New York State
Department of Environmental Conservation
Division of Environmental Remediation
625 Broadway
Albany, New York 12233-7016

ONONDAGA LAKE
BASELINE ECOLOGICAL RISK ASSESSMENT
Volume 1 of 2
(Text, Tables, and Figures)

Onondaga Lake Project
Site No. 7-34-030-002
Contract Number C004365, Task Order 1

NYSDEC revision prepared by

TAMS Consultants, Inc.
655 Third Ave.
New York, NY 10017
and
YEC, Inc.
Valley Cottage, NY

Original document prepared by

Exponent
15375 SE 30th Place, Suite 250
Bellevue, WA 98007
for
Honeywell
East Syracuse, NY

December 2002

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Volume 2 of 2: Appendices (contents for appendices follow appendix cover page)

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Acronyms and Abbreviations

ACJ	Amended Consent Judgment
AET	apparent effects threshold
AhR	aryl hydrocarbon receptor
AQUIRE	Aquatic Information Retrieval Database
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
AVS	acid volatile sulfide
AWQC	ambient water quality criterion
BBL	Blasland, Bouck & Lee, Inc.
BEHP	bis(2-ethylhexyl)phthalate
BERA	baseline ecological risk assessment
BSAF	biota-sediment accumulation factor
BTEX	benzene, toluene, ethylbenzene, and xylenes
CBR	critical body residue
CERCLA	Comprehensive Environmental Response Compensation and Liability Act of 1980
CFR	Code of Federal Regulations
CLP	contract laboratory program
COC	chemical of concern
COPC	chemical of potential concern
CSO	combined sewer overflow
CWA	Clean Water Act
DDT	dichlorodiphenyl trichloroethane
DO	dissolved oxygen
dw	dry weight
ECL	Environmental Conservation Law
EO	Executive Order
EPC	exposure point concentration
ER-L	effects range-low
ER-M	effects range-median
ERAGS	Ecological Risk Assessment Guidance for Superfund
ERED	Environmental Residue Effects Database
ERG	Eastern Research Group
ESA	Endangered Species Act
FCV	final chronic value
FMR	field metabolic rate
FIR	food ingestion rate
FS	feasibility study
ft	feet
FWA	Freshwater Wetlands Act

FWIA	Fish and Wildlife Impact Analysis
GB	Geddes Brook
GM –IFG	General Motors – former Inland Fisher Guide
HCB	hexachlorobenzene
HCl	hydrochloric or muriatic acid
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
Honeywell	Honeywell International Inc.
HPAH	high molecular weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IRIS	Integrated Risk Information System
km	kilometer
LCP	Linden Chemicals and Plastics
LDC	Lakefront Development Corporation
LEL	lowest effect level
LPAH	low molecular weight polycyclic aromatic hydrocarbon
LOAEL	lowest observed adverse effect level
m	meter
Metro	Metropolitan Syracuse Sewage Treatment Plant
mgd	million gallons per day
MGP	manufactured gas plant
mi	mile
N	nitrate
NAPL	non-aqueous phase liquid
NCDC	National Climatic Data Center
NCI	National Cancer Institute
NCO	non-chironomidae/oligochaeta
NMC	Ninemile Creek
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEC	no-effect concentration
NLM	National Library of Medicine
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NTP	National Toxicology Program
NWI	National Wetlands Inventory
NYNHP	New York Natural Heritage Program
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSDOL	New York State Department of Law
OCDDS	Onondaga County Department of Drainage and Sanitation

OCDWEP	Onondaga County Department of Water Environment Protection
OLMC	Onondaga Lake Management Conference
OME	Ontario Ministry of the Environment
ORNL	Oak Ridge National Laboratory
OU	operable unit
P	phosphorous
PAH	polycyclic aromatic hydrocarbon
PCA	principal component analysis
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-*p*-dioxin
PCDF	polychlorinated dibenzofuran
PCH	polychlorinated hydrocarbons
PEC	probable effect concentration
PEL	probable effect level
PMA	percent model affinity
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
PRP	potentially responsible party
PSA	preliminary site assessment
PTE	1-phenyl-1-[4-methylphenyl]-ethane, or PhenylTolyEthane
PTI	PTI Environmental Services
PXE	1-phenyl-1-[2,4-dimethylphenyl]-ethane, or PhenylXylylEthane
QA/QC	quality assurance/quality control
RAGS	Risk Assessment Guidance for Superfund
RfD	reference dose
RI	remedial investigation
ROD	Record of Decision
RME	reasonable maximum exposure
SARA	Superfund Amendments and Reauthorization Act
SCS	Soil Conservation Service
SEC	sediment effect concentration
SEL	severe effect level
SEM	simultaneously extracted metals
SIR	sediment/soil ingestion rate
SOC	stressor of concern
SOPC	stressor of potential concern
SPDES	State Pollutant Discharge Elimination System
SQB	sediment quality benchmark
SQV	sediment quality value
SUNY	State University of New York
SUNY ESF	SUNY College of Environmental Science and Forestry

SVOC	semivolatile organic compound
TAL	Target Analyte List
TAMS	TAMS Consultants, Inc.
TBC	to-be-considered
TCDD	tetrachlorodibenzo-*p*-dioxin
TCL	Target Compound List
TEC	toxic equivalent concentration
TEF	toxicity equivalence factor
TEL	threshold effects level
TEQ	toxicity equivalence quotient
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TOGS	Technical and Operational Guidance Series
TRV	toxicity reference value
TSCA	Toxic Substances Control Act
UCL	upper confidence limit
UF	uptake factor
UPL	upper prediction limit
UFI	Upstate Freshwater Institute
UNEP	United Nations Environment Programme
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
WHO	World Health Organization
WIR	water ingestion rate
WSDE	Washington State Department of Ecology
WSS	winter stress syndrome
ww	wet weight
YOY	young-of-year

Acid-Volatile Sulfide. The sulfides, consisting mainly of hydrogen sulfide and iron sulfide, removed from sediment by cold acid extraction. AVS is a method used to predict toxicity in sediment of simultaneously extracted divalent metals including cadmium, copper, lead, nickel, and zinc.

