ONONDAGA LAKE FEASIBILITY STUDY REPORT

VOLUME I – Executive Summary, Sections 1 through 6

Prepared For:

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NOVEMBER 2004

ONONDAGA LAKE FEASIBILITY STUDY REPORT

VOLUME II – Appendices A through G

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VOLUME III – Appendices H through N

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CERTIFICATION STATEMENT

FEASIBILITY STUDY REPORT
ONONDAGA LAKE
SYRACUSE, NEW YORK

The undersigned, on behalf of Honeywell International, Inc., certifies: that I am and at all pertinent times hereinafter mentioned was a Professional Engineer licensed or otherwise authorized under Article 145 of the Education Law of the State of New York to practice engineering; that I am the person who had primary direct responsibility for the implementation of the subject work plan; and that all requirements of the said work plan have been complied with and all activities described in this report have been performed in full accordance with the said work plan, the NCP and applicable guidance.

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ACRONYMS AND ABBREVIATIONS

AET	apparent effects threshold
AGC	(New York State) Annual Guideline Concentrations
ARCS	Assessment and Remediation of Contaminated Sediments (Program)
ARAR	applicable or relevant and appropriate requirement
ASCE	American Society of Civil Engineers
BERA	baseline ecological risk assessment
BMP	best management practice
BSQV	bioaccumulation-based sediment quality value
BTX	benzene, toluene, and xylene
BTEX	benzene, toluene, ethylbenzene, and xylene
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
cm	centimeter(s)
cm/sec	centimeter(s) per second
CPOI	chemical parameter of interest
CSRV	contaminated sediment removal vessel
CSTF	Contaminated Sediments Task Force
CT	central tendency
CWA	Clean Water Act
CY	cubic yard(s)
CY/yr	cubic yard(s) per year
DCOS	downflow contact oxygenation system
DDT	dichlorodiphenyltrichloroethane
DNAPL	dense non-aqueous phase liquids
DO	dissolved oxygen
DoD	Department of Defense
ECL	(New York State) Environmental Conservation Law
ER	electrokinetic remediation
ER-L	effects range-low
ER-M	effects range-median
Fe^0	zero-valent iron
FRTR	Federal Remediation Technologies Roundtable
FS	feasibility study

ACRONYMS AND ABBREVIATIONS (CONTINUED)

ft	foot; feet
g	gram(s)
GAC	granular activated carbon
GM	General Motors Corporation
gpm	gallon(s) per minute
gpm/ft^2	gallon(s) per minute per square foot
GRA	general response action
GWTP	groundwater treatment plant
ha	hectare(s)
HHRA	human health risk assessment
HPAH	high molecular weight PAH
HSRC	Hazardous Substance Research Centers
ILWD	in-lake waste deposit
IRM	interim remedial measure
KCl	potassium chloride
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
lb	pound(s)
LCP	Linden Chemicals and Plastics
LF	linear foot; linear feet
LEL	lowest-effect level
LOAEL	lowest-observed-adverse-effect level
LPAH	low molecular weight PAH: the sum of naphthalene, 2-methylnaphthalene, and fluorene
µg/L	microgram(s) per liter
m	meter(s)
MCSS	Major Contaminated Sediment Sites (Database)
Metro Plant	Onondaga County Metropolitan Wastewater Treatment Plant
MGP	manufactured gas plant
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
mL	milliliter(s)
MNR	monitored natural recovery
mph	mile(s) per hour
m/s	meter(s) per second
NAPL	non-aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ng/L	nanogram(s) per liter

ACRONYMS AND ABBREVIATIONS (CONTINUED)

NLSA	no loss of surface area
NOAEL	no-observed-adverse-effect level
NRMRL	National Risk Management Research Laboratory
NWI	National Wetlands Inventory
NYCRR	Codes, Rules, and Regulations of the State of New York
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
O&M	operation and maintenance
OCDD	octachlorodibenzodioxin
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD/PCDF	polychlorinated dibenzo-para-dioxin (dioxin) / polychlorinated dibenzofuran (furan)
PEC	probable effect concentration
PECQ	PEC quotient
PECQ1	PECG with a critical value of one
PECQ2	PECG with a critical value of two
PEL	probable effect level
ppb	part(s) per billion
PPE	personal protective equipment
ppm	part(s) per million
PRAP	proposed remedial action plan
ppt	part(s) per trillion
PRG	preliminary remediation goal
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RI/FS	remedial investigation and feasibility study
RME	reasonable maximum exposure
ROD	Record of Decision
SCA	sediment consolidation area
SEC	sediment effect concentration
SEL	severe effect level
SGC	(New York State) Short-term Guideline Concentration
SMU	sediment management unit
SPDES	State Pollutant Discharge Elimination System
SPM	suspended particulate material
SRB	sulfate reducing bacteria

ACRONYMS AND ABBREVIATIONS (CONTINUED)

SVOC	semivolatile organic compound
SWAC	surface-weighted average concentration
SWQS	(New York State) Surface Water Quality Standards
TBC	(unpromulgated advisories, criteria, or guidance) to be considered
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TEL	threshold effect level
TEQ	toxic equivalent
TRV	toxicity reference value
TSS	total suspended solids
UCL	upper confidence level
USACE	United States Army Corps of Engineers
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	volatile organic compound
WQI	water quality impact

SECTION 1

INTRODUCTION

1.1 INTRODUCTION

Onondaga Lake is a 4.6-square mile (3,000-acre) lake located just northwest of the city of Syracuse in central New York State (Figure 1.1). As a result of the presence of hazardous substances or hazardous wastes, the lake, its outlet, and its tributaries have been identified as a federal Superfund site on the United States Environmental Protection Agency (USEPA) National Priorities List. The Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) identification number for the site is NYD986913580. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and New York State Environmental Conservation Law (ECL), a Remedial Investigation (RI) and Feasibility Study (FS) process is required to determine appropriate remedial actions at the site. The New York State Department of Environmental Conservation (NYSDEC) is the lead environmental agency overseeing RI/FS activities within Onondaga Lake and at various sites and sub-sites adjacent to the lake.

Over 200 years of heavy industrial activity and population growth on the shores of Onondaga Lake and its nearby tributaries have impacted the lake. The lake, however, remains a valuable asset to the entire Syracuse community, potentially providing extensive opportunities for recreation as well as resources for fish and wildlife. Honeywell has therefore undertaken the FS process with the overarching goal of recommending a remedy that will result in the best lake-wide solution for humans and the environment.

On January 9, 1992, Honeywell[1] entered into a judicially overseen consent decree with the state of New York for the matter captioned *State of New York v. Allied-Signal Inc*. (N.D.N.Y. No. #89-CV-815) (consent decree). This FS is intended to meet the requirements of Paragraph 29 of the consent decree, which requires conformance with paragraphs 20, 21, and 22 of the decree (Table 1.1). A comprehensive 1991 work plan (PTI, 1991) was appended to the consent decree and guides the RI/FS process.

Much of the data upon which this FS is based were obtained following the consent decree by Honeywell through multiple investigations of Onondaga Lake from 1992 to 2000, which

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[1] Honeywell's predecessor companies operated industrial facilities along the southwest side of Onondaga Lake from 1881 to 1986. Predecessor companies were Allied Chemical and Dye Corporation (incorporated on December 17, 1920 and including General Chemical Company, National Aniline and Dye Company, Solvay Process Company, and the Semet Solvay Company), Allied Chemical Corporation (renaming of Allied Chemical and Dye Corporation on April 28, 1958), Allied Corporation (renaming of Allied Chemical Corporation on April 27, 1981), and AlliedSignal, Inc. (merging of Allied Corporation on September 18, 1985). In this document, Honeywell refers to Honeywell and all predecessor companies.

culminated in submittal of an RI Report, a human health risk assessment (HHRA), and a baseline ecological risk assessment (BERA) (Exponent, 2001a-c) to NYSDEC. In addition, Honeywell's investigations were documented in seven data reports issued from 1992 to 1996, a calcite modeling report, a mercury modeling report, and other deliverables (see Table 1.2 in TAMS, 2002c for list of reports). Following disapproval of the mercury and calcite modeling reports and the RI and risk assessments, the NYSDEC rewrote Honeywell's calcite and mercury modeling reports in 1998 (NYSDEC/TAMS, 1998a, b) and rewrote Honeywell's risk assessments and RI report in 2002 (TAMS, 2002a-c). The RI documents revised by NYSDEC (TAMS, 2002a-c) represent the RI Report and risk assessments that are referred to throughout this report and upon which this FS is based.

This FS, building on conclusions reached in the RI, analyzes site conditions, goals, requirements, and technologies relevant to remediation of hazardous substances or hazardous wastes associated with former Honeywell operations and other contamination that is commingled with such wastes in Onondaga Lake. In accordance with CERCLA, the NCP, ECL, the Codes, Rules, and Regulations of the State of New York (NYCRR), and other applicable guidance, this FS compares various remediation alternatives and identifies a recommended alternative. As requested by NYSDEC, Honeywell has addressed lake-wide remediation in this FS. However, the FS does not address the apportionment of remedial costs among responsible parties at the site.

The FS is organized into six sections:

- Section 1 summarizes the results of the RI and risk assessments and identifies key risk concerns for the lake.
- Section 2 presents the concept of sediment management units (SMUs) for the lake, identifies applicable or relevant and appropriate requirements (ARARs), and presents the remedial action objectives (RAOs) and preliminary remediation goals (PRGs) for the FS. Areas and volumes to be considered for remediation are also presented in Section 2.
- Section 3 provides a comprehensive review of remedial alternatives for lakes and a qualitative screening of those technologies suitable for Onondaga Lake.
- Section 4 develops, screens, and evaluates a full range of SMU-specific remedial alternatives and compares these alternatives per CERCLA and ECL evaluation criteria.
- Section 5 presents lake-wide alternatives that provide a comprehensive approach to lake remediation. The section also presents a comparative evaluation of the lake-wide alternatives per CERCLA and ECL evaluation criteria.
- Section 6 provides a thorough description of the recommended alternative and explains how the recommended alternative protects human health and the environment, can be timely implemented, and restores a valuable recreational and ecological resource for the community.

The multiple appendices to the report include references and technical supporting information. In addition, the appendices include five independent technical papers prepared by national experts on key technical issues. The references are in Appendix A. Technical supporting information and independent papers are provided in Appendices B through N as follows:

- Appendix B – *Description of Sediment Management Units* summarizes the physical, ecological, and chemical properties associated with each SMU.
- Appendix C – *ARARs and TBCs* summarizes the relevant regulations and guidance that pertain to remediation of Onondaga Lake.
- Appendix D – *Groundwater Flow to Onondaga Lake and Groundwater Model Documentation* describes groundwater flow and the magnitude of groundwater discharge to the lake in Part A. Part B presents the objectives, description, and documentation of Honeywell's groundwater flow computer model to simulate groundwater flow beneath and in the vicinity of the southwestern part of the lake.
- Appendix E – *Area and Volume Estimates for Onondaga Lake* provides documentation of the calculation of areas and volumes of sediment to be addressed by remedial alternatives.
- Appendix F – *Cost Estimates for Onondaga Lake Remediation* describes the approach and assumptions used to develop cost estimates for the lake-wide remedial alternatives.
- Appendix G – *Technical Basis for Preliminary Remediation Goals for Fish Tissue in Onondaga Lake* provides the technical basis for calculating target fish tissue concentrations for mercury, polychlorinated biphenyls (PCBs), and polychlorinated dibenzo-para-dioxins / polychlorinated dibenzofurans (PCDD/PCDFs) that are protective of humans and ecological receptors.
- Appendix H – *Technical Evaluation of* In Situ *Capping as a Remedy Component for Onondaga Lake* evaluates the applicability of *in situ* capping of sediment in Onondaga Lake and the basic design requirements for capping in various SMUs.
- Appendix I – *Implementation and Residual Risk Evaluation for Onondaga Lake* evaluates the risks to human health and the environment associated with implementation of the lake-wide alternatives as well as the risk remaining after implementation of the alternatives.
- Appendix J – *Application of Sediment Effects Concentrations for Evaluating Sediment Quality in Onondaga Lake* describes the development and application of an integrated index of sediment toxicity for Onondaga Lake.

- Appendix K – *Sediment Management and Supernatant Water Treatment Cost Estimates* describes the approach and assumptions used to develop cost estimates associated with sediment management and supernatant water treatment.
- Appendix L – *Evaluation of Dredging Options for Onondaga Lake Feasibility Study* assesses dredging alternatives for Onondaga Lake including detailed analysis of production rate estimates, water quality impacts, and other factors that influence selection of dredging alternatives.
- Appendix M – *Integrating Habitat Considerations in the Remedial Alternatives for Onondaga Lake* provides a detailed analysis of current habitat quality in the lake as well as the potential for habitat restoration and enhancement opportunities in each SMU.
- Appendix N – *Monitored Natural Recovery in Onondaga Lake* objectively evaluates information on lake processes to determine the feasibility of monitored natural recovery (MNR) as a component of remedial alternatives for the lake.

Appendices H, J, L, M, and N were prepared by national experts in the areas of capping, sediment toxicity, dredging, habitat, and monitored natural recovery, respectively. These areas are critical to the development of remedial alternatives that are effective in providing protection of human health and the environment. The conclusions of these technical papers helped to guide the development of remedial alternatives for Onondaga Lake.

1.2 SITE HISTORY

This subsection summarizes the industrial heritage of Onondaga Lake and key historical information regarding Honeywell operations. More extensive information is available in Chapter 1 of the RI Report (TAMS, 2002c) and in the previous lake investigation reports listed in Table 1.2 of the RI Report.

Salt springs in the vicinity of Onondaga Lake supported a major salt recovery industry throughout the 1800s and resulted in development of railroads and the Erie Canal in the region. This infrastructure supported the growth of additional industries, including former Honeywell operations (described in greater detail below), petroleum product storage adjacent to the southeastern shore of Onondaga Lake (a location once known as “Oil City”), fertilizer production, a steel foundry now operated by Crucible Specialty Metals, a vehicle accessory manufacturing facility formerly operated by General Motors, pottery and china manufacturing, a manufactured gas plant, and many other industries in the Syracuse area. An evolving municipal wastewater management system, now known as the Onondaga County Metropolitan Wastewater Treatment Plant (the Metro Plant), has been in existence since the 1800s and has also influenced the lake.

The Onondaga Lake region experienced significant population growth in the 20th century. The population of Onondaga County increased from approximately 160,000 in 1900 to 458,336 in 2000 (U.S. Census Bureau, 2003). The Syracuse metropolitan area makes up much of the population of Onondaga County and is located at the south end of Onondaga Lake. All of these factors (i.e., industry, infrastructure, and other development) have contributed to the current condition of Onondaga Lake.

1.2.1 Former Honeywell Operations: Production History

Honeywell operated manufacturing facilities in Solvay, New York from 1884 until 1986. These manufacturing processes were based on four major product lines:

- Soda ash (sodium carbonate) and related products such as baking soda (sodium bicarbonate), sodium nitrite, sodium sesquicarbonate, ammonium bicarbonate, ammonium chloride, calcium chloride, and caustic soda (sodium hydroxide [NaOH]) produced by a non-electrolytic cell process.
- Benzene, toluene, xylene, naphthalene, and tar products from the recovery of coke byproducts.
- Chlorobenzenes and byproduct hydrochloric acid from the chlorination of benzene.
- Chlor-alkali products, including chlorine, caustic potash (potassium hydroxide), caustic soda (sodium hydroxide) produced by an electrolytic cell process, and related products such as potassium carbonate, hydrogen gas, and hydrogen peroxide produced by further reacting chlor-alkali byproducts with other chemicals.

Four product lines were manufactured in three facilities that constituted the Syracuse Works as follows:

- The Main Plant: soda ash and related products and coke, benzene, toluene, xylene, and naphthalene;
- The Willis Avenue Plant: chlorinated benzenes, hydrochloric acid, and chlor-alkali products; and
- The Bridge Street Plant: chlor-alkali products and hydrogen peroxide.

The locations of these facilities are shown on Figure 1.2. Periods of operation for these facilities and product lines are shown in Table 1.2.

Soda ash production at the Main Plant relied on local supplies of sodium chloride (NaCl) brine and limestone ($CaCO_3$). Benzene, toluene, and xylene (BTX) production and naphthalene production at the Main Plant was based on fractional distillation of light oil, a coke oven byproduct that was initially provided by the Syracuse Works coke ovens (until 1924) and later shipped to Syracuse from other locations. Benzene produced at the Main Plant served as the raw material for production of chlorinated benzenes at the Willis Avenue Plant, while xylene and other imported chemicals were used to produce hydrogen peroxide at the Bridge Street Plant.

Chlor-alkali production at both the Willis Avenue Plant and the Bridge Street Plant used mercury cells and diaphragm cells. Both types of cells are electrolytic processes for the production of chlorine, sodium hydroxide, and potassium hydroxide from purified sodium chloride and potassium chloride (KCl) brine. At the Willis Avenue Plant, diaphragm cells were used throughout the period of operation. In 1947 and 1948 (or possibly earlier, according to the RI [TAMS, 2002c]), 100 mercury cells were installed to produce caustic soda from sodium chloride brine. In 1954, the number of mercury cells was reduced and the plant was converted to potassium chloride brine. Mercury cells were used at the Bridge Street facility throughout its operation; diaphragm cells were added to the operation in 1968.

In addition to the four major product lines, Honeywell facilities produced coke and producer gas (i.e., a mixture of carbon monoxide, nitrogen, hydrogen, methane, carbon dioxide, and oxygen). Other products were produced for short periods of time as pilot plant or developmental laboratory activity or as start-up operations that were later relocated. These products included:

- Nitric and picric acids;
- Salicylic acid and methylsalicylate;
- Benzyl chloride, benzoic acid, benzaldehyde, and phthalic anhydride;
- Phenol; and
- Ammonia (via nitrogen fixation at the Bridge Street Plant).

Although not generally considered part of the Syracuse Works, the Barrett Division of the Semet-Solvay Chemical Company (one of Honeywell's predecessor companies) operated a paving material production facility from 1919 to 1983. The site is currently owned by Penn-Can Road Materials and consists of several buildings, above-ground storage tanks, and a gravel parking lot.

1.2.2 Former Honeywell Operations: Waste Characterization, Management, and Disposal

Waste was generated by most manufacturing processes at the Syracuse Works. In many cases, a waste stream from one process was used as an input stream for another process. For example, the waste stream from the ammonia recovery step of soda ash production served as raw material for production of calcium chloride. Waste streams for disposal were discharged from the three plants to four different destinations: the Solvay wastebeds, the East Flume, the Semet Residue Ponds (coke byproduct recovery only), and the West Flume. Table 1.3 shows the major waste streams and disposal sites for the Syracuse Works. Two additional sites (Mathews Avenue Landfill and the Willis Avenue Ballfield Site) were used for disposal of, primarily, construction and demolition debris from the Syracuse Works. Finally, the dredge spoils area located on the lake shore northwest of the mouth of Ninemile Creek was used for disposal of dredged material from the Ninemile Creek delta and nearshore areas north of Ninemile Creek. The Syracuse Works also had a NYSDEC permitted sanitary landfill in the center of Wastebed 15.

In the 1970s and 1980s, changes in production, the routing of waste streams, and mercury discharges had a major impact on waste disposal. In 1970, the following events occurred:

- The Main Plant ceased production of BTX and naphthalene.

- Waste streams from the Willis Avenue and Bridge Street facilities were diverted from the East Flume and West Flume, respectively, to the waste handling station for discharge to the Solvay wastebeds (PTI, 1992b).
- Releases of mercury from the Willis Avenue Plant and the Bridge Street Plant were reduced from 22 pounds (lb) (10 kilograms [kg]) per day to less than 1 lb (0.5 kg) per day (Effler and Harnett, 1996).

In 1977, the Willis Avenue Plant closed (i.e., production of chlorinated benzenes and chlor-alkali products at the plant ceased). At this time, total mercury releases from the Syracuse Works were reduced to less than 0.5 pound (0.2 kg per day) (Effler and Harnett, 1996). In 1979, the Bridge Street Plant was sold to Linden Chemicals and Plastics (LCP), which operated the plant until it closed in 1988. In 1986, the Main Plant ceased production of soda ash and related products, marking the end of manufacturing at the Syracuse Works.

1.2.2.1 Solvay Wastebeds

The Solvay wastebeds were constructed as settling basins for the disposal of large volumes of predominantly mineral wastes generated by the Solvay process. Figure 1.3 shows the historical locations of the Solvay wastebeds. Initial disposal entailed filling low-lying land adjacent to Onondaga Lake. Eventually, timber bulkheads or containment dikes built from native soils, Solvay waste, and cinders were constructed to contain the waste material (BBL, 1990). Wastebeds A through E received Solvay wastes prior to 1926; some of these wastebeds received other materials such as production residues (Wastebed A). Wastebed A is also referred to as the Semet Residue Ponds. Residue from BTX production at the Main Plant was disposed in lagoons there. Wastebed B is located between the East Flume and Harbor Brook. In addition to Solvay waste, Wastebed B also contains two dredge spoils areas that were disposal areas for construction and maintenance dredging of the East Flume and for sediment removed during installation of a thermal diffuser pipe in the lake. Wastebeds F to H apparently received Solvay waste, but Wastebeds I to M received other types of fill, possibly related to road construction (Blasland & Bouck, 1989). Wastebeds F to M now contain industrial and commercial structures.

Wastebeds 1 to 8, located on the shore of Onondaga Lake south of Ninemile Creek, were used for disposal of Solvay waste from 1926 to 1944. After 1944, these wastebeds received metal-containing sludges, slag, and air pollution control dust from Crucible Specialty Metals and sewage sludge from Onondaga County. Some of this area is now a parking lot for the New York State fairgrounds.

Wastebeds 9 to 11, located adjacent to the north bank of Ninemile Creek, received Solvay waste, brine purification sediments, and boiler water purification wastes from 1944 to 1968. Wastebeds 12 to 15, located south of Ninemile Creek and west of Geddes Brook, received Solvay waste from the 1940s to 1986. Brine purification sediments, treated and untreated mercury cell wastewater, boiler purification wastes, and boiler bottom and fly ash were also disposed on these wastebeds.

1.2.2.2 East Flume and West Flume

Judging from aerial photographs, the East Flume was a drainage ditch constructed after 1926 (TAMS, 2002c) to carry waste from storm and process sewers at the Main Plant and the Willis Avenue Plant into Onondaga Lake. The mouth of the East Flume was extended or may have meandered eastward over time until the late 1960s (TAMS, 2002c). Wastes carried by the East Flume included cooling water, spills, leaks, washings, occasional still bottoms from chlorinated benzenes production, tail gas absorber discharge, and Solvay and other Honeywell industrial wastes (PTI, 1992b).

The West Flume was excavated to provide a drainage channel for waste streams from the calcium chloride facility at the Main Plant and from the Bridge Street Plant to Geddes Brook, a tributary of Ninemile Creek. Wastes carried by the West Flume included cooling water, spills, leaks, washings, and tail gas absorber discharge from the Bridge Street Plant. In addition, some cooling water, spills, leaks, washings, and Solvay and other Honeywell industrial wastes from the Main Plant were discharged to the West Flume (PTI, 1992b).

1.2.2.3 Other Disposal Sites

Although not considered disposal sites for production waste streams from the Syracuse Works, three additional sites received waste material either directly or indirectly from the Syracuse Works. Two nearby landfills received solid waste material from the Honeywell plants, and a dredge spoils area northwest of Ninemile Creek received dredged material from the Ninemile Creek delta and nearshore areas in Onondaga Lake. The Mathew Avenue Landfill, located south of Gerelock Road in Solvay and south of the Bridge Street Plant, was operated by Honeywell as a 6 NYCRR Part 360 construction and demolition debris disposal site during operation of the Honeywell facilities. Honeywell applied for closure of the landfill under Part 360 in 1988. The Willis Avenue Ballfield Site, located across from the Willis Avenue Plant on a portion of Wastebed C, received construction and demolition debris, miscellaneous metal debris, boiler slag, diaphragm cell bodies, and laboratory vials and flasks from Honeywell prior to 1960, when it was used as a baseball field.

The dredge spoils area, located northwest from the mouth of Ninemile Creek along the lake shoreline, contains dredged material in four basins (Basins 1 through 4) near the mouth of Ninemile Creek and 15 additional bermed basins (Basins 5 through 19) further northwest along the shoreline near and in Wetland SYW-6. The dredging was a joint project between Honeywell and Onondaga County to remove material from the delta at the mouth of the creek and to fill in marshland along the lakeshore to create parkland. Basins 1 through 3 likely contain material from the Ninemile Creek delta. Some of the remaining basins are thought to contain lake sediment dredged from nearshore areas adjacent to the basins (Exponent, 2000).

1.2.3 The Honeywell Upland Sites

The manufacturing and waste disposal sites described above are referred to collectively throughout this report as the “Honeywell upland sites” and “upland sources related to former Honeywell operations.” Many of these sites, as described in Subsection 1.5 of this report, are known to contribute hazardous and non-hazardous substances to Onondaga Lake. Most of these sites, as described in Subsection 4.2 of this report, are in various stages of investigation and remediation.

1.3 SITE CHARACTERISTICS

This subsection summarizes key background information on the lake, including a definition of key terms, the lake's setting and characteristics, hydrology and hydrogeology, limnology, ecology, and use. Additional information on the lake characteristics is presented in Chapter 3 of the RI (TAMS, 2002c).

1.3.1 Definition of Key Terms and Units

The discussion of the characteristics of the lake requires an understanding of certain terms used in the body of literature previously compiled on the lake. These terms may differ from one source to another. Accordingly, Table 1.4 presents a glossary of terms as they are used in this FS to discuss site characteristics.

Throughout Section 1, both English and metric units are usually provided. In the remainder of the report, some data are provided in English units while others are provided in metric units, depending on the source and ultimate use of the data.

1.3.2 Lake Setting and Topography

Onondaga Lake is situated in the midst of Syracuse and its suburbs, an urbanized area that makes up the largest metropolitan and industrial center in central New York State. With 146,435 people currently residing in Syracuse and 458,336 people residing in Onondaga County (2000 census), the lake and its environs have been influenced by development activities for over 200 years. Land around the southwest corner and southern portion of the lake is generally industrial. This section of the shoreline has been significantly modified as part of long-term development of the Syracuse area. Land around the rest of the lake is recreational, providing hiking and biking trails, picnicking, sports, and other recreational activities. No residential or other private properties directly adjoin the lake.

The primary tributaries to Onondaga Lake are Ninemile Creek, which empties into the lake along its western shore just north of the New York State Fairgrounds, and Onondaga Creek, which enters the lake along its southern shore (Figure 1.4). Other tributaries include Ley Creek in the southeastern corner, Harbor Brook in the southwestern corner, Sawmill Creek in the northeastern corner, and Bloody Brook along the eastern shore. Various local industries have discharged wastewater to these tributary streams and/or have waste sites that have affected the local environment downstream of the discharges, including the lake itself. Portions of the streambeds of Ninemile Creek, Onondaga Creek, and Ley Creek adjacent to the lake have all been rerouted and channelized over the years in conjunction with industrial activities.

In addition to the tributary streams, the Metro Plant located along the southern shore of Onondaga Lake near the mouth of Onondaga Creek releases an average of 80 million gallons of wastewater daily to the lake. Upgrades to the Metro Plant to control nutrient discharges are currently under construction, as are combined sewer overflow control facilities throughout the city of Syracuse where sewers carrying combined domestic and industrial wastewater and stormwater are subject to overflowing during periods of high runoff.

Onondaga Lake is approximately four and a half miles (7.2 kilometers [km]) long and one mile (1.6 km) wide, with an average water depth of 36 feet (ft) (10.9 meters [m]). The lake is approximately 4.6 square miles (3000 acres, 12 square kilometers) in area. Its volume is 34,600 million gallons (131 x 10^6 cubic meters) (Onondaga County Department of Water Environment Protection [OCDWEP], 2002). Lake bathymetry (i.e., water depth) is summarized on Figure 1.4. The lake has two deep basins – a northern basin and a southern basin – that have maximum water depths of approximately 62 and 65 ft (18.8 and 19.9 m), respectively (PTI, 1992a). The basins are separated by a saddle region at a water depth of approximately 56 ft (17 m). Most of the lake has a broad nearshore shelf in water depths of less than 12 ft (4 m). This nearshore shelf is bordered by a steep offshore slope in water depths of 12 to 24 ft (4 to 8 m).

1.3.3 Climate and Meteorology

The climate in the Onondaga Lake drainage basin is temperate continental (Trewartha, 1968). Proximity to Lake Ontario moderates extremes in air temperature relative to locations east of Syracuse, and the area has an average growing season (period between frosts) of 171 days (NOAA, 2003).

Winters are cold, with a mean average January temperature of 22 degrees Fahrenheit, resulting in ice formation on much of the lake surface during typical winters beginning in November, particularly in nearshore areas away from tributary and other inflows. Significant areas of the lake are iced over by late December or January of a typical winter. As the ice recedes during late winter and early spring, erosion of nearshore areas may result. Ice thickness varies from year to year and during the year, depending on weather conditions. Appendix H, capping issues, includes a discussion of ice on Onondaga Lake.

Moisture enters the area primarily through low-pressure systems that move east through the St. Lawrence Valley. Precipitation is relatively evenly distributed throughout the year, ranging on average from 2.5 inches (6.4 centimeters [cm]) in February to 3.7 inches (9.4 cm) in July (NCDC, 2004).

Winds are predominantly from the west and northwest throughout the year. The lake is oriented along a northwest/southeast axis, in line with prevailing winds. Most of the strongest winds (20 to 23 meters per second [m/s] or 44 to 51 miles per hour [mph]) occur between November and April (NCDC, 1998). This coincides with the period when ice typically covers much of the lake. These winds generate significant wave energy when they are aligned along the long axis of the lake and have the longest fetch. In protected areas along the western shore, such as the mouth of Ninemile Creek, wind fetch and wave action are significantly reduced. Wave energy is also reduced or eliminated during the winter months when ice cover is present on much of the lake. Appendix H, capping issues, includes a wind-wave analysis for Onondaga Lake.

1.3.4 Geologic Setting

1.3.4.1 Regional Geology

Onondaga Lake overlies a deep, northwest-trending glacial trough in the Vernon Shale, the bedrock formation beneath and in the vicinity of the lake. A schematic cross section through the southeastern end of the lake, which illustrates the trough, is shown on Figure DA.2. The lake lies at the northern end of the trough. The trough averages about 300 feet (ft; 91 meters) deep along the axis of the lake and is filled primarily with unconsolidated, fine-grained sediments. The thickness of the unconsolidated sediments decreases rapidly away from Onondaga Lake, except in the valleys of the main tributaries, which are also underlain by unconsolidated sediments.

The lake is located within the Ontario Lowland lake plain physiographic province. It is closely bordered by the Ontario Lowland drumlin fields to the west and the Appalachian Upland border scarp province to the south (Winkley, 1989). Much of the Onondaga Lake drainage basin is located in the Limestone Belt of central New York State (Berg, 1963). The Devonian-age Onondaga Limestone and limestones within the Helderberg Group overlie the Vernon Shale and subcrop in the upper reaches of the Onondaga Creek and Ninemile Creek drainage basins. Consequently, much of the surface water flowing into Onondaga Lake is influenced by the soils of this belt. Calcium, magnesium, bicarbonate, and alkalinity concentrations all tend to be much higher in lakes influenced by the Limestone Belt 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). The higher calcium concentrations observed in lakes of the Limestone Belt are unusual, given the general impoverishment of calcium in the region (Berg, 1963). In Onondaga Lake, calcium concentrations in the water column have decreased by approximately 70 percent since the Honeywell Main Plant ceased operation in 1986. Data from Onondaga County’s Onondaga Lake Ambient Monitoring Program show that calcium concentrations in the lake were approximately 550 milligrams per liter (mg/L = ppm) in 1985 to 1986 (OCDWEP, 2002). By 1990 and continuing through 2002, calcium concentrations in the lake had stabilized at approximately 150 mg/L. Despite this reduction, residual impacts from the wastebeds are still a significant portion of the ionic loads to the lake.

1.3.4.2 Site Geology

The thickness and characteristics of the unconsolidated sediments beneath the lake have been investigated by the United States Geological Survey (USGS) (Kappel, 2004b). The USGS has advanced three deep borings along the approximate centerline of the trough: one located southwest of the lake near the mouth of Onondaga Creek on Spencer Street (Spencer Street), one located in the center of the lake on the saddle between the northwest and southeast basins of the lake (Saddle site), and one located to the northwest of the lake outlet (Outlet site). The locations of the borings have been identified on Figure DA.1. In addition, the USGS has advanced one boring to bedrock about 400 ft (122m) off shore from the western shoreline of the lake northwest of the mouth of Ninemile Creek (West Trail site), and one boring to bedrock approximately 325 ft (99m) off-shore from the eastern shoreline northwest of the mouth of Ley Creek (Parkway site). The stratigraphic sequences observed in the borings are similar:

- Surficial sediments described as gray, marly silt with fine sand and shells;
- Gray clayey marl, gray-brown clayey silty marl (marl unit);
- Brown-gray clay, gray-brown silty clay (silt and clay unit);
- Gray-brown silt with sand layers (silt and fine sand unit);
- Hard sand (sand and gravel unit);
- Red Vernon till, dense with stones (till unit); and
- Green, red, and gray Vernon Shale (bedrock).

The boring at the saddle encountered about 25 ft (7.6 m) of marly sediments, 83 ft (24.4 m) of clay and silty clay, and 76 ft (23.2 m) of silt with sand layers. This boring terminated in a silt and fine sand unit due to difficult drilling conditions.

A large number of borings have been advanced along the western shoreline of the lake from the mouth of Ninemile Creek to mouth of Onondaga Creek as part of various investigation activities conducted in this area. The stratigraphic sequence along the shoreline is similar to that observed in the center of the lake, except that the surface unit is fill along much of this shoreline, and units are much thinner than in the center of the lake. Much of the fill along this portion of the shoreline is wastebeds composed primarily of ionic wastes from the Solvay process.

A geologic cross-section through the middle of the Willis Avenue Plant site, Figure 1.6, illustrates a rapid thinning of the unconsolidated deposits landward of Onondaga Lake. In the Willis Avenue area, a fine sand and silt unit occurs in a limited area between the marl and the silt and clay unit, as shown on the cross section.

1.3.5 Surface Soils

Soils in the Onondaga Lake watershed consist primarily of glacial till mixed with glacial outwash, alluvial deposits, and glaciolacustrine sediments. These soils tend to be medium-textured, well-drained, and high in lime (NYSDEC, 1989; SCS, 1977). Upland areas near the lake include fill deposits composed of peat, cinders, ash, and Solvay wastes. Due to the presence of steep-sided valleys in the watershed, large amounts of soil erode into valley streams during rainstorms (Lincoln, 1892; Murphy, 1978; NYSDEC, 1989). Some of these soils eventually make their way to Onondaga Lake through the tributaries, where they are deposited as lake sediment.

Soils along the western, southern, and eastern sides of the lake have been substantially altered by human activity, and portions of the original lake have been filled with a variety of materials. These soils are classified as "made land" and include stretches of the southern lakeshore filled with sand, silt, brick, ashes, cinders, and Solvay Wastebeds, as shown on Figure 1.3 (NYSDEC, 1989). These beds were used by Honeywell until 1986 for the settling of Solvay waste, whose primary chemical components were $CaCO_3$, calcium silicate, and magnesium hydroxide, with lesser amounts of calcium oxide-calcium chloride complex, silicon dioxide, sodium chloride, calcium chloride, aluminum or iron oxides, calcium hydroxide, calcium sulfate, and metals (e.g., aluminum, arsenic, copper, lead nickel, and zinc) (PTI, 1992b).

1.3.6 Surface Water Hydrology

Onondaga Lake receives surface runoff from a drainage basin of approximately 230 to 240 square miles (600 to 620 square kilometers). Surface water flows primarily from the south and southeast into the lake through six tributaries: Ninemile Creek, Onondaga Creek, Ley Creek, Harbor Brook, Bloody Brook, and Sawmill Creek. In addition, small amounts of surface water are contributed to the lake through two industrial conveyances: the East Flume and Tributary 5A. These surface water sources are shown on Figure 1.4.

Ninemile Creek and Onondaga Creek are the most significant sources of flow to the lake and together accounted for approximately 62 percent of the inflow into the lake from surface sources for the period 1971 to 1989 (Effler and Whitehead, 1996). Discharge from the Metro Plant accounted for approximately 19 percent of the total inflow during the same period. Ley Creek and Harbor Brook accounted for an estimated 8 and 2 percent of the total inflow, respectively. Contributions from all other tributaries, including Bloody Brook, the East Flume, Tributary 5A, and Sawmill Creek were minor in comparison and together accounted for the remaining 9 percent. The highest inflows of water and suspended solids from tributaries occur during the spring due to snowmelt and springtime rain events, peaking in March and April.

Based on data obtained from 1988 to 1990, the solids contributions of the tributaries are disproportionate to their relative flows. Onondaga Creek, which contributes approximately 31 percent of the flow, contributes the largest amount (57 percent) of the suspended solids loading to the lake (Effler and Whitehead, 1996). An additional 26 percent of the solids loading is contributed by Ninemile Creek. Lesser solids loadings are attributed to the Metro Plant (9 percent), Ley Creek (7 percent), and Harbor Brook (less than 2 percent).

The primary characteristics of the solids contributed by each of these sources vary by source. Based on studies conducted in 1981 and 1982, Yin and Johnson (1984) determined that the dominant component of the solids in Onondaga Creek, Ley Creek, and Ninemile Creek upstream of the wastebeds is clay, with silica-only particles the second most important classification. Solids originating from the wastebeds are primarily calcium carbonate. Solids discharged from the Metro Plant are primarily organic in origin. Since 1982, the tributary solids contributions and composition has changed somewhat as a result of remediation of the Tully Mud Boils in upper Onondaga Creek (Appendix N, monitored natural recovery).

A small amount of water also enters the lake through intermittent bi-directional flow from the Seneca River at the outlet of the lake (Effler and Whitehead, 1996). This bi-directional flow is possible because the outlet channel that connects the lake and 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 of the site. Flow from the outlet is sensitive to the rate of tributary inflow, wind speed and direction, water surface elevations in the river and lake, seiche activity in the lake, and other factors (Owens and Effler, 1996). Due to the shallow depth of the outlet channel, it is likely that only epilimnetic surface water flows out of the lake into the river (Owens and Effler, 1996). The annual contribution of the Seneca River to the lake has not been quantified but is believed to be less than 10 percent of the total flow to the lake.

The lake elevation can also influence the characteristics of the nearshore sediments, including wetlands and parts of the littoral sediments that are subject to wave and ice disturbance. The lake is generally at its highest elevation in the early spring due to increased tributary flows and at its lowest elevation during the summer months. For the 30-year period from 1971 to 2000, maximum annual variations in lake levels 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) (USGS 2001). Monthly mean elevation varied by approximately 1.4 ft (0.4 m) over the annual cycle during this period.

The USGS has maintained a water level gage on Onondaga Lake at the Onondaga Park Marina Basin since 1970. Based on the data collected over the past 34 years (1971 to 2004), the following observations have been made (all levels are referenced to NAVD 1988):

- The average lake elevation is 362.82ft;
- The highest lake level was 369.18 ft on 4/28/1993;
- The lowest level was 361.00 ft on 3/1/13/1978;

1.3.7 Hydrogeologic Setting

Regional groundwater flow in both the bedrock and the unconsolidated sediments is toward the valleys of the major tributaries and toward the lake (Winkley, 1989). Groundwater discharge areas include seven major tributaries: Nine Mile Creek, Geddes Brook, Harbor Brook, Bloody Brook, Onondaga Creek, Saw Mill Creek, and Ley Creek. Groundwater flow toward the lake is believed to originate primarily as precipitation that infiltrates into the unconsolidated sediments bordering the lake. Because the unconsolidated sediments are restricted to a relatively narrow band on either side of the lake, the total recharge area is relatively small, and as a result recharge to and discharge from the unconsolidated sediments is relatively small.

Most of the groundwater in the unconsolidated sediments that flows toward the lake discharges to creeks and drains on the shoreline and in near-shore areas. This occurs in part because of the thickening wedge of fine-grained, low-permeability materials beneath the lake and because of sodium chloride brines in the unconsolidated sediments beneath the lake.

The majority of bedrock groundwater originates from infiltration in the upland areas where the bedrock subcrops. Some bedrock groundwater flows toward the lake, where it discharges after moving upward through the overlying unconsolidated sediments. Groundwater flow through the bedrock is estimated to be small because the Vernon Shale has low permeability, with most flow occurring through widely spaced fractures. Winkley (1989) and Kantrowitz (1970) noted that the Vernon Shale most likely has a relatively low hydraulic conductivity on a regional scale. Winkley noted that locally the hydraulic conductivity of the Vernon Shale approaches $4x10^{-4}$ cm/sec (1.1 ft/day), and that the median yield from wells in the Vernon Shale is 12 gallons per minute (gpm).

Honeywell has conducted a groundwater upwelling investigation near the mouth of Ninemile Creek and the southwest corner of the lake to monitor groundwater flow into the littoral sediments. Hydraulic gradients were identified between the lake and shallow lake sediments by installing and monitoring *in situ* piezometers at 21 locations within the lake. Preliminary results from this investigation indicate that, in some locations, groundwater in the areas adjacent to the mouth of Ninemile Creek and the southwest corner of the lake currently discharges to the lake through the lake sediments. The draft version of the groundwater upwelling investigation report has been submitted to NYSDEC for review (Parsons, 2003a).

The presence of natural sodium chloride brines in the unconsolidated sediments and bedrock beneath the lake complicates the understanding of local groundwater flow conditions. These brines are believed to have originated from the dissolution of halite chips within the unconsolidated sediments that were scoured by glacial activity from halite beds in the Salina Group (Kappel, 2004b), a bedrock unit that overlies the Vernon Shale. The brines currently beneath the lake are relatively stagnant and likely formed during the last period of glaciation. USGS wells screened in the sodium chloride brines are the deep well at Spencer Street (screened ~ 300 feet below lake level) and the deep and shallow wells at the Outlet site (screened ~150 feet and ~110 feet below lake level, respectively; Kappel, 2004a). Wells that are screened in the sodium chloride brines along the western shoreline include DW-102 near the mouth of Ninemile Creek (screened ~90 feet below lake level) and HB-20D near the mouth of Harbor Brook (screened ~ 130 feet below lake level). The chloride concentrations in each of these wells exceed 100,000 milligrams per liter (mg/L). The origin of the brines is discussed in more detail by the USGS (USGS, 2000).

In the past, discharge of brines at salt springs was reported to have occurred around much of the shoreline of the southern basin of the lake (USGS, 2000). These discharges likely occurred where the fine-grained units thinned along the shoreline. The discharge of brines has ceased due to extraction of brines from wells along the southern shoreline of the lake from the early 1800s through the early 1900s. There are no known salt springs around the southern end of the lake today. The so-called Gale Springs along the northwestern shore is a flowing well with a chloride concentration of about 6,700 mg/L. However, there are salt springs in Onondaga Creek southeast of the lake (Kappel, 2004b).

In addition to the sodium chloride brines, there are mixed cation brines in the bedrock. These brines formed by the dissolution of evaporate beds within the Vernon Shale and overlying bedrock units. These brines are enriched in calcium, magnesium, and bromide relative to the sodium chloride brines. Water quality results from a groundwater sample collected by the USGS from the bedrock at the West Trail site indicate that the groundwater at this location is a mixed cation brine. The chloride concentration of the groundwater at this location is about 58,000 mg/L, the calcium concentration is 12,000 mg/L, the sodium concentration is 22,000 mg/L, the magnesium concentration is 1,400 mg/L, and the bromide concentration is 430 mg/L. These mixed cation brines have a composition similar to Appalachian providence brines as exemplified by the Bass Island brine (Kappel, 2004b).

In addition to natural brines, some brines in groundwater result from seepage from the wastebeds. These brines are comprised primarily of sodium, calcium and chloride. Monitoring well SP-4C, which is completed in the sand and gravel unit beneath Wastebed A in the Willis/Semet area, contains this type of brine. The composition of water from this well is 13,000 mg/L sodium, 21,000 mg/L calcium, and 64,000 mg/L chloride. The wastebed brines typically have sodium to calcium ratios that are 2:1 or less, whereas the natural sodium chloride brines have sodium to calcium rations of greater than 10:1. The mixed cation brines have sodium to calcium ratios that are similar to the wastebed brines.

The mixing of relatively fresh groundwater, natural sodium chloride brines, natural mixed cation brines, and brines from the wastebeds have created a wide variety of groundwater quality types in the vicinity of Onondaga Lake.

Honeywell has developed a groundwater flow model for the former Honeywell sites in the vicinity of Onondaga Lake. One use of this model will be to assess the effects of future upland groundwater containment options on groundwater discharge to Onondaga Lake. Information on this groundwater flow model and the effects of containment of upland groundwater are summarized in Appendix D, Part A, Groundwater Flow to Onondaga Lake, and Appendix D, Part B, Groundwater Model Documentation.

1.3.8 Limnology

1.3.8.1 Lake Stratification

Like many inland northern lakes, Onondaga Lake is stratified during summer, more weakly stratified in winter, and is vertically mixed in the spring and fall. Summer stratification is most pronounced from May through September due to temperature effects on water density. During summer stratification, the colder (and therefore denser) hypolimnion is unable to mix with the overlying warmer (and therefore less dense) epilimnion. The boundary between the epilimnion and the hypolimnion is called the thermocline and is the region in the water column where the temperature changes most rapidly with depth. In Onondaga Lake, the thermocline is located at approximately 30 ft (9 m) below the water surface. The epilimnetic waters continue to be mixed by wind and wave action, while the hypolimnion is isolated beneath the thermocline. The epilimnion and hypolimnion as well as a temperature profile for July 1992 are shown on Figure 1.7.

The hypolimnion receives organic and inorganic solids that settle by gravity from the epilimnion toward the lake bottom. As the summer progresses, biodegradation of the organic solids deplete the oxygen in the hypolimnion, creating anoxic conditions. The presence of an anoxic hypolimnion is not uncommon in stratified lakes. However, oxygen depletion in the hypolimnion of Onondaga Lake is exacerbated by loading of phosphorus to the lake from tributaries and the Metro Plant discharge (Effler and Whitehead, 1996). Phosphorus is the critical nutrient that promotes the growth or productivity of phytoplankton, which in turn increases the organic loading of settling solids to the hypolimnion. Increased phytoplankton productivity also leads to decreased water clarity (due to the high mass of phytoplankton in surface water). In addition to anoxia, elevated concentrations of sulfides and ammonia found in the hypolimnion are considered evidence of advanced cultural eutrophication.

During summer stratification (generally mid-May through mid-October), inflow from the tributaries is incorporated primarily into the epilimnion rather than the entire lake. Consequently, although the flushing rate (i.e., number of times a water body is emptied and refilled over a certain length of time) for the entire lake is 3.9 times per year, the rate is greater for the epilimnion during stratification (i.e., about three times from mid-May through mid-October) (Effler and Whitehead, 1996). Moreover, during periods of weak or no stratification, as typically occur during winter months, plunging flows from Ninemile and Onondaga Creeks may enter the deeper waters of the lake directly. Both effects indicate that the lake tends to respond rapidly to changes in chemical and sediment inputs from upland sources.

Waters within Onondaga Lake are more saline than in most inland lakes. Wastebeds 9 through 15 are known to contribute calcium, sodium, and chloride to Ninemile Creek. In addition, naturally occurring salt, which was mined in the vicinity of Onondaga Lake for many years, affects both groundwater and nearby surface water quality. Natural salt springs present near the lake result in saline wetlands. The USGS recently documented a saline spring in Onondaga Creek between Kirkpatrick and Spencer Streets; however, the daily load (on the order of 10 tons [9,000 kg]) is a minor contribution to the salt budget of the lake (W. Kappel, 2003, as cited in NYSDEC, 2003). The Geddes Brook / Ninemile Creek RI report (TAMS, 2003) estimated that the daily total dissolved solids load from Solvay Wastebeds 9 through 15 to Ninemile Creek is on the order of 333 tons (300,000 kg/day).

1.3.8.2 Lake Circulation

Lake Water

Circulation of water within the lake is dominated by wind speed and direction, tributary inflows, the outflow at the northern end of the lake, shoreline configuration, and stratification. Currents at the water surface tend to move in the direction of the wind except closest to shore, where currents move water parallel to the shoreline (Owens and Effler, 1996). Winds are typically from the west and northwest, although they may occur from any direction, depending on weather patterns. 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.

Sediment Circulation

Most solids that enter the lake from tributary inflows settle to the lake bottom and are not transported out of the lake through the outlet. Suspended solids from the tributaries initially settle in nearshore sediment, where water depth is less then 15 ft (4.5 m) (Johnson, 1989). With the exception of deltas formed at the mouth of some tributaries (e.g., Ninemile Creek, Ley Creek), nearshore sediment generally does not accumulate because it is frequently resuspended by wind and waves. Over time, sediment is carried to deeper waters by lake circulation and ultimately settles to the bottom in deeper parts of the lake. This movement of sediment from nearshore to deeper areas is termed sediment focusing. The time between deposition of tributary solids to nearshore sediment and redeposition to sediment in deeper areas is unknown but is probably long and variable, depending in part on grain size. The rate of sediment accumulation in the deep water zone (as measured by high resolution cores collected at the 56 ft (17 m) water depth in the saddle region) was most recently estimated by Hairston *et al*. (1999) as 0.3 inches per year (0.77 cm per year) for the time period 1986 to 1997. Appendix N, monitored natural recovery, includes a discussion of historical and current estimates of sediment accumulation rates.

1.3.8.3 Sediment Characteristics

Based on the depth of the thermocline during stratification, the RI report (TAMS 2002c) defined sediment located above the thermocline (i.e., 30 ft [9 m]) as littoral sediment and sediment located below the thermocline as profundal sediment. The intent of these designations was to distinguish between the different biological, physical, and chemical processes of the epilimnion and hypolimnion. For consistency, this FS considers 30 ft (9 m) to be the boundary between littoral and profundal sediments. The location of littoral and profundal sediments relative to the thermocline is shown on Figure 1.7.

Other reports divided sediments into different areas based on characteristics of the sediments themselves. Johnson (1989) split the sediments of Onondaga Lake into three zones: littoral (0 to 15 ft [4.5 m]), profundal (greater than 40 ft [12 m]), and littoroprofundal (between 15 and 40 ft [4.5 and 12 m]). According to Johnson (1989), littoral sediments contain fine silts and clays, sand, shell fragments, calcite, and oncolites, while the profundal sediments contain anoxic muds, hydrogen sulfide, and amorphous iron sulfides. Littoroprofundal sediments are transitional between the two. Auer *et al*. (1996) defined profundal sediment as located below 20 ft (6 m) in lake depth relatively undisturbed, and not subject to resuspension or bioturbation. The RI report and this FS report define littoral sediment as sediment located in water depths less than 30 ft [9 m] and profundal sediment as sediment located in water depths greater than 30 ft [9 m].

This subsection includes a general description of littoral and profundal sediment. More detailed information on physical and geotechnical characteristics is presented in Appendix B, sediment management units.

Littoral Sediment

As described by Johnson, much of the sediment in water depths of less than 15 ft (4.5 m) consists generally of fine silts and clays, sand, and shell fragments (1989). Figure 1.8 shows the fine-grained fraction and total organic carbon content of surficial sediments of Onondaga Lake as determined during the RI in 1992 (TAMS, 2002c).

In some areas, Johnson noted fine-grained calcitic sediments (1989). High concentrations of calcite exist within the littoral sediments throughout most of the lake, due to past and present input of naturally calcitic sediments from the tributaries and, while the former Honeywell Main

Plant was operating from 1884 to 1986, calcite precipitation in the lake. Available data indicate that external calcium loading to the lake decreased by 70 percent from 1983-85 to 1987-89, reflecting the cessation of Honeywell's activities at its Main Plant in 1986. Calcium carbonate deposition also decreased by 64 percent over the 1985 to 1989 timeframe (Effler *et al.*, 1996).

Oncolites are another form of calcite in littoral sediments of Onondaga Lake. Oncolites are small, oval or irregularly rounded, calcareous concretions that resemble elongated pebbles. Made up of calcium carbonate and a small fraction of organic material, they are found throughout the littoral sediments of the lake, especially along the northeast, north, and northwest shorelines. Oncolites are of relatively low mass and therefore are readily moved by waves and currents. Eventually, oncolites become stationary if they grow to a sufficient size (Golubic and Fisher, 1975). Oncolites are found in a variety of water environments around the world. In Onondaga Lake, oncolite formation may have occurred prior to lake eutrophication. Historical discharges of calcium-laden materials to the lake by Honeywell may have also enhanced oncolite formation (TAMS, 2002c).

While much of the littoral zone is considered non-depositional due to wind and wave action, discrete areas at the mouths of the tributaries are depositional. These areas, traditionally called deltas, are created when the tributary enters the lake, the flow rate drops sharply, and suspended solids settle to the lake bottom. Sediment in these areas accumulates and reflects the composition of the suspended solids that were transported by the tributary into the lake. At the mouth of Ninemile Creek, the delta was dredged in the 1960s to remove material that had accumulated over time.

Another historically depositional area within the littoral zone in the southwest corner of Onondaga Lake is an area referred to in the RI as the in-lake waste deposit (ILWD). This area was formed primarily through the precipitation of calcite (calcium carbonate) from the overflow of dikes around Wastebed B and discharges via the East Flume. The chief characteristics of this area are elevated concentrations of calcium, magnesium, sodium, and chloride within the lake sediments and a white to light green-gray color. Observations during the groundwater upwelling study and the Phase 2A coring included heavy sheens, non-aqueous phase liquid (NAPL), strong benzene, toluene, ethylbenzene, and xylene (BTEX) odors, and other chemical odors. As discussed in Subsection 1.4 of this report, the ILWD also contains mercury, BTEX, chlorinated benzenes, polycyclic aromatic hydrocarbons (PAHs) (including naphthalene), PCBs, and PCDD/PCDFs. Material found in this area has varying consistency, with discontinuous hard and soft layers, and is present to a depth of approximately 40 ft (12 m). The hard layers are composed primarily of calcium carbonate and are often referred to as a calcite crust.

The location of the ILWD was presented in the RI report; however, boring logs from the upwelling investigation conducted in 2002 (Parsons, 2003a), indicate that the ILWD may be larger than originally thought. Results from the sediment cores collected during the upwelling investigation indicated the presence of Solvay waste off the southern end of the causeway, the east and west ends of the East Flume, and in thin layers offshore from Harbor Brook. The Solvay waste was highly layered and displayed NAPL at a total of seven locations off the causeway and the East Flume. One location directly adjacent to the eastern end of the causeway

(TR02-A) displayed impacted granular fill material from 0 to 10.5 ft (3.2 m) below the sediment-water interface. Contaminant concentrations and dense nonaqueous phase liquids (DNAPL) in the ILWD are discussed more extensively in Subsection 1.4.1.3. Based on information presented in the RI report and the upwelling investigation report (Parsons, 2003a), the approximate extent of the ILWD is depicted on Figure 1.4. The surface area is approximately 84 acres.

Profundal Sediment

Profundal sediment (i.e., sediment in water depths greater than 30 ft [9 m]) is characterized by small particle size and relatively high moisture content and concentrations of phosphorus, nitrogen, and organic carbon (Auer *et al.*, 1996). This sediment is comprised of two units (Effler *et al.*, 1996). The first unit extends to approximately 35 inches (90 cm) below the sediment surface and is composed of black clay with distinct layers or laminations. The clay has a sulfide smell, and gas bubbles, presumably methane, are present. This unit is typical of culturally eutrophic lakes. The second unit extends from approximately 35 inches (90 cm) to at least 16 ft (500 cm) below the sediment surface and is composed of dark gray clay with occasional wood fragments and snail shells. This unit also contains laminations, though they are less distinct than in the first unit. The laminations are attributed to deposition of calcite, clays, and diatoms (silica) associated with erosion of the watershed, productivity cycles within the lake, and other annual events (Effler *et al.*, 1996).

The presence of layers or laminations in the depositional sediment indicates that the sediment is relatively undisturbed (i.e., not affected by wind-wave resuspension or bioturbation). Solids deposited in the depositional sediment are continually buried by new sediment that settles down from the water column. High-resolution cores (i.e., stratigraphic cores) depicting sharp gradations in chemical concentrations confirm that the depositional sediment is undisturbed. Changes in loading of various chemicals to the lake can be directly related to changes in concentrations of these chemicals by depth in the sediment (Effler *et al*., 1996). The depositional sediment acts as the ultimate sink for solids that enter the lake or that are produced within the lake.

1.3.9 Ecology

This subsection provides a summary description of ecological characteristics. More detailed information on habitat is provided in Appendix M, habitat issues.

1.3.9.1 Wetlands

Through the National Wetlands Inventory (NWI) program, the United States Fish and Wildlife Service (USFWS) maintain maps of wetlands and deep water systems. There are 205 individual NWI wetlands and deep water systems occurring within two miles (3.2 km) of Onondaga Lake, which consist of the following:

- Three limnetic lacustrine systems;
- Fifteen littoral lacustrine systems;

- Two low-perennial riverine systems; and
- One hundred eighty-five palustrine wetlands.

Twenty-two NYSDEC-regulated wetlands are located at least partially within two miles (3.2 km) of Onondaga Lake. Four of these wetlands are located along the lake's shoreline near the mouths of Ninemile Creek (SYW-10), Ley Creek (SYW-12), and Harbor Brook (SYW-19), and along the northwest shoreline (SYW-6), and are directly connected to the lake. These four wetland areas were preliminarily evaluated in the Onondaga Lake RI and risk assessments and are now part of other Honeywell sites under investigation. A fifth wetland (SYW-1) is located near the northern shoreline of the lake by Sawmill Creek but is not connected to the lake.

Wetland SYW-6 is a 100-acre (40 hectare [ha]), Class I wetland, located at the northwest end of Onondaga Lake. Hydrological flow within this wetland and between the wetland and the lake is inhibited by a series of elevated paths, which create cells or basins in the wetland. Some surface water flow occurs through culverts under these paths. The basins were created in the late 1960s in a joint project between Honeywell and Onondaga County to create parkland (Exponent, 2000). Some of the basins may have been filled with sediment dredged from the lake.

Wetland SYW-6 is a palustrine, forested scrub-shrub, broad-leaved deciduous wetland (TAMS, 2002a). The predominant vegetation in SYW-6 includes emergent vegetation, such as common reed (*Phragmites australis*) and cattail (*Typha angustifolia*) in deeper-water areas. Forested wetlands are dominated by silver maple (*Acer saccharinum*) and green ash (*Fraxinus pennsylvanica*). Eastern cottonwood (*Populus deltoids*) is dominant in higher elevations along the edges of the wetland. In addition, deciduous shrubs, living and dead deciduous trees, and floating-leaved vegetation are also present. SYW-6 is seasonally flooded and saturated.

Wetland SYW-10 is a 27.2-acre (11 ha), Class I wetland, located along Ninemile Creek. I-690 divides this wetland with the lake-side portion dominated by emergent vegetation such as common reed and floodplain forest similar to that in Wetland SYW-6. On the western side of I-690, the wetland is dominated by emergent vegetation (e.g., common reed). Part of the wetland on the western side of I-690 was filled with waste from the Crucible Metals Corporation. This portion, called the Maestri 2 site, is under investigation by the potentially responsible parties for the site.

Wetland SYW-12 is a 40.7-acre (16.3 ha), Class I wetland, located around the mouth of Ley Creek. SYW-12 is a palustrine, emergent, broad-leaved deciduous wetland (TAMS, 2002a). The eastern edge of SYW-12, near the railroad berm, consists of shrubs and saplings and is dominated by invasive species including common buckthorn (*Rhamnus cathartica*) and box elder (*Acer negundo*). Mature trees typical of floodplain forests occupy the central portion of this wetland and include red maple (*Acer rubum*), willow (*Salix spp.*), and cottonwood. The remainder of the wetland is dominated by thick stands of common reed with silky dogwood (*Cornus amomum*) along the outer edges (United States Army Corps of Engineers [USACE], 2003). SYW-12 is seasonally flooded.

Wetland SYW-19 is a 19.8-acre (8 ha), Class II wetland, located at the mouth of Harbor Brook. The wetland is dominated by common reed and is seasonally flooded.

1.3.9.2 Terrestrial Covertypes

A variety of vegetative communities and covertypes exist within 0.5 miles of the lake. Approximately 42 percent of the area is residential, 33 percent is urban/industrial, and 25 percent is open, forested, or palustrine. In general, the eastern shore of the 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, as shown on Figure 1.3, and many of these wastebeds are undergoing vegetative succession. Urban centers and industrial zones dominate the landscape on the south end of the lake from the Fairgrounds to Ley Creek.

1.3.9.3 Significant Habitats

Historically, inland salt marshes existed on the north side of Onondaga Lake but, according to the New York Natural Heritage Program (NYNHP), these marshes have been extirpated by development (Conrad, 2002). The remaining marsh area is degraded and no longer considered significant habitat. The USFWS reported that the area within a two-mile radius of Onondaga Lake contains no critical habitat, and none is under current consideration (Stilwell, 2002).

1.3.9.4 Aquatic Species

The most recent quantitative survey of macrophyte (i.e., aquatic plant) distributions in Onondaga Lake was conducted in 2000 (EcoLogic, 2001), and showed that ten species of macrophytes (nine submerged and one emergent) inhabited the lake. This survey was consistent with the survey conducted in 1993 by Madsen *et al.* (1998) and indicated substantial improvement compared to the five species found in 1991 by Madsen *et al.* (1996). However, this is still below the average of 15 species found in eutrophic lakes in New York State (Madsen *et al.*, 1993). The location of macrophytes in Onondaga Lake in 2000 is shown on Figure 1.9.

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, nonflagellated green algae, diatoms, cryptomonads, and cyanobacteria (PTI, 1993; Stearns and Wheler, 1994). Between 1986 and 1989, 25 zooplankton taxa were collected in Onondaga Lake, with clodocerans, copepods, and rotifers dominating zooplankton communities (Siegfried *et al.*, 1996).

Benthic macroinvertebrate communities were sampled at 68 stations throughout the lake during the RI sampling program in 1992 (PTI, 1993). More than 100 taxa were identified in the samples. Oligochaetes and chironomids numerically dominated the communities at most stations. The more recent species abundance survey conducted during the RI Phase 2A sampling program in 2000 also found that oligochaetes and chironomids dominated the communities at most stations (TAMS, 2002c).

Ringler *et al*. (1996) reported 48 species of fish from 20 different families in collections from Onondaga Lake from 1989 to 1992. The most numerous species included gizzard shad, white sucker, banded killifish, brook silverside, white perch, pumpkinseed, bluegill, and channel catfish. The variety of fish types indicates the presence of components of the lake ecological community necessary to support fish populations.

1.3.9.5 Terrestrial Species

The Breeding Bird Atlas survey conducted from 1980 to 1985 identified many species of birds (Andrle and Carroll, 1988), and a more recent Breeding Bird Atlas survey (beginning in 2000 and scheduled to extend until 2005) has identified additional species (TAMS, 2002a). At least 45 species of mammals occur near Onondaga Lake, including opossums, shrews, rabbits, chipmunks, woodchucks, squirrels, mice, rats, voles, muskrats, raccoons, and skunks.

1.3.9.6 Rare, Threatened, and Endangered Species

The New York Heritage Program reported that no comprehensive field survey had been performed for the area within a two-mile radius of Onondaga Lake (Conrad, 2002). The New York Heritage Program also reported that the state database contained only three occurrences of endangered plants within two miles of Onondaga Lake. These plants were the Sartwell’s sedge (*Carex sartwellii*), the little-leaf tick-trefoil (*Desmodiun ciliare*), and the red pigweed (*Chenopodium rubrum*). No fauna were listed.

The USFWS reported that a single threatened plant species, the American hart’s-tongue fern (*Asplenium scolopendrium*) has been identified in the town of Onondaga (Stilwell, 2002). The USFWS concluded, “Except for the American heart-tongue fern and occasional transient individuals, no other federally listed or proposed endangered or threatened species under our jurisdiction are known to exist in the projected impact area.”

Six state-listed birds of special concern have been observed near Onondaga Lake, including the common loon, osprey, sharp-shinned hawk, common nighthawk, redheaded woodpecker, and horned lark. A seventh bird, the common tern, is state-listed as threatened.

1.3.10 Lake and Water Use

1.3.10.1 Recreational Use

Onondaga Lake is part of the New York State system of canals maintained by the New York State Canal Corporation (part of the New York State Thruway Authority). A dam located approximately 15 miles downstream along the Oswego River at Phoenix, New York, maintains the water level in the lake. Lake waters are used by recreational boats, particularly in the area between the eastern shore and the northern end, where the lake outlet is located. The canal system connects waters in the east-west direction from Albany to Buffalo. Canal users do not need to enter Onondaga Lake, but the Canal Corporation maintains the lake as a waterway upstream to the Syracuse Harbor just south of the lake along Onondaga Creek.

The northern two thirds of the lake are classified by the State of New York as Class B waters, while the southern third of the lake and the area at the mouth of Ninemile Creek are classified as Class C waters. Best usages for these waters are defined as:

- Class B – “primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival” (6 NYCRR Part 701.7).
- Class C – “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 or sanctioned swimming areas exist at Onondaga Lake due to the presence of coliform bacteria and low water clarity (New York State Department of Health [NYSDOH], 1995).

A fish consumption advisory is in place (NYSDOH, 2003). The advisory recommends restricting the amount and species of fish from Onondaga Lake that are consumed, based on contaminant concentrations in fish as follows:

- Walleye – eat none due to mercury;
- Carp and channel catfish – eat no more than one meal per month due to dioxins, PCBs, and mercury; and
- All other species – eat no more than one meal per month due to mercury.

Infants, children under the age of 15, and women of childbearing age are advised to eat no fish from Onondaga Lake or other waters listed in the advisory (NYSDOH, 2003). In addition, NYSDOH has a general advisory that recommends people should eat no more than one meal (one-half pound) per week of fish from fresh waters in the state of New York.

1.3.10.2 Industrial and Potable Water Supply Uses

Groundwater adjacent to the lake is not currently used as an industrial or potable water supply (O’Brien & Gere, 1997). It is classified as Class GA with a best use being a potable water source. At this time, adjacent municipalities and businesses are supplied through local water utilities, which primarily use surface water sources distant from the lake, as well as some distant groundwaters. A map dated 1827 indicates that a spring house, reservoir, and pump house for the Geddes public water supply were located near the lakeshore in the area of Wastebed B (map provided by W. Kappel to TAMS, April 2004).

Groundwater in the unconsolidated sediment beneath the lake is generally not potable because of high total dissolved concentrations in the groundwater, which are the result of both anthropogenic and natural causes. From the late 1700's through the early 1900's, groundwater was extracted from springs and wells along the southern shoreline of the lake to produce salt (USGS, 2000). During the period 1797 through 1917, over 11.5 million tons of finished salt were produced from groundwater. This represents the salt content from the constant production of 500 gpm of brine with a chloride concentration of 60,000 mg/L over this period. Groundwater was also pumped in the past for industrial purposes (e.g., slurrying with fly ash to pump Solvay wastes to the wastebeds).

1.4 NATURE AND EXTENT OF CONTAMINATION

The Onondaga Lake system was the subject of an extensive RI conducted by Honeywell from 1992 to 2000, with additional investigation by NYSDEC in 2001. These field investigations generated more than 130,000 data points based on sampling of most lake media, including tributary water and sediment; lake water, sediment, and sediment porewater; lake biota (i.e., fish and benthic macroinvertebrates); shoreline groundwater; sediment in four adjacent wetlands; and soil in the dredge spoil area located west of the mouth of Ninemile Creek. In most cases, samples were analyzed for metals, semivolatile organic compounds (SVOCs), and volatile organic compounds (VOCs). More than 6,000 samples were collected and analyzed. Descriptions of the field investigations and the findings were presented in Chapters 2 and 4, respectively, in the RI (TAMS, 2002c). As described in Chapter 5 of the RI, the primary chemical parameters of interest (CPOIs) that emerged from the investigation were:

- Mercury and other metals;
- BTEX;
- Chlorinated benzenes;
- PAHs;
- PCBs; and
- PCDD/PCDFs.

This subsection summarizes information on the nature and extent of contamination by these CPOIs, including information on contaminant sources to the lake. This information provides a baseline of current conditions in the lake and is used in the FS to develop remedial action objectives and identify areas of the lake to address with remedial action.

The terms used to describe mercury concentrations in the lake deserve explanation. The two mercury species that were analyzed during the RI were total mercury and methylmercury. Total mercury encompasses all mercury species present in a sample, including inorganic species such as mercuric mercury and organic species such as methylmercury. Methylmercury usually makes up a very small fraction of mercury in water and sediment samples and was analyzed in only a limited number of sediment samples during the RI investigation. In contrast, methylmercury makes up most of the mercury detected in biological tissues. Methylmercury is the most bioaccumulative and potentially toxic form of mercury. In discussions of sediment below, total mercury is referred to as “mercury.”

1.4.1 Presence of CPOIs in Lake Sediment

Generally, littoral and profundal sediments in the lake contain all of the primary CPOIs listed above. The areal extent of contamination is variable, depending on the specific compounds involved, their external sources to the lake, and internal lake cycling processes. Mercury and other metals in the lake show a vertical distribution pattern in profundal sediment that reflects their strong association with sediment and sediment deposition.

1.4.1.1 Mercury

Mercury concentrations in surface littoral sediment were generally less than 3.16 parts per million (ppm) (Figure 1.10). Higher concentrations were found in littoral sediments along the southwest shoreline near the ILWD (greater than 32 ppm) and at the mouth of Ninemile Creek (up to 10 ppm). In subsurface littoral sediments at the mouth of Ninemile Creek, the mercury concentration in one of the cores was between 10 and 32 ppm to a depth of 16 ft (5 m) below the lake bottom. In subsurface littoral sediments within the ILWD, the mercury concentration in one of the cores was between 10 and 32 ppm at a depth of 16 ft (5 m) below the lake bottom and 1 to 3 ppm at a depth of 23 ft (7 m) below the lake bottom (Figure 1.10). With one exception, mercury concentrations were generally less than 1 ppm in subsurface sediment of other littoral areas. The exception was an area offshore of Ley Creek and Onondaga Creek where mercury concentrations of three to 10 ppm were observed to a depth of approximately 6.5 ft (2 m) and mercury concentrations ranging from one to three ppm were found to a depth of 13 ft (4 m) below the lake bottom.

Mercury concentrations in the top inch of profundal sediment were generally one to three ppm with the exception of two cores in the north basin, an area off Wastebeds 1 to 8, and the southern corner of the south basin. For example, the top two inches (4 cm) of two sediment cores collected at approximately 52 ft (16 m) water depth in the southern part of the lake in 2000 for porewater analysis had concentrations ranging from 2.1 to 6.6 ppm. Higher concentrations of mercury in profundal sediment, corresponding to higher historical mercury loadings to the lake, are located at approximately 7 to 30 inches (18 to 75 cm) below the lake bottom and have been covered by less contaminated sediment, as shown by the 1988 profile collected by Rowell (1992) from the north basin and shown on Figure 1.11. The lack of disturbance to these sediments is shown by the sharp decrease in mercury concentrations following 1970, when releases of mercury from the Willis Avenue Plant and the Bridge Street site were reduced from 22 pounds (10 kilograms) per day to less than 1 pound (0.5 kilograms) per day (Effler and Harnett, 1996). Mercury releases were reduced even further in 1977 (to less than 0.5 pound [0.2 kilograms per day]) (Effler and Harnett, 1996).

The 1988 sediment profile on Figure 1.11 shows a slightly higher mercury concentration near the sediment-water interface than in intervals immediately below. However, the 1992 sediment profile on Figure 1.12 shows that the mercury concentration at the sediment-water interface is lower than in intervals immediately below. The lower mercury concentrations at the surface of the 1992 cores suggest that cleaner sediment was deposited between 1988 and 1992 than was deposited in the few years prior to that time. The mercury profiles in sediment cores are also discussed in Appendix N, monitored natural recovery.

1.4.1.2 Other Metal CPOIs

Other metal CPOIs exhibit the same pattern of reduced concentrations near the surface of profundal sediment (Figure 1.12), indicating a similar reduction in sediment metals loadings to the lake sediment from all sources over the past 20 to 30 years.

Cadmium, chromium, copper, lead, nickel, and zinc were detected in profundal and littoral surface and subsurface sediments throughout the lake. The highest metal concentrations were observed in littoral sediments in the area of the ILWD (cadmium, chromium), Ninemile Creek (cadmium, chromium, lead), Ley Creek (cadmium, chromium), Tributary 5A (chromium, nickel), Harbor Brook (lead, zinc), and the southern end of the lake (lead).

1.4.1.3 Organic CPOIs

For organic CPOIs, the highest concentrations of BTEX, chlorinated benzenes, low molecular weight PAHs (LPAHs: the sum of naphthalene, 2-methylnaphthalene, and fluorene), PCBs, and PCDD/PCDFs (expressed in terms of toxic equivalents [TEQs]) in sediment were found in the area of the ILWD and along the southwest shoreline between Tributary 5A and Harbor Brook. Figures 1.13 to 1.25 show their respective concentrations by sediment depth in the lake. PCBs were also detected in the Ley Creek delta, and the highest concentrations of high molecular weight PAHs (HPAHs) were observed off the southeastern corner of the lake adjacent to the Carousel Center location.

Sheens and other evidence of NAPL were observed during sampling activities in several locations in the ILWD, along the southwest shoreline, and offshore of Oil City, as shown on Figure 1.26. Most recently, iridescent sheens were observed on the lake surface at each of the boring locations during installation of the piezometers and pumps for the upwelling investigation in 2002 (Parsons, 2003a). The Solvay waste was highly layered and displayed NAPL at a total of seven locations off the causeway and the East Flume. One location directly adjacent to the eastern end of the causeway (TR02-A) displayed impacted granular fill material from 0 to 10.5 ft (0 to 3.2 m) below the sediment-water interface. Results from the sediment and porewater samples at this location indicated the presence of benzene and chlorobenzene.

DNAPL related to former Honeywell operations has been identified in the Wastebed B area. Chlorinated benzene DNAPL is located at the northern end of the wastebed and is attributed to the former Willis Avenue operations (TAMS, 2002c). DNAPL consisting largely of naphthalene, BTEX, and lesser amounts of PAHs is located at the southern end of Wastebed B at Harbor Brook and is attributed to the former Barrett Paving facility (TAMS, 2002c).

1.4.1.4 Other Stressors

Calcium carbonate and oncolite distribution were assessed in lake sediment during the RI in 1992 and were considered as potential stressors to fish and wildlife (TAMS, 2002c). Figure 1.27 shows the distribution of calcium carbonate and oncolites in the surface sediment of Onondaga Lake in 1992. The concentrations of calcium carbonate in the top one inch (zero to two cm) of sediment were generally less than 60 percent by weight in sediment from deep areas of the lake and greater than 60 percent in nearshore areas. The highest concentrations (greater than 80 percent by weight) were found along much of the northern shoreline and near Ley Creek and Tributary 5A.

Regarding oncolite distribution in nearshore sediments, the lowest concentrations were observed along the southern shoreline of the lake between Tributary 5A and Ley Creek. The highest concentrations were found along the northern shoreline and in small areas near the mouths of Ley Creek and Tributary 5A. The possible effects of these stressors are discussed in greater detail in Subsection 1.7.

1.4.2 Presence of CPOIs in Tributary Sediments

The highest mercury concentrations in tributary sediments were found in the West Flume, Ninemile Creek, Geddes Brook, and Harbor Brook. Concentrations of other metals were highest in Tributary 5A and Ley Creek. Concentrations of organic contaminants were highest in the East Flume, Tributary 5A, and Harbor Brook, with the exception of PCBs, whose maximum concentration was found in Old Ley Creek (a branch of Ley Creek). DNAPL was identified in the sediments and underlying soils of Harbor Brook.

1.4.3 Presence of CPOIs in Wetlands SYW-6 and SYW-12

Sediment samples were collected from four locations in Wetlands SYW-6 and SYW-12 in 2000. In 2002, five additional locations in SYW-6 were sampled. These locations were taken in the vicinity of the one 2000 station that contained relatively higher concentrations of CPOIs. At each location, two intervals (i.e., 0 to 15 and 15 to 30 cm) were analyzed.

1.4.3.1 Mercury

In 2000, mercury concentrations in both wetlands were at or below the severe effects level (SEL) for mercury of 1.3 ppm, with the exception of the surface interval at S375 in SYW-6 (4 ppm) and the subsurface interval at S390 in SYW-12 (6 ppm) (Figure 1.28). Ten of the 16 samples exceeded the lowest effects level (LEL) of 0.15 ppm. In 2002, the mercury concentration at station SYW6-3 in SYW-6 was approximately 5 ppm in the surface interval (Figure 1.29). Two other samples slightly exceeded the SEL, and most samples exceeded the LEL. No relationship was established between mercury concentration and sediment depth.

1.4.3.2 Other Metal CPOIs

Thirteen other metals were detected, including aluminum, antimony, arsenic, barium, cadmium, chromium, copper, cyanide, iron, lead, selenium, thallium, and zinc. As was true for mercury, these metals did not exhibit a pattern between concentration and sediment depth. Generally, the highest inorganic concentrations were measured at sample location S390 (15 to 30 cm) in SYW-12 followed by sample location S375 in SYW-6.

1.4.3.3 Organic CPOIs

Chlorinated benzenes, PAHs, and PCBs were detected in SYW-6 and SYW-12 at concentrations generally below screening criteria from the NYSDEC *Technical Guidance for Screening Contaminated Sediment* (NYSDEC, 1999). Figures 1.30 and 1.31 show the sum of PAHs for the 2000 and 2002 sampling events. PCB concentrations reported as the sum of Aroclors exceeded NYSDEC screening criteria for wildlife bioaccumulation in SYW-12 but not in SYW-6 (Figure 1.32). TEQs calculated for SYW-6 were below the NYSDEC screening criteria for wildlife bioaccumulation. PCDD/PCDFs were not analyzed in SYW-12.

1.4.4 Presence of CPOIs in Lake Water

1.4.4.1 Mercury

Total mercury and methylmercury were analyzed in lake water samples during the RI. For each analyte, unfiltered and filtered (i.e., dissolved) results were reported. Distinguishing between unfiltered and dissolved water samples is critical for understanding mercury results, because most of the mercury present in an unfiltered water sample is associated with suspended solids. Therefore, dissolved mercury concentrations tend to be much lower than unfiltered mercury concentrations. One exception to this is in an anoxic hypolimnion, where the dissolved fraction can account for a significant portion of the unfiltered concentration. Dissolved mercury is considered more available for uptake by phytoplankton.

The distribution of total mercury and methylmercury follows a strong seasonal pattern, with concentrations of both building up in the hypolimnion during summer stratification in 1992. Figures 1.33 and 1.34 show the concentrations of unfiltered and filtered total mercury and methylmercury, respectively, from April to November 1992, as measured at various water depths in the north and south basins. Total mercury reached a maximum of approximately 23 nanograms per liter (ng/L) in September at the 15 to 18 m water depth. The maximum methylmercury concentration was 12 ng/L, measured in October.

Water samples were also collected during the RI in 1999 from the north and south basins and from several nearshore locations. Unfiltered total mercury concentrations in these samples ranged from 2.92 ng/L near Wastebeds 1-8 to 103 ng/L near the mouth of Harbor Brook. A concentration of 26.2 ng/L was reported from a sample collected at the mouth of Ninemile Creek. In 2000, a limited number of water samples were collected from just above the sediment/water interface at several stations where sediment porewater was collected (TAMS, 2002c). Unfiltered total mercury concentrations in these samples ranged from 6.79 to 595 ng/L. The highest concentrations were reported at stations S344 (595 ng/L) and S405 (264 ng/L). Finally, in 2001, water samples were collected during both calm and windy days from water overlying the ILWD, the southern deep basin, and the north shore (TAMS, 2002a). Unfiltered total mercury concentrations in these samples ranged from 3.57 to 49.4 ng/L, with the maximum concentration observed under windy conditions in water overlying the ILWD.

There are five New York State surface water quality standards for total mercury that are defined as follows:

- 1,400 parts per trillion (ppt; equivalent to ng/L) for protection of aquatic life (acute);
- 770 ppt for protection of aquatic life (chronic);
- 700 ppt for protection of human health (water source);
- 2.6 ppt on a dissolved basis for protection of wildlife; and
- 0.7 ppt on a dissolved basis for protection of human health (fish consumption).

Dissolved total mercury concentrations in the lake exceed only the two most stringent standards. The surface water quality standard for protection of human health via fish consumption was exceeded in water samples from Onondaga Lake collected in 1992 and 1999, with few exceptions. The surface water quality standard for protection of wildlife was sometimes exceeded in water samples from Onondaga Lake in 1992 and 1999. In 1992, the protection of wildlife standard was exceeded in April, August, and September at all depths in the water column of Onondaga Lake and in June, July, October, and November in the hypolimnetic waters only.

In 1999, the protection of wildlife standard was exceeded in the hypolimnion on two of the five sampling dates (i.e., September 27 and October 15, 1999). Exceedances in the hypolimnion reflect the increase in dissolved mercury concentrations during stratification. The protection of wildlife standard was also exceeded at 3.3 ft (1 m) water depth in nearshore stations on September 27, 1999, and at 3.3 ft (1 m) water depth at three nearshore stations and the southern basin on October 25, 1999. The protection of wildlife standard was not exceeded at the three nearshore stations between Tributary 5A and Harbor Brook on September 27, 1999. These stations were not sampled on October 25, 1999.

In 2000, all samples exceeded the protection of human health via fish consumption standard. Samples from stations S303, S354, and S355 also exceeded the protection of wildlife standard. These three stations were located at greater than 52 ft (16 m) water depth just above the sediment/water interface in the north (S303) and south (S354 and S355) basins.

Finally, in 2001, all samples collected from water overlying the ILWD, the southern deep basin, and the north shore exceeded both the protection of wildlife standard and the protection of human health via fish consumption standard.

1.4.4.2 Other CPOIs

Concentrations of most metal CPOIs in lake water other than mercury were close to or below analytical laboratory detection limits. However, surface water criteria were exceeded for barium, cadmium, copper, cyanide, lead, manganese, and zinc based on screening conducted in the BERA (TAMS, 2002a). Organic CPOIs were seldom detected in lake water except in nearshore samples collected in 1999. Dichlorobenzenes and trichlorobenzenes were detected in one out of 98 lake water samples in 1992. Chlorobenzene and benzene were detected in two samples (located in the lake near the East Flume) out of 11 from 1999. Dichlorobenzenes were also detected at nearshore stations in 1999, although the highest concentrations (greater than one part per billion [ppb = microgram per liter]) were found near the East Flume. Concentrations of benzene, chlorobenzene, and dichlorobenzenes (both individual and summed) exceeded NYSDEC ambient surface water quality standards in samples collected near the East Flume in 1999. Surface water criteria were also exceeded for trichlorobenzenes and bis(2-ethylhexyl) phthalate as described in the BERA (TAMS, 2002a).

1.4.4.3 Other Stressors

Although not identified as CPOIs, ammonia, phosphorus, sulfide, chloride, salinity, dissolved oxygen, and water transparency were considered stressors in the RI. Concentrations of ammonia, phosphorus, and sulfide followed a similar pattern to total mercury and methylmercury, increasing in the hypolimnion during stratification. Concentrations of dissolved oxygen decreased in the hypolimnion during stratification. Water transparency was low from April to October (Secchi disk depth of 3.3 to 6.6 ft [1 to 2 m]) and higher after fall turnover (Secchi disk depth of 20 ft [6 m] at the end of November).

Two of the New York State narrative water quality standards (6 NYCRR Part 703.2) were exceeded as described in the BERA (TAMS, 2002a). These standards are as follows:

- Turbidity – No increase that will cause a substantial visible contrast to existing conditions and
- Suspended, colloidal, and settleable solids – None from sewage, industrial wastes or other wastes that will cause deposition or impair the waters for their best usages.

While these standards may not be measurable, the BERA stated that high concentrations of calcite in the lake result in contravention of these standards. According to the BERA, calcite may deposit onto the surfaces of macrophytes and impair their growth. In turn, a decrease in macrophytes may impair fish populations.

1.4.5 Presence of CPOIs in Tributary Water and Other Discharges

1.4.5.1 Mercury

Mercury was detected in water sampled during the RI from all tributaries and other discharges (primarily the Metro Plant discharge). The highest concentrations of total mercury were found in the East Flume and Geddes Brook, while the highest concentrations of methylmercury were found in the East Flume and in the Metro Plant discharge.

It is difficult to assess exceedance of surface water quality standards in the tributaries of Onondaga Lake because there are limited data available for dissolved mercury concentrations. Details of exceedances based on the 1992 and 1999 sampling are provided in Subsection 10.3.2 of the BERA (TAMS, 2002a). The RI in 1992 sampled all of the tributaries on multiple occasions but only analyzed total mercury and methylmercury in unfiltered samples. Additional sampling in the West Flume, Geddes Brook, and Ninemile Creek in 1994 and 1995 included a few samples for dissolved mercury analysis taken during a rainfall event (PTI, 1996). The Geddes Brook / Ninemile Creek RI conducted by Honeywell in 1998 analyzed both unfiltered and dissolved mercury in water samples collected from the West Flume, Geddes Brook, and Ninemile Creek during two low-flow sampling events.

Analysis performed on samples from impacted and unimpacted (by former Honeywell operations) tributaries and/or sections of tributaries indicate varying levels of contamination. Samples taken during low flow conditions in Sawmill Creek and Bloody Brook (two tributaries to Onondaga Lake that are unaffected by former Honeywell operations) in 1992 were reported in the RI as containing primarily dissolved mercury at 2 and 3.6 ppt, respectively. During a rainfall event in 1995, two of the three samples taken in Ninemile Creek upstream from the confluence with Geddes Brook and any other influence from sources related to former Honeywell operations exceeded 0.7 ppt during the same sampling event, all samples taken in Geddes Brook and in Ninemile Creek below the Geddes Brook confluence exceeded both the 0.7 and 2.6 ppt water quality standards. Under low-flow conditions in 1998, the only samples that exceeded the NYSDEC wildlife and/or human health water quality standards were collected in the West Flume. It is unknown at this time if dissolved mercury concentrations in other tributaries to the lake meet these standards.

1.4.5.2 Other CPOIs

Other metals were occasionally detected in tributary water samples during the RI, with Tributary 5A and the East Flume having the most frequent detections. Organic CPOIs were detected to a limited extent in Tributary 5A (benzene, toluene), the East Flume (xylenes, chlorinated benzenes), and Harbor Brook (xylenes).

1.4.6 Presence of CPOIs in Biota

Numerous CPOIs were detected in fish tissue sampled during the RI. Initial screening in the BERA (TAMS, 2002a) identified concentrations of aluminum, antimony, arsenic, chromium, mercury, methylmercury, selenium, vanadium, bis(2-ethylhexyl)phthalate, Aroclor 1248, Aroclor 1254, PCBs, dichlorodiphenyltrichloroethane (DDT) and metabolites, endrin, gamma-hexachlorocyclohexane, 2,3,4,7,8-pentachlorodibenzofuran, and 2,3,7,8-tetrachlorodibenzofuran as exceeding screening values.

Mercury concentrations in fish in Onondaga Lake have decreased since mercury loading to the lake was reduced in 1970. Figure 1.35 shows a sharp decline in the average mercury concentration in various fish species between 1971 and 1972. Concentrations since then have leveled off, although there is considerable variability from year to year. For example, mercury concentrations in smallmouth bass increased between 1986 and 1989 but by the early 1990s had decreased to levels below that observed in 1986. Mercury concentrations appeared to increase again in the mid- to late-1990s and then decrease in 2000. In general, the mercury concentration in larger piscivorous fish (i.e., fish that eat other fish) such as walleye and bass is higher than in benthivorous fish (i.e., fish that eat benthic organisms) such as catfish and carp. This pattern is consistent with the general understanding of mercury bioaccumulation as discussed in Subsection 1.6.1. It should be noted, however, that white perch, a pelagic planktivore, often has higher mercury concentrations than the littoral zone piscivore smallmouth bass in Onondaga Lake.

Total mercury and methylmercury were found in most samples of phytoplankton, zooplankton, and benthic macroinvertebrates. Concentrations of total mercury and methylmercury in benthic macroinvertebrates collected in 2000 were higher than in sediment samples from the ILWD. With the exception of mercury, analysis of contaminants in biota other than fish was limited to PCB analysis in seven benthic macroinvertebrate samples collected in 2000.

1.5 SOURCES OF CPOIs TO ONONDAGA LAKE

1.5.1 Honeywell Upland Sources

The RI identified multiple sources of most of the CPOIs present in the lake system. Upland sources related to former Honeywell operations include the Willis Avenue site, the East Flume, Semet Residue Ponds, Tributary 5A, Harbor Brook/Wastebed B, Wastebeds 1 through 8, the LCP Bridge Street site, Wastebeds 9 through 15, and Geddes Brook / Ninemile Creek. Figure 1.36 shows the locations of Honeywell and non-Honeywell sites and subsites around Onondaga Lake. Potential contaminant transport pathways to the lake and CPOIs are summarized in Table 1.5. Most of these sites are in various stages of investigation and remediation, as summarized in Subsection 4.2 of this report.

1.5.2 Non-Honeywell Upland Sources

In addition to sources related to former Honeywell operations, many other industrial and municipal facilities and sites either were or are continuing sources of CPOIs to Onondaga Lake. Investigations to date have identified a number of historical and ongoing sources of contaminants. For example, several General Motors Corporation (GM) sites in the Ley Creek area (i.e., the GM former Inland Fisher Guide facility and Ley Creek Deferred Media Site, the GM Old Ley Creek Channel Site, and the GM Dredgings Site) as well as the town of Salina Landfill are contributors or potential contributors to CPOIs in Ley Creek and Onondaga Lake.

On the south side of the lake, between Ley Creek and Harbor Brook, historical operations from facilities in the Oil City area, former Niagara Mohawk Power Corporation manufactured gas plants (MGPs) on Hiawatha and Erie Boulevards, the Metro Plant, the American Bag and Metal Site, and the Roth Steel Site are contributors or potential contributors of CPOIs to Onondaga Creek and Onondaga Lake. The Crucible Materials Corporation facility and Crucible Lake Pump Station disposal site are contributors of CPOIs to Tributary 5A and Onondaga Lake. The Electronics Park facility formerly operated by General Electric and operated currently by Lockheed Martin is a contributor or potential contributor of CPOIs to Bloody Brook.

Potential contaminant transport pathways to the lake and CPOIs from non-Honeywell sources were discussed in the RI reports (TAMS, 2002c) and are summarized in Table 1.6 to the extent identified to date. As with the Honeywell upland sites, many of these sites are under investigation, as summarized in Subsection 4.2 of this report.

1.5.3 Background Sources

Concentrations of some CPOIs in the lake are also influenced by background sources (i.e., nonpoint sources or natural sources). These CPOIs include mercury, other metals (i.e., lead, chromium, copper, nickel, and zinc [Novotny and Chesters, 1981]), PAHs, and PCDD/PCDFs. Background sources of mercury include wet and dry deposition (e.g., rain, snow), tributaries, and groundwater. Mercury in wet and dry deposition originates in emissions from coal-burning power plants (often at great distances) and more regional or local sources to the atmosphere such as incineration. Some of the mercury that deposits on the Onondaga Lake watershed is adsorbed to soil and thereby sequestered; however, a measurable fraction is transported to the lake by the tributaries. Even in tributaries such as Ninemile Creek that are heavily influenced by former Honeywell operations, a significant fraction of the load is from background sources. Figure 6-6a of the Geddes Brook / Ninemile Creek RI report (TAMS 2003) indicated that upper Ninemile Creek supplied approximately 10 to 20 percent of the total mercury load in lower Ninemile Creek during the 1990 low flow sampling events.

Groundwater (other than near the southwest shoreline) is considered a background source of dissolved mercury to the lake. The RI estimated that the concentration of dissolved mercury in uncontaminated groundwater (i.e., the background concentration) around Onondaga Lake is two to 11 ppt, with a best-estimated value of six ppt. This value is consistent with studies of uncontaminated lakes, such as Pallette Lake, Wisconsin (Krabbenhoft and Babiarz, 1992), where uncontaminated groundwater contains two to four ppt dissolved mercury. These estimates of mercury concentrations in background sources to the lake exceed the two lowest NYSDEC surface water quality standards for mercury.

Principal components analysis in the RI report identified a source pattern for PAHs that indicated combustion byproducts. The pattern included a high proportion of four- and five-ring PAHs commonly associated with wood and coal burning, coke ovens, automobile exhaust, heat and power generation, and refuse burning. The pattern was low in concentration but ubiquitous in lake sediment, indicating a common, area-based phenomenon. One likely source is atmospheric deposition of combustion byproducts directly onto the lake surface and onto watershed soils, which are then transported to the lake by the tributaries. Another source of PAHs is roadway and parking lot runoff carrying vehicle engine residues.

Principal component analysis in the RI report also identified a source pattern for PCDD/PCDFs consistent with atmospheric deposition of byproducts from incineration. According to the RI report, atmospheric samples are composed of approximately 80 percent octachlorodibenzodioxin (OCDD) and are termed high OCDD mass fraction samples. Sediment samples determined to be influenced by atmospheric deposition of OCDD were usually found at greater depths and lower concentrations than samples containing PCDD/PCDFs attributed to former Honeywell operations or to the GM–Inland Fisher Guide site on Ley Creek.

1.5.4 Internal Sources of CPOIs to the Lake

Certain areas of Onondaga Lake are internal sources of CPOIs. These areas are littoral sediments (including the ILWD and other areas subject to resuspension and advective groundwater flow and diffusion), profundal sediments, and the hypolimnion. As tributary and Metro Plant discharges enter the lake, CPOIs enter the water column or are deposited with solids to either the littoral or profundal sediment. Wind and waves resuspend light and erodable solids from the littoral sediment. Through sediment focusing, these solids and the contamination they carry are transported over time onto the surface layer of the profundal sediments. Although profundal sediment is undisturbed, diffusion and, possibly, methane gas ebullition can transport CPOIs (in particular, mercury) from profundal sediment to the overlying water. Under anoxic conditions, the hypolimnion also becomes an internal source for methylmercury because methylmercury is produced there. The processes of resuspension, diffusion, methane gas ebullition, and methylmercury production are discussed in greater detail in the following subsection.

1.6 TRANSPORT AND FATE OF CPOIS IN ONONDAGA LAKE

The transport and fate of CPOIs refers to the movement of CPOIs into, within, and out of the lake, as well as the transformation of CPOIs (e.g., methylation of mercury) and their ultimate fate (e.g., burial in profundal sediment) within the lake. These processes are critical to understanding the relative importance of contaminant sources and the outcome of proposed remedial actions. Transport and fate processes need to be characterized at a level sufficient to support evaluation of remedial alternatives. The transport and fate of mercury and non-mercury CPOIs with respect to Onondaga Lake are discussed below.

1.6.1 Transport and Fate of Mercury

The RI included an extensive evaluation of mercury transport and fate within Onondaga Lake. Mercury was of particular interest because of its unique biogeochemistry and its importance to lake contamination. The evaluation considered both total mercury and methylmercury. Total mercury encompasses all mercury species present in a sample, including inorganic species such as mercuric mercury and organic species such as methylmercury. Methylmercury is formed naturally by bacteria in the environment in the absence of oxygen, such as in an anoxic hypolimnion or anoxic sediment. In sediment, soil, and water, methylmercury constitutes only a small fraction of total mercury; however, almost all of the mercury in fish tissue is methylmercury. Methylmercury is of primary concern for Onondaga Lake because of its potential toxicity and tendency to bioaccumulate in the lake ecosystem.

Methylmercury formed in sediment and the water column enters the food web through both benthic (i.e., sediment-associated) and pelagic (i.e., water column-associated) pathways. In the benthic pathway, benthic macroinvertebrates accumulate methylmercury from sediment and porewater. These organisms are then consumed by benthivorous fish, which are, in turn, consumed by piscivorous (i.e., fish-eating) fish. In the pelagic pathway, dissolved methylmercury in the water column is accumulated by phytoplankton, which are consumed by zooplankton. Zooplankton are, in turn, consumed by planktivorous (i.e., plankton-eating) fish, which are consumed by piscivorous fish. At each step of the pathway, methylmercury concentrations increase. According to Wiener et al. (2003), uptake of methylmercury through the diet probably accounts for more than 90 percent of total methylmercury uptake in wild fish. Presumably, less than 10 percent is derived from direct uptake from the water column. Organisms at the top of the food chain (e.g., wildlife that consume fish) receive the highest methylmercury exposures.

The primary tool in the RI for evaluating mercury transport and fate in Onondaga Lake was development of a mass balance. In developing the mass balance, external and internal sources of mercury to the lake as well as sinks for mercury (i.e., processes where mercury is removed within or from the lake) were quantified based on field and laboratory data. In addition, the change in mercury mass within the lake was estimated based on water column concentrations of mercury. The period covered in the mass balance was May 25 through September 21, 1992, a time when sufficient data were available to make reliable estimates and when methylmercury accumulates in the lake. Mathematically, sources minus sinks should equal the change in mass for the period of calculation. However, the complexity of environmental systems often prevents such closure. The mass balances for total mercury and methylmercury are shown on Figure 1.37 as part of the conceptual model for the lake. To maintain consistency with the RI (TAMS, 2002c), sources and processes are quantified in grams.

1.6.1.1 Quantification of External Sources and Sinks of Mercury

External Sources of Total Mercury

External sources of total mercury to Onondaga Lake include tributary discharges involving sources related to former Honeywell operations and non-Honeywell sources, the Metro Plant discharge, groundwater advection (i.e., discharge through sediments into the lake), and atmospheric deposition (e.g., rainfall) to the surface of the lake. The total mercury contribution from atmospheric deposition (71 grams) was small relative to other external sources. According to the loading analysis discussed in the RI, the largest external contributors of total mercury to the lake were Ninemile Creek, groundwater advection along the shoreline between Tributary 5A and Harbor Brook, and the Metro Plant, with loads of 1,268 grams, 752 grams, and 611 grams, respectively, for the May to September 1992 period. According to the RI report (TAMS, 2002c), upgrades to the Metro Plant since 1992 have resulted in reductions in loading of total mercury and methylmercury from the Metro Plant to the lake. The fourth largest source, Onondaga Creek, contributed 346 grams during this period, and the remaining tributaries each contributed less than 85 grams.

As discussed previously, the dominant source of mercury to Ninemile Creek is the former LCP Bridge Street facility, while the dominant sources of mercury to groundwater along the shoreline between Tributary 5A and Harbor Brook are the Willis Avenue and Harbor Brook/Wastebed B sites. Tributary 5A, the East Flume, and Harbor Brook are also considered to be impacted by former Honeywell operations. Sources of mercury to the Metro Plant likely include numerous residential and industrial discharges, dental wastewater, and stormwater.

With respect to the proportionate contributions of external total mercury sources to the lake, sources attributable to former Honeywell operations (Ninemile Creek, Tributary 5A, the East Flume, Harbor Brook, impacted groundwater) account for approximately 66 percent (i.e., two thirds) of the external total mercury sources while 18 percent is attributed to the Metro Plant discharge, and the remainder (16 percent) is attributed to background sources (Onondaga Creek, Ley Creek, groundwater, and atmospheric deposition). Within the tributaries impacted by former Honeywell operations, some of the total mercury load is attributable to background or regional conditions (e.g., the load carried by Ninemile Creek upstream of influence from the LCP Bridge Street site); however, the majority of the load is likely due to former Honeywell operations.

External Sources of Methylmercury

External sources of methylmercury to the lake include tributary discharge, the Metro Plant discharge, groundwater advection (i.e., primarily discharge through littoral sediments into the lake), and atmospheric deposition (e.g., rainfall) to the surface of the lake. As with total mercury, the largest external contributors of methylmercury were Ninemile Creek, groundwater along the shoreline between Tributary 5A and Harbor Brook, and the Metro Plant, with loads of 49 grams, 70 grams, and 42 grams of methylmercury, respectively, for the same period of May through September 1992. The groundwater contribution of methylmercury from sources related to former Honeywell operations was calculated in the RI by assuming that the total mercury discharged in groundwater between Tributary 5A and Harbor Brook has the same percent methylmercury as that observed in porewater samples in this area. Other external sources were only minor contributors.

Approximately 65 percent of external methylmercury is attributed to sources related to former Honeywell operations, 23 percent is attributed to the Metro Plant discharge, and the remainder (12 percent) is attributed to background sources (Onondaga Creek, Ley Creek, groundwater, and atmospheric deposition). As with total mercury, upgrades to the Metro Plant since 1992 have resulted in reductions in methylmercury loading from the plant to the lake. Some of the methylmercury load in tributaries impacted by former Honeywell operations is attributable to background or regional conditions (e.g., the load carried by Ninemile Creek upstream of influence from the LCP Bridge Street site); however, the majority of the load is likely due to former Honeywell operations.

Losses of and Sinks for Total Mercury and Methylmercury

The main loss of total mercury and methylmercury from the lake is outflow to the Seneca River, while the main sink within the lake is burial in profundal sediment. Flow through the lake outlet accounted for the loss of 660 grams of total mercury and 39 grams of methylmercury from Onondaga Lake for the May to September 1992 period. Burial in profundal sediment was approximated by the mass of mercury that settled to profundal sediment during the May to September period. Settling was calculated based on sediment trap data and therefore reflects gross sedimentation. Settling of solids to profundal sediment accounted for 10,700 grams total mercury and 557 grams methylmercury for the same period. Actual burial is probably less than settling because some mercury is released to overlying water or demethylated after settling.

