APPENDIX M: INTEGRATING HABITAT CONSIDERATIONS IN THE REMEDIAL ALTERNATIVES FOR ONONDAGA LAKE

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November 2004

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EXECUTIVE SUMMARY

APPROACH

As part of the Onondaga Lake Feasibility Study (FS), Honeywell is evaluating various remedial alternatives for addressing contaminated sediments in Onondaga Lake. To understand the full effects of the various alternatives being considered, it is important to consider and plan for the recreation, aesthetic, and natural resource values of the lake that are desired over the long term.

This appendix describes the existing habitat conditions in Onondaga Lake and uses them to develop habitat restoration and enhancement approaches that *could be implemented as part of, or following, remedial actions*. Habitat restoration is defined as the replacement of habitat in areas where remediation substantially alters existing conditions. Habitat enhancement is defined as improving habitat conditions in areas where CPOIs do not occur at levels that warrant active remediation. These approaches are designed to be integrated into the preferred alternatives to achieve ecological systems that emulate naturally functioning, self-regulating systems and that are integrated with the surrounding habitats in the lake. The approaches were developed following the general principles for habitat restoration and specific habitat restoration principles and objectives developed for this appendix. General habitat restoration principles include:

- Preserve existing valuable habitats to the extent practicable;
- Design restoration activities to take advantage of existing natural processes and conditions to the greatest extent practicable; and
- Focus on improving conditions in existing habitats over creation of new habitats.

Restoration principles specific to Onondaga Lake were developed after reviewing the general habitat restoration principles and the principles, goals, and objectives from other ongoing and planned programs in the lake. The Onondaga Lake-specific principles were then used to develop the habitat restoration objectives that form the basis for the potential restoration and enhancement activities for each SMU. These objectives include:

- 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 (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*)) by expanding the areal extent of suitable fish spawning substrates and nursery areas; and
- Increase connectivity of in-lake and shoreline/upland habitats where practicable, provided such connectivity does not facilitate the transfer of contaminants. The potential for adverse effects associated with connectivity should be closely monitored.

EXISTING CONDITIONS

One fundamental habitat restoration principle is preservation of existing habitat, which necessitates determining the nature and extent of existing habitats within Onondaga Lake and the factors most strongly related to the occurrence and condition of those habitats (e.g., depth, substrates, exposure). The largest habitats of Onondaga Lake are in the pelagic and profundal zones, with a relatively small band of littoral habitats along the perimeter of the lake. The relatively steep slopes around the shore of the lake, low water clarity, and other habitat factors described later restrict the lower depth distribution of macrophytes, limiting the lateral extent of the lake's littoral zone.

For the FS, Onondaga Lake is divided into eight SMUs. SMUs 1 through 7 constitute the entire nearshore littoral zone (0 to 30 ft [0 to 9 m] water depth) and SMU 8 includes the profundal zone. Each SMU has distinct physical and habitat characteristics to be considered in developing overall habitat restoration and enhancement concepts. Key factors that distinguish the SMUs are slope, presence of oncolites and calcium carbonate sediments, fish abundance and spawning activity, benthic macroinvertebrate community status, and presence of submerged macrophytes.

HABITAT RESTORATION AND ENHANCEMENT

Submerged macrophytes provide critical habitat functions in the littoral zone of Onondaga Lake including shelter, nesting sites, food for fish and wildlife, substrate and food for epiphytic macroinvertebrates, and stabilization of soft sediments. Macrophyte distributions in the lake are controlled by various factors, including light availability, nutrients, water depth, wave and ice exposure, salinity, grazing by animals, and substrate characteristics, such as grain size, chemistry, and stability (including slope). Many of these same factors, particularly substrate characteristics, also influence macroinvertebrate species composition and fish use (spawning) because they are related to food availability and substrate stability.

These factors were considered in developing the habitat restoration and enhancement options. The options were developed to create the maximum area within each SMU with the physical conditions (primarily substrate and depth) to support submerged macrophyte species and fish spawning based on the habitat requirements, taken from the literature and habitat suitability indices, for target species. The three target submerged macrophyte species identified for this report are Sago pondweed (*Potamogeton pectinatus*), wild celery (*Vallisneria Americana*), and American pondweed (*Potamogeton nodosus*). The target fish species used for this appendix include walleye (*Stizostedion vitreum*), largemouth bass, smallmouth bass , bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus)*. Target emergent wetland species include narrow-leaved cattail (*Typha angustifolia*), soft-stem bulrush (*Scirpus tabernaemontani*), and eastern bur-reed (*Sparganium eurycarpum*).

SMU-specific habitat restoration and enhancement projects were developed that identify the primary habitat, secondary habitat, and additional habitat features that could be considered for implementation at each SMU. Primary habitat represents the potential habitat type with greatest areal extent for each SMU. Secondary habitat represents potential habitat with a smaller spatial extent than the primary habitat. For each SMU, either fish spawning substrates or submerged macrophytes are identified as primary or secondary habitat types, depending on the areal extent of the SMU with a water depth of 2 to 6 ft (0.6 to 2 m) for submerged macrophytes or 6 to 15 ft (2 to 6 m) for fish spawning substrate. Additional habitat features for each SMU are also identified and include wetlands, shoreline treatments (e.g., riparian overhang), or large woody debris.

MONITORING PROGRAM

Monitoring and evaluation of the habitat restoration/enhancement projects should be used to determine the success of the actions confirming whether the defined objectives are being met. The monitoring program should also include adaptive management protocols to identify problems, to select and implement corrective actions to facilitate meeting project objectives, and to provide criteria for when monitoring is completed. Specific elements and the duration of the monitoring program would be dictated by the nature and extent of selected habitat restoration and enhancement projects and may include monitoring the use of restored or enhanced habitats by biological organisms, and monitoring in created or enhanced habitat areas and in reference areas for comparison.

SECTION M.1

INTRODUCTION

As part of the Onondaga Lake Feasibility Study (FS), Honeywell is evaluating various remedial alternatives for addressing contaminated sediments in Onondaga Lake. One component of these evaluations is documenting the existing habitat conditions in the lake and describing potential habitat conditions in the post-remediation lake. This appendix identifies specific habitat-based criteria to facilitate the selection of remedial alternative(s).

This appendix is organized as follows:

- Section M.2 presents an overview of the principles of habitat restoration in general, and the principles and objectives for habitat enhancement projects in Onondaga Lake.
- Section M.3 presents an overview of the existing habitat conditions in Onondaga Lake. This information is intended to complement the geologic, topographic, natural resources, and meteorologic conditions described in Section 1 and Appendix B of the FS.
- Section M.4 describes the potential habitat restoration/enhancement opportunities for each of the sediment management units (SMUs), focusing on the creation or enhancement of submerged macrophytes and fish spawning habitats.
- Section M.5 describes potential monitoring requirements and design considerations related to implementation of the habitat restoration and enhancement projects.
- Section M.6 presents the conclusions of this appendix.

Remedial alternatives being considered for Onondaga Lake include capping, dredging, monitored natural recovery, and combinations of these and other technologies that may modify existing habitat conditions in the lake. Effects of various remedial actions are evaluated as part of the FS. The habitat remediation and enhancement opportunities discussed in this report are not expected to constrain remedial alternatives, but were developed for consideration of incorporation into these alternatives. In addition, the habitat restoration and enhancement approaches may be considered as an alternative to avoid impacts on existing habitat in areas where more intrusive remedial actions (e.g., dredging and/or capping) may not be needed to address chemical parameters of interest (CPOIs).

Table M.1 contains a glossary of the terms used in this appendix.

SECTION M.2

HABITAT RESTORATION AND ENHANCEMENT

Habitat restoration and enhancement will be planned as part of remedial actions identified in the FS. The overall approach and end results are the same for restoring or enhancing the habitat conditions; the only difference is whether the habitat improvements are preceded by remedial actions. **Habitat restoration** is defined as the replacement of habitat in areas where remediation substantially alters existing conditions. **Habitat enhancement** is defined as improving habitat conditions in areas where CPOIs do not occur at levels that warrant active remediation. The overall goal of habitat restoration and enhancement is to achieve ecological systems that emulate naturally functioning, self-regulating systems that are integrated with the surrounding habitats.

M.2.1 GENERAL HABITAT RESTORATION AND ENHANCEMENT PRINCIPLES

The general principles are those that are equally applicable to any ecosystem where habitat restoration or enhancement is being considered, such as forests, tundra, coastal marshes, streams, or lakes (Bradshaw, 1996):

- Preserve existing valuable habitats to the extent practicable.
- Design restoration activities to take advantage of existing natural processes and conditions to the greatest extent practicable.
- Focus on improving conditions in existing habitats over creation of new habitats.
- Design restoration projects with a "safe-fail" approach, which involves incorporating heterogeneity into the physical design to hedge against uncertainties. Habitat heterogeneity (types of habitats) and species diversity should also be included in restoration projects.
- Clearly articulate restoration project objectives, ecological metrics, and criteria for judging success in the restoration plan. A monitoring program should assess the status of restored systems. Key ecological monitoring metrics should be defined and reference sites should be delineated for use in assessing restoration project success.
- Use adaptive management (Walters and Holling, 1990) to respond to unforeseen problems (e.g., invasion of nuisance species) or physical changes related to natural disturbances (e.g., extreme climatic events).
- Involve the public, environmental agencies, and key scientific researchers in designing and monitoring restoration projects.

Perhaps the most important of the principles above is the concept of a "safe-fail" approach (Pastorok *et al*., 1997). In contrast to the "fail-safe" approach of traditional civil and coastal engineering projects, which assumes a single "optimal" design and attempts to control as many variables as possible, the "safe-fail" approach works with the heterogeneity and unpredictability of natural systems. Incomplete or imprecise knowledge of what constitutes optimal habitat for the target species, the imprecision of constructing habitats, and natural disturbances may all interfere with the ability to achieve restoration objectives. Incorporating heterogeneity into the design (e.g., varying topography around the assumed optimum; planting several macrophyte species instead of a single "optimal" species) will increase the likelihood that at least a portion of the restored habitat area will become a self-sustaining system. Hence, even if a portion of the design fails, other aspects may succeed, ensuring a "safe" outcome that meets management objectives. Monitoring and adaptive management are also key elements in successful restoration projects (Thom and Wellman, 1996; Pastorok *et al*., 1997).

M.2.2 ONONDAGA LAKE HABITAT RESTORATION AND ENHANCEMENT PRINCIPLES

Using the framework provided by the overarching habitat restoration principles described above, habitat restoration and enhancement principles specific to Onondaga Lake were developed for this appendix. These principles are specific to the lake itself and are not intended to address the Onondaga Lake watershed, lake tributaries, or surrounding terrestrial habitats. Those areas are being addressed in the *Strategic Comprehensive Habitat Restoration Plan for the Onondaga Lake Watershed*, currently being prepared by the U.S. Army Corps of Engineers (see Attachment A).

The principles in Subsection M.2.2.1 were used to develop the habitat restoration objectives and goals listed in Subsections M.2.2.2 and M.2.2.3 respectively. The first step to meeting the objectives and goals was to identify the existing habitats in the lake and within each of the SMUs (see Section M.3). Then, based on the existing conditions, and in accordance with the principles described below, specific habitat restoration and enhancement opportunities were identified for each SMU (Section M.4). After review of ongoing and planned programs to restore Onondaga Lake (see Attachment A), warmwater fishes and submerged macrophytes were selected as the target organisms for the purposes of this appendix. The final list of target organisms will be determined during remedial design.

M.2.2.1. Onondaga Lake Habitat Restoration and Enhancement Principles

- Preserve valuable habitats present in the lake to the extent possible during remedial activities and restoration projects (e.g., current fish spawning, nursery, and foraging areas should not be destroyed or altered for habitat restoration, unless otherwise required by remedial alternatives).
- Provide an optimal combination of spawning, nursery, and foraging habitat for warmwater fish populations in the lake.
- Include habitat heterogeneity in habitat restoration activities by targeting a balance of macrophyte beds, fish spawning substrate, and cover (e.g., large woody debris) in proportions optimized for the target fish species.

- Be consistent with and take advantage of existing conditions such as water depth, bottom slope, type of substrate, current ecological function (fish spawning, foraging, etc.) and the energy level of the environment.
- Identify and, to the extent possible, be consistent with other programs and projects with habitat-related components in developing habitat restoration plans.
- Develop habitat improvements to complement engineering solutions for each SMU.

M.2.2.2 Objectives

- Increase diversity and abundance of desirable submerged macrophyte species (e.g., *P. pectinatus*, *P. nodosus*, *V. americana*).
- Increase 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. The potential for adverse effects associated with connectivity should be closely monitored.

M.2.2.3 Goals

- 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 connection of in-lake and shoreline/upland habitats where practicable, provided such connectivity does not facilitate the transfer of contaminants.

SECTION M.3

EXISTING HABITAT CONDITIONS

M.3.1 OVERVIEW

Onondaga Lake has a surface area of 4.6 square miles (12 square kilometers [km^2]), a volume of 34,600 million gallons (131×10^6 cubic meters [m^3]), a mean depth of 39 ft (12 m), and a maximum depth of 65 ft (19.9 m). The two basins of the lake are separated by a ridge, possibly a glacial moraine (PTI, 1992) approximately two-thirds of the way up the southeast-to-northwest axis of the lake (Figure M.1). The lake is relatively well-mixed horizontally but maintains vertical stratification associated with thermal gradients during the summer and winter (depending on the extent of ice cover).

The largest habitats of Onondaga Lake are in the pelagic and profundal zones, with a relatively small band of littoral habitats along the perimeter of the lake. The relatively steep slopes around the shore of the lake, low water clarity, and other habitat factors described later restrict the lower depth distribution of macrophytes, limiting the lateral extent of the lake's littoral zone.

Silt and sand substrates, which are characteristic of lakes the size of Onondaga Lake, are primarily found in the southeastern section of the lake. Oncolites cover most of the northwestern and eastern shoreline accounting for much of the littoral zone area. Calcium carbonate substrate is found in the northwestern and northeastern portions of the lake and intermittently in the southwestern and southeastern portions of the lake. A small patch of gravel is located at the south end of the lake. Lake-wide views of habitat conditions and use in Onondaga Lake are presented in Figures M.1 through M.14. Specific habitat characteristics for each SMU are shown in Figures M.15 through M.22

Based on the baseline ecological risk assessment (BERA) (TAMS, 2002a) and previous habitat surveys (e.g., Ecologic, 1999, 2001), habitats within and surrounding Onondaga Lake can be classified into the following general categories:

- Submerged macrophytes;
- Unconsolidated bottom;
- Wetlands; and
- Shoreline.

Additional details on physical, chemical, and biological conditions in Onondaga Lake can be found in Section 1 of the FS and in the BERA (TAMS, 2002).

M.3.2 PRIMARY HABITATS OF ONONDAGA LAKE

M.3.2.1 Submerged Macrophytes

Submerged macrophytes provide critical habitat functions in the littoral zone of Onondaga Lake, including shelter, nesting sites, food for fish and wildlife, substrate and food for epiphytic macroinvertebrates, and stabilization of soft sediments (EcoLogic, 1999). Macrophyte distributions in the lake are controlled by various factors, including light availability, nutrients, water depth, wave and ice exposure, salinity, grazing by animals, and substrate characteristics, such as grain size, chemistry, and stability.

A macrophyte survey conducted in 1991 identified five submerged species in Onondaga Lake, including sago pondweed , water stargrass (*Heteranthera dubia*), coontail (*Ceratophyllum demersum*), curly leaf pondweed (*Potamogeton crispus),* and Eurasian water-milfoil (*Myriophyllum spicatum*) (Madsen *et al*., 1992*)*. An additional five aquatic macrophyte species were found by Madsen *et al*. (1998) in 1993. These included waterthread pondweed (*P. diversifolius*), Canadian pondweed (*Elodea canadensis*), duckweed (*Lemna minor*), bur-reed (*Sparganium sp.*), and horned pondweed (*Zannichellia palustris*). The number of macrophyte species currently found in the lake is low compared to the 15 species found in Onondaga Lake before 1940 (Auer *et al*., 1996). Fifteen species of submerged macrophytes is typical for eutrophic lakes in New York State (Madsen *et al*. 1993), but lower than the New York State average of 18 species (Madsen *et al*. 1996). In addition, emergent or floating-leaved vegetation were absent from the littoral zone of Onondaga Lake, and have been noted as important to the aquatic vegetation community (EcoLogic, 1999). Both *P. crispus* and *M. spicatum*, which are considered nuisance species, were not present historically in the lake (EcoLogic, 1999). Results from the most recent Aquatic Macrophyte Monitoring Program suggest that the number of macrophyte beds within the lake is growing in size, although they currently occupy less than 10 percent of the littoral zone of Onondaga Lake (EcoLogic, 2001). The frequency of occurrence of macrophytes on various substrate types in Onondaga Lake is shown in Figure M.10.

Based on the work of Madsen *et al*. (1992) and others (Batuik *et al.*, 2000), EcoLogic listed optimal habitat conditions for transplanting submerged macrophyte species. As shown in Table M.2 and the referenced figures, conditions are generally suitable for restoring and enhancing submerged macrophytes in Onondaga Lake. The water quality conditions are expected to further improve as a result of several ongoing and planned projects (see Attachment A for more detail).

M.3.2.2 Unconsolidated Bottom

Unconsolidated bottom includes those areas with at least 25 percent cover of particles smaller than stones, and a vegetative cover less than 30 percent (Cowardin *et al*., 1979). Unconsolidated bottoms are characterized by the lack of large, stable surfaces for plant and animal attachment. Exposure to wave and current action, temperature, salinity, and light penetration determine the composition and distribution of organisms (Cowardin *et al*., 1979). In Onondaga Lake, two unique types of unconsolidated bottom are present in the littoral zone: oncolites and calcitic sediments.

M.3.2.3 Oncolite Beds

Shallow littoral areas covered by oncolites are prevalent in the eastern and northwestern areas of Onondaga Lake, particularly within SMU 5. Oncolites are ovoid calcium carbonate concretions ranging from less than 0.4 inch (1 cm) to several cm in diameter. Oncolites are found in a variety of environments around the world and may have formed in the lake prior to eutrophication. However, Dean and Eggleston (1984) suggest ionic discharges from the former Allied soda ash facility enhanced oncolite formation. Limited growth of rooted aquatic plants (i.e., macrophytes) in Onondaga Lake has been linked to oncolite beds in the nearshore sediments. The low density and susceptibility of oncolites to wave action may preclude the establishment of seedlings. However, oncolitic substrate provides suitable nesting habitat for fish, including bluegill, pumpkinseed, and largemouth bass, and enhances the abundance of benthic macroinvertebrates, such as amphipods, which serve as forage food for fish.

Although oncolites appear to have a positive impact on the fish in Onondaga Lake, the high prevalence of the oncolite substrate may limit growth of macrophytes in these areas. Macrophyte beds would provide shelter and an abundant food supply for benthic and epiphytic macroinvertebrates and may also support a greater diversity and abundance of fish nesting sites.

M.3.2.4 Calcium Carbonate Sediments

Sediments containing calcium carbonate are distributed throughout the lake (Figure M.6). The concentrations of calcium carbonate in the top 1 inch (0 to 2 cm) of sediment were measured in 1992. Concentrations were generally less than 60 percent dry weight in sediment from deep areas of the lake and greater than 60 percent in nearshore areas. The highest concentrations (greater than 80 percent dry weight) were found along much of the northern shoreline, near Ley Creek and Tributary 5A.

M.3.2.5 Wetlands

Historically, the land surrounding Onondaga Lake consisted of extensive wetlands. However, the total extent of these wetlands was likely affected when the level of Onondaga Lake was lowered by approximately 2 ft (0.6 m) in 1822 (Effler and Harnett, 1996) and by development.

Five wetlands occur along or near the lake's shoreline near the mouths of Harbor Brook (SYW-19), Ley Creek (SYW-12), and Ninemile Creek (SYW-10), along the northwest shoreline of the lake (SYW-6), and near Sawmill Creek (SYW-1) (Figure M.9). Four wetlands are directly connected to Onondaga Lake: SYW-6, SYW-10, SYW-12, and SYW-19. SYW-1 is not hydraulically connected to the lake. Wetland SYW-10 is being addressed under the Geddes Brook / Ninemile Creek remedial investigation and feasibility study (RI/FS). Wetlands SYW-12 and SYW-9 are being addressed under the Wastebed B / Harbor Brook RI/FS. SYW-6 will be addressed as part of the Dredge Spoils Area Operable Unit. Therefore, these wetlands will not be evaluated for habitat enhancement or restoration options under the Onondaga Lake FS. However, their location with respect to the lake will be noted during development of restoration and enhancement options.

Wetland SYW-6 is a 100-acre (ac) (40 hectare [ha]), Class I wetland, which is 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 in the wetland. Some surface water flow occurs through culverts under these paths. SYW-6 is a palustrine, forested scrub-shrub, broad-leaved deciduous wetland (TAMS, 2002). 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 deltoides*) 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/saturated.

Wetland SYW-12 is a 40.7-ac (16.3 ha) Class I wetland and is located between the mouths of Onondaga Creek and Ley Creek. SYW-12 is a palustrine, emergent, broad-leaved deciduous wetland (TAMS, 2002). 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 (USACE, 2003a). SYW-12 is seasonally flooded.

M.3.2.6 Shoreline

The shoreline of Onondaga Lake consists of maintained, natural, and disturbed areas. Maintained areas include industrial, commercial, and recreational properties immediately adjacent to the lake. Natural areas are limited and include wetlands and small areas of riparian vegetation adjacent to the lake. Disturbed areas include those previously used for industrial or commercial activities that are no longer active. The focus of this report is on in-lake habitat conditions, and as such, shoreline areas are addressed only to the extent necessary when describing the in-lake habitat and/or enhancement strategies (Section 4).

M.3.3 AQUATIC BIOTA COMMUNITIES

M.3.3.1 Fish Community

Onondaga Lake supports a warm-water fish community dominated by the pollution-tolerant gizzard shad (*Dorosoma cepedianum*), freshwater drum (*Aplodinotus grunniens*), carp (*Cyprinus carpio*), and white perch (*Morone americana*). Sunfish are abundant in the littoral zone. In addition, the lake supports several sportfish, including channel catfish (*Ictalurus punctatus*), largemouth bass , smallmouth bass , and walleye (*Stizostedion vitreum*) (Auer *et al*., 1996; Tango and Ringler, 1996). Thirty-four adult species were collected during the Onondaga County Ambient Monitoring Program (AMP) from 2000 to 2002 (OCDWEP 2003). Dominant species included gizzard shad, white perch, bluegill, pumpkinseed, carp, largemouth bass, smallmouth bass, yellow perch, and white sucker, contributing approximately 93 to 95 percent of the combined catch. Reproduction in Onondaga Lake is evident through identification of 29 species in early life stages (85 percent of adult population exhibit reproduction), of which 19 were larval fish and 23 were young-of-year (YOY) (OCDWEP, 2003). Pumpkinseed, bluegill, and gizzard shad dominate the YOY community in the lake.

A lake-wide view of use of nearshore habitats by selected fish species (i.e., sunfish, largemouth bass, and smallmouth bass) is presented in Figures M.11 through M.13. These data are based on surveys conducted in 1994 (Ringler and Arrigo, 1995). The abundance of fish nests in nearshore habitats is greatest (>300 nests/6,400 ft^2 [600 m^2] seine haul) along the northwestern shoreline near the border of SMU 4 and SMU 5. Several nearshore areas supported 100 to 300 nests/seine haul, including either side of the mouth of Sawmill Creek (SMU 5), either side of the lake outlet (SMU 5), the mouth of Ninemile Creek (SMU 4), and near the mouth of Tributary 5A (SMUs 2 and 3). The remainder of the shoreline, approximately half of the shoreline length, supported fish nest densities of <100 nests/seine haul, particularly in the southeastern portion of the lake. The low density of fish nests is likely due to suboptimal habitat conditions and has been documented in previous nest surveys (Beak and EcoLogic, 2002; Arrigo, 1998; Ichthyological Associates and EcoLogic, 2001).

M.3.3.2 Benthic Macroinvertebrate Communities

A lake-wide analysis of the status of benthic macroinvertebrate communities was presented in the BERA (TAMS, 2002). Over 70 taxa were identified in 1992 and 2000, dominated numerically by oligochaetes and chironomids both years. Although this analysis has some technical limitations for judging the absolute degree of benthic macroinvertebrate community impairment, the results provide perspective on the relative status of benthic macroinvertebrates in different parts of the lake. Figure M.14 shows that most of Onondaga Lake contains benthic macroinvertebrate communities with slight or moderate impairment as defined in the BERA (TAMS, 2002). Severely impaired benthic macroinvertebrate communities are present only in the southernmost portion of the lake (SMUs 1, 2, 6, and 7) and along the eastern shoreline near the north end of SMU 3. Benthic macroinvertebrate communities in the mouths of several tributaries (i.e., Ley Creek, Onondaga Creek, Harbor Brook, and Tributary 5A) were also severely impaired relative to reference conditions in Otisco Lake.

M.3.3.3 Phytoplankton and Zooplankton Communities

In 1992, 36 phytoplankton taxa were collected in Onondaga Lake (PTI, 1993; Stearns & Wheler, 1994). The major algal groups in 1992 were flagellated green algae, non-flagellated green algae, diatoms, cryptomonads, and cyanobacteria (blue-green algae). Between 1986 and 1989, 25 zooplankton taxa were collected in Onondaga Lake (Auer *et al*., 1996), dominated by cladocerans, copepods, and rotifers (TAMS, 2002).

