3. Physical Characteristics of the Site

Onondaga Lake is an urban lake that has been influenced by anthropogenic activities for more than 200 years (Effler and Harnett, 1996). The southern end of the lake borders the city of Syracuse and is a heavily developed urban area (Chapter 1, Figure 1-2). The town of Salina and the village of Liverpool border the north and northeast edges of the lake, respectively, while the town of Geddes and the village of Solvay border the west and southwest edges, respectively.

Onondaga Lake is encircled by several major roadways: Interstate 90 (I-90) runs along the northwest tip of the lake, I-690 runs along the west and southwest edges of the lake, Interstate 81 (I-81) passes by the southeast corner of the lake, and State Route 370 runs along the north and northeast edges. More than 75 percent of the lake's shoreline is owned by Onondaga County and is classified as parkland. The following sections describe the physical and ecological characteristics, demography, and land use of the area. This information is also discussed in Effler (1996) and the Onondaga Lake Baseline Ecological Risk Assessment (BERA) (TAMS, 2002a), which has been generated in concert with this RI report.

3.1 Topography and Surface Features

Onondaga Lake is located in Onondaga County, central New York State, in the Oswego River drainage basin (Chapter 1, Figure 1-1). The lake covers an area of approximately 4.6 square miles (sq mi) (12 sq kilometers [km]), or 3,000 acres, and is oriented along a northwest-southeast axis, with a length along this axis of 4.7 mi (7.5 km) and a maximum width of 1.2 mi (1.9 km) (based on PTI, 1992a). The lake has approximately 11.7 mi (18.8 km) of shoreline (based on PTI, 1992a).

Figure 3-1 shows the lake bathymetry as determined by Honeywell during the remedial investigation (RI) when the water surface elevation was 110.76 m (PTI, 1992a). The mean lake depth is 12 m, and the maximum is 19.9 m. The lake has two basins, northern and southern, which are separated by a slight ridge approximately 56 ft (17 m) deep. The maximum depths of these basins are 62 and 65 ft (18.8 and 19.9 m), respectively, and the volume of the lake is 139×10^6 cubic m (PTI, 1992a). The hypsographic curve (Figure 3-1 inset), which is based on the lake bathymetry, indicates that the nearshore shelf (depths less than 4 m) is relatively broad and is bordered by a steep offshore slope at depths of 4 to 8 m.

3.2 Climate and Meteorology

The climate in the Onondaga Lake drainage basin can be described as "temperate continental" (Trewartha, 1968) and somewhat humid. The area's geographic proximity to Lake Ontario results in moderated extremes in air temperature (the "lake effect") (Effler and Harnett, 1996), relative to areas at the same latitude that are farther east. The mean annual temperature is 47.8°F (8.8°C), with a mean July temperature of 71.1°F (21.7°C) and a mean January temperature of 23.7°F (-4.6°C) (National Oceanic and Atmospheric Administration [NOAA], 2001). Record temperatures range from 102°F (38.9°C) in July to -26°F (-32.2°C) in January, February, and December (NOAA, 2001). Based on the 1971 to 2000 period, the average first occurrence of freezing temperatures (daily low of 32°F [0°C]) in the fall is

November 15, and the average last occurrence of freezing temperatures in the spring is April 8 (NOAA, 2001).

Moisture enters the area primarily via low-pressure systems that move through the St. Lawrence Valley toward the Atlantic Ocean. Monthly precipitation averages approximately 8.2 cm and is relatively evenly distributed throughout the year, ranging from 6.4 cm in February to 9.4 cm in July (National Climatic Data Center [NCDC], 1995).

Winds in the Syracuse area are predominantly from the west and northwest (Figure 3-2). The predominant wind directions remain relatively constant throughout the year, although minor monthly variations occur (Figure 3-3). Most of the strongest winds (20 to 23 m/s, 44 to 51 mph) occur between November and April (NCDC, 1998).

3.3 Geologic Setting

3.3.1 Regional Geology

Onondaga Lake is located at latitude 43°6'54"N, longitude 76°14'34"W, which places it in the Ontario Lowland Lake Plain physiographic province. This province is bordered by the Ontario Lowland drumlin fields to the west and the Appalachian Upland border scarp province to the south (Winkley, 1989). The axis of the lake is aligned along the northward-draining Onondaga glacial trough. The trough was formed by glacial scouring and glaciofluvial erosion of bedrock. The trough is now filled with up to almost 300 ft (91 m) of unconsolidated sediment, including glacial deposits, post-glacial deposits (marl and peat), and artificial fill (Winkley, 1989).

Most of the Onondaga Lake drainage basin, including the lake, is located within the Limestone Belt of central New York State (Berg, 1963). This geologic province extends from Buffalo eastward to Albany (Figure 3-4), with the southern part of the drainage basin lying on the Northern Appalachian Plateau. The surfaces of some areas in the Limestone Belt consist of exposures of glacial till and lacustrine deposits, whereas outcrops of limestone (particularly Onondaga Limestone) and alkaline shales are exposed at other locations.

Since water flowing into Onondaga Lake is derived primarily from the Limestone Belt, soils within that belt play a major role in influencing the characteristics of the water. Calcium, magnesium, bicarbonate, and alkalinity concentrations all tend to be much higher in lakes influenced by the Limestone Belt, when compared to lakes influenced by the Northern Allegheny Plateau to the south (e.g., the Finger Lakes) or the Ontario-Oneida-Champlain Lake Plain to the north (e.g., Oneida Lake) and such is the case in Onondaga Lake. In addition to these natural sources, calcium and other ionic concentrations in Onondaga Lake have been heavily influenced primarily by Honeywell's (formerly AlliedSignal) industrial sources of Solvay waste since 1890. The current major source of industrially contaminated surface water, high in calcium, entering Onondaga Lake is Ninemile Creek. Ninemile Creek receives much of its calcium loading, among other contaminants, from Honeywell Wastebeds 1 through 15.

3.3.2 Site Geology

The bedrock geology in northern and central Onondaga County consists of sedimentary rock units from the Paleozoic-age Salina Group, which, in order of oldest to youngest, is comprised of the Vernon Formation, the Syracuse Formation, Camillus Shale, and the Bertie Formation. In the vicinity of Onondaga Lake, only the oldest two of these units are represented.

The Vernon Formation, which consists of red and green shale, underlies Onondaga Lake and is the thickest single formation in Onondaga County, consisting of approximately 492 to 590 ft (150 to 180 m) of grey, red, and green mudstones that are relatively soft and erodible. There are some localized, discontinuous gypsum seams within the shale. The primary permeability of the Vernon Formation shale is low, with some secondary porosity formed from mineral dissolution within the gypsum seams.

