected at three sites in basins containing greater than 10 percent urban land and at two of ten sites in basins containing greater than 80 percent agricultural land.

Concentrations of the pesticides atrazine, cyanazine, and diazinon exceeded MCL's at several sites. Elevated concentrations of agricultural pesticides were detected primarily at sites in basins containing greater than 80 percent agricultural land, in comparison to pesticide concentrations at sites in basins containing lesser amounts of agricultural land. Diazinon concentrations were higher at sites in basins containing more than 10 percent urban land compared to basins with little to no urban land.

Stream habitat at three sites was rated "good" on the basis of the semiquantitative Great Lakes Environment Assessment procedure. On the basis of the semiquantitative procedure, habitat at three other sites was impaired, likely because of agricultural influences and tendencies towards low flow in the summer.

Assessments of benthic community health based on benthic invertebrates showed that the communities were "very good" at one site, "good" at three sites, "fair" at one site, and "fairly poor" at one site. Mean tolerance values yielded similar assessments of the invertebrate communities. Taxa richness for pollution-sensitive insect orders indicates that water-quality is best at Thornberry Creek. Water-quality at Trout Creek and Lancaster Brook also rated fairly high. Shannon-Wiener diversity values indicate that the invertebrate communities at Dutchman Creek, and perhaps at Duck and Oneida Creeks, are under environmental stress.

Assessments of the benthic algal community provided relative results as did invertebrate community assessments. Shannon-Wiener diversity values for diatoms indicate that algal communities are under minor stress in four of five streams sampled and under moderate stress in Dutchman Creek. A pollution index based on the percentages of diatoms that are pollution sensitive and pollution tolerant revealed that pollution at Dutchman Creek likely is moderate; pollution at the other four sampled creeks is either minor or nonexistent in terms of effects on the diatom community.

INTRODUCTION

A strong Oneida Nation, sustained through land protection and environmental preservation, is one of the goals of the Seventh Generation Mission of the Oneida Tribe of Indians of Wisconsin. In order for the Oneida Nation to restore the water quality and quantity of the streams that run through the Oneida Reservation to pre-European-settlement conditions, information about the past and current state of the Reservation's water resources is needed.

The Oneida Nation and the U.S. Geological Survey entered into a cooperative agreement to examine and report the baseline surface-water quality conditions of the Oneida Reservation. This report describes the current quality of the surface waters of the Reservation and illustrates spatial and seasonal variations in that quality. This description of current conditions fills gaps in previous data and provides insight for choosing fixed sites for future water-quality monitoring. Analyses of historical water quality and a listing of reports pertaining to the water resources of the Oneida Reservation are given in Saad and Schmidt (1998).

Description of the Oneida Reservation Study Area

The Oneida Reservation is in east-central Wisconsin and comprises 102 mi^2 (fig. 1). About 17,600 people reside within the Reservation boundaries, of which 2,798 are Tribal members (Tina R. Pospychala, Oneida Nation Enrollment Office, written commun., 1998). Most of the population is concentrated in the northeastern part of the Reservation, which borders the Green Bay metropolitan area.

The Oneida Reservation is drained by four major streams. Duck Creek and its tributaries drain nearly 70 percent of the Reservation. Dutchman Creek drains 20 percent of the Reservation, and the headwaters of Ashwaubenon Creek and the South Branch of the Suamico River drain the rest of the land.

Agriculture is the dominant land use within the Reservation (table 1). More than half of the drainage-basins contain greater than 80 percent agricultural land. Urban, forest, and wetlands areas are minor land uses. Three basins contain at least 10 percent urban areas.

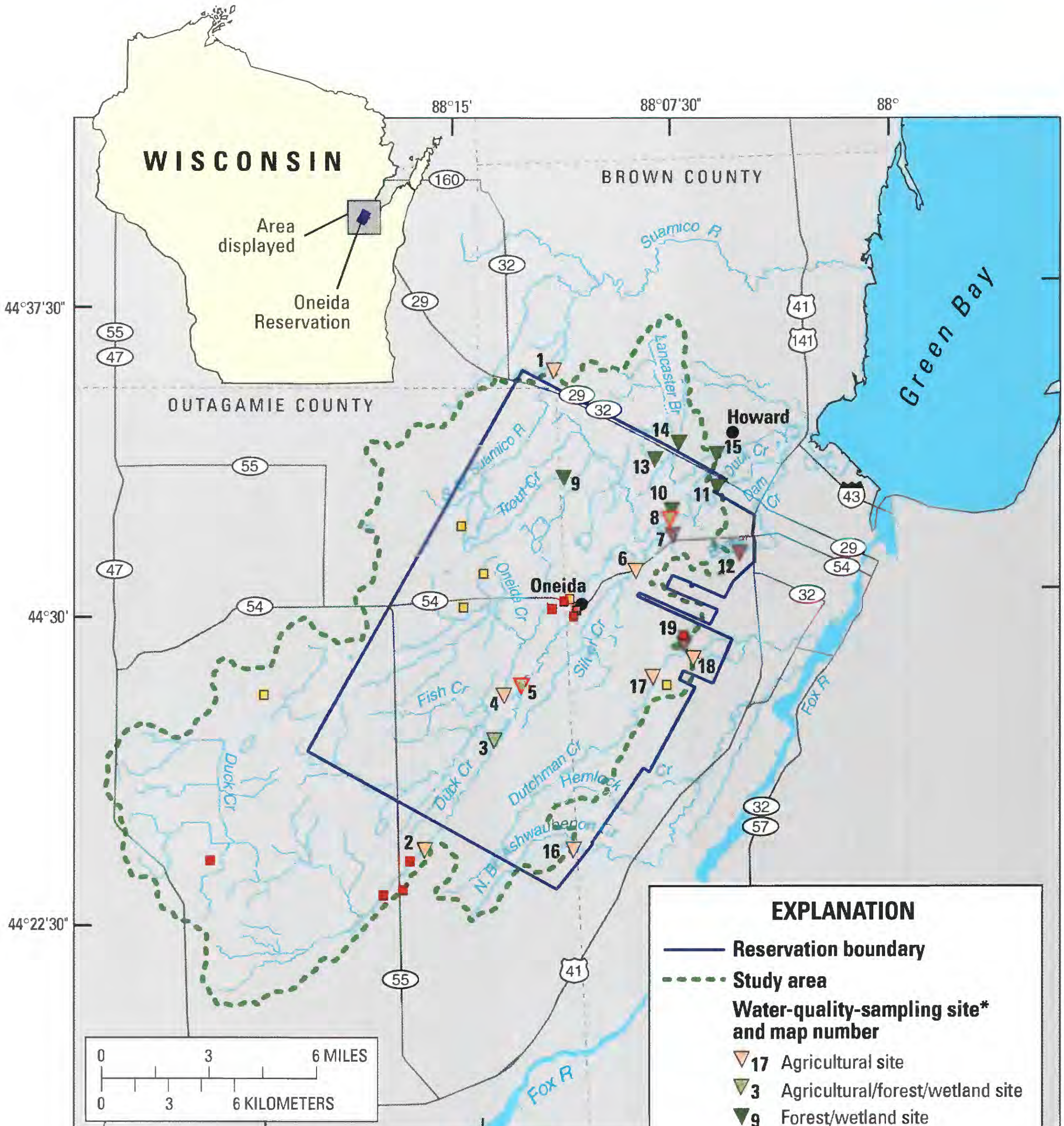
Precambrian crystalline rock lies deep below the surface of the Reservation. Sandstone and dolomite of the Cambrian and Ordovician age overlie the bedrock and provide water for residential and industrial needs by way of high-capacity wells (Mudrey and others, 1982; Krohelski, 1986). Quaternary unconsolidated surficial deposits range from sands and gravel to clays (Need, 1985).

Water quality on the Reservation is influenced by natural environmental features, land use (non-point sources of contamination), and point sources of contamination. Most point sources are within the Duck Creek Basin (U.S. Environmental Protection Agency, 1987; U.S. Geological Survey, 1988) (fig. 1). Point sources include discharges from wastewater-treatment plants and other municipal and industrial facilities. More detailed information regarding the natural and anthropogenic features of the Oneida Reservation and vicinity and their potential effect on water quality is provided in Saad and Schmidt (1998).

Factors Affecting Surface-Water Quality

Many factors, including natural drainage-basin characteristics and human activity, can affect surface-water quality. Land use or land cover within a basin influence the amounts and types of potential contaminants that may be present in storm runoff, and permeability of soil and subsoil influences how much contaminated runoff might infiltrate the ground or flow overland to streams. Drainage-basin size and the amount of flow of a stream can affect the degree to which contaminants are concentrated or diluted. The timing of sample collection and extreme flows also can affect results of water-quality sampling. Wastewater discharge from various sources may add nutrients, major ions, total suspended solids, and many other constituents directly to rivers. Examples of municipal and industrial companies which are permitted to discharge effluent to surface waters include wastewater-treatment-plants, cheese factories, paper mills, and other types of industry.

Agricultural chemicals, as well as farming practices, have the potential to degrade water quality in streams in agricultural areas. Fertilizers, herbicides, insecticides, and livestock wastes may contribute nutrients and pesticides to streams through surface runoff and ground-water recharge. Erosion of topsoil adds sediment to streams. The effects of agriculture on streams may be buffered by areas of forest and (or) wetland along stream margins. Urban areas may contribute contaminants such as nutrients and pesticides (which may



Base from U.S. Geological Survey 7.5 minute topographic quadrangles; modified from USEPA 1987; USGS, 1988

Map no.	USGS site no.	Location
1	040719491	South Br Suamico R at School Dr near Pittsfield, WI
2	04072031	Duck Creek near Freedom, WI
3	04072040	Fish Creek near Oneida, WI
4	040720447	Oneida Creek at Van Boxtel Road near Oneida, WI
5	04072050	Duck Creek at Seminary Road near Oneida, WI
6	04072100	Silver Creek at Highway 54 near Ashwaubenon, WI
7	04072140	Unnamed Duck Cr Trb at Haven Pl near Ashwaubenon, WI
8	04072150	Duck Creek near Howard, WI
9	04072153	Trout Creek at CT Highway U near Ashwaubenon, WI
10	04072185	Trout Creek near Howard, WI
11	04072217	Duck Creek Site No. 1 near Pamperin Park, WI
12	04072219	Beaver Dam Creek at Ashwaubenon, WI
13	04072228	Thornberry Creek near Howard, WI
14	04072231	Lancaster Brook at Shawano Avenue near Howard, WI
15	04072233	Lancaster Brook at Shawano Avenue at Howard, WI
16	04085064	North Branch Ashwaubenon Creek near Freedom, WI
17	04085074	Dutchman Creek at Cyrus Lane near Ashwaubenon, WI
18	040850745	Dutchman Creek at Pioneer Road at Ashwaubenon, WI
19	04085076	Dutchman Creek Tributary near De Pere, WI

***Agricultural sites** are in basins with greater than 80 percent agricultural land, and less than 10 percent forest or 8 percent wetlands. **Agricultural/forest/wetland sites** are in basins with greater than 80 percent agricultural land and either greater than 10 percent forest or 8 percent wetlands. **Forest/wetland sites** are in basins with less than 80 percent agricultural land and either greater than 10 percent forest or 8 percent wetlands. **Urban sites** are in basins with greater than 10 percent urban land.

Figure 1. Oneida Reservation and location of water-quality-sampling sites.

Table 1. Drainage-basin characteristics of water-quality-sampling sites, Oneida Reservation, Wisconsin, 1997–98

[USGS, U.S. Geological Survey; mi^2, square miles]

Map number	USGS station identifier	USGS site name	Drainage area (mi^2)	Bedrock (percent)		Surficial deposits (percent)		Land use (percent)								Number of point sources of contamination in basin
				Carbonate	Sandstone	Loam	Clay	Urban	Agriculture	Grassland	Forest	Water	Non-forested Wetland	Forested Wetland	Miscellaneous	
1	040719491	South Branch Suamico River at School Drive near Pittsfield, Wis.	11.9	100	0	100	0	0	82.50	2.28	6.50	0.00	1.72	6.22	0.78	--
2	04072031	Duck Creek near Freedom, Wis.	50.4	90.92	9.08	17.21	82.79	0	82.37	3.08	2.74	.01	3.16	7.69	.95	5
3	04072040	Fish Creek near Oneida, Wis.	17.1	99.42	.58	29.19	70.81	0	80.49	2.13	11.11	.04	2.66	3.34	.24	--
4	040720447	Oneida Creek at Van Boxtel Road near Oneida, Wis.	23.8	94.63	5.37	38.45	61.55	0	81.84	2.39	8.55	.02	2.50	4.32	.38	3
5	04072050	Duck Creek at Seminary Road near Oneida, Wis.	95.4	93.76	6.24	23.93	76.07	0	81.74	2.68	6.11	.02	2.85	5.93	.66	8
6	04072100	Silver Creek at Highway 54 near Ashwaubenon, Wis.	7.55	100	0	0	100	0	85.09	2.14	8.28	.05	.96	2.38	1.09	--
7	04072140	Unnamed Duck Creek Tributary at Haven Pl near Ashwaubenon, Wis.	.248	100	0	0	100	11.50	70.38	9.76	8.01	0	0	0	.36	--
8	04072150	Duck Creek near Howard, Wis.	108	94.50	5.50	21.07	78.93	.11	81.16	2.64	7.05	.03	2.61	5.64	.75	12
9	04072153	Trout Creek at CT Highway U near Ashwaubenon, Wis.	4.03	100	0	100	0	0	62.30	.40	6.16	.01	5.09	25.19	.85	1
10	04072185	Trout Creek near Howard, Wis.	15.3	100	0	64.31	35.69	.98	69.68	.89	16.00	.04	1.98	9.79	.64	1
11	04072217	Duck Creek Site No. 1 near Pamperin Park, Wis.	127	95.30	4.70	25.80	74.20	.72	78.79	2.53	8.61	.07	2.48	6.03	.75	13
12	04072219	Beaver Dam Creek at Ashwaubenon, Wis.	.649	100	0	0	100	51.58	.15	40.07	6.65	0	0	0	1.55	--
13	04072228	Thornberry Creek near Howard, Wis.	.344	100	0	0	100	0	67.67	4.06	25.95	.10	0	0	2.22	--
14	04072231	Lancaster Brook at Shawano Ave. near Howard, Wis.	7.19	100	0	13.84	86.16	0	75.49	.92	19.15	0	.63	2.65	1.16	--
15	04072233	Lancaster Brook at Shawano Ave. at Howard, Wis.	9.86	100	0	10.10	89.90	0	70.45	1.02	23.70	.00	.81	2.81	1.19	--
16	04085064	North Branch Ashwaubenon Creek near Freedom, Wis.	3.13	100	0	0	100	0	90.34	1.31	5.52	.01	.57	1.47	.78	--
17	04085074	Dutchman Creek at Cyrus Lane near Ashwaubenon, Wis.	11.9	100	0	0	100	0	91.65	1.73	4.81	0	.32	.77	.71	--
18	040850745	Dutchman Creek at Pioneer Road at Ashwaubenon, Wis.	15.7	100	0	0	100	.40	90.61	2.36	4.80	0	.35	.82	.65	1
19	04085076	Dutchman Creek Tributary near De Pere, Wis.	2.38	100	0	0	100	13.50	61.24	10.84	10.60	.07	.95	.55	2.25	1

be different than the pesticides from agricultural areas), as well as petroleum products, road salt, sediment, metals, and other contaminants from roads and industrial sites. Impervious surfaces such as roads, roofs, and driveways in urban areas reduce infiltration and lead to increased stormwater runoff and erosion.

