Section 4: Identification of Habitats for Restoration

The overall goal of habitat restoration is to achieve ecological systems that function naturally, are self-sustaining, and are integrated with the surrounding habitats. The Habitat TWG worked through a process to develop more specific habitat restoration goals and objectives for the Onondaga Lake site, and through extensive discussion, developed the habitat restoration approach described in this plan.

4.1 General Restoration Goals

There are three general restoration goals that directed the habitat restoration. These goals focus on those areas (*e.g.*, shoreline), species, or processes (*e.g.*, function of the littoral zone) that (1) have been altered over time through urbanization and industrialization, and (2) where physical changes will occur as a result of remediation.

Goal #1

The first general restoration goal is to maintain or improve

- size, diversity, and ecological function of wetlands;
- connectivity of the lake habitats with adjacent stream and upland habitats;
- ecological function of the littoral zone;
- ecological function of the shoreline habitat;
- habitat conditions of the profundal zone, and
- conserve and/or create habitats for threatened and/or endangered or rare species.

Goal #2

The second general restoration goal is to design conditions that discourage the establishment of invasive species (*e.g.*, avoid creating conditions conducive for invasive plant species) to the extent practicable.

For example, habitat restoration designs will include physical means to slow or impede the colonization of *Phragmites* into wetland areas. Diverse and robust native submerged and floating aquatics will be planted in Modules 4A and 6A to help minimize establishment of invasive species such as Eurasian watermilfoil and water chestnut into restored areas.

Eurasian watermilfoil is an aquatic plant that forms large, dense mats at the surface of lakes.

The mats prevent sunlight from penetrating through to native aquatic plants.

Goal #3

The third general restoration goal is to develop conditions that require minimal maintenance and promote public use. Habitat restoration designs are intended to provide self-sustaining, functioning habitats that require little or no maintenance (such as removal of invasive species) over the long term. Monitoring of the restored areas will be performed to

evaluate the physical characteristics and ecological function of the restored habitats. Restored areas should be open and accessible to the public to the extent practicable within the constraints of the remedy.

The TWG developed more specific restoration objectives as described in Section 4.3 in order to meet the three general restoration goals.

4.2 Assessing Habitat Conditions

The TWG reviewed existing and historical conditions of Onondaga Lake to identify habitat types and species to help define specific restoration objectives. Specifically, the identified habitats and species were those that either historically existed within the lake, but that are currently lacking, or those that currently exist within the lake, but are currently degraded (*e.g.*, wetlands dominated by *Phragmites* or limited in distribution).

Understanding the existing habitat conditions on a lake-wide basis is important in the development of the restoration plan because habitat restoration for a given remediation area must fit in with the adjacent areas not requiring remediation *and* contribute to the diversity and abundance of organisms in the overall lake-wide habitat complex.

Wetland Habitat Types

Floating aquatic: dominated by plants that float at the water's surface

Non-persistent emergent: dominated by plants that are rooted in the bottom substrate, emerge above the surface of the water, but die back and are not evident during the winter months

Persistent emergent: dominated by plants that are rooted in the bottom substrate, emerge above the water surface and remain standing at least until the beginning of the next growing season

Existing conditions in and around Onondaga Lake were presented in Section 2. Included within that section is information gathered from literature sources and contacts with resource agencies, as well as information obtained from studies performed as part of the development of the remedy for the lake. Habitat types in and surrounding the lake were mapped using aerial photographs, maps of land use, and previously published investigative reports including wetlands and floodplain assessments.

The assessment of existing habitat conditions provides useful information on where different habitat types currently exist and the extent of these habitats in the overall lake system. Also, this assessment reveals what habitat types are absent. Important wetland fringe habitats (*e.g.,* floating aquatic wetlands, non-persistent emergent wetlands, and persistent emergent wetlands) are notably lacking in the lake system and, as a result, are targeted in the habitat restoration design. Field observations also indicate that in-water physical structure is a missing habitat component in certain areas.

Upland habitats and land uses in shoreline areas are important factors to consider when selecting habitat types for a specific in-lake area. It is important that the restored habitats complement and become integrated with the adjacent shoreline habitats/land uses. For example, in the habitat restoration design at the mouths of Ninemile Creek, Harbor Brook, and Onondaga Creek, it is necessary to maintain a free-interchange connection of aquatic and terrestrial habitats between the lake and these primary tributaries.

4.3 Habitat Restoration Objectives

Only those species which may be impacted by the remedial activities are included on the list of objectives. In particular, those species or

The American eel is a native species to Onondaga Lake, but due to blockages in the waterways such as dams, they are currently prevented from populating the lake.

habitats for which the lake remediation will not change the suitability of the lake for their occurrence, or does not affect the factors which limit their occurrence, have not been included in the objectives. For example, the American eel, a species that was historically present, is currently prevented from reaching Onondaga Lake due to blockages (dams) and other factors in the rivers and lakes between the ocean and Onondaga Lake. Remedial activities will not change the relationship between the lake and the surrounding rivers and lakes, so the American eel has not been included as a representative species. If the American eel were to return to Onondaga Lake, however, it would not be negatively impacted by remedial activities, and it would be able to use the restored habitat.

The specific habitat and species restoration objectives developed for this Habitat Plan include the following:

- maintain or increase diversity of habitats for fish, benthic macroinvertebrates, birds, reptiles, amphibians, and mammals including improvement of wetlands;
- maintain or increase diversity of native plant communities;
- provide or improve gradual and natural transitions between the lake, its tributaries, and the adjacent shoreline;
- minimize or eliminate restrictions to public use and access;
- provide deep water (*e.g.*, greater than 7 feet) nearshore to provide the opportunity for future projects that will allow fishing access and fishing piers;
- provide or enhance habitats suitable for fish species with limited populations in the lake such as northern pike, lake sturgeon, and walleye;
- create or enhance suitable habitat for transient cold water fish species (*e.g.,* brown trout, Atlantic salmon) to access Ninemile Creek and/or Onondaga Creek for spawning;
- reconstruct wetlands to be compatible with establishing pike spawning habitat;
- do not increase the acreage of habitats along the profundal zone boundary that may be under anoxic conditions during portions of the year;
- integrate substrate requirements from the remedial design (*e.g.*, erosion protection) and habitat restoration needs;
- include the use of structure to improve habitat value;
- evaluate the feasibility of restoring/creating at least one inland salt marsh;
- evaluate the feasibility of recreating habitat for historically or culturally significant species;
- evaluate the feasibility of recreating unvegetated shorebird habitat (*e.g.*, mudflats);

Red-winged blackbird eggs

- minimize the need for maintenance following completion of the remedy;
- provide suitable habitat for foraging and reproduction of reptiles and amphibians;
- provide suitable habitat for foraging for semi-aquatic mammals; and
- provide suitable habitat for breeding birds.

Section 5 of this Plan details how these goals and objectives will be met through implementing the habitat restoration designs.

4.4 Identification of Representative Habitats and Associated Species Requirements

In certain instances, the habitat restoration goals and objectives discussed above are specific to particular habitats or species. In some cases, however, other goals and objectives were less specific—for example, "re-create shorebird habitat," and "maintain or improve the function of the littoral zone." For these more general goals, the TWG identified *representative* species and habitats that could be used to guide the development of the restoration designs to meet the goal or objective. For example, to re-create wetland habitat, representative wetland plants were identified and their habitat requirements were used to guide the habitat design.

Representative species from various groups including plants, fish, benthic macroinvertebrates, mammals, amphibians, reptiles, and birds were identified after review of the historical and existing ecological conditions. Once representative species were identified, the TWG reviewed the scientific literature (including peer reviewed journals, books, and project specific documents) to identify the habitat requirements of each species. These habitat requirements included physical characteristics (*e.g.*, water depth and energy and substrate type) and water quality characteristics (*e.g.*, dissolved oxygen, turbidity, pH, temperature), as well as other factors (*e.g.*, vegetation cover, minimum habitat size) that each species may need for various life stages.

Guilds

A guild is a collection of species that use the same habitat resources in the same way, but may not otherwise be related.

For example, ospreys and kingfishers are both in the fish eating guild (piscivores), yet they are different species with different nesting requirements.

4.4.1 Representative Habitat and Species Selection

The TWG selected species to be used during the habitat restoration activities from groups of fish, plants, benthic macroinvertebrates, mammals, amphibians, reptiles, and birds. These "representative" species *represent* a larger group or guild of species that shares similar habitat requirements. Individual species within each of these groups were selected based on various criteria including the following:

- represents different guilds;

- includes a variety of habitat types;
- has important ecological, cultural, recreational, or economic value;
- is a species with limited populations that could be potentially be increased;
- represents a habitat type not currently found in the lake;
- represents a habitat or species historically known from the lake that is no longer present; or
- is a rare, threatened, or endangered species.

The selection of representative species was designed to include species that historically were found in the lake, currently reside in or near the lake, or are likely to be found in the vicinity of or transiting the lake (*e.g.*, shorebirds, coldwater fish). Species within each group were selected to represent the larger group; that is, the list does not include every species that could potentially use Onondaga Lake. The premise is that if the habitat requirements are met for the representative species, then other species with similar habitat requirements will also find favorable conditions in the lake.

4.4.2 Requirements of Representative Species

The habitat requirements for each species were developed from Habitat Suitability Index Models (when available), the current literature, professional experience, and judgment gained from field observations. Habitat requirements were identified for various life stages of each species for the following physical parameters: water depth, substrate type, wave energy, structure-vegetation cover, structure-woody debris, and rooting/burrowing depth. In addition, habitat requirements were identified for water quality parameters, including dissolved oxygen, temperature, nutrient source, turbidity, and pH. These habitat requirements are summarized in Tables 4.1 to 4.7. Each species has multiple physical, chemical, and biological habitat requirements. While those have been included in the tables, it is important to recognize the few key parameters that can be materially changed by the remediation and restoration activities. Specifically, remediation and restoration activities will focus on water depth, substrate type and structure (*e.g.*, vegetation, logs, and boulders). Other factors, such as dissolved oxygen and water temperature, will not be altered by remediation and restoration activities. The rationale for the development of each table is discussed below.

Representative Fish Species
Northern Pike
Lake Sturgeon
Smallmouth Bass
Largemouth Bass
Walleye
Pumpkinseed Sunfish
Golden Shiner
Emerald Shiner
Brown Trout

Fish

Habitat requirements for representative fish species are provided in Table 4.1. Nine species were selected to represent the various types of temperature requirements (warm water, cool water, and coldwater), as well as various trophic levels (planktivores [those fish that eat plant material], piscivores [fish that eat other fish], benthivores [fish that each benthic macroinvertebrates]). Coldwater species are represented by the brown trout, which is currently a transient species in the lake. The

brown trout is considered representative for other coldwater species, such as Atlantic salmon and cisco (presumed by some experts to be the Onondaga Lake whitefish), which historically were found in the lake. The cool water species are represented by smallmouth bass, northern pike, walleye, and lake sturgeon. Three species were selected to represent this group due to different reproductive strategies (those fish that reproduce in river environments versus those that reproduce in lake environments) and feeding preferences (piscivorous versus benthivorous). Finally, four warm water species were selected: largemouth bass, pumpkinseed, golden shiner, and emerald shiner to represent various trophic levels and water depths. These species represent recreational fish species and trophic pathways within the lake.

Northern pike, lake sturgeon and walleye were identified as the top three priority species. Application of modules within each remediation area considered these three species first, prior to consideration of the other representative fish species. The walleye population in the lake appears to be limited based on spawning habitat, as juveniles have not been collected during recent sampling efforts (OCDWEP AMP, 2003; OCDWEP AMP, 2004; OCDWEP AMP, 2005; OCDWEP AMP, 2006). This species typically spawns in rocky crevices in tributaries or along shallow shoreline areas (McMahon *et al.,* 1984). Since the lake remedy is not targeted in the tributaries, there is limited opportunity for improving spawning habitat for walleye in the lake proper, but IRMs for adjacent sites are expected to improve habitat conditions in those areas. If tributaries became suitable for spawning populations, the lake would provide habitat for these life stages.

Northern pike require flooded wetlands within and adjacent to a water body for spawning (Inskip, 1982). In Onondaga Lake, northern pike are likely limited by spawning habitat because there are a limited number of flooded wetlands within and adjacent to the lake.

Lake sturgeon adults have been captured in the lake as recently as 2009 (Kirby, 2009). These fish have been stocked within the watershed, and adults are likely to occur in Onondaga Lake following remediation. Adult lake sturgeon are typically found in water 20 to 40 feet deep over a sand or cobble substrate with little or no vegetation. They are benthic invertivores and feed on a variety of organisms including insect larvae and nymphs, leeches, amphipods, snails, clams, and occasionally small fish. Substrate type is important for lake sturgeon as they are more commonly associated with these two substrates which allow for the colonization of benthic macroinvertebrates (Lemon, 2009).
Smallmouth bass and largemouth bass are two of the most abundant piscivores in the lake. While portions of the lake currently support all life stages, improvements can be incorporated into the remediation to create additional habitat for both species. Substrate type and plant cover are important factors that influence the sustainability of both species. Smallmouth bass prefer slightly cooler rocky areas, while largemouth can be found in areas with sufficient cover provided by vegetation and other types of cover (*e.g.*, woody debris). Pumpkinseed represents invertivores, and they will use similar habitats as the bass

Representative Aquatic Plant Species
Submerged Vegetation
Floating Vegetation/ Aquatic Beds
Nonpersistent Emergent Vegetation
Persistent Emergent Vegetation
Salt Marsh Vegetation
Unvegetated Shoreline/ Mudflats
Wet Meadow Wetland
Forested/Scrub-Shrub Wetlands
Forested Scrub-Shrub Uplands
Open Field Uplands

with preference for shallow water with adequate cover. Golden shiner and emerald shiner represent planktivorous minnows within the lake. These species have different habitat requirements; the golden shiner is typically located within the littoral zone associated with vegetation, and the emerald shiner typically inhabits the pelagic or open water zone of lakes moving within the water column with the planktonic food supply (Scott and Crossman, 1979).

Plants

For plants, physical and biological factors were identified for representative aquatic wetland and upland plant habitat types (Table 4.2a). These habitat types are representative of the different water regime zones that will be expected in the restoration areas. Several representative plant species are identified in Table 4.2a for each of these habitat types.