Aquatic macrophyte. Macroscopic (visible to the naked eye) forms of vegetation in the waters of the lake.

Area Use Factor. The ratio of an organism's home range, breeding range, or feeding/foraging range to the area of contamination of the site under investigation.

Assessment Endpoint. An explicit expression of the environmental value that is to be protected.

Benthic Community. The community of organisms dwelling at the bottom of a pond, river, lake, or ocean.

Bioaccumulation. General term describing a process by which chemicals are taken up by an organism, whether directly from exposure to a contaminated medium or by consumption of food containing the chemical.

Bioconcentration. A process by which there is a net accumulation of a chemical directly from an exposure medium into an organism.

Body Burden. The concentration or total amount of a substance in a living organism.

Charophytes. A group of green algae (class Charophyceae) found primarily in freshwater that are large, structurally complex algae. They range in size from a few millimeters to over a meter in length, and consist of a complex set of branching filaments.

Chronic. Involving a stimulus that is lingering or continues for a long time; often signifies periods from several weeks to years, depending on the reproductive life cycle of the species. Can be used to define either the exposure or the response to an exposure (effect). Chronic exposures typically induce a biological response of relatively slow progress and long duration.

Chronic Response. The response of (or effect on) an organism to a chemical that is not immediately or directly lethal to the organism.

Chronic Tests. A toxicity test used to study the effects of continuous, long-term exposure of a chemical or other potentially toxic material on an organism.

Community. An assemblage of populations of different species within a specified location and time.

Dietary Accumulation. The net accumulation of a substance by an organism as a result of ingestion in the diet.

Dose. A measure of exposure. Examples include (1) the amount of a chemical ingested, (2) the amount of a chemical absorbed, and (3) the product of ambient exposure concentration and the duration of exposure.

Ecosystem. The biotic community and abiotic environment within a specified location and time, including the chemical, physical, and biological relationships among the biotic and abiotic components.

Epilimnion. The upper, warm, circulating water in a thermally stratified lake in summer.

Eutrophic. Describing a body of water (e.g., a lake) with an abundant supply of nutrients and a high rate of formation of organic matter by photosynthesis. Pollution of a lake by sewage or fertilizers renders it eutrophic (a process called eutrophication). This stimulates excessive growth of algae; the death and subsequent decomposition of these increases the biochemical oxygen demand and thus depletes the oxygen content of the lake.

Exposure Pathway. The course a chemical or physical agent takes from a source to an exposed organism. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, transport/exposure media (i.e., air, water) also are included.

Exposure Point Concentration. The concentration of a contaminant occurring at an exposure point.

Exposure Route. The way a chemical or physical agent comes in contact with an organism (i.e., by ingestion, inhalation, or dermal contact).

False Negative. The conclusion that an event (e.g., response to a chemical) is negative when it is in fact positive.

False Positive. The conclusion that an event is positive when it is in fact negative.

Food-Chain/Food-Web Transfer. A process by which substances in the tissues of lower trophic level organisms are transferred to the higher trophic level organisms that feed on them.

Hazard Quotient (HQ). The ratio of an exposure level to a substance to a toxicity value selected for the risk assessment for that substance (e.g., LOAEL or NOAEL).

Home Range. The area to which an animal confines its activities.

Hypolimnion. The lower, cooler, non-circulating water in a thermally stratified lake in summer.

Littoral. Designating or occurring in the marginal shallow water zone of a lake.

Lowest Observable Adverse Effect Level (LOAEL). The lowest level of a contaminant evaluated in a toxicity test or biological field survey that has a statistically significant adverse effect on the exposed organisms compared with unexposed organisms in a control or reference site.

Measurement Endpoint. A measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint.

No Observed Adverse Effect Level (NOAEL). The highest level of a contaminant evaluated in a toxicity test or biological field survey that causes no statistically significant difference in effect compared with the control or a reference site.

Oncolite. Irregularly rounded, calcareous nodules that range in size from 0.5 to 30 cm and are not attached to substrates.

Plankton. Minute organisms that drift with the currents in seas and lakes. Plankton includes many microscopic animals (zooplankton) and plants (phytoplankton).

Probable Effect Concentrations (PECs). Sediment quality values established as the concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur.

Sediment Effect Concentrations (SECs). Concentrations of individual contaminants in sediments below which toxicity is rarely observed and above which toxicity is frequently observed.

Species. A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of morphologically similar individuals; the category below genus.

Taxa Richness. The total number of individual taxa in a sample. The term taxa instead of species is used, as the organisms in this study are not always identified to the species level.