Streams with small drainage basins and occasional very low flows are locations where contaminants can become concentrated. Larger rivers often have steadier flow rates, carry much more water, and generally have lower concentrations of contaminants than the tributaries that drain into them. The permeability of surficial deposits influences how much precipitation will infiltrate the ground and how much will run off overland. Clayey surficial deposits, for example, impede infiltration of water into soil, which means less recharge to ground water and an increase in overland runoff to surface waters. Water that runs overland can transport contaminants and sediment to streams. Streams in drainage basins with clayey surficial deposits will have lower base flows than streams in basins with more permeable surficial deposits due to smaller contributions of ground-water to total stream flow. More frequent and pronounced extreme flows can occur in streams in drainage basins with clayey surficial deposits due to the greater percentage of overland runoff in total stream flow.

Data results from water-quality samples are influenced by the time of year and flow conditions. Concentrations of contaminants in surface waters are often higher during periods of runoff than during times of base flow. However, concentrations of contaminants will differ between high flow samplings (or between low flow samplings) depending on the season. For example, even though they are both high flow events, pesticide concentrations will be higher in water samples collected during post-planting runoff sampling than during snowmelt runoff sampling because of the timing of pesticide applications. Base flow may have comparatively low concentrations of contaminants such as pesticides or sediment; however, comparatively high concentrations of contaminants such as certain major ions may be detected in samples collected at baseflow conditions as these substances can leach out of streambed sediments into the water column during times of low flow.

Sample and Survey Methods

Water samples were collected at 19 sites in and around the Oneida Reservation during 1997–98 (fig. 1). Two of the sites, referred to as "NAWQA sites," sampled for this study have also been sampled as part of the Western Lake Michigan Drainages study area of the National Water-Quality Assessment (NAWQA) program, which began data collection in 1991 (Peters and others, 1998).

Sample collection began in fall 1997 and ended in fall 1998. Four different flow conditions were sampled: late summer base flow (September 1997 and August 1998), late fall post-harvest base flow (November 1997), snowmelt runoff (February 1998), and post-planting runoff (June 1998). Field measurements of water properties and laboratory determinations of selected water-quality properties and constituents were made for each sample collected (table 2). Samples were collected, processed, and analyzed according to the methods of the NAWQA program (Shelton, 1994).

Ecological surveys were made in May 1998 at 5 of the 19 water sampling sites. An ecological survey was made at an additional site on the Oneida Reservation (Duck Creek) as part of the USGS NAWQA program, also in May 1998. Sampling methods for habitat (Fitzpatrick and others, 1998), benthic invertebrates (Cuffney and others, 1993), and algae (Porter and others, 1993) followed NAWQA specifications.

Benthic-invertebrate collections consisted of (1) a semiquantitative collection from the richest-targeted habitat (riffles), by means of a modified Surber sampler with 425-µm mesh; and (2) a qualitative sample of all available habitats in the reach (multihabitat), by means of a 210-µm mesh D-frame dipnet. For the quantitative sample, cobbles in a 0.5-m by 0.5-m area of the stream bottom were scrubbed with a stiff brush, and the streambottom was disturbed to a depth of approximately 10 cm with a rod and vigorous foot motion. Six subsamples were collected from riffles in each reach, field elutriated with a bucket, picked free of debris, and combined into one sample for a site. Samples were preserved with 70 percent non-denatured ethanol and shipped to Dr. Stanley W. Szczytko at University of Wisconsin–Stevens Point for identification and enumeration.

Benthic-algae collections were made in the same general locations as the invertebrate collections and consisted of (1) a quantitative collection from the richest-targeted habitat (riffles) and (2) a qualitative multi-

Table 2. Field measurements made and properties and constituents for which water samples from the Oneida Reservation, Wisconsin were analyzed, 1997–98

[--, not applicable: C, degrees Celsius; mm Hg, millimeters mercury; ft^3/s, cubic foot per second; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; std units, standard units; µg/L, micrograms per liter;]

Type	Property or constituent	Method Reporting Level	Units
Field	Water temperature	--	C
	Air temperature	--	C
	Barometric pressure	--	mm Hg
	Discharge	--	ft^3/s
	Specific conductance	--	µS/cm
	Dissolved oxygen	--	mg/L
	pH, field	--	std units
	pH, lab	--	std units
	Alkalinity	--	mg/L
	pH, laboratory	0.100	pH
	Specific conductance, laboratory	1.000	µS/cm
Sediment	Suspended sediment	--	mg/L
Nutrients	Phosphorus	.004	mg/L
	Phosphorus, phosphate, ortho	.010	mg/L
	Phosphorus	.004	mg/L
	Nitrogen, ammonia + organic nitro-	.10	mg/L
	Nitrogen, ammonia + organic nitro-	.10	mg/L
	Nitrogen, nitrite	.010	mg/L
	Nitrogen, ammonia	.02	mg/L
	Nitrogen, nitrite + nitrate	.050	mg/L
Major Ions	Silica	.05	mg/L
	Potassium	.100	mg/L
	Fluoride	.100	mg/L
	Sodium	.06	mg/L
	Calcium	.020	mg/L
	Magnesium	.004	mg/L
	Sulfate	.100	mg/L
	Chloride	.100	mg/L
	Manganese	3.0	µg/L
	Iron	10.000	µg/L
	Residue, 180 degrees Celsius	10.000	mg/L
Pesticides	2,6-diethylaniline	.003	µg/L
	Acetochlor	.002	µg/L
	Alachlor	.002	µg/L
	Atrazine	.001	µg/L
	Azinphos-methyl	.001	µg/L
	Benfluralin	.002	µg/L
	Butylate	.002	µg/L
	Carbaryl	.003	µg/L
	Carbofuran	.003	µg/L
	Chlorpyrifos	.004	µg/L
	Cyanazine	.004	µg/L
	Dacthal	.002	µg/L
	Deethylatrazine	.002	µg/L
	Diazinon	.002	µg/L
	Diazinon-d10 (surrogate)	.1	percent
	Dieldrin	.001	µg/L
	Disulfoton	.017	µg/L
	EPTC	.002	µg/L
	Ethalfluralin	.004	µg/L
	Ethoprophos	.003	µg/L
	Fonofos	.003	µg/L
	Lindane	.004	µg/L
	Linuron	.002	µg/L
	Malathion	.005	µg/L
	Metolachlor	.002	µg/L
	Metribuzin	.004	µg/L
	Molinate	.004	µg/L
	Napropamide	.003	µg/L
	Parathion	.004	µg/L
	Parathion-methyl	.006	µg/L
	Pebulate	.004	µg/L
	Pendimethalin	.004	µg/L
	Phorate	.002	µg/L
	Prometon	.018	µg/L
	Propachlor	.007	µg/L
	Propanil	.004	µg/L
	Propargite	.013	µg/L
	Propyzamide	.003	µg/L
	Simazine	.005	µg/L
	Tebuthiuron	.010	µg/L
	Terbacil	.007	µg/L
	Terbufos	.013	µg/L
	Terbuthylazine (surrogate)	.1	percent
	Thiobencarb	.002	µg/L
	Tri-allate	.001	µg/L
	Trifluralin	.002	µg/L
	alpha-HCH	.002	µg/L
	alpha-HCH-d6 (surrogate)	.1	percent
	cis-Permethrin	.005	µg/L
	p,p'-DDE	.006	µg/L

habitat sample. For the quantitative sample, algae were removed from a circular sampling area (about 2 cm in diameter) on each of five rocks in five locations from each reach. An SG-92 sampling device (Porter and others, 1993), constructed of a syringe barrel and sealing O-ring, was used with a small brush to remove the algae. The 25 algal-surface-area subsamples were composited into a single algal sample representing approximately 75 cm^2 for each site. Qualitative multihabitat algal samples were equal-weighted composites of all available habitat types. Algal samples were preserved with 100 percent buffered formalin and shipped to Dr. Frank Acker, Academy of Natural Sciences - Philadelphia, for identification and enumeration.

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SURFACE-WATER QUALITY

Chemical Indicators of Water Quality

A summary of the results of field measurements and laboratory analysis of water samples collected in 1997–98 is shown in table 3. Concentrations of selected nutrients, sediment, major ions, and pesticides are discussed below. These constituents were chosen because of their importance to stream-water quality and the availability of water-quality standards by which to measure their impact on streams. Concentrations are compared to selected U.S. Environmental Protection Agency (USEPA) drinking-water-quality criteria, including Maximum Contaminant Levels (MCL's), Secondary Maximum Contaminant Levels (SMCL's), and Health Advisories (HA's). USEPA drinking-water-quality criteria for selected constituents are listed in table 4. Although the surface waters of the Oneida Reservation are not used for drinking water supplies, drinking-water criteria were used for comparison because other established assessment criteria are not available. Concentrations of several constituents exceeded one or more of these criteria. Constituents that most often exceeded water-quality criteria were total phosphorus, sodium, manganese, and atrazine.

Maximum Contaminant Level (MCL)—The maximum permissible level of a contaminant in water delivered to users of a public water supply system.

Secondary Maximum Contaminant Level (SMCL)—Unenforceable federal guidelines regarding taste, odor, color and certain other non-aesthetic effects of drinking water. USEPA recommends these guidelines to the States as reasonable goals, but federal law does not require water systems to comply with them. States may, however, adopt their own enforceable regulations governing these concerns.

Health Advisory (HA)—Guidance values based on non-cancer health effects for different durations of exposure. HA's provide information on contaminants, either known or anticipated to occur in drinking water, that can cause human health effects.

(United States Environmental Protection Agency, Drinking-Water Standards can be viewed at URL: http://www.epa.gov/OGWDW/creg.html, accessed October 18, 1999)

Nutrients and Suspended Sediment

Sources of nutrients in the vicinity of the Oneida Reservation include agricultural fertilizers, wastewater-treatment-plant effluent, and animal wastes. Erosion from agricultural fields or urban areas can contribute to suspended-sediment concentrations in streamwater.

Concentrations of total phosphorus and dissolved nitrite plus nitrate nitrogen frequently exceeded water-quality limits for many sites during most sampling conditions (fig. 2). Suspended-sediment concentrations were highest for the post-planting and post-harvest samplings.

Concentrations of total phosphorus ranged from below 0.010 to 3.92 mg/L, and exceeded 0.1 mg/L, the USEPA suggested limit for flowing waters, in 50 of 82 samples collected during this study. The USEPA recommends that total-phosphorus concentrations not exceed this limit to discourage excessive aquatic growth in flowing waters. The highest phosphorus concentrations

Table 3. Summary statistics for selected properties and constituents calculated for all samples and for each of the five samplings, Oneida Reservation, Wisconsin, 1997–98

[C, degrees Celsius; --, not applicable; ft³/s, cubic foot per second; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; std units, standard units; µg/L, micrograms per liter]