Table 4.2b presents phenology (*e.g.*, flowering season) information for six selected aquatic plants. Four submerged and two floating-leaved aquatic plant species were selected as representative species within the littoral zone of the lake. In general, these plants require sandy, silty sand, or silt substrates for root development. Details regarding the substrate requirements for specific plant species will be provided in subsequent design submittals.

Benthic Macrointertebrates

Six representative orders (rather than species) of benthic macroinvertebrates were selected for the lake (Table 4.3). These orders included mayflies, caddisflies, true flies, dragonflies and damselflies, scuds, and crayfish and represent various trophic levels, such as grazers (herbivores), collector/gatherers (herbivores/detritivores), and predators (carnivores). They also represent substrate requirements, such as vegetation, rocks, woody debris, and soft organic sediments. Littoral areas of the lake provide most of the suitable habitat for benthic macroinvertebrates.

Benthic macroinvertebrates are represented by several insect orders, as well as amphipods and decapods (crayfish). Species within these groups are fairly diverse in their habitat requirements. Currently, species diversity is limited within the lake and is comprised primarily of amphipods and dipterans. The majority of the species within each of the representative groups is found in the littoral zone of lakes or within streams. Mayflies (*Ephemeroptera*) are typically found in lotic (moving-water) environments, however, a few families are found in lentic (still-water) habitats; most mayfly species are sensitive to water quality changes and typically their presence indicates high water quality. Caddisflies (*Trichoptera*) also are most diverse in cool running waters, however, several families are represented in lentic habitats; many caddisfly species are sensitive to water quality changes and typically their presence indicates high water quality. Damselflies (*Odonata:Zygoptera*) are typically found in association with aquatic plants, while dragonflies *(Odonata:Anisoptera)* tend to dominate in sand, silt, and detritus. Many species are moderately sensitive to water quality

Representative Benthic Macro-Invertebrates Species
Mayfly
Caddisfly
True Flies
Dragonfly/ Damselfly
Scud
Crayfish

changes, while some species can withstand periods of low dissolved oxygen. Amphipods *(Amphipoda)* are currently present in the lake residing on the surface sediment within the littoral zone. They are commonly found in association with aquatic plants, detritus, and gravel and cobble. The majority of species in this taxon are tolerant of moderate disturbance (including impaired water quality).

Crayfish are present within the Onondaga Lake watershed, but may be limited in the lake due to current conditions. These species typically live within the substrate among the interstitial spaces or within the woody debris, plants, and detritus along the littoral zone. The majority of species in this taxon are tolerant of moderate disturbance (including impaired water quality). Application of the habitat modules within each remediation area will improve conditions for these representative species and may result in greater diversity within each group. Substrate composition (type and size), such as sand, gravel, and cobble, which contain oxygen within the top several inches, is a critical component for invertebrate colonization.

Amphibians and Reptiles

Representative Amphibian and Reptile Species	
Spotted Salamander	Northern Water Snake
Mudpuppy	Snapping Turtle
Leopard Frog	Painted Turtle
Wood Frog	Musk Turtle
Green Frog	Red Spotted Newt

Habitat requirements for six representative amphibian species are provided in Table 4.5. Three salamander species (red-spotted newt [*Notophthalmus v. viridescens*], mudpuppy, and spotted salamander [*Ambystoma maculatum*] and three frog species (green frog [*Rana clamitans melanota*], leopard frog [*Rana pipiens*], and wood frog [*Rana sylvatica*]) were selected to represent the various habitats and food sources used by amphibians. Two distinct life stages (egg/juvenile and adult/eft) must be considered for amphibians because species may be aquatic during one phase and terrestrial during the other. Mudpuppy represents the only species that is entirely aquatic throughout its life cycle. For the other five species, adults generally utilize terrestrial and aquatic habitats for foraging and hibernation with reproduction and rearing occurring in permanent or temporary shallow water.

The TWG identified four representative reptile species: musk turtle (*Sternotherus odoratus*), snapping turtle, painted turtle, and northern water snake (Table 4.6). These species represent the range of habitat required for foraging and feeding, basking, and reproduction. The three representative turtles require softer upland substrates near water for nest excavation and egg deposition and use the littoral zone as adults and/or juveniles. Northern water snake is a live-bearer (meaning that it does not lay eggs) and does not require any specific habitat for reproduction. Depending on the species, the representative reptiles forage on both plants and animals (aquatic invertebrates, amphibians, and small fish), in shallow water areas. Other habitat considerations include basking sites, deeper water areas for overwintering for turtles, and structure in terrestrial areas (fissures and crevices) for northern water snake hibernation.

Representative Bird Species
Mallard
Common Goldeneye
Spotted Sandpiper and Semi-palmated Sandpiper
Bank Swallow
Red-winged Black Bird
Common Tern
Belted Kingfisher
Osprey
Great Blue Heron
Green Heron

Birds

Eleven bird species were selected to represent the various trophic levels (invertivores, piscivores, omnivores) nesting requirements and feeding strategies. The list of representative bird species includes diving and dabbling ducks, shorebirds, birds of prey, and wading birds. Habitat needs vary for each species, so a variety of habitats both in-water and along the shoreline will provide the most suitable habitat for each. Habitat requirements for the bird species are provided in Table 4.7.

Five of the representative bird species represent those birds that nest in available vegetation (green heron, great blue heron, osprey [*Pandion haliaetus*], common goldeneye [*Bucephala clangula*], and red-winged blackbird). These species typically nest in herbaceous wetlands, shrubs, or trees. Red-winged black bird will share the same habitat requirements as the snipe, which is a culturally significant species.

The remaining six species (mallard, common tern [*Sterna hirundo*], belted kingfisher, bank swallow, spotted sandpiper, and semi-palmated sandpiper) nest on the ground or in trees. The species with the most restrictive nesting requirements is bank swallow, which requires steep, unvegetated banks composed of soft substrate for burrow excavation. Foraging habitats range from grasslands adjacent to the lake (red-winged blackbird) to the profundal regions of the lake proper (common goldeneye).
The most common foraging habitat for the representative bird species is the littoral zone of the lake. Six of the 11 species (great blue heron, green heron, mallard, belted kingfisher, spotted sandpiper, and semi-palmated sandpiper) feed on aquatic vegetation, invertebrates, amphibians, or small fish in the shallow nearshore areas. The common tern and osprey feed on fish in the top several feet of the open water area of the lake proper, while the bank swallows feed on emerging insects above the open water.

Representative Mammal Species
Muskrat
Mink
Otter
Beaver
Indiana Bat

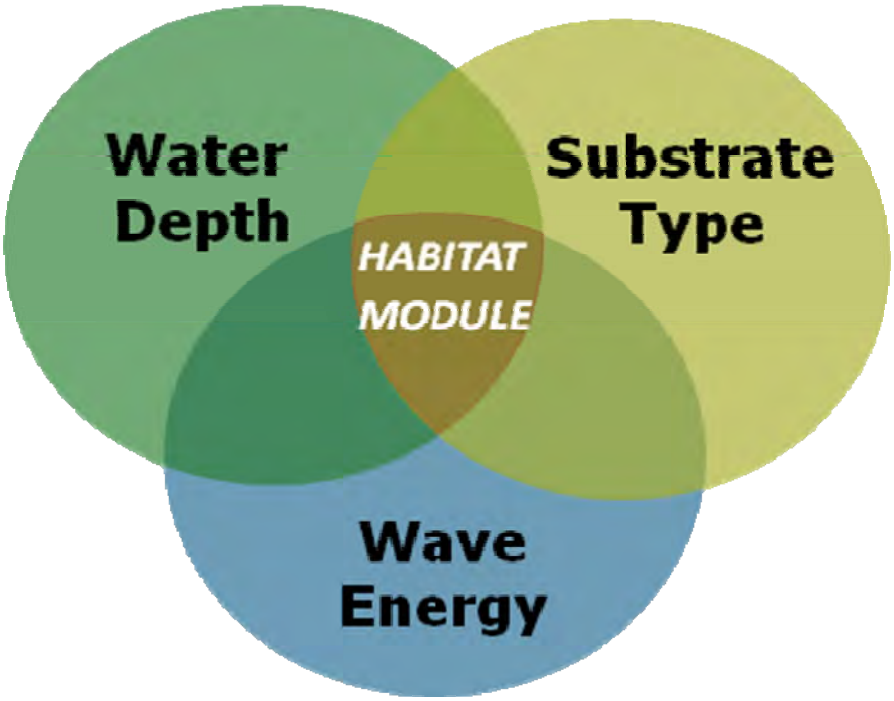
Mammals

Five species of mammals were identified as representative species, including Indiana bat, mink (*Mustela vison*), beaver (*Castor canadensis*), muskrat, and river otter (*Lontra canadensis)* (Table 4.4). With the exception of the Indiana bat, the mammal species are considered semi-aquatic and are found along shorelines of lakes, rivers, and streams. In general, these species prefer low energy environments with low water level fluctuations. Beaver, muskrat, mink, and otter also prefer habitat with sufficient cover (provided by woody debris, emergent vegetation or trees and shrubs) along the shoreline.

Indiana bat was included as a representative species because it is on the state endangered species list and federal threatened species list. Although suitable habitat for the bat does not occur within the lake, the bat may feed on flying insects and roost in large trees with exfoliating or cracked bark during the summer in areas adjacent to the lake.

4.5 Habitat Module Development

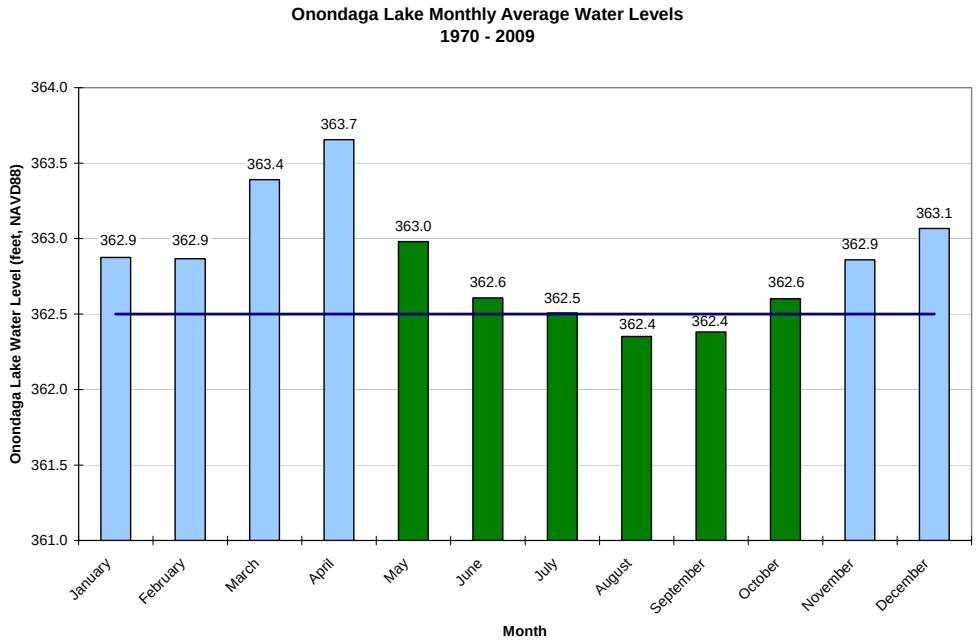
Following the identification of the habitat requirements of each representative species, the TWG developed a method to combine the representative species and their habitat requirements into areas, or "modules," which could be readily integrated with the remediation activities. The in-lake habitat modules are defined by three basic habitat parameters: water depth, substrate type, and wave energy (Table 4.8). Two upland modules were also developed. These habitat modules serve as the basis for the habitat restoration design.



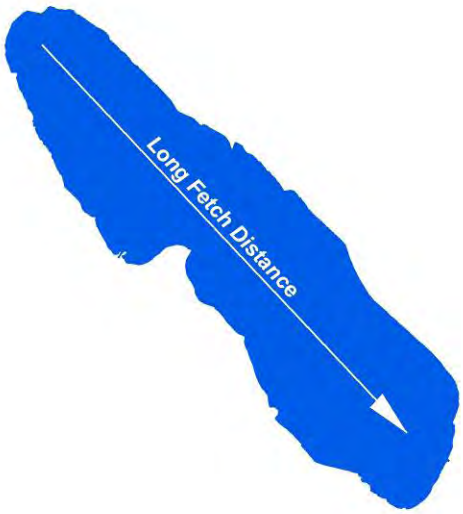
Fluctuations in lake water levels occur on a seasonal basis and during precipitation events, but levels are primarily controlled by the Phoenix Dam on the Oswego River in the Village of Phoenix. Lake levels are generally higher during the winter months than during the summer months. For habitat restoration purposes, the elevation of the lake water is critical during the late spring through early fall month (April to October). Lake level elevations are fairly consistent during this time as indicated by the record of lake water levels presented in Table 2.2. The water depths designated for the in-lake modules are assumed to be relative to the normal summer Onondaga Lake water level elevation of 362.5 feet (NAVD 88). This water level was based on an evaluation of the average water level during the growing season (May 1 to October 31) for the period of record from 1970 to 2008.

The bar chart shown here represents the average water level in the lake for each month of the year. During the growing season (green bars) the average fluctuates very close to 362.50 ft (NAVD 1988).

According to the United States Geological Society, the 100-year floodplain elevation for Onondaga Lake is 371.23 ft (NAVD 88).



Wave energy was identified as another basic parameter for in-lake habitat modules because it materially affects the type of substrate and structure that can occur within specific areas. Winds blowing across the surface of bodies of water transmit energy to the water, and waves are formed. The size of these wind-generated waves depends on the wind speed, the length of time the wind is blowing, and the extent of open water over which it blows (fetch). The longer the fetch distance or the faster the wind speed, the higher the waves are that are formed. To maximize the chance for success for the various types of habitat modules, the littoral regions of the lake were divided into "energy zones" based on the size of waves that could impact that area. The goal is to match the habitat module best suited for each area. A *low energy* zone is an area where there is a limited fetch and the wave heights are small. A *high energy* zone has longer fetches and higher wave heights. A *medium energy* zone lies in between these two zones.



Winds are predominately from the west and northwest near Onondaga Lake. Based on a review of 68 years of wind data collected from Hancock International Airport, as well as an assessment of wind-generated wave heights for various wind speeds and directions, the Remediation Areas have been divided into the following energy zone:

- Remediation Area A: A *low energy* zone. This area located along the western shore of the lake is protected from waves approaching from the southeast and has only a limited fetch in which waves could develop from the north and east. Wave heights, even during extreme events, are relatively low in this area.