Thermocline. A steep temperature gradient that exists in the middle zone (the metalimnion) of a lake and gives rise to thermally induced vertical stratification of the water. The metalimnion lies between the relatively warm epilimnion above and the cold hypolimnion below.

Toxicity Test. The means by which the toxicity of a chemical or other test material is determined. A toxicity test is used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical) compared with an unexposed control.

Trophic Level. A functional classification of taxa within a community that is based on feeding relationships (e.g., aquatic and terrestrial plants make up the first trophic level, and herbivores make up the second).

Type I Error. Rejection of a true null hypothesis. The percentage of stations predicted to have effects (i.e., based on exceedance of one or more of the sediment effect concentrations) that actually had no observed effects based on the chironomid survival results.

Type II Error. Acceptance of a false null hypothesis. The percentage of stations predicted to have no effects (i.e., based on lack of exceedance of any of the sediment effect concentrations) that actually had observed effects based the chironomid survival results.

EXECUTIVE SUMMARY

This document presents the New York State Department of Environmental Conservation (NYSDEC)/TAMS Consultants, Inc. (TAMS) rewrite of Honeywell International Inc.'s (Honeywell; formerly AlliedSignal) revised baseline ecological risk assessment (BERA) report. A draft BERA report was submitted to NYSDEC by Honeywell in May 1998. Based on its review and that of the US Environmental Protection Agency (USEPA), NYSDEC and the New York State Department of Law (NYSDOL) disapproved the draft document and provided comments to Honeywell in March 1999. After completing additional sampling in 1999 and 2000, Honeywell submitted a revised BERA report in April 2001. This revised report was similarly disapproved by NYSDEC and NYSDOL in July 2001. The reasons for disapproval are outlined in the determination accompanying this BERA.

For the purposes of this report, the Onondaga Lake site includes the following areas:

- The entire lake, including all pelagic and littoral areas.
- The mouths of all tributaries to the lake, including Ley Creek, Onondaga Creek, Harbor Brook, the East Flume, Tributary 5A, Ninemile Creek, Sawmill Creek, and Bloody Brook.
- The area from the lake outlet to the water sampling location in the outlet (Station W12), approximately 650 feet (ft) (200 meters [m]) downstream of the lake near the New York State Thruway bridge.
- Two of the New York State-regulated wetlands contiguous to the lake (Wetlands SYW-6 and SYW-12).

In addition to the investigations performed at the above-listed areas, ongoing or completed investigations conducted separately by Honeywell, NYSDEC, and others at hazardous waste sites and areas of concern near Onondaga Lake are discussed in the BERA.

The implementation of the BERA follows the Superfund risk assessment process specified by USEPA (1997a) to evaluate the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more contaminants or stressors (see text box below). The specifications of NYSDEC (1994a), particularly those specifications that are not identified by USEPA (1997a, 1998), have been incorporated into this BERA, so that the relevant New York State guidance was accommodated within the structure recommended by USEPA.

The first seven steps of the Superfund ecological risk assessment process were completed from 1990 through the present, inclusive of this report, and the final step will be determined by the NYSDEC and USEPA, with the assistance of NYSDOH and NYSDOL, during the feasibility study (FS) and Record of Decision (ROD) process.

The Eight Steps of the Superfund Ecological Risk Assessment Process	
1.)	Screening-level problem formulation and ecological effects evaluation.
2.)	Screening-level preliminary exposure estimate and risk calculation.
3.)	Baseline risk assessment problem formulation.
4.)	Study design and data quality objectives.
5.)	Field verification of sampling design.
6.)	Site investigation and analysis of exposure and effects.
7.)	Risk characterization.
8.)	Risk management.

1. Honeywell History Associated with Onondaga Lake

Honeywell's predecessor companies have operated manufacturing facilities in Solvay, New York, since 1884. The location was primarily chosen due to its natural deposits of salt and limestone. The Solvay Process Company, founded in 1881, used the ammonia soda (Solvay) process to produce soda ash. Honeywell (as AlliedSignal) subsequently expanded the operation to three locations which shall be referred to in this BERA as the Main Plant, the Willis Avenue Plant and the Bridge Street Plant, collectively known as the Syracuse Works. The Main Plant manufactured soda ash and related products from 1884 to 1986 and benzene, toluene, xylenes, and naphthalene from 1917 to 1970. The Willis Avenue plant manufactured chlorinated benzenes and chlor-alkali products from 1918 to 1977. Chlor-alkali production by the mercury cell electrolytic process began in approximately 1947 at the Willis Avenue plant. The Bridge Street plant produced chlor-alkali products and hydrogen peroxide using the mercury cell electrolytic process starting in 1953. This plant was sold to Linden Chemicals and Plastics (LCP) of New York in 1979, which operated it until 1988.

An important feature of the waste management at the Syracuse Works was the use of approximately 2,000 acres of wastebeds located in Solvay (Solvay Wastebeds) to dispose of waste from the manufacture of soda ash. Honeywell disposed of Solvay wastes in these wastebeds and organic wastes in the Semet Residue Ponds in Wastebed A; organic wastes were also disposed of in Wastebed B near Harbor Brook. In addition, Honeywell disposed of large quantities of combined Solvay wastes and mercury and organic wastes directly into the lake through the East Flume. Further discussion of these and other sources is provided in Chapter 2 and Appendix G of this BERA and in the Onondaga Lake Remedial Investigation (RI) report (TAMS, 2002b).