Property or constituent	Units	Method Reporting Level[1]	All samplings				Fall base flow (9/97)				Post-harvest base flow (11/97)			
			Minimum	Maximum	Median	Mean[2]	Minimum	Maximum	Median	Mean[2]	Minimum	Maximum	Median	Mean[2]
Water temperature	C	--	0.2	26.9	14.4	10.9	11.8	20.2	14.6	14.7	0.2	3.0	0.9	1.1
Discharge	ft³/s	--	.00	182	1.4	16	.02	35	.88	3.9	.00	7.3	.25	1.2
Specific conductance	µS/cm	--	106	1,550	766	809	560	1,160	753	776	660	1,550	990	1,070
Dissolved oxygen	mg/L	--	2.0	20.0	9.0	9.3	3.2	12.5	8.6	8.4	2.1	14.8	11.4	10.4
pH (field)	std units	--	7.1	9.0	7.8	7.9	7.6	8.4	7.9	8.0	7.2	8.2	7.8	7.8
Alkalinity	mg/L	--	37	517	230	232	160	348	234	234	258	517	336	351
Suspended sediment	mg/L	--	6	1,390	42	82	7	103	22	34	7	154	74	76
Nitrogen, ammonia, dissolved	mg/L	.02	<.015	2.43	.054	.210	<.015	.361	.018	.039	<.020	1.12	<.020	.086
Nitrogen, ammonia + organic, dissolved	mg/L	.10	.12	6.1	.81	1.1	.20	2.1	.94	.97	.12	2.4	.48	.66
Nitrogen, nitrite + nitrate, dissolved	mg/L	.050	<.050	74.1	1.40	3.43	.397	3.58	1.09	1.48	<.050	4.93	.486	1.24
Phosphorus, total	mg/L	.004	<.010	3.92	.195	.373	<.010	1.26	.195	.340	<.010	3.92	.051	.446
Phosphorus, ortho, dissolved	mg/L	.010	<.010	2.87	.090	.253	.018	.997	.121	.262	.012	2.87	.044	.344
Calcium	mg/L	.020	50	219	83	88	56	110	81	83	75	173	105	112
Magnesium	mg/L	.004	19	73	35	36	19	44	31	31	35	67	44	47
Sodium	mg/L	.06	9.2	187	25	34	9.2	63	21	26	14	119	33	39
Potassium	mg/L	.100	1.4	58	6.5	9.2	1.5	25	8.0	10	1.4	22	4.8	7.2
Chloride	mg/L	.100	28	290	64	77	61	120	56	59	32	210	73	87
Sulfate	mg/L	.100	25	630	54	77	25	150	49	56	35	320	56	82
Fluoride	mg/L	.100	<.10	.82	.12	.17	<.10	.42	.16	.16	<.10	.78	.14	.22
Silica	mg/L	.05	.76	23	9.0	9.9	4.2	17	12	12	2.5	23	9.6	10
Iron	µg/L	10.000	<10	330	36	55	11	140	36	53	13	330	43	75
Manganese	µg/L	3.00	5.6	1,440	28	83	6.4	192	30	42	5.9	1,440	13	201
Simazine	µg/L	.005	<.005	.527	.013	.044	<.005	.017	.007	.008	<.005	.086	.008	.027
Deethylatrazine	µg/L	.002	.006	.936	.032	.148	.025	.170	.089	.083	.006	.033	.017	.019
Cyanazine	µg/L	.004	<.004	15.6	.010	1.06	<.004	.119	<.004	.024	<.004	<.004	<.004	--
Metolachlor	µg/L	.002	<.002	53.2	.064	3.30	<.002	.421	.175	.180	<.002	.034	.014	.014
Diazinon	µg/L	.002	<.002	1.18	<.002	.042	<.002	.004	<.002	--	<.002	<.002	<.002	--
Atrazine	µg/L	.001	.027	76.2	.133	5.61	.042	.392	.245	.227	.027	.083	.048	.049
Alachlor	µg/L	.002	<.002	.385	<.002	.025	<.002	.005	<.002	--	<.002	<.020	<.002	--
Acetochlor	µg/L	.002	<.002	19.2	.007	1.35	<.002	.016	.004	.005	<.002	<.002	<.002	--
Metribuzin	µg/L	.004	<.004	1.76	<.004	.083	<.004	<.100	<.004	--	<.004	<.004	<.004	--
EPTC	µg/L	.002	<.002	1.64	<.002	.050	<.002	<.002	<.002	--	<.002	<.002	<.002	--

[1]The method reporting level is defined as the minimum concentration of a substance that can be identified, measured, and reported with 99 percent confidence that the analyte concentration is greater than zero. Values reported below the method reporting level are estimated because while the lab has identified the substance as being present in the sample, quantification is reported with less than 99 percent confidence. On occasion, values may be reported above the method reporting level are estimated based on the results of equipment calibration.

[2]For the purpose of mean calculations, values reported as less than the minimum limit were set at one half of the minimum limit.

Table 3. Summary statistics for selected properties and constituents calculated for all samples and for each of the five samplings, Oneida Reservation, Wisconsin, 1997–98—Continued

Property or constituent	Units	Method Reporting level[1]	Snowmelt runoff (2/98)				Post-planting runoff (6/98)				Fall base flow (8/98)			
			Minimum	Maximum	Median	Mean[2]	Minimum	Maximum	Median	Mean[2]	Minimum	Maximum	Median	Mean[2]
Water temperature	C	--	0.2	4.5	0.2	0.9	14.3	20.2	16.7	16.8	17.0	26.9	20.5	20.6
Discharge	ft^3/s	--	.40	182	12	33	.56	175	27	40	.00	3.1	.17	.46
Specific conductance	µS/cm	--	542	1,050	710	745	106	1,220	565	550	618	1,550	798	907
Dissolved oxygen	mg/L	--	9.1	13.9	11.8	11.6	6.5	8.8	7.6	7.6	2.0	20.0	8.6	8.3
pH (field)	std units	--	7.1	8.2	7.8	7.7	7.3	8.2	7.7	7.7	7.4	9.0	8.0	8.1
Alkalinity	mg/L	--	94	340	205	206	37	231	100	111	159	386	250	260
Suspended sediment	mg/L	--	6	61	19	27	9	1,390	110	199	8	67	24	28
Nitrogen, ammonia, dissolved	mg/L	.02	<.020	2.00	.212	.388	.065	1.14	.186	.272	.037	2.43	.085	.287
Nitrogen, ammonia + organic, dissolved	mg/L	.10	.23	3.6	1.0	1.3	.35	4.0	1.1	1.2	.17	6.1	.67	1.1
Nitrogen, nitrite + nitrate, dissolved	mg/L	.050	.585	14.0	1.92	3.02	.080	74.1	3.71	10.5	<.050	3.86	.408	1.13
Phosphorus, total	mg/L	.004	.021	.583	.247	.241	.076	1.26	.342	.419	.011	3.00	.124	.425
Phosphorus, ortho, dissolved	mg/L	.010	.022	.435	.144	.176	.010	.480	.120	.166	.017	2.10	.083	.317
Calcium	mg/L	.020	50	87	70	70	78	78	78	78	60	219	79	90
Magnesium	mg/L	.004	21	36	29	28	38	38	38	38	24	73	37	40
Sodium	mg/L	.06	12	75	26	33	43	43	43	43	10	187	25	41
Potassium	mg/L	.100	1.5	22	8.5	8.6	5.8	5.8	5.8	5.8	1.6	58	6.9	11
Chloride	mg/L	.100	37	170	71	78	93	93	93	93	28	290	57	83
Sulfate	mg/L	.100	35	90	58	58	50	50	50	50	29	630	60	120
Fluoride	mg/L	.100	<.10	.14	<.10	.08	.18	.18	.18	.18	<.10	.82	.16	.24
Silica	mg/L	.05	5.7	13	8.1	8.5	3.6	3.6	3.6	3.6	.76	18	8.1	9.2
Iron	µg/L	10.000	15	110	50	53	23	23	23	23	<10	240	12	40
Manganese	µg/L	3.00	14	91	29	35	34	34	34	34	5.6	226	26	63
Simazine	µg/L	.005	<.005	.174	.016	.041	.005	.527	.034	.066	.013	.013	.013	.013
Deethylatrazine	µg/L	.002	.010	.044	.021	.024	.008	.936	.088	.276	.018	.018	.018	.018
Cyanazine	µg/L	.004	<.004	<.004	<.004	--	<.004	15.6	.203	2.31	<.020	<.020	<.020	--
Metolachlor	µg/L	.002	<.002	.064	.036	.033	.010	53.2	1.40	7.13	.038	.038	.038	.038
Diazinon	µg/L	.002	<.002	<.002	<.002	--	<.002	1.18	<.002	.090	<.002	<.002	<.002	--
Atrazine	µg/L	.001	.030	.036	.033	.033	.043	76.2	3.07	12.1	.133	.133	.133	.133
Alachlor	µg/L	.002	<.002	<.002	<.002	--	<.002	.385	.009	.053	<.002	<.002	<.002	--
Acetochlor	µg/L	.002	<.002	<.002	<.002	--	<.007	19.2	.044	2.94	<.002	<.002	<.002	--
Metrabuzin	µg/L	.004	<.004	<.004	<.004	--	<.004	1.76	<.004	.173	<.004	<.004	<.004	--
EPTC	µg/L	.002	<.002	<.002	<.002	--	<.002	1.64	.006	.109	<.002	<.002	<.002	--

[1]The method reporting level is defined as the minimum concentration of a substance that can be identified, measured, and reported with 99 percent confidence that the analyte concentration is greater than zero. Values reported below the method reporting level are estimated because while the lab has identified the substance as being present in the sample, quantification is reported with less than 99 percent confidence. On occasion, values may be reported above the method reporting level are estimated based on the results of equipment calibration.

[2]For the purpose of mean calculations, values reported as less than the minimum limit were set at one half of the minimum limit

Table 4. U.S. Environmental Protection Agency drinking-water-quality criteria for selected constituents
[mg/L, milligrams per liter; µg/L, micrograms per liter]

USEPA Drinking-Water-Quality Criteria[1]	Nutrients (mg/L)			Major ions (mg/L)			Major ions (µg/L)		Pesticides (µg/L)					
	Total phosphorus	Nitrite plus nitrate nitrogen	Dissolved nitrite	Sodium	Sulfate	Chloride	Iron	Manganese	Atrazine	Cyanazine	Diazinon	Metolachlor	Simazine	EPTC
MCL		10	1		500				3				4	
SMCL						250	50	300						
HA				20						1	0.6	70		25
Suggested limit for flowing waters	0.1[2]													

[1]Source: U.S. Environmental Protection Agency, Drinking-Water Standards at URL: http://www.epa.gov/OGWDW/creg.html, accessed October 18, 1999.

[2]The U.S. Environmental Protection Agency has recommended a limit of 0.1 mg/L for total phosphorus concentrations in flowing waters to discourage excessive aquatic growth.

were measured during the post-planting runoff sampling, when every site but Thornberry Creek (site 13) had concentrations of total phosphorus greater than the suggested limit. Nearly every sample (35 of 36) collected at sites representing basins containing greater than 80 percent agricultural land use had total phosphorus concentrations that exceeded the suggested limit. Total phosphorus concentrations at sites with basins containing more than 8 percent of forest, wetland, or urban areas, and less than 80 percent agricultural land use exceeded the suggested limit only during the post-planting runoff sampling.

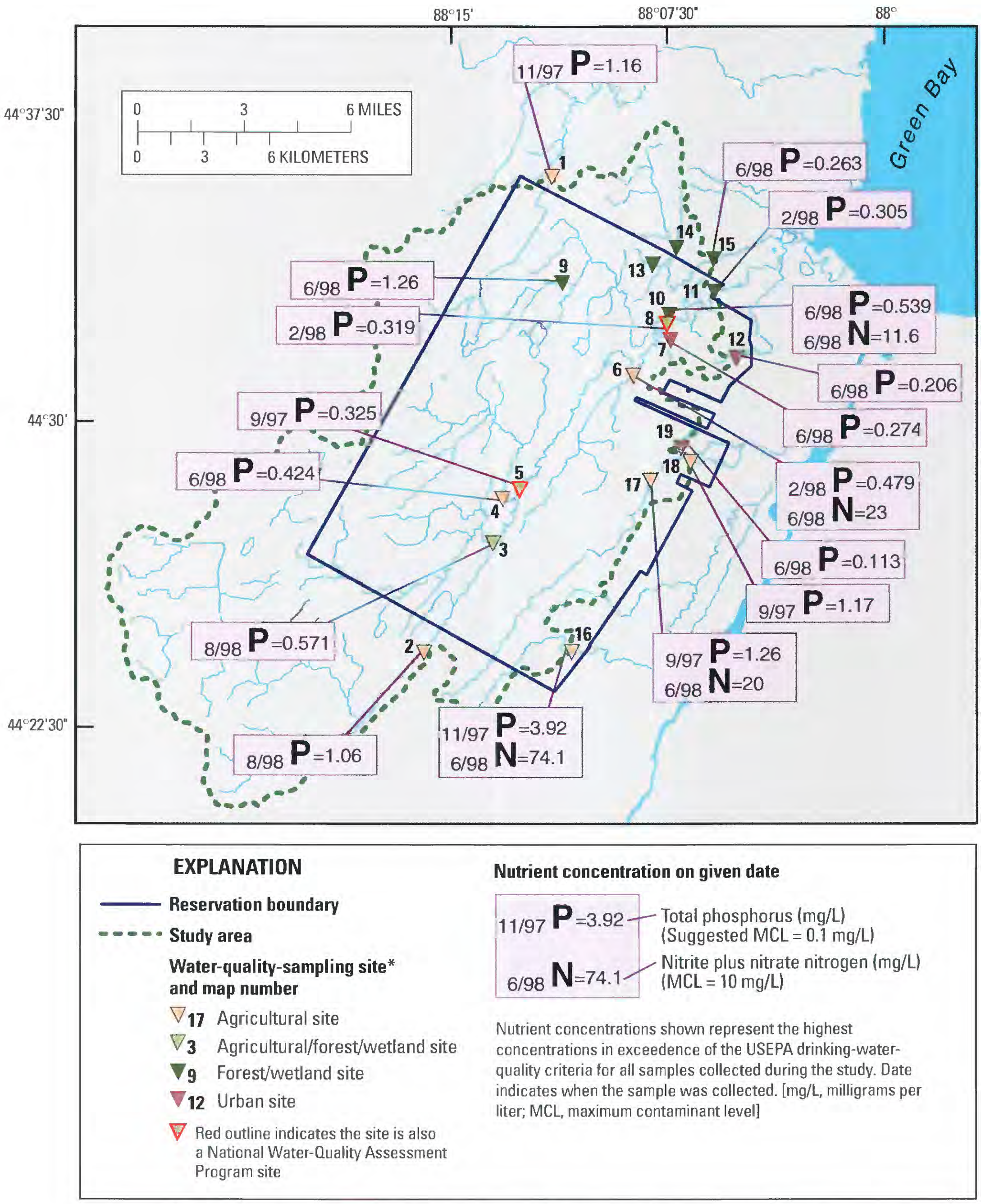
Concentrations of dissolved nitrite plus nitrate nitrogen ranged from the analytical method reporting level (MRL) of 0.050 mg/L to 74.1 mg/L. The concentrations exceeded the MCL of 10 mg/L in samples collected at four sites during the post-planting sampling. Three of the four sites contained more than 80 percent agricultural land and only small areas of forest or wetland. During the post-planting sampling, the dissolved nitrite plus nitrate nitrogen concentration detected in a sample from the North Branch Ashwaubenon Creek (site 16), downstream from a cattle yard, was 74.1 mg/L. Results from the same site on the same day indicated a dissolved-nitrite concentration of 0.701 mg/L, the highest concentration recorded among all sites sampled in the Western Lake Michigan Drainages study unit of the NAWQA program during the period 1991–99 (Kevin Richards, U.S. Geological Survey, written commun., 1999).