In areas to the south of Onondaga Lake, the Syracuse Formation overlies the Vernon Formation. In the Syracuse Formation (which is approximately 148 to 220 ft [45 to 67 m] thick and consists of shales, dolostones, gypsum, and rock salt [Blasland & Bouck, 1989]), groundwater flows to the north toward Onondaga Lake and is the source of naturally occurring brines in the area. As groundwater flows through the Syracuse Formation, evaporites are dissolved and carried along in the water. The dissolution of the evaporites results in many void spaces in the Syracuse Formation (Rickard and Fisher, 1975), which offer a conduit for the rapid transportation of groundwater (Phillips, 1955).

The unconsolidated deposits overlying the bedrock around Onondaga Lake vary in thickness, with much of the lake underlain by approximately 98 ft (30 m) of deposits which thicken to approximately 328 ft (100 m) at the mouth of Onondaga Creek at the southern end of the lake. Most of these deposits are glacial in origin, consisting of till, outwash, and lacustrine materials ranging in size from boulders and cobbles to gravels and sands to silts and clays. The stratigraphic sequence is highly variable in the area of the lake. Naturally occurring materials found at the surface may include the glacial deposits, or deposits of more recent origin such as clay, peat, and marl formed in and at the edges of the lake. In addition to natural deposits, large areas around the lake have been modified by human activities, including fill and waste disposal.

The glacial deposits found beneath the lake also extend beyond the lake margins and fill the major drainage channels leading into and out of the lake. Deposits within these channels are primarily outwash in origin and consist of sand and gravel, with an interbedded fine component. These outwash deposits are locally heterogeneous and receive recharge from upland areas from both groundwater and surface water flow.

In some limited areas around the lake, post-glacial deposits consisting of marl, peat, and organically enriched, fine-grained sediments overlie the glacio-lacustrine sediments. Along the southern end of the lake, marshy areas containing organic-rich sediments have formed on top of the lacustrine sediments (Blasland & Bouck, 1989). Sub-bottom profiling of the lake during the geophysical investigation (PTI, 1992a) revealed approximately 46 to 59 ft (14 to 18 m) of fine-grained lacustrine sediment overlying glacial till where acoustic penetration of the lake sediment was possible (in some littoral areas) (PTI, 1992a).

The thickness of materials – of both recent and glacial origin – is highly variable. At Honeywell's Willis Avenue site, for example (see Chapter 6, Figure 6-1), the thickness of unconsolidated deposits ranges between 12 and 34 m (O'Brien & Gere, 2002e). Glacial till lies directly above bedrock at the Willis Avenue site and thicknesses of till vary between about 40 ft (12 m) in the former Petroleum Storage Area and about 1 ft (0.3 m) in the Chlorobenzene Hot Spot Area. Glacio-lacustrine silts and fine sands overlie bedrock and the till (except where a discontinuous layer of sand and gravel lies between the till and the glacio-lacustrine deposits). The thickness of the glacio-lacustrine deposits varies between 98 ft (30 m) along the lake and approximately 10 ft (3 m) along the southern margin of the Willis Avenue site. A layer of freshwater marl lies above the glacio-lacustrine deposits along the lake, where it is approximately 23 ft (7 m) thick. Although the marl is generally of low porosity, the presence of shell interbeds creates higher-porosity zones. Artificial fill of varying composition overlies the natural sediments and ranges in thickness between approximately 5 and 40 ft (1.5 and 12 m).

As a further example, Solvay waste between 30 and 50 ft (9 and 15 m) thick overlies the unconsolidated deposits (i.e., the till, sand, silt, marl, and peat discussed above) in the area of the Honeywell Semet Residue Ponds. The till unit is relatively thin (under 2 ft [0.6 m]) at the Semet Residue Ponds. Overlying the till is a layer of sand and silt, ranging between 1 and 15 ft (0.3 and 4.5 m) thick, followed by 2 ft (0.6 m) of coarse sand and gravel in some locations. Overlying the sand and gravel layer (or the sand and silt layer where the sand and gravel is absent) is a fine-grained sand-and-silt deposit up to 50 ft (15 m) thick, and a freshwater marl up to 4 m thick. A thin (less than 2 ft [0.6 m]) layer of peat overlies the marl.

3.4 Surface Soils

The surface soils of the Onondaga Lake watershed consist of deposits of glacial origin, including till, outwash, alluvial, and glacio-lacustrine sediments. The soils tend to be medium-textured, well drained, and high in lime (NYSDEC, 1989; Soil Conservation Service [SCS], 1977). Above the unconsolidated sediments in many upland areas near the site are fill deposits composed of peat, cinders, ash, and Solvay wastes. As mentioned earlier, the drainage basin of the lake is in the northern portion of a region characterized by drumlins with narrow, steep-sided valleys. Significant amounts of soil erode into the valley streams during rainstorm events (Lincoln, 1982; Murphy, 1978; NYSDEC, 1989).

Humans have substantially altered most of the soils along the western, southern, and eastern sides of the lake, such that the original soils are unrecognizable or absent. These soils are classified as "made land" (e.g., stretches of the southern lakeshore filled with sand, silt, brick, ashes, cinders, and the Solvay Wastebeds as identified in Figure 1-7) and "urban land" (e.g., developed areas covered by concrete and buildings, such as parking lots, business parks, and shopping malls) (NYSDEC, 1989).

3.5 Surface Water Hydrology

Onondaga Lake receives surface runoff from a drainage basin of 248 sq mi (642 sq km) (Effler and Harnett, 1996) (Figure 3-5). Surface water flows into the lake via six tributaries: Ninemile Creek, Onondaga Creek, Ley Creek, Harbor Brook, Bloody Brook, and Sawmill Creek (Figure 3-5). In addition, effluent from Metro is discharged into the lake, and a relatively small amount of water is added to the lake through two industrial conveyances: the East Flume and Tributary 5A.

Bloody Brook and Sawmill Creek flow into Onondaga Lake on the northeastern shore. The terminus of several tributaries on the south and west sides of Onondaga Lake border several current and former Honeywell Solvay Wastebeds (Figure 1-7), specifically:

- Ley Creek borders Solvay Wastebeds L and H.
- Onondaga Creek borders Solvay Wastebeds G, H, J, K, and M.
- Harbor Brook borders Solvay Wastebeds B, D, and E.
- Tributary 5A borders Solvay Wastebed A.
- Ninemile Creek borders Solvay Wastebeds 1 through 15.

