ONONDAGA LAKE SEDIMENT REMEDIATION – DREDGING AND CAPPING ALTERNATIVES

Michael Palermo[1], Don Hayes[2], Danny Reible[3], John Verduin[4], Steve Warren[5], and John McAuliffe[6]

ABSTRACT

Onondaga Lake is a 12.14 square kilometer (4.6 square mile or 3,000 acre) lake located just northwest of the city of Syracuse in central New York State. The lake has been identified as a federal Superfund site, with the New York State Department of Environmental Conservation (NYSDEC) acting as lead agency overseeing RI/FS activities at the site. The contaminants potentially of interest at the site vary by location in the lake, but include mercury, benzene, toluene, ethylbenzene, and xylene (BTEX compounds), chlorinated benzenes, polycylic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). A Feasibility Study for the site and a proposed cleanup plan developed by NYSDEC were completed in November 2004. The site was divided into eight Sediment Management Units (SMUs), based on both physical and chemical characteristics, and remedial alternatives for each of the SMUs as well as combined lake-wide alternatives were developed in the FS. The lake-wide remedial alternatives under consideration include combinations of environmental dredging and in-situ subaqueous capping as remedy components. Several of the alternatives also call for extensive habitat enhancements for the lake. The final selection of a remedy is pending, but will potentially involve one of the largest combined environmental dredging and capping sediment projects in the country. This paper describes the site conditions, remedial alternatives, and the technical basis for the dredging and capping remedy components developed for the FS.

Keywords: Superfund; Environmental Dredging; In-Situ Capping; Feasibility Studies

INTRODUCTION

Onondaga Lake (see Figure 1) is a central feature of the Syracuse, NY community. The lake is located in an urbanized area, and 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 and the lake shoreline has been significantly modified. 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 lake has several tributaries, the main ones being Onondaga Creek and Ninemile Creek.

Industrial activities adjacent to Onondaga Lake included production of soda ash and related products; benzene, toluene, xylene, naphthalene and tar products from the recovery of coke byproducts; chlorobenzenes and byproduct hydrochloric acid from the chlorination of benzene; and chlor-alkali products. These activities included construction of a number of containments for residuals, called wastebeds, in upland areas adjacent to the lake. Discharges to the lake also created a large In Lake Waste Deposit (ILWD) (TAMS, 2002a-d).

The lake has been identified as a federal Superfund site on the United States Environmental Protection Agency (USEPA) National Priorities List. The New York State Department of Environmental Conservation (NYSDEC) is the lead environmental agency overseeing Remedial Investigation (RI) and Feasibility Study (FS) activities within Onondaga Lake and at various sites and sub-sites adjacent to the lake. In 1992, Allied Signal (now known as Honeywell), one of several parties associated with historical discharges to the lake, entered into a consent decree

[1] Consulting Engineer, Mike Palermo Consulting, P.C., 3046 Indiana Ave., Suite R, PMB 204, Vicksburg, MS 39180, 601-831-5412, mike@mikepalermo.com
[2] Associate Professor, Civil & Environmental Engineering, University of Utah, Salt Lake City, UT, 801-581-7110, hayes@civil.utah.edu.
[3] Professor, Chemical Engineering, University of Texas, Austin, TX, 512-471-4642, reible@mail.utexas.edu .
[4] Project Manager, Anchor Environmental, Seattle, WA, 206-287-9130 jverduin@anchorenv.com .
[5] Project Manager, Parsons, Liverpool, NY, 315-451-9560, Stephen.Warren@parsons.com .
[6] Syracuse Projects Director, Honeywell, East Syracuse, NY, 315-431-4443, John.McAuliffe@Honeywell.com .

Figure 1. Aerial view of Onondaga Lake, Syracuse, NY.

with the state of New York, to initiate a RI/FS for Onondaga Lake. The RI was conducted by Honeywell from 1992 to 2000, with additional investigations by the New York State Department of Environmental Conservation in 2001 (Exponent, 2001a-c). The FS was conducted by Honeywell from 2003 to 2004 (Parsons 2004), and involved extensive evaluations of a number of remedial technologies. This paper summarizes the site and sediment conditions, remedial technologies and alternatives, and the technical basis for the dredging and capping remedy components developed for the FS.