Settling solids come from external sources, such as tributaries, and internal sources, such as phytoplankton biomass and resuspension of littoral sediment. Therefore, the concentrations of mercury in settling solids reflect ongoing, current conditions in the lake. Volatilization was a minor loss process for total mercury (46 grams for the May to September 1992 period). Net demethylation was a minor loss process for methylmercury (60 grams) during the May to September 1992 period.

1.6.1.2 Quantification of Internal Sources for Mercury and Methylmercury

As discussed previously, internal sources of waterborne mercury and methylmercury to the lake are littoral sediments such as the ILWD, the surface layer of profundal sediments, and transformations within the anoxic hypolimnion. To explain the importance of these internal sources, the RI identified and quantified internal processes that result in the release of mercury from these sources and/or the transformation of mercury within the lake. The internal processes evaluated in the RI were wind-driven resuspension of the ILWD, porewater diffusion from littoral and profundal sediments into overlying lake water, methane gas ebullition from the profundal sediments, and methylmercury production in the hypolimnion. Quantification of these internal processes provides information on the relative importance of internal sources. The complete mercury mass balance, including external and internal sources, sinks, and internal processes, is summarized on Figure 1.37.

Littoral Sediments

According to the RI, the main process governing release of mercury from the ILWD and/or littoral areas is wind-driven resuspension. Winds from the north and west were found to result in the highest turbidity measurements at a monitoring station in the lake near the East Flume during the fall of 2001. An estimate of mercury release from the ILWD due to wind resuspension was calculated as follows. A numerical relationship was established in the RI between northwest wind speed and turbidity in water overlying the ILWD using data obtained during four wind events in the fall of 2001. A small percentage of observed wind speed (i.e., 1.25 percent) was assumed to represent the mean horizontal current over the deposit, thereby allowing movement of water and suspended material from the waste deposit to be quantified based on wind speed. The potential movement of suspended material (i.e., resuspension) was then calculated as a function of wind speed and predicted turbidity concentrations for three categories of wind speed.

For the mass balance period of May through September of 1992, the RI estimated that a total of 20,000 grams of total mercury was released from the ILWD. Most of this total (i.e., 18,000 grams) was associated with wind events in the highest wind speed category (wind speeds between approximately 15 and 40 miles per hour) that occurred only five percent of the time. The report stated that even if actual resuspension of bottom material were one-tenth of the estimate (i.e., 2,000 grams), it would still be significant. Wind-driven resuspension of solids from the ILWD is mentioned in the remedial action objectives presented in the RI and is therefore included in the mass balance presented on Figure 1.37, despite uncertainties associated with the estimate.

A minor process involving release of total mercury and methylmercury from littoral sediments is porewater diffusion, the movement of dissolved constituents from sediment porewater to overlying water based on diffusion along a concentration gradient. This process was quantified based on measured concentrations of mercury in porewater from the surface layer (i.e., the top 0 to 4 cm) of sediment and overlying water, an assumed diffusion coefficient, and assuming non-reactive sediment (i.e., no ongoing production of dissolved mercury available for diffusion). Porewater diffusion from littoral sediments accounted for 72 grams of total mercury and two grams of methylmercury entering the epilimnion during the May through September 1992 period.

Profundal Sediments

According to the RI, the main process governing the release of total mercury from profundal sediment is methane gas ebullition. Bubbles of methane gas, produced in sediment by bacteria under anoxic conditions, can be released to overlying water in the hypolimnion. These bubbles can carry sediment with them a process termed entrainment. Mercury release from profundal sediments due to methane gas ebullition was not measured in Onondaga Lake. It was estimated in the RI based on two values: 1) the mean total entrained material on a daily basis (attributed to methane gas ebullition) for five stations at the St. Louis River/Interlake/Duluth/Tar site, a Superfund site in Duluth, Minnesota; and 2) an average surface sediment mercury concentration of 10 ppm in Onondaga Lake, based on the top 12 inches (30 cm) of the sediment profile. In addition to entraining particles, methane gas ebullition may also enhance advective and diffusive migration (TAMS, 2002c). Martens *et al*. (1980), Martens and Klump (1980), and Klump and Martens (1981) stated that methane ebullition occurs through “bubble tubes” and that when these tubes are present, the molecular diffusivities of porewater constituents increased by a factor of more than three. Methane gas ebullition is mentioned in the remedial action objectives presented in the RI, and the estimate for mercury released by methane gas ebullition (via particle entrainment) is included in the mass balance presented on Figure 1.37, despite uncertainties associated with the estimate.

Another process involving release of mercury from profundal sediments is porewater diffusion. This process was quantified for littoral sediments based on measured concentrations of mercury in porewater (from the surface layer of profundal sediment) and overlying water, an assumed diffusion coefficient, and assuming non-reactive sediment (i.e., no ongoing production of dissolved mercury that would be available for diffusion). The RI report estimated that porewater diffusion accounted for 43 grams of total mercury and 22 grams of methylmercury entering the hypolimnion during the May to September 1992 period. However, these values may underestimate actual diffusion from profundal sediment because, as stated in the RI, dissolved mercury is continually produced in the surface layer of profundal sediment, and higher concentrations of dissolved mercury probably exist there. The porewater data from the top 0 to 4 cm of sediment are, in effect, averages rather than maximum mercury concentrations for this interval. In any case, diffusion is driven by the porewater concentration in the surface layer of profundal sediments, which have most recently been deposited.

Hypolimnion

Methylmercury production in the hypolimnion is a greater source of methylmercury to the lake than any of the external sources. Methylmercury production is a naturally occurring process by which inorganic mercury is transformed to the potentially toxic and bioaccumulative methylmercury. The process occurs in the hypolimnion of Onondaga Lake, where oxygen is absent. Sulfate-reducing bacteria, which are found in anoxic environments, are primarily responsible for methylmercury production. This production is a function of the concentration of inorganic mercury available for methylation and the metabolic activity of sulfate-reducing bacteria. Factors affecting mercury bioavailability and rates of sulfate-reduction include oxygen, sulfate/sulfide, organic carbon, and temperature. Inorganic mercury in the hypolimnion is supplied by particles that settle through the hypolimnion from the epilimnion, by profundal sediments from which mercury is released by methane gas ebullition, and by diffusion, as discussed above. The sources of mercury to profundal sediments are both external (e.g., tributary discharge) and internal (e.g., resuspension from the ILWD). Net methylmercury production in the hypolimnion accounted for 230 grams of methylmercury during the May to September 1992 period.

Anoxic conditions are not uncommon in stratified lakes such as Onondaga Lake, but the depth and duration of anoxia is exacerbated by the eutrophic conditions of the lake. Because methylmercury production primarily occurs in the absence of oxygen, any factors that contribute to oxygen depletion in the hypolimnion may enhance production of methylmercury (TAMS, 2002c). Once formed in the hypolimnion, methylmercury mixes upward to the epilimnion, where it is taken up by phytoplankton and thereby enters the pelagic food web.

1.6.1.3 Summary of Mercury Transport and Fate

The mercury mass balance clearly identifies the importance of external sources, internal sources, and internal transformations in controlling the concentration and chemical speciation of mercury in lake water and in the surface layer of profundal sediment. Feedback between profundal sediment and overlying water at least partially controls the buildup of mercury in the hypolimnion and the rate of methylmercury production. In addition, the net rate of methylmercury production controls the amount of methylmercury available for uptake into biota (i.e., bioaccumulation). Although some biogeochemical processes are incompletely understood and difficult to quantify, it is clear that external sources, internal sources, and internal transformations directly influence the concentration of mercury in fish from Onondaga Lake.

1.6.2 Transport and Fate of Non-Mercury CPOIs

Like mercury, the transport and fate of non-mercury CPOIs within the lake were addressed in the RI through assessments of sources and sinks. Some of these CPOIs are known to bioaccumulate. In particular, PCBs and PCDD/PCDFs were detected in fish tissue from the lake. As discussed in Subsection 1.4, these bioaccumulative compounds were generally found in Onondaga Lake sediment and were undetected in lake water. The benthic pathway (i.e., sediment to benthic macroinvertebrates to fish) is therefore likely to dominate bioaccumulation of these substances.

Annual balances, rather than May to September 1992 balances, were estimated for non-mercury CPOIs. Data limitations (i.e., lack of analysis for all parameters in all media and numerous undetected values) limited the conclusions of these mass balance analyses. The non-mercury contaminants that were evaluated included metals other than mercury (primarily cadmium, chromium, copper, lead, nickel, and zinc), BTEX, chlorinated benzenes, PCBs, and PCDD/PCDFs. As with mercury, sources (such as tributaries, groundwater, porewater diffusion, and precipitation) and losses/sinks (such as volatilization, outflow, settling) were evaluated.

Quantitative estimates of the annual loading of BTEX and chlorinated benzenes to the lake are provided below, because these contaminants result primarily from sources related to former Honeywell operations.

For metals, tributaries were the largest external sources, and settling to the lake bottom was the largest sink. As with mercury, concentrations of metals in sediment cores from the deep basin are lower near the surface than at depth, indicating that inputs of metals to the lake have decreased over time. Other contaminant loads have probably decreased as well, although data on other contaminants were not collected in these cores.

For BTEX and chlorinated benzenes, the primary identified source is groundwater discharging to the lake between Tributary 5A and Harbor Brook from Willis Avenue and Semet Residue Ponds and the Harbor Brook/Wastebed B sites. When groundwater-related contributions (i.e., the I-690 drain and porewater advection) are included with the groundwater estimate, the total loads of BTEX and chlorinated benzenes attributed to groundwater are 9,590 and 7,352 grams per year, respectively. Chlorinated benzene in the form of NAPL along the lake shoreline in this area may also be contributing chlorinated benzenes to nearshore sediment. During the upwelling investigation (Parsons, 2003a), one location directly adjacent to the eastern end of the causeway (TR02-A) displayed impacted granular fill material from 0 to 10.5 ft (4.6 m) below the sediment surface. Results from the sediment and porewater samples at this location indicated high concentrations of benzene and chlorobenzene, which are most likely related to the DNAPL plume present along the shoreline in this area. Other sources and sinks could not be quantified with confidence due to data limitations. The most likely sinks for these contaminants are volatilization and microbial degradation (for the BTEX and less chlorinated benzenes), and settling to sediment (more highly chlorinated benzenes that are less biodegradable).

For PAHs, the largest identified ongoing sources are groundwater, porewater diffusion, and DNAPL related to former Honeywell operations along the southwest shoreline. Principal component analysis in the RI report (TAMS, 2002c) indicated that PAHs in this area of the lake consist mainly of LPAHs, specifically naphthalene. Based on the predominance of LPAH contamination in sediments closest to the East Flume, the occurrence of the maximum PAH concentrations in sediment off of the East Flume, the presence of a DNAPL (predominantly naphthalene) plume beneath the Wastebed B/Harbor Brook site, and the close match between PAH patterns in sediment from the East Flume and soil and sediment from the Wastebed B/Harbor Brook site, the RI report (TAMS, 2002c) concluded that former Honeywell facilities are the likely source of naphthalene-based PAH contamination in the lake. In addition to former Honeywell facilities, naphthalene at 120 ppm in lake sediment adjacent to near Onondaga Creek is believed to have originated from an onshore source (possibly Oil City) in the local vicinity.

According to Hubbard (1996), there is also a source of PAHs along the southern shore between Ley Creek and Onondaga Creek (i.e., in front of the Oil City area). The principal components analysis (TAMS, 2002c) indicated that sediment samples furthest from the East Flume (i.e., in the vicinity of Ley Creek) had the lowest PAH concentrations, which primarily consisted of HPAHs. The RI report (TAMS, 2002c) suggested that the most likely primary sources of HPAHs to the lake were fuel spills (possibly from historical Oil City operations), the

GM-Inland Fisher Guide site on Ley Creek, and the Niagara Mohawk Erie Boulevard facility. LPAHs tend to volatilize, while HPAHs have a greater tendency to partition to solids and settle to sediment.

For PCBs and PCDD/PCDFs, the overall loading to the lake is relatively small compared to other contaminants; however, potential risks associated with their toxicity and the ability of low concentrations in sediment to bioaccumulate to concentrations of potential concern in biota are significant. The primary ongoing sources of these CPOIs are tributaries, based on the presence of these contaminants in their sediments. Ley Creek (Aroclors 1221, 1242, and 1260) and Onondaga Creek (Aroclor 1260) are most important for PCB loadings, while Ley Creek, Geddes Brook / Ninemile Creek, and the East Flume may be important for PCDD/PCDF loadings. The presence of PCBs (Aroclors 1248 and 1254) in sediment along the causeway near the Willis Avenue site and in front of Harbor Brook suggests that former Honeywell operations may have contributed PCBs to the lake in these areas. The RI concluded that the likely original sources of PCDD/PCDFs to these tributaries were the General Motors-Inland Fisher Guide site to Ley Creek, the LCP Bridge Street site to Geddes Brook / Ninemile Creek, and the Willis Avenue site to the East Flume.

DNAPL currently enters the lake through groundwater and sediment transport in the Harbor Brook/Wastebed B area. Historically, DNAPL may have been commingled with Solvay wastes from former Honeywell operations that entered the lake from the East Flume or adjacent wastebeds. Local deposition in the area of the ILWD is the likely fate of this material, as indicated by the sheens observed when the sediment is disturbed. DNAPL from former Honeywell operations may serve as a secondary source of CPOIs such as chlorinated benzenes to the surrounding sediments and water column.

1.7 BASELINE RISK ASSESSMENTS

The risk assessments developed in conjunction with the RI evaluated the potential for adverse effects to ecological and human health associated with current exposures (and potential future exposures for the human health risk assessment) to chemicals present in Onondaga Lake in the absence of any remedial action. As required, uncertainties were addressed with conservative assumptions and by estimating a range of risks for each chemical of concern. The baseline ecological and human health risk assessments prepared in conjunction with the RI (TAMS, 2002a, b) are summarized in this subsection, with particular emphasis placed on conclusions relevant to this FS. The conceptual site model summarizing the risk assessments is presented on Figure 1.38.

1.7.1 Human Health Risk Assessment

The human health risk assessment evaluated exposure to Onondaga Lake surface water, sediment, and fish. The risk assessment also evaluated exposure to sediment in adjacent wetlands and to soil in the dredge spoils area. The assessment assumed unrestricted recreational use of the lake, including no reduction in fish consumption and no fishing advisories. Exposure pathways included fish consumption and incidental ingestion of and dermal contact with contaminants in sediment (nearshore littoral sediments in the lake and wetland sediment) and in lake surface water.

The calculated risks are summarized in Tables 1.7 and 1.8. For cancer risks, the risk estimates between one in ten thousand (10^{-4}) and one in one million (10^{-6}) are presented. These values refer to excess cancer risk and represent the range between one-in-ten-thousand and one-in-one-million probability that an individual may develop cancer over a 70-year lifespan as a result of the exposure conditions assessed. The NCP indicates that the "10^{-6} (one-in-one-million) risk level shall be used as the point of departure for determining remediation goals." For non-cancer risks, exposure assessment is used to calculate a hazard index. Hazard indices less than or equal to one are unlikely to cause adverse health effects.

Fish consumption was the primary driver for both cancer and non-cancer risk estimates. Risk through this pathway was related primarily to PCBs, PCDD/PCDFs, and methylmercury in fish tissue. Both reasonable maximum exposure (RME) and central tendency (CT) (i.e., typical exposure) cancer risks exceeded one in ten thousand, the upper end of the target risk range. The hazard index for fish consumption exceeded one.

For sediment exposure via incidental ingestion and dermal contact, none of the non-cancer hazards exceeded the target threshold of one, and cancer risks were less than one in ten thousand, except for an older child recreational visitor exposed to sediment in Wetland SYW-6. The RME cancer risk exceeded one in one hundred thousand for recreational visitors exposed to nearshore sediment in the south end of the lake and to sediments in each of the wetlands. RME cancer risks exceeded one in one million for recreational visitors exposed to nearshore sediment in the south and north ends of the lake and in the wetlands, and for a hypothetical construction worker exposed to nearshore sediment in the south end of the lake and in all wetlands except Wetland SYW-10. The CT cancer risk exceeded the midpoint of the target risk range for an older child exposed to sediment in Wetland SYW-6. The CT cancer risk exceeded one in one million for children exposed to nearshore sediment in the south end of the lake and sediment in Wetlands SYW-6, SYW-10, and SYW-12. The CT cancer risk also exceeded one in one million for construction workers exposed to sediment in Wetlands SYW-6 and SYW-19 and for adults exposed to sediment in Wetland SYW-6.

For soil exposure in the dredge spoils area, only the RME cancer risks exceeded one-in-one-million, for recreational visitors exposed to surface soil and for construction workers exposed to subsurface soil. All other cancer risks associated with soil exposure were less than one-in-one-million.

Risks associated with the remaining exposure pathway, surface water, were less than one in one million. All RME and CT risks associated with exposure to surface water were below the one-in-one-million level. In addition, none of the non-cancer hazards exceeded the target threshold hazard index of one.

1.7.2 Baseline Ecological Risk Assessment

The BERA evaluated exposure of ecological receptors to Onondaga Lake surface water, sediment, and fish; tributary mouths (surface water and sediment); and the lake outlet. The assessment also evaluated ecological exposure to Wetlands SYW-6, SYW-10, SYW-12, SYW-19, and the dredge spoils area near the mouth of Ninemile Creek; however, these areas will be further evaluated as part of other Honeywell sites under investigation. The BERA also provided a comprehensive description of the lake ecosystem. Multiple lines of evidence were used to determine if CPOIs or stressors had adversely affected plants and animals associated with the lake. Stressors were defined in the BERA as nutrients (i.e., nitrite, phosphorus, sulfide), calcite, salinity, ammonia, depleted dissolved oxygen (DO), and reduced water transparency. A diagram of the ecological food web in Onondaga Lake, illustrating these plant and animal communities and showing benthic and pelagic pathways within the lake, is presented on Figure 1.39.

In addition to the factors discussed in the BERA (TAMS, 2002a), the ecological conditions of Onondaga Lake are strongly influenced by the eutrophic state of the lake and conditions common to other lakes in the region. Low DO concentrations in summer, low water clarity, and high nutrient concentrations are functions of existing discharges to the lake and adversely affect all major groups of aquatic organisms. The lake is also affected by historical and ongoing ionic discharges from former Honeywell operations as well as high background concentrations of calcite (due to its location in the limestone belt). These factors have contributed to the formation of a marl bench in the nearshore areas of the lake, the presence of oncolites, and the resulting unstable, resuspendable sediments in parts of the lake. The BERA concluded that resuspendable sediments (including oncolites) might adversely affect macrophyte colonization. Both macrophyte cover and biomass showed negative trends against calcium carbonate. The salinity of the lake water is relatively high, as discussed in Subsection 1.3.4, reflecting the naturally saline groundwater in the area and historical discharges.

The BERA evaluated the health of the many ecological receptors in and around Onondaga Lake, finding that all receptors are at potential risk due to exposure to contaminants and stressors, such as ionic waste. Evaluations included comparison of contaminant concentrations in site media (e.g., water, sediment, soil, fish) to screening guidelines and modeling of food webs to predict exposures for birds and mammals. In addition, field observations were reviewed, where appropriate. CPOIs were identified in water, sediment, soil, and plants based on this initial screening against guidelines. The results of the screening for water, sediment, soil, and plants are presented in Table 1.9. Hazard quotients were calculated for fish, birds, and mammals by comparing measured (fish) or modeled (birds and mammals) CPOI tissue concentrations in tissue to toxicity reference values (TRVs). These hazard quotients for fish, birds, and mammals are summarized in Table 1.10. A summary of the risk characterization for each receptor is provided below.

Aquatic Macrophytes, Phytoplankton, Zooplankton, Terrestrial Plants

Reduced densities of macrophytes found in parts of the lake may result from stress of eutrophic conditions (i.e., low water transparency) as well as wind/wave action, unstable calcitic sediments, oncolites, and chemicals. The BERA determined that phytoplankton and zooplankton communities were adversely impacted by chemicals and/or stressors in lake water (TAMS, 2002a). In addition, phytoplankton and zooplankton serve as food sources for invertebrates, fish, and wildlife and may pass bioaccumulative chemicals such as mercury through the food chain. For terrestrial plants in the wetlands and dredge spoils area, mercury and chromium concentrations may be high enough to adversely impact the plant community and, subsequently, invertebrates and wildlife that live or forage in these areas.

Benthic Macroinvertebrates

The diversity of the benthic macroinvertebrate community was impaired throughout the littoral areas (defined as less than 5m (16 ft) water depth in Section 8 of the RI report [TAMS, 2002c]) of the lake. Sediment toxicity test results indicated that the most toxic sediments (as measured by increased mortality and reduced growth and fecundity) were located in the nearshore sediments in the southern part of the lake, between Tributary 5A and Ley Creek, including the ILWD. Most of the moderately and severely impacted stations were located between Tributary 5A and Ley Creek; the most severely impacted stations were located between Tributary 5A and Onondaga Creek (Appendix M, habitat issues).

Using the results of the sediment toxicity tests, the BERA (TAMS, 2002a) developed five kinds of site-specific sediment effect concentrations (SECs) similar in concept to those previously published in the scientific literature. The various SECs can be defined as representing three different thresholds for predicting the presence of toxic effects as follows:

- Effects range–low (ER-L) and threshold effect level (TEL): Concentrations *below which* toxic effects are predicted to *rarely occur*;
- Effects range–median (ER-M) and probable effect level (PEL): Concentrations *above which* toxic effects are predicted to *frequently (but not always) occur*; and
- Apparent effects threshold (AET): Threshold *above which* toxic effects are predicted to *always occur.*

These SECs were based on the mortality results for the chironomid sediment toxicity test in 1992, which were evaluated at 79 stations in Onondaga Lake and five stations in Otisco Lake (the reference lake). Although information was also collected on chironomid biomass and amphipod mortality and biomass at the 79 stations, NYSDEC used chironomid mortality to develop the SECs because it was the most sensitive endpoint (i.e., it identified the largest number of stations with significant effects). Significant effects ($P \leq 0.05$ comparison-wise) were determined by statistical comparisons with the results from one of two locations in Otisco Lake, which had chironomid mortalities of 2 percent.

NYSDEC assembled the five SECs for each CPOI and derived a consensus-based probable effect concentration (PEC) for each CPOI by calculating the geometric mean of the five SECs. The PECs for each CPOI, therefore, were based on five individual SECs that were derived using the same database of matching sediment chemistry and sediment toxicity information. The PEC was defined in the BERA as the contaminant concentration above which adverse effects are expected to frequently occur (TAMS, 2002a). The site-specific SECs and PECs for Onondaga Lake are presented in Table 1.11.

Additional analysis was performed during preparation of this FS report to confirm which of the CPOIs identified in the BERA are contributing to the sediment toxicity to benthic macroinvertebrates observed in 1992. To accomplish this, PEC quotients (i.e., the ratio of CPOI concentration to corresponding PEC) were calculated for each CPOI at each sampling station in the 1992 dataset. These PEC quotients were then compared to chironomid mortality results from the 1992 sediment toxicity tests. This analysis is described in greater detail in Appendix J, application of SECs. Twenty-three of the 46 CPOIs in Table 1.11 were identified as having a measurable dose-response relationship with sediment toxicity. Table 1.12 shows the refined list of CPOIs that contribute to sediment toxicity to benthic macroinvertebrates in Onondaga Lake. Occurrence of these CPOIs was discussed previously. In general, the areas of moderate and severe impairment of the benthic community correspond to areas where concentrations of these CPOIs are elevated relative to other areas in the lake.

Fish and Herpetofauna

The fish of Onondaga Lake exhibited community diversity similar to other New York lakes, but most species do not reproduce in the lake. The fish community appears to be stressed by eutrophic conditions (i.e., low DO concentrations, high ammonia), altered forage bases (i.e., zooplankton and benthos), reduced macrophyte densities (i.e., feeding and nursery areas), unstable calcitic sediments, oncolites, ionic waste, and contaminants. During summer stratification, fish are limited to the epilimnion, where DO concentrations are sufficiently high.

Concentrations of CPOIs in fish tissue were compared to literature-derived TRVs to determine hazard quotients for each CPOI. Four sets of hazard quotients were developed for each fish species based on the 95 percent upper confidence limit (UCL) on the mean of the measured concentrations and the mean of the measured concentrations. The four hazard quotients were as follows: 95 percent UCL no-observed-adverse-effect level (NOAEL), mean NOAEL, 95 percent UCL lowest-observed-adverse-effect level (LOAEL), and mean LOAEL. The LOAEL represents the lowest CPOI concentration shown to produce adverse effects on specific receptors exposed to a range of doses. In contrast, the NOAEL is the highest CPOI concentration shown to produce no adverse effects on specific receptors exposed to a range of doses. The NOAEL is often derived by dividing the LOAEL by a factor of 10.

As shown in Table 1.10, some fish are at risk from CPOIs in lake media (i.e., water, sediment, and prey organisms), based on measured tissue concentrations and hazard quotients that exceed 1.0. The CPOIs with hazard quotients equal to or greater than 1.0 for the mean and/or 95 percent UCL LOAEL are arsenic, chromium, mercury, methylmercury, selenium, vanadium, zinc, and PCDD/PCDFs.

The herpetofauna communities (reptiles and amphibians) are underrepresented or absent around the lake. The stressors are unknown but may include ionic waste, salinity, CPOIs, and habitat alterations.

Birds and Mammals

Concentrations of CPOIs in bird and mammal tissue were estimated using food web models based on measured CPOI concentrations in sediment, soil, water, and fish (as appropriate) and then compared to literature-derived TRVs to determine hazard quotients for each CPOI. Four sets of hazard quotients were developed, consistent with the assessment of risk to fish. As shown in Table 1.10, birds and mammals are at risk from contaminants in lake media (i.e., water, sediment, soil, and fish) based on hazard quotients that equal or exceed 1.0. For insectivorous/benthivorous birds (i.e., tree swallow, mallard), the CPOIs with hazard quotients equal to or greater than 1.0 for the mean and/or 95 percent UCL LOAEL are barium, chromium, mercury, methylmercury, selenium, and PAHs. These risk estimates were based on modeled CPOI concentrations in insects and benthic macroinvertebrates. For piscivorous birds (i.e., belted kingfisher, great blue heron, osprey), the CPOIs with hazard quotients equal to or greater than 1.0 for the mean and/or 95 percent UCL LOAEL are methylmercury, PAHs, DDT, and PCBs. These risk estimates were based on measured CPOI concentrations in fish tissue.

For piscivorous/benthivorous mammals (i.e., mink, river otter), CPOIs with hazard quotients equal to or greater than 1.0 for the mean and/or 95 percent UCL LOAEL include methylmercury, DDT, PAHs, PCBs, and PCDD/PCDFs. For the little brown bat, which is exposed to CPOIs through consumption of insects, the following CPOIs had mean and/or 95 percent UCL LOAEL hazard quotients greater than 1.0: barium, chromium, copper, methylmercury, xylenes, PAHs, and PCDD/PCDFs. Preliminary evaluation of potential risks to the short-tailed shrew, which is exposed to CPOIs primarily through consumption of terrestrial invertebrates (i.e., worms) in the wetlands and dredge spoils area, indicated mean and/or 95 percent UCL LOAEL hazard quotients greater than 1.0 for the following CPOIs: cadmium, methylmercury, selenium, hexachlorobenzene, PAHs, dieldrin, and PCDD/PCDFs.

1.7.3 Identification of Key Risk Concerns

Results of the HHRA and BERA provide a comprehensive evaluation of potential risk to human health and the environment associated with Onondaga Lake. The risk estimates range from a lower end (e.g., mean LOAEL for ecological receptors, 1×10^{-6} for cancer risks to humans) to an upper end (e.g., 95 percent UCL NOAEL for ecological receptors, 1×10^{-4} for cancer risks to humans). These risk estimates help to guide risk management decisions and to evaluate remedial alternatives. The presence of multiple CPOIs and exposure pathways in Onondaga Lake complicates the risk management process.

Key risk concerns for humans and ecological receptors are summarized in Tables 1.13 and 1.14. The CPOIs identified in these tables generally pose risk to multiple receptors and result in the highest risk estimates (i.e., mean LOAEL hazard quotients equal to or greater than 1.0). Some CPOIs that pose risk based on the lower end of the risk range but not the upper end (e.g., dichlorobenzenes for the mallard) are not included; however, these CPOIs tend to be co-located in lake sediment with other more prominent CPOIs (see Figures 1.10 through 1.25 and other figures in the RI report [TAMS, 2002c]). Tables 1.13 and 1.14 include the CPOIs identified in the HHRA, BERA and RI as presenting the greatest risk from chemical toxicity (i.e., mercury, chlorinated benzenes, PAHs, PCBs, and PCDD/PCDFs). The preliminary results of the short-tailed shrew risk evaluation are not included. Besides risks related to chemical toxicity, various stressors in the lake (e.g., calcitic sediment, salinity) pose risk to ecological receptors. These stressors are included in Table 1.14 and will be addressed during evaluation of remedial alternatives.

1.8 SUMMARY OF KEY FINDINGS OF THE REMEDIAL INVESTIGATION

Located within a heavily populated and urbanized area, Onondaga Lake is a complex ecosystem that has been influenced by unique natural characteristics and by a long history of industrial and municipal impacts. Understanding the transport and fate of mercury and other CPOIs as well as the potential risk to human health and the environment is therefore critical to development of remedial action alternatives that will achieve the remedial goals of this FS. The following findings are principally based on the key conclusions of the RI (TAMS, 2002c) that were used to develop the preliminary RAOs identified in the RI.

1.8.1 Mercury

- The major external sources of mercury are the tributaries to the lake and the groundwater from the various upland sources associated with former Honeywell operations.
    - Primary external sources of mercury from former Honeywell operations are related to the former LCP Bridge Street Site as it affects Ninemile Creek, and groundwater along the shoreline between Tributary 5A and Harbor Brook.
    - For the remedial actions at Onondaga Lake to be effective, these external sources will need to be remediated under separate, ongoing programs.
- The major internal sources of mercury are the ILWD, other littoral sediments, and profundal sediments.
    - The ultimate fate of mercury that enters the lake water from tributaries, groundwater, and the ILWD is deposition to profundal sediment.
    - Mercury is released from profundal sediment to the hypolimnetic water column. The likely mechanism is methane gas ebullition with its associated particle resuspension and increased diffusion.
- Methylmercury production occurring in the anoxic hypolimnion is a key internal process controlling methylmercury concentrations in the hypolimnion and in biota via upward diffusion to the epilimnion.

    - Any factors that exacerbate oxygen depletion during stratification would increase methylmercury production in the hypolimnion.

1.8.2 Other CPOIs

- Groundwater and DNAPL releases from the several upland sources associated with former Honeywell operations are major external sources of organic CPOIs such as chlorobenzenes, BTEX, and PAHs.
- The ILWD is believed to be an internal source of organic CPOIs such as chlorobenzenes, BTEX, PAHs, PCBs, and PCDD/PCDFs.
- CPOIs from sources unrelated to former Honeywell operations include BTEX, PAHs, PCBs, PCDD/PCDFs, cadmium, chromium, and lead.

1.8.3 Human Health and Ecological Risk Concerns

Sediment, fish tissue, and water are the primary media in Onondaga Lake that pose risk to humans and ecological receptors. Potential risk is direct (e.g., contact with or ingestion of sediment or water) and indirect (e.g., sediments release CPOIs to water, CPOIs in water are accumulated by fish, fish are consumed by humans and wildlife). These risks are summarized as follows:

- Sediment containing CPOIs poses direct risks to humans, benthic macroinvertebrates, fish, and wildlife as well as indirect risks to humans, aquatic organisms, fish, and wildlife through bioaccumulation.
    - Sediment exposure poses cancer risks above one-in-one-hundred thousand (10^{-5}) based on reasonable maximum exposure for recreational visitors due to incidental ingestion of and dermal contact with surface sediment in the southern basin and Wetlands SYW-6 and SYW-12. Primary chemicals posing risk are as follows:
        - South basin sediments: arsenic, hexachlorobenzene, PAHs, and PCDD/PCDFs
        - Wetland sediments: PAHs (both wetlands), arsenic (Wetland SYW-6)
    - The most toxic sediments for benthic macroinvertebrates (as determined by sediment toxicity testing) and the most severely impaired benthic communities are located in the nearshore zone in the southern part of the lake between Tributary 5A and Ley Creek.
    - Finally, oncolites and calcitic sediments may pose an indirect risk to wildlife by impacting macrophyte colonization and fish spawning.
- Fish containing CPOIs pose risk to humans and wildlife that consume them. In addition, CPOIs in fish tissue exceed TRVs, indicating potential risk to fish themselves.
    - The primary chemicals posing risk to humans by fish consumption are arsenic (cancer), PCDD/PCDFs (cancer), PCBs (non-cancer and cancer), and mercury (non-cancer).

  - The primary chemicals contributing to risk due to fish consumption by wildlife are methylmercury, DDT, and PCBs.
- Lake water poses direct risk to aquatic organisms and indirect risk to humans and wildlife that consume fish.
  - Bioaccumulation of methylmercury from water into fish tissue results in potential risk to humans and wildlife that consume fish.

Stressors such as nutrients, calcite, salinity, and reduced water transparency may adversely impact ecological communities in the lake.

SECTION 1

TABLES

SECTION 1

FIGURES

SECTION 2

DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS

2.1 INTRODUCTION

In accordance with the NCP, Section 2 develops the PRGs that will be used to evaluate the various remedial alternatives presented in Section 4 of the FS. The PRGs will be developed to address each RAO identified in the RI (TAMS, 2002c).

For this FS, Onondaga Lake has been divided into nine SMUs. Subsection 2.2 identifies the location of these SMUs, and provides a brief rationale for their individual designations. Subsection 2.3 identifies the ARARs, which consist of federal and state statutes and regulations. Subsection 2.4 briefly summarizes the RAOs identified in the RI (TAMS, 2002c). In Subsection 2.5, the ARARs and RAOs are used to develop PRGs in accordance with the NCP. The PRGs developed in Section 2 are quantitative (e.g., SECs, surface water quality standards), but will be used in conjunction with other non-quantitative criteria (e.g., habitat enhancement, improvement of recreation use) to evaluate remedial alternatives in Section 4. Subsection 2.6 describes a method(s) for achieving the PRGs by applying a range of SECs identified in Section 1 through the use of the mean probable effect concentration quotient (PECQ). Subsection 2.7 identifies the areas and volumes associated with the applicable SECs. A short summary of Section 2 is presented in Subsection 2.8.

2.2 SEDIMENT MANAGEMENT UNITS

For this FS, Onondaga Lake has been divided into eight SMUs, based on the following criteria: water depth, sources of water entering the lake, and ecological and chemical risk drivers. Table 2.1 presents a summary of the rationale for the selection of each SMU. The division of Onondaga Lake into SMUs allows the development and evaluation of remedial alternatives appropriate to each area. The remedial alternatives evaluated for each SMU are then used in combination to develop a comprehensive, lake-wide solution benefiting humans and the environment through improved habitat and recreational use of the lake.

The eight SMUs used throughout the remainder of this FS are listed below:

- SMU 1: ILWD
- SMU 2: Causeway
- SMU 3: Wastebeds 1 through 8
- SMU 4: Mouth of Ninemile Creek
- SMU 5: Northern Shore
- SMU 6: Ley Creek to 700 ft south of Onondaga Creek
- SMU 7: 700 ft south of Onondaga Creek to the ILWD
- SMU 8: Profundal Area

SMUs 1 to 7 are located in the littoral zone of the lake (i.e., in water depths of 0 to 30 ft [9 m]) and SMU 8 is located in the profundal zone (i.e., in water depths greater than 30 ft [9 m]). Figure 2.1 identifies the locations of each of the SMUs. A more detailed physical, ecological, and chemical characterization (including presence of non-aqueous phase liquid, debris, geology, geotechnology, habitat characteristics, and chemical concentrations) of each SMU can be found in Appendix B, SMUs. Appendix M, habitat issues, presents a description of habitat conditions in each SMU.

Table 2.2 presents a summary of the risk concerns and associated CPOIs and stressors for each SMU (identification of risk concerns for each SMU was based on information in the RI and risk assessments). Where specific CPOIs are identified as risk drivers for various exposure pathways, or ecological risks, the rationale for their inclusion is footnoted in Table 2.2. The SMUs are carried forward throughout this FS to allow the development and evaluation of remedial alternatives that are most appropriate for the different physical, chemical, and ecological characteristics of each SMU and, subsequently, for the overall lake-wide ecosystem.

2.3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The remediation of Onondaga Lake is subject to federal and state environmental statutes and regulations in accordance with the CERCLA process for determining ARARs. Section 121(d)(1) of CERCLA generally requires that response actions attain a threshold degree of cleanup that assures protection of human health and the environment. Section 121(d)(2) of CERCLA and its implementing regulations in the NCP further require that response actions meet the threshold criteria of compliance with federal ARARs as well as state ARARs identified consistent with the NCP requirements (unless an ARAR waiver becomes necessary). In addition, unpromulgated advisories, criteria, or guidance (known as TBCs) may be considered in connection with the selection of CERCLA remedies. The NCP allows the identification of TBCs by the lead and support agencies.

Three categories of potential federal and state ARARs and TBCs were considered for possible utilization at this site: (1) chemical-specific, (2) location-specific, and (3) action-specific. For each of these categories, NYSDEC lists recommended ARARs and TBCs for use in the remediation of Onondaga Lake in Section 9 of the RI (TAMS, 2002c).

Appendix C, ARARs and TBCs, summarizes all of the recommended ARARs and TBCs for Onondaga Lake, with several additional TBCs, and provides discussion and analysis of each. Subsection C.2 and Tables C.1 through C.6 describe each ARAR and TBC. Subsection C.3 lists the ARARs and TBCs specifically for each alternative evaluated in the FS. Subsection C.4 lists the ARARs and TBCs for the recommended alternative. All NYSDEC-recommended TBCs for appropriate consideration in connection with the site were included as TBCs, and were considered in connection with the FS. For this ARAR analysis, the FS followed the NCP, the preamble to the NCP, 46 Fed. Reg. 8665 (Mar. 8, 1990), and USEPA guidance (USEPA, 1991a).

One of the quantitative PRGs presented in Subsection 2.5 is based on chemical-specific ARARS for surface water in 6 NYCRR Parts 608 and 700 through 706. The water quality standards presented in 6 NYCRR Part 703 are based on protection of human health, aquatic life, aesthetics, potable use, and fish consumption by humans and wildlife. Accordingly, achievement of these standards would provide improved habitat and recreational use of the lake.

2.4 REMEDIAL ACTION OBJECTIVES

The preliminary RAOs developed in the RI (TAMS, 2002c) are based on site-specific information as summarized in Section 1, including the nature and extent of CPOIs, the transport and fate of mercury and other CPOIs, and the baseline human health and ecological risk assessments. The RAOs are focused on controlling CPOIs within the lake, as well as addressing ecological and human health risk and surface water quality. The RAOs addressed in this FS are consistent with the preliminary RAOs developed in the RI, and are as follows:

- RAO 1: To eliminate or reduce, to the extent practicable, methylation of mercury in the hypolimnion.
- RAO 2: To eliminate or reduce, to the extent practicable, releases of contaminants from the ILWD and other littoral areas around the lake.
- RAO 3: To eliminate or reduce, to the extent practicable, releases of mercury from profundal sediments.
- RAO 4: To eliminate or reduce, to the extent practicable, existing and potential future adverse ecological effects on fish and wildlife resources, and potential risks to humans.
- RAO 5: To achieve surface water quality standards, to the extent practicable, associated with CPOIs.

The following subsection describes the development of PRGs based on the RAOs listed above.

2.5 PRELIMINARY REMEDIATION GOALS

The NCP requires the establishment of PRGs that can be used to select applicable remediation technologies and to develop remedial alternatives in an FS. The PRGs represent the primary goals of the remedial efforts, and can provide a range of quantitative values to be used during the evaluation of the various remedial alternatives. The ability of various remedial alternatives to actually achieve the PRGs was not a factor in their development; the effectiveness of various remedial alternatives will be evaluated in Section 4 of this FS.

For this FS, PRGs were developed to address each of the five RAOs through the application of a variety of quantitative measures. Onondaga Lake contains three primary media that have been impacted by CPOIs: sediments, fish tissue, and surface water. Table 2.3 presents the risk concern (e.g., human and wildlife exposure, benthic macroinvertebrate exposure) associated with each RAO due to impacts on these media, and demonstrates how these risks are addressed by each PRG. Three PRGs have been developed and are discussed below, each addressing one of the affected media. The first PRG addresses sediment toxicity and the associated release of CPOIs from profundal and littoral surface sediments in the lake. The second PRG addresses CPOI concentrations in fish tissue. The third PRG addresses surface water contamination. Each PRG is presented below, along with a discussion of how the PRG addresses the RAOs.

2.5.1 PRG 1: Reduce, Contain, or Control CPOIs in Profundal and Littoral Sediments by Achieving Applicable and Appropriate SECs, to the Extent Practicable.

As described in Section 1, NYSDEC developed five site-specific SECs (ER-L, TEL, ER-M, PEL, and AET) and a consensus-based PEC by calculating the geometric mean of the five SECs. The ER-L, PEC, and AET, which are representative of the range of SECs (with the ER-L typically representing the lowest value and the AET typically representing the highest value of the three), were used to develop the PRGs presented in this section. Table 2.4 includes the focused list of CPOIs, previously presented in Section 1, which will be carried forward in this FS.

The SECs were derived from testing the toxicity of lake sediments to benthic macroinvertebrates in the laboratory (i.e., statistical analyses were performed to match chemical concentrations and toxicity data from the same samples). Because these guidelines were derived from data generated during toxicity tests of benthic macroinvertebrates, they can be used, in turn, to estimate the chemical concentrations that should represent either relatively low or relatively high risks of adverse biological effects among these organisms.

In addition to SECs, which pertain to sediment toxicity to benthic macroinvertebrates, a bioaccumulation-based sediment quality value (BSQV) for mercury in sediment was developed in Appendix I, implementation and residual risk. The BSQV was developed from a biota-sediment accumulation factor (BSAF) based on mercury concentrations in fish tissue and sediment in the lake. The BSQV will be used in Appendix I to evaluate the efficiency of the lake-wide remedial alternatives in meeting PRG 1.

PRG 1 addresses RAOs 1 through 4 to various degrees, depending on the RAO. RAO 1 is to eliminate or reduce, to the extent practicable, methylation of mercury in the hypolimnion. Methylation of mercury in the hypolimnion is influenced by two primary factors: anoxic conditions and the availability of mercury for methylation. First, by reducing mercury concentrations in the littoral areas to achieve a specific SEC value, PRG 1 reduces the amount of mercury that may be resuspended from littoral areas and sink to the hypolimnion. Second, by reducing mercury concentrations in the surface profundal sediments to achieve a specific SEC value, PRG 1 reduces the amount of mercury available for release from profundal sediments into the hypolimnion. The reduction in the amount of mercury released from littoral and profundal sediments into the hypolimnion would, in turn, reduce methylation of mercury in the hypolimnion. The extent to which this process takes place will be evaluated for a variety of remedial alternatives in Section 4.

RAO 2 is to eliminate or reduce, to the extent practicable, releases of contaminants from the ILWD and other littoral areas around the lake. As discussed in the RI, the main process governing release of mercury from the ILWD and other littoral areas is wind-driven resuspension. Other CPOIs are also released from littoral areas as sediments are resuspended by wind and waves. Reducing, containing, or controlling CPOIs in littoral surface sediments (using the range of SECs as defined above) would limit the amount of CPOIs available for release when surface sediments are resuspended. Therefore, PRG 1 addresses RAO 2 directly by reducing releases of CPOIs from the littoral sediments.

RAO 3 is to eliminate or reduce, to the extent practicable, releases of mercury from profundal sediments. Profundal sediments are the ultimate sink for all solids that enter the lake. The profundal area receives settling solids that have been resuspended and transported from littoral sediments into the hypolimnion, as well as organic matter that is produced in the lake (i.e., phytoplankton biomass) and settles into the hypolimnion. Reducing, containing, or controlling mercury concentrations in profundal sediments would limit the amount of mercury available for release into the lake through methane gas ebullition or diffusion. Therefore, PRG 1 addresses RAO 3 directly by reducing releases of mercury from the profundal sediments. In addition, as discussed above, littoral sediments are frequently resuspended and carried to the profundal zone, where they are deposited. PRG 1 reduces releases of CPOIs, including mercury, from the littoral sediments, thereby reducing mercury concentrations in sediments that are deposited in the profundal zone. Reducing the concentration of mercury deposited in surface profundal sediments addresses RAO 3 by reducing the amount of mercury available for release from profundal sediments.

RAO 4 is to eliminate or reduce, to the extent practicable, existing and potential future adverse ecological effects on fish and wildlife resources and potential risks to humans. The range of SECs defined above was developed by NYSDEC specifically on the basis of ecological data (using chironomid mortality results of sediment toxicity testing). Therefore, PRG 1 would directly reduce adverse ecological effects (specifically, toxicity to benthic macroinvertebrates) by limiting profundal and littoral surface sediment concentrations to the SECs. Reductions of CPOI concentrations in surface sediment would reduce adverse effects associated with direct exposure of humans, fish, and wildlife to sediment as well as adverse effects associated with bioaccumulation of CPOIs from sediment. In addition, reductions of mercury concentrations in surface sediment would reduce the amount of mercury released to the water column, thereby reducing mercury methylation in the hypolimnion. This, in turn, would make CPOIs less available for uptake by lake biota and would ultimately reduce potential risks to fish, wildlife, and humans. Mercury, in particular, would be less available for methylation in the hypolimnion, and would therefore be less likely to bioaccumulate within fish and, ultimately, humans and wildlife that consume fish.

RAO 5 is to achieve surface water quality standards, to the extent practicable, associated with CPOIs. Reducing the concentrations of CPOIs in surface sediment would reduce the mass of CPOIs available for resuspension or dissolution into surface water, thereby providing a means for reducing surface water concentrations of CPOIs.

2.5.2 PRG 2: Achieve CPOI Concentrations in Fish Tissue That Are Protective of Humans and Wildlife That Consume Fish, to the Extent Practicable.

PRG 2 addresses primarily RAO 4, which is to eliminate or reduce, to the extent practicable, existing and potential future adverse ecological effects on wildlife resources and potential risks to humans. The BERA and HHRA identified several CPOIs and associated pathways of concern related to fish consumption in Onondaga Lake (TAMS 2002a, b). Quantitative target concentration ranges for each of these CPOIs in fish tissue have therefore been developed that address each of the following two exposure pathways identified in the BERA and HHRA:

1. **Consumption of fish by wildlife.** The BERA identified fish consumption as a pathway of concern for wildlife: Target concentration ranges for fish tissue have been developed for mercury and PCBs (see Appendix G, fish tissue goals). The calculated fish tissue target concentration ranges are included in Table 2.5.
2. **Consumption of fish by humans.** The HHRA identified fish consumption as the pathway with the highest risk estimates for human health. Accordingly, target concentration ranges for fish tissue have been developed for mercury, PCBs, and PCDD/PCDFs. A more detailed description of the development of these target concentration ranges is included in Appendix G, fish tissue goals. The calculated fish tissue target concentration ranges are included in Table 2.5.

These quantitative ranges for the relevant CPOIs (Table 2.5), in addition to the BSQV developed for mercury, will be used in Appendix I, implementation and residual risk, to evaluate the efficiency of the lake-wide remedial alternatives in meeting PRG 2, and ultimately in achieving RAO 4, eliminating or reducing, to the extent practicable, existing and potential future adverse ecological effects due to wildlife and humans due to the consumption of fish.

2.5.3 PRG 3: Achieve Surface Water Quality Standards, to the Extent Practicable, Associated with CPOIs.

This PRG directly addresses RAO 5, which is to achieve surface water quality standards, to the extent practicable, associated with chemical parameters of interest. State surface water quality standards have been promulgated for several CPOIs detected in Onondaga Lake, including mercury and chlorobenzene. Data presented in the RI indicate that only mercury consistently exceeds surface water quality standards, specifically the standard for protection of wildlife (i.e., 2.6 ppt [equivalent to 2.6 ng/L, or 0.0000026 mg/L] dissolved mercury) and the standard for protection of human health [via fish consumption] (i.e., 0.7 ppt or 0.0000007 mg/L dissolved mercury). These two standards are considered to be protective of wildlife and humans exposed to mercury via fish consumption. They therefore take into account bioaccumulation of mercury from water into fish tissue.

Data presented in the RI indicate that other CPOIs generally met the surface water quality standards; however, PRG 3 addresses achieving water quality standards, to the extent practicable, associated with all CPOIs.

2.5.4 Other Goals

Although this section has focused on quantitative goals consistent with each of the three PRGs discussed above, there exist other non-quantitative remedial goals that will also be evaluated, as appropriate, throughout the remainder of this FS. For example, stressors of concern (e.g., oncolites and calcitic sediments) are not directly addressed by the quantitative goals listed above. However, such stressors are addressed by the remedial alternatives in this FS report.

Since it is the overarching goal of this FS to recommend a remedy that will result in the best lake-wide solution for humans and the environment, this FS has not been limited to the evaluation of only the quantitative goals associated with the PRGs. Instead, more qualitative goals, including habitat enhancement and improving conditions for recreational use of the lake, will also be considered when evaluating remedial alternatives.

Some specific examples of qualitative criteria that are used to evaluate the various remedial alternatives include:

- Habitat enhancement resulting in increased macrophyte coverage and diversity;
- Habitat enhancement resulting in improved spawning areas for fish;
- Habitat enhancement resulting in greater diversity of fish species in the lake;
- Habitat enhancement for fish-eating wildlife in and around the lake;
- Improved lake conditions for recreational fishing; and
- Improved lake conditions for recreational boating.

All of the above qualitative criteria are considered in addition to the quantitative PRGs when evaluating and recommending an optimal lake-wide remedial alternative for Onondaga Lake.

2.6 METHOD(S) FOR DETERMINING EXTENT OF POTENTIAL REMEDIATION

Given the three media-based PRGs described above, this section details how these PRGs are used to develop preliminary areas and volumes that may require remediation. These areas and volumes will be used as a basis for analysis in Sections 4 and 5 of this FS.

The PRG that is most directly applicable to the development of areas of sediment that may require remediation is PRG 1: Reduce, contain, or control CPOIs in profundal and littoral sediments by achieving applicable and appropriate SECs, to the extent practicable. Comparing the SECs referenced in this PRG to site-specific sediment data offers a direct and quantifiable way to determine areas of sediment that may require remediation. The specific manner in which this analysis is completed is detailed later in this section.

PRGs 2 and 3 address CPOIs in fish tissue and surface water quality standards, respectively. These PRGs, although very relevant to measuring the ultimate effectiveness of the remediation, are less directly applicable to the development of preliminary areas and volumes of sediment to be considered for remediation. Fish tissue concentrations of mercury and surface water concentrations of CPOIs are indirectly affected by contaminated sediments. The extent to which remedial alternatives for sediment impact CPOI concentrations in fish tissue and water is evaluated through residual risk analysis in Appendix I, risk of remedy.

2.6.1 Use of the SECs

For this FS, three of the SECs developed in the BERA have been identified as representative of the entire range of SECs that should be used to evaluate areas and volumes of impacted sediment to be considered for remediation: the ER-L, the PEC, and the AET. Accordingly, these SECs are used in Section 4, development and evaluation of remedial alternatives, for the evaluations noted above. The ER-L and PEC are also used in Section 5, development and evaluation of lake-wide alternatives.

The method(s) used in applying the SECs to lake sediments in determining areas and volumes for remediation merits further discussion. Applying the SECs on an individual basis for each CPOI in Onondaga Lake can result in areas and volumes that do not fully account for the relative concentration of chemicals, the presence of chemicals in various mixtures, and their additive effects. For example, individual exceedances of specific SECs at a given location within the lake may not be associated with measurable toxicity at that same location.

This can be addressed and/or overcome by using a single index of sediment quality that integrates the information provided by the individual SECs. A single chemical index provides a uniform, consistent basis for classifying sediment quality throughout a water body. If calibrated against measures of biological effects, such an index retains the toxicological relevance on which the underlying SECs were derived.

An integrative index, known as the mean PECQ, provides a consistent basis for classifying sediment quality and accounts for chemical additivity. The mean PECQ (as described by MacDonald *et al*., 2000) has been defined below, and in more detail in Appendix J, SECs. The mean PECQ is an appropriate means for providing a holistic application of the Onondaga Lake SECs to develop potential areas and volumes to be remediated. As such, the mean PECQ can be considered an alternative SEC by which potential remedial strategies may be evaluated. Appendix J, SECs, contains a more detailed discussion of the technical basis for using the mean PECQ approach.

2.6.2 Use of the Mean PECQ

The benefits of including the mean PECQ approach (as described by MacDonald *et al*., 2000) as an alternative SEC include the following:

- It condenses information on numerous CPOIs into a single index of relative risk that can be used quantitatively to rank stations and contour areas that may warrant different kinds of potential remedial actions;
- It can be used to estimate which CPOIs pose the highest degree of risk at individual stations, and thereby help guide remedial decisions;
- It can be related to site-specific biological effects, so that its toxicological meaning can be determined empirically;
- It has been used in the published literature and therefore has been peer reviewed, enhancing its credibility; and

- The mean PECQ approach recognizes that remedial actions are developed and implemented to reduce the overall risks of the mixtures of chemicals, not for multiple chemicals individually.

The PECQ for a given CPOI is calculated as the concentration of that CPOI in a given location within the lake divided by the PEC value associated with that CPOI. The mean PECQ is then calculated by summing the individual PECs quotients at a given station and then dividing by the total number of quotients calculated at the station. For example, in a simplified hypothetical case where only five CPOIs are present at a station and PECQs of 1.0, 2.0, 3.0, 4.0 and 5.0 were calculated for the five chemicals, the mean PECQ for the station would be the sum of the five individual PECQs (i.e., 1.0 + 2.0 + 3.0 + 4.0 + 5.0 = 15) divided by the total number of PECQs calculated at the station (i.e., 5), resulting in a mean PECQ of 3.0 (i.e., 15/5) for the overall station.

The mean PECQ for each station in Onondaga Lake is considered an index of the relative risk of sediment toxicity posed at that station by the full suite of CPOIs evaluated at the station. Mean PECQs can therefore be used to rank various stations with respect to relative risk and thereby to prioritize stations for various kinds of potential remedial actions. In addition to ranking various stations with respect to relative risk, by contouring the PECQs, mean PECQs can quantitatively delineate the areal extent of sediments with different degrees of risk.

The mean PECQ approach was applied using data collected from surface sediments in Onondaga Lake in 1992 (i.e., 0 to 2 cm) and 2000 (i.e., 0 to 15 cm). Because the SECs were originally derived from toxicological testing of benthic macroinvertebrates in the biologically active zone (surface sediments), the application of the mean PECQ is most appropriate for these surface sediments. This point will be addressed again when the potential volume of contaminated sediments is considered, both in Subsection 2.7 (Areas and Volumes) and in Section 4.

The mean PECQs calculated for Onondaga Lake were biologically calibrated with benthic macroinvertebrate mortality results from sediment toxicity tests conducted during the RI. A detailed description of the calibration process is presented in Appendix J, SECs. During calibration, the list of CPOIs was further refined by omitting contaminants for which no response (i.e., chironomid mortality) was found as concentration increased. Table 2.4 shows the 23 CPOIs for which areas and volumes and mean PECQs were calculated.

The analysis presented in Appendix J provides a rationale for selecting critical mean PECQ values for use in the FS. These critical values are based on the exposure/response relationship determined empirically with the lake-wide database. Such critical values would be both predictive of toxic effects to benthic macroinvertebrates when exceeded and protective of such effects when not exceeded. As discussed in Appendix J, sediments having mean PECQs greater than one to two were identified as posing potential ecological risks with respect to sediment toxicity. Both mean PECQ values of one and two are used in the following section to define areas and volumes of sediment that may require remediation.

2.7 AREAS AND VOLUMES

Consistent with CERCLA guidance, this subsection develops the areas and volumes that may require remediation based on the PRGs established in Subsection 2.5 and the application of the SEC values discussed in Subsection 2.6. Areas and volumes are developed for each SMU defined in Subsection 2.2. These areas and volumes will be used to guide the development and screening of remedial technologies in Section 3, and in the development, screening, and detailed evaluation of remedial alternatives for each SMU in Section 4.

2.7.1 Areal Extent

As the ER-L, PEC, and AET have been determined to be representative of the range of SECs developed by the NYSDEC, Table 2.6 and Figures 2.2 through 2.4 show the areal extent of sediments to be considered for remediation based on exceedances of these same three SECs for the 23 CPOIs listed in Table 2.4. Because of the limitations of the application of individual SECs to determine the cumulative degree of toxicity impact (see Subsection 2.6 above), the areal extents of sediments exceeding the mean PECQ1 and mean PECQ2 have been presented in Table 2.6, and on Figures 2.5 and 2.6, respectively. These figures include Station S48, which had a mean PECQ less than one but an observed chironomid mortality of greater than 50 percent in the 1992 toxicity tests.

Because of the relevance of both the mean PECQ (for all CPOIs) and the specific relevance of mercury in Onondaga Lake, both the mean PECQ and the mercury PEC have been used in evaluating potential remedial alternatives throughout the remainder of this FS. Accordingly, Figure 2.7 shows the areal extent of sediments exceeding *either* the mean PECQ1 *or* the mercury PEC (2.2 ppm). Figure 2.8 shows the areal extent of sediments exceeding *either* the mean PECQ2 *or* the mercury PEC. Figures 2.7 and 2.8 include Station S48, as discussed above.

2.7.2 Volumes (Depth)

The existing data set was used to calculate the areal extent of sediments exceeding the relevant SECs and the mean PECQ. Calculating the depth of sediments (volumes) that exceed these same parameters proves more challenging. In general, there were a significant number of data points to a depth of 6.5 ft (2 m). Cores to 26 ft (8 m) were collected less frequently. In some cases, the SECs were exceeded at the deepest extent of the data. Therefore, the estimated volumes shown in Table 2.6 to be considered for remediation are based on the limits of data in each SMU.

Another complicating factor in determining the volume (depth) of sediments to be considered for remediation is that the SECs (and mean PECQ) are based on toxicity data relevant only for benthic macroinvertebrates in the biologically active surficial sediments. The SECs may therefore be less relevant at depths deeper than six inches (15 cm). However, the SECs do provide a quantitative means to identify areas and volumes. Although Table 2.6 provides volumes based on the limits of data in each SMU, this has been done only for the sake of clarity. Other criteria may be more relevant for determining depth of remediation (i.e., improvement of ecological habitat, no net loss of lake surface area, logistical practicability) that will be investigated in more detail in Section 4.

As shown in tables and figures referenced in this section, the entire areas of SMUs 1 and 7 may require remedial action regardless of the SEC used. In SMUs 1 and 7, this is driven by CPOIs in the surface sediments. SMUs 3, 5, and 8 show the greatest variability in areas and volumes, based on the range of SECs, because contamination in these SMUs is generally lower than that present in the other SMUs.

Details regarding development of areas and volumes are provided in Appendix E, areas and volumes, including a discussion regarding how non-detects and background concentrations were considered in developing areas and volumes.

2.8 SUMMARY

This section has described the development of PRGs based on the RAOs identified in the RI, the ARARs listed in Appendix C, ARARs and TBCs, and the site-specific information presented in Section 1. Three media-based PRGs have been developed and will be used to address CPOIs in the various SMUs. PRG 1, which references a range of SECs to be achieved in sediments, was used to develop areas and volumes of sediments to be considered for remediation. In carrying out these calculations, the mean PECQ was used as an appropriate way to holistically compare the entire range of SECs to all of the CPOI concentrations found in Onondaga Lake. The remainder of this FS focuses on the remedial techniques and alternatives that may be used to achieve the PRGs in the various SMUs.

SECTION 2

TABLES

SECTION 2

FIGURES

SECTION 3

IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

3.1 INTRODUCTION

Consistent with state and federal guidance, this FS uses a multi-step evaluation process in identifying a recommended remedial alternative for Onondaga Lake (NYSDEC, 1990; USEPA, 1988). The multi-step process helps to ensure 1) that the full range of potentially applicable and/or available remedial technologies is evaluated, and 2) that an adequate range of technologies is included in developing a manageable set of remedial alternatives for detailed evaluation.

Before proceeding with a description of the evaluation process, it is worthwhile to consider some important definitions of terms that will be used throughout the remainder of this FS:

Remedial Technology – A discreet remedial technique, control method, tool, or process that may be useful for addressing some aspect of remediation at a site. A particular remedial technology may only address one type of contamination, situation, location, or contaminated matrix (e.g., soils, water, air), and therefore may only be useful in combination with other technologies or activities.

General Response Action (GRA) – This is a category or group of remedial technologies or overall processes that have some common element or approach. A GRA usually does not consider specific techniques or methods of application to a particular site.

Remedial Alternative – A comprehensive remediation scenario intended to provide overall remediation of a SMU or the lake. Remedial alternatives consist of combinations of remedial technologies that can be applied to various locations, situations, and/or matrices within the site to provide a comprehensive approach to remediation of the site. The term "alternative" is used because a number of different, alternative approaches to site-wide remediation are normally considered and compared to each other in the FS evaluation process.

The evaluation of remedial technologies and alternatives for this FS follows *Technical and Administrative Guidance Memorandum #4030: Selection of Remedial Actions at Inactive Hazardous Waste Sites* (NYSDEC, 1990) and *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* (USEPA, 1988). These two processes are very similar, and the NYSDEC guidance is consistent with much of the USEPA CERCLA guidance.

The overall evaluation process for this FS, which draws from these two documents, consists of the following steps:

1. Develop RAOs and PRGs;
2. Identify areas and volumes of media that require remedial action;
3. Develop GRAs;
4. Identify and screen remedial technologies to eliminate those that cannot be implemented technically;
5. Assemble the representative remedial technologies into appropriate remedial alternatives;
6. Conduct preliminary screening of remedial alternatives; and
7. Perform detailed analysis of remedial alternatives.

Steps 1 and 2 are described in Subsections 2.3 (RAOs) and 2.4 (areas and volumes by SMU), respectively. Step 3 is discussed in Subsection 3.3, with each subsection addressing a different GRA. Within each GRA subsection, specific remedial technologies are identified and described for that GRA. These technologies are screened in Subsection 3.4 on a site-wide basis and then on a SMU basis in 3.5, resulting in a list of technologies that warrant further evaluation for each SMU. Steps 5, 6, and 7 are presented in Section 4.

The screening methods for Step 4 are described in detail in Subsections 3.4 and 3.5. In summary, screening follows the process identified by the state and federal guidance noted above. State guidance provides that individual remedial technologies should be preliminarily screened on their implementability as well as their short-term and long-term effectiveness, including their ability to meet media-specific objectives. Screening for short-term and long-term effectiveness considers three important aspects:

- The ability of each remedial technology to meet the RAOs and PRGs;
- The potential for remedial technology to impact human health and/or the environment during implementation; and
- The reliability and record of performance for each remedial technology.

Implementability screening encompasses:

- Technical feasibility;
- Availability of the remedial technologies; and
- Administrative feasibility (e.g., work force availability, organizational logistics).

Availability includes issues such as whether a technology requires equipment, specialists, or facilities that are not available within a reasonable period of time. Both conventional and innovative remedial technologies are presented in this section. Innovative technologies are those with limited full-scale applications and performance data.

Detailed methods for Steps 5, 6, and 7 are described in Section 4. However, it is worthwhile to review this evaluation process here so that the flow of information from Section 3 to Section 4 is clear. The screening of technologies in Step 4 (Section 3) is conducted on an SMU-by-SMU basis. That is, the applicability of each technology to the particular chemical and physical characteristics of each SMU is individually evaluated. This refined list of technologies by SMU is then carried forward into Section 4 (Steps 5, 6, 7), where alternatives (combinations of technologies) that would provide complete remediation of a particular SMU are developed for each SMU individually. Each alternative for each SMU is evaluated against FS criteria and then compared against each other. Finally, in Section 5 of this document, lake-wide alternatives that remediate all SMUs are developed. These lake-wide alternatives consist of combinations of alternatives previously developed and evaluated for each SMU in Section 4. The lake-wide alternatives are evaluated against FS criteria (the same criteria used in Section 4) and compared against each other, and an overall Honeywell-recommended alternative is presented based on these evaluations.

This section primarily addresses remedial technologies for chemical contamination to sediments and physical impacts to sediments and nearshore habitats. However, it should be noted that in many cases, these technologies also indirectly address impacts to other media such as water and fish tissue (the subjects of PRGs 2 and 3). For example, remediation of contaminated littoral sediments would reduce the resuspension of chemicals to the water column and the mass of chemicals available in the water column for uptake by fish species. Similarly, remediation of the profundal sediments would reduce the chemical concentrations in those sediments, which in turn would reduce the flux of chemicals (particularly mercury) from those sediments to the hypolimnion. Although not a part of the FS, upland source controls conducted for other operable units would also reduce the inputs of chemicals to the water column.

In addition, some remedial technologies addressed herein, such as oxygenation of the hypolimnion, are intended to directly affect water quality, with the potential for consequent effects to fish tissue chemical concentrations.

3.2 INFORMATION SOURCES USED TO IDENTIFY GENERAL RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

This subsection builds on a review of the types of GRAs and remedial technologies generally applied to contaminated sediment sites. The three most important sources, which provide good overviews of sediment remediation techniques, include:

- USEPA Office Solid Waste and Emergency Response – contaminated sediment remediation guidance for hazardous waste sites, November 2002 Draft (USEPA 2002a)[2] and remediation techniques for contaminated sediment (USEPA, 1993).

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[2] This information comes from a draft document. The conclusions contained therein may be subject to change in whole or in part before finalization. However, this document provides a good summary of the general positions on sediment remediation currently being formulated within the USEPA and contains a variety of accurate technical information regardless of its potential inclusion in the final document.

- USACE Center for Contaminated Sediments (http://www.wes.army.mil/el/dots/ccs/) – documents on sediment remediation such as guidance for *in situ* subaqueous capping of contaminated sediments; dredging and dredged material disposal engineer manual; dredged material beneficial uses engineer manual; confined disposal of dredged material engineer manual; evaluation of dredged material proposed for placement in island, nearshore, or upland confined disposal facilities (CDFs); and guidance for subaqueous dredged material capping.
- Assessment and Remediation of Contaminated Sediments (ARCS) Program by the USEPA in the Great Lakes region – remediation guidance document (USEPA, 1994a).

In addition to these major sources, additional documents and programs were reviewed including:

- Federal Remediation Technologies Roundtable (FRTR) Web site (FRTR, 2003) (http://www.frtr.gov).
- Major Contaminated Sediment Sites Data Base (MCSS, 2002) (http://www.hudsoninformation.com/mcss).
- Hazardous Substance Research Centers Web site (HSRC, 2002) (www.hsrc.org/capping).
- Los Angeles Region Contaminated Sediments Task Force (CSTF) (www.coastal.ca.gov/sediment/sdindex)

Other commonly referenced Internet sites used in this evaluation process include:

- USEPA Mercury Web Site (http://www.epa.gov/mercury/index.html).
- USEPA Site Program (http://www.epa.gov/ORD/SITE/).
- USEPA Reach It Program (http://www.epa.gov/tio/reachit.html).
- USEPA Clu-In Technology Innovation Program (http://clu-in.org/).
- United States Department of Energy (USDOE) Environmental Management Program (http://www.em.doe.gov/).
- USDOE Technical Information Exchange (http://www.em.doe.gov/tie/).
- NYSDEC (http://www.dec.state.ny.us/).
- NYSDOH (http://www.health.state.ny.us/home.html)).

Descriptions of several of the most significant information sources used are provided below.

3.2.1 Contaminated Sediment Remediation Guidance for Hazardous Waste Sites – USEPA

This document is currently in draft form and is not yet promulgated guidance by USEPA. The conclusions contained therein may be subject to change in whole or in part before finalization. However, once finalized, the document will describe USEPA policies regarding the evaluation of commonly applied sediment remediation. In its current form, the document provides a summary of general positions on sediment remediation currently being formulated within USEPA, an overview and description of the sediment remediation technologies available, and technical information pertaining to these technologies.

3.2.2 U.S. Army Corps of Engineers Center for Contaminated Sediments

The USACE Center for Contaminated Sediments in Vicksburg, Mississippi, consolidates research expertise to deal with contaminated sediments. The center coordinates and facilitates contaminated sediment activities among USACE organizations, the Department of Defense (DoD), other federal and state agencies, academia, and the private sector. Research and development activities support the USACE navigation mission, as well as work related to military cleanup activities, the USEPA Superfund and Assessment and Remediation of Contaminated Sediments Programs, and the National Oceanic and Atmospheric Administration Natural Resource Trustee Program. This USACE Web site contains links to a number of technical guidance documents, engineering guidance documents, field design information, and examples of laboratory-scale studies in addition to full-scale sediment remediation projects.

3.2.3 Assessment and Remediation of Contaminated Sediments Program

The 1987 amendments to the Clean Water Act (CWA) authorized the USEPA Great Lakes National Program Office to coordinate and perform a five-year study and to complete demonstration projects relating to the appropriate treatment of toxic pollutants in bottom sediments. To fulfill the requirements of the act, the USEPA initiated the ARCS Program. Five Great Lakes locations were specified in the act as requiring priority consideration in performing demonstration projects for contaminated sediment treatment: Saginaw Bay, Michigan; Sheboygan Harbor, Wisconsin; Grand Calumet River, Indiana; Ashtabula River, Ohio; and the Buffalo River, New York. Results of the USEPA ARCS program are presented in the remediation guidance document (USEPA, 1994a). The 1994 guidance document also includes information on the selection, design, and implementation of sediment remediation technologies.

3.2.4 Federal Remediation Technologies Roundtable

The FRTR is a federal interagency group developed to build a collaborative atmosphere among federal agencies involved in hazardous waste site cleanup. Member agencies include the DoD, USEPA, USDOE, U.S. Department of the Interior, and National Aeronautics and Space Administration. The FRTR Web site contains links and information regarding innovative technology development, cost and performance of remedial technologies, and evaluations of technology optimization.

3.2.5 Major Contaminated Sediment Sites Database

The MCSS Database is a joint effort of the General Electric Company and others. This compilation of information on major contaminated sediment remediation projects in the United States presently contains information on 118 major projects representing 100 sites.

3.2.6 Hazardous Substance Research Center

The HSRCs are a competitively awarded, peer-reviewed research consortium led by Louisiana State University with the cooperation of the Georgia Institute of Technology, Rice University, and Texas A&M University to address critical hazardous substance problems, especially as they relate to contaminated sediments. The HSRCs performed extensive research assessing the physical, chemical, and biological processes influencing contaminant availability, evaluating and enhancing biotransformation processes in sediments, and improving the science of risk management for contaminated sediments. Their Web site contains publications presenting the results of current sediment research, innovative technologies, guidance literature, and technical briefs on contaminated sediment sites.

3.3 GENERAL RESPONSE ACTIONS

This subsection describes remedial technologies for each GRA category. The remedial technologies focus on sediment remediation, given the known impacts to the lake, and the expectation that improvements in environmental quality would result from sediment remediation. Remedial technologies have been categorized into the following ten GRAs, discussed in Subsections 3.3.1 through 3.3.10:

- No action;
- Institutional controls;
- Monitored natural recovery;
- Sediment containment;
- Sediment removal;
- Sediment consolidation or disposal;
- *In situ* treatment;
- *Ex situ* treatment;
- Aeration (oxygenation) of the hypolimnion; and
- Habitat enhancement.

Table 3.1 lists the remedial technologies identified in this subsection. These technologies are introduced and described below and are then screened on a lake-wide and SMU-by-SMU basis in subsections 3.4, and 3.5, respectively. The technologies are discussed below from the generally least active (e.g., no action) to the most active (e.g., dredging, *ex situ* treatment) for ease of presentation.

3.3.1 No Action

Under the no action alternative, no remedial action would be implemented. The no action alternative reflects lake site conditions as described in the RI and baseline risk assessments. However, it assumes that upland remedies have been implemented, which is likely to reduce levels of CPOIs entering the lake. No action may be appropriate for a site if 1) the site poses no current or potential threat to human health or the environment; 2) CERCLA does not provide the authority to take remedial action; or 3) a previous response has eliminated the need for further remedial response. Generally, where institutional controls are required to control risks caused by contamination at a site, the no action remedy is not appropriate. No action was retained as a GRA to serve as a baseline for comparison with other methods, technologies, and process options.

3.3.2 Institutional Controls

Institutional controls are activities that do not involve active remediation. In most cases, these are activities, documents, informational devices, or legal restrictions that minimize, limit, or prevent human exposures to CPOIs. Table 3.1 summarizes the remedial technologies that fall under institutional controls. This GRA can include physical site activities such as installation of warning signs, fencing, and surveillance. It can also include purely legal documents and methods of public communication such as deed restrictions, new regulations, and fishing advisories.

Institutional controls are widely recognized as a potential remedial technology for sediment sites (USEPA, 2002a). However, these controls are often only suitable when used in combination with other, more active remedial technologies. Further, the NCP preamble states that institutional controls are not intended to be a substitute for active response measures unless such measures are not practicable. Thus, institutional controls should be viewed as a means to further reduce risks where other technologies are infeasible, partially effective, or require some period of time before they become effective.

USEPA has placed institutional controls into four broad categories:

- Governmental controls;
- Property controls;
- Enforcement and permit tools with institutional control components; and
- Informational devices.

The specific technologies or activities recognized by EPA as most applicable to sediment sites (USEPA, 2002a) are:

- Fish consumption advisories and commercial fishing bans;
- Waterway use restrictions; and
- Land use restriction/structure maintenance.

Based on these categories and general information on the lake, institutional controls that may be applicable to Onondaga Lake include use restrictions preventing exposure to or disturbance of sediments or other impacted media, such as:

- Health advisories regarding specific activities, such as restrictions on fish consumption and swimming;
- Limitations on recreational use, such as swimming bans, anchoring prohibitions, or “no wake” zones to reduce sediment disturbance; and
- Bans on, or permit requirements for, dredging or certain waterfront improvements or alterations.

These types of restrictions would be most applicable in combination with other active remedial technologies. In the case of a health advisory, institutional controls may be a temporary remedial technology until a determination that active remedial technologies targeting sediment and/or water have been effective at decreasing fish tissue or chemical concentrations in water.

Several drawbacks exist for institutional controls. The most obvious is that they do not provide protection to ecological receptors. In addition, many of these controls reduce or eliminate the recreational value of the lake to users because they directly affect fishing, swimming, boating, and water access. Further, controls such as fish consumption advisories are typically unenforced and in many cases, unmonitored. Such advisories can be combined with enforcement, monitoring, and permitting tools and/or implemented as outright bans on fish consumption to decrease the likelihood of unacceptable levels of consumption by people. However, for logistical reasons, it is usually impossible to completely eliminate human consumption of fish. Boating controls such as no wake or no anchorage zones can also be difficult to enforce, and also decrease the value of the resource. Compliance can be increased, particularly in sensitive areas such as shallow water caps, by including visible barriers to boats such as buoy lines or by having patrolled enforcement. However, again it is often impossible to completely eliminate the undesired use.

Institutional controls could include either temporary or permanent extension of existing controls. For example, the NYSDOH has issued restrictive fish consumption advisories for Onondaga Lake warning against any consumption of walleye, with all other species to be consumed no more than once per month. This fish consumption advisory is well known in Onondaga County and is published in the *NYSDOH 2003-2004 Health Advisories: Chemicals in Sportfish and Game* (NYSDOH, 2003).

Limiting access to the water could be used alone for particular areas or in combination with other institutional controls, such as health advisories. The NYSDOH placed a ban on swimming in the lake in the 1960s, and a separate swimming ban was also in place in the 1940s. Currently, potential exposure to the lake via swimming is limited by the lack of swimming areas and the lack of private property along the shoreline. Zoning or other restrictions that discourage a change in this existing land use could form part of an institutional control. The county-owned lands include a shoreline trail that extends around the northern half of the lake. There are proposals to extend this trail to the east side of the lake or even further, so that it could eventually encircle the lake. Controls to limit or discourage access to the water at critical points along the existing or proposed trails could be considered.

3.3.3 Monitored Natural Recovery

MNR involves allowing natural processes to decrease the concentration, mobility, bioavailability, toxicity, and/or exposure of chemicals. Generally, it is allowed to occur over a given time frame and is expected to achieve specified goals within that time frame. MNR always includes a monitoring component to confirm that decreases in chemical concentrations or exposures are actually taking place as expected. It also includes contingency planning procedures in case sufficient natural recovery is not observed. Such contingency planning might involve a range of activities from additional monitoring to implementing more active remedial technologies in those SMUs where MNR was attempted.

3.3.3.1 Mechanisms of MNR

MNR can occur through a variety of physical, chemical, and biological processes (Figure 3.1) that act alone or in combination to reduce chemical concentrations, exposure, and/or mobility in sediments. MNR usually includes the following primary mechanisms that affect the surface of the sediment bed:

- Mixing of incoming clean sediments from the water column with lakebed sediment chemicals, causing dilution of the chemical concentrations (often the first step before burial);
- Burial of lakebed sediments containing chemicals by incoming clean sediments from the water column;
- Degradation of organic compounds within sediments;
- Reduction of chemical mobility and/or toxicity by conversion to less toxic forms and/or forms that are more highly adsorbed to lakebed sediments;
- Diffusion/advection of chemicals to the water column (i.e., loss to the water column); and
- Transport of sediments containing chemicals and dispersion over wider areas at lower concentrations.

It is important to note that these processes are interrelated and do not always work synergistically. For example, if sediments from the water column containing high chemical concentrations are settling onto lakebed sediments, these chemical inputs may offset any decreases in sediment chemical concentrations caused by burial, diffusion/advection, and/or degradation. This is why source control is a necessary first step in any MNR scenario.

The last two of these MNR mechanisms may not always be desirable. Clearly, dispersion of chemicals over wider adjacent areas or to other media that increases toxicity in those areas and media cannot be considered natural recovery. Thus, it is important that natural recovery evaluations considering these processes evaluate the potential impact of substantial reduction in one area or medium to toxicity and risks elsewhere in the system.

Reduction of chemical mobility and/or toxicity by conversion as well as degradation is highly dependent on a number of factors, including the type of chemicals present, concentrations of those chemicals, and the rates of any conversion or degradation processes. Consequently, MNR may not degrade or reduce the toxicity of contaminated sediments in many circumstances. In some cases (such as heavy metals), the primary mechanism of MNR is isolation by burial over time.

3.3.3.2 MNR as a Remedial Technology

According to USEPA, MNR has been selected as a remedial technology for contaminated sediment at about a dozen Superfund sites, both freshwater and marine, containing a variety of chemical contaminants (2002a). It is typically used in combination with dredging and/or capping of other areas of a site. For example, MNR was selected as part of the preferred remedial alternative for portions of the Eagle Harbor Superfund Site in Washington to address mercury and PAHs (USEPA, 1994b) and for Lake Hartwell, South Carolina, to remediate PCB contamination (Magar *et al*., 2002). Eagle Harbor is an estuary embayment that is relatively quiescent and depositional, similar to, although not exactly like, conditions in Onondaga Lake. Lake Hartwell is a lake environment with many similarities to Onondaga Lake. MNR is also part of the remedy currently being reviewed for the state of Washington site in Bellingham Bay, where mercury in sediments from a chlor/alkali plant is the primary chemical of concern (Washington DOE, 2002). Bellingham Bay is also a relatively quiescent and depositional estuary embayment, which is similar to, although not exactly like, conditions in Onondaga Lake. MNR has also been selected for some operable units of the Fox River in Wisconsin (WDNR and USEPA 2003). The Fox River is a dynamic river system that includes both depositional and more dispersive sediment conditions that are relatively dissimilar to Onondaga Lake.

USEPA has also noted that although partial natural recovery has been observed in many areas, there is not yet an extensive body of literature documenting complete recovery at contaminated sediment sites in general. However, monitoring results from some areas such as Lake Hartwell in South Carolina and Eagle Harbor in Washington are promising (e.g., USEPA, 2001a; USEPA, 2001b; Swindoll *et al*., 2000).

As noted above, when MNR is applied as a remedial technology, it is generally required to occur within a pre-defined period of time. Two examples are the Fox River, Wisconsin (WDNR, 2003) and Commencement Bay, Washington Superfund Sites. The Fox River ROD describes a time period of 10 to 30 years (depending on the exposure pathways involved) for the recovery of PCB concentrations in sediments (in some areas) and fish tissue. The Commencement Bay ROD specifies that areas that are expected to meet the ROD sediment quality objectives within 10 years are considered suitable for natural recovery. Chemicals of concern at this site include mercury, several other metals, chlorobenzenes, PAHs, pesticides, PCBs, and other chemicals.

MNR includes a monitoring component explicitly in its name. The primary difference between MNR and “no action” is that the former requires monitoring and contingency plans along with their implementation during the natural recovery period. Selection of MNR as a remedial technology involves a prediction of future conditions. Regardless of the amount of existing data and/or detail of predictive modeling, some amount of uncertainty will exist regarding future conditions at a site. The monitoring component of MNR is needed to track the progress of changes in the media of interest and to determine whether the expected and/or acceptable changes are occurring. The monitoring plan would focus on those measures that would be used to determine the acceptability of future conditions and to answer questions of scientific, regulatory, or public concern about the future environment. Thus, the monitoring plan should have measures and specific performance criteria tailored to each SMU where MNR would be implemented.

In addition to monitoring, it is necessary to have contingency planning procedures in case the expected natural recovery does not appear to be occurring. Contingency plans should contain a detailed set of procedures for triggering additional activities and a description of those activities in case performance criteria are not met.

3.3.3.3 Evaluation of MNR

USEPA is currently formulating the framework for evaluating MNR at sediment remediation sites (USEPA, 2002a). USEPA is taking comments from and working with groups such as the Sediment Management Work Group of the Remedial Technologies Technical Forum (Patmont, 2003). These efforts include the concept that MNR should be evaluated as a remedial technology following several “lines of evidence” (USEPA, 2002a). The most recent discussions of these approaches have focused on five primary lines of evidence:

1. Characterize contaminant sources and controls;
2. Characterize fate and transport processes;
3. Establish historical record for contaminants in sediment;
4. Corroborate MNR based on biological endpoints; and
5. Develop acceptable and defensible predictive tools.

MNR is most often considered a viable remedial technology where substantial evidence exists in each of these five areas. However, a site with less clear evidence in one or more of these areas may still be a potential candidate for MNR, depending on the particular circumstances. For example, a particular site may show no historical record of natural recovery due to a lack of source controls. If source controls are implemented as a part of an overall remedy, future natural recovery may, in fact, be indicated by the other lines of evidence.

There appears to be substantial information relative to most of these lines of evidence indicating that MNR is worth further evaluation in this FS. Appendix N, monitored natural recovery, presents a detailed analysis of the potential for natural recovery in the lake for each line of evidence.

3.3.4 Sediment Containment

Sediment containment technologies can reduce potential exposure to human and ecological receptors by preventing direct contact with contaminated sediments and reducing the flux of chemicals into the water column. The most common aquatic containment technology is isolation capping (hereafter called capping). Where CPOIs are present along shoreline areas, containment could also include implementation of erosion controls (e.g., coarser sized rock, vegetative controls) and structures (e.g., breakwaters) needed to keep contaminated sediments isolated from potential physical impacts such as wind/wave action. (Breakwaters need to be designed so that they consider and mitigate the impacts of any re-directed forces to other parts of the lake.) In addition, isolation berms can be used to prevent downslope movement of capped contaminated sediments and/or build up areas to create new aquatic habitat.

One other type of containment possibly applicable to Onondaga Lake relates to prevention of ongoing source migration to the lake. The most likely example would be the installation of a vertical barrier wall that prevents the upwelling of groundwater and/or the subsurface movement of shoreline or near-shoreline NAPL or dissolved-phase chemicals from deep sediments in to shallower sediments on the water column.

These containment technologies as well as reactive capping and thin-layer capping are discussed in more detail below.

3.3.4.1 Capping

Capping is a demonstrated remedial technology for containing chemicals in sediments and preventing or reducing the exposure and mobility of those sediment chemicals from their existing location. It is one of the most commonly evaluated and implemented remedial technologies for contaminated sediments (USEPA, 2002a; Palermo *et al*., 1998). A detailed evaluation of capping as remedial technology for Onondaga Lake is presented in Appendix H, capping issues.

Figure 3.2 shows a typical cap cross-section schematic (although the details of cap design can vary widely from site to site). Various types of technologies are sometimes termed “capping.” In this case, capping is defined as a designed system that is intended to isolate the chemicals underlying the cap and is referred to as “isolation” capping to differentiate it from other similar technologies such as “thin-layer capping” (see Subsection 3.3.4.3). Typically, isolation caps are mostly composed of sand and/or clean sediment and can range from approximately one to several feet thick, depending on the particular site. This primary isolation layer may be augmented by layers of other materials for various purposes, such as providing habitat or erosion controls on the cap surface (e.g., spawning gravels, cobble, or even rip-rap). Regardless of the particular design, the primary objectives of cap design are:

- Stabilizing the sediment and preventing resuspension, contaminant mobilization, and sediment transport;
- Chemically isolating the contaminated sediment and reducing contaminant flux into the water column; and
- Physically isolating the contaminated sediment from benthic organisms (Palermo *et al*., 1998).

The feasibility of isolation capping as a remedial technology is related to several factors, including sediment strength, contaminant characteristics, physical and hydrological conditions at a site, and potential future uses of the water body. Important fate and transport properties of the chemicals in question include partitioning rates to solid materials, solubility, and biodegradation rates (in the case of organic compounds). Important site physical characteristics include groundwater upwelling rates (which affect the pace of chemical advection through the cap) and surface water velocities due to currents, propwash, wind/wave action, or ice scour (which potentially affect the stability of the cap). Isolation capping may be infeasible in some areas if it negatively affects future hydraulic conditions (e.g., increases flooding) or limits habitat or potential uses of the waterway, such as navigation and recreation. As with any sediment remediation effort, it is also important that the source of contamination be controlled before capping occurs to prevent recontamination of the cap surface. In addition, as with any invasive remediation technology (e.g., dredging), any existing habitats or biological communities would be impacted in the short-term during construction of capping.

The engineering basis for sediment isolation cap design is unique for each application and depends on site-specific conditions and project objectives. Several factors are considered in a cap design, such as:

- Amount of erosion protection required to secure the cap in place;
- Cap thickness required to prevent the activities of benthic organisms from mixing contaminated layers with cap material layers (i.e., bioturbation); and
- Cap thickness and permeability required to effectively reduce the migration of contaminants (flux) to the water column via advection and diffusion.

Issues related to cap construction should also be considered, such as the availability of cap materials, stability of the underlying material, potential placement techniques, short-term effects of cap placement on the aquatic environment, cost, long-term monitoring and maintenance, and aquatic habitat enhancements provided by the cap.

An armoring layer may be designed, where necessary, to protect the cap from erosional forces such as wind/wave action, currents, tributary flows, storm water outfalls, and ice, as well as human disturbances such as propeller wash, anchor dragging, and fishing activities. At sites where these forces are prevalent, a layer of gravel or riprap (sometimes used in conjunction with a filter layer and/or geotextile) may be used to prevent resuspension and transport of cap material. Vegetative erosional controls may sometimes be employed, but can be difficult to establish in many situations. If a sediment cap were to be installed in the littoral SMUs (i.e., SMUs 1 through 7) of the lake, an armoring layer would likely be required in areas shallower than about 3 to 6 ft (0.9 to 1.9 m), depending on the SMU, to prevent erosion by a 100-year storm (Appendix H, capping issues)[3]. Some type of erosion layer may also be required near

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[3] The 100-year storm is the recommended design storm for caps (Palermo *et al.*, 1998). Additional information on cap design requirements is discussed in Section 4.

active outfalls, stream inlets, or in areas where propeller wash or ice scour might be significant. An alternative approach for wind/wave protection is to design a breakwater or other barrier that dissipates wave action in some areas to reduce the size requirements for the surface material of the cap itself. Design of breakwaters must evaluate and mitigate the impact of any re-directed forces on other portions of the lake. Dissipation of forces may also be important in areas where a particular type of habitat is desired for the cap surface. A demarcation layer (a material or non-toxic solid tracer) can be incorporated into a cap design so that erosion to that layer can be visually and readily identified. Also, dredging in shallower areas before capping can be used to reduce wind/wave forces on the cap surface (i.e., dredge and cap).

To physically isolate contaminated sediments from the mixing effects of burrowing benthic organisms, a sediment cap must be designed with characteristics and/or thicknesses that prevent substantial contact between organisms and the contaminated layer. In the design process, the required thickness for bioturbation protection is added to the thickness required for chemical isolation. The thickness of the bioturbation layer is determined through an analysis of site-specific benthic community data or can be approximated from literature values. The benthic community may become more diverse and dense after the affects of contaminants are removed or may have different characteristics where the cap material differs from the existing surface sediments (e.g., sand versus silt). Consequently, the bioturbation analysis may use information from other uncontaminated lakes or areas of the site to help determine the likely future benthic community and bioturbation depths after remediation. This level of analysis is generally required for final design to ensure that the correct cap thickness is proposed.

Clarke *et al.* indicate that extensive bioturbation in freshwater environments occurs in the upper 10 cm of sediment (2001). A deeper zone from about 4 to 16 in (10 to 20 cm) usually contains larger but less dense bioturbators, which would likely arrive during the later stages of colonization of a cap. However, these deep bioturbators would probably represent a small percentage of the overall bioturbation activity (<20%; as discussed in Appendix H, capping issues). This deeper zone shows a general pattern of decreasing activity and biological abundance with depth. A review of bioturbation depths for freshwater systems is presented in the Appendix H, capping issues. Based on this review, 6 in (15 cm) is a reasonable assumed design depth for significant bioturbation for FS purposes. This depth could be optimized as needed during the design phase.

A one-dimensional (i.e., vertical) contaminant transport model is typically used to evaluate the long-term performance of an isolation sediment cap and its ability to reduce contaminant flux to the overlying water column. Contaminant transport through a cap is driven by advective and/or diffusive forces. While the amount of advection varies according to the presence (or lack) of groundwater upwelling, diffusion is an ever-present condition driven by concentration gradients. Where sufficient information is available, these models can be used to conservatively estimate the thickness and type of material (e.g., permeability and organic carbon content) that would effectively reduce the flux of contaminants from the underlying sediments (Palermo *et al.*, 1998). Modeling for cap isolation effectiveness is presented in Appendix H, capping issues.

In areas where sediments are soft, special sediment cap placement techniques may be needed to prevent cap materials from penetrating into the underlying sediments. Depending on the softness of the sediment, these techniques include:

- Hydraulically washing the sand from a flat-top barge (e.g., Eagle Harbor; USEPA, 1994b);
- Box diffuser at the end of a hydraulic dredge that allows cap material to rain down onto the sediment surface (e.g., St. Paul Waterway; Weiner, 1991);
- Placement by cracking a clamshell containing cap material and swinging it just above the surface of the sediments (e.g., Ketchikan Pulp; Keeley and Wakemen, 2001); and
- Cracking a split hull barge and moving laterally over the area to be capped (e.g., Los Angeles Pilot Studies; Anchor *et al*., 2002).

Hydraulic techniques usually provide greater cap placement production rates. Of the two hydraulic techniques, a box diffuser provides better control of cap placement. Of the mechanical techniques, placement by clamshell provides a very high degree of control but has a very slow production rate. Split hull barge placement provides relatively high production rates, but can result in greater variability in the material thickness placed in any one location.

A detailed analysis of the properties of the bed sediments and thickness of the lifts required to place cap materials to minimize mixing and disturbance has been conducted and is presented in Appendix H, capping issues. This analysis indicates that the maximum placement lift to minimize this disturbance should be approximately 6 in (15 cm) thick, which could be achieved using hydraulic or mechanical techniques.

Another important consideration for isolation capping is the overall habitat provided by the cap. Caps can provide a means to create additional or more desirable habitats in a water body. In deeper areas, additional thickness can be added to the cap (beyond what is needed for the functional purposes described above) so that the cap surface is at a more productive water depth. Such an approach along with other habitat features was used at the St. Paul Waterway cap and habitat restoration in Commencement Bay, Washington (Weiner, 1991). In addition, the substrate at the surface of the cap can also be selected to provide some desired type of habitat (e.g., spawning sands or gravels). In the case of the ILWD and other locations where Solvay wastes are present, capping could provide new habitat and isolate the current waste substrates that do not provide any useful habitat.

It is important to consider the needs of providing habitat and protecting against erosional forces. In some cases, erosional protection might indicate the need for substrates that are not desirable from a habitat perspective. However, many types of design features can be incorporated to maximize desired habitats and minimize the amounts and types of “hard” erosional protection needed. These may include maintaining sufficient water depths to limit erosional affects, incorporating energy dissipation features such as breakwaters or underwater near-surface berms, and using vegetative erosional controls (such as large woody debris). In addition, features such as emergent wetlands, embayments, and large woody debris can be incorporated into cap designs to achieve an overall improvement of habitat features over existing conditions. To create these restoration designs, combinations of dredging and capping are often needed to achieve the overall profile and layout desired in a particular case. General design goals regarding habitat for caps include:

- Provide net increases in water surfaces and desirable habitats;
- Maximize the amount of desired habitat water depths in the cap profile, including dredging and capping back to the extent feasible;
- Reduce the amount of hard armoring;
- Maximize the use of vegetative erosion controls; and
- Maximize the development of desired habitats and habitat features (e.g., large woody debris, embayments, emergent vegetation, rock substrate for macrophyte attachment, spawning gravels) in the design.

It can be difficult to establish aquatic vegetation for restoration projects involving capping, dredging, and combinations thereof. This may be particularly true in Onondaga Lake, which currently has a low macrophyte biomass. Pilot-scale testing of vegetation restoration methods may be warranted during the remedial design phase of the project to determine the feasibility of establishing aquatic vegetation (see Subsection 3.3.10).

Finally, it is important to note that isolation capping is often conducted in combination with other technologies. A prime example is combination dredging/capping, as noted above, to achieve desired water or habitat depths. In addition, capping can be used in areas where residual contamination remains after dredging (see Subsection 3.3.5.1.2), either in the area of original concern or in adjacent areas if residuals have dispersed.

3.3.4.2 Reactive Capping

A standard isolation cap, like those described above, is designed to reduce the flux of chemicals from underlying sediments to the water column, primarily through adsorption of chemicals onto the cap material. This adsorption process acts as a barrier by greatly increasing the travel time of chemicals through the cap and, in the case of organic compounds, allowing additional time for biodegradation processes to occur.

Reactive materials can be placed within an isolation cap to supplement this adsorption process or to provide some other physical/chemical processes that reduce the mobility of the CPOIs. Use of reactive materials may be warranted where evaluations of standard capping indicate that a sufficiently thick cap cannot be created to adequately reduce the flux of chemicals over time. This condition may be due to a variety of reasons, such as the need to maintain certain water depths for navigation or habitat purposes and/or high rates of groundwater advection.

Use of reactive materials with a sediment isolation cap has not been demonstrated at a full scale. The effectiveness of reactive materials is currently being studied at a pilot test on the Anacostia River, which flows into the Potomac River just south of Washington D.C. (Reible, 2003). The reactive media under consideration at the Anacostia site are potentially capable of increased sorption, enhanced biodegradation, and dechlorination and/or metal reduction. Options under investigation, some of which could also be applicable for Onondaga Lake under certain conditions, include:

- Zero-valent iron (Fe^0) dechlorinating compounds such as chlorobenzenes; these may also be capable of precipitating other compounds;
- Carbon, coke, or coal to increase the adsorptive properties in the sediment cap, thus reducing the flux of organic compounds;
- Activated alumina incorporated into the sediment cap to increase adsorption processes and enhance surface binding;
- Additives such as Biosoil™ that provide nutrients to enhance degradation of certain organic compounds and may increase the adsorptive capacity of the sediment cap;
- Additives such as Aquablok, a mixture of gravel and bentonite that reduces permeability and advective transport; currently the focus of a USEPA assessment under the Superfund Innovative Technology Evaluation Program;
- Apatite phosphate to encourage adsorption and reaction of metals; and
- Natural organic compounds to enhance adsorption of certain organic compounds and reduce chemical flux.

Lab testing and site characterization is currently under way for the Anacostia River project. A report summarizing project results is anticipated in the third quarter of 2005. Unlike standard caps, reactive caps are often intended to have a finite design life. Depending on the quantity of chemical sources underlying the cap, as the reactive material is used up, cap material may need to be periodically removed and replaced with new reactive materials. Where fluxes of large quantities of chemicals are involved, this may add a considerable ongoing periodic maintenance cost to reactive caps.

As an innovative technology, the applicability of reactive materials within a sediment cap for Onondaga Lake would need to be determined through bench-scale testing and possibly through pilot-scale application at the lake. Reactive materials may be useful in those areas where standard capping appears to be infeasible.

It has been commented that ebullition of methane gas may have adverse effects on reactive cap materials. There is no readily available literature on this subject. Potential unwanted reactions between the reactive material and methane should be assessed before such a cap is designed. If necessary, bench-scale tests could be conducted to determine whether there were any likely undesired or unexpected reactions in any particular case.

3.3.4.3 Thin-Layer Capping

Thin-layer capping is similar to standard isolation capping except that the cap is specifically designed using a minimum amount of material, generally a layer that is between 0.25 and 1 ft thick. Thin-layer capping provides many similar benefits to standard isolation capping, while often being easier to implement and less costly. Unlike standard isolation capping, thin-layer capping is not intended to provide complete isolation of the underlying contaminated sediments. In thin-layer cap design, it is expected that some amount of chemicals from the underlying layer would be distributed into the cap material through physical or chemical processes over time.

Thin-layer capping has several benefits in a remediation context, including:

- Immediate reduction of the surface layer chemical concentrations;
- Reduction of chemical flux from the underlying sediment layer to the water column;
- Reduction or elimination (depending on the benthic community and thickness of the cap in question) of bioturbation of the underlying sediment layer;
- Reduction of physical movement and transport of underlying sediment chemicals; and
- Reduced exposure of unsuitable habitat substrates (e.g., waste materials).

Thin-layer capping can be particularly useful at sites where ongoing natural recovery is expected. Placement of the thin-layer cap may provide sufficient isolation of contaminated sediments to allow deposition of new clean material, which further reduces migration of chemicals. Eventually, this deposition can completely bury the thin cap, providing complete isolation of chemicals over the long term similar to a standard cap. In this case, the “isolation cap” is built by natural processes; during the building process, risks from chemical migration are reduced (although not necessarily eliminated).

Thin-layer capping is ideal in more stable depositional environments where sources are controlled. However, thin-layer capping can also be used in areas that undergo periodic resuspension, assuming the overall trend is one of net deposition of material over time. In this case, a small amount of gravel-sized material can be incorporated into the typically sandy cap materials to provide self-armoring capacity. The sands on the surface of the thin layer cap may erode under some conditions, temporarily creating a more stable gravel surface that eventually becomes buried over the longer-term.

Thin-layer capping has been successfully used at Superfund sediment remediation sites, in both pilot and full scale, including Asarco Tacoma (Parametrix, 1998) (less than 1 ft to 2 ft thick), Eagle Harbor (USEPA, 1994b) (less than 1 ft to 3 ft thick), and Middle Waterway (USEPA, 2002b) (less than 1 ft to 2 ft thick), all in Washington State.

3.3.4.4 Vertical Containment

Vertical containment can be used to provide hydraulic containment or to retain soil. Hydraulic containment is referred to in this FS as a barrier wall. Physical containment of soil or sediment is referred to as a retaining wall. Retaining walls, berms, or dams may be employed with capping as described above to keep contaminated sediments physically in place (see Subsection 3.3.4.1).

Figure 3.3 shows a typical upland barrier wall; the specifics of design can vary substantially from site to site. Barrier walls on the upland side of the shoreline are being considered for several of the ongoing upland site feasibility studies, most notably the Willis/Semet site and Wastebed B. These are installed to reduce groundwater upwelling in the lake and eliminate groundwater or product-phase transport of chemicals to the lake. Similar barriers in aquatic nearshore areas could also be considered to further reduce upwelling and limit the movement of NAPL or other chemicals in subsurface sediments to other areas of the lake, particularly to surface sediments or the water column.

In the aquatic environment, a barrier wall can generally be a soil mix (some mixing of soils or sediments that have properties that reduce groundwater advection), slurry mix, or sheetpiling. For aquatic applications, sheetpiling is the most versatile and generally the most effective form of chemical containment. Interlocking sheets can be designed and placed to provide watertight seals. Use of soil mixing is less preferred due to resuspension of sediment that takes place during the construction process and the potential effects on slope stability along the shoreline. Slurry mixing is generally difficult to implement in standing water conditions and is used almost exclusively in upland environments.

Any of these in-water barrier walls would end at the sediment surface and would not need to extend into the surface water; thus, they would provide no barrier to navigation. However, the presence of these walls may be incompatible with the development of some types of littoral restoration habitats due to the need for minimal disturbance of the up-gradient sediments and chemicals where vertical barriers are employed.

3.3.5 Sediment Removal

Removal includes dredging contaminated sediments from their existing location and consolidating/disposing the sediments in a new location that minimizes the mobility, exposure, or impacts to human health and the environment. It is one of the most commonly evaluated and implemented contaminated sediment remediation technologies (USEPA, 2002a). Removal and on-site consolidation or off-site disposal are presented in Table 3.1 as separate GRAs, but in reality, they can only occur in combination. However, these technologies are evaluated in two separate subsections, with the details of consolidation and disposal technologies discussed in Subsection 3.3.6.