Ninemile and Onondaga Creeks account for most of the inflow to the lake, together comprising approximately 62 percent (30.4 percent from Ninemile Creek, 31.4 percent from Onondaga Creek) of the total inflow for the period from 1971 to 1989 (Effler and Whitehead, 1996). During the same period, Metro discharge, Ley Creek, and Harbor Brook accounted for approximately 19, 8, and 2 percent of the total inflow, respectively, and the combined contributions from all other tributaries, including Bloody Brook, the East Flume, Tributary 5A, and Sawmill Creek, were relatively minor (approximately 9 percent).

The East Flume is an excavated drainage ditch that runs through Wastebed B and receives stormwater from the village of Solvay; process waters from General Chemical Corp. and Salt City Energy Venture, L.P.; historic releases from Honeywell's plant; and likely some groundwater discharges. Based on historical aerial photographs obtained from Cornell University's Institute for Resource Information Systems (D. Ayers, pers. comm., 2001) (see Chapter 4), it is found that, in 1938, Honeywell discharged into Onondaga Lake near the western edge of Wastebed B, and by 1951 it was extended so that the discharge point was close to the midpoint of the wastebed's shoreline (see Chapter 4, Section 4.5.1). In 1977, the upper portion of the East Flume was widened to a maximum of about 100 ft (30.5 m) and deepened to a maximum of about 6 ft (1.8 m), in order to serve as a holding pond for the process cooling waters prior to their entry into a thermal diffuser and subsequent discharge to the lake. At the eastern end of the upper East Flume is the thermal diffuser building and a dam. Below the dam, the lower East Flume retains the original manmade drainage-ditch configuration, approximately 25 ft (7.6 m) wide and 3 to 4 ft (0.9 to 1.2 m) deep, and meanders to the east, where it discharges at about the midpoint of Wastebed B (O'Brien & Gere, 2002g).

Tributary 5A receives process water from the Crucible Materials Corporation plant, as well as surface runoff and shallow groundwater from Honeywell's Wastebed A, Willis Avenue, and Semet Residue Ponds sites and the Church and Dwight facility.

A small amount of water is also added to the lake through intermittent bidirectional flow from the Seneca River at the outlet of the lake (Owens and Effler, 1996). Bidirectional flow is possible because the 6.2-ft (1.9-km) outlet channel that connects Onondaga Lake to the Seneca River has no natural gradient. Onondaga Lake is part of the New York State Barge Canal System, and the elevation of the lake is controlled by a dam on the Oswego River at Phoenix, New York, downstream from the lake. Flow through the outlet is sensitive to several parameters, including rate of tributary inflow to the lake, wind speed and direction, water surface elevation in the river, water surface elevation in the lake, and seiche activity in the lake (Owens and Effler, 1996). It is likely that only epilimnetic water flows out of the lake, as the outlet channel is only 12 ft (3.7 m) deep, while the bottom of the epilimnion is typically about 23 to 30 ft (7 to 9 m) deep (Owens and Effler, 1996). The annual contribution from Seneca River backflow is difficult to quantify, but is believed to be less than 10 percent of total flow to the lake.

The highest average inflow of water to Onondaga Lake occurs in March and April, and the lowest average inflow occurs in August (USGS, 1990). Water exits the lake via the outlet and flows into the Seneca River (Figure 3-5). The Seneca River merges with the Oneida River to form the Oswego River, which discharges to Lake Ontario.

In addition to influencing flow through the outlet, lake elevation can influence numerous characteristics of the nearshore zone because it affects shoreline wetlands, as well as parts of the littoral zone that are subjected to wave and ice disturbance. The elevation of the lake generally is greatest in early spring (due to rainfall and melting snow) and lowest during the summer period. For the period from 1971 to 2000, the monthly mean elevation of the lake varied by approximately 1.4 ft (0.4 m) over the annual cycle (Figure 3-6). The maximum annual variations in lake level ranged from 1.6 ft (0.5 m) (in 1988) to 7.2 ft (2.2 m) (in 1993), with an overall mean of 4.1 ft (1.25 m) for the entire 30-year period (Table 3-1). Comparison of the monthly mean lake elevations in 1992 to the long-term monthly mean values (1971 to 2000; Figure 3-6) indicates that, with the exception of August and September, mean monthly elevations in 1992 lie within two standard deviations of the long-term mean monthly elevations observed in the lake.

3.6 Hydrogeologic Setting

3.6.1 Regional Hydrogeology

Regional groundwater flow in the area is from south to north, with many small, localized groundwater systems caused by mounding associated with topographic relief. Flow through the Onondaga trough outwash deposits is controlled by recharge originating in high elevations to the south and discharge to the north. Potentiometric maps (Pagano et al., 1986) indicate that regional groundwater flow follows this pattern, with northward flow through the Onondaga bedrock trough and continued flow northward from the Onondaga Lake outlet.

3.6.1.1 Site Hydrogeology

Two main hydrogeologic units are in hydraulic communication with Onondaga Lake: unconsolidated deposits surrounding and underlying the lake, and the Vernon Formation, with its red and green shale, that underlies the sediments. The unconsolidated deposits form an unconfined aquifer of variable thickness. The aquifer consists of well-sorted glacial outwash sands and gravels, with occasional interbeds of lacustrine silts and clays. Precipitation, streamflow, and bedrock groundwater flow recharge the aquifer. Onondaga Lake does not recharge the aquifer under normal (i.e., non-flood) conditions (NYSDEC, 1989).

Historically, the contribution of groundwater to Onondaga Lake has been assumed to be negligible (Effler and Driscoll, 1986; Doerr et al., 1994). The Onondaga Lake Management Conference (OLMC) (1994) concluded that "groundwater inputs and outputs to Onondaga [Lake] are probably a minor (<5 percent) component of the water budget." However, a review by NYSDEC/TAMS (1998b) suggested that this estimated inflow of groundwater was made without the benefit of any site-specific data. Although the inflow of groundwater to the lake might be a relatively small component of the Onondaga Lake water budget, groundwater flow, in fact, represents an important means for contaminant migration, including mercury and organic compounds, to the water column.

Unconsolidated Deposits

Unconsolidated outwash fills glacial meltwater channels or troughs throughout Onondaga County to form some of the major water-bearing deposits of the region. Onondaga Lake occupies a depression in the northern end of the Onondaga trough, and is underlain and surrounded by glacial-fluvial deposits that extend to underlie the major tributaries to the lake. The thickness of the glacial-fluvial deposits ranges from approximately 100 to 330 ft (30 to 100 m) beneath the lake, and decreases quickly away from the lake margins and tributary valleys. Although the entire outwash sequence is hydraulically connected, little information is available regarding the integration of highly permeable deposits within the outwash that would control localized groundwater flow. Regional flow is from south to north, with groundwater discharging locally to the many streams and lakes within the Onondaga drainage basin.