REMEDIATION GOALS

Preliminary Remediation Goals (PRGs) were established in the FS, consistent with preliminary Remedial Action Objectives developed in the RI, and based on a Baseline Ecological Risk Assessment (BERA) and Human Health Risk Assessment (HHRA) (TAMS, 2002a-d). The PRGs included:

- PRG 1 (Sediments): Reduce, contain, or control contaminants potentially of interest (CPOIs) in profundal and littoral sediments by achieving applicable and appropriate sediment effects concentrations (SECs), to the extent practicable. This PRG is addressed in the FS by comparing contaminant concentrations in the sediments to SECs developed by the NYSDEC, using a mean probable effects concentrations quotient (PECQ), condensing information from the numerous chemicals into one effects-based index. This process was used to establish the areas and volumes of sediment considered for remediation in the FS.

- PRG 2 (Fish Tissue): Achieve CPOI concentrations in fish tissue that are protective of humans and wildlife that consume fish, to the extent practicable. This PRG is evaluated in the FS by comparing these concentrations to target fish tissue concentrations developed based on the BERA and HHRA.

- PRG 3 (Surface Water): Achieve surface water quality standards, to the extent practicable, associated with CPOIs. This PRG is evaluated in the FS by comparing concentrations in lake water to NYS surface water quality standards.

The FS evaluations were not limited to those associated with meeting the above PRGs. The overarching goal of the FS was to recommend a remedy that would result in the best lake-wide solution to protect human health and the environment. Therefore, more qualitative goals, including enhancement of habitat for wildlife and improving recreational potential for the lake, were also considered.

SITE AND SEDIMENT CONDITIONS

The site has been divided into eight sediment management units (SMUs) as shown in Figure 2. The SMUs were created based on water depth, sediment type, available chemical data, sources of water entering the lake, and potential sources of CPOIs in the lake. SMUs 1 (the ILWD) to 7 are located in the littoral zone of the lake (i.e., in water depths of 0 to 9 meters [0 to 30 feet]), and SMU 8 is located in the profundal zone (i.e., in water depths greater than 9 meters [30 feet]). Evaluations of remedial approaches and alternatives were conducted for specific SMUs as appropriate. Capping and dredging remedy components, the main focus of this paper, were evaluated in detail for SMUs 1, 2, 3, 4, 5, 6, and 7.

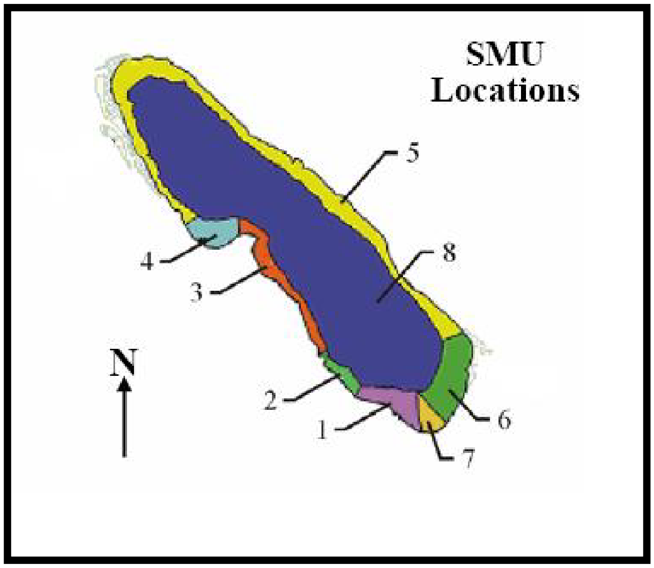

Figure 2. Locations of Sediment Management Units.

The CPOIs at the site vary by location in the lake, but include mercury, benzene, toluene, ethylbenzene, and xylene (BTEX) compounds, chlorinated benzenes, polycylic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and metals. The physical characteristics of the sediments are variable, but include silts and clays with high water contents, sands, and in the case of the ILWD, materials with characteristics differing from conventional sediments.