The Onondaga County AMP performed a detailed analysis of the structure and abundance of the phytoplankton and zooplankton communities in Onondaga Lake. Data from 2002 indicated the dominant phytoplankton community consisted of Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta, Euglenophyta, Pyrrhophyta, miscellaneous microflagellates, and Xanthophyta (yellow-green algae, documented for the first time since 1996). The two dominant types of cyanobacteria found in 2002 algal blooms were *Oscillatoria amphibia* and

Aphanizomenon flos-aquae (OCDWEP, 2003). The 2002 monitoring program identified the continued presence of cladocerans, copepods, and rotifers.

M.3.3.4 Amphibian and Reptile Communities

The amphibian and reptile species found near Onondaga Lake between 1994 and 1997 included five species of anurans (i.e., frogs and toads) and two species of salamanders (TAMS, 2002). In addition, six reptile species, including three species of aquatic snakes and three species of turtles, were identified. In general, the numbers of amphibian and reptile species found near Onondaga Lake were much lower than the numbers found in similar areas of central New York State (Ducey *et al*., 1998).

M.3.3.5 Terrestrial Communities

Over 30 species of birds and 13 species of waterfowl have been identified in habitat adjacent to Onondaga Lake. Forty-five mammalian species that potentially occur near Onondaga Lake are listed in the BERA (TAMS, 2002), including opossums, shrews, rodents, muskrats, raccoons, skunks, and deer.

M.3.4 SMU-BY-SMU DESCRIPTION OF EXISTING HABITAT

For the FS, Onondaga Lake is divided into eight SMUs (Figure M.1). SMUs 1 through 7 constitute the entire nearshore littoral zone (0 to 30 ft [0 to 9 m] water depth) and SMU 8 includes the profundal zone.

The spatial distributions of a number of physical characteristics are shown in Figures M.2 through M.7 and M.9. The littoral zones of SMUs 6 and 7 are gently sloped. The northeastern and southeastern portions of SMU 5 and portions of SMU 3 are the most steeply sloped. The southeastern portion of SMU 5 and SMU 6 are the most exposed (to wave energy) areas of the lake. Oncolites are common in SMU 5, with only isolated patches in SMUs 2, 3, and 4 (Figure M.5). Calcium carbonate sediments are also common in SMU 5, and are prevalent in SMUs 1, 2, and 3. This pattern corresponds to that for total organic carbon (TOC), i.e., areas with higher percentages of calcium carbonate correspond with areas of lower percentages of TOC.

Selected habitat characteristics were used to create a map of existing habitat value in 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 M.23). The most recent spatial distribution of macrophytes was used to develop the submerged macrophyte habitat value data layer (EcoLogic, 2001). The frequency of fish nesting (number of nests per lake segment) for the dominant fish species was the second parameter used to assess habit value in Onondaga Lake (Ringler and Arrigo, 1995). The third indicator of habitat value used in this analysis was the status of benthic macroinvertebrate communities, as summarized by TAMS (2002). These three indicators were not differentially weighted in the analysis. Criteria used to rank habitat value for each indicator are described below.

Percent Macrophyte Cover: The macrophyte habitat value data layer was created by overlaying a 1- ac cell grid on the entire lake. Each 1-ac cell was scored based on the percent macrophyte cover as shown in Figure M.8. If a cell fell beyond the depth at which macrophytes grow, or there were no data, then it received a score of "0" for 0 percent cover. Scores of 1, 2, 3, 4, and 5 were assigned to cells with 1 to 20 percent cover, 21 to 40 percent cover, 41 to 60 percent cover, 61 to 75 percent cover, and 76 to 100 percent cover, respectively.

Frequency of Fish Nesting: The fish habitat value data layer was created by overlaying a 1-ac cell grid on the entire lake. Each 1-ac cell was scored based on the frequency of fish nesting sites in each 600 m^2 area of the lake as shown in Figure M.11. Because the magnitude of the nesting frequencies for bass (generally in the hundreds) and sunfish (generally in the thousands) are different, they were evaluated separately. Polygons that fell below the depth at which either species nest (e.g., 3 m for sunfish; 7 m for bass), or for which there were no data, received a score of "0." In cells where fish nests were absent for either species, a score of “1” was assigned. In cells where the number of bass nests/600 m^2 area equaled 1 to 100, 101 to 300, or were greater than 300, received a score of 2, 3, or 4, respectively. In cells where the number of sunfish nests/600 m^2 area equaled 1 to 1000, 1001 to 3000, or were greater than 3000, received a score of 2, 3, or 4, respectively.

Status of Benthic Macroinvertebrate Community: The macroinvertebrate habitat value data layer was created by overlaying the 1-ac cell grid on the entire lake. Each 1-ac cell was scored based on levels of impairment to the macroinvertebrate community using the data shown in Figure M.14. Cells with no data received a score of “0.” Cells with impairment rankings of severe, moderate, slight, or non-impaired, received a score of 1, 2, 3, or 4, respectively.

Integrated (Final) Habitat Value Map: An integrated habitat value map was developed based on data layers created from: 1) macrophyte percent total cover (all species combined), 2) degree of benthic macroinvertebrate community impairment, and 3) number of fish nests/600 m^2. The value for each 1-ac cell in the integrated habitat value map was calculated by averaging the values from the individual data layers (Figure M.23).

Fish spawning activity (number of nests) are highest in the northwestern portion of SMU 5. Moderate spawning activity occurs in the southeastern portion of SMU 5 and near Ninemile Creek (SMU 4). In general, the lowest spawning activity is in the southern portion of the lake. Benthic macroinvertebrate community status varies throughout the lake, with the most impaired communities found in SMUs 1, 2, 6, and 7 in the southern portion of the lake. Submerged macrophytes are distributed throughout the littoral zone, with larger beds in SMU 6, at the intersection of SMUs 3 and 4, and in the northern portion of SMU 5.

As shown by the existing in-lake habitat value (Figure M.23), overall habitat conditions are generally poorest in the southern portion of Onondaga Lake, with the exception of large macrophyte beds (SMUs 6 and 7) and contiguous wetland (SMU 6). As such, the southern portion of the lake should be prioritized for habitat restoration and enhancement activities to meet the objectives stated in Subsection M.2.2.2. SMUs 1, 2, and 3, in particular, have steeper slopes, calcitic sediments, and limited macrophyte cover, which present significant challenges that should be addressed. As previously discussed, submerged macrophytes provide critical habitat functions in the littoral zone of Onondaga Lake, including shelter, nesting sites, food for fish and wildlife, substrate and food for epiphytic macroinvertebrates, and stabilization of soft sediments (EcoLogic, 1999).

SECTION M.4

POTENTIAL HABITAT RESTORATION AND ENHANCEMENT OPPORTUNITIES IN ONONDAGA LAKE

As discussed in Section M.2, habitat restoration and enhancement will be planned as part of remedial actions identified in the FS. The overall approach and end results are the same for restoring or enhancing the habitat conditions, the only difference is whether any habitat improvements are preceded by remedial actions. **Habitat restoration** is defined as the replacement of habitat in areas where remediation substantially alters existing conditions (Figures M.4 through M.29). **Habitat enhancement** is defined as improving habitat conditions in areas where CPOIs do not occur at levels that warrant active remediation (Figures M.24 through M.29). Section M.2 described the habitat restoration and enhancement principles that are being followed and the following habitat restoration and enhancement objectives:

- Increase diversity and abundance of desirable submerged macrophyte species (e.g., *P. pectinatus, P. nodosus, V. americana*).
- Increase 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.

These objectives are consistent with those of ongoing and planned federal, state, and county programs aimed at improving habitat conditions in Onondaga Lake (see Attachment A for a summary of those other programs). Many of those programs have objectives targeting increases in submerged macrophyte distribution and cover, and improvements in fish reproduction in the lake.

The distribution and extent of macrophytes is one of the primary factors related to the success of fish reproduction in Onondaga Lake (Auer *et al*., 1996; EcoLogic, 1999, 2001; OCDWEP, 2003). Macrophyte distributions in the lake are controlled by various factors, including light availability, nutrients, water depth, wave and ice exposure, salinity, grazing by animals, and substrate characteristics, such as grain size, chemistry, and stability (including slope). Many of these same factors, particularly substrate characteristics, also influence macroinvertebrate species composition and fish use (spawning) because they are related to food availability and substrate stability. These habitat characteristics are shown for SMUs 1 through 8 in Figures M.15 through M.22. These factors were considered in developing the habitat restoration and enhancement options discussed below. These options were developed to maximize the area within each SMU with the physical conditions (primarily substrate and depth) to support submerged macrophyte species and fish spawning.

The SMU-specific habitat restoration and/or enhancements described below focused on improving conditions related to the fish community in the lake through providing physical conditions (e.g., depth and substrate) suitable for macrophyte colonization and fish spawning – the latter in areas that are likely too deep for macrophyte colonization. These two habitat types are not mutually exclusive, and there is overlap in the depth and substrate conditions in which they exist. Emergent wetlands and riparian habitat features are also being considered to enhance habitat conditions for terrestrial wildlife (i.e., birds and mammals) around the lake and to increase connectivity between upland, shoreline, and in-lake habitats (Figure M.25). These habitat restoration and/or enhancement projects focus on improving biological and physical conditions in the littoral zone and depend on maintaining sufficient areas of the lake in water less than 15 ft (5 m) deep. The remainder of this section discusses the following:

- Overview of habitat types, target species, and associated requirements considered.
- SMU-specific habitat restoration and enhancement projects.

M.4.1 HABITAT TYPES, TARGET SPECIES, AND ASSOCIATED REQUIREMENTS

Habitat types and target species identified in this subsection were derived from those identified by other environmental programs for Onondaga Lake (see discussion in Attachment A). The restoration and enhancement of these target species and/or their habitats should provide a foundation for the immigration and colonization of a broad range of related species. Three habitat types (in-lake habitat, submerged macrophytes, and emergent wetlands) were considered in the overall identification of habitat restoration and enhancement approaches for Onondaga Lake. The remainder of this subsection discusses the following:

- In-Lake Habitat (Table M.3 – Subsection M.4.1.1);
- Submerged Macrophytes (Table M.4 – Subsection M.4.1.2);
- Emergent Wetlands (Table M.5 – Subsection M.4.1.3); and
- Habitat Area Calculations by SMU (Table M.6 – Subsection M.4.1.4).

M.4.1.1 In-Lake Habitat

In-lake habitats are those conditions that would support warm-water fish populations. The primary habitat features identified to address in-lake habitat include fish spawning substrates, large woody debris, and submerged macrophytes. The target fish species include walleye (*Stizostedion vitreum*), largemouth bass, smallmouth bass, bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*). Their habitat requirements are shown in Table M.3.

Based on information for the target species and to account for possible settling or erosion of material, a water depth of 6 to 15 ft (2 to 5 m) was selected for determining the areal extent of fish spawning substrates in each SMU (Tables M.6 and M.7), except for the walleye, which is known to spawn in shallower areas. The amount of large woody debris varies based on the target species (Table M.6).

M.4.1.2 Habitat Area Calculations by SMU

Submerged macrophytes provide important habitat in the littoral zone of Onondaga Lake (EcoLogic, 1999). For example, macrophytes provide shelter, nesting sites, and food for fishes and wildlife, substrate and food for epiphytic macroinvertebrates, and a stabilizing influence on soft sediments. Macrophyte distributions in the lake are controlled by various factors, including light intensity, nutrients, water depth, wave and ice exposure, salinity, grazing by animals, and substrate characteristics, such as grain size, chemistry, and stability. The submerged macrophyte beds in Onondaga Lake are currently dominated by *P. pectinatus*, *H. (Zosterella) dubia*, *E. canadensis*, *C. demersum*, *P. crispus*, and *M. spicatum*.

Onondaga County's AMP has shown "substantial positive changes" in the macrophyte distribution between 1991 and 2000 (EcoLogic, 2001). There are currently 10 species documented in the lake; however, recent results show that greater than 90 percent of the cover and biomass was dominated by only three species (*P. pectinatus*, *E. canadensis*, and *Z. dubia*). The 2000 survey of macrophytes indicated a substantial increase in the frequency of macrophytes from 13 percent of the study subplots in 1991 to 47 percent of the subplots in 2000, with the majority of new macrophyte beds found in areas with low wave energy. However, although 40 percent of the littoral zone of the lake had macrophytes, the beds are relatively sparse, and biomass is low except in the northwest portion of the lake.

Table M.4 lists three target-species submerged macrophyte habitat restoration and enhancement: *P. pectinatus*, *P. nodosus*, and *V. americana*. These native species are currently found in Onondaga Lake or adjacent tributaries and have propagules that are easily handled and are readily available from other commercial sources for revegetation efforts (if necessary). In addition, *P. pectinatus* and *P. nodosus* performed well in oncolitic sediments in laboratory experiments (Madsen *et al*., 1996). A water depth of 2 to 6 ft (0.6 to 2 m) was selected for determining the areal extent of submerged macrophyte habitat in each SMU. The areal extent of submerged macrophytes varies based on the specific requirements of the target macrophyte species and target fish species (Table M.6).

M.4.1.3 Emergent Wetland

Emergent wetlands are being considered in nearshore shallow areas with water depths of 6 inches to 2 ft (15 to 60 cm) (Table M.5, Figures M.26, M.27, and M.28). The specific areas where emergent wetlands are being considered are either directly adjacent to existing wetlands (e.g., SMU 7) or where wetlands historically occurred (e.g., SMU 3). Target species are narrow-leaved cattail (*Typha angustifolia*), soft-stem bulrush (*Scirpus tabernaemontani*), and eastern bur-reed (*Sparganium eurycarpum*). Narrow-leaf cattail was selected because of its tolerance of deep water. Deeper water would exclude *Phragmites* from colonizing created wetlands. Soft-stem bulrush and eastern bur-reed do well when planted in shallow water or at the edge. If conditions are favorable, they will colonize deeper water. These shallow-water wetlands are designed to provide cover for juvenile fish and can also serve as breeding habitat for wading birds such as the American bittern and Virginia rail. Additional wetland species will be considered during remedial design.

M.4.1.4 Habitat Features for Each SMU

The areal extent of habitat restoration or enhancement features for each SMU is shown in Table M.6. These areas are based on habitat requirements for the target species from Tables M.3 through M.5, and show the range of habitat features (e.g., acres of submerged macrophytes) for each SMU. As shown on Table M.6, a range of habitat cover is acceptable for each target fish species. This habitat cover could be provided by large woody debris structures, by submerged macrophytes, or by a combination of the two. As stated in Subsection M.4.1.2 (and Table M.4), 95 percent of submerged macrophytes have been found in water depths less than approximately 6 ft (2 m) (EcoLogic, 2001). Fish spawning substrates are generally in the 6- to 15-ft (2- to 6-m) depth range, with the exception of walleye, which spawn in shallower waters. This information was combined to estimate the number of large woody debris structures and the acres of submerged macrophytes for each SMU that could be used to meet the habitat restoration and enhancement objectives. The specific areal extent of each habitat feature would be determined during the design phase.

M.4.2 SMU-SPECIFIC HABITAT RESTORATION AND ENHANCEMENT

SMU-specific habitat restoration and enhancement projects for consideration are summarized in Table M.7, and conceptual cross sections are illustrated on Figures M.24 through M.29. Primary, secondary, and additional habitat elements are identified for each SMU, based on consideration of existing bathymetry (Figure M.1), existing adjacent shoreline wetland habitat (Figure M.9), existing in-lake habitat (Figures M.2 through M.9, Figures M.11 through M.14 and Figure M.23), wind/wave exposure (i.e., the velocity regime as defined by EcoLogic, 2001), and habitat requirements for target species (Tables M.3 through M.5). Target species and habitat requirements are discussed in greater detail in Subsection M.4.2. Although this subsection is written on a SMU-specific basis, it will ultimately be necessary to evaluate remedial alternatives on a lake-wide basis to ensure that conditions are apportioned to facilitate meeting the habitat goals and objectives on a lake-wide scale. In specific locations, preservation of existing habitats may be the most appropriate and reasonable approach to achieve lake-wide objectives.

In Table M.7, the primary habitat represents the potential habitat type with greatest areal extent for each SMU, based on existing bathymetry and slope (Figures M.1 and M.2). Secondary habitat represents potential habitat with a smaller spatial extent than the primary habitat. For each of the SMUs, either fish spawning substrates or submerged macrophytes are identified as primary or secondary habitat types (Table M.7). Substrates (e.g., fine gravel, sand) and water depths are directly related to the target species identified in Subsection M.4.2. Substrates are expected to make up 100 percent of the areal extent of the habitat areas identified in Table M.7. The estimated areal extent of submerged macrophyte beds will vary from SMU to SMU, to provide variable habitat suitable for the target fish species (e.g., 15 to 60 percent macrophyte cover, depending on species). However, the substrates in which the macrophytes will be established (i.e., sand or existing substrates) will comprise 100 percent of the area targeted for submerged macrophytes.

Additional habitat features for each SMU are also identified on Table M.7 and include wetlands, shoreline treatments (e.g., shoreline stabilization, riparian overhang), or large woody debris. Emergent wetlands are identified as an additional habitat feature for SMUs where contiguous emergent or forested wetlands currently exist (SMU 1, 4, 5, 6, and 7). In addition, wetlands are also included as an additional habitat feature for SMU 3 where wetlands do not currently exist. The designation of wetlands as a habitat feature does not imply that wetlands are being considered for the entire spatial extent of the SMU.

Large woody debris provides cover for fishes, generally increases their reproductive success, and can create velocity breaks allowing for greater macrophyte colonization. Large woody debris (weighted, as shown in Figures M.24 through M.29) is identified in conjunction with primary and secondary habitat types. This habitat feature is identified in areas with high oncolite conditions or high velocity regimes where the large woody debris can potentially stabilize existing substrates. The percentage of large woody debris will be variable from SMU to SMU (Table M.7), with an overall objective of having debris cover of 25 percent to 60 percent suitable for the target species identified in Subsection M.4.1.2.

The remainder of this subsection discusses the SMU-specific habitat analysis summarized in Table M.7 in relation to current conditions and provides a brief rationale for the approach described. Subsection M.4.1 identifies the target species and habitat requirements for each of these habitat types. Energy regimes listed in the descriptions are based on EcoLogic (1999).

M.4.2.1 SMU 1 – In-Lake Waste Deposit

The primary habitat that should be considered for SMU 1 is fish spawning substrate based on bathymetry and slope, with secondary habitat of submerged macrophytes (Table M.4). Figures M.24, M.25, and M.26 illustrate the types of habitats that could be developed in this area as part of the remedial alternatives analysis. Figures M.24 and M.25 identify habitat cross sections that take into account the slope and armor likely to be necessary for the medium/high velocity regime of the lake in this area. The difference between the approaches shown in these two figures is the riparian overhang, which could increase shoreline cover for fishes and benthic macroinvertebrates. Figure M.26 illustrates a habitat option that includes extension of the existing contiguous forested wetlands into an emergent wetland, which is also a viable habitat for this area of the lake given adjacent contiguous wetlands. (Note: creation of an emergent wetland in this area is contingent on remediation of upland areas.)

M.4.2.2 SMU 2 – Causeway Littoral Area

The primary habitat that should be considered for SMU 2 is fish spawning substrate, with secondary habitat of submerged macrophytes (Table M.3). Large woody debris interspersed within these areas would provide habitat variability. SMU 2 lacks contiguous wetlands and shoreline cover due to the adjacent roadway and land use in the area. Figures M.24 and M.25 provide illustrations of potential habitat conditions that could be established or enhanced in this area.

M.4.2.3 SMU 3 – Wastebeds 1 through 8 Littoral Area

A range of habitat approaches can be considered for SMU 3. The shoreline of SMU 3 is unstable and has the potential to erode during wind/wave events. Stabilization of the shoreline would reduce erosion and potentially improve water quality conditions in the nearshore littoral zone. Shoreline stabilization could include rock riprap with joint plantings, live fascines (e.g., woody vegetation bundles, such as *Salix* spp.), and/or vegetative mattresses (e.g., brush material buried in trenches). Over time, plant species will root and expand to cover and protect the shoreline. For the littoral zone of SMU 3, the primary habitat that should be considered is fish spawning substrate, with a secondary habitat type of submerged macrophytes (Table M.7). Current conditions in the lake show that this area has some macrophyte colonization (Figure M.9) but only very limited densities of fish nests or YOY fishes (Figures M.11 through

M.13). Due to the shallow slope of the adjacent uplands and shoreline (except in the northern portion of the SMU, which has steep slopes at the shoreline), this area may be suitable for the establishment of a constructed forested wetland, emergent wetland, and other in-lake habitats, as illustrated on Figure M.27. Figures M.28 and M.29 also illustrate habitats that could be considered for this area.

M.4.2.4 SMU 4 – Mouth of Ninemile Creek Littoral Area

SMU 4 consists of the Ninemile Creek delta, with shallow depths that could support submerged macrophytes as a primary habitat type. However, as is the nature of deltaic areas, sediment deposition and movement during high flow events creates variable conditions that may inhibit macrophyte colonization. Studies in the lake have documented considerable use of this area by YOY fishes (Figures M.11 through M.13). Therefore, the primary habitat that should be considered for SMU 4 is fish spawning substrates, with secondary habitat of submerged macrophytes (Table M.7). Preservation of existing habitat in this area is recommended (Figure M.23). Figures M.26, M.28, and M.29 illustrate the types of habitats that could be developed or enhanced at SMU4. Emergent wetlands (Figure M.26) could be considered in the vicinity of the contiguous forested wetlands near the mouth of Ninemile Creek (Figure M.9). (Note: creation of an emergent wetland in this area is contingent on remediation of upland areas).

M.4.2.5 SMU 5 – Littoral Area

SMU 5 is the largest of the littoral zone SMUs and includes areas of differing energy regimes and existing habitat conditions (Figure M.30). Therefore, SMU 5 has been divided into three separate areas based on energy regime, discussed separately in Table M.7 as SMU 5 Northwest (NW), Northeast (NE), and Southeast (SE).

SMU 5 NW

The northwestern portion of SMU 5 is in the area with the lowest energy (EcoLogic, 2001) and with elevated levels of calcium carbonate and oncolites in sediments (Figures M.5 and M.6). Existing conditions also include an adjacent forested wetland (SYW-6) (Figure M.9), and macrophytes (Figure M.8; EcoLogic 2001). However, the macrophyte beds are not very dense (EcoLogic, 2001). Preservation of existing habitats in this area is recommended, as considerable densities of fish nests and YOY fishes have been documented in the northwestern portion of SMU 5 (Figures M.11 through M.13 and Figure M.23). Habitat approaches considered include placement of large woody debris to provide stabilization of oncolites during high energy events and to potentially enhance colonization of those areas by submerged macrophytes. Submerged macrophyte interspersed with large woody debris should be considered as the primary habitat for this portion of SMU 5, with fish spawning substrate as the secondary habitat (Table M.7). Emergent wetlands can also be considered for this area due to proximity to contiguous forested wetlands (SYW-6). Figure M.26 illustrates the type of habitat that could be developed for this area.

SMU 5 NE

The northeast portion of SMU 5 is in the area with a medium energy regime (EcoLogic, 2001), and also has elevated levels of calcium carbonate and oncolites in sediments (Figures M.5 and M.6). Wetland SYW-1 is located inshore of this area but is not hydraulically connected to the lake (it is connected to Sawmill Creek). Submerged macrophytes have colonized this area of the lake (Figure M.8), and studies have indicated an increase in density and diversity over time (EcoLogic, 2001). Similar to the northwestern portion of the SMU, the northeast portion of SMU 5 supports fish reproduction, but the densities of fish nests and YOY fishes are lower than those in the northwestern portion of SMU 5 (Figures M.11 through M.13 and Figure M.23). Preservation of existing habitats in this area is recommended. The primary habitat that should be considered for this area is fish spawning substrates, with secondary habitat of submerged macrophytes and large woody debris. The latter would provide stabilization of oncolites during high energy events, potentially enhancing macrophyte colonization. Figure M.29 illustrates the type of habitat that could be developed for this area.

SMU 5 SE

SMU 5 SE is located in a high-energy part of the lake (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 (see Attachment A). The southeastern portion of SMU 5 shows less use by YOY fishes than either the northwestern or northeastern portions of SMU 5. Submerged macrophytes exist in this area (Figure M.8) and may expand if the wave energy could be abated. The primary habitat that should be considered for this area is fish spawning substrate, with large woody debris to provide cover and increase fish reproductive success. The secondary habitat is submerged macrophytes with large woody debris. However, habitat improvements in this portion of SMU 5 should only be considered once details regarding the in-lake portion of the Onondaga Lake Trail are finalized. Figure M.29 illustrates the type of habitat that could be developed for this area.

M.4.2.6 SMU 6 – Ley Creek to Onondaga Creek Littoral Area

A portion of SMU 6 is currently being considered for habitat restoration/enhancement as part of the in-lake portion (Trail Section 3c) of the Onondaga Lake Trail project (see Attachment A). SMU 6 is located in the high-energy regime of the lake (Appendix H; EcoLogic, 2001). Studies show limited fish nesting in this area (Figure M.11). Data on YOY fishes in this area have not been collected. Current habitat conditions include submerged macrophytes, and preservation of this habitat is recommended (Figure M.23). Due to the existence of these beds, the primary habitat that should be considered is submerged macrophytes (Figure M.9). The secondary habitat is fish spawning substrate with large woody debris to provide cover and wave energy abatement (Table M.7). Figure M.26 illustrates the type of habitat that could be developed in this area. Land use in the portion of SMU 6 southwest of Onondaga Creek limits the opportunity for development of habitat in this area. Conceptual approaches for habitat improvements for this portion of SMU 6 are shown in Figure M.24. However, habitat improvements in SMU 6 should only be considered once details regarding the in-lake portion of the Onondaga Lake Trail are finalized.