- Remediation Areas B, C, and D: *Medium energy* zones. These areas are also located along the western shore of the lake and are protected from winds from the northwest. While having a limited fetch for winds from the south, these areas have longer fetch distances for waves approaching from the north and east.
- Remediation Area E. A *high energy* zone. This area is located at the southern end of the lake is has a long fetch for winds from the north and northwest. As a result, higher waves can impact this area.

Habitat Modules

The in-lake habitat modules presented on Table 4.8 are indicated by a number from 1 to 7, with each number corresponding to a specific water depth range. Limits of the water depth zones for each habitat module were established to define a recognized habitat type. Deep water limits of the habitat modules were established by the remedial activities. The majority of remedial activities will occur in the littoral zone, which was defined to a water depth limit of approximately 30 feet (9 meters) in the ROD. As a result, 30 ft was selected as the deep water limit of the modules (Table 4.8). The shallow water limit of Module 1 is 20 feet and represents the deep water habitats of the littoral zone. The profundal zone is defined as the area with water greater than 30 feet deep and the deep water module (Module 1) would also be applicable in this area if needed.

Generally, submerged aquatic vegetation in the lake is most abundant at a water depth less than 7 feet (approximately 2 meters). With this in mind, the mid-water depth of 7 to 20 feet (Module 2) represents the lake habitat from the approximate limit of submerged aquatic vegetation out to the limit of the deeper water module (Table 4.8).

Because of their water depths, Modules 1 and 2 are habitats that are primarily important to fish species, deeper water benthic macroinvertebrates, and some bird species. These two modules are generally beyond the limit of significant wave energy influences from wind/wave activities.

As indicated, the deep water limit of abundant submerged aquatic vegetation is approximately 7 feet. There is also a shallow water limit of about 2 feet for submerged aquatic vegetation, because wave energy is one of the factors limiting aquatic plant occurrence at shallow depths. As a result, a water depth zone of 2 to 7 feet (Module 3) is used to define the area for submerged aquatic vegetation (Table 4.8). This habitat module area is important for certain nesting fish species, benthic macroinvertebrates, and waterfowl, particularly dabbling ducks such as mallards.

The shallow water fringe areas of the lake were divided into three modules that are primarily defined by the zones of the dominant wetland vegetation. Wetland vegetation is known to occur in certain water depth zones and wetland classification systems use this recognized wetland zonation to define wetland types. As indicated on Table 4.8, the three water depth zones are: 1 to 3 feet deep – floating aquatic wetland

vegetation (Module 4); 0.5 to 2 feet deep – non-persistent emergent wetlands (Module 5); and 1 foot above normal summer lake elevation to a water depth of 1 foot deep – persistent emergent wetlands (Module 6). These shallow water wetlands are noticeably lacking around the lake and are important habitat types for various fish and wildlife species.

Module 7 was originally planned as mudflat habitat, but it has not been included in the conceptual designs due to the lack of control over fluctuating water levels required to maintain mudflats along the shoreline. The relatively recent introduction of *Phragmites* (within the last 75 years) has also made the creation and long-term effectiveness of this type of environment very difficult. Additional details on Module 7 can be found in Section 5.3.

Two additional habitat modules (8 and 9) were also developed based on elevation and the habitat cover of adjacent areas. Upland areas may be part of the habitat restored as part of the restoration plan, especially in the transition zone between the lakeshore and landward habitat areas. These upland habitats (Module 8) would have water more than 1 foot below the ground surface - that is, having no standing water or saturation near the surface (Table 4.8).

Onshore or inland wetlands are also recognized as a habitat type identified as part of this plan. It is assumed that these wetlands are not necessarily associated with the lake waters, but generally have water at the surface or near the surface for extended duration during the growing season. These wetlands are represented by Module 9 (Table 4.8).

As is the nature of any biological entity, the water depth limits of the habitat modules are not discrete boundaries. There will be a transition or overlap zone from one module to the next at the specified outer limits of water depth for each module. The lake is a dynamic system that will cause changes to the lake bottom over time and the boundaries noted on the figures in this plan are intended to be a representation of the habitats that will exist following restoration.

For this reason, the wetland habitat modules (Modules 4, 5, and 6) have overlapping water depth limits. For example, it is expected, that submerged aquatic vegetation (Module 3) will occur at the deeper limit of the floating aquatic wetland (Module 4), and that non-persistent emergent wetland vegetation (Module 5) will occur at the shallow end of this module.

Habitat Module Modifiers

An “A” or “B” modifier is used to further define each numbered habitat module to reflect substrate and wave energy categories. The modifier A represents a finer substrate in an area of low wave energy, and the modifier B represents a coarser substrate in an area of medium to high wave energy (Table 4.8).

Modules 8 and 9 are not associated with lake water, so substrate types related to wave energy zones are not necessary. For Modules 8 and 9, the A and B modifiers relate to whether the dominant vegetation is herbaceous or woody, respectively.

Structure is another habitat module modifier. Structure can be tree stumps, rock piles, submerged vegetation, logs, or woody debris on the lake bottom or shoreline in any habitat module Certain species are dependent upon or benefit from the provision of physical structure as noted on Table 4.8. For example, mudpuppy, an aquatic salamander, requires some form of physical structure for many of its life stages.

Each habitat modifier can be applied to the appropriate habitat module. Module 3, for example, can have a habitat module subtype of 3A, which would represent Habitat Module 3 with a finer substrate in an area of low wave energy. It could be further defined to add in-water structure with the (s) modifier. So Habitat Module 3A(s) would represent Habitat Module 3, with a finer substrate in an area of low energy, and added in-water structure.

Certain modifiers would not be appropriate to apply to certain habitat modules. For example, Habitat Module 4 represents a floating aquatic wetland habitat type. The floating aquatic vegetation (*e.g.* water lilies such as *Nymphaea* or *Nuphar* spp.) that dominates this habitat type requires fine substrates and very low energy. The B habitat modifier, which is coarse substrate in areas of medium to high energy, would not be appropriate to apply to this habitat module.

4.6 Habitat Module Species Use

The ring-neck duck is a type of diving duck that will be supported by Habitat Module 1.

Each habitat module provides suitable habitat for many different plant and animal species. Table 4.8 summarizes how the different habitat modules can support the representative plant and animal species selected to guide the restoration designs. This table was developed using the physical and biological requirements of the representative species groups (Tables 4.1 – 4.7) as they relate to the characteristics provided by each individual habitat module. Table 4.8 describes the species or species group for which the module provides suitable habitat conditions, or in other words, what species would use that module.

A column is provided in Table 4.8 for each of the major species groups, which includes fish, aquatic and wetland plants, benthic macroinvertebrates, mammals, reptiles and amphibians, and birds. In the row across from each habitat module, the species, or in certain instances the life stage of a species, that would use that habitat module are provided for each of these species groups. Major benefits provided by each module are discussed in the following text.

Habitat Module 1

Habitat Module 1 (water depth of 20 to 30 feet) represents the deep water portion of the littoral zone. This module also generally applies to the Profundal zone, specifically Remediation Area D – Addendum. Transient cold water fish species and adult warm-water fish species will use this habitat area. Certain benthic macroinvertebrates, birds (diving ducks, osprey and over-water feeders) would use the area.

Habitat Module 2

Habitat Module 2 (water depth of 7 to 20 feet) will provide habitat for lake sturgeon, transient cold water fish, and adult warm-water species (Table 4.8). This module is beyond the limit of most submerged aquatic vegetation, although some will occur in the shallower water limits of this module. Coarse substrate habitats (B modifier) may limit vegetation growth. Benthic macroinvertebrates in various groups will occupy this habitat and some additional groups will benefit from the coarse substrates or added structure modifiers of B and (s), respectively. Although not currently known to occur in the lake, river otter would be the only mammal to use this area. Mudpuppy, an aquatic salamander that is also not currently known to be present in the lake, may occur in the future with the addition of in-water structure, a necessary habitat component for this species. A few birds that use deeper water habitat would be expected in this area.

Tapegrass (*Vallisneria americana*) is an aquatic plant that will be supported by Habitat Module 3.

Habitat Module 3

Habitat Module 3 (water depth of 2 to 7 feet) provides important spawning habitat for bass (*Micropterus* spp.) and other warm-water fish species, and young-of-year cover habitat for various species (Table 4.8). Cover habitat is provided by the abundant submerged aquatic vegetation that occurs within this module's depth range. Typical submerged plant species include: sago pondweed, tapegrass (*Vallisneria americana*), coontail, and water star grass (Table 4.2b). Coarse substrates may reduce the abundance of these aquatic plants. Various benthic macroinvertebrates will find this habitat suitable and may be more abundant where coarse substrates occur. Mammals may use the shallow water portion of this habitat module primarily for travel corridors, although river otters, if present, would feed in this area. Dabbling ducks, diving ducks, and other birds that feed by diving into the water, and certain wading birds, like great blue heron, would use this habitat type.

Habitat Module 4

Habitat Module 4 (water depth of 1 to 3 feet) represents a floating aquatic vegetation wetland habitat (Table 4.8). It provides habitat for panfish, like pumpkinseed, and cover for various other fish species. Water lilies will likely populate this area. Use by benthic macroinvertebrates and mammals would be similar to Habitat Module 3. Snapping turtles and the basking turtles (painted (*Chrysemys picta*) and musk turtles will prefer the quiet water in this habitat and would further benefit from structure in the form of logs or other surface features. Dabbling ducks, herons, kingfisher, and other birds will use the area.

Wood frogs would find suitable conditions in Habitat Module 5.

Habitat Module 5

Habitat Module 5 (water depth of ½ to 2 feet) represents non-persistent emergent wetlands (Table 4.8). Non-persistent emergent plants are rooted in the substrate, emerge above the surface of the water, but do not persist during the winter months. Northern pike (*Esox lucius*) may spawn in this habitat and cover would be provided for pumpkinseed and

various other young-of-year fish species. Added structure would enhance the habitat for these species, and coarse substrates would provide better habitat for walleye. Non-persistent emergent wetland plants, such as pickerelweed (*Pontederia cordata*), are targeted in this habitat area (Table 4.2b). Coarse substrates can reduce the abundance of these plant species. Caddisflies (*Trichoptera*), mayflies (*Ephemeroptera*), and crayfish (*Decapoda*) are the representative benthic macroinvertebrates for this habitat area. The aquatic mammals previously mentioned would use this area. Muskrat would feed on some of the plant species. Turtles and frogs would use this habitat, as would northern water snakes, which would prey on the frogs and small fish in the area. With the addition of structure, this habitat may be used by mudpuppy. Bird species use of this habitat module area would be similar to that indicated for Habitat Module 4.

Habitat Module 6

Habitat Module 6 (ground surface 1 foot above water to a water depth of 1 foot) represents a persistent emergent wetland habitat type (Table 4.8). Persistent emergent plants are rooted in the bottom substrate, emerge above the surface of the water, and persist during the winter months. Cattails are a good example of a persistent emergent species.

Great blue herons would use fringe areas that are unvegetated at certain times of the year.

Persistent emergent wetlands are an important habitat type for many plants and animals. With the exception of areas around the lake that are degraded by the invasive *Phragmites*, an emergent wetland fringe is lacking in the lake ecosystem and therefore it is targeted for restoration in many areas. It should also be noted that this habitat module includes salt marshes, which have similar physical requirements to persistent emergent wetlands.

Northern pike, an early spring spawner in wetland areas, can use persistent emergent wetlands for spawning. The deeper water portions of the persistent emergent wetland will provide cover for various other fish species. Persistent emergent plants (*e.g.* cattails, bulrushes (*Scirpus* spp.), burreed (*Sparganium* spp.), and sedges (*Carex* spp.)) and salt marsh plants (*e.g.* salt marsh cordgrass (*Spartina alterniflora*), salt marsh hay (*Spartina patens*), prairie cordgrass (*Spartina pectinata*), rose mallow (*Hibiscus mocheutos*), and black grass (*Juncus gerardii*)) could be abundant in these areas (Table 4.2b). Control of *Phragmites* would be necessary in this habitat module to avoid habitat degradation by this invasive grass species. Various benthic macroinvertebrates would occur in this habitat module, especially dragonflies (*Odonata*), mayflies, and crayfish. All representative aquatic mammals would find this habitat suitable. Persistent emergent marshes, especially cattail marshes, are the primary habitat for muskrats. Various salamanders, frogs, turtles, and snakes would use the area. Dabbling ducks, herons and other wading birds, and both native and migratory shorebirds would use this habitat module. Emergent marshes provide primary habitat for red-winged blackbird.

Habitat Module 7

Habitat Module 7 (ground surface 0.6 feet above water to a water depth of 0.6 feet) represents mudflats or exposed shoreline areas (Table 4.8). Mudflats were once present at the mouths of both Ninemile Creek and Harbor Brook, but these areas were overrun with *Phragmites*. Mudflats, by definition, provide limited to no habitat for fish and plants. They provide travel corridors for aquatic mammals and turtles. Mudflats and exposed shoreline areas are, however, important habitat for resident and migratory shorebirds, such as spotted sandpipers and semi-palmated sandpiper. They are also used by herons.

Habitat Module 8

Open field uplands is one option for Habitat Module 8.

Habitat Module 8 is an upland habitat of herbaceous or woody species cover (Table 4.8). These habitats would likely be transition areas between restored lake habitats or fringe wetland habitats and adjacent uplands. In the open field uplands, various grasses, goldenrods, and asters would be common. In restored wooded uplands, common trees would be eastern cottonwood, trembling aspen (*Populus tremuloides*), shagbark hickory (*Carya ovata*), hackberry (*Celtis occidentalis*), and paper birch (*Betula papyrifera*). Representative shrub species are shadbush (*Amelanchier* sp.), gray-stem dogwood (*Cornus foemina* ssp. *racemosa*), silky dogwood (*Cornus amomum*), and staghorn sumac. Mammals would forage in these areas, and with suitable trees in woody areas, food would be provided for beavers. Open fields, especially those near wetlands are good foraging areas for leopard frogs () and possibly nesting habitat for certain turtle species. Red-winged blackbirds and several other bird species would occupy this habitat.

Habitat Module 9

Forested wetland would be a suitable condition for Habitat Module 9.