Dredging (i.e., removal of sediments with overlying water present) can be conducted by various methods, including mechanical devices (e.g., clamshells), hydraulic systems, pneumatic systems, and/or hybrid (i.e., combination) systems. Figure 3.4 shows a typical dredge prism schematic (i.e., 3-dimensional volume of sediments to be dredged) cross section, but the specific design features can vary widely from site to site. Dredging can also be conducted “in-the-dry” (also called dry removal), which involves excluding water from the area to be dredged via sheetpile wall or similar structure and removing sediments with no overlying water in place. Figure 3.5 shows a typical dry removal cross section schematic. Dredging may include best management practices (BMPs); discussed more in Appendix L, dredging issues, to reduce the resuspension and/or loss of sediment during the dredging process, including operational controls, physical barriers such as silt curtains, and specialty dredging equipment such as closed or "environmental" buckets.

In addition, some amount of water is present in the sediments and/or entrained in the dredging process. This water must be managed, and often treated, before it can be discharged back to receiving waters. For this evaluation, transport to the consolidation or disposal sites is considered the final step in the removal process, and all subsequent activities at the consolidation or disposal sites are discussed in Subsection 3.3.6. The various removal and removal-related technologies are described in the following subsections.

As with capping, dredging (either alone or in combination with other technologies) can improve habitat functions while remediating chemical contamination. This can include removing wastes that impact shoreline habitat functions (e.g., Solvay wastes) and creating new, desired water depths or habitat design features (usually in combination with capping). As discussed in the capping subsection, it is sometimes difficult to establish vegetation for restoration projects. This may be particularly true in Onondaga Lake, which currently has a low macrophyte biomass. In addition, as with any invasive remediation technology, any existing habitats or biological communities would be impacted in the short term by the removal process.

3.3.5.1 Dredging

Sediment may be removed from a water body using various dredging techniques (Herbich, 2000; Appendix L, dredging issues). Dredging involves mechanically penetrating, grabbing, raking, cutting, and/or hydraulically scouring the bottom of a water body to dislodge and remove sediment. After the sediment has been dislodged, it is lifted out of the water body either mechanically, as with a clamshell bucket, or hydraulically through a pipeline. Dredging at a site can also be based on a combination of mechanical and hydraulic methods. Hybrid dredges can remove sediments by either mechanical or hydraulic means, depending on site conditions. Pneumatic dredges, a subset of hydraulic dredges, use compressed air systems to remove sediments. Hybrid and pneumatic dredges are generally less available than purely mechanical or hydraulic systems. In addition, their historical use at contaminated sediment projects is relatively limited. Consequently, the majority of this section focuses on mechanical and hydraulic techniques.

Mechanical dredging for contaminated sediment removal is typically accomplished using a clamshell bucket with a capacity of 2 to 6 cubic yards (CY) (1.5 to 4.6 cubic meters) in shallow waters. Other types of mechanical dredging equipment include open clamshells, backhoe dredges (excavators), dragline dredges, dipper dredges, and bucket ladder dredges (Herbich, 2000). Larger bucket sizes (e.g., 6 CY) can be useful in softer sediments to increase the rate of production. If the consolidation or disposal location is proximate to the water body being dredged, mechanically dredged material is typically placed on a haul barge, which is then transported to the consolidation or disposal area. If the consolidation or disposal site is located upland, the dredged material is generally off-loaded, dewatered, and then transported via truck or rail to the consolidation/disposal facility.

Hydraulic dredging typically involves the removal of sediments using a cutter head or suction dredge that creates sediment/water slurry of 5 to 20 percent solids by weight (Herbich, 2000; Appendix L, dredging issues). All hydraulic dredges ultimately remove sediment via water suction; the methods for loosening the sediment so that they can be suctioned up vary among equipment types. A cutter head dredge has a rotating head that bites into the sediment and loosens it. A horizontal auger dredge pushes sediment toward the intake using rotating augers on either side of the intake. Plain suction dredges have no loosening device and therefore are mostly used with unconsolidated silty sediments. Variations on suction methods, both with and without mechanical loosening, also exist, including eddy pumps and Toyo pumps. Eddy pumps use a pumping mechanism that often allows higher solids content in the dredge slurry. Toyo pumps are located on the dredge head itself (rather than further up the dredge arm), which often can provide additional suction power and higher solids content in the dredge slurry.

The sediment slurry created by these various hydraulic methods is then pumped (via pipeline) to a consolidation or other site for dewatering. A large amount of water is entrained during the hydraulic dredging process (typically the dredge slurry is 80 to 95 percent water by weight), while mechanical dredging entrains very little additional water above the *in situ* moisture content. The dredge design must account for the handling and potential treatment of entrained water as needed before returning it to the receiving water body (Herbich, 2000). (These water management issues at the consolidation site are discussed further in Subsection 3.3.5.3.) Hydraulic dredging is most practical where the dredged slurry can be pumped directly to a nearby dewatering, and/or consolidation site.

Often, one obstacle to dredging (and in other in-water work, such as capping) during construction is interference with navigation and ship/boating traffic. Onondaga Lake has very few such ongoing uses except for vessel traffic from Onondaga Creek to the Seneca River, so it is likely that this traffic would cause infrequent obstacles to dredging or capping operations. Other potential obstacles include dredging in very shallow water and/or in and around shoreline structures or other obstructions. Dredging around structures can require specialty-dredging equipment such as very small dredges or diver-directed systems. In other cases, it may be difficult or impossible to remove contaminated sediments without removing the structures or obstructions.

3.3.5.1.1 Resuspension Losses During Dredging

Some sediment is typically resuspended and lost during the dredging process (Herbich and Brahme, 1991; Collins, 1995; Appendix L, dredging issues). Studies have shown that the amount of resuspension loss varies across site conditions but can range from fractions of a percent to nearly 10 percent of in place sediments, measured by weight (CSTF, 2002). Measurements at the high end of this range may be made very close to the dredge and include some sediments that quickly settle back to the sediment bed and/or may be observed near hopper dredges that also create suspended sediments due to overflow from the dredge hopper. Appendix L, dredging issues, indicates that resuspension rates from 0.2 to 0.9 percent for mechanical dredges and 0.1 to 0.5 percent for hydraulic dredges are more typical. (Note that for purposes of assessing dredging resuspension impacts, Appendix L used a conservative resuspension value of 1 percent). Other reviews have indicated potentially higher resuspension rates in some cases (CSTF 2002). However, Appendices K and L indicate that dredging is a feasible option for Onondaga Lake with some exceedances of water quality criteria (due to resuspension) expected within a 100-ft diameter of the dredging operation in the example case of SMU 1.

The primary source for resuspension losses from a hydraulic dredge is the cutting and suction head as it moves through the sediment. For mechanical dredges, the primary sources for losses are disturbance of the sediment by the clamshell or bucket and spillage and leakage from the bucket as is moves up through and out of the water column. During mechanical dredging, losses can also occur during material transfer from the barge to onshore handling facilities.

Evidence exists that resuspension of uncontaminated sediments may cause a variety of potential ecosystem impacts from the clean suspended sediments themselves and from ancillary issues such as turbidity (i.e., reduced water visibility) (Wilbur and Clark, 2001; Nightingale and Simenstad, 2001; and CSTF, 2002 all contain literature reviews on this subject). Although there appears to be little evidence of acute (short-term) impacts from the levels of uncontaminated suspended sediments typically associated with dredging, there appears to be some potential for such impacts over chronic (long-term) durations in excess of four days (CSTF, 2002).

Dredging of contaminated sediments may also cause potential ecosystem impacts due to the chemical concentrations created in the water column around the dredging operations. Typically, dredging of contaminated sediments includes water quality monitoring at the dredge site. It is not unusual for this monitoring to reveal water chemical concentrations in excess of ambient water quality criteria at contaminated sediment dredging projects (Nightingale and Simenstad, 2001 and CSTF, 2002 contain literature reviews on this subject). It has also been noted that bioaccumulation of some chemicals (e.g., PCBs and mercury) may increase in caged mussels or fish held downstream or near dredging operations of contaminated sediments (CSTF, 2002).

The literature reviewed for the Contaminated Sediments Task Force (CSTF, 2002) suggest that chronic physical and chemical impacts of resuspended sediments often vary across types of organisms. Mobile organisms such as fish would be unlikely to receive exposures to dredge plumes for more than four days. Because there are often gaps in dredging activities (at night or during equipment maintenance) and because dredge plumes tend to move around with varying currents, even sessile organisms are unlikely to receive continual chronic exposures to dredge plumes.

BMPs, discussed in Subsection 3.3.5.1.3, can provide a means to reduce, although rarely eliminate, the potential water quality impacts associated with contaminated sediment dredging.

3.3.5.1.2 Residual Sediment Surface Concentrations

Experience at many sites has shown that 100 percent removal of all contaminants associated with sediments is not achievable (Herrenkohl *et al*., 2003; Appendix L, dredging issues). Each type of dredge leaves behind some residual sediment and associated contaminants. This lack of complete chemical removal results from various factors, including:

- Resuspension of fine materials during dredging followed by resedimentation;
- Flow and localized slope failures due to low strength sediments;
- Water currents induced by dredging equipment eroding nearby sediments in dredge cuts;
- Incomplete coverage during dredging due to cratering of the sediment bed by mechanical clamshells or due to uneven use of a hydraulic dredge, creating windrows and furrows between swaths;
- Difficulty dredging in and around shoreline structures, boulders, debris, or hard bottoms;
- Inability of the dredging process to capture all sediments loosened by the dredging; and
- Issues inherent to performing work underwater, out of sight of the operator.

Depending on the currents at the site and the type of material being dredged, some contaminants may end up resettling to the surface outside the area of original concern. Resuspension of fine materials occurs in any dredging operation, as described above. However, incomplete coverage and issues related to out-of-sight work can often be minimized with proper contractor methods and quality control procedures or by making additional passes of dredges. Obstacles along the shoreline areas of Onondaga Lake would present challenges during dredging and might require specialty dredging equipment to remove all materials around these obstacles.

Dredging operations seem to consistently leave a mixture of targeted sediments along the dredge cut, similar to that described in Appendix L, dredging issues. Herrenkohl *et al*. (2003) summarize available data on the existence of residual sediments after attempts to completely dredge contaminated sediment layers. Unfortunately, the available data are limited to only a few projects, insufficient to fully characterize post-dredging residual sediments. Some suggest that newer dredging methods reduce the residual sediment problem, but insufficient data are available to substantiate that claim.

Due to the lack of adequate data for all types of dredges, it is difficult to accurately predict residual sediment concentrations after dredging. For this reason, a simple approximation of a depth-weighted average concentration of the dredged sediments is often used. A horizontal profiling bucket has been recently developed, which is intended to reduce the residual concentrations after dredging. However, because this technology is new, there is very little, if any, data are available to confirm whether this bucket actually decreases residual concentrations.

Consequently, use of the depth-weighted average residual concentration for all dredging equipment appears to be a reasonable conservative assumption for the FS.

Under this approach, multiple dredge passes require the sediment depth from any prior passes be considered as an additional sediment layer. For this site, Appendix L, dredging issues, recommends that an assumption that 10 percent of sediment attacked is left behind. Probably the most common method of addressing this issue is to conduct additional passes with the dredge. However, at some point, this process provides little additional net benefit in terms of chemical concentration reduction and becomes time consuming and costly (Herrenkohl *et al*., 2003). Another common method of addressing residuals is to place a "residual" cap over such areas after dredging has been completed.

3.3.5.1.3 Best Management Practices

BMPs can limit, although rarely eliminate, the loss of dredged materials (Appendix L, dredging issues). BMPs to reduce the resuspension and loss of sediments during dredging can be separated into four main categories:

- Silt curtains, gunderbooms, or sheetpiling;
- Operational controls;
- Specialty dredging equipment; and
- Other innovative technologies such as air curtains.

With ***silt curtains, gunderbooms, or sheetpiling***, the objective is to create a physical barrier around the dredge equipment to allow resuspended sediments to settle out of the water column in a controlled area. Figure 3.6 shows a typical silt curtain deployment around a dredging operation.

Silt curtains are typically constructed of flexible, reinforced, thermoplastic material with flotation devices in the upper hem and ballast in the lower hem. They are most effective on projects where it is not necessary to open and close them to allow equipment access. Because they are impermeable, silt curtains can be difficult to consistently deploy in areas of high currents (CSTF, 2002). Standard silt curtains can be deployed to extend within approximately 2 ft of the bottom where currents may exist. Where minimal currents exist such as in Onondaga Lake, curtains may extend to the bottom. Silt curtains can reduce surface turbidity and impacts to adjacent resources. However, silt curtains are less effective in high-energy environments, and where they cannot be extended to the bottom, may have little effect on bottom turbidity.

A gunderboom curtain is made of a permeable geotextile fabric that allows the water to pass through but filters out the particulates. While silt curtains are typically deployed to extend downward through part of the water column, gunderbooms are designed to be installed from the water surface to the lake or river bottom. Gunderbooms allow unlimited curtain depth and permit less restricted water flow, but they are more expensive than silt curtains and can become clogged with silt, which makes them more resistant to currents over time (CSTF, 2002).

In some cases, complete isolation of the dredge area may be desired, and sheetpile walls can be placed to form a complete temporary barrier. Dredging can then take place behind the walls either with water in place or with water removed. Sheetpiles can take longer to install and remove, and may be difficult to deploy in deeper water. However, they have the advantage of complete isolation

Air-curtain technology is also available to create vertical circulation barriers that allow boats to pass but restrict the movement of water between various parts of the remediation area. The curtains can consist of steel pipes, fitted with diffuser orifices, which have leg supports raising them about 1 ft (0.4 m) off the bottom. Divers place the pipe and anchors, connect the supply lines, and verify proper operation once the equipment is in place. This technology, although successfully implemented at the St. Lawrence River Remediation Project, has not been used widely, and the data available from that site on its ability to limit movement of resuspended sediments and/or chemicals appear limited.

Water-filled bladder dams might also theoretically be used to restrict resuspended sediment movement during dredging. The typical use of bladder dams is to temporarily dewater an area, rather than create a barrier with water present on both sides of the dam. Consequently, bladder dam technology is discussed more below in the Subsection 3.3.5.2 below.

Operational controls for dredging projects involve modifications in the operation of the dredging equipment to minimize resuspension of materials. Operational controls can be employed with either mechanical dredges or hydraulic dredges. Examples of operational control methods (CSTF, 2002) for mechanical dredges include:

- Slowing ascending rate and time at water line – Slowing the rate of bucket ascension and holding the bucket at the water line reduces potential to wash sediment from the bucket. Slowing the final rate of impact may also product benefits. Sediment resuspension for a clamshell dredge also occurs when the bucket hits the bottom.
- Eliminating multiple bites – When the clamshell bucket hits the bottom, an impact wave of suspended sediment travels along the bottom away from the dredge bucket. When the clamshell bucket takes multiple bites, the bucket loses sediment as it is reopened for subsequent bites. Sediment is also released higher in the water column as the bucket is raised, opened, and lowered.
- Eliminating lake-bottom stockpiling – Bottom stockpiling of the dredged sediment in silty sediment has an effect similar to multiple bite dredging: an increased volume of sediment is released into the water column from the operation.

Example operational controls for hydraulic dredges include:

- Reducing cutterhead rotation speed – Reducing cutterhead rotation speed reduces the potential for side-casting the excavated sediment away from the suction entrance and resuspending sediment. This measure is typically effective only on maintenance or relatively loose, fine-grain sediment.

- Reducing swing speed – Reducing swing speed ensures that the dredge head does not move through the cut faster than it can hydraulically pump the sediment, thereby reducing the volume of resuspended sediment. The goal is to swing the dredge head at a speed that allows as much of the disturbed sediment as possible to be removed with the hydraulic flow. Typical swing speeds are 5 to 30 ft/minute.
- Eliminating the process of bank undercutting – This can be achieved by removing the sediment in maximum lifts equal to 80 percent or less of the cutterhead diameter.

Note that all of these controls would reduce the solids content of the slurry, causing more water to be managed.

Operational controls can be very effective at limiting resuspension of sediments and are often used in lieu of barriers such as silt curtains. In addition, they do not require deployment of additional equipment and can be less costly than installing barriers. Operational controls can slow production rates, but in many cases, these production rates are still superior to production rates involving barriers that must be constantly maintained and moved throughout the dredging operations.

Specialty dredging equipment includes techniques designed to further reduce the creation of resuspended sediments. Examples include:

- Pneuma® Pump – The Pneuma® pump is used primarily for removal of fine-grained sediment and could be used in the lake. It offers high solids concentration in the dredge slurry, with minimal turbidity.
- Closed or Environmental Bucket – Specially constructed dredging buckets designed to reduce or eliminate increased turbidity of suspended solids from entering a waterway.
- Precision Dredging – Dredging using special tools and techniques to restrict the material dredged to that specifically identified. This may mean thin layers, either surficial or imbedded, or specific boundaries.

As with the operational controls described above, these specialty equipment options have the potential to reduce sediment resuspension, but also may increase costs. In some cases, if not properly applied, some of these equipment types have been shown to create greater resuspension problems. For example, most closed or environmental buckets, because of their lighter weight, are only suitable for use in relatively soft sediments. When used in more solid sediments, they have difficulty penetrating and removing sediments and closing once sediments are removed from the sediment bed, all of which creates greater sediment losses. Similarly, closed buckets can cause as much or more resuspension due to the “bow wake” created as the bucket approaches the sediment surface, which can be a substantial source of sediment resuspension (CSTF, 2002).

Another form of specialty dredging equipment is a contained dredging system developed by Seaway Environmental Technologies. Two types of containment dredging systems are in the demonstration phase of development: one for open-water operation and the other for confined dredging sites. Because Onondaga Lake has few if any confined areas, such as small bays or inlets, the second type of system does not appear applicable here.

The first system, a specially designed contaminated sediment removal vessel (CSRV), is a barge with a rectangular 100 by 35 ft (30 by 11 m) opening through which vertical barrier walls are set to surround the target dredge work zone. The barrier wall is formed by interlocking steel piling walls that control water flow across the confined area. Dredging is conducted mechanically through the barge inside the confined area. Water pumped from the confined area is treated onboard the barge using a microfiltration membrane system. The CSRV dredging system is also designed to provide on-barge dewatering of sediments using the on-board water treatment system, eliminating or minimizing the need for on-shore dewatering.

Seaway Environmental Technologies claims that the costs and production rates of this system are comparable to other environmental dredging methods. However, specific production and cost data that would be applicable to a large site were not found. Another potential limitation is the small area that is confined by the CSRV, which would require 12 setups to dredge a one-acre area and would likely result in a relatively large proportion of time spent breaking down and redeploying the system when dredging large areas. It is also unclear what water depth and excavation depth (below the existing sediment-water interface) limitations exist for this system.

Although all of these BMPs have the potential to reduce resuspension and loss of materials, these techniques cannot eliminate all impacts to water quality around dredges. Monitoring is typically conducted to measure any exceedances of ambient water quality criteria near dredging operations (CSTF, 2002). Some resuspension and loss can be expected even with BMPs, which would result in some residual concentration of chemicals in bed sediments once these resuspended sediments have resettled. However, some BMPs (silt curtains, for example) may be able to limit the spread of these chemicals associated with sediments.

3.3.5.2 Dry Removal

Dry removal of sediments involves isolating an area using a temporary dam, removing the enclosed surface water, and excavating the contaminated sediment with conventional earthwork equipment. The equipment may need to be placed on support mats to avoid sinking in the soft sediments during construction. This technique allows a visual verification that the appropriate sediment is being removed. It also significantly reduces the amount of sediment dewatering required and eliminates the short-term problem of sediment resuspension in the water column during removal. Dry removal is often used where extremely high concentrations or pooled NAPL may be expected in nearshore areas, because it allows complete temporary isolation of the area to be removed. This isolation prevents the potential for resuspension losses to the surrounding water column.

A review of sediment characteristics in the southwest corner of the lake, where pooled NAPL is known to exist, indicates that nearshore sediment could be effectively excavated from shore using excavators or cranes supported by mats or operating on a stabilized sediment base if the area could be successfully, temporarily drained to allow dry removal. Options available for isolating specific areas for dewatering and sediment removal include installation of sheetpiling, installation of an earthen berm, and/or deployment of a portable water-filled dam structure. Steel sheetpiling and earthen berms to provide a temporary water dam are unlikely options due to the soft, unconsolidated lake sediment. For the southwest corner of Onondaga Lake, use of a temporary water-filled dam using impermeable liner bags encased inside a separate fabric bag (to prevent rolling movement of the two water-filled bags) could effectively divert surface water during excavation. The maximum height of such dams is approximately 10 to 12 ft (3 to 3.7 m) and in many cases due to site-specific characteristics such as slope and sediment consistency, the feasible heights may be significantly less. Thus, the amount of area that could be dewatered would be confined to the nearshore zone less than 12 ft (3.7 m) in water depth due to hydrostatic pressure. In the event of upwelling through or around the diversion structure, a variety of dewatering controls could be used, such as collection trenches, sumps, pumps, well points, and berms.

3.3.5.3 Transport and Dewatering

Once the sediments are dredged, they must be handled and transported to a consolidation or disposal site. In addition, water in the sediments or entrained during the dredging process may need to be managed during these steps. The issues of dewatering and transport are considerably different for mechanical versus hydraulic dredging. Figure 3.7 provides a flow chart comparing the processes.

For mechanical dredging, material is typically moved to a barge, the barge is transported to the shoreline, and sediments are then moved to a land-based holding facility or transport system. Typically, mechanically dredged sediments are dewatered in a temporary holding facility at an upland shoreline site before upland transport. Dewatering technologies are commonly used to reduce the amount of water in dredged sediment and to prepare the sediment for upland transport and on-site consolidation or off-site disposal. Dewatering technologies include:

- Gravity Dewatering – natural evaporation, consolidation, and drainage are employed to remove water. The process is able to handle large volumes of sediment and variable flow rates; however, it requires sufficient land and time, which depend on the physical characteristics of the sediment. The process can typically achieve up to 50 percent solids by weight for fine-grained sediment and 70 to 90 percent solids for sands.
- Mechanical Dewatering – water is squeezed, pressed, or drawn out. The process requires operator attention, consistent favorable flow rate, consistent sediment feed quality, conditioning chemicals, and removal of dewatered solids on a regular basis. This is a relatively quick method of dewatering and requires relatively little space. If vaporization is a problem or winter operations are anticipated, the equipment would require housing in a building or sprung structure. Mechanical dewatering options include:
    - Centrifugation;
    - Filtration with a belt filter press;

- Filtration with a plate and frame filter press;
- Filtration with a vacuum filter;
- Gravity thickening; and
- Active evaporative technologies.

Unless specifically controlled, some dewatering would likely also occur on the transport barge. Where sediments are extremely contaminated, barge dewatering can be completely prevented by welding shut all ports on the barge. In other cases, barge dewatering is a specifically designed part of the dewatering approach, and various systems have been employed to filter or treat these discharges. These systems include relatively simple steps of placing hay bales and/or filter fabric in front of dewater ports to provide removal of particulates prior to release. More complex systems have also been employed at some sites, including a fabricated sediment pen and sand filtration system constructed on a derrick barge. In this approach, each barge contains a specially constructed sand filter system designed to allow drainage and filtering of free water from the sediments. If environmentally acceptable, barge dewatering can reduce the extent or time needed for onshore dewatering operations.

Dewatering would be necessary prior to some *ex situ* treatment technologies such as thermal treatment. Removal of water would decrease the weight of the sediment but may or may not reduce sediment volume, depending on the characteristics of the sediment. Once sediments are dewatered, they can either be transported via land-based methods (e.g., excavators, dump trucks, train cars) or confined in place at the dewatering site. Water generated during dewatering is discharged from the upland holding facility either directly to receiving waters or after additional treatment as warranted.

For hydraulic dredging, a substantial amount of additional water is entrained with the sediments; the resulting slurry can be 80 to 95 percent water by weight. Typically, the slurry is pumped directly to the final consolidation site, which must be relatively close to the dredge site. Booster pumps can increase the transport distance, but this generally increases costs and creates more logistical issues as well. Once placed, the sediment slurry is allowed to settle and clarify. Clarified water is discharged either directly or after treatment. Once a consolidation cell's capacity has been met, the resulting sediments are normally allowed to further dewater by gravity, as noted above for mechanical dredging. After a suitable period of dewatering, it is possible to mechanically excavate the sediments and place them at another location.

Typical water treatment options associated with sediment placement activities can include settling and/or filtration with or without chemical additives. Other treatment options include air stripping of volatile organics, chemical precipitation to remove metals, and activated carbon adsorption. These water treatment technologies are generally implementable due to their widespread availability for industrial water treatment. However, less commonly implemented, more sophisticated water treatment technologies, such as ion exchange, can be much more difficult to implement long term. Selection of preferred water treatment technologies primarily depends on the characteristics of the water being treated, the required effluent quality, the magnitude and variability of the flow rate, the required time period for treatment, the availability of land and utilities, operator availability and experience, and the required level of equipment decommissioning.

3.3.6 Sediment Consolidation or Disposal

As noted above, on-site sediment consolidation or off-site disposal cannot take place until sediments are removed from their existing location. Thus, this technology is only feasible in combination with one of the removal technologies described in the previous subsection.

On-site consolidation sites can be in-water (aquatic), along shorelines (nearshore), or in upland areas. Disposal sites are typically off-site in upland areas. They can be unconfined (e.g., land application), partially confined, or completely confined from the surrounding environment by relatively impermeable barriers and caps. In addition, placements of sediment can be in sediment consolidation sites specifically created for the project, sites created and shared by other cooperating entities that also need to place materials, or existing off-site disposal facilities that accept contaminated or treated materials (e.g., privately or publicly owned landfills). A nearshore aquatic confined consolidation facility is technically possible in Onondaga Lake, but such a facility would not be in compliance with 6 NYCRR Part 608.5 (excavation and placement of fill in navigable waters), so it is not discussed further. Figure 3.8 shows a schematic for a typical upland sediment consolidation area. Designs for such facilities can vary widely from site to site.

A discussion of dredging and placement must consider the logistics of transport from one location to the other. A variety of methods can be used, depending on the sites in question. Generally, mechanical dredging requires some rehandling of the material between its source and destination, while hydraulically dredged sediment may be transported via pipeline as discussed in the previous subsection. For off-site disposal, direct transport via hydraulic pipeline is not possible due to the distances involved. In this case, sediments would have to be consolidated on-site in the short-term and then transported to the long-term off-site disposal facility. Rehandling steps can create another potential source of CPOI or sediment loss to the water column. Transport to off-site facilities would generally be by truck, rail, and/or barge. All methods of dredging create some surplus water, which must be managed using the technologies discussed in Subsection 3.3.5.3.

Potentially applicable locations for Onondaga Lake sediment placement are evaluated in detail in Section 4 and include on-site sediment consolidation at a site near the lake (such as an existing waste management unit) or off-site disposal at a permitted solid waste or hazardous waste facility. Depending on the volumes of sediments being removed, an existing site near the lake could be used as a long-term, on-site, sediment consolidation area, including:

- Wastebed B (48 acres; 19 hectares);
- Semet/Willis Ave. Site (62 acres; 25 hectares);
- Wastebeds 9 through 11 (126 acres; 51 hectares);

- Wastebeds 12 through 15 (536 acres; 217 hectares); and
- LCP Operable Unit 1 (21 acres; 8.5 hectares).

These areas are all within a suitable distance from shore to allow placement by either hydraulic or mechanical means. An on-site sediment consolidation area for receiving lake sediments would be an upland structure designed to contain sediment in accordance with USACE (2003) guidance. Such a sediment consolidation area would be managed as a containment facility that does not adversely affect the soil or water outside the containment unit. Sediments with different characteristics can be segregated and contained using various methods within the sediment consolidation area.

The USACE has defined a sediment consolidation area as a structure designed to provide the required area and volume to contain dredged material and to control contaminant releases from the structure (USACE, 2003). Such a facility may be designed to prevent adverse impacts to the soil or water outside its boundaries. Containment techniques applied at a sediment consolidation area vary by site and application. These techniques can be implemented at one or more of the existing sites listed above and may include one or more of the following:

- Alternating layers of clean and contaminated material to provide for attenuation (e.g., sorption, ion exchange, filtration, biodegradation) and/or containment of contaminants;
- Allowing or promoting consolidation of fine-grained materials so that their permeability is greatly reduced, resulting in a self-sealing/self-lining of the facility;
- Placing and compacting dredged material with suitable chemical and physical properties as the final cover layer;
- Drainage layers using sand layers to enhance dewatering and consolidation;
- Control of ponded water to reduce hydrostatic head or to maintain a negative hydraulic gradient, so that seepage flows into the unit rather than migrating away;
- Impermeable caps, if needed;
- Constructed underliners, if needed; and
- Leachate collection and treatment systems, if needed.

Many of these items are not needed at a given consolidation site. The need for items such as caps, underliners, and leachate collection and treatment systems must be analyzed to determine whether the consolidation are would adversely impact soil or water outside the site. If such impacts are possible, one or more of these additional measures might be employed, but otherwise they are not necessary.

For offsite disposal, consolidated and dewatered sediments would be transported to a currently operating permitted landfill. Table 3.2 summarizes the off-site disposal facilities that are the most likely candidates for Onondaga Lake sediments. Important criteria for selecting an off-site disposal facility are the distance to the facility and the method of transport (e.g., truck or rail). This information is also summarized in Table 3.2. Generally, costs for disposal increase with increasing distance, decreasing size of transport (e.g., truck is more expensive than rail), and need for managing any sediment as hazardous waste.

3.3.7 *In Situ* Treatment

To date, *in situ* treatment is largely an experimental technique that has had little full-scale application. It can include a number of methods that alter sediments in their existing environment to reduce chemical concentration, mobility, bioavailability, and/or toxicity; Table 3.1 lists the primary treatment categories. Agents added to the sediment can include energy (e.g., electricity), chemicals (e.g., binding agents, catalyzing agents, nutrients that speed degradation), microorganisms (e.g., bacteria or fungi that degrade organic compounds), or plants (e.g., certain shrubs and fast growing trees). In some cases, the treatment may involve physical mixing or other manipulation of the sediments. Some forms of *in situ* treatment require isolation (via berms or dams) of the area to be treated to prevent loss of chemicals or other agents to surrounding areas. In other cases, such as electrokinetic methods, physical isolation of the area to be treated is not typically necessary. In addition, as with any invasive remediation technology, any existing habitats or biological communities would be impacted in the short-term during *in situ* treatment implementation. Several of the more common *in situ* treatment technologies are discussed below.

3.3.7.1 *In Situ* Chemical or Biological Treatment

In situ biological treatment refers to the microbial degradation of contaminants by organisms, typically involving the addition of enhancement materials, such as oxygen and nutrients, into the sediment. *In situ* chemical treatment occurs when processes such as oxidation or reductive dehalogenation are employed for contaminant destruction by application of a chemical reagent such as calcium nitrate, potassium permanganate, hydrogen peroxide, or potassium hydroxide.

In situ treatment of sediment via biological and/or chemical treatment is an innovative technology with no known full-scale demonstrations. A process termed Limnofix™, which uses a combination of chemical and biological treatment, has been developed and pilot-tested by Environment Canada. This process may be capable of reducing mercury methylation through the injection of an oxidant (typically calcium nitrate) into the sediment. In theory, oxidant injection would increase the redox potential within the sediment and create a more oxic environment. It is anticipated that the rate of mercury methylation would be reduced or possibly reversed as the injection of an oxidant changes sediment conditions from anoxic (favorable for mercury methylation) to oxic (considerably less favorable for mercury methylation). However, oxidizing agents generally tend to increase mobility of metals; therefore, a decision on use of oxidizing agents would need to assess effects on other metals in addition to mercury.

The Limnofix™ technology has been applied to PAH and petroleum hydrocarbon contamination in Hamilton Harbor and a coal tar-contaminated site in Salem, Massachusetts (Renholds, 1998) and has been used to effectively reduce sulfide toxicity and control odors in the cities of Ontario, Michigan, and Hong Kong. This technology has not specifically been applied to reduce mercury methylation; however, the biological and chemical mechanisms would be similar to those proven effective at other sites. Thus far, applications of the Limnofix™ technology have been unsuccessful in reducing the chlorine content of chlorobenzenes using calcium nitrate as an oxidant (Golder, 2003).

3.3.7.2 Phytoremediation

Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain, and/or immobilize sediment contaminants within the root zones. Phytoremediation mechanisms include extraction of contaminants from soil or groundwater, concentration of contaminants in plant tissue, degradation of contaminants by various biotic or abiotic processes, volatilization or transpiration of volatile contaminants from plants to the air or water, immobilization of contaminants in the root zone, hydraulic control of contaminated groundwater and runoff, and erosion and infiltration control by vegetative cover.

In Onondaga Lake, phytoremediation using emergent vegetation may be an effective technology for reducing concentrations of mercury and organic contaminants within the upper few inches of sediment (i.e., the root zone of appropriate plants) in shallow waters. However, chemicals immobilized by roots or plant tissue would need to be removed by periodically harvesting the plants from the lake. Bench-scale and/or pilot studies would be required to determine the treatment mechanisms and the applicability and appropriateness of phytoremediation, based on site-specific conditions. It is likely that phytoremediation would, at best, be a polishing step for managing impacted shallow nearshore sediment within the root zone of suitable emergent aquatic plants.

3.3.7.3 *In Situ* Solidification/Stabilization

Solidification or stabilization of contaminated sediments occurs through the addition of Portland cement, fly ash, lime, or other additives which encapsulate the sediment in a solid matrix or chemically stable form (less soluble, less mobile, and/or less toxic). Solidification/stabilization is a potential option for solidifying and/or stabilizing mercury and other heavy metals. Long-term performance may be an issue, because *in situ* solidification may not change the toxicity of some chemicals within the sediments. In some instances it may alter some chemicals, resulting in changes in toxicity. In addition, the sediment may still be subject to erosion, so some erosion control layer is likely to be needed as discussed for capping.

Solidification/stabilization is a proven and viable technology for land-based sites. However, application of this technology has been problematic in the relatively few instances where it has been applied in lake or river environments. Lead stabilization through chemical addition was performed in the Fox River, Wisconsin (Renholds, 1998). Although better than 99.7 percent treatment efficiency for lead was observed, the mixing process resulted in resuspension of the majority of sediment into the water column. Field application of *in situ* solidification through injection of cement or fly ash slurries in Wisconsin was problematic due to the inability to control mixing conditions and curing temperatures during application (Renholds, 1998).

3.3.7.4 Electrokinetic Treatment

The electrokinetic remediation (ER) process removes metals and organic contaminants from low permeability soil, sludge, and sediments. ER uses electrochemical and electrokinetic processes to desorb, and then remove, metals and polar organics. This *in situ* soil/sediment processing technology is primarily a separation and removal technique for extracting contaminants from soils (FRTR, 2003).

The principle of electrokinetic remediation relies on application of a low-intensity direct current through the soil between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions to move toward the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move toward the cathode. Anions such as chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move toward the anode. Metals that concentrate at the electrodes can be physically removed. Organics can be made to degrade *in situ* by periodically switching the polarity of the electrodes. Targeted contaminants for electrokinetics are heavy metals, anions, and polar organics (FRTR, 2003).

Limitations for the technology include:

- Maximum effectiveness in soils has been shown to occur at moisture contents between 14 and 18 percent, much lower than the moisture content of most sediments;
- The presence of buried metallic or insulating material can induce variability in the electrical conductivity of the sediment;
- Extreme pH at the electrodes can inhibit the process; and
- Undesirable products such as free chlorine gas can be generated (FRTR, 2003).

There have been few, if any, commercial applications of electrokinetic remediation in the United States, and no known projects in sediments. The electrokinetic technology has been operated for test and demonstration purposes at the pilot scale and at full scale at Louisiana State University, Electrokinetics, Inc., Geokinetics International, Inc., and Battelle Memorial Institute. Geokinetics International, Inc. has successfully demonstrated the *in situ* electrokinetic remediation process in five field sites in Europe (FRTR, 2003).

3.3.7.5 Chemical Treatments of Profundal Sediments (SMU 8)

The revised RI (TAMS, 2002c) indicates that profundal sediments of Onondaga Lake (SMU 8) are a potential source of total mercury and methylmercury release to the water column. The revised RI also discusses the possibility that ebullition of methane gas may increase the release of both total mercury and methylmercury. NYSDEC (2003) hypothesized that *in situ* chemical treatments of the profundal sediments may provide a means to reduce these releases from profundal sediments.

In situ chemical treatment would involve the introduction of a substance to sequester chemicals in the profundal area to reduce or eliminate releases of mercury and other CPOIs from the profundal sediments, reduce future adverse effects of mercury contamination and other CPOIs, and achieve surface water quality standards. This application was originally intended to control internal cycling of phosphorus and minimize the release of phosphorus from the sediments by ebullition and diffusion. It is uncertain whether these techniques would have similar effects on mercury cycling. Profundal sediment chemical treatments (floccing agents) used to control internal nutrient cycling include alum (aluminum sulfate) or gypsum (calcium sulfate) (Salonen and Varjo, 2000; Monroe County Health Department, 2002; Minnehaha Creek Watershed District, 2003; WDNR and USEPA, 2003) or a calcium nitrate blend (e.g., Limnofix™). Alum and gypsum are typically placed as a thin layer over the surface sediments, whereas Limnofix™ is typically raked into the surface sediments to a depth of about 1 ft (0.3 m).

In situ chemical treatment has proven effective to minimize transport of phosphorus out of the sediments with both alum (Monroe County Health Department, 2002) and gypsum (Varjo *et al*., 2003). NYSDEC (2003) hypothesized that inorganic mercury would behave in a similar fashion as phosphorus. However, chemical treatment may not be an effective control to reduce methylmercury transport from the sediments. Benoit *et al*., (1999) indicate that the addition of sulfate to sediment would tend to inhibit methylation by reducing the ability of bacteria to absorb mercury. However, addition of high concentrations of sulfate to the sediments may counteract this effect and increase the activity of sulfate reducing bacteria (SRB), the principal methylators of mercury in aquatic sediments, anoxic hypolimnia and wetland soils (Rudd, 1995). High sulfate addition to the sediments is a concept with some theoretical and experimental support but has not been demonstrated as a treatment method for methylmercury production.

A case study on Little Rock Lake in Wisconsin evaluated the effects of flourishing SRB communities on methylmercury production with respect to available sulfate (Watras *et al*., 1995). The results indicated that as sulfate was added to Little Rock Lake, the abundance of SRB and the production of methylmercury in anoxic, hypolimnetic waters increased to very high levels. Fish contamination also increased in Little Rock Lake, confirming the link to SRB activity. After sulfate addition to Little Rock Lake was stopped, methylmercury production and fish contamination both declined (Hrabik and Watras, 2002).

The potential for mercury methylation is not limited to the activity of SRB; it is also dependent on the bioavailability of inorganic mercury. Both the activity of SRB and the bioavailability of inorganic mercury would increase over a moderate range of sulfate and sulfide concentrations. Then, as sulfide concentrations rise above a certain threshold, the bioavailable fraction of the inorganic mercury pool hypothetically declines, causing a reduction in methylation. But the available data from environmental studies on methylation are contradictory at very high sulfate and sulfide concentrations. For example, high rates of mercury methylation have been reported in some salt marsh sediments, even though sulfide concentrations also are very high (King *et al*., 2001).

The issue is complicated by the fact that the chemical speciation of mercury in anoxic sulfidic environments is incompletely understood and by the fact that the rate laws governing methylation in nature are also incompletely known. Nevertheless, it seems prudent to avoid enhancing the concentrations of either sulfate or inorganic mercury in habitats where mercury methylation is likely to occur. Because adding solid material such as gypsum is not a reversible technique, caution is needed in gypsum capping of mercury-rich areas, especially because as the sulfate is used up by SRB, the original dose applied will change and could result in a sulfate concentration that favors mercury methylation.

Limnofix^{TM} methods, unlike sulfate addition methods, are expected to reduce both mercury methylation and ebullition due to the introduction of the nitrate oxidant. However, it is unclear to what extent these effects would be reduced. Addition of nitrate into anoxic lake sediments would cause nitrate gas bubbles to be released in large quantities, presumably taking mercury with them in the same manner as methane bubbles. Secondly, nitrate is reduced to nitrogen gas during denitrification under anoxic conditions. Nitrogen gas is not very soluble in water and usually forms bubbles when denitrification occurs because lake water is already saturated with atmospheric nitrogen. Some of the nitrate will pass unchanged into the epilimnion water because nitrate is a very soluble and highly mobile ion. The introduction of large amounts of nitrate into a lake that shows low nitrate concentrations is likely to increase eutrophication and enhance anoxic conditions that favor formation of methylmercury and release of mercury from the sediments by ebullition and diffusion.

If application of *in situ* chemicals were successful at reducing bubbles of methane and nitrate, this capping technique would likely retain particulate mercury in sediments in much the same way as it retains phosphorus. However, it is unlikely that *in situ* chemical treatment would affect the formation of bubbles below the surface microlayers or minimize subsequent entrainment and transport of bubbles carrying mercury contaminated sediments to the overlying water.

Additional testing of these technologies for the specific effects on mercury would be needed to determine the feasibility of this remedial technology. It is likely that evaluation of these technologies for their applicability to mercury would need to be conducted in both bench-scale and pilot-scale studies.

3.3.8 *Ex Situ* Treatment (with Removal and Placement)

This GRA is a combination of the treatment and removal actions described above. Table 3.3 reviews the various *ex situ* treatment technologies in detail; this detailed review is only summarized in the following text. This technology is often considered separately from removal, but in reality, *ex situ* treatment and removal must occur in combination. Once removed and treated, the sediments must be managed by placement in a suitable location. If sediments have been rendered non-toxic, some form of beneficial reuse can also be considered. Because removal and placement technologies have been previously described, this subsection focuses on the treatment phase of such an application. As noted in the removal subsection, removal would impact any existing lake habitats or biological communities in the short term during technology implementation.

Table 3.3 presents information on potential types of *ex situ* sediment treatment technologies in detail. Usually, the location of treatment is in an upland area temporarily used for treatment purposes, although some forms of on-barge treatment also exist for mechanically dredged sediment. There is a vast array of different treatment types, and as with *in situ* treatment, they reduce the concentration, mobility, bioavailability, and/or toxicity of the chemicals present in the sediments. Depending on the physical and chemical characteristics of the sediment after the treatment process, sediments might have a variety of end uses or placement options. In some cases, sediments might be left where they are treated and used as, for example, fill for a wastebed for eventual upland development. In other cases, the material might be taken to another location for disposal, including the options listed in Subsection 3.3.6. In still other cases, treated sediments that have some commercial or other real value can be sold or given away and beneficially reused. Examples of beneficial reuse include vitrified glass used as road grade material, cement-stabilized material used as construction fill, and washed sands being used for habitat or beach restoration.

Sediment treatment technologies reduce contaminant concentration, mobility, and/or toxicity through:

- Destruction of the contaminant;
- Conversion of the contaminant to a less toxic form;
- Separation or extraction of the contaminant from the solid phase and treatment of the water or solvent containing the CPOI;
- Volume reduction of contaminated sediment by separating cleaner particles from the contaminated fraction; and
- Physical and/or chemical stabilization of the sediment.

Sediment treatment following removal can occur through one process or a combination of processes. The effectiveness of each technology to treat the CPOIs depends on sediment characteristics such as particle size, solids content, and contaminant concentration. In addition to effectiveness and technical feasibility, other factors to consider in the implementation of sediment treatment include land requirements, water treatment, and air emissions control.

3.3.9 Aeration (Oxygenation) of the Hypolimnion

Aeration (oxygenation) is an *in situ* treatment technology for lake water that can also affect the upper layers (likely less than the top 0.5 in [1 cm]) of profundal sediments. Aeration (oxygenation) techniques involve introducing oxygen into the lake water. This technology is intended to reduce the rates of mercury methylation (which occurs in anoxic environments) and thereby decrease the bioaccumulation of mercury into the food chain. Because aeration (oxygenation) technologies address a particular aspect of the chemical fate and transport system (e.g., mercury methylation, primarily in the water column), they would likely be performed in conjunction with other types of direct sediment remediation in various SMUs of the lake.

Production of methylmercury can be suppressed if oxygen is present in the deep water and surface sediments. Several types of mechanical devices exist that can introduce oxygen into lake water. Using a mechanical device placed in the hypolimnion of the lake, supplemental oxygen can be added either as air (20 percent oxygen) or as 100 percent oxygen. Equipment also exists for bubbling air through the water column from underwater emitters. These latter systems can cause destratification of lakes, which can have numerous undesirable consequences. Therefore, it is expected that hypoliminetic oxygenation, which would not be expected to destratify the lake, would be a preferred method. However, pilot or additional paper studies would need to be conducted to confirm this assumption.

Hypolimnetic oxygenation or similar technologies would be expected to reduce methylmercury production in the hypolimnion. Although there are uncertainties regarding the methylmercury budget of the lake, the revised RI (TAMS, 2002c) indicates that approximately 50 percent of the methylmercury production occurs in the hypolimnion. Consequently, hypolimnetic oxygenation or similar technologies would be expected to create as much as a 50 percent decrease in methylmercury production in Onondaga Lake. There are considerable uncertainties associated with making an exact prediction of methylmercury reductions, and clearly, the reduction levels could be less. However, it is reasonable to assume that a considerable portion of the methylmercury production in the water column would be eliminated by oxygenation. There may also be decreases in methylmercury production in the top layers of the profundal sediments, to the extent that oxygen penetrates these layers. Oxygen penetration into the sediments would be expected to be only a few millimeters in firm sediments but may extend to 1 to 2 inches (3 to 5 cm) in flocculent sediments. However, it is not expected that this oxygen penetration would cause substantial decreases in profundal sediment methylmercury production, due to the fact that sediment underlying layers would still be anoxic.

Drawbacks to aeration (oxygenation) may include expansion of nuisance species of submerged plants, such as the Eurasian Milfoil, into the clearer water and invasion of zebra mussels into the deep waters of the lake. In addition, aeration (oxygenation) may lead to an increased food chain length that could increase methylmercury at the highest trophic level, although the overall reduction in methylmercury should offset this effect. Further oxygenation of the profundal surface sediment may result in changes in the redox conditions of other metals or chemicals with those sediment, which may or may not be beneficial to the lake in general. Ancillary benefits of aeration (oxygenation) are elimination of toxic ammonia, hydrogen sulfide, and reduction of methane/nitrogen bubbles that may transport mercury particles from sediments into water.

All types of aeration (oxygenation) systems currently available would require annual operation and maintenance. In addition, prior to implementing any such system, it would be necessary to conduct a pilot study to understand the full impacts to the lake. A preliminary experimental design plan report for an in-lake air/oxygenation delivery system is being prepared by ENSR, Inc. (under contract with the USACE) for the Onondaga Lake oxygenation demonstration project to determine the feasibility and viability of oxygenation and to recommend appropriate design and monitoring plans. The contract for this work was awarded in September 26, 2003. The final preliminary experimental design plan report is scheduled for release in August 2004. The report will include a detailed evaluation of the feasibility of oxygenation, along with engineering and cost factors, so that more detailed plans and specifications can be developed. Consequently, if it appears that aeration (oxygenation) is a potentially useful technology, any remedial design pilot study of the technology should be integrated with these already proposed demonstration projects. In addition, if these demonstration studies indicate the technology is useful, it would be necessary to integrate the findings of this study to determine a full-scale approach compatible with the long-term lake management goals.

3.3.10 Habitat Enhancement Technologies

Habitat enhancement is an important goal within Onondaga Lake. It is a component of sediment removal and capping remedial technologies, as discussed above. However, it is important to understand and consider habitat enhancement as a stand-alone technology, since in some areas (e.g., SMUs 3 and 5), remediation of physical impacts from wastes (e.g., calcitic sediments and oncolites) may be required regardless of the need for any chemical remediation efforts.

For remediating physical wastes, habitat enhancement focuses on stabilizing the existing substrates and includes the use of lake shore structures to establish plant growth and the potential use of submerged structures such as large woody debris to create habitat. It also includes adding substrates (e.g., fine gravel) suitable for spawning habitats. Temporary energy barriers might also be used as a part of these efforts to minimize potential adverse effects of waves on habitat establishment and plant growth.

Shoreline stabilization can be accomplished by using several different methods, including conventional physical armoring with rock riprap and bioengineering techniques that use native plant materials. Advantages of bioengineering techniques are that they: 1) create a natural aesthetic appearance; 2) provide wildlife habitat and cover; and 3) are environmentally compatible. Disadvantages are that they: 1) need an establishment period; 2) may require higher initial maintenance; and 3) are more sensitive to seasonal changes (ESCSWCS, 1997).

In addition to stabilization of the shoreline, techniques for habitat enhancement include:

- Establishment of woody vegetation on the shoreline;
- Placement of large woody debris to increase aquatic habitat structure;
- Placement of fine gravels as spawning substrate;
- Establishment of macrophytes to stabilize oncolites in sediments (if possible);
- Stabilizing oncolites using vertical (e.g., hay bales) or horizontal (e.g., degradable chicken wire) treatments to allow macrophyte establishment; and
- Promoting macrophyte establishment in stabilized oncolite areas through seeding, planting, or constructing temporary wave breaks and/or herbivore protection.

Some of these techniques would only be applicable to some portions of the lake (e.g., oncolite stabilization), while others (e.g., spawning gravel) would be potentially suitable for a wide variety of locations either in conjunction with chemical remediation efforts such as dredging/capping or by themselves.

3.4 REMEDIAL TECHNOLOGY SCREENING

Ten major GRAs and numerous specific remedial technologies within each GRA were discussed in detail above. When considering the variety of physical, chemical, and biological environments at the site (broken into 9 SMUs presented in Subsection 2.2), numerous combinations of remedial technologies could conceivably be applied across the lake. As recognized by both New York State (NYSDEC, 1990) and USEPA (1988) FS guidance, there is typically a screening step in the evaluation of remedial technologies that might be applied to the site. This is explicitly recognized in Step 4 of the evaluation process presented in Subsection 3.1, which is based on state guidance.

3.4.1 Screening Methods

According to state guidance (NYSDEC, 1990), "Screening is used as a tool throughout the alternative selection process to narrow the options being considered." Further, the guidance indicates that the objective of screening steps in the evaluation process is to narrow the list of remedial technologies or alternatives that will be evaluated in detail. Because of the myriad potential remedial technologies, the screening step should use comparatively simple methods that can quickly screen those technologies. More detailed evaluations are left to the evaluation of alternatives in Section 4. Again the guidance states, "Because the purpose of the screening evaluation is to reduce the number of alternatives that will undergo a more thorough and extensive analysis, alternatives should be evaluated *more generally* in this phase than during the detailed analysis" (emphasis added).

The general method for screening remedial technologies recommended by state guidance (NYSDEC, 1990) is: "When alternatives are being developed, individual remedial technologies should be screened primarily on their ability to meet *medium-specific remedial action objectives, their implementability, and their short-term and long-term effectiveness*" [emphasis added]. Because a technology that does not meet medium-specific remedial action objectives can usually be deemed ineffective, the following two overall evaluation criteria were used in this subsection to screen remedial technologies:

- Implementability and
- Effectiveness (both short and long term).

Following guidance, the screening used a relatively simple qualitative and comparative approach. The results of this analysis are presented in Table 3.4, which provides a general discussion of each technology's performance relative to each screening criterion. This is intended to be a "common sense" approach, and is based on knowledge of the various technologies, an understanding of their advantages and disadvantages (as summarized by documents like USEPA 2002a), and best professional judgment. GRAs are screened on a site-wide basis (results in Subsection 3.4.2) and then on a SMU basis (see results in Subsection 3.5).

3.4.2 Screening Results

While Table 3.4 provides a description of reasoning behind screening decisions for every technology, the text in this subsection provides an overall summary of some key factors that resulted in screening out certain GRAs and technologies. Technologies screened out for all SMUs were: *ex situ* treatment, *in situ* treatment, and reactive capping. Key factors for screening out these technologies for all SMUs are discussed below.

3.4.2.1 *Ex Situ* Treatment

Many treatment technologies have limited effectiveness because they only apply to one category of chemical (e.g., organic compounds) that exists in the lake sediments. Other treatment technologies are theoretically effective, but have never been proven on the scale that would be required for this project, or even on a pilot-scale. Finally, some treatment technologies may be proven effective on a smaller scale, but significant uncertainties remain about one or more implementation issues. In combination, these limitations appear to make these technologies less favorable in comparison to more proven technologies that tend to be more implementable for a variety of reasons detailed in Table 3.4. Thus, *ex situ* treatment was screened out for all SMUs.

This conclusion is consistent with draft USEPA guidance (USEPA, 2002a). Although the USEPA draft guidance presents *ex situ* treatment as the most viable potential treatment GRA, it does so in the context of ensuring that on-site consolidation or off-site disposal does not simply transfer risks to another site. If the contaminated sediments can be properly placed in a manner that effectively minimizes the potential for long-term impacts at the consolidation site, treatment steps may not be necessary. For Onondaga Lake, a consolidation site can be designed to minimize risks. Thus, it appears unnecessary to further evaluate treatment prior to placement and consolidation. It should be noted that in this context, *ex situ* treatment does not include processes that are generally employed as a normal part of dredging, placement, and consolidation of sediments. These can include active or passive dewatering, treatment of discharge water from consolidation or dewatering areas, and active or passive consolidation of sediments in a sediment consolidation area. These types of specific technologies are retained as a part of the overall dredge and consolidation technologies discussed previously.

3.4.2.2 *In Situ* Treatment

The same issues that apply to *ex situ* treatment also apply to the majority of existing *in situ* treatment technologies. For many such treatment technologies, the problem of proven effectiveness on a large-scale is an even greater issue, because many have rarely, or even never, been applied on a full scale to sediments. These limitations are particularly relevant to biological/chemical treatment, phytoremediation, solidification/stabilization, and electrokinetic treatment. Thus, these technologies are relatively infeasible, as compared to other technologies, for all SMUs.

The one potential exception is *in situ* treatment of profundal sediments. As noted in Subsection 3.3.7.5, there are considerable uncertainties associated with the effectiveness of such treatments to control mercury flux and, in some cases, applications could increase the production of methylmercury in the sediments. Based on these concerns and uncertainties, this alternative is not expected to be effective or implementable; therefore, this alternative was not retained for detailed evaluation in Section 4.

3.4.2.3 Reactive Capping

Reactive capping was screened out because it is essentially an augmentation of more standard isolation capping techniques. Generally, reactive capping has been investigated or implemented where standard capping was found to be potentially ineffective. Thus, reactive materials are considered as one way to improve the overall performance of cap material. The performance and effectiveness of standard capping techniques has been extensively reviewed in Appendix H, capping issues; and it was found that standard capping techniques appear effective in all SMUs. Thus, compared to standard capping techniques, reactive capping is more difficult to implement and may only be effective for specific chemicals. It should be noted that if design-level evaluations determine that standard capping may not be effective for particular chemicals or in currently undiscovered areas of NAPL or very high chemical concentrations, reactive capping that targets those chemicals and/or areas would be re-evaluated. For now, it appears unnecessary to carry this technology through to the detailed evaluation of alternatives.

Finally, “no action” was retained as a “remedial technology.” In actuality, this option is the absence of any technology, and is deemed inappropriate for the site. It is retained for evaluation purposes only and is used in Section 4 as a baseline condition for comparison with other, active alternatives.

Based on the evaluation presented above, the technologies are screened specifically by SMU in the next subsection.

3.5 REMEDIAL TECHNOLOGY APPLICATION BY SMU

Some technologies may be better applied to some SMUs than to others. For example, dredging gravels and cobbles, although often possible, presents greater logistical and implementation challenges than dredging finer materials. This subsection applies the information from the general screening approach in the previous subsection on a SMU basis to determine which areas are better suited to particular remedial technologies. The results of this SMU-based screening are shown in Table 3.5 and discussed below. It should be noted that technologies screened out in Subsection 3.4 are not discussed further below. As noted above, the no action alternative is only retained for comparative purposes in Section 4. Key factors for screening out technologies by SMU are discussed below.

3.5.1 Institutional Controls

In general, institutional controls can be applied to the entire site. Examples of controls that could apply to any SMU include restrictions, advisories, or regulations against dredging, using lake water for human consumption, swimming, fishing, and/or boating. These controls have several potential compliance and enforcement drawbacks, as discussed in Section 3.3.2.

Controls attempting to limit people's exposure to the lake would apply mostly to littoral SMUs (i.e., SMUs 1 through 7). Examples of this type of control include fencing and signs along shorelines, land use plans limiting parks or waterfront access, restrictions on development and land use along shorelines, and restrictions of shoreline construction such as docks or piers.

Institutional controls are one of the most likely remedial technologies to be applied in combination with other remedial alternatives. In some cases, the institutional control would be implemented specifically to protect some aspect of another remedial technology. For example, dredging, in-lake construction, and boating controls (e.g., no wake zones, anchorage prohibitions) would likely be necessary in littoral SMUs where capping technologies have been employed to ensure that the cap integrity is maintained. Dredging controls would also be needed for MNR areas (likely applicable to SMU 8 profundal areas, see Subsection 3.5.2) to ensure that deeper, more contaminated sediments are not exposed by these activities. Consistent with the approach recommended by USEPA in draft guidance for sediment sites, institutional controls by themselves would rarely be considered an effective overall remediation (USEPA, 2002a).

3.5.2 Monitored Natural Recovery

There are two primary factors determining the applicability of MNR to any particular SMU:

1. The presence of fate and transport processes that support and drive MNR and
2. The severity of chemical contamination in that SMU.

Appendix N, monitored natural recovery, includes an evaluation of the fate and transport processes for each of the SMUs; it found that the SMU 8 profundal sediments appear to have the types of processes that support natural recovery. Specifically, these areas have ongoing deposition of sediments and limited, if any, resuspension, resulting in contaminant burial over time. In addition, the deeper littoral zone from approximately 20 to 30 ft (6 to 9 m) water depth appears to have similar types of processes as SMU 8, with net deposition of material and some limited resuspension. However, there is uncertainty associated with natural recovery processes in the deeper littoral zone due to the limited amount of data collected. At this time, it is estimated that MNR is potentially feasible in the 20- to 30-ft (6- to 9-m) zone of SMUs 1 through 7, but that further evaluation and data collection at the design level is warranted to confirm this FS-level estimate.

Regarding severity of chemical contamination, some areas of SMU 8, particularly near the border with SMUs 1, 2, 4, 6, and 7, may have CPOI concentrations (particularly of mercury) that are too far above most chemical benchmarks to achieve natural recovery in a reasonable time. The exact areas within SMU 8 that are suitable for natural recovery would need to be determined once chemical-specific remediation goals have been finalized for the preferred remedial alternative.

3.5.3 Thin-Layer Capping

As with MNR, the primary determining factors for applicability of thin-layer capping are the physical processes and chemical concentrations present in the various SMUs. However, unlike

MNR, thin-layer capping can be designed to be effective in a wider range of physical systems. For example, MNR in the shallow littoral areas appears infeasible due to the frequent resuspension and transport of sediments in these areas through wind/wave action. However, thin-layer capping with materials containing a substantial gravel component could be designed for these areas to limit the amount and frequency of resuspension and provide an effective barrier to underlying contaminants. In some SMUs (e.g. SMU 1), upland groundwater controls that are currently contemplated would likely need to be constructed for thin-layer capping to perform effectively. Thin-layer capping might also be feasible in combination with prior dredging to achieve final water depths that are less susceptible to erosion from wind/wave action in any of these SMUs.

Because the objective of thin-layer capping is not necessarily to provide complete isolation of the contaminated sediment layer, existing areas with chemical concentrations well above any target remedial action concentration would probably fail to achieve an acceptable chemical concentration within an acceptable time period. However, there is a considerable range of chemical concentrations within every SMU as depicted in the modified RI figures (TAMS, 2002c). In addition, there is a considerable range of remedial goals (in terms of specific chemical concentrations) that may eventually be applied to any particular SMU, and this entire range of remedial goals is evaluated in Section 4. Consequently, it is possible that portions of every SMU might achieve one or more of these potential cleanup concentrations.

Thin-layer capping is also a viable alternative in SMU 8, particularly where chemical concentrations are not expected to be sufficiently low after an acceptable period through MNR alone. Thus, thin-layer capping would likely be feasible in combination with MNR to achieve an overall remedy for SMU 8.

Based on both physical and chemical information for the SMUs, thin-layer capping has been retained for further evaluation in SMU 8 (Table 3.5).

3.5.4 Isolation Capping

For isolation capping, the thickness of the capping layer is limited by physical (e.g., water depth) and habitat constraints of the system. Appendix H, capping issues, indicates that a cap thickness for the chemical isolation layer of approximately 1 to 2.5 ft (0.3 to 0.8 m) would provide the necessary chemical isolation in all SMUs. The total cap thickness would also include other layers for habitat, erosion protection, safety factors, and to achieve desired water depths. As noted in Section 4, potential overall cap design thicknesses that account for all these layers would be substantially thicker than 2.5 ft (0.8 m). When combined with removal technologies, capping systems that preserve and even enhance the water depths and habitats could be designed for every SMU. To achieve the overall desired profile and habitats in any given case, capping might need to be performed in combination with prior dredging. Thus, even areas with relatively high chemical concentrations could conceivably receive an engineered cap that would provide effective remediation and limit chemical migration. Obviously, specific design parameters that provide chemical isolation, physical isolation, and bioturbation protection as well as desired water depths and habitats would need to be evaluated for each SMU, as discussed in Section 4. However, for initial screening, isolation capping was retained as a potentially viable technology for every SMU at the site. Because thin-layer capping appears feasible in SMU 8, isolation capping would also be feasible and is included as a potential technology for further evaluation in SMU 8.

3.5.5 Dredging with On-Site Consolidation or Off-Site Disposal

Dredging and on-site consolidation or off-site disposal appear to be potentially feasible for any of the SMUs and have been retained for further evaluation for each SMU. Both mechanical and hydraulic dredging methods have been retained for each SMU. However, it should not be inferred that dredging is equally viable in all SMUs. For example, dredging in deeper areas (e.g., SMU 8) generally requires larger equipment and involves slower production times. Dredging in shoreline areas with relatively coarse substrate (e.g., gravel or cobble) or shoreline structures may require specialized techniques, while dredging in areas with relatively fine sediments (silt/clays), such as SMUs 6 and 8, may have the potential for greater resuspension and loss of chemicals during the dredging process regardless of any BMPs used. However, dredging appears potentially viable in some form in all SMUs and is further evaluated in Section 4.

Both off-site disposal and on-site consolidation technologies also appear to be feasible for all SMUs.

3.5.6 Dry Removal

Dry removal is a proven technology that can have fewer short-term impacts to water quality than conventional dredging (USEPA, 2002a). However, dry removal can only be conducted over relatively limited shallow areas of the lake, and only then with considerable implementation issues associated with construction and removal of retaining structures. Additional dredging by more conventional means would be necessary in deeper areas of each SMU, regardless of the use of dry removal techniques. Consequently, mobilizing one type of more conventional dredging equipment that can effectively remove materials throughout each SMU appears to be more readily implementable. Further, the short-term effectiveness of conventional dredging can be improved by using a variety of BMPs that can reduce resuspension and loss of chemicals. However, because dry removal is both implementable and effective for at least a portion of the littoral SMUs, it is retained for further evaluation in SMUs 1 through 7 and 9.

3.5.7 Vertical Containment

An onshore barrier wall is expected to be part of the upland remediation at the Willis/Semet and Wastebed B sites, and is not part of the in-lake remediation considered in this FS. This onshore wall would provide reduction of groundwater advection as well as a barrier to any product-phase transport up-gradient of the onshore wall. Other onshore barrier walls may also be needed for areas of SMU 7 for some in-lake remedial alternatives such as capping to be feasible (see Section 4 for more detail). However, because these are upland technologies associated with these other operable units, these vertical containment technologies are not discussed further in this document. It appears that additional in-lake barrier walls could be contemplated, but it is unclear that these technologies would provide any additional benefit beyond the onshore barriers currently being considered for upland sites. Consequently, in-water barrier walls have been screened out for all SMUs.

3.5.8 Aeration (Oxygenation) of the Hypolimnion

The primary purpose of aeration (oxygenation) would be to prevent or reduce anoxic conditions in the hypolimnion. This, in turn, is expected to reduce the production of methyl mercury from the profundal sediments of SMU 8, so this technology is retained for that area. Aeration (oxygenation) has the potential to reduce mercury cycling in the food chain, as called for by one of the remedial action objectives and a lake PRG. Reduction of mercury levels in biota would be an important improvement for all portions of the lake, not just SMU 8. Due to the diffusive processes associated with aeration (oxygenation), this remedial activity would not be required in all SMUs to be effective throughout the lake. However, for this FS, remedial activity associated with aeration (oxygenation) would target the hypolimnion in SMU 8.

3.5.9 Habitat Enhancement

Some type of habitat enhancement is essentially applicable to any littoral SMU (SMUs 1 through 7) in the lake. This particularly includes the establishment of spawning gravel, shoreline vegetation, or placement of large woody debris. These technologies could be integrated with chemical remediation efforts such as dredging and capping in most SMUs. The specific applications and areas that would receive habitat enhancement integrated with chemical remediation might vary considerably among areas. Habitat enhancement techniques focused on shoreline erosion stabilization and oncolite stabilization would be primarily applicable to SMUs 3 and 5. Habitat enhancements of the types discussed in this section would not be applicable to SMU 8.

SECTION 3

TABLES

SECTION 3

FIGURES

SECTION 4

DEVELOPMENT AND DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

4.1 DEVELOPMENT AND SCREENING OF LAKE ALTERNATIVES

4.1.1 Development of SMU-Specific Alternatives

Due to the large and complex nature of Onondaga Lake, the lake system has been segregated into SMUs that address areas with similar physical characteristics and common CPOIs, as detailed in Section 2. Remedial technologies were developed and screened by SMU in Section 3. Table 3.5 presented technologies potentially applicable to each SMU. These retained technologies are now developed into remedial alternatives for each SMU to address the RAOs and PRGs for Onondaga Lake. The SMUs have been segregated into two groups: the littoral area and the profundal area.

The fully developed remedial alternatives and comparative analyses are evaluated for each SMU as follows:

- Littoral Area SMUs: Subsection 4.3, 4.4, and 4.5 and
- Profundal Area SMUs: Subsection 4.6, 4.7, and 4.8.

Components common to all alternatives, such as sediment management and wastewater treatment, are evaluated and analyzed in Subsection 4.9. The discussion includes a detailed analysis comparing on-site consolidation with off-site disposal. Section 5 presents and evaluates lake-wide remedial alternatives based on the SMU-specific alternatives evaluated and screened in this section.

All of the alternatives include upland source control, including the No Action Alternative; however, the costs associated with upland source controls are not included as part of this FS. In general, upland sources related to former Honeywell operations must be controlled in conjunction with any remedial alternative selected for Onondaga Lake. In some situations, it may be possible for some components of a particular remedial alternative to be implemented before upland source control has taken place (e.g., habitat enhancement alternatives for the littoral area). Subsection 4.2 presents a detailed description of upland source controls considered during the remedial alternatives development process.

4.1.2 CERCLA Criteria Analysis

This section presents the remedial alternatives developed for each of the SMUs in Onondaga Lake and an evaluation of those alternatives based on the requirements of CERCLA and its implementing regulations set forth in the NCP. The remedial alternatives were developed to address the impacted media described in Section 1, consistent with the RAOs and PRGs discussed in Section 2.

The remedial alternatives for Onondaga Lake are assessed based on the evaluation criteria outlined in the NCP at 40 Code of Federal Regulations (CFR) Part 300.430. USEPA and NYSDEC have provided direction for evaluating these criteria in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988) and in Technical and Guidance Memorandum 4030: *Selection of Remedial Actions at Inactive Hazardous Waste Sites* (NYSDEC, 1990). These nine evaluation criteria are:

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Criteria

- Short-term effectiveness
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Implementability
- Cost

Modifying Criteria

- Community acceptance
- Support agency acceptance

An alternative (with the exception of the No Action Alternative) must meet the two threshold criteria to be carried through the detailed analysis of alternatives. If the threshold criteria are met, the primary balancing criteria are evaluated to provide the best overall remedy among the alternatives. The two modifying criteria of state acceptance and community acceptance will be addressed as part of the upcoming proposed remedial action plan and record of decision (ROD) that will be prepared by NYSDEC. Support agency acceptance indicates whether, based on its review of the RI/FS reports and proposed plan, NYSDOH (the support agency for NYSDEC) concurs with, opposes, or has no comments on the preferred remedy. Community acceptance, which will be assessed in the ROD, refers to the public's general response to the alternatives described in the proposed plan and the FS report.

In addition, further consideration is generally given by the NCP to "practicable" remediation. For the Onondaga Lake site in particular, NYSDEC has identified RAOs in the RI that are to be met, in each case, "to the extent practicable." As the term "practicable" is not specifically defined in the RI or in the NCP, the term must be understood on a site-specific, fact-specific basis. For the Onondaga Lake site, this FS assesses the "practicability" of various remedial alternatives on the basis of cost effectiveness, short-term and long-term impacts, implementability, and the extent of compliance with ARARs.

The threshold and primary balancing criteria are defined below, and the remedial alternatives described in this section are evaluated based on these criteria.

4.1.2.1 Threshold Criteria

4.1.2.1.1 Overall Protection of Human Health and the Environment

Current, ongoing potential risks have been identified within the baseline ecological risk and human health assessments (TAMS, 2002a, b). The preliminary RAOs presented in the RI have as their goal the protection of human health and the environment. The PRGs established in Section 2 have been developed to meet these RAOs. Evaluating the degree to which the potential alternatives would meet the PRGs in effect evaluates their ability to meet the threshold criteria of protection of human health and the environment and compliance with ARARs, unless a waiver is justified.

In addition, Section 4 will discuss the objective measures related to the magnitude of human health and ecological risk that would remain following implementation of the remedial alternatives.

4.1.2.1.2 Compliance with ARARS

Section 4 assesses ARAR compliance by determining the extent to which implementing an alternative would meet the federal and state chemical-specific, location-specific, and action-specific requirements identified in Section 2 and Appendix C, ARARs and TBCs, of this FS.

Constituents of ARARS

CERCLA ARARs are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site. These may be promulgated under federal environmental or facility siting laws or under more stringent state environmental or facility siting laws that were timely identified by the state (40 CFR 300.5).

Applicable ARARS

The determination of whether an ARAR is "applicable" is primarily a legal and jurisdictional determination. An "applicable requirement is one with which a private party would have to comply by law if the same action was being undertaken apart from CERCLA authority" (USEPA, 1991a). "For a requirement to be applicable, all jurisdictional prerequisites of the requirement must be met, including: (1) the party subject to the law; (2) the substances or activities that fall under the authority of the law; (3) the time period during which the law is in effect; and (4) the types of activities the statute or regulation requires, limits, or prohibits" (USEPA, 1991a).

Relevant and Appropriate ARARs

A relevant and appropriate ARAR is one that may lack one or more jurisdictional prerequisites for applicability but still may be well-suited for use at the CERCLA site because it addresses problems or situations sufficiently similar to those encountered at the site (40 CFR 300.5).

While a determination of applicability is primarily a legal one, a determination of whether a requirement is relevant and appropriate is site-specific and is based on best professional judgment, taking into account circumstances of the release or threatened release. There is more flexibility and discretion in making relevant and appropriate determinations, and it is possible for only a portion of a requirement to be considered relevant and appropriate, while other parts may not. However, only non-applicable requirements that are both relevant and appropriate qualify as ARARs.

Once a requirement (or part of a requirement) is found to be relevant and appropriate, it must be complied with to the same degree as if it were applicable.

To Be Considered

TBCs are non-promulgated criteria, advisories, guidance, and policies. Unlike ARARs, identification of and compliance with TBCs are not mandatory. However, where a TBC is used as a cleanup level, its use for this purpose should be explained and justified.

Detailed Analysis of ARARs in Feasibility Study

The NCP requires feasibility study evaluations of the effectiveness of each remedial alternative that address whether the alternative "complies with ARARs" (40 CFR 300.430[e][7][i]). A detailed analysis also is required of a limited number of alternatives "against each of nine evaluation criteria and a comparative analysis that focuses upon the relative performance of each alternative against those criteria" (40 CFR 300.430[e][9][ii]). One of the mandated nine criteria is compliance with ARARs, including those that were identified by lead and support agencies (40 CFR 300.430[e][9][i] and [iii)[B]). The determination of compliance with ARARs requires assessment of the alternatives "to determine whether they attain applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility siting laws or provide grounds for invoking one of the [ARAR] waivers." (40 CFR 300.430[e][9)[iii][B]).

4.1.2.2 Primary Balancing Criteria

4.1.2.2.1 Short-Term Effectiveness

Short-term effectiveness evaluates the effects of an alternative on human health and the environment during the construction or implementation phase of a remedial action. The following elements are considered while evaluating the short-term effectiveness of each alternative:

- Protection of the community during remedial construction;
- Environmental impacts and impacts to site employees and remediation workers during remedial construction;
- Air and surface water monitoring to be performed during implementing the remedial alternative(s);
- Elapsed time until remedial action objectives would be achieved; and
- Impacts on the ecological community, such as habitat loss.

4.1.2.2.2 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of a remedial action are evaluated in Section 4 based on the following:

- Permanence of the remedial alternative;
- Magnitude of the human health and ecological risk remaining after remediation; and
- Adequacy and reliability of controls, if any, used to manage treatment residuals or untreated wastes that remain at the site following remediation.

4.1.2.2.3 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion is evaluated in this section by measuring the effectiveness of material management technologies included as part of an overall remedial alternative. The evaluation of the reduction of toxicity, mobility, or volume involves consideration of the following:

- Type of treatment system;
- Degree of expected reduction in toxicity, mobility, or volume;
- Degree to which treatment would be irreversible;
- Type and quantity of residuals that would be present following treatment; and
- The USEPA preference for treatment as a principal remedy element.

4.1.2.2.4 Implementability

Implementability considers the technical and administrative feasibility of implementing an alternative and the availability of the services and materials required during its implementation. The following factors are examined in Section 4 as part of implementability to the extent each factor is relevant for each remedial alternative:

- Anticipated remedial construction and/or operation steps;
- Reliability of technology;
- Extent and complexity of monitoring remediation effectiveness following implementation;
- Ease of undertaking additional remedial actions as needed;
- Activities needed to coordinate with other offices and agencies to obtain necessary approvals and permits;
- Availability of adequate on-site or off-site treatment, storage capacity, and disposal services;
- Availability of necessary equipment, specialists, skilled operators, and provisions to ensure any necessary additional resources; and
- Amount of material that would need to be contained and/or treated.

4.1.2.2.5 Cost

Cost estimates were not completed for SMU-specific alternatives. Estimating costs based on lake-wide alternatives allows consideration of economies of scale and more accurate distribution of costs associated with issues such as sediment management facility and water treatment facility construction. This allows more accurate cost estimating and provides an appropriate basis for evaluating and comparing alternatives. A cost estimate has been prepared for each lake-wide alternative in accordance with *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (USEPA, 2000a). The cost evaluation assesses estimated capital, annual operation and maintenance (O&M), periodic costs, and total net present value.

Capital costs are those expenditures that are quantifiable and required to construct or implement a remedial action; they consist of present, future, and direct and indirect expenses. Direct capital costs include construction, site development, transport and disposal, startup, and shakedown costs necessary to implement the remedial alternative. Indirect capital costs include expenditures for engineering, regulatory approvals, construction oversight, contingency allowances, and any other services that are not part of the actual installation costs.

O&M costs are those post-construction costs necessary to ensure or verify the continued effectiveness of a remedial action. These costs are typically estimated on an annual basis and may include, but are not limited to, labor, equipment, and energy associated with activities such as monitoring; operating and maintaining extraction, containment, treatment systems, and disposal.

Periodic costs are those expenditures that occur occasionally (e.g., five-year reviews, equipment replacement, etc.) during the entire O&M period or remedial timeframe. These costs may include either capital or O&M costs.

The net present value for each remedial alternative has been estimated using a consistent maximum period of analysis following remediation of 30 years and a discount rate of 7.0 percent. This discount rate is based on an economic analysis performed by the Office of Management and Budget. The approximate accuracy of the cost evaluation is minus 30 percent to plus 50 percent, consistent with FS guidance documents, based on the fact that none of the remedial alternatives have been through a detailed design effort.

In addition to development of an estimated cost, alternatives are evaluated on the basis of cost-effectiveness under the comparative evaluation of alternatives. CERCLA Section 121 and the NCP require that the selected remedy must be cost-effective. A remedial alternative is cost-effective if its “costs are proportional to its overall effectiveness” (40 CFR 300.430[f][1][ii][D]). Overall effectiveness of a remedial alternative is determined by evaluating the following three of the five balancing criteria: long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness. Consistent with that requirement, the NCP further provides that costs that are grossly excessive compared to the overall effectiveness of an alternative can be relied upon as a basis for eliminating that alternative from consideration (40 CFR 300.430[e][7][iii]).

4.2 UPLAND SOURCE CONTROLS

The control of upland sources is an integral part of the overall remediation of Onondaga Lake. The RI (TAMS, 2002c) recognized that, for long-term remedial actions at Onondaga Lake to be effective, significant external sources of mercury and other CPOIs have to be remediated. The lake will continue to be subject to external contributions from both former Honeywell operations and non-Honeywell sources until significant external upland sources of mercury and other CPOIs, such as chlorinated benzenes and PCBs, are eliminated.

Upland sources include those related to former Honeywell operations and those from other sources. Significant upland sources related to former Honeywell operations include the Willis Avenue and Semet Residue Ponds Sites, the East Flume, the LCP Bridge Street Site, Geddes Brook / Ninemile Creek, and Harbor Brook / Wastebed B. Several other upland sources related to former Honeywell operations are subject to additional investigative efforts under separate programs; these may or may not require remediation, depending on the results of these investigative efforts. While these investigative and remedial efforts are not part of the remedial alternatives developed and evaluated in this FS, they do impact potential remedial efforts in certain areas of the lake, particularly near the proposed hydraulic containment system near the Willis Avenue, Semet Residue Ponds, and Wastebed B Sites and near the Ninemile Creek discharge. The status of these investigative and remedial efforts for the upland sites related to former Honeywell operations are shown in Table 4.1 and discussed in Subsection 4.2.1 below.

The status of some non-Honeywell upland sites are shown on Table 4.2 and discussed in Subsection 4.2.2.

4.2.1 Major Upland Sites Related to Former Honeywell Operations

4.2.1.1 Willis Avenue/Semet Residue Ponds Hydraulic Containment System Interim Remediation Measure

A hydraulic containment system is proposed for the lakefront in the Willis Avenue / Semet Residual Ponds area. This interim remediation measure (IRM) is planned to eliminate, to the extent practicable, the discharge of contaminated groundwater and NAPL to Onondaga Lake. The Willis/Semet IRM is also intended to eliminate, to the extent practicable, direct point source discharges to the lake through storm water conveyances, and to eliminate, to the extent practicable, potential impacts to fish and wildlife resources associated with ongoing discharges from the site.

4.2.1.2 East Flume IRM

Remediation associated with the East Flume IRM and hydraulic control (i.e., abandonment of sewer line) would address a small percentage (about 1.5 percent) of the external sources of mercury to Onondaga Lake, based on the mercury mass balance presented in the RI and summarized in Section 1.

The East Flume IRM includes the abandonment of an existing 72-inch concrete pipe that discharges to the Upper East Flume, extension of an existing 60-inch concrete pipe into Onondaga Lake, and excavation of approximately 19,000 CY of sediment from within the Upper East Flume.

4.2.1.3 LCP Bridge Street Site / West Flume

The LCP Bridge Street Site / West Flume includes removal of impacted sediments, restoration of Wetlands A and B and the West Flume, installation of a low-permeability barrier wall around the site, installation of a low-permeability cap, and pumping of groundwater inside the barrier wall.

Remediation of the LCP Bridge Street Site OU-1 and OU-2 would control discharges to the West Flume that ultimately end up in Onondaga Lake through Ninemile Creek. These discharges primarily impact Onondaga Lake, especially SMUs 1, 7, and 8..

4.2.1.4 Ninemile Creek / Geddes Brook

Remedial action involving removal of impacted sediments for Ninemile Creek and Geddes Brook channel sediments and Geddes Brook / Ninemile Creek floodplain soils/sediments has been proposed. The remediation would significantly reduce the contribution of mercury and other CPOIs to Onondaga Lake, particularly SMUs 4 and 8. In conjunction with the remediation of the LCP Bridge Street site, these remedial efforts would control up to 38 percent of the external sources of mercury to Onondaga Lake, based on the mercury mass balance presented in the RI (TAMS, 2002c) and summarized in Section 1.

4.2.1.5 Harbor Brook

A RI, BERA, and HHRA are currently proceeding for Harbor Brook and are scheduled to be submitted to NYSDEC.

An IRM has been proposed for Harbor Brook / Wastebed B consisting of a hydraulic containment system that would collect contaminated groundwater including NAPL to the extent practicable. The IRM is intended to isolate and collect residuals from groundwater before they enter Onondaga Lake and Harbor Brook via the Harbor Brook / Wastebed B and potentially impact SMUs 1, 7, and 8.

4.2.2 Non-Honeywell Upland Sites

There are a number of non-Honeywell upland sources that may contribute CPOIs to Onondaga Lake, as discussed in Section 1. Table 4.2 summarizes the current status of investigative and remedial efforts, as applicable, for some of these sites.

Although the lake trail extension is not an upland source, it may impact the development, evaluation and implementation of remedial alternatives and has therefore been included in the upland source control section. The southeastern area of SMU 5 and SYW-12 are currently being investigated as part of the Onondaga Lake trail and habitat project being conducted by the USACE. The trail project as currently envisioned may include creation of wetland and submerged macrophyte habitat. In addition, a portion of the existing trail passes through wetland SYW-6. The lake trail is recognized as an important recreational asset for Syracuse, therefore potential impacts to the trail are considered as part of the alternative evaluation process.

4.3 DEVELOPMENT AND SCREENING OF LITTORAL AREA ALTERNATIVES

In this subsection, remedial technologies retained from Section 3 are assembled into remedial alternatives that address the littoral area SMUs (SMUs 1 through 7). Considering the RAOs and PRGs applicable to the littoral area, this subsection then screens these alternatives against effectiveness, implementability, and cost to identify alternatives that will be retained for detailed evaluation in Subsection 4.4.

Two primary remedial technologies were retained to address sediments exceeding SECs: dredging and isolation capping. In addition, technologies applicable to habitat optimization in areas subject to ecological stressors, specifically calcitic sediments in SMU 3 and oncolites in SMU 5, were retained. These technologies were assembled into the following alternatives potentially applicable to the littoral area SMUs:

Alternative 1: No Action

Alternative 2: Habitat Enhancement

Alternative 3: Isolation Capping / Habitat Optimization

Alternative 4: Dredging / Isolation Capping / Habitat Optimization

Alternative 5: Full Removal

Alternatives that include a sediment removal component can be further subdivided based on treatment technologies to treat and/or address dredged sediments and the water resulting from dredging activities. Options to address dredged sediments and resulting water are discussed in detail in Subsection 4.9.

Alternatives 3, 4, and 5 are divided into options based on whether the remedial goal is the mean PECQ2, mean PECQ1, AET, PEC, or ER-L, as discussed below. These SECs are introduced in Sections 1 and 2, and explained in detail in Appendix J, sediment effects concentrations. The SECs are based on acute sediment toxicity tests conducted in 1992 during the RI and are used in the FS to identify areas and volumes of sediment that pose risk of toxicity to benthic macroinvertebrates. The SECs used in the FS address 23 CPOIs that contributed to sediment toxicity in Onondaga Lake, as described in Appendix J. Areas of exceedance for each of these SECs in SMUs 1 through 7 are shown in Figures 2.2 through 2.8. To ensure that potential risks presented by mercury are addressed, areas and volumes associated with exceedances of the mean PECQ2 and mean PECQ1 have been expanded to include exceedances of the mercury PEC.

The alternatives developed to address littoral area SMUs are discussed in detail below. The results of the alternative development and screening are discussed below and summarized in Tables 4.3 through 4.5. Table 4.3 summarizes the alternatives developed for each SMU. Table 4.4 provides the results from the SMU-specific screening of alternatives. Table 4.5 provides a summary of the alternatives for each SMU that were retained for detailed evaluation.

4.3.1 Alternative 1 – No Action

For the No Action Alternative, no action is implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals. This alternative assumes upland source controls are implemented to control external sources of CPOIs to the lake. The alternative does not include institutional controls, such as a fish consumption advisory. The No Action Alternative is retained for all SMUs as a baseline for comparison to other alternatives, consistent with CERCLA guidance and the NCP.

4.3.2 Alternative 2 – Habitat Enhancement

As discussed in Sections 2 and 3 and in Appendix M, habitat issues, habitat restoration and enhancement are important considerations for Onondaga Lake. They are also significant components of the sediment removal and capping remedial alternatives. However, under Alternative 2, habitat enhancement is designed as a stand-alone alternative to specifically address calcitic sediments and oncolites associated with SMU 3 (primarily calcitic sediments) and SMU 5 (primarily oncolites). The goals of the habitat enhancement alternative are to modify or enhance physical site conditions to facilitate meeting the habitat restoration and enhancement objectives, such as increasing the abundance of desirable submerged macrophytes, thus increasing the abundance of fishes (see Appendix M, habitat issues, for full description of the objectives). The habitat enhancement alternative focuses on stabilizing the existing substrates and includes the use of lake-shore structures to establish plant growth and the potential use of submerged structures such as large woody debris to create habitat. Temporary energy barriers would minimize potential adverse effects of waves on habitat establishment and plant growth.

SMU 3: Habitat enhancement would improve the littoral area of SMU 3 by stabilizing the shoreline to improve conditions to facilitate macrophyte establishment and fish spawning. The habitat enhancement alternative is designed to reduce the erosion of the calcite deposits located along the shoreline and to provide structure for fish spawning and protective cover.

Shoreline stabilization would be accomplished by using a combination of conventional physical armoring (i.e., rock riprap) and bioengineering techniques that use native plant materials. These techniques are viable for the majority of the SMU 3 shoreline (Figure 4.1). For this FS, the steeper banks at the northernmost portion of SMU 3 are considered to be part of the upland areas being addressed under a separate consent agreement. The preferred approach would be to establish woody vegetation on the shoreline using live fascines or brush mattresses to slow water movement, increase infiltration, trap slope sediments, and stabilize the substrate with the root system (ESCSWS, 1997). On steeper slopes (greater than 10 percent), riprap would be placed at the ordinary low water line to stabilize the toe of the slope and reduce wave energy to protect the plantings during establishment.

For live fascines, planting troughs would be created in the existing substrate and filled with planting medium to facilitate the initial establishment of the vegetation. Live fascines (bundles of tree saplings), typically willow (*Salix* spp.) would be planted within the planting troughs at irregular intervals and staked. On steeper slopes, brush mattresses would be used. Brush mattresses include live fascines, live stakes, and branch cuttings to cover and protect the shoreline with vegetation. The dimensions of the planting troughs, sediment amendments, and species composition and extent of live fascines and brush mattresses would be determined during remedial design.

To create fish habitat, large woody debris structures would be placed in the shallow littoral area to provide cover and increase foraging opportunities for fish (Moring *et al.*, 1989). These structures (e.g., log bundles or AquaCribs) would be placed in select areas between 4 and 15 ft

(1.2 to 4.6 m) below the annual low water level. These structures would be placed in clusters to form a "reef" at ten locations within the SMU (Figure 4.1). Six inches of fine gravel would be placed underneath these structures to serve as spawning substrate. The specific locations and the type and size of the large woody debris would be determined during remedial design.

SMU 5: Results from previous studies suggest that macrophytes may be able to colonize oncolitic sediments in Onondaga Lake if the oncolites are stabilized to prevent movement caused by wave action (Madsen *et al*., 1993; Madsen *et al.*, 1998). Although laboratory studies have demonstrated that macrophytes grow in oncolitic sediments (Madsen *et al.*, 1993), there is uncertainty with respect to what would occur in the field. Because it has never been demonstrated that macrophytes would successfully colonize oncolitic sediments in Onondaga Lake, treatment of all oncolitic sediments with any one approach contains significant risk. Alternatively, smaller-scale projects targeted to meet specific criteria for improving habitat conditions in SMU 5 are more prudent.

Targeted areas would be treated to stabilize the oncolitic sediments to allow macrophytes to colonize an area (Figure 4.2). The area targeted for treatment is based on the habitat suitability index for the largemouth bass, which prescribes 25 to 60 percent cover (for this FS, cover is provided by the submerged macrophytes) (Gebhart & Maughan, 1982). Forty percent cover was used to calculate the areal extent of the treatment areas for SMU 5.

For evaluating habitat enhancement, SMU 5 has been subdivided into three areas, illustrated on Figure 4.2: Northwest, Northeast, and Southeast. These three areas represent three different energy regimes and existing habitat conditions:

- **Northwestern shoreline:** a low-energy zone between Ninemile Creek and Sawmill Creek (EcoLogic, 2001), with elevated levels of calcium carbonate and oncolites in sediments. Existing conditions also include an adjacent forested wetland (SYW-6) and macrophytes..
- **Northeastern shoreline:** a moderate-energy zone between Sawmill Creek and Bloody Brook (EcoLogic, 2001), also with elevated levels of calcium carbonate and oncolites in sediments. Wetland SYW-1 is located inshore of this area but is not hydraulically connected to the lake. (It is connected to Sawmill Creek.)
- **Southeastern shoreline:** a high-energy zone between Bloody Brook and Ley Creek (EcoLogic, 2001). The southernmost portion of this area is under consideration for the in-lake portion (Trail Section 3c) of the Onondaga Lake Trail project. The southeastern portion of SMU 5 shows less use by young-of-year (YOY) fishes than either the northwestern or the northeastern portions of SMU 5 (Ringler and Arrigo, 1995).

Treatment is recommended for the low energy and moderate energy zones associated with the northwestern and northeastern portions of SMU 5, respectively. There are approximately 40 acres between the 2 to 6 ft (0.6 to 1.8 m) depth contours (the range of water depths where macrophytes occur in Onondaga Lake) in the low energy (northwestern) portion of SMU 5. The northwestern area currently supports approximately 6.8 acres of submerged macrophytes, leaving a targeted treatment area of 9.2 acres to achieve 40 percent cover. There are approximately 64 acres between the 2 to 6 ft (0.6 to 1.8 m) depth contours in the moderate-energy (northeastern) portion of SMU 5. The northeastern area currently supports approximately 11 acres of submerged macrophytes, leaving a targeted treatment area of 15 acres to achieve 40 percent cover.

The southeastern area of SMU 5 is currently being investigated as part of the Onondaga Lake trail and habitat project (see Appendix M, habitat issues). The trail project may include creation of wetland and submerged macrophyte habitat. Because habitat improvements would likely be addressed under the Onondaga Lake trail project, treatment is not recommended for this portion of SMU 5. However, depending on how and/or when the trail project is implemented, the habitat enhancement could be expanded to include this area.

The recommended approach (modified from Madsen *et al.*, 1998) would be completed within an experimental framework to test the hypothesis that *in situ* stabilization of oncolitic sediments would facilitate macrophyte colonization and expansion. The following two major treatments would be employed:

- Oncolites would be stabilized using a vertical treatment (e.g., hay bales)
- Oncolites would be stabilized using a vertical (e.g., hay bales) and horizontal treatment (e.g., chicken wire or similar degradable material to further stabilize the oncolites).

Vertical barriers (i.e., fencing, hay bales) would be placed perpendicular to the shoreline at all depths, and parallel to the shoreline at shallow depths to minimize the potential migration of oncolites from off-site areas into the treatment areas. Within each of the two major treatments, the following subtreatments would be used to provide additional information on the requirements for successful macrophyte colonization:

- Macrophytes would be planted/seeded within most test plots, while other plots would not be planted/seeded, to determine whether colonization from the native seed bank is sufficient for the establishment of macrophyte beds
- Protection from herbivores would be provided (e.g., by temporary fencing) for approximately half of the test plots to determine the degree to which successful colonization is affected by these organisms, as opposed to physical conditions (Madsen *et al.*, 1998).
- Wave breaks would be maintained for various periods of time to assess the need for continued protection from waves (Madsen *et al.*, 1998).

The treatments would likely require from three to five years to effectively test the long-term requirements for wave protection and to allow experiments to be repeated and/or modified. Modifications of the original framework (modified from Madsen *et al.*, 1998) may be desirable, if early results suggest that they would potentially enhance the value of the original treatments.

The habitat enhancement program would be developed based on results from related evaluations and studies, including the macrophyte evaluations that were completed during the RI sampling in 1992, as well as subsequent studies that were completed by others (e.g., Ecologic 2001; Madsen *et al*., 1998). For example, results from the 1992 evaluation were compromised due to disturbances from waves and/or herbivores. The evaluation and implementation program would be designed to reduce such disturbances. The program would also be developed taking into account evaluations and recommendations provided by others with expertise in this area, such as local State University of New York (SUNY) staff and the USACE.

The following habitat restoration and enhancement objectives are associated with Alternative 2:

- Increase diversity and abundance of desirable submerged macrophyte species (e.g., *Potamogeton pectinatus*; *Potamogeton nodosus*; *Vallisneria americana*).
- Increase diversity and abundance of fish species (e.g., largemouth bass, smallmouth bass) by expanding the areal extent of suitable fish spawning substrates and nursery areas.
- Increase connectivity of in-lake and shoreline/upland habitats where practicable, provided such connectivity does not facilitate the transfer of contaminants.

In addition, the following habitat restoration and enhancement goals are associated with Alternative 2:

- Enhance physical site conditions (e.g., substrate, depth) to create conditions more suitable for target submerged macrophyte species.
- Enhance physical site conditions (e.g., substrate, cover) to expand the areal extent of spawning substrates and nursery areas for target fish species.
- Modify physical site conditions (e.g., slope, substrate) to allow for connection of in-lake and shoreline/upland habitats where practicable, provided such connectivity does not facilitate the transfer of contaminants.

The goals generally describe measures that can be incorporated into the remedial design that will ultimately facilitate meeting the habitat restoration and enhancement objectives. Determining whether the goals have been met, i.e., whether site-specific conditions have been modified to meet target species habitat requirements, can be conducted as part of construction monitoring. Determining whether the habitat restoration and enhancement objectives have been met would require post-construction monitoring. The plan for post-construction monitoring would be developed during remedial design.

4.3.3 Alternative 3 – Isolation Capping / Habitat Optimization

This alternative includes the following components:

- Completion of habitat studies and significant pre-design investigations to optimize implementation and ensure effectiveness of a sediment isolation cap;
- Installation of an isolation cap over those portions of a SMU that exceed the SEC established as the cleanup criterion,
- Installation of various substrate and vegetation establishment on the cap surface to optimize habitat value;
- Long-term monitoring and maintenance of the cap; and
- Institutional controls to protect the integrity of the remedy and to ensure long-term protectiveness of human health and the environment.

In addition, this alternative assumes that source control of CPOIs related to Honeywell and non-Honeywell upland sites that impact a particular SMU, as described in Subsection 4.2, would be implemented prior to implementing the in-lake remedy at a SMU. Details regarding each of the remedial components included in this alternative are provided below. The habitat optimization component is an integral part of the cap design, and is therefore included in the isolation cap discussion. The detailed description of the alternative is followed by a discussion of SMU-specific considerations.

Thin-layer Capping: For evaluation purposes, it is assumed that isolation capping would be applied throughout the littoral area based on SEC exceedances. However, thin-layer capping may be appropriate for portions of the littoral area in water depths between 20 and 30 ft (6 to 9 m). Although this area is part of the littoral area as defined by the depth of the thermocline at 30 ft (9m), in many ways, this area is best described as a transitional zone between the littoral and profundal areas. As discussed in Section 1, this is an area of net sediment deposition. However, the rate of deposition in this area relative to that in the profundal area is uncertain. In addition, groundwater upwelling in this area is predicted to be negligible (see Appendix D, groundwater issues). It is beyond the depth where fish would typically spawn but is aerobic, so benthic macroinvertebrates are present. In addition, insufficient data are available in this area to assess the degree of CPOI impacts.

Insufficient information is available to determine whether an isolation cap or a thin-layer cap would be most appropriate in this area. Therefore, for evaluation and costing purposes, it is assumed that an isolation cap would be placed in this area. Additional evaluation would be completed as part of the pre-design investigation to determine the areas of exceedance as well as determine whether isolation capping or thin-layer capping would be most appropriate cap design for this area.

Isolation Cap and Habitat Optimization: This alternative includes applying an isolation cap over areas of a SMU that exceed SECs. The multi-media sediment cap would be designed to resist upwelling of CPOIs through chemical partitioning and natural biodegradation and to resist erosion by wave and wind action in the littoral area. A capping evaluation was performed in accordance with USEPA and USACE guidelines to assess sediment cap materials and required thickness (see Appendix H, capping issues). For Onondaga Lake, the recommended performance standards for capping include the following:

- The cap would be designed to provide physical isolation of the contaminated sediments from benthic organisms and other receptors, where applicable.
- The cap would be physically stable from scour by currents, waves, and ice. A return period for episodic events of 100 years would be considered in these evaluations.
- The cap would be designed so that there would be no impedance of tributary flow (e.g., in SMUs 4, 6, and 7) following capping and associated habitat enhancement.
- The cap would provide long-term isolation of impacted sediments from flux or resuspension into the overlying surface waters. The performance criteria for chemical isolation would require limiting the upper cap layer sediment concentration for CPOIs to their respective PECs (and to the NYSDEC sediment screening criteria [SSC] for benzene, toluene, and phenol) in the biologically active zone of the cap or overlying habitat layers. As a construction standard, this would ensure that the isolation layer of the cap is initially placed as a clean layer; as a long-term limit, it would ensure chemical isolation.

Specific factors evaluated to ensure that these standards would be met include erosion, bioturbation, chemical isolation, habitat, settlement, placement issues, and seismic stability, as detailed in Appendix H, capping issues, and summarized below.

Erosion: A sediment cap in the shallower portion of Onondaga Lake would require an armoring layer to prevent erosion of the cap. Site conditions across the SMUs vary, and different erosive processes may control the armor design for different SMUs. There are four primary forcing functions or processes that would potentially cause erosion of a constructed cap at this site:

- Scour due to ice forces,
- Wind-induced waves due to episodic storm events,
- Currents resulting from flood flows from tributaries, and
- Scour due to propeller wash from vessels.

The ice scour mechanisms of concern for lakes such as Onondaga Lake are the expansion and contraction of ice associated with temperature changes through the winter and spring before breakup, and the subsequent movement and pilings of ice at the shoreline due to wind. Ice scour in Onondaga Lake is not considered severe. Thermal expansion of ice and winds during breakup can cause minor ice pilings on the shore, and freezing of ice to bottom sediments at water depths less than about 16 inches (41 cm) may occur, as detailed in the Appendix H, capping issues.

Rip-rap with a diameter of 16 inches (41 cm) or less along the shoreline is expected to protect against ice scour in the lake. However, this is likely conservative, especially in areas not exposed to high wind-driven ice scour. An alternative acceptable approach, and the assumption used herein for evaluation purposes, is to assume that smaller rip-rap overlain by a habitat layer can be used, but that annual monitoring, and maintenance if appropriate, would be required. The actual approach for ensuring protection from ice scour would be determined as part of the detailed design.

USEPA design guidance for caps calls for consideration of the 100-year return interval storm event in design for armor layers. Based on resulting predicted wind/wave action, required armoring depths were estimated for each SMU (see Appendix H, capping issues). These armoring requirements were used for development of preliminary cap designs for evaluation herein.

Evaluation indicates that design to the wind/wave armoring requirements would protect against erosive forces resulting from propeller wash and tributary inflow.

Bioturbation: To ensure protection of macroinvertebrates, the cap would be required to ensure CPOI concentrations are below SECs throughout the depth typically inhabited by macroinvertebrates. The normal feeding and burrowing activities of benthic organisms leads to rapid movement of particles and the contaminants with which they are associated, as well as pore water. In freshwater systems, most measurements of mixing depth are of the order of 1 to 2 inches (3 to 5 cm), although they may exceed 4 inches (10 cm). Based on a review of published information, 4 inches (10 cm) was selected as an appropriate depth for bioturbation in Appendix N, monitored natural recovery, which applies to the profundal zone and the littoral-profundal transition zone (20 to 30 ft water depth). A 6-inch (15 cm) bioturbation layer overlying the chemical isolation layer is assumed for preliminary cap evaluation in the littoral zone. This is consistent with the recommended thickness for various habitat layers as well, as discussed in Appendix M, habitat issues.

Chemical Isolation: It is assumed that the chemical isolation layer would consist of sand with an organic carbon content of 0.1 percent, which is readily available. Long-term organic carbon content in the habitat/bioturbation surface layer is assumed to eventually reach an organic carbon content of 1 percent to 5 percent, consistent with current organic carbon contents measured in the RI. Detailed modeling of chemical transport through the cap was completed to estimate the required thickness for the chemical isolation layer using site-specific porewater data. However, when site-specific data were lower in concentration than expected, or not available, porewater concentrations were calculated from maximum sediment concentrations using literature-based partitioning coefficients. To support the cap chemical isolation modeling, estimates of maximum groundwater velocities through each SMU were also developed. This included evaluation of maximum groundwater velocities in the presence of a shoreline hydraulic containment system (to contain upland sources and effectively eliminate groundwater upwelling) for specific SMUs where this would be part of the upland remedy or could be readily implemented as part of the lake remedy. Predicted chemical isolation layer thickness requirements were used for development of preliminary cap designs for evaluation herein.

In some cases, modeling indicates that the required chemical isolation layer would be less than 1 ft (0.3 m; see Appendix H, capping issues). However, to be conservative, it is assumed that the minimum chemical isolation layer thickness would be 1 ft. A safety factor of 1.5 is applied to all isolation layer thicknesses, consistent with USACE capping guidance documents (Palermo, 1998). It is also assumed that an additional 6 inches (15 cm) of sand would be placed to account for mixing with the underlying sediments and to account for uneven distribution of the cap material during placement. Thus, the minimum assumed chemical isolation layer placement thickness is 2 ft (0.6 m) to ensure that an effective 1.5-ft (0.5-m) chemical isolation layer would be achieved.