Concentrations of suspended-sediment ranged from 6 to 1,390 mg/L. Trout Creek at CT Highway U (site 9) had the highest suspended-sediment concentration. The highest suspended-sediment concentrations were usually measured during the post-planting runoff sampling (81 percent) and occasionally during the post-harvest sampling (13 percent). Suspended-sediment concentrations were often lowest in samples collected during the fall base flow and snowmelt samplings.

Major Ions

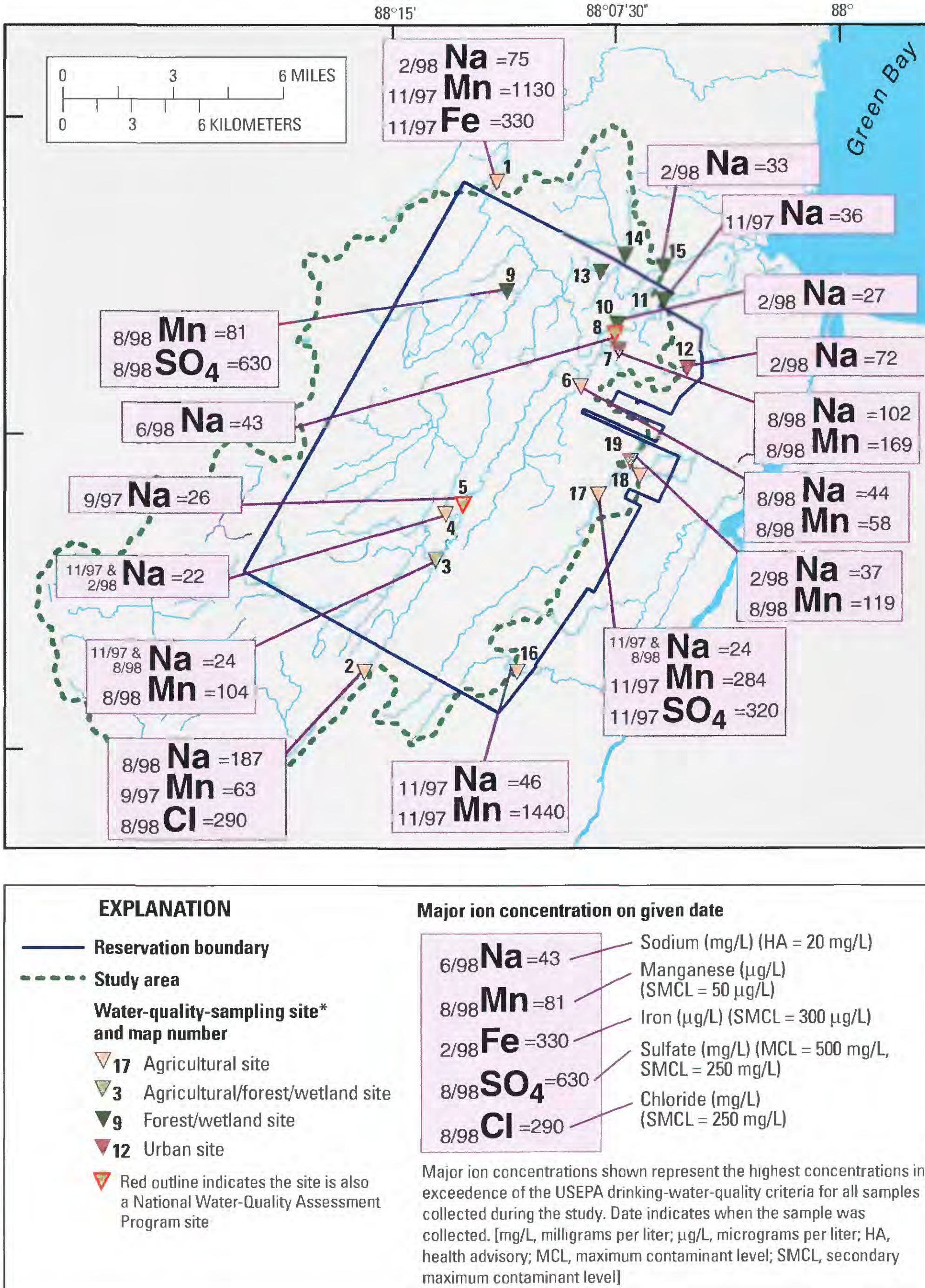
Concentrations of sodium and chloride above those of background concentrations may be linked to road salt applications (Hem, 1985), and point source discharge from, for example, wastewater-treatment plants. Sources of sulfate, manganese, and iron, other than natural background concentrations related to ground water contributions and streambed sediment leaching, can include point source discharge.

Excedeeences of drinking-water quality criteria occurred most frequently for the major ions sodium and manganese (fig. 3). Concentrations of other major ions were moderate to low relative to drinking-water-quality standards.



***Agricultural sites** are in basins with greater than 80 percent agricultural land, and less than 10 percent forest or 8 percent wetlands. **Agricultural/forest/wetland sites** are in basins with greater than 80 percent agricultural land and either greater than 10 percent forest or 8 percent wetlands. **Forest/wetland sites** are in basins with less than 80 percent agricultural land and either greater than 10 percent forest or 8 percent wetlands. **Urban sites** are in basins with greater than 10 percent urban land.

Figure 2. Highest nutrient concentrations in exceedance of U.S. Environmental Protection Agency drinking-water-quality criteria at water-quality-sampling sites.



***Agricultural sites** are in basins with greater than 80 percent agricultural land, and less than 10 percent forest or 8 percent wetlands. **Agricultural/forest/wetland sites** are in basins with greater than 80 percent agricultural land and either greater than 10 percent forest or 8 percent wetlands. **Forest/wetland sites** are in basins with less than 80 percent agricultural land and either greater than 10 percent forest or 8 percent wetlands. **Urban sites** are in basins with greater than 10 percent urban land.

Figure 3. Highest major-ion concentrations in exceedance of U.S. Environmental Protection Agency drinking-water-quality criteria at water-quality-sampling sites.

Sodium concentrations ranged from 9.2 to 187 mg/L, and concentration in 72 percent of the samples exceeded the 20-mg/L HA level. For all samples collected at sites representing basins with greater than 10 percent urban land, sodium concentrations exceeded the HA level. Sodium concentrations were lowest for sites with more than 10 percent forest or 8 percent wetlands in their basins. Samples collected from Duck Creek near Freedom (site 2), downstream from five point-sources including four wastewater-treatment plants and one industrial outfall (U.S. Environmental Protection Agency, 1987), had the two highest sodium concentrations observed in this study.

The concentration range of chloride samples was 28 to 290 mg/L. The chloride concentration in one sample taken from Duck Creek near Freedom (site 2), where the two highest sodium concentrations were recorded, exceeded the SMCL of 250 mg/L. As with the sodium concentrations, chloride concentrations were the lowest for sites with either 10 percent forest or 8 percent wetland areas within their basins.

Sulfate concentrations ranged from 25 to 630 mg/L. The 500-mg/L MCL was exceeded at Trout Creek at CT Highway U (site 9), and the 250-mg/L SMCL was exceeded at Dutchman Creek at Cyrus Lane (site 17). The highest sulfate concentrations were measured during low flow, at 80 percent of the sites.

The range of manganese concentrations was 5.6 to 1,440 µg/L. The 50-µg/L SMCL was exceeded in 25 percent of the samples, at nine different sites. Concentrations of manganese in excess of the SMCL were measured most often at sites with either greater than 80 percent agricultural land use and less than 10 percent forest or 8 percent wetland areas or sites with greater than 10 percent urban land use.

Concentrations of iron ranged from the MRL of 10 µg/L to 330 µg/L. The iron concentration in one sample at the South Branch Suamico River (site 1) exceeded the 300-µg/L SMCL. Samples collected from sites in basins with less than 80 percent agricultural land and either 10 percent forested or 8 percent wetland areas had the lowest concentrations of iron.

Pesticides

Agricultural practices may be a substantial source of pesticides in the Oneida Reservation study area. However, pesticides are also used in residential and commercial land use settings for control of insects in buildings and on grasses in residential lawns and road rights-of-way. Atrazine, cyanazine, metolachlor, simazine, EPTC, and acetochlor are used primarily in agricultural practices. Diazinon is used most often in residential and commercial settings (University of California—Davis and others, accessed October 20, 1999).

Water-quality samples were collected at 16 sites during the post-planting sampling and at 6 of the 16 sites during the three other types of samplings and were analyzed for pesticides. Drinking-water-quality criteria for pesticides (fig. 4) were exceeded only during the post-planting sampling; pesticide concentrations were lower, at, or near the MRL, in samples collected during all other samplings. Pesticides and pesticide metabolites most commonly detected included atrazine, deethylatrazine, metolachlor, and simazine. Atrazine, deethylatrazine, and metolachlor were detected in at least one sample at every site. Pesticides detected at concentrations exceeding drinking-water-quality criteria were atrazine, diazinon, and cyanazine.

Concentrations of atrazine, which was detected in every sample collected, ranged from 0.027 to 76.2 µg/L. Atrazine was detected above the 3-µg/L MCL at eight sites. The highest concentration (76.2 µg/L) was in a sample collected at the South Branch Suamico River (site 1).

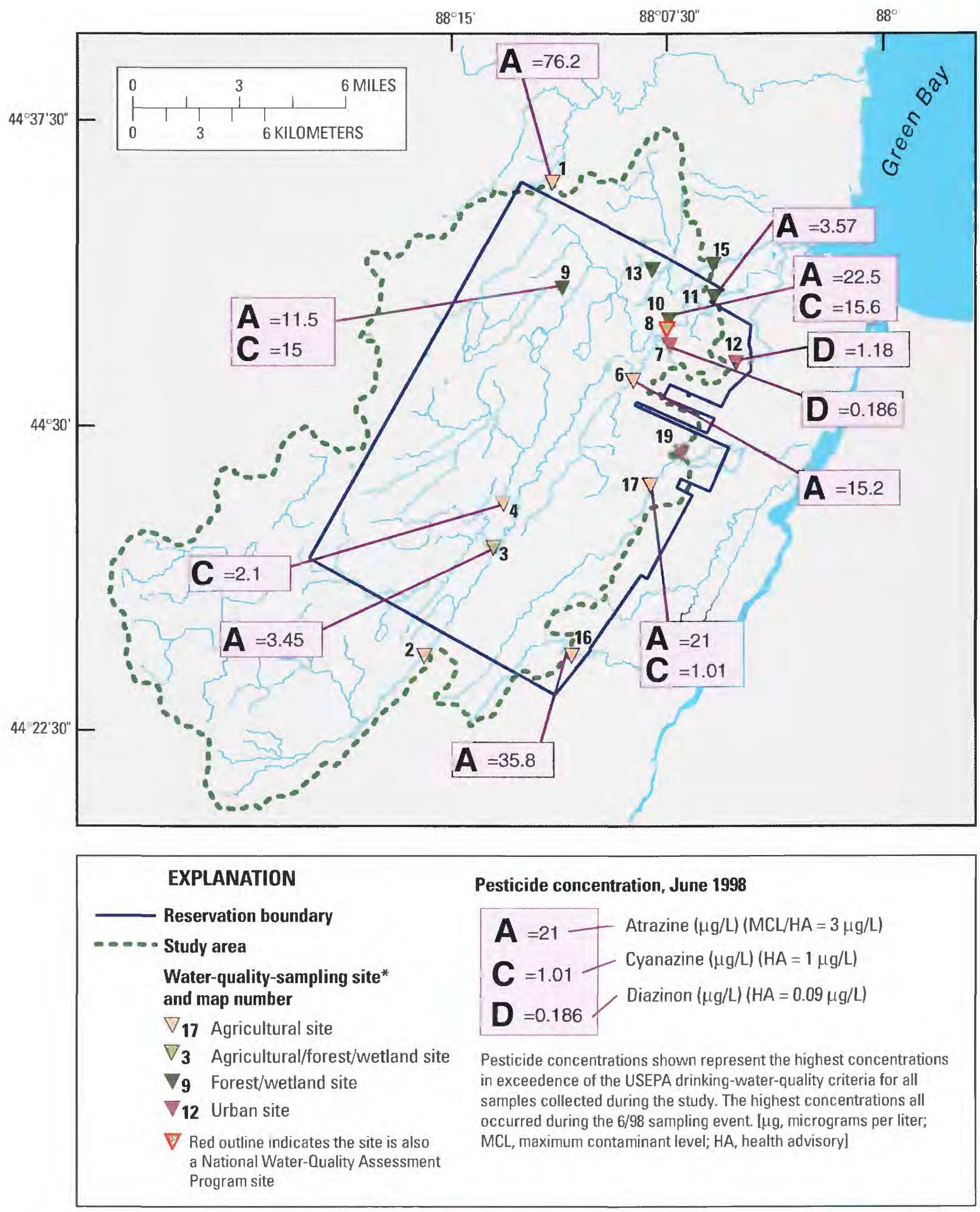
Concentrations of cyanazine ranged from less than the MRL to 15.6 µg/L. Five samples exceeded the HA of 1 µg/L. The samples with the two highest cyanazine concentrations were from the two Trout Creek sites (sites 9 and 10).

Metolachlor concentrations ranged from below the MRL to 53.2 µg/L. No exceedances of the 70-µg/L HA were found. The samples with the highest concentrations were at sites with greater than 80 percent agricultural land in their basins.

Concentrations of simazine ranged from below the MRL to 0.527 µg/L. No exceedances of the 4-µg/L MCL were found. Samples from two sites, each with more than 10 percent urban land within their basins, had the highest concentrations of simazine.

EPTC concentrations ranged from less than the MRL to 1.64 µg/L. The HA of 25 µg/L was not exceeded, and at only one site, the South Branch Suamico River (site 1), was a concentration reported that was substantially above the MRL.

Acetochlor concentrations ranged from below the MRL to 19.2 µg/L. Samples from five sites had concentrations substantially above the MRL. Trout Creek at CT Highway U (site 9) had the highest acetochlor concentration, 19.2 µg/L.



***Agricultural sites** are in basins with greater than 80 percent agricultural land, and less than 10 percent forest or 8 percent wetlands. **Agricultural/forest/wetland sites** are in basins with greater than 80 percent agricultural land and either greater than 10 percent forest or 8 percent wetlands. **Forest/wetland sites** are in basins with less than 80 percent agricultural land and either greater than 10 percent forest or 8 percent wetlands. **Urban sites** are in basins with greater than 10 percent urban land.

