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Pesticide Residues in Hemlock and Canadice Lakes and their Tributaries in Western New York, 1997-98

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PESTICIDE RESIDUES IN HEMLOCK AND CANADICE LAKES AND THEIR TRIBUTARIES IN WESTERN NEW YORK, 1997-98

In 1997, the U.S. Geological Survey (USGS) and the City of Rochester began a cooperative program to study the presence of pesticides (herbicides and insecticides) that occur at trace levels in Hemlock and Canadice Lakes and their tributaries. The most frequently detected pesticides in streamflow and lake-water samples were herbicides commonly used in agriculture — atrazine, metolachlor, and simazine. None of the concentrations of these compounds in the samples exceeded Federal or State water-quality standards. Differences in the concentrations among stream samples can be attributed to land use and streamflow, and the timing of rainfall in relation to herbicide application.

The north (lower) end of Hemlock Lake can receive pesticides in agricultural runoff from northern parts of its watershed and Canadice Creek. These pesticide inputs bypass most of the lake and could periodically affect the water quality at the City of Rochester intake. Pesticide concentrations in samples from the intake during this study, however, were about 100 times less than current Federal and State standards for drinking water.

Residues of DDT, dieldrin, and mirex are present in low concentrations in the bottom sediments of both lakes, but none were detected in water samples. The use of these insecticides was banned in 1972, and their persistence in the lakebed sediments is probably due to erosion of contaminated soils from agricultural lands.

Aerial view of Canadice Lake (left) and Hemlock Lake (right), from north.

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INTRODUCTION

The City of Rochester, N.Y., is partly supplied with water from two western Finger Lakes — Hemlock Lake and Canadice Lake, which lie side by side in Livingston and Ontario Counties (fig. 1). Rochester's Department of Environmental Services, Water Bureau - Upland Water Supply, is charged with administering and protecting the water supply for the city. The watersheds of these lakes are relatively pristine; 11 percent of the land is agricultural, and only 5 percent contains urban development. Development in these watersheds has been limited because the City of Rochester owns the land along the entire shore of both lakes — 18 percent of the combined watershed areas. The undeveloped setting of the lake shores is unique among the Finger Lakes. Much of the watershed area is privately owned, however, and activities on these lands can affect the quality of the water supply.

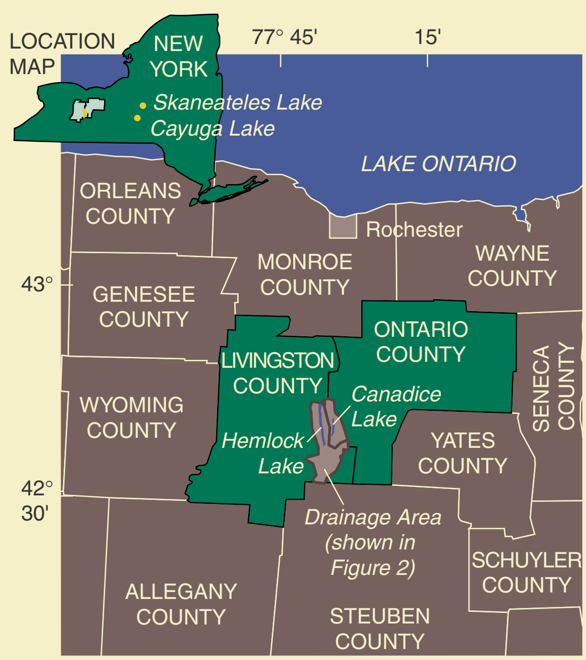
Agricultural and domestic activities can introduce pesticides into the lakes by several means: (1) through direct runoff into tributaries, (2) indirectly through the ground-water system, and (3) as deposition from atmospheric sources. Pesticides are frequently present in many streams and rivers of New York but at concentrations that generally meet drinking-water standards (Phillips and others, 1998). The occurrence and distribution of pesticides in these waters are of concern, however, because the potential effects of chronic exposure on aquatic and human life are unknown. Detection of pesticides at low concentrations can alert water suppliers of potential problems and trends, and this early warning in turn can lead to enhanced management of water quality.
This report describes current conditions and identifies the effects of hydrologic factors and land use on pesticide occurrence in these relatively pristine waters.