The site and sediment conditions are obviously complex, and several factors were of critical importance for evaluation of capping and dredging alternatives. The site is unusual in that the layers of contaminated sediment in some of the SMUs are very thick. For example, at the ILWD, contaminated sediments extend to thicknesses of 12.2 meters (40 feet). Groundwater flow is an important factor for cap design at the site. Most groundwater inflow to the lake occurs to the littoral zone, and a three-dimensional groundwater flow model was developed to estimate groundwater flows. Groundwater flows in critical nearshore regions will be controlled by cutoff walls and pumping systems to be implemented as a component of upland remedies. Non-aqueous phase liquids are present in the on-shore sites both as a distributed and weathered NAPL that may have been introduced into the lake and lake sediments with the surface discharges of waste material, and may be present as nearshore accumulations related to subsurface NAPL plumes on shore. The potential presence and mobility of the NAPL is important in evaluation of both dredging and capping.

REMEDIAL TECHNOLOGIES AND ALTERNATIVES

A complete range of remedial technologies were identified and screened in the FS to include no action (required in the FS), dredging, in-situ capping, habitat optimization, monitored natural recovery, oxygenation and thin layer capping (for the profundal zone), and institutional controls. Dredging and in-situ capping were identified as the primary remedial approaches for the littoral zones of the lake, while monitored natural recovery, thin-layer capping, and oxygenation were identified as potential approaches for the profundal zone. Although total capping and total dredging were evaluated as alternatives, most of the options involved a combined remedy approach with partial dredging followed by capping in the littoral zones. Habitat enhancement was also included in each of the combined dredging and capping alternatives and indeed became a driver for determining dredging depths in a number of alternatives to allow for installation of the isolation cap and a habitat layers.

With eight SMUs and a variety of remedial approaches and possible combinations, the number of possible remedial alternatives was tremendous. The FS initially evaluated 102 separate alternatives for the littoral areas, performed detailed evaluations of 58 alternatives, and screened these to 35 alternatives. The screened alternatives for each SMU were then combined to develop lake-wide alternatives, to include full capping, full dredging and a number of combined dredging/capping approaches for the littoral zone. Each of the alternatives were developed and evaluated with respect to CERCLA criteria, including implementability, effectiveness, and cost. The technical evaluations described in the following sections of the paper provided the basis for the FS level of design and the cost estimates of the dredging and capping components of the alternatives.

DREDGING EVALUATIONS

The technical basis for evaluation of dredging for the FS was documented in an independently prepared white paper and appended to the FS (Hayes, Palermo, Reible, and Verduin 2004). The dredging evaluations included estimates of production rates; residual sediment depths and concentrations; water quality impacts during dredging; and deposition of resuspended sediments. The effluent quality resulting from placement of the dredged sediments in an upland Sediment Consolidation Area (SCA) was also evaluated.

Most conventional dredging methods should be capable of removing existing bottom sediments in the littoral areas of Onondaga Lake. Difficulties and limitations associated with transporting dredging equipment to the lake as well as water depths in the dredging areas and disposal types and locations may restrict the size of dredges that can be used and possibly eliminate some from consideration. Accordingly, mechanical dredges using 2.3- and 4.6-cubic-meter (3- and 6-cubic-yard), enclosed clamshell buckets and 0.3- to 0.4-meter (12- to 16-inch) hydraulic pipeline dredges were evaluated for the FS. Estimated production rates varied from 38 to 191 cubic meters per hour (50 to 250 CY/hr), depending on the size and type of dredging equipment. Mechanical dredging would require a nearshore offloading facility to remove dredged sediment from haul barges to be placed into trucks. Mechanically dredged sediments could also be pumped directly from haul barges to a nearby disposal site. Hydraulic dredges would pump the material straight to the SCA.

The Solvay wastebeds appear suitable for siting the SCA. The SCA was sized to account for a sediment bulking factor of 1.3 and to have enough surface area and ponding depth to allow settling of the solids in the slurry. The SCA would require containment berms, a low permeability layer at the base, and a final cover over the sediments for closure. The SCA area may require pre-construction stabilization of the subsurface material, and will likely require pre-consolidation of all or part of the SCA footprint.

Two distinctly different dredging operations in SMU 1 were considered illustrative of dredging in SMU 1 and other SMUs for purposes of evaluating production, resuspension, releases and residuals. First, a single-cut dredging operation representing the removal of about 1 m (3 ft) of sediment over 0.18 square kilometers (45 acres) of SMU 1 was evaluated (over 229,000 cubic meters [300,000 CY] of dredging). This was estimated to require about 2,120 dredging hours to complete, pumping 5,000 to 5,500 gallons per minute and moving 115 cubic meters/hr (150 CY/hr). Second, a multiple-pass, extended-depth, dredging event removing almost 8 m (30 ft) of sediment over 0.34 square kilometers (84 acres) of SMU 1 was evaluated (3 million cubic meters [4 million CY] of dredging). This was estimated to require about 27,000 dredging hours at 115 cubic meters (150 CY/hr).