The glacial-fluvial sediments provide the majority of groundwater recharge to Onondaga Lake, with underflow occurring along the lake margins. This is consistent with the understanding that most water exchange between groundwater systems and lakes occurs in the littoral zone (McBride and Pfannkuch, 1975). To estimate the magnitude of this underflow along the lake margins, "representative" aquifer conditions along this boundary were evaluated. Detailed stratigraphic information is available from the Semet Residue Ponds and Willis Avenue sites RIs (O'Brien & Gere, 1991, 2002e).

At the Semet Residue Ponds and Willis Avenue sites, the shallow unconsolidated sediments near the shore of Onondaga Lake have been divided into five hydrostratigraphic zones which are, in order from shallow to deep: fill, Solvay waste, marl, fine sand and silt, and sand and gravel (O'Brien & Gere, 1991, 2002e). The thicknesses of the five hydrostratigraphic units are somewhat variable in the area of the Semet Residue Ponds and Willis Avenue sites. The thickness of the Solvay waste and marl at the Semet Residue Ponds site ranges from 43 ft (13 m) downgradient to 15 ft (4.5 m) upgradient of the site, with a saturated thickness of 5 to 25 ft (1.5 to 7.5 m). The underlying silts and fine-grained sands are approximately 50 ft (15 m) thick along the lake (O'Brien & Gere, 1991). The basal sand and gravel layer, approximately 10 ft (3 m) thick, overlies till and bedrock.

At the Willis Avenue site, the fill zone has a saturated thickness of approximately 10 to 35 ft (3 to 10.5 m) along the lake, and is underlain by up to 35 ft (10.5 m) of marl along the lake. The silts and fine sands are about 50 ft (15 m) thick along the lake. The thickness of the basal sand and gravel varies from less than 0.3 to 15 ft (0.1 to 4.5 m) throughout the Willis Avenue site (O'Brien & Gere, 2002e). This analysis indicates that the thickness of aquifer units varies between the Semet Residue Ponds and Willis Avenue sites. This variability is likely to increase at other areas along the lakeshore. The effect of variability on groundwater inflow rates is addressed in Chapter 6.

A review of stratigraphic logs presented in Winkley (1989) and Blasland & Bouck (1989) indicates that although the thickness and types of geologic units vary, hydrogeologic conditions in unconsolidated materials that exist at the Semet Residue Ponds and Willis Avenue sites may be similar to most other nearshore areas around the lake (with the exception of the Solvay waste itself). Sediments are generally thicker and coarser in the Onondaga glacial trough and associated tributaries, but they are thinner and finer on the northeast side of the lake. It is therefore reasonable to consider the hydrogeologic conditions in the unconsolidated sediments at the Semet Residue Ponds and Willis Avenue sites to be generally representative of average conditions around the lake.

The direction of groundwater flow in all the hydrogeologic zones is toward the lake. Chapter 6 of this RI presents a summary of hydraulic conductivities and groundwater loadings based on the Willis Avenue and Semet Residue Ponds RI reports, as well as more recent investigations conducted by Honeywell in the area between Tributary 5A and Harbor Brook. These include the Willis/Semet aquifer pump testing investigation (O'Brien & Gere, 2002f, to be finalized); the Wastebed B/Harbor Brook Preliminary Site Assessment (PSA) Work Plan (O'Brien & Gere, 2000b) and RI/FS Work Plan (O'Brien & Gere, 2002a); and the Willis Avenue Ballfield PSA Work Plan (O'Brien & Gere, 2000a) and RI/FS Work Plan (O'Brien & Gere, 2002c), which have been approved.

Vernon Formation

The Vernon Formation's mudstones have a low permeability, thus inhibiting vertical flow and impeding percolation of meteoric waters (Kantrowitz, 1970). Winkley (1989) states that, "although the Vernon yields usable amounts of water to wells, it probably has relatively low hydraulic conductivity on a regional scale." Therefore, the rate of groundwater discharge from the Vernon Formation into the unconsolidated sediments and lake is likely to be insignificant in comparison to the overall lakewater budget.

Saline Groundwater

Saline groundwater within the bedrock discharges to the lower overburden groundwater zone at the southwestern and southern ends of the lake (both onshore and in the lake) and along the tributary valleys in this area (Blasland & Bouck, 1989). The saline groundwater forms as freshwater moves down from the surface and dissolves salt from the Syracuse and Salina Formations (O'Brien & Gere, 1997). Ratios of chloride to calcium and chloride to sodium in groundwater monitoring wells screened in the deeper units in this area are characteristic of naturally occurring brine (saline water) such as Tully Brine, the raw brine solution in the Syracuse Formation (O'Brien & Gere, 1997) and may be distinguished from Honeywell's historic ionic discharges of Solvay waste, which are generally characterized by higher proportions of calcium than the natural brines (BBL, 1999).

3.6.2 Groundwater Use

The groundwater is classified as Class GA (defined as a source of drinking water [6 NYCRR Part 701.15]) by New York State regulations; however, some areas of groundwater in the vicinity of the lake may not currently be appropriate for use as sources of potable water due to natural occurrences of salinity (e.g., brine fields in the area) and contributions from anthropogenic salinity sources, including Honeywell. Groundwater at the southwestern and southern ends of Onondaga Lake is not currently used for drinking water or industrial purposes (O'Brien & Gere, 1997). However, based on information provided to NYSDEC by Niagara Mohawk, the Niagara Mohawk facility on Erie Boulevard did use groundwater for cooling water. The high chloride and total dissolved solid (TDS) concentrations in the groundwater from the surface aquifer, which has been influenced by Solvay waste, exceed Class GA fresh groundwater standards for chloride (500 mg/L) and TDS (1,000 mg/L). However, because the high chloride and TDS concentrations in the shallow groundwater are likely due to industrial activities (such as disposal of Solvay waste), and because groundwater classifications reflect natural or indigenous conditions only, Class GA standards apply to this portion of the groundwater system. The soils (silt and marl) and Solvay waste materials in this area have low hydraulic conductivity and would likely not yield sufficient water to be a supply source (O'Brien & Gere, 1997).

3.7 Limnology

3.7.1 Lake Stratification and Circulation

Like most inland northern lakes, Onondaga Lake is stratified during winter and summer and is vertically mixed (isothermal) in spring and fall. The difference in density of the overlying lighter epilimnion and the more dense hypolimnion is associated with vertical temperature differences (Wetzel, 1983; Owens and Effler, 1996), and can vary in timing and intensity from year to year.