SOURCES OF PESTICIDES

Pesticide concentrations in lakes and streams are affected by natural and human factors. Natural factors include climate, geologic conditions, topography, and soils. Human factors include pesticide-application rate, the types of pesticides used, the timing of pesticide applications, and the methods of disposal. Proper use of pesticides, combined with effective soil- and water-conservation measures, can help prevent these chemicals from reaching streams and lakes by keeping them in the soil, where they degrade naturally.

Herbicides are a specific class of pesticides that are used to control broadleaf weeds and undesirable grasses in agricultural fields, lawns, and other open areas that require control of vegetation. For example, atrazine, a herbicide that is widely used in corn agriculture, generally enters streams and lakes in runoff from late-spring and early-summer storms that follow herbicide applications during planting. These herbicides are highly soluble, and their toxicity to humans is relatively low in relation to that of insecticides.

Insecticides are a class of pesticides that are used to control insects in agricultural, commercial, and domestic settings. Rates of insecticide application typically are far lower than those for the herbicides, but insecticides are generally more toxic to humans. Organochlorine insecticides (such as DDT) and other toxic organic compounds such as PCBs (polychlorinated biphenyls) are no longer in use in the United States but were widely used in the past. These compounds have low solubility in water and are chemically stable; therefore they can they can persist in the bottom material of streams and lakes for decades. Many of these compounds have a broad toxicity to many organisms; they also can move through the food chain from benthic organisms to fish, birds, and mammals.



Base from USGS digital data,
Universal Transverse Mercator projection, 1:100,000

Figure 1. Location of Hemlock and Canadice Lakes in western New York.

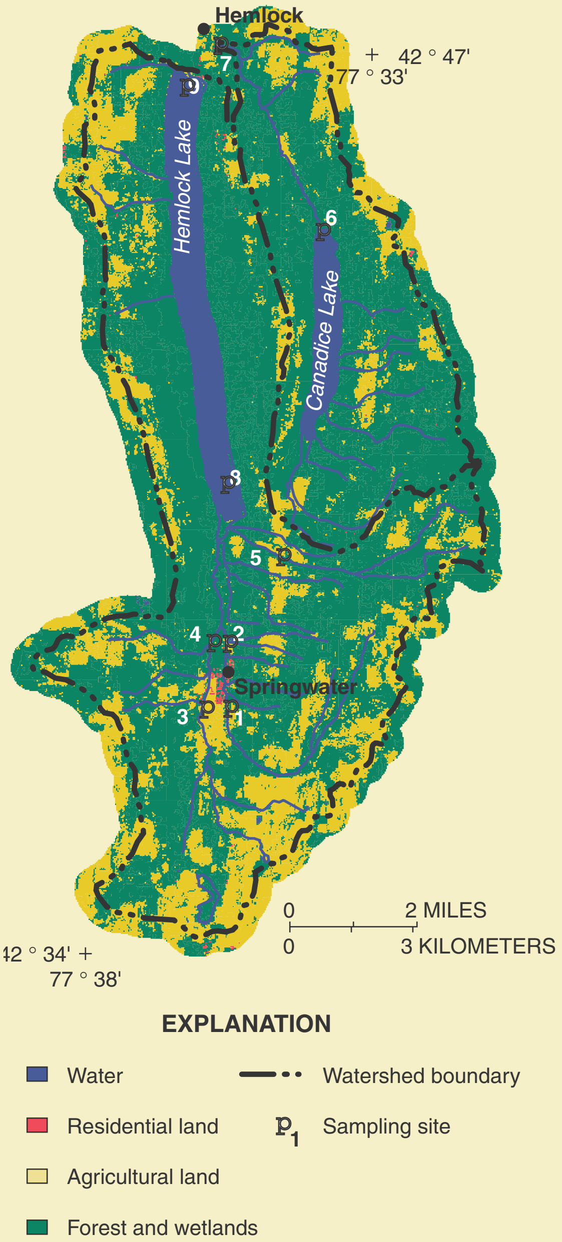


Figure 2. Land use and locations of streamflow and lake-sampling sites in the Hemlock and Canadice Lake watersheds. (Site names are given in tables 3 and 4)

SAMPLING FOR PESTICIDES

Seasonal and hydrologic factors affect the occurrence of pesticides; therefore, water samples were collected during periods of storm runoff and during dry-weather periods, when most of the streamflow consists of ground water (base flow). Stormflow and base-flow samples were collected in June and July of 1997 and 1998, directly after herbicide applications; and also in April 1998, after the previous year's residues had dissipated, but before the 1998 applications. Locations of the sampling sites are shown in figure 2, which also depicts land use within the watershed.