The dredging was assumed to occur within silt curtains for control of resuspended sediments. Estimates were made for sediment resuspension and water column concentrations around the dredging operation using the USEPA's CSTR-CHEM model. For the single pass dredging event, water quality modeling results indicate water column concentrations for several contaminants exceed water quality criteria in the immediate vicinity of the dredging operation with no mixing allowance. For the extended depth dredging event, water quality conditions were estimated for the maximum constituent concentrations found across the SMU 1 sediment profile. Since the highest concentrations of most constituents are found in the upper layer, water quality modeling assumed that all maximum constituent concentrations occurred in the first dredging pass. Numerous contaminant concentrations will likely exceed water quality criteria around the dredge during some point in the dredging operation with no mixing allowance.

The water quality of the SCA's primary effluent was also estimated for the FS using equilibrium partitioning. SCA effluent predictions for the single-pass dredging indicate that the effluent will not meet assumed water quality standards for mercury and some organics with only primary treatment and no allowance for mixing. SCA effluent predictions for the maximum concentrations in extended depth removal indicate that the effluent will exceed the assumed water quality standards with only primary treatment and no mixing allowance. The FS alternatives assumed that SCA effluent will require additional treatment (beyond primary treatment levels) prior to discharge to the lake.

Residual sediment concentrations after dredging the 1-m (3-ft) cut are expected to be comparable to the sediment concentrations within the dredge cut. The thickness of the residuals was estimated to be 10 percent by volume left behind, with an average concentration of the previous 1 m (3 ft) of sediments removed. It shows that higher surface concentrations may exist during the dredging operation. Impacts to profundal sediments from this dredging operation, using conservative assumptions, are estimated to be equivalent to only 0.1 percent of the current natural sedimentation mercury flux. Therefore, impacts to profundal sediments are minimal.

CAPPING EVALUATIONS

As with dredging, the technical basis for evaluation of capping for the FS was documented in an independently prepared white paper and appended to the FS (Palermo, Reible, Hayes and Verduin 2004). The capping evaluations were conducted in accordance with published USEPA technical guidance for sediment remediation and in-situ capping (USEPA 2002; and Palermo *et al*.1998). The performance standards for the cap design were as follows:

- The cap will be designed to provide physical isolation of the contaminated sediments from benthic organisms and other receptors.
- The cap will be physically stable from scour by currents, waves, and ice. A return period for episodic events of 100 years will be considered in these evaluations. Consideration of 100 year events to assess the threshold stability for the cap will likely ensure that lower frequency large events will not result in catastrophic failure of the cap.
- The cap will provide isolation of the contaminated sediments in the long term from flux or resuspension into the overlying surface waters. The performance criteria for chemical isolation will be a limiting upper cap layer sediment concentration for CPOIs equivalent to an SEC value in the biologically active zone of the cap or overlying habitat layers. This standard would apply as a construction standard to ensure the isolation layer of the cap is initially placed as a clean layer, and would also apply as a long-term limit with respect to chemical isolation.

In-situ capping implemented as the sole remedial approach may result in loss of lake surface area and water depths. Therefore, dredging followed by capping was evaluated in the FS as a remedial approach for most of the alternatives. The capping materials considered for the designs were granular sands and gravels, which may be obtained from nearby sources.

An appropriate level of conservatism was considered in approaching the cap designs for the FS. The total thickness of a cap and the composition of the cap components were based on an evaluation of all the pertinent processes for the site and the ability of the design to achieve the intended functions of the cap. Pertinent processes included physical isolation of benthic organisms, bioturbation, cap consolidation, erosion, operational factors, and chemical isolation. Some of the processes for design of cap components were evaluated rigorously with models, but others required engineering judgment.