Figure 4. Highest pesticide concentrations in exceedance of U.S. Environmental Protection Agency drinking-water-quality criteria at water-quality-sampling sites.

Concentrations of diazinon ranged from below the MRL to 1.18 µg/L. The 0.6-µg/L HA was exceeded at Beaver Dam Creek (site 12), a site representing a basin with more than 50 percent urban land. The Unnamed Duck Creek Tributary (site 7), with more than 10 percent urban land in its basin, had a diazinon concentration of 0.186 µg/L. Concentrations of diazinon were at or slightly above the MRL at all other sites.

Ecological Indicators of Water Quality

Ecological information, including aquatic habitat and benthic invertebrate and algal community data, was collected at 5 of the 19 sites (sites 4, 10, 13, 14, and 17) during May 5–7, 1998. Site 5 (Duck Creek) also was sampled on May 4, 1998, as part of the NAWQA study. These sites are on major tributaries of interest on the reservation. The most notable limiting constraint on stream biota at Duck, Oneida, and Dutchman Creeks was intermittent flow. During extended periods of little or no rainfall, the only water remaining in the streambed is in discontinuous pools. During the course of the work done on the Oneida Reservation, these three streams had extended periods of very low flow (less than 0.1 ft^3/s). Dutchman Creek also had a higher degree of embeddedness, the degree to which gravel-sized and large particles in the streambed are covered by fine grained particles, and siltation than the other sites.

Habitat

Habitat characteristics were measured at five sites in addition to Duck Creek. A summary of habitat data for Duck Creek also may be found in Fitzpatrick and Giddings (1997). These measurements were used in a semiquantitative habitat rating system developed as part of Great Lakes Environmental Assessment (GLEAS) Procedure 51 (Michigan Department of Natural Resources, 1991). GLEAS habitat scores were determined on the basis of physical measures of nine channel and streamside features: bottom substrate and available cover, embeddedness/siltation, velocity/depth, flow stability, bottom deposition, pools-riffles-runs-bends, bank stability, bank vegetation stability, and streamside cover. The scores are assigned summary ratings within four categories: excellent (111–135), good (75–102), fair (39–66), and poor (0–30). The GLEAS scores for the sites included in the ecological assessment ranged from a low of 59 ("fair") at Dutchman Creek at Cyrus Lane (site 17) to a high of 83 ("good") at Trout Creek near Howard (site 10). Each of the three sampling sites with more than 10 percent forest or 8 percent wetlands in their basins scored "good" in the GLEAS habitat assessment (table 5). The habitat score at Duck Creek (site 5), which has over 80 percent agricultural land plus more than 8 percent wetlands, scored "fair." Habitat at the other two sites, for which the land use of the drainage basins was greater than 80 percent agriculture and less then 10 percent forest or 8 percent wetlands, scored "fair to good" and "fair."

Benthic Invertebrates

The abundance and distribution of aquatic organisms in streams have been used as a measure of water-quality for many years in water-quality assessments. Some organisms are more tolerant than others to various types of environmental stress. Organisms attached to the stream bottom, also known as benthic organisms, provide an indication of the water-quality of a particular site that is integrated over days, weeks, and sometimes even years depending on the lifespans of the organisms. Benthic organisms are in close contact with chemicals in streambed sediment and may reflect stresses from this medium.

Benthic macroinvertebrates, large enough to be visible to the naked eye, collected at the five water-quality sites and at Duck Creek are listed in table 6. Several biotic indexes were calculated (table 5), including the Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1987), the Mean Tolerance Value or TBI (Lenat, 1993; Lillie and Schlesser, 1994), and taxa richness for EPT (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]) (Lenat, 1988) and Shannon-Wiener diversity (Brewer, 1979). The HBI is a measure of water-quality based on macroinvertebrate tolerance to organic chemicals and reduced dissolved oxygen concentrations in the water. High HBI values indicate poor water-quality. The TBI is the mean tolerance value for all taxa present in the HBI sample, and is independent of the number of individuals represented by each taxon. Rare and intolerant taxa therefore have greater emphasis in the TBI than in the HBI. The TBI is calculated as the sum of the assigned pollution-tolerance value for each taxon divided by the total number of taxa in the sample. Higher mean tolerance values indicate the presence of more pollution-tolerant species at a site. The TBI value is used as a companion metric with the standard HBI. EPT taxa richness differs from total taxa

Table 5. Ecological information for six water-quality-sampling sites based on habitat and benthic community indices, Oneida Reservation, Wisconsin, May 1998

[GLEAS, Great Lakes Environmental Assessment score; HBI, Hilsenhoff Biotic Index; EPT, Ephemeroptera, Plecoptera, and Trichoptera; taxa richness for invertebrates is by genus and for algae is by species; %, percent; ND, no data]

Map number	Site name	Habitat index	Benthic invertebrate indices						Benthic algal indices				
		Overall GLEAS score[1]	HBI score[2]	Mean tolerance value	Total taxa richness	EPT taxa richness	% EPT of total taxa richness	Shannon-Wiener diversity	Total taxa richness	Diatom taxa richness	% diatoms of total taxa richness	Shannon-Wiener diversity[3]	Diatom Pollution Index
13	Thornberry Creek near Howard, Wis.	79 Good	3.80 Very good	3.19 Excellent	18	10	56	2.28	43	37	86	3.85 Minor	2.26 Minor
10	Trout Creek near Howard, Wis.	83 Good	5.25 Good	5.03 Good	32	10	31	4.22	44	36	82	3.25 Moderate	2.39 Minor
14	Lancaster Brook at Shawano Avenue near Howard, Wis.	78 Good	5.12 Good	4.93 Good	34	11	32	4.13	47	41	87	3.52 Minor	2.55 None
5	Duck Creek at Seminary Road near Oneida, Wis.[4]	66 Fair	6.35 Fair	5.48 Good	27	6	22	3.54	ND	ND	ND	ND	ND
4	Oneida Creek at Van Boxtel Road near Oneida, Wis.	68 Fair to good	5.32 Good	5.33 Good	20	8	40	2.74	46	37	80	3.33 Minor	2.64 None
17	Dutchman Creek at Cyrus Lane near Ashwaubenon, Wis.	59 Fair	6.75 Fairly poor	7.06 Fairly poor	22	1	5	2.76	38	28	74	3.05 Moderate	1.70 Moderate

[1]GLEAS score categories: excellent (111–135), good (75–102), fair (39–66), and poor (0–30).

[2]HBI score categories.

Excellent	(0–3.50)
Very good	(3.51–4.50)
Good	(4.51–5.50)
Fair	(5.51–6.50)
Fairly-poor	(6.51–7.50)
Poor	(7.51–8.50)
Very poor	(8.51–10.00)

[3]Calculated for diatoms only according to Bahls (1993) to assess water quality stress.

[4]Algal data for Duck Creek were not available at the time this report was published.

richness, which is the total number of taxa in a sample for all orders of aquatic invertebrates. Taxa richness is considered to be inversely related to the amount of stress on the benthic community, and EPT taxa richness is a measure of those invertebrates that are most intolerant of stress indicated by water of impaired quality. Therefore, decreasing EPT taxa richness generally indicates decreasing water-quality (Plafkin and others, 1989; Lenat, 1993). The Shannon-Wiener diversity index incorporates species richness as well as dominance. Low diversity values generally indicate poor water quality; however, low EPT and diversity values also may be found for small, pristine (low-productivity or low-pH) headwater streams (Plafkin and others, 1989).

Results of the HBI calculations indicated "good" to "very good" water quality at most sites sampled. The HBI for the Thornberry Creek site indicates that the benthic macroinvertebrate community is characteristic of a stream with "very good" water quality. The Thornberry Creek drainage basin consists primarily of forests and wetlands, and receives ground-water discharge that helps maintain its base flow. Trout Creek, Lancaster Brook, and Oneida Creek (sites 10, 15, and 4) had benthic communities that would indicate "good" water quality according to the results of the HBI. The HBI for Duck Creek in 1998 was "fair" and therefore unchanged from that reported for this site by Lenz and Rheaume (2000) for sampling in 1993 through 1995. The HBI evaluation of Dutchman Creek (site 17) indicates "fairly poor" water quality with respect to the macroinvertebrate community. The macroinvertebrates at Dutchman Creek may be limited by a drainage basin that is heavily farmed, with little or no riparian corridor; moreover, many fields are tile drained, resulting in intermittent flow during dry periods.

HBI scores generally correlated with the TBI values. According to both indices, Thornberry Creek has the fewest pollutant-tolerant species. Dutchman Creek, with a basin consisting of 92 percent agricultural land, has the most pollutant-tolerant species. The mean tolerance value for Duck Creek was higher in 1998 than in 1993–95, when TBI values ranged from 4.67 to 5.00 (Lenz and Rheaume, 2000). With the exception of Thornberry Creek, HBI and TBI values for sites sampled in 1997–98 were, on average, higher than those reported by Rheaume and others (1996) for minimally affected or "benchmark" streams in the same RHU (relatively homogeneous units, areas of similar land use, surficial deposits and bedrock type).

Total taxa richness ranged from a low of 18 and 20 genera for Thornberry and Oneida Creeks, respectively, to a high of 32 and 34 genera for Trout and Lancaster Creeks. Abundant mayfly larvae were found during qualitative sampling in a small ponded sidechannel near the top of the reach at Oneida Creek. EPT taxa richness was lowest at Dutchman Creek and was represented by one genus (5 percent of total taxa richness). The highest EPT values were found at Thornberry Creek, Trout Creek, and Lancaster Brook. However, EPT taxa represented the greatest percentage of all taxa at Thornberry Creek, where 10 of 18, or 56 percent of the total number of genera, were EPT genera. This result agrees with the HBI and TBI and indicates that this site has the best water quality of all sampled sites. Rheaume and others (1996) found maximum percent EPT values of 46 to 57 in benchmark streams in this RHU. Percent EPT taxa during the 1997–98 sampling also may be compared to a range of 9 to 31 at the Duck Creek site for 1993–95 reported by Lenz and Rheaume (2000).

The low Shannon-Wiener diversity value at Thornberry Creek is likely due to the low productivity in this small headwater stream and not the result of impaired water-quality; this conclusion is supported by the other invertebrate indices for this site. High diversity indices are evidence that the invertebrate communities have minor stress or no stress at Trout Creek and Lancaster Brook. Progressively lower diversity values at Duck, Oneida, and Dutchman Creeks, when considered together with the other indices, are evidence that invertebrate communities at these sites may be stressed.

Benthic Algae

Benthic algae found at the five ecological sampling sites are listed in table 7. Algal data was not available for Duck Creek at the time this report was published. Indices calculated for algae included total taxa (species) richness, diatom taxa (species) richness, percent diatom taxa, Shannon-Wiener diversity (Brewer, 1979) for diatoms only, percentage of diatoms that are pollution sensitive or tolerant (Lange-Bertalot, 1979; Bahls, 1993), and a diatom pollution index (Bahls, 1993). Bahls' diatom pollution index is calculated from the fraction of diatoms that are considered most tolerant, less tolerant, and sensitive based on the tolerance groups of Lange-Bertalot (1979). The evaluation of diatom pollution index scores in this report is based on four categories presented in Bahls (1993) for Montana streams: severe pollution (< 1.50), moderate pollution (1.50 to 2.00),

Table 6. Benthic invertebrates collected at selected water-quality-sampling sites, Oneida Reservation, Wisconsin, May 1998

Scientific name	Organism ID	Occurrence at site by map number					
		4	5	10	13	14	17
Phylum: Arthropoda							
Class: Insecta/Hexapoda							
Order: Plecoptera	01000000					X	
Family: Capniidae	01010000	X	X	X		X	
Family: Nemouridae							
Genus: *Amphinemura*							
Species: *delosa*	01040101				X		
Genus: *Nemoura*							
Species: *trispinosa*	01040201				X		
Family: Perlidae							
Genus: *Perlesta*	01050500	X	X	X		X	
Family: Perlodidae							
Genus: *Isoperla*							
Species: *nana*	01060408	X					
Genus: *Clioperla*							
Species: *clio*	01060501				X		
Order: Ephemeroptera							
Family: Baetidae	02010000	X		X		X	X
Genus: *Baetis*	02010100			X	X	X	X
Species: *brunneicolor*	02010101			X		X	
Species: *flavistriga*	02010104	X	X	X		X	X
Genus: *Acerpenna*							
Species: *pygmaea*	02011102		X				
Family: Heptageniidae	02060000	X		X			
Genus: *Stenacron*							
Species: *interpunctatum*	02060501					X	
Genus: *Stenonema*	02060600	X		X			
Species: *femoratum*	02060602	X	X				
Species: *vicarium*	02060608			X			
Family: Leptophlebiidae							
Genus: *Leptophlebia*	02070100	X					X
Order: Odonata							
Family: Cordulegastridae							
Genus: *Cordulegaster*	03040100				X		
Order: Trichoptera							
(pupae)	04000200			X			
Family: Glossosomatidae							
Genus: *Agapetus*	04020100			X			
(pupae)	04020400				X		
Family: Hydropsychidae	04040000			X		X	
Genus: *Cheumatopsyche*	04040100	X	X	X	X	X	
Genus: *Hydropsyche*	04040200					X	
Species: *betteni*	04040201			X		X	
Genus: *Diplectrona*							
Species: *modesta*	04040301				X		
Genus: *Ceratopsyche*	04040700					X	
Species: *slossonae*	04040706			X		X	
(pupae)	04040900			X		X	
Family: Hydroptilidae	04050000	X		X		X	
Genus: *Stactobiella*	04050900	X		X			X
Family: Lepidostomatidae							
Genus: *Lepidostoma*	04060100				X		
Family: Limnephilidae	04080000				X		
Genus: *Ironoquia*	04080600					X	
Genus: *Limnephilus*	04080700				X		
Genus: *Pycnopsyche*	04081300			X	X	X	
Family: Philopotamidae							
Genus: *Wormaldia*							
Species: *moesta*	04110301	X					
Family: Psychomyiidae							
Genus: *Psychomyia*							
Species: *flavida*	04140201					X	
Family: Uenoidae							
Genus: *Neophylax*	04190100			X	X	X	
Order: Lepidoptera	06000000			X		X	
Order: Coleoptera							
Family: Dryopidae							
Genus: *Helichus*							
Species: *striatus*	07010103		X			X	
Family: Elmidae	07020000		X				
Genus: *Dubiraphia*	07020200			X			
Genus: *Optioservus*	07020500	X	X	X	X	X	
Species: *fastiditus*	07020501		X	X	X	X	
Genus: *Stenelmis*	07020600		X	X		X	
Species: *crenata*	07020601		X	X		X	
Family: Dytiscidae	07050000	X					
Family: Hydrophilidae							
Genus: *Anacaena*							
Species: *lutescens*	07090102		X				
Family: Staphylinidae							
Genus: *Stenus*	07130200		X				
Family: Curculionidae	07140000					X	
Genus: *Bagous*	07140300		X				
Order: Diptera	08000200						X
Family: Ceratopogonidae	08030000					X	
Genus: *Probezzia*	08030600					X	
Family: Empididae	08070000	X					
Genus: *Hemerodromia*	08070200		X	X		X	
Genus: *Chelifera*	08070300			X		X	
(pupae)	08071600			X			