The six streamflow-sampling sites were selected to represent high-, medium-, and low-density agricultural land use and to evaluate the effects of urban development (the hamlet of Springwater) on stream-water quality. The drainage areas of the sites range from 3.47 to 10.1 square miles. Lake-water samples were collected near the outlet of each lake and, when possible, near the inlet of Hemlock Lake. Additionally, samples of bottom material were collected at the lower (north) end of each lake in July 1997 and 1998 for analysis for organochlorine insecticide residues and related compounds, which include DDT and PCBs.

Water samples were collected and filtered according to methods of Shelton (1994). Pesticides were processed through solid-phase extraction with carbon-resin (C-18) cartridges and analyzed by gas chromatography and mass spectrometry by the methods of Zaugg and others (1995) at the USGS National Water Quality Laboratory in Arvada, Colo. Method detection limits (MDLs) for the pesticide analytes (tables 1 and 2) ranged from 0.001 to 0.018 µg/L (micrograms per liter).

Samples of lake-bottom material were obtained with a USGS BM-60 rotary-scoop sampler that was winched from a boat. At least five samples from a 4-inch (10-cm) depth were composited at each site, and the composite samples were analyzed according to methods described in Wershaw and others (1983).

PESTICIDE CONCENTRATIONS IN CONTRIBUTING STREAMS

The most frequently detected pesticides in stream-water samples were herbicides commonly used in agriculture; these included atrazine, metolachlor, and simazine. None exceeded Federal or State water-quality standards (table 1). These pesticides have been frequently detected in surface waters throughout agricultural regions in New York (Wall and others, 1997; Phillips and others, 1998) and the midwestern United States (Thurman and others, 1991). Herbicides that were infrequently detected at or near the MDL include alachlor, prometon, cyanazine, metribuzin, and EPTC. Two insecticides were infrequently detected at or near the MDL — carbaryl and DDE (a metabolite of DDT). The pesticides listed in table 2 were not detected in any samples.

Reynolds Brook, tributary to Hemlock Lake, near sampling site 5. (Site location is shown on fig. 2.)

Pesticide concentrations in stream water samples did not exceed any Federal or State water-quality standards.

The concentrations of atrazine and metolachlor in stormflow and base-flow samples from the six stream sites are given in figure 3 and table 3. Differences in the observed concentrations can be attributed to land use, streamflow, and timing of rainfall in relation to herbicide application. Land use affects the type of pesticides that are applied within a stream's watershed and the amount applied; for example, atrazine and metolachlor are used only in agricultural areas, and their presence in streamwater is directly correlated with the amount of agricultural land that contributes runoff and ground water to the stream.