2. Screening-Level Problem Formulation and Screening

Initial screening-level problem formulation for Onondaga Lake was largely completed during preparation of the Onondaga Lake RI/FS Work Plan (PTI, 1991). As part of the work plan, a conceptual site model was developed, preliminary chemicals of potential concern/stressors of potential concern (COPCs/SOPCs) and representative ecological receptors were identified, assessment and measurement endpoints were defined, the objectives of the BERA were formulated, and a study design was developed to collect the data needed to satisfy the BERA objectives. Although initial problem formulation for the work plan was largely completed in 1991, several elements of the screening-level problem formulation have been refined since that time, based on information collected during the 1992 and 1999/2000 RI field investigations, or by using information collected by other parties, such as NYSDEC. The RI field investigations conducted by Honeywell in 1992 and 1999/2000 and by NYSDEC in 2002 cover the site investigation portions of Steps 4 to 6 of the USEPA Superfund ecological risk assessment process.

The preliminary conceptual site model for the Onondaga Lake BERA, which was retained with minor revisions as the site conceptual model for the BERA, is presented in Figure ES-1. The conceptual site model identifies primary and secondary sources, potential pathways, major contaminants/stressor groups, potential exposure routes and receptors, and effects to be initially evaluated as part of the BERA. Animals and plants are directly exposed to contaminants and stressors primarily from contaminated sediments and lake water and animals are indirectly exposed through ingestion of food (e.g., prey) containing contaminants.

3. Contaminants/Stressors of Concern

Numerous potentially toxic chemicals, including mercury, cadmium, chromium, copper, lead, nickel, zinc, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene, xylenes (BTEX), chlorinated benzenes, and dioxins/furans, were detected at elevated concentrations in various lake media. For each complete exposure pathway, route, and chemical, a screening ecotoxicity value was selected to establish contaminant exposure levels that represent conservative thresholds for adverse ecological effects. COCs selected for water, surface sediment, surface soil, plants, fish, and wildlife receptors are presented in Tables ES-1 and ES-2.

Stressors identified in Superfund guidance are referred to as chemical contaminants in this BERA, whereas non-Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) stressors, such as chloride, depleted dissolved oxygen (DO), and reduced water transparency, are referred to as stressors. Only chemicals covered under CERCLA Section 40 CFR Part 302.4, which lists the CERCLA hazardous substances, were included in the COC selection. The exception to this is ammonia which is listed as a hazardous substance in the CFR, but is treated as an SOC in this BERA since it is associated with discharges from the Metropolitan Syracuse Sewage Treatment Plant (Metro), as well as various Honeywell sites, and is a nutrient. The major groups of stressors in Onondaga Lake, including nutrients (i.e., nitrite, phosphorus, sulfide), calcite, salinity, ammonia, depleted DO, and reduced water transparency, were retained for further examination in the BERA.

4. Assessment Endpoints

Assessment endpoints are explicit expressions of the actual environmental values that are to be protected and focus a risk assessment on particular components of the ecosystem that could be adversely affected due to contaminants and stressors at the site. Assessment endpoints are often expressed in terms of populations or communities. Because mercury and some of the other COCs, such as PCBs and polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDFs), at Onondaga Lake are known to bioaccumulate, an emphasis was also placed on indirect exposure at various levels of the food chain to address COC-related risks at higher trophic levels. In addition, assessment endpoints were also selected for communities that may have been affected by stressors. The 13 assessment endpoints that were selected for Onondaga Lake are:

- Sustainability (i.e., survival, growth, and reproduction) of an aquatic macrophyte community that can serve as a shelter and food source for local invertebrates, fish, and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of a phytoplankton community that can serve as a food source for local invertebrates, fish, and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of a zooplankton community that can serve as a food source for local invertebrates, fish, and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of a terrestrial plant community that can serve as a shelter and food source for local invertebrates and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of a benthic invertebrate community that can serve as a food source for local fish and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of local fish populations.

- Sustainability (i.e., survival, growth, and reproduction) of local amphibian and reptile populations.

- Sustainability (i.e., survival, growth, and reproduction) of local insectivorous bird populations.

- Sustainability (i.e., survival, growth, and reproduction) of local benthivorous waterfowl populations.

- Sustainability (i.e., survival, growth, and reproduction) of local piscivorous bird populations.

- Sustainability (i.e., survival, growth, and reproduction) of local carnivorous bird populations.

- Sustainability (i.e., survival, growth, and reproduction) of local insectivorous (aquatic and terrestrial insect phases) mammal populations.

- Sustainability (i.e., survival, growth, and reproduction) of local piscivorous mammal populations.

5. Measurement Endpoints

Measurement endpoints provide the actual values used to evaluate each assessment endpoint. Measurement endpoints generally include measured or modeled concentrations of chemicals and stressors in water, sediment, fish, birds, and/or mammals, laboratory toxicity studies, and field observations. Measurement endpoints in relation to their respective assessment endpoints were phrased in relation to respective risk questions contained in the BERA. Each assessment endpoint in this BERA had a minimum of two measurement endpoints that were used as lines of evidence. Measurement endpoints identified for the Onondaga Lake BERA include:

- Community structure (aquatic macrophytes, phytoplankton, zooplankton, fish, amphibians and reptiles) as compared to reference communities.

- Laboratory (greenhouse studies) and field experiments measuring macrophyte growth and survival.

- Laboratory toxicity studies measuring macroinvertebrate, growth, survival, and reproduction.