M.4.2.7 SMU 7 – Onondaga Creek to ILWD Littoral Area

SMU 7 is a small area of the lake identified as having a high energy regime (Appendix H, capping issues; EcoLogic, 2001). This area offers little shoreline cover, and adjacent land is predominantly developed. Expansion of macrophyte beds in this area has been observed over the last 10 years (EcoLogic, 2001). *Potomagetan pectinatus,* one of the target species discussed in Subsection M.4.1, has colonized this area of the lake; however, the density of macrophyte beds is limited (Figure M.8). The primary habitat that should be considered for SMU 7 is submerged macrophytes (Table M.7), and secondary habitat is fish spawning substrate with large woody debris. Emergent wetlands could also be considered for this area due to proximity to the wetland (SYW-19) hydraulically connected to the lake. The spatial extent of the emergent wetland would likely be less than 0.5 ac (0.2 ha). (Note: creation of an emergent wetland in this area is contingent on remediation of upland areas). Figures M.24, M.28, and M.29 provide conceptual habitat cross sections for SMU 7.

M.4.2.8 SMU 8 – Profundal Area

SMU 8 is the profundal zone of Onondaga Lake at water depths greater than 30 ft (9 m). Soft-bottom habitat for benthic macroinvertebrate communities is the primary habitat type. The use of the profundal zone by benthic macroinvertebrates and fishes is limited due to the anoxic conditions that develop during the period of lake stratification (i.e., from approximately May to October). However, should these conditions change, the existing substrates of the lake could provide suitable habitat for benthic macroinvertebrate colonization of the profundal zone of the lake.

SECTION M.5

MONITORING AND DESIGN CONSIDERATIONS

M.5.1 MONITORING PROGRAM

A monitoring program should be developed to assess the performance of the habitat replacement/enhancement actions, showing whether the defined objectives are being met. Monitoring would also provide information that can improve the implementation and performance of the actions. The monitoring program should also include adaptive management protocols to identify problems and to select and implement corrective actions that facilitate meeting project objectives.

Monitoring is a critical element of adaptive management, an interactive process that regularly reexamines prior choices in the light of current outcomes (Wilber and Titre, 1996). This incremental management process employs a flexible design, in which management actions may continually change to respond to new information, generated by monitoring, on progress and attainment of desired functional trajectories. This approach maximizes the ability of management activities to achieve desired trajectories and defines when the project can be considered successful and the monitoring ends (Yozzo *et al.,* 1996; Thom and Wellman, 1996).

Following Thom and Wellman (1996), the monitoring program should be used to:

- Assess the performance of the restoration/enhancement activities relative to the project goals;
- Provide information that can be used to improve the performance of the project through the adaptive management protocols; and
- Provide information to interested parties.

Specific elements and the duration of the monitoring program would be dictated by the nature and extent of selected habitat restoration/enhancement projects and may include:

- Monitoring of percent survival of installed material (submerged macrophytes, emergent vegetation, shrubs, trees);
- Monitoring the use of restored/enhanced habitats by biological organisms; and
- Monitoring in both created/enhanced habitat areas and reference areas for comparison.

M.5.2 DESIGN CONSIDERATIONS

Lacustrine systems are complex, with diverse and abundant populations of animals and plants. To attempt to incorporate every component of each habitat in the restoration and enhancement designs is beyond the scope of normal operating guidelines. However, certain components of restoration and enhancement designs are commonly used in design plans and specifications. These components were shown conceptually in Section M.4, and more specific details will be developed during the remedial design phase. At a minimum, details for the design components described in the following sections will be developed during the remedial design phase.

M.5.2.1 Planting Plans

Submerged macrophyte species that could be restored would include species native to Onondaga Lake and readily available from nearby sources. These species include Sago pondweed (*P. pectinatus*), wild celery (*V. Americana*), and American pondweed (*P. nodosus*). Planting densities would depend on whether seeds, tubers, or adult shoots were installed.

Emergent wetlands could be restored on the shore of Onondaga Lake and could incorporate species that presently occur within the lake and surrounding wetlands. Three species have been selected for planting. Narrow-leaf cattail was selected because of its tolerance of deep water. Deeper water would exclude *Phragmites* from colonizing created wetlands. Soft-stem bulrush and eastern bur-reed do well when planted in shallow water or at the edge. If conditions are favorable, they will colonize deeper water.

Consideration for use of other species in the planting plans will be made during the design phase and in consultation with NYSDEC.

M.5.2.2 Elevation/Topographic Requirements

Water depth is a critical factor when establishing wetland communities. Elevation gradients for constructed wetlands depend on final grades after the remedial measures are implemented. For example, the forested wetland at the mouth of Ninemile Creek is located at 366 ft (112 m) above mean sea level. This elevation provides a benchmark for establishing a forested wetland community on the shore of Onondaga Lake.

M.5.2.3 Subgrade and Soil Requirements

Soil conditions for wetland creation must be appropriate to promote growth of the target species. An organic substrate is needed to allow initial rooting depth for the planted species. Subsoil material is needed to provide for root expansion and stability for the planted species in places where shoreline areas cover abandoned waste beds.

M.5.2.4 Hydrologic Monitoring

Establishment of wetland restoration areas depend on achieving targeted water depths. Prior to wetland restoration, hydrologic monitoring during one complete growing season is recommended. Monitoring wells, staff gauges, and/or automated data loggers should be installed in wetland restoration areas. Once these data have been collected, they can be compared with long-term lake level data to predict water level elevations in the wetland restoration areas.

M.5.2.5 Invasive Species Control

Common reed grass (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*) are invasive exotic species found in wetland restoration projects. Several methods can be used to control these species, including designing the wetland restoration area with a water depth that will exclude the invasive species. Proper substrate preparation includes removing all invasive species and their rootstock and removing nearby seed sources.

Control methods for invasive species after they have become established are much more difficult. Purple loosestrife can be limited by release of biological control agents such as specific beetles that use purple loosestrife exclusively for a food source. The release of the beetles may be required several years in a row to establish control.

Common reed grass is a very aggressive invasive species that frequently requires using both burning and chemical control methods (Ailstock *et al*., 2001). Control of common reed grass by cutting and spot application of an herbicide can be effective if implemented before the plant becomes established.

SECTION M.6

CONCLUSIONS

The main conclusions are based largely on the Onondaga Lake habitat restoration and enhancement principles described in Section 2 and on review of existing conditions in the lake:

- Valuable habitats currently exist in the lake and should be preserved to the extent possible during remedial activities and restoration projects (e.g., current fish spawning, nursery, and foraging areas should not be destroyed or altered for habitat restoration, unless otherwise required by remedial alternatives). In areas where valuable habitat conditions exist, the more these areas are altered, the more difficult it will be to attain desired habitat related outcomes following remediation.
- Habitat restoration and enhancement should include habitat heterogeneity by targeting a balance of macrophyte beds, fish spawning substrate, and cover (e.g., large woody debris) in proportions optimized for the target fish species.
- Existing physical conditions such as water depth, bottom slope, type of substrate, current ecological function (fish spawning, foraging, etc.) and the energy level of the environment need to be considered when developing habitat restoration and enhancement opportunities.
- Connectivity of in-lake and shoreline/upland habitats should be increased where practicable, provided such connectivity does not facilitate the transfer of contaminants. The potential for adverse effects associated with connectivity should be closely monitored.

SECTION M.7

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APPENDIX M

TABLES

TABLE M.1
GLOSSARY OF TERMS

Term	Definition
anoxic	Containing no dissolved oxygen. Commonly used to indicate an environment that cannot support life, except for some types of bacteria.
benthic macro-invertebrate	Small but visible animals (e.g., insects, worms, clams, and snails) that live in or on the sediment at the bottom of a lake or stream.
bioaccumulation	The uptake and retention of substances from their surroundings by plants and animals.
biologically active sediment	The top 6 inches (15 centimeters [cm]) of sediment where the majority of benthic macroinvertebrates reside and biological activity occurs.
calcite	A mineral composed of calcium and carbonate.
diffusion	The movement of dissolved constituents from areas of high concentration to areas of low concentration.
epilimnetic	Associated with the epilimnion.
epilimnion	During summer stratification, the upper portion of the water column located between the 0 and 30 feet (ft) (9 meters [m]) water depth in Onondaga Lake. The epilimnion is warm and well mixed by wind and waves.
eutrophication	The change in biological, chemical, and physical conditions in a lake caused by increasing concentrations of algal nutrients (e.g., phosphorus) usually caused by human activities. Results of eutrophication include low water clarity, low dissolved oxygen, floating algae, anoxic conditions in the hypolimnion, changes in biological communities, and unpleasant odors.
hypolimnetic	Associated with the hypolimnion.
hypolimnion	During summer stratification, the lower portion of the water column between the 30 and 60 ft (9 to 18 m) water depth in Onondaga Lake. The hypolimnion is cool and not well mixed by wind and waves.
littoral sediment	Sediments located beneath epilimnetic water in water depths less than 30 ft (9 m).
macrophyte	Plants large enough to be seen without magnification. They may be rooted or free floating.
mass balance analysis	A method to account for the amount (mass or weight) of material that enters, exits, or accumulates in a lake by identifying and quantifying sources, sinks, and changes in concentration over a period of time. Ideally, the sum of sources and sinks equals the amount that accumulates.

TABLE M.1 (Continued)
GLOSSARY OF TERMS

Term	Definition
mercury methylation	The process of bonding an organic molecule (a methyl group) to a mercury atom (mercuric ion) to form a new chemical, methylmercury.
methane gas ebullition	The process whereby gas bubbles that contain methane formed by bacteria in the sediments are released from the sediment to overlying lake water.
oncolites	Irregularly rounded, calcareous nodules that range in size from 0.5 to 30 cm and are not attached to substrates.
oxic	Containing dissolved oxygen. Commonly used to indicate a chemically oxidizing environment where substances like sulfide are not stable.
oxygenated	Water that was exposed to air/oxygen and as a result has dissolved oxygen.
pelagic	Living or occurring in the deeper waters of the lake as opposed to near the shore.
phytoplankton	Microscopic plant life (i.e., algae) that live in the water column of a lake and serve as food for zooplankton and some fish species.
plankton	Passively floating or weakly swimming, usually minute animals and plant life of a body of water.
profundal	The area of deep water at the bottom of a lake below the effective penetration of light.
profundal sediment	Sediments located beneath hypolimnetic water in water depths greater than 30 ft (9 m).
resuspension	The process of lifting sediment particles from the bottom of a lake into the overlying water. Resuspension can be caused by forces such as water turbulence from waves and currents, bottom-feeding fish (e.g., carp), and methane gas ebullition. The particles may settle back to the bottom or be carried away by currents.
stratification	Containing distinct layers. During summer stratification from approximately mid-May to mid-October, Onondaga Lake consists of two layers of water (i.e., the hypolimnion and the epilimnion).
substrate	The base on which organisms live. For this appendix, substrate is the sediment (either existing or placed) for plant colonization or fish spawning.
surface layer of profundal sediment	Under current anoxic conditions, the top 0 to 4 cm of profundal sediment in Onondaga Lake may be considered the surface layer of the profundal sediments. However, after oxidation, a minimum of 10 cm should be considered as the surface layer.

TABLE M.1 (Continued)
GLOSSARY OF TERMS

Term	Definition
thermocline	The boundary between the epilimnion and hypolimnion where the water temperature changes the fastest.
unconsolidated bottom	Those areas with at least 25 percent cover of particles smaller than stones, and a vegetative cover less than 30 percent (Cowardin *et al*. 1979). Unconsolidated bottoms are characterized by the lack of large, stable surfaces for plant and animal attachment.
zooplankton	Small planktonic animals that live in the water column of the lake and serve as food for some fish species.

Note: Definitions specific to Onondaga Lake are so noted.

TABLE M.2
SUBMERGED MACROPHYTE TRANSPLANTING REQUIREMENTS

Submerged Macrophyte Transplanting Requirement	Criteria	Existing Conditions in Onondaga Lake
Depth (shoreline configuration)	1 to 5 ft (0.3 to 1.5 m) below mean low water	See Figure M.1.
Light attenuation	<6 ft^{-1} (<2 m^{-1})	Historical trends in Secchi disk transparency: South Deep Station June 1 to Sept 30 from 1990 to 2002. Average is 6.72 ft (2.05 m) with an increasing trend (OCDWEP, 2003).
Total suspended solids	<15 milligrams per liter (mg/L)	The upper water of the lake is approximately 4 mg/L (OCDWEP, 2003).
Chlorophyll *a*	<15 micrograms per liter (μg/L)	Historical trends (1992 to 2002) in upper waters from mid-May to mid-September. Average is 17.6 μg/L (OCDWEP, 2003).
Dissolved inorganic phosphorus	<0.02 mg/L	Average total phosphorus is 40 *m*g/L during the summer in upper waters (OCDWEP, 2003).
Sediments	Sandy silts with 1 to 5 percent organic matter	See Figures M.3 and M.4.
Wave and current protection	More exposed areas generally less suitable, unless protection from wind/wave energy is provided.	See Figure M.7.

TABLE M.3
IN-LAKE HABITAT

Habitat Requirement	Target Species			
	Walleye[a]	Largemouth Bass[b]	Smallmouth Bass[c]	Bluegill and Pumpkinseed[d]
Depth	Shallow shoreline areas	25 to 60 percent < 18 ft (6 m)	3 to 15 ft (1 to 5 m)	3 to 9 ft (1 to 3 m)
Fish spawning substrate	Gravel, rubble	Gravel: 0.08 to 2.5 inches (0.2–6.4 cm)	Gravel: 0.63 to 0.78 inches (1.6–2.0 cm)	Sand, fine gravel
Velocity (during spawning)	Moderate	< 0.13 ft/sec (4 cm/sec)	NA	< 0.26 ft/sec (8 cm/sec)
Macrophyte cover	25 to 45 percent	40 to 60 percent	25 to 50 percent (fry)	15 to 30 percent
Large woody debris (logs, brush)	25 to 45 percent	40 to 60 percent	25 to 50 percent (adults)	20 to 60 percent

[a] McMahon *et al*. (1984). Note that the total of 25-45 percent cover can be provided by macrophytes and/or large woody debris.

[b] Stuber *et al*. (1982a). Note that the total of 40-60 percent cover can be provided by macrophytes and/or large woody debris.

[c] Edwards *et al*. (1983)

[d] Stuber *et al*. (1982b)

TABLE M.4
SUBMERGED MACROPHYTES

Habitat Requirement	Target Species		
	Sago pondweed (*Potamogeton pectinatus*)	**American pondweed (*Potamogeton nodosus*)**	**Wild celery (*Vallisneria americana*)**
Depth[a]	< 6 ft (2 m)	< 6 ft (2 m)	< 6 ft (2 m)
Energy	Wave tolerant	Moderately wave tolerant	Moderately wave tolerant
Habitat Structure	Meadow forming	Canopy forming	Meadow forming
Substrates	6 inches (15 cm) of sand or silty sand		

[a] Depth is identified based on current conditions of water clarity and water velocity. Ninety-five percent of macrophytes are located in water depth of 6 ft (2 m) or less (EcoLogic, 2001). Water clarity will be positively influenced by aeration, such that increased oxygen will increase the depth at which macrophyte colonization can be expected. Thus, substrates planned for this zone (e.g., sand) of habitat may extend beyond the 6-ft (2-m) depth currently observed.

TABLE M.5
EMERGENT WETLAND

Habitat Requirement	Target Species		
	Narrow-leaved cattail (*Typha angustifolia*)	**Soft-stem bulrush (*Scirpus tabernaemontani*)**	**Eastern bur-reed (*Sparganium americanum*)**
Water depth	6 to 24 inches (15 to 60 cm)	0 to 6 inches (0 to 15 cm)	0 to 15 inches (0 to 15 cm)
Rooting depth	12 to 24 inches (30 to 60 cm)	12 to 24 inches (30 to 60 cm)	12 to 24 inches (30 to 60 cm)
Substrates	Surface: 6 inches (15 cm) of organic matter Subsurface: 6 inches (15cm) of fine/coarse sand		

TABLE M.6

HABITAT AREA CALCULATIONS BY SMU[a]

Habitat Type:	Fish Spawning Substrate - Large Woody Debris (LWD)												#LWD			#LWD		
Species:	Walleye			Largemouth Bass			Smallmouth Bass			Bluegill/Pumpkinseed			Structures[c]			Structures[c]		
Depth interval:	2-6 ft[b]			6-15 ft			6-15 ft			6-15 ft			2-6 ft			6-15 ft		
Percent cover:	25%	35%	45%	40%	50%	60%	25%	38%	50%	20%	40%	60%	25%	to	45%	20%	to	60%
Acres:																		
SMU 1	8	11	14	8	10	12	5	7	10	4	8	12	1	to	2	1	to	2
SMU 2	2	3	3	3	4	4	2	3	4	1	3	4	0	to	1	0	to	1
SMU 3	7	10	12	11	14	17	7	10	14	6	11	17	1	to	2	1	to	3
SMU 4	5	8	10	8	10	12	5	7	10	4	8	12	1	to	2	1	to	2
SMU5 NW	10	14	18	13	16	20	8	12	16	7	13	20	2	to	3	1	to	4
SMU5 NE	16	22	28	15	19	23	10	14	19	8	15	23	3	to	5	1	to	4
SMU5 SE	14	20	26	17	21	26	11	16	21	9	17	26	3	to	5	2	to	5
SMU 6	12	16	21	19	24	28	12	18	24	9	19	28	2	to	4	2	to	5
SMU 7	4	5	6	5	6	7	3	5	6	2	5	7	1	to	6	0	to	1

Habitat Type:	Submerged Macrophytes (SM)												SM			SM		
Species:	Walleye			Largemouth Bass			Smallmouth Bass			Bluegill/Pumpkinseed			Acres[d]			Acres[d]		
Depth interval:	2-6 ft[b]			2-6 ft			2-6 ft			2-6 ft			2-6 ft			2-6 ft		
Percent cover:	25%	35%	45%	40%	50%	60%	25%	38%	50%	15%	23%	30%	25%	to	45%	15%	to	60%
Acres:																		
SMU 1	8	11	14	12	15	18	8	11	15	5	7	9	8	to	14	5	to	18
SMU 2	2	3	3	3	4	5	2	3	4	1	2	2	2	to	3	1	to	5
SMU 3	7	10	12	11	14	17	7	10	14	4	6	8	7	to	12	4	to	17
SMU 4	5	8	10	9	11	13	5	8	11	3	5	7	5	to	10	3	to	13
SMU5 NW	10	14	18	16	20	24	10	15	20	6	9	12	10	to	18	6	to	24
SMU5 NE	16	22	28	25	32	38	16	24	32	9	14	19	16	to	28	9	to	38
SMU5 SE	14	20	26	23	29	34	14	21	29	9	13	17	14	to	26	9	to	34
SMU 6	12	16	21	19	23	28	12	18	23	7	11	14	12	to	21	7	to	28
SMU 7	4	5	6	6	7	9	4	5	7	2	3	4	4	to	6	2	to	9

[a] Calculations were rounded to the nearest acre.

[b] Note that percent cover for large woody debris and submergered macrophytes combined should be considered for the walleye (i.e., LWD = SM = 25 percent to 45 percent coverage). This does not apply for other species, as LWD and SM are planned for separate depth regimes.

[c] Number of LWD structures illustrates the range of structures that could be used to provide habitat for the range of species in a given depth regime. 0.179 structures per acre is suggested. See footnote b, as lesser numbers of LWD may apply for the 2 to 6 ft depth regime when SM is combined for coverage.

[d] Acres of SM represents the range of acres of coverage required for the variety of species and the depth regimes (e.g., for the 2 to 6 ft depth regime, bluegill/pumpkinseed require as little as 15 percent coverage, while largemouth bass require as much as 60 percent coverage.

TABLE M.7
HABITAT RESTORATION AND ENHANCEMENT PROJECTS BY SMU

SMU	Energy Regime[b]	Habitat Analysis[a]: Primary Habitat: Type	Water Depth (ft)	Substrate	Total Acres[b2]	#LWD Struct.[b2]	Acres SM[b2]	Secondary Habitat: Type	Water Depth (ft)	Substrate	Total Acres[b2]	#LWD Struct.[b2]	Acres SM[b2]	Additional Habitat Features: Type	Water Depth (ft)	Substrate	Estimated Areal Extent[b2]	Figures with Example Habitat Cross Sections	Figures with Existing Habitat Conditions
1	Medium/ High Energy	FSS	6 to 15	6 in. fine gravel	20	1-2	NA	SM	2 to 6	6 in. sand	30	1-2	5-18	EW or Riparian Overhang (RO)	0.5 to 2	EW - 6 in. organics over sand; RO - silty loam	Wetlands adjacent to existing wetlands	4-1; 4-2; 4-3	3-15
2	Medium Energy	FSS	6 to 15	6 in. fine gravel	7	0-1	NA	SM	2 to 6	6 in. sand	8	0-1	1-5	LWD	5 to 10	Not applicable	LWD - 10% for habitat variability	4-1; 4-2	3-16
3	Medium Energy	FSS; LWD	6 to 15	6 in. fine gravel	27	1-3	NA	SM	2 to 6	6 in. sand	28	1-2	4-17	EW or SHORE	0.5 to 2 (EW) or OLW (SHORE)	EW - 6 in. organics over sand; SHORE - topsoil	EW - < 1.0 acres; SHORE - < 7380 LF	4-4; 4-5; 4-6	3-17
4	Medium Energy (Ninemile	FSS; LWD	6 to 15	fine gravel or existing substrates[c]	19	1-2	NA	SM	2 to 6	sand or existing substrate[c]	22	1-2	3-13	EW	0.5 to 2	6 in. organics over sand	EW - < 0.5 acres	4-3; 4-5; 4-6	3-18
5 NW[c]	Low Energy (Northwest)	SM; LWD	2 to 6	existing substrate[c]	33	2-3	6-24	FSS	6 to 15	existing substrates[e]	96		NA	EW	0.5 to 2	6 in. organics over sand	EW - <0.5 acres	4-3	3-19
5 NE[c]	Medium Energy (Northeast)	FSS	6 to 15	fine gravel or existing substrates[c]	129	1-4	NA	SM; LWD	2 to 6	existing substrates[e]	38	3-5	9-38	None proposed	NA	NA	NA	4-6	3-20
5 SE[c,d]	High Energy (Southeast)	FSS; LWD	6 to 15	fine gravel or existing substrates[c]	121	2-5	NA	SM; LWD	2 to 6	existing substrates[e]	42	3-5	9-34	None proposed	NA	NA	NA	4-6	3-21
6[d]	High Energy	SM	2 to 6	6 in. sand	47	2-4	-35	FSS; LWD	6 to 15	6 in. fine gravel	47	2-5	NA	None proposed	NA	NA	NA	4-3; 4-1	3-22
7	High Energy	SM	2 to 6	6 in. sand	14	1-6	2-9	FSS; LWD	6 to 15	6 in. fine gravel	12	0-1	NA	EW	0.5 to 2	6 in. organics over sand	EW - <0.5 acres	4-1; 4-2	
8	Not Applicable	BMI	>15	sand or existing substrate[c]			NA	None proposed	NA	Not applicable			NA	None proposed	NA	NA	NA		

Notes on following page

TABLE M.7 (CONTINUED)

HABITAT RESTORATION AND ENHANCEMENT PROJECTS BY SMU

Notes:

[a] Proposed habitats for each SMU are identified based on existing conditions, water depth, and velocity regime.

[b] Energy regime identifed in EcoLogic, 2001. Habitats in high energy areas may require energy breaks to maximize macrophyte colonization.

[b2] Estimated areal extent of particular habitat type. Substrates (e.g., sand or gravel) may be required over entire areal extent. However, LWD and SM are only suggested for a limited portion of the the areal extent. Refer to Table 4-5 for information regarding estimates of LWD structures and SM.

[c] Due to the broad range of conditions represented by SMU 5 it is discussed separately for each velocity regime.

[d] Note that the United States Army Corps of Engineers Onondaga Lake Trail project includes an in-lake portion (Trail Section C) in this area of the lake. The Onondaga Lake Trail project includes a habitat restoration component.

[e] Fish nest studies and young of year studies of sunfish and bass show that the northwestern portion of SMU 5 is supporting fish reproduction (Figures 3-11, 3-12, and 3-13) and a forested wetland is located adjacent to the SMU (Figure 3-9). Remedial design should take into account these areas so that they do not get buried or capped by substrates (if applicable), as existing conditions are providing reproductive habitat. Enhancement could include large woody debris to provide stablization of oncolites during high energy events, creating more stability for submerged macrophyte colonization.

[f] Studies of sunfish and bass show that the northeastern portion of SMU 5 is supporting young of the year fish, but the numbers of young of the year and fish nests are less than those seen in the northwestern portion of SMU 5 (Figures 3-11, 3-12, and 3-13). Similarly, the southeastern portion of SMU 5 shows less use of the area for fish young of the year than both the northwest and northeast portions of SMU 5. This trend is likely due to the combination of energy conditions (EcoLogic, 2001) and oncolites (Figure 3-5). However, submerged macrophytes have colonized these areas (Figure 3-8) and may expand if conditions that diminish wind / wave energy are enhanced. Enhancement could include large woody debris to provide stablization of oncolites during high energy events, creating more stability for submerged macrophyte colonization.

[g] BMI condition of SMU 8 is more likely related to anoxic conditions than substrate type. Oxygenation of the hypolimnion and increased water clarity should increase BMI colonization of SMU 8 without changes to the substrates.