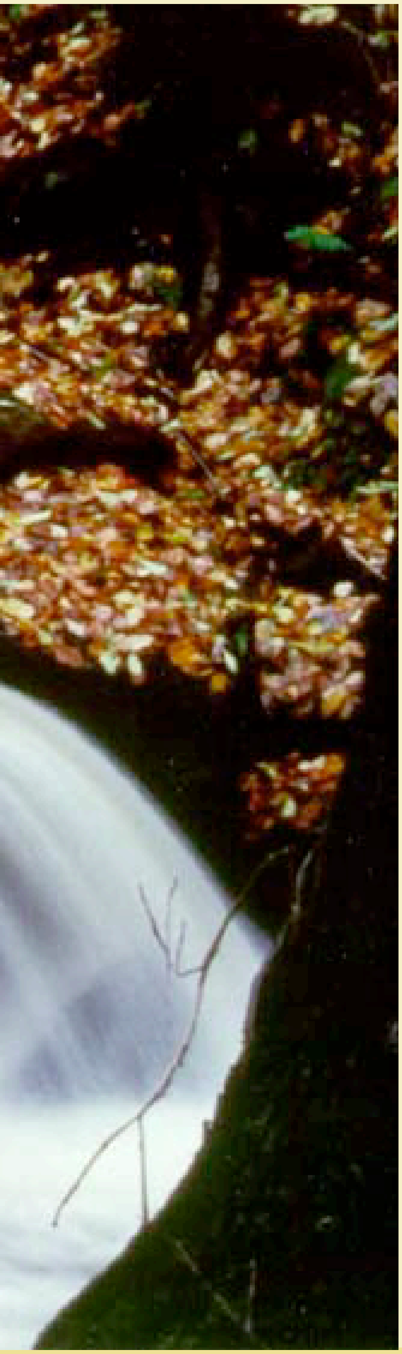


Table 1. Concentrations of pesticides detected at three lake and six stream sites in the Hemlock and Canadice Lake watershed, 1997-98

[All values are in micrograms per liter; e, estimated]

Pesticide	Use	Detection limit	MCL or HA[a]	Maximum concentration detected	
				Lakes	Streams
Alachlor	Herbicide	0.002	2	0.004	0.004
Atrazine	Herbicide	0.001	3	0.040	1.58
Carbaryl	Insecticide	0.003	700	<.003	0.039
Deethylatrazine	Metabolite	0.002	none	e 0.012	e 0.064
EPTC	Herbicide	0.002	none	0.011	e 0.003
Linuron	Herbicide	0.002	none	<.002	0.430
Metolachlor	Herbicide	0.002	100	0.048	1.84
Metribuzin	Herbicide	0.004	200	<.004	0.006
Simazine	Herbicide	0.005	4	0.025	0.007

[a] MCL, Federal maximum contaminant level; HA, health advisory level

Table 2. Pesticides not detected in water samples from stream and lake sites

[MDL, method detection limit, in micrograms per liter]

Compound	MDL	Compound	MDL	Compound	MDL
Propachlor	0.007	2,6-Diethylaniline	0.003	Carbofuran	0.003
Butylate	0.002	Methylazinphos	0.001	Trifluralin	0.002
Terbufos	0.013	Disulfoton	0.017	Propargite	0.013
Pronamide	0.003	Triallate	0.001	Parathion	0.004
Diazinon	0.002	Propanil	0.004	Prometon	0.018
Fonofos	0.003	*cis*-Permethrin	0.005	Benfluralin	0.002
alpha-HCH	0.002	Pendimethalin	0.004	Phorate	0.002
p,p′-DDE	0.006	Ethalfluralin	0.004	Terbacil	0.007
Chlorpyrifos	0.004	Methyl Parathion	0.006	Ethoprop	0.003
Lindane	0.004	Napropamide	0.003	Pebulate	0.004
DCPA	0.002	Cyanazine	0.004	Molinate	0.004
Dieldrin	0.001	Tebuthiuron	0.010	Acetochlor	0.002
Malathion	0.005	Thiobencarb	0.002		

Streamflow and the timing of herbicide applications affect pesticide concentrations because storm runoff from croplands can rapidly transport pesticides and their residues from application areas to streams. This is true especially when the runoff closely follows the applications, which are usually in late May and early June. The July 1997 and June 1998 storm-runoff concentrations from the high-density agricultural areas (figs. 2, 3) were more than 10 times the concentrations of base-flow samples collected 2 to 3 weeks after the storm-runoff period. The June 1998 storm produced much higher pesticide concentrations (table 3 and fig. 3) than the July 1997 storm because it produced higher discharges and followed the pesticide application more closely.

The lowest concentrations of herbicides detected were in the April 1998 samples; these concentrations reflect the dormant-season conditions about 11 months after herbicide applications. The amount of time elapsed after application is an important factor because pesticides that remain in contact with soil will degrade and dissipate naturally.