Table 6. Benthic invertebrates collected at selected water-quality-sampling sites, Oneida Reservation, Wisconsin, May 1998—Continued

Scientific name	Organism ID	Occurrence at site by map number					
		4	5	10	13	14	17
Family: Simuliidae	08110000			X		X	X
Genus: *Cnephia*							
Species: *ornithophila*	08110102						X
(pupae)	08110104						X
Genus: *Simulium*	08110200	X	X	X		X	X
Species: *venustum*	08110215						X
Species: *verecundum*	08110216	X	X	X	X	X	X
Species: *vittatum*	08110217						X
(pupae)	08110245	X		X		X	X
Genus: *Prosimulium*	08110300		X				
Family: Tabanidae							
Genus: *Chrysops*	08130100				X		
Family: Tipulidae							
Genus: *Antocha*	08140100			X		X	
Genus: *Limnophila*	08140800				X		
Genus: *Tipula*	08141200				X		
(pupae)	08141300			X			
Family: Dixidae							
Genus: *Dixa*	08150200				X		
Family: Chironomidae	08250000	X	X	X		X	X
(pupae)	08250002		X	X		X	
Subfamily: Tanypodinae	08270000			X	X	X	
(pupae)	08270001	X	X	X		X	X
Genus: *Ablabesmyia*							
Species: *mallochi*	08270105		X				
Genus: *Conchapelopia*	08270700	X	X	X		X	
Genus: *Nilotanypus*	08271900			X		X	
Subfamily: Orthocladiinae	08300000	X	X	X		X	X
(pupae)	08300001	X	X	X		X	X
Genus: *Brillia*							
Flavifrons Group	08300407		X				
Genus: *Chaetocladius*	08300600	X		X			X
Acutricornis Group	08300601	X					
Piger Group	08300603			X	X	X	
Genus: *Corynoneura*	08300800	X					
Species: *taris*	08300804	X		X		X	
Genus: *C. (Cricotopus)*							
Bicinctus Group	08300901	X		X		X	X
Festivellus Group	08300903	X				X	
Tremulus Group	08300906		X	X		X	X
Genus: *C. (Isocladius)*							
Sylvestris Group	08301007						X
Genus: *Diplocladius*	08301200					X	
Genus: *Eukiefferiella*	08301400	X	X	X		X	X
Brehmi Group	08301401	X	X	X		X	X
Claripennis Group	08301402			X			
Genus: *Hydrobaenus*	08301700						X
Genus: *Limnophyes*	08301800					X	X
Genus: *N. (Nanocladius)*	08302300					X	X
Species: *rectinervis*	08302306					X	X
Genus: *O. (Orthocladius)*	08302600	X	X	X		X	X
Genus: *Thienemanniella*	08304700	X				X	X
Genus: *Tvetenia*							
Species: *Sp. A*	08304801			X		X	
Genus: *Xylotopus*							
Species: *par*	08304901			X			
Subfamily: Tanytarsini	08310000				X	X	X
(pupae)	08310001	X		X		X	
Genus: *Cladotanytarsus*							
Vanderwulpi Group	08310114			X		X	
Genus: *Micropsectra*	08310300			X		X	
Genus: *Paratanytarsus*							
Species: *Sp. A*	08310401					X	X
Genus: *Rheotanytarsus*	08310500			X			
Genus: *Stempellinella*	08310700					X	
Genus: *Tanytarsus*	08310800		X	X		X	X
Subfamily: Chironomini	08320000	X					X
(pupae)	08320001			X		X	
Genus: *Chironomus*	08320600					X	X
Genus: *Cryptochironomus*	08320800					X	
Genus: *Cryptotendipes*	08320900					X	
Genus: *Microtendipes*	08322500					X	
Genus: *Paratendipes*	08323200	X		X		X	X
Genus: *Polypedilum*	08323400		X				
Species: *Nr. convictum*	08323425	X	X	X		X	
Species: *Nr. fallax*	08323426	X	X	X		X	
Species: *Nr. illinoense*	08323428	X		X		X	
Species: *Nr. scalaenum*	08323429			X			
Genus: *Stictochironomus*	08324000	X		X		X	X
Order: Heteroptera/ Hemiptera							
Family: Veliidae							
Genus: *Microvelia*	19050100			X			
Family: Corixidae							
Genus: *Sigara*	19070900						X
Class: Crustacea							
Order: Amphipoda							
Family: Gammaridae							
Genus: *Gammarus*							
Species: *pseudolimnaeus*	09010201			X	X	X	X

Table 6. Benthic invertebrates collected at selected water-quality-sampling sites, Oneida Reservation, Wisconsin, May 1998—Continued

Scientific name	Organism ID	Occurrence at site by map number					
		4	5	10	13	14	17
Order: Eucopepoda							
Family: Cyclopidae	21020000	X		X		X	X
Order: Isopoda							
Family: Asellidae	10010000					X	
Genus: *Asellus*	10010100		X			X	
Order: Ostracoda							
Family: Unknown	27000000					X	
Class: Arachnoidea							
Order: Acari							
Family: Unknown	11000000	X			X	X	X
Phylum: Platyhelminthes							
Class: Turbellaria							
Unknown	13000000		X				
Phylum: Mollusca							
Class: Gastropoda							
Unknown	14000000					X	
Order: Limnophila							
Family: Physidae							
Genus: *Physa*	14040200						X
Family: Planorbidae							
Genus: *Gyraulus*	14050100					X	X
Class: Pelecypoda							
Order: Veneroida							
Family: Sphaeriidae							
Genus: *Sphaerium*	15010200			X		X	X
Genus: *Pisidium*	15010300		X				
Phylum: Annelida							
Class: Oligochaeta							
Unknown	16000000			X		X	X
Order: Haplotaxida							
Family: Naididae	16020000			X		X	X
Family: Haplotaxoida	16060000				X		
Family: Tubificidae	16030000		X	X		X	X

minor pollution (2.01 to 2.50), and no pollution (> 2.50). These ratings have not been calibrated for Wisconsin and should be applied with caution. The algal complement to EPT in invertebrates, diatoms are generally sensitive to changes in water quality, and a decrease in number of diatom taxa is usually associated with decreasing water quality. Various metrics related to the abundance and distribution of diatoms have been successfully used in water-quality assessment worldwide for decades.

Overall algal relative abundance was greatest at Oneida Creek (> 2×10^7 cells/cm^2) and smallest at Thornberry and Dutchman Creeks (< 9×10^5 cells/cm^2) (table 8). Algal biovolume per unit area also followed this pattern. Taxa richness was lowest at Dutchman Creek, and the percentage of diatom taxa was 74 percent, compared to 80 to 87 percent at the other sampled sites. The lower percentage of diatom taxa at Dutchman Creek indicates some water-quality impairment; however, a substantial diatom community still exists here. Visible algal mats and abundant growth of the filamentous green alga *Cladophora* were found at Dutchman Creek, which suggest high nutrient concentrations in the water.

The Shannon-Wiener diversity values for just diatoms ranged from 3.05 to 3.85 and were ranked as follows from lowest to highest: Dutchman Creek<Trout Creek<Oneida Creek<Lancaster Brook<Thornberry Creek. These values indicate increasing water quality in this order. If ratings are calibrated with a method similar to that of Lenat (1993) using the 25th and 75th percentiles of data for 37 sites in the Western Lake Michigan drainages USGS NAWQA program (Barbara Scudder, U.S. Geological Survey, unpublished data), then diversity values may indicate community stress as follows: < 2.30 (high stress), 2.30 to 3.29 (moderate stress), 3.30 to 4.29 (minor stress), and > 4.30 (no stress). Although this ranking should be interpreted with caution because of the small sample size, it indicates that four of five streams sampled in this study are subject to only minor stress as shown by diversity values. Only the diversity scores for Dutchman Creek indicate moderate stress.

The diatom pollution index (Bahls, 1993) indicates increasing pollution stress on the diatom community with decreasing scores. As was seen with other invertebrate and algal metrics discussed previously, the score for Dutchman Creek (1.70) indicates moderate pollution in this stream. Pollution indices for Thornberry and Trout Creeks indicate possible minor pollution in these streams, and indices for Lancaster Brook and Oneida Creek appear to show no stress due to pollution. Percentages of diatoms that were pollution sensitive were greatest at Oneida Creek (66 percent) and at Lancaster Brook (56 percent), and lowest by far at Dutchman Creek (10 percent). In contrast, pollution-tolerant

Table 7. Algae collected at selected water-quality-sampling sites, Oneida Reservation, Wisconsin, May 1998

Scientific name	Occurrence at site by map number				
	4	10	13	14	17
Phylum: Chlorophycophyta					
Family: Chaetophoraceae					
Genus: *Stigeoclonium*					
Species: *lubricum*	X	X			
Family: Chlamydomonadaceae					
Genus: *Chlamydomonas* sp.	X		X		X
Family: Cladophoraceae					
Genus: *Cladophora*					
Species: *Glomerata*	X	X		X	
Family: Desmidiaceae					
Genus: *Closterium*					
Species: *acerosum*		X			X
Family: Oedogoniaceae					
Genus: *Oedogonium* sp.	X		X		X
Family: Oocystaceae					
Genus: *Ankistrodesmus*					
Species: *falcatus*	X	X		X	
Genus: *Kirchneriella*					
Species: *lunaris*	X	X			
Genus: *Oocystis* sp.					X
Family: Scenedesmaceae					
Genus: *Actinastrum*					
Species: *hantzschii*				X	
Genus: *Scenedesmus*					
Species: *quadricauda*	X				
Genus: *Tetrastrum*					
Species: *staurogeniaeforme*	X				
Family: Ulvaceae					
Genus: *Schizomeris*					
Species: *leibleinii*	X				
Phylum: Chrysophycophyta					
Family: Achnanthaceae					
Genus: *Achnanthes*					
Species: *affinis*			X		
Species: *deflexa*				X	
Species: *detha*			X		
Species: *exigua*					
Variety: *elliptica*			X		
Species: *exigua*			X		
Species: *lanceolata*					
Variety: *dubia*	X		X		
Species: *lanceolata*	X	X	X	X	X
Genus: *Achnanthes*					
Species: *minutissima*	X	X	X	X	
Species: *pinnata*	X	X		X	X
Genus: *Cocconeis*					
Species: *placentula*					
Variety: *euglypta*		X	X	X	X
Species: *placentula*					
Variety: *lineata*	X	X	X	X	X
Species: *placentula*	X			X	X
Family: Diatomaceae					
Genus: *Diatoma*					
Species: *vulgare*	X	X		X	
Genus: *Fragilaria*					
Species: *capucina*					
Variety: *mesolepta*	X				X
Species: *capucina*					
Variety: *rumpens*				X	
Species: *construens*					
Variety: *pumila*	X				
Species: *fasciculata*	X			X	X
Species: *leptostauron*			X		
Species: *pinnata*			X		
Species: *tenera*				X	
Species: *vaucheriae*	X	X			X
Genus: *Meridion*					
Species: *circulare*	X		X		X
Species: *circulare*					
Variety: *constrictum*	X	X	X		
Genus: *Opephora*					
Species: *martyi*			X		
Genus: *Synedra*					
Species: *parasitica*		X		X	
Species: *ulna*	X	X	X	X	X
Genus: *Tabellaria*					
Species: *fenestrata*					X
Family: Dinobryaceae					
Genus: *Dinobryon sp.*	X				
Family: Melosiraceae					
Genus: *Melosira*					
Species: *italica*					X
Species: *varians*	X	X		X	
Family: Naviculaceae					
Genus: *Amphora*					
Species: *ovalis*					
Variety: *affinis*		X			
Species: *perpusilla*	X	X	X	X	X

Table 7. Algae collected at selected water-quality-sampling sites, Oneida Reservation, Wisconsin, May 1998—Continued