Prior to 1987, the lake regularly failed to turn over in the spring due to salinity stratification (Owens and Effler, 1996). The water inputs from the surrounding tributaries tended to plunge due to their saline nature into the hypolimnion and caused a significant saline stratification. The failure of the lake to turn over caused a depletion of the dissolved oxygen (DO) in the hypolimnion and prevented the normal heating of these waters (Owens and Effler, 1996). Turnover resumed after the Honeywell Main Plant closed in 1986, although some saline inputs (i.e., from the wastebeds) continue to enter the lake. Dissolved oxygen is also generally depleted in the late summer or early fall due to cultural eutrophication (Owens and Effler, 1996).

Data collected for the RI (PTI, 1993c) and plotted in Figure 3-7 show the progression of thermal stratification of Onondaga Lake in 1992. Thermal stratification was just beginning when the first temperature measurements were made on April 13, 1992. Surface water temperatures in the southern basin were 5°C in the top 10 ft (3 m), declining to and remaining at 4.7°C from 23 ft (7 m) to the bottom. Thermal stratification was well established by May, when surface water temperature in the southern basin was greater than 15°C. The most rapid temperature decrease with increasing depth (the thermocline) in May occurred over the depth interval of 20 to 30 ft (6 to 9 m). Over the subsequent summer months, the water column warmed and the depth of the thermocline increased. By September, surface and bottom water temperatures were approximately 20 and 10°C respectively, and the depth of the top of the thermocline was about 30 ft (9 m). By October, thermal stratification was declining. Surface water temperatures had decreased to approximately 15°C, and the vertical temperature gradient was diminished. The November data indicate a complete absence of thermal stratification. A weak inverse thermal stratification occurs once the lake is covered with ice (which prevents wind-driven mixing). Water with temperatures near 4°C (the temperature at which water is at maximum density) are found at the lake bottom, and the water temperature gradually declines until it reaches 0°C (freezing) at the surface.

The concentration of TDS, which can be measured as chloride concentration, has a much smaller influence on lake stratification. For example, in July 1992, the average density of the epilimnion (30 ft [9 m] and less) was 0.99859 g/cm^3 and in the hypolimnion (below 30 ft [9 m]) was 1.00067 g/cm^3, a density difference of 0.00208 g/cm^3. The corresponding average chloride concentrations were 466 mg/L in the epilimnion and 579 mg/L in the hypolimnion. If, for the purpose of this example, the chloride concentrations were reduced by 100 mg/L in the hypolimnion only and the temperature did not change, the average density of the hypolimnion would decrease by 0.00013 g/cm^3 and the resulting density difference between epilimnion and hypolimnion would be 0.00195 g/cm^3. This same decrease in the density of the hypolimnion (0.00013 g/cm^3) would be achieved if the water temperature decreased by about 0.5°C and the chloride concentration did not change. These calculations indicate the significance of temperature in the lake's stratification.

Circulation of surface water in Onondaga Lake is dominated by wind speed and direction, with surface currents moving in the direction of the wind except along the shore, where currents run parallel to the shore (Owens and Effler, 1996). At depth, currents move in the opposite direction to wind. Current velocity is greatest when winds are situated along the major axis of the lake basin (i.e., northwest-southeast) (Owens and Effler, 1996). Under calm conditions and high tributary inflow, currents generally move toward the outlet.

Onondaga Lake had an annual flushing rate (i.e., the number of times the lake is emptied and refilled each year) of 3.9 flushes per year for the 1971 to 1989 period (Effler and Whitehead, 1996). The flushing rate is greater for the epilimnion during summer stratification, with three flushes under average flow conditions (Effler and Whitehead, 1996). Tributary inflow is, therefore, incorporated primarily into the epilimnion and not the entire lake volume during stratification. Owens and Effler (1996) indicates that the zone of neutral buoyancy is the thermocline. Plunging flows from Ninemile and Onondaga Creeks do not enter the hypolimnion unless under weak or no stratification.

3.7.2 Sediment Characteristics

For the purposes of assessing the distribution of chemical parameters of interest (CPOIs) (Chapter 5) and the transport and fate of CPOIs (Chapter 6), this RI divided the lake sediments into two zones, the littoral and the profundal zones, based on the depth of the summertime thermocline (30 ft [9 m]). This was done to take into account the different biological, physical, and chemical processes of the epilimnion and the hypolimnion. The littoral zone extends from the shore to the 30 ft (9 m) depth contour. The profundal zone includes all sediments located in water deeper than 30 ft (9 m). As summarized below, in other reports the sediments have been divided into various zones based on characteristics of the sediments themselves.

Johnson (1989) divided the sediments of Onondaga Lake into three zones based on sediment characteristics, as follows:

- The littoral zone extends out to approximately 15 ft (4.5 m) in lake depth and contains fine silts and clays, sand and shell fragments, and oncolites. Littoral sediments throughout most of the lake contain high concentrations of calcite.

- The profundal zone extends below 40 ft (12 m) in lake depth, and the associated sediments contain anoxic muds as well as hydrogen sulfide and amorphous iron sulfides.

- The littoroprofundal zone is a steeply sloping area containing sediments that are transitional between littoral and profundal.

In another study, Auer et al. (1996) described the profundal zone as the area of lake sediments below about 20 ft (6 m) in lake depth that are relatively undisturbed and reflective of sediment focusing (where fine-grained sediment from the littoral zone is resuspended and deposited in the deep basins). The profundal sediments are not subject to resuspension or bioturbation, in contrast to sediments in the littoral zone. Laminations in sediment cores (Rowell, 1992) support Auer et al.'s description of these sediments as undisturbed. Auer et al. identified another sediment zone (group) located at the south end of Onondaga Lake. Sediments at the south end made up 14 percent of the sediment area and were generally higher in total organic carbon (TOC) and clastics (terrigenous solids), and lower in calcium carbonate, than were the other groups of sediments.

Grain-size distribution and TOC content were closely associated in Onondaga Lake in 1992 (Figure 3-8). The highest percentages of fine-grained sediment (>90 percent) and TOC (>3.0 percent) were found in the deeper parts of both the northern and southern basins. By contrast, the coarsest sediments (<10 percent fine-grained fraction) and lowest TOC values (<1.0 percent) were found throughout most of the nearshore zone along the entire eastern shoreline and the western shoreline north of Ninemile Creek. The sedimentary patterns observed in Onondaga Lake in 1992 are similar to the patterns found by others (Johnson, 1989; Auer et al., 1996).