- Benthic community indices, such as richness, abundance, diversity, and biomass.

- Observed effects on fish foraging and nesting.

- Observed fish abnormalities.

- Measured total COC body burdens in fish to determine exceedance of effect-level thresholds based on toxicity reference values (TRVs).

- Laboratory toxicity studies examining effects of lake water on amphibian embryos.
- Modeled total COC body burdens in wildlife receptors to determine exceedance of effect-level thresholds based on TRVs.
- Exceedance of criteria for concentrations of COCs/SOCs in lake water that are protective of aquatic organisms, fish, and wildlife.
- Exceedance of guidelines for concentrations of COCs/SOCs in sediments that are protective of aquatic life.
- Exceedance of guidelines for concentrations of COCs/SOCs in soils that are protective of plant life.
- Field observations.

6. Ecological Receptors

The risks to the environment were evaluated for receptors that were selected to be representative of various communities, feeding preferences, predatory levels, and aquatic and wetland habitats. Individual assessment endpoints were evaluated with a minimum of one "model" (receptor) species. The following receptors were selected for the Onondaga Lake BERA:

- Aquatic macrophyte community.
- Phytoplankton community.
- Zooplankton community.
- Terrestrial plant community.
- Benthic invertebrate community.
- Fish: bluegill (*Lepomis macrochirus*); carp (*Cyprinus carpio*); channel catfish (*Ictalurus punctatus*); gizzard shad (*Dorosoma cepedianum*); largemouth bass (*Micropterus salmoides*); smallmouth bass (*Micropterus dolomieui*); walleye (*Stizostedion vitreum*); and white perch (*Morone americana*).
- Amphibian and reptile communities.
- Insectivorous birds: tree swallow (*Tachycineta bicolor*).

- Benthivorous waterfowl: mallard (*Anas platyrhynchos*).

- Piscivorous birds: belted kingfisher (*Ceryle alcyon*); great blue heron (*Ardea herodias*); and osprey (*Pandion haliaetus*).

- Carnivorous birds: red-tailed hawk (*Buteo jamaicensis*).

- Insectivorous mammals: little brown bat (*Myotis lucifugus*) – aquatic invertebrates; short-tailed shrew (*Blarina brevicauda*) – terrestrial invertebrates.

- Piscivorous mammals: mink (*Mustela vison*) and river otter (*Lutra canadensis*).

7. Exposure Assessment

The exposure assessment describes complete exposure pathways and exposure parameters. The contaminants and ecological components of the Onondaga Lake ecosystem were temporally and spatially characterized to obtain an exposure profile. The distribution of chemicals and stressors in each medium (i.e., lake water, surface sediments, wetland surface soil, dredge spoil surface soils, plankton, macroinvertebrates, and fish) to which ecological receptors may be exposed was examined and exposure point concentrations (EPCs) were calculated. Biota uptake and food-web exposure models were developed.

Receptor parameters, such as body weight, prey ingestion rate, home range, etc., were used in the food-web models to calculate COC dietary doses for wildlife. Exposure parameters were obtained from USEPA references, the scientific literature, and directly from researchers. The resulting exposure profiles for each receptor quantified the spatial and temporal patterns of exposure as they relate to the assessment endpoints and risk questions.

8. Effects Assessment

The effects assessment describes the methods used to characterize effects on aquatic and terrestrial organisms due to exposure to chemicals and stressors. Chemical exposure was evaluated using measures of toxicological effects (TRVs) that provide a basis for estimating whether the chemical exposure at a site is likely to result in adverse ecological effects. Exposure to stressors was evaluated using available literature, concentrating on studies specific to Onondaga Lake when possible.

For chemical exposure, TRVs were selected based on lowest observed adverse effects levels (LOAELs) and/or no observed adverse effects levels (NOAELs) from laboratory and/or field-based studies reported in the scientific literature. These TRVs examine the effects of COCs on the survival, growth, and reproduction of fish and wildlife species in Onondaga Lake. Reproductive effects (e.g., egg maturation, egg hatchability, and survival of juveniles) were generally the most sensitive exposure endpoints and were selected when available and appropriate.

Site-specific sediment effect concentrations (SECs) using toxicity and chemistry data were derived to allow assessment of whether the sediment chemical concentrations found at various stations in the lake would result in adverse biological effects. Five site-specific SECs were developed for Onondaga Lake using the apparent effects threshold (AET) approach and calculation of effects range-low (ER-L), effects range-median (ER-M), probable effect level (PEL), and threshold effects level (TEL) concentrations. These SECs were then used to derive a consensus-based probable effect concentration (PEC) for use in determining areas of the lake bottom that potentially pose a risk to the benthic community.

9. Risk Characterization

Risk characterization integrates the exposure and effects assessments and examines the likelihood of adverse ecological effects occurring as a result of exposure to chemicals and/or stressors. The Onondaga Lake BERA employed a strength-of-evidence approach, using several lines of evidence to evaluate each assessment endpoint.

Toxicological risks were estimated by comparing the results of the exposure assessment (measured or modeled concentrations of chemicals in receptors of concern) to the TRVs developed in the effects assessment, resulting in a ratio of these two numbers, called a hazard quotient (HQ). HQs equal to or greater than 1.0 ($HQ \geq 1$) are typically considered to indicate potential risk to ecological receptors; for example, with reduced or impaired reproduction or recruitment. The HQs provide insight into the potential for adverse effects upon individual animals in the local population resulting from chemical exposure. If an HQ suggests that effects are not expected to occur for the average individual, then they are probably insignificant at the population level. However, if an HQ indicates that risks are present for the average individual, then risks may be present for the local population.