APPENDIX M

FIGURES

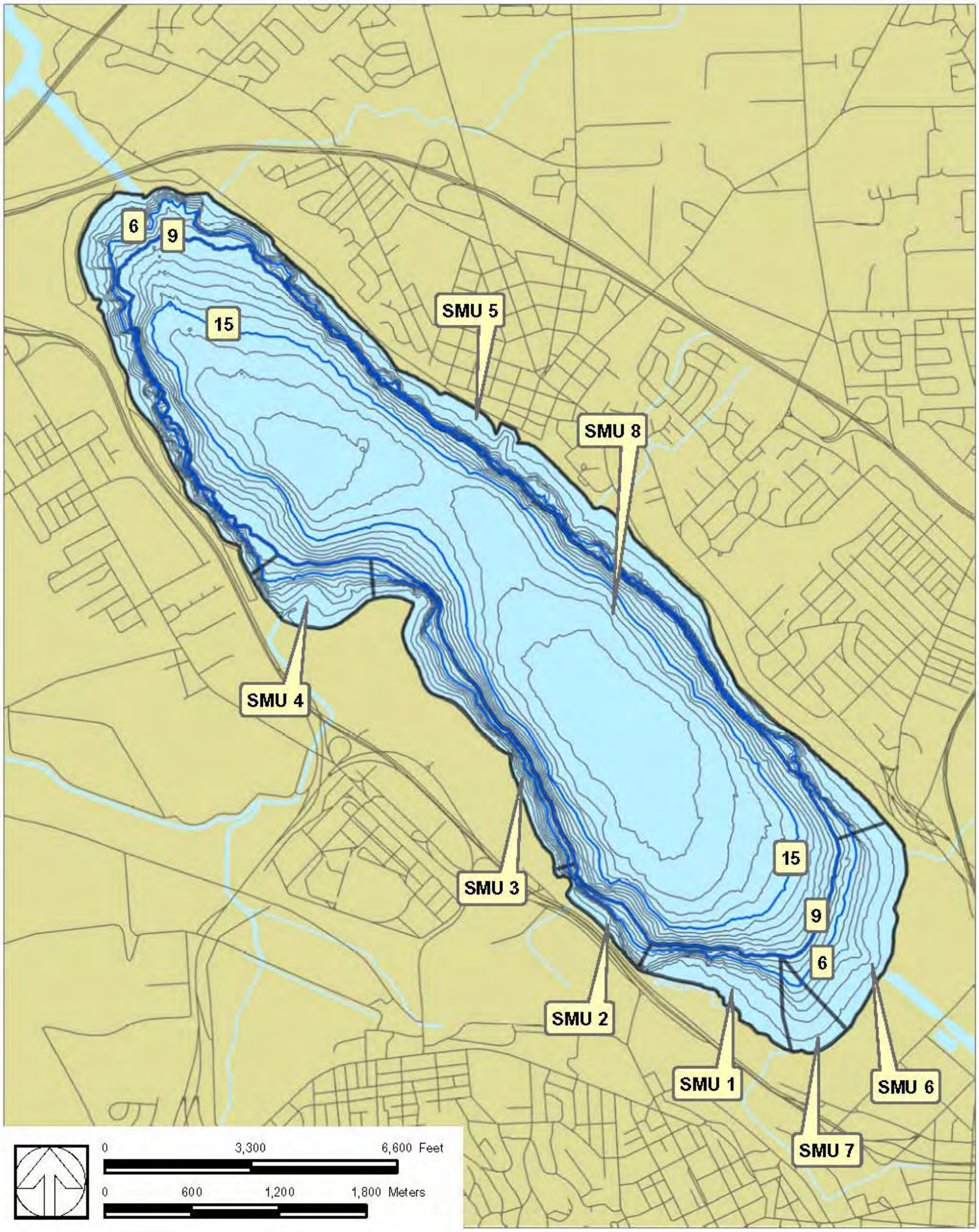


FIGURE M.1

ONONDAGA LAKE
SYRACUSE, NEW YORK

BATHYMETRY OF
ONONDAGA LAKE (METERS)