Habitat: As discussed in Appendix M, habitat issues, habitat restoration and optimization is an important goal for Onondaga Lake, and is consistent with goals developed by Onondaga County, NYSDEC, and others. Appendix M provides recommendations for habitat based on substrate and water depth. For example, sand is the recommended substrate for submerged macrophyte colonization and establishment in water depths from 2 to 6 ft (0.6 to 1.8 m), while gravel is the recommended substrate for fish spawning in water depths from 6 to 15 ft (1.8 to 4.6 m). Habitat recommendations include establishment of areas of emergent wetlands adjacent to existing upland wetlands. These recommendations were incorporated into the cap surface layer for development of the preliminary cap design. This includes placement of large woody debris structures in the shallow littoral area to provide cover and increase foraging opportunities for fish. As discussed under Subsection 4.3.2, these structures would be placed in select areas in water depths between 4 and 15 ft (1.2 to 4.6 m) below the annual low water level.

Establishment of wetland vegetation typically requires more effort than establishment of submerged macrophyte vegetation. For this evaluation, it is assumed that habitat optimization would include planting of wetland plants in areas designated as emergent wetlands. In areas designated for submerged macrophyte colonization and establishment, it is assumed that natural establishment of submerged macrophytes would be augmented by broadcast seeding and addition of tubers. Broadcast seeding is typically appropriate for species such as wild celery. Addition of tubers is typically appropriate for species such as sago pond weed and American pond weed, and could be achieved by mixing the tubers with the cap habitat layer material prior to placement.

Settlement: The unconsolidated underlying sediments are expected to settle under the weight of the sediment cap. The amount of settlement depends on the underlying sediment thickness and properties, the amount of sediment (if any) removed prior to capping, and the weight (i.e., thickness) of the cap. Settlement analysis (see Appendix H, capping issues) was incorporated into the preliminary cap design to estimate the final elevation of the cap following settlement.

Cap Placement: A variety of equipment types and placement methods have been used for capping projects, including the use of hopper barges at larger, open-water sites, and of hydraulic and mechanical systems for placement at near shore or shallow-water sites. Important considerations in selection of placement methods include the need for controlled, accurate placement of capping materials. Slow, uniform application that allows the capping material to accumulate in layers is often necessary to avoid displacement of or mixing with the underlying contaminated sediment. Based on detailed evaluations, if the cap height differential (i.e., the thickness placed in any one pass) for placement of sand and gravel cap components is kept below 6 inches (15 cm), bearing failure of the cap material into the underlying sediment should not occur (see Appendix H, capping issues).

To maintain a low differential thickness during each pass during cap construction, a hydraulic capping approach would likely be used. For this approach, the capping material would be slurried and pumped to a diffuser barge over the capping area. The diffuser barge would move back and forth, allowing the capping material to gently fall through the water column. Any armor material would likely be placed using a clamshell bucket after the full sand cap thickness is in place. Armor material would also be placed in lifts on top of the base cap layer. The actual cap placement method would be determined during design and contracting.

Debris may be present in the near-shore areas of the lake. Debris may preclude the construction of a continuous and effective cap and would be removed, if necessary, prior to construction. A side-scan sonar survey performed in 1992 indicated some debris present in limited areas of the lake (PTI, 1992a). Similarly, cap design and construction would take into consideration existing lake infrastructure, such as piers, jetties, discharge outfalls, boating channels, etc.

Seismic Stability: A slope stability analysis was performed on the submerged in-lake waste for two slope profiles in the southeast corner of Onondaga Lake using available geotechnical and other relevant data (see Appendix H, capping issues). The first location was selected because it was identified in the hydrographic survey completed by Exponent in 1992 as the area of a possible submarine slump. The second location was selected because it is currently the area with the steepest slope in the ILWD. The slope stability analysis was run using:

1. The existing static conditions;
2. A pseudo-static earthquake loading; and
3. Static and earthquake loading with a 5-ft (1.5 m) sand cap installed.

The evaluation was completed using a return period of once in 475 years, which is consistent with American Society of Civil Engineers (ASCE) guidance for seismic design of waterfront structures. It is also consistent with evaluations used at other sediment capping sites, including the Eagle Harbor sediment site and the Bellingham Bay sediment site. The analysis indicates that the sediment would be stable after capping; however, there may be potential for cap failure in some portions of the ILWD where shear strengths are low. Design sampling would be used to determine the stability of the ILWD, and, if needed, additional material would be removed from the ILWD and/or engineered controls would be placed to stabilize a cap under static and seismic conditions.

Cap Monitoring and Maintenance: A monitoring program would be initiated during the pre-design process that includes a baseline survey to document the bathymetry of the lake, interim surveys during cap installation, and a post-cap installation survey to verify the actual thickness of the cap. The final installation survey would also be used for future cap monitoring purposes. The long-term monitoring program would be designed to confirm that the cap remains in place over time, and may include periodic core sampling to verify that the cap integrity is maintained. Surface water and fish tissue monitoring may also be part of the long-term lake monitoring program following remediation. Periodic cap maintenance would be performed to ensure the long-term integrity and protectiveness of the remedy.

Institutional Controls: Institutional controls would be used, as warranted, to ensure the long-term integrity of the remedy and to help protect the public from exposure to CPOIs within the lake. This would include, at the discretion of NYSDOH, any necessary, ongoing health advisories regarding human consumption of fish from the lake. Additional institutional controls to prevent disruption of the sediment cap and prevent worker exposure, such as restrictions on dredging, would be implemented as necessary.

Pre-Design Investigation and Pilot Testing: Prior to any in-lake activity, a pre-design program would establish a more precise delineation of the nature and extent of contamination. Testing would establish the site-specific parameters related to the sediment cap design and geotechnical aspects of the lake bottom, as well as refine the habitat optimization components of the alternative.

The cap model would be rerun and fine tuned as part of the remedial design. The cap model would incorporate any new remedial design data, and the cap design would be modified as appropriate.

The total organic carbon content of the actual habitat layer would be verified as part of the remedial design.

The sediment caps would be designed to protect against erosive forces from the tributaries discharging into the lake, provide a natural transition (i.e., a buffer zone) between fish and wildlife habitats, and ensure the cap would not disrupt the flow into the lake (including under 100-year flow conditions). If it is determined that flow into the lake would be affected, additional dredging would be included to ensure that the impact to the flow is minimized to the extent practicable.

Sampling would be performed to verify the stability of the ILWD, and to determine if additional material and/or engineering controls implemented to ensure that the cap is stable under static and seismic conditions.

Finally, the predicted settlement of the cap would be determined based on design sampling and additional removal beyond that estimated in the FS may be necessary to achieve target water depths.

4.3.3.1 SMU 1 Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – A, and detailed in Appendix E, areas and volumes, all of SMU 1 would require capping regardless of whether exceedances of the mean PECQ1, mean PECQ2, AET, PEC, or ER-L are used to define the area of the cap. Therefore, the only capping alternative retained for detailed evaluation in SMU 1 is Alternative 3.A – Capping of Entire SMU.

Applying the preliminary cap design criteria discussed above to SMU 1 results in the conceptual plan views and cross-sections shown in Figures 4.3 and 4.4. Cap chemical isolation modeling predicts that with the Wastebed B hydraulic containment system in place to effectively eliminate groundwater upwelling in SMU 1, a 2.5-ft (0.8 m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state using assumed worst-case conditions, i.e. maximum measured CPOI sediment concentrations and 5 percent organic carbon. The assumed 5 percent organic carbon is consistent with current organic carbon content of littoral sediments, and is the maximum expected in the habitat layer immediately overlying the chemical isolation layer. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 4.25-ft (1.3-m) thick chemical isolation layer placement to achieve a 3.75-ft (1.1-m) thick isolation layer in SMU 1.

As discussed in Subsection 4.2, Honeywell has entered into a consent order to install a hydraulic containment system at Wastebed B. However, groundwater and cap modeling indicate that capture of deep groundwater would also likely be required to ensure long-term cap effectiveness, which is not included as part of the consent order. Groundwater data from this aquifer indicates the groundwater is not contaminated with CPOIs. Nevertheless, capture of this groundwater would be necessary and would be implemented to effectively eliminate groundwater that upwells through the ILWD. To be conservative, it is assumed that captured groundwater may require treatment prior to being discharged to the lake. However, the costs associated with this treatment are not part of the Onondaga Lake site, but will be included in the Wastebed B/Harbor Brook FS.

Placement of a cap would result in settlement of the underlying sediments. However, in SMU 1, settlement analysis predicts the settlement would be less than the cap thickness in areas where rip-rap is required. Therefore, placement of an isolation cap in SMU 1 with no sediment removal would result in conversion of some lake surface area into emergent wetland (7 acres) and upland area (5 acres), as shown in Figure 4.3.

Capping in SMU 1 would take into consideration any existing in-lake infrastructure, cultural artifacts, and debris. The side-scan radar identified one potential sunken vessel, as well as a discharge pipe and diffuser in SMU 1 (PTI, 1992a).

4.3.3.2 SMU 2 Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – B and detailed in Appendix E, areas and volumes, all of SMU 2 would require capping regardless of whether exceedances of the PEC or ER-L are used to define the area of the cap. Use of the mean PECQ2, mean PECQ1, or AET exceedances to define the cap area would result in capping similar areas of SMU 2. Therefore, the following two capping alternatives are retained for detailed evaluation for SMU 2:

- Alternative 3.A – Capping to Mean PECQ2, Mean PECQ1, or AET / Habitat Optimization
- Alternative 3.D – Capping of Entire SMU / Habitat Optimization

Applying the preliminary cap design criteria discussed above to SMU 2 results in the conceptual plan views and cross-sections for these alternatives shown in Figures 4.5 and 4.6. Cap chemical isolation modeling predicts that, with the Willis/Semet hydraulic containment system in place to effectively eliminate groundwater upwelling in SMU 2, a 2.5-ft (0.8-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state using assumed worst-case conditions, i.e. maximum measured CPOI sediment concentrations and 5 percent organic carbon. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 4.25-ft (1.3-m) thick chemical isolation layer placement to achieve a 3.75-ft (1.1-m) thick isolation layer in SMU 2.

As discussed in Subsection 4.2, Honeywell has entered into a consent order to install a hydraulic containment system at the Willis/Semet site. However, groundwater and cap modeling indicate that capture of deep groundwater would also likely be required to ensure long-term cap effectiveness, which is not included as part of the consent order. Groundwater data from this aquifer indicates the groundwater is not contaminated with CPOIs. Nevertheless, capture of this groundwater would be necessary and would be implemented to effectively eliminate groundwater that upwells in SMU 2. To be conservative, it is assumed that captured groundwater would require treatment prior to being discharged to the lake. However, the costs associated with this treatment are not part of the Onondaga Lake site, but are included in the Willis/Semet FS. For evaluation purposes, it is assumed that the Willis/Semet barrier wall associated with the hydraulic containment system would be located on the lake side of the causeway. This assumes that high concentrations of VOCs measured in porewater adjacent to the causeway are contained or reduced by the Willis/Semet hydraulic containment system.

The I-690 storm drains discharge into SMU 2. In addition, existing 72-inch and 84-inch cast iron intake pipes are present between Outfalls 40 and 41. These structures would be taken into consideration during cap design, including additional armoring if necessary. No other in-lake infrastructure, potential cultural artifacts, and/or debris that would potentially impact the remedy have been identified to date in SMU 2.

Placement of a cap would result in settlement of the underlying sediments. However, in SMU 2, settlement analysis predicts the settlement would be less than the cap thickness. Therefore, placement of an isolation cap in SMU 2 with no sediment removal would result in minor loss of lake surface area, as shown in Figure 4.5. It is estimated that three acres of lake surface area would be lost in SMU 2 under Alternative 3.A and six acres would be lost under 3.D. Habitat optimization, including establishment of emergent wetlands, would be used to offset habitat concerns associated with loss of lake surface area.

4.3.3.3 SMU 3 Isolation Capping / Habitat Optimization

Cap chemical isolation modeling indicates that dredging in near shore areas is required in SMU 3 for isolation capping to be effective due to high groundwater upwelling velocities near shore; therefore, isolation capping with no removal is not retained for SMU 3. Capping with targeted dredging for SMU 3 is developed in Subsection 4.4.

4.3.3.4 SMU 4 Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – D and detailed in Appendix E, areas and volumes, all of SMU 4 would require capping regardless of whether exceedances of the mean PECQ2, mean PECQ1, AET, PEC, or ER-L are used to define the cap area. As shown in Figures 2.5 through 2.9, mercury does not exceed the PEC in the surface interval at several of the sampling locations. However, where deeper samples are available at these sampling locations, the mercury PEC was always exceeded in samples within the top 3.3 ft (1 m). A relatively thin layer of cleaner sediments overlies sediments with higher mercury concentrations in SMU 4, and these cleaner sediments may be subject to erosion. Therefore, it is assumed that all of SMU 4 would require capping. Therefore, only one capping alternative is retained for detailed evaluation for SMU 4: Alternative 3.A – Capping of Entire SMU./ Habitat Optimization

Applying the preliminary cap design criteria discussed above to SMU 4 results in the conceptual plan view and cross-section shown in Figures 4.7 and 4.8. Cap chemical isolation modeling predicts that a 1-ft (0.3-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state using worst-case assumptions, i.e. maximum predicted groundwater upwelling velocity, maximum measured CPOI sediment concentrations, and 5 percent organic carbon. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 2-ft (0.6-m) thick chemical isolation layer placement to achieve a 1.5-ft (0.5-m) thick isolation layer in SMU 4.

Placement of a cap would result in settlement of the underlying sediments. However, in SMU 4, settlement analysis predicts the settlement would be less than the cap thickness. Therefore, placement of an isolation cap in SMU 4 with no sediment removal would result in loss of an estimated 6 acres of lake surface area, as shown in Figure 4.7. Habitat optimization, including establishment of emergent wetlands, would be used to offset habitat concerns associated with loss of lake surface area. The cap would be designed so that there would be no impedance of tributary flow following cap placement and associated habitat enhancement.

Side-scan radar identified what appears to be a sunken barge near the eastern end of SMU 4 (PTI, 1992a). Further evaluation is necessary to determine the appropriate means for addressing this debris, but options include removal and covering in-place. No other in-lake infrastructure, potential cultural artifacts, and/or debris that would potentially impact the remedy have been identified to date in SMU 4.

4.3.3.5 SMU 5 Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – E and detailed in Appendix E, areas and volumes, much of SMU 5 would require capping if exceedances of the ER-L are used to define the cap area, while smaller portions of SMU 5 would require capping if the mean PECQ2, mean PECQ1, or PEC are used to define the cap area. Because there is only one data point in SMU 5 where the AET is exceeded, it is assumed that the AET exceedance area is negligible. Therefore, the following four capping alternatives are retained for detailed evaluation in SMU 5:

- **Alternative 3.A – Capping to Mean PECQ2 / Habitat Optimization**
- **Alternative 3.B – Capping to Mean PECQ1 / Habitat Optimization**
- **Alternative 3.D – Capping to PEC / Habitat Optimization**
- **Alternative 3.E – Capping to ER-L / Habitat Optimization**

Applying the preliminary cap design criteria discussed above to SMU 5 results in the conceptual plan views and cross-sections shown in Figures 4.9 through 4.13.

As shown in Figures 4.9 and 4.10, three polygons[4] exceed the mercury PEC and four polygons exceed the mercury PEC and the mean PECQ1 in SMU 5. No polygons exceed the mean PECQ2 in SMU 5. Evaluating the required cap area for exceedances of the PEC or ER-L is difficult due to the hit-or-miss pattern of exceedances throughout SMU 5. In general, the contamination in SMU 5 is present at concentrations close to their respective PECs or ER-Ls. It is likely that these CPOIs are primarily a result of impacts from sources other then Honeywell, as evidenced by the higher levels seen near the mouth of Bloody Brook and the general lack of mercury in excess of the PEC throughout most of SMU 5. The hit-or-miss pattern of relatively low level exceedances also makes it difficult to model cap effectiveness in SMU 5. Therefore, based on the relatively low concentrations, it was assumed that a 1-ft (0.3-m) thick chemical isolation layer would be effective in SMU 5. A cross-section is shown in Figure 4.13. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 2-ft (0.6-m) thick chemical isolation layer placement to achieve a 1.5-ft (0.5-m) thick isolation layer in SMU 5.

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[4] Polygons where determined using the Thiessen polygon method.

Placement of a cap would result in settlement of the underlying sediments. However, in SMU 5, settlement analysis predicts the settlement would be less than the cap thickness. Therefore, placement of an isolation cap in SMU 5 with no sediment removal would result in minor loss of lake surface area, as shown in Figures 4.9 through 4.12. Habitat optimization, including establishment of emergent wetlands, would be used to offset habitat concerns associated with loss of lake surface area.

Located within SMU 5 are a marina, jetties near the discharge to the Seneca River, and at least two outfall pipes. Side-scan radar also identified one potential sunken vessel or other cultural artifact. An in-lake trail is also in the planning stages for the southern end of SMU 5. Remedy implementation in SMU 5 would take into consideration these issues.

4.3.3.6 SMU 6 Isolation Capping / Habitat Optimization

Cap chemical isolation modeling indicates that dredging in near shore areas is required in SMU 6 for isolation capping to be effective due to high groundwater upwelling velocities near shore; therefore, isolation capping with no removal is not retained for SMUs 6. Capping with targeted dredging for SMU 6 is developed in Subsection 4.4.

4.3.3.7 SMU 7 Isolation Capping / Habitat Optimization

Cap chemical isolation modeling predicts that a hydraulic containment system would be required to effectively eliminate groundwater upwelling in SMU 7. Therefore, either targeted dredging in areas of high groundwater upwelling, or a shoreline hydraulic barrier wall and hydraulic containment system to minimize groundwater upwelling would be required. Based on current data, a hydraulic barrier wall and hydraulic containment system would be the most cost-effective approach, and therefore is the basis for evaluation. However, both approaches would be effective, and the determination regarding which approach would be utilized would be made as part of the pre-design investigation process.

With the hydraulic barrier wall and hydraulic containment system in place, modeling indicates a 2.5-ft (0.8m) thick chemical isolation layer would result in no exceedance of the PEC in the bioturbation layer at steady state using assumed worst-case conditions, i.e., maximum measured CPOI sediment concentrations and 5 percent organic carbon. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 4.25-ft (1.3 m) thick chemical isolation layer placement to achieve a 3.75-ft (1.1-m) thick isolation layer in SMU 7.

As shown in Figures 2.5 through 2.8 and Table 4.4 - G, and detailed in Appendix E, areas and volumes, all of SMU 7 would require capping regardless of whether exceedances of the mean PECQ2, mean PECQ1, AET, PEC, or ER-L are used to define the area of the cap. Therefore, the only capping alternative retained for detailed evaluation in SMU 7 is Alternative 3.A – Capping of Entire SMU / Habitat Optimization.

Placement of a cap would result in settlement of the underlying sediments. However, in SMU 7, settlement analysis predicts the settlement would be greater than the cap thickness. Therefore, placement of an isolation cap in SMU 7 with no sediment removal would result in no loss of lake surface area, based on current settlement estimates, as shown in Figures 4.14 and 4.15. Habitat optimization, including establishment of emergent wetlands, would be used to offset habitat concerns associated with loss of lake surface area. The cap would be designed so that there would be no impedance of tributary flow following cap placement and associated habitat enhancement.

4.3.4 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

This alternative is similar to Alternative 3 – Isolation Capping, with the addition of dredging a portion of the sediment from a SMU, based on specific performance goals. This alternative includes the following components:

- Completion of pilot testing and significant pre-design investigations to optimize implementation and to ensure effectiveness of the removal activities and sediment cap;
- Dredging of a portion of the sediments that exceed a specific SEC and consolidation in a Sediment Consolidation Area (SCA);
- Installation of an isolation cap over those portions of each SMU that exceed the SEC established as the cleanup criterion;
- Installation of various substrate and vegetation establishment on the cap surface to optimize habitat value;
- Long-term monitoring and maintenance of the cap; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

In addition, this alternative assumes implementation of source control of CPOIs related to Honeywell and non-Honeywell upland sites that impact a particular SMU, as described in Subsection 4.2, prior to implementing the in-lake remedy for a particular SMU. Details regarding each of the remedial components included in this alternative are described below, followed by a discussion of the SMU-specific considerations.

Pre-Design Investigation and Pilot Testing: Prior to any in-lake activity, a pre-design investigation program would be implemented as discussed for Alternative 3 (Isolation Capping). If pre-design sampling results in higher concentrations than the RI sampling, the cap design would be modified accordingly.

Dredging: Sediments would be removed to a specific design depth, as described below. Sediments would be dredged hydraulically, mechanically, or using a hybrid approach. As discussed in Section 3 and Appendix L, for this report, hydraulic dredging was selected as the representative process option for detailed evaluation due to the high production rates and, under many situations, economic advantages associated with it. The actual dredging method would be determined during design and contracting. Dredging options are described below, followed by discussion of how dredging would be implemented. Dredging activities would be designed so that there would be no impedance of tributary flow (e.g., SMUs 4, 6, and 7) following dredging and associated habitat enhancement.

Dredging Options: In developing alternatives that incorporate partial removal of impacted sediments prior to capping, several potential approaches were considered for SMUs 1 through 7:

- Option 1: Targeted dredging in areas with high CPOI concentrations or high groundwater upwelling velocities to enhance cap effectiveness and/or for NAPL removal in SMU 2 (either to a depth of 4 meters or for full NAPL removal [~ 9 meters]);
- Option 2: Dredging so that there is no loss of lake surface area following cap placement;
- Option 3: Dredging to a depth that optimizes habitat and further reduces erosive forces on the cap;
- Option 4: Dredging for mass removal to remove 25 percent of the ILWD (applicable to SMU 1 only);
- Option 5: Dredging for mass removal to 3 meters (applicable to SMU 1 only);
- Option 6: Dredging for mass removal to 4 meters (applicable to SMU 1 only); and
- Option 7: Dredging for mass removal to 5 meters (applicable to SMU 1 only).

These options are discussed below. Details regarding calculation of dredge volumes for each SMU, based on these removal options, are provided in Appendix E, areas and volumes. Estimated dredge volumes are summarized in Table 4.5.

Option 1: Targeted dredging: Under this option, sediments would be removed in areas with elevated concentrations of CPOIs compared to surrounding or underlying sediments or in areas where high groundwater upwelling velocities impact cap effectiveness,. Sediment data, porewater data, and the results of the cap chemical upwelling evaluation (see Appendix H, capping issues) were used to identify specific areas of sediment where hot spots could be identified or where targeted removal would significantly improve the effectiveness of the isolation cap. Based on this evaluation, areas were identified in SMUs 2, 3 and 6 where targeted dredging may be appropriate, as detailed below. As discussed in Section 4.3.3.7, it is assumed that a hydraulic barrier system would be installed in SMU 7, negating the need for targeted dredging in SMU 7. Therefore, targeted dredging in SMU 7 is not discussed further.

A targeted dredging area was identified in SMU 2, based on elevated levels of VOCs such as chlorobenzene in porewater and sediment immediately adjacent to the causeway at sample location TR02-A. Porewater concentrations of VOCs at porewater sample location TR02-A were one to three orders of magnitude higher than at any other sampling location (Parsons, 2003). This sampling location is immediately adjacent to the on-shore NAPL plume, which consists primarily of chlorobenzene and its derivatives. Review of the boring log from this sample indicates that material in this area consists of higher permeability fill, perhaps placed as part of the causeway construction. It is possible that this area has been impacted by the on-shore NAPL plume, either directly through NAPL migration or indirectly via migration of groundwater that has been heavily impacted by the on-shore NAPL contaminant plume. Sediment concentrations of VOCs in samples collected immediately adjacent to the causeway are also significantly higher than elsewhere in SMU 2.

Cap modeling indicates that an isolation cap would be effective in this area. Nevertheless, this area was identified as a potential area for removal prior to capping due to the high VOC concentrations and potential NAPL in these sediments compared to surrounding sediments.

There are insufficient data to evaluate the areal extent and depth of elevated porewater, sediment concentrations, and NAPL in SMU 2. For evaluation purposes, two potential removal depths were developed, 4 meters and 9 meters. The 4-meter removal is based on the extent of data along the causeway. The 9-meter depth is based on the bottom of the marl layer, which is the depth of NAPL that has been identified onshore adjacent to this area. Following dredging, backfill would be placed to provide a smooth transition (assumed to be 1:10 slope) from the shoreline out to deeper water following capping.

Potential targeted dredging areas were also identified in near-shore sediments in SMUs 3 and 6. Although CPOI concentrations in near-shore sediments are not elevated in comparison to the rest of the sediments in SMUs 3 and 6, groundwater modeling indicates that predicted upwelling velocities are at their greatest near shore, preventing the cap from providing complete chemical isolation in areas where the upwelling velocity exceeds approximately 5 cm/yr in SMU 3 and approximately 3 cm/yr in SMU 6. Based on this evaluation, it is estimated that sediments from the shoreline out to an estimated 260 ft (80 m) from shore would require removal in SMU 3 and from the shoreline out to an estimated 220 ft (70 m) in SMU 6, for caps to be effective in these SMUs. Near-shore 26-ft (8-m) sediment cores indicate that the required removal depth would be approximately 6.6 ft (2 m) in SMUs 3 and 6. Following the pre-design investigation, the most effective method for addressing this area would be determined. However, for evaluation purposes, it is assumed that this area would be removed prior to capping.

Other maximum sediment and porewater concentrations were examined to evaluate whether they represent potential areas to target for removal. However, no additional candidate areas were identified. Maximum measured CPOI concentrations in a SMU, other than the “hot spots” identified in SMU 2 discussed above, were assumed to be representative of the maximum concentrations that may be encountered throughout that SMU; therefore, the isolation cap would be designed to be effective based on the maximum measured concentrations.

Option 2: Dredging to result in no loss of lake surface area: Placement of a cap with no sediment removal may result in loss of lake surface area, depending on the amount of settlement of the underlying sediment due to the weight of the cap. For instance, if cap placement results in 2 ft (0.6 m) of settlement, placement of a 3-ft (1-m) thick cap would result in loss of lake surface area out to the current 1 ft (0.3 m) bathymetry contour. Therefore, under this alternative, sufficient sediment would be removed such that there would be no loss of lake surface area following cap placement.

Option 3: Dredging to a depth that optimizes habitat and reduces erosive forces on the cap: Habitat restoration and optimization is an important goal for Onondaga Lake, and is consistent with goals developed by Onondaga Lake Partnership, Onondaga County, NYSDEC, and others (see Appendix M, habitat issues). Water depth is an important factor in optimizing habitat. As detailed in Appendix M (habitat issues), a water depth of 0.5 to 2 ft (0.2 to 0.6 m) is most appropriate for emergent wetlands, a water depth of 2 to 6 ft (0.6 to 1.8 m) is most appropriate for growth of submerged macrophytes, and a water depth of 6 to 15 ft (1.8 to 4.6 m) is most appropriate for fish spawning. Therefore, under this alternative, sufficient sediment would be removed such that the water depth following capping would support the habitat optimization recommendations detailed in Appendix M, habitat issues.

Removal to an optimal habitat depth can be synergistic with removal to a depth that reduces the erosive forces on the cap, which would reduce the reliance on armoring in near-shore areas. As a result, both criteria are considered under this alternative. For example, the optimal water depth for growth of submerged macrophytes is 2 to 6 ft (0.6 to 1.8 m). In SMU 1, the wind-wave analysis indicates rip-rap is only required to a water depth of approximately 5 ft (1.5 m) to provide erosion protection in a 100-year storm event. Therefore, removal of sediment to result in a post-capping water depth in near-shore areas of SMU 1 of 5 ft (0.3 to 1.5 m) would minimize rip-rap requirements and maximize the area where the water depth was optimal for submerged macrophyte colonization and establishment. Therefore, the goal under this option is to remove near-shore sediments to a depth where significant armoring is not required, and to maximize the area that has a water depth between 2 and 6 ft (0.6 to 1.8 m) to promote macrophyte colonization and establishment. Increased macrophyte colonization and establishment has been identified as an important goal for Onondaga Lake (see Appendix M, habitat issues). The actual required depth to minimize erosive forces varies by SMU, which has been taken into consideration in the evaluation.

Options 4, 5, 6, and 7: Dredging for mass removal. These options are being considered for SMU 1 only. Taking into consideration the volume and CPOI concentrations present in SMU 1 (the ILWD), this area likely represents the largest repository of CPOIs within the lake. To ensure that a full range of alternatives is evaluated, Options 4, 5, 6, and 7 have been developed, incorporating removal of approximately 25 percent of SMU 1 and removal to 3, 4 and 5 meters prior to isolation capping. The 25 percent removal option was developed because the resulting water depth following cap placement remains within an acceptable water depth for fish spawning. The 3, 4 and 5 meter removal options were developed to facilitate evaluation of progressively deeper removals in SMU 1. Additional details are provided in Subsection 4.3.4.1.

Following dredging, backfill would be placed to provide a smooth transition (assumed to be 1:10 slope) from the shoreline out to deeper water following capping.

Dredging Implementation: As discussed in Appendix L, dredging issues, this evaluation assumes that hydraulic dredging would be used. Hydraulic dredging would involve the removal of sediments using a cutterhead dredge that creates a sediment/water slurry (5 to 20 percent solids by weight) and pumps it to the surface. The sediment slurry would then be pumped via pipeline to a staging or consolidation site. The design would account for the handling and treatment of entrained water prior to its return to the receiving water. Additional details regarding dredging implementation are provided in Appendix L, dredging issues. Handling, treatment, and final disposition of dredged material and water resulting from dredging are addressed in detail in Subsection 4.9.

For this evaluation, it is assumed that each dredge can remove 12,000 CY/week for seven months (30 weeks) a year, for an estimated total annual production rate of 360,000 CY/year per dredge (see Appendix L, dredging issues). Based on this production rate, estimated dredging durations for each retained alternative are shown in Table 4.5. These dredging durations are all based on the use of either one or two dredges. These estimated durations do not include mobilization and demobilization and construction of other necessary components of the alternative, such as water treatment facilities and sediment handling and consolidation facilities. Multiple dredges may be used, depending on the total volume dredged. The number of dredges used and the actual duration would depend on the alternative selected for the entire lake. Additional discussion on dredging durations using multiple dredges is provided during evaluation of lake-wide alternatives in Section 5.

Controls on sediment resuspension and transport would be used as necessary to help minimize the release of resuspended sediments. These may include silt curtains, silt screens, and/or bubble screens to contain sediments during sediment removal from Onondaga Lake.

Isolation Cap and Habitat Optimization: Isolation capping and habitat optimization would be implemented as discussed for Alternative 3 – Isolation Capping / Habitat Optimization in Subsection 4.3.3. However, the cap design would vary depending on the location and volume of sediment dredged prior to capping. Because significant sediment removal would occur prior to capping under dredging Option 2, the resulting bathymetry changes would alter the armoring profile and depths. The areas in which submerged macrophyte colonization and establishment is optimized are also larger under Option 2. Cap areas for each SMU are shown in Table 4.5.

Cap Monitoring and Maintenance: Cap monitoring and maintenance would be implemented as discussed for Alternative 3 – Isolation Capping / Habitat Optimization in Subsection 4.3.3.

Institutional Controls: Institutional controls would be implemented as discussed for Alternative 3 – Isolation Capping / Habitat Optimization in Subsection 4.3.3.

4.3.4.1 SMU 1 Dredging / Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – A and detailed in Appendix E, areas and volumes, all of SMU 1 would require capping, regardless of whether exceedances of the mean PECQ2, mean PECQ1, AET, PEC, or ER-L are used to define the area of the cap. No targeted dredging to enhance cap effectiveness was identified in SMU 1; however, the other dredging options are potentially applicable. Therefore the following dredging/capping alternatives are retained for detailed evaluation for SMU 1:

- Alternative 4.A.2 – Dredging to Result in No Loss of Lake Surface Area / Capping of Entire SMU / Habitat Optimization
- Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping of Entire SMU / Habitat Optimization
- Alternative 4.A.4 – Dredging for Mass Removal to Remove 25 Percent of the ILWD / Capping of Entire SMU / Habitat Optimization
- Alternative 4.A.5 – Dredging for Mass Removal to 3 Meters / Capping of Entire SMU / Habitat Optimization
- Alternative 4.A.6 – Dredging for Mass Removal to Remove 4 Meters / Capping of Entire SMU / Habitat Optimization
- Alternative 4.A.7 – Dredging for Mass Removal to Remove 5 Meters / Capping of Entire SMU / Habitat Optimization

Applying the preliminary cap design criteria discussed above to SMU 1 results in the conceptual plan views and cross-sections shown in Figures 4.16 through 4.25. Figures 4.19 through 4.25 illustrate cross-sections for Alternative 4.A.2, 4.A.3, 4.A.4, 4.A.5, 4.A.6 and 4.A.7 in areas with and without emergent wetlands. Habitat optimization in SMU 1 would include an area of emergent wetland adjacent to the on-shore wetland. Capping considerations, including considerations associated with existing in-lake infrastructure, cultural artifacts (such as sunken vessels) and debris, are consistent with those discussed in Subsection 4.3.3.1.

4.3.4.2 SMU 2 Dredging / Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – B and detailed in Appendix E (areas and volumes), the areas and volumes requiring capping would be the same if the mean PECQ2, mean PECQ1, or AET are used to define the area of the cap. A different area would be required if the PEC or ER-L is used to define the area of the cap. Alternatives 4.A.3 and 4.D.3 include targeted dredging to a depth of 4 meters for NAPL removal. Alternatives 4.A.4 and 4.D.4 include targeted dredging for full NAPL removal to an estimated depth of approximately 9 meters. Therefore, the following dredging/capping alternatives are retained for detailed evaluation for SMU 2:

- Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging to 4 Meter Depth (for NAPL Removal) / Capping to Mean PECQ2, Mean PECQ1 or AET / Habitat Optimization
- Alternative 4.A.4 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and for Full NAPL Removal / Capping to Mean PECQ2, Mean PECQ1 or AET / Habitat Optimization
- Alternative 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging to 4 Meter Depth (for NAPL Removal) / Capping of Entire SMU / Habitat Optimization
- Alternative 4.D.4 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and for Full NAPL Removal / Capping of Entire SMU / Habitat Optimization

Applying the preliminary cap design criteria discussed above to SMU 2 results in the conceptual plan views and cross-sections shown in Figures 4.26 and 4.27. Capping considerations, including considerations associated with existing in-lake infrastructure, cultural artifacts and debris, are consistent with those discussed for capping SMU 2 in Subsection 4.3.3.2.

4.3.4.3 SMU 3 Dredging / Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – C and detailed in Appendix E (areas and volumes), use of the mean PECQ2, mean PECQ1, or PEC exceedances to define the cap area would result in capping the same areas of SMU 3. Use of the ER-L would require a larger area to be capped. Use of the AET to define remedial areas would result in a similar total area requiring capping as would result from the mean PECQ2, but it would be less protective. Therefore, capping to the AET is not retained. Dredging volumes are similar for several of the dredging options, allowing elimination of some of the dredging options by combining them. Therefore, the following dredging/capping alternatives are retained for detailed evaluation for SMU 3:

- Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Capping to Mean PECQ2, Mean PECQ1, or PEC / Habitat Optimization
- Alternative 4.E.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Capping to ER-L / Habitat Optimization

Sampling station S48 did not exceed the mean PECQ2, mean PECQ1, or mercury PEC. However, high chironomid mortality was noted at this station during sediment toxicity testing in the RI, as discussed in Section 2 and Appendix J. Therefore, the area associated with this sampling station is included in Alternative 4.A.3.

Applying the preliminary cap design criteria discussed above to SMU 3 results in the conceptual plan views and cross-sections shown in Figures 4.28 and 4.29. Cap chemical isolation modeling predicts that, following dredging, a 1-ft (0.3 m) thick chemical isolation layer would result in no exceedances of the PECs, where available, for CPOIs (or the NYSDEC SSC for benzene, toluene, and phenol) in the bioturbation layer at steady state using assumed worst-case conditions, i.e., maximum measured CPOI sediment concentrations and 5 percent organic carbon. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 2-ft (0.6 m) thick chemical isolation layer placement to achieve a 1.5-ft (1.1-m) thick isolation layer in SMU 3.

No in-lake infrastructure, potential cultural artifacts, and/or debris that would potentially impact the remedy have been identified to date in SMU 3.

4.3.4.4 SMU 4 Dredging / Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – D and detailed in Appendix E (areas and volumes), all of SMU 4 would require capping regardless of whether exceedances of the mean PECQ2, mean PECQ1, AET, PEC, or ER-L are used to define the cap area. As shown in Figures 2.7 and 2.8, mercury does not exceed the PEC in the surface interval at several of the sampling locations. However, where deeper samples are available at these sampling locations, the mercury PEC was always exceeded in samples within the top 3.3 ft (1 m). A relatively thin layer of cleaner sediments overlies sediments with higher mercury concentrations, and these cleaner sediments may be subject to erosion. Therefore, it is assumed that all of SMU 4 would require capping. No targeted dredging to enhance cap effectiveness was identified in SMU 4, and the remaining two dredging options result in similar volumes, allowing them to be combined. Thus, only dredging to the optimal habitat and erosive depth is retained. Therefore, there is only one dredging / isolation cap alternative retained for detailed evaluation for SMU 4: Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping of Entire SMU / Habitat Optimization.

Applying the preliminary cap design criteria discussed above to SMU 4 results in the conceptual plan view and cross-sections shown in Figures 4.30 through 4.33. Habitat optimization in SMU 4 would include an area of emergent wetland adjacent to the on-shore wetland. Other capping considerations, including considerations associated with existing in-lake infrastructure, cultural artifacts, and debris, are consistent with those presented for capping SMU 4 in Subsection 4.3.3.4. The cap would be designed so that there would be no impedance of tributary flow following cap placement and associated habitat enhancement. Figures 4.31 through 4.33 show cross-sections for Alternative 4.A.3 with and without emergent wetlands.

4.3.4.5 SMU 5 Dredging / Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – E and detailed in Appendix E, areas and volumes, much of SMU 5 would require capping if exceedances of the ER-L are used to define the cap area, while progressively smaller portions of SMU 5 would require capping if the PEC, mean PECQ1, or mean PECQ2 are used to define the cap area. There is only one data point in SMU 5 where the AET is exceeded, at the mouth of Bloody Brook; therefore, it is assumed that the AET exceedance area is negligible. No targeted dredging to enhance cap effectiveness was identified in SMU 5. Thus, only alternatives that include dredging to result in no loss of lake surface area and to a depth to optimize habitat and minimize erosive forces is retained. Therefore, the following dredging/capping alternatives are retained for detailed evaluation in SMU 5:

- Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping to Mean PECQ2 / Habitat Optimization
- Alternative 4.B.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping to Mean PECQ1 / Habitat Optimization
- Alternative 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping to PEC / Habitat Optimization
- Alternative 4.E.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping to ER-L / Habitat Optimization

Applying the preliminary cap design criteria discussed above to SMU 5 results in the conceptual plan views and cross-sections shown in Figures 4.34 through 4.38 Other capping considerations, including considerations associated with existing in-lake infrastructure, cultural artifacts, and debris, are consistent with those presented in Subsection 4.3.3.5.

4.3.4.6 SMU 6 Dredging / Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – F and detailed in Appendix E, areas and volumes, all of SMU 6 would require capping regardless of whether exceedances of the AET, PEC, or ER-L are used to define the area of the cap. Using exceedances of the mean PECQ2 or mean PECQ1 to define the cap area would result in capping different portions of SMU 6. Use of the AET to define remedial areas would result in a similar total area requiring capping as would result from the mean PECQ2, but it would be less protective. Therefore, capping to the AET is not retained. As discussed in Subsection 4.3.4, targeted dredging of a significant volume of sediment near shore is recommended to enhance performance of the cap. Predicted settlement due to cap placement exceeds the cap thickness in SMU 6, and the targeted dredging would remove sediments near shore; therefore, no removal is required to maintain the current lake surface area. Thus, the following dredging/capping alternatives are retained for detailed evaluation for SMU 6:

- Alternative 4.A.1 – Targeted Dredging / Capping to Mean PECQ2 / Habitat Optimization

- Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Capping to Mean PECQ2 / Habitat Optimization
- Alternative 4.B.1 – Targeted Dredging / Capping to Mean PECQ1 / Habitat Optimization
- Alternative 4.B.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Capping to Mean PECQ1 / Habitat Optimization
- Alternative 4.D.1 – Targeted Dredging / Capping of Entire SMU / Habitat Optimization
- Alternative 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Capping of Entire SMU / Habitat Optimization

Applying the preliminary cap design criteria discussed above to SMU 6 results in the conceptual plan views and cross-sections shown in Figures 4.39 through 4.42. Cap chemical isolation modeling predicts that a 1-ft (0.3-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state using assumed worst-case conditions, i.e. maximum measured CPOI sediment concentrations and 5 percent organic carbon. This assumes that targeted dredging to remove sediments in near shore areas where groundwater upwelling velocities are high is implemented prior to capping, as discussed in Subsection 4.3.4. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 2-ft (0.6-m) thick chemical isolation layer placement to result in a 1.5-ft (0.5-m) thick chemical isolation layer in SMU 6.

Dredging and capping in SMU 6 would take into consideration existing in-lake infrastructure, such as the Metro discharge. It would also take into consideration the boating channel and any future navigational dredging requirements associated with access to the Onondaga Creek Inner Harbor. In addition, the cap would be designed so that there would be no impedance of tributary flow following cap placement and associated habitat enhancement.

4.3.4.7 SMU 7 Dredging / Isolation Capping / Habitat Optimization

As shown in Figures 2.5 through 2.8 and Table 4.4 – G and detailed in Appendix E, areas and volumes, all of SMU 7 would require capping regardless of whether exceedances of the mean PECQ2, mean PECQ1, AET, PEC, or ER-L are used to define the area of the cap. As discussed in Subsection 4.3.3.7, it is assumed that a shoreline barrier and hydraulic containment system would be implemented as part of the lake remedy; therefore no targeted dredging of sediment near shore would be required to enhance the performance of the cap. Predicted settlement due to cap placement exceeds the cap thickness in SMU 7; therefore, it is anticipated that no removal is required to maintain the current lake surface area. Thus, Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and

Minimize Erosive Forces / Capping of Entire SMU / Habitat Optimization is retained for detailed evaluation for SMU 7.

Applying the preliminary cap design criteria discussed above to SMU 7 results in the conceptual plan views and cross-sections for these alternatives shown in Figures 4.43 through 4.45. Cap chemical isolation modeling predicts that a 2.5-ft (0.8-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state using assumed worst-case conditions, i.e. maximum measured CPOI sediment concentrations and 5 percent organic carbon. This assumes that a shoreline barrier wall and hydraulic containment system (or targeted dredging to remove sediments in near shore areas where groundwater upwelling velocities are high) is implemented prior to capping, as discussed in Subsection 4.3.4. Figures 4.44 and 4.45 show cross-sections of Alternative 4.A.3 with and without emergent wetlands. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 4.25-ft (1.3-m) thick chemical isolation layer placement to result in a 3.75-ft (1.1-m) thick chemical isolation layer in SMU 7.

No in-lake infrastructure, potential cultural artifacts, or debris that would potentially impact the remedy have been identified to date in SMU 7. In addition, the cap would be designed so that there would be no impedance of tributary flow following cap placement and associated habitat enhancement.

4.3.5 Alternative 5 – Full Removal

This alternative includes the following components:

- Completion of pilot testing and significant pre-design investigations to optimize implementation;
- Installation of a shoreline retention wall, or reinforcement of currently planned groundwater barrier walls, in select SMUs to allow deep removal along the shoreline;
- Dredging of all sediments in a SMU that exceed the SEC established as the cleanup criterion and consolidation within a SCA;
- Placement of backfill or a residual cap, if necessary; and
- Institutional controls to ensure long-term protectiveness of human health and the environment.

In addition, it is assumed under this alternative that source control of CPOIs related to Honeywell and non-Honeywell upland sites that impact a particular SMU, as described in Subsection 4.2, would be implemented prior to implementing the in-lake remediation of a particular SMU. Details regarding each of the remedial components included in this alternative are described below.

Pre-Design Investigation and Pilot Testing: Prior to any in-lake activity, a pre-design investigation program would establish a more precise delineation of the nature and extent of contamination. Testing would also establish the site-specific parameters and gather all other information necessary to design the remedy. This may include evaluation of dredging methods and treatability testing for treatment of water generated during dredging.

Shoreline Retention Wall: The need for a shoreline retention wall or for reinforcement of currently planned shoreline groundwater barrier walls is SMU-specific, and therefore is discussed for each SMU in Subsections 4.3.5.1 through 4.3.5.7.

Dredging: As discussed in Subsection 4.4, hydraulic dredging would involve the removal of sediments using a cutterhead dredge that creates a sediment/water slurry (5 to 20 percent solids by weight) and pumps it to the surface. The sediment slurry would then be pumped via pipeline to a staging or consolidation site. The design would account for the handling and treatment of entrained water prior to its return to the receiving water (or public water treatment plant). Additional details regarding dredging implementation are provided in Appendix L, dredging issues. Handling, treatment, and final disposition of dredged material and water resulting from dredging are addressed in detail in Subsection 4.9.

For evaluation purposes, it is assumed that each dredge can remove 12,000 CY/week for seven months (30 weeks) a year, for an estimated total annual production rate of 360,000 CY/year per dredge (see Appendix L, dredging issues). Based on this production rate, dredging durations are shown in Table 4.5. These dredging durations are all based on the use of one or two dredges. It may be feasible to use more than two dredges simultaneously. However, implementation issues such as the number of dredges and dredging duration would be decided based on factors such as the total volume dredged on a lake-wide basis, the dredge method used, and the water treatment method. Therefore, to facilitate evaluation of SMU-specific alternatives, the simplifying assumption is made that two dredges would be used in estimating SMU-specific dredging durations. Additional discussion on dredging durations using multiple dredges is provided during evaluation of lake-wide alternatives in Section 5.

Controls on sediment resuspension and transport would be used as necessary to help minimize the release of resuspended sediments. These may include silt curtains, silt screens, and/or bubble screens to contain sediments during sediment removal from Onondaga Lake.

Because the depth of impacts that exceed the various SECs has not typically been delineated, significant uncertainty exists regarding the volumes that would require removal to achieve a specific SEC. For example, RI borings indicate that the ILWD or exceedances of SECs extends to at least 26 ft (8 m) deep in SMU 1, which was the maximum depth of SMU 1 borings. This results in the estimated dredge volume shown in Table 4.5 and detailed in Appendix E, areas and volumes. However, it is likely that contaminated material extends significantly beyond 26 ft (8 m). For example, two borings completed as part of the pre-design investigation for installation of a discharge diffuser in SMU 1 show ILWD material extended to a depth of greater than 40 ft (12 m). Similar uncertainty regarding the depth limit of SEC exceedances is present in all SMUs. Therefore, actual removal volumes may be significantly greater for many of the SEC-based dredge volumes estimated herein for the various SMUs.

Backfilling or Residual Capping: As discussed in Appendix L, dredging issues, achieving numeric cleanup criteria via dredging is often difficult due to recontamination via mechanisms such as settling of contaminated sediments disturbed during dredging. Therefore, this evaluation assumes that one additional dredge pass would be completed in an attempt to achieve numeric goals, and then a minimum six-inch residual cap would be placed over the dredged surface to ensure surface sediment goals are achieved. In addition, in some cases the sediment surface following dredging may be so deep that it is of minimal habitat value. As discussed in Appendix M, habitat issues, in water depths beyond 15 ft (4.6 m), which is the maximum fish spawning depth, habitat value is limited. Therefore, it is assumed for evaluation purposes that backfill would be added to the dredged area to result in a uniform slope from the shoreline out to where dredging concludes. Additional backfilling would improve habitat value, but would increase remedial costs and increase short-term risks due to transportation of the increased volume of imported backfill required. Less backfill would result in lower costs, but may result in impaired habitat value. Therefore, this level of backfilling was selected for evaluation purposes as a reasonable backfill depth. Actual required backfilling requirements would be determined based on further evaluation as part of the design process, and would take into consideration the selected remedy on a lake-wide basis.

In areas where the water depth is appropriate for submerged macrophyte colonization and establishment, i.e. 2 to 6 ft (0.6 to 1.8 m), it is assumed that natural establishment of submerged macrophytes would be augmented by broadcast seeding and addition of tubers, as discussed under capping in Subsection 4.3.3. However, the area with a final water depth of 2 to 6 ft (0.6 to 1.8 m) where submerged macrophytes are expected to grow would be significantly less under the dredging alternatives due to the deeper post-dredging water depths. Should there be a loss of habitat in any portion of a SMU, adequate mitigation would be performed at other parts of the lake to result in no net loss of habitat lake-wide.

A significant volume of backfill material would be required. It is anticipated that this material could be readily acquired locally and transported to the site either via truck or via barge through the New York Canal System. Sources with direct access to the barge canal are limited. Therefore, for evaluation purposes it is assumed that material would be imported via truck.

4.3.5.1 SMU 1 Full Removal

As shown in Table 4.4 – A and detailed in Appendix E, areas and volumes, all of SMU 1 would require dredging to at least the depth limits of available data, which is 26 ft (8 m), regardless of whether exceedances of the mean PECQ2, mean PECQ1, AET, PEC, or ER-L are used to define the removal volume. As a result, the alternatives based on removal to these SECs cannot be differentiated for evaluation purposes. Therefore, although the volumes would likely differ, the various options are merged into one alternative for evaluation purposes: Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, AET, PEC, or ER-L). Removal to depths less than 26 ft (8 m) may be possible in select areas of this SMU.

Based on the RI and the history of waste deposition in SMU 1, it is likely that exceedances of SECs are present to at least 26 ft (8 m) immediately offshore. Historical borings have shown visual evidence of ILWD materials to 40 ft deep. Dredging to 26 ft (8 m) or deeper immediately adjacent to the shoreline would require use of a structural wall along the shoreline to avoid significant sloughing of upland material into the dredged area. As discussed in Subsection 4.2, Honeywell has entered into a consent order to install a shallow barrier wall and groundwater collection and treatment system at Wastebed B. However, it is unlikely that this wall would have sufficient structural integrity to allow dredging to 26 ft (8 m) or deeper immediately adjacent to it. Therefore, estimated costs are included for additional anchoring and reinforcing of this wall. Because the wall itself is required as part of the Wastebed B remedy, costs are not included herein for installation of the wall itself.

Considerations associated with existing in-lake infrastructure, cultural artifacts, and debris are consistent with those discussed in Subsection 4.3.4.1. Following dredging, it is assumed backfilling would be implemented as discussed in Subsection 4.3.5.

4.3.5.2 SMU 2 Full Removal

As shown in Table 4.4 – B and detailed in Appendix E, areas and volumes, all of SMU 2 would require dredging to at least the depth limits of available data, which is 6.6 ft (2 m), regardless of whether exceedances of the PEC or ER-L are used to define the removal volume. Therefore, although the volumes would likely differ, these options are merged into one alternative for evaluation purposes. If exceedance of the mean PECQ2, mean PECQ1, or AET is used to define the removal volume, similar areas of SMU 2 would require removal to at least the depth limits of available data. Therefore, the following dredging alternatives are retained for detailed evaluation for SMU 2:

- Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or AET)
- Alternative 5.D – Full Removal (to PEC or ER-L)

Each of these alternatives also includes the assumed sediment removal volume required for full NAPL removal, as discussed in Subsection 4.3.4. This evaluation assumes that the Willis/Semet groundwater barrier wall would be located on the lake side of the causeway.

Considerations associated with existing in-lake infrastructure, cultural artifacts, and debris are consistent with those discussed in Subsection 4.3.4.2. Following dredging, it is assumed backfilling would be implemented as discussed in Subsection 4.3.5.

4.3.5.3 SMU 3 Full Removal

As shown in Table 4.4 – C and detailed in Appendix E, areas and volumes, all of SMU 3 would require removal to at least the depth limits of available data, which is 6.6 ft (2 m), if exceedances of the ER-L are used to define the dredged area. Use of the mean PECQ2, mean PECQ1, or PEC exceedances to define the dredged area would result in dredging similar areas of SMU 3 to at least the depth limits of available data. Therefore, although the volumes would likely differ, these options are merged into one alternative for evaluation purposes. Use of the AET to define remedial areas would result in a similar total area requiring capping as would result from the mean PECQ2, it would be less protective. Therefore, full removal to the AET is not retained. Thus, the following dredging alternatives are retained for SMU 3:

- Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or PEC)
- Alternative 5.E – Full Removal (to ER-L)

Considerations associated with existing in-lake infrastructure, cultural artifacts, and debris are consistent with those discussed in Subsection 4.3.4.3. Following dredging, it is assumed backfilling would be implemented as discussed in Subsection 4.3.5.

4.3.5.4 SMU 4 Full Removal

As shown in Table 4.4 – D and detailed in Appendix E, areas and volumes, it is estimated that all of SMU 4 would require dredging to close to or exceeding the depth limits of available data, which is 26 ft (8 m), regardless of whether exceedances of the PEC or ER-L are used to define the removal volume. Therefore, the resulting alternatives based on removal to these SECs cannot be differentiated for evaluation purposes. Because dredging to these SECs cannot be differentiated, the options are merged into one alternative for evaluation. If exceedances of the mean PECQ2, mean PECQ1, or AET are used to define the removal volume, all of SMU 4 would require removal to an estimated depth of approximately 16 ft (5 m). Therefore, the following dredging alternatives are retained for detailed evaluation for SMU 4:

- Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or AET)
- Alternative 5.D – Full Removal (to PEC or ER-L)

Because impacted sediments in SMU 4 likely have resulted from deposition from Ninemile Creek, and adjacent upland areas other than Ninemile Creek are not contaminated, it is likely that the depth of SEC exceedances is shallower in near shore areas then in offshore areas. Therefore, it is assumed that the sediment dredge cut can be sloped appropriately from the shore, and no shoreline structural wall is necessary to facilitate dredging.

Considerations associated with existing in-lake infrastructure, cultural artifacts, and debris are consistent with those discussed in Subsection 4.3.4.4. Following dredging, it is assumed backfilling would be implemented as discussed in Subsection 4.3.5. Any dredging or backfilling would be designed not to impede tributary flow.

4.3.5.5 SMU 5 Full Removal

As shown in Table 4.4 – E and detailed in Appendix E, areas and volumes, differing areas would require dredging if exceedances of the mean PECQ2, mean PECQ1, PEC, or ER-L are used to define the dredge area. There is only one data point in SMU 5 where the AET is exceeded; therefore, it is assumed that the AET exceedance area is negligible. As a result, the following dredging alternatives are retained for detailed evaluation for SMU 5:

- Alternative 5.A – Full Removal (to PECQ2)
- Alternative 5.B – Full Removal (to PECQ1)
- Alternative 5.D – Full Removal (to PEC)
- Alternative 5.E – Full Removal (to ER-L)

Because estimated volumes are based on a 3-ft (1-m) dredge depth, which is the limit of available data, it is assumed that no shoreline structural wall would be required to facilitate dredging.

Considerations associated with existing in-lake infrastructure, cultural artifacts, and debris are consistent with those discussed in Subsection 4.3.4.5. Following dredging, it is assumed backfilling would be implemented as discussed in Subsection 4.3.5.

4.3.5.6 SMU 6 Full Removal

As shown in Table 4.4 – F and detailed in Appendix E, areas and volumes, all of SMU 6 would require dredging, to estimated depths ranging from 3 ft (1 m) to at least the depth limits of available data, which is 26 ft (8 m), regardless of whether exceedances of the PEC or ER-L are used to define the removal volume. Dredging to the AET was not retained because it results in greater volume but is no more protective than dredging to the mean PECQ2. Because dredging to these SECs cannot be differentiated, the various options are merged into one alternative for evaluation purposes. If exceedances of the mean PECQ1 or mean PECQ2 are used to define the removal volume, differing portions of SMU 6 would require removal, to estimated depths ranging from 3 to 20 ft (1 to 6 m) across the SMU. Dredging to the AET was not retained because it results in greater volume but provides little more protectiveness than dredging to the mean PECQ2. Therefore, the following dredging alternatives are retained for detailed evaluation for SMU 6:

- Alternative 5.A – Full Removal (to Mean PECQ2)
- Alternative 5.B – Full Removal (to Mean PECQ1)
- Alternative 5.D – Full Removal (to PEC or ER-L)

Because impacted sediments in SMU 6 likely resulted from deposition from tributaries and sediment migration from other areas of the lake, it is assumed that the depth of SEC exceedances is shallower in near shore areas then in offshore areas. Therefore, it is assumed that the sediment dredge cut can be sloped appropriately from the shore, and no shoreline structural wall is necessary to facilitate dredging. However, non-Honeywell upland sources are presented adjacent to SMU 6, as detailed in Subsection 4.2. It is uncertain whether these sources have resulted in deeper contamination near shore as a result of mechanisms such as subsurface migration of contaminated groundwater or NAPL. If these conditions are present, sediment removal in this area may be more complex.

Considerations associated with existing in-lake infrastructure, cultural artifacts, and debris are consistent with those discussed in Subsection 4.3.4.6. Following dredging, it is assumed backfilling would be implemented as discussed in Subsection 4.3.5. Any dredging or backfilling would be designed not to impede tributary flow.

4.3.5.7 SMU 7 Full Removal

As shown in Table 4.4 – G and detailed in Appendix E, areas and volumes, it is estimated that all of SMU 7 would require dredging to at least the depth limits of available data in portions of SMU 7, which is 26 ft (8 m), regardless of whether exceedances of the AET, PEC, or ER-L are used to define the removal volume. Because dredging to these SECs cannot be differentiated, the various options are merged into one alternative for evaluation purposes. If exceedances of the mean PECQ2 or mean PECQ1 are used to define the removal volume, only a portion of SMU 7 would require removal, to an estimated depth of 23 ft (7 m). Therefore, the following dredging alternatives are retained for detailed evaluation for SMU 7:

- Alternative 5.A – Full Removal (to Mean PECQ2 or Mean PECQ1)
- Alternative 5.C – Full Removal (to AET, PEC, or ER-L)

Based on the RI and the history of waste deposition in SMU 1, it is likely that exceedances of SECs are present to at least 26 ft (8 m) immediately offshore in the area adjacent to SMU 1. Dredging to this depth immediately adjacent to the shoreline would require use of a structural wall along the shoreline to avoid significant sloughing of upland material into the dredged area. However, near-shore borings in the area not adjacent to SMU 1 indicate that near shore impacted sediments may be relatively shallow. Therefore, for evaluation herein, it is assumed that no shoreline structural wall is required to facilitate dredging in SMU 7.

Considerations associated with existing in-lake infrastructure, cultural artifacts, and debris are consistent with those discussed in Subsection 4.3.4.7. Following dredging, it is assumed backfilling would be implemented as discussed in Subsection 4.3.5. Any dredging or backfilling would be designed not to impede tributary flow.

4.4 DETAILED EVALUATION OF LITTORAL ALTERNATIVES

Based on the remedial alternative screening conducted in Subsection 4.3, the retained alternatives are evaluated in this subsection on a SMU-specific basis. Table 4.5 summarizes the retained remedial alternatives for the littoral area SMUs (i.e., SMUs 1 through 7).

The detailed alternative evaluation, using the seven CERCLA evaluation criteria, typically results in similar conclusions regardless of the SMU. Therefore, for brevity, this subsection provides a detailed evaluation for an alternative only for the SMU where it is first being considered, with the assumption that the evaluation of an alternative is the same for subsequent SMUs. The exception to this is the threshold evaluation criteria of overall protection of human health and the environment, which is more SMU-specific than the other criteria, and is therefore discussed for each SMU-specific alternative below. To ensure that a detailed evaluation of each

SMU-specific alternative is performed for each of the evaluation criteria, an evaluation of each of the CERCLA criteria is performed in Tables 4.6 through 4.12.

RAOs and PRGs were developed taking into consideration the entire lake, while alternatives in this subsection are SMU-specific. Each of the SMU-specific alternatives evaluated in this subsection, other than the No Action Alternative and Habitat Enhancement Alternative, would satisfy all RAOs and PRGs as they pertain directly to the SMU they are considered for, and to the extent that individual SMUs contribute to lake-wide conditions. Achievement of RAOs and PRGs would depend on the alternative that would be implemented lake-wide due to the complexities and interactions between the SMUs and how they impact lake-wide conditions. Therefore, achievement of RAOs and PRGs is addressed in more detail during evaluation of lake-wide alternatives in Section 5, and the evaluation below focuses primarily on which SMU-specific risks are addressed under each SMU-specific alternative.

Short-term effectiveness issues such as implementation risks associated with CPOI releases during capping and dredging are SMU-specific due to the varying CPOI concentrations present in the various SMUs. However, quantitatively evaluating implementation risks is more appropriate when evaluating lake-wide alternatives than SMU-specific alternatives, due to the cumulative nature of the risks and interrelationships between each SMU and the lake. Therefore, short-term risks are more quantitatively evaluated in Section 5, Lake-Wide Alternatives.

4.4.1 SMU 1 Alternatives

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 1:

- Alternative 1 – No Action
- Alternative 3 – Isolation Capping / Habitat Optimization
  - Alternative 3.A – Capping of Entire SMU / Habitat Optimization
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
  - Alternative 4.A.2 – Dredging to Result in No Loss of Lake Surface Area / Isolation Capping of Entire SMU / Habitat Optimization
  - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping of Entire SMU / Habitat Optimization
  - Alternative 4.A.4 – Dredging for Mass Removal to Remove 25 percent of SMU 1 / Isolation Capping of Entire SMU / Habitat Optimization
  - Alternative 4.A.5 – Dredging for Mass Removal to Remove 3 Meters / Isolation Capping of Entire SMU / Habitat Optimization
  - Alternative 4.A.6 – Dredging for Mass Removal to Remove 4 Meters / Isolation Capping of Entire SMU / Habitat Optimization

  - Alternative 4.A.7 – Dredging for Mass Removal to Remove 5 Meters / Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
  - Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, AET, PEC, or ER-L)

Each alternative is evaluated below considering the CERCLA evaluation criteria. See Table 4.6 for additional detail.

4.4.1.1 SMU 1 Alternative 1 – No Action

For the No Action Alternative, upland source controls are implemented, but no action would be implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals, as discussed in Subsection 4.3.

4.4.1.1.1 SMU 1 Alternative 1 – No Action
Overall Protection of Human Health and the Environment

The No Action Alternative would not be protective of human health and the environment, since this would not actively address the contaminated sediments, which present unacceptable risks of exposure to human health and the environment presented by CPOIs in SMU 1.

4.4.1.1.2 SMU 1 Alternative 1 – No Action
Compliance with ARARs

Alternative 1 would not meet location- and action-specific ARARs, since no action is being performed.

4.4.1.1.3 SMU 1 Alternative 1 – No Action
Short-Term Effectiveness

The No Action Alternative does not include any physical construction measures in any areas of contamination and, therefore, would not present any potential adverse impacts to the community or workers as a result of its implementation.

4.4.1.1.4 SMU 1 Alternative 1 – No Action
Long-Term Effectiveness and Permanence

This alternative would not provide significant long-term effectiveness. Since the No Action Alternative would involve no active remedial measures, it would not be effective in eliminating the potential exposure to contaminants in sediment. The SMU would be expected to continue to improve naturally over time; however, it would not effectively eliminate the potential exposure to contaminants in sediment, and the rate of improvement is unpredictable and would not be verified due to the lack of monitoring under this alternative. Existing risks to fish and wildlife would likely remain unchanged or would improve slowly at an unpredictable rate. Considering the levels of contamination that are present, it is unlikely that there would be significant natural improvement.

4.4.1.1.5 SMU 1 Alternative 1 – No Action
Reduction of Toxicity, Mobility, or Volume through Treatment

The toxicity and volume of CPOIs in sediment would not be reduced under the No Action Alternative, because no treatment would be conducted. The overall bioavailability and mobility of contaminants in the sediment may be reduced over time as deposition of cleaner sediments over more impacted sediments would occur in some areas of the lake.

4.4.1.1.6 SMU 1 Alternative 1 – No Action
Implementability

The No Action Alternative would be easy to implement, as there are no activities to undertake.

4.4.1.2 SMU 1 Alternative 3 – Isolation Capping / Habitat Optimization

For SMU 1, there is one retained capping alternative: Alternative 3.A – Capping of Entire SMU / Habitat Optimization. Refer to Table 4.5 and Subsection 4.3.3.1 for additional detail. This alternative assumes that upland source control, including installation of an onshore hydraulic containment system, would be implemented. Installation of the hydraulic containment system was shown to be necessary for an isolation cap to effectively isolate residual contamination (see Appendix H, capping issues).

4.4.1.2.1 SMU 1 Alternative 3 – Isolation Capping / Habitat Optimization
Overall Protection of Human Health and the Environment

Sediment capping would provide overall protection of human health and the environment by eliminating the potential human health and ecological exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment. The cap, in conjunction with the Willis/Semet hydraulic containment system, would effectively eliminate release of CPOIs to the water column via groundwater upwelling. Reduction in direct exposure to CPOIs and in potential CPOI releases to the water column are expected to reduce lake-wide potential risks to fish and to humans and wildlife that consume fish. SMU 1 represents an internal sources of mercury to the water column; therefore, this alternative is expected to result in lake-wide reduction of the mass of mercury available for methylation and reduced methylmercury concentrations in water and fish.

Cap chemical isolation modeling predicts that with the Wastebed B hydraulic containment system in place to effectively eliminate groundwater upwelling in SMU 1, a 2.5-foot (0.8-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state using assumed worst-case conditions, i.e. maximum measured CPOI sediment concentrations and 5 percent organic carbon. Therefore, potential risks due to toxicity to benthic macroinvertebrates would be virtually eliminated.

The cap is also expected to provide long-term effectiveness in preventing any exposures due to migration through the cap of any residual NAPL present in SMU 1 (See Appendix H, capping issues). The NAPL in SMU 1 is primarily distributed weathered NAPL, consisting of disconnected globules, that was likely introduced to the lake with the surface discharges of waste material. The further migration of such residual NAPL is very unlikely under current conditions or following capping because of the resistance by capillary forces. Cap placement may result in short-term releases of NAPL, such as has been observed during boring installations. However, no migration of NAPL through the cap is anticipated during consolidation of the underlying sediment following cap placement, or long-term. Should NAPL migrate through the cap, removal and/or placement of additional cap material would be required.

Specifically, the cap, in conjunction with the upland Willis/Semet hydraulic control system, would have the following long-term beneficial effects on potential risks to human health:

- Reduce lake-wide potential risks associated with consumption of fish containing PCBs, PCDD/PCDFs, mercury, and arsenic to the extent that sediment in this SMU contributes to lake-wide concentrations of these contaminants in fish; and
- Eliminate potential risks in this SMU and reduce potential risks in the south basin associated with exposure to sediment containing individual PAHs, hexachlorobenzene, PCDD/PCDFs, and arsenic.

The cap would have the following long-term beneficial effects on potential risks to the environment:

- For fish and wildlife that consume fish, reduce lake-wide potential risks from exposure to mercury and other CPOIs (e.g., arsenic, PCBs, PCDD/PCDFs) to the extent that sediment in this SMU contributes to lake-wide concentrations of these contaminants in fish;
- Eliminate sediment toxicity to benthic macroinvertebrates in this SMU;
- Improve benthic macroinvertebrate community in this SMU;
- Eliminate release of mercury and other CPOIs to lake water via diffusion, advection, and sediment resuspension from this SMU; and
- Improve habitat conditions for fish and wildlife in this SMU.

All of SMU 1 would be capped; therefore, all potential risks presented by SMU 1 would be eliminated.

The cap would provide new sediment for benthic species to colonize, thereby increasing long-term taxa richness and diversity. Fish would benefit from the increased abundance and diversity of benthic macroinvertebrate prey species that would result following capping, and from the placement of fine gravel substrate designed to satisfy fish spawning requirements. Gravel and cobble substrates are preferred spawning substrate for species such as smallmouth bass and largemouth bass. Terrestrial receptors would benefit from potential enhancement of the prey base resulting from in-lake habitat improvements, including benefits resulting from the creation of new emergent wetlands. These habitat improvements would offset any potential negative habitat impacts associated with loss of a relatively small area of lake surface.

4.4.1.2.2 SMU 1 Alternative 3 – Isolation Capping / Habitat Optimization

Compliance with ARARs

This alternative is expected to comply with all of the designated chemical-specific ARARs to the extent that this SMU contributes to lake-wide conditions. Exceedances of surface water ARARs result from CPOI contributions from multiple sources other than SMU 1; therefore, remediation of SMU 1 alone is not expected to result in achievement of surface water ARARs. However, all of SMU 1 would be capped under this alternative; therefore, contributions from SMU 1 to exceedances of the surface water ARARs would be negligible. In addition, the hydraulic containment system associated with the upland remediation of Wastebed B would significantly reduce loading of CPOIs to the lake from upland sources and subsequent upwelling into the lake.

Even with remediation of SMU 1 and other sources, achievement of surface water ARARs may be difficult. Surface water quality data in the RI indicate that surface water quality standards for CPOIs are generally being achieved in Onondaga Lake, with the possible exception of two state surface water quality standards for dissolved mercury (i.e., standards for protecting wildlife and human health via fish consumption; the other three mercury standards were not exceeded). The water quality standard for the protection of wildlife from exposure to mercury is 2.6 ppt as dissolved mercury. The water quality standard for the protection of human health is 0.7 ppt as dissolved mercury. Sources of dissolved mercury to the surface water in the lake include discharge of surface water and sediment associated with sources related to former Honeywell operations, groundwater discharge related to some of these operations, other groundwater discharges, tributary discharges, point source discharges including the Metro Plant, releases from internal sources including littoral areas subject to resuspension, and other sources. The dissolved phase mercury standards are extremely low, and one or both standards are exceeded in groundwater that is not impacted by industrial or municipal sources that enters Onondaga Lake (2 to 11 ppt), in two tributaries unaffected by mercury-related industrial activities (Sawmill Creek and Bloody Brook, 2 and 3.6 ppt, respectively), and in at least one tributary of Onondaga Lake upstream of influences by sources related to Honeywell operations (Ninemile Creek upstream of Geddes Brook, 1.98 ppt on September 9, 1995).

To further assess the feasibility of meeting the state water quality standards for mercury in Onondaga Lake, a review of mercury concentrations in uncontaminated lakes and other media was performed. Of the studies that report dissolved mercury values, several lakes in Wisconsin and the Northeast that have not received industrial or municipal discharges had dissolved mercury concentrations that exceeded the two state water quality standards that are currently exceeded in Onondaga Lake. In Little Rock Lake, Wisconsin, the mean epilimnetic dissolved mercury concentration was approximately 0.5 ng/L. The mean hypolimnetic mercury concentration ranged from 1 to 7 ng/L. The maximum dissolved mercury concentration in the lake with no industrial or municipal discharges was 7 ppt (Back and Watras, 1995; Hurley *et al*., 1991; Watras *et al*., 1995). In addition, 19 lakes were sampled in Wisconsin in the spring and fall with the dissolved mercury concentrations in these lakes ranged from 0.23 to 4.5 ng/L, the mean concentration was 1.2 ng/L, and the median concentration was 0.71 ng/L (Watras *et al*., 1995).

In the Northeast, 16 of 20 lakes surveyed exceeded the human health (fish consumption) standard, and eight of 20 lakes surveyed exceeded the wildlife standard (Chen *et al*., 2000). The human health (fish consumption) standard was frequently exceeded, and the wildlife standard was exceeded once (3.9 ppt) in samples from streams in a watershed in northeast Vermont that had not received industrial or municipal discharges (Shanley *et al.*, 2002). Detected dissolved mercury concentrations ranged from 1 to 21 ppt; the average concentration for all 20 lakes was 6 ppt (Chen *et al*., 2000). These data indicate that sources including atmospheric deposition can result in exceedances of the standards.

Due to ongoing sources of mercury to the lake that are unrelated to the former Honeywell operations, it may be difficult to meet all of the surface water quality standards for mercury in Onondaga Lake. However, it is anticipated that remediation of SMU 1 and other upland and in-lake mercury sources would significantly reduce mercury loading, resulting in progress toward meeting these ARARs to the extent practicable. It is anticipated that these remedial actions would also result in achieving surface water ARARs for other CPOIs, including chlorobenzene, which has been detected in surface water in excess of ARARs.

There are no chemical-specific ARARs for sediment quality in Onondaga Lake. Chemical-specific SECs were developed specifically for Onondaga Lake, as detailed in Section 2.

Remedy implementation for the in-lake portion of this alternative may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment. Cap placement may result in short-term exceedances of surface water criteria due to sediment disturbances. However, sediment disturbance and short-term exceedances of surface water ARARs is expected to be significantly greater during dredging under other alternatives. Short-term water quality impacts resulting from remedy implementation are addressed quantitatively as part of the evaluation of lake-wide alternatives in Section 5.

This alternative is expected to comply with all designated location-specific and action-specific ARARs. Sediment caps are routinely installed in compliance with all action-specific and location-specific ARARs. These relevant and appropriate ARARs would include substantive requirements of the dredge and fill permit program under Section 404 of the federal Clean Water Act. It is anticipated that actions to minimize aquatic habitat loss would be similar to efforts that would be undertaken along the southeastern portion of Onondaga Lake, where the USACE is working currently to evaluate impacts of a proposed bike trail extension. The proposed trail would parallel the shoreline and would likely be located in the lake due to land use constraints onshore from an existing rail line and parkway.

Under this and other alternatives for SMU 1 and other SMUs, remedial actions would result in changes to the existing bathymetric conditions. The degree of these changes would be based on the depth and extent of any dredging, thickness of the cap, and extent of the habitat improvements integrated into the final design. These changes may result in either loss or gain of water depth in different areas. Addressing how these bathymetry changes impact compliance with NYS Article 15, Part 608 should consider how habitat improvements are incorporated into the remedial alternative and are more appropriately considered on a lake-wide basis. In addition, NYSDEC would evaluate the application of NYS Article 15, Part 608 for the remedial actions selected for each SMU and on a lake-wide basis. Since the overall remedy is being considered on a lake-wide basis, compliance with NYS Article 15, Part 608 is addressed in Section 5.

Complete listings of ARARs are provided in Appendix C (ARARs and TBCs).

4.4.1.2.3 SMU 1 Alternative 3 – Isolation Capping / Habitat Optimization

Short-Term Effectiveness

Physical construction of this alternative could likely be completed in approximately one construction season. The effects of this alternative during the construction and implementation phase would potentially include:

- Temporary loss of lake habitat;
- Temporary impacts associated with sedimentation (even clean sediment) to surrounding areas resulting from cap placement, particularly sedimentation on submerged macrophytes or fish spawning substrates, which can diminish productivity;
- Temporary impacts of resuspension of CPOIs and potential release of NAPL into the water column during cap placement, and potential impacts of resuspension on the natural recovery of the profundal sediments;
- Quality of life impacts associated with odor and increased truck traffic on local roads;
- Potential for on-site worker and transportation accidents associated with remedial construction issues related to capping; and
- Potential for on-site workers to receive adverse impacts through dermal contact with contaminated sediment. However, since no sediment is being removed, the potential risk associated with adverse dermal contact is minimal.

It is anticipated that the potential risks to on-site workers could be mitigated by following appropriate health and safety protocols, by exercising sound engineering practices, and by utilizing proper protective equipment. Short-term risks are evaluated in greater detail during evaluation of lake-wide alternatives in Section 5 and in Appendix I, risk of remedy, including quantitative estimation of releases of CPOIs to the air and surface water and estimation of transportation and worker risks. Short-term risks are discussed qualitatively below.

Potential short-term risks include the short-term resuspension of in-lake sediments during remedy implementation associated with desorption of CPOIs and the potential release of NAPLs to the water column during cap placement. Also, the resuspended sediment would be redeposited to the lake sediments with the potential to delay the recovery of the profundal sediments. Based on experience at other capping sites, these impacts are not anticipated to be significant. Proven, available engineering controls would be employed during implementation of this alternative to minimize the rate of sediment resuspension and material transport during capping activities, if required. For example, barriers such as silt curtains and sheet piling can help minimize potential adverse impacts related to sediment resuspension. In addition, the cap would be carefully installed to avoid recontaminating the area already capped.

The primary short-term negative ecological impact under this alternative would be the temporary elimination of benthic macroinvertebrate communities and submerged macrophytes by burial with clean sediments. Sediment disturbance would last approximately one construction season under this alternative. In addition to direct effects on benthic macroinvertebrates in the affected areas, fish that forage in the affected areas could experience indirect effects because the base of the benthic food web would be temporarily impacted.

Such impacts would be transitory, however, as macroinvertebrates and macrophytes would quickly begin to re-colonize suitable areas based on natural decolonization as well through application of seed and tubers during capping, as discussed in Subsection 4.3. Studies have found that communities may recolonize within one year (Niemi *et al.*, 1990). In addition, because fish are mobile, they could feed on benthic macroinvertebrates available in parts of the lake not affected by remediation. The negative ecological effects of this alternative would be limited and temporary, as the affected area would be a relatively small area of the lake at any one time. In addition, Honeywell would work closely with NYSDEC prior to and during construction to ensure that remediation activities would be scheduled to minimize impacts on fish spawning activities, if required.

Increased risk of vehicular accidents would occur during the import of capping materials by truck to the site. Construction risks would be associated with the operation of heavy equipment required to place the sediment cap. Engineering controls would be put in place to minimize potential hazards associated with cap placement, as appropriate. Construction risks would be related to the volume of materials used to install the sediment cap.

In general, this alternative could be implemented within a relatively short timeframe and would not have significant impacts to the surrounding community. Therefore, there are no anticipated significant quality of life issues, such as significant delays in completing the planned walking and biking trail around the lake, impacts to areas where people congregate, proximity to residences, or impacts on canoeing, fishing, or other recreational uses of Onondaga Lake associated with this alternative.

4.4.1.2.4 SMU 1 Alternative 3 – Isolation Capping / Habitat Optimization

Long-Term Effectiveness and Permanence

This alternative would provide long-term effectiveness and permanence by eliminating the potential human health and ecological exposure pathways associated with impacted sediment. The cap would be designed and constructed to ensure long-term stability. Gravel, rock, and riprap would be incorporated into the cap design as necessary to minimize erosion or ice scour of the cap. Consistent with USEPA design guidance for caps, the cap would be designed to withstand erosional forces resulting from the 100-year return interval storm event (USEPA, 2002). Institutional controls, such as bans on dredging the capped area, would be implemented as necessary to help ensure the long-term integrity of the cap.

Numerous long-term sediment capping projects have been effectively implemented in this country. The contaminant movement processes are for the most part well understood, and tools are available to model the long-term behavior of contaminants under a cap. Appendix H, capping issues, summarizes major capping projects performed to date.

A slope stability analysis was performed on the submerged in-lake waste for two slope profiles in the southeast corner of Onondaga Lake using available geotechnical and other relevant data, as discussed in Subsection 4.3 and detailed in Appendix H, capping issues. The analysis indicates that the sediment would be stable after capping; however, there may be potential for cap failure in some portions of the ILWD where shear strengths are low. Design sampling would be used to determine the stability of the ILWD, and, if needed, additional material would be removed from the ILWD and/or engineered controls would be placed to stabilize a cap under static and seismic conditions.

When contaminated materials or sludges containing organic material are capped, the organic material has the potential to decompose under the influences of anaerobic and pressure-related processes, resulting in production of methane and hydrogen sulfide gases. As these dissolved gases accumulate and transfer into a gaseous phase, they could begin to percolate through the capped matrix by convective or diffusive transport (see Appendix H, capping issues). This potential exists at almost all sediment capping sites. With the exception of unusual conditions such as pooled NAPL, gas generation has not been documented as a problem with respect to contaminant migration through caps or the long-term cap effectiveness. Furthermore, gas formation is not expected to be a design issue for Onondaga Lake because organic contaminants at the site are not a significant source of gas. The primary source of any gas is expected to be fresh organic matter deposited with runoff, leaf litter, and sediment loads from tributaries. In addition, gas formation is highly temperature dependent, with gas generation increasing with increasing temperature. Placement of a cap would result in insulation of the contaminated sediment surface from temperature changes (Service Engineering Group, 2004). Beneath a cap, the removal of the flux of organic matter and insulation from temperature increases should minimize gas generation from the contaminated sediment layer within a period of months to years.

Navigation and anchorage are not expected to impact the long-term effectiveness of the cap. Anchorage by recreational vessels would not affect the integrity of the cap, since the depth of penetration of recreational anchors is limited and the isolation cap is protected by a habitat layer and an armor layer. However, the isolation cap does extend beyond the bench, following the lake slopes to depths of 30 feet (9 m). Some anchorage restrictions for larger vessels would be appropriate in these areas.

A monitoring program to confirm that the cap remains in place and effective over time may include elements such as periodic core sampling to verify sediment cap integrity and chemical isolation. Any warranted repairs identified during monitoring would be made as needed. Proper design of the cap would provide long-term effectiveness and permanence of the remedy and would minimize maintenance requirements.

Significant maintenance of the cap is not anticipated. There are essentially two types of events that could be considered relevant in evaluating the potential maintenance requirements (see Appendix H, capping issues). First, a cap could be physically damaged by an extreme episodic event, one exceeding the magnitude of the design events for which the cap armor layer is designed. An example of such an event would be a wind-driven wave event that exceeds the 100 year return interval for which the armor material sizes have been selected. Another example may be the occurrence of an ice cover of thicker dimension than the anticipated 16 inches (41 cm) and the subsequent breakup and piling of the ice on shore with greater than expected ice scour impacts to the near shore armor stone. In both of these examples, catastrophic failure of large areas of the cap would not occur (see Appendix H, capping issues). Regardless, even small failures of the cap may be significant and would be addressed through appropriate corrective actions and maintenance of the cap. The caps would be routinely monitored for cap failure or damage.

Another example of this type of failure is a possible slope failure in the ILWD resulting from a seismic event, which exceeds the return interval considered in the design. This failure scenario would apply only to SMU 1. Considering the overall factors of safety against sliding calculated for the FS, such a failure would occur only in the areas of steepest slope in the ILWD. Damage to the cap resulting from a slump could be repaired by some material removal at the head of the slump and subsequent replacement of the cap. It should be assumed that no more than 10 percent of the total area capped in SMU 1 would require repair, and that such repairs would be made to similar specifications and using similar materials as in the original construction.

The second type of event that might result in required maintenance is a “failure” of the chemical isolation effectiveness of the cap. The cap designs for chemical isolation are based on well-accepted scientific principles governing the chemical migration of contaminants due to diffusive and advective transport processes and appropriately conservative engineering principles. Therefore, the only cause for such an effectiveness failure would be the mischaracterization of sediment physical and chemical properties during design. Since any design of a capping remedy would be based on a refined sediment characterization effort, such a mischaracterization would be limited to a missed hotspot of high sediment contaminant concentrations. The area subject to any such mischaracterization should be assumed limited to no more than 5 percent of the total area capped in any SMU, and could be readily repaired and/or upgraded (see Appendix H, capping issues).

4.4.1.2.5 SMU 1 Alternative 3 – Isolation Capping / Habitat Optimization Reduction of Toxicity, Mobility, or Volume through Treatment

Capping relies on isolation rather than treatment to achieve effectiveness. The cap would effectively isolate impacted sediment, thereby reducing the mobility of the impacted sediments and potential adverse exposure to contaminated sediments. Capping would result in relatively insignificant reduction in the volume of the impacted sediment due to compaction resulting from the weight of the cap. In addition, natural processes that reduce toxicity, such as biological degradation of organic compounds, would continue to occur beneath the cap following construction, although these processes may be insignificant and would not be monitored or verified.

4.4.1.2.6 SMU 1 Alternative 3 – Isolation Capping / Habitat Optimization Implementability

Appropriate sediment capping technologies are readily available and implementable, and construction procedures are well established. Capping has been demonstrated as an effective remedial technology for impacted sediments at numerous sites, as discussed in Appendix H, capping issues. Guidance documents are also available from numerous sources, including the USEPA and the USACE, on how to successfully design, construct, and monitor sub-aqueous cap projects. The technology, equipment, subcontractors, personnel, and facilities required to successfully complete this alternative are available in the environmental marketplace.

A potential implementability issue for caps is related to stable placement in soft sediments and on slopes. Appendix H, capping issues, provides an analysis of sediment types and slopes related to capping in this SMU. This analysis indicates that various techniques of placing relatively thin lifts of cap material would allow stable placement on even extremely soft sediments. These techniques include allowances for some mixing with underlying sediments in the initially placed layers, with this “mixed” layer assumed to make no contribution to cap effectiveness; appropriate design thicknesses for isolation are added to this mixed layer. In addition, stable capping on slopes similar to those currently found within this SMU or likely to exist after dredging has been successfully conducted on other projects (see Appendix H, capping issues).

Short-term and long-term monitoring of this alternative can be easily implemented to verify effectiveness. Additional remedial actions can readily be undertaken, such as repairing or upgrading the cap, should the alternative prove to be ineffective or partially ineffective.

4.4.1.3 SMU 1 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

This alternative includes six dredging options (Alternatives 4.A.2, 4.A.3, 4.A.4, 4.A.5, 4.A.6, and 4.A.7), as listed in Subsection 4.4.1. The estimated amount of sediment to be removed and capped under each alternative is provided in Table 4.5. The entire SMU would be capped regardless of which SEC approach is used. This alternative assumes that upland source control, including installation of an onshore hydraulic control system, has been implemented. Installation of the hydraulic containment system was shown to be necessary for an isolation cap to effectively isolate residual contamination (see Appendix H, capping issues).

4.4.1.3.1 SMU 1 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Overall Protection of Human Health and the Environment

Consistent with the discussion provided for capping of SMU 1 in Subsection 4.4.1.2.1, dredging followed by capping in SMU 1 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. Dredging to result in no loss of lake surface area under Alternative 4.A.2 or to a depth that optimizes habitat value and minimizes erosive forces under Alternative 4.A.3 prior to capping would provide additional benefit by further improving the habitat value of the cap. Dredging to a depth that optimizes habitat value and minimizes erosive forces prior to cap placement would provide additional benefit by further improving the habitat value of the cap.

The habitat value under Alternatives 4.A.4, 4.A.5, 4.A.6, and 4.A.7, would be less than those associated with the other dredging/capping alternatives because of the greater water depth. Even though these alternatives would include backfilling, they would provide less macrophyte habitat due to the greater water depth and steeper slopes associated with these alternatives. All of the alternatives associated with Alternative 4 in SMU 4 would provide added habitat value relative to the current conditions. The existing water depth in SMU 1 is due, in part, to the presence of the ILWD. Detailed comparison of the resulting habitat values under the various alternatives is provided under the comparative evaluation of SMU 1 alternatives in Subsection 4.5.1.1.

All of SMU 1 would be capped, so all potential risks presented by SMU 1 would be eliminated.

4.4.1.3.2 SMU 1 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Compliance with ARARs

Consistent with the ARAR evaluation provided for the SMU 1 capping alternative in Subsection 4.4.1.2.2, this alternative is expected to comply with all designated chemical-specific ARARs to the extent that this SMU contributes to lake-wide conditions, with the possible exception of two surface water quality standards for dissolved mercury. It is also anticipated that this alternative would be completed in compliance with any location-specific and action-specific ARARS.

4.4.1.3.3 SMU 1 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Short-Term Effectiveness

Physical construction of any of the Alternative 4 options could likely be completed in five or fewer construction seasons. The short-term impacts associated with capping under this alternative are consistent with those discussed under capping in Subsection 4.4.1.2.3. Dredging under this alternative would present the following additional potential short-term impacts:

- Impacts of discharge of dewatering effluent on lake water quality;
- Volatilization of organics during dredging and materials handling;
- Potential release of NAPL, which could adversely affect human health and the environment. This risk can be mitigated by exercising management practices (e.g., using specialized dredging equipment and dredging at a slow rate), using containment measures such as silt curtains, surface absorbent booms, and gunderbooms, following appropriate health and safety protocols, and by using proper protective equipment; and
- Potential for on-site workers to receive adverse impacts through dermal contact with contaminated sediment.

It is anticipated that the potential risks to on-site workers could be mitigated by following appropriate health and safety protocols, by exercising sound engineering practices, and by utilizing proper protective equipment. Short-term risks are evaluated in greater detail during evaluation of lake-wide alternatives in Section 5 and in Appendix I, risk of remedy, including quantitative estimation of releases of CPOIs to the air and surface water, and estimation of transportation and worker risks. These potential short-term risks are discussed qualitatively below.

Dredging, sediment handling, and dewatering may create air emissions and odors through release of SVOCs and VOCs from the dredge materials. This short-term impact may be mitigated through engineering controls, including controlled dredging, wearing proper personal protective equipment (PPE), and adequate monitoring.

Access to the construction area, including the dredging operations, sediment processing area, water treatment area, and trucking areas, would be restricted and should present no community exposure issues. The community would be restricted from using portions of the lake during construction. Suitable engineering controls would be employed, including air monitoring and emission suppression as needed. If mechanical dredging rather than hydraulic dredging were used, sediment transport would involve use of local roadways and would cause a short-term increase in traffic.

In general, this alternative could be implemented within a relatively short timeframe and would not have significant impacts to the surrounding community. Therefore, there are no anticipated significant quality of life issues, such as significant delays in completing the planned walking and biking trail around the lake, impacts to areas where people congregate, proximity to residences, or impacts on canoeing, fishing, or other recreational uses of Onondaga Lake, associated with this alternative.

4.4.1.3.4 SMU 1 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Long-Term Effectiveness and Permanence

Dredging followed by capping in SMU 1 would provide long-term effectiveness and permanence by eliminating the potential human health and ecological exposure pathways associated with impacted sediment. Long-term effectiveness and permanence of the cap would be consistent with the discussion provided for capping of SMU 1 in Subsection 4.4.1.2.4.

Dredged sediments would be contained within an on-site or off-site facility that would isolate dredged sediments from the environment, assuming proper design and monitoring.

4.4.1.3.5 SMU 1 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 relies on isolation rather than treatment to achieve effectiveness. However, capping would result in insignificant reduction in the volume of the impacted sediment due to compaction resulting from the weight of the cap. Natural processes that reduce toxicity, such as biological degradation of organic compounds, would continue to occur beneath the cap following construction, although these processes may be insignificant and would not be monitored or verified.

The dredging and associated processes included in Alternative 4 would result in reducing the toxicity, mobility, and volume through treatment of the dredged sediment. The volume of sediment would be reduced through consolidation and dewatering prior to final placement in an on-site or off-site facility. Dewatering would also reduce the mobility of the removed sediment. Treatment of water resulting from the dredging operations, as detailed in Subsection 4.9, would result in reduced toxicity, mobility, and volume of CPOIs that are mobilized from the sediment into the water stream. In addition, natural processes that reduce toxicity, such as biological degradation of organic compounds would continue to occur beneath the cap following construction, although these processes may be insignificant and would not be monitored or verified. The greater the volume of sediment removed, the greater the reduction in toxicity, mobility, and volume that would result from these processes.

4.4.1.3.6 SMU 1 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Implementability

Appropriate dredging and sediment capping technologies are readily available and implementable, and construction procedures are well established. Dredging and capping have been demonstrated as effective remedial technologies for impacted sediments at numerous sites, as discussed in Appendices L (dredging issues) and H (capping issues), respectively. Guidance documents are also available from numerous sources, including the USEPA and the USACE, on how to successfully design, construct, and monitor dredging and sub-aqueous cap projects. The technology, equipment, subcontractors, personnel, and facilities required to successfully complete this alternative are available in the environmental market place.

Onondaga Lake can be mechanically dredged or hydraulically dredged. Low-draft hydraulic dredges could be used in water depths of 3 ft (1 m) or greater. Mechanical dredging can be used in shallow areas and where cobbles, large rocks, or debris are present. One potential implementation issue in most near-shore dredging operations is dredging around shoreline structures and obstacles such as docks, piers, bulkheads, large rocks, or debris. Techniques exist to implement dredging in most shoreline situations. For example, dredging around structures can be conducted by removal and replacement. For small areas, small hydraulic dredges or diver-deployed dredges (e.g., for use under small piers) are available and often logistically preferable. Other types of obstacles and debris (logs, fallen pilings, disused footings, etc.) can often be removed through mechanical means such as claws or dredge buckets prior to sediment dredging.

Another common implementation issue for dredging is controlling sediment resuspension. As discussed above, many proven technologies exist to minimize resuspension loss, although some of these techniques have limitations. The primary limitations for silt curtains and gunderbooms are water currents, large waves or wakes, and interference with navigation traffic. However, currents in Onondaga Lake are expected to be less than critical velocities, except in unusual storm events (which would likely temporarily shut down operations because of associated waves). Navigation traffic is minimal in the lake and is unlikely to be affected by silt curtains or similar sediment control devices. Operational controls are implementable to some degree in almost all circumstances, with no major limitations expected for these controls. Because water barriers and operational controls are expected to be effective, use of sheet pile walls or other complete barriers would likely be unnecessary.

Another common obstacle for environmental dredging is contractor knowledge of environmental dredging techniques. Only dredging contractors experienced with environmental dredging projects and with proven records in such projects would be employed for these operations.

Duration of dredging can also be an issue for large scale dredging operations. Longer duration of construction increases the potential for resuspension impacts. In general, experienced contractors and/or deployment of multiple dredges can be used to decrease the duration of dredging events to manageable periods.

A potential implementability issue for caps is related to stable placement in soft sediments and on slopes. Appendix H, capping issues, provides an analysis of sediment types and slopes related to capping in this SMU. This analysis indicates that various techniques of placing relatively thin lifts of cap material would allow stable placement on even extremely soft sediments. These techniques include allowances for some mixing with underlying sediments in the initially placed layers, with this "mixed" layer assumed to make no contribution to cap effectiveness; appropriate design thicknesses for isolation are added to this mixed layer. In addition, stable capping has been successfully conducted on other projects involving slopes similar to those currently found within this SMU or that are likely to exist after dredging (see Appendix L, dredging issues).

Short-term and long-term monitoring of this alternative can be easily implemented to verify effectiveness. Additional remedial actions can readily be undertaken should the alternative prove to be ineffective or partially ineffective. All options under this alternative are similarly implementable, although greater dredge volumes would require either longer durations or additional dredging equipment.

4.4.1.4 SMU 1 Alternative 5 – Full Removal

Alternative 5 includes sediment removal to SEC levels with subsequent on-site disposal. As shown in Table 4.5 and detailed in Appendix E, areas and volumes, all of SMU 1 would require dredging to at least the depth limits of available data, which is 26 ft (8 m), regardless of which SEC approach is used to define the removal volume. Therefore, evaluating SMU 1 based on the site-specific SEC values does not result in any changes in the amount of impacted sediment being removed. As a result, the various options are merged into one alternative: Alternative 5.A - Full Removal (to Mean PECQ2, Mean PECQ1, AET, PEC, or ER-L).

4.4.1.4.1 SMU 1 Alternative 5 – Full Removal
Overall Protection of Human Health and the Environment

Consistent with the discussion provided for capping of SMU 1 in Subsection 4.4.1.2.1, Alternative 5 provides overall protection of human health and the environment through removal of impacted sediments. Following dredging, SMU 1 would be backfilled, which would effectively isolate any residual contamination from humans and the environment. All of SMU 1 would be dredged; therefore, potential risks presented by SMU 1 would be eliminated.

As discussed in Subsection 4.3.5, this evaluation assumes that backfill would be placed following dredging to achieve a constant slope from the shoreline out to the limits of dredging. Additional backfilling would improve habitat value, but would increase remedial costs and increase short-term potential risks due to transportation of the large volume of imported backfill required. Therefore, this backfilling strategy was selected for evaluation purposes as a reasonable assumption. Actual required backfilling requirements would be determined based on further evaluation as part of the design process, and would take into consideration the selected remedy on a lake-wide basis. It is assumed that a 6-inch (15-cm) layer of fine gravel would be placed where the final water depth is between 6 and 15 ft (1.8 and 4.6 m) to promote fish spawning. In addition, in areas where the water depth is appropriate for submerged macrophyte colonization and establishment, i.e. 2 to 6 ft (0.6 to 1.8 m), it is assumed that natural establishment of submerged macrophytes would be augmented by broadcast seeding and addition of tubers, as discussed under capping in Subsection 4.3.3.

4.4.1.4.2 SMU 1 Alternative 5 – Full Removal Compliance with ARARs

Consistent with the ARAR evaluation provided of the SMU 1 capping alternative in Subsection 4.4.1.2.2, this alternative is expected to comply with all designated chemical-specific ARARs to the extent that this SMU contributes to lake-wide conditions, with the possible exception of two surface water quality standards for dissolved mercury. It is also anticipated that this alternative would be completed in compliance with any location-specific and action-specific ARARS.

4.4.1.4.3 SMU 1 Alternative 5 – Full Removal Short-Term Effectiveness

Dredging the sediment volume required under this alternative would require approximately three to four years, assuming use of two dredges, as shown in Table 4.5. It may be feasible to use more than two dredges simultaneously. However, implementation issues such as the number of dredges and dredging duration would be decided based on the total volume dredged on a lake-wide basis, the final dredge method used, and the disposal method. Therefore, to facilitate evaluation of SMU-specific alternatives, the simplifying assumption is made that two dredges would be used in estimating SMU-specific dredging durations. Additional discussion on dredging durations using multiple dredges is provided during evaluation of lake-wide alternatives in Section 5.

The effects of this alternative during the construction and implementation phase would be similar to those discussed in Subsection 4.4.1.3.3 for the dredging component of Alternative 4 (see Table 4.6), but would be significantly greater in magnitude and duration, reflecting the much larger quantities of sediment being removed. The greater the volume of sediment removed and/or disturbed, the greater likelihood of releases from pore fluids, desorption of CPOIs from the resuspension of sediments, and air emissions associated with VOCs. Sediment disturbance impacting benthic and other aquatic communities would last an estimated five to six years under this alternative. The potential for short-term risks due to resuspension of CPOIs, release of NAPLs, and air emissions of volatile CPOIs would also occur over this period. Potential release of NAPL can be mitigated by exercising management practices (e.g., using specialized dredging equipment and dredging at a slow rate), using containment measures (e.g., silt curtains, surface absorbent booms, and gunderbooms), following appropriate health and safety protocols, and using proper protective equipment. Short-term risks are evaluated in greater detail during evaluation of lake-wide alternatives in Section 5 and in Appendix I, risk of remedy, including quantitative estimation of releases of CPOIs to the air and surface water and estimation of transportation and worker risks.

Implementation of this alternative would occur over an extended period, as noted above, and may have significant impacts to the surrounding community. Because of the longer period of implementation, quality of life issues could include delays in completing the planned walking and biking trail around the lake, impacts to areas where people congregate, proximity to residences, and impacts on canoeing, fishing, or other recreational uses of Onondaga Lake.

4.4.1.4.4 SMU 1 Alternative 5 – Full Removal
Long-Term Effectiveness and Permanence

Alternative 5 provides long-term effectiveness and permanence by removing from the lake environment sediments that present unacceptable risks to human health and the environment.

Dredged sediments would be contained within an on-site or off-site facility, which would isolate dredged sediments from the environment, assuming proper design and monitoring.

4.4.1.4.5 SMU 1 Alternative 5 – Full Removal
Reduction of Toxicity, Mobility, or Volume through Treatment

The dredging and associated processes included in Alternative 5 would result in reduction in toxicity, mobility, and volume through treatment of the dredged sediment. The volume of sediment would be reduced through consolidation and dewatering prior to and/or subsequent to placement within an on-site or off-site facility. Dewatering would also reduce the mobility of the removed sediment. Treatment of water resulting from the dredging operations, as detailed in Subsection 4.9, would result in reduction in the toxicity, mobility, and volume of CPOIs that are mobilized from the sediment into the water stream.

4.4.1.4.6 SMU 1 Alternative 5 – Full Removal
Implementability

The same implementability issues related to dredging in Alternative 4 discussed in Subsection 4.4.1.3.6 apply to Alternative 5. However, significant additional implementability issues would be presented by this alternative due to the large volume of sediment that would be dredged. Approximately 4,000,000 cubic yards of sediment would be dredged in SMU 1 under this alternative. This would be a monumental undertaking, and the large volume would have significant impacts on implementability. The implementation of a 4,000,000 cubic yard project is significantly more complicated and difficult than implementing a 200,000 to 300,000 cubic yard project. The sediment from SMU-1 only would be larger than any other contaminated sediment dredging project every done in the United States (MCSSD, 2002). If the material was placed 40 feet high, it would take about 70 acres to hold the dredged material.

As described in Subsection 4.3, contaminated sediment of unknown depth, but deeper than 26 ft (8 m), is located along the shoreline. The contaminated sediment appears to be continuous with the material deposited in Wastebed B. As part of the remediation for Wastebed B, a barrier wall is planned to be constructed parallel to the shoreline. In order to remove all sediment above the SEC levels, it is expected that all sediment on the lake side of the wall would have to be removed. In order to safety remove all contaminated sediment, the wall would have to provide structural support for soil on one side and only lake water on the other side. Design and construction of an underwater retaining wall 30 ft high would be a complicated project that would be difficult to implement. The retaining wall may have to be designed and constructed similar to walls used to support tunnels or foundation walls for high-rise buildings in major urban areas. These have been constructed in areas where there is high groundwater and very soft soils (such as Boston and Washington, D.C.), which is the condition in SMU 1, but construction is difficult, dangerous, slow, and expensive.

SMU 1 has a surface area of about 80 acres, and there would be sufficient room for two hydraulic dredges to operate at the same time. With two dredges working 16 hours per day, four crews would be required for the project. Environmental dredging is specialized work, and there are relatively few experienced operators in the United States. However, there are enough operators for four crews to be devoted to this one SMU for six years. It would probably be necessary to relocate the superintendent and foreman to Syracuse from the Great Lakes or from coastal parts of the country.