Scientific name	Occurrence at site by map number				
	4	10	13	14	17
Genus: *Caloneis*					
Species: *amphisbaena*	X	X	X	X	
Species: *bacillum*	X	X	X	X	
Species: *limosa*				X	
Genus: *Cymbella*					
Species: *minuta*					
Variety: *silesiaca*		X			
Genus: *Entomoneis*					
Species: *paludosa*				X	
Genus: *Frustulia*					
Species: *vulgaris*			X		
Genus: *Gomphonema*					
Species: *acuminatum*					X
Species: *affine*	X	X		X	
Species: *angustatum*	X	X	X	X	X
Species: *intricatum*					
Variety: *pumila*	X	X			
Species: *minutum*	X				
Species:*olivaceum*	X	X		X	
Species: *parvulum*	X	X	X	X	X
Species: *truncatum*					
Variety: *capitatum*	X	X			X
Genus: *Gyrosigma*					
Species: *acuminatum*	X				
Species: *attenuatum*		X		X	X
Species: *scalproides*		X			
Genus: *Navicula*					
Species: *accomoda*	X				X
Species: *aikenensis*		X			
Species: *atomus*	X	X			X
Species: *bryophila*			X		
Species: *canalis*					X
Species: *capitata*	X	X	X	X	X
Species: *capitata*					
Variety: *hungarica*				X	
Species: *capitata*					
Variety: *lunebergensis*			X		
Species: *cincta*				X	X
Species: *circumtexta*					X
Species: *costulata*			X		
Species: *cryptocephala*	X	X		X	
Genus: *Navicula*					
Species: *cryptocephala*					
Variety: *veneta*		X	X		X
Species: *decussis*	X		X	X	
Genus: *Navicula*					
Species: *halophila*					
Variety: *tenuirostris*					X
Species: *gregaria*	X	X	X	X	X
Species: *ignota*					
Variety: *palustris*			X		
Species: *incerta*		X			
Species: *lanceolata*	X	X	X		X
Species: *libonensis*					X
Species: *luzonensis*	X	X			X
Species: *menisculus*	X		X		
Species: *menisculus*					
Variety: *upsaliensis*	X		X	X	
Species: *minima*	X	X	X	X	X
Species: *molestiformis*	X				X
Species: *mutica*			X		X
Species: *omissa*				X	
Species: *pelliculosa*			X	X	
Species: *protracta*	X	X	X		
Species: *pseudoscutiformis*				X	
Species: *radiosa*					
Variety: *tenella*	X	X	X	X	X
Species: *reinhardtii*			X		
Species: *rhynchocephala*					
Variety: *germainii*					X
Species: *salinarum*					
Variety: *intermedia*	X	X	X	X	X
Species: *sanctae-crucis*			X	X	
Species: *seminuloides*	X	X			
Species: *seminulum*			X		X
Species: *subhamulata*				X	
Species: *tenelloides*	X			X	
Species: *tenera*	X				X
Species: *tripunctata*					
Variety: *schizonemoides*		X			
Species: *tripunctata*	X	X	X	X	X
Species: *viridula*					
Variety: *avenacea*		X	X	X	
Genus: *Neidium*					
Species: *affine*		X			
Genus: *Pinnularia*					
Species: *subcapitata*			X		
Genus: *Reimeria*					
Species: *sinuata*			X		
Genus: *Rhoicosphenia*					
Species: *curvata*	X	X		X	X

Table 7. Algae collected at selected water-quality-sampling sites, Oneida Reservation, Wisconsin, May 1998—Continued

Scientific name	Occurrence at site by map number				
	4	10	13	14	17
Genus: *Stauroneis*					
Species: *ignorata*					
Variety: *rupestris*			X		
Species: *kriegeri*			X		
Family: Nitzschiaceae					
Genus: *Hantzschia*					
Species: *amphioxys*			X		
Genus: *Nitzschia*					
Species: *accommodata*	X	X		X	X
Species: *acicularis*	X	X	X	X	X
Species: *amphibia*	X	X			X
Species: *capitellata*	X	X		X	X
Species: *constricta*	X	X			X
Species: *dissipata*					
Variety: *media*	X	X		X	
Species: *dissipata*	X	X	X	X	X
Species: *fonticola*					X
Species: *frustulum*					
Variety: *perminuta*				X	
Species: *frustulum*	X	X	X		X
Species: *gracilis*	X	X			
Species: *hungarica*	X				X
Species: *inconspicua*	X	X	X	X	X
Species: *intermedia*			X	X	
Species: *liebethruthii*	X				
Species: *linearis*	X	X	X	X	X
Species: *littoralis*					X
Species: *palea*	X	X	X	X	X
Species: *recta*	X	X	X	X	X
Species: *sigma*		X			X
Species: *sigmoidea*		X	X	X	X
Species: *tryblionella*					
Variety: *levidensis*					X
Genus:*simonsenia*					
Species: *delogni*			X		
Family: Surirellaceae					
Genus: *Cymatopleura*					
Species: *solea*	X	X			
Genus: *Surirella*					
Species: *angusta*	X	X			X
Species: *minuta*	X	X			X
Species: *ovata*	X	X	X	X	X
Family: Thalassiosiraceae					
Genus: *Cyclotella*					
Species: *meneghiniana*	X	X		X	X
Species: *ocellata*			X		
Genus: *Cyclotella*					
Species: *pseudostelligera*			X		
Genus: *Stephanodiscus*					
Species: *hantzschii*	X	X			
Species: *minutus*		X			X
Genus: *Thalassiosira*					
Species: *pseudonana*					X
Species: *weissflogii*					X
Family: Vaucheriaceae					
Genus: *Vaucheria sp.*					X
Phylum: Cyanophycophyta					
Undetermined Blue-green sp.					
(coccoid 5–10 μ)	X	X	X	X	X
Family: Chroococcaceae					
Genus: *Merismopedia*					
Species: *elegans*			X		
Species: *glauca*					X
Family: Nostocaceae					
Genus: *Amphithrix*					
Species: *janthina*	X	X		X	X
Family: Oscillatoriaceae					
Genus: *Hydrocoleum*					
Species: *brebissonii*	X	X	X		X
Genus: *Lyngbya*					
Species: *aestuarii*	X	X	X	X	
sp. 1 ANS FWA	X	X			X
Genus:*oscillatoria*					
sp. 1 ANS FWA	X	X	X	X	X
Genus: *Oscillatoria*					
Species: *limosa*					X
Species: *splendida*		X			
Phylum: Euglenophycophyta					
Family: Euglenaceae					
Genus: *Euglena sp.*		X		X	
Genus: *Phacus sp.*	X			X	
Genus: *Tachelomonas*					
Species: *hispida*	X	X			
Species: *volvocina*	X	X	X	X	X
Phylum: Rhodophycophyta					
Family: Chantransiacea					
Genus: *Audouinella*					
Species: *violacea*	X	X		X	X
Phylum: Undetermined					
(flagellate <10 μg/L)			X	X	X

Table 8. Percent relative abundance and biovolume of all algae in five streams according to taxonomic division, May 1998
[No algal data available for Duck Creek at Seminary Road near Oneida, Wis. (site 5)]

Map number	Site	Measure	Algal division (percent)					
			Diatoms	Green	Bluegreen	Euglenoid	Red	Unidentified Flagellate
4	Oneida Creek at Van Boxtel Road near Oneida, Wis.	Relative abundance	7.14	0.224	92.0	0	0.628	0
		Biovolume	74.5	.147	22.3	0	3.04	0
10	Trout Creek near Howard, Wis.	Relative abundance	30.2	0	68.3	.117	1.41	0
		Biovolume	93.8	0	5.09	.017	1.13	0
13	Thornberry Creek near Howard, Wis.	Relative abundance	58.5	.243	28.6	0	0	12.6
		Biovolume	97.0	.017	2.24	0	0	.784
14	Lancaster Brook at Shawano Avenue near Howard, Wis.	Relative abundance	67.6	0	22.0	0	8.70	1.69
		Biovolume	93.3	0	1.26	0	5.29	.142
17	Dutchman Creek at Cyrus Lane near Ashwaubenon, Wis.	Relative abundance	63.1	2.17	25.5	0	1.69	7.47
		Biovolume	31.2	66.1	1.69	0	.623	.380

diatoms made up 40 percent of the abundance of all diatoms at Dutchman Creek and only 1.2 percent (Lancaster Brook) to 5.3 percent (Thornberry Creek) at the other four sites where benthic algal communities were sampled.

Nitrogen-fixing algae were represented by one species of blue-green algae, *Amphithrix janthina*, and its relative abundance was highest (24.3 percent) at Oneida Creek. This alga was not found in Thornberry Creek. Nitrogen-fixing algae are typically found in streams that are nitrogen limited (Lowe, 1974), but their presence also may indicate low nitrogen to phosphorus ratios in the water column (Burkholder (1996). A. janthena is a suspected nitrogen fixer (Stephen Porter, U.S. Geological Survey, oral commun., May 12, 2000).

With regard to relative abundance (cells/cm^2), diatoms were the dominant algal division at Dutchman Creek, Thornberry Creek, and Lancaster Brook, and blue-green algae were subdominant at these sites. Blue-green algae were the dominant algal division at Oneida and Trout Creeks in relative abundance. The largest biovolume was due to diatoms (>74 percent) at all sites except at Dutchman Creek, where a large amount of green algae biovolume (66 percent) indicated decreased water quality. Green algae composed <1 percent of the relative abundance and biovolume at all other sampled sites. An abundance of green algae is commonly related to elevated nitrogen concentrations in streams. Euglenoids were found only at Trout Creek, and in minor amounts. Relative abundance of red algae was less than 2 percent except at Lancaster Brook and was due entirely to *Audouinella violacea*. A value of 8.7 percent for this filamentous red alga indicates good water-quality at this site because occurrence of this alga generally is associated with relatively cool, clean-flowing water (Sheath and Hambrook, 1990); however, it also was found in very low abundance in Dutchman Creek.

EFFECTS OF ENVIRONMENTAL FACTORS ON SURFACE WATER

Major Influences In and Near the Oneida Reservation

Results of surface-water-quality sampling indicated that the dominance of agricultural land (more than 80 percent of the land use in the basin) was the strongest determining factor on water quality in streams of the Oneida Reservation. Secondary influences included 15 point sources of contaminants within the vicinity of the Oneida Reservation, size of the drainage basin, and clayey surficial deposits. Timing and flow conditions of samplings were reflected in the results of water-quality analyses. The effects of secondary factors were commonly masked by the influences of land use on surface-water-quality.

The amount of agricultural land within drainages basins of more than half the sampling sites was greater than 80 percent. Nearly half the basins contained either 10 percent forest or 8 percent wetlands. Three basins contained more than 10 percent urban land. Average concentrations of dissolved nitrite plus nitrate nitrogen and total phosphorus were highest for sites dominated by agricultural land (agricultural land use of greater than 80 percent). Sites in basin dominated by agricultural land also had the highest average concentrations of iron and manganese. Sites with greater than 80 percent agricultural or 10 percent urban land had the highest average concentrations of sodium, chloride, and sulfate. Highest average concentrations of pesticides also corresponded to land use; the highest concentrations of atrazine, an agricultural pesticide, occurred at sites dominated by agricultural land while the highest concentrations of diazinon, a pesticide used in residential and commercial settings, occurred at sites with at least 10 percent urban land within their drainage basin.

On average, higher concentrations of most constituents were reported for sampling sites with small drainage basins (drainage areas less than 25 mi^2) than for sites with drainage basins greater than 25 mi^2. Samples collected at sites with drainage basins areas greater than 50 mi^2, all of which were on the main stem of Duck Creek, had lower concentrations of most analyzed constituents than did samples collected at tributary sampling sites. Average concentrations of nutrients, suspended sediment, major ions such as iron and manganese, and pesticides all were higher for tributary sampling sites than main-stem sampling sites. Only major-ion concentrations for chloride, sodium, potassium, and fluorine were higher at main-stem sampling sites.

Concentrations of major ions above those of background levels at sites located on the Duck Creek main stem may be due to input from 13 point sources of contaminants discharging to the stream. Point sources on the Oneida Reservation include wastewater-treatment plants and municipal and industrial outflows. Samples collected from streams in basins that contain at least one point source had average concentrations of major ions that were higher than basins without any point sources.

Timing and flow conditions of samplings were reflected in surface-water-quality results. Average concentrations of dissolved nitrite plus nitrate nitrogen and pesticides were highest in samples collected during the post-planting runoff sampling. Iron and manganese average concentrations were highest in the samples collected during the post-harvest base flow sampling. Average concentrations of suspended-sediment in samples collected during runoff samplings were more than twice suspended-sediment concentrations from samples collected during base flow samplings. At most sites, average concentrations of major ions were highest during base flow samplings.

Clayey surficial deposits were the dominant type in the vicinity of the Oneida Reservation. Eight sampling sites were in basins that have 100 percent clayey surficial deposits. Three other sites are in basins with greater than 80 percent clayey surficial deposits. Samples collected at sites representing basins with 100 percent clayey surficial deposits had higher average concentrations of some major ions and pesticides than sites with basins with less than 80 percent clayey surficial deposits.

Comparison by Land-Use Categories

Because land use appeared to be the dominating factor in surface-water quality at sampling sites in the Oneida Reservation, water-quality between sites was compared according to the dominant land use in the drainage basin to each site. Four categories of sites emerge when grouped by land use: (1) sites with greater than 80 percent agricultural land and less than 10 percent forest or 8 percent wetland land in their draining basins (these will be referred to as "Ag" sites) (2) sites with greater than 80 percent agricultural land and either greater than 10 percent forest or greater than 8 percent wetlands in their basins (these will be referred to as "Ag/For/Wtld" sites) (3) sites with either greater than 10 percent forest or greater than 8 percent wetlands and less than 80 percent agricultural land in their basins (these will be referred to as "For/Wtld" sites) and (4) and sites with greater than 10 percent urban land in their basins (these will be referred to as "Urban" sites) (table 9). Within each land-use site type, an attempt was made to differentiate between water quality at individual sites based on secondary influences such as drainage basin area, presence of point sources, flow conditions, timing of sampling, and surficial deposits.

Agricultural Sites

Water quality was affected by the dominance of agricultural land at the Ag sites. Nutrient concentrations—especially total phosphorus, which exceeded the USEPA suggested limit in every sample but one—were

Table 9. Water-quality summary of water-quality-sampling sites based on surface-water-quality sampling and ecological assessments, Oneida Reservation, Wisconsin, 1997–98

[X in cell indicates value exceeded USEPA drinking-water-quality criteria (see table 4). Color of cell indicates what quartile the sample result fell into. Red indicates upper quartile (greater than 75th percentile), yellow indicates middle quartiles (25–75 percent), green indicates lower quartile (less than 25th percentile). Gray cells indicate no sample was collected.]