Other measurement endpoints, such as field observations and toxicity studies, were evaluated in conjunction with toxicological risks on a receptor-specific basis. Use of several lines of evidence resulted in the following risk characterizations for each assessment endpoint.

9.1 Sustainability (i.e., Survival, Growth, and Reproduction) of an Aquatic Macrophyte Community That Can Serve as a Shelter and Food Source for Local Invertebrates, Fish, and Wildlife

Sustainability of an aquatic macrophyte community that can serve as a shelter and food source for local invertebrates, fish, and wildlife was assessed using three lines of evidence. The first was comparison of the Onondaga Lake macrophyte community to reference location communities. The second was to evaluate growth and survival of macrophytes in Onondaga Lake using field and laboratory studies. The third was a qualitative evaluation of lake conditions relative to NYSDEC narrative water quality standards (6 NYCRR Part 703.2). All three measurement endpoints indicate that the macrophyte community of Onondaga Lake has been adversely affected by the input of chemicals and stressors into the lake. These impacts may affect animals that use the macrophytes in Onondaga Lake for food and shelter.

9.2 Sustainability (i.e., Survival, Growth, and Reproduction) of a Phytoplankton Community That Can Serve as a Food Source for Local Invertebrates, Fish, and Wildlife

Sustainability of a phytoplankton community that can serve as a food source for local invertebrates, fish, and wildlife was assessed using two lines of evidence. The first was field observations of the Onondaga Lake phytoplankton community and the second was a qualitative evaluation of NYSDEC narrative water quality standards. Both measurement endpoints indicate that the phytoplankton community has been impacted by chemicals and/or stressors in lake water. Mercury has been shown to bioaccumulate in phytoplankton in Onondaga Lake and may be passed on to higher trophic levels feeding on phytoplankton in Onondaga Lake. Stressors have been shown to influence the abundance and distribution of phytoplankton species.

9.3 Sustainability (i.e., Survival, Growth, and Reproduction) of a Zooplankton Community That Can Serve as a Food Source for Local Invertebrates, Fish, and Wildlife

Sustainability of a zooplankton community that can serve as a food source for local invertebrates, fish, and wildlife was assessed using three lines of evidence. The first was field observations of the Onondaga Lake zooplankton community. The second was to compare surface water concentrations to water quality criteria developed for the protection of aquatic life. The third was a comparison of contaminant concentrations in sediment to NYSDEC and/or USEPA sediment guidelines. All three of these lines of evidence indicate that the zooplankton community of Onondaga Lake has been impacted by high levels of chemicals and/or stressors in lake water. In particular, high levels of salinity and mercury appear to have influenced community structure and abundance. Although the zooplankton community has been impacted by lake conditions, it still serves as a food source for local invertebrates, fish, and wildlife, and as such passes bioaccumulative contaminants (e.g., mercury) through the food chain.

9.4 Sustainability (i.e., Survival, Growth, and Reproduction) of a Terrestrial Plant Community That Can Serve as a Shelter and Food Source for Local Invertebrates and Wildlife

Sustainability of a terrestrial plant community that can serve as a shelter and food source for local invertebrates and wildlife was assessed using two lines of evidence. The first was field observations of the Onondaga Lake terrestrial plant community. Only obvious effects, such as the sparse vegetation found on the wastebeds, can be directly attributed to activities at Honeywell facilities (i.e., disposal of Solvay and other industrial wastes). The second was to compare surface soil concentrations to plant toxicity values. Comparisons of soil chemical concentrations to plant toxicity values indicate that high levels of contaminants, in particular chromium and mercury, may adversely affect the plant community and subsequently local invertebrates and wildlife that live or forage in local habitats. These results suggest the potential for adverse effects on plants via exposure to COCs in soils at all four wetland areas and the dredge spoils area.

9.5 Sustainability (i.e., Survival, Growth, and Reproduction) of a Benthic Invertebrate Community That Can Serve as a Food Source for Local Fish and Wildlife

The potential effect of COCs and SOCs on the benthic community in Onondaga Lake was evaluated using the following four lines of evidence: exceedance of water quality criteria, benthic community metrics analysis, sediment toxicity testing, and sediment chemistry through the derivation of site-specific PECs.

Concentrations of chemicals in Onondaga Lake water were found to exceed surface water criteria in certain areas of the lake. There were more exceedances of surface water criteria in the tributaries to Onondaga Lake than in the lake itself. In addition, stressors in Onondaga Lake, including chloride, salinity, ammonia, nitrite, and phosphorus, generally exceeded guidelines (when available) or background levels. A qualitative evaluation of NYSDEC narrative water quality standards indicated that those standards were also exceeded.

The benthic invertebrate community metrics analyzed in the BERA included: taxa richness, dominance, abundance of indicator species, species diversity, and percent model affinity (PMA). The analysis of these metrics showed that many of the benthic invertebrates communities living in the littoral zone (less than 5 m depth) in Onondaga Lake and the mouths of its tributaries have been impacted to some degree. The majority of moderately and severely impacted stations were located between Tributary 5A and Ley Creek, with the most severely impacted stations located between Tributary 5A and Onondaga Creek.