The dredged slurry would have to be discharged evenly throughout the settling basin. One way to accomplish this is to connect the dredge pipeline to a flexible, floating pipeline in the settling basin and install a diffuser at the end of the flexible pipeline. The diffuser would have to be continuously moved in the basin to provide uniform distribution of material.

Since the dredge slurry that is discharged into the settling basin would have essentially zero shear strength, the perimeter berms would have to be designed as earth dams. The design and operation would have to be carefully engineered to control the lateral loads on the perimeter berms to ensure that the SCA facility was stable during all construction seasons. The existing wastebed material under the perimeter dikes may not have sufficient shear strength to support the dikes. This is often the case for the foundations of earth dams, and the soil has to be strengthened or replaced prior to building dams. The sequence of construction would require thorough analysis during design.

The dredged slurry would experience several feet of self-weight consolidation settlement after it was placed into the SCA. The magnitude and rate of consolidation settlement depends on the thickness and properties of the material. With perimeter dikes 50 feet high and contaminated dredged material 40 to 45 feet thick, the consolidation settlement would take decades. The low strength and highly compressible nature of the dredged slurry would restrict future use of the SCA site.

Construction of the SCA to contain 4,000,000 to 10,000,000 CY would be a major earthwork project. A facility of that size would entail literally creating a new hill in the city, which would make a visual impact on the community. The town of Camillus previously has restricted the height of Wastebed 15, which is near Wastebed 13, to 468 feet above mean sea level. If that restriction were applied to Wastebed 13, the dike height would be limited to about 23 ft (7 m).

Additional implementability issues associated with construction of a large SCA are discussed in Subsection 4.9.

4.4.2 SMU 2 Alternatives

Provided below is a detailed evaluation of how each SMU 2 alternative satisfies the criteria of overall protection of human health and the environment. Evaluation of the SMU 2 alternatives against the other evaluation criteria is consistent with the evaluation provided for these alternatives in SMU 1, as discussed in Subsection 4.4.1. To ensure complete evaluation of each SMU 2 alternative, the CERCLA evaluation criteria are discussed in detail for each SMU 2 alternative in Table 4.7. Evaluations that are not present because they are similar to other alternatives can be found in Tables 4.6 through 4.12.

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 2:

- Alternative 1 – No Action
- Alternative 3 – Isolation Capping / Habitat Optimization
    - Alternative 3.A – Isolation Capping to the Mean PECQ2, Mean PECQ1, or AET / Habitat Optimization
    - Alternative 3.D – Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - Option 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging to 4 Meter Depth (for NAPL Removal) / Isolation Capping to Mean PECQ2, Mean PECQ1, and AET / Habitat Optimization
    - Option 4.A.4 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Full NAPL Removal / Capping to Mean PECQ2, Mean PECQ1, or AET / Habitat Optimization
    - Option 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging to 4 Meter Depth (for NAPL Removal) / Isolation Capping of Entire SMU / Habitat Optimization.
    - Option 4.D.4 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize habitat and Minimize Erosive Forces and Full NAPL Removal / Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
    - Option 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or AET)
    - Option 5.D – Full Removal (to PEC or ER-L)

4.4.2.1 SMU 2 Alternative 1 – No Action

For the No Action Alternative, upland source controls are implemented but no action would be implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals, as discussed in Subsection 4.3.

4.4.2.1.1 SMU 2 Alternative 1 – No Action
Overall Protection of Human Health and the Environment

The No Action Alternative would not be protective of human health and the environment, since this would not actively address the contaminated sediments, which present unacceptable risks of exposure to human health and the environment presented by CPOIs in SMU 2.

4.4.2.2 SMU 2 Alternative 3 – Isolation Capping / Habitat Optimization

Under SMU 2 Alternative 3, there are two options: Alternative 3.A and Alternative 3.D. Refer to Table 4.5 and Subsection 4.3.3.1 for additional detail.

4.4.2.2.1 SMU 2 Alternative 3 – Isolation Capping / Habitat Optimization
Overall Protection of Human Health and the Environment

Capping in SMU 2 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. The cap, in conjunction with the Willis/Semet hydraulic containment system, would effectively eliminate release of CPOIs to the water column via groundwater upwelling, provided the barrier wall encompasses or reduces any high VOC concentrations consistent with those observed in one porewater sample immediately adjacent to the causeway. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. This would include establishment of new emergent wetland.

Cap chemical isolation modeling predicts that, with the Willis/Semet hydraulic control system in place to effectively eliminate groundwater upwelling in SMU 2, a 2.5-foot (0.8-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state using assumed worst-case conditions, i.e. maximum measured CPOI sediment concentrations and 5 percent organic carbon. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 4.25-ft (1.3-m) thick chemical isolation layer placement to achieve a 3.75-ft (1.1-m) thick isolation layer in SMU 2. This assumes that the barrier wall encompasses or reduces any high VOC concentrations consistent with those observed in one porewater sample immediately adjacent to the causeway. Therefore, potential risks due to toxicity to benthic macroinvertebrates would be virtually eliminated.

As detailed in Appendix H, capping issues, the cap is also expected to provide long-term effectiveness in preventing any exposures due to migration through the cap of any residual

NAPL present in SMU 2 (Feenstra, 2004). The NAPL in SMU 2 adjacent to the causeway may be a result of migration of the on-shore DNAPL plume. However, migration of this DNAPL would be directly proportional to the rate of groundwater flow upward into the cap material. Because hydraulic controls are planned to significantly reduce or eliminate groundwater flows and upwelling rates in the near shore area, DNAPL migration would be prevented. Cap placement may result in short-term releases of NAPL, such as has been observed during boring installations. However, no migration of NAPL through the cap is anticipated during consolidation of the underlying sediment following cap placement, or long-term.

Specifically, the cap, in conjunction with the upland Willis/Semet hydraulic containment system, would have the following long-term beneficial effects on potential risks to human health:

- Reduce lake-wide potential risks associated with consumption of fish containing PCBs, PCDD/PCDFs, mercury, and arsenic to the extent that sediment in this SMU contributes to lake-wide concentrations of these contaminants in fish and
- Eliminate potential risks in this SMU and reduce potential risks in the south basin associated with exposure to sediment containing individual PAHs, hexachlorobenzene, PCDD/PCDFs, and arsenic.

The cap would have the following long-term beneficial effects on potential risks to the environment:

- For fish and wildlife that consume fish, reduce lake-wide potential risks from exposure to mercury and other CPOIs (e.g., arsenic, PCBs, PCDD/PCDFs) to the extent that sediment in this SMU contributes to lake-wide concentrations of these contaminants in fish;
- Eliminate sediment toxicity to benthic macroinvertebrates in this SMU;
- Improve benthic macroinvertebrate community in this SMU;
- Eliminate release of mercury and other CPOIs to lake water via diffusion, advection, and sediment resuspension from this SMU; and
- Improve habitat conditions for fish and wildlife in this SMU.

Areas of SMU 2 that present unacceptable risk would be capped; therefore, all potential risks presented by SMU 2 would be eliminated.

Alternative 3.A addresses sediment that exceeds the mean PECQ2 and that, therefore, poses a risk of sediment toxicity to benthic macroinvertebrates, as detailed in Appendix J, sediment effects concentrations. Use of the mean PECQ1 to define remedial areas is more conservative and would provide an additional factor of safety in ensuring that sediments that may exhibit toxicity are addressed. However, in SMU 2, remedial areas are the same regardless of whether the mean PECQ2 or mean PECQ1 is used to define remedial areas. Alternative 3.D, which includes capping of the additional area that exceeds the ER-Ls or PECs for individual CPOIs, would not result in measurable improvement in reducing benthic toxicity. Based on the meaningful exposure/response relationships determined empirically with the lake-wide database (see Appendix J, sediment effects concentrations), these sediments are not expected to contribute significantly to sediment toxicity.

4.4.2.3 SMU 2 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

Alternative 4 includes four options (Alternatives 4.A.3, 4.A.4, 4.D.3, and 4.D.4) for SMU 2, as listed in Subsection 4.4.2. Table 4.5 shows areas and volumes for consideration for each of the three options.

4.4.2.3.1 SMU 2 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Overall Protection of Human Health and the Environment

Consistent with the discussion provided for capping of SMU 2 in Subsection 4.4.2.2.1, dredging followed by capping in SMU 2 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. Targeted dredging would remove any contamination that would prevent the cap from providing effective chemical isolation. Areas of SMU 2 that present unacceptable risk would be capped; therefore, potential risks presented by SMU 2 would be eliminated.

Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 and mean PECQ1 compared to remediation of additional sediments exceeding other SEC approaches in Subsection 4.4.2.2.1, remediation to the mean PECQ2 and mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates.

4.4.2.4 SMU 2 Alternative 5 – Full Removal

Under SMU 2 Alternative 5, there are two remedial options, Alternative 5.A and Alternative 5.D. As shown in Table 4.5 and detailed in Appendix E, areas and volumes, all of SMU 2 would require dredging to at least the depth limits of available data, which is 6.6 ft (2 m), regardless of whether exceedances of the PEC or ER-L are used to define the removal volume. Because dredging to these SECs cannot be differentiated, these two options are merged into one alternative. If exceedance of the mean PECQ2, mean PECQ1, or AET is used to define the removal volume, only a portion of SMU 2 would require removal to at least the depth limits of available data.

4.4.2.4.1 SMU 2 Alternative 5 – Full Removal Overall Protection of Human Health and the Environment

Alternative 5 provides overall protection of human health and the environment through removal of impacted sediments. Areas of SMU 2 that present unacceptable risk would be dredged; therefore, all potential risks presented by SMU 2 would be eliminated.

Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 or mean PECQ1 compared to remediation of additional sediments exceeding the PEC and/or the ER-L in Subsection 4.4.2.2.1, remediation to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates.

Following dredging, a residual cap would be placed if necessary to isolate any residual contamination, and a 6-inch (15-cm) layer of fine gravel would be placed where the final water depth is between 6 and 15 ft (1.8 and 4.6 m) to promote fish spawning. In addition, in areas where the water depth is appropriate for submerged macrophyte colonization and establishment, i.e. 2 to 6 ft (0.6 to 1.8 m), it is assumed that natural establishment of submerged macrophytes would be augmented by broadcast seeding and addition of tubers, as discussed under capping in Subsection 4.3.3.

4.4.3 SMU 3 Alternatives

Provided below is a detailed evaluation of how each SMU 3 alternative satisfies the criteria of overall protection of human health and the environment. Evaluation of Alternatives 4 and 5 in SMU 3 against the other evaluation criteria is consistent with the evaluation provided for these alternatives in SMU 1, as discussed in Subsection 4.4.1. To ensure complete evaluation of each SMU 3 alternative, the CERCLA evaluation criteria is discussed in detail for each SMU 3 alternative in Table 4.8. Alternative 2 – Habitat Enhancement is unique to SMUs 3 and 5, and therefore a discussion of how this alternative satisfies each of the evaluation criteria is provided below.

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 3:

- Alternative 1 – No Action
- Alternative 2 - Habitat Enhancement
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping to Mean PECQ2, Mean PECQ1, or PEC / Habitat Optimization
    - Alternative 4.E.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping to ER-L / Habitat Optimization
- Alternative 5 – Full Removal
    - Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or PEC)
    - Alternative 5.E – Full Removal (to ER-L)

4.4.3.1 SMU 3 Alternative 1 – No Action

For the No Action Alternative, upland source controls would be implemented, but no action would be implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals, as discussed in Subsection 4.3.

4.4.3.1.1 SMU 3 Alternative 1 – No Action
Overall Protection of Human Health and the Environment

The No Action Alternative would not be protective of human health and the environment, since this would not actively address the contaminated sediments, which present unacceptable risks of exposure to human health and the environment presented by CPOIs in SMU 3.

The HHRA did not specifically identify human health potential risks associated with SMU 3 other than the possible contribution of sediment to mercury concentrations in the water column. Baseline conditions in SMU 3 contribute to the following potential risks to the environment (based on the BERA [TAMS, 2002a] and summarized in Subsection 1.6 of this report):

- Sediment toxicity to benthic macroinvertebrates in limited areas in this SMU;
- Impaired benthic macroinvertebrate community in some areas of this SMU; and
- Poor habitat conditions for fish and wildlife in this SMU.

These potential risks are expected to continue in the absence of active remediation. Under the No Action Alternative, the RAOs and PRGs would not be achieved.

Limited areas of sediment in SMU 3 exceeded the mean PECQ2 or mean PECQ1, indicating probable risk to benthic macroinvertebrates due to sediment toxicity in these areas. The remainder of SMU 3 is not expected to cause measurable toxicity, as discussed in Appendix J, sediment effects concentrations.

Baseline conditions in SMU 3 likely have little effect on lake-wide potential risks to human health related to consumption of fish. Concentrations of bioaccumulative CPOIs (e.g., PCBs, PCDD/PCDFs) are not elevated relative to other areas of the lake; therefore, SMU 3 is not considered a significant source of these CPOIs to the food web. While concentrations of mercury exceed 3 ppm in some areas of SMU 3, these areas are expected to contribute little to lake-wide concentrations of mercury in water and fish tissue. The HHRA (TAMS, 2002b) considered SMU 3 to be part of the north basin, and potential risks associated with wading in near-shore sediment in the north basin only exceeded 10^{-6} for the reasonable maximum exposure scenario.

Poor baseline habitat conditions in SMU 3 are primarily associated with the presence of calcitic sediment that is easily resuspended. According to the BERA, macrophyte cover and biomass are negatively correlated with calcium carbonate concentration in the sediment of Onondaga Lake. In addition, resuspended calcitic sediment may contribute to the exceedance of narrative water quality standards, as described in the BERA. These conditions, in turn, may negatively impact benthic macroinvertebrate populations, fish foraging, and fish nesting and spawning.

4.4.3.2 SMU 3 Alternative 2 – Habitat Enhancement

The habitat enhancement goal is to reduce the erosion of the calcium carbonate present along the shoreline. A secondary goal is to provide structure for fish spawning and protective cover.

As discussed in Subsection 4.3, two habitat enhancement techniques are potentially viable for most of the SMU 3 shoreline (for this FS, the steep banks at the northernmost portion of SMU 3 are considered part of the upland areas being addressed under a separate consent agreement). The first technique involves the establishment of woody vegetation on the shoreline. The second technique, vegetative (brush) mattresses, is another variation of plant material bundles that can be integrated into the shoreline. This method includes live fascines, live stakes, and branch cuttings to vegetatively cover and protect the shoreline.

4.4.3.2.1 SMU 3 Alternative 2 – Habitat Enhancement
Overall Protection of Human Health and the Environment

This alternative would enhance overall protection of the environment by addressing ecological stressors identified in the BERA through creation of conditions suitable for macrophyte establishment and fish spawning. Resuspension of calcitic material that result in exceedances of narrative water quality standards would also be minimized. However, some areas of sediment that exceed the mean PECQ2 and therefore potentially pose risk to benthic macroinvertebrates would remain. Therefore, this alternative would not protect benthic macroinvertebrates in these areas.

4.4.3.2.2 SMU 3 Alternative 2 – Habitat Enhancement
Compliance with ARARs

Consistent with the ARAR evaluation provided for the SMU 1 capping alternative in Subsection 4.4.1.2.2, this alternative is expected to comply with all of the designated chemical-specific ARARs to the extent that this SMU contributes to lake-wide conditions. It is also anticipated that this alternative would be completed in compliance with any location-specific and action-specific ARARS.

4.4.3.2.3 SMU 3 Alternative 2 – Habitat Enhancement
Short-Term Effectiveness

Physical construction of this alternative could likely be completed in less than one year, and would result in minimal disturbance of impacted sediments. There would be no significant implementation risks or quality-of-life issues associated with Alternative 2.

4.4.3.2.4 SMU 3 Alternative 2 – Habitat Enhancement
Long-Term Effectiveness and Permanence

The shoreline stabilization enhancements would be designed to create a vegetated shoreline that would persist over time. The substrate would be augmented as needed to create a suitable growing medium over the short-term. As the plants grow and coalesce, their roots and stems would help to stabilize the shoreline over the long-term. In steeper areas of the shoreline, the slope would also be stabilized with riprap material. The material would be sized to provide long-term protection of the shoreline while the vegetation matures.

Fish habitat structures (i.e., large woody debris or similar) would be used in the shallow littoral areas (between 4 to 15 ft [1.2 to 4.6 m] below ordinary low water [OLW]), to provide habitat and cover for fish. The structures would be placed below 4 ft (1.2 m) OLW to avoid wave energy associated with the 100-year storm events. These structures would be anticipated to last several decades depending on the decay rate of the woody material used for their construction.

Long-term effectiveness related to habitat growth and establishment due to erosion or the inability to establish habitat due to substrate issues is uncertain. However, this alternative is expected to provide long-term effectiveness for stabilization of calcitic sediment and enhancement of macrophyte colonization and fish spawning. Biological monitoring (e.g., abundance and diversity of macrophytes) would be necessary to ensure that the alternative is effective in achieving enhanced macrophyte establishment and fish spawning.

This alternative is only designed for areas where CPOI concentrations are below action levels. Therefore, long-term effectiveness and permanence for Alternative 2 are primarily related to the establishment of habitat, macrophyte colonization, and fish spawning.

4.4.3.2.5 SMU 3 Alternative 2 – Habitat Enhancement
Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative does not reduce the toxicity, mobility, or volume of impacted sediments.

4.4.3.2.6 SMU 3 Alternative 2 – Habitat Enhancement
Implementability

This alternative is readily implementable.

4.4.3.3 SMU 3 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

Alternative 4 includes two options (Alternatives 4.A.3 and 4.E.3) for SMU 3, as listed in Subsection 4.4.3. Table 4.5 shows areas and volumes for consideration for each of the options.

4.4.3.3.1 SMU 3 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
Overall Protection of Human Health and the Environment

Dredging followed by capping in SMU 3 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. As discussed in Subsection 4.3, cap chemical isolation modeling predicts that, following targeted dredging, a 1-foot (0.3 m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state, virtually eliminating toxicity to benthic macroinvertebrates. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 2-ft (0.6 m) thick chemical isolation layer placement to achieve a 1.5-ft (0.5-m) thick isolation layer in SMU 3.

Dredging to a depth that optimizes habitat value and minimizes erosive forces would provide additional benefit by further improving the habitat value of the cap.

Areas of SMU 3 that present unacceptable risk would be capped, therefore all potential risks presented by SMU 3 would be eliminated.

Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 or mean PECQ1 compared to remediation of additional sediments exceeding other SEC approaches in Subsection 4.4.2.2.1, remediation to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates.

4.4.3.4 SMU 3 Alternative 5 – Full Removal

Under SMU 3 Alternative 5, there are two options: Alternative 5.A and Alternative 5.E. Refer to Table 4.5 and Subsection 4.3.5.3 for additional detail.

4.4.3.4.1 SMU 3 Alternative 5 – Full Removal
Overall Protection of Human Health and the Environment

Alternative 5 provides overall protection of human health and the environment through removal of impacted sediments. Areas of SMU 3 that present unacceptable risk would be dredged; therefore, all potential risks presented by SMU 3 would be eliminated.

Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 or mean PECQ1 compared to remediation of additional sediments exceeding the other SEC approaches in Subsection 4.4.2.2.1, remediation to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates.

4.4.4 SMU 4 Alternatives

Provided below is a detailed evaluation of how each SMU 4 alternative satisfies the criteria of overall protection of human health and the environment. Evaluation of the SMU 4 alternatives against the other evaluation criteria is consistent with the evaluation provided for these alternatives in SMU 1, as discussed in Subsection 4.4.1. To ensure complete evaluation of each SMU 4 alternative, the CERCLA evaluation criteria is discussed in detail for each SMU 4 alternative in Table 4.9.

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 4:

- Alternative 1 – No Action
- Alternative 3 – Isolation Capping / Habitat Optimization
  - Alternative 3.A – Isolation Capping to Mean PECQ2, Mean PECQ1, AET, PEC, or ER-L / Habitat Optimization
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
  - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
  - Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or AET)
  - Alternative 5.D – Full Removal (to PEC or ER-L)

4.4.4.1 SMU 4 Alternative 1 – No Action

For the No Action Alternative, upland source controls would be implemented, but no action would be implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals, as discussed in Subsection 4.3.

4.4.4.1.1 SMU 4 Alternative 1 – No Action
Overall Protection of Human Health and the Environment

The No Action Alternative would not be protective of human health and the environment, since this would not actively address the contaminated sediments, which present unacceptable risks of exposure to human health and the environment presented by CPOIs in SMU 4.

4.4.4.2 SMU 4 Alternative 3 – Isolation Capping / Habitat Optimization

Under SMU 4 Alternative 3, there is one option: Alternative 3.A. Refer to Table 4.5 and Subsection 4.3.3.1 for additional detail.

4.4.4.2.1 SMU 4 Alternative 3 – Isolation Capping / Habitat Optimization

Overall Protection of Human Health and the Environment

Capping in SMU 4 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. This would include establishment of new emergent wetland. As discussed in Subsection 4.3, cap chemical isolation modeling predicts that a 1-foot (0.3-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state, virtually eliminating toxicity to benthic macroinvertebrates.

Specifically, the cap would have the following long-term beneficial effects on potential risks to human health:

- Reduce lake-wide potential risks associated with consumption of fish containing mercury to the extent that sediment in this SMU contributes to lake-wide concentrations of mercury in fish and
- Reduce potential lake-wide potential risks associated with exceedances of surface water ARARs, to the extent that this SMU contributes to exceedances of surface water ARARs.

The cap would have the following long-term beneficial effects on potential risks to the environment:

- For fish and wildlife that consume fish, reduce lake-wide potential risks from exposure to mercury to the extent that sediment in this SMU contributes to lake-wide concentrations of mercury in fish;
- Eliminate sediment toxicity to benthic macroinvertebrates in this SMU;
- Improve benthic macroinvertebrate community in this SMU;
- Eliminate release of mercury to lake water via diffusion, advection, and sediment resuspension from this SMU; and
- Improve habitat conditions for fish and wildlife in this SMU.

All of SMU 4 would be capped; therefore, all potential risks presented by SMU 4 would be eliminated.

4.4.4.3 SMU 4 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

Under SMU 4 Alternative 4, there is one option: Alternatives 4.A.3. Refer to Table 4.5 and Subsection 4.3.4.4 for additional detail.

4.4.4.3.1 SMU 4 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Overall Protection of Human Health and the Environment

Consistent with the discussion provided for capping of SMU 4 in Subsection 4.4.4.2.1, dredging followed by capping in SMU 4 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. As discussed in Subsection 4.3, cap chemical isolation modeling predicts that a 1-foot (0.3-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state, virtually eliminating toxicity to benthic macroinvertebrates. Dredging to a depth that optimizes habitat value and minimizes erosive forces would provide additional benefit by further improving the habitat value of the cap. This would include establishment of a significant area of new emergent wetland. In SMU 4, cleaner sediments overlie sediments with higher levels of mercury. Dredging prior to capping would result in higher levels of mercury at the bottom of the cap than if no dredging were completed prior to capping, which would slightly reduce the potential effectiveness of the cap. However, cap modeling indicates that the cap would be effective in either case in providing long-term effectiveness. All of SMU 4 would be capped; therefore, all potential risks presented by SMU 4 would be eliminated.

4.4.4.4 SMU 4 Alternative 5 – Full Removal

Under SMU 4 Alternative 5, there are two options: Alternative 5.A and Alternative 5.D. Refer to Table 4.5 and Subsection 4.3.5.4 for additional detail.

4.4.4.4.1 SMU 4 Alternative 5 – Full Removal Overall Protection of Human Health and the Environment

Alternative 5 provides overall protection of human health and the environment through removal of impacted sediments. All of SMU 4 would be dredged; therefore, all potential risks presented by SMU 4 would be eliminated.

Consistent with the discussion of dredging of SMU 1 in Subsection 4.4.1.4, this evaluation assumes that backfill would be placed following dredging to achieve a constant slope from the shoreline out to the limits of dredging. In addition, in areas where the water depth is appropriate for submerged macrophyte colonization and establishment, i.e. 2 to 6 ft (0.6 to 1.8 m), it is assumed that natural establishment of submerged macrophytes would be augmented by broadcast seeding and addition of tubers, as discussed under capping in Subsection 4.3.3.

4.4.5 SMU 5 Alternatives

Provided below is a detailed evaluation of how each SMU 5 alternative satisfies the criteria of overall protection of human health and the environment. Evaluation of Alternatives 3, 4, and 5 in SMU 5 against the other evaluation criteria is consistent with the evaluation provided for these alternatives in SMU 1, as discussed in Subsection 4.4.1. Evaluation of Alternative 2 in SMU 5 against the other evaluation criteria is consistent with the evaluation provided for this alternative in SMU 3, as discussed in Subsection 4.4.3. To ensure complete evaluation of each SMU 5 alternative, each evaluation criterion is discussed for each SMU 5 alternative in Table 4.10.

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 5:

- Alternative 1 – No Action
- Alternative 2 - Habitat Enhancement
- Alternative 3 – Isolation Capping / Habitat Optimization
    - o Alternative 3.A – Isolation Capping to Mean PECQ2 / Habitat Optimization
    - o Alternative 3.B – Isolation Capping to Mean PECQ1 / Habitat Optimization
    - o Alternative 3.D – Isolation Capping to PEC / Habitat Optimization
    - o Alternative 3.E – Isolation Capping to ER-L / Habitat Optimization
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - o Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping to Mean PECQ2 / Habitat Optimization
    - o Alternative 4.B.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping to Mean PECQ1 / Habitat Optimization
    - o Alternative 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping to PEC / Habitat Optimization
    - o Alternative 4.E.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping to ER-L / Habitat Optimization
- Alternative 5 – Full Removal
    - o Alternative 5.A – Full Removal (to Mean PECQ2)
    - o Alternative 5.B – Full Removal (to Mean PECQ1)
    - o Alternative 5.D – Full Removal (to PEC)
    - o Alternative 5.E – Full Removal (to ER-L)

4.4.5.1 SMU 5 Alternative 1 – No Action

For the No Action Alternative, upland source controls would be implemented, but no action would be implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals, as discussed in Subsection 4.3.

4.4.5.1.1 SMU 5 Alternative 1 – No Action Overall Protection of Human Health and the Environment

The No Action Alternative is protective of human health and the environment with respect to hazardous substances based on the RI data. There were no exceedances in SMU 5 of the mean PECQ2, a minor exceedance of the mean PECQ1, and three minor exceedances of the mercury PEC (i.e., 2.3 ppm, 2.9 ppm, and 3.0 ppm), indicating no predicted risk to benthic macroinvertebrates due to sediment toxicity.

Baseline conditions in SMU 5 have little effect on lake-wide potential risks to fish, wildlife, and human health related to consumption of fish. Concentrations of bioaccumulative CPOIs (e.g., mercury, PCDD/PCDFs) are not significantly elevated relative to other areas of the lake; therefore, SMU 5 is not considered a significant source of these CPOIs to the food web. Additional sampling would be required to verify this. Regarding sediment exposure, the HHRA (TAMS, 2002b) considered the majority of SMU 5 to be part of the north basin, and potential risks associated with wading in near-shore sediment in the entire north basin only exceeded 10^{-6} for the reasonable maximum exposure scenario.

Regarding habitat, SMU 5 generally contains some of the highest densities of macrophytes and fish nests in Onondaga Lake. However, portions of the SMU support few macrophytes and fish nests. The presence of oncolites in SMU 5 has been identified as an ecological stressor that impacts biological conditions, particularly submerged macrophyte colonization and establishment. These conditions are expected to continue in the absence of active remediation.

4.4.5.2 SMU 5 Alternative 2 – Habitat Enhancement

4.4.5.2.1 SMU 5 Alternative 2 – Habitat Enhancement Overall Protection of Human Health and the Environment

This alternative would enhance the environment by creating conditions suitable for macrophyte establishment and fish spawning. Baseline conditions in SMU 5 do not contribute significantly to human health or environmental potential risks in the lake, as discussed under the SMU 5 No Action Alternative. Therefore, this alternative would be protective of human health and the environment.

Hay bales and netting would be used initially to stabilize the substrates to allow colonization by submerged macrophytes. Once established, the macrophytes would act to stabilize the substrate both aboveground (where their shoots act to baffle wind and wave energy) and belowground (where their roots and rhizomes help to bind the sediment). In addition, the increase in macrophytes would increase the number of seeds and propagules available to help maintain and potentially expand the population and ensure long-term protection.

4.4.5.3 SMU 5 Alternative 3 – Isolation Capping / Habitat Optimization

Under SMU 5 Alternative 3, there are four options: Alternatives 3.A, 3.B, 3.D, and 3.E. Refer to Table 4.5 and Subsection 4.3.3.1 for additional detail.

4.4.5.3.1 SMU 5 Alternative 3 – Isolation Capping / Habitat Optimization Overall Protection of Human Health and the Environment

Sediment capping in Alternative 3 would provide no additional protection of human health and little additional protection of the environment compared to baseline conditions, but would result in additional short-term potential risks. As discussed under the No Action Alternative, baseline conditions do not contribute to human health potential risks in the lake. Although there are three minor exceedances of the mercury PEC (i.e., 2.3 ppm, 2.9 ppm, and 3.0 ppm) and one minor exceedance of the mean PECQ1 in SMU 5, capping of portions of SMU 5 is expected to provide little, if any, additional protection for benthic macroinvertebrates. Furthermore, concentrations of bioaccumulative CPOIs (e.g., mercury, PCDD/PCDFs) are not significantly elevated relative to other areas of the lake; therefore, SMU 5 is not considered a significant source of these CPOIs to the food web. Additional sampling would be required to verify this assumption. Capping would address ecological stresses associated with oncolites by covering them and providing new substrate.

4.4.5.4 SMU 5 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

Under SMU 5 Alternative 4, there are four options: Alternatives 4.A.3, 4.B.3, 4.D.3, and 4.E.3. Refer to Table 4.5 and Subsection 4.3.4.5 for additional detail.

4.4.5.4.1 SMU 5 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Overall Protection of Human Health and the Environment

Consistent with the discussion of capping in SMU 5, dredging and capping in SMU 5 would provide no additional protection of human health and little additional protection of the environment compared to baseline conditions, but would result in increased short-term potential risks. Capping would address ecological stresses associated with oncolites by covering them and providing new substrate.

4.4.5.5 SMU 5 Alternative 5 – Full Removal

Under SMU 5 Alternative 5, there are four options: Alternatives 5.A, 5.B, 5.D, and 5.E. Refer to Table 4.5 and Subsection 4.3.5.5 for additional detail.

4.4.5.5.1 SMU 5 Alternative 5 – Full Removal

Overall Protection of Human Health and the Environment

Consistent with the discussion of capping in SMU 5, dredging in SMU 5 would provide no additional protection of human health and little additional protection of the environment compared to baseline conditions. Dredging would address ecological stresses associated with oncolites by removing them. However, dredging would increase the average water depth in SMU 5. This would reduce the area with a water depth of 2 to 6 ft (0.6 to 1.8 m), which is the optimal water depth for submerged macrophyte colonization and establishment, unless backfill material was added.

4.4.6 SMU 6 Alternatives

Provided below is a detailed evaluation of how each SMU 6 alternative satisfies the criteria of overall protection of human health and the environment. Evaluation of the SMU 6 alternatives against the other evaluation criteria is consistent with the evaluation provided for these alternatives in SMU 1, as discussed in Subsection 4.4.1. To ensure complete evaluation of each SMU 6 alternative, each evaluation criterion is discussed for each SMU 6 alternative in Table 4.11.

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 6:

- Alternative 1 – No Action
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
  - Alternative 4.A.1 – Targeted Dredging / Isolation Capping to Mean PECQ2 / Habitat Optimization
  - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping to Mean PECQ2 / Habitat Optimization
  - Alternative 4.B.1 – Targeted Dredging / Isolation Capping to Mean PECQ1 / Habitat Optimization
  - Alternative 4.B.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping to Mean PECQ1 / Habitat Optimization
  - Alternative 4.D.1 – Targeted Dredging / Isolation Capping of Entire SMU / Habitat Optimization
  - Alternative 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
  - Alternative 5.A – Full Removal (to Mean PECQ2)

- Alternative 5.B – Full Removal (to Mean PECQ1)
- Alternative 5.D – Full Removal (to PEC or ER-L)

4.4.6.1 SMU 6 Alternative 1 – No Action

For the No Action Alternative, upland source controls would be implemented, but no action would be implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals, as discussed in Subsection 4.3.

4.4.6.1.1 SMU 6 Alternative 1 – No Action
Overall Protection of Human Health and the Environment

The No Action Alternative would not be protective of human health and the environment, since this would not actively address the contaminated sediments, which present unacceptable risks of exposure to human health and the environment presented by CPOIs in SMU 6.

4.4.6.2 SMU 6 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

Under SMU 6 Alternative 4, there are six options: Alternatives 4.A.1, 4.A.3, 4.B.1, 4.B.3, 4.D.1, and 4.D.3. Refer to Table 4.5 and Subsection 4.3.4.5 for additional detail.

4.4.6.2.1 SMU 6 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
Overall Protection of Human Health and the Environment

Dredging followed by capping in SMU 6 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. As discussed in Subsection 4.3, cap chemical isolation modeling predicts that, following removal of near-shore impacted sediments where groundwater upwelling is highest, a 1-ft (0.3-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state, virtually eliminating toxicity to benthic macroinvertebrates.

Specifically, the cap, in conjunction with the targeted dredging prior to capping, would have the following long-term beneficial effects on potential risks to human health:

- Reduce lake-wide potential risks associated with consumption of fish containing PCBs, PCDD/PCDFs, mercury, and arsenic to the extent that sediment in this SMU contributes to lake-wide concentrations of these contaminants in fish and
- Eliminate potential risks in this SMU and reduce potential risks in the south basin associated with exposure to sediment containing individual PAHs, PCBs, PCDD/PCDFs, and arsenic.

The cap would have the following long-term beneficial effects on potential risks to the environment:

- For fish and wildlife that consume fish, reduce lake-wide potential risks from exposure to mercury and other CPOIs (e.g., arsenic, PCBs, PCDD/PCDFs) to the extent that sediment in this SMU contributes to lake-wide concentrations of these contaminants in fish;
- Eliminate sediment toxicity to benthic macroinvertebrates in this SMU;
- Improve benthic macroinvertebrate community in this SMU;
- Eliminate release of mercury and other CPOIs to lake water via diffusion, advection, and sediment resuspension from this SMU; and
- Improve habitat conditions for fish and wildlife in this SMU.

Areas of SMU 6 that present unacceptable risk would be capped; therefore, all potential risks presented by SMU 6 would be eliminated.

Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 or mean PECQ1 compared to remediation of additional sediments exceeding the other SEC approaches in Subsection 4.4.2.2.1, remediation to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates.

4.4.6.3 SMU 6 Alternative 5 – Full Removal

Under SMU 6 Alternative 5, there are three options: Alternative 5.A, Alternative 5.B, and Alternative 5.D. Refer to Table 4.5 and Subsection 4.3.5.6 for additional detail.

4.4.6.3.1 SMU 6 Alternative 5 – Full Removal Overall Protection of Human Health and the Environment

Alternative 5 provides overall protection of human health and the environment through removal of impacted sediments. Areas of SMU 6 that present unacceptable risk would be dredged; therefore, all potential risks presented by SMU 6 would be eliminated.

Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 or mean PECQ1 compared to remediation of additional sediments exceeding the other SEC approaches in Subsection 4.4.2.2.1, remediation to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates.

Consistent with the discussion of dredging of SMU 1 in Subsection 4.4.1.4, it is assumed for evaluation purposes that backfill would be placed following dredging to achieve a constant slope from the shoreline out to the limits of dredging. It is assumed that a 6-inch (15-cm) layer of fine gravel would be placed where the final water depth is between 6 and 15 ft (1.8 and 4.6 m) to promote fish spawning. In addition, in areas where the water depth is appropriate for submerged macrophyte colonization and establishment, i.e. 2 to 6 ft (0.6 to 1.8 m), it is assumed that natural establishment of submerged macrophytes would be augmented by broadcast seeding and addition of tubers, as discussed under capping in Subsection 4.3.3.

4.4.7 SMU 7 Alternatives

Provided below is a detailed evaluation of how each SMU 7 alternative satisfies the criteria of overall protection of human health and the environment. Evaluation of the SMU 7 alternatives against the other evaluation criteria is consistent with the evaluation provided for these alternatives in SMU 1, as discussed in Subsection 4.4.1. To ensure complete evaluation of each SMU 7 alternative, each evaluation criterion is discussed for each SMU 7 alternative in Table 4.12.

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 7:

- Alternative 1 – No Action
- Alternative 3 – Isolation Capping
    - Alternative 3.A Capping of Entire SMU
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
    - Alternative 5.A – Full Removal (to Mean PECQ2 or Mean PECQ1)
    - Alternative 5.C – Full Removal (to AET, PEC, or ER-L)

4.4.7.1 SMU 7 Alternative 1 – No Action

For the No Action Alternative, upland source controls would be implemented, but no action would be implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals, as discussed in Subsection 4.3.

4.4.7.1.1 SMU 7 Alternative 1 – No Action
Overall Protection of Human Health and the Environment

The No Action Alternative would not be protective of human health and the environment, since this would not actively address the contaminated sediments, which present unacceptable risks of exposure to human health and the environment presented by CPOIs in SMU 7.

4.4.7.2 SMU 7 Alternative 3 – Isolation Capping / Habitat Optimization

Under SMU 7 Alternative 3, there is one option, Alternative 3.A. Refer to Table 4.5 and Subsection 4.3.3.1 for additional detail.

4.4.7.2.1 SMU 7 Alternative 3 – Isolation Capping / Habitat Optimization Overall Protection of Human Health and the Environment

Consistent with the discussion provided for capping of SMU 1 in Subsection 4.4.1.2.1, in the absence of targeted dredging, a hydraulic containment system would be required to effectively eliminate groundwater upwelling in SMU 7 prior to cap installation. Capping in SMU 7 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. This would include establishment of new emergent wetland. As discussed in Subsection 4.3, cap chemical isolation modeling predicts that a 1-foot (0.3-m) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state, virtually eliminating toxicity to benthic macroinvertebrates. Applying a safety factor of 1.5 and adding in 6 inches (15 cm) to account for mixing with underlying sediment and non-uniform application results in a 4.25-ft (1.3 m) thick chemical isolation layer placement to achieve a 3.75-ft (1.1-m) thick isolation layer in SMU 7. Areas of SMU 7 that present unacceptable risk would be capped, eliminating potential risks presented by SMU 7.

Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 or mean PECQ1 compared to remediation of additional sediments exceeding the other SEC approaches in Subsection 4.4.2.2.1, remediation to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates. .

4.4.7.3 SMU 7 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

Under SMU 7 Alternative 4, there is one option, Alternative 4.A.3. Refer to Table 4.5 and Subsection 4.3.4.7 for additional detail.

4.4.7.3.1 SMU 7 Alternative 4 – Dredging / Isolation Capping / Habitat Optimization Overall Protection of Human Health and the Environment

Dredging followed by capping in SMU 7 would provide overall protection of human health and the environment by eliminating the potential exposure pathways associated with impacted sediment. Clean cap material would prevent direct exposure of humans and ecological receptors to contaminated sediment, reduce or eliminate release of CPOIs from sediment to the water column, and provide enhanced habitat value through use of appropriate cap surface substrate. As discussed in Subsection 4.3, cap chemical isolation modeling predicts that a 1-ft (15-cm) thick chemical isolation layer would result in no exceedances of the PEC in the bioturbation layer at steady state, virtually eliminating toxicity to benthic macroinvertebrates. Dredging to a depth that optimizes habitat value and minimizes erosive forces would provide additional protectiveness by further improving the habitat value of the cap.

Specifically, the cap, in conjunction with the targeted dredging prior to capping, would have the following long-term beneficial effects on potential risks to human health:

- Reduce lake-wide potential risks associated with consumption of fish containing PCBs, PCDD/PCDFs, mercury, and arsenic to the extent that sediment in this SMU contributes to lake-wide concentrations of these contaminants in fish and
- Eliminate potential risks in this SMU and reduce potential risks in the south basin associated with exposure to sediment containing individual PAHs, hexachlorobenzene, PCDD/PCDFs, and arsenic.

The cap would have the following long-term beneficial effects on potential risks to the environment:

- For fish and wildlife that consume fish, reduce lake-wide potential risks from exposure to mercury and other CPOIs (e.g., arsenic, PCBs, PCDD/PCDFs) to the extent that sediment in this SMU contributes to lake-wide concentrations of these contaminants in fish;
- Eliminate sediment toxicity to benthic macroinvertebrates in this SMU;
- Improve benthic macroinvertebrate community in this SMU;
- Eliminate release of mercury and other CPOIs to lake water via diffusion, advection, and sediment resuspension from this SMU; and
- Improve habitat conditions for fish and wildlife in this SMU.

All of SMU 7 would be capped; therefore, all potential risks presented by SMU 7 would be eliminated.

4.4.7.4 SMU 7 Alternative 5 – Full Removal

Under SMU 7 Alternative 5, there are two options: Alternative 5.A and Alternative 5C. Refer to Table 4.5 and Subsection 4.3.5.7 for additional detail.

4.4.7.4.1 SMU 7 Alternative 5 – Full Removal
Overall Protection of Human Health and the Environment

Alternative 5 provides overall protection of human health and the environment through removal of impacted sediments. All of SMU 7 would be dredged; therefore, all potential risks presented by SMU 7 would be eliminated.

Consistent with the discussion of dredging of SMU 1 in Subsection 4.4.1.4, this evaluation assumes that backfill would be placed following dredging to achieve a constant slope from the shoreline out to the limits of dredging. It is assumed that a 6-inch (15-cm) layer of fine gravel would be placed where the final water depth is between 6 and 15 ft (1.8 and 4.6 m) to promote fish spawning. In addition, in areas where the water depth is appropriate for submerged macrophyte colonization and establishment, i.e., 2 to 6 ft (0.6 to 1.8 m), it is assumed that natural establishment of submerged macrophytes would be augmented by broadcast seeding and addition of tubers, as discussed under capping in Subsection 4.3.3.

4.5 COMPARATIVE ANALYSIS OF LITTORAL ALTERNATIVES

This section provides a summary comparison of the alternatives developed in Subsection 4.3 for the littoral area (SMUs 1 through 7) based on CERCLA and NCP evaluation criteria (detailed in Table 4.13). The comparative evaluation against the CERCLA evaluation criteria typically results in similar conclusions regardless of the SMU. The exception is the threshold evaluation criteria of overall protection of human health and the environment, which is more SMU-specific than the other criterion. Therefore, this criterion is discussed for the range of alternatives for each SMU. The other evaluation criteria are discussed for the range of alternatives considered for all SMUs.

As discussed in Subsection 4.4, RAOs and PRGs were developed to consider the entire lake, while alternatives in this subsection address SMU-specific issues. Therefore, achievement of RAOs and PRGs is assessed in more detail during evaluation of lake-wide alternatives in Section 5, while the evaluation below focuses primarily on comparing how each alternative addresses SMU-specific risks.

Section 5 includes cost estimates associated with each of the lake-wide alternatives evaluated. As discussed in Subsection 4.4, this allows more accurate cost estimating, helps ensure remedial costs are not over estimated, and provides an appropriate basis for evaluating and comparing alternatives. Therefore, this section provides no discussion of costs for SMU-specific alternatives.

4.5.1 Overall Protection of Human Health and the Environment

4.5.1.1 SMU 1 - Overall Protection of Human Health and the Environment

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 1:

- Alternative 1 – No Action
- Alternative 3 – Isolation Capping / Habitat Optimization
    - o Alternative 3.A – Capping of Entire SMU / Habitat Optimization
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - o Alternative 4.A.2 – Dredging to Result in No Loss of Lake Surface Area / Isolation Capping of Entire SMU / Habitat Optimization
    - o Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping of Entire SMU / Habitat Optimization

  - Alternative 4.A.4 – Dredging for Mass Removal to Remove 25 percent of SMU 1 / Isolation Capping of Entire SMU / Habitat Optimization
  - Alternative 4.A.5 – Dredging for Mass Removal to Remove 3 Meters / Isolation Capping of Entire SMU / Habitat Optimization
  - Alternative 4.A.6 – Dredging for Mass Removal to Remove 4 Meters / Isolation Capping of Entire SMU / Habitat Optimization
  - Alternative 4.A.7 – Dredging for Mass Removal to Remove 5 Meters / Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Dredging
  - Alternative 5.A – Full Removal to Mean PECQ2, Mean PECQ1, AET, PEC, or ER-L

Alternative 1 would not meet RAOs or PRGs and would not be protective of human health and the environment, since it does not actively address the contaminated sediments that present unacceptable risks of exposure in SMU 1. Each of the other retained alternatives would achieve the RAOs and PRGs as they apply to SMU 1, and would provide overall protection of human health and the environment. Alternatives 3.A through 4.A.4 would rely on the long-term integrity of the cap to provide overall protection of human health and the environment, while impacted sediments exceeding the mean PECQ2 would be removed under Alternative 5.A and contained within an upland consolidation area. However, as detailed in Subsection 4.4, containment via capping is expected to provide long-term isolation of impacted sediments. Therefore, Alternatives 3.A through 5.A would provide similar levels of long-term protection of human health and the environment.

Habitat in SMU 1 is currently compromised, due in part to the presence of the ILWD and elevated CPOI levels. Several of the alternatives would result in significantly improved habitat, in part through establishment of new substrate. Alternative 3.A would result in loss of lake surface area, although this loss would be off-set by the increased habitat value, including establishment of emergent wetlands. Alternatives 4.A.2, 4.A.3, 4.A.4, 4.A.5, 4.A.6, and 4.A.7 would remove sufficient sediment so that there would be no loss of lake surface area. Of the Alternative 4 options, Alternative 4.A.3 provides the greatest habitat value because the area where water depth and substrate are suitable for submerged macrophyte colonization and establishment would be maximized. Other alternatives would provide decreasing areas where valuable habitat conditions would be provided. The areas (in acres) of valuable habitat (shoreline buffer, submerged macrophyte, and fish spawning) resulting from each of the SMU 1 alternatives is presented on the next page.

Alternative (Dredge Basis)	Recreational/ Habitat Buffer (acres)	Submerged Macrophyte (acres)	Fish Spawning (acres)	Emergent Wetlands (acres)	Total (acres)
3.A (None)	7	17	28	7	59
4.A.2 (No Loss of Surface Area)	19	17	28	NA	64
4.A.3 (Optimal Habitat Depth)	4	32	28	0.5	65
4.A.4 (25 percent)	11	45	8	NA	64
4.A.5 (3 meters)	2	6	46	NA	54
4.A.6 (4 meters)	2	6	36	NA	44
4.A.7 (5 meters)	2	6	14	NA	22
5.A (Full Removal)	NA	NA	NA	NA	NA

Under the deeper removal alternatives, the resulting habitat value would be lower than that for the Alternative 4 options because of the assumed backfill depth. Additional backfill could be placed under Alternative 5 to result in shallower water depths and thus greater habitat value. However, this would result in an increase in cost as well as in short-term potential risks due to the transportation of large volumes of backfill.

In summary, Alternatives 3.A through 4.A.3 provide equivalent levels of overall protection of human health and the environment and increasing levels of habitat value. Alternatives 4.A.4 and 5.A provide a similar level of overall protection of human health and the environment and less habitat value compared to Alternatives 3.A through 4.A.3. Alternatives 4.A.5 through 5.A provide a similar level of overall protection of human health and the environment and decreasing habitat value as compared to Alternative 3.A through 4.A.3. Alternatives 4.A.4 through 5.A would provide added mass removal in SMU 1, but no additional overall protection to human health and the environment.

4.5.1.2 SMU 2 Overall Protection of Human Health and the Environment

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 2:

- Alternative 1 – No Action
- Alternative 3 – Isolation Capping / Habitat Optimization
    - Alternative 3.A – Isolation Capping to the Mean PECQ2, Mean PECQ1, or AET / Habitat Optimization
    - Alternative 3.D – Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization

  - Option 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging to 4 Meter Depth (for NAPL Removal) / Isolation Capping to Mean PECQ2, Mean PECQ1, and AET / Habitat Optimization
  - Option 4.A.4 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Full NAPL Removal / Capping to Mean PECQ2, Mean PECQ1, or AET / Habitat Optimization
  - Option 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging to 4 Meter Depth (for NAPL Removal) / Isolation Capping of Entire SMU / Habitat Optimization
  - Option 4.D.4 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Full NAPL Removal / Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
  - Option 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or AET)
  - Option 5.D – Full Removal (to PEC or ER-L)

Alternative 1 would not meet RAOs or PRGs and would not be protective of human health and the environment since it does not actively address the contaminated sediments that present unacceptable risks of exposure in SMU 2. Each of the other retained alternatives would achieve the RAOs and PRGs as they apply to SMU 2, and would provide overall protection of human health and the environment. Although Alternative 4 options would achieve protectiveness through containment and Alternative 5 options would achieve protectiveness through removal, they would provide similar levels of overall protection of human health and the environment in SMU 2, consistent with the SMU 1 discussion.

Alternatives 4 and 5 include options based on capping or dredging to various SECs. Dredging and/or capping to the mean PECQ2 or mean PECQ1 would result in the removal or isolation of all sediment reasonably expected to pose elevated potential risks to benthic macroinvertebrates through direct toxicity. Based on the exposure/response relationships determined empirically with the lake-wide database (Appendix J, sediment effects concentrations), sediments that do not exceed the mean PECQ2 or mean PECQ1 are not expected to contribute significantly to sediment toxicity. Areas that exceed the mercury PEC would also be addressed, which would remediate all areas of elevated mercury within SMU 2.

Habitat in SMU 2 is currently compromised, due in part to the presence of elevated CPOI levels. Alternatives 3.A through 4.D.3 would result in improved habitat through establishment of clean new substrate. Alternatives 4.A.3 and 4.D.3 would provide greater habitat value than Alternatives 3.A and 3.D because the area where water depth and substrate are suitable for submerged macrophyte colonization and establishment would be maximized.

Under Alternative 5 options, the resulting habitat value would be lower than that for the Alternative 3 and Alternative 4 options because of the assumed backfill depth. Additional backfill could be placed under Alternative 5 options to result in shallower water depths and thus greater habitat value. However, this would result in a significant increase in cost as well as in short term potential risks due to the transportation of large volumes of backfill.

In summary, Alternatives 3.A, 4.A.3, and 5.A would provide equivalent levels of overall protection of human health and the environment, however Alternative 4.A.3 would provide the greatest habitat value. Alternatives 3.D, 4.D.3 and 5.D compared to Alternative 3.A, 4.A.3, and Alternative 5.D, would result in increased volumes of sediment capped and/or dredged and an increase in the resulting short-term potential risks, but would provide similar levels of overall protection of human health and the environment and habitat value.

4.5.1.3 SMU 3 Overall Protection of Human Health and the Environment

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 3:

- Alternative 1 – No Action
- Alternative 2 - Habitat Enhancement
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping to Mean PECQ2, Mean PECQ1, or PEC / Habitat Optimization
    - Alternative 4.E.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping to ER-L / Habitat Optimization
- Alternative 5 – Full Removal
    - Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or PEC)
    - Alternative 5.E – Full Removal (to ER-L)

Alternative 1 would not meet RAOs or PRGs and would not be protective of human health and the environment since it does not actively address the contaminated sediments that present unacceptable risks of exposure in SMU 3. Alternative 2 would improve habitat conditions but would not address risks presented by contaminated sediments in SMU 3, and therefore would not be protective of human health and the environment. Each of the other retained alternatives would achieve the RAOs and PRGs as they apply to SMU 3, and would provide overall protection of human health and the environment. Although Alternative 3 and Alternative 4 options would achieve protectiveness through containment and Alternative 5 options would achieve protectiveness through removal, they would provide similar levels overall protection of human health and the environment in SMU 3, consistent with the SMU 1 discussion.

Alternatives 4 and 5 include options based on capping and/or dredging to various SECs. Dredging and/or capping to the mean PECQ2 or mean PECQ1 would result in the removal or isolation of all sediment reasonably expected to pose elevated potential risks to benthic macroinvertebrates through direct toxicity. Based on the exposure/response relationship determined empirically with the lake-wide database (Appendix J, sediment effects concentrations), sediments that do not exceed the mean PECQ2 or mean PECQ1 are not expected to contribute significantly to sediment toxicity.

Habitat in SMU 3 is currently compromised, due in part to the presence of elevated CPOI levels as well as due to stressors associated with calcitic material, as detailed in the Habitat Appendix M (dredging issues). Alternatives 4.A.3 and 4.E.3 would result in improved habitat through establishment of clean new substrate.

Under Alternative 5 options, the resulting habitat value would be lower than that for the Alternative 4 options because of the greater water depth following remedy completion. Backfill could be placed under Alternative 5 options to result in shallower water depths and thus greater habitat value. However, this would result in a significant increase in cost as well as in short term potential risks due to the transportation of large volumes of backfill.

In summary, Alternatives 4.A.3 and 5.A would provide equivalent levels of overall protection of human health and the environment, however, Alternative 4.A.3 would provide the greatest habitat value. Alternatives 4.E.3 and 5.E compared to Alternatives 4.A.3 and 5.A would result in increased volumes of sediment capped and/or dredged and an increase in the resulting short-term potential risks, but would provide similar levels of overall protection of human health and the environment and habitat value based on consideration of impacts resulting from CPOIs.

4.5.1.4 SMU 4 Overall Protection of Human Health and the Environment

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 4:

- Alternative 1 – No Action
- Alternative 3 – Isolation Capping / Habitat Optimization
    - Alternative 3.A – Isolation Capping to Mean PECQ2, Mean PECQ1, AET, PEC, or ER-L / Habitat Optimization
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
    - Alternative 5.A – Full Removal (to Mean PECQ2, Mean PECQ1, or AET)
    - Alternative 5.D – Full Removal (to PEC or ER-L)

Alternative 1 would not meet RAOs or PRGs and would not be protective of human health and the environment since it does not actively address the contaminated sediments that present unacceptable risks of exposure in SMU 4. Each of the other retained alternatives would achieve the RAOs and PRGs as they apply to SMU 4, and would provide overall protection of human health and the environment. Although Alternatives 3.A and 4.A.3 would achieve protectiveness through containment and Alternatives 5.A and 5.C would achieve protectiveness through removal, they would provide similar levels of overall protection of human health and the environment in SMU 4, consistent with the SMU 1 discussion.

Alternatives 3, 4, and 5 include options based on capping or dredging to various SECs. Consistent with the evaluation for SMU 2, capping or dredging to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates.

Habitat in SMU 4 is currently compromised, due in part to the presence of elevated CPOI levels. Alternatives 3.A and 4.A.3 would result in improved habitat through establishment of clean new substrate. Alternative 3.A would result in loss of a small area of lake surface, although this loss would be off-set by the increased habitat value, including establishment of new emergent wetlands. Alternative 4.A.3 would remove sufficient sediment so that there would be no loss of lake surface area, and would provide greater habitat value because the area where water depth and substrate are suitable for submerged macrophyte colonization and establishment would be maximized.

Under Alternative 5 options, the resulting habitat value would be lower than that for the Alternative 3 and 4 options because of the assumed backfill depth. Additional backfill could be placed under Alternative 5 to result in shallower water depths and thus greater habitat value. However, this would result in a significant increase in cost as well as in short term potential risks due to the transportation of large volumes of backfill.

In summary, Alternatives 3.A and 4.A.3 would provide equivalent levels of overall protection of human health and the environment and increasing levels of habitat value. Alternative 5.A would provide a similar level of overall protection of human health and the environment, but less habitat value as compared to Alternatives 3.A through 4.A.4. Alternative 5.D compared to Alternative 5.A, would result in increased volumes of sediment dredged and an increase in the resulting short-term potential risks, but would provide similar levels of protectiveness and habitat value. Alternatives associated with remediation to SECs other than the mean PECQ2 or mean PECQ1 would result in increased volumes of sediment capped and/or dredged, but provide similar levels of protectiveness and habitat value as alternatives associated with remediation to the mean PECQ2 or mean PECQ1. However, those alternatives would not provide any meaningful increases in protectiveness and habitat value compared to alternatives associated with remediation to the mean PECQ2 or mean PECQ1.

4.5.1.5 SMU 5 Overall Protection of Human Health and the Environment

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 5:

- Alternative 1 – No Action
- Alternative 2 - Habitat Optimization
- Alternative 3 – Capping / Habitat Optimization
    - Alternative 3.A – Capping to Mean PECQ2 / Habitat Optimization
    - Alternative 3.B – Capping to Mean PECQ1 / Habitat Optimization
    - Alternative 3.D – Capping to PEC / Habitat Optimization
    - Alternative 3.E – Capping to ER-L / Habitat Optimization
- Alternative 4 – Dredging / Capping / Habitat Optimization
- Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping to Mean PECQ2 / Habitat Optimization
- Alternative 4.B.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping to Mean PECQ1 / Habitat Optimization
- Alternative 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping to PEC / Habitat Optimization
- Alternative 4.E.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Capping to ER-L / Habitat Optimization
- Alternative 5 – Full Removal
    - Alternative 5.A – Full Removal (to Mean PECQ2)
    - Alternative 5.B – Full Removal (to Mean PECQ1)
    - Alternative 5.D – Full Removal (to PEC)
    - Alternative 5.E – Full Removal (to ER-L)

Sediment capping or dredging would provide no significant additional protection of human health and little additional protection of the environment compared to baseline conditions. As discussed under the No Action Alternative, baseline conditions do not contribute significantly to human health potential risks in the lake based on the RI data, there were no exceedances in SMU 5 of the mean PECQ2, and there was only a minor exceedance of the mean PECQ1, indicating little risk to benthic macroinvertebrates due to sediment toxicity. Although there are three minor exceedances of the mercury PEC (i.e., 2.3 ppm, 2.9 ppm, and 3.0 ppm) in SMU 5, capping or dredging of sediments in SMU 5 is expected to provide little, if any, additional protection for benthic macroinvertebrates. Furthermore, concentrations of bioaccumulative CPOIs (e.g., mercury, PCDD/PCDFs) are not elevated relative to other areas of the lake based on the RI data; therefore, SMU 5 is not considered a significant source of these CPOIs to the food web. Additional sampling would be required to verify this assumption.

All of the alternatives would address ecological stresses associated with oncolites by covering them and providing new substrate, removing them, or stabilizing them.

4.5.1.6 SMU 6 Overall Protection of Human Health and the Environment

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 6:

- Alternative 1 – No Action
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - Alternative 4.A.1 – Targeted Dredging / Isolation Capping to Mean PECQ2 / Habitat Optimization
    - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping to Mean PECQ2 / Habitat Optimization
    - Alternative 4.B.1 – Targeted Dredging / Isolation Capping to Mean PECQ1 / Habitat Optimization
    - Alternative 4.B.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping to Mean PECQ1 / Habitat Optimization
    - Alternative 4.D.1 – Targeted Dredging / Isolation Capping of Entire SMU / Habitat Optimization
    - Alternative 4.D.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces and Targeted Dredging / Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
    - Alternative 5.A – Full Removal (to Mean PECQ2)
    - Alternative 5.B – Full Removal (to Mean PECQ1)
    - Alternative 5.D – Full Removal (to PEC or ER-L)

Alternative 1 would not meet RAOs or PRGs and would not be protective of human health and the environment since it does not actively address the contaminated sediments that present unacceptable risks of exposure in SMU 6. Each of the other retained alternatives would achieve the RAOs and PRGs as they apply to SMU 6, and would provide overall protection of human health and the environment. Although Alternative 4 options would achieve protectiveness through containment and Alternative 5 options would achieve protectiveness through removal, they would provide similar levels of long-term protection of human health and the environment in SMU 6, consistent with the SMU 1 discussion. However, dredging under Alternative 5 options would eliminate the need for long-term maintenance and monitoring and institutional controls to ensure long-term effectiveness.

Alternatives 4 and 5 include options based on capping or dredging to various SECs. Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 or mean PECQ1 compared to remediation of additional sediments exceeding other SEC approaches in Subsection 4.4.2.2.1, remediation to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates. Habitat in SMU 6 is currently compromised, due in part to the presence of elevated CPOI levels. All of the Alternative 4 options would result in equivalent improved habitat through establishment of clean new substrate. In other SMUs, except SMU 7, the option associated with dredging to a depth to optimize habitat and minimize erosive forces results in greater habitat value that other options because the area where water depth and substrate are suitable for submerged macrophyte colonization and establishment would be maximized. However, in SMU 6, the sediments are softer and less consolidated than in most other SMUs, resulting in significantly greater settlement resulting from the weight of the cap. This results in increased water depths near shore even with no removal, and thus no significant difference in submerged macrophyte colonization and establishment area between the options, as shown in Figures 4.39 through 4.42.

Under Alternative 5 options, the resulting habitat value would be lower than that for the Alternative 4 options because of the assumed backfill depth. Additional backfill could be placed under Alternative 5 options to produce shallower water depths and thus greater habitat value. However, this would increase cost as well as in short-term-potential risks due to the transportation of large volumes of backfill.

In summary, Alternatives 4.A.1 and 4.A.3 would provide equivalent levels of overall protection of human health and the environment and equivalent levels of habitat value. Alternative 5.A would provide a similar level of protection of human health and the environment, but less habitat value, as compared to Alternatives 4.A.1 and 4.A.3. Compared to Alternative 5.A, Alternatives 5.D and 5.B would result in increased volumes of sediment dredged and an increase in the resulting short-term potential risks, but would provide similar levels of protectiveness and habitat value. Alternatives associated with remediation to SECs other than the mean PECQ2 would result in increased volumes of sediment capped and/or dredged, but would provide similar levels of protectiveness and habitat value as alternatives associated with remediation to the mean PECQ2.

4.5.1.7 SMU 7 Overall Protection of Human Health and the Environment

As detailed in Subsection 4.3, the following remedial alternatives were retained for SMU 7:

- Alternative 1 – No Action

- Alternative 3 – Isolation Capping
    - Alternative 3.A – Capping of Entire SMU
- Alternative 4 – Dredging / Isolation Capping / Habitat Optimization
    - Alternative 4.A.3 – Dredging to Result in No Loss of Lake Surface Area and to a Depth to Optimize Habitat and Minimize Erosive Forces / Isolation Capping of Entire SMU / Habitat Optimization
- Alternative 5 – Full Removal
    - Alternative 5.A – Full Removal (to Mean PECQ2 or Mean PECQ1)_
    - Alternative 5.C – Full Removal (to AET, PEC, or ER-L)

Alternative 1 would not meet RAOs or PRGs and would not be protective of human health and the environment since it does not actively address the contaminated sediments that present unacceptable risks of exposure in SMU 7. Each of the other retained alternatives would achieve the RAOs and PRGs as they apply to SMU 1, and would provide overall protection of human health and the environment. Although Alternative 4 options would achieve protectiveness through containment and Alternative 5 options would achieve protectiveness through removal, they would provide similar levels of long-term protection of human health and the environment in SMU 7, consistent with the SMU 1 discussion.

Habitat in SMU 7 is currently compromised, due in part to the presence of elevated CPOI levels. Alternative 4.A.3 would result in equivalent improved habitat through establishment of clean new substrate. In other SMUs, except SMU 6, the option associated with dredging to a depth to optimize habitat and minimize erosive forces results in greater habitat value that other options because it would maximize the area where water depth and substrate are suitable for submerged macrophyte colonization and establishment would be maximized. However, in SMU 7, the sediments are softer and less consolidated than in most other SMUs, resulting in significantly greater settlement resulting from the weight of the cap. This results in increased water depths near shore even with no removal, and thus no significant difference in submerged macrophyte colonization and establishment area between the options, as shown in Figures 4.43 through 4.45.

Under Alternative 5 options, the resulting habitat value would be lower than that for the Alternative 4 options because of the assumed backfill depth. Additional backfill could be placed under Alternative 5 options to result in shallower water depths and thus greater habitat value. However, this would result in an increase in cost as well as in short-term potential risks due to the transportation of large volumes of backfill.

Consistent with the discussion regarding remediation of sediments exceeding the mean PECQ2 or mean PECQ1 compared to remediation of additional sediments exceeding other SEC approaches in Subsection 4.4.2.2.1, remediation to the mean PECQ2 or mean PECQ1 would address all sediments likely to exhibit toxicity to benthic macroinvertebrates.

In summary, Alternative 4.A.3 would provide equivalent levels of overall protection of human health and the environment and habitat value. Alternatives 5.A and 5.C would provide a similar level of protection of human health and the environment, but less habitat value, as compared to Alternative 4.A.3.

4.5.2 Compliance with ARARs – All SMUs

Consistent with the ARAR evaluation provided for the SMU 1 capping alternative in Subsection 4.4.1.2.2, it is anticipated that all of the remedial alternatives, with the exception of the No Action Alternative, would comply with all of the designated chemical-specific ARARs to the extent that the given SMU contributes to lake wide conditions. It is also anticipated that any of the alternatives would be completed in compliance with any location-specific and action-specific ARARs. In addition, the selected remedy for SMU 7 would be designed to comply with NYSDEC Article 15, Part 608.

4.5.3 Short-Term Effectiveness – All SMUs

Alternative 1 – No action would present no short-term implementation risks. Similarly, there are minimal short-term effectiveness issues associated with Alternative 2 – Habitat Enhancement because minimal disturbance of impacted sediment or other activities that present risk would result. Alternative 1 does not include any physical construction measures in any areas of contamination and therefore would not present any potential adverse impacts to on-property workers or the community as a result of implementation.

Alternatives 3, 4 and 5 options would include some degree of short-term impacts to the lake during the construction and implementation phase, including:

- Temporary loss of lake habitat (Alternatives 3, 4 and 5);
- Impacts associated with sedimentation (even clean sediment) to surrounding areas, particularly sedimentation on submerged macrophytes or fish spawning substrates, which can diminish productivity (Alternatives 3, 4 and 5);
- Impacts of resuspension of CPOIs and potential release of NAPL into the water column and potential impacts of resuspension on the natural recovery of the profundal sediments (Alternatives 3, 4 and 5);
- Impacts of discharge of dewatering effluent on lake water quality (Alternatives 4 and 5);
- Volatilization of organics during dredging and materials handling (Alternatives 4 and 5);
- Potential for on-site worker and transportation accidents associated with remedial construction issues related to sediment removal and capping (Alternatives 3, 4 and 5);
- Quality of life impacts associated with odor and increased truck traffic on local roads (Alternatives 4 and 5); and

- Potential for on-site workers to receive adverse impacts through dermal contact with contaminated sediment.

It is anticipated that the potential risks to on-site workers could be mitigated by following appropriate health and safety protocols, by exercising sound engineering practices, and by utilizing proper protective equipment. In general, the short-term potential risks would increase as the area capped, volume dredged, and duration of the remedial alternative increases. These potential risks are discussed qualitatively below. Short-term potential risks are evaluated in greater detail during evaluation of lake-wide alternatives in Section 5, including quantitative estimation of releases of CPOIs to the air and surface water, and estimation of transportation potential risks.

Alternative 3 does not include any removal of impacted sediment. Therefore, short-term potential risks would be primarily associated with importing and placing cap materials and related activities. Alternatives 4 and 5 include dredging, sediment handling, and dewatering that would result in CPOI releases to the water and that would create air emissions and odors through release of SVOCs and VOCs from the dredge materials. Alternatives that remove greater volumes of sediment would have greater resuspension durations and other implementation potential risks than those alternatives that remove a smaller volume of sediment. However, it is anticipated that engineering controls would successfully mitigate any potential risks.

Remedy implementation for the in-lake portion of each alternative may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment. Cap placement may result in exceedances of surface water criteria due to sediment disturbances. However, sediment disturbance and short-term exceedances of surface water ARARs would be expected to be significantly greater during dredging. The greater the volume of sediment dredged, the longer the duration of the exceedance would be. Short-term water quality impacts resulting from dredging are addressed quantitatively as part of the evaluation of lake-wide alternatives in Section 5.

Alternatives 3, 4, and 5 would present increased risk of vehicular accidents related to the import of capping and backfill materials by truck. Short-term potential risks would increase with increases in the area being capped or volume of backfill imported. Alternatives 3, 4, and 5 also have construction potential risks associated with operating the dredge and land-based heavy equipment required to remove and consolidate high volumes of sediment and to place the cap.

Alternatives 3, 4 and 5 include covering and/or removing impacted sediment, which would temporarily impact the existing benthic macroinvertebrates and terrestrial species by removing them and/or their habitat. In addition to directly impacting the habitat of the benthic organisms in the affected areas, indirect effects experienced by fish that forage in the affected areas could include temporary disruption of the benthic food web. Studies of benthic recolonization indicate that individual organisms may begin to recruit to the area soon after completion of remediation. The longer it would take to implement the remedy, the longer this disruption would occur.

The in-lake portion of Alternatives 2, 3, or 4 could be implemented within an estimated five construction seasons or less and therefore would provide short-term effectiveness in meeting PRGs. Alternative 5 would take longer to implement due to the large volumes of sediment dredging involved; therefore it would take longer to meet PRGs. Alternative durations are addressed in greater detail in the Section 5 evaluation of lake-wide alternatives.

Implementation potential risks associated with CPOI releases during capping and dredging would be SMU-specific due to the different CPOI concentrations present in the various SMUs. These risks would include release of pore fluids, desorption of CPOIs from the resuspended sediments, and air emissions/releases associated with encountering NAPL-containing VOCs. Due to the cumulative nature of the potential risks and interrelationships among the SMUs, implementation risks are quantitatively evaluated for the lake-wide alternatives in Section 5.

Short-term impact may be mitigated at least in part through engineering controls, including controlled dredging, using dredging controls such as silt curtains, wearing proper PPE, and performing adequate monitoring. It is assumed that engineering controls would be used as appropriate during implementation of alternatives.

4.5.4 Long-Term Effectiveness and Permanence – All SMUs

Alternatives 1 and 2 would provide no long-term effectiveness or permanence in reducing potential risks associated with CPOIs. However, Alternative 2 would provide long-term effectiveness and permanence related to habitat establishment in SMUs 3 and 5. This would improve habitat and reduce stressors to the environment associated with calcitic waste and oncolites. Alternative 2 may increase contaminant uptake in Onondaga Lake by increasing the abundance and diversity of the biological community, thus providing greater opportunity for exposure to and uptake of contaminants. The potential impact of this increase on contaminant uptake is not well understood. Contaminant concentrations in biota may increase (e.g., if another trophic level is added, thereby resulting in greater bioaccumulation) or decrease (e.g., if greater biomass dilutes contaminant concentrations in tissue). However, the habitat benefits would far outweigh any potential negative bioaccumulation effects. Alternatives 3, 4, and 5 are all considered long-term, effective, and permanent solutions for impacted sediment in the littoral area as long as the proper monitoring and maintenance programs are maintained.

Alternatives 3, 4 and 5 would provide long-term effectiveness and permanence by isolating CPOIs present in sediment under a cap or within an upland SCA, thereby reducing or eliminating the potential risks to human health and the environment. Under Alternatives 3 and 4, containment would be achieved by capping the sediments *in situ*. As detailed in Subsection 4.3 and Appendix H (capping issues), the cap would provide long-term chemical isolation, taking into consideration chemical migration through the cap as well as processes that would potentially damage the cap. Under Alternative 5, sediments would be permanently removed from the lake, but long-term effectiveness would still rely on containment within the upland SCA. As described in Subsection 4.9, the SCA would provide long-term isolation of the dredged sediments. Long-term maintenance and monitoring and institutional controls would be integral components of the long-term effectiveness of the cap and the SCA.

Alternative 4 includes an option that removes sufficient sediment such that all of the cap surface would be below the water depth where wind/wave energy necessitates reliance on rip-rap for erosion control. This may provide an additional safety factor in ensuring long-term effectiveness of the cap. Sediment removal to this depth would not typically uncover sediment with higher CPOI concentrations; therefore, the long-term effectiveness of the cap due to migration of CPOIs through the cap would not be compromised by sediment removal prior to capping. The exception to this is in SMU 4. In SMU 4, cleaner sediments overlie sediments with higher levels of mercury. This would result in higher levels of mercury at the bottom of the cap under Alternative 4 options than in Alternative 3, which would slightly reduce the potential effectiveness of the cap. However, cap modeling indicates that the cap would be effective in either case in providing long-term effectiveness.

4.5.5 Reduction of Toxicity, Mobility, or Volume through Treatment – All SMUs

Alternatives 1 and 2 would provide no reduction in toxicity, mobility, or volume through treatment.

Alternative 3 and the capping component of Alternative 4 rely on isolation rather than treatment to achieve effectiveness. However, capping would result in minor reduction in the volume of the impacted sediment due to compaction resulting from the weight of the cap. In addition, natural process that reduce toxicity such as biological degradation of organic compounds would continue to occur beneath the cap following construction, although these processes may be insignificant and would not be monitored or verified.

The dredging and associated processes included in Alternatives 4 and 5 would result in reducing the toxicity, mobility and volume through treatment. The volume of sediment would be reduced through consolidation and dewatering within the SCA. Dewatering would also reduce the mobility of the removed sediment, resulting in increased assurance that the SCA would provide long-term containment of the sediment. Treatment of water resulting from the dredging operations, as detailed in Subsection 4.9, would result in reduction in the toxicity, mobility and volume of CPOIs that are mobilized from the sediment into the water stream. In addition, natural processes that reduce toxicity, such as biological degradation of organic compounds, would continue to occur beneath the cap or within the SCA following construction, although these processes may be insignificant and would not be monitored or verified. The greater the volume of sediment removed, the greater the reduction in toxicity, mobility, and volume that would result from these processes.

4.5.6 Implementability – All SMUs

It is anticipated that any of the littoral area remedial alternatives are readily implementable, with the exception of dredging under Alternative 5 for those SMUs that would result in extremely large volumes of sediment. For example, Alternative 5 for SMU 1 would require removal of at least 4 million CY of sediment, which would be larger than any environmental dredging project ever completed in this country. The size and duration of this removal, in combination with the remedial alternatives selected for the other SMUs would present numerous implementation challenges, as detailed in Subsection 4.4.1.4.6.

4.5.7 Summary

Under the CERCLA FS process, a recommended alternative is selected based on the detailed and comparative evaluation of alternatives. However, as discussed throughout Subsection 4.4, short-term effectiveness, overall protection of human health and the environment, and cost cannot be accurately evaluated based on SMU-specific alternatives. Therefore, based on the evaluation of SMU-specific alternatives, provided below are recommendations regarding which ones should be considered for incorporation into lake-wide alternatives and evaluated in additional detail in Section 5. A list of the SMU-specific alternatives, which were evaluated as part of the evaluation of lake-wide alternatives in Section 5, is provided in Table 4.13.

The No Action Alternative does not meet the threshold criteria of overall protection of human health and the environment for any of the SMUs. However, the No Action Alternative should be evaluated on a lake-wide basis, consistent with CERCLA guidance, to serve as a baseline for comparison of other alternatives.

The alternatives for each SMU vary significantly in how they satisfy the evaluation criteria. Of significance is that all of the alternatives provide similar levels of overall protection of human health and the environment, except in the value of the post-remediation habitat, while Alternative 5 – Full Removal would result in significantly greater short-term potential risks and remedial costs for each of the SMUs versus the other alternatives. Nevertheless, Alternative 5 for each of the SMUs should be incorporated into a lake-wide alternative to allow additional evaluation and ensure that a full range of alternatives is evaluated.

Alternatives 3, 4, and 5 include options based on capping or dredging to various SECs. Capping or dredging to SEC approaches other than the mean PECQ2 would result in greater short-term potential risks and cost, but would result in minimal or no improvement in the other evaluation criteria. Capping or dredging to the mean PECQ1 would provide an additional safety factor with respect to sediment toxicity, relative to the mean PECQ2. To ensure that a full range of lake-wide alternatives is evaluated, capping and dredging alternatives based on remediation to the mean PECQ2, mean PECQ1, or ER-L should be considered as part of the evaluation of lake-wide alternatives in Section 5. In addition, habitat enhancement under Alternative 2 should be included for those portions of SMU 3 and SMU 5 that are not addressed through capping and/or dredging.

4.6 DEVELOPMENT & SCREENING OF PROFUNDAL AREA ALTERNATIVES

In this section, remedial technologies retained from Section 3 are assembled into preliminary remedial alternatives that address the profundal area (SMU 8). SMU 8 is located in the profundal area of Onondaga Lake and consists of sediment in water depths greater than 30 ft (9 m). Considering the RAOs applicable to the profundal area, this section then screens the alternatives against effectiveness, implementability, and cost to identify alternatives that would be subject to a detailed evaluation in Subsection 4.7. The results of this screening are discussed below and summarized in Table 4.14.

It is assumed for all alternatives discussed in this subsection that implementation of source control of CPOIs related to Honeywell and non-Honeywell upland sites is implemented, as described in Subsection 4.2, and active remediation in other SMUs is implemented.

It is also assumed for all alternatives that prior to any in-lake activity a pre-design investigation program would establish a more precise delineation of the nature and extent of contamination. Approximately 12 years have elapsed since sediment in SMU 8 was sampled on a comprehensive basis. Ongoing natural recovery is likely to have altered CPOI concentrations since that time. The natural recovery model described in Appendix N, monitored natural recovery, would be updated with those conditions following implementation of the upland source controls and lake remedies for key modeling parameters (e.g., mercury concentrations in surface sediment). Other pre-design activities that may be undertaken specific to some alternatives are discussed individually in each subsection below.

Based on the remedial technologies retained in Section 3 for SMU 8, the following preliminary alternatives were developed for the profundal area:

Alternative 1. No Action
Alternative 2. MNR
Alternative 3. Thin-Layer Capping
Alternative 4. Phased Thin-Layer Capping / MNR
Alternative 5. Aeration (Oxygenation) / MNR
Alternative 6. Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR
Alternative 7. Isolation Capping
Alternative 8. Dredging

Each of these alternatives is developed and discussed in the following subsections.

The alternatives that include active remediation of sediments (i.e., capping or dredging) can be further divided into options based on whether the remedial goal (SEC value) is the mean PECQ2, mean PECQ1, AET, PEC, or ER-L. Areas of exceedance for each of these SECs in the surface sediment of SMU 8 are shown in Figures 2.2 through 2.8. Areas and SEC exceedances at all depths are shown in Appendix E, areas and volumes. These options are discussed below in detail for the remedial alternatives to which they apply.

For MNR alternatives in profundal sediments, evaluations presented in Appendix N, monitored natural recovery, are for mercury. Information is insufficient to derive natural recovery estimates for other CPOIs, and thus they are not addressed in detail in the MNR estimates for the profundal area. However, as discussed in Appendix N, monitored natural recovery, mercury provides a good surrogate chemical for the evaluation of the potential for natural recovery. Unlike organic chemicals, total mercury does not degrade with time, and thus natural recovery estimates based on mercury are conservative in this regard. In addition, mercury is found throughout the profundal sediments at concentrations exceeding SEC values such as the PEC and ER-L (see Figures 1.11 and 2.6). However, as shown in Figure 2.8, there are no profundal areas that are likely to exhibit toxicity as measured by the mean PECQ2.

Based on the above considerations, for the evaluation of MNR in the profundal area, determination of areas that meet various total mercury SEC levels (e.g., total mercury AET, PEC, and ER-L) appears to provide a good estimate of the overall effectiveness of MNR as a remedial alternative. Mercury SEC values (AET, PEC, and ER-L) are used throughout Appendix N, monitored natural recovery, and this section for remedial alternatives involving MNR.

4.6.1 Alternative 1 – No Action

For the No Action Alternative, no action is implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals. The No Action Alternative assumes upland source controls are implemented to control external sources of CPOIs to the lake. The alternative does not include institutional controls, such as a fish consumption advisory. The No Action Alternative is retained for all SMUs as a baseline for comparison to other alternatives, consistent with CERCLA guidance and the NCP.

4.6.2 Alternative 2 – Monitored Natural Recovery

This alternative includes the following components:

- Completion of pre-design investigations to refine the application of MNR;
- Long-term monitoring; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

As discussed in Section 3, MNR is a recognized sediment management tool and can occur through a variety of physical, chemical, and biological processes that act alone or in combination to reduce chemical concentrations, exposure, or mobility. These processes can occur in all matrices at a site (e.g., water, sediments, fish tissue). Because sediments are usually both an important sink for chemicals and a potential exposure pathway to organisms, the focus of MNR is often on contaminated sediments and the mechanisms that affect them. Natural recovery in sediments, which explicitly includes a monitoring component implemented over the recovery period, is not to be equated with “no action.”

MNR is evaluated through five primary lines of evidence, including: 1) source characterization, 2) fate and transport processes, 3) historical chemistry trends, 4) historical biological trends, and 5) predictive modeling. For the reasons noted above, mercury is used as a surrogate chemical to understand the potential for recovery of all chemicals in profundal sediments. Appendix N (monitored natural recovery) presents an evaluation of MNR in SMU 8 with a focus on mercury using the five lines of evidence and concludes that:

- Ongoing source control by Honeywell and others can be expected to lead to a small reduction in total suspended solids (TSS) loading and a more substantial reduction in mercury loading to the lake.
- Fate and transport processes indicate profundal (at depths of more than 30 ft [9 m]) and deeper littoral (at depths between 20 and 30 ft [6 and 9 m]) sediments are more stable. Thus, they are more amenable to natural recovery, while recovery of sediments in upper littoral areas (water depths of less than 20 ft [6 m]) is expected to be less effective.
- Water column, sediment, and biological tissue chemistry trends all appear to have been relatively stable (neither increasing nor decreasing) over the last 10 years, though statistical uncertainty/variability associated with the historical database preclude a rigorous trend analysis.
- These stable historical trends do not account for source control efforts expected to significantly reduce mercury loads to the lake. Thus, predictive modeling is needed to reliably forecast future conditions in the lake associated with MNR.
- Predictive modeling indicates that decreases in mercury surface sediment concentrations can be expected for all profundal and deeper littoral sediments. The specific mercury concentrations potentially achieved depend on the assumptions made about issues such as the potential effectiveness of source controls and changes in bioturbation due to other remedial technologies such as aeration (oxygenation). However, under all reasonably likely scenarios, substantial decreases in profundal surface sediment mercury concentrations are expected.
- Modeling indicates that surface sediment mercury concentrations would approach the settling sediment mercury concentrations over time.
- Evaluation of methylmercury fluxes from the profundal sediments using the predictive model indicates overall, with considerable uncertainty, that profundal sediments are a sink rather than a source of methylmercury to the hypolimnion. There may be seasonal variations that cause this balance to reverse, which are not reflected in the predictive model.
- The predictive model suggests that MNR could cause a reduction in the upward flux rate of methylmercury from the profundal sediments, if source controls have an impact on the amount of methylmercury in suspended particulate matter (SPM).

- Overall, MNR appears to be a feasible technology that can effectively meet one or more of the RAOs applicable to the profundal area.

In addition to mercury, some of the CPOIs in the profundal sediments (e.g., PCBs) may pose potential bioaccumulative risks if the sediments were to become accessible to benthic macroinvertebrates and fish. However, mercury exists at measurable concentrations (usually in excess of 1.3 milligrams per kilogram [mg/kg]) in surface sediments throughout the profundal area (Figure 1.11) and therefore is commingled to a considerable extent with all other potentially bioaccumulative CPOIs. Upland source control and remediation of littoral sediments is expected to reduce inputs of all CPOIs to SMU 8. Therefore, mercury recovery in surface sediments would likely be associated with simultaneous recovery of other CPOIs.

Monitoring for the effectiveness of natural recovery would be described in a long-term monitoring plan and would include evaluations of mercury and other CPOI concentrations in surface sediment and sediment cores over time.

Based on these considerations, MNR is expected to be implementable at a relatively low cost. As described above, it would likely be effective in significantly reducing CPOI concentrations in general in SMU 8 and the corresponding risks present (RAO 4). In conjunction with source controls, MNR could reduce the amounts of methylmercury production in the hypolimnion and reduce the flux of mercury from the profundal sediments (RAOs 1 and 3).

MNR relies on future predictions of reductions in mercury concentrations, and with any predictive method, uncertainty exists. This MNR alternative does not include a contingency action that would be implemented if MNR did not meet the predicted goals. Therefore, it is uncertain whether this alternative would be protective of human health and the environment. Therefore, this alternative was not retained for detailed evaluation; however, MNR has been retained as a component of other remedial alternatives discussed below.

4.6.3 Alternative 3 – Thin-Layer Capping

This alternative includes the following components:

- Completion of pre-design investigations to optimize implementation and ensure effectiveness of the thin-layer cap;
- Installation of a thin-layer cap over those portions of the SMU that exceed the SEC values for all CPOIs that are established as the cleanup criteria;
- Long-term monitoring; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

As discussed in Section 3, thin-layer capping involves the placement of clean material (sand or sediment created to meet some specific composition) in areas with surface sediment concentrations that exceed the SEC values. As discussed in Section 3, thin-layer caps are typically less than 1 ft (30 cm). In many cases, thin-layer caps are 2 to 8 inches (5 to 20 cm) thick, and are very effective in low energy environments like the profundal area. Thin-layer capping has been demonstrated to be an effective approach (see Section 3 and Appendix N, monitored natural recovery). The objective of thin-layer capping is not to isolate surface sediments, but to augment the natural sedimentation rate by introducing clean sediment. The new cap sediment would mix with the underlying material during the construction process, and thereby immediately reduce chemical concentrations in the surface sediments and reduce any associated ecological impacts. Clean sediment can be placed through "sprinkling" to achieve coverage over portions of the SMU or in windrows.

Monitoring would be necessary to confirm the location and depth of placed sediment and to assess the predicted reduction of chemical concentrations in the surface sediments. Assessments of the effectiveness of thin-layer capping would be described in monitoring plans and would include evaluations of surface and suspended sediment chemical concentrations over time. This alternative does not depend on MNR to help reduce contaminant concentrations in surface sediment.

Thin-layer capping is implementable, but more costly than alternatives involving elements of MNR. It would be effective at reducing ecological impacts to the profundal surface sediments (RAO 4). It would also likely be effective in reducing the flux of mercury from the profundal sediments (RAO 3), because the concentrations available for movement from surface sediments to the hypolimnion would be immediately reduced. This flux reduction would decrease the amount of methylmercury present in the hypolimnion (RAO 1) to the degree that those concentrations are determined by profundal flux. Appendix N, monitored natural recovery, indicates that the surface sediment concentrations are controlled by settling particulate matter (SPM) concentrations. Consequently, over the long term, the surface sediment concentrations would not differ between thin-layer capping and MNR, and differences in effectiveness between these two alternatives are only temporary. Although it has higher overall costs than MNR, thin-layer capping was retained for further evaluation in profundal sediments.

4.6.4 Alternative 4 – Phased Thin-Layer Capping / MNR

This alternative includes the following components:

- Completion of pre-design investigations to optimize implementation and ensure effectiveness of the MNR and the thin-layer cap;
- Installation of a thin-layer cap prior to the start of the MNR period (Phase I) in those areas of the SMU where modeling predicts the total mercury SEC values established as the cleanup criteria are unlikely to be met by natural recovery;
- Long-term monitoring (Phase II);
- Installation of a thin-layer cap or continued MNR (Phase III) after the end of the initial MNR period in any areas of the SMU that exceed SEC values established as the cleanup criteria; and

- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

In addition to a general delineation of contamination, pre-design activities for this alternative would also establish site-specific parameters and gather other information necessary to design the thin-layer cap (e.g., the most effective method of applying a thin-layer cap).

This alternative differs from Alternative 3, where thin-layer capping is performed immediately in all areas that currently exceed the established cleanup criterion, regardless of any future predictions of natural recovery. Rather, this alternative would take place in a phased approach. Phase I activities in the profundal area would initially include limited thin-layer capping in areas that have mercury concentrations that possibly exceed the maximum concentration expected to naturally recovery to the total mercury SEC value established for cleanup. Phase II monitoring of natural recovery throughout the profundal areas for all CPOIs with cleanup criteria would follow.

For example, modeling of natural recovery based on total mercury in SMU 8 predicts that surface sediments (the top 4 inches [10 cm]) with mercury concentrations up to 6.7 ppm as measured in 1992 would recover to the mercury PEC (2.2 ppm) within 10 years of implementing source control. Thus, if the mercury PEC becomes the established mercury cleanup criterion, then profundal areas exceeding 6.7 ppm total mercury would be designated for immediate thin-layer capping in Phase 1 of this alternative.

While no profundal surface sediment samples from the 1992 sampling event exceeded 6.7 ppm, pre-design sampling of profundal sediments adjacent to SMU 1 could possibly indicate some marginal areas that have total mercury concentrations that are not expected to recover within 10 years of source controls. Where this is the case, thin-layer capping would be conducted in Phase 1 of this alternative. An area of 20 acres for Phase I thin-layer capping is assumed for estimation purposes.

Ongoing results from MNR (Phase II) would then be used to evaluate the need and location of additional thin-layer capping and/or continued MNR after the initial MNR period. For any areas that do not meet the established cleanup criteria at the end of the MNR period, additional thin-layer capping and/or additional MNR would be conducted (Phase III).

Monitoring (in addition to MNR monitoring) would be necessary to confirm the location and depth of sediment placed for thin-layer capping and to assess the predicted reduction of chemical concentrations in the surface sediments. Assessments of the effectiveness of thin-layer capping would be described in monitoring plans and would include evaluations of the changes in surface and suspended sediment mercury concentration over time.

MNR and phased thin-layer capping are implementable and relatively cost effective. However, as the SEC value established for the cleanup criterion becomes more stringent, the cost of this alternative rapidly increases due to the extensive additional areas that may require thin-layer capping.

This alternative would be effective at reducing ecological impacts to the profundal surface sediments (RAO 4). It would also likely be effective in reducing the flux of mercury from the profundal sediments (RAO 3) in areas of thin-layer capping, because the concentrations available for movement from surface sediments to the hypolimnion would be immediately reduced. The reduction in flux from profundal sediment would decrease the amount of methylmercury present in the hypolimnion (RAO 1), to the degree that those concentrations are determined by profundal flux. In addition, as noted for the MNR alternative, source controls implemented with MNR could reduce the profundal flux of mercury over time, which would also address RAOs 1 and 3. Based on these considerations, MNR with phased thin-layer capping was retained for further evaluation.

4.6.5 Alternative 5 – Aeration (Oxygenation) / MNR

This alternative includes the application of Alternative 2 (MNR), with the application of aeration (oxygenation) technology to further address methylation of mercury in the hypolimnion (RAO 1). This alternative includes the following components:

- Completion of pre-design investigations for refinement of the MNR application and pilot testing of aeration (oxygenation) of the water column;
- Installation of a full-scale aeration (oxygenation) system, as appropriate, following pilot testing;
- Long-term monitoring; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

In addition to an updated delineation of contamination, the pre-design investigation program would collect any additional needed information on anoxia in the hypolimnion and corresponding methylmercury concentrations in the water column. Pilot testing of an aeration (oxygenation) system for Onondaga Lake would help determine its full scale applicability and effectiveness.

Aeration (oxygenation) is generally described in Section 3. A specific aeration (oxygenation) system technology would be determined as appropriate, as a part of the pre-design process. The specific technology assumed for the purposes of this FS involves a downflow contact oxygenation system (DCOS) that mixes pure oxygen bubbles with oxygen-depleted water inside a contact chamber so that no bubbles are released to the surrounding water column (Brown & Caldwell, 1995; Beutel & Horne, 1999). This system uses a submersible pump, which draws water from the hypolimnion into the conical unit. Oxygen supplied from an onshore facility is injected at the top of the cone. The oxygenated water is then discharged back to the lake through a horizontal diffuser pipe at the same depth from which it was withdrawn.

Aeration (oxygenation) has not been widely used for this purpose, but is expected to reduce mercury methylation in the water column and is expected to reduce mercury bioaccumulation in fish by reducing the mass of methylmercury available for bioaccumulation. However, aeration (oxygenation) is also expected to directly affect biological productivity and even the composition of the food web in the lake. This may have unexpected consequences on fish tissue, perhaps including decreased biodilution (i.e., increased mercury concentrations in some fish tissues) due to changes in food chain length. In addition, aeration (oxygenation) would impact the redox conditions of profundal surface sediments, which may in turn have consequences on the availability or toxicity of chemicals, particularly metals, in those sediments. Aeration (oxygenation) may also reduce the ebullition of methane gas, which was linked in the RI to increased methylmercury flux, in the upper layers of surface sediments, where oxic conditions would be created. It should also be noted that creation of an oxic hypolimnion would promote colonization of the profundal sediments by benthic organisms, increase bioturbation depth in those sediments, and thereby reintroduce previously buried CPOIs to the biologically active zone. The overall outcome of this process would be to decrease the rate of natural recovery in surface sediments (Appendix N, monitored natural recovery). Consequently, while this alternative helps to meet RAO 1 regarding hypolimnetic mercury methylation, it potentially hinders attainment of RAO 4 regarding reduction in risks due related to direct sediment exposure.

Aeration is also expected to increase biological activity in sediments. Introduction of oxygen to the lake bottom would likely create an oxic microzone in at least the top few millimeters of sediment and as much as the top 2 inches (5 cm) if sediments are flocculent. This would increase the depth of the biologically active zone (from essentially zero today) in the profundal sediment. A benthic community would likely colonize the surface sediments within the first season of oxygenation. However, one to two decades may be required for the community to attain full species diversity comparable to reference lakes (Horne *et al*., 1986).

Once the community is established, it is unlikely that the bioturbation layer would extend to more than 2 to 6 inches (5 to 15 cm) into the sediments (Cohen, 2003). (Note that for MNR evaluation in Appendix N, monitored natural recovery, a mid-value of 4-inch (10-cm) mixed depth was used for aeration (oxygenation) scenarios consistent with this information.) The increased bioturbation and subsequent mixing of deeper, more contaminated sediments with aeration (oxygenation) is expected to slow the overall rate of natural recovery as noted above. In Appendix N, model runs were conducted with and without the increased bioturbation depths expected with aeration (oxygenation). These model runs predicted average surface sediment mercury concentrations of 0.71 ppm without aeration (oxygenation) and 1.19 ppm with aeration (oxygenation). The current surface sediment mercury concentration was assumed to be 2.59 ppm.

Aeration (oxygenation) has been performed in other lakes and reservoirs, but rarely to specifically control methylmercury production. Consequently, pilot studies are recommended to aid in further evaluation of the potential effectiveness of the alternative at reducing formation of methylmercury in the water column, fish tissue methylmercury concentrations, and methane gas ebullition as well as to understand other impacts on surface sediment toxicity. After operational design specifications are confirmed, the assessment of the effectiveness of aeration (oxygenation) would be described in monitoring plans and would likely include measurements of dissolved oxygen, methylmercury, and total mercury concentrations in the water column; changes in total suspended solids; primary production; establishment of a benthic community; and changes in the surface sediments. This monitoring constitutes the MNR portion of the remedy. Similar to Alternative 2, there are no additional contingencies such as thin-layer capping after the MNR period built into this alternative.

Based on these considerations, MNR with aeration (oxygenation) is expected to be implementable at a cost somewhat higher than MNR alone (Alternative 2) but lower than thin-layer capping (Alternative 3). It would likely be effective in significantly reducing mercury and other CPOI concentrations in SMU 8 and the corresponding risks (RAO 4). In conjunction with source controls, aeration (oxygenation) would reduce the amount of methylmercury production in the hypolimnion and reduce the flux of mercury from the profundal sediments (RAOs 1 and 3). Appendix N, monitored natural recovery, indicates that aeration (oxygenation), even without source controls, would reduce the methylmercury flux from profundal sediments due to changes in the balance of methylmercury cycling in the lake. Consequently, this alternative appears to have the potential to directly address RAOs 1, 3, and 4. However, this alternative does not include potential additional remedial technologies (such as thin-layer capping) on a contingency basis after the MNR period is complete. Consequently, this alternative may not be complete in comparison to Alternative 6, and was not retained for further evaluation.

4.6.6 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

This alternative includes the following components:

- Completion of pre-design investigations to optimize implementation and ensure effectiveness of MNR, aeration (oxygenation), and thin-layer capping, including pilot testing for aeration (oxygenation);
- Installation of a thin-layer cap prior to the start of the MNR period (Phase I) in those areas of the SMU where modeling predicts that the SEC values established as the cleanup criteria are unlikely to be met by natural recovery, full scale implementation of aeration (oxygenation) if shown to be effective during pilot testing, and establishment of the monitoring program;
- Continued MNR monitoring to assess the effectiveness of natural recovery and aeration (oxygenation);
- Long-term monitoring (Phase II);
- Installation of a thin-layer cap and/or continued MNR (Phase III) after the end of the initial MNR period in any areas of the SMU that exceed the SEC values established as the cleanup criteria; and

- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

This alternative is essentially the same as Alternative 5, with the addition of thin-layer capping. It would include those pre-design elements discussed above including pilot testing of an aeration (oxygenation) system for Onondaga Lake to help determine its full scale applicability and effectiveness

Following aeration (oxygenation) pilot testing and other pre-design investigations, this alternative would be implemented in a phased approach similar to the one described in Alternative 4. Phase I activities in the profundal area would include thin-layer capping in those areas not expected to meet the total mercury SEC value (established as the cleanup criteria) after the MNR period, full-scale implementation of an aeration (oxygenation) system (if shown to be effective during pilot testing), and establishment of the MNR monitoring program. Phase II would include continued MNR monitoring to assess the effectiveness of natural recovery and aeration (oxygenation). Phase III would include thin-layer capping and/or continued MNR as contingency measures (if necessary) in any areas that did not meet the established cleanup criteria after the initial MNR period, and continuation of aeration (oxygenation), if it has proven to be effective. As with Alternative 4, it is assumed that 20 acres adjacent to SMU 1 and SMU 6 would be considered for Phase I thin-layer capping for estimation purposes.

MNR with aeration (oxygenation) and phased thin-layer capping is expected to be implementable at a cost somewhat higher than MNR with either aeration (oxygenation) (Alternative 5) or thin-layer capping (Alternative 4) alone, but lower than thin-layer capping (Alternative 3). It would likely be effective in significantly reducing mercury and other CPOI concentrations in SMU 8 and the corresponding risks presented (RAO 4). In conjunction with source controls, aeration (oxygenation) would reduce the amounts of methylmercury production in the hypolimnion and reduce the flux of mercury from the profundal sediments (RAOs 1 and 3). Thin-layer capping would also reduce the flux of mercury from sediment in those areas where it was conducted. Consequently, this alternative would directly address RAOs 1, 3, and 4, and therefore was retained for further evaluation.

4.6.7 Alternative 7 – Isolation Capping

This alternative includes the following components:

- Completion of pre-design investigations to optimize implementation and ensure effectiveness of a sediment isolation cap;
- Installation of an isolation cap over those portions of a SMU that exceed the SEC established as the cleanup criterion;
- Long-term monitoring and maintenance of the cap; and
- Institutional controls to protect the integrity of the remedy and to ensure long-term protectiveness of human health and the environment.

In addition to an updated delineation of contamination, pre-design testing would establish the site-specific parameters related to the sediment cap design and geotechnical aspects of the lake bottom. This alternative assumes that all areas exceeding the established cleanup criteria would be immediately capped and that no natural recovery period would be included for those sediments. Construction specification compliance and long-term monitoring would be described in construction quality assurance and operations, monitoring, and maintenance plans.

Isolation capping is implementable, although the construction may be slower and less precise in the deeper waters of the profundal area as compared to similar isolation capping in littoral areas. In addition, this alternative would require very large volumes of suitable isolation cap material, which may be difficult to obtain. Isolation capping would have much higher costs than any of the previously discussed profundal alternatives. Isolation capping would effectively and immediately address areas that exceed SEC values, thus addressing RAO 4. It would also substantially reduce the amount of mercury flux from the profundal sediments (RAO 3). It would not have any direct effect on methylation in the water column (RAO 1), other than that associated with source controls and reduction of methylmercury flux from the profundal sediments.

This alternative provides effectiveness similar to thin-layer capping and MNR/thin-layer capping alternatives, although the short-term impacts may be less than alternatives involving MNR, because isolation capping results in immediate cleanup rather than some short-term period of ongoing risks as sediments recover. The long-term effectiveness of capping is the same as MNR and thin-layer capping, because SPM concentrations would control surface sediment concentrations over time. Isolation capping does not directly address RAO 1, and thus is considered less effective than alternatives that include an aeration (oxygenation) component. Because this alternative has similar effectiveness as other retained alternatives, but with substantially higher costs, it was not retained for further evaluation.

4.6.8 Alternative 8 – Dredging

This alternative includes the following components:

- Completion of pre-design investigations to optimize implementation;
- Dredging of all sediments in SMU 8 that exceed the SEC values established as the cleanup criteria;
- Placement of a residual cap, if necessary; and
- Institutional controls to ensure long-term protectiveness of human health and the environment.

Dredging would address mercury in buried profundal sediment that may enter the water column through diffusion and sediment entrainment associated with methane gas ebullition. However, the magnitude of buried mercury as a source to the water column is unresolved at this time.

This alternative includes immediate dredging with no allowance for natural recovery. Because the vertical extent of SEC exceedances are largely undefined in SMU 8, prior to any in-lake activity, a pre-design investigation program would establish a more precise delineation of the nature and extent of contamination. Testing would also establish the site-specific parameters and gather other information necessary to design the remedy. This may include evaluation of dredging methods and treatability testing for treatment of water generated during dredging.

Sediments that exceed the SEC values in SMU 8 can be addressed through removal, either by mechanical or hydraulic methods. However, hydraulic dredging was selected as the representative process option for detailed evaluation due to the high production rates and, under many situations, economic advantages associated with hydraulic dredging. The effectiveness, implementability, and cost of dredging would depend on numerous site-specific factors, such as volume dredged, water quality impacts during dredging, and consolidation requirements, that are beyond the scope of consideration of this preliminary screening section.