Habitat Module 9 (saturated soils to seasonally pooled water) represents a wetland habitat that is not necessarily contiguous with the lake (Table 4.8). No or limited fish habitat would be provided in this module. The wetlands in this habitat module could be wet meadow or persistent emergent wetland types dominated by herbaceous plant species or they could be scrub-shrub or forested wetlands dominated by woody plant species. Plants common in the persistent emergent wetlands would be similar to those listed for Module 6. In the forested wetlands, silver maple, green ash, swamp white oak, and black willow are expected dominants. Wetland shrub species would include silky dogwood, red-osier dogwood (*Cornus sericea*), pussy willow (*Salix discolor*), peach-leaf willow (*Salix amygdaloides*), and musclewood (*Carpinus caroliniana*). Muskrat, mink, and beaver would use this habitat when it is vegetated with herbaceous species and smaller shrub species. Mink would use the wooded areas. Frogs, red-spotted newts, and water snakes would utilize these wetland habitats. Leopard frogs are found in emergent wetland and forage extensively in wet meadow areas. Various bird species noted under the Habitat Module 6 description would occur in these wetlands. Nesting for green heron would be provided in the forested wetlands.

4.7 Existing Conditions Illustrated as Modules

In order to better characterize the existing conditions in and around the lake, and to quantify the changes in habitat types before and after remediation, the TWG applied the newly defined habitat modules to illustrate existing conditions.

Existing habitat conditions in and around the lake were categorized out to the limits of an area called the habitat plan boundary, which is identified as a dashed red line on Figure 4.1. This boundary takes into account the need for connected habitats between the lake and upland areas.

The distribution of existing habitats is presented on Figures 4.2 through 4.5. The habitat modules described above were applied to the lake and acreages were estimated of the various types of habitat that currently exist within and immediately adjacent to the lake.

A summary of the existing and restored habitat acreages for in-lake and lakeshore areas is presented on Table 4.9. These tables illustrate changes in habitat modules with the planned restoration.

TABLE 4.1
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR FISH

Representative Species / Habitat Considerations

Habitat Requirements	Northern Pike[1**]	Lake sturgeon[2**]	Walleye[3**]
Water Depth - Adult	Rarely below thermocline	Prefer depths <29.5 ft (9 m) in cooler months, may go deeper in summer or to overwinter; in deeper lakes typically 19.7-39.3 ft (6-12 m); shallow lakes with depths <22.9 ft (7 m) will occupy all depths	Shallow shoreline areas. Adults typically <49.2 ft (15 m) during day; move to shoreline at night;
Water Depth - Fry/Juvenile	< 13.1 ft (4m)	Shallow river mouths or adjacent bays	NA
Water Depth - Spawning	3.9-27.5 in 1(0-70 cm (best))[10]	0.3-6.5 ft (0.1-2 m)	Spawning depth 0.9-4.9 ft (0.3-1.5 m)
Spawning location	7.9-11.8 in (20-30 cm)[(3)]	Tributary	Shallow shoreline areas, shoals, riffles; lacustrine populations typically migrate up rivers or streams to spawn
Spawning Substrate	Dense mat of short vegetation; eggs broadcast	Coarse gravel, cobble; broadcast eggs	Gravel, rubble [1-5.9 in (2.5 to 15 cm)]; eggs broadcast (no nest)
Fry/Juvenile Substrate	Primary habitat need regarding substrate is area with adequate cover	Silt	Primary habitat need regarding substrate is area with adequate cover
Adult Substrate	Primary habitat need regarding substrate is area with adequate cover	Sand, cobble, mud, silt, and boulder	Primary habitat need regarding substrate is area with adequate cover
Energy (Velocity) during spawning	<1.96 in/sec (5 cm/sec)	1.6-4.2 ft/sec (0.5-1.3 m/sec)	Moderate
Energy (Velocity) Fry/juveniles	NS	NS	Critical velocity for 7.9 in (20 cm) (FL) fish is 23.6 in/sec (60 cm/sec)
Energy (Velocity) Adults	NS	NS	Critical velocity for 11.8 in (30 cm) (FL) fish is 29.1 in/sec (74 cm/sec)

TABLE 4.1
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR FISH

Representative Species / Habitat Considerations

Habitat Requirements	Northern Pike[1**]	Lake sturgeon[2**]	Walleye[3**]
Macrophyte Cover (Juveniles)	Fry dense vegetation; juveniles 30-70 % midsummer area	Little; generally avoid aquatic vegetation	25 to 45 %
Macrophyte Cover (Adults)	30-70 % midsummer area; prefer the interface between vegetation and open water	Little; generally avoid aquatic vegetation	25 to 45 %
Large Woody Debris; Boulders (Adults)	NA	Shoals	25 to 45 %[9]
Large Woody Debris; Boulders (Juveniles)	NA	Shoals	25 to 45 %[9]
Rooting / Burrowing/Nest Depth	NA	NA	NA
Dissolved Oxygen	≥ 5 ppm	≥ 5ppm	≥ 5ppm
Growing Season Temperature (Adult)	20-25°C	12-19°C	20-24°C
Growing Season Temperature (Fry/Juveniles)	Fry 18-25°C; juvenile 19-21C optimum	12-19°C	Fry 22-31°C; juveniles 20-24°C
Food Source	Piscivorous (primarily clupeids, yellow perch, white sucker; also invertebrates)	Benthic invertivore (insect larvae, leeches, snails, small clams, small fish)	Piscivorous (primarily yellow perch, clupeids, centrarchids; also invertebrates)
Turbidity/ Suspended Solids	NS	NS	Secchi depth 3.2-6.5 ft (1-2 m)
pH	6.0-9.0	6.5-8.5	6.0-9.0
Minimum Habitat Size	Not specified in Inskip 1982. Farrell (2001)[11] reported spawning in patches as small as 1205 ft^2 (112 m^2)	Minimum size of spawning habitat is not specified, but high gradient reaches of large rivers are ideal; rocky, wave-washed lake shores are sometimes used.	Minimum habitat area unknown; however, lakes >247 acres (100 ha) are more likely to provide suitable conditions for spawning, i.e., 20 percent of area of lake is between 0.9 and 4.9 ft (0.3 and 1.5 m) deep with gravel/cobble substrate)[1]

TABLE 4.1
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR FISH

Representaitve Species / Habitat Considerations

Habitat Requirements	Smallmouth Bass[4]	Largemouth Bass[5]	Pumpkinseed Sunfish[6]	Golden Shiner[7]	Emerald Shiner[7]	Brown Trout[8]
Water Depth - Adult	<39.3 ft (12 m) deep; typically drops off away from vegetation; dark, quiet water	9.8-49.2 ft [(3-15 m) for overwintering]	Littoral zone; deeper water to overwinter	NS	deep water during day move to surface at night to feed	>15 cm
Water Depth - Fry/Juvenile	Fry shallow water; juveniles slightly shallower than adults	Similar to adults	Littoral zone	NS	NS	<15 cm
Water Depth - Spawning	0.9-22.9 ft (0.3-7 m)	1.64-24.6 ft (0.15-7.5 m)	1 to 3 m	NS	NS	0.122 to 0.914 m
Spawning location	Rocky lake shoals, river shallows or backwaters	Littoral zone	Littoral zone	Littoral zone	Profundal zone	Tributary
Spawning Substrate	Gravel, cobble 0.63 to 0.78 in (1.6-2.0 cm) and boulder with interstitial space; nest builder	Gravel: 0.02-2.5 in (0.2-6.4 cm); nest builder	Sand, fine gravel; nest builder	Vegetation	Open water	0.3 to 10 cm
Fry/Juvenile Substrate	Gravel, broken rock and boulders with large amount of interstitial space	Primary habitat need regarding substrate is area with adequate cover	primary habitat need regarding substrate is area with adequate cover	NS	NS	NA
Adult Substrate	Gravel, broken rock and boulders with large amount of interstitial space	Primary habitat need regarding substrate is area with adequate cover	primary habitat need regarding substrate is area with adequate cover	NS	sand or gravel	
Energy (Velocity) during spawning	Quiet water or very slow current	< 0.13 ft/sec (4 cm/sec)	<7.5 cm/sec	NS	NS	40-70 cm/s
Energy (Velocity) Fry/juveniles	Quiet water [4.3-12.6 in/sec (10.9 - 32.0 cm/sec) reported from one lake]	Fry <0.13 ft/sec (4 cm/sec); juvenile <2.4 ft/sec (6 cm/sec)	<5.0 cm/sec	NS	NS	NA
Energy (Velocity) Adults	Quiet water [4.3-12.6 in/sec (10.9 - 32.0 cm/sec) reported from one lake]	<2.4 ft/sec (6 cm/sec)	<10 cm/sec	NS	NS	

TABLE 4.1
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR FISH

Representaitve Species / Habitat Considerations

Habitat Requirements	Smallmouth Bass[4]	Largemouth Bass[5]	Pumpkinseed Sunfish[6]	Golden Shiner[7]	Emerald Shiner[7]	Brown Trout[8]
Macrophyte Cover (Juveniles)	25-50 %	Fry 40-80 percent of littoral area; juvenile: 40 to 60 percent of littoral area[10]	15 to 30 percent	some	NS	NA
Macrophyte Cover (Adults)	Prefer rocky cover	40 to 60 % of littoral area[10]	15 to 30 percent	some	NS	NA
Large Woody Debris; Boulders (Adults)	25 to 50 percent; stumps, trees, boulders	40 to 60 % of littoral area[10]	20 to 60 percent	NS	NS	>35%
Large Woody Debris; Boulders (Juveniles)	Adults: 25 to 50 %	40 to 60 % of littoral area[10]	20 to 60 percent	NS	NS	NA
Rooting / Burrowing/Nest Depth	NS	NS	NS	NA	NA	16 cm below water substrate interface
Dissolved Oxygen	≥ 5 ppm	≥ 5 ppm	≥ 5ppm	≥ 5ppm	≥ 5ppm	≥ 5ppm
Growing Season Temperature (Adult)	21-27°C	24-30°C	20-27C	NS	NS	12-19C
Growing Season Temperature (Fry/Juveniles)	Fry 25-29°C; juveniles 25-31°C	Fry: 27-30°C; juveniles 24-30°C	fry 25-32C; juveniles 22-34C	NS	NS	NA
Food Source	Piscivorous (species dependent on abundance and availability); crayfish	Piscivorous (fish; crayfish), amphibians	Invertivore	Planktivore (diatoms, green algae; zooplankton)	Planktivore (algae; zooplankton; midge larvae)	Invertivore/piscivore (alewife)
Turbidity/ Suspended Solids	<25 JTU	5-25 ppm	<50 ppm (max. monthly average)	NS	NS	NS
pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
Minimum Habitat Size	NS	NS	NS	NS	NS	NS

TABLE 4.1
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR FISH

NOTES:

NA - Not applicable to this species

NS - Information not specified

*Species that utilize the tributaries for spawning also contribute an important forage base for the lake (e.g., white sucker)

**Walleye, northern pike, and lake sturgeon are considered priority species since viable habitat is limited in the lake

REFERENCES:

1. Inskip 1982. Habitat Suitability Index Models: Northern Pike. USFWS.
2. Peterson, D.L., P. Vecsei, and C.A. Jennings. 2007. Ecology and biology of the lake sturgeon: a synthesis of current knowledge of a threatened North American Acipenseridae. Abstracts from Update on Lake Sturgeon in NYS Waters January 2000. Data from Cornell University Oneida Lake lake sturgeon research program
3. McMahon et al. (1984). Habitat Suitability Information: Walleye. USFWS. Note that the total of 25-45 percent cover can be provided by macrophytes and/or large woody debris.
4. Edwards et al. (1983). Habitat suitability Information: Smallmouth Bass. USFWS.
5. Stuber et al. (1982a). Habitat Suitability Information: Largemouth bass. USFWS. Note that the total of 40-60 percent cover can be provided by macrophytes and/or large woody debris.
6. Stuber et al. (1982b). Habitat Suitability Index Models: Bluegill. USFWS.
7. Hasse and Stegemann. 1992. http://www.dec.ny.gov/animals/7040.html; http://www.fishbase.org
8. Hasse and Stegemann. 1992. http://www.dec.ny.gov/animals/7040.html; http://www.fishbase.org
9. Raleigh et al. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown trout, revised. USFWS. Atlantic salmon habitat requirements are covered under this category.
10. Note that the total percent cover can be provided by macrophytes and/or large woody debris.
11. Casselman, JM and CA Lewis. 1996. Habitat requirements of northern pike (Esox lucius). Can. J. of Fisheries and Aquatic Sciences 53 (Suppl. 1): 161-174.
12. Farrell, J.M. 2001. Reproductive success of sympatric northern pike and muskellunge in an upper St. Lawrence River Bay. Trans. Amer. Fish. Soc. 130:796-808.