Short-term (10-day) and long-term (40/42-day) bulk sediment toxicity tests were performed for this BERA using sediments collected from all lake environs. The results of the sediment toxicity tests confirmed that some Onondaga Lake sediments are toxic to benthic invertebrates and may increase mortality and reduce the growth and fecundity of these organisms. The most toxic sediments are found in the nearshore zone in the southern part of the lake between Tributary 5A and Ley Creek.

Five SECs (i.e., calculation of AET, ER-L, ER-M, PEL, and TEL values) were derived to allow site-specific assessment of whether the sediment chemical concentrations found at various Onondaga Lake stations would result in adverse biological effects. These SECs were then used to derive a consensus-based PEC (i.e, the contaminant concentration above which adverse effects are expected to frequently occur) to determine areas of the lake bottom that pose some degree of risk to the benthic community. The PECs were derived as the geometric mean of the five site-specific SECs and are presented in Table ES-3.

Using the consensus PECs, measured surface sediment concentrations exceed the values at many locations throughout Onondaga Lake. Only 14 of approximately 200 locations sampled in 1992 and 2000 do not have at least one compound exceeding an HQ of 1.0 (i.e., sediment concentration less than the PEC). Many of the ratios of measured sediment concentrations to PECs exceed 10, or even 100, between Tributary 5A and Ley Creek. In addition, these sediment locations have the highest number of compounds – between 11 and over 30 compounds per sample – that exceed their PECs in a sample.

Based on the above, all four lines of evidence suggest an adverse effect from COCs and SOCs on the benthic invertebrate populations in Onondaga Lake, particularly in the southern part of the lake from Tributary 5A to Ley Creek. Based on these analyses it can also be concluded that local fish and wildlife populations using the benthic invertebrate community as a food source in turn are impacted.

9.6 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Fish Populations

The sustainability of local fish populations was assessed using six lines of evidence. The first was to examine the fish community structure as compared to similar lakes and historic accounts of Onondaga Lake (prior to industrial activities) in relation to the health of local fish populations. The second was to look for potential effects of chemicals/stressors on fish foraging and nesting. The third was to compare visual abnormalities (e.g., tumors, lesions) in Onondaga Lake fish to fish from other lakes. The fourth was to compare measured water column concentrations to water quality criteria for the protection of aquatic life, including NYSDEC narrative standards. The fifth was to compare measured sediment concentrations to guidelines for the protection of aquatic life for benthic-dwelling species of fish. The sixth and final line of evidence was to compare measured concentrations of chemicals in fish representing various feeding strategies and trophic levels to TRVs.

Risks to fish from chemicals were evaluated on a species-specific basis using measured body burdens for eight fish species representing the Onondaga Lake fish community (Table ES-4). A limited number of chemicals (e.g., methylmercury) were analyzed in some species (e.g., gizzard shad and largemouth bass). Therefore, actual risks from chemicals in lake water may be greater for these species than calculated. HQs greater than 1.0 were calculated for the following chemicals (by species):

- Bluegill – arsenic, chromium, endrin, mercury, selenium, vanadium, and zinc.
- Carp – arsenic, chromium, dioxin/furans, endrin, mercury, total PCBs, selenium, vanadium, and zinc.
- Catfish – chromium, endrin, methylmercury, mercury, total PCBs, selenium, vanadium, and zinc.
- Gizzard shad – methylmercury.
- Largemouth bass – methylmercury and dioxins/furans.
- Smallmouth bass – arsenic, chromium, mercury, methylmercury, total PCBs, selenium, vanadium, and zinc.
- Walleye – chromium, mercury, methylmercury, and total PCBs.
- White perch – chromium, mercury, methylmercury, selenium, and total PCBs.

Five of the six lines of evidence evaluated suggest adverse effects from COCs on the Onondaga Lake fish community and the remaining line of evidence, incidence of visual abnormalities, was inconclusive. This strength-of-evidence approach indicates that local fish populations are adversely affected by the chemicals and stressors present in Onondaga Lake.

9.7 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Amphibian and Reptile Populations

Sustainability of local amphibian and reptile populations was assessed using three lines of evidence. The first was to conduct a field survey of local amphibian and reptile populations around Onondaga Lake. The second was to compare measured water column concentrations to water quality criteria for the protection of aquatic life, including NYSDEC narrative standards. The third and final line of evidence was laboratory studies examining the effects of Onondaga Lake water on amphibian embryos. All three lines of evidence strongly indicate that amphibian and reptile populations have been adversely affected by chemicals and/or stressors found in Onondaga Lake water.

9.8 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Insectivorous Bird Populations

Sustainability of local insectivorous bird populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that insectivorous birds have been adversely affected to some degree by chemicals found in Onondaga Lake and taken up by the aquatic phases (e.g., egg, larvae) of invertebrates. Mercury HQs were up to an order-of-magnitude greater than 1.0 and PAH HQs were up to two orders-of-magnitude greater than 1.0, with both COCs exceeding a HQ of 1.0 over the full concentration and toxicity range evaluated (Table ES-5). The third line of evidence, field observations, was inconclusive.

9.9 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Benthivorous Waterfowl Populations

Sustainability of local waterfowl populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that waterfowl have been adversely affected to some degree by chemicals found in Onondaga Lake via exposure to contaminated water and food sources. Mercury HQs were up to an order-of-magnitude greater than 1.0 and PAH HQs were up to two orders-of-magnitude greater than 1.0, with both COCs exceeding a HQ of 1.0 over the full concentration and toxicity range evaluated (Table ES-5). The third line of evidence, field observations, was inconclusive.