Physical stability of the caps was evaluated assuming that an armor layer would be included as a cap component where necessary. The site conditions across the SMUs vary, and different erosive processes controlled the armor design for different SMUs. Processes evaluated for physical stability included scour due to ice forces, wind-induced waves due to episodic storm events, currents resulting from flood flows in tributaries, and scour due to propeller wash from vessels. The resulting water depth following any partial dredging and cap construction was a major consideration in determining the erosive force resulting from an episodic event such as a flood or storm. EPA design guidance for caps calls for consideration of the 100-year return interval event in design for armor layers (USEPA 2002). Each of the above erosive processes was evaluated independently to determine design requirements for a cap-armoring component. The resulting armor layers consisted of coarse sand or gravel-size materials, depending on location of the SMUs and water depths, while larger stone materials were required in the very shallow shoreline areas to resist ice scour forces. As mentioned earlier, habitat constraints should also be a major factor in selecting the post-capping water depths and material properties for the cap components. A separate habitat layer was therefore incorporated in the cap design to provide optimum substrate for fish habitat.

The chemical isolation component of the cap was designed to control the movement of contaminants by both advection and diffusion. An analytical steady-state model of chemical fate and transport was applied to determine the required thicknesses of the chemical isolation component of the cap (Reible, Kiehl-Simpson, and Marquette 2005). The model was applied using conservative assumptions for groundwater flow velocities, partitioning coefficients, etc. Cap effectiveness was based on the comparison of the steady-state predicted concentration in the biologically active layer (the habitat layer) with the appropriate SEC values for each COPI. If these criteria were exceeded at steady state, the time required to achieve steady state were evaluated and the cap was considered effective if more than 1000 years was required to achieve steady state conditions. For the FS evaluations, the cap designs incorporated a factor of safety of 1.5 applied to the cap thickness deemed necessary for chemical isolation to account for uncertainty in site conditions, sediment properties, and migration processes. As mentioned earlier, control of groundwater flows (as a part of the upland remedies) will be required in some nearshore areas to ensure cap effectiveness.

The cap design requirements generally included the following:

- Pre-cap dredging, resulting in a level cut extending from shoreline at a selected depth, providing room for armor and cap, and resulting in the optimum combination of habitat enhancement, no loss of water surface area, and armor surface below the wave-break depth. As stated before, the FS does consider capping alternatives that do not include some pre-dredging, which is technically feasible.
- Cap placed over the entire post-dredging surface area of the SMUs, except localized areas around infrastructure, navigational channels, etc.
- Cap layers from top to bottom will include:
    - Habitat/bioturbation layer – minimum of 15 cm (6 inches) of gravel or sand,
    - Backfill layer – fill as needed in immediate nearshore zones to bring habitat layer up into shallow water,
    - Armor layer – consisting of gravel or coarse sand with a minimum thickness of 15 cm (6 inches), and
    - Isolation/operational component – sand with 0.1 percent total organic carbon (TOC) at thickness of 0.6 to 1 m (2 to 3.5 feet) (0.6-meter [2-foot] isolation layer needed in SMU 1 and 2) (includes a 15 cm [6-inch] operational allowance and a safety factor of 1.5 applied to the isolation thickness).

Geotechnical issues regarding the bearing capacity of the sediments and their ability to support a cap and slope stability for the capped deposits were also evaluated. The base chemical isolation layer of the cap (sandy material) will need to be placed slowly and evenly to minimize mixing of cap material with the soft sediments. The armor layers can be placed mechanically. Slope stability was evaluated for SMU 1, the ILWD, for both static and dynamic (earthquake) conditions. The analyses showed that adequate factors of safety were maintained, and partial dredging and consolidation due to cap placement would result in increased stability.

The FS also developed the requirements for monitoring to ensure that the cap is placed as intended and that the cap is performing the basic functions (physical isolation, sediment stabilization, and chemical isolation) as required to meet the remedial objectives. Specific items or processes in the monitoring plan included cap integrity, thickness, and consolidation; the need for cap nourishment (subsequent filling or capping); benthic recolonization; and chemical migration potential.

RECOMMENDED ALTERNATIVES AND NEXT STEPS

The preferred alternative in the FS was a combined dredging and capping approach for the littoral zones of the lake. Under this alternative, a total of 390,000 cubic meters (510,000 cubic yards) would be dredged, resulting in no loss of lake surface area for SMU 1 and optimum habitat enhancement in other littoral areas. Following dredging, a total of 1.5 square kilometers (356 acres) would be capped, with the cap design providing habitat enhancements in the littoral and medium depth areas of the lake. The total estimated present worth cost of the FS preferred remedy is $243 million, and the estimated duration for dredging and capping is 3 years.