Exponent

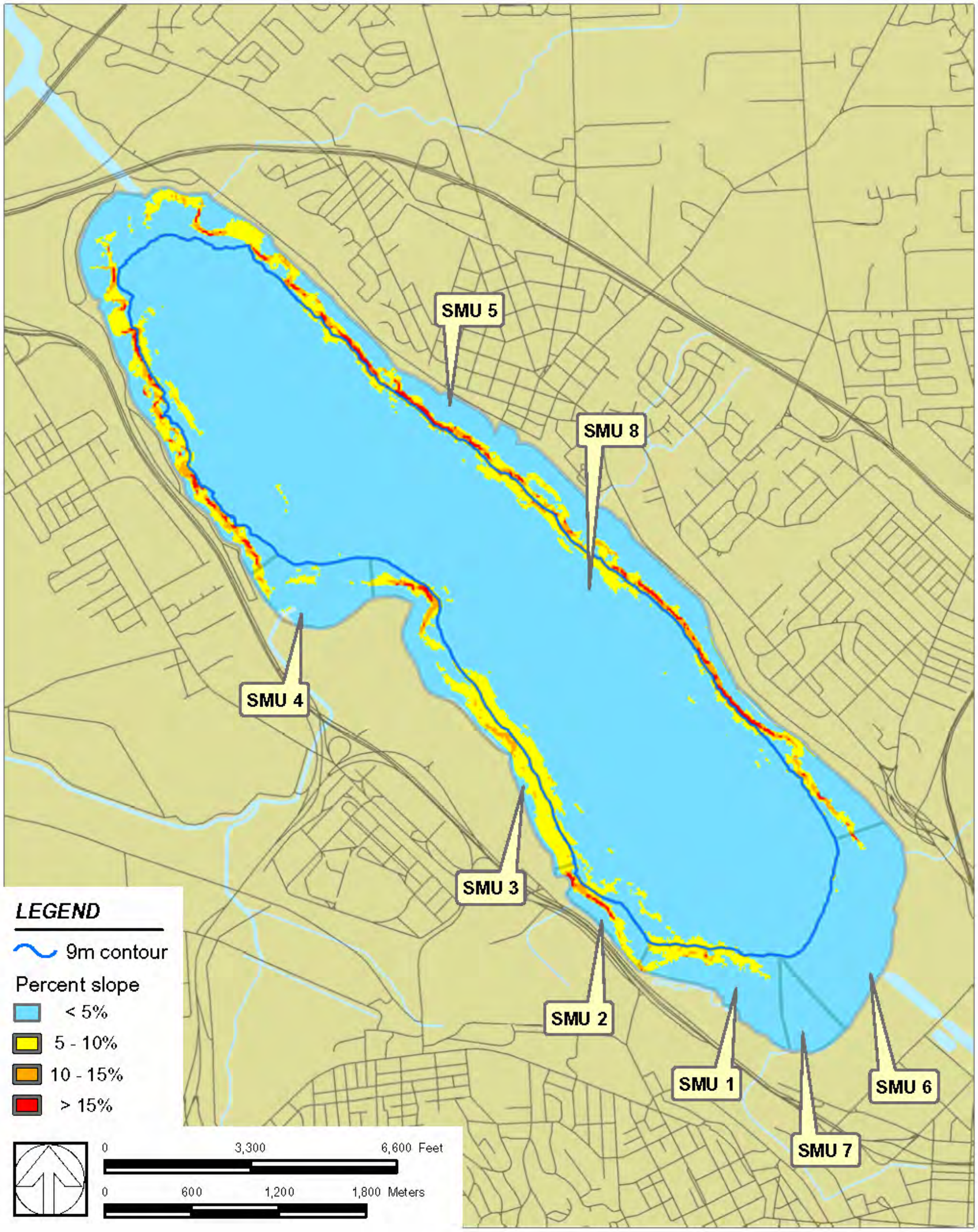


FIGURE M.2

ONONDAGA LAKE
SYRACUSE, NEW YORK

BOTTOM SLOPE (PERCENT) IN
ONONDAGA LAKE

Exponent®

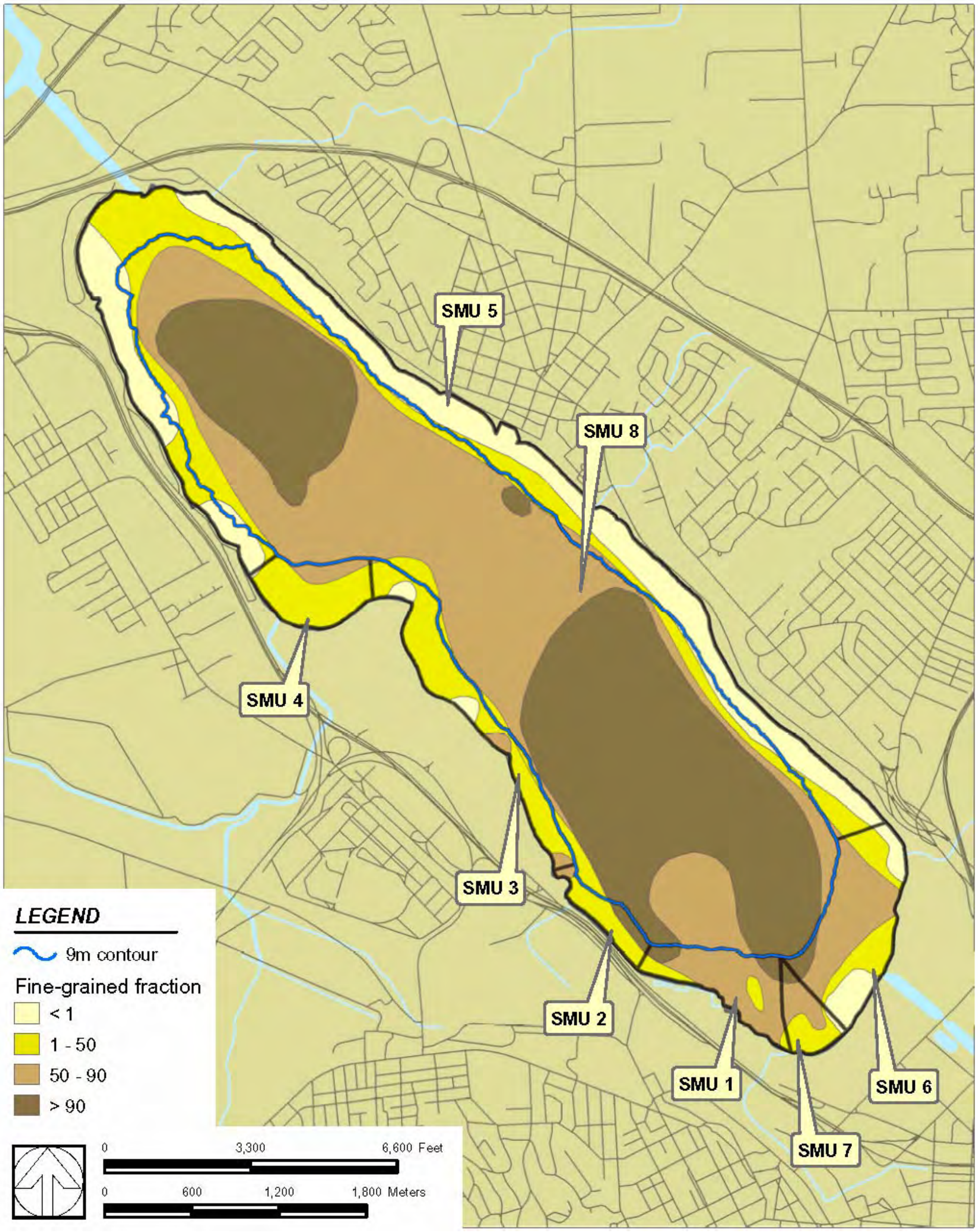


FIGURE M.3

ONONDAGA LAKE
SYRACUSE, NEW YORK

SEDIMENT GRAIN SIZE AS PERCENT FINE-GRAINED MATERIAL IN ONONDAGA LAKE

Exponent®

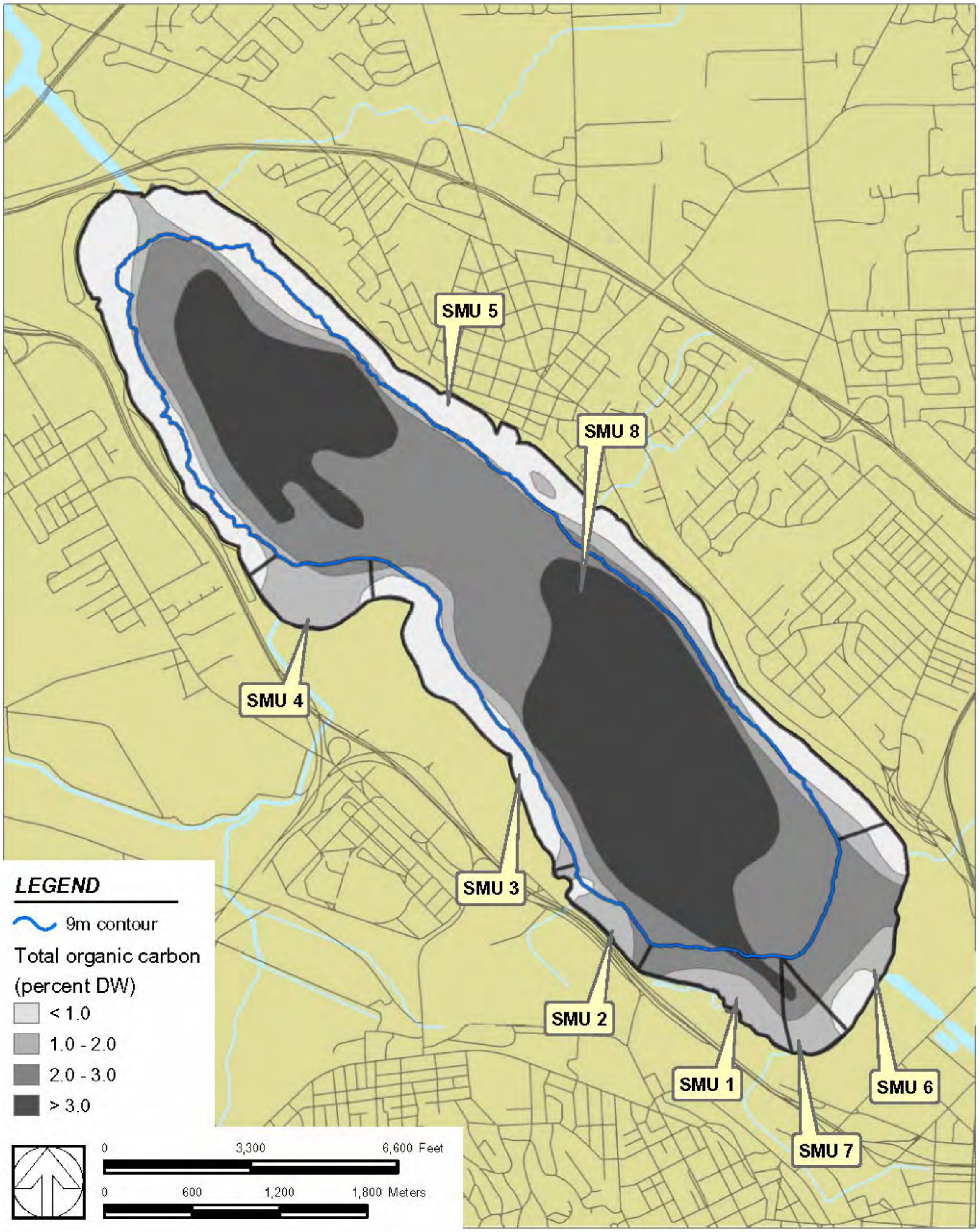


FIGURE M.4

ONONDAGA LAKE
SYRACUSE, NEW YORK

TOTAL ORGANIC CARBON (% DW) IN SEDIMENTS OF ONONDAGA LAKE

Exponent

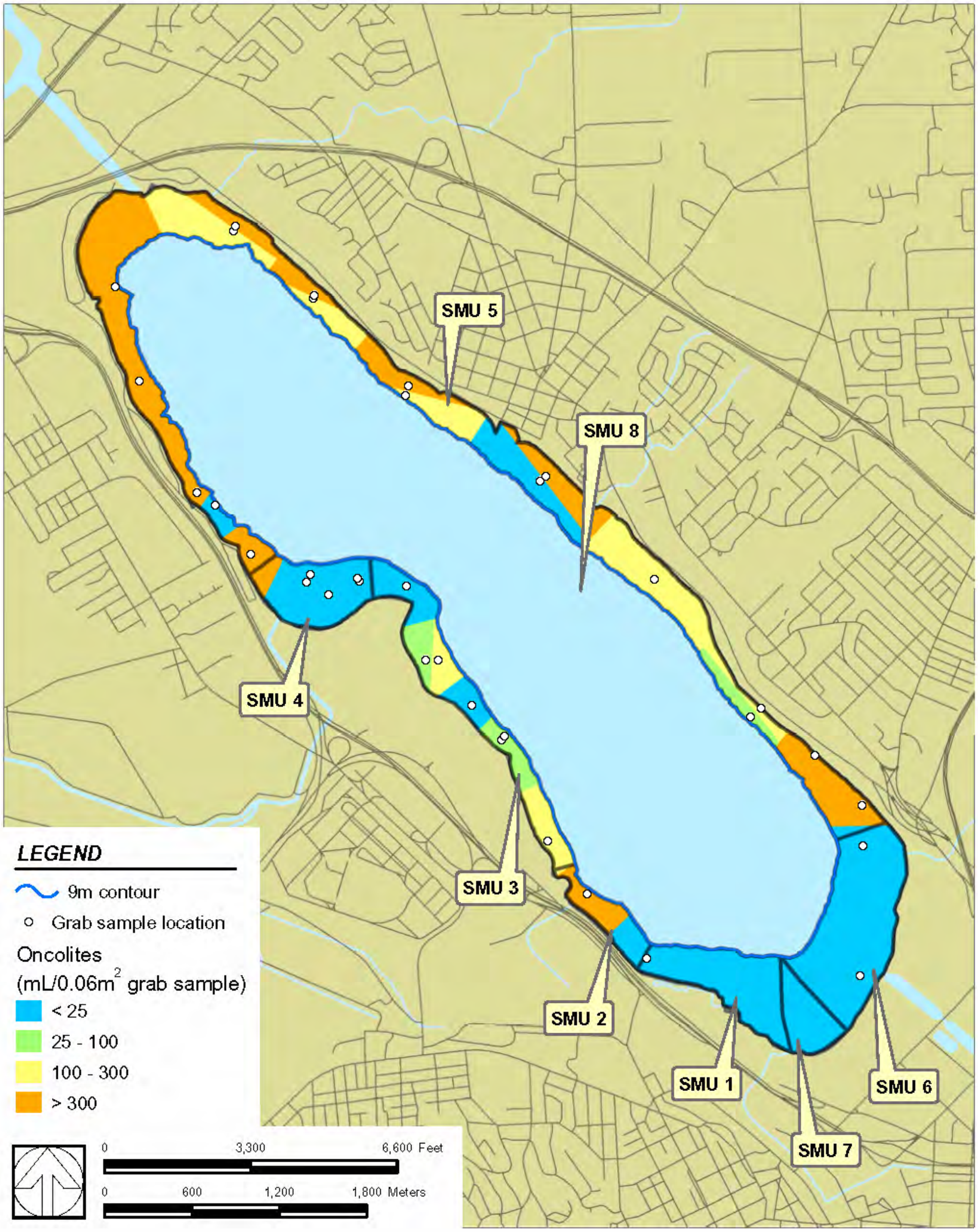


FIGURE M.5

ONONDAGA LAKE
SYRACUSE, NEW YORK

ONCOLITES (mL/0.06 M^2) IN
ONONDAGA LAKE

Exponent

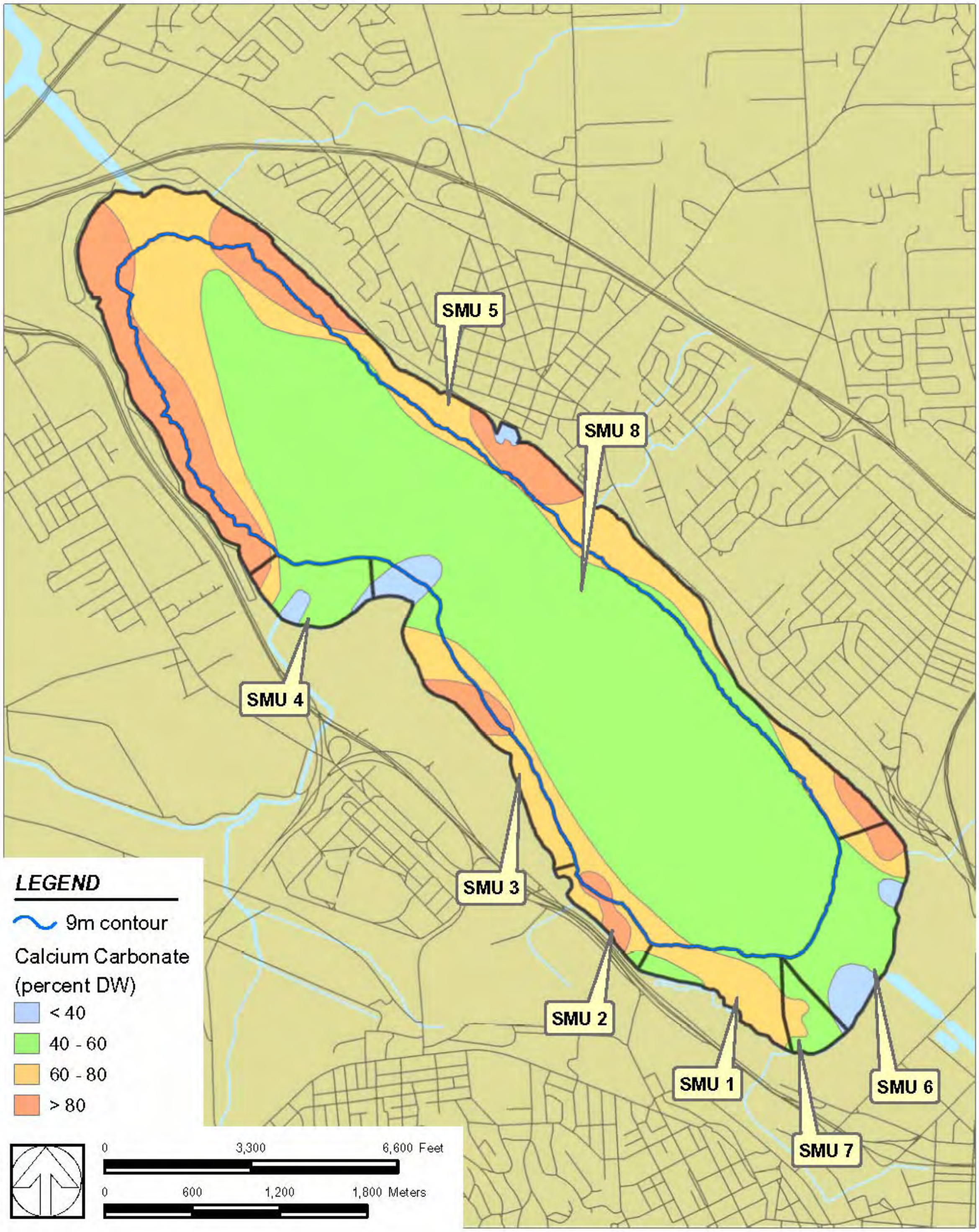


FIGURE M.6

ONONDAGA LAKE
SYRACUSE, NEW YORK

CALCIUM CARBONATE (%DW) IN
SEDIMENTS OF ONONDAGA LAKE

Exponent®

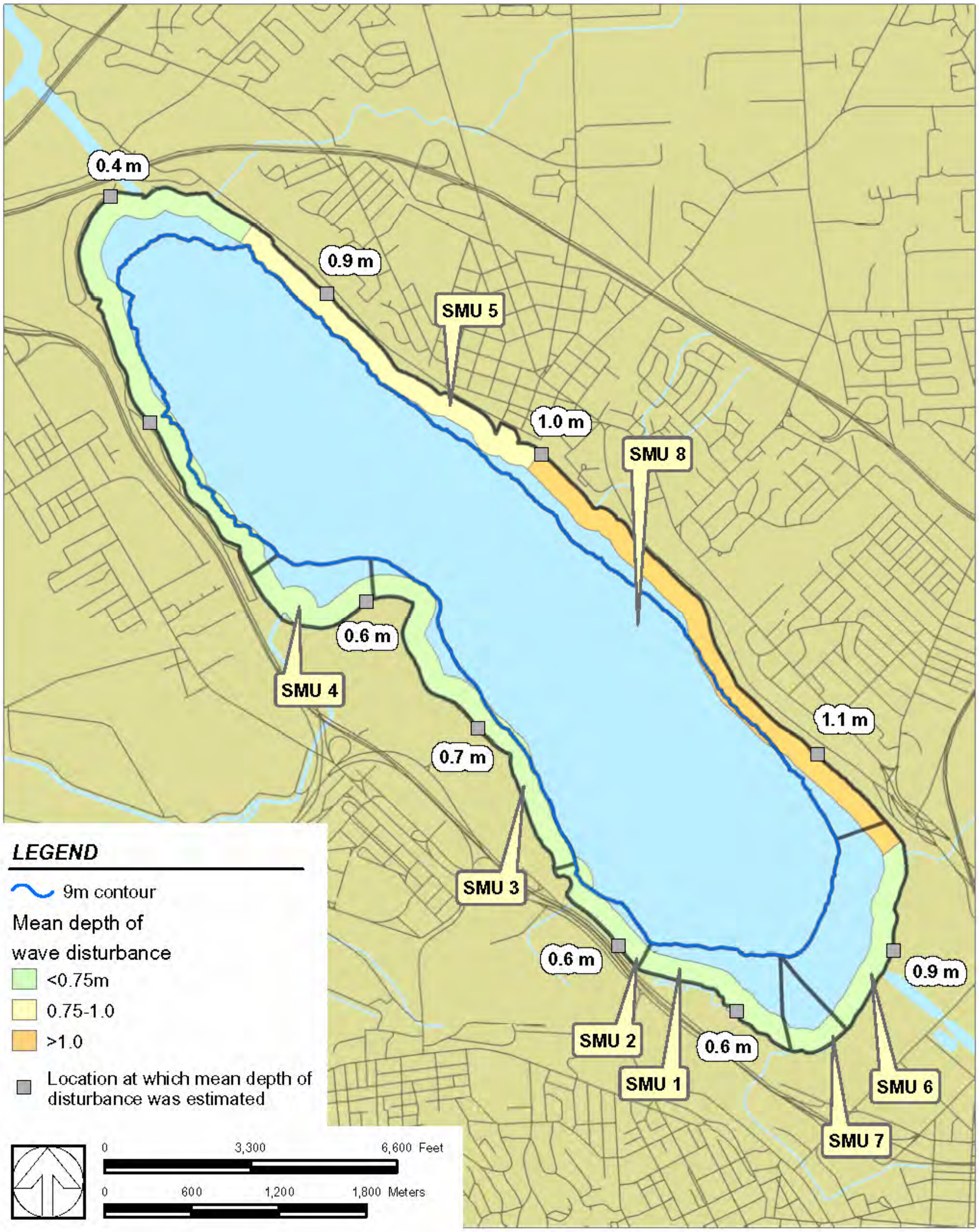


FIGURE M.7

ONONDAGA LAKE
SYRACUSE, NEW YORK

EXPOSURE INDEX (MEAN DEPTH OF WAVE DISTURBANCE) IN ONONDAGA LAKE

Exponent®

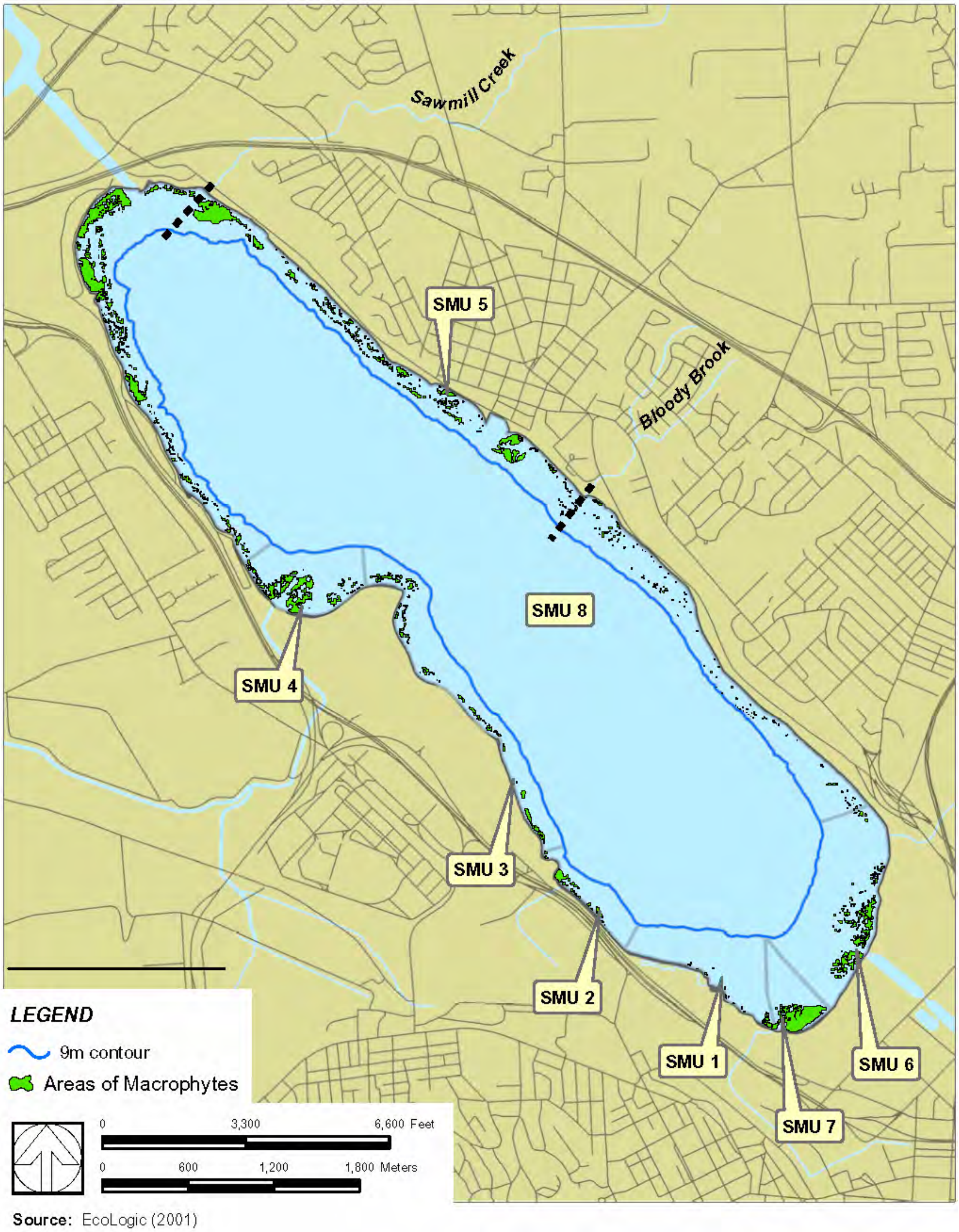


FIGURE M.8

ONONDAGA LAKE
SYRACUSE, NEW YORK

DISTRIBUTION OF MAJOR MACTROPHYTE BEDS IN ONONDAGA LAKE, 2000

Exponent®

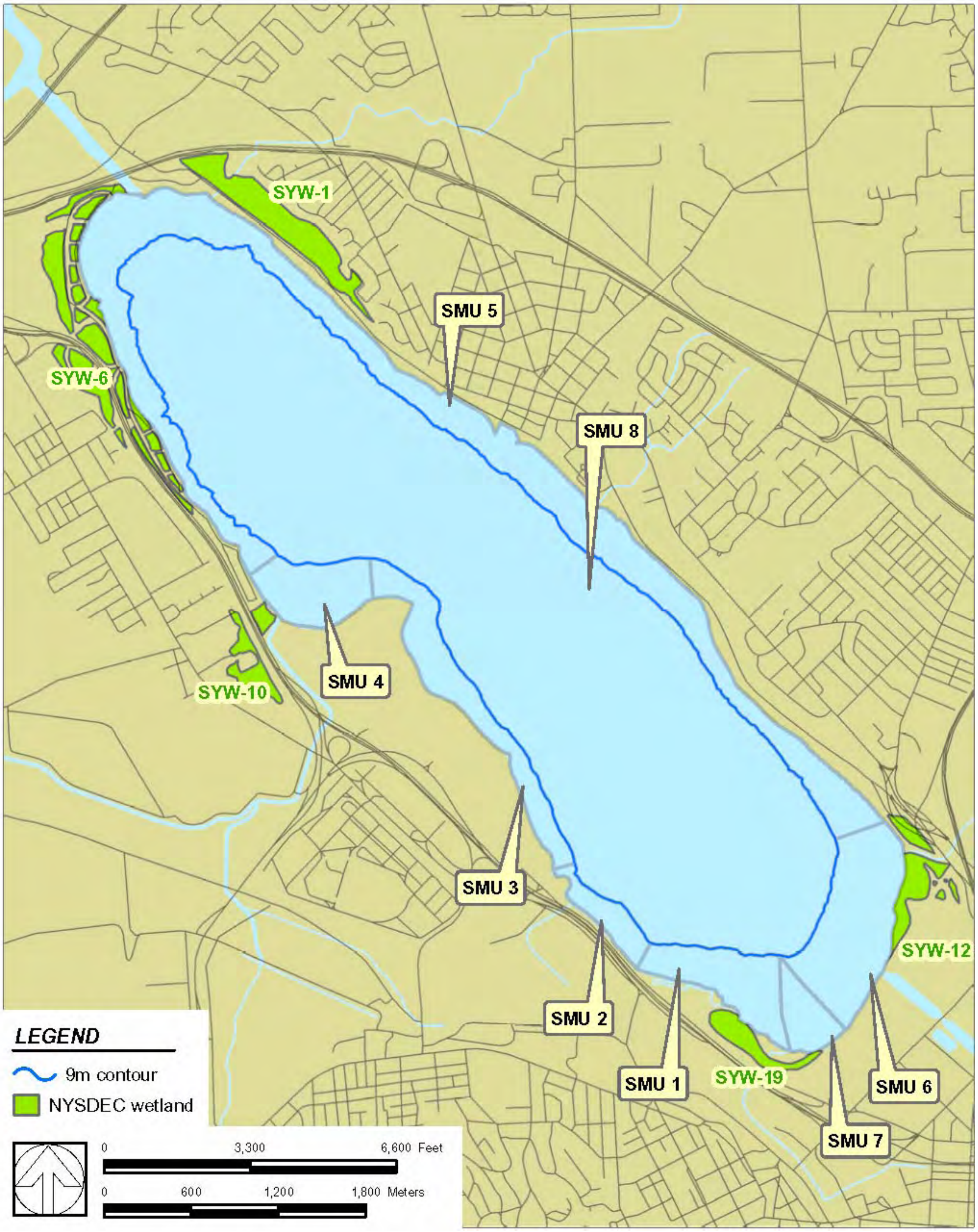
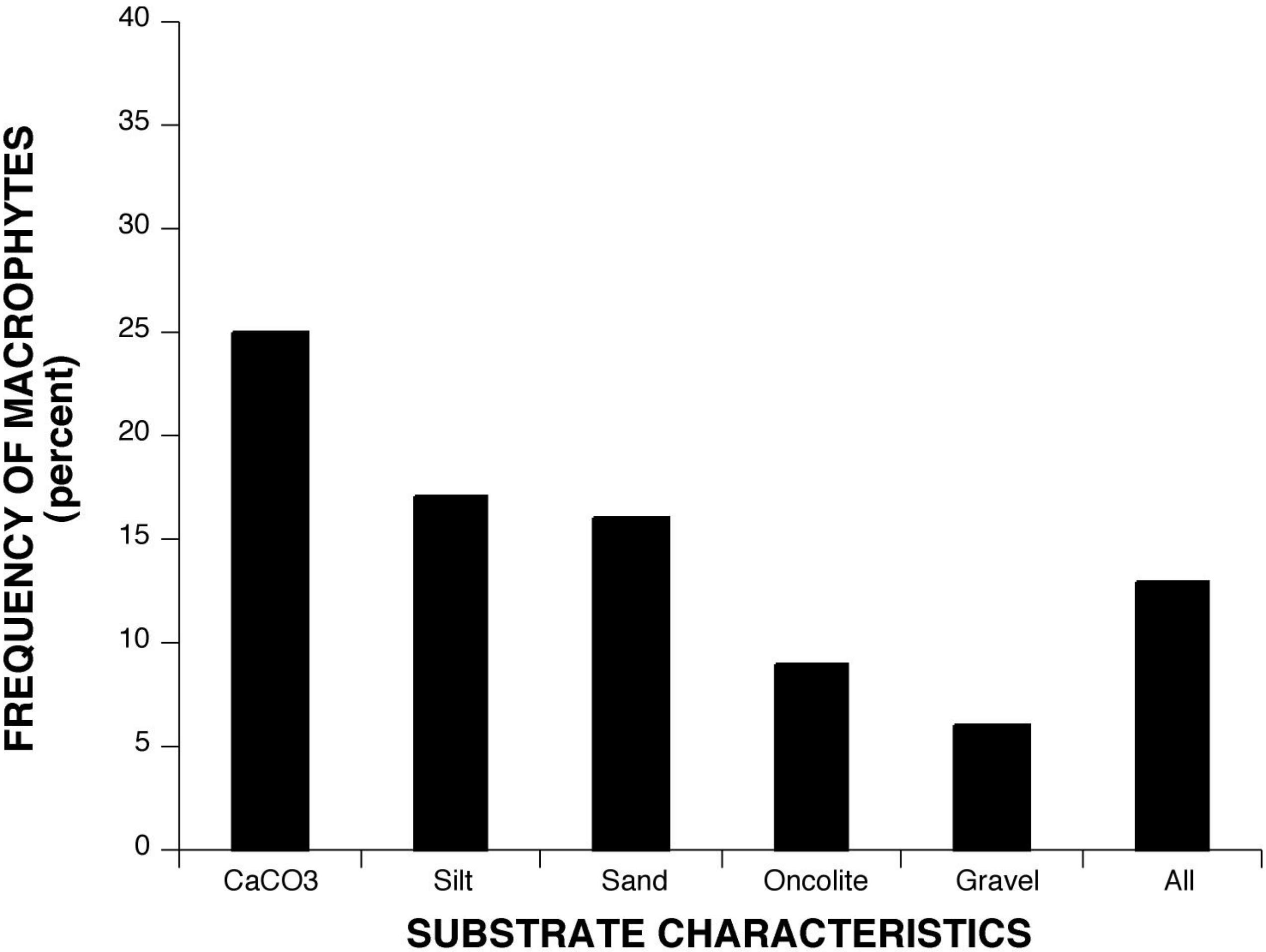


FIGURE M.9

ONONDAGA LAKE
SYRACUSE, NEW YORK

WETLANDS CONTIGUOUS WITH THE SHORELINE OF ONONDAGA LAKE

Exponent



Source: Data from Madsen 1992

FIGURE M.10

ONONDAGA LAKE
SYRACUSE, NEW YORK

FREQUENCY OF MACROPHYTE OCCURRENCE ON VARIOUS SUBSTRATE TYPES IN ONONDAGA LAKE

Exponent

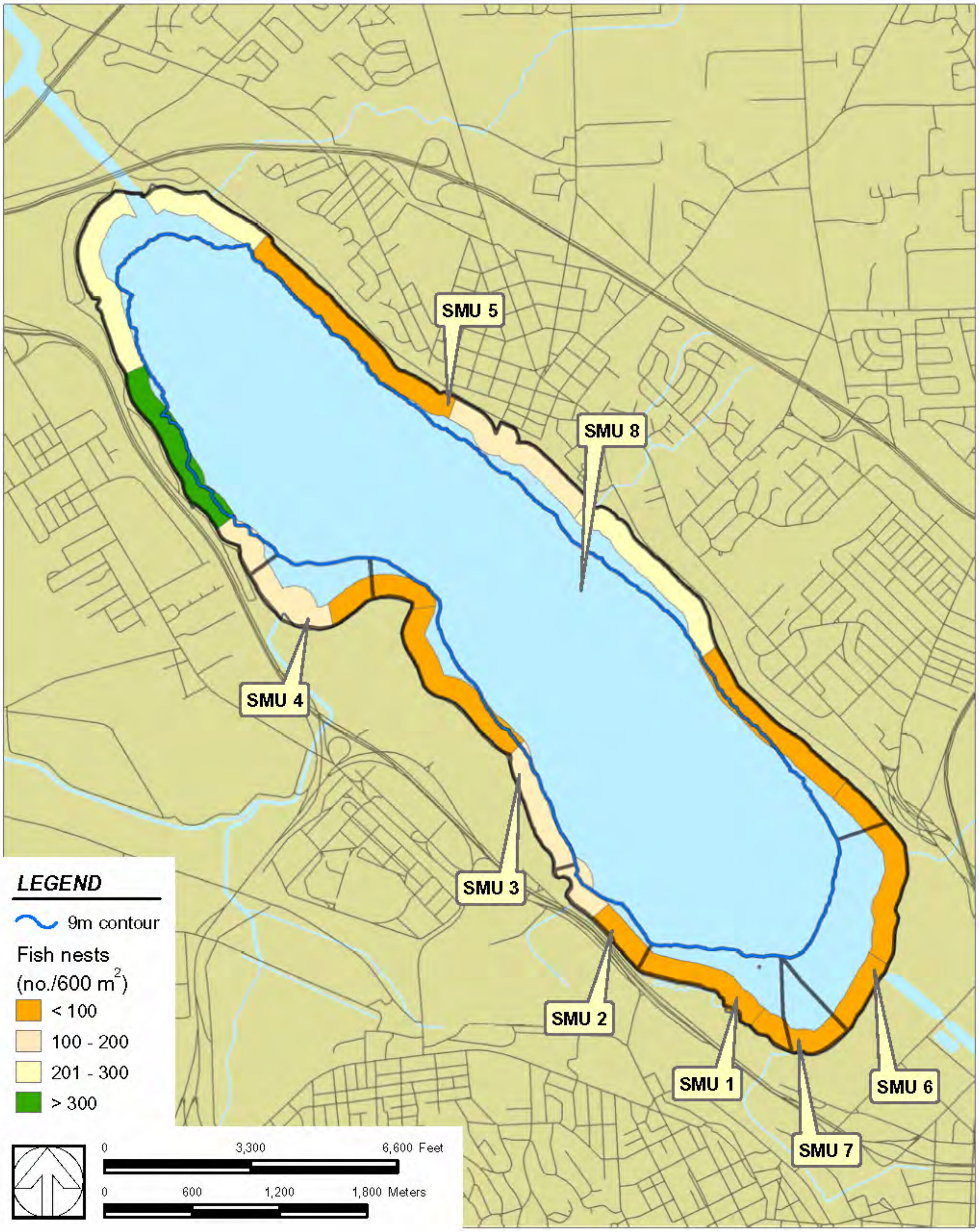


FIGURE M.11

ONONDAGA LAKE
SYRACUSE, NEW YORK

AREAL DENSITY OF FISH NESTS (NO./600m2) OBSERVED IN ONONDAGA LAKE

Exponent®

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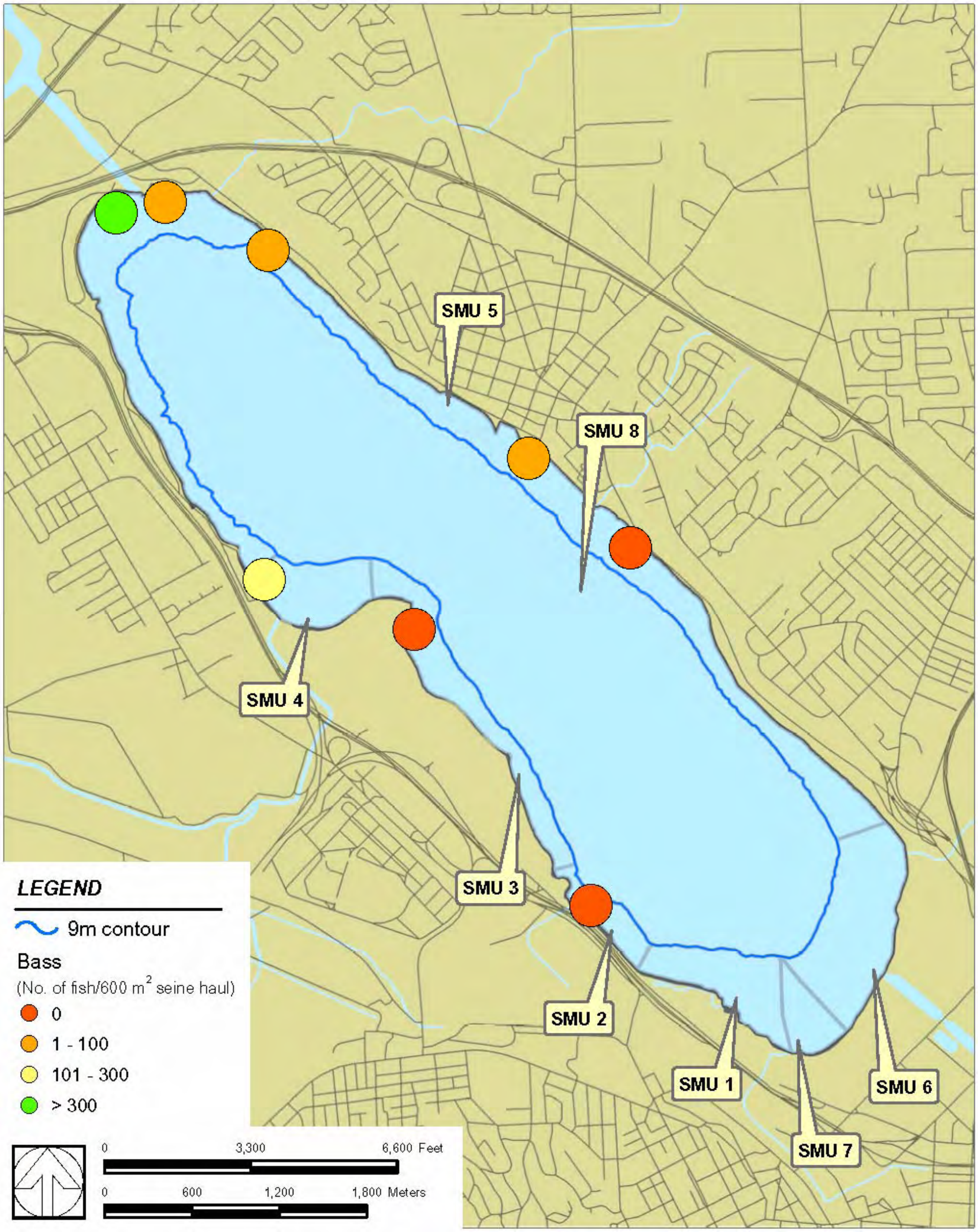

FIGURE M.12

ONONDAGA LAKE
SYRACUSE, NEW YORK

ESTIMATED ABUNDANCE (NO./600m2 SEINE HAUL) OF YOUNG-OF-THE-YEAR BASS IN ONONDAGA LAKE

Exponent®

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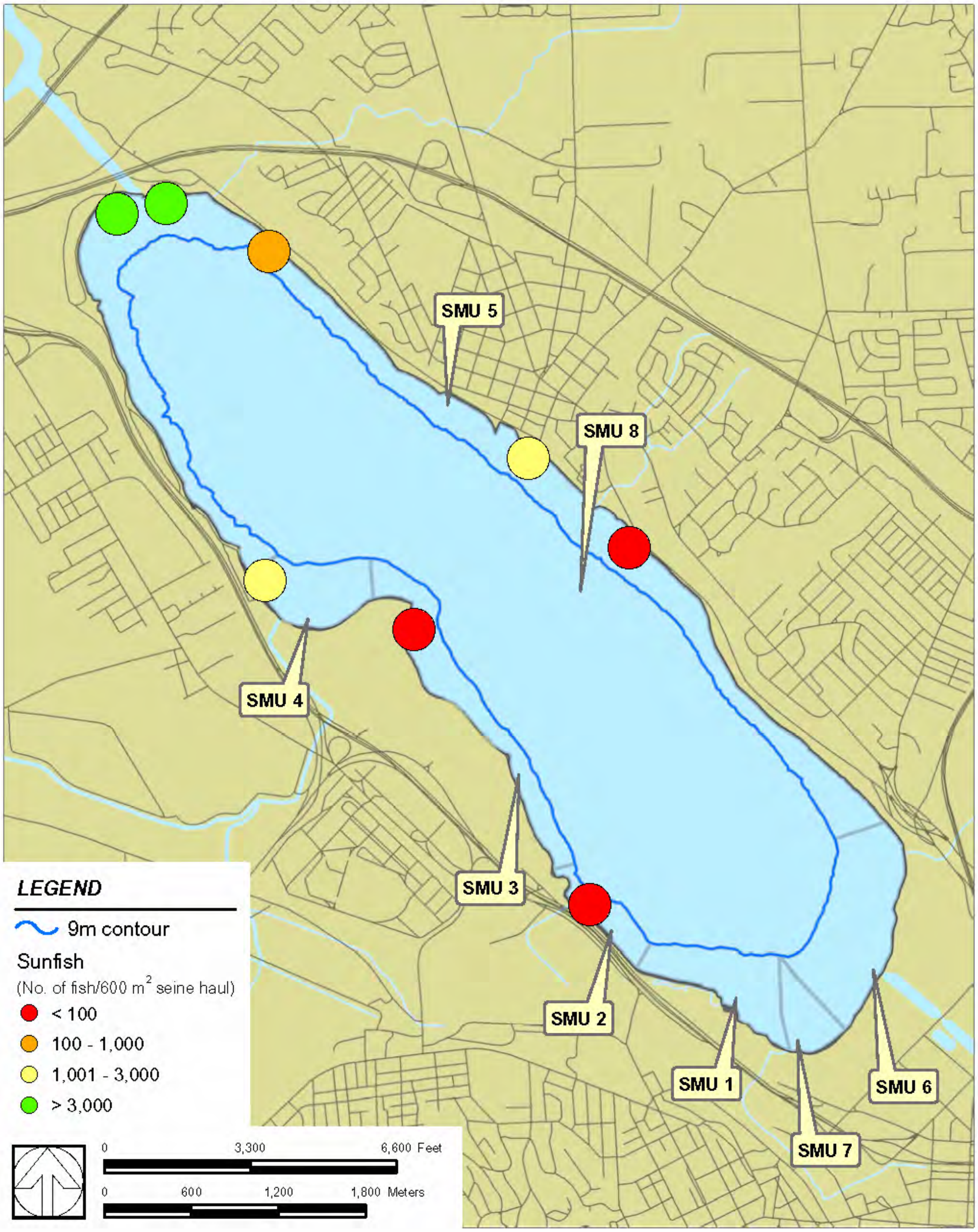