9.10 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Piscivorous Bird Populations

Sustainability of local piscivorous bird populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that piscivorous birds have been adversely affected to some degree by chemicals found in Onondaga Lake, and by mercury in particular. Mercury HQs were greater than 1.0 for the full point estimate range of risk for all three piscivorous receptor species and were over an order-of-magnitude greater than the NOAELs (Table ES-5). The third line of evidence, field observations, was inconclusive.

9.11 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Carnivorous Bird Populations

Sustainability of local carnivorous bird populations was assessed using two lines of evidence. The first was modeling dietary doses of chemicals and the second was field-based observation. Modeled dietary doses suggested that carnivorous birds have been adversely affected to some degree by chemicals found in Onondaga Lake, and by total PAHs in particular, for which HQs were greater than 1.0 for the full point estimate range of risk (Table ES-5). The second line of evidence, field observations, was inconclusive.

9.12 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Insectivorous (Aquatic and Terrestrial Insect Phases) Mammal Populations

Sustainability of local insectivorous mammal populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that insectivorous mammals feeding on aquatic invertebrates have been adversely affected to some degree by chemicals found in Onondaga Lake. Methylmercury and PAHs had the highest HQs, with HQs greater than 1.0 for the full point estimate range of risk and values up to an order-of-magnitude above 1.0 (Table ES-6).

Insectivorous mammals feeding on terrestrial invertebrates in the four wetlands around Onondaga Lake may also be adversely affected by chemicals found in Onondaga Lake. Risk varied by wetland area, with SYW-19, located near the mouth of Harbor Brook, having the greatest number of COCs with HQs above 1.0 (Table ES-7). In the wetland areas, risks from exposure to methylmercury for the full point estimate range of risk in all four wetlands were up to two orders-of-magnitude above 1.0. Risks from exposure to total PAHs, hexachlorobenzene, and dioxins/furans were up to three orders-of-magnitude above 1.0. Risks to insectivorous mammals in the dredge spoils soils were primarily due to exposure to hexachlorobenzene. The third line of evidence, field observations, was inconclusive.

9.13 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Piscivorous Mammal Populations

The sustainability of local piscivorous mammal populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that piscivorous mammals feeding around Onondaga Lake have been adversely affected to some degree by chemicals found in the lake, and in particular by mercury and total PCBs (Table ES-6). The third line of evidence, field observations, was inconclusive.

10. Uncertainties

To integrate the various components of the BERA, the results of the risk characterization and associated uncertainties were evaluated to assess the risk of adverse effects to Onondaga Lake receptors as a result of exposure to chemicals and stressors originating in the lake. Uncertainty exists because of data limitations (e.g., extrapolating between species for TRVs) and natural variability (e.g., fish tissue concentrations, ingestion rates). Uncertainty is an inherent component of risk assessments. Elements of uncertainty in this BERA were identified and efforts were made to minimize them. For components in which a moderate degree of uncertainty was unavoidable (e.g., sampling data), efforts were made to minimize any systematic bias associated with the data. The Onondaga Lake BERA uses various point estimates of exposure and response to develop a range of point estimates of risk (i.e., 95 percent UCL, mean, NOAEL, and LOAEL) to aid in judging the ecological significance of risks.

In addition to the uncertainties that are common to many risk assessments, there were several uncertainties associated with this BERA that are specific to Onondaga Lake. Uncertainties associated with factors limiting the distribution and abundance of macrophytes, the effects of calcium and oncolites on the aquatic community, the effects on the Onondaga Lake ecosystem if conditions allow the return of an oxic hypolimnion, and the effects of eutrophication on the lake ecosystem were examined and discussed in the BERA.

11. Conclusions

Multiple lines of evidence were used to evaluate major components of the Onondaga Lake ecosystem to determine if lake contamination has adversely affected plants and animals around Onondaga Lake. Almost all lines of evidence indicate that the Honeywell-related contaminants and ionic waste in Onondaga Lake have produced adverse ecological effects at all trophic levels examined.

The aquatic macrophytes in the lake have been adversely affected by lake conditions, and the resulting loss of macrophyte habitat that formerly provided valuable feeding and nursery areas has undoubtedly affected the aquatic invertebrates and vertebrates living in Onondaga Lake. In addition to general habitat loss, there has been bioaccumulation of mercury and possibly other chemicals in most organisms serving as a food source in the lake, including phytoplankton, zooplankton, benthic invertebrates, and fish. Exceedances of site-specific sediment PECs suggest adverse effects to benthic invertebrates will frequently occur (Ingersoll et al., 2000) in most areas of the lake. The greatest number and magnitude of exceedances were found in areas in the southern portion of the lake and near Ninemile Creek (see Chapter 10, Figure 10-3).

Comparisons of measured tissue concentrations and modeled doses of chemicals to TRVs show exceedances of HQs for site-related chemicals throughout the range of the point estimates of risk. Many of the contaminants in the lake are persistent and therefore, the risks associated with these contaminants are unlikely to decrease significantly in the absence of remediation. On the basis of these comparisons, it has been determined through this BERA that all receptors of concern are at risk. Contaminants and stressors in the lake have either impacted or potentially impacted every trophic level and feeding preference examined in this BERA.