In November 2004, the NYSDEC issued a Proposed Remedial Action Plan (PRAP) (NYSDEC 2004). The proposed remedy in the PRAP was also a combined dredging and capping approach in the littoral zones of the lake. Under the PRAP alternative, a total of 2,028,000 cubic meters (2,653,000 cubic yards) would be dredged, which included a 2 m depth of sediment removal in SMU 1. Following dredging, a total of 1.7 square kilometers (425 acres) would be capped. Total estimated present worth cost of the PRAP remedy is $451 million, and the estimated duration for dredging and capping is 4 years.

As of this writing, a Record of Decision (ROD) for the project has not been issued by NYSDEC. Once a ROD is issued, the technical basis for both dredging and capping components of the selected remedy will be refined as appropriate in the Remedial Design. This will include additional sampling in the lake and pilot tests conducted as part of the pre-design investigation.

ACKNOWLEDGEMENTS

This paper summarizes technical evaluations conducted by a large technical team of scientists and engineers. The contributions of the entire Onondaga Lake FS study team, including individuals from Honeywell, Parsons, Anchor Environmental, and Exponent are gratefully acknowledged.

REFERENCES

Exponent, Inc. (2001a). *Onondaga Lake RI/FS Baseline Ecological Risk Assessment*. Prepared for Honeywell, Inc., East Syracuse, New York. Bellevue, Washington.

Exponent, Inc. (2001b). *Onondaga Lake RI/FS Human Health Risk Assessment*. Prepared for Honeywell, Inc., East Syracuse, New York. Bellevue, Washington.

Exponent, Inc. (2001c). *Onondaga Lake RI/FS Remedial Investigation*. Prepared for Honeywell, Inc., East Syracuse, New York. Bellevue, Washington.

Hayes, D.F., M. Palermo, D. Reible, , and J. Verduin. (2004). "Appendix L: Evaluation of Dredging Options for the Onondaga Lake Feasibility Study," Appendix L of *Onondaga Lake Feasibility Study Report, Onondaga County, New York*. November 2004. Prepared for Honeywell by Parsons, Liverpool, N.Y.

New York State Department of Environmental Conservation (NYSDEC). (2004). *Onondaga Lake Subsite of the Onondaga Lake Superfund Site, Syracuse, New York – Proposed Plan*. November 29, 2004.

Palermo, M.R., J. Miller, S. Maynord, and D. Reible. (1998). *Assessment and Remediation of Contaminated Sediments (ARCS) Program Guidance for In situ Subaqueous Capping of Contaminated Sediments*. EPA 905/B-96/004. Prepared for USEPA, Great Lakes National Program Office, Chicago, Illinois. Available at http://www.epa.gov/glnpo/sediment/iscmain.

Palermo, M.R., D. Reible, D. Hayes, and J. Verduin. (2004). "Appendix H: Technical Evaluation of In Situ Capping as a Remedy Component for Onondaga Lake," Appendix H of *Onondaga Lake Feasibility Study Report, Onondaga County, New York*. November 2004. Prepared for Honeywell by Parsons, Liverpool, N.Y.

Parsons. (2004). *Onondaga Lake Feasibility Study Report.* November 2004. Prepared for Honeywell, Inc., East Syracuse, New York.

Reible, D., Kiehl-Simpson, C., and Marquette, A. (2005). "An Improved Modeling Approach for Cap Design". *Proceedings, 3rd International Conference on Remediation of Contaminated Sediments*, January 24-27, 2005, New Orleans, LA.

TAMS (2002a). *Onondaga Lake Baseline Ecological Risk Assessment*. Prepared with YEC, Inc. for NYSDEC, Division of Environmental Remediation, Albany, New York.

TAMS (2002b). *Onondaga Lake Human Health Risk Assessment.* Prepared with YEC, Inc. for NYSDEC, Division of Environmental Remediation, Albany, New York.

TAMS (2002c) *Onondaga Lake Remedial Investigation Report*. Prepared with YEC, Inc. for NYSDEC, Division of Environmental Remediation, Albany, New York.

USEPA. (2002). *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. Draft. Office of Solid Waste and Emergency Response. OSWER 9355.0-85.