This alternative would provide reduction of risks by meeting the established cleanup criterion (RAO 4). It would reduce the flux of methylmercury from the profundal sediments (RAO 3) in the long-term, but would greatly increase this flux due to dredging disturbance over a considerable period that the alternative takes to implement. It would have no direct effect on methylation in the hypolimnion (RAO 1).

The alternative is theoretically implementable; however, the potential volumes are several times larger than any environmental dredging projects completed to date. Production rates may be slower in the deeper waters of the profundal zone as compared to dredging in shallower littoral areas. Because of the large volumes of sediment involved, it would be necessary to dredge over multiple seasons. Capping of residual after dredging may be needed, especially to attain lower SEC values such as the ER-L, so the large amounts of suitable cap material that may be needed could be difficult to obtain. Extensive dredging of this magnitude would likely cause water quality issues over potentially long periods of time, which may be more difficult to mitigate with barriers in the deeper open waters at the center of the lake. Further, there would be logistical issues associated with locating, operating, and closing a consolidation area that would be able to receive such large volumes of sediments. The costs associated with this alternative are much higher than for any other profundal alternative.

The long-term effectiveness of dredging is similar to MNR, because SPM concentrations would control surface sediment concentrations over time. However, dredging may be less effective, due to short-term water quality impacts, than some of the other alternatives, has considerable implementation issues, and is the most costly alternative. However, this alternative was retained for detailed evaluation for comparative purposes, allowing detailed evaluation of a full range of alternatives.

4.7 DETAILED EVALUATION OF PROFUNDAL ALTERNATIVES

This subsection provides a detailed evaluation of the five remedial alternatives retained in Subsection 4.6. The detailed evaluation is based on the seven CERCLA and NCP evaluation criteria. The evaluation of each CERCLA criteria is presented in Table 4.15.

The remedial alternatives retained in Subsection 4.6 and subjected to this detailed evaluation are:

Alternative 1:	No Action
Alternative 3:	Thin-Layer Capping
Alternative 4:	Phased Thin-Layer Capping / MNR
Alternative 6:	Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR
Alternative 8:	Full Removal

Alternatives 3, 4, 6, and 8, which include active remediation of sediments (i.e., capping or dredging), can be further divided into options based on whether the remedial goal (SEC value) is the mean PECQ2, mean PECQ1, AET, PEC, or ER-L. Table 4.16 shows the various areas and volumes associated with these options for these two alternatives. For both alternatives, only two options (mean PECQ2 and ER-L) are considered. The area and volume of sediment exceeding the mean PECQ2 is approximately equivalent to the areas and volumes exceeding the mean PECQ1 and the PEC values; therefore, the mean PECQ2 option was considered. The area and volume exceeding the AET values were not considered because they do not address risks related to mercury.

The subsections that follow provide detailed analysis of the retained remedial alternatives for the profundal area. Appendix N, monitored natural recovery, provides additional detail on MNR, including predictive modeling of mercury concentrations in surface sediment over time.

Costs have not been estimated for SMU-specific alternatives. Section 5 includes cost estimates associated with each of the lake-wide alternatives evaluated. Estimating costs based on lake-wide alternatives allows consideration of economies of scale and more accurate distribution of costs associated with issues such as mobilization/demobilization and water treatment facility construction. This allows more accurate cost estimating, helps ensure that remedial costs are not over estimated, and provides an appropriate basis for evaluating and comparing alternatives.

4.7.1 SMU 8 Alternative 1 – No Action

For the No Action Alternative, no action is implemented to address SMU 8 or to monitor progress toward remedial goals. The No Action Alternative assumes upland source controls are implemented to control external sources of CPOIs to the lake. The alternative does not include institutional controls, such as a fish consumption advisory. The No Action Alternative is retained for SMU 8 as a baseline for comparison to other alternatives, consistent with CERCLA guidance and the NCP.

4.7.1.1 SMU 8 Alternative 1 – No Action
Overall Protection of Human Health and the Environment

The No Action Alternative would not be protective of human health and the environment, since it would not actively address the contaminated sediments that present unacceptable risks of exposure.

4.7.1.2 SMU 8 Alternative 1 – No Action
Compliance with ARARs

The No Action Alternative would not meet location-and action-specific ARARs.

4.7.1.3 SMU 8 Alternative 1 – No Action
Short-Term Effectiveness

The No Action Alternative does not include any physical construction measures in any areas of contamination and, therefore, would not present any potential adverse impacts to the community or workers as a result of its implementation.

4.7.1.4 SMU 8 Alternative 1 - No Action
Long-Term Effectiveness and Permanence

This alternative would not provide significant long-term effectiveness. Since the No Action Alternative would involve no active remedial measures, it would not be effective in eliminating the potential exposure to contaminants in sediment. The SMU would be expected to continue to improve naturally over time; however, the No Action Alternative would not effectively eliminate the potential exposure to contaminants in sediment, and the rate of improvement is unpredictable and would not be verified due to the lack of monitoring under this alternative. Existing risks to fish and wildlife would likely remain unchanged or would improve slowly at an unpredictable rate. Considering the levels of contamination that are present, it is unlikely that there would be significant natural improvement.

4.7.1.5 SMU 8 Alternative 1 – No Action
Reduction of Toxicity, Mobility, or Volume through Treatment

The toxicity and volume of mercury and other key CPOIs in sediment would not be reduced under the No Action Alternative, because no treatment would be performed. The overall bioavailability and mobility of contaminants in the sediment would be reduced over time because deposition of cleaner sediments over more impacted sediments would occur.

4.7.1.6 SMU 8 Alternative 1 – No Action
Implementability

The No Action Alternative would be easy to implement, as there are no activities to undertake.

4.7.1.7 SMU 8 Alternative 1 – No Action
Cost

There are no costs associated with the No Action Alternative.

4.7.2 SMU 8 Alternative 3 – Thin-Layer Capping

This alternative includes the following components:

- Completion of pre-design investigations to optimize implementation and ensure effectiveness of the thin-layer cap;
- Installation of a thin-layer cap over those portions of the SMU that exceed the SEC values (i.e., three options, to the mean PECQ2. mean PECQ1, and ER-L), that are established as the cleanup criteria;
- Long-term monitoring; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

This alternative has a total of three options based on the SEC values adopted for the site:

- Alternative 3.A – Thin-Layer Capping to the Mean PECQ2
- Alternative 3.B – Thin-Layer Capping to the Mean PECQ1
- Alternative 3.E – Thin-Layer Capping to the ER-L

Thin-layer capping is based on current exceedances of the SEC adopted. As a result, only three alternatives are being considered for Alternative 3 (i.e., Alternatives 3.A, 3.B, and 3.E) in SMU 8 (see Figures 4.46, 4.47, and 4.48). Thin-layer capping to the AET requires capping of minimal area (i.e., 82 acres), and with no long-term monitoring component, it is less protective and has not been retained. Thin-layer capping to the PEC is very similar to Alternative 3.E (i.e., thin-layer capping to the ER-L) with the exception of six polygons. Therefore, thin-layer capping to the PEC has not been retained.

Areas for thin-layer capping to the mean PECQ2, mean PECQ1, and the ER-L are provided in Table 4.16 (i.e., 1562 acres, 1562 acres, and 1980 acres, respectively). It should be noted that the areas for the capping to the mean PECQ2 and mean PECQ1 include current exceedances of the mercury PEC.

4.7.2.1 SMU 8 Alternative 3 – Thin-Layer Capping
Overall Protection of Human Health and the Environment

This alternative would protect human health and the environment by:

- Immediately reducing surface sediment chemical concentrations through the placement of a thin-layer cap in SMU 8 and

- Immediately reducing the flux of mercury and methylmercury from profundal sediments to the hypolimnion.

Due to the reduction of profundal mercury and methylmercury flux, the amount of methylmercury (and mercury available for methylation) in the hypolimnion would decrease, to the extent profundal flux impacts water column concentrations. Decreased water-column methylmercury concentrations would result in decreased concentrations of mercury in fish tissue and risk to fish consumers. However, anoxic conditions in the hypolimnion would continue to promote mercury methylation and limit benthic macroinvertebrate and fish populations in this region of the lake. In addition to mercury, concentrations of other CPOIs that exceed SEC values would be immediately reduced by thin-layer capping.

The construction of the thin-layer cap would have some impact to any existing benthic communities in the profundal zone. However, because of the anoxic conditions, there is likely little if any community to be impacted. The addition of clean sand would reduce chemical concentrations (and thereby toxicity), and to the extent that anoxic conditions allow, could result in development of a healthier benthic population. The thin layers associated with this type of capping are expected to have a low impact on any existing benthic organisms.

The alternative would make significant progress toward achieving the Onondaga Lake RAOs and PRGs. This alternative meets PRG 1 for SMU 8 and contributes to meeting PRGs 2 and 3 by reducing mercury methylation and bioaccumulation in the hypolimnion to the extent that mercury concentrations in profundal sediment control theses processes. RAOs and PRGs were developed taking into consideration the entire lake, while this alternative addresses SMU 8 only. Achievement of RAOs and PRGs depends on the alternative that would be implemented lake-wide, due to the complexities and interactions among the SMUs and how they impact lake-wide conditions. Therefore, achievement of RAOs and PRGs on a lake-wide basis is addressed in more detail during evaluation of lake-wide alternatives in Section 5.

4.7.2.2 SMU 8 Alternative 3 – Thin-Layer Capping

Compliance with ARARs

As described in Section C.3 of Appendix C, ARARs and TBCs, this option would comply with chemical-specific and action-specific ARARs, with the possible exception of the two most stringent surface water criteria for mercury.

There are no chemical-specific ARARs for sediment quality in Onondaga Lake. The SEC values identified for sediment in Onondaga Lake were used as TBCs in developing PRGs, as detailed in Section 2.

Remedy implementation for the in-lake portion of this alternative may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment during thin-layer capping. Short-term water quality impacts resulting from remedy implementation are addressed quantitatively as part of the evaluation of lake-wide alternatives in Section 5.

This alternative is expected to comply with all designated location-specific and action-specific ARARs. Sediment caps are routinely installed in compliance with all action-specific and location-specific ARARs. These relevant and appropriate ARARs would include substantive requirements of the dredge and fill permit program under Section 404 of the federal Clean Water Act.

4.7.2.3 SMU 8 Alternative 3 – Thin-Layer Capping Short-Term Effectiveness

This alternative would present a low short-term risk to the public because sediments would not be excavated or handled. Reductions in surface sediment total mercury concentrations would occur immediately. There would be some short-term impacts to workers placing the thin-layer cap. Transportation risks increase due to the import of cap materials. In addition, some resuspension of sediments would occur during cap placement affecting the local environment. Overall, this alternative would present little negative impact to the local community.

No sediments would be dredged or handled, so risks to the public and workers associated with a release would be very small. Water quality (turbidity and TSS) is not expected to be an issue; duration of negative impacts to water quality is expected to be short. Surface sediment concentrations would be reduced immediately after placement. Minimal implementation/ residual risk or quality of life issues are associated with this alternative.

4.7.2.4 SMU 8 Alternative 3 – Thin-Layer Capping Long-Term Effectiveness and Permanence

This alternative, in conjunction with upland source control, would provide long-term effectiveness by immediately reducing contaminant concentrations within profundal surface sediments. Further, this alternative is permanent in that profundal sediments have remained relatively undisturbed for hundreds of years (see Appendix N, monitored natural recovery); thus, CPOIs under the thin-layer cap would be expected to remain there permanently. Monitoring would include elements such as periodic core sampling to verify that this alternative is effective and permanent (e.g., reduced CPOI concentrations in sediment).

4.7.2.5 SMU 8 Alternative 3 – Thin-Layer Capping Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative would reduce toxicity by reducing the concentration of CPOIs in profundal surface sediments, the release of mercury to overlying water, and (indirectly) the rate of mercury methylation and bioaccumulation in the water column to the extent that these processes are controlled by the concentration of inorganic mercury. The mobility of CPOIs would also be reduced by thin-layer capping impacted sediments. However, this reduced toxicity and mobility would be achieved through containment rather than through active treatment. This alternative is not expected to reduce the volume of sediments that exceed the SEC values.

4.7.2.6 SMU 8 Alternative 3 – Thin-Layer Capping
Implementability

This alternative is readily implementable. Construction equipment to deliver, place, and spread a thin layer of material (dump trucks, loaders, barges, dredges, etc.) and the required ancillary equipment are locally available. Local contractors are experienced in performing this type of task. Capping material is available from a variety of sources, including regional quarries. Construction specification compliance and long-term monitoring would be described in construction quality assurance and operations, monitoring, and maintenance plans.

4.7.2.7 SMU 8 Alternative 3 – Thin-Layer Capping
Cost

Section 5 includes detailed costs associated with each of the developed lake-wide alternatives. This method allows consideration of economies of scale, providing more realistic overall costs to implement the selected lake-wide remedy.

4.7.3 SMU 8 Alternative 4 – Phased Thin-Layer Capping / MNR

This alternative includes the following components:

- Completion of pre-design investigations to optimize implementation and ensure effectiveness of the MNR and thin-layer cap;
- Installation of a thin-layer cap prior to the start of the MNR period (Phase I) in those areas of the SMU where modeling predicts that the total mercury SEC values established as the cleanup criteria are unlikely to be met by natural recovery;
- Long-term monitoring (Phase II);
- Installation of a thin-layer cap or continued MNR (Phase III) after the end of the initial MNR period in any areas of the SMU that exceed SEC values established as the cleanup criteria; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

This alternative differs from Alternative 3, in which thin-layer capping is performed immediately in all areas that currently exceed the established cleanup criterion, regardless of any future predictions of natural recovery. Rather, this alternative would take place in a phased approach. Phase I activities in the profundal area would initially include limited thin-layer capping in areas that have mercury concentrations that possibly exceed the maximum concentration expected to naturally recover to the total mercury SEC value established for cleanup. This is followed by Phase II monitoring of natural recovery throughout the profundal areas for all CPOIs with cleanup criteria. Phase III would occur after the initial MNR period, and would include additional thin-layer capping and/or continued MNR in areas that did not achieve established cleanup criteria during Phase II. This alternative is described in detail in Subsection 4.6.

This alternative has three options based on the SEC values adopted for the site.

- Alternative 4.A – Phased Thin-Layer Capping to the Mean PECQ2 / Aeration (Oxygenation) / MNR
- Alternative 4.B – Phased Thin-Layer Capping to the Mean PECQ1 / Aeration (Oxygenation) / MNR
- Alternative 4.E – Phased Thin-Layer Capping to ER-L, / Aeration (Oxygenation) / MNR

Thin-layer capping is based on the current (for mean PECQ1, mean PECQ2, AET, PEC, and ER-L) and estimated future (for mercury PEC) exceedances of the SEC adopted. No profundal sediment currently exceeds the mean PECQ2, and only a small area exceeds the mean PECQ1. While a large area currently exceeds the mercury PEC, no profundal surface sediment samples from the 1992 sampling event exceeded the maximum mercury concentration expected by the MNR model to recover to the mercury PEC, as explained in Subsection 4.6.4. To address the possibility that pre-design sampling could identify some marginal areas that have total mercury concentrations that are not expected to recover within 10 years of source controls, an area of 20 acres for Phase I thin-layer capping was assumed for estimation purposes and considered in the mean PECQ2 and mean PECQ1 alternatives.

Thus, three alternatives are being considered for Alternative 4 (i.e., Alternatives 4.A, 4.B, and 4.E) in SMU 8 (see Figures 4.46, 4.47, and 4.48). Thin-layer capping to the AET requires capping of only slightly less area (i.e., 82 acres vs. 154 acres) than Alternative 4.B (i.e., thin-layer capping to the mean PECQ1); therefore, it is less protective and has not been retained. Thin-layer capping to the PEC is very similar to Alternative 4.E (i.e., thin-layer capping to the ER-L) with the exception of six polygons. Therefore, thin-layer capping to the PEC has not been retained.

4.7.3.1 SMU 8 Alternative 4 – Phased Thin-Layer Capping / MNR

Overall Protection of Human Health and the Environment

By using a phased approach, this alternative would protect human health and the environment by:

- Immediately reducing surface sediment chemical concentrations through the placement of a thin-layer cap in portions of SMU 8;
- Reducing surface sediment chemical concentrations over time through MNR and effective source control in other SMUs (e.g., ILWD [SMU 1]);
- Further reducing surface sediment chemical concentrations through additional thin-layer placement, if necessary; and
- Reducing the flux of mercury (using MNR and thin-layer capping) and methylmercury (using thin-layer capping) from profundal sediments to the hypolimnion.

Because upland source control is assumed, the concentration of chemicals in profundal surface sediments would decrease over time, providing protection of human health and the environment. In particular, decreased mercury concentrations in surface sediment would result in decreased releases of total mercury and methylmercury to overlying water. Mercury methylation in the hypolimnion, in turn, would decrease to the extent that methylation is controlled by these profundal fluxes. Decreased mercury methylation would result in decreased concentrations of mercury in fish tissue and risk to fish consumers. However, anoxic conditions in the hypolimnion would continue to promote mercury methylation and to limit benthic macroinvertebrate and fish populations in this region of the lake.

Modeling of natural recovery based on total mercury in SMU 8 (see Appendix N, monitored natural recovery) predicts that surface sediments (4 inches [10 cm]) with mercury concentrations up to 6.7 ppm would recover to the mercury PEC (2.2 ppm) within 10 years of implementing source control. This prediction is based on the conservative assumption that mercury concentrations on SPM would remain at the mean of concentrations observed in sediment traps during the RI (i.e., 1.39 ppm). According to the model, the mercury concentration in surface sediment is controlled by the mercury concentration on SPM. Therefore, the minimum mercury concentration achievable in surface sediments is equal to the SPM mercury concentrations. Thus, using these modeling assumptions, the ER-L is not achievable in profundal sediments via MNR.

In addition to mercury, concentrations of other CPOIs that exceed SEC values would be expected to be reduced as less contaminated particulate material settles to the sediment surface. As discussed in Appendix N, monitored natural recovery, and Subsection 4.6, there is insufficient information to determine the rates of natural recovery for other CPOIs. However, because mercury is ubiquitous in the profundal sediments and, unlike many organic compounds, does not degrade, it is expected to be a suitable indicator chemical for the general recovery of profundal sediments over time.

Where thin-layer capping is performed, this alternative would immediately reduce the concentration of contaminants where applied. As discussed for Alternative 3, thin-layer capping is expected to result in minimal impacts to any benthic communities that may exist in the anoxic conditions of the profundal sediments.

The alternative would make significant progress toward achieving the Onondaga Lake RAOs and PRGs. This alternative meets PRG 1 for SMU 8 over time and contributes to meeting PRGs 2 and 3 by reducing mercury methylation and bioaccumulation in the hypolimnion to the extent that mercury concentrations in profundal sediments control these processes. RAOs and PRGs were developed taking into consideration the entire lake, while this alternative addresses SMU 8 only. Achievement of RAOs and PRGs depends on the alternative that would be implemented lake-wide due to the complexities and interactions among the SMUs and how they impact lake-wide conditions. Therefore, achievement of RAOs and PRGs on a lake-wide basis is addressed in more detail during evaluation of lake-wide alternatives in Section 5.

4.7.3.2 SMU 8 Alternative 4 – Phased Thin-Layer Capping / MNR Compliance with ARARs

As described in Appendix C, ARARs and TBCs, this option would comply with chemical-specific and action-specific ARARs, with the possible exception of the two most stringent surface water criteria for mercury.

There are no chemical-specific ARARs for sediment quality in Onondaga Lake. The SEC values identified for sediment in Onondaga Lake were used as TBCs in developing PRGs, as detailed in Section 2.

Remedy implementation for the in-lake portion of this alternative may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment during thin-layer capping. Short-term water quality impacts resulting from remedy implementation are addressed quantitatively as part of the evaluation of lake-wide alternatives in Section 5.

This alternative is expected to comply with all designated location-specific and action-specific ARARs. Sediment caps are routinely installed in compliance with all action-specific and location-specific ARARs. These relevant and appropriate ARARs would include substantive requirements of the dredge and fill permit program under Section 404 of the federal Clean Water Act.

4.7.3.3 SMU 8 Alternative 4 – Phased Thin-Layer Capping / MNR Short-Term Effectiveness

This alternative would present a low short-term risk to the public because sediments would not be excavated or handled. Reductions in surface sediment total mercury concentrations would not occur immediately in areas without thin-layer capping; rather, they would decrease over time as predicted by the natural recovery model (see Appendix N, monitored natural recovery). There would be some short-term impacts to workers laying the thin-layer cap. Transportation risks increase due to the import of cap materials. In addition, some resuspension of sediments would occur during cap placement, affecting the local environment. Overall, this alternative would present little negative impact to the local community.

No sediments would be dredged or handled, so risks to the public and workers associated with a release would be very small. Water quality (turbidity and TDS) is not expected to be an issue; negative impacts to water quality are expected to be short in duration. Surface sediment concentrations would be reduced immediately after placement. Minimal implementation/ residual risk or quality of life issues are associated with this alternative.

4.7.3.4 SMU 8 Alternative 4 – Phased Thin-Layer Capping / MNR Long-Term Effectiveness and Permanence

This alternative, in conjunction with upland source control, would provide long-term effectiveness by reducing contaminant concentrations within profundal surface sediments. Reductions in mercury concentrations anticipated with natural recovery (as detailed in

Appendix N, monitored natural recovery) would be supplemented by thin-layer capping. Further, this alternative is permanent in that profundal sediments have remained relatively undisturbed for hundreds of years (see Appendix N); thus, CPOIs covered by new SPM with lower chemical concentrations would be expected to remain there permanently. Monitoring may include elements such as periodic core sampling to verify that this alternative is effective and permanent (e.g., reduced CPOI concentrations in sediment).

4.7.3.5 SMU 8 Alternative 4 – Phased Thin-Layer Capping / MNR Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative would reduce toxicity by reducing the concentration of CPOIs in profundal surface sediments, the release of mercury to overlying water, and (indirectly) the rate of mercury methylation and bioaccumulation, to the extent that these processes are controlled by the concentration of inorganic mercury. The mobility of CPOIs would also be reduced by capping impacted sediments. However, this reduced toxicity and mobility would be achieved through containment rather than through active treatment. This alternative is not expected to reduce the volume of sediments that exceed the SEC values.

4.7.3.6 SMU 8 Alternative 4 – Phased Thin-Layer Capping / MNR Implementability

This alternative is readily implementable. Construction equipment to deliver, place, and spread a thin layer of material (dump trucks, loaders, barges, dredges, etc.) and the required ancillary equipment are locally available. Local contractors are experienced in performing this type of task. Material for thin-layer capping is available from a variety of sources, including regional quarries. Construction specification compliance and long-term monitoring would be described in construction quality assurance and in operations, monitoring, and maintenance plans.

4.7.3.7 SMU 8 Alternative 4 – Phased Thin-Layer Capping / MNR Cost

Section 5 includes detailed costs associated with each of the developed lake-wide alternatives. This method allows consideration of economies of scale, providing more realistic overall costs to implement the selected lake-wide remedy.

4.7.4 SMU 8 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

This alternative is similar to Alternative 4 – Phased Thin-Layer Capping / MNR, with the addition of aeration (oxygenation) technology to directly address methylation of mercury in the anoxic hypolimnion. Alternative 6 includes the following components:

- Completion of pre-design investigations to optimize implementation and ensure effectiveness of MNR, aeration (oxygenation), and thin-layer capping, including pilot testing for aeration (oxygenation);

- Installation of a thin-layer cap prior to the start of the MNR period (Phase I) in those areas of the SMU where modeling predicts that the mercury PEC is unlikely to be met by natural recovery, full scale implementation of aeration (oxygenation) if shown to be effective during pilot testing, and establishment of the monitoring program;
- Continued MNR monitoring to assess the effectiveness of natural recovery and aeration (oxygenation) (Phase II);
- Long-term monitoring (Phase III);
- Installation of a thin-layer cap or continued MNR or other contingency action as appropriate (Phase III) after the end of the initial MNR period in any areas of the SMU that exceed the SEC values established as the cleanup criteria; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

This alternative is described in detail in Subsection 4.6. This alternative has three options based on the SEC values adopted for the site.

- Alternative 6.A – Phased Thin-Layer Capping to the Mean PECQ2, Mercury PEC, and BSQV / Aeration (Oxygenation) / MNR
- Alternative 6.B – Phased Thin-Layer Capping to the Mean PECQ1, Mercury PEC, and BSQV / Aeration (Oxygenation) / MNR
- Alternative 6.E – Phased Thin-Layer Capping to ER-L, Mercury PEC, and BSQV / Aeration (Oxygenation) / MNR

Thin-layer capping is based on current (for mean PECQ1, mean PECQ2, AET, PEC, and ER-L) and estimated future (for mercury PEC and mercury bioaccumulation-based sediment quality value [BSQV]) exceedances of the SEC adopted. As discussed in Subsection 4.7.3, no profundal sediment currently exceeds the mean PECQ2, and only a small area exceeds the mean PECQ1. While a large area currently exceeds the mercury PEC, no profundal surface sediment samples from the 1992 sampling event exceeded the maximum mercury concentration expected by the MNR model to recover to the mercury PEC, as explained in Subsection 4.6.4. To address the possibility that pre-design sampling could identify some marginal areas that have total mercury concentrations that are not expected to recover within 10 years of source controls, an area of 20 acres for Phase I thin-layer capping was assumed for estimation purposes and considered in the mean PECQ2 and mean PECQ1 alternatives.

Thus, three alternatives are being considered for Alternative 6 (i.e., Alternatives 6.A, 6.B, and 6.E) in SMU 8 (see Figures 4.46, 4.47, and 4.48). Thin-layer capping to the AET requires capping of only slightly less area (i.e., 82 acres vs. 154 acres) than Alternative 6.B (i.e., thin-layer capping to the mean PECQ1); therefore, it is less protective and has not been retained. Thin-layer capping to the PEC is very similar to Alternative 6.E (i.e., thin-layer capping to the ER-L) with the exception of six polygons. Therefore, thin-layer capping to the PEC has not been retained.

The BSQV for mercury is considered the long-term goal of remediation in the lake. Section 2 briefly describes the BSQV, and Appendix I provides a detailed description. It is anticipated that the area requiring thin-layer capping in SMU 8, if any, to achieve the BSQV-based goal would be determined as part of the pre-design investigation and design process, including revision of the MNR predictions based on additional data to be collected. The BSQV will be compared to a surface area weighted average mercury concentration calculated for a combination of littoral and profundal sediment (described generally in Appendix I), taking into account predicted mercury concentrations in sediment derived from the MNR model, as revised during the pre-design investigation. Additional thin-layer capping in SMU 8 (beyond the area identified in this FS) may be needed in Phase I (not just Phase II) to meet this long-term criterion.

4.7.4.1 SMU 8 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

Overall Protection of Human Health and the Environment

This alternative combines the overall protection provided by Alternative 4 with additional protection through the direct reduction of anoxic conditions in the hypolimnion that contribute to mercury bioaccumulation in the lake. The concentration of chemicals in profundal surface sediments would decrease immediately in areas receiving a thin-layer cap and over time in other areas due to natural recovery. Aeration (oxygenation) would reduce mercury methylation in the hypolimnion which, in turn, should result in decreased concentrations of mercury in fish tissue and risk to fish consumers. This component of the alternative is expected to reduce the flux of methylmercury from profundal sediments (see Appendix N, monitored natural recovery), and would create conditions suitable for colonization of sediment by benthic macroinvertebrates. Given the length of time to re-establish a benthic community and the expected rate of MNR (see Appendix N, monitored natural recovery), sediment available for benthic colonization is not expected to pose risks due to direct toxicity. Recolonization of profundal sediments may increase the potential for contaminants in the profundal zone to be taken up into the food chain. However, this uptake would occur at the same time that contaminant concentrations are declining. Meeting the BSQV as a criterion in Alternative 6 may provide additional protectiveness to wildlife that consume fish.

The alternative would make significant progress toward achieving the Onondaga Lake RAOs and PRGs. This alternative meets PRG 1 for SMU 8 over time and contributes to meeting PRGs 2 and 3 by reducing mercury methylation in the hypolimnion and reducing the profundal flux of mercury and methylmercury to the hypolimnion. RAOs and PRGs were developed taking into consideration the entire lake, while this alternative addresses SMU 8 only. Achievement of RAOs and PRGs depends on the alternative that would be implemented lake-wide, due to the complexities and interactions among the SMUs and how they impact lake-wide conditions. Therefore, achievement of RAOs and PRGs on a lake-wide basis is addressed in more detail during evaluation of lake-wide alternatives in Section 5.

4.7.4.2 SMU 8 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

Compliance with ARARs

As described in Appendix C, ARARs and TBCs, this option would comply with chemical-specific and action-specific ARARs, with the possible exception of the two most stringent surface water criteria for mercury.

There are no chemical-specific ARARs for sediment quality in Onondaga Lake. The SEC values identified for sediment in Onondaga Lake were used as TBCs in developing PRGs, as detailed in Section 2.

Remedy implementation for the in-lake portion of this alternative may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment during thin-layer capping. Short-term water quality impacts resulting from remedy implementation are addressed quantitatively as part of the evaluation of lake-wide alternatives in Section 5.

This alternative is expected to comply with all designated location-specific and action-specific ARARs. Sediment caps are routinely installed in compliance with all action-specific and location-specific ARARs. These relevant and appropriate ARARs would include substantive requirements of the dredge and fill permit program under Section 404 of the federal Clean Water Act.

4.7.4.3 SMU 8 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

Short-Term Effectiveness

This alternative would present a low short-term risk to the public because no public access would be allowed to the construction area. No sediments would be excavated (or dredged) or handled, so risks to the public and workers associated with a release would be very small. Water quality (turbidity and low dissolved oxygen) is not expected to be an issue, because construction disturbances of profundal sediments would be minor. Surface sediment concentrations would be reduced immediately in those areas where a thin-layer cap was placed. The impact of the aeration (oxygenation) system is difficult to predict, which is the main reason for the proposed pilot study prior to full-scale implementation. It is possible that aeration (oxygenation) could cause changes in mercury tissue concentrations in some species due to changes in productivity and food chain length. It is also possible that conversion of profundal surface sediments to oxic conditions could change the toxicity and/or availability of chemicals in those sediments.

4.7.4.4 SMU 8 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

Long-Term Effectiveness and Permanence

By using multiple technologies in a phased approach, this alternative provides long-term effectiveness and permanence by:

- Reducing methylation of mercury in the hypolimnion;
- Reducing surface sediment chemical concentrations through the placement of a thin-layer cap in portions of SMU 8;
- Reducing surface sediment chemical concentrations over time through MNR and effective source control in other SMUs (e.g., ILWD);
- Reducing the flux of mercury and methylmercury from profundal sediments to the hypolimnion; and
- Further reducing surface sediment chemical concentrations through additional thin-layer placement, if necessary.

While it is possible that other measures (e.g., reduction in phosphorus loading from the Metro Plant) would remove the need for active aeration (oxygenation), the future ability of the lake to maintain oxic conditions in the hypolimnion without active intervention (e.g., aeration) is unknown. The aeration (oxygenation) system would therefore need to be maintained into the foreseeable future. As discussed for previous profundal alternatives, naturally recovered and capped sediments are expected to be permanently isolated due to the lack of disturbance expected in the profundal areas of the lake (see Appendix N, monitored natural recovery). Assuming long-term maintenance of the aeration (oxygenation) system coupled with MNR and phased thin-layer capping, this alternative is both effective in the long-term and permanent.

4.7.4.5 SMU 8 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative would reduce toxicity in sediment by reducing the concentration of CPOIs in profundal surface sediments (due to natural recovery) and the release of mercury to overlying water. However, this reduced toxicity and mobility would be achieved through containment rather than through active treatment. Toxicity in water that results from methylmercury, dissolved sulfide, and low dissolved oxygen concentrations would be reduced by this alternative. This alternative is not expected to reduce the volume of sediments that exceed the SEC values. However, it would reduce the volume of water that poses risk due to elevated methylmercury and dissolved sulfide concentrations and low dissolved oxygen concentrations.

4.7.4.6 SMU 8 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

Implementability

Implementation of MNR and phased thin capping, if feasible, is discussed above for similar alternatives. An aeration (oxygenation) system is feasible and could be performed at a relatively low cost. Equipment and trained personnel are readily available. However, pilot studies are recommended to further evaluate the potential effectiveness for reducing formation of methylmercury in the water column and reducing methylmercury concentrations in fish tissue as well as other impacts to the lake system. Measurements of dissolved oxygen, methylmercury, and total suspended solids concentrations in the water column and assessment of changes to primary productivity, the benthic community, ebullition, and the sediment mixing layer would be useful to determine the efficacy of the alternative. Construction specification compliance and long-term monitoring would need to be described in construction quality assurance and in operations, monitoring, and maintenance plans. It is expected that regulatory approval of this alternative could be obtained pending a successful pilot study. In the event this technology was shown to be ineffective, additional remedial actions could readily be implemented.

4.7.4.7 SMU 8 Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR

Cost

Section 5 includes detailed costs associated with each of the developed lake-wide alternatives. This method allows consideration of economies of scale, providing more realistic overall costs to implement the selected lake-wide remedy.

4.7.5 SMU 8 Alternative 8 – Full Removal

Similar to the removal alternatives associated with the littoral area (i.e., Alternative 5 for SMUs 1 through 7), this alternative involves removal of large volumes of sediment to achieve various SEC values. These three options are:

- Alternative 8.A – Full Removal to the Mean PECQ2
- Alternative 8.B – Full Removal to the Mean PECQ1
- Alternative 8.E – Full Removal to the ER-L

Sediment removal is based on the SEC adopted. As a result, only three alternatives are being considered for Alternative 8 (i.e., Alternatives 8.A, 8.B, and 8.E) in SMU 8 (see Figures 4.46, 4.47, and 4.48). Sediment removal to the AET (i.e., approximately 3,440,000 CY) requires less removal than to the mean PECQ1 (i.e., 9,400,000 CY); therefore, it is less protective and has not been retained. Sediment removal to the PEC is very similar to Alternative 6.B (i.e., sediment removal to the mean PECQ1), only approximately 300,000 CY difference. Therefore, sediment removal to the PEC has not been retained.

Removed sediments would be offloaded, transported, and managed at an on-site consolidation area. In addition, residual capping would be implemented if necessary to isolate any residual contamination after dredging. The alternative assumes that upland source control has been implemented independently of the lake remedy.

4.7.5.1 SMU 8 Alternative 8 – Full Removal
Overall Protection of Human Health and the Environment

Dredging under this alternative would reduce or eliminate the risk to human health and the environment associated with the profundal area, with the exception of mercury methylation in the hypolimnion. This alternative would reduce mercury methylation and bioaccumulation to the extent that the concentration of mercury in sediment influences these processes. However, mercury methylation is expected to continue in the presence of anoxic conditions in the hypolimnion. The dredging would take considerable time, particularly to the lower SEC values, and mercury flux to the water column would be greatly increased in this period, creating uncertain long-term effects. The alternative protects benthic macroinvertebrates and fish in the long term that could be at risk due to direct exposure to sediment in the profundal area, if oxic conditions existed in the profundal area. However, dredging would eliminate any limited benthic communities that may exist in the anoxic conditions of the profundal sediments. Assuming that the profundal sediment remains anoxic, little net change in the benthic communities is expected over the long term for this alternative.

The alternative would make significant progress toward achieving the Onondaga Lake RAOs and PRGs. This alternative meets PRG 1 for SMU 8 and contributes to meeting PRGs 2 and 3 by reducing mercury methylation and bioaccumulation in the hypolimnion to the extent that the concentration of mercury in sediment controls these processes. RAOs and PRGs were developed taking into consideration the entire lake, while this alternative addresses SMU 8 only. Achievement of RAOs and PRGs depends on the alternative that would be implemented lake-wide, due to the complexities and interactions among the SMUs and how they impact lake-wide conditions. Therefore, achievement of RAOs and PRGs on a lake-wide basis is addressed in more detail during evaluation of lake-wide alternatives in Section 5.

4.7.5.2 SMU 8 Alternative 8 – Full Removal
Compliance with ARARs

As described in Appendix C, ARARs and TBCs, this option would comply with chemical-specific and action-specific ARARs, with the possible exception of the two most stringent surface water criteria for mercury.

There are no chemical-specific ARARs for sediment quality in Onondaga Lake. The SEC values identified for sediment in Onondaga Lake were used as TBCs in developing PRGs, as detailed in Section 2.

Remedy implementation for the in-lake portion of this alternative may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment during thin-layer capping. Short-term water quality impacts resulting from remedy implementation are addressed quantitatively as part of the evaluation of lake-wide alternatives in Section 5.

This alternative is expected to comply with all designated location-specific and action-specific ARARs. Sediment caps are routinely installed in compliance with all action-specific and location-specific ARARs. These relevant and appropriate ARARs would include substantive requirements of the dredge and fill permit program under Section 404 of the federal Clean Water Act.

4.7.5.3 SMU 8 Alternative 8 – Full Removal
Short-Term Effectiveness

Physical construction of this alternative could likely be completed in approximately six to 30 years. Sediment disturbance leading to benthic impacts, if any, and short-term water quality issues would be expected to occur throughout this period. Increased risk of vehicular accidents would result during the import of backfill materials by truck to the site and when the sediment is hauled for consolidation following dredging. There is also the potential for pipeline rupture if the material is hydraulically removed and transferred to the SCA by pipeline. The incidence of fatal and non-fatal accidents due to consolidation of the removed material and import of residual cap material may be significant.

Implementation of this alternative would occur over an extended period, as noted above, and may have significant impacts to the surrounding community. Because of the longer period of implementation, quality of life issues could include delays in completing the planned walking and biking trail around the lake, impacts to areas where people congregate, proximity to residences, and impacts on canoeing, fishing, or other recreational uses of Onondaga Lake.

4.7.5.4 SMU 8 Alternative 8 – Full Removal
Long-Term Effectiveness and Permanence

This alternative would be effective in the long term by removing sediments with chemical concentrations greater than the SEC vales from within the profundal area. Any residual contamination following removal would be covered by backfill to reduce or eliminate CPOI mobility and potential toxic effects on human health and fish and wildlife resources. With source control in place, this alternative would provide a permanent remedy for the existing contaminated sediments in the profundal zone. However, mercury methylation would continue to occur as long as the hypolimnion remains anoxic. Therefore, the alternative is not considered effective in directly reducing mercury methylation.

Dredged sediments would be contained within the SCA, which would isolate them from the environment, assuming proper design and monitoring at the landfill site. A proven long-term O&M program would ensure the adequacy and reliability of the SCA, as discussed in Subsection 4.9.

4.7.5.5 SMU 8 Alternative 8 – Full Removal
Reduction of Toxicity, Mobility, or Volume through Treatment

The volume of impacted media within the lake would be reduced under this alternative by removal of impacted sediment to site-specific SEC concentrations. The sediment removed would be transferred to the on-site SCA, where the total volume and mobility of sediment would be reduced through in-place sediment consolidation and removal of water. Toxicity, mobility, and volume of CPOIs would be further reduced under these options through treatment of water generated during dredging and sediment consolidation prior to discharge back to the lake.

4.7.5.6 SMU 8 Alternative 8 – Full Removal
Implementability

The same implementability issues related to dredging in the littoral zone apply to Alternative 8 in the profundal zone. However, significant additional implementability issues would be presented by this alternative to due the large volume of sediment that would be dredged. Over 9,000,000 cubic yards of sediment would be dredged in SMU 8 under this alternative. This would be a monumental undertaking, and the large volume would have significant impacts on implementability. The sediment from SMU 8 only would be larger than any other contaminated sediment-dredging project ever done in the United States (MCSSD, 2002). If the material was placed 40 feet high, it would take over 140 acres to hold the dredged material.

The dredged slurry would have to be discharged evenly throughout the settling basin. One way to accomplish this is to connect the dredge pipeline to a flexible, floating pipeline in the settling basin and install a diffuser at the end of the flexible pipeline. The diffuser would have to be continuously moved in the basin to provide uniform distribution of material.

Since the dredge slurry that is discharged into the settling basin would have essentially zero shear strength, the perimeter berms would have to be designed as earth dams. The design and operation would have to be carefully engineered to control the lateral loads on the perimeter berms to ensure that the SCA facility was stable during all construction seasons. The existing wastebed material under the perimeter dikes may not have sufficient shear strength to support the dikes. This is often the case for the foundations of earth dams, and the soil has to be strengthened or replaced prior to building dams. The sequence of construction would require thorough analysis during design.

The dredged slurry would experience several feet of self-weight consolidation settlement after it was placed into the SCA. The magnitude and rate of consolidation settlement depends on the thickness and properties of the material. With perimeter dikes 50 ft high and contaminated dredged material 40 to 45 ft thick as assumed for the littoral dredging alternative of 4,000,000 CY, the consolidation settlement would take decades. The low strength and highly compressible nature of the dredged slurry would restrict future use of the SCA site.

As discussed for littoral dredging, construction of the SCA to contain 9,000,000 to 15,000,000 CY would be a major earthwork project. With up to 15,000,000 CY dredged from the profundal zone alone, there may be space limitations in areas that are currently considered for siting the SCA. In addition, height restrictions would make implementation difficult. A facility to contain these dredged sediments would entail literally creating a new hill in the city, which would make a visual impact on the community. The town of Camillus previously has restricted the height of Wastebed 15, which is near Wastebed 13, to 468 ft above mean sea level. This would restrict the height of dikes in Wastebed 13 to about 23 ft (7 m).

Additional implementability issues associated with construction of a large SCA are discussed in Subsection 4.9.

4.7.5.7 SMU 8 Alternative 8 – Full Removal

Cost

Section 5 includes detailed costs associated with each of the developed lake-wide alternatives. This method allows consideration of economies of scale, providing more realistic overall costs to implement the selected lake-wide remedy.

4.8 COMPARATIVE ANALYSIS FOR PROFUNDAL AREA ALTERNATIVES

This subsection provides a summary comparison of the five alternatives evaluated in Subsection 4.7 for the profundal area based on CERCLA and NCP evaluation criteria. As detailed in Subsection 4.6, the following alternatives were retained for SMU 8:

Alternative 1:	No Action
Alternative 3:	Thin-Layer Capping
Alternative 4:	Phased Thin-Layer Capping / MNR
Alternative 6:	Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR
Alternative 8:	Full Removal

These alternatives are compared for each of the seven CERCLA criteria below.

4.8.1 Overall Protection of Human Health and the Environment

Alternative 1 is not protective of human health and the environment. Alternatives 3, 4, 6, and 8 are protective of human health and the environment and to lesser or greater extents address RAOs 1, 3, and 4. Alternatives relying on MNR or dredging as a major component would require a longer time after source control activities are implemented to fully protect human health and the environment. The benthic community within the anoxic profundal sediments is limited, so Alternative 6, which includes aeration of the hypolimnion, would have greater potential benefits to the benthic community. Other alternatives would be expected to reduce toxicity, but these sediments are unlikely to be colonized under anoxic conditions. Although colonization results in increased bioturbation of deeper, more impacted sediments, natural recovery modeling (see Appendix N, monitored natural recovery) indicates that natural recovery would still proceed under oxic conditions at a rate that would be protective of the benthic community in the long term.

Alternatives 3, 6, and 8 would likely cause more appreciable reductions in mercury and methylmercury flux from the profundal sediment (RAO 3) as compared to other alternatives. Alternative 6, using aeration (oxygenation), would provide the greatest reduction in methylmercury profundal flux and may provide additional protectiveness to wildlife that consume fish because the BSQV should be achieved. In addition, it is the only alternative that is expected to have a direct impact on methylation of mercury in the hypolimnion (RAO 1) and a resulting appreciable positive impact on fish tissue mercury concentrations. The ongoing presence of an anoxic hypolimnion in Alternatives 3, 4, and 8 would allow mercury methylation to continue at some rate.

Compared to the other alternatives, Alternative 8 has much greater risk to human health and the environment during implementation (e.g., during removal, transportation, and disposal). Dredging would provide similar long-term effectiveness as MNR, because SPM concentrations would control surface sediment concentrations over time. The importance of buried profundal sediment (which Alternative 8 would address) as a source of mercury to the water column is unresolved at this time. Thus, dredging may be less effective, due to short-term water quality impacts, than some of the other alternatives, has considerable implementation issues, and is the most costly alternative. The areas requiring dredging under this alternative are 1562 acres for Alternative 8.A, 1562 acres for Alternative 8.B, and 1980 acres for Alternative 8.E.

Similar but significantly lower-level impacts could occur during thin-layer cap placement under Alternative 3. Additionally, impacts to the water quality, air emissions, odor, etc. would be sustained for a significantly longer time under Alternative 8.

It is important to note that all active alternatives (3, 4, 6, and 8) are predicted to achieve similar final long-term sediment concentrations (RAO 1). This was determined by the post-source control SPM chemical concentrations. Thus, over the long term, the risks from surface sediment chemical concentrations would be essentially the same under every alternative.

The options under Alternatives 3 and 8 are based on meeting the various SEC values. The areas exceeding the mean PECQ2 are relatively small in the profundal sediments. Thus, the exceedance of mercury PEC is the primary factor in determining areas and volumes under these alternatives. As noted above, dredging or capping to achieve levels below the SPM mercury concentrations is only viable in the short-term, and eventually all areas would approach the SPM mercury concentrations. Consequently, dredging or capping to below these SPM levels appears to provide no addition long-term protection to human health and the environment.

In summary, Alternative 6 provides the greatest combination of long-term protectiveness because it directly addresses methylation in the hypolimnion (RAO 1) as well as the benefits of the other alternatives that address RAOs 3 and 4.

4.8.2 Compliance with ARARS

Alternatives 3, 4, 6, and 8 are expected to comply with all designated chemical-specific ARARs to the extent that this SMU contributes to lake-wide conditions. Exceedances of surface water ARARs result from CPOI contributions from multiple sources other than SMU 8; therefore, remediation of SMU 8 alone is not expected to result in achievement of surface water ARARs.

As noted throughout Subsection 4.7, even with remediation of SMU 8 and other sources, achievement of surface water ARARs for Onondaga Lake may be difficult. In particular, two state surface water quality standards for dissolved mercury (i.e., standards for protecting wildlife and human health via fish consumption) are currently exceeded in the lake. Due to ongoing sources of mercury to the lake that are unrelated to the former Honeywell operations, it may be difficult to meet these surface water quality standards for mercury in Onondaga Lake. However, it is anticipated that remediation of SMU 8 and other upland and in-lake mercury sources would significantly reduce mercury loading, resulting in achievement of these ARARs or progress toward meeting these ARARs to the extent practicable.

There are no chemical-specific ARARs for sediment quality in Onondaga Lake. TBCs identified for sediment in Onondaga Lake include the SECs developed in the RI. As detailed in Section 2, these TBCs were used to develop remedial alternatives evaluated herein.

The implementation of Alternatives 3 and 8 may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment. Alternatives 4 and 6 would have similar water quality impacts as Alternative 3, but over smaller areas and with less duration. However, sediment disturbance and short-term exceedances of surface water ARARs are expected to be significantly greater during dredging under Alternative 8. Short-term water quality impacts resulting from remedy implementation are addressed quantitatively as part of the evaluation of lake-wide alternatives in Section 5.

Alternatives 4 through 8 are expected to comply with all designated location-specific and action-specific ARARs. Sediment caps are routinely installed in compliance with all action-specific and location-specific ARARs. These relevant and appropriate ARARs would include substantive requirements of the dredge and fill permit program under Section 404 of the federal Clean Water Act.

4.8.3 Short-Term Effectiveness

Alternative 1 would present no short-term implementation risks because no action would be taken.

Alternatives 3, 4, 6, and 8 would include some degree of short-term impacts to the lake during the construction and implementation phase, including:

- Temporary loss of lake habitat (Alternatives 3, 4, 6, and 8);

- Water quality issues during placement of the thin-layer cap (Alternatives 3, 4, and 6) and dredging with backfilling (Alternative 8);
- Potential for on-site worker and transportation accidents associated with remedial construction issues related to capping (Alternatives 3, 4, and 6) and dredging (Alternative 8); and
- Quality of life impacts associated with increased truck traffic on local roads (Alternatives 3, 4, 6, and 8).

In general, the greater the volume of capping material or dredging, the higher the short-term impacts. Therefore, Alternatives 3 and 8 would have the greatest short-term impacts of these types, with Alternative 8 greatly exceeding all other alternatives.

Short-term impacts may be mitigated at least in part through engineering controls, including controlled dredging, use of dredging controls such as silt curtains, wearing proper PPE, and adequate monitoring. It is assumed that engineering controls would be used as appropriate during implementation of all alternatives. Thus, even with these controls, the ranking of short-term impacts discussed above would be similar.

4.8.4 Long-Term Effectiveness and Permanence

Alternative 1 would not provide long-term effectiveness or permanence. Under the remaining alternatives, long-term effectiveness and permanence would depend on the effectiveness of upland source control measures and actions taken in the littoral SMUs in large part. It is expected that Alternatives 3, 4, 6, and 8 would provide long-term effectiveness and permanence. Natural recovery areas would take more time to be effective than those areas that receive either a thin-layer or residual cap (particularly Alternatives 3 and 8), though the overall magnitude of the human health and ecological risk over the recovery period would vary with the size of the MNR area and the effectiveness of other actions (e.g., source control, aeration). It should be noted that the duration of profundal dredging in Alternative 8 is so great (e.g., 6 to 30 years) that the time it takes to achieve cleanup criteria may be similar to or longer than under MNR. Aeration (oxygenation) in Alternative 6 would have to be continued for the foreseeable future until or unless other factors (e.g., reduced phosphorus loading to the lake) result in oxic conditions throughout the water column.

With the exception of Alternative 1, long-term monitoring and the implementation of contingent response actions over the recovery period would ensure the adequacy and reliability of these actions to control untreated wastes that remain.

4.8.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 8 would reduce the toxicity, mobility, and volume of impacted sediments through dredging. Under Alternatives 3, 4, and 6, natural recovery processes and thin-layer capping are expected to reduce the toxicity and mobility of CPOIs in sediment over time, although not through treatment. With the exception of Alternatives 6 and 8, these alternatives are not expected to reduce the volume of impacted sediments, since no treatment is taking place. Alternative 6 includes aeration (oxygenation), which is a form of treatment; however, aeration may negatively affect MNR in the profundal area, as previously stated. It may help reduce the toxicity of mercury in water through the reduction in methylmercury concentrations in water and the removal of sulfide and low dissolved oxygen conditions that limit biological activity in this area.

For Alternative 8, the volume of impacted media within the lake would be reduced by removal of impacted sediment to site-specific SEC concentrations. The sediment removed would be transferred to the on-site SCA, where the total volume and mobility of sediment would be reduced through in-place sediment consolidation and removal of water. Toxicity, mobility and volume of CPOIs would be further reduced through treatment of water generated during dredging and sediment consolidation prior to discharge back to the lake.

4.8.6 Implementability

No technical or administrative issues have been identified that would limit the feasibility of implementing any of the alternatives for the profundal area, with the exception of Alternative 8. Alternative 8 would require removal of almost 6 million cubic yards of sediment, which would be larger than any environmental dredging project ever completed in this country. The size and duration of this removal would present numerous implementation challenges.

Aeration (oxygenation) does not have a well-documented history in terms of remediation of mercury contamination and would require pilot testing to identify the most reliable and effective technology as well as impacts on mercury methylation and bioaccumulation and other fundamental lake parameters and processes.

Monitoring of all the alternatives is well understood, and there are minimal limitations on the implementation of additional, contingent remedial actions, if necessary.

4.8.7 Costs

Costs vary significantly by alternative. In general, the greater the area capped and the greater the volume dredged, the higher the cost. Section 5 includes detailed cost estimates associated with each of the lake-wide alternatives evaluated. Estimating costs based on lake-wide alternatives allows consideration of economies of scale and more accurate distribution of costs associated with issues such as SCA and water treatment facility construction. This allows more accurate cost estimating and provides an appropriate basis for evaluating and comparing alternatives.

4.8.8 Summary

The No Action Alternative does not meet the threshold criterion of overall protection of human health and the environment for SMU 8. The other alternatives meet the threshold. Alternative 6 is the only alternative that directly addresses mercury methylation in the hypolimnion; although, aeration may slow down MNR in the profundal area. Alternative 6 may also provide additional protectiveness to wildlife that consume fish because the BSQV would be achieved. Alternatives 3, 4, and 8 indirectly address mercury methylation by reducing the mass of mercury available for release to the hypolimnion and subsequent methylation, but if anoxia in the hypolimnion persists, mercury methylation would continue. Alternative 8 would result in significantly greater short-term risks and remedial costs than the other alternatives.

Based on this analysis, Alternative 6 – Thin-Layer Capping / Aeration (Oxygenation) / MNR is the only alternative recommended to be carried forward in the lake-wide alternatives section. This alternative presents the best balance in meeting all seven of the CERCLA screening criteria.

Alternative 6 would provide immediate benefits to potential benthic communities through the immediate reduction in surface sediment concentrations after thin-layer capping. Natural recovery modeling (see Appendix N, monitored natural recovery) has shown that natural recovery would proceed at a rate protective of the benthic community even in the presence of increased bioturbation created by an oxic hypolimnion. Aeration (oxygenation) would likely reduce mercury methylation in the hypolimnion and is expected to result in reduced mercury concentrations in fish tissue, but further study is required. Alternative 6 would also help reduce the toxicity of water through the reduction in methylmercury concentrations in water and the removal of sulfide and low dissolved oxygen conditions that limit biological activity in this area. However, MNR is an important aspect of Alternative 6, and the positive and negative effects of aeration would need to be thoroughly evaluated and monitored prior to and during implementation of this remedy.

Thin-layer capping and aeration in Alternative 6 would have minor, short-term impacts to the community, site employees, remediation workers, air, and surface water during construction compared to Alternative 8. Short-term impacts may be mitigated at least in part through engineering controls. It is assumed that engineering controls would be used as appropriate during implementation of alternatives. Long-term monitoring and the implementation of contingent response actions over the recovery period would ensure the adequacy and reliability of these actions to control remaining untreated wastes.

4.9 DETAILED EVALUATION OF SEDIMENT MANAGEMENT AND SUPERNATANT TREATMENT COMPONENTS

As discussed in previous sections, several potential remedial alternatives would require removal of large volumes of sediments through dredging. Two important components of these dredging alternatives are management of the dredged sediments and treatment of the entrained water in a manner that is protective of human health and the environment. This section presents the detailed evaluation of sediment management and supernatant water treatment components of the dredging alternatives presented for each of the SMUs.

Large sediment-dredging projects require large areas for management of the dredged sediment. Typically, the dredged sediment from a remediation project is either consolidated in an on-site location, if sufficient land area is available, or solidified and transported to an off-site permitted landfill (USEPA, 1994a). In addition to the Onondaga Lake remediation discussed herein, Honeywell is undertaking remedial activities at several upland areas to put these properties into productive use for the community. These areas have various sizes, locations, and reuse plans, and may be able to accommodate consolidated lake sediment consistent with the proposed reuse. A screening evaluation of these Honeywell properties based on estimated sediment capacity, accessibility, and planned reuse is presented in Subsection 4.9.1.

Subsection 4.9.2 discusses and evaluates the on-site consolidation and off-site disposal options. The on-site consolidation options consider both hydraulic dredging and mechanical dredging with sediment consolidation in a SCA. As discussed in Appendix L, dredging issues, hydraulic dredging has been shown to be an effective and efficient dredging technology that results in fast removal of sediments under a variety of conditions. The off-site disposal option assumes transportation to and disposal in a commercial non-hazardous waste landfill. However, a key element of off-site disposal is solidification to meet acceptance criteria at the selected landfill. Mechanical dredging is usually the most efficient approach with use of an off-site disposal facility, since this dredging method minimizes the water content of the sediment to be solidified and therefore minimizes costs associated with water treatment. However, for completeness of this FS and the detailed evaluations of sediment management options, dredging for off-site disposal options are evaluated using both hydraulic and mechanical dredging techniques. These evaluations are presented in Appendix K.

Therefore, the sediment management options considered herein are:

- Option 1 – Hydraulic Dredging with On-Site Consolidation at a SCA,
- Option 2 – Mechanical Dredging with Off-Site Disposal at a Non-hazardous Waste Landfill,
- Option 3 – Mechanical Dredging with On-Site Consolidation at a SCA, and
- Option 4 – Hydraulic Dredging with Off-Site Disposal at a Non-hazardous Waste Landfill.

The dredging / sediment management systems evaluation concluded that Option 1 was the most cost effective method for dredging with onsite sediment management and Option 2 was the most cost effective option for dredging with off-site sediment disposal. Therefore, only these two options are being carried through for detailed analysis of lake-wide alternatives.

To provide a consistent basis for evaluation of sediment management alternatives, two important assumptions are required. First, since conclusive data and information on past waste disposal practices are not presently available, an accurate Resource Conservation and Recovery Act (RCRA) waste determination cannot be made at this time. However, limited toxicity characteristic leaching procedure (TCLP) data show, in general, average concentrations of contaminants in TCLP extracts well below RCRA regulatory levels. Dichlorobenzene exceeded the TCLP regulatory limit in one sample, and the average TCLP concentration for dichlorobenzene was not far below the RCRA regulatory levels for two of the three cores where TCLP samples were collected. However, for this FS, it is assumed that the sediment removed from Onondaga Lake would be managed and disposed as RCRA non-hazardous waste. It is possible that TCLP exceedances may be detected during the pre-design sampling; the appropriate measures would be implemented, as required.

Second, it is assumed that consolidation of sediment in one or more of the Solvay wastebeds or elsewhere on Honeywell property near the lake would be accomplished as a CERCLA "on-site action." Honeywell will work with NYSDEC to further evaluate these assumptions.

Subsection 4.9.3 considers various supernatant water treatment options for the lake water entrained with the hydraulically-dredged sediment. Five possible treatment scenarios are presented and evaluated in detail. All of these options incorporate discharge back to Onondaga Lake. A sixth treatment option includes pretreatment and discharge to the Metro Plant. However, this option has not undergone detailed analysis, since the Metro Plant does not currently accept these types of water discharges. Therefore, the five supernatant water treatment options retained for detailed evaluation are:

- Option 1 – Primary Treatment;
- Option 2 – Enhanced Primary Treatment;
- Option 3 – Enhanced Primary Treatment with Multimedia Filtration;
- Option 4 - Advanced Treatment; and
- Option 5 – Enhanced Primary Treatment plus Organics Removal.

The mechanical dredging/off-site disposal option results in much lower volumes of entrained water to be managed. For this these analysis, it is assumed that water resulting from the dewatering/solidification efforts would be conveyed by pipe to the Willis Avenue Groundwater Treatment Plant (GWTP), which is being built to address not only long-term groundwater discharges but also construction water resulting from implementation of the upland sites IRMs. In essence, the flow would be treated as construction water from the implementation of the lake remediation.

Each of the two sediment management options, as well as the five supernatant water treatment options corresponding to the on-site sediment management option, are evaluated under four *in situ* sediment volume dredging scenarios: 100,000 CY, 500,00 CY, 1,000,000 CY, and 10,000,000 CY. It should be noted that the endpoints of this broad range of sediment volumes are not necessarily consistent with the dredging volumes that are identified elsewhere in this document and that are determined on technical merit. However, the evaluation over this large range of volumes serves two purposes. First, it identifies possible implementation constraints at various volume levels. Second, the evaluation provides a full range of estimated costs and implementation risks to assess relative strengths and weaknesses of the two options at various volume points.

As presented and described in Subsection 4.1, the detailed evaluations in Subsections 4.9.2 and 4.9.3 are based on seven criteria. The two most important, or threshold criteria, are 1) overall protection of human health and the environment and 2) compliance with ARARs. The remaining five primary balancing criteria are 3) short-term effectiveness; 4) long-term effectiveness and permanence; 5) reduction of toxicity, mobility, or volume through treatment; 6) implementability, and 7) cost. Two additional modifying criteria are 8) community acceptance and 9) agency acceptance, which need to be addressed by the public and by agencies, respectively. Specific elements within each of these criteria are outlined in Subsection 4.1.

4.9.1 Site Screening Evaluation for the On-Site SCA

As discussed in the previous section, large sediment remediation projects require a significant area for on-site management of dredged sediments, i.e. a SCA. Management of hydraulically-dredged remediation sediments on site is typically accomplished in what the USACE terms a confined disposal facility (CDF). CDFs are engineered impoundments consisting of dikes specifically designed to retain sediment solids while allowing the clarified supernatant water to return to the water body of origin (USACE, 1987; USEPA, 1994a). CDFs may be constructed in an upland area (above the water table), near shore (partially in the water), or within the water body undergoing remediation (island CDFs), depending on site-specific requirements and the availability of land suitable for CDF construction. Several large sediment projects that have used CDFs for management of remediation sediments are summarized below:

- Grand Calumet River, Indiana: Approximately 790,000 CY of PCB-, PAH-, and metals-impacted sediment were hydraulically dredged and piped to a 38-acre upland CDF. The Calumet CDF is constructed 10 ft (3 m) below grade with 20-ft (6-m) dikes (30 ft [9 m] total depth) and has a total capacity of 1,300,000 CY.
- Lavaca Bay, Texas: Approximately 170,000 CY of sediment impacted by mercury and PAHs from chlor-alkali processes were hydraulically dredged to a 200-acre CDF with 30-ft (9-m) dikes constructed on a man-made island in the bay. Remaining capacity in the CDF will be used for future dredging and remedial activities.
- Sitcum Waterway, Commencement Bay, Washington: Approximately 500,000 CY of impacted sediment and 1,500,000 CY of unimpacted sediment were hydraulically dredged and managed in a 24-acre near-shore CDF with 40-ft (12-m) dikes.

The SCA proposed for on-site sediment management for Onondaga Lake would be constructed and operated to be protective of human health and the environment as provided in USACE and USEPA guidance documents for CDFs (USACE, 1983, 1987, 2003; USEPA, 1991c, 1994a, 1996). Since restoration of Onondaga Lake and its shoreline to optimal recreational use is an important objective for Honeywell, consolidation of sediments in an in-water and near-shore SCA are not considered in this FS. However, several upland areas owned by Honeywell are currently in the remedial planning stage and are potentially suitable for construction and operation of a SCA, consistent with possible reuse plans (Figure 4.49). These areas are:

- LCP Bridge Street;
- Willis Avenue/Semet;
- Wastebed B; and
- Wastebeds 9 through 15.

In the following paragraphs, these areas are screened, based on accessibility, estimated capacity, and consistency with the planned reuse of the area, to identify the optimal location for construction and operation of a SCA. A fully detailed evaluation using the seven criteria was not performed, since data on the areas are incomplete and additional testing and evaluation will be required prior to final selection of the SCA site. The purpose of this site evaluation, therefore, is to summarize current information on the areas to identify a suitable area for evaluation and cost estimating of the on-site consolidation alternative for the FS. A final determination of the SCA location would be made once additional geotechnical testing and evaluation are performed.

Accessibility to the SCA location, for both truck traffic and for piping of the sediment slurry, is another primary screening criterion considered in the site screening evaluation. All areas under consideration are readily available to truck traffic (Figure 4.49). The LCP site, Willis Ave/Semet site, and Wastebed B are located in or near industrial areas and have generally better access to major traffic thoroughfares than Wastebeds 9 through 15. For running sediment slurry piping to the SCA from the lake, areas close to the lake or Ninemile Creek are favored, as the piping is anticipated to be located along surface waterways to avoid overland obstacles. Wastebed B and the Willis Ave/Semet site have optimal accessibility for sediment slurry piping, as they are located on or near the shore of the lake. Wastebeds 9 through 11 and Wastebed 13 are also good locations as they lie adjacent to Ninemile creek. The LCP site and Wastebeds 12, 14, and 15 are not adjacent to Ninemile Creek but may be accessed through one of its tributaries.

All of the areas discussed are currently planned for restoration by Honeywell for productive future use and redevelopment. Planned future use of the area is an important consideration in the SCA site screening evaluation, since the designed SCA would have to be consistent with that use. Each area has been evaluated by engineers, developers, and landscape architects to determine:

- The areas with the highest potential for reuse, both recreational and commercial;
- The specific types of reuse (i.e., recreational facilities, parking, industrial/commercial use, environmental enhancements, etc.), including development of conceptual plans and renderings; and,
- The volumes of additional material that the areas can accept under the conceptual planned reuse scenarios.

A general description of the potential reuse scenarios for each of the areas is summarized in Table 4.17. Both the LCP and Willis Ave/Semet sites have potential to be returned to productive industrial use and parking following remedial activities undertaken by Honeywell. However, the potential remedial activities and reuse scenarios for the LCP and Willis Ave/Semet sites would limit the volume of sediments these areas could receive to 120,000 and 300,000 CY, respectively. Similarly, Wastebed B has potential for recreational use as a lakeside park with commercial amenities. The capacity of this area for additional material is limited to 200,000 CY, due to elevation constraints applicable to the planned reuse. The reuse plan for Wastebeds 9 and 10 includes parking for the state fairgrounds, recreation facilities (soccer stadium and track), and environmental enhancements. Although significant capacity is potentially available at these wastebeds, geotechnical concerns associated with future use may limit the actual volumes that may be placed at these areas. Wastebeds 11 through 15 have potential for environmental enhancements and recreational features, possibly including athletic fields and bike/pedestrian paths. Because of the areal size of the wastebeds, volumes of dredged sediments approaching and over 8,000,000 CY could be managed at Wastebeds 11 through 15 without any significant impacts on the planned reuse.

To evaluate the capacities of potential SCA siting areas, the maximum thickness of the sediment within the SCA was conservatively assumed to be 10 ft (3 m) (14-ft [4.3-m] dike height). This maximum thickness was selected to address potential stability issues associated with the underlying Solvay waste material in the wastebeds. However, it should be noted that for detailed evaluation of the 10,000,000 CY volume scenario, it was necessary to assume a 46-ft (14-m) sediment thickness within the SCA (50-ft [15-m] dike height).

To minimize the variables in cost estimating and comparing the lake-wide alternatives, two dike heights were chosen: 14-foot-high dikes for the lower dredge volume scenarios and 50-foot-high dikes for the higher dredge volume scenarios. The design of the SCA would incorporate several variables:

- Pumping rate of the slurry inflow,
- Settling velocity of the suspended sediment from the slurry,
- Depth of slurry (a component of total dike height),
- Depth of settled-out sediment (a component of total dike height), and
- Area of the SCA.

This dike height was used because it represents the most cost-effective design for the SCA at this volume scenario and allows sediment consolidation at one location. During the design stage, the above-listed variables would be defined by construction planning and further laboratory testing; it would be possible to adjust the other variables and optimize the design of the SCA to result in the most cost-efficient design. Because this refinement would come during the design stage, the goal in the FS was to select variables for the SCA that would be feasible for as many alternatives as possible, so that alternatives could be cost-estimated and compared on a uniform basis.

The depth of SCA over the wastebeds would be determined in the design phase based on additional geotechnical data collected from the wastebeds, but a dike height of 14 feet (with 10 feet of deposited sediment) is likely to be feasible. The dike height was set to this constant value and the area of the SCA was adjusted until the volume requirement for each alternative had been met. This constant dike height allows comparisons between alternatives with similar design assumptions and perhaps similar levels of feasibility. Estimated sediment capacities using the 10-ft (3-m) sediment thickness criterion for the areas evaluated are presented in Table 4.17. Based on this screening criterion, Wastebed 13 has the largest potential capacity for dredged sediment and the greatest flexibility for design of the SCA.

As shown on Table 4.17, overall, Wastebed 13 could accommodate a sediment volume of 2,400,000 CY, without any impact to the planned reuse scenario. The areal dimensions of Wastebed 13 also provide the most flexibility for SCA design. Although easily accessed by truck and slurry pipeline, its relatively remote location away from the lake and commercial areas would minimize disruption to and impacts on the community during construction and operation of an SCA. Therefore, for evaluating the on-site sediment management option for this FS, Wastebed 13 is used as the assumed location for construction and operation of the SCA. If more than 2,400,000 CY of sediment is removed from the lake, then additional capacity may have to be located at other wastebeds. Furthermore, detailed evaluation of the wastebed sites may result in the selection of a different location for the SCA.

Potential SCA locations and sediment capacities would be more completely evaluated during the predesign geotechnical investigation and IRM investigations of the wastebeds. These studies would determine the optimal location, given the sediment volumes anticipated and site-specific geotechnical data.

4.9.2 Sediment Management Options

As discussed above, two sediment management options are evaluated in this FS: on-site consolidation at a SCA and off-site disposal at a non-hazardous waste landfill. For each option, four different in-place sediment volumes are considered, representing a range of lake-wide dredging alternatives: 100,000 CY, 500,000 CY, 1,000,000 CY, and 10,000,000 CY.

The following two sections present the development of the on-site consolidation and off-site disposal options.

Development of the On-Site Sediment Consolidation Option

The process required to hydraulically dredge with consolidation at a SCA is shown schematically in Figure 4.50. These processes include:

- Constructing the SCA, including preloading and stabilization (if required);
- Hydraulically dredging the sediment;
- Pumping the dredged sediment slurry to the SCA through piping;
- Processing and dewatering sediment in the SCA;
- Treating separated supernatant water from the SCA; and

- Capping the consolidated sediments in the SCA and restoring the area in accordance with the planned reuse.

Construction and operation of the SCA would be in accordance with applicable USACE and USEPA guidance to ensure protection of human health and the environment (USACE, 1987, 2003; USEPA, 1991c, 1994a, 1996). The primary objectives of the SCA are:

- Attain the highest possible efficiency in retaining solids during the dredging operation to reduce contaminant discharges in the effluent;
- Provide adequate storage capacity to meet dredging requirements and to provide storage for equalization of inflow and outflow;
- Provide sufficient dewatering and long-term containment of the consolidated sediment that is protective of human health and the environment; and
- Provide an area available for reuse following closure.

These considerations are interrelated and depend upon effective design, operation, and management of the containment area. This option assumes hydraulically dredged slurry would be pumped from the lake to the SCA for dewatering. The SCA would use diked impoundments to retain dredged solids while allowing the supernatant to be released from the containment area, either by direct return to the lake or to water treatment. Although the ultimate design may vary, depending on the type of sediments dredged, this option assumes a single-cell SCA for containment of all sediments from the lake. Alternate designs could include more than one cell for differing solid waste or supernatant treatment requirements. Interior dikes are used in the SCA design to prevent “short-circuiting” of the water flowpath and to enhance settling efficiency. A conceptual plan view of the SCA layout is shown in Figure 4.51.

The wastebeds historically have been used for disposal of Solvay material (calcium carbonate residue) that was discharged to the wastebed as a slurry. This practice has left an approximate 55- to 70-ft (17- to 21-m) thick Solvay material layer at the wastebeds. Geotechnical data from several of the wastebeds have shown that the Solvay material has low permeability ($1x10^{-5}$ to 1×10^{-7} centimeters per second [cm/sec]). The large thickness of Solvay material would be an effective barrier layer to prevent migration of water out of the SCA. The Solvay material, therefore, could act as an underliner for the SCA.

Additionally, it should be noted that consolidation of fine-grained materials within a SCA typically forms a low-permeability layer (i.e., self-sealing layer); typically with permeabilities less than 10^{-6} cm/sec (Palermo, 2000). For this FS report, however, it is assumed that an impermeable liner layer will be incorporated into the design of the SCA as a barrier layer. Geotechnical data (stability and permeability) would be collected during the pre-design investigation to better assess the permeability of the wastebeds, the stability of the Solvay material, and the need for the impermeable layer prior to constructing the SCA. The decision would be based on the results of this geotechnical investigation and use of USACE and USEPA guidance documents.

It is assumed that the SCA would be constructed on top of the Solvay material by constructing 3:1 (horizontal:vertical) dikes with imported soil (Figure 4.51), although Solvay material may be used for dike construction pending satisfactory results of the geotechnical investigation. As noted, it is assumed for the FS that hydraulic containment of the sediment and entrained water would be provided by an impermeable liner layer. A drainage layer would be constructed above the liner layer and below the sediment mass for sediment dewatering during operation and leachate collection during closure and post-closure. The impermeable liner and sand drainage layer are shown schematically in Figure 4.52.

Upon completion of the dredging, the sediment would be managed and contoured to facilitate dewatering and capping. Solvay material available at the wastebed may be suitable for some of the borrow material used for capping, consistent with the planned closure of the C&D landfill at Wastebed 15. The cap design could also include beneficial reuse of biosolids produced at the Metro Plant. Actual capping requirements would be determined during remedial design. However, for this evaluation, the assumed SCA cap would consist of, from the bottom up, a sediment-isolation layer consisting of sand, clean fill, and a topsoil/vegetative cover providing additional protection from infiltration. The need for geomembrane and geocomposite layers in the cap would be determined as part of the SCA design to be consistent with the site reuse plans. Although some settling is expected as the sediment dewaters and compacts, the material would be graded to ensure that final slopes for the cap are approximately 3 percent. A schematic depiction of the SCA underliner, drainage layer, and cap construction is provided in Figure 4.52. Complete cost calculations for the conceptual design are provided in Appendix K, sediment management and water treatment cost estimates.

Development of the Off-Site Disposal Option

Mechanical dredging and solidification of the removed sediment followed by off-site disposal in a non-hazardous landfill is shown schematically in Figure 4.53. These processes include:

- Mechanically dredging (clamshell bucket) the sediment into a tender barge;
- Transporting the barge to a (constructed) bulkhead southeast of the causeway, adjacent to Wastebed B;
- Off-loading the sediment from the barge into trucks for transport to a processing area located on Wastebed B;
- Mixing the dredged sediment with a solidifying agent, for this FS assumed to be lime;
- Loading the solidified sediment into trucks for transport to the selected off-site landfill(s);
- Transporting by truck and disposing the sediments at an off-site non-hazardous waste landfill;

- Treatment of water generated in the solidification process at the Willis Avenue GWTP; and
- Segregation of non-contact runoff (stormwater) and discharge to the lake.

As discussed in Subsection 4.9, available data indicate that the dredged sediment would be classified as RCRA non-hazardous waste. The FS therefore assumes that all sediment removed from Onondaga Lake would be managed as non-hazardous waste.

Several commercial non-hazardous waste landfills were evaluated for off-site disposal of the dredged and solidified sediment. Principal evaluation criteria for selection of the landfills were proximity to Onondaga Lake, currently permitted daily and total capacity, hours of operation, and cost. All of the landfills contacted were approved to accept CERCLA wastes in accordance with the CERCLA off-site rule. Specific compliance with this rule would be determined by USEPA at the appropriate time; however, it is anticipated that the sediment material will be acceptable under the provisions of the regulations. Accordingly, all subsequent handling provisions and cost estimates were made assuming that the material can be accepted under the provisions of these requirements by the identified landfills. Table 4.18 provides a summary of distances to the subject landfills, disposal costs, and current daily and permitted capacities.

Based on proximity to the site and cost, both High Acres Landfill in Fairport, New York, and Niagara Falls / Pine Avenue Landfill in Niagara Falls, New York, were selected for evaluation of the 100,000 CY, 500,000 CY, and 1,000,000 CY disposal volumes. Since the most cost-effective landfill (Niagara Falls/Pine Ave) cannot currently accept the 2,400 CY (3,400 tons) daily production of sediment anticipated, it was assumed that these two landfills would each accept 50 percent of the daily production. For the 10,000,000 CY volume, none of the three landfills in New York currently have sufficient capacity to accept the total sediment volume produced. Therefore, it was assumed for this volume that 50 percent of the daily production would be transported to American Landfill in Waynesburg, Ohio, and 50 percent would be transported to Atlantic Waste Disposal in Waverly, Virginia.

Shipment by rail and truck were both considered. Based on the information obtained from preliminary investigations, it was determined that trucking was the most cost-effective method of transportation at this time, assuming off-site disposal at nearby (regional) facilities. The selection of transportation mode and disposal location depends on the market, and rail may eventually be found to be a preferred method of transportation if it is determined to be more economical at the time of transportation.

Similar consideration would be give to the method of transportation of cap materials; cost savings may be realized by using barge transportation. An evaluation would be conducted during the design and implementation phase to determine, based on practicality and availability, whether cap materials would be transported to the site via truck, barge, or rail.

It was assumed that solidification activities would be performed on the sediments by the addition and mixing of 10 percent lime by volume. The actual solidification agent type and volume would be determined during the remedial design. The lime would be mixed into the sediments on a covered asphalt pad constructed on Wastebed B using heavy equipment and loaded into trucks for transport to the off-site landfill. The processing area would be covered to minimize the impact of precipitation on the solidification activities and to control contact of stormwater with contaminated material.

Daily sediment dredging volume for one 6 CY clamshell bucket mechanical dredge is predicated on an average rate of 130 CY/hour of *in situ* sediment removed over a 16-hour workday. Total daily production is thus estimated at 2,100 *in situ* CY. Dewatering and solidification with lime yield a net volume increase from the *in situ* conditions to approximately 2,400 CY/day. Assuming approximately 15 CY (20 tons) per truckload results in approximately 160 loads of sediment produced daily for off-site disposal.

The proposed local trucking route from Wastebed B to the highway is shown on Figure 4.54. Truck transportation of the solidified sediments to the off-site landfill and return of the trucks for the next day’s load are anticipated to occur between the hours of 6:00 a.m. and 6:00 p.m. Due to the limited available daily capacity at the nearby landfills (Table 4.18), potential impacts on local traffic, and area constraints for staging the sediment, the off-site disposal option would be limited to the daily production rate of one mechanical dredge (or about 2,100 CY of *in situ* sediment).

Based on the anticipated dredging rate using one 6 CY mechanical dredge, a 20-acre process area should be sufficient for solidification, stockpiling, and truck loading. The process area would be a bermed asphalt-lined area, which slopes from its center to the edges. The processed sediment stockpile and loading area, approximately 5 acres, would be covered by a temporary structure. A contaminated water control system, consisting of catch basins and pipes, would be constructed around the perimeter of the solidification process area. Water from the solidification process would be discharged to the Willis Avenue GWTP, as discussed in the supernatant water treatment options presented in Appendix K, sediment management and water treatment cost estimates. Non-contact stormwater would be discharged to the lake.

The following subsections provide descriptions of the two sediment management options evaluated in this FS. Specific design criteria, assumptions, and cost information are provided in Appendix K, sediment management and water treatment cost estimates. Table 4.19 provides a detailed evaluation of the two options against the seven criteria. Table 4.20 summarizes the estimated costs for the two options using the four volume scenarios and four possible supernatant treatment options. The comparative analysis of the two options is presented in Subsection 4.9.2.3.

4.9.2.1 Sediment Management Option 1 – Hydraulic Dredging with On-Site Consolidation at a SCA

The following tasks are required to implement Option 1:

- Construction of the SCA;

- Construction/installation of the transfer pipeline and booster pump stations;
- Transfer of dredged sediments to the SCA;
- Dewatering sediments in the SCA;
- Treatment of supernatant water in a dedicated water treatment plant;
- Return of treated supernatant to the SMU being dredged;
- Capping the SCA once dredging is completed; and
- Supernatant water treatment plant decommissioning.

It was assumed that under all four volume scenarios, the SCA would be constructed and operated at Wastebed 13. For the 10,000,000 CY volume scenario, sediment thickness of 46 ft (14 m) and dike heights of 50 ft (15 m) instead of 10 ft (3 m) were assumed, since this is the most cost-effective configuration for a large SCA. Additionally, use of one SCA is much more cost-effective than constructing and managing multiple SCAs in different areas. It should be noted that construction of a 50-ft (15-m) high SCA on top of one of the wastebeds may require substantial wastebed stabilization prior to construction and may likely not be acceptable to local government due to the overall height and size of the facility. However, this scenario is evaluated as one SCA, since it is the most cost-effective method of managing the sediment. Final selection of the SCA location, as well as dike height, footprint, and design specifics of the SCA, would be determined during remedial design after additional testing and evaluation of the wastebeds.

To determine dredging durations for Option 1, it was assumed that one 14-inch dredge would be used for the 100,000 CY volume, two 14-inch dredges for the 500,000 and 1,000,000 cubic yard volumes, and four 14-inch dredges for the 10,000,000 cubic yard option. Dredging durations assume a 2,400 *in situ* CY/day per dredge production rate over a five-day work week and seven-month dredging season. These assumptions yield the following dredging durations for each volume:

- 100,00 CY: one dredge for nine weeks (one year);
- 500,000 CY: two dredges for 21 weeks (one year);
- 1,000,000 CY: two dredges for 42 weeks (two years); and
- 10,000,000 CY: four dredges for 209 weeks (seven years).

It is assumed that the dredge slurry would be pumped to the SCA via double-contained HDPE pipelines. Manned booster pumps would be stationed approximately every linear mile of pipeline to maintain sufficient pressure and velocity. The pipeline would be floated when in the lake or creek and laid overland when on land. A water treatment system, as described in Subsection 4.9.3, would be located adjacent to the SCA to treat the supernatant and residual leachate from the SCA, as necessary. Additional assumptions used to calculate costs for each of the four sediment volumes evaluated in this option are provided in Appendix K, sediment management and water treatment cost estimates.

4.9.2.2 Sediment Management Option 2 – Mechanical Dredging with Off-Site Disposal at a Non-Hazardous Waste Landfill

The following tasks are required to implement Option 2:

- Construction of the bulkhead off-loading area;
- Construction of the processing area, including cover system;
- Construction of a water transfer system, using infrastructure installed as part of the Harbor Brook/Wastebed B IRM;
- Off-loading sediments (by clamshell and crane) from the transfer barge to trucks;
- Transfer of dredged sediments from the bulkhead off-loading area to the processing area by trucks;
- Solidification by mixing sediments with lime (10 percent) using front end loaders;
- Loading stabilized sediment into trucks for transport to a landfill;
- Truck transport to off-site commercial non-hazardous waste landfill; and
- Process area decommissioning.

Under this option, the water treatment for the excess water generated at the process area would be treated in the Willis Avenue GWTP. The lake remediation project would include construction of a contact water collection and conveyance system using the infrastructure constructed for the Harbor Brook / Wastebed B IRM for conveyance. For the purposes of this FS, it is assumed there is an incremental cost associated with this treatment, estimated as (flow) proportional to the O&M cost for advanced treatment developed for Option 1. A more detailed description of the bulkhead and process areas components and assumptions used to develop costs for this option are provided in Appendix K, sediment management and water treatment cost estimates.

Based on currently available daily capacities at the landfills (Table 4.18), the following use of off-site landfills were assumed for each of the sediment volumes considered:

- 100,000, 500,000, and 1,000,000 CY: 50 percent of volume to High Acres Landfill and 50 percent of volume to Niagara Falls/Pine Avenue and
- 10,000,000 CY: 50 percent of volume to American Landfill and 50 percent of volume to Atlantic Waste Disposal.

Due to logistical limitations, including daily landfill capacities, local traffic impacts, and sufficient staging area, dredging durations for Option 2 assume operation of one 6 CY clamshell mechanical dredge for all four sediment volumes evaluated. Dredging durations assume a 2,100 *in situ* CY/day production rate over a five-day work week and seven-month dredging season. These assumptions yield the following dredging durations for each volume:

- 100,000 CY: one dredge for 10 weeks (one year);
- 500,000 CY: one dredge for 48 weeks (two years);
- 1,000,000 CY: one dredge for 97 weeks (four years); and
- 10,000,000 CY: one dredge for 962 weeks (35 years).

4.9.2.3 Comparative Analysis of the Sediment Management Options

The following subsection summarizes the detailed evaluation of the two sediment management options against the seven criteria, found in Table 4.19. This section highlights and compares the relative strengths and weaknesses of the two options considered: Option 1 – Hydraulic Dredging with On-Site Consolidation at a SCA and Option 2 – Mechanical Dredging with Off-Site Disposal at a Non-hazardous Waste Landfill. The subsection concludes with the selection of a preferred management option that is carried forward as the management component for the evaluation of the SMU-specific and lake-wide alternatives.

Overall Protection of Human Health and the Environment

This comparative analysis addresses only sediment management options after the sediment has been dredged from the lake. The RAOs and PRGs are relevant to the remedial activities conducted at the lake, but are not relevant to the upland sediment management activities discussed in this section. Therefore, it is inappropriate to evaluate sediment management options for their ability to meet RAOs and PRGs. The following discussion does, however, summarize the overall protectiveness of the sediment management options, including both short-term and long-term risks.

Options 1 and 2 are both protective and offer reliable methods for long-term management and containment of the dredged sediments. The SCA in Option 1 would be operated as a CDF consistent with USACE and USEPA guidance and would be effectively equivalent to the non-hazardous waste landfill in Option 2. Short-term risks associated with implementation of the remedy are approximately two times greater for Option 2 as a result of the increased truck miles associated with this option. The transportation risks for Option 2 increase dramatically at the 10,000,000 CY volume as a result of the out-of-state transport. An estimated 530 injuries and 21 fatalities would result if Option 2 were used for the 10,000,000 CY volume (see Appendix I, risk of remedy, Tables I.6 and I.7). Although the short-term risks posed by Option 1 would be an order of magnitude lower for the 10,000,000 CY volume, removal and containment of the 10,000,000 CY sediment volume under both options would result in extremely high incidences of injury and fatalities associated with truck transportation.

Compliance with ARARs

Both Options 1 and 2 would comply with the ARARs listed and described in Appendix C, ARARs and TBCs. The options are rated equal for this evaluation criterion.

Short-Term Effectiveness

Option 1 has short-term risks associated with construction activities, transportation of borrow material to the construction site, operation of the SCA, and air releases. The most significant potential for releases to the environment are air emissions from the SCA during dredging operations. Appendix I, risk of remedy, Subsection I.2.7, assesses exposure from air releases associated with dredging of each SMU. A comparison of air emission risks from a SCA and a solidification mixing pad indicates that, generally, air emission risks from the mixing pad would be higher. Sediment management in a SCA did not result in exceedances of non-cancer and cancer threshold values. Additionally, the SCA did not exceed the naphthalene odor threshold, whereas releases from the solidification mixing pad for off-site disposal could exceed this threshold by a factor of three. Active air monitoring and engineering controls at the SCA, including positioning of the slurry discharge pipe and application of activated carbon to the water surface during periods of high organic flow, would minimize potential air release at the SCA.

Transportation risks associated with trucking clean fill to the site for preloading and dike construction yield very high risks of an estimated 47 injuries and 1.8 fatalities for the 10,000,000 CY sediment volume (see Appendix I, risk of remedy). Transportation risks for the lower sediment volume scenarios are one to two orders of magnitude lower and are more typical of a large remediation project. The transportation risks associated with on-site management of the sediment may also be significantly reduced by using available Solvay materials for preloading and construction of the SCA dike and cap.

Remedial implementation risks associated with Option 2 include construction of the process area and solidification system, air releases during solidification and handling, and transportation risks during transport of the sediment to the off-site non-hazardous waste landfill. Short-term risks presented by air release of naphthalene from a sediment mixing pad are higher than risks posed by sediment management in a SCA (see Appendix I, risk of remedy).

The impacts of increased traffic along the local trucking route and along State Fair Boulevard in front of the state fairgrounds and parking area (Figure 4.55) may be a significant community concern. Even more importantly, as noted above, the transportation risks are higher for Option 2, and these risks increase substantially as the dredged sediment volume increases. For the 10,000,000 CY sediment volume, the incidence of injuries and fatalities were estimated at 530 and 21, respectively, approximately one order of magnitude higher than Option 1 (Appendix I, risk of remedy). These short-term risks indicate that this scenario would present extremely high transportation risks to workers and the public.

As a result of daily volume limitations associated with Option 2, dredging activities for the three larger volumes may be completed under Option 1 in less than one-half the duration of dredging under Option 2 (Table 4.20). For the 10,000,000 CY volume, dredging duration is estimated at 35 years for Option 2 compared to seven years for Option 1. Therefore, Option 1 has a significant advantage in achieving remedial goals faster for volumes exceeding approximately 100,000 CY of *in situ* sediment.

Long-Term Effectiveness and Permanence

The SCA in Option 1 would be designed in accordance with USACE and USEPA guidance for CDFs in a manner that is protective of human health and the environment. Although the consolidated sediments within the SCA may retain some pore water as the sediment consolidates during closure and post-closure, the SCA would be designed to contain and convey this water to a treatment plant for processing. SCAs (CDFs) are a proven, effective, and reliable method for long-term management of dredged sediments.

Option 2 uses an off-site, non-hazardous landfill for containment of the dewatered and solidified sediment. Use of landfills is a proven, effective, and reliable method for permanent containment of solid wastes. As a result, Options 1 and 2 would provide similar long-term containment elements for the sediment.

Reduction of Toxicity, Mobility, or Volume through Treatment

Both Option 1 and Option 2 integrate treatment into the sediment management and containment operations via supernatant water treatment. The sediment is dewatered using gravity drainage in Option 1, which also reduces both sediment volume and contaminant mobility. In Option 2, the sediment is dewatered through the dredging process and is then solidified by adding lime (10 percent by volume). Although this method of solidification further reduces contaminant mobility, it also increases the volume of the solidified portion of the sediment by approximately 15 percent.

Implementability

Option 1 would be implementable for the three lower sediment volumes evaluated. For the 10,000,000 CY sediment volume, the SCA would be implementable but would be more challenging to construct as a result of the large volumes of imported fill required to construct the dikes. The 50-ft (15-m) dike height was based on a cost-efficiency analysis; however, other SCA configurations would need to be evaluated in the design phase. Additionally, the town of Camillus may object to the additional 50 ft of elevation on the existing 55-ft (17-m) wastebed. The local government previously has restricted the height of Wastebed 15, which is located near Wastebed 13, to 468 ft (143 m) above msl. If that restriction were applied to Wastebed 13, the dike height would be limited to about 23 ft (7 m).

For Option 1, the wastebed on which the SCA is constructed may require stabilization through preloading and/or deep soil mixing to mitigate potential subsidence during construction and filling. The degree and type of stabilization required would be determined from geotechnical data collected prior to SCA design. Clean fill and construction materials for the SCA are readily available nearby. The SCA in Option 1 would be designed as a CDF and would operate as a CDF during the closure and the post-closure periods. CDFs are proven technologies for management of dredged sediments. Air monitoring would be performed during SCA operations, and groundwater monitoring during the operation and post-closure periods would provide regular assessment of the effectiveness of the SCA.

Option 2 is also implementable for the three smaller sediment volumes evaluated. The larger 10,000,000 CY sediment volume would be implementable but far more challenging, as it would likely require transport to out-of-state landfills due to currently limited available capacity at nearby in-state landfills. Daily production of sediment would be limited to approximately 2,100 CY/day under all sediment volumes evaluated under Option 2 as a result of local traffic and constraints on adequate truck and sediment staging areas. Local government may be opposed to excessive truck traffic required to access Interstate Route 690 from Wastebed B. Additionally, the production constraint for Option 2 would result in extending the duration of the entire remedial action, including dredging in the lake, to 35 years for the 10,000,000 CY option (correspondingly less for the lower volume options), which would not be favorable from any perspective.

Cost

Costs for Option 1 are primarily capital costs associated with wastebed stabilization and preloading, construction of the SCA, and capping. Supernatant treatment for this option is assumed to be the advanced treatment option as discussed in Subsection 4.9.3. Table 4.20 provides a summary of costs and durations for Options 1 and 2, including supernatant treatment costs applicable to Option 1. The capital cost for the advanced treatment system is estimated at approximately $27,000,000 for the lower three volume scenarios and $41,000,000 for the 10,000,000 CY volume scenario. Use of a lower level of supernatant treatment would result in a lower cost for this option (Table 4.20). The cost estimates include the costs for engineering and design and 25 percent contingency. Complete assumptions and calculations of the costs for this option are provided in Appendix K. Estimated total costs for each of the four volumes, assuming advanced treatment of the supernatant, are:

- 100,000 CY: $45,000,000
- 500,000 CY: $70,000,000
- 1,000,000 CY: $101,000,000
- 10,000,000 CY: $582,000,000

Option 2 has a fixed capital cost of $18,500,000 for all four sediment volumes evaluated, representing the cost of construction of the bulkhead (including channel dredging and disposal) and the process area. The operating cost consists of operation of the solidification and loadout, truck transportation, and landfill disposal fees and increase linearly with sediment volume for the three lower sediment volumes evaluated. The unit cost for transportation and disposal under the 10,000,000 CY sediment volume increases as a result of the existing shortage of nearby landfill capacity and the need to transport the sediment long distances for disposal of this total volume. Complete assumptions and calculations of the costs for this off-site option are provided in Appendix K, sediment management and water treatment cost estimates. The estimated total costs for each of the four volumes are:

- 100,000 CY: $32,000,000
- 500,000 CY: $84,000,000

- 1,000,000 CY: $150,000,000
- 10,000,000 CY: $1,900,000,000.

Assuming advanced treatment of the supernatant, the estimated costs indicate that Option 2 is more cost effective than Option 1 at lower volume points, but Option 1 is more cost effective than Option 2 at higher volume points (Table 4.20). As dredge volumes increase from the baseline 100,000 CY, on-site management of the sediment becomes more favorable from a cost perspective. At the mid-range sediment volumes of 500,000 and 1,000,000 CY, the costs associated with Option 2 are approximately 20 percent and 50 percent higher, respectively, than the cost of Option 1. If a lower level of supernatant treatment is required for Option 1, the cost advantage for Option 1 increases. The estimated cost for Option 2 would be even greater if the sediments require management and disposal as RCRA hazardous waste at a Subtitle C landfill. However, available data indicate that the sediments would not be classified as hazardous waste.

Preferred Sediment Management Option

Both Options 1 and 2 are protective, effective, and implementable at the three lower (100,000, 500,000, and 1,000,000 CY) sediment volumes evaluated. Short-term risk concerns, cost, and implementability issues are problematic for effective and safe implementation of the 10,000,000 CY sediment volume under both options. Option 1 represents an effective and reliable method of sediment management and long-term containment. Short-term risks are lower for Option 1 than Option 2, especially transportation risks associated with larger volumes of sediment. Additionally, dredging activities at the lake could be completed in less than one-half the dredging duration required under Option 2, which is limited to the use of one dredge. Finally, as the volume of sediment to be dredged increases, Option 1 with advanced treatment of the supernatant becomes increasingly more cost-effective than Option 2.

Therefore, Option 1, on-site consolidation at a SCA, is the preferred sediment management option and is carried forward as the sediment management component in the SMU-specific and lake-wide alternatives discussed in Sections 5.0 and 6.0, respectively.

4.9.3 Supernatant Water Treatment Options

Water treatment requirements vary considerably between the mechanical dredging and off-site disposal approach and the hydraulic dredging and on-site consolidation approach. The mechanical dredging process generates relatively little water requiring treatment, while hydraulic dredging, by nature, generates a significant flow of supernatant water. Subsection 4.9.3 provides a description of the proposed method for addressing management of water resulting from mechanical dredging and sediment processing, and a detailed evaluation of options for addressing the large volume flow from the hydraulic dredging and on-site consolidation alternatives.

4.9.3.1 Mechanical Dredging and Off-Site Disposal Approach

Typical practice for mechanical dredging operations is to return clarified water resulting from sediment handling and processing to the water body being dredged. If treatment is required, volumes are typically low enough that the water is stored in temporary tanks and then hauled off-site for disposal.

The estimated flow from the process area is 50 gpm. For this FS, it was assumed that the water resulting from the mechanical dredging options would be handled similarly to the construction water resulting from the implementation of the upland sites IRMs. Treatment in the Willis Avenue GWTP is assumed to be the most cost effective water management strategy. In summary, the anticipated water management process is:

1. Any excess water resulting from the onshore sediment handling and solidification activities would be collected in a drainage/sump system. This "contact water" would be pumped to the Willis Avenue GWTP by connection to the infrastructure constructed for the Harbor Brook / Waste Bed B IRM (which would include a groundwater containment/collection and transfer system). The actual mechanism, such as whether a separate transfer line would be used, will be determined during the design of the Harbor Brook / Wastebed B IRM.
2. Treatment for the duration of the dredging and solidification would be through the Willis Avenue GWTP. As noted, for this FS it was assumed that the incremental treatment O&M cost would be flow proportional to the cost for advanced treatment as estimated in Appendix K, sediment management and water treatment cost estimates. In general, the cost of this water management strategy, exclusive of water collection facilities associated with the construction of the process area, is a capital cost of $50,000 for the conveyance facilities and a treatment system (incremental) O&M cost of $130,000 per year or $0.018 per gallon treated.

4.9.3.2 Hydraulic Dredging and On-Site Sediment Consolidation Approach

The conceptual approach for hydraulic dredging, on-site sediment consolidation, and supernatant water treatment is shown in Figure 4.55. Figure 4.56 depicts the in-lake components of this conceptual approach. Hydraulic dredging in Onondaga Lake would be performed SMU by SMU. Silt barriers would be used to contain resuspended silt within the SMU dredging work zone. Sediment slurry, containing approximately 10 percent solids by weight, would be transported via double-contained HDPE piping to a SCA for sediment consolidation and primary treatment of the entrained water. Additional supernatant water treatment, as necessary, would be performed at a temporary treatment system constructed adjacent to the SCA. The treated water would be returned to the lake at the SMU dredging work zone that generated the water. Samples for lake water quality measurements would monitor both resuspension from the dredging operations and SCA return flow at compliance points located outside the silt containment barriers.

As noted in 6 NYCRR 750-1.5(a)(7), dredge and fill operations that return the water to state waters are not required to have a State Pollutant Discharge Elimination System (SPDES) permit. Instead, a dredge and fill permit under Section 404 of the federal Clean Water Act along with a water quality certification under Section 401 would be the relevant and appropriate requirements for monitoring water quality associated with the dredging operations and return of the supernatant water to the lake (see Appendix C, ARARS and TBCs). It is assumed that the monitoring point to demonstrate compliance with (eventually established) discharge criteria would be at the point of discharge, i.e., end of the pipe. In establishing the discharge criteria, consideration should be given to returning treated supernatant water to the active dredging area, as shown schematically in Figure 4.56. Actual water quality compliance standards would be established during design, after collection and evaluation of treatability data.

This FS considers four different treatment options for the supernatant water that would provide incrementally higher degrees of treatment. The four treatment options are presented to assess contaminant removal effectiveness and costs associated with various levels of treatment. The specific treatment process used will be developed during the remedial design after additional sampling and treatability testing. The four treatment options consist of the following:

- **Option 1 – Primary Treatment**: This treatment consists of primary solids removal (i.e., gravity settling) within the SCA. The treatment schematic is presented on Figure 4.57.
- **Option 2 – Enhanced Primary Treatment**: This treatment train consists of primary treatment plus addition of flocculant and a secondary settling in a basin or clarifier for further suspended solids removal. The treatment schematic is presented on Figure 4.58.
- **Option 3 – Enhanced Primary Treatment with Multimedia Filtration**: This treatment train consists of enhanced primary treatment plus multimedia filtration (with filters that include activated carbon) for further suspended solids removal and partial VOC removal. The treatment schematic is presented on Figure 4.59.
- **Option 4 – Advanced Treatment**: This treatment train consists of enhanced primary treatment with multimedia filtration plus air stripping and granular activated carbon (GAC) treatment for additional VOC removal. This option would include pH adjustment in addition to flocculant to promote chemical precipitation of metals, including mercury. Evaluation of an advanced treatment option in the pre-design treatability testing stage would include consideration of the sulfide precipitation method, as well as other mercury removal technologies. The treatment schematic is presented on Figure 4.60.
- **Option 5 – Enhanced Primary Treatment plus Organics Removal**: This treatment option focuses on practical achievement of organics removal. The treatment train consists of enhanced primary treatment plus GAC treatment for additional VOC removal. Option 5 would provide a level of anticipated effluent quality between Options 3 and 4. However, for clarity, this option is not shown between Options 3

> and 4, as Options 1 through 4 build sequentially on a common treatment train. The treatment schematic is presented on Figure 4.61.

Other treatment process configurations may be evaluated during predesign treatability studies.

An additional treatment option not evaluated in this FS is discharge to the Metro Plant based on an agreed-upon level of pretreatment prior to discharge. Onondaga County's current pretreatment requirements primarily focus on maintaining a sludge quality from the county's wastewater treatment processes that allows the sludge to be easily managed. As a result, the county currently does not accept any waters from CERCLA sites. However, this option is implementable from an engineering perspective and would be a viable alternative should the county's requirements change in the future.

For all dredge volume scenarios, except the 10,000,000 CY scenario, the supernatant water treatment system would be designed to operate at 4,500 gpm continuous flow for 24 hours a day. The treatment system size was estimated to accommodate the estimated flow from two 14-inch hydraulic dredges operating at 70 percent efficiency (i.e., operating 70 percent of the work day) for 16 hours per day. For each option, two treatment trains, each sized for 2,250 gpm, are proposed to treat this flow for the 500,000 or 1,000,000 CY sediment volume scenarios.

For the 10,000,000 CY sediment volume scenario, it is assumed that four 14-inch hydraulic dredges would be used concurrently; therefore, four treatment trains, each sized for 2,250 gpm, would be required. Solids generated during the primary and secondary solids removal steps would be managed on-site in an SCA, as discussed in Subsection 4.9.2.

It is assumed that the supernatant treatment system would be next to the SCA for the on-site consolidation option, that power would be available in the proposed plant area, and that a new substation would not be required. The level of instrumentation could vary greatly, depending on preference and the need to control the process. It is assumed that the instrumentation required would be consistent with a normal treatment facility, with a combination of field-mounted and locally controlled instruments and some remote capabilities.

The following subsections describe the four supernatant water treatment options in greater detail. Supernatant treatment costs and assumed dredging durations for each of the four sediment volumes evaluated are provided in Subsection 4.2.1. Specific design criteria, assumptions, and cost information are provided in Appendix K, sediment management and water treatment cost estimates. The detailed evaluation of each option with respect to the seven criteria is provided in Table 4.21. The comparative analysis is presented in Subsection 4.9.3.5.