TABLE 4.2a
OVERVIEW OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR AQUATIC PLANTS

Habitat Requirements	Representative Species/Habitat Considerations				
	Submerged Vegetation	**Floating Vegetation/Aquatic Beds**	**Nonpersistent Emergent Vegetation**	**Persistent Emergent Vegetation**	**Salt Marsh Vegetation**
Water Depth	Depth of light penetration will determine maximum colonization depth. The majority of macrophytes are located in water depth of 7 ft (2 m) or less[5]. Submerged vegetation can typically colonize up to two times the secchi transparency[8, 10]	From 2-4 ft (0.6-1.2 m) for floating aquatic vegetation[7].	Water depth ranges from 0.5-2 ft (15-60 cm) for nonpersistent emergent vegetation. Water depth should be 12-18 in (30-45 cm) or greater to prevent *Phragmites* colonization.	Area from 0.5 ft (15 cm) above mean summer lake level to a water depth of 1.0 ft (30 cm). Initial eradication and future control of *Phragmites* required.	Area from 1.0 ft (30 cm) above mean summer lake level to a water depth of 1.0 ft (15 cm). Initial eradication and future control of *Phragmites* required.
Representative Species	Examples of typical species are: *Stuckenia pectinata, Elodea canadensis, Vallisneria americana, Ceratophyllum demersum* and *Zosterella dubia.*	Examples of typical species are: *Nuphar, Nymphaea* and *Potamogeton nodosus.*	Examples of typical species are: *Pontederia cordata, Peltandra virginica, Sagittaria latifolia, Polygonum amphibium* and *Alisma subcordatum.*	Examples of typical species are: *Typha latifolia, Typha angustifolia, Scirpus tabernaemontani, Scirpus americanus, Scirpus robustus, Sparganium eurycarpum, Justicia americana, Decodon verticillatus* and *Carex lacustris.*	Examples of typical species are: *Spartina alterniflora, Hibiscus moscheutos, Spartina patens, Spartina pectinata, Juncus gerardii, Distichlis spicata, Solidago sempervirens, Aster subulatus* and *Panicum virgatum.*
Substrate	Sand and finer grained material to support colonization; organic content less than 20%[2].	Silty sand or finer material with organic matter content of 3-8%.	Silty sand or finer material with organic matter content of 3-8%.	Silty sand or finer material with organic matter content of 3-8%.	Silty sand or finer material with organic matter content of 3-8%.
Energy	Wave energy may preclude colonization in near shore areas (1-3 ft deep) (0.3-1 m)[(6)].	Wave energy may preclude plant establishment. Energy breaks or low energy areas required fro establishment (Rea *et al.* 1998).	Wave energy may preclude plant establishment. Energy breaks or low energy areas required for establishment (Weisner 1991).	Wave energy may preclude plant establishment. Energy breaks or low energy areas required for establishment.	Wave energy may preclude plant establishment. Energy breaks or low energy areas required for establishment.
Vegetation Cover	NA	NA	NA	NA	NA
Large Woody Debris	NA	NA	NA	NA	NA
Rooting/Burrowing Depth	7.9-11.8 in (20-30 cm)[(3)]	5.9-17.7in (15-45 cm)	11.8-23.6 in (30-60 cm)	11.8-23.6 in (30-60 cm)	11.8-23.6 in (30-60 cm)
Dissolved Oxygen	NA	NA	NA	NA	NA
Temperature	NA	NA	NA	NA	NA

TABLE 4.2a
OVERVIEW OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR AQUATIC PLANTS

Habitat Requirements	Representative Species/Habitat Considerations				
	Submerged Vegetation	Floating Vegetation/Aquatic Beds	Nonpersistent Emergent Vegetation	Persistent Emergent Vegetation	Salt Marsh Vegetation
Nutrient Source	Nutrients in sediment, water column; dissolved inorganic carbon[1].	Nutrients within the sediment.	Nutrients within the sediment.	Nutrients within the sediment.	Nutrients within the sediment.
Turbidity/Suspended Solids	Influences depth of the photic zone-see water depth[1].	NA	NA	NA	NA
pH	5.5-9.0[9].	6.0-8.5	6.0-8.5	6.0-8.5	7.0-8.5 Appropriate salinity in water or substrate required for plants to persist. Water salinity range of 20 to 35 parts per thousand or average soil conductivity of 25-60 decisiemans per meter may be appropriate[a].

NOTES:

NA: Not applicable to this species.

NS: Information not specified.

REFERENCES:

1. Barko, J. W., M. S. Adams, and N. L. Clesceri. 986. Environmental factors and their consideration in the management of submersed aquatic vegetation: A review. Journal of Aquatic Plant Management 24:1-10.
2. Barko, J. W. and R. M. Smart. 1986. Sediment-related mechanisms of growth limitation in submersed macrophytes. Ecology 67:1328-1340.
3. Bottomley, E. Z. and I. L. Bayley. 1984. A sediment porewater sampler used in root zone studies of the submerged macrophyte, *Myriophyllum spicatum* .Limnology and Oceanography 29:671-673.
4. Chambers, P. A., and J. Kalff. 1985. Depth distribution and biomass of submersed aquatic macrophytes communities in relation to Secchi depth. Canadian Journal of Fishers and Aquatic Sciences 42:701-709.
5. EcoLogic 2006: Onondaga County Ambient Monitoring Program.
6. Madsen, J. D., P.A. Chambers, W. F. James, E. W. Koch, and D. F. Westlake. 2001. The interaction between water movement, sediment dynamics, and submersed macrophytes. *Hydrobiologia* 444:71-84.
7. Madsen, J. D., R. M. Stewart, K. D. Getsinger, R. L. Johnson, and R. M. Wersal. 2008. Aquatic plant communities in Waneta Lake and Lamoka Lake, New York. Northeastern Naturalist 15:97-110.
8. Middleboe, A. L. and S. Markager. 1997. Depth limits and minimum light requirements of freshwater macrophytes. Freshwater Biology 37:553-568.
9. Pagano, A. M. and J. E. Titus. 2004. Submersed macrophyte growth at low pH: Contrasting responses of three species to dissolved inorganic carbon enrichment and sediment type. Aquatic Botany 79:65-74.
10. Sheldon, R. B., and Boylen, C. W. 1977. Maximum depth inhabited by aquatic vascular plants. American Midland Naturalist 97, 248- 254.

TABLE 4.2a

OVERVIEW OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR AQUATIC PLANTS

Habitat Requirements	Representative Species/Habitat Considerations					State Listed Species of Concern	
	Unvegetated Shoreline/Mudflats	**Wet Meadow Wetland**	**Forested/Scrub-Shrub Wetlands**	**Forested/Scrub-Shrub Uplands**	**Open Field Uplands**	**Narrowleaf Pondweed (*Potamogeton strictifolius*)**	**Southern Naiad (*Najas guadalupensis*)(b)**
Water Depth	Areas from 0.5 ft (15 cm) above mean summer lake level to water depth of 0.5 ft (15 cm).	Seasonally inunundated, water primarily below ground during growing season.	Seasonally inundated, water primarily below ground surface during growing season.	No water at or near the soil surface.	17.7-23.6 in (45-60 cm)	Submerged vegetation can typically colonize to two times the secchi transparency. Minimum depth of colonization may be limited by high wave energy. Narrowleaf pondweed has the highest relative abundance in transects with an average maximum depth of 13.5	Submerged vegetation can typically colonize to two times the secchi transparency. Minimum depth of colonization may be limited by high wave energy. Southern naiad has the highest relative abundance in transects with an average maximum depth of 15.9 ft (
Representative Species	NA	Common species are: *Scirpus cyperinus, Scirpus atrovirens, Carex vulpinoidea, Carex stipata, Carex lurida, Juncus effusus, Glyceria striata,* and *Agrostis gigantea.*	Common trees are: *Acer saccharinum, Fraxinus pennsylvanica, Ulmus americana, Salix nigra,* and *Quercus bicolor.* Common shrubs are: *Cornus amomum, Cornus sericea, Salix discolor, Carpinus caroliniana,* and *Salix amygdaloides.*	Examples of typical species are: *Typha latifolia, Typha angustifolia, Scirpus tabernaemontani, Scirpus americanus, Scirpus robustus, Sparganium eurycarpum, Justicia americana, Decodon verticillatus* and *Carex lacustris.*	Examples of typical species are: *Spartina alterniflora, Hibiscus moscheutos, Spartina patens, Spartina pectinata, Juncus gerardii, Distichlis spicata, Solidago sempervirens, Aster subulatus* and *Panicum virgatum.*		
Substrate	Gravel to silty sand or finer material with organic matter content of 2-8%.	Good quality topsoil, sand or loamy texture, organic matter content 3-5%.	Good quality topsoil; sand or loamy texture, organic matter content 3-8+%.	Good quality topsoil, sand or loamy textures, organic matter content 2-4%.	Good quality topsoil, sand or loamy textures, organic matter content 2-4%.	Sand and finer grained material to support colonization; organic content less than 20% [1].	Sand and finer grained material to support colonization; organic content less than 20% [1].
Energy	Wave energy may preclude colonization in near shore areas (1-3 ft deep) (0.3-1 m)[(6)].	NA	NA	NA	NA	Wave energy may preclude colonization in near shore areas [1-3 ft (0.3-0.9 m) deep].	Wave energy may preclude colonization in near shore areas [1-3 ft (0.3-0.9 m) deep].
Vegetation Cover	NA	NA	NA	NA	NA	NA	NA
Large Woody Debris	NA	NA	NA	NA	NA	NA	NA
Rooting/ Burrowing Depth	7.9-11.8 in (20-30 cm)[(3)]	17.7-23.6 in (45-60 cm)	17.7-23.6 in (45-60 cm)	17.7-23.6 in (45-60 cm)	17.7-23.6 in (45-60 cm)	7.9-11.8 in (20-30 cm) [(2)]	7.9-11.8 in (20-30 cm) [(2)]
Dissolved Oxygen	NA	NA	NA	NA	NA	NA	NA
Temperature	NA	NA	NA	NA	NA	25-30°C	25-30°C

TABLE 4.2a

OVERVIEW OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR AQUATIC PLANTS

Habitat Requirements	Representative Species/Habitat Considerations					State Listed Species of Concern	
	Unvegetated Shoreline/Mudflats	Wet Meadow Wetland	Forested/Scrub-Shrub Wetlands	Forested/Scrub-Shrub Uplands	Open Field Uplands	Narrowleaf Pondweed (*Potamogeton strictifolius*)	Southern Naiad (*Najas guadalupensis*)(b)
Nutrient Source	NA	Nutrients from topsoil.	Nutrients from topsoil.	Nutrients from topsoil.	Nutrients from topsoil.	Nutrients in sediment, water column; dissolved inorganic carbon[1].	Nutrients in sediment, water column; dissolved inorganic carbon[1].
Turbidity/ Suspended Solids	NA	NA	NA	NA	NA	Influences depth of the photic zone-see water depth[1].	Influences depth of the photic zone-see water depth[1].
pH	NA	6.0-8.5	6.0-8.5	6.0-8.5	6.0-8.5	5.5-9.0	5.5-9.0

NOTES:
NA: Not applicable to this species.
NS: Information not specified.

a. Salinity ranges based on information provided by Tony Eallonardo and Don Leopold of ESF from their work on settling basins and other NY inland salt marshes.
b. In New York, there are two state-listed subspecies of *N. guadalupensis* (ssp. *munscheri* and spp. *olivacea*) and one common subspecies (ssp. *guadalupensis*) Although *N. guadalupensis* was found in the lake during the 2005 macrophyte surveys, it was not identified to subspecies, so it it not known whether what was found in the lake is rare.
c. Appendix 10: 2005 Onondaga Lake Aquatic Macrophyte Survey (Ecologic 2006).

REFERENCES:
1. Barko, J. W., M. S. Adams, and N. L. Clesceri. 1986. Environmental factors and their consideration in the management of submersed aquatic vegetation: A review. Journal of Aquatic Plant Management 24:1-10.
2. Bottomley, E. Z. and I. L. Bayley. 1984. A sediment porewater sampler used in root zone studies of the submerged macrophyte, *Myriophyllum spicatum*. Limnology and Oceanography 29:671-673.

TABLE 4.2b

PHENOLOGY INFORMATION FOR SELECTED AQUATIC PLANTS

	Submersed Aquatic Plants				Floating Leaved Aquatic Plants	
Event	**Sago pondweed[1]** (*Stuckenia pectinata*)	**Water celery[2]** (*Vallisneria americana*)	**Coontail[3]** (*Ceratophyllum demersum*)	**Canadian waterweed** (*Elodea canadensis*)	**American pondweed[4,5,6, 7]** (*Potamogeton nodosus*)	**White water lily[6]** (*Nymphaea odorata*)
Seed germination	April [8]	10-14°C, April	NS	NA	NS	April
Propagule sprouting	April [1,4]	10-14°C, April [2,4]	NA	NA	April [5]	April
Maximum biomass	July	28-32C, August-September	NS	August-September	September [6]	September
Flowering	July	July-August	April - September	July-August	June [6]	May
Fruiting	July	June-September, 20°C	June - September	August-September	July-October [7]	June
Propagule formation	July-August	August - October	NA	NA	NS	NS
Senescence	August-September	September-October	Evergreen perennial	September-October	October [4]	October

NOTES:

NA: Not applicable to this species

NS: Information not specified

REFERENCES:

[1] Madsen, J.D. and M.S. Adams. 1988. The seasonal biomass and productivity of the submerged macrophytes in a polluted Wisconsin stream. Freshwater Biology 20:41-50.

[2] McFarland, D. 2006. Reproductive ecology of Vallisneria americana Michaux. SAV Technical Notes Collection (ERDC/TN SAV-06-4). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

[3] Flora of North America Project, www.eFloras.org, Ceratophyllum demersum page, http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=200007091, accessed 4/13/2009.

[4] David, J.D. and A.J. McDonnell. 1997. Development of a partitioned-biomass model for rooted macrophyte growth. Aquatic Botany 56:265-276.

[5] Spencer, D.F., G.G. Ksander, J.D. Madsen, and C.S. Owens. 2000. Emergence of vegetative propagules of *Potamgeton nodosus* , *Potamogeton pectinatus* , *Vallisneria americana* , and *Hydrilla verticillata* based on accumulated degree-days. Aquatic Botany 67:237-249.

[6] Penfound, W.T., T.F. Hall, and D. Hess. 1945. The spring phenology of plants in and around the reservoirs in north Alabama with particular reference to malaria control. Ecology 26:332-352.

[7] Magee, D.W. and H. E. Ahles. Flora of the Northeast. Amherst, MA. University of Massachusetts Press. 1999

[8] Yeo, R. R. 1965. Life history of sago pondweed. Weeds 13:314-321.

TABLE 4.3
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR BENTHIC MACROINVERTEBRATES

Habitat Requirements	Representative Species/Habitat Considerations					
	Mayfly (Ephemeroptera)	Caddisfly (Trichoptera)	True Flies (Diptera)	Dragonfly/Damselfly (Odonata)	Scud (Amphipoda)	Crayfish (Decapoda)
Water Depth	Varilable	Variable	Variable	Variable	< 3.2 ft (1 m)	3.2-6.6 ft (1-2 m)
Substrate	Cobble, gravel, aquatic plants, coarse detritus, sand and silt	Variable	Variable	Aquatic plants, sand, silt and detritus	Littoral benthos (one species *Pontoporeia affinis* occurs in profundal benthos)	Coarse mineral or organic substrates
Energy	Flowing water (lotic-erosional); some lentic littoral species	Lotic and lentic	Variable	Still water (lentic littoral or loctic depositional)	Lentic littoral	Variable
Macrophyte Cover	7.9-11.8 in (20-30 cm)[3]	NS	NS	For phytophilous species	NA	Important
Large Woody Debris	NS	NS	NS	NS	NS	NS
Rooting / Burrowing Depth	Up to 3.9 in (10 cm) for *Hexagenia limbata*[1,2]	Up to 3.1 in (8 cm) for *Polycentropus* spp.[1]	Up to 2.9 in (7.5 cm) for *Chironomus* spp and 2 cm for *Glyptotendipes* spp. and *Procladius* spp.[1]	5.9 in (15 cm)	5.9 in (15 cm)	5.9 in (15 cm)
Dissolved Oxygen	> 5 mg/l	NS	NS	NS	NS	NS
Temperature	NS	NS	variable	NS	NS	NS
Food Source	Detritus and plant material	Diatoms, algae and decaying plant matter	Detritus, plankton and benthic organisms	Zooplankton and insects	Detritus	Plant material, invertebrates and carrion
Turbidity/Suspended Solids	NS	NS	NS	NS	NS	NS
pH	NS	NS	NS	NS	NS	NS

NOTES:

NA: Not applicable to this species

NS: Information not specified

1. Charbonneau, P. and L. Hare. 1998. Burrowing behavior and biogenic structures of mud-dwelling insects. J. N. American Benthological Soc. 17:239-249.
2. Charbonneau and Hare (1998) reference Hilsenhoff (1966) observation of *Chironomus plumosus* larvae burrowing up to 50 cm at 5°C

REFERENCES:

Voshell, 2002. A guide to common freshwater invertebrates of North America. The McDonald & Woodward Publishing Company, Blacksburg, VA.