FIGURE M.13

ONONDAGA LAKE
SYRACUSE, NEW YORK

ESTIMATED ABUNDANCE (NO./600m2 SEINE HAUL) OF YOUNG-OF-THE-YEAR SUNFISH IN ONONDAGA LAKE

Exponent

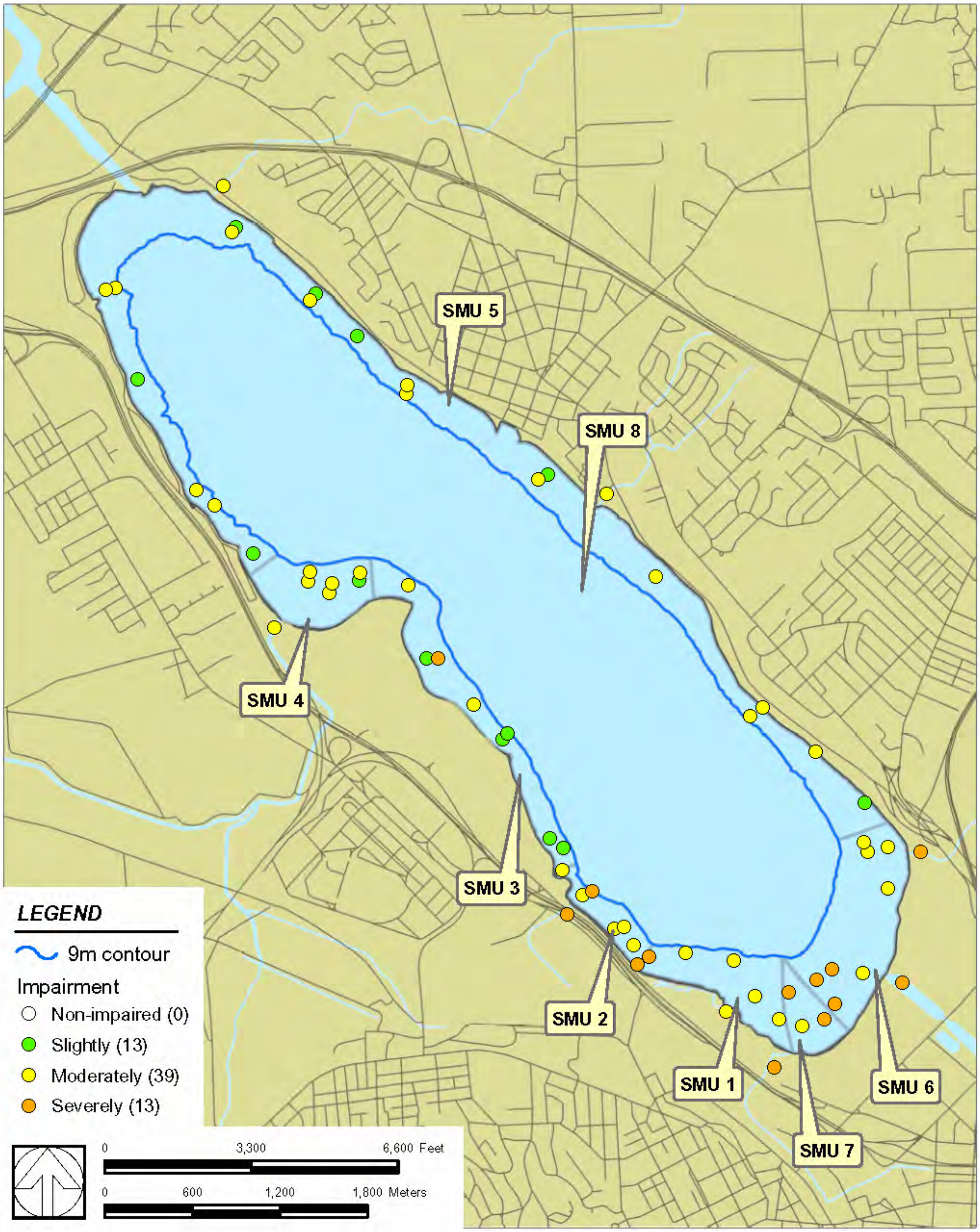


FIGURE M.14

ONONDAGA LAKE
SYRACUSE, NEW YORK

IMPAIRMENT OF BENTHIC MACROINVERTEBRATE COMMUNITIES IN ONONDAGA LAKE ACCORDING TO TAMS

Exponent®

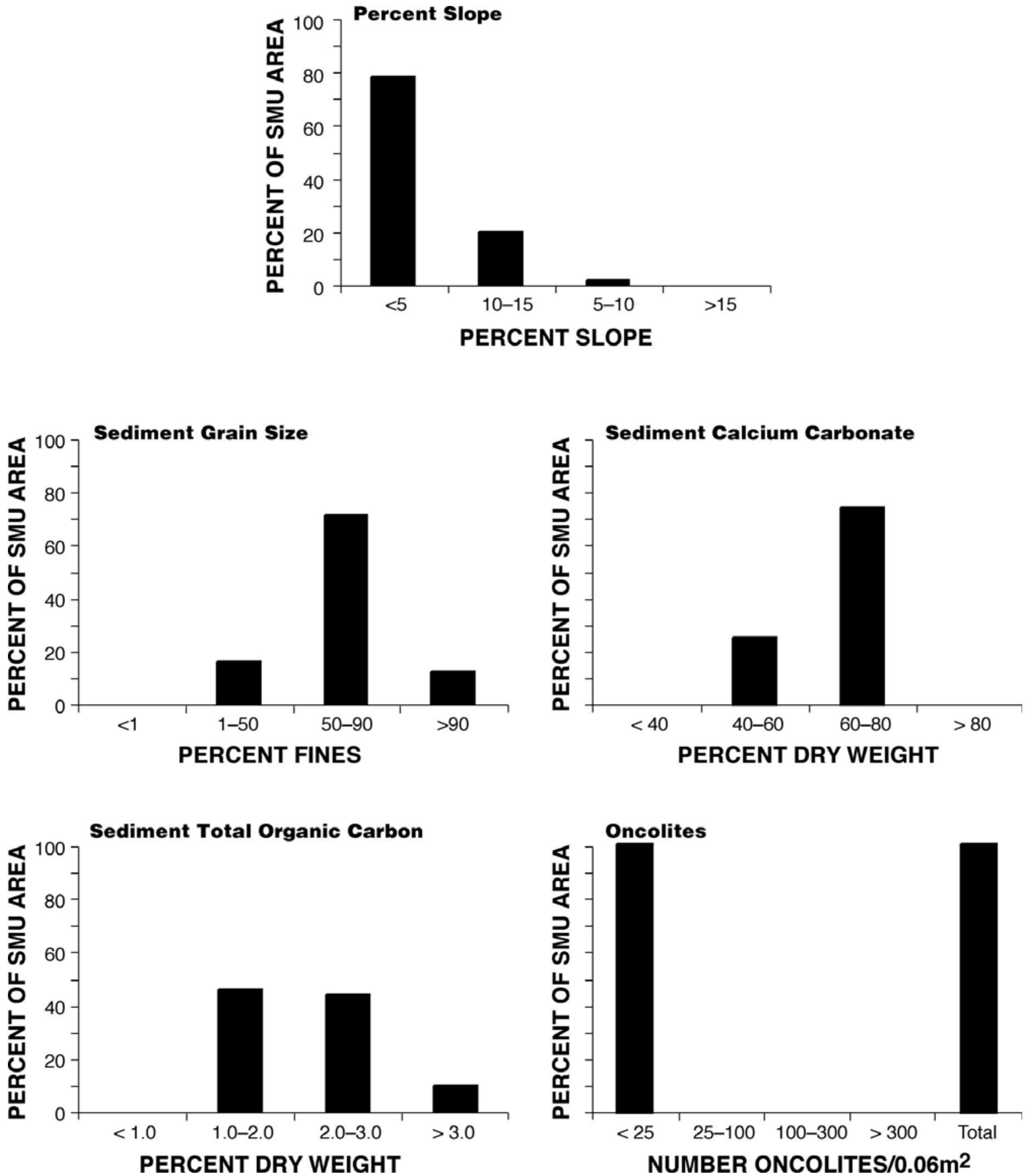


FIGURE M.15

ONONDAGA LAKE
SYRACUSE, NEW YORK

SUMMARY OF HABITAT
CONDITIONS IN SMU 1

Exponent

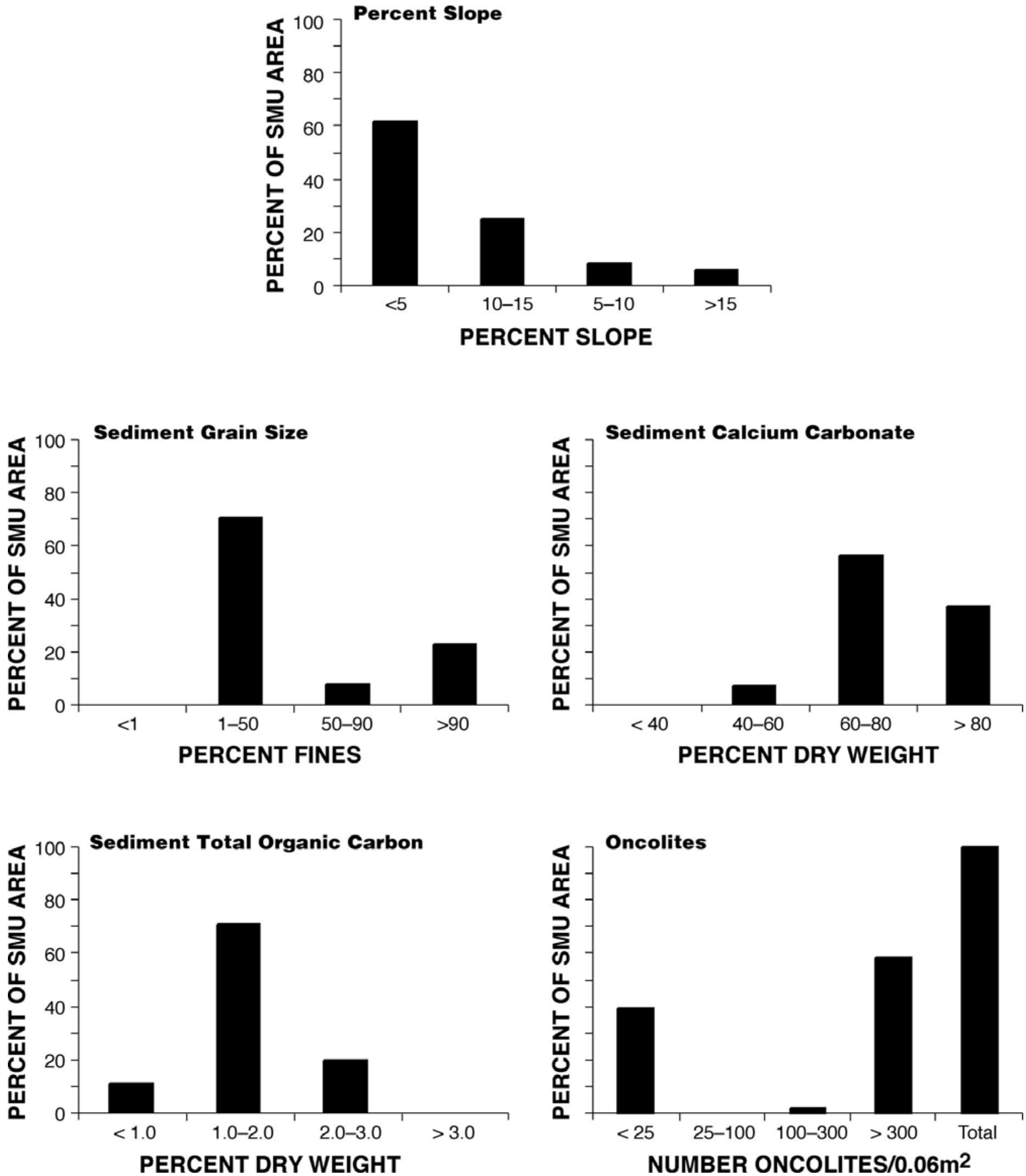


FIGURE M.16

ONONDAGA LAKE
SYRACUSE, NEW YORK

SUMMARY OF HABITAT CONDITIONS IN SMU 2

Exponent

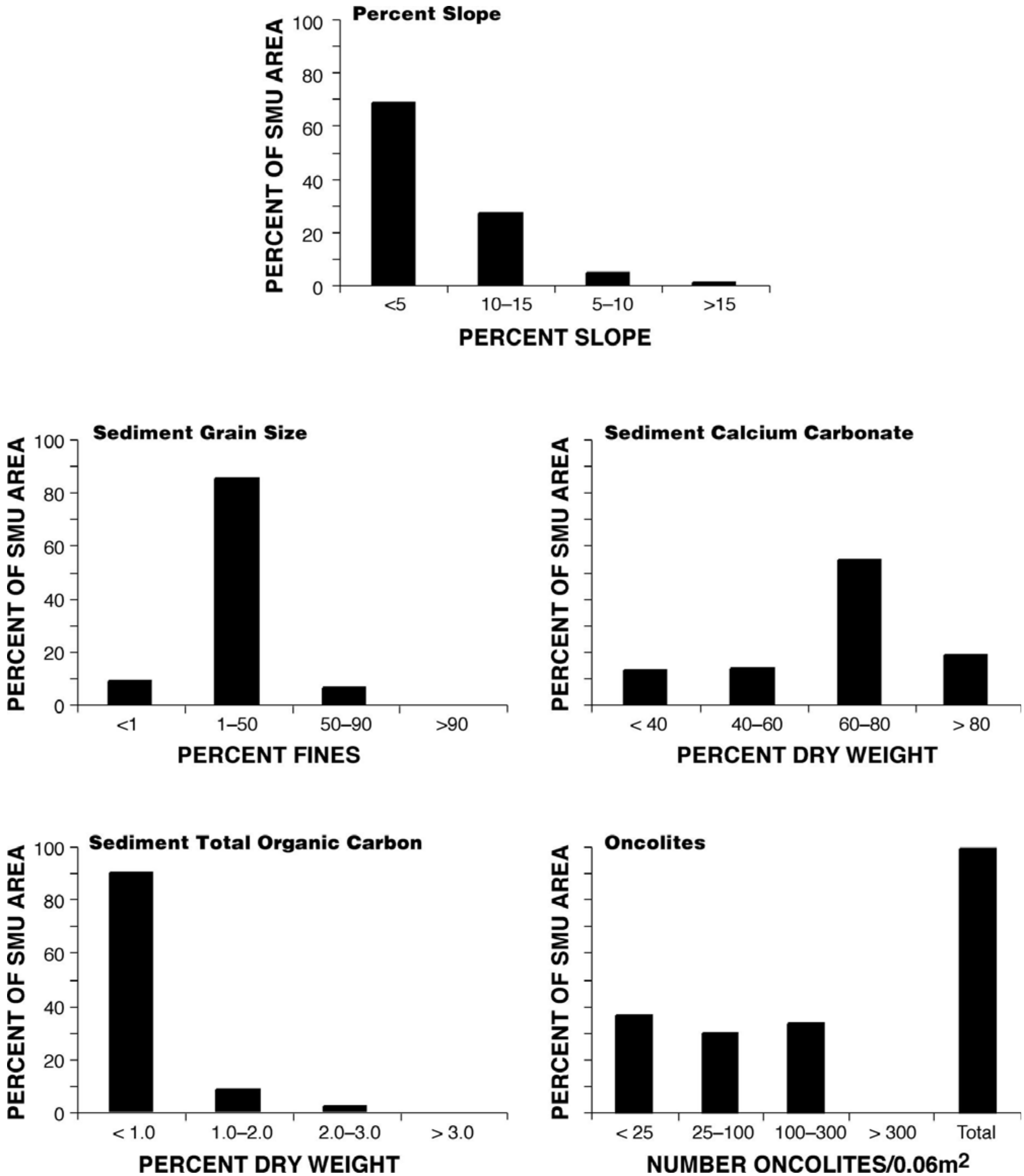
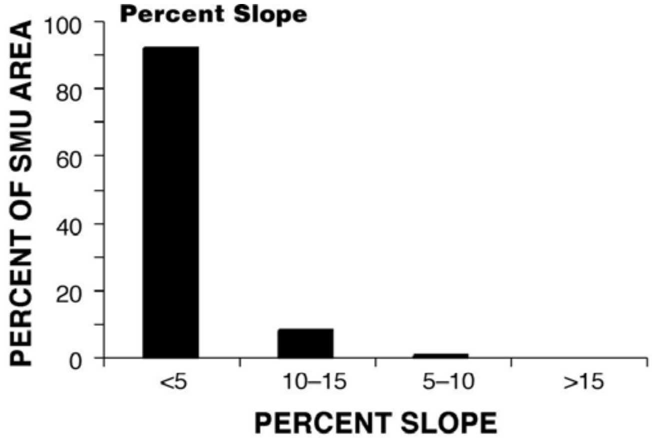