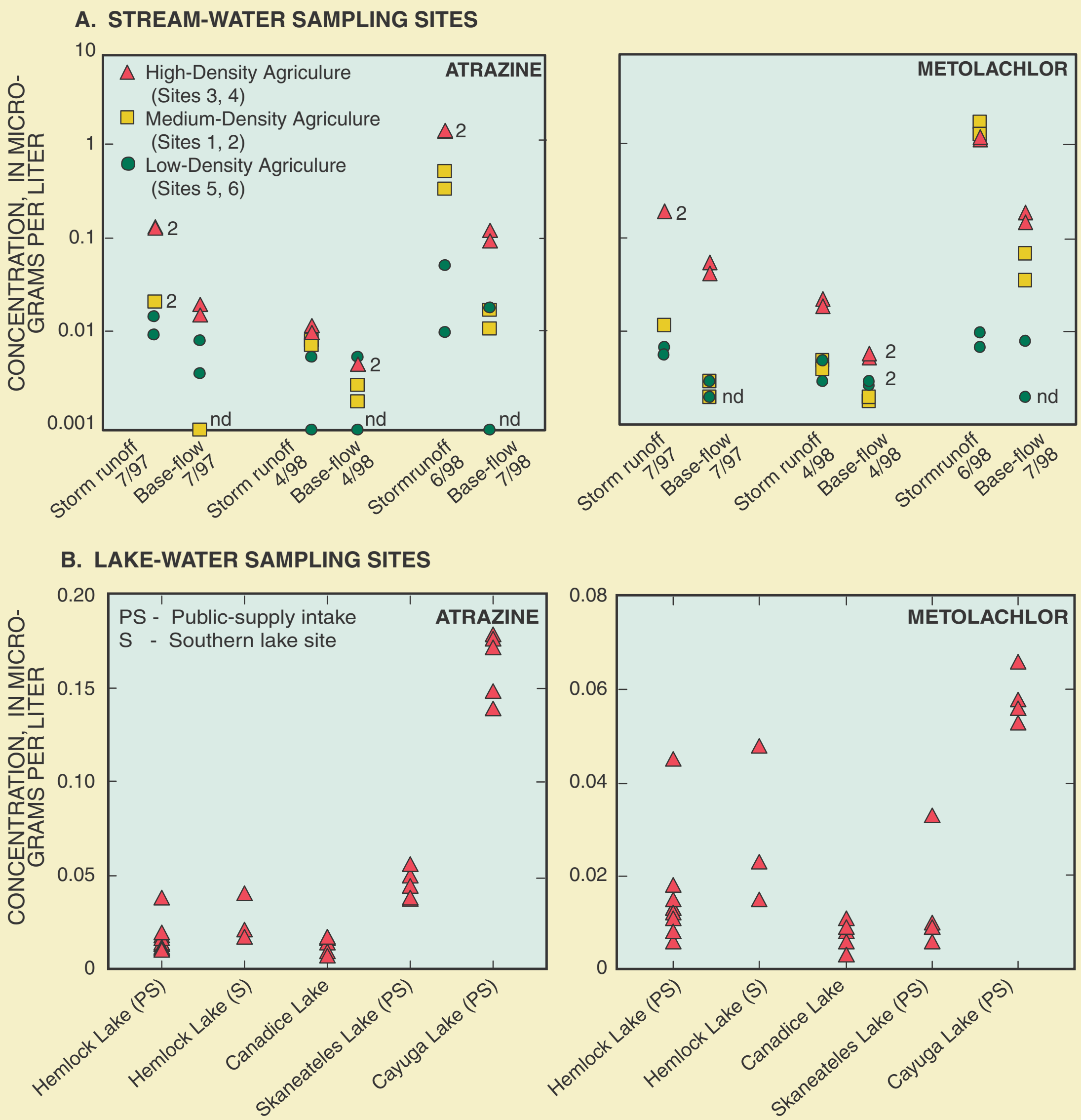


Figure 3. Concentrations of atrazine and metolachlor at six stream sites and five lake sites in western New York, 1997-98. (Locations are shown in figure 2; numbers indicate two samples with same concentrations.)

PESTICIDE CONCENTRATIONS IN LAKE WATER

The most frequently detected pesticides in lake-water samples were the herbicides atrazine, metolachlor, and simazine (table 4); their concentrations were about 100 times less than current Federal MCLs (U.S Environmental Protection Agency, 1996). Atrazine and metolachlor concentrations in samples from the three lake-sampling sites are given in figure 3 for comparison with those in samples from two nearby Finger Lakes — Cayuga and Skaneateles Lakes (fig. 1) — that also serve as public-water supplies. Canadice Lake is less affected by pesticides than are Hemlock, Skaneateles, or Cayuga Lakes, mainly because only 2.3 percent of its watershed is agricultural, compared to 13.5 percent in the Hemlock Lake watershed (Martin, 1998). The samples from Cayuga Lake had higher pesticide concentrations than the other lakes (fig. 3, table 4) because its watershed has more agricultural land than the other lake basins. In general, Hemlock and Skaneateles Lakes had similarly low concentrations of most pesticides, although simazine concentrations in Hemlock Lake were slightly higher, and atrazine concentrations slightly lower, than in Skaneateles Lake.