Merritt, R.W., and K.W. Cummins. 1984. An introduction to the aquatic insects of North America. Second Edition. Kendall/Hunt Publishing Co. Dubuque, IA

Peckarsky, B.L., P.R. Fraissinet, M.A. Penton, and D.J. Conklin, Jr. 1990. Freshwater macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca, NY.

TABLE 4.4
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR MAMMALS

Habitat Requirements	Representative Species/Habitat Considerations				
	Otter[1]	Beaver[2]	Muskrat[3]	Mink[4]	Indiana Bat[5]
Water Depth	Variable - ditches to deep lakes	Low water fluctuations	1.5-4 ft (0.5-1.2 m) low water fluctuations	Variable, hunts along shoreline	NA
Substrate	NA	Variable	Sediments fine w/ some organics; bank material < 90% sand and gravel with slope greater than 30%	NA	NA
Energy	Low to high velocity	Low velocity	Low velocity	Low velocity	NA
Vegetative Cover	7.9-11.8 in (20-30 cm) (3)	NA	Persistent emergent herbaceous vegetation within 32.8 ft (10 m) of waters edge; no woody material	Trees and shrubs along waters edge for cover; persistent emergent vegetation. Canopy cover comprised of trees and shrubs within 328 ft (100 m) of waters edge	Larger trees with exfoliating bark or narrow cracks required for summer roosting
Large Woody Debris	Submerged hollow logs provide cover	Created by beaver activity	Downfall, debris, log jams provide cover along shoreline	Downfall, debris, exposed roots, undercut banks provide cover along shoreline	NA
Rooting / Burrowing Depth	NA	Entrance to bank dens 2-5 ft (0.6-1.5 m) below water surface	Entrance to bank dens 1-3 ft (0.3-0.9 m) below surface	Will use abandoned muskrat and beaver dens	NA
Dissolved Oxygen	NA	NA	NA	NA	NA
Temperature	NA	NA	NA	NA	NA
Food Source	Fish and crayfish	Water lily, duck potato, aspen, willow and cottonwood	Cattail, sweetflag, water lily, arrowhead, olney 3-square and bulrush	Fish, crayfish, waterfowl, muskrats, rabbits and rodents	Insects (flies and caddis flies)
Turbidity/Suspended Solids	NA	NA	Low	NA	NA
pH	NA	NA	NA	NA	NA
Minimum Habitat Size	NA	Minimum area of 0.5 mi^2 (1.3 km^2) of lake or marshland habitat for colonization[2]	Any freshwater or estuarine cover type large enough to be classified assuming adequate food, water stability, and cover are provided[3]	Any wetland or wetland associated habitat large enough to be identified and evaluated should be large enough for mink	NA

NOTES:

NA: Not applicable to this species

REFERENCES:

1. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.127). 23 PP. [First printed as: FWS/OBS-82/10.61, October 1983]
2. Allen, A. W. 1983. Habitat suitability index models: Beaver. US. Fish and Wild. Serv. FWS/OBS-W10.30 Revised. 20 pp.
3. Allen, A. W., and R. D. Hoffman. 1984. Habitat suitability index models: Muskrat. U.S. Fish Wildl. Serv. FWS/OBS-82/10.46. 27 pp.
4. Allen, A.W. 1986. Habitat suitability index models: mink, revised.
5. U.S. Fish and Wildlife Service (USFWS). 2007. Indiana Bat (Myotis sodalis) Draft Recovery Plan: First Revision. U.S. Fish and Wildlife Service, Fort Snelling, MN. 258 pp.

USDA Forest Service Species Database; http://www.fs.fed.us/database/feis/animals/mammal/luca/all.html

TABLE 4.5

SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR AMPHIBIANS

Habitat Requirements	Representative Species/Habitat Considerations[1]		
	Red-spotted newt	**Mudpuppy**	**Spotted salamander**
Water Depth	Shallow, permanent water bodies which are wet long enough for development to the eft stage.	Completely aquatic. Adults can live in a variety of water depths (large deep lakes or shallow, muddy streams), but generally nest in 3 ft (1 m) of water; water must be deep enough not to freeze or go anoxic where larvae overwinter.	Adults prefer fishless ponds and vernal pools to breed in; larvae spend several months in pool before emerging.
Substrate	Prefer mud bottoms, but will use rocky and sandy bottoms. Prefer densely vegetated shallow waters. Efts require sufficient forest floor litter for dry periods.[7]	Require rocks or other debris for shelter and for egg laying.	Prefer "muddy" substrate in water. Nests generally under rocks on sandy bottoms. Prefer soils with low, but variable moisture (loamy soil). Spotted salamander egg masses laid on underwater structure.
Energy	Low	Low	Low
Structure/ Macrophyte Cover	Terrestrial life stage (juveniles): prefer deciduous or mixed hardwood forest with $\geq$80% of the trees with a dbh$\leq$19.1 cm; aquatic life stages: $\geq$75% submergent or emergent herbaceous vegetation in the littoral zone, especially for larval stage.[7]	Always associated with some form of aquatic cover (logs, rocks, or even bottom vegetation). In streams, more often found in pools than riffles, likely because of available cover rather than depth.	Terrestrial life stage: prefer deciduous or mixed hardwood forest; aquatic life stage: prefer some submergent vegetation, especially for juveniles.
Structure/Large Woody Debris	Stumps and other woody debris and litter, herbaceous canopy cover of 20-40% important to red eft (juvenile) stage for moisture retention.[7]	Submerged shelters of some sort are required (e.g. rocks or sunken logs).	Rocks, logs, and floating vegetation are important for shelter and egg laying. Rotting logs and woody debris on forest floor important for spotted salamanders.
Burrowing Depth	Adults and efts may overwinter in terrestrial hibernacula, but efts rarely burrow.[7]	The mudpuppy is totally aquatic species. A female digs a nest cavity under stones or logs, at water depths of 4 - 60 in (10 -150 cm). Mudpuppies are active year round and do not hibernate. [8]	Some bury themselves in mud underwater; others hibernate under cover of vegetative debris, rocks, and/or soil pockets. On land, adults spend most of their time in burrows made by other animals. Most hide within a few centimeters of the soil surface.
Dissolved Oxygen	Sensitive to significant fluctuations.	Can survive in water with very low oxygen concentrations.	Sensitive to significant fluctuations.

TABLE 4.5 (Continued)

SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR AMPHIBIANS

Habitat Requirements			
	Green frog	**Leopard frog**	**Wood frog**
Water Depth	Green frogs prefer permanent pools and small ponds where water is deep enough not to freeze for larval and adult overwintering.	Hibernate in streams with minimum depth 35 in (90 cm), moderate mid-depth water velocity, minimal sedimentation, and rocks with average diameter of 8 in (20 cm).	Wood frogs breed in seasonal pools, shallow ponds, marshy lake edges, flooded meadows, and quiet stretches of streams. Tadpoles usually live in the shallowest, warmest parts of the wetland.[5]
Substrate	Prefer a soft-muddy substrate in water.	Prefer wetlands with gradual slope at edge. Hibernates in surface mud of ponds and streams.	Prefer a "muddy" substrate in water. On land frogs prefer loose soil and/or a vegetated ground layer.
Energy	Low	Low	Low
Structure/ Macrophyte Cover	Prefer vegetated to thickly vegetated riparian area in and out of the water.	Prefer open areas like meadows and grasslands.	Frequents temporary pools in or near woodlands with emergent vegetation such as willows, sedges, or winter-killed cattails; forages along forest floor, often near seepage areas; hibernates in leaf litter; prefer forested areas.
Structure/Large Woody Debris	Not necessary for green frogs.	Prefer rocks, logs, floating vegetation or dams to sun on, with adjacent access to water. Submerged vegetation, logs or rocks to hide in.	Wood frogs are largely terrestrial, but are not usually found far from water. They inhabit marshes, riparian areas, wet meadows, moist brush, forested areas and open grassy areas adjacent to such habitats. [5]
Burrowing Depth	Larvae can overwinter in unfrozen mud at the bottom of pond along and in water greater than 6.5 feet (>2m) in depth.	Some bury themselves in mud underwater; others hibernate under cover of vegetative debris, rocks, and/or soil pockets.	Wood frogs hibernate in the soil, using root channels and burrows made by other animals. The soil and snow pack provide insulation and protection to the frogs.[5]
Dissolved Oxygen	Sensitive to significant fluctuations.	Sensitive to significant fluctuations.	Sensitive to significant fluctuations.

TABLE 4.5 (Continued)

SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR AMPHIBIANS

Habitat Requirements	Representative Species/Habitat Considerations[1]		
	Red-spotted newt	**Mudpuppy**	**Spotted salamander**
Temperature	Activity rates increase significantly as temperature rises.[7] Adults and larvae require permanent lentic waters deep enough not to completely freeze in winter.	Sensitive to significant fluctuations.	Sensitive to significant fluctuations.
Food Source	All life stages are opportunistic predators eating available invertebrates and/or smaller amphibians and larvae.[7]	Adults eat mainly invertebrates (e.g. insects, earthworms, and crustaceans) and small fish. Juveniles feed mainly on insects and their larvae.	Adults eat mainly terrestrial and aquatic invertebrates (e.g. earthworms, spiders, insects, crustaceans, snails and slugs); larvae are generalized predators.
Turbidity/ Suspended Solids	Sensitive to significant fluctuations.	Sensitive to significant fluctuations. During winter mudpuppies are found in waters with slow to moderate current, often near outlets.	Sensitive to significant fluctuations.
pH	Sensitive to significant fluctuations.	Sensitive to significant fluctuations.	Sensitive to significant fluctuations; breed successfully above pH 5.5 (optimal pH 7-9).
Minimum Habitat Size	Average eft home range 0.07 acres (270 $m^{2)}$, density of 300 efts/ha. Terrestrial eft habitat (mixed and deciduous forests) may be up to 0.5 mile (800 m) from water.[7]	Individuals can live entire life in small stretch of one river [likely < 0.6 miles (1 km)].	Spotted salamanders tend to stay in an area of 0.002-0.004 acres (8-15 m^2) of forest floor.[8] Most live within 328 ft (100 m) of their breeding pond, though a few have been found as far as 820 ft (250 m).[8]

TABLE 4.5 (Continued)
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR AMPHIBIANS

Habitat Requirements	Green frog	Leopard frog	Wood frog
Temperature	Can survive freezing temperatures. Tadpole feeding rates increase with temperature.[3]	Feeding rates decrease significantly below 20°C.[4]	Can survive temperatures as low as 21°F (-6°C). The frogs actually freeze solid at these low temperatures, but protect their cells from damage by producing their own cryoprotectant or "antifreeze". Juvenile and adult frogs hibernate terrestrially to survi
Food Source	Green frogs east insects, worms, snails, millipedes, molluscs, and other small invertebrates. Tadpoles are herbivores, and feed on algae and other plant material.[6]	Adults are carnivorous and eat beetles, ants, flies, worms, smaller frogs, including their own species, and even birds, and garter snakes.[4]	Wood frogs east insects, worms, snails, millipedes, molluscs, and other small invertebrates. Tadpoles are herbivores, and feed on algae and other plant material.[5]
Turbidity/ Suspended Solids	Sensitive to significant fluctuations - moderate mid-depth water velocity, mineral sedimentation.	Sensitive to significant fluctuations - moderate mid-depth water velocity, minimal sedimentation.	Sensitive to significant fluctuations.
pH	Sensitive to significant fluctuations; acid tolerance increases during development and varies within and between populations.[2]	Sensitive to significant fluctuations; acid tolerance increases during development and varies within and between populations.[2]	Sensitive to significant fluctuations; acid tolerance increases during development and varies within and between populations.[2]
Minimum Habitat Size	Territories are found in shallow water and are reported to be 3 - 20 feet (0.9 to 6.1 m) in diameter.[8] In New York, green frogs migrate up to 0.3 miles (560 m) from breeding ponds to overwintering sites.[9]	Leopard frogs do not establish territories, except in the breeding pond, where males will establish small calling territories. Leopard frogs migrate to breeding ponds in the spring and may forage in meadows and grasslands during the summer. In the winter	Wood frogs tend to be territorial and generally occupy an area of about 0.025 acres (100 m^2).[8]

NOTES:

1. Unless otherwise noted, information was collected from: Environment Canada. *Habitat Rehabilitation in the Great Lakes Techniques for Enhancing Biodiversity*.http://www.on.ec.gc.ca/wildlife/docs/habitat-rehabilitation4-e.html.

REFERENCES:

2. Mazerolle, M. J., Cormier, M. 2003. *Effects of peat mining intensity on green frog (Rana clamitans) occurrence in bog ponds*. Wetlands 23:709-716. http://www.theses.ulaval.ca/2004/21842/ch03.html.
3. K. M. Warkentin. 1992. *Effects of Temperature and Illumination on Feeding Rates of Green Frog Tadpoles (Rana clamitans).* http://links.jstor.org/sici?sici=0045-8511(19920818)3%3A1992%3A3%3C725%3AEOTAIO%3E2.0.CO%3B2-O.
4. National Geographic's Northern Leopard Frog Profile. 2007. http://animals.nationalgeographic.com/animals/amphibians/northern-leopard-frog.html.
5. British Columbia Ministry of Environment. *Wood frog Factsheet* . B.C. Frogwatch Program. Environmental Stewardship Division. Accessed November 27, 2007 at http://www.env.gov.bc.ca/wld/frogwatch/whoswho/factshts/woodfrog.htm.
6. British Columbia Ministry of Environment. *Green frog Factsheet* . B.C. Frogwatch Program. Environmental Stewardship Division. Accessed November 27, 2007 at http://www.env.gov.bc.ca/wld/frogwatch/whoswho/factshts/greenfrog.htm.
7. USFWS. 1985. *Habitat Suitability Index Models: Red-Spotted Newt*. Biological Report 82(10.111).
8. University of Michigan Museum of Zoolology. 2006. Animal Diversity Web - *Spotted Salamander, Mudpuppy, Northern Leopard Frog, Wood Frog and Green Frog.* http://animaldiversity.ummz.umich.edu/site/index.html.
9. NatureServe Explorer Database. 2007. http://www.natureserve.org/explorer/servlet/NatureServe.