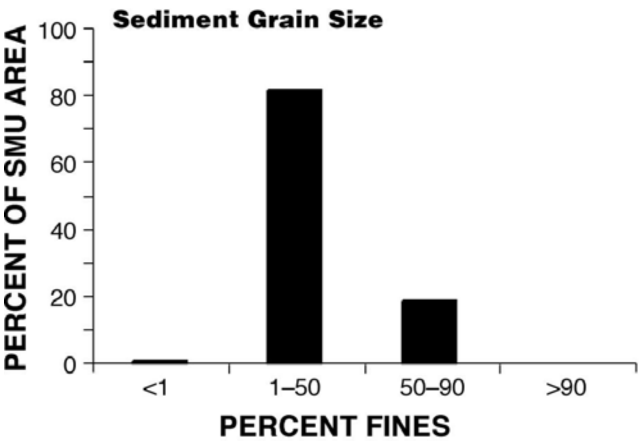
FIGURE M.17

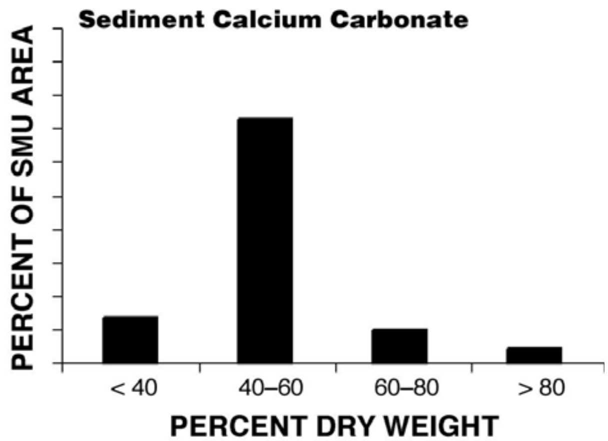
ONONDAGA LAKE
SYRACUSE, NEW YORK

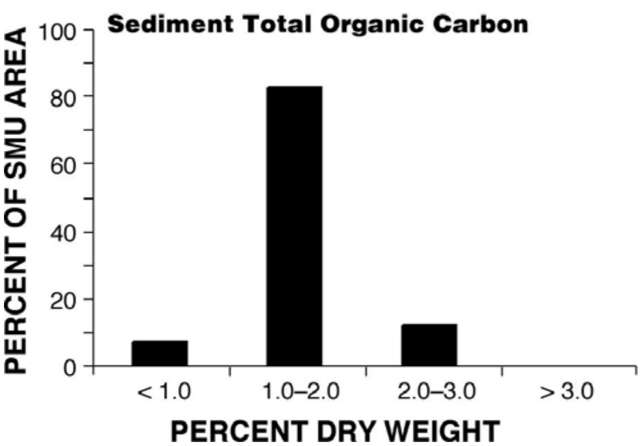
SUMMARY OF HABITAT
CONDITIONS IN SMU 3

Exponent









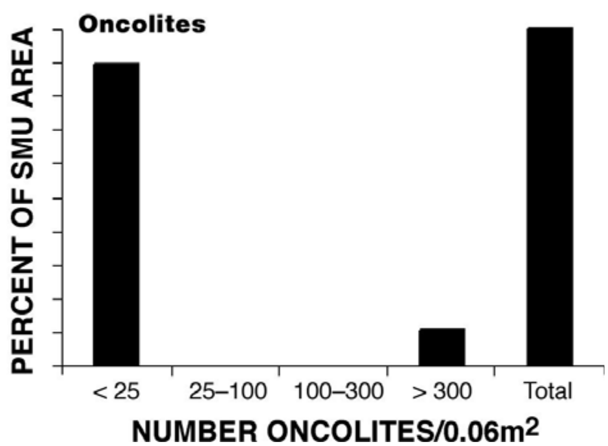


FIGURE M.18

ONONDAGA LAKE
SYRACUSE, NEW YORK

SUMMARY OF HABITAT
CONDITIONS IN SMU 4

Exponent

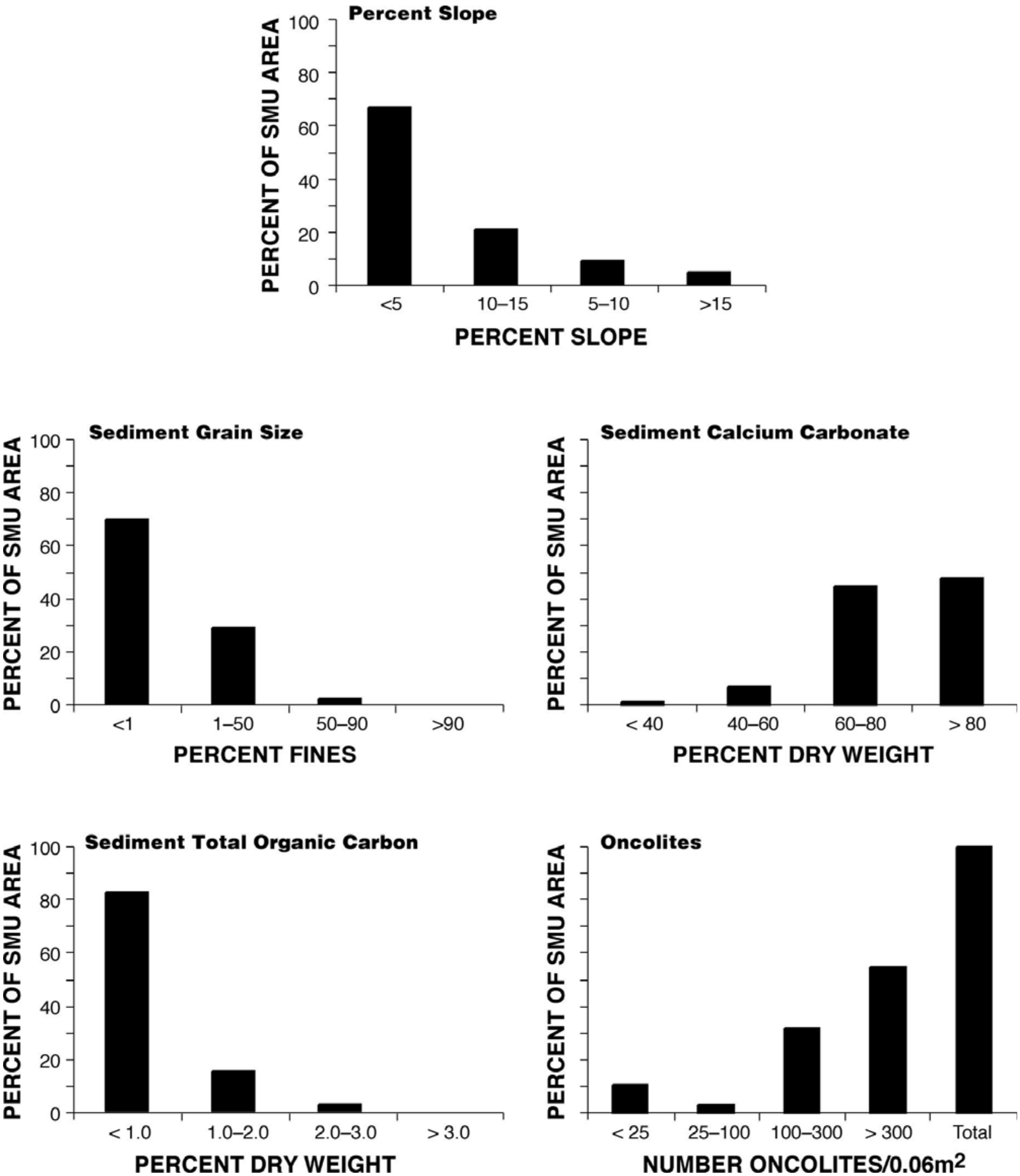


FIGURE M.19

ONONDAGA LAKE
SYRACUSE, NEW YORK

SUMMARY OF HABITAT CONDITIONS IN SMU 5

Exponent®

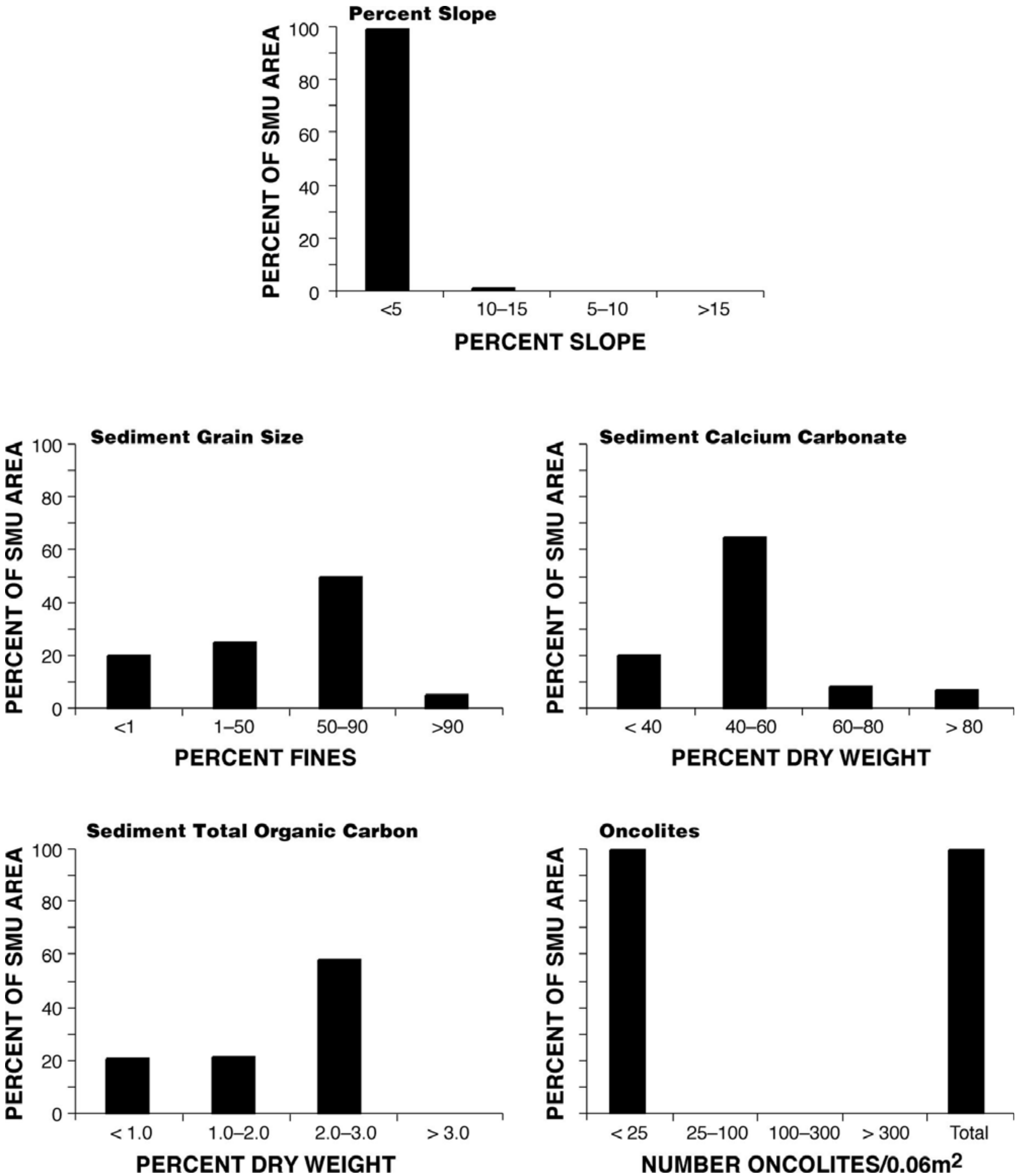


FIGURE M.20

ONONDAGA LAKE
SYRACUSE, NEW YORK

SUMMARY OF HABITAT
CONDITIONS IN SMU 6

Exponent

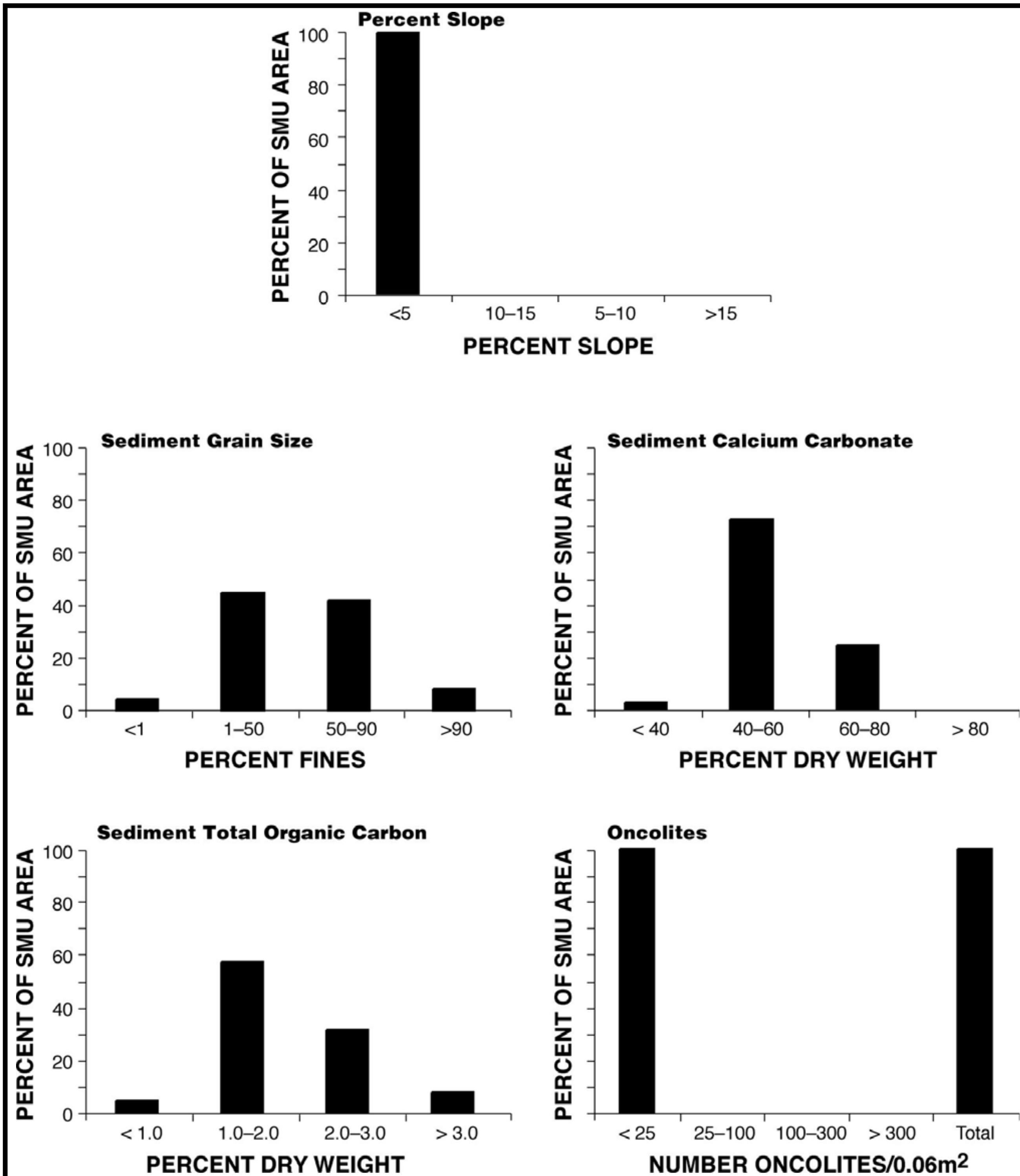


FIGURE M.21

ONONDAGA LAKE
SYRACUSE, NEW YORK

SUMMARY OF HABITAT CONDITIONS IN SMU 7

Exponent

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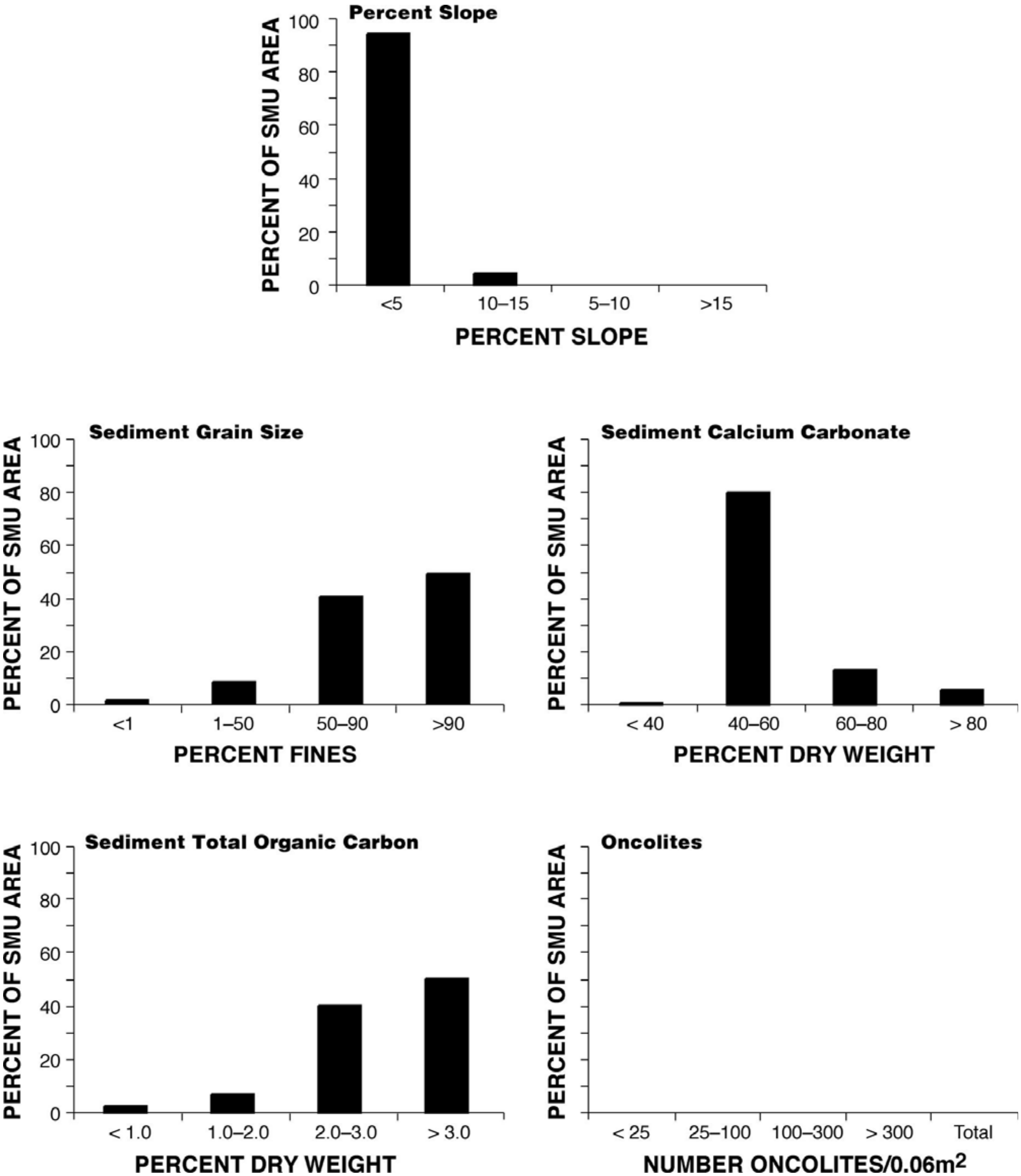

FIGURE M.22

ONONDAGA LAKE
SYRACUSE, NEW YORK

SUMMARY OF HABITAT
CONDITIONS IN SMU 8

Exponent

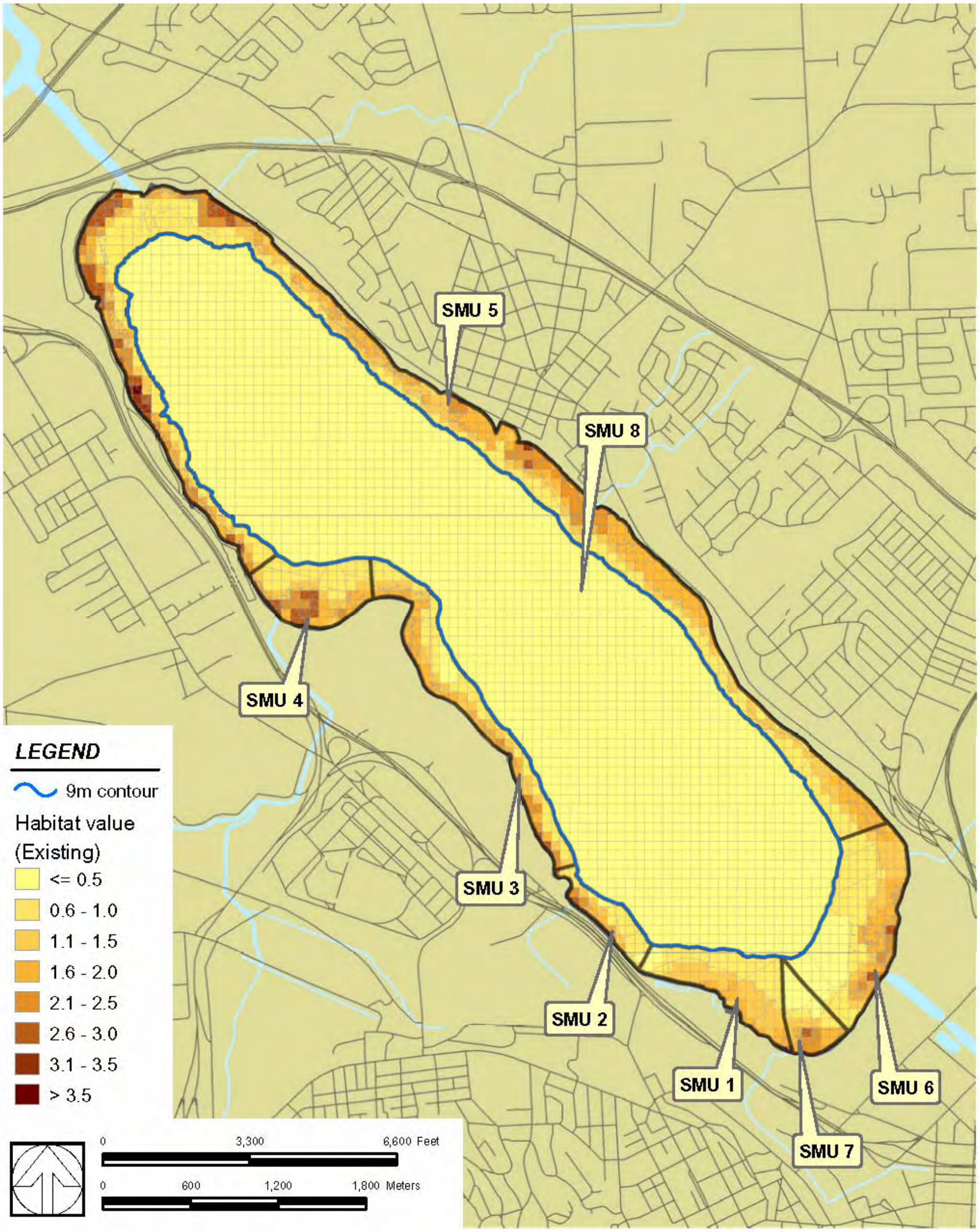

FIGURE M.23

ONONDAGA LAKE
SYRACUSE, NEW YORK

SUMMARY OF HABITAT VALUE IN ONONDAGA LAKE

Exponent

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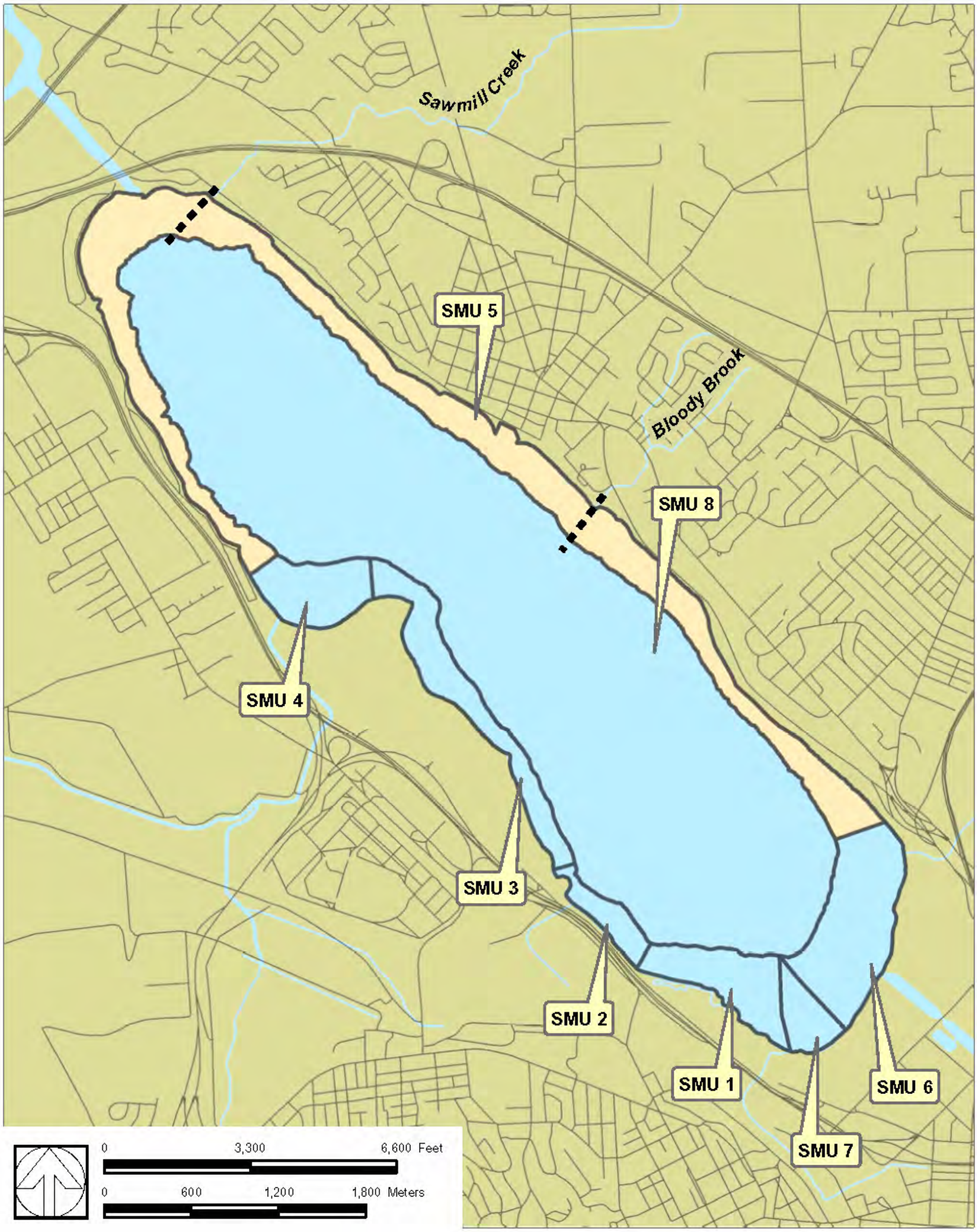
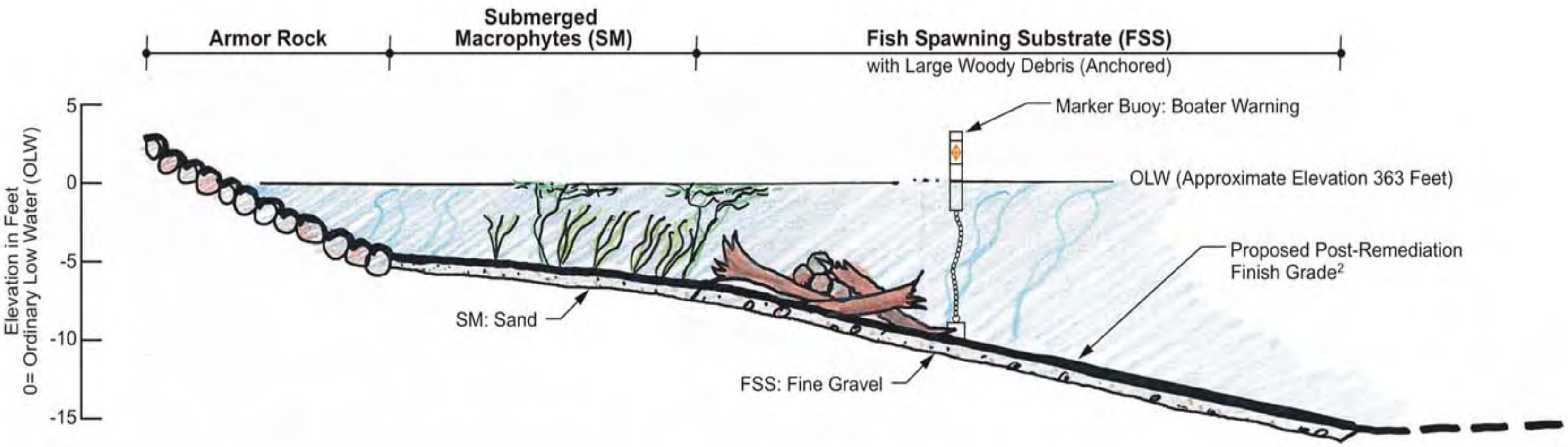


FIGURE M.30

ONONDAGA LAKE
SYRACUSE, NEW YORK

ENERGY ENVIRONMENTS IN SMU 5 IN ONONDAGA LAKE

Exponent



1 Typical Habitat Section:

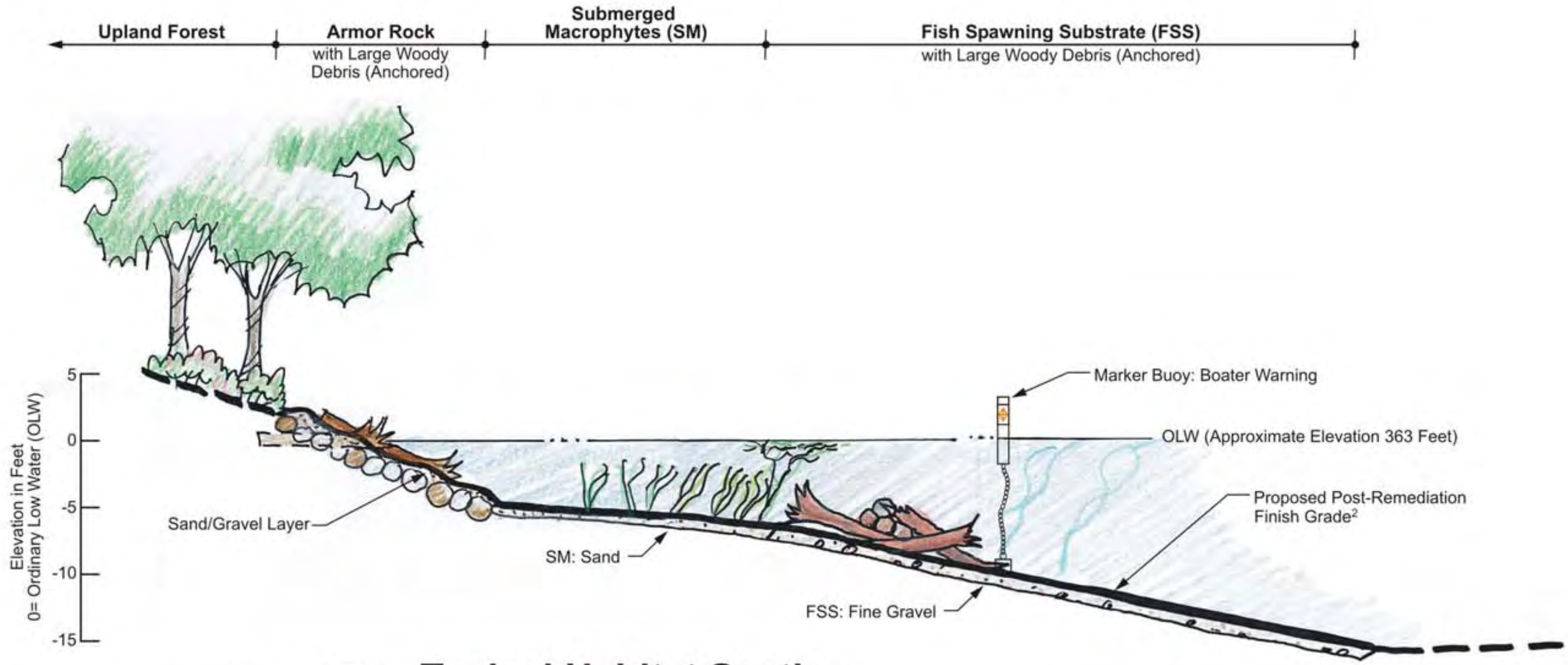
Constrained Shoreline Edge Concept

Not to Scale

Notes:

1. Applies to sites constrained by upland infrastructure (roads, railways), or unstable/steepslope conditions.
2. Habitat substrates are placed above capping layer. 6” thickness SM : Sand & FSS: Fine Gravel.
3. SM depths based on no lake aeration.

FIGURE M.24
ONONDAGA LAKE
SYRACUSE, NEW YORK
TYPICAL HABITAT SECTION: CONSTRAINED SHORELINE EDGE CONCEPT
ANCHOR ENVIRONMENTAL, L.L.C.



2 Typical Habitat Section:

Constrained Shoreline with Riparian Concept

Not to Scale

Notes:

1. Applies to sites constrained by upland infrastructure (roads, railways), or unstable/steepslope conditions.
2. Habitat substrates are placed above capping layer. 6" thickness SM : Sand & FSS: Fine Gravel.
3. SM depths based on no lake aeration.