Lake-water samples collected in July 1998 showed that atrazine and metolachlor concentrations in Hemlock Lake had increased significantly from the previous sampling as

Table 3. Concentrations of selected herbicides detected in stream samples

[mi^2, square miles; ft^3/s, cubic feet per second; *e*, estimated; <, less than; µg/L, micrograms per liter. Stormflow dates are in boldface.]

Site no.	USGS station name and number	Drainage area (mi^2)	Percentage of basin used for agriculture	Sampling date (mo-d-yr)	Stream discharge (ft^3/s)	Pesticide: Atrazine (µg/L)	Pesticide: Metolachlor (µg/L)
1	Limekiln Creek at Springwater	4.20	27	**7-09-97**	6.0	0.023	0.013
				7-23-97	0.64	0.009	*e* 0.003
	04228905			**4-20-98**	41.0	0.009	0.005
				4-29-98	4.71	*e* 0.003	*e* 0.002
				6-26-98	22.9	0.574	1.84
				7-16-98	2.46	0.019	0.070
2	Limekiln Creek north of Springwater	5.69	22	**7-09-97**	9.0	0.023	0.012
				7-23-97	0.82	<0.001	<0.002
				4-20-98	60.4	0.008	*e* 0.004
	04228908			4-29-98	7.5	*e* 0.002	*e* 0.002
				6-26-98	35.8	0.368	1.35
				7-16-98	3.36	0.012	0.036
3	Springwater Creek southwest of Springwater	8.26	32	**7-09-97**	11.6	0.147	0.204
				7-23-97	3.5	0.022	0.058
				4-20-98	57.6	0.013	0.023
	04228890			4-29-98	14.7	0.005	0.006
				6-26-98	29.9	1.52	1.19
				7-16-98	13.1	0.135	0.200
4	Springwater Creek at Springwater	10.1	29	**7-09-97**	14.7	0.142	0.204
				7-23-97	2.92	0.017	0.043
	04228900			**4-20-98**	70.8	0.011	0.019
				4-29-98	17.1	0.005	0.006
				6-26-98	43.0	1.58	1.30
				7-16-98	15.0	0.103	0.154
5	Reynolds Brook near Springwater	3.47	6	**7-09-97**	5.6	0.011	0.006
				7-23-97	0.69	*e* 0.004	<0.002
	04228915			**4-20-98**	33.3	*e* 0.001	0.005
				4-29-98	4.55	<0.001	*e* 0.003
				6-26-98	16.3	0.011	0.007
				7-16-98	2.77	<0.001	<0.002
6	Canadice Creek at Hemlock	4.98	4	**7-09-97**	4.1	0.016	0.007
				7-23-97	0.99	0.009	*e* 0.003
	04229019			**4-20-98**	153.0	0.006	*e* 0.003
				4-29-98	14.5	0.006	*e* 0.003
				6-26-98	47.0	0.057	0.010
				7-16-98	6.16	0.020	0.008

a result of the June 1998 runoff. Concentrations of these herbicides in samples from the lower (north) end of Hemlock Lake appear similar to those in samples from the upper end, which indicates that the lake is well mixed by wind action and by the annual turnovers that occur each winter in response to the seasonal change in water temperature and density. The increase in herbicide concentrations in the July 1998 samples from the public-

Table 4. Concentrations of selected herbicides detected in lake samples

[*e*, estimated; <, less than. Locations are shown in fig. 2.]