Data from sampling stations located on the eastern and western shores of the southern basin of the lake and on the western shore of the southern basin of the lake were compared to determine the possible extent of Solvay waste along the western shore. Some of the primary chemical components of Solvay waste material are calcium, magnesium, sodium, and chloride (Kulhawy et al., 1977), and these components are not found together in indigenous sediments. The calcium, magnesium, sodium, and chloride concentrations in 1992 and 2000 sediment data and 2000 porewater data were also reviewed. A station that had at least three of these four compounds elevated was considered to be possibly impacted by Solvay waste material. In addition, the core logs of the sediment descriptions for the 2000 sampling event were reviewed for color (i.e., white to light green-gray) and texture (i.e., moist layers usually associated with calcareous material) similarities to Solvay waste material. These descriptions were used to refine the boundary of Solvay waste material in the lake. Based on this qualitative assessment, it was determined that two areas (i.e., Areas A and B), comprising approximately 69 acres (280,000 sq m) along the western shore of the southern basin of the lake, consist of Solvay waste material (Figure 3-9). Additional information on the waste material found in this area of the lake is included in Chapter 4.

Results of geotechnical testing (e.g., vane shear and consolidation testing) in 2000 (Appendix E) indicated that both the Solvay waste material and the natural lake sediments were heterogeneous. In particular, relatively hard layers were found to be present within the Solvay waste material, although the horizontal and vertical extent of these layers was variable. The hard layers may have an effect on the cumulative geotechnical properties of the overall sediment sequence; for example, they were brittle in nature and had higher shear strengths than the surrounding layers. The physical (e.g., hard layer) and chemical (e.g., high pH) characteristics of Solvay waste material also have the potential to affect transport and fate of CPOIs, as discussed in Chapter 6.

Cores collected during this RI suggest variable sedimentation rates in the lake (see Chapter 6), and show that rates from one location cannot be used to describe the entire lake. However, different cores from the central portions of the profundal zone were relatively consistent in terms of relatively recent (post-1963) deposition rates. There is evidence that the sedimentation rate has declined since the closure of the Honeywell Main Plant in 1986. Rowell (1992) reported sedimentation rates of 0.83 and 0.88 cm/year for the northern and southern basins, respectively, based on cesium-137, but considered these values to be overestimated as a result of sediment undercompaction. He later revised the sedimentation rate to approximately 0.6 cm/year, based on his estimate of sediment undercompaction (Effler et al., 1996a). Hairston et al. (1999) used Pb-210 to date cores collected from the saddle region. They estimated sedimentation rates of 0.97 cm/year from 1967 to 1986, with a decrease to 0.77 cm/year after 1986.

Effler and Brooks (1998) used sediment traps to measure rates of sediment deposition in Onondaga Lake from 1980 to 1992 and found that deposition rates had declined by over 40 percent since the closure of the Honeywell Main Plant in 1986, which agrees with the work of Hairston et al. (1999). The studies utilizing cores also suggest that the sediments in the central areas of the profundal zone are relatively undisturbed, and that the profiles of several metal CPOIs reflect the historical disposal of waste into the lake.

3.7.3 Oncolites

Oncolites are irregularly rounded, calcareous nodules that range in size from 0.5 to 30 cm and are not attached to substrates (Pentecost, 1989). Oncolites have existed since the Precambrian era (more than three billion years ago) and are currently found in a variety of freshwater, estuarine, and marine environments (Golubic and Fisher, 1975; Dahanayake et al., 1985). In freshwater environments, oncolites are found in numerous lakes, rivers, and streams around the world (Table 3-2).

Under natural conditions, oncolite formation is facilitated by epilithic or epiphytic (i.e., attached to rocks or plants) cyanobacteria (blue-green algae). Cyanobacteria induce calcite precipitation from the water column during photosynthesis and by trapping and bonding calcite particles that form by inorganic precipitation during periods of calcite supersaturation. Oncolites form around various kinds of nuclei, including shells, plant fragments, woody twigs, and oncolite fragments (Jones and Wilkinson, 1978; Dean and Eggleston, 1984). The concentric layers found in oncolites reflect seasonal changes in cyanobacteria activity and growth (Jones and Wilkinson, 1978; Ordonez and Garcia del Cura, 1983).

Other than the presence of cyanobacteria, the primary factors related to the formation of oncolites are specific chemical and physical characteristics of the aquatic system. The conditions in the water column (e.g., temperature, pH, alkalinity, calcite concentration) must be saturated with respect to calcite to be favorable to calcite precipitation. In many cases, biogenic precipitation of calcite is facilitated by increases in pH in microenvironments as a result of photosynthesis. Conditions in the water column must also be suitable for growth of cyanobacteria. Requirements for light for photosynthesis and oxygen for respiration limit the distribution of oncolites to relatively shallow environments. Low levels of turbidity are required to ensure adequate light for photosynthesis. Sufficient energy in the form of waves and currents is required to prevent oncolites from becoming cemented to hard substrates or becoming buried by sediments. Oncolite formation also requires suitable nuclei (e.g., shells, plant fragments), which are generally not found in most shallow, soft-bottom sediments.

Oncolites were first documented in Onondaga Lake by Dean and Eggleston (1984). They found oncolites ranging in size from several millimeters to 15 cm in diameter on the sediment surface approximately 30 to 330 ft (10 to 100 m) offshore in 3.3 to 6.5 ft (1 to 2 m) of water. The Onondaga Lake oncolites have a relatively uniform composition of 92 percent calcium carbonate and 3 percent organic matter. In 1992, oncolite concentrations were documented for the nearshore zone, as described in Chapter 5, Section 5.1. Chapter 10 of the Onondaga Lake BERA (TAMS, 2002a) discusses how the coverage of much of the littoral zone of the lake with oncolites may have significant impacts on macrophyte and macrobenthos communities.

Oncolites have formed in Onondaga Lake as a result of discharges of calcium-contaminated Solvay waste (Dean and Eggleston, 1984). This is based on evidence of the absence of charophytes in the lake at least as far back as 1925 (Effler et al., 1996a). Charophytes are common in other hard-water lakes in central New York (Effler and Rand, 1976; Effler et al., 1985). Dean and Eggleston (1984) suggested that, prior to ionic waste discharge to the lake, the lake supported a healthy standing crop of charophytes. However, with the introduction of the soda-ash manufacturing and the discharge of calcium-carbonate wastes to the lake, the increased salinity and rate of calcium-carbonate precipitation eliminated the charophytes. Dean and Eggleston (1984) further stated that the stems of the dead charophytes coated with calcium carbonate broke into fragments that behaved as sediment particles and substrates for growth of cyanobacteria, which promoted the precipitation and continued growth of the oncolites.

3.8 Ecology

The ecological features and organisms described in this section include the following, found in the lake and surrounding area:

- Surrounding wetlands and terrestrial covertypes.
- Significant habitats.
- Macrophytes, aquatic, and terrestrial organisms.
- Rare, threatened, or endangered species.