Table 4.22 provides an evaluation of treatment efficiencies and effluent concentrations for each of the treatment options using an example average dredge slurry influent calculated from the 3-ft (1-m) dredge cut from SMU 1. Treatment efficiencies used in Table 4.22 were obtained from USEPA's treatability database provided by the National Risk Management Research

Laboratory (NRMRL) (USEPA, 1993b). The table also provides a comparison of the incremental increases of key water quality parameters in the lake from both enhanced primary treatment effluent and dredging, averaged over the SMU dredging work zone, to the Class B water quality standards and Onondaga Lake background concentrations.

NYSDEC requested that this FS provide a comparison of the estimated chloride load returned to the lake from supernatant return flow versus the contribution from the Wastebeds 9 through 15. NYSDEC noted that these wastebeds contribute an estimated 300,000 kg/day total dissolved solids (TDS) and that this is assumed a reasonable estimate. The comment directed the FS to provide the comparison using both lake water background concentrations and sediment pore water concentrations. As a conservative approach, the comparison is based on the addition of these two "sources," rather than an estimation of the fraction of the total dredge slurry flow attributed to pore water versus lake water. In reality these are chloride returns and not a new source, as the chloride load originates in the lake, albeit partly in sediment pore water.

This estimate assumes that the supernatant water flow is a 24-hour average flow rate of 4,500 gpm at a lake background concentration of 450 mg/l chloride. To this is added the pore water contribution calculated based on two hydraulic dredges operating at 150 CY/hr, 16 hr/day; the sediment is 50 percent water; and pore water concentration is 2,000 mg/L chloride (as noted in the comment as the typical concentration for the ILWD). It is also assumed that the treatment would provide no reduction in chloride concentration. Total chloride returned to the lake from the dredging process is thus conservatively estimated to be 15,000 kg/day, or 5 percent of the wastebeds' contribution (assuming that the noted TDS return is as chloride). The chloride return to the lake would only occur during the dredging operations, which are limited in duration both in the number of months per year (assumed seven) and the number of seasons required to implement the remedy.

4.9.3.3 Supernatant Water Treatment Option 1 – Primary Treatment

This treatment system consists of primary solids removal in a SCA as described in Subsection 4.9.2.

Components of this treatment system include:

- Primary treatment (gravity settling) in the SCA and
- Effluent discharge to Onondaga Lake.

The SCA is designed with sufficient capacity to allow a detention time of 36 hours, which would allow heavier solids to settle out. The SCA would also act as an equalization basin to allow 24-hour treatment at a flow rate below the dredge slurry flow rate. Effluent from the SCA would be pumped and discharged to Onondaga Lake through a diffuser and at a location within the active SMU dredging zone that generated the water (Figure 4.55).

Details regarding construction and operation of an SCA are provided in Subsection 4.9.2. This treatment schematic is presented in Figure 4.56. Expected influent water contaminant loading, primary treatment removal efficiencies, anticipated effluent concentrations, and comparative water quality criteria are provided in Table 4.22.

4.9.3.4 Supernatant Water Treatment Option 2 – Enhanced Primary Treatment

This treatment train consists of primary treatment, as discussed above, plus addition of flocculant and settling for further suspended solids removal.

Components of this treatment system are:

- Primary treatment in the SCA;
- Addition of flocculant;
- Mixing and flocculation;
- Additional suspended solids removal;
- Solids consolidation in a SCA; and
- Supernatant return to Onondaga Lake.

After primary treatment, a flocculant would be added at a weir to a secondary settling basin within the SCA or at a rapid mix/flocculator tank to promote additional settling. The flocculant addition is intended to flocculate colloidal solids and finer particulates, as well as adsorbed mercury, in the secondary clarifier following rapid mixing and flocculation.

Flocs generated would be settled in the secondary settling basin of the SCA or by using an inclined plate clarifier. The inclined plate clarifier would be sized between 0.25 gallons per minute per square foot (gpm/ft^2) and 0.5 gpm/ft^2 hydraulic loading rates. As in the SCA, it is assumed that the settling characteristics observed in the 2003 settling study (Harrington, 2003) would apply. Discharge of the treated water to Onondaga Lake would be to the SMU dredging zone that generated the water through a diffuser (Figure 4.55).

The treatment schematic for this option is presented in Figure 4.57. Expected SCA influent contaminant loading, enhanced primary treatment removal efficiencies, anticipated effluent concentrations, and comparative water quality criteria are provided in Table 4.22.

4.9.3.5 Supernatant Water Treatment Option 3 – Enhanced Primary Treatment with Multimedia Filtration

This option consists of enhanced primary treatment, discussed above, plus multimedia filtration for further suspended solids removal and partial VOC removal.

Components of this treatment system are:

- Primary solids removal in the SCA;

- Addition of flocculant;
- Mixing and flocculation;
- Additional suspended solids removal;
- Multimedia filtration;
- Solids consolidation in a SCA and/or off-site disposal, as required; and
- Supernatant return to Onondaga Lake.

The additional feature of this treatment system is the multimedia filter (incorporating activated carbon) that would be added to the treatment train of Option 2 after the primary and secondary solids removal. Multimedia filters facilitate removal of VOCs, TSS, and mercury in a single step. Two units (four for the 10,000,000 CY volume scenario) operating in parallel would allow continuous operation during backwashing. Supernatant return to Onondaga Lake would be through a diffuser to the SMU dredging work zone that generated the water (Figure 4.55).

This treatment schematic is presented in Figure 4.58. Expected SCA influent contaminant loading, enhanced primary treatment with multimedia filtration removal efficiencies, anticipated effluent concentrations, and comparative water quality criteria are shown in Table 4.22.

4.9.3.6 Supernatant Water Treatment Option 4 – Advanced Treatment

The treatment train for the advanced treatment option consists of enhanced primary treatment with multimedia filtration plus air stripping and GAC treatment for additional VOC removal. This option would include pH adjustment for chemical precipitation of mercury and other metals prior to the flocculation step.

Components of this supernatant water treatment system are:

- Primary solids removal in the SCA;
- pH adjustment for metals (primarily mercury) precipitation;
- Addition of flocculant;
- Mixing and flocculation;
- Additional suspended solids removal in a secondary clarifier;
- Multimedia filtration;
- Air stripping;
- GAC adsorption for polishing;
- Solids consolidation in a SCA and/or off-site disposal, as required; and
- Supernatant return discharge to Onondaga Lake

In the advanced treatment option, a pH adjustment step is included prior to rapid mixing to raise pH to the level where soluble metals (including mercury) form an insoluble hydroxide that can be precipitated for additional removal. The costs for pH adjustment and metals precipitation are substantial, over $9,000,000 per year for the 4,500-gpm treatment system and over $18,000,000 per year for the 9,000-gpm system. The basis for conceptual design and cost estimate for metals precipitation is the treatability work done for the Willis Ave GWTP. Actual treatability testing on dredge slurry supernatant may alter this estimated operating cost. This step could also be incorporated into Options 2 or 3; it is evaluated separately in this advanced treatment option, since it represents over 80 percent of the O&M costs associated with this option.

The effluent from the multimedia filters in Option 3 would be routed to an air stripper for further removal of VOCs. For this conceptual design, it is assumed that ammonia treatment would not be required. If required, additional aeration capacity in the stripper, along with pH adjustment, may be needed.

For this conceptual design, it is assumed that treatment of the stripper off-gases would not be required. This is based on the assumption that the Syracuse area is not a non-attainment area for VOCs. However, if air modeling indicates health effects on the surrounding receptors, then off-gas treatment via a combustion device, such as a thermal oxidizer, would need to be included in the design.

Two GAC units (four for the 10,000,000 CY sediment volume scenario) would be included as a polishing step for VOCs and mercury removal. The two units would operate in parallel to allow continuous operation during change out. Each unit would consist of two 10-ft (3-m) diameter adsorption columns, each containing approximately 10,000 pounds of GAC. It is expected that the media in the units would need to be changed once a year. Removal efficiencies for the air stripper and GAC units were estimated from the USEPA's NRMRL treatability database (USEPA, 1993b).

It is assumed that no pH adjustment of the final effluent would be needed, as the effluent pH is expected to be less than 9. This assumption, however, would not be valid if pH adjustment is required for ammonia stripping. Effluent would discharge to Onondaga Lake at a fixed location to be determined during remedial design.

The treatment schematic for this option is presented in Figure 4.59. Expected SCA influent contaminant loading, advanced treatment removal efficiencies, anticipated effluent concentrations, and comparative water quality criteria are provided in Table 4.22.

4.9.3.7 Supernatant Water Treatment Option 5 – Enhanced Primary Treatment plus Organics Removal

This treatment train consists of enhanced primary treatment, as discussed above, plus a GAC adsorption step for additional VOC removal.

Components of this treatment system are:

- Primary treatment in the SCA;
- Addition of flocculant;
- Mixing and flocculation;
- Additional suspended solids removal in a secondary clarifier;
- GAC adsorption and air stripping for polishing;
- Solids consolidation in a SCA; and
- Supernatant return to Onondaga Lake.

The additional feature of this treatment system are two GAC units (four for the 10,000,000 CY sediment volume scenario) that would be included as a polishing step for VOC removal. The two units would be operated in parallel to allow continuous operation during change out. Each unit would consist of two 10-ft (3-m) diameter adsorption columns, each containing approximately 10,000 pounds of GAC. It is expected that the media inside the units would need to be changed once a year. Removal efficiencies for the air stripper and GAC units were estimated from the USEPA's NRMRL treatability database (USEPA, 1993b). In addition, a sand filtration step may be required before the GAC adsorption step. The need for this additional step would be evaluated during the design phase.

Discharge of the treated water to Onondaga Lake would be through a diffuser to the SMU dredging zone that generated the water (Figure 4.55).

The treatment schematic for this option is presented in Figure 4.60. Expected SCA influent contaminant loading, removal efficiencies for this treatment train, anticipated effluent concentrations, and comparative water quality criteria are provided in Table 4.22.

4.9.3.8 Comparative Analysis of the Supernatant Water Treatment Options

The following subsection summarizes the detailed evaluation of the five supernatant water treatment options against the seven CERCLA criteria found in Table 4.21. The relative strengths and weaknesses of the five options are compared under each of the seven criteria to determine the preferred option for supernatant water treatment. The subsection concludes with the selection of a preferred treatment option that is carried forward as the supernatant water treatment component for the evaluation of the SMU-specific and lake-wide alternatives.

4.9.3.8.1 Overall Protection of Human Health and the Environment

As noted in the Subsection 6.12.2, the evaluation of an option against its ability to meet the RAOs and PRGS is relevant to remedial activities at the lake but not to the supernatant treatment options discussed in this section, and it would be inappropriate to address them here. These options are evaluated against the Clean Water Act criteria that are relevant and appropriate to the dredging and supernatant return operations. All options would meet the Class B water quality criteria, with the exception of mercury, at compliance points located just outside the dredge work zone. None of the five options are expected to meet the Class B criterion for mercury (0.0007 micrograms per liter [µg/L]), which is over two orders of magnitude below existing lake background concentrations (Table 4.22).

4.9.3.8.2 Compliance with ARARs

All options would comply with the ARARs listed and described in Appendix C, ARARs and TBCs, with the possible exception of the two most stringent surface water quality for mercury. Since none of the five options are expected to meet the 0.0007 µg/L mercury criterion, the options are rated equal for this evaluation criterion.

4.9.3.8.3 Short-Term Effectiveness

Option 4 would provide the highest degree of removal efficiency, especially for mercury and VOCs and would result in lower concentrations returning to the lake. Option 3 would return somewhat higher concentrations, especially for VOCs, than Option 4. Option 5 would provide a higher degree of VOC removal than Option 3. Concentrations in the effluent from Option 2 would be higher than from Options 3, 4, and 5; and Option 1 would yield the highest effluent concentrations of the five options. However, Option 4 does not provide a significantly greater short-term benefit to the lake than the other options. Using any of the options, lake water concentrations at the compliance points outside the dredge work zone would be within the Class B water quality criteria, except for the mercury criterion.

4.9.3.8.4 Long-Term Effectiveness and Permanence

All supernatant water treatment options result in net reduction of long-term contaminant concentrations in the lake. However, the treatment systems would be operational only during remedial implementation, and long-term effectiveness is not directly applicable to this component of the alternatives. Residual concentrations in water retuned to the lake for Options 1 through 5 would be addressed through resuspension controls used during dredging and through final capping of the sediment after dredging.

4.9.3.8.5 Reduction of Toxicity, Mobility, or Volume through Treatment

All options provide treatment to the supernatant water that results in reduced toxicity and mobility of the returned water (Table 4.22).

Option 5 provides higher levels of removal of VOCs in the return water than all other options, but mercury removal levels are lower than Option 4. Clarifier solids would be returned to the SCA for consolidation, and GAC media, which may contain higher concentrations of contaminants, may require off-site disposal as hazardous waste.

Option 4 provides the highest level of toxicity and mobility reduction. However, this option also yields the greatest volume of residual solids requiring management. Clarifier solids would be returned to the SCA for consolidation. Multimedia filter and GAC media, may require off-site disposal as hazardous waste.

Option 3 provides reduction of organic compound concentrations in the returned water, but at levels below the capabilities of Option 4. Additional volumes of contaminated solids would be generated requiring management. The clarifier solids would be returned to the SCA; however, the contaminated multimedia filter and GAC media may require off-site disposal as hazardous waste, depending on waste characterization analyses.

Option 2 provides lower levels of toxicity and mobility reductions than provided by Option 3, but provides more reduction than Option 1. However, use of flocculating agents would slightly increase the volume of contaminated solids from the clarifier returned to the SCA for permanent containment.

Option 1 provides the least reduction in contaminant toxicity and mobility through gravity settling in a SCA. Since additional treatment is not conducted outside the SCA, this option also results in the lowest volume of contaminated material generated by the treatment process.

4.9.3.8.6 Implementability

All five options use reliable technologies, and the effluents can easily be sampled to monitor effectiveness. Options 3, 4, and 5 would require more operational controls, personnel, and monitoring as a result of the multiple treatment steps involved in these options. All of the options can be constructed; however, the difficulty associated with construction increases with complexity of the treatment systems from Option 1 to Option 5.

4.9.3.8.7 Cost

Estimated costs and durations for each of the four treatment options for the five volume scenarios evaluated are summarized in Table 4.20. Complete assumptions and calculations of the costs for the supernatant water treatment options are provided in Appendix K, sediment management and water treatment cost estimates. The costs for Option 1 consist of water quality monitoring for the total flow estimated for each sediment volume removed and ranged from $6,500 for the 100,000 CY volume to $650,000 for the 10,000,000 CY volume. Operating costs are $0.05 per 1,000 gallons

The costs for Option 2 include capital costs of $9,000,000 (or $13,000,000 for the 9,000 gpm system, 10,000,000 CY sediment volume scenario) for construction of the treatment system and dismantling of the system upon completion of dredging. Estimated operating costs are $0.40 per 1,000 gallons for Option 2. Total costs for Option 2 are $9,000,000 for the three lower volume scenarios and $18,000,000 for the 10,000,000 CY scenario (Table 4.20).

Option 3 costs also include a significant capital cost of $14,000,000 (or $21,000,000 for the 9,000 gpm system) and increased operating costs to monitor and manage the system. The operating costs estimated for this treatment system are $0.57 per 1,000 gallons. Total costs for Option 3 are $14,000,000 for the two lower volume scenarios, $15,000,000 for 1,000,000 CY, and $28,000,000 for 10,000,000 CY.

Capital and operating costs for Option 4 are substantial as a result of the many components required for the treatment system. Capital costs for Option 4 are $27,000,000 (or $41,000,000 for the 9,000 gpm system), and operating costs are $5.00 per 1,000 gallons. A substantial portion (over 80 percent) of the operating cost for this option is the cost for caustic used for precipitation of metals, including mercury. Total costs for Option 4 are $28,000,000 for the 100,000 CY scenario, $30,000,000 for the 500,000 CY scenario, $34,000,000 for the 1,000,000 CY scenario, and $105,000,000 for the 10,000,000 CY scenario. The treatment provided by Option 4 cannot meet the Class B water quality standard for mercury and provides no improvement over Options 1, 2, and 3 in attaining the other water quality standards. Although Option 4 provides the greatest reduction in effluent concentrations, the reduction is not commensurate with the increased cost.

Option 5 costs include capital costs of $12,000,000 (or $18,000,000 for the 9,000 gpm system) and increased operating costs to monitor and manage the system. The operating costs estimated for this treatment system are $0.57 per 1,000 gallons. Total costs for Option 5 are $12,000,000 for the 100,000 CY scenario, $13,000,000 for the 500,000 CY scenario, $13,000,000 for 1,000,000 CY, and $26,000,000 for 10,000,000 CY. Although Option 5 provides greater reduction in effluent concentrations than Option 2, the incremental reduction provides no additional benefit, since dredging zone concentrations resulting from Option 2 would also meet the Class B water quality standards.

4.9.3.9 Water Treatment Option Used in Analysis of Lake-wide Alternatives

Per the request of NYSDEC, Option 4 – Advanced Water Treatment was used for the analysis of lake-wide alternatives in Section 5. Associated cost estimates for these alternatives will include the higher costs for this treatment train.

4.10 SECTION 4 SUMMARY

Section 4 accomplishes the following tasks for SMU-specific alternatives, consistent with CERCLA guidance:

- Develops preliminary remedial alternatives;
- Screens preliminary remedial alternatives based on effectiveness, implementability and cost;
- Evaluates in detail and completes a comparative evaluation of the retained alternatives based on the seven CERCLA evaluation criteria; and

- Develops a short list of feasible alternatives, which are incorporated into lake-wide alternatives for further evaluation in Section 5.

These tasks are completed for littoral areas (SMUs 1 through 7) and the profundal area (SMU 8), as summarized below in Subsections 4.10.1 through 4.10.2. Management of dredged sediments and treatment of water generated during dredging are common components to most of the alternatives. Therefore, to facilitate clarity and reduce repetition within the FS, these components are evaluated separately, as summarized in Subsection 4.10.3.

Subsection 4.10.4 provides a summary of the SMU-specific alternatives recommended for incorporation into lake-wide alternatives in Section 5. Selection of a preferred alternative is justified based on the evaluation of lake-wide alternatives rather than the evaluation of SMU-specific alternatives based on:

- RAOs and PRGs were developed taking into consideration the entire lake. Achievement of RAOs and PRGs would be dependent on the alternative that would be implemented lake-wide due to the complexities and interactions between the SMUs and how they impact lake-wide conditions.
- Short-term effectiveness issues such as implementation risks associated with CPOI releases during capping and dredging are SMU-specific due to the varying CPOI concentrations present. However, quantitatively evaluating implementation risks is more appropriate when evaluating lake-wide alternatives due to the cumulative nature of the risks and interrelationships between SMUs. The time required to implement alternatives is also more appropriate based on consideration of lake-wide alternatives to ensure that implementation time frames are not over estimated.
- Estimating costs based on lake-wide alternatives rather than SMU-specific alternatives allows consideration of economies of scale and more accurate distribution of costs associated with issues such as mobilization/demobilization and water treatment facility construction. This allows more accurate cost estimating, helps ensure remedial costs are not over estimated, and provides an appropriate basis for evaluating and comparing alternatives.
- Improvements to habitat that would result from the remedial alternatives are more appropriate to consider on a lake-wide basis to ensure that issues such as diversity of habitat throughout the lake are appropriately evaluated.

4.10.1 Littoral Area (SMUs 1 through 7) Summary

Alternatives for the littoral area were developed to address RAOs and PRGs established in Section 2, including alternatives that would address a full range of benthic toxicity-based SECs (mean PECQ2, mean PECQ1, AET, PEC, and ERL). This also included alternatives based on capping, dredging, and various combinations of dredging and capping. Habitat considerations were addressed by developing a specific habitat enhancement alternative, and by incorporating habitat optimization components into each of the alternatives developed. This resulted in initial consideration of over 200 potential SMU-specific alternatives. This was reduced during the screening process to fewer than 50 SMU-specific alternatives, which were evaluated in detail. During the screening evaluation, potential SMU-specific alternatives were screened and evaluated based on implementability and effectiveness, not cost. The findings of the screening results did not eliminate any alternatives based on implementability or cost considerations.

The majority of the alternatives that were not retained resulted in the same or similar areas and/or volumes as other alternatives. Habitat enhancement as a stand-alone alternative was eliminated based on lack of effectiveness for all SMUs except SMUs 3 and 5.

Provided below is a summary of the detailed and comparative evaluation completed for the retained SMU-specific alternatives. The No Action Alternative (Alternative 1) is retained for consideration as a lake-wide alternative to serve as a baseline for comparison of the other alternatives. Therefore, it is not included in the discussion below. Habitat Enhancement (Alternative 2) is only being considered for areas where significant risks due to CERCLA substances are not present, so habitat enhancement is not included in the summary of the detailed evaluation below.

Overall Protection of Human Health and the Environment: All of the capping (Alternative 3), dredging/capping (Alternative 4) and dredging (Alternative 5) alternatives provide similar levels of overall protection of human health and the environment. All of the alternatives include capping and/or dredging to the mean PECQ2 or mean PECQ1. Based on the exposure/response relationship determined empirically with the lake-wide database (see Appendix J, sediment effects concentrations), sediments that do not exceed the mean PECQ2 or mean PECQ1 are not expected to contribute significantly to sediment toxicity. In addition, areas and volumes for alternatives that would remediate to the mean PECQ2 or mean PECQ1 were expanded to include all sediments that exceed the mercury PEC, ensuring that all areas that present significant risk based on mercury and other CPOIs would also be remediated. Alternatives that address areas and volumes beyond those defined by the mean PECQ2 or mean PECQ1 would not result in significant additional risk reduction.

Alternatives 3, 4 and 5 all incorporate habitat enhancement components, including placement of substrate appropriate for establishment and growth of submerged macrophytes and fish spawning. The dredging / capping alternative that incorporates dredging to a depth that minimizes erosive forces on the cap and optimizes habitat typically results in the best overall post-remediation habitat value.

Compliance with ARARs: It is anticipated that Alternatives 3, 4, and 5 would comply with all of the designated chemical-specific ARARs to the extent practicable and to the extent that the given SMU contributes to lake wide conditions. Due to the very low concentrations associated with some of the mercury criteria and other technical considerations, it may be difficult to meet all of the surface water ARARs for mercury. However, it is anticipated that remediation of SMUs with elevated levels of mercury, as well as upland mercury sources, would significantly reduce mercury loading, resulting in progress toward meeting these ARARs to the extent practicable. It is anticipated that any of the alternatives would be completed in compliance with any location-specific and action-specific ARARS.

Remedy implementation for the in-lake portion of each alternative may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment. Sediment disturbance and short-term exceedances of surface water ARARs would be expected to be significantly greater during dredging than during capping. The greater the volume of sediment dredged, the longer the duration of the exceedance would be. Engineering controls would be used as necessary to minimize the magnitude and extent of exceedances of surface water criteria.

Short-Term Effectiveness: Alternatives 3, 4, and 5 all present potential short-term impacts during the construction and implementation phase, including: temporary loss of lake habitat; mobilization of CPOIs into the water column; volatilization of organics during dredging and materials handling; potential for on-site worker and transportation accidents during construction and material transport; and quality of life impacts such as odors and increased truck traffic on local roads. In general, dredging presents greater potential risks than capping due to the removal and handling of impacted sediments. The short-term potential risks would increase as the area capped, volume dredged, and duration of the remedial alternative increases. It is anticipated that engineering controls would be used as necessary to mitigate any potential risks.

Long-Term Effectiveness and Permanence: Alternatives 3, 4, and 5 are considered to be long-term effective and permanent solutions for impacted sediment in the littoral area as long as the proper monitoring and maintenance programs are maintained. Alternatives 3, 4, and 5 would provide long-term effectiveness and permanence by isolating CPOIs present in sediment under a cap and/or within an upland SCA, thereby reducing or eliminating the potential risks to human health and the environment. Under Alternatives 3 and 4, containment would be achieved via capping the sediments *in situ*. The cap would provide long term chemical isolation, taking into consideration chemical migration through the cap as well as processes, which would potentially damage the cap. Under Alternative 5, sediments would be permanently removed from the lake, but long-term effectiveness would still rely on containment within the upland SCA.

Reduction of Toxicity, Mobility, or Volume through Treatment: Alternative 3 and the capping component of Alternative 4 rely on isolation rather than treatment to achieve effectiveness. The dredging and associated processes included in Alternatives 4 and 5 would result in reducing the toxicity, mobility and volume through treatment. The volume and mobility of sediment would be reduced through consolidation and dewatering within the SCA. Treatment of water resulting from the dredging operations would result in reduction in the toxicity, mobility, and volume of CPOIs that are mobilized from the sediment into the water stream.

Implementability: Any of the littoral area remedial alternatives are readily implementable, with the exception of dredging under Alternative 5 for those SMUs that would result in extremely large volumes of sediment. For example, Alternative 5 for SMU 1 would require removal of at least 4 million cubic yards of sediment, which would be larger than any environmental dredging project ever completed in this country. The size and duration of this removal would present numerous implementation challenges.

4.10.2 Profundal Area (SMU 8) Summary

Alternatives for the profundal area were developed to address RAOs and PRGs applicable to the profundal area established in Section 2, including alternatives that would address benthic macroinvertebrate toxicity-based SECs and the BSQV for mercury. These alternatives were based on MNR, thin-layer capping, isolation capping, aeration (oxygenation), dredging, and various combinations of these, resulting in eight preliminary SMU-specific alternatives. The eight preliminary alternatives were reduced to five SMU-specific alternatives, which were evaluated in detail.

Overall Protection of Human Health and the Environment: Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) /MNR provides the greatest level of overall protectiveness because it addresses RAOs 3 and 4, which are also addressed by the other profundal alternatives, plus it directly addresses methylation in the hypolimnion (RAO 1) through aeration. In addition, Alternative 6 includes a long-term goal of achieving the mercury BSQV in the lake. The addition of aeration (oxygenation) and consideration of the BSQV in Alternative 6 is expected to result in greater reduction in mercury concentrations in biota than the other alternatives. Aeration (oxygenation) of the hypolimnion would also allow benthic colonization in the profundal area. All of the alternatives would achieve the same final long-term sediment concentrations of mercury and other CPOIs because these concentrations are driven by concentrations in settling sediments.

Compliance with ARARS: All profundal alternatives (except no action) are expected to comply with all of the designated chemical-specific ARARs to the extent practicable and to the extent that this SMU contributes to lake-wide conditions. The implementation of Alternatives 3 – Thin-Layer Capping and, to a greater extent Alternative 8 – Dredging, may result in short-term localized exceedances of surface water criteria due to suspension of impacted sediment. Alternative 4 – Phased-Thin Layer Capping / MNR and Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR would have similar water quality impacts as Alternative 3, but over smaller areas and with less duration. It is anticipated that any of the alternatives would be completed in compliance with any location-specific and action-specific ARARS.

Short-Term Effectiveness: In general, the greater volume of capping material placed or sediment dredged, the higher the short-term impacts. In most situations, dredging presents greater potential risks than capping due to the removal and handling of impacted sediments. Therefore, Alternative 8 would have by far the greatest short-term impacts. These impacts include temporary loss of habitat, water quality issues, potential for on-site worker and transportation accidents, and quality of life impacts. It is anticipated that engineering controls would be used as necessary to mitigate any potential risks under all of the alternatives. Aeration of the hypolimnion under Alternative 6 could be implemented independently of any upland or sediment remediation, allowing expedited implementation.

Long-Term Effectiveness and Permanence: It is expected that all profundal alternatives (except no action) would eventually provide long-term effectiveness and permanence because sediment concentrations in the biologically active zone are driven by concentrations in settling sediments. MNR would take more time to be effective than more active alternatives, although the duration of profundal dredging in Alternative 8 is so great (e.g., 6 to 30 years) that the time it takes to achieve cleanup criteria may be similar to or longer than under MNR. Aeration (oxygenation) in Alternative 6 would have to be continued for the foreseeable future until or unless other factors (e.g., reduced phosphorus loading to the lake) result in oxic conditions throughout the water column.

Reduction of Toxicity, Mobility, or Volume through Treatment: The dredging and associated processes included in Alternative 8 would reduce the toxicity, mobility and volume through treatment. The volume and mobility of sediment would be reduced through consolidation and dewatering within the SCA. Treatment of water resulting from the dredging operations would result in reduction in the toxicity, mobility and volume of CPOIs that are mobilized from the sediment into the water stream. Under Alternatives 3, 4, and 6, natural recovery processes and thin-layer capping are expected to reduce the mobility of CPOIs in sediment over time, although not through treatment. Alternative 6 includes aeration (oxygenation), which is a form of treatment that would reduce the toxicity of mercury in water through the reduction in methylmercury concentrations and the removal of sulfide and low dissolved oxygen conditions that limit biological activity in this area.

Implementability: No technical or administrative issues have been identified that would limit the feasibility of implementing any of the alternatives for the profundal area, with the exception of Alternative 8. Alternative 8 would require removal of almost 6 million cubic yards of sediment, which would be larger than any environmental dredging project ever completed in this country. The size and duration of this removal would present numerous implementation challenges.

4.10.3 Sediment Management and Supernatant Treatment Components

Two options were considered for the management of sediments produced during dredging of the lake: on-site consolidation in a SCA and off-site disposal at a commercial non-hazardous waste landfill. The SCA in the on-site option would be designed and constructed at Wastebed 13 in accordance with USACE and USEPA guidance for CDFs. Using the available data, a screening evaluation of available locations to construct the SCA identified Wastebed 13 as the preferred location. Wastebed 13 has large capacity and good accessibility, and a SCA could be designed and constructed there consistent with possible reuse plans for the wastebed and with minimal impact on the community.

Based on the analysis of dredging-sediment management systems conducted in Appendix K, the on-site option assumed use of hydraulic dredging techniques, while the off-site option assumed mechanical dredging would be used to limit the volume of water and associated costs with this option. The specific dredging / sediment management approach would be determined during design and implementation. Since the hydraulic dredging used for the on-site option yields a large volume of entrained lake water that is returned to the lake, five supernatant treatment options were evaluated as integral components of the on-site management option. The supernatant treatment options evaluated for on-site sediment management were primary treatment, enhanced primary treatment, enhanced primary treatment with multimedia filtration, advanced treatment, and enhanced primary treatment plus organics removal. Each of these sediment management and supernatant treatment options was evaluated over a range of four *in situ* sediment dredge volumes to assess possible sediment management and water treatment constraints as they relate to the volume of sediment removed from the lake and to provide an evaluation of costs and risks associated with implementation of the remedy at the various volume points. The volumes elevated are 100,000 CY, 500,000 CY, 1,000,000 CY, and 10,000,000 CY.

On-site consolidation of the sediment in a SCA is the preferred sediment management option. On-site management in a SCA, designed and constructed in accordance with USACE and USEPA guidance for CDFs, is a proven and reliable technology for sediment management that is protective of human health and the environment. A SCA would allow use of multiple dredges that could facilitate faster cleanup of the lake than mechanical dredging and off-site disposal. Management of the dredged sediments in a SCA would also present fewer short-term risks and traffic impacts to the community and would be more cost-effective than off-site disposal, especially at sediment volumes exceeding 100,000 CY.

Advanced water treatment was assumed for comparison of lake-wide alternatives in the FS. Specific discharge criteria, and thus required level of treatment, would be determined during the pre-design and design phases. It was also assumed that treated supernatant would be returned to the lake at the dredging work zone of origin.

This sediment and supernatant treatment approach is carried forward as the sediment management and supernatant treatment component to the SMU-specific and lake-wide alternatives discussed in Sections 5 and 6.

4.10.4 Recommendations for Inclusion in Lake-Wide Alternatives

Table 4.13 provides a list of the SMU-specific alternatives that were evaluated as part of the evaluation of lake-wide alternatives in Section 5. The No Action Alternative does not meet the threshold criteria of overall protection of human health and the environment. However, the No Action Alternative should be evaluated on a lake-wide basis to serve as a baseline for comparison of other alternatives.

The littoral alternatives for each SMU vary significantly in how they satisfy the evaluation criteria. Of significance is that all of the alternatives provide similar levels of overall protection of human health and the environment, except in the value of the post-remediation habitat, while Alternative 5 – Full Removal would result in significantly greater short-term potential risks and remedial costs for each of the SMUs versus the other alternatives. Nevertheless, Alternative 5 for each of the SMUs should be incorporated into a lake-wide alternative to allow additional evaluation and to ensure that a full range of alternatives is evaluated.

Capping or dredging to SEC approaches other than the mean PECQ2 would result in greater short-term potential risks and cost, but would result in minimal or no improvement in the other evaluation criteria. However, capping and dredging to the mean PECQ1 and the ER-L should be considered for inclusion in lake-wide alternatives in Section 5 in order to provide an additional safety factor with respect to sediment toxicity (i.e., mean PECQ1) and an upper end criterion for sediment toxicity to benthic macroinvertebrates.

Habitat enhancement under Alternative 2 should be included for those portions of SMU 3 that are not addressed through capping and/or dredging. There are no significant potential risks presented by CPOIs in SMU 5. However, a full range of alternatives has been provided to address the minor exceedances of the mercury PEC and the one exceedance of the mean PECQ1 in SMU 5. Several of these alternatives were considered for inclusion in lake-wide alternatives in Section 5.

For profundal sediments (SMU 8), all alternatives evaluated in detail meet the threshold criterion of protecting human health and the environment. However, Alternative 6 – Phased Thin-Layer Capping / Aeration (Oxygenation) / MNR is the only alternative that directly addresses mercury methylation in the hypolimnion. Therefore, it is the only alternative recommended to be carried forward in the lake-wide alternatives section.

Based on the SMU-specific alternative evaluation completed in Section 4 as summarized above, Table 4.13 summarizes the recommended alternatives for inclusion in lake-wide alternatives in Section 5.

SECTION 4

TABLES

SECTION 4

FIGURES

SECTION 5

DEVELOPMENT AND EVALUATION OF LAKE-WIDE ALTERNATIVES

5.1 RATIONALE AND DEVELOPMENT FOR EVALUATION OF LAKE-WIDE ALTERNATIVES

This section combines the SMU-specific alternatives retained in Section 4 to develop and evaluate lake-wide alternatives for Onondaga Lake. The rationale for development and evaluation of each lake-wide alternative is presented herein, followed by descriptions of each alternative. Detailed evaluations and a comparative analysis of the lake-wide alternatives are then provided based on the seven CERCLA criteria outlined in the NCP at 40 CFR Part 300.430.

While the alternatives retained in Section 4 evaluate the range of approaches that may be appropriate for each SMU, lake-wide alternatives are necessary because the lake functions as an integrated system, and action in one SMU impacts other SMUs. For example, reduction of mercury concentrations on resuspended particles from SMU 1 would enhance natural recovery in SMU 8. Development of the lake-wide alternatives includes:

- Alternatives retained for each SMU (see Subsection 4.10) as building blocks for the lake-wide alternatives;
- SMU-specific alternatives (except for the no action alternative) that meet the site-specific RAOs and PRGs, and the threshold CERCLA evaluation criteria (i.e., protection of human health and the environment, and compliance with ARARs);
- A range of lake-wide alternatives, from no action to complete removal of all littoral sediment exceeding the ER-L (except in SMU 5); and
- SMU-specific alternatives integrated to maximize recreational, aesthetic, and ecological benefits for the lake as a whole (see Appendix M, habitat issues).

Since achieving RAOs and PRGs on a SMU-specific and lake-wide basis is one of the criteria used in developing the lake-wide alternatives, the RAOs and PRGs presented in Section 2 are repeated below for discussion purposes.

RAOs

- RAO 1: To eliminate or reduce, to the extent practicable, methylation of mercury in the hypolimnion.
- RAO 2: To eliminate or reduce, to the extent practicable, releases of contaminants from the ILWD and other littoral areas around the lake.

- RAO 3: To eliminate or reduce, to the extent practicable, releases of mercury from profundal sediments.
- RAO 4: To eliminate or reduce, to the extent practicable, existing and potential future adverse ecological effects on fish and wildlife resources, and potential risks to humans.
- RAO 5: To achieve surface water quality standards, to the extent practicable, associated with CPOIs.

PRGs

- PRG 1: Reduce, contain or control CPOIs in profundal and littoral sediments by achieving applicable and appropriate SECs, to the extent practicable.
- PRG 2: Achieve CPOI concentrations in fish tissue that are protective of humans and wildlife that consume fish, to the extent practicable.
- PRG 3: Achieve surface water quality standards, to the extent practicable, associated with CPOIs.

The ability to achieve these RAOs and PRGs is discussed for each alternative in the detailed evaluation and comparative analysis provided for the lake-wide alternatives (see Subsection 5.3).

This section integrates the most technically sound and protective alternatives for each SMU to develop lake-wide alternatives that also provide recreation and redevelopment opportunities for the community. For example, the distribution of emergent wetland, aquatic plant habitat, benthic substrate, and fish spawning habitat for each alternative was developed to reflect the diverse habitat needs of the ecological community and the recreational needs of the public. In addition, providing habitat continuous over several SMUs was considered preferable to several smaller scattered habitats. Based on the remedial screening in Section 4 and the criteria for the development of lake-wide alternatives described above, SMU-specific alternatives were combined to develop the following lake-wide alternatives:

- **Alternative A – No Action.** This alternative is retained to provide a baseline of the impacts of the existing approach carried into the future. Active alternatives are compared against the No Action Alternative to determine relative magnitude and intensity of their impacts.
- **Alternative B – Capping with Targeted Dredging.** Alternative B has the least amount of dredging feasible while still being protective of human health and the environment, complying with ARARs, and meeting the RAOs and PRGs. This alternative includes capping to the mean PECQ2 in all littoral areas with targeted dredging in SMUs 3 and 6 for cap effectiveness, and dredging in SMU 3 to ensure no loss of surface area in the SMU, optimize habitat, and minimize erosive forces. Profundal sediments would be addressed with a phased approach of MNR, aeration (oxygenation), and thin-layer capping. Dredged sediments would be consolidated at Wastebed 13.

- **Alternative C – Dredging/Capping with Recreation and Habitat Diversification.** Alternative C is similar to Alternative B except that additional dredging is proposed in SMUs 1 and 2 for no loss of lake surface area in these SMUs to optimize the diversity of the lake-wide habitat, and remove sediments potentially containing NAPL to 4 meters in SMU 2.
- **Alternative D – Dredging/Capping with Minimal Armoring.** Alternative D is similar to Alternative C, except that additional dredging is proposed in SMUs 1 and 4 to reduce the amount of cap armoring (i.e., rock) required.
- **Alternative D2 – Dredging/Capping.** Alternative D2 is similar to Alternative D, except that additional dredging would be conducted in SMUs 5, 6, and 7 for no loss of lake surface area in these SMUs and for habitat optimization and minimization of erosive forces. Additional capping to the mean PECQ2 would be conducted in SMU 5.
- **Alternative E – Dredging.** Alternative E is a full removal alternative where all littoral sediments exceeding the mean PECQ2 would be dredged (except SMU 5). Profundal sediments would be addressed similarly to Alternatives B through D.
- **Alternative F – Dredging/Capping.** Alternative F is similar to Alternative D2, except that dredging and/or capping would be done to the mean PECQ1 rather than the mean PECQ2, resulting in additional dredging and capping in SMUs 5 and 6, and additional capping in SMU 8. Alternatives F1 through F4 differ only in the amount of sediment dredged from SMU 1. Alternative F1 involves dredging for no loss of lake surface area and for habitat optimization and minimization of erosive forces in SMU 1. Alternative F2 involves dredging of 25 per cent of the volume of the ILWD. Alternative F3 involves dredging of the top 3 meters of the ILWD, and Alternative F4 involves dredging of the top 4 meters of the ILWD.
- **Alternative G – Dredging/Capping.** Alternative G is the same as Alternatives F1 through F4, except that the dredging in SMU 1 would be to a depth of 5 meters.
- **Alternative H – Dredging/Capping.** Alternative H is the same as Alternative G, except that dredging in SMU 2 would be conducted for full removal of NAPL.
- **Alternative I – Dredging/Capping.** Alternative I involves full removal of all littoral sediments exceeding the mean PECQ1 (except SMU 5). This alternative is similar to Alternative E, except that dredging and/or capping would be conducted to the mean PECQ1 rather than the mean PECQ2, and dredging followed by capping in SMU 5 would be conducted for no loss of lake surface area in SMU 5 and for habitat optimization and minimization of erosive forces.
- **Alternative J – Dredging/Capping.** Alternative J involves full removal of all littoral sediments exceeding the ER-L (except SMU 5, which would be capped). This alternative is similar to Alternative I, except the ER-L is used rather than the mean PECQ1.

Alternative A is a baseline for development and evaluation of the other alternatives. Alternatives B through D2 were developed as impacted sediment removal/isolation (to the mean PECQ2) and habitat improvement alternatives, whereas Alternative E focuses on impacted sediment removal (to the mean PECQ2). Alternatives F1 through H provide a range of sediment removal/isolation and habitat improvement alternatives, based on the mean PECQ1. Alternatives B through D2 and F1 through H represent a range of dredge/cap alternatives that provide different habitat and erosive force control options through increased dredging and variations in cap design, as well as different endpoints (mean PECQ2 or mean PECQ1). These alternatives also include aeration (oxygenation), thin-layer capping, and MNR in the profundal area (SMU 8). Alternatives I and J, like Alternative E, focus on impacted sediment removal, but to different endpoints (mean PECQ1 for Alternative I, and ER-L for Alternative J). These alternatives provide a full range of alternatives from no action to full sediment removal to the ER-L.

Following development of the lake-wide alternatives, a holistic approach was used to evaluate and compare the lake-wide alternatives based on the seven CERCLA criteria. In particular, impacts to fish and wildlife, short and long-term effectiveness, implementation issues, community/worker exposure issues, sediment consolidation, supernatant treatment, and cost were considered on a lake-wide basis. This evaluation is provided in Subsection 5.3.

5.2 DESCRIPTION OF LAKE-WIDE ALTERNATIVES

The lake-wide alternatives described in Subsection 5.1 are further developed in this subsection. It is assumed under all lake-wide alternatives that upland source control of CPOIs related to Honeywell and non-Honeywell sites would be performed prior to implementing the in-lake remedy. In addition, remedy design and implementation of all lake-wide alternatives would consider in-lake infrastructure, potential cultural artifacts, and/or debris in the lake, as described in Section 4.

Table 5.1 presents a summary of the lake-wide alternatives by SMU. Total cap area, dredge volume, implementation duration, and cost are included in this table. The SMU-specific capping areas and dredging volumes corresponding to each of these lake-wide alternatives are provided in Table 5.2.

5.2.1 Alternative A – No Action

For the No Action Alternative, no action is implemented to address any of the SMUs within the lake or to monitor progress toward remedial goals. The No Action Alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The alternative does not include institutional controls, such as a fish consumption advisory. The No Action Alternative is retained for all SMUs as a baseline for comparison to other alternatives, consistent with CERCLA guidance and the NCP.

5.2.2 Alternative B – Capping with Targeted Dredging

The Capping with Targeted Dredging Alternative (Lake-wide Alternative B) includes a combination of targeted dredging, capping, habitat optimization, habitat enhancement, MNR, aeration (oxygenation), and phased thin-layer capping, as summarized on a SMU-specific basis in Table 5.1. Table 5.2 provides a summary of capping areas and dredging volumes for each SMU. Specifically, the components of Lake-wide Alternative B include:

- Dredging of an estimated 223,000 CY of sediment;
- Isolation capping over an estimated 336 acres of the littoral area (i.e., approximately 30 percent of the littoral area) to isolate CPOIs;
- Thin-layer capping over an estimated 20 acres of the profundal area to reduce CPOI concentrations in the surface layer of sediment and enhance natural recovery;
- Habitat optimization over approximately 336 acres of the littoral and shoreline areas to improve habitat value by providing substrate for fish habitat, macrophytes, and benthic organisms;
- Habitat enhancement along an estimated 1.5 miles (2,500 m) of shoreline (SMU 3) and over approximately 23 acres (SMU 5) to stabilize calcite deposits and oncolites, and promote submerged macrophyte growth;
- Aeration (oxygenation) of the hypolimnion to reduce methylation of mercury, reduce methylmercury flux from profundal sediments, and thereby reduce mercury bioaccumulation in fish tissue;
- MNR in the profundal area with a potential contingency of thin-layer capping if predicted goals are not achieved during the MNR period;
- Consolidation of dredged sediment in an on-site SCA;
- Treatment of SCA supernatant prior to discharge back to Onondaga Lake; and
- Continuation of institutional controls on fish consumption as necessary and implementation of other institutional controls as needed to ensure long-term effectiveness.

The dredging and capping components of this alternative would occur over a period of approximately three years, assuming two dredging and four capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the remedial technologies that would be employed during remediation (i.e., targeted dredging, capping, etc.).

5.2.2.1 Dredging of Impacted Littoral Sediments

Targeted dredging is a component of the selected remedy for SMUs 3 and 6 for Lake-wide Alternative B. This portion of the remedy (i.e., dredging of an estimated 223,000 CY of sediment) would include the following elements:

- Completion of pilot testing and pre-design investigations to optimize implementation and ensure effectiveness of the removal activities;
- Targeted dredging (hydraulic dredging assumed for evaluation purposes) in the nearshore area, where the predicted upwelling velocities are highest, to remove an estimated 6.6 ft (2 m) of sediment within 260 ft (80 m) of the shoreline in SMU 3, and an estimated 6.6 ft (2 m) of sediment within 220 ft (70 m) of the shoreline in SMU 6; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

Pre-design investigation work would be performed to provide site-specific design parameters, additional impacted sediment delineation, and geotechnical data required for remedy design. In addition to a lake bottom bathymetric survey, an evaluation of dredging methods and treatability testing for supernatant generated through sediment consolidation would be performed. RI/FS data of acceptable quality will be used, as appropriate, in addition to data to be collected during pre-design for decisions regarding the final design of the lake remedy.

Targeted dredging would be performed to enhance long-term cap effectiveness through removal of sediments in nearshore elevated upwelling velocity areas. Although CPOI concentrations in nearshore sediments are not elevated in comparison with the rest of SMUs 3 and 6, groundwater modeling indicates that predicted upwelling velocities are at their greatest near shore, and may prevent the cap from providing complete chemical isolation in this area. Pre-design investigation results would be used to determine whether sediment removal or groundwater containment would be the most appropriate approach to ensure cap effectiveness. However, for evaluation purposes, it is assumed that this area would be removed prior to capping.

Dredging would also be performed in SMU 3 to optimize habitat and minimize erosive forces on the cap. Since removal to an optimal habitat depth to promote submerged macrophyte growth can be synergistic with removal to a depth that reduces the erosive forces on the cap, both criteria were considered. Therefore, the goal is to remove nearshore sediments to a depth that requires no significant armoring and that maximizes the area with a water depth between 2 and 6 ft (0.6 to 1.8 m), as recommended in Appendix M, habitat issues.

5.2.2.2 Capping of Impacted Littoral and Profundal Sediments

The capping component of Lake-wide Alternative B includes isolation or thin-layer capping to the mean PECQ2 in SMUs 1, 2, 3, 4, 6, and 7. In SMU 8, capping would also address the mean PECQ2, including estimated future exceedances of the Hg PEC, and the mercury BSQV (as applied to a combination of littoral and profundal sediment). Isolation or thin-layer capping would incorporate the following elements:

- Completion of pre-design investigations to optimize implementation and ensure effectiveness of the sediment isolation or thin-layer cap (same as described for dredging in Subsection 5.2.2.1);
- Installation of an estimated 336 acres of isolation cap over those portions of the littoral area with mean PECQ2 exceedances, as further delineated during the pre-design investigation;
- Installation of a thin-layer cap over portions of the profundal area (currently estimated at approximately 20 acres in SMU 8) that would otherwise be expected to exceed the mercury PEC after an MNR period in the presence of aeration (oxygenation). No profundal sediment currently exceeds the mean PECQ2.
- Installation of a thin-layer cap over portions of the profundal area that, in combination with littoral sediments, would otherwise be expected to exceed the mercury BSQV on a surface area weighted concentration basis, after an MNR period in the presence of aeration (oxygenation). The pre-design investigation (including new data and a revised MNR model) may result in a recommendation for additional thin-layer capping in SMU 8 during Phase I to meet the BSQV.
- Long-term monitoring and maintenance of the isolation and thin-layer cap; and
- Use of institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

The isolation cap would be designed to meet the following performance standards:

- Provide physical isolation of the impacted sediments from benthic organisms, where applicable;
- Be physically stable; and
- Provide chemical isolation of impacted sediments from flux or resuspension into the overlying surface waters.

Specific factors that would be evaluated as part of the design of the isolation layer include erosion, bioturbation, chemical isolation, habitat, settlement, static and seismic stability, and placement techniques. The results of a preliminary capping evaluation performed in accordance with USEPA and Corps of Engineers guidance (USEPA, 2002a; Palermo, Clausner, *et al.*, 1998; and Palermo, Miller, *et al.*, 1998) are provided in Subsection 4.3.3 and Appendix H, capping issues.

Chemical isolation modeling predicts that the following preliminary cap designs would result in no exceedances of the PECs for the modeled individual compounds used in the calculation of the mean PECQ and no exceedances of the NYSDEC SSCs for benzene, toluene, and phenol in the bioturbation layer at steady state, assuming worst case conditions (i.e., maximum groundwater upwelling velocity, maximum measured CPOI concentrations, and 5 percent organic carbon):

- **SMUs 1, 2, and 7**: 2.5-ft (0.8-m) thick chemical isolation layer (4.25-ft [1.3-m] placement thickness to include a factor of safety of 1.5 and an additional 6 inches [15 cm] for mixing with underlying sediment and uneven application).
- **SMUs 3, 4, and 6**: 1-ft (0.3-m) thick chemical isolation layer (2.0-ft [0.6-m] placement thickness to include a factor of safety of 1.5 and an additional 6 inches [15 cm] for mixing with underlying sediment and uneven application).

Evaluations of wind-generated waves, flood flows at the mouths of tributaries, prop wash from vessels, and ice scour predict that a cap armor layer consisting of gravel or sand (depending on location and water depth) and armor stone along the shoreline would provide physical stability for the cap. A habitat layer incorporated as part of the armor layer or placed above the armor layer would complete the isolation cap design (see Subsection 5.2.2.3 for details).

In addition, for the isolation cap to be effective in SMUs 1 and 2, the Wastebed B and Willis/Semet hydraulic control systems are assumed to be in place to minimize upwelling velocities in these SMUs. In SMU 2, the Willis/Semet hydraulic control system would have to be located on the lake side of the causeway and contain or reduce areas with elevated porewater concentrations for the isolation cap to be effective. This hydraulic control system configuration would result in some lake surface area being converted to upland area (i.e., primarily the lake area under the causeway). A similar hydraulic control system adjacent to SMU 7 would also be necessary for the isolation cap in SMU 7 to be effective, and is included as part of this alternative.

As indicated previously, in addition to isolation capping, thin-layer capping is an integral component of this alternative. The objective of thin-layer capping in the profundal area is not to isolate surface sediments, but to provide an immediate decrease in surface sediment concentrations by introducing clean sediment into the upper layer of sediment. Construction and subsequent natural processes, primarily bioturbation, would mix the new sediment with the underlying material and thereby reduce ecological effects associated with CPOIs. Based on the modeling in Appendix N, monitored natural recovery, it is estimated that a thin-layer cap consisting of 6 inches (15 cm) of sand would provide a sufficient decrease in surface sediment CPOI concentrations to be protective.

It is assumed for costing purposes that 20 acres of thin-layer capping would occur in the profundal area adjacent to SMUs 1 and 6. Additional thin-layer capping would be performed in the profundal area, if necessary based on the results of the phased MNR and aeration (oxygenation) approach described in Subsection 5.2.2.4.

All of SMUs 1, 4, and 7 would be capped with an isolation or thin-layer cap. For this evaluation, it is assumed that an isolation cap would be required up to the shallow littoral zone (i.e., 20-ft (6-m) water contour), as well as the deeper littoral (transition) zone between the 20- and 30-ft (6- and 9-m) water contour. Current data indicate the transition zone is in an area of net sediment deposition and lower CPOI concentrations, as compared to the rest of the littoral area. In addition, although benthic macroinvertebrates are present, groundwater upwelling (see Appendix D, groundwater issues) and fish spawning are considered to be negligible in this area. Additional data from the pre-design investigation is required to determine whether an isolation or a thin-layer cap is appropriate.

Since no sediment removal would occur in SMUs 1, 2, and 4 prior to capping, and settlement analyses predict that the settlement would be less than the cap thickness, some lake surface area would be lost as a result of capping. This area would be converted into upland habitat and/or emergent wetlands. No sediment removal would occur in SMU 7, but settlement is estimated to exceed the cap thickness, so there is projected to be no loss of lake surface area in that SMU due to the capping.

A long-term monitoring program would be designed to confirm that the cap remains in place and is effective over time. Cap surveys would be performed and compared with a post-cap installation survey to determine maintenance requirements and ensure the long-term integrity and protectiveness of the cap. In addition, periodic core sampling may be performed to verify cap integrity and effectiveness.

5.2.2.3 Aquatic Habitat Optimization and Enhancement

Habitat optimization and enhancement under Lake-wide Alternative B would improve aquatic habitat throughout the lake by optimizing the surface characteristics of the isolation cap to enhance growth of submerged macrophytes, increase fish spawning, and resist erosive forces. In other areas of the lake where capping is not needed to protect human health and the environment, habitat would also be improved through various enhancements, as discussed below.

Habitat Optimization

The habitat optimization component of Lake-wide Alternative B would provide additional habitat value to the lake and shoreline through installation of various substrates and vegetative communities on the cap surface. Habitat optimization would be implemented over an estimated 336 acres of the littoral and shoreline area (not including SMU 5, which is discussed later in this subsection), as follows:

- **Upland Habitat** - Approximately 13 acres of upland habitat area would be created from existing aquatic habitat in SMUs 1, 2, and 4. The upland habitat would provide connectivity of in-lake and shoreline/upland habitats. Terrestrial wildlife receptors would benefit from provision of cover and access to the enhanced prey base resulting from in-lake habitat improvements. The upland habitat would also serve as a recreational area.
- **Emergent Wetlands** - Approximately 15 acres of emergent wetland would be established over the isolation cap in SMUs 1, 2, and 4. Emergent wetlands would improve the connectivity of in-lake and shoreline/upland habitats and provide cover and nursery areas for juvenile fishes. Terrestrial wildlife receptors would benefit from

access to the enhanced prey base resulting from in-lake habitat improvements. The emergent wetlands would also dissipate wind-wave energy and help stabilize the shoreline.

- **Recreational / Habitat Buffer Zone** - Approximately 12 acres of a recreational / habitat buffer zone would be established in SMUs 1, 3, and 7 over the isolation cap. This zone would consist primarily of a sand layer over a rock layer that would protect the isolation cap from erosive forces within the lake. The larger rock size layer provides protection against erosive forces to ensure cap integrity. Addition of the sand layer over the rock provides a suitable substrate for colonization of benthic macroinvertebrates and possibly submerged macrophytes. These changes would increase the prey base for insectivorous fish species (e.g., juvenile largemouth bass). The sand would also provide a recreational buffer more suitable for direct contact (e.g., wading, boating) than the underlying rock.
- **Macrophyte / Benthic Area** - Approximately 58 acres of submerged macrophyte / benthic area within SMUs 1, 2, 3, 4, 6, and 7 would be created with a sand layer over the isolation cap. The submerged macrophyte colonization and benthic macroinvertebrate recruitment of the sand layer would increase the prey base for benthivorous and insectivorous fish species and provide protective cover for juvenile fish including largemouth and smallmouth bass. In shallower areas, piscivorous fish and terrestrial receptors would benefit from the enhanced prey base resulting from in-lake habitat improvements.
- **Fish Spawning Habitat** - Approximately 134 acres of fish spawning habitat for game fish (e.g., bass) would be created over the isolation cap within SMUs 1, 2, 3, 4, 6, and 7. The thin gravel layer would provide additional microhabitats for benthic macroinvertebrates, thereby increasing the diversity of benthic communities. Addition of large woody debris structures would provide cover for fish species and a substrate for colonization by epifaunal invertebrates. The colonization of the large woody debris would increase the prey base for insectivorous fish species and provide protective cover for juvenile fish including largemouth and smallmouth bass. In addition, piscivorous fishes would benefit from the enhanced prey base resulting from in-lake habitat improvements.
- **Benthic Substrate Area** - Approximately 113 acres of benthic substrate area would be created within SMUs 1, 2, 3, 4, 6, and 7 with a thin sand layer above the isolation cap. This includes approximately 77 acres in the transition zone between the littoral and profundal zones. The sand layer would provide a suitable substrate for colonization of benthic macroinvertebrates. The colonization of these areas would increase the prey base for benthivorous fish species.

As part of the pre-design investigation described for the capping component, habitat studies would be performed to refine the habitat optimization approach described above to provide maximum benefits for the environment. Final details will be established during remedial design based on the lake-wide habitat restoration plan that will also incorporate habitat restoration associated with other remedial actions along the shoreline of Onondaga Lake.

Habitat Enhancement

The habitat enhancement portion of this alternative focuses on stabilizing existing substrates in SMUs 3 and 5. The objectives for habitat enhancement in SMU 3 are as follows:

- Reduce erosion of existing calcite deposits along the shoreline of SMU 3 through stabilization; and
- Provide structure for fish spawning and protective cover for macrophyte establishment.

Stabilization of the calcite deposits along SMU 3 can be achieved through the use of conventional physical armoring with rock riprap and/or bioengineering techniques that use native plant species. Potential bioengineering techniques would include the establishment of woody vegetation through embedment of live fascines and/or the use of vegetative (brush) mattresses along the shoreline. Once established, both techniques would slow water movement across the slope, increase infiltration, trap slope sediments, and increase soil stability with the root system. Specific techniques, sediment amendments, and species composition would be selected during remedial design.

As discussed previously, large woody debris would be used to provide structure for fish spawning and protective cover for macrophyte establishment. The specific locations, types, and sizes of large woody debris would be determined during remedial design.

Stabilization of the steep slopes of wastebed material along the upland portions of SMU 3 would also be desirable to prevent future erosion of wastebed material and improve the aesthetics of the area. Stabilization of the wastebed face would be part of the remediation of Wastebeds 1-8 and would be integrated with future plans for the wastebeds, including future land use and redevelopment plans. Options for addressing these areas could include cutting back the slope of the wastebeds along the lake, providing landscaping, or providing physical stability through the use of sheet piling, etc. These and other options would be evaluated in concert with the evaluation of remedial options for the wastebeds.

The primary objective of habitat enhancement in SMU 5 is to facilitate colonization of macrophytes through stabilization of oncolitic sediments. Areas of SMU 5 would be selected for enhancement based on their habitat suitability index for largemouth bass, which is usually in the 25 percent to 60 percent cover range (assumed to be macrophyte cover in this evaluation). A target of 40 percent cover was used to calculate the areal extent of the treatment areas for SMU 5 in the low and moderate wave-energy zones along the northwestern (between Ninemile Creek and Sawmill Creek) and northeastern shoreline (between Sawmill Creek and Bloody Brook). These targeted areas consist of approximately 23 acres. Because habitat improvements may be addressed under the Onondaga Lake Trail project (Trail Segment 3C), enhancement is not recommended for the southeastern shoreline of SMU 5 (between Bloody Brook and Ley Creek).

However, depending on how and/or when the trail project is implemented, the habitat enhancement could be expanded to include this area.

At this time, the recommended approach for habitat enhancement would be completed within an experimental framework to test the hypothesis that *in situ* stabilization of oncolitic sediments would facilitate macrophyte colonization and expansion. Habitat enhancement would include stabilization using vertical treatments (e.g., hay bales) or a combination of vertical and horizontal treatments (e.g., hay bales combined with chicken wire or a biodegradable mesh). The purpose of the treatments is to minimize potential migration of oncolites from offsite areas into the treatment areas and to stabilize oncolites within the treatment areas.

In addition to the vertical and/or horizontal treatments, several subtreatments would be applied to the targeted areas. These subtreatments would be varied in test plots within the treatment area to establish the most effective methods for macrophyte colonization. Subtreatments and variations would include seeding/planting versus no seeding/planting of macrophytes, herbivore protection versus no herbivore protection, and extent and duration of wave-break protection. The combinations of treatments and subtreatments required to assess effectiveness, to assess long-term requirements for wave protection, and to allow experiments to be repeated and/or modified would likely take three to five years to complete.

Construction of a public swimming beach in SMU 5 may be desirable between the marina and the outlet along the northeast portion of the lake, if it is consistent with community goals for the lake and land use planning. This beach would be constructed through the placement of sand in and adjacent to the lake, and would further assist with the control of oncolites and habitat enhancement in SMU 5. Considering the anticipated improvements in water quality resulting from the nutrient removal improvements being implemented by the County, adding a beach as a public resource would likely be well regarded by the local community.

5.2.2.4 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

MNR / aeration (oxygenation) of the hypolimnion / phased thin-layer capping would be implemented in the profundal area under Lake-wide Alternative B and includes the following:

- Completion of pre-design investigations and pilot testing to optimize implementation and ensure effectiveness of aeration (oxygenation), MNR, and phased thin-layer capping. Pilot efforts would be coordinated with the Onondaga Lake Partnership, which is planning similar pilot aeration studies on the lake;
- Installation of a thin-layer cap (assumed for costing purposes to be 20 acres in the profundal area adjacent to SMUs 1 and 6, as discussed in Subsection 5.2.2.2) prior to the start of the MNR period. In addition, installation of a full-scale aeration (oxygenation) system, as appropriate following pilot testing (Phase I);
- Long-term monitoring (Phase II);

- Installation of a thin-layer cap and/or continued MNR (Phase III) after the end of the initial MNR period in areas of the SMU that exceed the SEC value established as the cleanup criteria; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

As indicated above, following pilot testing and pre-design investigations, MNR, aeration (oxygenation), and thin-layer capping would be implemented in a coordinated, phased approach. Phase I activities would include the initiation of natural recovery monitoring and implementation of aeration (oxygenation) if shown to be effective during the pilot test, and limited thin-layer capping in areas predicted to not meet the mercury PEC through natural recovery (as described in Subsection 5.2.2.2). In addition, thin-layer capping in Phase I may include capping of portions of the profundal area that, in combination with littoral sediments, would otherwise be expected to exceed the mercury BSQV on a surface area weighted concentration basis, after an MNR period in the presence of aeration (oxygenation). Phase II would include continued monitoring to assess the effectiveness of natural recovery and a full-scale aeration (oxygenation) system. Phase III would include additional thin-layer capping as a contingency, continuation of aeration (oxygenation) if it has proven to be effective, and ongoing monitoring.

5.2.2.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative B, an estimated 28-acre SCA with 14-ft dikes would be constructed at Wastebed 13. Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment option with the recommended lake-wide alternative is discussed in detail in Section 6.

5.2.2.6 Institutional Controls

Health advisories regarding human consumption of fish from the lake and other institutional controls would be used as required to protect the public from exposure to contaminants of concern within the lake and its sediments. Additional institutional controls would be used, as warranted, to ensure the long-term integrity of the remedy and to help protect the public from exposure to CPOIs within the lake.

5.2.3 Alternative C – Dredging/Capping with Recreation and Habitat Diversification

Implementation of the Dredging/Capping with Recreation and Habitat Diversification Alternative (Lake-wide Alternative C) would include a combination of dredging, capping, habitat optimization, habitat enhancement, aeration (oxygenation), and MNR, as summarized on a SMU-specific basis in Table 5.1. Table 5.2 provides a summary of capping and dredging areas and volumes for each SMU. Specifically, the components of Lake-wide Alternative C would be the same as described for Lake-wide Alternative B, except that the dredging portion would include an estimated 543,000 CY of sediment (i.e., an additional 320,000 CY of dredging). Compared to Lake-wide Alternative B, the additional dredging under this alternative would be performed to prevent a loss of lake surface area in SMUs 1 and 2, provide more habitat diversification, and minimize erosive forces. Targeted dredging for NAPL removal would also be conducted in SMU 2.

The dredging and capping components of this alternative would occur over a period of approximately three years, which assumes two dredging and four capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the remedy in terms of the remedial technologies that would be employed during remediation (i.e., dredging, capping, etc.).

5.2.3.1 Dredging of Impacted Littoral Sediments

The targeted dredging in SMUs 3 and 6 described under Lake-wide Alternative B would also occur under Lake-wide Alternative C. In addition, dredging would be performed in SMUs 1, 2, and 3. Dredging in SMU 1 would remove sufficient sediment to achieve no loss of lake surface area following cap placement; the amount removed by dredging would be estimated based on the predicted settlement of SMU 1 sediment as a result of cap placement. Data gathered during the pre-design investigation (specifically bathymetry and geotechnical consolidation parameters) would also provide necessary information to estimate this removal depth. Based on currently available information, removal of approximately 151,000 CY of sediment would be sufficient to achieve no loss of lake surface area.

Under this alternative, targeted dredging would also be performed in SMU 2 along the causeway in the vicinity of sample location TR02-A because of elevated levels of VOCs in porewater and sediment as compared to surrounding sediments. Cap modeling indicates that an isolation cap would be effective in this area. Nevertheless, this area was identified as a potential area for removal prior to capping due to the high VOC concentrations and potential NAPL in these sediments compared to surrounding sediments. The areal extent of elevated porewater and sediment concentrations in SMU 2 would be evaluated as part of the pre-design investigation to determine whether removal is the most effective method for addressing this area. For purposes of this evaluation, removal of this sediment is assumed.

Dredging would also be performed in SMUs 2 and 3 to optimize habitat and minimize erosive forces on the cap. Since removal to an optimal habitat depth to promote submerged macrophyte growth can be synergistic with removal to a depth which reduces the erosive forces on the cap, both criteria were considered. Therefore, the goal is to remove nearshore sediments to a depth where significant armoring is not required and the area that has a water depth between 2 and 6 ft (0.6 to 1.8 m) is maximized, as recommended in Appendix M, habitat issues.

5.2.3.2 Capping of Impacted Littoral and Profundal Sediments

The capping components for Lake-wide Alternative C would be the same as those described for Lake-wide Alternative B; an estimated 336 acres of isolation cap (shallow and deep littoral), and 20 acres of thin-layer cap (profundal) would be installed under this alternative. Since no sediment removal would occur in SMU 4 prior to capping, and settlement analyses predict that the settlement would be less than the cap thickness, some lake surface area would be lost as a result of capping; however, diversified habitat, potentially including upland habitat and emergent wetlands, would be created. As described in Subsection 5.2.3.3, the habitat value of these areas would be optimized. Loss of lake surface area in SMUs 6 and 7 is not anticipated because the predicted settlement due to cap placement exceeds the cap thickness in these SMUs.

5.2.3.3 Aquatic Habitat Optimization and Enhancement

The habitat optimization component of Lake-wide Alternative C would provide additional habitat value to the lake and shoreline through installation of various substrates on the cap surface. Habitat optimization would be implemented over an estimated 336 acres of the littoral and shoreline area (not including SMU 5), as follows (see Subsection 5.2.2.3 for discussion of benefits for each habitat type):

- **Upland Area** - approximately six acres would be created from existing aquatic habitat in SMU 4;
- **Emergent Wetland** - approximately ten acres would be created in SMU 4;
- **Recreational/Habitat Buffer Zone** - approximately 25 acres would be created in SMUs 1, 2, 3, 6, and 7;
- **Submerged Macrophyte/Benthic Area** - approximately 48 acres would be created in SMUs 1, 2, 3, 4, 6, and 7;
- **Fish Spawning Habitat** - approximately 133 acres would be created in SMUs 1, 2, 3, 4, 6, and 7; and
- **Benthic Substrate Area** - approximately 114 acres would be created in SMUs 1, 2, 3, 4, 6, and 7, including 37 acres in the shallow littoral zone, and 77 acres in the deep littoral zone.

Although the types of habitat optimization are the same, the quantities of certain types of habitat are different. Lake-wide Alternatives B and C differ primarily in the amount of upland habitat, emergent wetlands, and recreational / habitat buffer areas; Alternative C has approximately 14 more acres of recreational / habitat buffer, approximately five less acres of emergent wetlands, and approximately eight less acres of upland habitat than Alternative B. A portion of the wetlands created/optimized under this alternative would be constructed contiguous with the existing wetlands adjacent to Ninemile Creek.

As part of the pre-design investigation described for the capping component, habitat studies would also be performed to refine the habitat optimization design described above. The habitat enhancement components (i.e., stabilization in SMUs 3 and 5) of Lake-wide Alternative C are the same as described for Lake-wide Alternative B.

5.2.3.4 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-layer Capping in the Profundal Area

Under Lake-wide Alternative C, the remedial activities related to MNR / aeration (oxygenation) of the hypolimnion / phased thin-layer capping in the profundal area would be the same as described for Lake-wide Alternative B (Subsection 5.2.2.4). Additional area may need capping to achieve the BSQV.

5.2.3.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative C, an approximately 54-acre SCA with 14-ft dikes would be constructed at Wastebed 13. Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the recommended lake-wide alternative is discussed in Section 6.

5.2.3.6 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternative C.

5.2.4 Alternative D – Dredging/Capping with Minimal Armoring

Implementation of the Dredging/Capping with Minimal Armoring Alternative (Lake-wide Alternative D) would include a combination of dredging, capping, habitat optimization, habitat enhancement, aeration (oxygenation), and MNR, as summarized on a SMU-specific basis in Table 5.1. Table 5.2 provides a summary of capping and dredging areas and volumes for each SMU. Specifically, the components of Lake-wide Alternative D would be the same as described for Lake-wide Alternative C, except that the dredging portion would include an estimated 881,000 CY (i.e., approximately 338,000 CY additional dredging compared to Alternative C). Compared to Lake-wide Alternative C, the additional dredging under this alternative would be performed to prevent a loss of lake surface area in SMU 4 and to optimize habitat and minimize erosive forces on the cap in SMUs 1 and 4. As a result of this additional dredging, Lake-wide Alternative D would provide less habitat diversification than Alternative C.

The dredging and capping components of this alternative would occur over a period of approximately three years, assuming two dredging and four capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the alternative in terms of the remedial technologies that would be employed during remediation (i.e., dredging, capping, etc.).

5.2.4.1 Dredging of Impacted Littoral Sediments

The dredging described under Lake-wide Alternative C would also occur under Lake-wide Alternative D; however, additional dredging would be performed in SMUs 1 and 4. In both SMUs 1 and 4, dredging would be performed to a depth that optimizes submerged macrophyte habitat and minimizes erosive forces on the cap.

Under this alternative, sufficient sediment would be removed from SMUs 1 and 4 such that the water depth following capping would support the habitat optimization recommendations detailed in Appendix M, habitat issues. Removal to an optimal habitat depth to promote submerged macrophyte growth can be synergistic with removal to a depth that reduces the erosive forces on the cap. As a result, both criteria are considered under this alternative. Therefore, the goal under this alternative is to remove nearshore sediments to a depth where significant armoring of the cap is not required, and to maximize the area that has a water depth between 2 and 6 ft (0.6 to 1.8 m) to promote submerged macrophyte growth.

5.2.4.2 Capping of Impacted Littoral and Profundal Sediments

The capping components for Lake-wide Alternative D would be the same as those described for Lake-wide Alternative B; an estimated 336 acres of isolation cap (shallow and deep littoral), and 20 acres of thin-layer cap (profundal) would be installed under this alternative. In addition, implementation of Lake-wide Alternative D would not result in the creation of upland habitat or wetlands as described for Lake-wide Alternatives B and C.

5.2.4.3 Aquatic Habitat Optimization and Enhancement

The habitat optimization component of Lake-wide Alternative D would provide additional habitat value to the lake and shoreline through installation of various substrate and vegetation establishment on the cap surface. Habitat optimization would be implemented over an estimated 336 acres of the littoral and shoreline area (not including SMU 5), as follows (see Subsection 5.2.2.3 for discussion of benefits for each habitat type):

- **Emergent Wetland** - approximately one acre would be created in SMUs 1 and 4;
- **Recreational/Habitat Buffer Zone** - approximately 13 acres would be created in SMUs 1, 2, 3, 4, 6, and 7;
- **Submerged Macrophyte/Benthic Area** - approximately 75 acres would be created in SMUs 1, 2, 3, 4, 6, and 7;
- **Fish Spawning Habitat** - approximately 134 acres would be created in SMUs 1, 2, 3, 4, 6, and 7; and

- **Benthic Substrate Area** - approximately 114 acres would be created in SMUs 1, 2, 3, 4, 6, and 7, including 37 acres in the shallow littoral zone, and 77 acres in the deep littoral zone.

Since the types of habitat optimization under Lake-wide Alternative D are the same as for Lake-wide Alternative B (Subsection 5.2.2.3), the descriptions are not repeated here. Although the types of habitat optimization are the same, the quantities of certain types of habitat are different. Implementing Lake-wide Alternative D would result in significantly less emergent wetlands than Alternatives B and C (i.e., 14 acres and 9 acres less as compared to Alternatives B and C, respectively). In addition, Alternative D has approximately half the amount of recreational / habitat buffer area as Alternative C (i.e., approximately 12 acres less), and slightly more than Alternative B (about two acres more). However, Alternative D does provide significantly more substrate to promote submerged macrophyte growth (approximately 17 acres more than Alternative B, and 26 acres more than Alternative C).

As part of the pre-design investigation described for the capping component, habitat studies would also be performed to refine the habitat optimization design described above. The habitat enhancement components (i.e., stabilization in SMUs 3 and 5) of Lake-wide Alternative D are the same as described for Lake-wide Alternative B.

5.2.4.4 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

Under Lake-wide Alternative D, the remedial activities related to MNR / aeration (oxygenation) of the hypolimnion / phased thin-layer capping in the profundal area would be the same as described for Lake-wide Alternative B (Subsection 5.2.2.4). Additional area may need capping to achieve the BSQV.

5.2.4.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative D, an approximately 84-acre SCA with 14-ft dikes would be constructed at Wastebed 13. Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the recommended lake-wide alternative is discussed in Section 6.

5.2.4.6 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternative D.

5.2.5 Alternative D2 – Dredging/Capping

Implementation of Lake-wide Alternative D2 (Dredging/Capping) would include a combination of dredging, capping, habitat optimization, habitat enhancement, aeration (oxygenation), and MNR, as summarized on a SMU-specific basis in Table 5.1. Table 5.2 provides a summary of capping and dredging areas and volumes for each SMU. Specifically, the components of Lake-wide Alternative D2 would be the same as described for Lake-wide Alternative D, except that areas of SMU 5 would be capped with an isolation cap, and the dredging portion would include an estimated 1,180,000 CY (i.e., approximately 300,000 CY additional dredging compared to Alternative D). Compared to Lake-wide Alternative D, the additional dredging under this alternative would be performed to prevent a loss of lake surface area and optimize habitat and minimize erosive forces on the cap in SMUs 5, 6, and 7. As a result of this additional dredging, Lake-wide Alternative D2 would provide more habitat diversification than Alternative D.

The dredging and capping components of this alternative would occur over a period of approximately three years, assuming two dredging and four capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the alternative in terms of the remedial technologies that would be employed during remediation (i.e., dredging, capping, etc.).

5.2.5.1 Dredging of Impacted Littoral Sediments

The dredging described under Lake-wide Alternative D would also occur under Lake-wide Alternative D2; however, additional dredging would be performed in SMUs 5, 6, and 7. In these SMUs, dredging would be performed to a depth that optimizes submerged macrophyte habitat and minimizes erosive forces on the cap.

Under this alternative, sufficient sediment would be removed from SMUs 5, 6, and 7 such that the water depth following capping would support the habitat optimization recommendations detailed in Appendix M, habitat issues. Removal to an optimal habitat depth to promote submerged macrophyte growth can be synergistic with removal to a depth that reduces the erosive forces on the cap. As a result, both criteria are considered under this alternative. Therefore, the goal under this alternative is to remove nearshore sediments to a depth where significant armoring of the cap is not required, and to maximize the area that has a water depth between 2 and 6 ft (0.6 to 1.8 m) to promote submerged macrophyte growth.

5.2.5.2 Capping of Impacted Littoral and Profundal Sediments

The capping components for Lake-wide Alternative D2 would be the same as those described for Lake-wide Alternative D, with the addition of approximately 36 acres in SMU 5, resulting in an estimated 375 acres of isolation cap (shallow and deep littoral), and 20 acres of thin-layer cap (profundal) that would be installed under this alternative. In addition, implementation of Lake-wide Alternative D2 would not result in the creation of upland habitat or wetlands as described for Lake-wide Alternatives B and C, or in the loss of lake surface area.

5.2.5.3 Aquatic Habitat Optimization and Enhancement

The habitat optimization component of Lake-wide Alternative D2 would provide additional habitat value to the lake and shoreline through installation of various substrate and vegetation establishment on the cap surface. Habitat optimization would be implemented over an estimated 372 acres of the littoral and shoreline area (including SMU 5), as follows (see Subsection 5.2.2.3 for discussion of benefits for each habitat type):

- **Emergent Wetland** - approximately one acre would be created in SMUs 1, 4, and 7;
- **Recreational/Habitat Buffer Zone** - approximately 20 acres would be created in SMUs 1 through 7;
- **Submerged Macrophyte/Benthic Area** - approximately 95 acres would be created in SMUs 1 through 7;
- **Fish Spawning Habitat** - approximately 139 acres would be created in SMUs 1 through 7; and
- **Benthic Substrate Area** - approximately 117 acres would be created in SMUs 1 through 7, including 39 acres in the shallow littoral zone, and 78 acres in the deep littoral zone.

Since the types of habitat optimization under Lake-wide Alternative D2 are the same as for Lake-wide Alternative B (Subsection 5.2.2.3), the descriptions are not repeated here. Although the types of habitat optimization are the same, the quantities of certain types of habitat are different. Implementing Lake-wide Alternative D2 would create no upland habitat and would result in significantly less emergent wetlands than Alternatives B and C, but is comparable to Alternative D. In addition, Alternative D2 has more recreational/habitat buffer area than Alternatives B and D, but less than Alternative C. However, Alternative D2 does provide more substrate to promote submerged macrophyte growth, and provides slightly greater amounts of fish spawning habitat and benthic substrate habitat than Alternatives B through D.

As part of the pre-design investigation described for the capping component, habitat studies would also be performed to refine the habitat optimization design described above. The habitat enhancement components (i.e., stabilization in SMUs 3 and 5) of Lake-wide Alternative D2 are the same as described for Lake-wide Alternative B.

5.2.5.4 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

Under Lake-wide Alternative D2, the remedial activities related to MNR / aeration (oxygenation) of the hypolimnion / phased thin-layer capping in the profundal area would be the same as described for Lake-wide Alternative B (Subsection 5.2.2.4). Additional area may need capping to achieve the BSQV.

5.2.5.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative D2, an approximately 112-acre SCA with 14-ft dikes would be constructed at Wastebed 13. Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the recommended lake-wide alternative is discussed in Section 6.

5.2.5.6 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternative D2.

5.2.6 Alternative E – Dredging

Implementation of the Dredging Alternative (Lake-wide Alternative E) would include a combination of dredging, backfilling, residual capping (if needed), habitat re-establishment, habitat enhancement, aeration (oxygenation), MNR, and phased thin-layer capping, as summarized on a SMU-specific basis in Table 5.1. Table 5.2 provides a summary of dredging and backfilling areas and volumes for each SMU. Development of this alternative focused on the removal of all sediment in the littoral zone that exceeds the mean PECQ2. Specifically, the components of Lake-wide Alternative E include:

- Based on existing data, hydraulic dredging of at least 11,247,000 CY of sediment from 336 acres of the littoral area (i.e., approximately 33 percent of the littoral area);
- Backfilling dredged areas with approximately 7,600,000 CY of material;
- Thin-layer capping (approximately 20 acres) to reduce CPOI concentrations in the surface layer of sediment and enhance natural recovery in the profundal area;
- Habitat re-establishment;
- Habitat enhancement over approximately 23 acres (SMU 5 only) to stabilize oncolites and promote submerged macrophyte growth;
- Aeration (oxygenation) of the hypolimnion to reduce methylation of mercury, reduce methylmercury flux from profundal sediments and thereby reduce mercury bioaccumulation in fish tissue;

- MNR in the profundal area with a potential contingency of thin-layer capping if predicted goals are not achieved during the MNR period;
- Consolidation of dredged sediment in an on-site SCA;
- Treatment of SCA supernatant prior to discharge back to Onondaga Lake; and
- Continuation of institutional controls on fish consumption until PRGs are achieved along with implementation of other institutional controls as needed to ensure long-term effectiveness.

It should be recognized, as discussed in Section 4, that the depth of impacts that exceed the mean PECQ2 has not been fully delineated in all areas. Therefore, significant uncertainty exists regarding the volumes that would be removed under this alternative. Actual removal volume under this alternative may be significantly greater than 11,247,000 CY. For example, in SMU 1 the depth of impacted sediment that exceeds the mean PECQ2 is currently not delineated. As indicated in Subsection 4.3, the RI borings indicate that impacted sediment exceeding the mean PECQ2 extends to a depth of at least 26 ft (8 m); however, it is likely that impacted material extends beyond this depth (i.e., potentially to a depth greater than 40 ft). Similar uncertainty regarding the depth limit of mean PECQ2 exceedances is present in all the SMUs.

The dredging and capping components of this alternative would occur over a period of approximately nine years, assuming four dredging and eight capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the remedy in terms of the remedial technologies that would be employed during remediation (i.e., dredging, backfilling, etc.).

5.2.6.1 Dredging and Backfilling

The dredging and backfilling components of this alternative would include the following elements:

- Completion of pilot testing and pre-design investigations to optimize dredging implementation;
- Installation of a shoreline retention wall or reinforcement of currently planned hydraulic control systems, in select SMUs, to allow deep sediment removal along the shoreline;
- Dredging of all sediments in SMUs 1, 2, 3, 4, 6, and 7 (i.e., littoral area except SMU 5) that exceed the mean PECQ2;
- Backfilling would be performed in the dredged area to result in a uniform slope from the shoreline out to where dredging concludes;
- Residual capping, if necessary; and

- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

As described for the other lake-wide alternatives, pilot testing and pre-design investigations would be required to more completely delineate the nature and extent of contamination, to establish site design parameters, and to gather geotechnical data for remedy design. At this time, the depth of removal is not conclusive because of data limitations.

Following dredging under this alternative, in some cases the sediment surface may be so deep that it is of minimal habitat value. As discussed in Appendix M, habitat issues, habitat value is minimal in water depths beyond 15 ft (4.6 m), which is the maximum fish spawning depth. Therefore, it is assumed for evaluation purposes that backfill would be added to the dredged area to result in a uniform slope from the shoreline out to where dredging concludes. Additional backfilling would improve habitat value, but would increase remedial costs and increase short-term risks due to transportation of the large volume of imported backfill required. Therefore, backfilling to a uniform slope was selected for evaluation purposes as a reasonable backfill depth. Actual required backfilling requirements would be determined based on further evaluation as part of the design process.

5.2.6.2 Habitat Re-establishment and Enhancement

The habitat re-establishment component of Alternative E would include:

- Augmentation of natural establishment of submerged macrophyte growth in the 2 to 6 ft (0.6 to 1.8 m) depth by broadcast seeding and addition of tubers; and
- Placement of a six-inch (15-cm) layer of fine gravel in water depths between 6 and 15 ft (1.8 and 4.6 m) to promote fish spawning.

As described above, augmentation of the natural establishment of submerged macrophytes would occur during habitat re-establishment. However, it should be recognized that the area with a final water depth of 2 to 6 ft (0.6 to 1.8 m) where submerged macrophytes are expected to grow would be significantly less than the other alternatives due to the deeper post-dredging water depths and the backfilling strategy described in Subsection 5.2.6.1.

The components of habitat enhancement for SMU 5 under Lake-wide Alternative E are the same as those described for SMU 5 under Lake-wide Alternative B in Subsection 5.2.2.3. In addition, wetlands would not be created in any of the SMUs as a result of implementation of Lake-wide Alternative E.

5.2.6.3 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

The remedial activities for thin-layer capping, aeration (oxygenation) of the hypolimnion, and MNR in the profundal area under Lake-wide Alternative E would be the same as described for Lake-wide Alternative B. Additional area may need capping to achieve the BSQV.

5.2.6.4 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative E an estimated 262-acre SCA with 50-ft dikes would be constructed at Wastebeds 13 and 14 (as needed). Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the selected lake-wide alternative is discussed in Section 6.

5.2.6.5 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternative E.

5.2.7 Alternative F – Dredging/Capping

Implementation of Lake-wide Alternative F (Dredging/Capping) would include a combination of dredging, capping, habitat optimization, habitat enhancement, aeration (oxygenation), and MNR, as summarized on a SMU-specific basis in Table 5.1. There are four variations of Alternative F (Alternatives F1 through F4), addressing sequentially increasing sediment removal in SMU 1. Table 5.2 provides a summary of capping and dredging areas and volumes for each SMU.

Specifically, the components of Lake-wide Alternative F1 would be the same as described for Lake-wide Alternative D2, except that the dredging and capping would be based on the mean PECQ1 rather than the mean PECQ2. This would result in additional capping in SMUs 5 and 6, and increasing the dredged volume to an estimated 1,207,000 CY (i.e., approximately 27,000 CY additional dredging compared to Alternative D2). In SMU 5, the dredged volume would increase from 124,000 to 140,000 CY, and the capped area would increase from approximately 36 to 60 acres. In SMU 6, the dredged volume would increase from approximately 234,000 to 245,000 CY, and the capped area would increase from approximately 94 to 123 acres. In addition, in SMU 8, the phased thin-layer capping area would increase from an estimated 20 to 154 acres. Additional capping would be conducted as needed to achieve the BSQV.

Alternative F2 would be the same as Alternative F1, with additional dredging in SMU 1 to a depth of approximately 13 feet (4 meters) below the mean lake water level. This would result in the removal of approximately 25 per cent of the volume of the ILWD, and would increase the dredged volume in SMU 1 from approximately 354,000 CY over 84 acres to 1,015,000 CY over the same acreage (an increase of approximately 661,000 CY). The total dredged volume for this alternative would increase from approximately 1,207,000 CY to 1,868,000 CY.

Alternative F3 would be the same as Alternatives F1 and F2, with additional dredging in SMU 1 resulting in the removal of the top 3 meters of the ILWD. This would increase the dredged volume in SMU 1 from approximately 1,015,000 CY for Alternative F2 to 1,566,000 CY for Alternative F3 (an increase of approximately 551,000 CY), over the same 84 acre area. The total dredged volume for this alternative would increase from approximately 1,868,000 CY to 2,419,000 CY.

Alternative F4 would be the same as Alternatives F1 through F3, with additional dredging in SMU 1 resulting in the removal of the top 4 meters of the ILWD. This would increase the dredged volume in SMU 1 from approximately 1,566,000 CY for Alternative F3 to 2,094,000 CY for Alternative F4 (an increase of approximately 528,000 CY), over the same 84 acre area. The total dredged volume for this alternative would increase from approximately 2,419,000 CY to 2,947,000 CY.

The dredging and capping components of this alternative would occur over a period of approximately four years for Alternatives F1 through F4, assuming two dredging and four capping crews for Alternatives F1 and F2, and four dredging and eight capping crews for Alternatives F3 and F4. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the alternative in terms of the remedial technologies that would be employed during remediation (i.e., dredging, capping, etc.).

5.2.7.1 Dredging of Impacted Littoral Sediments

The dredging previously described under Lake-wide Alternative D2 would also occur under Lake-wide Alternative F; however, additional dredging would be performed in SMU 1 as follows:

- Dredging to Mean PECQ1 for no loss of surface area and for habitat optimization and minimization of erosive forces (Alternative F1);
- Dredging to remove approximately 25 percent of the sediment volume in the ILWD (Alternative F2);
- Dredging to a sediment depth of 3 meters (Alternative F3); and
- Dredging to a sediment depth of 4 meters (Alternative F4).

Sediment removal under Alternatives F1 through F4 would range from approximately 1,207,000 to 2,947,000 CY, with the difference being the amount removed in SMU 1.

Under Alternative F1, sufficient sediment would be removed from SMUs 1, 2, 3, 4, 5, 6, and 7 such that the water depth following capping would support the habitat optimization recommendations detailed in Appendix M, habitat issues. Removal to an optimal habitat depth to promote submerged macrophyte growth can be synergistic with removal to a depth that reduces the erosive forces on the cap. As a result, both criteria are considered under this alternative. Therefore, the goal under this alternative is to remove nearshore sediments to a depth where significant armoring of the cap is not required, and to maximize the area that has a water depth between 2 and 6 ft (0.6 to 1.8 m) to promote submerged macrophyte growth.

Under Alternatives F2 through F4, portions of the ILWD in SMU 1 would be removed to below the depth for optimal submerged macrophyte growth, so these alternatives provide for less habitat for submerged macrophytes. However, habitat created under these alternatives is preferable to the impacted habitat under Alternative A.

5.2.7.2 Capping of Impacted Littoral and Profundal Sediments

The capping components for Lake-wide Alternatives F1 through F4 would increase by approximately 187 acres from those described for Lake-wide Alternative D2, due to the use of the mean PECQ1 rather than the mean PECQ2 to define areas subject to dredging and/or capping. This would result in an estimated 425 acres of isolation cap (320 to 344 acres of shallow littoral isolation cap, and 91 to 105 acres of deep littoral isolation cap), and 154 acres of profundal thin-layer cap that would be installed under this alternative. The additional profundal cap area compared to Alternatives B through D2 is the result of the use of the mean PECQ1 to define areas to be addressed. Capping of additional profundal area may be needed to achieve the BSQV.

Implementation of Lake-wide Alternatives F1 through F4 would not result in the creation of upland habitat as described for Lake-wide Alternatives B and C. Approximately one acre of emergent wetlands would be created in SMUs 1, 4, and/or 7 under Alternative F.

5.2.7.3 Aquatic Habitat Optimization and Enhancement

The habitat optimization component of lake-wide Alternatives F1 through F4 would provide additional habitat value to the lake and shoreline through installation of various substrate and vegetation establishment on the cap surface. Habitat optimization would be implemented over an estimated 425 acres of the littoral and shoreline area (including SMU 5), as follows (see Subsection 5.2.2.3 for discussion of benefits for each habitat type):

- **Emergent Wetland** - approximately one acre would be created in SMUs 4 and 7 under Alternatives F2 through F4, and an additional acre would be created in SMU 1 under Alternative F1;
- **Recreational/Habitat Buffer Zone** – Alternative F1 would create approximately 21 acres of recreational / habitat buffer zone, Alternative F2 would create 29 acres, and Alternatives F3 and F4 would create 19 acres in SMUs 1 through 7;
- **Submerged Macrophyte/Benthic Area** – Alternative F1 would create approximately 98 acres of submerged macrophyte / benthic area, Alternative F2 would create 112 acres, and Alternatives F3 and F4 would create 73 acres in SMUs 1 through 7;

- **Fish Spawning Habitat** – Alternative F1 would create approximately 144 acres of fish spawning habitat, Alternative F2 would create 124 acres, Alternative F3 would create 163 acres, and Alternative F4 would create 152 acres in SMUs 1 through 7; and
- **Benthic Substrate Area** – Alternatives F1 and F2 would create approximately 40 acres of benthic substrate, Alternative F3 would create 42 acres, and Alternative F4 would create 48 acres of shallow littoral isolation cap in SMUs 1 through and 7. Alternatives F1 and F2 would include approximately 91 acres of deep littoral isolation capping, Alternative F3 would include 99 acres, and Alternative F4 would include 105 acres in SMUs 1 through 7.

Since the types of habitat optimization under Lake-wide Alternatives F1 through F4 are the same as for Lake-wide Alternative B (Subsection 5.2.2.3), the descriptions are not repeated here. Although the types of habitat optimization are the same, the quantities of certain types of habitat represent tradeoffs in habitat areas for the various Alternative F options, as noted above. However, implementing Lake-wide Alternatives F1 through F4 would not create any upland areas as would Alternatives B and C, and would result in less emergent wetlands than Alternatives B and C. The amount of recreational / habitat buffer area and submerged macrophyte / benthic area created by Alternative F2 would be greater than any of the Alternatives B through F4, whereas fish spawning habitat would be less than any of these alternatives except Alternative E. Alternative F4 would have more isolation capping of the deeper littoral area, and more benthic substrate area, than any of these alternatives.

As part of the pre-design investigation described for the capping component, habitat studies would also be performed to refine the habitat optimization design described above. The habitat enhancement components (i.e., stabilization in SMUs 3 and 5) of Lake-wide Alternatives F1 through F4 are the same as described for Lake-wide Alternative B.

5.2.7.4 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

Under Lake-wide Alternatives F1 through F4, the remedial activities related to MNR / aeration (oxygenation) of the hypolimnion / phased thin-layer capping in the profundal area would be similar to those described for Lake-wide Alternative B (Subsection 5.2.2.4), but would cover a larger area (an estimated 154 versus 20 acres). Additional area may need capping to achieve the BSQV.

5.2.7.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative F1, an approximate 112-acre SCA with 14-ft dikes would be constructed at Wastebed 13. Lake-wide Alternative F2 would require an approximate 172-acre SCA with 14-ft dikes at Wastebed 13. Lake-wide Alternative F3 would require an approximate 215-acre SCA with 14-ft dikes at Wastebeds 13 and 14 (as needed). Lake-wide Alternative F4 would require an approximate 257-acre SCA with 14-ft dikes at Wastebeds 13 and 14 (as needed). Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the recommended lake-wide alternative is discussed in Section 6.

5.2.7.6 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternatives F1 through F4.

5.2.8 Alternative G – Dredging/Capping

Implementation of Lake-wide Alternative G (Dredging/Capping) would include a combination of dredging, capping, habitat optimization, habitat enhancement, aeration (oxygenation), and MNR, as summarized on a SMU-specific basis in Table 5.1. Table 5.2 provides a summary of capping and dredging areas and volumes for each SMU. Specifically, the components of Lake-wide Alternative G would be the same as described for Lake-wide Alternative F4, except that additional dredging would be conducted in SMU 1, resulting in the removal of the top 5 meters of the ILWD. This would increase the dredged volume in SMU 1 from approximately 2,094,000 CY for Alternative F4 to 2,637,000 CY for Alternative G (an increase of approximately 543,000 CY), over the same 84 acre area. The total dredged volume for this alternative would increase from approximately 2,947,000 CY to 3,490,000 CY.

The dredging and capping components of this alternative would occur over a period of approximately four years, assuming four dredging and eight capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the alternative in terms of the technologies that would be employed during remediation (i.e., dredging, capping, etc.).

5.2.8.1 Dredging of Impacted Littoral Sediments

The dredging envisioned under Alternative G would cover the same area of the lake as for Alternatives F1 through F4, except that additional dredging to 5 meters in SMU 1 would increase the overall dredged volume to 3,490,000 CY.

Under Alternative G, sufficient sediment would be removed from SMUs 1 through 7 such that the water depth following capping would support the habitat optimization recommendations detailed in Appendix M, habitat issues. Removal to an optimal habitat depth to promote submerged macrophyte growth can be synergistic with removal to a depth that reduces the erosive forces on the cap. As a result, both criteria are considered under this alternative. Therefore, the goal under this alternative is to remove a significant amount of sediment from SMU 1 through a 16-ft (5-m) cut and to remove nearshore sediments in SMUs 2 through 7 to a depth where significant armoring of the cap is not required, and to maximize the area that has a water depth between 2 and 6 ft (0.6 to 1.8 m) to promote submerged macrophyte growth.

Under Alternative G, portions of the ILWD in SMU 1 would be removed to below the depth for optimal submerged macrophyte growth, so this alternative provides less habitat for submerged macrophytes than Alternatives F1 or F2 unless additional backfill is placed. However, habitat created under this alternative is an improvement over the impacted habitat under Alternative A.

5.2.8.2 Capping of Impacted Littoral and Profundal Sediments

The capping components for Lake-wide Alternative G would be the same as those described for Lake-wide Alternatives F1 through F4, resulting in an estimated 425 acres of isolation cap (including 311 acres of shallow littoral and 114 acres of deep littoral isolation cap), and 154 acres of profundal thin-layer cap that would be installed under this alternative. In addition, implementation of Lake-wide Alternative G would not result in the creation of upland habitat as described for Lake-wide Alternatives B and C, or in the loss of lake surface area.

5.2.8.3 Aquatic Habitat Optimization and Enhancement

The habitat optimization component of Lake-wide Alternative G would provide additional habitat value to the lake and shoreline through installation of various substrate and vegetation establishment on the cap surface. Habitat optimization for Alternative G would be the same as for Alternative F4, except that approximately 22 acres of fish spawning habitat would be converted to benthic substrate area, and an additional 9 acres of deeper littoral area would receive a thin-layer cap.

5.2.8.4 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

Under Lake-wide Alternative G, the remedial activities related to MNR / aeration (oxygenation) of the hypolimnion / phased thin-layer capping in the profundal area would be the same as described for Lake-wide Alternative F (Subsection 5.2.7.4). Additional area may need capping to achieve the BSQV.

5.2.8.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative G, an approximate 308-acre SCA with 14-ft dikes would be constructed at Wastebeds 13 and 14 (as needed). Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the recommended lake-wide alternative is discussed in Section 6.

5.2.8.6 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternative G.

5.2.9 Alternative H – Dredging/Capping

Implementation of Lake-wide Alternative H (Dredging/Capping) would include a combination of dredging, capping, habitat optimization, habitat enhancement, aeration (oxygenation), and MNR, as summarized on a SMU-specific basis in Table 5.1. Table 5.2 provides a summary of capping and dredging areas and volumes for each SMU. Specifically, the components of Lake-wide Alternative H would be the same as described for Lake-wide Alternative G, except that full dredging would be conducted in SMU 2, to an estimated depth of 30 ft (9 m), for full NAPL removal. This would increase the dredging volume in SMU 2 from approximately 169,000 CY to 403,000 CY (an increase of 234,000 CY), and would increase the total dredged volume under this alternative from 3,490,000 CY to 3,724,000 CY.

The dredging and capping components of this alternative would occur over a period of approximately four years, assuming four dredging and eight capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the alternative in terms of the remedial technologies that would be employed during remediation (i.e., dredging, capping, etc.).

5.2.9.1 Dredging of Impacted Littoral Sediments

The dredging envisioned under Lake-wide Alternative H would be the same as for Lake-wide Alternative G, except that additional dredging to remove NAPL in SMU 2 would increase the overall dredged volume from an estimated 3,490,000 CY to 3,724,000 CY (an increase of 234,000 CY).

Under Alternative H, sufficient sediment would be removed from SMUs 1 through 7 such that the water depth following capping would support the habitat optimization recommendations detailed in Appendix M, habitat issues. Removal to an optimal habitat depth to promote submerged macrophyte growth can be synergistic with removal to a depth that reduces the erosive forces on the cap. As a result, both criteria are considered under this alternative. Therefore, the goal under this alternative is to remove nearshore sediments to a depth where significant armoring of the cap is not required, and to maximize the area that has a water depth between 2 and 6 ft (0.6 and 1.8 m) to promote submerged macrophyte growth.

Under Alternative H, portions of the ILWD in SMU 1 would be removed to below the depth for optimal submerged macrophyte growth, so this alternative provides less habitat for submerged macrophytes than Alternatives F1 or F2 unless additional backfill is placed.

However, habitat created under this alternative is an improvement over the impacted habitat under Alternative A.

5.2.9.2 Capping of Impacted Littoral and Profundal Sediments

The capping components for Lake-wide Alternative H would be the same as those described for Lake-wide Alternative G, resulting in an estimated 425 acres of isolation cap (including 311 acres of shallow littoral isolation cap, and 114 acres of deep littoral isolation cap), and 154 acres of thin-layer cap (profundal) that would be installed under this alternative. In addition, implementation of Lake-wide Alternative H would not result in the creation of upland habitat as described for Lake-wide Alternatives B and C, or in the loss of lake surface area.

5.2.9.3 Aquatic Habitat Optimization and Enhancement

The habitat optimization component of Lake-wide Alternative H would provide additional habitat value to the lake and shoreline through installation of various substrate and vegetation establishment on the cap surface, compared to Alternative B. Habitat optimization for Alternative H would be the same as for Alternative G.

5.2.9.4 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

Under Lake-wide Alternative H, the remedial activities related to MNR / aeration (oxygenation) of the hypolimnion / phased thin-layer capping in the profundal area would be the same as described for Lake-wide Alternative B (Subsection 5.2.2.4), except that areas exceeding the mean PECQ1 rather than the mean PECQ2 would be capped. Additional area may need capping to achieve the BSQV.

5.2.9.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative H, an approximately 325-acre SCA with 14-ft dikes would be constructed at Wastebeds 12, 13, and 14 (as needed). Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the recommended lake-wide alternative is discussed in Section 6.

5.2.9.6 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternative H.

5.2.10 Alternative I – Dredging/Capping

Implementation of Lake-wide Alternative I (Dredging/Capping) would include a combination of dredging, capping, habitat optimization, aeration (oxygenation), and MNR, as summarized on a SMU-specific basis in Table 5.1. Table 5.2 provides a summary of capping and dredging areas and volumes for each SMU. Specifically, the components of Lake-wide Alternative I would be the same as described for Lake-wide Alternative E, except that full dredging would be conducted in SMUs 1, 2, 3, 4, 6, and 7 to the mean PECQ1 rather than the mean PECQ2, additional dredging would be performed in SMU 5 to prevent a loss of lake surface area and optimize habitat and minimize erosive forces on the cap, and additional phased thin-layer capping would be performed in SMU 8 to the mean PECQ1, mercury PEC, and BSQV. This would involve dredging approximately 140,000 CY in SMU 5 and capping approximately 60 acres. In SMU 8, this would entail capping approximately 154 acres (an increase of 134 acres from Alternative E). Overall, Alternative I would increase the total dredged volume from 11,247,000 CY to 12,814,000 CY.