Site no.	USGS station name and number	Sampling date	Herbicide concentration (in micrograms per liter) Atrazine	Cyanazine	Simazine	Alachlor	Metolachlor
7	Canadice Lake at outlet near Hemlock	7-09-97	0.016	<0.004	0.005	*e* 0.004	0.007
		7-23-97	0.014	<0.004	<0.005	<0.002	0.006
	04228950	4-20-98	0.009	<0.004	*e* 0.004	<0.002	*e* 0.003
		4-29-98	0.007	<0.004	*e* 0.004	<0.002	*e* 0.003
		6-26-98	0.017	<0.004	<0.005	*e* 0.003	0.011
		7-16-98	0.016	<0.004	<0.005	<0.002	0.009
8	Hemlock Lake, south end	7-09-97	0.021	<0.004	0.008	<0.002	0.023
		7-23-97	0.017	<0.004	0.008	<0.002	0.015
	424054077355701	7-16-98	0.040	<0.004	<0.005	<0.002	0.048
9	Hemlock Lake public-water supply intake	5-06-97	0.013	<0.004	0.025	<0.002	0.006
		7-02-97	0.013	*e* 0.003	0.010	<0.002	0.013
	424618077364701	7-09-97	0.014	<0.004	0.009	*e* 0.003	0.013
		7-23-97	0.018	<0.004	0.008	<0.002	0.015
		9-09-97	0.016	<0.004	<0.005	*e* 0.002	0.012
		2-02-98	0.012	<0.004	0.007	<0.002	0.011
		4-20-98	0.010	<0.004	0.007	<0.002	0.008
		4-29-98	0.010	<0.004	0.006	<0.002	0.008
		6-26-98	0.019	<0.004	0.009	0.004	0.018
		7-16-98	0.038	<0.004	<0.005	<0.002	0.045
--	Cayuga Lake, Bolton Point public-water supply intake	5-06-97	0.178	0.021	0.031	<0.002	0.056
		7-02-97	0.176	0.020	0.017	<0.002	0.058
	422950076305901	9-09-97	0.171	0.014	0.016	*e* 0.002	0.053
		2-03-98	0.148	0.021	0.014	*e* 0.003	0.056
		7-17-98	0.139	0.022	0.011	<0.002	0.066
--	Skaneateles Lake public-water-supply intake #1	5-06-97	0.050	0.006	<0.005	<0.002	0.009
		7-02-97	0.044	<0.004	<0.005	<0.002	0.010
	422549076250201	9-09-97	0.037	*e* 0.004	<0.005	<0.002	0.006
		2-03-98	0.038	<0.004	*e* 0.002	<0.002	0.009
		7-17-98	0.056	<0.004	<0.005	<0.002	0.033

Table 5. Concentrations of selected pesticides, PCBs, and organic carbon in bottom material from Hemlock and Canadice Lakes

[Concentrations are in micrograms per kilogram. A dash indicates no data. Sampling locations are shown in fig. 2.]

Lake	Station Number	Date (mo-d-yr)	*p,p′*-DDT	*p,p′*-DDD	*p,p′*-DDE	Dieldrin	Mirex	Gross PCB	Organic carbon (percent)
Hemlock	424618077364703	7-23-97	0.99	12	7.8	0.28	0.30	<5	--
		7-16-98	.55	7.2	2.9	<.20	<.20	<5	2.8
Canadice	424424077341403	7-23-97	.60	6.8	4.7	.25	<.20	24	--
		7-16-98	.58	4.4	3.0	.20	.49	20	2.8

supply intake near the outlet of Hemlock Lake indicates that the northern end of the lake probably receives pesticides from agricultural runoff in the northern part of the watershed, which includes Canadice Creek. Pesticide inputs from tributaries in this part of the watershed bypass most of the lake and can thereby periodically affect the water quality at the intake.

PESTICIDE CONCENTRATIONS IN LAKE-BOTTOM MATERIAL

Analyses of lake-bottom material (table 5) near site 6 in Canadice and site 9 in Hemlock Lakes (fig. 2) indicate that DDT (and its metabolites DDD and DDE), dieldrin, and mirex are present in low concentrations in both lakes. These compounds were used as insecticides until they were banned in 1972, but their residues persist in water, soil, suspended sediment, bottom sediments, and animal tissues. None of the compounds listed in table 5 are expected to be detected in water samples because of their low concentrations and relative insolubility. Their persistence in the lakebed sediments is probably due to erosion of contaminated soils from agricultural land. The concentrations of DDT and dieldrin in these bottom-material samples are typical of those in bottom material elsewhere in agricultural areas of New York (Larsen and others, 1997; Phillips and others, 1997).

Gross PCB (table 5) is a measure of the total concentration of all polychlorinated biphenyl (PCB) compounds in bottom material. PCBs are not pesticides but are chemically similar to the chlorinated insecticides listed in table 3. PCBs were used in electrical power transformers until 1980, when they were banned. They are relatively insoluble and are not expected to be in lake waters. They are present in relatively low concentrations only in the bottom material of Canadice Lake, where a local point source of PCBs was discovered in 1983.