The BERA (TAMS, 2002a) provides greater detail on each of these aspects of the Onondaga Lake ecosystem.

3.8.1 Wetlands

There is little information regarding the original condition of the wetlands surrounding Onondaga Lake. Onondaga County is noted for conditions that lead to the formation of marl fens (Olivero, 2001), and the marl found in the soil and sediments surrounding the lake suggests that some of the original wetlands surrounding the lake were marl fens. The remnant inland salt ponds and marshes, Natural Heritage records (BERA Appendix C), and historical accounts of salt springs on the lakeshore as summarized in Effler and Harnett (1996), indicate that inland salt marshes were also present in the area surrounding the lake. The total extent of wetlands was likely affected when the level of Onondaga Lake was lowered in 1822 (Effler and Harnett, 1996). In addition, development and waste disposal by Honeywell (e.g., Solvay waste, dredge spoils) along the shoreline has buried much of the original wetland habitat. Also, as discussed in Chapter 5, transport of contaminants from Honeywell sites has impacted lake-connected wetlands, including wetlands adjacent to Harbor Brook and Ninemile Creek.

NYSDEC classifies and regulates wetlands in New York State pursuant to 6 NYCRR Part 664. Regulated wetlands must be at least 12.4 acres (5.02 hectares) in area and must be dominated by hydrophytic vegetation. Smaller wetlands having "unusual local importance as determined by the Commissioner" may also be regulated by the state.

There are 22 NYSDEC-regulated wetlands either wholly or partially located within 2 mi (3.2 km) of Onondaga Lake (Figure 3-10) (NYSDEC, 1986). Five of these wetlands occur along the shoreline of the lake near the mouths of Harbor Brook, Ley Creek, Ninemile Creek, and Sawmill Creek, as well as along the northwest shoreline of the lake. The wetland classification scheme developed by NYSDEC and the general characteristics of the wetlands in the Onondaga Lake area are discussed in the BERA.

In addition, the National Wetlands Inventory (NWI) of the US Fish and Wildlife Service (USFWS) has evaluated wetlands in the vicinity of Onondaga Lake. Figure 3-10 also shows NWI mapping of federal wetlands along the shoreline and within two miles of the shoreline of Onondaga Lake. The federal wetlands in this area fall under three main categories:

- **Lacustrine** (limnetic or littoral) – Lacustrine systems include wetlands and deepwater habitats situated in topographic depressions or dammed rivers or channels with a lack of trees, shrubs, or persistent emergents.

- **Palustrine** (emergent, forested, scrub-shrub, or unconsolidated bottom) – Palustrine systems are non-tidal wetlands dominated by trees, shrubs and emergents, mosses, and lichens.

- **Riverine** (low perennial) – Riverine systems are wetlands and deep water habitats contained in natural or artificial channels that are periodically flooded, continuously containing flowing water, or which form a connecting link between two bodies of standing water.

Most of the federal and state wetlands surrounding Onondaga Lake are north and northwest of the lake along a meandering riverine wetland (Erie Canal). The great majority of these wetlands are palustrine systems. Approximately 2 mi (3.2 km) west of Onondaga Lake are some patches of lacustrine and palustrine wetlands. Also, the northwest and southeast ends of Onondaga Lake are perennial riverine wetlands (manmade channels). NWI wetlands are further described by plants (hydrophytes), soils (hydric soils), and frequency of flooding and are discussed in greater detail in the BERA (TAMS, 2002a).

3.8.2 Terrestrial Covertypes

The terrestrial covertypes occurring within 0.5 mi (0.8 km) of Onondaga Lake are shown in Figure 3-11. Mapping of covertypes involved a combination of aerial photography and ground-level surveys. Detailed descriptions of each covertype appear in the BERA.

A variety of vegetative communities and covertypes occupy the landscape surrounding Onondaga Lake within a radius of 0.5 mi (0.8 km) (Figure 3-11). Approximately 42 percent of the areal extent of covertypes identified in Figure 3-11 is residential, 33 percent is urban/industrial, and 25 percent is open, forested, or palustrine. The least-disturbed habitats and the greatest variety of "natural" (as opposed to "cultural") (Reschke, 1990) communities are concentrated at the north end of the lakeshore. "Cultural" communities, some of which are suitable habitat for wildlife, dominate the remaining lakeshore.

In general, the eastern shore of Onondaga Lake is mainly urban and residential, and the northern shore is dominated by parkland, wooded areas, and wetlands. The northwest upland is primarily residential, with interspersed urban structures and several undeveloped areas. Wastebeds cover much of the western lakeshore (Chapter 1, Figure 1-7); many of the wastebeds support some vegetation. Urban centers and industrial zones dominate the landscape surrounding the south end of Onondaga Lake from approximately the New York State Fairgrounds to Ley Creek. The BERA provides greater detail on the covertypes found along each section of the lakeshore.

3.8.3 Significant Habitats

According to the database maintained by the Natural Heritage Program (BERA Appendix C), sensitive aquatic communities found currently or historically near Onondaga Lake include inland salt ponds and marshes (Figure 3-11). An inland salt pond in poor condition is located along the northeastern shoreline of the lake. Two inland salt marshes, one west of the New York State Fairgrounds near Ninemile Creek and the other on the northeastern side of the lake, appear to have been extirpated by filling, development, mowing, and invasive plants.

3.8.4 Aquatic Species

3.8.4.1 Macrophytes

Little information is available on the historical occurrence of macrophytes in Onondaga Lake. There are accounts of macrophyte beds at the northern end of the lake, near the mouths of tributaries, and immediately south of the discharge point of Tributary 5A (Murphy, 1978). The most recent studies of macrophytes in Onondaga Lake were conducted between 1991 and 1995 (Madsen et al., 1993, 1996a,b; PTI, 1993c; Arrigo, 1995). The six species identified in the lake during those studies are coontail (*Ceratophyllum demersum*), waterweed (*Elodea canadensis*), water star grass (*Heteranthera dubia*), water milfoil (*Myriophyllum spicatum*), pondweed (*Potamogeton crispus*), and Sago pondweed (*P. pectinatus*). During the RI/FS investigation in 1992, five of the above species were identified in the lake (all but waterweed), and macrophyte beds throughout much of the lake were sparsely populated. During the 1995 investigation, waterweed was again identified in the lake, and the distribution of macrophyte beds had expanded considerably since 1992 throughout the nearshore zone.