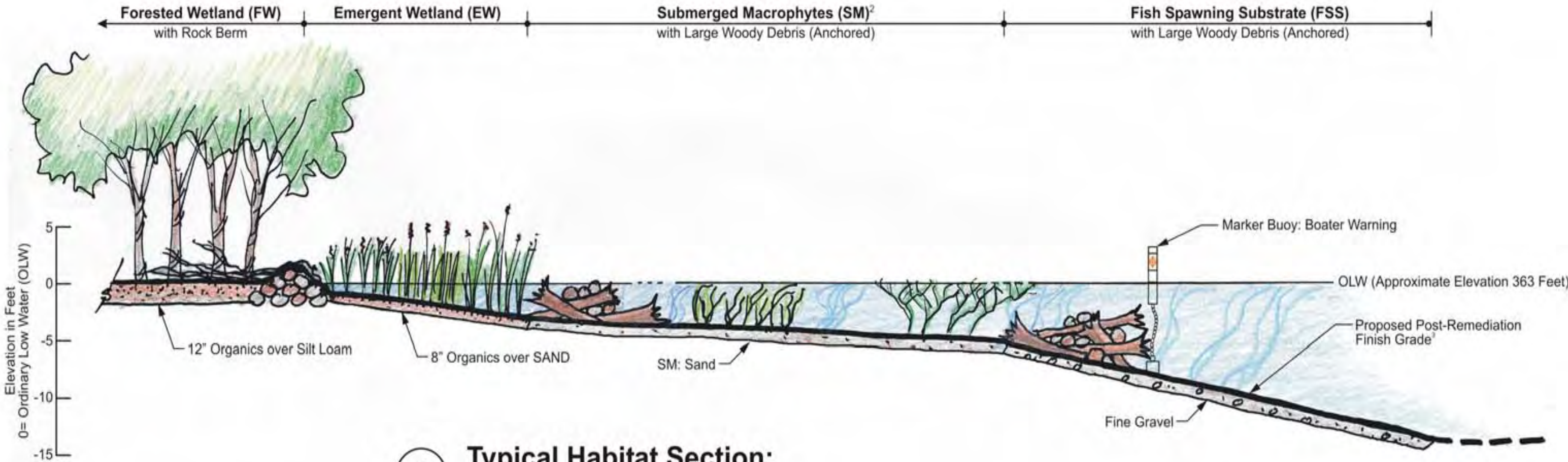
FIGURE M.25

ONONDAGA LAKE

SYRACUSE, NEW YORK

TYPICAL HABITAT SECTION: CONSTRAINED SHORELINE EDGE WITH RIPARIAN CONCEPT

ANCHOR ENVIRONMENTAL, L.L.C.



3 Typical Habitat Section:

Full Range of Habitat Types Concept
Not to Scale

Notes:

1. Applies to sites with least slope, depth or other constraints to the full range of habitat types.
2. SM substrate also includes Benthic Macroinvertebrate (BMI) substrate.
3. Habitat substrates are placed above capping layer:
   - SM: Sand and FSS: Fine Gravel: 6" thickness
   - FW: 12" organics over Silt Loam: 24" thickness total.
   - EW: 6" organics over 6" Sand: 12" thickness total.

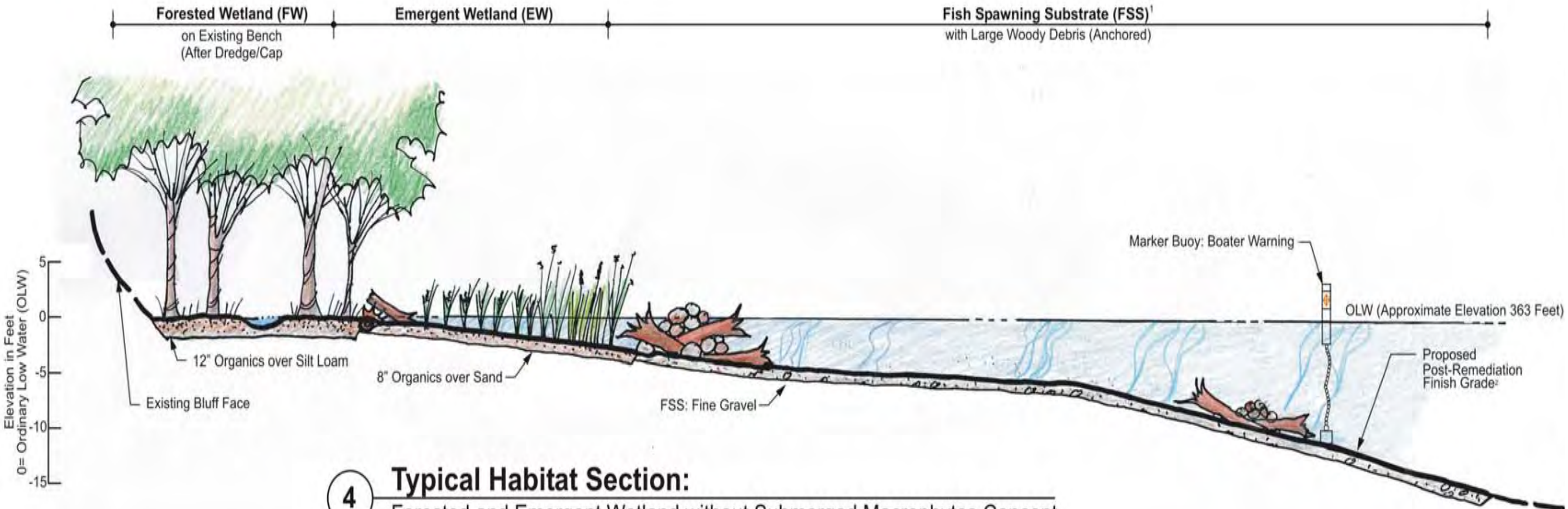
FIGURE M.26

ONONDAGA LAKE

SYRACUSE, NEW YORK

TYPICAL HABITAT SECTION: FULL RANGE OF HABITAT TYPES CONCEPT

ANCHOR ENVIRONMENTAL, L.L.C.



4 **Typical Habitat Section:**
Forested and Emergent Wetland without Submerged Macrophytes Concept
Not to Scale

Notes:
1. Applies to sites where wave energy or other factors limit success of submerged macrophytes colonization.
2. Habitat substrates are placed above capping layer.
   - FW: 12" organics over Silt Loam: 24" thickness total.
   - EW: 6" organics over 6" SAND: 12" thickness total.
   - FSS: Fine Gravel: 6" thickness.

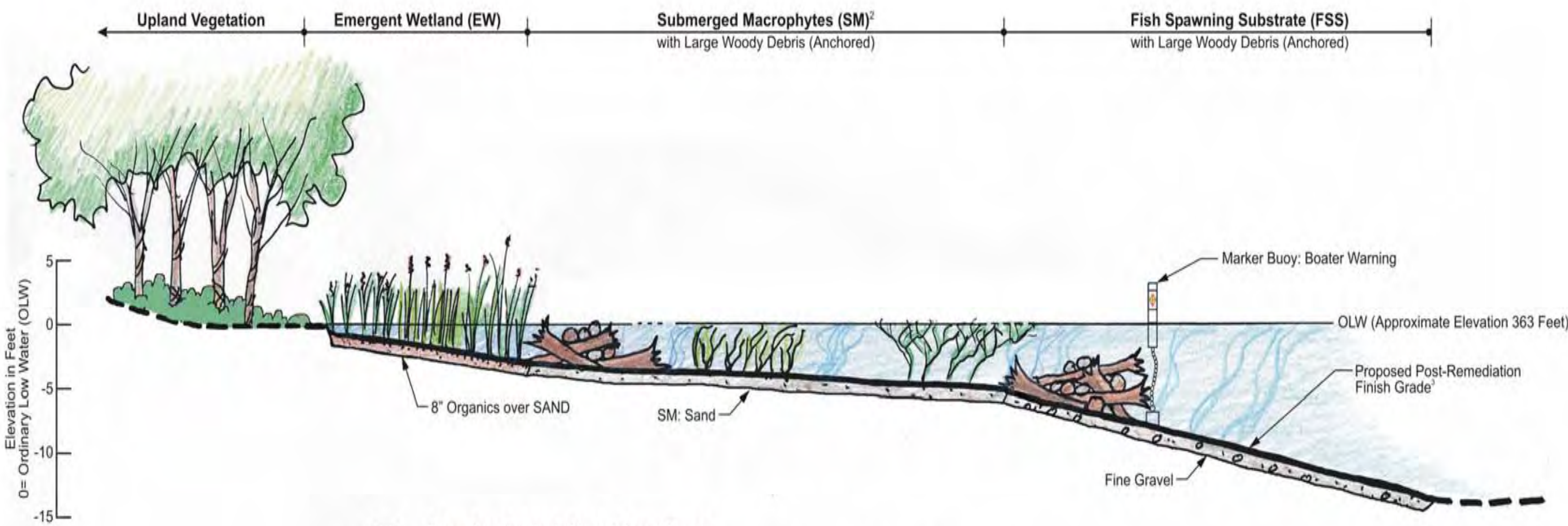
FIGURE M.27

ONONDAGA LAKE

SYRACUSE, NEW YORK

TYPICAL HABITAT SECTION: FORESTED AND EMERGENT WETLAND WITHOUT SUBMERGED MACROPHYTE CONCEPT

ANCHOR ENVIRONMENTAL, L.L.C.



5 **Typical Habitat Section:**
Vegetated Upland Edge with Full Range of Aquatic Habitat Types Concept
Not to Scale

Notes:
1. Applies to sites with least slope, depth or other constraints to the full range of habitat types.
2. SM substrate also includes Benthic Macroinvertebrate (BMI) substrate.
3. Habitat substrates are placed above capping layer:
   - SM: Sand and FSS: Fine Gravel: 6" thickness
   - FW: 12" organics over Silt Loam: 24" thickness
   - EW: 6" organics over Sand: 12" thickness total.

FIGURE M.28

ONONDAGA LAKE

SYRACUSE, NEW YORK

TYPICAL HABITAT SECTION: VEGETATED UPL AND EDGE WITH FULL RANGE OF AQUATIC HABITAT TYPES CONCEPT

ANCHOR ENVIRONMENTAL, L.L.C.

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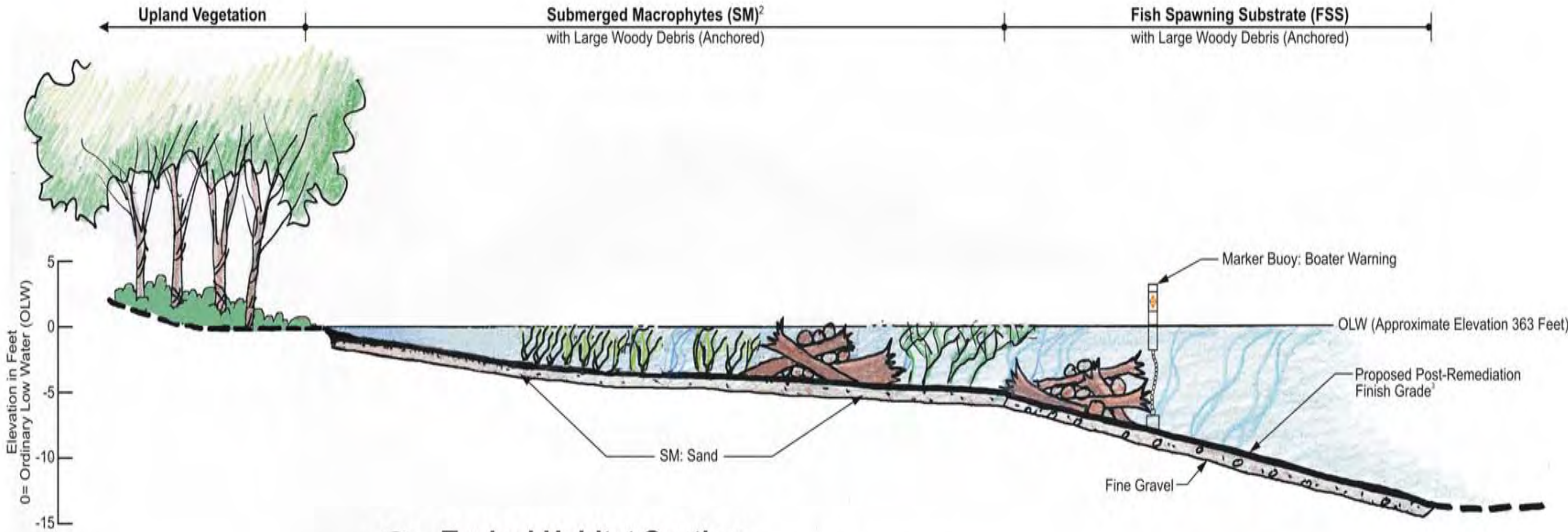

6 **Typical Habitat Section:**

High Wave Energy with Limited Habitat Types Concept

Not to Scale

Notes:

1. Applies to sites with least slope, depth or other constraints to the full range of habitat types.
2. SM substrate also includes Benthic Macroinvertebrate (BMI) substrate.
3. Habitat substrates are placed above capping layer:
   - SM: Sand and FSS: Fine Gravel: 6” thickness
   - FW: 12” organics over Silt Loam: 24” thickness total.

FIGURE M.29

ONONDAGA LAKE

SYRACUSE, NEW YORK

TYPICAL HABITAT SECTION: HIGH WAVE ENERGY WITH LIMITED HABITAT CONCEPT

ANCHOR ENVIRONMENTAL, L.L.C.

APPENDIX M

ATTACHMENT A

OVERVIEW OF HABITAT ISSUES IN EXISTING PROJECTS AND PROGRAMS IN ONONDAGA LAKE

APPENDIX M

ATTACHMENT A

OVERVIEW OF HABITAT ISSUES IN EXISTING PROJECTS AND PROGRAMS IN ONONDAGA LAKE

A variety of projects, programs, and plans are under way, in addition to this FS, that address habitat issues in and around Onondaga Lake. This appendix identifies these projects and, to the extent possible, identifies their goals and objectives. Ideally, the goals and objectives for habitat restoration and habitat enhancement associated with remedial alternatives identified in this FS should be interrelated with the goals and objectives of these other projects to maximize the success of all activities. Contradictory goals and objectives would likely result in a waste of environmental and financial resources. For example, the identification of habitat restoration as part of the remedial alternative in the area planned for the in-lake portion (Trail Section 3C) of the Onondaga Lake Trail is pointless, as construction of the trail would directly affect the habitats in that area.

Similarly, the enhancement of a macrophyte bed in an area planned for public swimming is counterproductive, as disturbance from human activities will diminish colonization of the plants, and people generally prefer to swim in areas free from plants. While the general public does not currently swim in the lake, future restoration objectives include an increase of the lake's accessibility for swimming (OLMC 1993), so this should be considered as part of the planning process. Other examples exist where interconnected and consistent goals and objectives between programs can maximize ecological services in Onondaga Lake. For example, in an area ultimately planned for public fishing access or wildlife management, habitat restoration following remedial action would be sensible and facilitate achieving such long-term management objectives.

The following projects, plans, or programs are under way or in development for Onondaga Lake. (The discussion of goals, objectives, and recommendations for each project, plan, or program is presented as available). While some of the more recent project and programs are an outgrowth or refinement of the earlier planning efforts, others have developed independently:

- **Land Use Master Plan** (Reimann Buechner Partnership, 1992): As described in Effler and Harnett (1996), the land use master plan was jointly developed by the Metropolitan Development Association, the city of Syracuse, Onondaga County, and the New York State Urban Development Corporation. The plan is used to coordinate development of the lakeshore and surrounding land. The plan includes short-term and long-term projects, including the construction of waterfront housing, corporate offices, and expansion of the marina.

- **OLMC Citizens Advisory Committee** (CAC): The Onondaga Lake Management Conference (OLMC) was established in 1990 and provided a framework for federal, state, and local governments to cooperate in the cleanup of the lake and revitalize the waterfront. The OLMC was made up of six voting members: the assistant secretary of the army for civil works, the administrator of the U.S. Environmental Protection Agency, the governor of the state of New York, the New York State attorney general, the Onondaga County executive, and the mayor of Syracuse (OLMC 1993). The OLMC created the CAC following nonscientific surveys of public concerns regarding the lake. The vast majority of returned surveys (1,045 of 1,161 returned surveys) indicated that the community was interested in spending more time at the lake if it were made "safe" for swimming. The CAC developed five objectives that reflect the desire of the community to "reclaim the resources of Onondaga Lake" (Effler and Harnett, 1996):
  - The aesthetic qualities of the surface water and shoreline of Onondaga Lake shall be enhanced and improved.
  - Onondaga Lake shall be made fit for contact recreation from the mouth of Onondaga Creek to the Seneca River outlet.
  - The wildlife habitat of Onondaga Lake shall be restored and enhanced to sustain a thriving ecosystem in the lower tributaries of Onondaga Lake and the lake proper.
  - Any water quality remediation of Onondaga Lake shall not result in adverse impact to Seneca and Oswego River system.
  - The remediation of Onondaga Lake shall ultimately allow consumption of fish from the lake.
- **Management Plan**: In 1993, the OLMC developed a management plan for the lake that included 53 specific recommendations intended to reclaim many of the resources of the lake. The management plan identifies the following subset of goals and recommendations associated with fish, wildlife habitat, shoreline use, and lake use (OLMC, 1993):
  - A suitable year-round habitat should be established for a sustainable consumptive warm- and coldwater fishery in the lake and its tributaries.
  - Specific reaches of both Ninemile and Onondaga Creeks should be made suitable for spawning, migration, and residence of indigenous fish species.
  - The New York State Department of Environmental Conservation (NYSDEC) should develop a fisheries management plan specific to Onondaga Lake to work toward achieving the OLMC recommendations.
  - The ongoing study to evaluate methods for littoral zone rehabilitation should continue. The results of such study should be considered in determining remedial options for the lake.
  - An artificial in-lake oxygenation pilot project should be developed to evaluate the potential for in-lake oxygenation on lake restoration.

  - NYSDEC should undertake experimental stocking of Ninemile Creek with Atlantic salmon smolts to assess remediation needs to allow future Atlantic salmon migratory runs.
  - A comprehensive biological monitoring program should be developed.
  - An annual fish monitoring program should be initiated for Onondaga Lake and its tributaries.
  - A natural history information and education program should be developed.
  - A plan to hydrologically connect selected wetlands areas to Onondaga Lake should be developed and implemented.
  - Environmentally sensitive areas and significant wildlife habitat around the lake shoreline should be identified. Incompatible development in these areas should be discouraged.
  - NYSDEC, Onondaga County, and the City of Syracuse should work to expand and improve access to the lake for fishing and boating as the fishery and public demand warrant. Facilities should provide access for boating and shoreline anglers and may include boat access and public fishing piers.
  - The development and construction of a fishing access site on the west shore of the lake should be pursued.
  - Dredging of the Inner Harbor should be conducted before 1996.
- **Habitat Improvement Project for Onondaga Lake** (EcoLogic, 1999): Studies have indicated that the fisheries habitat of Onondaga Lake would be improved by an increase in macrophytes. The Onondaga County Department of Health initiated a study with the following objective:
  - To evaluate a number of small (three to five acre [1.2 to 2 ha]) pilot habitat improvement projects that could eventually be implemented for larger, appropriate areas on the lake.
- **Administrative Consent Judgment**: The Amended Consent Judgment (ACJ) specifies projects to be undertaken to improve water quality in Onondaga Lake. The ACJ was signed in January 1998 and incorporated into the OLMC Management Plan (1993) in September 1999. The ACJ specifies more than 30 projects to be undertaken over a 15-year timeframe. The projects can be divided into three main categories (OLP, 2003b):
  - Improvements and upgrades to the county's main sewage treatment plant;
  - Elimination and/or reduction of the impacts of the combined sewer overflows on the lake and its tributaries; and
  - A lake and tributary monitoring program designed to evaluate the impacts of the improvement projects on the water quality of the lake and tributary streams.

- **Onondaga Lake Ambient Monitoring Program** (OCDWEP, 2003): The Onondaga County Department of Water Environment Protection's Ambient Monitoring Program (AMP) is a requirement of an ACJ signed by Onondaga County in 1998. The ACJ requires the county to "complement the chemical monitoring program with a biological monitoring effort to assess the densities and species composition of phytoplankton, macrophytes, macrobenthos, and fish" (OCDWE, 2003). Further, the ACJ requires that the county "evaluate the success of walleye, bass, and sunfish propagation (quantitative lakewide nest surveys, recruitment estimates, and juvenile community structure) in the lake" (OCDWEP, 2003). The AMP includes the following clearly defined program objectives (OCDWEP, 2003):
  - Compliance with the applicable ambient water quality standard in the upper waters and/or removal of ammonia toxicity as impairment to designated best use for survival and propagation of a warmwater fish community.
  - Compliance with the applicable ambient water quality standard in the upper waters and/or removal of toxicity as an impairment to designated best use for survival and propagation of a warmwater fish community.
  - Reduction in phosphorus sufficient to reduce the frequency and duration of nuisance algal blooms. Elimination of turbidity as an impairment to use of the lake for secondary water contact recreation (Class C segment) and primary water contact recreation (Class B segment). Compliance with narrative standard and site-specific guidance value appropriate for this urban lake, considering all watershed sources of phosphorus.
  - Reduction in volume-days of anoxia and volume-days of dissolved oxygen (DO) less than 2 mg/L. Maintenance of daily average DO >5 mg/L throughout the water column during fall mixing. Maintenance of DO >3.0 mg/L above the hypolimnion at least 80 percent of the time to provide suitable habitat for cool water fish such as walleye and tiger musky.
  - Reduction in average and peak algal biomass and frequency and duration of bloom conditions. Less than 10 percent chlorophyll *a* measurements exceed 30 μg/L (threshold for nuisance blooms). Less than 25 percent chlorophyll *a* measurements exceed 15 μg/L.
  - Summer average Secchi disk transparency at South Deep at least 4.9 ft (1.5 m) (for aesthetic quality); transparency at nearshore stations at least 3.9 ft (1.2 m) daily during recreational season (bathing beach swimming safety guidance value).
  - Abundance and composition of the algal community typical of a eutrophic lake in the same geologic and climatic setting. Decreased importance of cyanobacteria (blue-green algae).
  - Abundance and composition of the zooplankton community are comparable to reference eutrophic lake in same geologic and climatic setting.
  - Expansion of the areal coverage and increase in diversity of macrophyte community. Number of species and biomass of macrophytes in the littoral zone

comparable to other regional lakes. Increase percent cover of littoral zone to optimal levels for smallmouth bass (40 to 60 percent).

- Designation of the macroinvertebrate community by NYSDEC macroinvertebrate biological assessment profile as "slightly impacted" or better at all sites.
- Expanded habitat for fish community and promotion of water quality conditions that support diverse warmwater fish community. Self-sustaining sport fishery.

- **United States Army Corps of Engineers (USACE) Watershed Management Plan**: This project is still in the conceptual phase and includes a non-point source pollution plan and a sewer outfall plan intended to reduce the chemical and non-chemical stressors in the Onondaga watershed, thereby increasing water quality.
- **USACE Onondaga Lake Trail** (OLP, 2003a; USACE, 2003a): USACE has a project under way for the development of a trail around Onondaga Lake that includes an in-lake trail and associated wildlife habitat extending from Onondaga Creek northward approximately 1 mile (1.6 km). The objectives of the project are to "rehabilitate aquatic, shoreline, and upland habitat and provide public access and recreational opportunities" (OLP, 2003). The lake trail and habitat project integrates the creation, restoration, and enhancement of wetlands and shallow aquatic habitats. A report that describes the trial and the habitat restoration objectives, "Trail Section 3C of the Onondaga Lake Trail and Habitat Project: Baseline Conditions Memorandum" is available through the Onondaga County Public Library (USACE, 2003a). Appendix D of the memorandum contains a description of the wetlands and the general ecology of a field investigation conducted in early 2003.
- **USACE Strategic Comprehensive Habitat Restoration Plan** (OLP, 2003b; USACE 2003b): USACE is coordinating with NYSDEC, Onondaga County, the New York Health Department, and others on a strategic comprehensive habitat restoration plan for the Onondaga Lake Watershed, which includes the lake and its tributaries. A public meeting was held December 10, 2003, in Liverpool, New York, to introduce the program to citizens of the community. Habitat restoration goals and objectives for Onondaga Lake, as identified in the public meeting are the following (USACE, 2003b):
  - Restore and protect wetlands, floodplains, and terrestrial habitat surrounding Onondaga Lake

    A. Improve functionality of affected wetlands along the lakeshore, such that the number of functions and values supported by the wetlands are increased (based on the 13 functions and values identified by USACE [1995]).

    B. Restore floodplain hydrology and vegetative cover along the lakeshore where practical.

    C. Improve functionality of terrestrial habitat cover along the lakeshore where practical, such that the number of functions and values supported by the terrestrial cover are increased (based on the 10 functions and values identified by USACE [2000] for stream/lake buffer zones).

    D. Improve connectivity between fragmented habitats along the lakeshore.

E. Utilize Reschke's *Ecological Communities of New York State* (1990) as the reference document for selecting species to be used in the wetland, floodplain, and terrestrial habitat restorations to create native New York plant communities around the lake.

F. Reduce the overabundance and proliferation of invasive plant species.

G. Protect threatened and endangered species habitat and improve/expand the habitat where practical.

H. Encourage public support for implementing measures for lakeshore protection on the public and private lands surrounding the lake.

- Restore and protect aquatic habitat within Onondaga Lake

A. Improve habitat for aquatic fauna (e.g., fish, invertebrates) and semi-aquatic fauna (e.g., amphibians, reptiles)

B. Improve water quality to support native aquatic and semi-aquatic communities.

C. Improve native aquatic flora (i.e., macrophyte communities).

D. Reduce the introduction and proliferation of exotic or overabundance of nuisance/invasive plant and animal species.

APPENDIX M

ATTACHMENT A

REFERENCES

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