— by David Eckhardt and Sarah Burke

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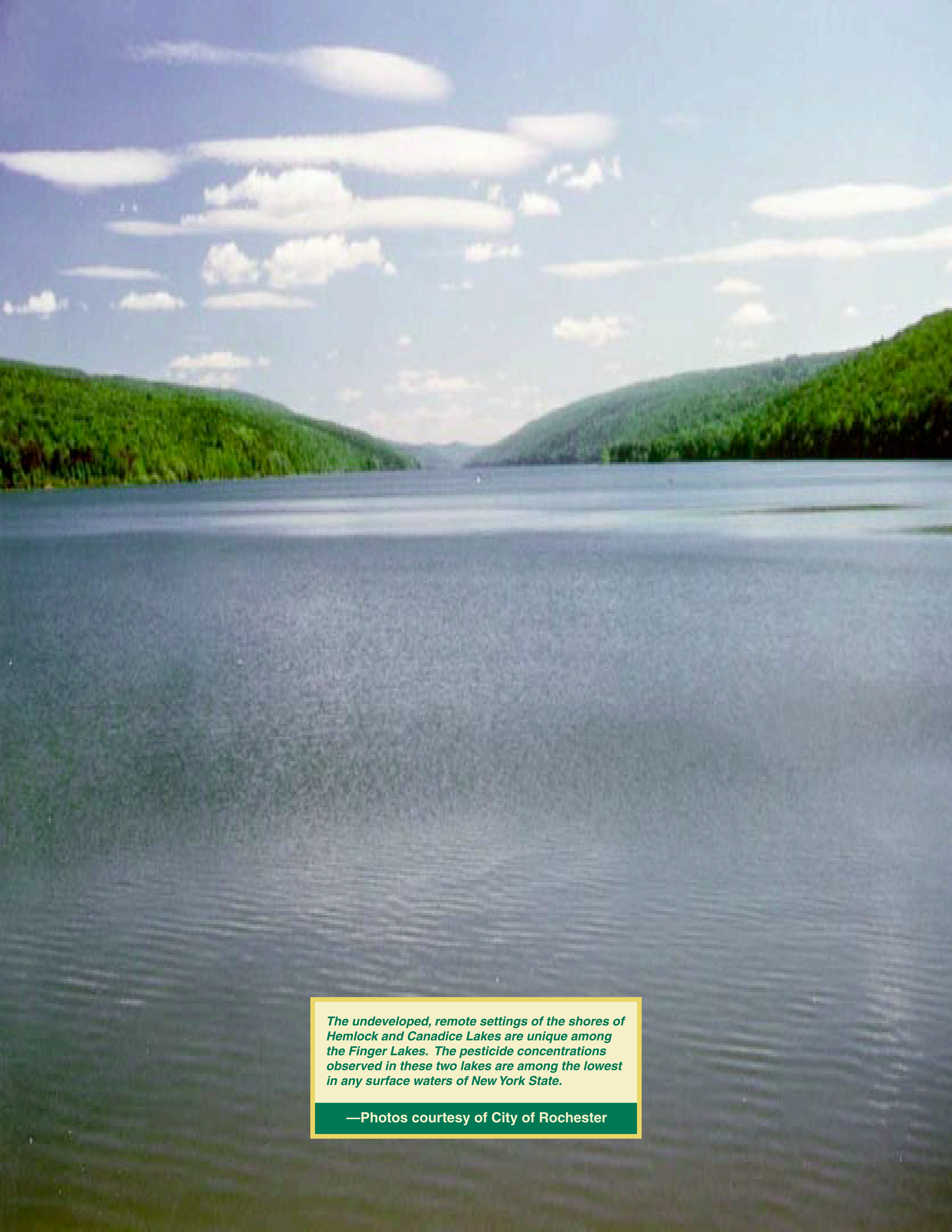

The undeveloped, remote settings of the shores of Hemlock and Canadice Lakes are unique among the Finger Lakes. The pesticide concentrations observed in these two lakes are among the lowest in any surface waters of New York State.

—Photos courtesy of City of Rochester