Results for selected constituents, by sampling period

Site category	Map number	Total phosphorus: Late summer base flow 9/97	Total phosphorus: Late summer base flow 8/98	Total phosphorus: Post-harvest base flow 11/97	Total phosphorus: Snowmelt runoff 2/98	Total phosphorus: Post-planting runoff 6/98	Dissolved nitrite plus nitrate nitrogen: Late summer base flow 9/97	Dissolved nitrite plus nitrate nitrogen: Late summer base flow 8/98	Dissolved nitrite plus nitrate nitrogen: Post-harvest base flow 11/97	Dissolved nitrite plus nitrate nitrogen: Snowmelt runoff 2/98	Dissolved nitrite plus nitrate nitrogen: Post-planting runoff 6/98	Sodium: Late summer base flow 9/97	Sodium: Late summer base flow 8/98	Sodium: Post-harvest base flow 11/97	Sodium: Snowmelt runoff 2/98	Sodium: Post-planting runoff 6/98
Ag	17	X	X	X	X	X					X		X	X	X	
Ag	18	X														
Ag	16	X	X	X	X	X					X	X	X	X		
Ag	6	X	X	X	X	X					X	X	X	X	X	
Ag	2	X	X	X	X	X						X	X	X	X	
Ag	1		X	X	X	X							X	X	X	
Ag	4	X	X		X	X								X	X	
Ag/For/Wtl	5	X										X				
Ag/For/Wtl	8	X	X		X	X							X	X	X	X
Ag/For/Wtl	3	X	X	X	X	X						X	X	X	X	
For/Wtl	11	X	X		X	X							X	X	X	
For/Wtl	9					X										
For/Wtl	10					X					X				X	
For/Wtl	14															
For/Wtl	15					X						X	X	X	X	
For/Wtl	13															
Urban	12					X						X	X	X	X	
Urban	19	X				X						X	X	X	X	
Urban	7					X						X	X	X	X	

Site category	Map number	Chloride: Late summer base flow 9/97	Chloride: Late summer base flow 8/98	Chloride: Post-harvest base flow 11/97	Chloride: Snowmelt runoff 2/98	Chloride: Post-planting runoff 6/98	Sulfate[1]: Late summer base flow 9/97	Sulfate[1]: Late summer base flow 8/98	Sulfate[1]: Post-harvest base flow 11/97	Sulfate[1]: Snowmelt runoff 2/98	Sulfate[1]: Post-planting runoff 6/98	Iron: Late summer base flow 9/97	Iron: Late summer base flow 8/98	Iron: Post-harvest base flow 11/97	Iron: Snowmelt runoff 2/98	Iron: Post-planting runoff 6/98
Ag	17								o							
Ag	18															
Ag	16															
Ag	6															
Ag	2		X													
Ag	1													X		
Ag	4															
Ag/For/Wtl	5															
Ag/For/Wtl	8															
Ag/For/Wtl	3															
For/Wtl	11															
For/Wtl	9							X								
For/Wtl	10															
For/Wtl	14															
For/Wtl	15															
For/Wtl	13															
Urban	12															
Urban	19															
Urban	7															

Site category	Map number	Manganese: Late summer base flow 9/97	Manganese: Late summer base flow 8/98	Manganese: Post-harvest base flow 11/97	Manganese: Snowmelt runoff 2/98	Manganese: Post-planting runoff 6/98	Atrazine: Late summer base flow 9/97	Atrazine: Late summer base flow 8/98	Atrazine: Post-harvest base flow 11/97	Atrazine: Snowmelt runoff 2/98	Atrazine: Post-planting runoff 6/98	Cyanazine: Late summer base flow 9/97	Cyanazine: Late summer base flow 8/98	Cyanazine: Post-harvest base flow 11/97	Cyanazine: Snowmelt runoff 2/98	Cyanazine: Post-planting runoff 6/98
Ag	17			X							X					X
Ag	18															
Ag	16	X	X	X							X					
Ag	6		X								X					
Ag	2	X														
Ag	1		X	X	X						X					
Ag	4															X
Ag/For/Wtl	5															
Ag/For/Wtl	8															
Ag/For/Wtl	3		X								X					
For/Wtl	11										X					X
For/Wtl	9		X								X					X
For/Wtl	10										X					X
For/Wtl	14															
For/Wtl	15															
For/Wtl	13															
Urban	12															
Urban	19		X	X												
Urban	7	X	X	X	X											

Site category	Map number	Diazinon: Late summer base flow 9/97	Diazinon: Late summer base flow 8/98	Diazinon: Post-harvest base flow 11/97	Diazinon: Snowmelt runoff 2/98	Diazinon: Post-planting runoff 6/98	Habitat rating (GLEAS score)	Benthic community rating of water quality (HBI score)	Algae rating Lowest stress/pollution rating
Ag	17						Fair	Fairly poor	Mod-erate
Ag	18								
Ag	16								
Ag	6								
Ag	2								
Ag	1								
Ag	4						Fair-good	Good	Minor
Ag/For/Wtl	5						Fair	Fair	
Ag/For/Wtl	8								
Ag/For/Wtl	3								
For/Wtl	11								
For/Wtl	9								
For/Wtl	10						Good	Good	Mod-erate
For/Wtl	14						Good	Good	Minor
For/Wtl	15								
For/Wtl	13						Good	Very good	Minor
Urban	12					X			
Urban	19								
Urban	7								

[1]Large 'X' indicates exceedance of MCL and SMCL, small 'o' indicates exceedance of only SMCL.

high at every Ag site relative to other site types, especially those with less than 80 percent agricultural land in their basins. The MCL for dissolved nitrite plus nitrate nitrogen was exceeded at three of the seven sites. Water from North Branch Ashwaubenon Creek (site 16) had the highest nutrient concentrations, including a concentration of dissolved nitrite plus nitrate nitrogen that was seven times the MCL. Water from Duck Creek near Freedom, Wis. (site 2), which has five point sources in its basin consisting of four wastewater-treatment plants and one industrial outfall, had the highest sodium and chloride concentrations of all the water-quality sites. Sodium concentrations in samples collected at five of the seven sites had exceedances of the sodium HA for at least 75 percent of the samples. Concentrations of manganese were elevated for samples collected at five of the seven Ag sites, as compared to drinking-water-quality criteria and concentrations of water samples collected at site types other than Ag and Urban sites. Exceedances of the USEPA drinking-water-quality criteria were found for atrazine in samples from four sites and for cyanazine in samples from two sites.

Habitat was reported to be "fair" for the Dutchman Creek site and "fair to good" at Oneida Creek. On the basis of the HBI calculation, the water quality at Dutchman Creek at Cyrus Lane (site 17) rated "fairly poor." The HBI calculated for Oneida Creek (site 4) indicates that the benthic-macroinvertebrate community is characteristic of a stream with "good" water quality. For benthic algae, the Shannon-Wiener diversity index and the pollution index for Dutchman Creek indicate that diatoms in this stream are under moderate environmental stress. A large number of tolerant diatoms and green algae were present at this site. Results for algal metrics were somewhat conflicting for Oneida Creek and indicated possible minor environmental stress with regard to diatom diversity. This is despite the fact that the greatest percentages of pollution-sensitive diatoms and suspected nitrogen-fixing blue-green algae of all ecological sampling sites were found here.

Agricultural/Forest/Wetland Sites

Eighty percent of land use in Ag/For/Wtld basins is agricultural, which greatly influences water quality at the sampling sites in those basins. The concentration of total phosphorus in nearly every sample exceeded the USEPA suggested limit. In contrast, the concentrations of dissolved nitrite plus nitrate nitrogen were moderate to low as compared to drinking-water-quality criteria, with no exceedances of the MCL. Eight point sources (five wastewater-treatment plants and three industrial outfalls) were in the basin of the upstream Duck Creek site (site 5). Four more point sources (three wastewater-treatment plants and one municipal outfall) were located along Duck Creek between the upstream site (site 5) and the downstream site (site 8). Sodium concentrations in samples collected at the three Ag/For/Wtld sites were high, like the Ag and Urban sites, with 9 of 10 samples exceeding the HA. Iron and manganese concentrations were moderate to low compared to concentrations at other sites, with the exception of one exceedance of the manganese SMCL at Fish Creek (site 3). The MCL for atrazine was exceeded at only one site, Fish Creek (site 3).

The GLEAS habitat rating for Duck Creek was "fair" (Fitzpatrick and Giddings, 1997), and the HBI and mean tolerance values indicated that the benthic invertebrate community also was in "fair" condition at this site. Analyses for Duck Creek algae data are not yet available.

Forest/Wetland Sites

At For/Wtld sites, which are those in basins containing less than 80 percent agricultural land and either more than 10 percent forest or 8 percent wetlands, concentrations of nutrients and pesticides was lower than at sites with more than 80 percent agricultural land. Less than 30 percent of the samples collected had total phosphorus concentrations that exceeded the USEPA suggested limit for flowing waters. Only one sample, collected at Trout Creek near Howard, Wis. (site 10), had a concentration of dissolved nitrite plus nitrate nitrogen greater than the MCL. The most downstream sampling site on Duck Creek (site 11) had thirteen point sources (eight wastewater-treatment plants and five industrial and municipal outfalls) within its basin. Trout Creek at CT Highway U (site 9) had one point source, an industrial outfall, within its basin. Concentrations of sodium in samples collected at For/Wtld sites were comparable to sodium concentrations at Ag/For/Wtld sites, and both were lower than concentrations of sodium from the Ag and Urban sites. Concentrations of sodium were consistently moderate for Lancaster Brook at Howard, Wis. (site 15) as compared to other For/Wtld sites. The sulfate concentration in one sample collected at Trout Creek at CT Highway U (site 9) exceeded the MCL. The manganese SMCL was exceeded at only one site, Trout Creek at CT Highway U (site 9). Pesticide concentrations were elevated in samples collected from three of the five For/Wtld sites sampled as compared to concentrations of pesticides in samples collected at other Ag/For/Wtld and Urban sites.

Habitat evaluations for the three For/Wtld sites were rated "good" at all sites. On the basis of the benthic-macroinvertebrate community at each site, the HBI's calculated for each of the For/Wtld sites indicate that water quality is "very good" to "good." Shannon-Wiener diversity indices for diatoms indicate only minor stress on the algal community, and the pollution index for diatoms indicates minor stress or no stress. Diatoms or nitrogen-fixing blue-green algae were dominant at these sites, an indication of relatively good water quality.

Urban Sites

Concentrations of total phosphorus in samples collected at Urban sites were low to moderate compared to concentrations at sites in basins with more than 80 percent agricultural land, with concentrations of 4 of 15 samples exceeding the suggested MCL. No exceedances were found for dissolved nitrite plus nitrate nitrogen. Dutchman Creek (site 18) and the Dutchman Creek tributary (site 19) each had one point source within their drainage basins (an industrial outfall in the basin of site 18 and a wastewater-treatment plant in the basin of site 19). Sodium concentrations for every sample collected at Urban sites exceeded the HA. Chloride concentrations for samples collected at two of the three sites were high as compared to chloride concentrations of samples from the Ag/For/Wtld and For/Wtld sites. Like the Ag sites, manganese concentrations in samples collected at two sites were high, especially at the Unnamed Duck Creek tributary (site 7), where concentrations for each of the four samples exceeded the SMCL. The concentration of diazinon, an urban insecticide, exceeded the HA in a sample collected at Beaver Dam Creek (site 12) and was present at moderate concentrations, as compared to drinking-water-quality criteria, in a sample collected at the Unnamed Duck Creek tributary at Haven Place (site 7). No habitat, benthic invertebrate, or benthic algal collections were done at Urban sites.

SUMMARY

Streamwater samples were collected at 19 sites on the Oneida Reservation during four different sampling periods in 1997–98. Ecological samples and information were collected at six of those sites.

Physical characteristics of drainage-basins such as land use and surficial deposits, point-source discharges of contaminants, drainage-basin area, and the flow conditions and time of year of the sampling (fall base flow, post-harvest base flow, snowmelt runoff, post-planting runoff) influenced surface-water quality measured by the USGS of the Oneida Reservation and vicinity. Land use—agricultural in particular—affected water quality at many sites.

Total phosphorus and dissolved nitrite plus nitrate nitrogen concentrations, often exceeding USEPA suggested limits and drinking-water-quality criteria, were relatively high compared to those criteria during all sampling periods for many sites. Nutrient concentrations were influenced by agricultural fertilizers as well as by point sources.

Concentrations of major ions, like sodium and chloride, in the samples collected were likely influenced by discharge from point sources. Concentrations of major ions, such as iron and manganese, can be influenced by naturally occurring background concentrations resulting from ground water discharge or streambed sediment leaching, and by discharge from point sources. Sodium and manganese were the most common major ions that exceeded drinking-water-quality criteria.

Concentrations of pesticides such as atrazine, cyanazine, and diazinon exceeded USEPA drinking-water-quality criteria at various sites during the different sampling periods. Atrazine, cyanazine, metolachlor, and acetochlor were found at elevated concentrations in samples collected at several sites other than those in basins with greater than 10 percent urban land. Diazinon was the pesticide found at concentrations exceeding USEPA drinking-water-quality criteria at the sites in basins with more than 10 percent urban land.

Habitat evaluations show Thornberry Creek, Trout Creek, and Lancaster Brook to have "good" stream habitat. The habitat assessment of Oneida, Duck, and Dutchman Creeks indicated that agricultural land use and intermittent flows reduce stream-habitat quality. Dutchman Creek is further impaired by siltation and embeddedness.

Hilsenhoff Biotic Index results indicate that the benthic-invertebrate community is characteristic of "good" water quality at three sites, "fair" at one site, and "fair-good" and "poor-fair" water quality at the remaining two sites. Mean tolerance values gave a similar

assessment of the invertebrate communities at sites. Together with Ephemeroptera, Plecoptera, and Trichoptera taxa richness results, these invertebrate measures indicate that water quality is best at Thornberry Creek. Trout Creek and Lancaster Brook also rated well. Shannon-Wiener diversity values indicate that the invertebrate communities at Dutchman Creek, Duck Creek, and possibly Oneida Creek, are under environmental stress.

Assessments of the benthic algal community provided similar information to invertebrate-community assessments. Shannon-Wiener diversity indices for diatoms indicate that diatom communities are under minor stress in four of five streams sampled and under moderate stress in Dutchman Creek. A pollution index based on the percentages of diatoms that are pollution sensitive and pollution tolerant gave slightly different results. According to this index, pollution likely is moderate at Dutchman Creek and may be minor at Thornberry and Trout Creeks; however, this index showed no pollution effects for Oneida Creek and Lancaster Brook with regard to the diatom community.

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