The dredging and capping components of this alternative would occur over a period of approximately ten years, assuming four dredging and eight capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the alternative in terms of the remedial technologies that would be employed during remediation (i.e., dredging, capping, etc.).

5.2.10.1 Dredging and Backfilling

The dredging envisioned under Alternative I would be the same as for Alternative E, except that dredging would be conducted to the mean PECQ1 rather than the mean PECQ2, and additional dredging would be conducted in SMU 5 for no loss of lake surface area and for habitat optimization and to minimize erosive forces. The dredging and backfilling components of this alternative would include the following elements:

- Completion of pilot testing and pre-design investigations to optimize dredging implementation;
- Installation of a shoreline retention wall or reinforcement of currently planned hydraulic control systems, in select SMUs, to allow deep sediment removal along the shoreline;
- Dredging of all sediments in SMUs 1, 2, 3, 4, 6, and 7 (i.e., littoral area except SMU 5) that exceed the mean PECQ1;
- Dredging in SMU 5 for no loss of lake surface area, for habitat optimization, and for minimization of erosive forces on the cap;
- Backfilling in the dredged area to result in a uniform slope from the shoreline out to where dredging concludes;

- Residual capping, if necessary; and
- Institutional controls to protect the integrity of the remedy and ensure long-term protectiveness of human health and the environment.

As described for the other lake-wide alternatives, pilot testing and pre-design investigations would be required to more completely delineate the nature and extent of contamination, to establish site design parameters, and to gather geotechnical data for remedy design. At this time, the depth of removal is not conclusive because of data limitations.

Following dredging under this alternative, in some cases the sediment surface may be so deep that it is of minimal habitat value. As discussed in Appendix M, habitat issues, habitat value is minimal in water depths beyond 15 ft (4.6 m), which is the maximum fish spawning depth. Therefore, it is assumed for evaluation purposes that backfill would be added to the dredged area to result in a uniform slope from the shoreline out to where dredging concludes. Additional backfilling would improve habitat value, but would also increase remedial costs and increase short-term risks due to transportation of the large volume of imported backfill required. Therefore, this level of backfilling was selected for evaluation purposes as a reasonable backfill depth. Actual required backfilling requirements would be determined based on further evaluation as part of the design process.

5.2.10.2 Capping of Impacted Littoral and Profundal Sediments

Capping under Lake-wide Alternative I would include an estimated 60 acres of isolation capping in SMU 5 and approximately 154 acres of thin-layer capping in SMU 8. A total of 214 acres would be capped under this alternative.

5.2.10.3 Aquatic Habitat Optimization and Enhancement

The habitat re-establishment component of Alternative I would include:

- Augmentation of natural establishment of submerged macrophyte growth in the 2 to 6 ft (0.6 to 1.8 m) depth by broadcast seeding and addition of tubers; and
- Placement of a six-inch (15 cm) layer of fine gravel in water depths between 6 and 15 ft (1.8 and 4.6 m) to promote fish spawning.

As described above, augmentation of the natural establishment of submerged macrophytes would occur during habitat re-establishment. However, it should be recognized that the area with a final water depth of 2 to 6 ft (0.6 to 1.8 m) where submerged macrophytes are expected to grow would be significantly less than Alternatives B through D2 and F1 through H, due to the deeper post-dredging water depths and the backfilling strategy described in Subsection 5.2.5.1. Similarly, the amount of recreational / habitat buffer area, fish spawning habitat, benthic substrate area, and capping in the deeper littoral area would also be less than any of these alternatives.

The components of habitat enhancement for SMU 5 under Lake-wide Alternative I are the same as those described for SMU 5 under Lake-wide Alternative B in Subsection 5.2.2.3, except that areas exceeding the mean PECQ1 rather than the mean PECQ2 would be addressed. In addition, wetlands would not be created in any of the SMUs as a result of implementation of Lake-wide Alternative I.

The habitat optimization component of Lake-wide Alternative I would provide additional habitat value to the lake and shoreline in SMU 5 through the installation of various substrate and vegetation establishment on the cap surface.

5.2.10.4 MNR / Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

Under Lake-wide Alternative I, the remedial activities related to MNR / aeration (oxygenation) of the hypolimnion / phased thin-layer capping in the profundal area would be the same as described for Lake-wide Alternative B (Subsection 5.2.2.4), except that areas exceeding the mean PECQ1 rather than the mean PECQ2 would be capped. Additional area may need capping to achieve the BSQV.

5.2.10.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative I, an estimated 282-acre SCA with 50-ft dikes would be constructed at Wastebeds 13 and 14 (as needed). Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the selected lake-wide alternative is discussed in Section 6.

5.2.10.6 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternative I.

5.2.11 Alternative J – Dredging/Capping

Implementation of Lake-wide Alternative J (Dredging/Capping) is similar to Alternative I, except that full removal in SMUs 1, 2, 3, 4, 6, and 7 would be conducted to the ER-L rather than the mean PECQ1, dredging and capping in SMU 5 for no net loss of surface area and optimization of habitat and minimization of erosive forces would be based on the ER-L rather than the mean PECQ1, and thin-layer capping in SMU 8 would be based on the ER-L, mercury PEC, and BSQV. This would increase the total dredging volume in SMUs 2, 3, 4, 5, 6, and 7, and increase the profundal thin-layer capping area in SMU 8 from approximately 154 acres to 1,980 acres. In SMU 5, the capped area would increase from approximately 60 acres to

349 acres, and the dredged volume would increase from 140,000 CY to 610,000 CY. In total, this alternative would result in an increase in dredged volume from 12,184,000 CY to 20,121,000 CY, and an increase in the capped area from 214 acres to 2,329 acres.

The dredging and capping components of this alternative would occur over a period of approximately seventeen years, assuming four dredging and eight capping crews. This alternative assumes upland source controls are implemented through other programs to control external sources of CPOIs to the lake. The following subsections provide a description of the alternative in terms of the remedial technologies that would be employed during remediation (i.e., dredging, capping, etc.).

5.2.11.1 Dredging and Backfilling

The dredging envisioned under Alternative J would be the same as for Alternative I, except that dredging would be conducted to the ER-L rather than the mean PECQ1. This would result in the dredging of an estimated 20,121,000 CY, almost 8,000,000 CY more than for Alternative I.

5.2.11.2 Capping of Impacted Littoral and Profundal Sediments

Capping under Lake-wide Alternative J would include an estimated 349 acres of isolation capping in SMU 5, and approximately 1,980 acres of thin-layer capping in SMU 8. An estimated total of 2,329 acres (more than 75 percent of the lake bottom surface) would be capped under this alternative.

5.2.11.3 Aquatic Habitat Re-establishment, Optimization, and Enhancement

The habitat re-establishment, optimization, and enhancement components of Alternative J would be the same as for Lake-wide Alternative I for SMUs 1, 2, 3, 4, 6, and 7, although a larger area would be impacted since dredging would be conducted to the ER-L rather than the mean PECQ1. In SMU 5, an estimated 73 acres of recreational/habitat buffer area would be created, 86 acres of submerged macrophyte /benthic area would be created, 102 acres of fish spawning habitat would be created, 29 acres of benthic substrate area would be created in the shallow littoral zone, and 100 acres of deeper littoral zone would receive an isolation cap. This would result in the greatest amount of recreational / habitat area and submerged macrophyte/benthic area created of any of the alternatives. However, the amount of fish spawning habitat and benthic substrate habitat would be less than any alternatives except E and I.

5.2.11.4 Aeration (Oxygenation) of the Hypolimnion / Phased Thin-Layer Capping in the Profundal Area

Under Lake-wide Alternative J, the remedial activities related to aeration (oxygenation) of the hypolimnion / phased thin-layer capping in the profundal area would be the same as described for Lake-wide Alternative I (Subsection 5.2.10.4), except that areas exceeding the ER-L rather than the mean PECQ1 would be addressed. This would significantly increase the area of thin-layer capping to an estimated 1980 acres.

5.2.11.5 Consolidation of Dredged Materials and Treatment of SCA Supernatant

As described in Subsection 4.10, dredging with consolidation of materials at an on-site location owned by Honeywell is recommended. For Lake-wide Alternative J, an estimated 442-acre SCA with 50-ft dikes would be constructed at Wastebeds 12, 13, and 14 (as needed). Subsection 4.10 also assumes advanced water treatment for the supernatant produced by the SCA through sediment consolidation, although additional evaluation is needed to determine the appropriate level of treatment. Since the recommended consolidation and treatment options apply to all active alternatives (i.e., Alternatives B through J), the details provided in Subsection 4.10 are not repeated here. The integration of the recommended SCA and supernatant treatment options with the selected lake-wide alternative is discussed in Section 6.

5.2.11.6 Institutional Controls

The same institutional controls proposed under Lake-wide Alternative B would be implemented under Lake-wide Alternative J.

5.3 DETAILED EVALUATION AND COMPARATIVE ANALYSIS OF LAKE-WIDE ALTERNATIVES

This subsection provides a detailed evaluation and a comparative analysis of the five lake-wide alternatives using the criteria outlined in the NCP at 40 CFR Part 300.430. A summary of this analysis is provided in Table 5.3.

5.3.1 Overall Protection of Human Health and the Environment

All the alternatives, except for the No Action Alternative, would provide sufficient but varying degrees of overall protection of human health and the environment and would meet the RAOs and PRGs presented in Subsection 5.1. Alternatives F1 through I would provide an additional safety factor with respect to the protection of benthic macroinvertebrates from sediment toxicity through the use of the mean PECQ1 rather than the mean PECQ2 to estimate areas and volumes to be remediated.

Lake-wide Alternatives B through J would be protective by reducing sediment toxicity to benthic macroinvertebrates, reducing releases of CPOIs to the water column, and reducing concentrations of CPOIs in the surface sediment. These alternatives meet RAOs 2, 4, and 5 and PRGs 1, 2, and 3 in the littoral area through different combinations of dredging, capping, and/or habitat enhancement in SMUs 1 through 7. These alternatives also meet RAOs 1 and 3 and PRGs 1, 2, and 3 in the profundal area (SMU 8) through MNR, aeration (oxygenation), and phased thin-layer capping.

Specifically, the sediment remediation in Lake-wide Alternatives B through J would reduce CPOI releases into the water column through isolation or removal, which would reduce surface sediment concentrations, prevent direct exposure of humans and ecological receptors to impacted sediment, and reduce bioaccumulation of CPOIs from sediment. In all areas where sediment currently exceeds the mean PECQ2, Alternatives B through E would reduce surficial CPOI concentrations to or below the mean PECQ2, thus meeting the requirements of PRG 1 and providing protection of benthic macroinvertebrates. Following remediation, the mean PECQ throughout the lake would be less than 2. Although there may be localized exceedances of individual SECs, such as the ER-L, in areas not addressed by remediation, these exceedances are not expected to contribute significantly to sediment toxicity, and these alternatives would all be protective.

Alternatives F1 through I would further reduce CPOI concentrations in surface sediment to or below the mean PECQ1 (i.e., the mean PECQ for surface sediment throughout the lake would be less than 1), and would provide an additional safety factor for benthic macroinvertebrates potentially impacted by sediment toxicity. Alternative J would reduce surficial CPOI concentrations to or below the ER-L, providing, to a limited degree, a safety factor for chronic (long-term) toxicity to benthic macroinvertebrates.

In addition, in-lake source control (i.e., Lake-wide Alternatives B through J), in conjunction with upland source control through other programs, would immediately reduce CPOI concentrations in the water column, and, in the case of mercury, would reduce the amount available for methylation and bioaccumulation (RAO 5 and PRG 3). Aeration (oxygenation) would reduce mercury methylation, which would also decrease the mass of methylmercury available for bioaccumulation (RAO 1), thus protecting humans and wildlife from exposure via the bioaccumulation pathway. In general, reductions in direct exposure to CPOIs (through direct contact or incidental ingestion), CPOI releases to the water column, and mercury methylation are expected to reduce lake-wide risks to fish and humans, and to wildlife that consume fish (RAOs 2, 3, and 4 and PRG 2).

Alternatives that minimize erosive forces provide slightly greater protection against potential erosion due to wave energy and ice scour due to the greater depth. Therefore, Alternatives B, C, and D provide slightly increasing protection from Alternatives B to D due to increasing dredging depth. Similarly, Alternatives D2 and F1 through H would progressively minimize erosive forces due to increased dredge depths.

Habitat enhancement would facilitate the creation of conditions suitable for macrophyte establishment and fish spawning by reducing the mobility of oncolites.

By converting lake surface area into wetlands through capping in Alternatives B and C (and to a minimal extent through Alternatives D, D2, and F1 through H), there would be slightly less habitat available for aquatic species as compared to Alternatives I and J. Alternative C provides habitat diversity similar to Alternatives D2 and F1 through H, and it provides more substrate for submerged macrophyte growth than Alternative B. Habitat diversity enhances the variety of fauna and flora present in the lake, including fish species.

Residual risks to human health and the environment following implementation of the lake-wide alternatives were estimated based on multiple lines of evidence. Together, these approaches show that Lake-wide Alternatives B through J will reduce to varying degrees risk to humans and ecological receptors though all alternatives will achieve levels that are protective of human health and the environment. Residual risks were estimated based on multiple lines of evidence (see Appendix I, risk of remedy) and can be summarized as follows:

- The residual risk analysis associated with the bioaccumulation pathway indicates that concentrations of total mercury and methylmercury in water and concentrations of mercury and PCBs in fish tissue would decline as a result of implementation of these alternatives, thereby reducing risk to wildlife and humans that consume fish. If one assumes that reductions in CPOI concentrations in fish tissue are proportional to reductions in CPOI concentrations in sediment, then residual concentrations in fish would be within the target tissue concentration ranges developed in Appendix G, fish tissue goals, for mercury and total PCBs, regardless of whether the remediation endpoint is the mean PECQ2, mean PECQ1, or ER-L. Comparison of the littoral mercury SWAC to the BSQV for mercury indicates that all alternatives are protective of the fish-consuming wildlife that were modeled. Comparison of lake-wide mercury SWACs to the BSQV indicates that all alternatives, with the exception of Alternative J, result in residual risk to the river otter but are protective of all other fish-consuming wildlife;
- The residual risks associated with exposure to PAHs by wildlife that consume benthic macroinvertebrates/insects were estimated to be less than the lowest observed adverse effect level (Appendix I, risk of remedy) under Alternatives B through J. In addition, exposure of wildlife to metals in these prey items would be significantly reduced;
- Measurable residual risks to benthic macroinvertebrates from direct sediment toxicity would be significantly reduced as a result of implementation of Alternatives B through J. Alternatives F1 through I would provide an additional safety factor over Alternatives B through E with respect to protection of benthic macroinvertebrates from sediment toxicity; and
- The residual cancer risks associated with humans hypothetically exposed to CPOIs by wading in nearshore sediment in the south basin were estimated to be below levels of concern. The HHRA determined that the RME cancer risk under baseline conditions exceeded $1x10^{-5}$ (one in 100,000), whereas post-remediation risk decreases to a maximum value of $2 x10^{-6}$ (see Appendix I, risk of remedy).

In summary, multiple lines of evidence were used in this overall protectiveness/residual risk analysis to evaluate remedy protectiveness and to estimate the risks remaining to humans and ecological receptors following implementation of Lake-wide Alternatives B through J. Together, these approaches show that Alternatives B through J all provide sufficient protection and would to varying degrees reduce risks to humans and ecological receptors to levels that are protective of all receptors.

5.3.2 Compliance with ARARs

The No Action Alternative (Alternative A) would not meet location-, action-, or chemical-specific ARARs. Future exceedances of surface water ARARs would likely decrease due to upland remedial actions, but exceedances may continue to exist under the No Action Alternative. The ARARs associated with Lake-wide Alternatives B through J are provided in Appendix C, ARARs and TBCs.

Lake-wide Alternatives B through J would comply with all chemical-, location-, and action-specific ARARs, with the possible exception of the two most stringent surface water criteria for dissolved mercury (i.e., standards for protecting wildlife and human health via fish consumption), which may be technically impracticable to achieve. Surface water quality data in the RI indicate that surface water quality standards for CPOIs are generally being achieved in Onondaga Lake, except for these two standards. It is anticipated that remediation of SMUs 1 through 8 and other upland sources would significantly reduce mercury loading, resulting in meeting these ARARs to the extent practicable. It is also anticipated that Alternatives B through J would achieve surface water ARARs for other CPOIs, including chlorobenzene and dichlorobenzenes, which has been detected in surface water in excess of ARARs (see Section 4 for additional discussion of surface water standards).

There are no chemical-specific ARARs for sediment quality in Onondaga Lake. Chemical-specific SECs and TBCs were developed specifically for Onondaga Lake, as detailed in Section 2. These TBCs were used to develop the remedial alternatives evaluated herein.

As indicated previously, Lake-wide Alternatives B through J are expected to comply with the designated location-specific and action-specific ARARs. The relevant and appropriate ARARs include substantive requirements of the dredge and fill permit program under Section 404 of the federal Clean Water Act. Although there would be some conversion of lake surface area to upland habitat in Alternatives B and C, and conversion of lake surface area to emergent wetlands in Alternatives B through D2 and F1 through H, Honeywell would work with the NYSDEC and the USACE to ensure there is no loss in aquatic habitat value through the creation and enhancement of additional habitat. Such cooperation would work towards the protection and enhancement of shoreline habitat in the lake, and should be consistent with the requirements of 6 NYCRR Part 608 and Section 404.

Compliance with Part 608 would be determined by NYSDEC through the ROD and Proposed Action Plan, allowing the implementation of an alternative to proceed, if it is in the public interest. Alternatives B through J may or may not comply with Part 608, pending NYSDEC review. Alternatives B and C would result in the conversion of an estimated 13.2 and 5.5 acres of lake surface area to upland habitat, respectively.

5.3.3 Short-Term Effectiveness

Since no remedial actions are implemented under Lake-wide Alternative A, there are no short-term risks or impacts associated with the alternative. Alternatives B through J all involve major construction efforts due to dredging and/or capping, and materials management, which have inherent short-term risks. Remedy implementation for each active alternative may result in short-term localized exceedances of surface water criteria within the work zone due to suspension of impacted sediment, sedimentation of capping materials, and SCA supernatant discharge. In general, sediment disturbance and short-term exceedances are expected to be the greatest during dredging, as compared to other remedial activities such as capping. With the exception of potential impacts of dredging on the recovery of the profundal sediments and the impacts of air emissions, a similar pattern of results was observed for each risk element. In general, the predicted measure of risk increases gradually from Alternatives B, C, D, D2, and F1 to Alternatives F2, F3, F4, G, and H, with a sharp increase in going from Alternative H to the high dredged volume Alternatives E, I, and J. Since the duration of short-term exceedances increases with dredge volume, exceedances would last much longer with Alternatives E, I, and J than the other alternatives, which would differ to a lesser extent depending on dredge volume. An analysis of the impacts of these differences in terms of lake habitat loss, vehicular and on-site worker accidents, resuspension, supernatant discharge, air quality, and quality of life issues is provided in the paragraphs that follow. A more detailed discussion of these impacts is provided in Appendix I, risk of remedy.

Temporary Loss of Lake Habitat: Implementation of Alternatives B through J would result in the temporary loss of lake habitat during remedy implementation, although the resulting habitat would be of greater value to both human and environmental receptors. Dredging and/or capping would temporarily impact the existing benthic macroinvertebrate and submerged macrophyte communities by either removing them and/or their habitat, or by burying them under clean cap materials. In addition to directly impacting the habitat of the benthic organisms in the affected areas, indirect effects may be experienced by fish and terrestrial wildlife that forage on these organisms, or fish that use submerged macrophytes for spawning or nursery areas. During remediation, an effort would be made to schedule remedial activities to minimize impacts on fish migration and spawning activities.

The total implementation time for dredging/capping under Lake-wide Alternatives B, C, D, and D2 is similar, approximately three construction seasons each, slightly increasing with increased dredging volume. Alternatives F1 through H are estimated to take approximately four construction seasons each, also increasing slightly with increased dredge volume. In contrast, the corresponding time period for Alternative E is estimated to be nine construction seasons, ten construction seasons for Alternative I, and seventeen construction seasons for Alternative J. With the addition of one year for habitat recolonization following completion of dredging and/or capping (Niemi *et al.*, 1990), Alternative E would require an estimated 10 years, Alternative I 11 years, and Alternative J 18 years; whereas the others would require only four to five years.

On-Site Worker Accidents and Vehicular Accidents During Implementation: Alternatives B through J involve a significant construction effort, including material transport volumes typical of major construction projects. Accordingly, an increased risk of on-site worker accidents exists due to the handling of dredging, capping, and SCA construction materials. The predicted incidence of worker accidents increases gradually from Alternative B to Alternative D2 and from Alternative F1 to Alternative H, while the accident rates for Alternatives E, I, and J are several times higher than Alternative B for both fatalities and non-fatal accidents. The predicted incidences of fatalities and non-fatal injuries for on-site workers are summarized on Figure 5.1. Note that the predicted fatal injury frequencies related to worker accidents for Alternatives E and I are 0.43 and 0.47, respectively (i.e., for every two similar projects, one would expect to experience a fatality), and for Alternative J is 0.80 (one would expect an 80% chance of a single fatality for each similar project). Alternatives B through D2 and F1 through H have a typical expectation of 6 to 16 non-fatal injuries, increasing to 45, 49, and 84 for Alternatives E, I, and J, respectively. Stringent safety policies and attention to safety issues during the implementation period are expected to keep any accidents or injuries to a minimum.

Similarly, increased risk of vehicular accidents is anticipated during remedy implementation, if trucks are used for material transport. Alternative transport methods (e.g., barge and/or rail) may be used and will be evaluated during design. Assuming trucks will be used, for both fatalities and non-fatal injuries due to vehicular accidents, the predicted incidences increase gradually from Alternative B to Alternative D2, and from Alternative F1 to Alternative H, while the risk is several times higher for Alternatives E, I, and J. This increase is due to the greater magnitude and duration of dredging required and the associated increases in volumes of SCA construction materials transported. The predicted incidences of fatalities and non-fatal injuries related to vehicular accidents are also summarized on Figure 5.2. Note that the predicted fatality and non-fatal injury frequencies related to vehicular accidents for Alternatives E, I, and J are 2.7, 3.0, and 5.1, respectively (i.e., a typical expectation of two to five fatalities, depending on the alternative) and 70, 77, and 130 (i.e., a typical expectation of 70 to 130 non-fatal injuries), respectively. A summary of the risks for fatalities and non-fatal injuries resulting from construction and vehicular accidents is provided in Table 5.4.

There is also some potential for pipeline rupture during transfer of hydraulically dredged material from the lake to the SCA. Short-term risks associated with pipeline rupture are directly related to the quantity of dredge material transported; therefore, risk increases gradually from Alternatives B to D2, and from Alternatives F1 to H, but increases sharply from Alternative H to Alternatives E, I, and J. Engineering controls (e.g., double-walled pipe) can significantly lower such risks and have been assumed for Alternatives B through J.

Impacts of Resuspension: The resuspension of in-lake sediments during dredging and the desorption of CPOIs to the water column, in the absence of controls, is predicted to result in concentrations in the dredged area of the lake temporarily exceeding surface water quality standards for several CPOIs (PCBs, hexachlorobenzenes, mercury, and benzo(a)pyrene). The relative sediment resuspension impacts of Alternatives B through J on water quality were evaluated using an index based on the water volume exceeding Surface Water Quality Standards (SWQS) and the duration of those exceedances. The water quality impact (WQI) index value for each lake-wide alternative was calculated as the sum of the products obtained for each dredged

SMU by multiplying the dredging duration (in 80-hour weeks) by the volume of the dredge area (see Appendix L, dredging issues, and Appendix I, risk of remedy, for details).

The WQI index does not attempt to account for the nature or the degree of the exceedances; however, it does indicate that the duration and extent of the water quality impacts associated with the various lake-wide dredging alternatives range over three orders of magnitude. The relative measures of impact to water quality are summarized in Figure 5.3 (see Appendix I, risk of remedy, for calculations). The impacts increase gradually from Alternative B to Alternative D2. Alternative F1 impacts are slightly higher than Alternative D2. Impacts for alternatives increase sharply from Alternatives F1 through H, and Alternative H impacts are more than two orders of magnitude greater than Alternative B. Impacts increase significantly for Alternatives E, I, and J, increasing by another order of magnitude for Alternative J. Alternative J would have impacts estimated to be greater than 2,600 times more severe than Alternative B.

Since the water quality is impacted for a significantly longer period of time for Alternatives E, I, and J compared to the other alternatives, aquatic species such as fish would be impacted for a longer period of time by elevated PCB and mercury concentrations in the water. Alternatives F2 through H also would impact water quality significantly longer than Alternatives B through D2, and Alternative F1. Although there is a slight increase in risk to aquatic species when progressing from Alternatives B to D2 and Alternative F1 due to the increased dredge volume, impacts would likely be similar because of comparable durations (three to four years).

Since placement of cap materials can also contribute to resuspension, its relative impact as compared to dredging was considered in this evaluation. Capping or backfilling was estimated to contribute approximately one to eight percent of the total resuspended material generated during remedy implementation (see Appendix I), depending on the alternative (another less representative technique yielded estimated contributions of less than one to twenty-five percent). Because the amount of resuspension due to capping is reasonably consistent across most of the lake-wide alternatives and is only a minor contributor to the total amount of resuspension, the impact of resuspension associated with capping was not included in the quantitative evaluation of impacts on lake water quality.

Proven engineering controls are available and would be employed during implementation of this alternative to minimize the rate of sediment resuspension and material transport during dredging and capping activities. For example, resuspension of in-lake sediments can be minimized by operator proficiency in placing and moving the dredging head and by implementing best management practices. Barriers such as silt curtains can be used to help minimize potential adverse impacts related to sediment resuspension.

Impact of Supernatant Discharge: The impact of SCA supernatant discharge into the lake was also evaluated in terms of the volume of effluent discharge. To minimize impacts on lake water quality, the treated supernatant from sediment dewatering would be released back into the work zone in the SMU being dredged (i.e., the active dredging zone). Water quality monitoring of the effluent would be conducted to ensure that end-of-pipe discharge limits (to be established by NYSDEC) are being met.

Assuming an advanced water treatment system would be used for Lake-wide Alternatives B through J and a mixing zone is not assumed, the concentrations of some sediment-related chemicals (including PCBs, hexachlorobenzenes, mercury, and benzo(a)pyrene) in the supernatant may exceed the surface water quality standards in the short term in the immediate area of discharge. In relative terms, the impact of Alternatives E, I, and J would be approximately 50 to 90 times higher than Alternative B, based on the volume of effluent discharged. Alternatives C, D, D2, F1, and F2 would result in discharge volumes of less than ten times Alternative B, while Alternatives F3, F4, G, and H would result in the discharge of 11 to 17 times the volume of Alternative B. However, these impacts are both transient and relatively insignificant, inasmuch as the volume of supernatant released would be relatively small compared to the volume of lake water in the work zone of the SMU being dredged. The low impact of the supernatant on the active dredging zone is discussed in Subsection 4.10 and Appendix I, risk of remedy.

Air Quality Impacts: The impact of air emissions over the entire remedy implementation period was evaluated relative to the New York State Annual Guideline Concentration (AGC) and by using a risk assessment method consistent with USEPA guidance (USEPA, 1991). Long-term predicted cancer risks associated with emissions from the point of dredge were evaluated quantitatively for Alternative J, the alternative with the greatest acreage and volume of sediments dredged during the implementation period. At the point of maximum exposure, the $^{-}$cumulative predicted cancer risk associated with point of dredge emissions for Alternative J was 6.0×10^{-10}, well below the USEPA's regulatory benchmark for Superfund remedy evaluation of $1x10^{-6}$. The cumulative predicted cancer risk from SCA emissions for all alternatives was also well below the USEPA's regulatory benchmark for Superfund remedy evaluation of $1x10^{-6}$.

For non-cancer risk over the entire remedy implementation period, the primary constituent of concern is naphthalene. The hazard quotient for the dredging operations for Alternative J is 0.0003, which is well below the regulatory benchmark of 1. All other alternatives would also fall below the regulatory benchmark for noncancer risk for dredging operations. The hazard quotient for emissions from the SCA ranges from less than 1 to 5.4 for the alternatives, without emission controls. Controls would be used to address emissions from the SCA if they occur.

Short-term risks associated with air emissions were evaluated by comparison to the NYS Short-term (1-hour) Guideline Concentrations (SGCs) and odor thresholds for one-hour averaging periods. No exceedances of any of the SGCs are predicted for off-site receptors from emissions at the point of dredge or the SCA. In addition, emissions from the point of dredge are not expected to exceed the odor threshold. The odor threshold was exceeded for the SCA for Alternatives D2 and F1 through J by factors ranging from 1.1 to 2.2. The odor threshold at the SCA was equal to the maximum predicted hourly concentration for Alternatives D and E and was not exceeded for Alternatives B and C. Additionally, exposures to workers operating the dredge were not estimated to exceed the OSHA permissible exposure limit, with the possible exception of situations when NAPL may be encountered (see Appendix I Subsection 2.7.3.4). Mitigating measures (e.g., use of sorbents) would be employed if NAPL is encountered and would be effective in reducing these concentrations.

Quality of Life Issues: Quality of life issues associated with odors, increased truck traffic on local roads, potential delays in the planned walking and biking trail around the lake and other redevelopment projects, and restrictions in recreational uses of the lake would be much more significant for Alternatives E, I, and J as compared to Alternatives B, C, D, and D2 because of the increased magnitude and duration of construction. Potential impacts to quality of life issues for Alternatives F1 through H fall somewhere in between, but are closer to Alternatives B through D2 than Alternatives E, I, and J.

Increased truck traffic on local roads could potentially disturb the community, depending on the volume and duration of the trucking activities. For example, the total number of truckloads required for transporting capping and backfill materials to the site are estimated to range from approximately 150,000 to 200,000 for Alternatives B through D2 (three construction seasons), F1 through H (four construction seasons), and from approximately 500,000 to 1,200,000 for Alternatives E, I, and J (nine to seventeen construction seasons). If Wastebed B were to be selected as the staging area for imported cap/backfill materials, trucks (either empty or full, depending on the truck route) would pass by the New York State Fairgrounds, which is the venue of a variety of community activities year-round, including the annual New York State Fair.

The total number of truckloads required for transporting SCA construction materials to the site ranges from approximately 45,000 to 200,000 for Alternatives B through D2, and F1; approximately 300,000 to 600,000 for Alternatives F2 through H; and approximately 1,400,000 to 2,400,000 for Alternatives E, I, and J. Since the trucks would need to pass through a residential area (approximately 0.5 miles long) to access the highway after exiting Wastebed 13, the volume of trucks required for SCA construction materials for Alternatives E, I, and J could potentially be very disruptive to the community. Community disturbance due to truck traffic would depend on the location of the source material (i.e., the required truck route) for capping, backfilling, and/or SCA construction materials.

In summary, the issues related to short-term effectiveness are similar for Lake-wide Alternatives B through D2, somewhat greater for Alternatives F1 through H, and significantly greater for Alternatives E, I, and J because of the magnitude and duration of the dredging and backfilling activities. Alternatives E, I, and J would disturb the most sediment and result in the most habitat disturbance, resuspension, CPOI releases, NAPL releases, lake water quality impacts, CPOI volatilization, worker risks, transportation risks, and community disturbance.

5.3.4 Long-Term Effectiveness and Permanence

Lake-wide Alternative A would not provide long-term effectiveness or permanence in reducing risks associated with CPOIs, whereas Lake-wide Alternatives B through J are considered effective and permanent solutions for handling impacted sediment in the littoral and profundal areas, as long as the proper monitoring and maintenance programs are developed and implemented, and barrier systems and other source control measures are effective in preventing migration of CPOIs from upland sources.

Alternatives B through J would provide long-term effectiveness and permanence by isolating impacted sediment under an isolation cap and/or within an upland SCA, while addressing sediments in the profundal zone through placement of a thin-layer cap. Specifically, under Alternatives B through D2 and Alternatives F1 through H, long-term effectiveness and permanence in the littoral zone would primarily be achieved via targeted dredging and/or dredging to optimize habitat and minimize erosive forces followed by capping, which would provide chemical isolation. For Alternatives E, I, and J, sediments would be permanently removed from the lake, and long-term effectiveness would rely on containment within the upland SCA. Long-term maintenance, monitoring, and institutional controls would be integral components of the long-term effectiveness and permanence of both the sediment cap and the SCA. The effectiveness and permanence of Alternatives B through D2 and F1 through H rely in part on the construction of on-shore barrier systems adjacent to SMUs 1, 2, and 7 that would operate to address ongoing migration of CPOIs to the lake from adjacent upland areas.

For the profundal area, lake-wide Alternatives B through J would provide long-term effectiveness and permanence through a combination of MNR, aeration (oxygenation), and phased thin-layer capping. Aeration (oxygenation) would effectively reduce mercury methylation, likely reduce methane production (ebullition), and increase biological activity in the sediments. The long-term effects on productivity and the food web are unclear; however, a net reduction in methylation is expected to reduce mercury fish tissue concentrations. The effectiveness of aeration (oxygenation) and natural recovery would also be monitored.

Capping under lake-wide Alternatives B through D2 and F1 through H would provide long-term effectiveness and permanence by eliminating the potential human health and ecological exposure pathways associated with impacted sediment. The cap would be designed and constructed to ensure long-term stability. Gravel, rock, and riprap would be incorporated into the cap design as necessary to minimize propeller, wind, and current erosion or ice scour of the cap. Consistent with EPA design guidance for caps, the cap would be designed to withstand erosional forces resulting from the 100-year return interval storm event (USEPA, 2002a). As discussed in Subsection 4.3, a slope stability analysis was performed on the submerged ILWD for two slope profiles in the southeast corner of Onondaga Lake using available geotechnical and other relevant data (also see Appendix H, capping issues). The results indicate adequate safety factors against a failure of the existing slope under static and seismic conditions both with and without the cap. This assessment was based on limited data, and the stability of the ILWD sediments (including potential failure at lower shear stresses than evaluated) would be fully addressed during design. Institutional controls, such as bans on dredging the capped area, would be implemented as necessary to help ensure the long-term integrity of the cap.

Numerous long-term sediment capping projects have been effectively implemented in this country. The contaminant movement processes are for the most part well understood, and tools are available to model the long-term behavior of contaminants under a cap. Appendix H, capping issues, summarizes major capping projects performed to date.

A monitoring program to confirm that the cap remains in place and effective over time may include elements such as periodic core sampling and bathymetric surveys to verify sediment cap integrity and chemical isolation. Although proper design of the cap would provide long-term effectiveness and permanence of the remedy, periodic maintenance of the cap would be required. In the unlikely event of an extreme episodic event that damages the cap and/or “failure” in isolation cap effectiveness, the monitoring and maintenance program would identify cap integrity issues and make repairs, as warranted. Maintenance could include additional dredging and/or capping of previously clean areas newly impacted. It is anticipated that potential damage due to an extreme episodic event and/or a “failure” in isolation cap effectiveness would be limited, and the effectiveness of the remedy as a whole would not be compromised. A more detailed discussion of this issue is included in Appendix H, capping issues.

As indicated previously, there are essentially three types of events that could be considered relevant in evaluating potential maintenance requirements (see Appendix H, capping issues). First, a cap could be physically damaged by an extreme episodic event (i.e., an event exceeding the magnitude of the design events for which the cap armor layer was designed). It is anticipated that under this type of episodic event, only limited areas of the cap would be affected.

The second type of event that might require maintenance is a slump failure of the ILWD. As noted above, adequate safety factors would be incorporated into the cap design to protect against such a failure. In the unlikely event that such a failure did occur, repair would likely consist of removal of the slumped material, and replacement of the damaged portion of the cap.

The third type of event that might result in required maintenance is a “failure” of the chemical isolation effectiveness of the cap. As described in Section 4.4.1.2.4 and Appendix H, capping issues, the most likely cause of a failure would be the mischaracterization of physical and chemical properties of the sediment during design (e.g., a missed hotspot of high sediment contaminant concentrations or pooled NAPL). The area subject to any such mischaracterization should be assumed limited to no more than five percent of the total area capped in any SMU. Two of the potential repair approaches include: hot spot removal and replacement or supplement of the existing cap with a new reactive cap. Such a major reconstruction should be limited to a one-time occurrence.

In general, habitat enhancement under lake-wide Alternatives B through D2 and F1 through H is also expected to provide long-term effectiveness for stabilization of calcitic deposits and enhancement of macrophyte colonization and fish spawning. Shoreline stabilization enhancements would be designed to create a permanent vegetated shoreline. Substrate would be augmented as needed to create a suitable growing medium over the short-term. As the plants grow, their roots and stems would help to stabilize the shoreline over the long-term. In steeper areas of the shoreline, the slope would also be stabilized with riprap material. The material would be sized to provide long-term protection of the shoreline while the vegetation matures.

For lake-wide Alternatives B through D2 and F1 through H, fish habitat structures (i.e., large woody debris or similar structures) would be used in the shallow littoral areas of SMU 3 (between 4 to 15 ft [1.2 to 4.6 m] below ordinary low water) to provide habitat and cover for fish. The structures would be placed 4 ft (1.2 m) below ordinary low water to avoid wave energy associated with the 100-year storm events. These structures would be anticipated to last several decades, with their long-term effectiveness depending on the decay rate of the woody material used for their construction. Biological monitoring (e.g., abundance and diversity of macrophytes) would be necessary to ensure that Alternatives B through D2 and F1 through H are effective in achieving enhanced macrophyte establishment and fish spawning. Habitat enhancement under Alternatives E, I, and J would provide long-term effectiveness through stabilization of the oncolitic sediments in SMU 5, which would promote macrophyte colonization.

Lake-wide Alternatives E, I, and J have the least potential for in-lake remedy failure. Of the remaining alternatives, Alternatives F1 through H have the next lowest risks of long-term remedy failure in the lake because sufficient sediment would be removed from SMUs 1 through 7 such that all of the cap surface would be below the water depth where wind/wave energy necessitates reliance on rip-rap for erosion control. This depth would also optimize habitat for submerged macrophytes.

The long-term remedy failure potential for Alternatives B through D2 and F1 through H is very similar with minor variations based on the amount of material and the location dredged. Dredging sediment in SMU 4 under Lake-wide Alternatives D, D2, and F1 through H would expose underlying sediments that contain higher levels of mercury than existing surface sediments. However, dredging in SMU 1 under Lake-wide Alternatives F1 through H would reduce levels of mercury in the underlying sediments.

Although implementation of lake-wide Alternatives B through J would provide long-term effectiveness and permanence, Alternatives B through D2 and F1 through H provide more long-term habitat diversification, enhancement, and optimization than Alternatives E, I, and J.

5.3.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Lake-wide Alternative A would not provide any reduction in toxicity, mobility, or volume through treatment. However, the overall bioavailability and mobility of contaminants in the sediment may be reduced over time, as cleaner sediments are naturally deposited over more impacted sediments in some areas of the lake.

Alternatives B through J provide reduction in toxicity, mobility, or volume of CPOIs through treatment including aeration (oxygenation) of the hypolimnion, consolidation and dewatering of dredged material in the SCA, and treatment of SCA supernatant prior to discharge back into the lake. Specifically, the volume of sediment and mobility of CPOIs in the sediment would be reduced through consolidation and dewatering within the SCA. Treatment of water resulting from dredging operations (i.e., SCA supernatant) would result in a reduction in the toxicity, mobility, and volume of CPOIs contained in the supernatant, through the partitioning of CPOIs into the supernatant, exposure of sediments and supernatant to aerobic conditions, and subsequent supernatant treatment. Capping would also reduce the mobility of CPOIs in the sediment remaining in the lake, although not through treatment.

Lake-wide Alternatives B through D2 and F1 through H provide similar reductions in mobility of CPOIs in the littoral area, although not through treatment, with each successive alternative providing sequentially greater volume reduction through increased sediment dredging in SMUs 1 through 7. Lake-wide Alternatives E, I, and J provide the greatest reduction in impacted sediment volume in the lake. Alternatives B through D2 include dredging volumes ranging from an estimated 223,000 CY for Alternative B to 1,180,000 CY for Alternative D2. Alternatives F1 through H further increase this volume from an estimated 1,207,000 CY for Alternative F1 to 3,724,000 CY for Alternative H. For full removal to various endpoints, Alternative E would remove an estimated 11,274,000 CY at the mean PECQ2, increasing to an estimated 12,184,000 CY for Alternative I at the mean PECQ1 and an estimated 20,121,000 CY for Alternative J at the ER-L.

Although capping (without dredging) in certain SMUs for Alternatives B and C would not reduce the toxicity or the volume through treatment of the impacted sediment that is present in the lake, it would effectively reduce the mobility of the impacted sediments through chemical isolation. Dredging followed by capping in Alternatives B through D2 and F1 through H would reduce the volume of impacted sediment and isolate residual CPOIs, which would significantly reduce their mobility and bioavailability. In addition, natural processes that reduce toxicity, such as biological degradation of organic compounds, would also continue to occur beneath the cap following construction; however, these processes may be insignificant and would not be monitored and verified. Habitat enhancement in SMUs 3 and 5 (i.e., Alternatives B through D2 and F1 through H) and SMU 5 only (Alternatives E, I, and J) would reduce the mobility of calcite deposits and oncolites.

For lake-wide Alternatives B through I, MNR and aeration (oxygenation) in SMU 8 (the profundal area) would reduce chemical toxicity to aquatic organisms by decreasing the CPOI concentrations in profundal surface sediments. Aeration (oxygenation) would reduce dissolved sulfide concentrations and increase dissolved oxygen concentrations in water. In addition, the concentration of methylmercury in the water column would be reduced over time, as would the uptake of methylmercury by aquatic organisms. Thin-layer capping would also reduce the mobility of mercury by providing cleaner material for the upper biologically active zone of the profundal sediments. Alternative J would cap all sediments exceeding the ERL, and would also employ aeration (oxygenation) of the hypolimnion.

5.3.6 Implementability

All of the lake-wide alternatives are considered implementable; however, lake-wide Alternatives A through D2 and F1 through H are more practical than Alternatives E, I, and J given the scale of dredging and backfilling required.

Capping reliability and implementation for Alternatives B through D2 and F1 through H can be demonstrated through examples at similar sites (see Appendix H, capping issues). The two major implementability issues related to capping are protection of cap materials from physical stressors and placement of cap material on soft sediments and on slopes. Both issues are readily addressed in final design, and have been preliminarily evaluated as part of this FS (see Appendix H, capping issues). Shoreline armoring and surface materials of appropriate sizes can be used to protect the cap from wind, wave, current, and propeller erosion, bioturbation, consolidation, and ice scour; and placement of cap material in thin lifts typically addresses the soft sediment issue. In addition, the cap is overdesigned to allow for a “mixed” layer (i.e., cap material that combines with existing soft surface sediment during initial cap placement) that does not contribute to cap effectiveness.

As discussed under long-term effectiveness and permanence, periodic monitoring and maintenance of the cap and SCA would be performed for lake-wide Alternatives B through D2 and F1 through H. In addition, biological monitoring would be conducted to establish the effectiveness of habitat enhancements and aeration (oxygenation). The monitoring types listed previously are all readily implementable at this site.

Dredging under lake-wide Alternatives B through J could be conducted using hydraulic or mechanical dredging, which are both considered reliable methods based on effective use at similar sites (see Appendix L, dredging issues). For this evaluation, hydraulic dredging is assumed; however, both types would be evaluated during pre-design, and the optimal method or methods would be selected. In addition, the numerous engineering controls (e.g., silt curtains) to minimize potential impacts that can result from dredging (e.g., resuspension) are readily implementable.

Although Lake-wide Alternatives E, I, and J have the same basic implementability issues related to dredging and capping (backfilling for Alternatives E, I, and J) as described for the other lake-wide alternatives, the impacts are significantly greater due to the significantly larger dredging volume (i.e., over 10,000,000 CY more compared to Alternatives B through D, and from 8,000,000 to 19,000,000 CY more for Alternatives F1 through H), greater dredging depths, and longer duration required. Although removal of all littoral sediment exceeding the mean PECQ2, mean PECQ1, or ER-L may be implementable, it may not be practical for the reasons discussed in the following paragraphs.

First, the dredging volumes under Alternatives E, I, and J are substantial. Dredging in SMU 1 alone (an estimated 4,000,000 CY for Alternatives E, I, and J) is approximately four times greater than any other contaminated sediment dredging project that has occurred to date in the United States (MCSS, 2002). To contain such a large volume of sediment, construction of an estimated 260-acre SCA with 50-ft (15 m) dikes was assumed for this evaluation. As discussed in Subsection 4.10, other SCA configurations would need to be evaluated in the design phase because the SCA size presented herein was selected as the most cost-effective configuration (i.e., it minimizes, to the extent practical, the amount of imported material required for dike and cap construction). Although there is sufficient area available at the wastebeds for this facility (e.g., a combination of Wastebeds 12, 13, and 14 could be used), the SCA would be challenging to construct as a result of the large volume of fill required to construct the dikes. An additional factor related to the design is the height of the facility. For example, the town of Camillus may object to the additional elevation on the existing 55-ft (17 m) thick wastebed; the local government previously has restricted the height of Wastebed 15 to 468 ft above mean sea level (msl), which is 23 ft (7 m) above the existing Wastebed 13 dikes.

Another implementation issue is that the depth of sediment removal for Alternatives E, I, and J would likely require construction of retaining walls along a significant portion of the shoreline of SMUs 1, 2, 3, 4, 6, and 7. In some areas (e.g.,SMU 1) construction of a retaining wall that would provide adequate stability for dredging to depths of at least 26 ft could be problematic because of the weak anchoring materials on the landside (i.e., Wastebed B).

The duration required for Alternatives E, I, and J also makes them impractical to implement. Approximately nine years would be required to implement Alternative E, ten years for Alternative I, and seventeen years for Alternative J, as compared to approximately three years for Alternatives B through D2, and four years for Alternatives F1 through H. The equipment and personnel are available in the marketplace, but the ability to monopolize use of that equipment over that long a period, given other dredging projects, could be problematic, although equipment purchase may be an option. In addition, approximately a decade of community disturbance may not be acceptable, and the use of additional dredging and/or backfilling crews would require importing an unrealistic volume of material on a daily basis and would overwhelm the available staging areas.

Finally, lake-wide Alternatives E, I, and J also have a higher risk of partial remedy failure during implementation due to the cessation of remedial activities each winter and the corresponding startup in the spring. In addition, the issue of potential recontamination of previously dredged and backfilled areas would be more of a concern because of the larger area and multiple construction seasons involved. In terms of the SCA, placement of temporary cover may be required between construction seasons to isolate dredged sediment. Additional institutional controls would also likely be required to handle stormwater issues at the SCA over a longer operational period.

The remedial actions for lake-wide Alternatives B through J could all be readily supplemented with additional remedial actions. In addition, the ability to obtain approvals from other agencies for Alternatives B through D2 and F1 through H should be high. Obtaining approvals from other agencies to implement Alternatives E, I, or J may be slightly more difficult because of the extended duration and the short- and long-term effects associated with these remedies.

In summary, lake-wide Alternatives B through J are implementable; however, implementation of lake-wide Alternatives E, I, and J may not be practical due to the dredging volume, dredging depth, and construction duration.

5.3.7 Costs

The capital costs, O & M costs (present value) and total costs of Alternatives A through J are provided in Table 5.5.

SECTION 5

TABLES

SECTION 5

FIGURES

SECTION 6

RECOMMENDED REMEDIAL ACTION ALTERNATIVE

Based on the comparative analysis performed in Section 5, the Dredging / Capping with Recreation and Habitat Diversification Alternative (lake-wide Alternative C) was selected as the recommended alternative.

The Dredging / Capping with Recreation and Habitat Diversification Alternative is protective of human health and the environment and provides the best balance between the evaluation criteria. This alternative includes the following key attributes:

- Achieves RAOs and PRGs and is compliant with ARARs, to the extent practicable, through a combination of dredging and capping;
- Diversifies habitat in and around the lake (an estimated 336 acres) through creation of approximately six acres of upland area, ten acres of emergent wetlands, 25 acres of recreational / habitat buffer area, 48 acres of submerged macrophyte / benthic area, 133 acres of fish spawning habitat, 37 acres of benthic habitat, and 77 acres of isolation cap over the six- to nine-meter (20- to 30-foot) depth;
- Includes habitat enhancement of approximately 23 acres of the littoral zone;
- Can be implemented in a timely manner;
- Is effective in the long-term; and
- Restores a valuable recreational and ecological resource.

In comparison with the other lake-wide alternatives, Alternative C is preferred over Alternative A because the No Action Alternative would not be protective of human health and the environment. Alternatives B through J are all sufficiently protective of human health and the environment and have varying degrees of residual risk; however, the implementation cost and duration increases significantly from Alternative B to D2, from F1 to H, and from Alternatives E to I to J. Among Alternatives B through J, the short-term impacts related to potential surface water exceedances, transportation and construction risks, and quality of life impacts related to truck traffic are significantly greater for Alternatives E, I, and J. In addition, implementation of Alternatives E, I, and J may not be practical because of the large volumes, dredging depths, risk of partial remedy failure during implementation, and long duration required for construction. Although these alternatives are sufficiently protective, Alternative C is preferred over Alternatives E, I, and J because of the significant costs, short-term impacts, and implementability issues associated with these alternatives.

Alternatives B through D2 and F1 through H are very similar based on the evaluation criteria; however, the amount of dredging to provide no loss of lake surface area and/or to optimize habitat and minimize erosive forces increases progressively from Alternative B to D. Since habitat optimization is a primary goal of remediation, and Alternative C includes dredging to optimize habitat and minimize erosive forces, and Alternative B does not, Alternative C is preferred over Alternative B.

Alternative D provides additional dredging to reduce armoring requirements, as compared to Alternative C; however, the additional dredging in SMU 4 would expose sediments with higher concentrations prior to capping. In addition, although the same area of the lake would be capped under both alternatives, the habitat would be managed differently under the two alternatives because of the increased dredging volume in Alternative D. Alternative C would provide more recreational and habitat diversification than Alternative D. For example, the additional recreational / habitat buffer area in SMU 1 under Alternative C would provide more area suitable for direct contact (e.g., wading) compared to Alternative D. Since Alternatives C and D are both sufficiently protective, Alternative D has more short-term impacts, and Alternative C provides a better mix of habitats and is less costly, Alternative C is preferred over Alternative D.

Alternative D2 includes additional dredging in SMUs 5, 6, and 7 to maximize habitat for submerged macrophytes and minimize erosive forces. The resulting habitats would be similarly diverse as Alternative C, but the alternative would have additional short-term impacts, which would persist for the longer time period of implementation needed for this alternative. Since both alternatives would be similarly protective, and Alternative D2 would create additional short-term impacts and would be more costly to implement, Alternative C is preferred over Alternative D2.

Alternatives F1 through H include significant additional dredging to an endpoint of the mean PECQ1 rather than the PECQ2. These alternatives would be significantly more costly than Alternative C to implement, and all are sufficiently protective of human health and the environment. The short-term impacts of each of these alternatives are greater than for Alternative C, and will persist for a longer period of time during implementation. Balancing these considerations, Alternative C is preferred over these alternatives.

In summary, Alternative C is sufficiently protective, provides good habitat diversity, and is cost-effective. Compared to the other lake-wide alternatives, their levels of protectiveness, the magnitude and duration of short-term impacts, and estimated capital and operation and maintenance costs, Alternative C provides the best balance between the evaluation criteria. Therefore, the Dredging / Capping with Recreation and Habitat Diversification Alternative was selected as Honeywell's recommended alternative.

6.1 DESCRIPTION OF RECOMMENDED REMEDIAL ACTION ALTERNATIVE

Honeywell's recommended alternative for Onondaga Lake protects human health and the environment, diversifies and enhances habitat, and restores a valuable recreational and ecological resource for the community. Lake-wide Alternative C - Dredging/Capping with Recreation and Habitat Diversification meets the RAOs and PRGs described in Section 2, and provides the most balanced attainment of the seven CERCLA evaluation criteria as determined through the comparative analysis of all of the lake-wide alternatives (Section 5). This remedy maximizes the recreational, aesthetic, and ecological benefits for the entire lake through creation and enhancement of habitat, dredging and/or capping of impacted sediments, aeration of the hypolimnion, and management of residuals to ensure remedy effectiveness.

The recommended remedy for the entire lake comprises the following primary elements, as shown on Figures 6.1 through 6.4:

- Dredging of an estimated 543,000 CY of impacted sediments to actively address the most impacted shallow sediments in the lake;
- Isolation capping of an estimated 259 acres of sediment within the shallow littoral zone of Onondaga Lake to ensure impacted undredged sediments and any remaining post-dredging residuals are permanently isolated from the lake ecosystem;
- Isolation or thin-layer capping of an estimated 77 acres of sediment within the less-impacted deeper littoral zone of Onondaga Lake to provide an immediate reduction in surface sediment impacts and enhance the recovery of the lake;
- Restoration and improvement of an estimated 336 acres of benthic habitat in the littoral zone, integrated with the capped areas, to promote habitat diversity throughout the lake;
- Consolidation and dewatering of dredged sediments in an on-site SCA placed on Wastebed 13, consistent with USACE guidance documents, to ensure reliable long-term management of the sediments consistent with wastebed redevelopment and reuse;
- Treatment of SCA supernatant prior to release back to the dredging zone in Onondaga Lake, to minimize the impact of dredging/consolidation on lake water quality;
- Stabilization of the approximately 1.5 miles (2,500 m) of SMU 3 shoreline to prevent erosion and stabilize and improve adjacent littoral habitat (additional stabilization of the bluffs along the lake in SMU 3 would be addressed through future remedial actions for Wastebeds 1 through 8);
- Enhancement of an estimated 23 acres of littoral habitat to reduce the impact of oncolites and improve submerged macrophyte coverage, thereby enhancing fish habitat throughout the littoral zone;
- Thin-layer capping of the profundal zone sediments (estimated at 20 acres) to reduce CPOI concentrations in the surface layer of sediments and enhance natural recovery of the area;
- Aeration (oxygenation) of the hypolimnion to reduce methylation of mercury in Onondaga Lake, reduce the flux of methylmercury from profundal sediments, and thereby reduce mercury bioaccumulation in fish tissue, as well as greatly expand the

areas of the lake suitable for fish and benthic colonization. This work would be conducted in phases, with Phase I evaluating the effectiveness and potential risks associated with implementation of aeration. The work would be coordinated with the pilot studies planned by the Onondaga Lake Partnership;

- Monitored natural recovery of the profundal zone, with detailed monitoring and contingency measures for any areas that may not naturally recover, including additional thin-layer capping, modification of the aeration process, and/or other methods, to achieve goals aimed at restoring and improving the deeper portion of the lake;
- Improvement of habitats throughout the entire lake through a coordinated program of optimization and enhancement;
- Construction of a swimming beach in and adjacent to SMU 5, between the marina and the lake outlet, if consistent with community goals for the lake and local land use planning;
- Continuation of institutional controls on fish consumption and other institutional controls as needed to ensure the long-term effectiveness of the remedy; and
- Operation and maintenance of the remedial components to ensure long-term effectiveness.

Implementation of the recommended remedy, in conjunction with upland site source control being addressed under separate projects, would have a significant and permanent beneficial impact on Onondaga Lake and the local community. The recommended remedy would be fully protective of human health and the environment, achieve RAOs and PRGs, and be implementable, effective and permanent in the long term. The inherent short-term impacts of the proposed remedy implementation are acceptable in the context of lake restoration, and would be relatively short-lived.

In addition to remediating the historical industrial impacts to the lake, the recommended remedy would create substantial improved habitat for over one third of the entire littoral zone of the lake through the capping of an estimated 356 acres of lake sediments, using designs that target providing optimal habitats in each area of the lake, including submerged macrophytes, fish spawning areas, and substrate for benthic organism recolonization. The overall remedy provides a substantial improvement in the quantity and quality of habitats available within the lake. An estimated six acres of shallow lake habitat would be converted to upland habitat. More than 20 acres of littoral habitat would be enhanced through treatments designed to limit the impacts of oncolites and calcitic material and improve submerged macrophyte cover for fish habitat, particularly bass. Moreover, the recommended remedy would create or enhance large contiguous areas of improved habitat by integrating the proposed remedial approach across the entire lake. Although there would be some loss of lake surface area and water depth, NYSDEC will determine whether the overall remedy is consistent with the requirements of 6 NYCRR Part 608, and is in the public interest.

The proposed habitat improvements for the remedy would be coordinated with and would augment the ongoing efforts of other parties including the Onondaga Lake Partnership. In combination with the lake remediation, Onondaga County's ongoing successes in addressing combined sewer overflows and nutrient additions to the lake are expected to improve lake water conditions, enhance the physical improvements to the lake bottom substrate, improve conditions for lake biota, and improve recreational opportunities such as boating, water skiing, and fishing. The improvement in water quality may support the construction of a public swimming beach in SMU 5 along the northeast shoreline between the marina and the lake outlet. In conjunction with Onondaga Lake Partnership's proposed lakeside bike trail (Trail Segment 3C) and potential habitat enhancements, the recommended remedy would result in substantial improvements to the littoral habitat in Onondaga Lake, benefiting the entire lake and community.

The following subsections describe each aspect of the proposed lake-wide remedy in detail, with respect to littoral and profundal sediments.

6.2 IMPROVING THE LITTORAL AREAS OF ONONDAGA LAKE

The littoral zone of Onondaga Lake is comprised of approximately 1,000 acres forming a peripheral ring from the existing shoreline to depths of approximately 20 ft (6 m). The deeper littoral zone is the transition from the littoral zone to the profundal zone at depths greater than 30 ft (9 m). Under the recommended remedy, existing conditions in the shallow and deeper littoral zones would be significantly improved through a combination of dredging and consolidation of impacted sediments in an on-site SCA, isolation of impacted sediments in Onondaga Lake through capping, and habitat improvement. Each of these remedial components are described in the following subsections.

6.2.1 Dredging and Consolidation of Impacted Littoral Sediments

6.2.1.1 Dredging of Impacted Littoral Sediments

An estimated 543,000 CY of impacted littoral sediments would be dredged and removed from the lake, ranking this project among the largest contaminated sediment removal projects ever conducted in the United States. Dredging would achieve several objectives, including optimization of aquatic and benthic habitat and recreational opportunities, preservation of lake surface area following capping of the dredged area, targeted removal of sediments to enhance the effectiveness of the sediment cap, and/or minimization of erosive forces on the cap. Dredging would be conducted in the following areas:

- Dredging of an estimated 151,000 CY of impacted sediment in SMU 1, so that cap placement would result in no net loss of lake surface area;
- Dredging of an estimated 169,000 CY of impacted sediment in SMU 2 to achieve no loss of lake surface area, optimize habitat value, minimize the impact of erosive forces on the cap, and enhance cap effectiveness;

- Dredging of an estimated 75,000 CY of impacted sediment in SMU 3 to achieve no loss of lake surface area, optimize habitat value, minimize the impact of erosive forces on the cap, and enhance cap effectiveness; and
- Dredging of an estimated 148,000 CY of impacted sediments in SMU 6 to enhance cap effectiveness.

Hydraulic dredging was assumed for evaluation purposes, although either hydraulic or mechanical dredging, or some form of hybrid dredging, may be determined to be most practical during the remedial design process. A final determination on the dredging method would be made during remedial design and contractor procurement.

The removal depth required for no loss of lake surface area in SMU 1 would be carefully estimated based on the predicted settlement of sediments as a result of cap placement. Data gathered during the pre-design investigation (specifically bathymetry and geotechnical consolidation parameters) would provide the necessary information to estimate accurately the required dredge cuts. Additional information on the degree of settlement expected is detailed in Appendix H, capping issues.

Dredging would be performed in SMUs 2 and 3 to provide a post-remediation water depth that fully supports the habitat enhancement recommendations detailed in Appendix M, habitat issues, and achieves no loss of lake surface area. Removal would occur to depths that reduce the erosive forces on the cap. Dredging in SMUs 2 and 3 would promote submerged macrophyte growth and increase water depth to between 2 and 6 ft (0.6 and 1.8 m) where significant armoring of the cap is not required. In addition, targeted dredging in SMUs 2 and 3 would be performed to remove sediment with elevated CPOI concentrations (i.e., elevated compared to surrounding sediments) to ensure the isolation cap provides sufficient isolation of remaining CPOIs.

In SMU 6, targeted dredging of impacted sediments would enhance the effectiveness of the cap by removing impacted sediment in nearshore areas that are subject to elevated groundwater upwelling velocities. By removing sediments in these areas, the success of the cap can be ensured, even as the capped areas can be engineered to maximize habitat improvements.

It was assumed that two 14-inch hydraulic dredges would be used to complete the dredging portion of the project. Assuming a 2,400 *in situ* CY/day per dredge production rate over a five-day work week and a seven-month dredging season, the estimated volume to be dredged under the recommended remedy (543,000 CY) could be dredged over approximately 24 weeks (equivalent to a single construction season, although the work may be conducted over two seasons to facilitate capping requirements and habitat restoration efforts).

Pre-design investigation work would provide the site-specific data needed to refine and ensure the success of the remedial design, including a more detailed contamination profile and sediment geotechnical data. In addition, a baseline survey would be performed to document the current bathymetry of the lake. Pre-design testing would facilitate refinement of dredging methods.

6.2.1.2 Consolidation of Dredged Materials in an On-Site SCA

Littoral sediments dredged from Onondaga Lake would be consolidated and contained in an SCA constructed on Wastebed 13. Wastebed 13 would accommodate the estimated volume of dredged material. This wastebed is easily accessed by truck and pipeline, is relatively remote from the lake and commercial areas and would be minimally disruptive to the community during construction and operation. Furthermore, the use of Wastebed 13 supports productive future reuse and development scenarios for the wastebeds, such as the tree farm in support of the SUNY Environmental Science and Forestry (ESF) woody biomass resources for bioproducts and bioenergy project. Given current ownership of Wastebed 13 by Honeywell, the sediment consolidation can be implemented in a timely manner, with no purchase of additional land or negotiation of leases.

The process required to hydraulically dredge and consolidate impacted sediments into an SCA includes the following tasks:

- Constructing the SCA, including preloading and stabilization (if required);
- Hydraulically dredging the sediment;
- Pumping the dredged sediment slurry to the SCA through double-walled HDPE piping;
- Processing and dewatering sediment in the SCA;
- Treating supernatant water from the SCA and returning it to the lake; and
- Capping the consolidated sediments in the SCA and restoring the area in accordance with planned reuse and redevelopment.

The SCA would be constructed on top of the approximately 55- to 70-ft (17- to 20-m) thick Solvay material by constructing dikes to provide containment of the dredged material, while allowing the supernatant to be treated prior to release back to the dredging area work zone. The SCA would provide substantial and permanent containment of the dredged material removed from the lake, and would be capped following dredged material settlement and dewatering. The SCA would be designed in accordance with USACE guidance (USACE, 1987, 2003) to ensure successful operation, and that the facility is protective of human health and the environment. Geotechnical investigation during pre-design would be conducted to confirm the suitability of the Solvay material layer for confinement purposes, as well as the need for preloading and/or stabilization of underlying Solvay material. Consistent with USACE guidance, this investigation would develop data on compressible foundation characteristics, fine-grained dredged material characteristics, and incompressible foundation characteristics. Based on experience at other dredge sites with fine-grained sediment, the dredged material is expected to form a low permeability barrier during the consolidation process. Permeabilities of less than 10^{-6} cm/sec have been experienced at other sites (see Appendix K, cost estimates). A drainage layer was assumed in the FS for costing purposes and if needed would be constructed above the wastebed material and below the sediment mass for sediment dewatering during operation, closure, and post-closure. A final cap would be placed over the material following dredged material settlement to provide another containment barrier, resulting in the permanent containment of the material.

The dredge slurry from each of the areas to be dredged would be pumped to the SCA via double-contained HDPE pipelines, with manned booster stations approximately every mile of pipeline. The pipeline would be floated when in the lake or creek and laid overland when on land.

Upon completion of the dredging, the sediment in the SCA would be effectively managed and contoured to facilitate capping. Final capping requirements would be established during the remedial design, considering the plan for wastebed reuse and redevelopment. However, for this evaluation, the assumed SCA cap would consist of, from the bottom up, a sediment-isolation layer consisting of sand, clean fill, and a topsoil/vegetative cover providing additional protection from infiltration. The need for geomembrane and geocomposite layers in the cap would be determined as part of the SCA design, based on the pre-design geochemical investigation, to be consistent with the site reuse and redevelopment plans. Although some settling is expected as the sediment dewaters and compacts, final slopes for the cap are expected to be approximately 3 percent. A schematic depiction of the dewatering layer and cap construction is provided on Figure 4.52.

As the dredged material consolidated in the SCA settles and dewaters, the water (supernatant) produced must be removed and treated prior to release back to the dredged area work zone in the lake, since it would contain residual CPOIs that are present in the dredged material. Supernatant treatment was assumed to consist of advanced primary treatment based on projected supernatant characteristics and supernatant treatment requirements (see Subsection 4.9.3.2), although additional evaluation of the appropriate level of treatment is required to ensure that effluent discharge criteria can be achieved. This treatment approach includes the unit treatment processes shown on Figure 4.60. Components of this supernatant treatment system may include:

- Primary solids removal in the SCA;
- pH adjustment for metals (primarily mercury) precipitation;
- Addition of flocculant;
- Mixing and flocculation;
- Additional suspended solids removal in a secondary clarifier;
- Multimedia filtration;
- Air stripping;

- GAC adsorption for polishing;
- Solids consolidation in a SCA and/or off-site disposal, as required; and
- Supernatant return discharge to Onondaga Lake.

Primary treatment, consisting of gravity settling, would be accomplished in the SCA itself. After primary treatment, pH adjustment and a chemical precipitation step would be performed for removal of finer and other insoluble particulates by adding coagulation and flocculating chemicals to enhance solids settling. These solids would be removed in a secondary basin or clarifier, followed by multimedia filtration. Air stripping would remove volatile organic compounds, followed by GAC adsorption for polishing prior to release of the supernatant back to the dredging area work zone in Onondaga Lake, where the sediment and entrained water originated. Solids generated during the solids removal steps would be consolidated in the SCA.

Although advanced primary treatment is the treatment option described above, final treatment requirements would be determined during pre-design. Testing would be conducted to establish geotechnical and geochemical design requirements for the SCA and treatability testing for water generated through sediment consolidation and dewatering, to ensure that the lake water quality is maintained and improved. Complete cost calculations for the SCA and supernatant treatment are provided in Appendix F, cost estimates.

6.2.2 Capping of Impacted Littoral Sediments

Under the recommended remedy, an estimated 336 acres of shallow and deep littoral sediments in SMUs 1, 2, 3, 4, 6, and 7 exceeding the mean PECQ2 would be capped to permanently isolate remaining CPOIs and enhance littoral habitat. In areas of the deep littoral zone, between the 20- and 30-ft (6- and 9-m) water contours, where net sediment deposition is present with lower CPOI concentrations with no significant upwelling, thin-layer capping would also be considered. Data collected during the pre-design investigation would be used to determine optimal capping requirements for each area.

The isolation cap would be designed to:

- Provide physical isolation of the impacted sediments from human contact and benthic organisms, where applicable;
- Be physically stable; and
- Provide long-term and permanent chemical isolation of impacted sediments from flux or resuspension into the overlying surface waters.

Specific factors that would be evaluated as part of the capping final design include potential for erosion, failure during extreme events, bioturbation, chemical isolation, habitat, settlement, static and seismic stability, and placement. The results of a preliminary capping evaluation performed by nationally-recognized experts for this FS, in accordance with USEPA and USACE guidance (USEPA, 2002; Palermo, Clausner, *et al.*, 1998a; and Palermo, Miller, *et al.*, 1998b), are provided in Subsection 4.3 and in Appendix H, capping issues. Consistent with USEPA design guidance for caps, the cap would be designed to withstand erosional forces resulting from the 100-year return interval storm event (USEPA, 2002). As discussed in Subsection 4.3, a slope stability analysis was performed on the submerged ILWD for two slope profiles in the southeast corner of Onondaga Lake using available geotechnical and other relevant data (see also Appendix H, capping issues). The results indicate adequate safety factors against a failure of the existing slope under static and seismic conditions.

A conservative approach protective of human health and the environment was taken with respect to isolation cap chemical modeling conducted as part of the FS (Appendix H, capping issues). The model predicts that a 4.25-ft (1.3-m) final placement thickness, with a 3.75-ft (1.1-m) thick chemical isolation cap layer, including a 50 percent safety factor and an additional 6 in (15 cm) to account for mixing with underlying sediment and non-uniform application, would be fully protective for SMUs 1, 2, and 7. Using similar conservative conceptual design criteria, a 2.0-ft (0.6-m) thick chemical isolation cap layer would be protective for SMUs 3, 4, and 6. The isolation layer thickness assumes the control of potential groundwater upwelling by the shallow hydraulic control system along the southwestern shoreline of the lake. A habitat/armor layer overlying the isolation layer provides physical stability and habitat enhancement. Deep groundwater control would be included in SMU 1, where needed to reduce groundwater upwelling through the ILWD.

This FS also analyzed settlement issues related to the proposed cap. Settlement under the cap load would likely vary by location, depending on the characteristics of the underlying sediments, and would exceed the cap thickness in SMUs 6 and 7. Pre-design testing would be conducted to more accurately estimate the degree of settlement expected to properly design the cap. Given current data, the proposed capping would not cause any loss of lake surface area in SMUs 1, 2, 3, 6, and 7. In only one area, SMU 4, would the proposed isolation cap result in the loss of lake surface area. Settlement analysis predicts that placement of an isolation cap in SMU 4 with no sediment removal would result in the conversion to upland habitat of an estimated 5.5 acres of lake surface in the area currently shallower than approximately 1 ft (0.3 m). Habitat optimization, including the conversion of this lake habitat in SMU 4 to upland, the establishment of an estimated 6.4 acres of emergent wetlands in the 1-ft to 2.5-ft (0.3- to 0.8-m) depth range in SMU 4, and the other habitat improvements throughout the lake, could mitigate this conversion of lake surface area.

Capping in the littoral zone would take into consideration any existing in-lake infrastructure, cultural artifacts (e.g. man-made objects that have been placed or lost in the lake), and debris. Side-scan sonar has identified potential sunken vessels and/or other cultural artifacts in the areas that would be capped, as well as a discharge pipe and diffuser in SMU 1 (PTI, 1992a). Further evaluation would determine the appropriate means for addressing these cultural artifacts or debris; options include removal or covering in place. Capping in SMUs 6 and 7 would also take into consideration existing in-lake infrastructure, such as the Metro Plant discharge, as well as the boating channel and any future navigational dredging requirements associated with access to the Onondaga Creek Inner Harbor.

Following capping, an effective long-term monitoring program would be designed and implemented to ensure the cap effectiveness by confirming that the cap remains in place over time and is not subject to CPOI breakthrough. This may include periodic core sampling to verify cap integrity, and contaminant sampling to confirm cap effectiveness. In addition, cap surveys would be performed and compared with a post-cap installation survey to determine routine maintenance requirements and ensure the long-term integrity and protectiveness of the cap. A detailed, long-term monitoring program would be developed as part of the remedial design.

6.2.3 Habitat Improvement

The recommended remedy would restore Onondaga Lake to a valued community resource by improving aquatic habitat throughout the littoral areas of the lake and enhancing its recreational value while simultaneously achieving RAOs and PRGs. This is accomplished via three approaches:

- **Optimizing surface characteristics of the isolation cap.** In areas of the lake where an isolation cap would be installed to provide permanent isolation of impacted sediments, the surface characteristics of the cap would be optimized to enhance growth of submerged aquatic plants, increase fish spawning, improve aquatic habitat, and resist erosive forces, depending on water depth, to take full advantage of the available cap surface.
- **Introducing clean sediment into the biologically-active zone.** Habitat benefits are an integral component of the thin-layer capping scenario by introducing clean sediment into the upper sediment layer and immediately reducing surface sediment CPOI concentrations and their impacts on biota.
- **Enhancing existing habitat throughout the lake.** In other areas of the lake where dredging and/or capping is not needed to protect human health and the environment, habitat would also be improved under the recommended remedy through various habitat enhancements, as discussed below, to provide a comprehensive approach to habitat improvement throughout the lake.

Each of these habitat improvement aspects for the littoral zone are discussed in the following subsections.

6.2.3.1 Littoral Habitat Improvement Through Isolation Capping

Under the recommended remedy, an estimated 336 acres within the littoral zone of the lake would receive an isolation cap. In addition to providing long-term and essentially permanent isolation of impacted sediments, the cap would be engineered to create recreational and habitat enhancements as shown on Figures 6.5 through 6.10 and described on the next page:

- New **upland habitat** would be created in SMU 4, replacing an estimated 5.5 acres of aquatic habitat, as shown on Figure 6.5. Terrestrial wildlife would benefit from provision of cover and access to the enhanced prey base resulting from in-lake habitat improvements. The upland habitat would also serve as a recreational area.
- **Emergent wetlands** would be established over an estimated 10.4 acres of isolation cap within SMU 4. The wetlands would extend from the existing shoreline to depths ranging from approximately 1 to 2.5 ft (0.3 to 0.8 m). Emergent wetlands would provide cover and nursery areas for juvenile fishes. Terrestrial wildlife receptors would benefit from access to the enhanced prey base resulting from in-lake habitat improvements. The emergent wetlands would also dissipate wind-wave energy and help stabilize the shoreline.
- A **recreational/habitat buffer** zone would be established over an estimated 25 acres of the isolation cap, within SMUs 1, 2, 3, 6, and 7. This zone, illustrated for SMU 2 on Figure 6.6, would consist primarily of a thin sand layer over a rock layer that would protect the isolation cap from erosive forces within the lake, and would extend from the shoreline to approximately the 2-ft (0.6-m) water depth. The larger rock size layer provides protection against erosive forces to ensure cap integrity. Addition of the thin sand layer over the rock provides a suitable substrate for colonization of benthic macroinvertebrates and possibly submerged macrophytes. These changes would increase the prey base for insectivorous fish species (e.g., juvenile largemouth bass). The sand would also provide a recreational buffer more suitable for direct contact (e.g., wading) than the underlying rock.
- Additional **habitat suitable for submerged macrophytes** (aquatic plants) would be created over an estimated 48 acres within SMUs 1, 2, 3, 4, 6, and 7 by a sand layer over the isolation cap, at depths ranging from approximately 2 to 5 ft (0.6 to 1.5 m). This habitat is illustrated for SMU 1 on Figure 6.7. The addition of the sand layer would provide a suitable substrate for submerged macrophyte colonization and benthic macroinvertebrate recruitment. The colonization of the sand layer would increase the prey base for benthivorous and insectivorous fish species (i.e., fish that consume benthic organisms and insects) and provide protective cover for juvenile fish including largemouth and smallmouth bass. In shallower areas, piscivorous fishes (fish that consume other fish) and terrestrial receptors would benefit from the enhanced prey base resulting from in-lake habitat improvements.
- **Fish spawning habitat** would be created and enhanced by a gravel layer over an estimated 133 acres of isolation cap within SMUs 1, 2, 3, 4, 6, and 7 at depths ranging from approximately 5 to 15 ft (1.5 to 4.6 m). This habitat is illustrated for SMUs 6 and 7 on Figures 6.8 and 6.9. The thin gravel layer would provide additional microhabitats for benthic macroinvertebrates, thereby increasing the diversity of benthic communities. Addition of large woody debris structures would provide cover for fish species and a substrate for colonization by epifaunal invertebrates. The colonization of the large woody debris structures would increase the prey base for insectivorous fish species and provide protective cover for juvenile fish, including

largemouth and smallmouth bass. In addition, piscivorous fishes would benefit from the enhanced prey base resulting from in-lake habitat improvements.

- Improved **benthic habitat** would be created over an estimated 114-acre area within SMUs 1, 2, 3, 4, 6, and 7 with a thin sand layer above the isolation cap and depths ranging from approximately 15 to 30 ft (4.6 to 9 m). This habitat is illustrated for SMU 3 on Figure 6.10. The sand layer would provide a suitable substrate for colonization of benthic macroinvertebrates. The colonization of these areas would increase the prey base for benthivorous fish species.

Isolation cap requirements would be developed during remedial design to optimize habitat value and protect the cap from erosion. Specific elements of the habitat improvements would be refined with input from the community and the Onondaga Lake Partnership.

6.2.3.2 Littoral Habitat Improvement Through Thin-Layer Capping

Thin-layer capping provides an immediate decrease in surface sediment CPOI concentrations by introducing clean sediment into the upper layer of sediment. Construction methods and natural processes, primarily bioturbation, would mix the new sediment with the underlying material and thereby reduce ecological effects associated with the CPOIs. This would enhance natural recovery of the area, as well as improve its habitat value through the addition of clean sediment. Available data and evaluation presented in Appendix N, monitored natural recovery, indicates the deeper littoral zone between the 20- and 30-ft (6- and 9-m) water contours is an area of net sediment deposition and lower CPOI concentrations with no significant upwelling. In this zone, a thin-layer cap consisting of 6 inches (15 cm) of sand may be appropriate rather than an isolation cap and may still be fully protective of human health and the environment at depths greater than 20 ft (6 m). For this FS, it is estimated that an isolation cap in the littoral zone would be applied to an estimated 77 acres of the deeper littoral zone adjacent to the isolation cap in the shallow littoral zone in SMUs 1, 2, 3, 4, 6, and 7. However, a thin-layer cap may be more appropriate given site-specific conditions. The actual areas requiring an isolation cap or a thin-layer cap in the littoral zone would be determined during pre-design.

6.2.3.3 Other Areas of Littoral Habitat Improvement

Littoral habitat improvements would be integrated into the isolation cap and thin-layer capping scenarios described above and would enhance habitat over an estimated 336 acres of the littoral zone. However, the recommended remedy would also further improve aquatic habitat in other littoral areas where dredging and/or capping is not necessary for the protection of human health and the environment, to restore habitat diversity for the entire lake. This would be accomplished primarily through the stabilization of littoral habitat that contains oncolites and calcitic material in SMU 5 and through shoreline stabilization and the enhancement of littoral habitat in SMU 3.

Results from previous studies suggest that macrophytes may be able to colonize oncolitic sediments in Onondaga Lake if existing oncolites are stabilized to prevent movement caused by wave action (Madsen *et al*., 1993; Madsen *et al.,* 1998). The primary ecological benefit of stabilizing the oncolitic sediments would be to facilitate colonization by macrophytes. Although laboratory studies have demonstrated that macrophytes grow in oncolitic sediments (Madsen *et al.*, 1993), there is uncertainty with respect to what would occur in the field. Because it has never been demonstrated that macrophytes would successfully colonize oncolitic sediments in Onondaga Lake, the recommended remedy would examine multiple mechanisms for stabilizing oncolitic and calcitic sediments to promote successful macrophyte colonization.

Under the recommended remedy, targeted areas in SMU 5 would be treated to stabilize the oncolitic sediments to allow macrophytes to colonize the area. These target treatment areas are shown on Figure 6.4, and consist of low-to-moderate wave-energy zones along the northwestern and northeastern shorelines of SMU 5. Between the two wave-energy zones, targeted treatment areas total approximately 23 acres, based on a goal of achieving sufficient macrophyte cover to provide bass habitat. Various treatments would be examined to determine optimal strategies for minimizing potential oncolite migration and promoting submerged macrophyte growth. Additional details on the treatments envisioned are provided in Appendix M, habitat issues.

The southeastern area of SMU 5 is currently being investigated as part of the Onondaga Lake trail and habitat project, Trail Segment 3C (see Appendix M, habitat issues). The trail project would likely include creation of wetland and submerged macrophyte habitat. Because habitat improvements are already being addressed under this project, no additional treatment is recommended for this portion of SMU 5.

Construction of a public swimming beach in SMU 5 may be desirable and could possibly be constructed between the marina and the outlet along the northeast shoreline of the lake, if it is consistent with community goals for the lake and local land use planning. This beach would be constructed through the placement of sand in and adjacent to the lake, and would further enhance the control of oncolites and provide habitat enhancement in SMU 5. It could also create additional recreational/habitat buffer areas along the lakeshore. A swimming beach may become practical in the future, considering the anticipated improvement in water quality resulting from the nutrient removal improvements being implemented by the County.

In SMU 3, littoral habitat would be enhanced through shoreline stabilization along approximately 1.5 miles (2,500 m) to stabilize the calcitic sediments in this area and to create conditions suitable for macrophyte establishment and fish spawning. Figure 6.3 illustrates the area over which the shoreline protection would be applied. The primary habitat enhancement goal is to reduce the erosion of the calcium carbonate shoreline, with a secondary goal of providing aquatic structures for fish spawning and protective cover. Shoreline stabilization would be accomplished by using a combination of conventional physical armoring (i.e., rock riprap) and bioengineering techniques that use native plant materials. Additional stabilization of the steep slopes above the lake in SMU 3 would be addressed through the evaluation of potential remedial options for Wastebeds 1 through 8 under a separate program. To create additional fish habitat in portions of the lake that would be capped, large woody debris structures would be placed in the shallow littoral area to provide cover and increase foraging opportunities for fish.

The specific locations and the type and size of the structures would be refined during remedial design.

6.2.3.4 Habitat Value Analysis

All habitat improvements and enhancements described above would have a profound and permanent beneficial impact on Onondaga Lake. To illustrate the improvements in habitat that the recommended remedy would create, selected habitat characteristics were used to create pre- and post-remediation maps of the existing and projected future habitat "value" in littoral areas of Onondaga Lake by quantitatively evaluating the spatial distribution of macrophyte beds, the frequency of fish nesting, and the status of the benthic macroinvertebrate community (Figure 6.11), as described in Appendix M, habitat issues. The assigned habitat "values" range from less than 0.5 to 3.5, with the higher numbers indicating a higher habitat "value".

As shown on Figure 6.11, current overall littoral habitat conditions are generally poorest in the southern portion of Onondaga Lake, with the exception of large macrophyte beds (within SMUs 6 and 7) and contiguous wetland (SMU 6). Accordingly, the recommended remedy includes substantial littoral habitat restoration and enhancement activities in the southern portion of the lake to meet the qualitative remedial objectives stated in Subsection 2.5.4, including habitat enhancement to improve fish spawning areas and increase diversity of fish species, habitat improvement for fish-eating wildlife in and around the lake, improved lake conditions to promote fishing and boating activities, and control of oncolites and calcitic materials. SMUs 1 and 2 (limited macrophyte cover and calcitic sediments), and SMU 3 (steeper slopes, calcitic sediments, and limited macrophyte cover) were a particular focus.

Figure 6.11 also shows the projected long-term post-remediation habitat value map for the littoral areas of the lake, once the recommended remedy has been implemented and benthic colonies reestablished, a process that is estimated to take several years beyond the completion of proposed dredging and capping activities. Habitat conditions would be significantly improved in many littoral areas of the lake, particularly in the southern end of the lake and around the mouth of Ninemile Creek. This would be reflected by increased submerged macrophyte coverage, improved benthic habitat, increased diversity of fish populations, and a more robust food web for the lake.

6.3 IMPROVING THE PROFUNDAL AREAS OF ONONDAGA LAKE

Under the recommended remedy, the profundal zone of Onondaga Lake would be addressed through a phased approach involving the optimal combination of monitored natural recovery, aeration (oxygenation) of the hypolimnion, and/or phased thin-layer capping. Each of these elements of the profundal remedy are described in the following subsections.

6.3.1 Aeration (Oxygenation) of the Hypolimnion

Aeration (oxygenation) of the hypolimnion is included in the recommended remedy to significantly reduce methylation of mercury and reduce the flux of methylmercury from the profundal sediments. Because the mass of methylmercury available for bioaccumulation would be reduced, aeration (oxygenation) would thereby reduce mercury bioaccumulation in fish tissue. In addition, aeration may minimize methane production (and ebullition) in the upper layers of profundal sediment and increase biological activity in the profundal sediments. Pilot testing is necessary and is part of the recommended remedy, since the total effects of aeration on productivity, the food web, and the geochemistry of the profundal sediments are unclear, as discussed in Subsection 4.6. Pilot efforts would be coordinated with the Onondaga Lake Partnership, which is planning similar pilot aeration studies on the lake.

Aeration (oxygenation) would involve the addition of air or oxygen to the water column of Onondaga Lake to oxygenate the hypolimnion that is currently anoxic. Introduction of air or oxygen to the lake bottom would likely create an oxic microzone of at least a few millimeters at the sediment surface, would increase the depth of the biologically active zone in the profundal sediment, and would likely reduce the production of methylmercury. A benthic community would likely colonize the surface sediments within the first season of oxygenation, although one to two decades may be required for the community to attain full species diversity comparable to reference lakes (Horne *et al.*, 1986). The amount of bioturbation and subsequent mixing of clean depositing material with underlying sediments containing elevated concentrations of CPOIs is expected to be small.

Based on available data, implementation of aeration (oxygenation) appears feasible, and may provide significant positive benefits to the hypolimnion, such as reduction in methylation of mercury and reduction in mercury fish tissue concentrations. However, pilot studies are included in the recommended remedy to aid in further evaluation of the potential effectiveness of the remedy at reducing formation of methylmercury in the water column, limiting the entrainment of bubbles from the sediments, and reducing concentrations of methylmercury in fish tissue.

6.3.2 Monitored Natural Recovery/Thin-Layer Capping of Profundal Sediments

MNR is an active beneficial component of the recommended remedy for the profundal zone. MNR is a recognized sediment management tool and can occur through a variety of physical, chemical, and biological processes that act alone or in combination to reduce chemical concentrations, exposure, and/or mobility. Although these processes can occur in all matrices at a site (e.g., water, sediments, fish tissue, etc.), the focus on MNR for Onondaga Lake is on the profundal sediments.

The applicability of MNR to Onondaga Lake was established for this FS through an evaluation of source characterization, fate and transport processes, historical chemistry trends, historical biological trends, and predictive modeling, as described in Appendix N, monitored natural recovery. Fate and transport processes indicate profundal sediments (at depths greater than 30 ft [9 m]) and deeper littoral sediments (at depths between 20 and 30 ft [6 and 9 m]) are more stable than shallower sediments, and thus are more amenable to natural recovery. Water column, sediment, and biological tissue chemistry trends all appear to have been relatively stable (neither increasing nor decreasing) over the last 10 years, though statistical uncertainty/variability associated with the historical database precludes a rigorous trend analysis. These stable historical trends do not account for ongoing source control efforts expected to significantly reduce mercury loads to the lake. Thus, predictive modeling is needed to reliably forecast future conditions in the lake associated with MNR.

Predictive modeling indicates that significant decreases in mercury surface sediment concentrations can be expected for all profundal sediments under MNR. Surface sediment mercury concentrations are expected to approach the concentration of mercury in the settling sediments over time; these concentrations are expected to decline as upland sources of mercury resulting from historical industrial operations are remediated. In conjunction with the remediation of these upland sources of mercury to the lake, MNR is expected to measurably decrease mercury in the surface profundal sediments. The predictive model indicates that sediments in areas of the lake that contain up to 6.7 mg/kg (or ppm) total mercury, as measured in 1992, are expected to achieve the PEC (one potential benchmark) of 2.2 ppm within a period of 10 years following upland site and lake source remediation. The model also suggests that MNR combined with aeration (oxygenation) may also cause a substantial reduction in methylmercury fluxes from the profundal sediments over time.

Prior to any in-lake activity, an extensive pre-design investigation program would refine the delineation of the nature and extent of contamination of the profundal zone and include pilot testing of aeration (oxygenation). Because approximately 12 years have elapsed since sediment in the profundal zone was sampled on a comprehensive basis, and on-going natural recovery may have altered CPOI concentrations, this delineation would establish a current baseline. The natural recovery model described in Appendix N, monitored natural recovery, would then be updated with current values for key parameters (e.g., mercury concentrations in surface sediment). The pre-design testing would also establish site-specific parameters and gather all other information necessary to design the remedy (e.g., the most effective means of applying a thin-layer cap). In addition, pilot testing of an aeration (oxygenation) system for Onondaga Lake would be necessary, as discussed in Subsection 6.3.1.

MNR and thin-layer capping would be most effectively implemented with a phased approach. Phase I activities in the profundal zone would include full-scale implementation of an aeration (oxygenation) system if shown to be effective in pilot testing, thin-layer capping in those areas not expected to meet the total mercury PEC after the MNR period, thin-layer capping in those areas that, in combination with littoral sediments, are not expected to meet the mercury BSQV on a surface area weighted average concentration basis, and establishment of the MNR monitoring program. Phase II would include continued MNR monitoring to assess the effectiveness of natural recovery and aeration (oxygenation). Phase III would include thin-layer capping and/or continued MNR or other contingency measures (if necessary) to achieve remedial goals, and continuation of aeration (oxygenation), if proven to be effective. It is assumed in this FS for cost estimation purposes that 20 acres adjacent to SMU 1 and SMU 6 would include Phase I thin-layer capping. Additional thin-layer capping may be necessary in order to achieve the BSQV.

6.4 THE RECOMMENDED REMEDY AND NCP EVALUATION CRITERIA

The recommended remedy for Onondaga Lake meets all RAOs and PRGs while achieving the best balance among the lake-wide alternatives using the evaluation criteria specified in the NCP at 40 CFR Part 300.430. The recommended remedy and the evaluation criteria used in the evaluation are summarized below.

6.4.1 Overall Protection of Public Health and the Environment

The recommended remedy is fully protective of human health and the environment, and all RAOs and PRGs would be met through the implementation of this remedy. The recommended remedy would reduce sediment toxicity to benthic macroinvertebrates, releases of CPOIs to the water column, and concentrations of CPOIs in the surface sediment, and would address all of the human health risks shown on Table 6.1 and ecological risks shown on Table 6.2. This remedy meets RAOs 2, 4, and 5 and PRGs 1, 2, and 3 through dredging, capping, and/or habitat enhancement in the littoral zone. In addition, this remedy is protective of the profundal zone and meets RAOs 1 and 3 and PRGs 1, 2, and 3 through thin-layer capping, MNR, and aeration (oxygenation).

Specifically, dredging to a depth to optimize habitat and minimize erosive forces (SMUs 2 and 3) combined with capping would remove sediment expected to pose a risk to human and ecological receptors through direct toxicity and would provide new sediment for benthic species colonization. Targeted dredging (SMUs 2, 3, and 6) would increase cap effectiveness through removal of impacted sediment in hot spot and high upwelling velocity areas. The clean cap material placed in SMUs 1, 2, 3, 4, 6, 7, and 8 would prevent direct exposure of humans and ecological receptors to impacted sediment and reduce CPOI releases into the water column through isolation and/or reduction of surface sediment concentrations. In all areas of the lake with sediments that currently exceed the mean PECQ2, the recommended remedy would reduce CPOI concentrations to below this value (PRG 1). Reduced CPOI concentrations in surface sediments would result in reduced CPOI concentrations in benthic macroinvertebrates and other receptors in the benthic food chain.

An evaluation of residual risks to human health and the environment following implementation of the recommended remedy indicates that post-remediation risks would be at levels that are protective of all receptors. These risks were estimated based on multiple lines of evidence (Appendix I, implementation and residual risk) and can be summarized as follows:

- The residual risk analysis associated with the bioaccumulation pathway for the recommended alternative indicates that concentrations of total mercury and methylmercury in water and concentrations of mercury and PCBs in fish tissue would decline as a result of implementation of the alternative, thereby reducing risk to wildlife and humans that consume fish. If one assumes that reductions in CPOI concentrations in fish tissue are proportional to reductions in CPOI concentrations in sediment, then residual concentrations in fish would be within the target tissue concentration ranges developed in Appendix G, fish tissue goals, for mercury and total

PCBs. Comparison of the littoral mercury SWAC to the BSQV for mercury indicates that the proposed remedy is protective of the fish-consuming wildlife that were modeled. Comparison of lake-wide mercury SWACs to the BSQV indicates that the recommended alternative, like the other lake-wide alternatives, results in residual risk to the river otter but is protective of all other fish-consuming wildlife.

- The residual risks associated with exposure to PAHs by wildlife that consume benthic macroinvertebrates/insects were estimated to be less than the lowest observed adverse effect level. In addition, exposure of wildlife to metals in these prey items would be significantly reduced.
- Implementation of the recommended remedy would result in elimination of measurable risk to benthic macroinvertebrates from direct sediment toxicity.
- The residual cancer risks associated with humans hypothetically exposed to CPOIs by wading in nearshore sediment in the south basin were estimated to be below levels of concern. The HHRA determined that the RME cancer risk under baseline conditions exceeded $1x10^{-5}$ (one in 100,000), whereas post-remediation risk decreases to a maximum value of $2 x10^{-6}$ (see Appendix I, risk of remedy).

The additional qualitative remedial goals described in Subsection 2.5.4 related to the habitat restoration and enhancement, as well as control of oncolitic and calcitic materials, would be addressed through the implementation of the recommended remedy.

6.4.2 Compliance with ARARs

The recommended remedy would comply with all chemical-, location-, and action-specific ARARs, with the possible exception of the two most stringent surface water quality criteria for dissolved mercury (i.e., standards for protecting wildlife and human health via fish consumption). Even natural water bodies that have no industrial discharges may not achieve these surface water quality criteria, as discussed in Section 4. However, the proposed remediation of SMUs 1 through 8 and other upland sources would significantly reduce mercury loading, making progress toward meeting these ARARs to the maximum extent practicable. These remedial actions would also result in achieving surface water ARARs for other CPOIs, including chlorobenzene, which has been detected in surface water in excess of ARARs.

The proposed remedy would result in the conversion of some lake surface area to upland habitat, and loss of water depth would create emergent wetlands in SMU 4. Compliance with 6 NYCRR Part 608 would be determined by NYSDEC through the Record of Decision and Proposed Remedial Action Plan, allowing the implementation of the proposed remedy to proceed, if it is determined to be in the public interest.

6.4.3 Short-Term Effectiveness

Implementation of the recommended remedy has inherent and acceptable short-term impacts typical of major construction projects. The short-term effects of this remedy during the construction and implementation phase (estimated construction period of two years) include temporary loss of lake habitat, increased risk of onsite worker accidents, increased truck traffic and risk of transportation accidents, temporary impacts on water quality during dredging and capping activities, temporary impacts on water quality from supernatant release to the work zone during dredging, short-term risks and odors from air emissions at the point of dredging, and quality of life impacts such as temporary use restrictions on the lake and operational areas. These short-term impacts are presented in greater detail in Section 5 and in Appendix I, risk of remedy. These impacts can be effectively managed through the use of common engineering controls and through safe work practices. The benefits of remedy implementation outweigh the short-term impacts of implementation.

6.4.4 Long-Term Effectiveness and Permanence

The recommended remedy would provide long-term effectiveness and permanence by placing impacted sediment under an isolation cap or within an upland SCA, addressing sediments in the profundal zone and the littoral-profundal zone, and by reducing concentrations of CPOIs in fish lake-wide. The effectiveness and permanence of the proposed remedy relies in part on the construction of on-shore barrier systems adjacent to SMUs 1, 2, and 7 that would operate to address ongoing migration of CPOIs to the lake from adjacent upland areas. Long-term effectiveness and permanence would primarily be achieved by dredging and capping, by containment of the dredged sediments within the upland SCA, and by addressing the profundal zone through a combination of aeration (oxygenation), thin-layer capping, and MNR. Effective long-term maintenance, monitoring, and institutional controls would be integral components of the long-term effectiveness and permanence of the sediment cap, the SCA, and habitat improvements.

6.4.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

The recommended remedy would reduce the toxicity, mobility, and/or volume of CPOIs through treatment including aeration (oxygenation) of the hypolimnion, consolidation and dewatering of dredged material in the SCA, and treatment of SCA supernatant prior to release back into the dredged area work zone. Treatment of water resulting from dredging operations (i.e., SCA supernatant) would result in a reduction in the toxicity, mobility, and volume of CPOIs contained in the supernatant, through the partitioning of CPOIs into the supernatant, exposure of sediments and supernatant to aerobic conditions, and subsequent supernatant treatment. Capping would also reduce the mobility of CPOIs in the sediment remaining in the lake, although not through treatment.

MNR and aeration (oxygenation) in SMU 8 would reduce chemical toxicity to aquatic organisms through treatment by decreasing CPOI concentrations in profundal surface sediments, and by reducing the conversion of mercury to methylmercury. The concentration of methylmercury in the water column would be reduced over time, as would the uptake of methylmercury by aquatic organisms. Thin-layer capping in the profundal zone and (possibly) in the deeper littoral zone would reduce the mobility of mercury and the overall bioavailability of CPOIs in the sediments as cleaner sediments are naturally deposited over more impacted sediments in the biologically active zone of the littoral-profundal and profundal sediments. The volume of sediment would be reduced through consolidation and dewatering of dredged material within the SCA. Dewatering would also reduce the mobility of CPOIs in the removed sediment. Treatment of the SCA supernatant would result in a reduction in the toxicity, mobility, and volume of CPOIs which could be mobilized from the sediments.

Dredging, capping, and/or habitat enhancement in SMUs 1, 2, 3, 4, 6, and 7 would provide a reduction in toxicity, mobility, and volume of impacted sediments in the littoral zone, although this reduction is not achieved through treatment. Capping would effectively reduce the mobility of the impacted sediments through chemical isolation; however, it would not reduce the toxicity or the volume of the impacted sediment isolated under the cap. Habitat enhancement in SMUs 3 and 5 would reduce the mobility of calcitic sediments and oncolites in these areas.

6.4.6 Implementability

The recommended remedy is readily implementable. The technology, equipment, subcontractors, personnel, and facilities required to implement this remedy successfully and to restore the lake in a timely manner as a valued community resource are readily available in the environmental marketplace. The dredging, capping, habitat improvements, and post-remediation monitoring components are all readily implementable. The ability to obtain approvals from other agencies should be high.

6.4.7 Cost and Cost Sensitivity

The estimated total cost of the recommended remedy is approximately $243,000,000. This includes $210,000,000 in capital costs and a present worth value of $33,000,000 in operating and maintenance costs. Details of the cost estimate, including assumptions, are presented in Appendix F, cost estimates. In recommending this lake-wide remedy, Honeywell does not address how the costs of this remedy should be apportioned among responsible parties.

Cost sensitivity analyses were performed to assess the significance of potential changes to the principal features of the recommended remedy. Factors that have some uncertainty and that could substantially affect the overall cost of the remedy were evaluated, and are discussed in Appendix F, cost estimates. Factors considered in the cost sensitivity analysis included stabilization and preloading of SCA area, inclusion of geosynthetics in SCA liner and cover, supernatant treatment, volume of sediments to be dredged, areal extent of sediment cap, aeration and thin-layer capping of the profundal zone, duration of O&M period, remedy failure by damage to sediment cap, remedy failure of chemical isolation effectiveness of the cap, habitat enhancement failure; and the discount factor.

Based on the cost sensitivity analysis, the cost of the recommended remedy is most sensitive to the level of supernatant treatment that would be needed prior to discharge back to the dredged area working zone. Other important factors are the stabilization and preloading requirements in the SCA area and the areal extent of the sediment cap. Considering that the costs may increase or decrease from those presented based on the changes reflected by the potential cost sensitivities, the magnitude of these cost sensitivities supports the 25 percent overall contingency applied to the cost estimates presented in this FS.

6.5 REMEDIATION SEQUENCING AND SCHEDULE

Figure 6.12 shows the projected schedule for implementation of the recommended remedy. As shown, the ROD for Onondaga Lake is scheduled to be issued in April 2005 by NYSDEC. Following issuance of the ROD, and the signing of the design consent order in June 2005, the following activities would commence, consistent with current NYSDEC remedial design guidance:

- Work would begin on the design of the SCA and supernatant treatment system. This would include geotechnical analyses for containment berm design, SCA foundation design, and settling and contaminant mobility characteristics of dredged material.
- Active improvement of the lake habitat would occur simultaneously with the design and testing of potential treatments of the littoral zone to maximize submerged macrophyte cover and control oncolites and calcitic material, which in turn would improve fish (bass) habitat.
- Investigation of the profundal zone sediments, and bathymetric survey of the lake areas subject to remediation, would occur.
- The pilot program for the aeration (oxygenation) system would be developed and implemented.
- Pre-design investigations and remedial design for the proposed dredging and capping operations would occur. The design would include an extensive field sampling and laboratory analysis program. Physical, geotechnical, chemical, and contaminant mobility analyses would be conducted on sediments to support dredge and cap designs in littoral areas.

Construction of the SCA and advanced primary treatment components is anticipated to begin in 2007 and be completed in 2011.

The recommended remedy assumes that the upland sites would be remediated as necessary to reduce CPOI inputs into Onondaga Lake. Remedial activities involving dredging and capping in the lake would follow the substantial completion of upland site remediation to avoid recontaminating the remediated portions of the lake. These sites are being addressed under separate projects.

Following upland site remediation, remedial activities involving dredging and capping in the lake would occur between 2011 and 2012. Remaining habitat improvement and enhancement efforts would be integrated into the capping effort. Capping of the SCA would occur several years after the last dredged material was consolidated to allow the material to settle and compact. Operation and maintenance of the remedy, including O&M for the SCA, and long-term monitoring of the lake, including capped areas, would commence after remedial activities were completed.

6.6 SUMMARY

This FS builds upon the conclusions reached in the RI, BERA, and HHRA (TAMS, 2002 a, b, and c), to select an appropriate remedy through an analysis of the site conditions, remedial goals and objectives, and technologies pertaining to the remediation of hazardous substances and wastes associated with former Honeywell operations and other commingled contamination in Onondaga Lake. The remedy selection process is consistent with the NCP, CERCLA, ECL, the NYCRR, and other guidance. The recommended remedy provides the best combination of alternatives for individual SMUs based on a comparative analysis of all of the lake-wide alternatives. In summary, Honeywell's recommended remedy for Onondaga Lake protects human health and the environment, diversifies and enhances habitat, and restores a valuable recreational and ecological resource for the community.

SECTION 6

TABLES

SECTION 6

FIGURES