TABLE 4.6

SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR REPTILES

Habitat Requirements	Representative Species/Habitat Considerations[1]	
	Musk turtle	**Snapping turtle**
Water Depth	Prefers a permanent body of water, like shallow streams, ponds, rivers, or clear water lakes, and it is rare to find the turtle elsewhere. While in the water, the musk turtle stays mainly in shallow areas.	Located anywhere there is slow-moving or permanent impoundments of water.
Substrate	Inhabits virtually any permanent body of freshwater having a slow current and soft bottom. [5]	Prefers water bodies with muddy bottoms; need well-drained soils for egg-laying.
Energy	Low	Low
Structure/ Plant Cover	7.9-11.8 in (20-30 cm)[(3)]	They prefer water bodies with muddy bottoms and abundant vegetation because concealment is easier.[4]
Structure/Large Woody Debris	Muskrat lodges are favorite for nesting. Bask on nearby fallen tree trunks or in the branches of trees overhanging the water.[3]	Basks on shore, logs and rocks near water. Generally bottom dwellers.[4]
Burrowing Depth	Usually hibernate buried in as much as 12 in (30.48 cm) of mud on the bottoms of ponds or other water areas.[9] Females known to dig shallow nests at the water's edge under rotting logs or dead leaves, and sometimes will nest two or more times a year.	Hibernates on bottom of ponds or in excavations along banks of rivers. Female excavates a hole, normally in sandy soil, to lay eggs.[4]
Temperature	Above freezing, as hibernation requires that ice not reach the bottom.	Above freezing, as hibernation requires that ice not reach the bottom.
Food Source	Active night feeder, eats small amounts of plants, mollusks, small fish, insects, and even carrion. Generally forages on the muddy bottom of streams or ponds.[3]	Snapping turtles will eat nearly anything that they can get their jaws around. They feed on carrion, invertebrates, fish, birds, small mammals, amphibians, and a surprisingly large amount of aquatic vegetation (leaves and algae).[4]
Turbidity/ Suspended Solids	Generally tolerant of turbidity.	Generally tolerant of turbidity.
pH	Generally tolerant of variability.	Generally tolerant of variability.
Minimum Habitat Size	Home range is likely confined to one waterbody. Males mean home range 4.32 acres (1.75 ha) and females 2.32 acres (0.94 ha).[8]	Will live in even the smallest of water bodies; HSI model assumes any permanent or semi-permanent body of water will be suitable.[7]

Notes:

1. Unless otherwise noted, information was collected from: Environment Canada. *Habitat Rehabilitation in the Great Lakes Techniques for Enhancing Biodiversity.* http://www.on.ec.gc.ca/wildlife/docs/habitat-rehabilitation4-e.html.

REFERENCES:

2. Shine, R., G.P. Brown & M.J. Elphick. 2004. *Field experiments on foraging in free-ranging water snakes Enhydris polylepis (Homalopsinae).* http://www.bio.usyd.edu.au/Shinelab/publications/reprints/418fieldexps.pdf.
3. University of Michgan Museum of Zoology. 2006a. Animal Diversity Web - *Common Musk turtle.* http://animaldiversity.ummz.umich.edu/site/accounts/information/Sternotherus_odoratus.html.
4. University of Michgan Museum of Zoology. 2006b. Animal Diversity Web - *Snapping turtle* . http://animaldiversity.ummz.umich.edu/site/accounts/information/Chelydra_serpentina.html.
5. NatureServe Explorer Database. 2007. http://www.natureserve.org/explorer/servlet/NatureServe.
6. Gibbs, James P. 2007. *The amphibians and reptiles of New York State.* Oxford University Press. New York, New York.
7. Graves, B.M., and S.H. Anderson. 1987. Habitat suitability index models: snapping turtle. USFWS Biol. Rep. 82(10.141).
8. Northeast Partners in Amphibian and Reptile Conservation; Species Data matrices Version 1.0. http://www.pwrc.usgs.gov/neparc/Products/riskassessment.htm.
9. *American Mud and Musk Turtles, Natural History Information* . Accessed at: http://members.aol.com/TheWyvernsLair/turtles/MudMusk-1.html. Last updated July 31, 2001.

TABLE 4.6 (Continued)

SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR REPTILES

Habitat Requirements	Representative Species/Habitat Considerations[1]	
	Painted turtle	**Northern water snake**
Water Depth	Prefers a permanent body of water in which ice does not reach to the bottom. They will avoid open water, but will cross deep water either just above submerged vegetation or the substrate.	Generally still, quiet water bodies with 1 inch (2 cm) to 2 ft (0.6 m) depth. Small snakes generally use shallow water because these areas contain fish of the appropriate size to consume.[2]
Substrate	In water, fine grain silty soils that allow for burrowing/hibernating and as anchor for plants used for basking and feeding. On land, sandy, loose soil with adequate drainage required for nesting sites.	Various, including rock, gravel, sand, and mud.
Energy	Low	Low
Structure/ Plant Cover	Prefer porous vegetated mats (e.g., filamentous algae) that allow easy access and escape and surrounding stands of emergent vegetation for cover.	Cattails (*Typha latifolia*) and flooded meadow (primarily *Phalaris spp.* and *Carex spp.*) are preferred. Feed in thick vegetation mats and emergent vegetation.
Structure/Large Woody Debris	Bask in large groups on logs in ponds, rocks, or floating vegetation.	Bask in shrubs, low trees, driftwood, on loose rocks adjacent to water, wharfs, docks, stone walls, beaver lodges, dried cattail stems, causeways, and most shallow areas.
Burrowing Depth	Muddy bottom for burrowing to hibernate, and as anchor for plants used for basking and feeding.	Use fissures and crevices in limestone, brush piles, shoreline ledges, rock piles in abandoned quarries, old cisterns, sink holes, hollow logs, stone causeways, flood walls, levees, ant mounds, crayfish burrows, muskrat bank burrows, muskrat and beaver lodges.
Temperature	Above freezing, as hibernation requires that ice not reach the bottom; feeding occurs when water temperature is above 15°C; breeding starts in late May to early June, when temperature is 8°C; nest temperatures generally below 29°C.	Maximum basking temperature is 33°C.
Food Source	Omnivorous, equally divided between plant and animal sources - eats aquatic invertebrates, frogs, small fish, and aquatic plants (no plant preference).	Aquatic invertebrates, frogs, small fish, and aquatic plants.
Turbidity/ Suspended Solids	Generally tolerant of turbidity.	Generally tolerant of turbidity.
pH	Generally tolerant of variability.	Generally tolerant of variability.
Minimum Habitat Size	Home range fluctuates depending on available conditions; not territorial.	Home range of 13.34 acres (5.4 ha) has been reported with a concentrated core area of 7.7% (0.98 acres or 0.4 ha).

Notes:

1. Unless otherwise noted, information was collected from: Environment Canada. *Habitat Rehabilitation in the Great Lakes Techniques for Enhancing Biodiversity.* http://www.on.ec.gc.ca/wildlife/docs/habitat-rehabilitation4-e.html.

REFERENCES:

2. Shine, R., G.P. Brown & M.J. Elphick. 2004. *Field experiments on foraging in free-ranging water snakes Enhydris polylepis (Homalopsinae).* http://www.bio.usyd.edu.au/Shinelab/publications/reprints/418fieldexps.pdf.
3. University of Michgan Museum of Zoology. 2006a. Animal Diversity Web - *Common Musk turtle.* http://animaldiversity.ummz.umich.edu/site/accounts/information/Sternotherus_odoratus.html.
4. University of Michgan Museum of Zoology. 2006b. Animal Diversity Web - *Snapping turtle*. http://animaldiversity.ummz.umich.edu/site/accounts/information/Chelydra_serpentina.html.
5. NatureServe Explorer Database. 2007. http://www.natureserve.org/explorer/servlet/NatureServe.
6. Gibbs, James P. 2007. *The amphibians and reptiles of New York State.* Oxford University Press. New York, New York.
7. Graves, B.M., and S.H. Anderson. 1987. Habitat suitability index models: snapping turtle. USFWS Biol. Rep. 82(10.141).
8. Northeast Partners in Amphibian and Reptile Conservation; Species Data matrices Version 1.0. http://www.pwrc.usgs.gov/neparc/Products/riskassessment.htm.
9. *American Mud and Musk Turtles, Natural History Information*. Accessed at: http://members.aol.com/TheWyvernsLair/turtles/MudMusk-1.html. Last updated July 31, 2001.

TABLE 4.7
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR BIRDS

Habitat Requirements	Representative Species/Habitat Considerations [1]			
	Great blue heron (Wading Birds)	**Green heron (Wading Birds)**	**Mallard (Dabbling Ducks)**	**Common goldeneye (Diving Ducks)**
Water Depth	Feed by wading in water generally less than <20 in (50 cm) deep.[4]	Feeds by standing next to water.	Water depth of 1-5 ft (0.3-1.5 m) for feeding and brood rearing.	Can dive deep for food - up to approximately 90-160 ft (27-49 m) or more.[2]
Substrate	Muddy margins of ponds/lakes or sand flats during low tides of estuarine habitats.	Muddy margins of ponds/lakes or streams.	Highly variable ranging from sand to heavy clay to exposed bedrock. Wetland soils with high fertility, preferably those on a limestone substrate.	Dives underwater to capture prey on soft bottoms of ponds, lakes, or rivers.[5]
Energy	Forages in still open water and edges of lakes, marshes, streams, ponds and bays.[2]	Forages in edges of lakes, ponds, marshes, and streams.[5]	Still or slowly moving water is preferred; however, use fast flowing water that doesn't freeze on northern wintering areas.	Still or slow moving water is preferred.
Structure/Cover	Aquatic habitat with bushes, thickets, or small trees. Supporting vegetation may provide dense cover, or may be dead and provide little cover.	Aquatic habitat with bushes, thickets, or small trees.	Approximately 50:50 ratio of emergent vegetation to open water. Utilizes scattered islands, floating logs, cattail mats and muskrat houses.	NA
Structure/Nesting	Nest - often colonial in high snags or live trees (up to 130 ft) with open canopy, near water.[10] Has also nested on duck blinds.[2] May build nest on the ground, rock ledges, or cliffs.[2]	Breeds in swampy thickets.[5]	Often nests on the ground, utilizing vegetation for nest and cover. Natural nesting structures also include tree cavities, tree crotches and muskrat houses.	Nests usually near pond, lake, or river, but may nest in woodland up to a mile from water. Nests in natural cavity in large hardwood tree, in abandoned woodpecker hole or nest-box.[6]

TABLE 4.7
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR BIRDS

Habitat Requirements	Target Species/Habitat Considerations [1]			
	Great blue heron (Wading Birds)	**Green heron (Wading Birds)**	**Mallard (Dabbling Ducks)**	**Common goldeneye (Diving Ducks)**
Temperature	Above freezing.[9]	Above freezing.[9]	Above freezing.[9]	Enjoys cold water, but must be above freezing.[7]
Food Source	Primarily fish. Amphibians and a wide variety of vertebrates and invertebrates are also eaten. Generally stabs prey with its bill.[2]	Small fish, invertebrates, insects, frogs, and other small animals.[5]	Invertebrates, aquatic and upland seeds, aquatic tubers, vegetation, and some species make extensive use of waste agricultural grain. Additional food sources: insects, minnows, frogs, tadpoles, snails and small salamanders.[2]	Herbivore and invertivore -aquatic insects, crustaceans and aquatic plants in summer and fall, and crustaceans, mollusks, small fishes and some plant material during winter.[6]
Turbidity/ Suspended Solids	Water clarity makes foraging easier.	Water clarity makes foraging easier.	NA	Water clarity very important for diving/foraging. High turbidity may limit diving abilities and forage base.
Minimum Habitat Size	Shoreline length 423.2 ft (129 m) and mean area of 1.48 acres (0.6 ha).	NS	Breeding territory 988 acres (400 ha).[11]	Breeding territory 1.98 acres (0.8 ha).[11]

TABLE 4.7
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR BIRDS

Habitat Requirements	Representative Species/Habitat Considerations [1]					
	Osprey (Birds of Prey)	Spotted sandpiper and Semi-palmated sandpiper (Shorebirds)	Common tern (Gulls/Terns)	Belted kingfisher (Kingfishers)	Bank swallow (Swifts/Swallows)	Red-winged blackbird (Perching Birds)
Water Depth	An osprey is capable of diving up to 3.3 ft (1 m).[8]	Depth generally less than 4 in (<10 cm).	Water depth varies from 1.6-5 ft (0.5-1.5 m). Water level fluctuations and actual drought are important to recycle nutrients so that large invertebrate blooms result on reflooding.	Fishing confined to maximum depth of 24 in (60 cm), and most done at 4.5-6 in (12-15 cm), usually shallow.	Forages over water especially with emerging invertebrates.	NA
Substrate	NA	Muddy soils, where invertebrate abundance is highest.	Variable. In wetlands: soils with high fertility, preferably those on a limestone substrate.	NA	Muddy soils, where invertebrate abundance is highest.	NA
Energy	Open water with good visibility.	Slow falling water levels create a continuous supply of food.	Both flat and moving water habitats are used. Water quality high enough to produce adequate fish and aquatic invertebrates.	Still waters and streams for foraging.	Variable	NA
Structure/Cover	Elevated perches such as trees, posts, and telephone wires important for foraging.[8]	Prefers shores with rocks, wood, or debris.[6] Also utilizes mudflats and shallow water with less than 25% vegetation cover. When vegetation is present it is usually very short.	Grasses and miscellaneous herbaceous wetlant plant species.[6] Perching sites quite important, may get 1-2 dozen perched on dead snags near their nesting area.	Bare tree branches at water's edge are a favorite perch. Elevated perches such as trees, posts, and telephone wires important for foraging. Woody vegetation around a wetland also provides foraging perches, roosting sites and cover for young birds.	Grasslands with miscellaneous herbaceous plant species for foraging.[6]	Use scattered trees and fenceposts near their breeding territories as observation posts.[14] Forages in grasslands and meadows adjacent to water.
Structure/Nesting	Nesting: built of sticks in tall dead trees or snags. Will nest on buoys and man-made nesting platforms.[8] Nests often used in successive years.[6]	Nests are grass-lined with leaves and moss. Nests generally built near water on grassy slope or mound surrounded by short vegetation.[16]	Nesting: among pebbles, gravel, grasses, and other vegetation. Scratch a slight depression in soil, smooth and shape it by sitting in the hollow and turning body.[2]	Nesting: nest built in well drained, sandy clay soil on bank or steep side slopes. Minimum sand content of 75% and maximum clay content of 7% . Excavate burrows in vertical earth banks to nest. Banks may be natural (e.g. eroded stream banks) or man-made.	Nesting areas: burrowing into soft banks, nest of mud and grass on cliff sides or other vertical surfaces.[7]	Nests in freshwater and herbaceous wetlands, bushes, and small trees along watercourses and certain upland cover types.[14]