3.8.4.2 Phytoplankton and Zooplankton

Phytoplankton and zooplankton have been collected and identified for several studies in Onondaga Lake. Thirty-six phytoplankton taxa were identified in 1992, including flagellated green algae, non-flagellated green algae, diatoms, cryptomonads, and cyanobacteria (i.e., blue-green algae) (PTI, 1993d; Stearns & Wheler, 1994). Between 1986 and 1989, 25 zooplankton taxa were collected in Onondaga Lake (Siegfried et al., 1996). Cladocerans, copepods, and rotifers dominated zooplankton communities. From 1990 to 1992, zooplankton abundances remained relatively constant. However, it should be noted that

Hairston et al. (2000) have documented shifts in the zooplankton community reflecting the changes in salinity in the lake due to Honeywell operations.

3.8.4.3 Benthic Macroinvertebrates

Benthic macroinvertebrate communities were sampled at 68 stations throughout Onondaga Lake during the 1992 RI sampling program (PTI, 1993d). More than 100 taxa were identified in the samples. Oligochaetes and chironomids numerically dominated the communities at most stations. Benthic macroinvertebrate communities were sampled at 15 stations throughout Onondaga Lake and two stations in Otisco Lake in July 2000 for a species abundance survey, and oligochaetes and chironomids again dominated the communities at most stations.

3.8.4.4 Fish

Fish representing 48 species from 20 families were collected in Onondaga Lake between 1989 and 1992 (Ringler et al., 1996). The most numerous species captured during this period included gizzard shad (*Dorosoma cepedianum*), white sucker (*Catostomus commersoni*), banded killifish (*Fundulus diaphanus*), brook silverside (*Labidesthes sicculus*), white perch (*Morone americana*), pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis macrochirus*), and channel catfish (*Ictalurus punctatus*). A fish species and abundance survey was conducted in September 2000, during which young-of-year (YOY) fish were collected at the mouths of all tributaries to Onondaga Lake, except Tributary 5A. Species captured included pumpkinseed, bluegill, and largemouth bass (*Micropterus salmoides*). Adult fish were collected at the mouth of and in Ninemile Creek as well as along the southwest shoreline in Onondaga Lake. Species captured included bluegill, channel catfish, carp, and smallmouth bass (*Micropterus dolomieui*).

3.8.5 Terrestrial Species

Onondaga Lake provides a variety of habitats for bird species. Table 3-11 of the BERA lists species of birds found around Onondaga Lake during the Breeding Bird Atlas survey conducted from 1980 to 1985 (Andrle and Carroll, 1988). More recent data suggest that additional species have started to use the lake. The recent Breeding Bird Atlas survey (beginning in 2000 and scheduled to extend until 2005) has recorded additional species (Chapter 3, Table 3-11 of the BERA [TAMS, 2002a]).

A list of 45 mammalian species that occur near Onondaga Lake is presented in the BERA (Chapter 3, Table 3-14). Some of the more common species include opossums, shrews, rabbits, chipmunks, woodchucks, squirrels, mice, rats, voles, muskrats, raccoons, and skunks.

3.8.6 Rare, Threatened, or Endangered Species

Ten state-listed and one federally listed rare, threatened, endangered, or special-concern species have been observed near Onondaga Lake, including four plant species and seven species of birds.

The three state-listed plant species within two miles of Onondaga Lake are Sartwell's sedge (*Carex sartwella*), little-leaf ticktrefoil (*Desmodium ciliare*), and red pigweed (*Chenopodium rubrum*). All three plant species are state-listed as threatened and are known only from historical records. They have not been sighted in the Onondaga Lake area recently, but may be rediscovered. Hart's tongue fern (*Asplenium scolopendrium var americanum*), a federally listed threatened species, is present within 2 mi (3.2 km) of Onondaga Lake.

The six state-listed bird species of special concern observed near Onondaga Lake are the common loon (*Gavia immer*), osprey (*Pandion haliaetus*), sharp-shinned hawk (*Accipiter striatus*), common nighthawk (*Chordeiles minor*), red-headed woodpecker (*Melanerpus erythrocephalus*), and horned lark (*Eremophila alpestris*). The common tern (*Sterna hirundo*) is state-listed as threatened.

3.9 Demography and Land/Water Use

Onondaga Lake is located in an urban area and is surrounded by industrial, commercial, and recreational areas. Most of the northern half of the shoreline is parkland. The areas located along the northeast and west lakeshores are zoned "residential open land" or "residential A," although no residential property directly abuts the lake as these areas are parkland. Commercial and industrial areas near Onondaga Lake are concentrated around the southern end, in the Syracuse metropolitan area.

The population of Onondaga County grew to 469,000 in 1970; however, since then it has decreased to 458,336 (US Census Bureau, 2002). Projections in 1991 anticipated slow growth over the next 20 years (Reimann-Buechner Partnership, 1991). Most of the population currently is, and historically has been, concentrated in the Syracuse metropolitan area (Chapter 1, Figure 1-2), which includes Solvay, Westvale, and Fairmount on the western side of the lake and Galeville, Liverpool, Mattydale, and North Syracuse on the eastern side of the lake (Murphy, 1978). Other population centers in the Onondaga Lake drainage basin are the villages of Camillus, Marcellus, Otisco, LaFayette, and East Syracuse, and the Onondaga Nation Territory.

Approximately the northern two-thirds of Onondaga Lake are classified by the State of New York as Class B water (best usages defined as "primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival" [6 NYCRR Part 701.7]), and the southern third of Onondaga Lake and the area at the mouth of Ninemile Creek are classified as Class C water (best usage defined as "fishing. These waters shall be suitable for fish propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes" [6 NYCRR Part 701.8]). No permitted swimming beaches or sanctioned swimming areas exist at Onondaga Lake (NYSDOH, 1995).

Some fishing occurs, but a specific, restrictive advisory warns against any consumption of walleye (*Stizostedion vitreum*), with all other species to be consumed no more than once per month (NYSDOH, 1999, 2002). The general advisory also carries the stipulation that infants, children under the age of 15, and women of childbearing age should eat no fish from the lake (NYSDOH, 2002). Boating is allowed in all parts of the lake. Onondaga Lake and the associated tributaries do not serve as potable-water sources (Syracuse Water Department, 2000). The shoreline of the lake (especially in the park) is used for water-related recreation such as fishing and boating. In 1990, more than one million people used Onondaga Lake County Park, located along the northern half of the lake, for recreational activities such as boating (Moore, pers. comm.,1991).

The State of New York, Onondaga County, and the city of Syracuse have jointly sponsored the preparation of a land-use master plan to guide future development of the Onondaga Lake area (Reimann-Buechner Partnership, 1991). The primary objective of land-use planning efforts is to enhance the quality of the lake and lakeshore for recreational and commercial uses. Anticipated recreational uses of the lake include fishing without consumption restrictions and swimming.