TABLE 4.7
SUMMARY OF PHYSICAL AND BIOLOGICAL FACTORS IN HABITAT DESIGNS FOR BIRDS

Habitat Requirements	Representative Species/Habitat Considerations [1]					
	Osprey (Birds of Prey)	**Spotted sandpiper and Semi-palmated sandpiper (Shorebirds)**	**Common tern (Gulls/Terns)**	**Belted kingfisher (Kingfishers)**	**Bank swallow (Swifts/Swallows)**	**Red-winged blackbird (Perching Birds)**
Temperature	Usually migrates south by October.	Migrate south for winter.[6]	Above freezing.[9]	Above freezing.[9]	Migrate south for winter.[6]	Migrates south for winter.[14]
Food Source	Primarily fish. Captures fish by diving into water and using their talons. Opportunistic feeder on a variety of other non-fish prey.[8]	Terrestrial and aquatic invertebrates.	Adults: aquatic and flying insects, small fish, and occasionally, tadpoles, snails, mollusks, worms, crayfish, and can be scavengers of urban areas. Young: are fed a variety of insects and small fish.[1, 7]	Capture fish by diving into the water. Sometimes, when fish are less accessible, as when turbidity is high or ice is present, crayfish comprise a large proportion of the diet. Other food: amphibians, reptiles, insects, young birds, and small mammals.	Flying insects, emergent invertebrates, and some small fruits and/or berries when insects are not available. [7]	Omnivores, eating seeds, grains, and insects.[5]
Turbidity/ Suspended Solids	Water clarity very important for foraging. High turbidity may limit fish as a forage base.[8]	NA	NA	Water clarity very important for foraging. High turbidity may limit fish as a forage base.	NA	NA
Minimum Habitat Size	Breeding ospreys are known to travel as far as 8.7 mi (14 km) from their nest during hunting forays. Non-breeding individuals are known to travel as far as 6.2 mi (10 km) between their daytime feeding grounds and their roosts.[13]	Spotted Sandpiper-NS; Semi-palmated sandpiper: breeding territory-0.25 acres (0.1 ha).[11]	NS	Territory averages 3,168 ft (960 m) long.[5]	The length of nesting banks in California ranges between 42.6 ft (13 m and 6,233.6 ft (1,900 m).[12]	Wetland must contain at least 0.25 acres (0.10 ha) in emergent herbaceous vegetation.[14]

NOTES:

NS - Not specified.

NA - Requirements are not applicable.

1. Unless otherwise noted, information was collected from: Environment Canada. *Habitat Rehabilitation in the Great Lakes Techniques for Enhancing Biodiversity: Significant Biological Parameters.* http://www.on.ec.gc.ca/wildlife/docs/habitat-rehabilitation4

REFERENCES:

2. Terres, John. 1991. *The Audubon Society Encyclopedia of North American Birds* . Wings Books - Outlet Book Company, Inc. New York, NY.
3. Based on professional judgement.
4. USFWS. 1985. *Habitat Suitability Index Models: Great Blue Heron* . Biological Report 82 (10.99). US Department of Interior, Washington, DC.
5. Cornell Lab of Ornithology. 2003. All About Birds Bird Guide.http://www.birds.cornell.edu/AllAboutBirds/BirdGuide.
6. NatureServe Explorer Database. 2007. http://www.natureserve.org/explorer/servlet/NatureServe.
7. Vanner, Michael. 2005. *The Complete Encyclopedia of North American Birds.* Parragon Publishing. Bath, United Kingdom.
8. USFWS. 1987. *Habitat Suitability Models: Osprey* . U.S. Department of the Interior. Washington, D.C.
9. Open water required for foraging.
10. US EPA. Species Profile: Great Blue Heron. http://www.epa.gov/NE/ge/thesite/restofriver/reports/final_era/B%20-%20Focus%20Species%20Profiles/EcoRiskProfile_great_blue_heron.pdf.
11. Environment Canada. http://wildspace.ec.gc.ca/life.cfm?ID=BCNH&Page=More&Lang=e#BH.
12. Garrison, B.A. 1999. Bank swallow (Riparia riparia). No. 414. In A. Poole and F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania and the American Ornithologists' Union, Washington, D.C.
13. University of Michigan Museum of Zoology. 2006. Animal Diversity Web - *Osprey* . http://animaldiversity.ummz.umich.edu/site/accounts/information/Pandion_haliaetus.html.
14. USFWS. 1985. *Habitat Suitability Index Models: Red-winged Blackbird* . Biological Report 82 (10.95). US Department of Interior, Washington, DC.
15. USFWS. 1987. *Habitat Suitability Index Models: Mallard (Winter Habitat, Lower Mississippi Valley)* . Biological Report 82 (10.132). US Department of Interior, Washington, DC.
16. Sibley, D. A. 2000. *National Audobon Society The Sibley Guide to Birds* . Chanticleer Press , Inc. New York.

TABLE 4.8
HABITAT MODULE CHARACTERISTICS
ONONDAGA LAKE REMEDIAL DESIGN PROGRAM

HABITAT MODULE AREAS[a] [b] [e]	REPRESENTATIVE SPECIES/HABITAT						
	Fish	Plants	Benthic Macroinvertebrates[c]	Mammals	Reptiles and Amphibians	Birds	Minimum Habitat Layer Thickness[d]
1. Deep water (20-30 ft) (6-9 m) Sand substrate Low to medium energy Note: This module also generally applies to deeper water (profundal) areas. [f]	Transient cold water fish (brown trout), lake sturgeon, emerald shiner, bass, walleye and pumpkinseed	None	Amphipoda (Pontoporeia affinis), Annelida (Oligochaeta, Diptera (Chironomidae), Mollusca, and Annelida	None	None	Common goldeneye, mallard, osprey and bank swallow	1 ft. (30 cm) (Average of 1.25 ft.)
2A. Mid water depth (7-20 ft) (2-6 m) Sand/fine gravel substrate Low to medium energy	Lake sturgeon, transient cold water fish, bass, northern pike and pumpkinseed; additionally, walleye and bass if structure is present	Submerged aquatics in shallow portion	Diptera (Chironomidae) Annelida, Ephemeroptera, Odonata, and Mollusca; diptera if structure is present	Otter	None; mudpuppy if structure is present	Mallard, common tern, osprey and bank swallow	1 ft. (30 cm) (Average of 1.25 ft.)
2B. Mid water depth (7-20 ft) (2-6 m) Coarse gravel/cobble substrate High energy	Lake sturgeon, transient cold water fish, bass, smallmouth bass and pumpkinseed; additionally walleye if structure is present	Limited	Diptera (Chironomidae)	Otter	None; mudpuppy if structure is present	Mallard, common tern, osprey and bank swallow	1 ft. (30 cm) (Average of 1.25 ft.)
3A. Shallow water depth (2-7 ft) (0.5-2 m) Sand/fine gravel substrate Low energy	Largemouth bass, pumpkinseed, golden shiner and northern pike	Medium to dense submerged aquatic vegetation	Ephemeroptera, Trichoptera, Diptera, Odonata, Amphipoda, and Decapoda	Otter, mink, beaver; additionally muskrat if structure is present	Snapping turtle; additionally mudpuppy if structure is present	Mallard, belted kingfisher, osprey, great blue heron and bank swallow	1.5 ft. (45 cm) (Average of 2.0 ft.)
3B. Shallow water depth (2-7 ft) (0.5-2 m) Coarse gravel/cobble substrate High energy	Bass, pumpkinseed, golden shiner and northern pike	Sparse to medium submerged aquatic vegetation	Ephemeroptera, Trichoptera, Diptera, Odonata, Amphipoda, and Decapoda	Otter, mink, beaver, muskrat	Limited/none; mudpuppy and snapping turtle if structure is present	Mallard, belted kingfisher, great blue heron, common tern and bank swallow	1.5 ft. (45 cm) (Average of 2.0 ft.)

Footnotes:
a. High, medium, and low energy designations were developed by Anchor-QEA in the Wind/Wave Analysis from the Capping and Dredge Area and Depth Technical Document (Parsons, 2009).
b. Selection of modules for specific areas around the lake will consider the presence/occurrence of invasive species.
c. Diversity of species for benthos will be evaluated during the next phase of design.
d. See representative species Tables 4.1 to 4.7 for substrate depth and minimum habitat size information for specific organisms.
e. Structure can be added to any module. Species that would benefit from structure have been noted on the table.
f. A habitat layer will not be required in areas of the Profundal zone that do not have an isolation cap.

TABLE 4.8 (Continued)
HABITAT MODULE CHARACTERISTICS
ONONDAGA LAKE REMEDIAL DESIGN PROGRAM

HABITAT MODULE AREAS[a] [b] [e]	REPRESENTATIVE SPECIES/HABITAT						
	Fish	Plants	Benthic Macroinvertebrates[c]	Mammals	Reptiles and Amphibians	Birds	Minimum Habitat Layer Thickness[d]
4A. Floating aquatics wetland (1-3 ft) (0.3-1 m) Organics/fines/sand substrate Very low energy	Northern pike and Pumpkinseed	Floating aquatics, some submerged aquatics in deeper portions, some nonpersistent emergents in shallower portion	Ephemeroptera, Trichoptera, Diptera, Odonata, Amphipoda, and Decapoda	Otter, mink, muskrat and beaver	Snapping turtle, painted turtle, musk turtle and water snake; additionally mudpuppy if structure is present	Mallard, belted kingfisher, great blue heron, common tern, green heron and bank swallow	2.0 ft. (60 cm) (Average of 2.5 ft.)
5A. Non-persistent emergent wetland (0.5-2 ft) (0.1-0.6 m) Organics/fines/sand substrate Low energy	Northern pike and pumpkinseed	Non-persistent emergent vegetation. Some persistent emergents in shallows.	Ephemeroptera, Trichoptera, Diptera, Odonata, Amphipoda, and Decapoda	Otter, mink, muskrat and beaver	Snapping turtle, painted turtle, musk turtle, water snake, red spotted newt, green frog and leopard frog; additionally mudpuppy if structure is present	Mallard, belted kingfisher, great blue heron, green heron, common tern and bank swallow	2.0 ft. (60 cm) (Average of 2.5 ft.)
5B. Shoreline shallows/limited emergent wetland (0.5-2 ft) (0.1-0.6 m) Gravel/cobble substrate High energy	Smallmouth bass; additionally walleye if structure is present	Limited/none	Limited numbers Trichoptera, Ephemeroptera; Trichoptera, Ephemeroptera and Decapoda if structure is present	Otter and mink	Limited/none; Turtle, water snake, and mudpuppy if structure is present	Mallard, belted kingfisher, great blue heron, green heron and bank swallow	2.0 ft. (60 cm) (Average of 2.5 ft.)

Footnotes:
a. High, medium, and low energy designations were developed by Anchor-QEA in the Wind/Wave Analysis from the Capping and Dredge Area and Depth Technical Document (Parsons, 2009).
b. Selection of modules for specific areas around the lake will consider the presence/occurrence of invasive species.
c. Diversity of species for benthos will be evaluated during the next phase of design.
d. See representative species Tables 4.1 to 4.7 for substrate depth and minimum habitat size information for specific organisms.
e. Structure can be added to any module. Species that would benefit from structure have been noted on the table.
f. A habitat layer will not be required in areas of the Profundal zone that do not have an isolation cap.

TABLE 4.8 (Continued)
HABITAT MODULE CHARACTERISTICS
ONONDAGA LAKE REMEDIAL DESIGN PROGRAM

HABITAT MODULE AREAS[(a) (b) (e)]	REPRESENTATIVE SPECIES/HABITAT						
	Fish	Plants	Benthic Macroinvertebrates[(c)]	Mammals	Reptiles and Amphibians	Birds	Minimum Habitat Layer Thickness[(d)]
6A. Persistent emergent wetland or salt marsh (1 ft above water to 1 ft deep) (0.3 m above water to 0.3 m deep) Organics/fines/sand substrate Low energy	Northern pike	Persistent emergent vegetation, salt marsh vegetation	Trichoptera, Diptera, Odonata and Decapoda; additionally Amphipoda if structure is present	Otter, mink, muskrat and beaver	Snapping turtle, painted turtle, musk turtle, water snake, red-spotted newt, leopard frog and green frog; additionally mudpuppy if structure is present	Mallard, spotted sandpiper, semi-palmated sandpiper, red-winged blackbird, great blue heron, green heron, common tern and bank swallow	2.0 ft. (60 cm) (Average of 2.5 ft.)
6B. On shore to shallows/limited emergent wetland or salt marsh (1 ft above water to 1 ft deep) (0.3 m above water to 0.3 m deep) Cobble/coarse gravel/sand High energy	Limited use	Limited/none	Trichoptera, Ephemeroptera and Decapoda	Otter and mink	Limited/none, snapping turtle	Mallard, spotted sandpiper, semi-palmated sandpiper, great blue heron, green heron and bank swallow	2.0 ft. (60 cm) (Average of 2.5 ft.)cm)
7A. Mudflats/unvegetated shoreline (0.7 ft above water to 0.7 ft deep) (0.2 m above water to 0.2 m deep) Fines/sand substrate or cobble/gravel High energy or fluctuating water levels	None	Limited/none	Limited-Annelida	Otter and mink	Snapping turtle	Mallard, spotted sandpiper, semi-palmated sandpiper, great blue heron and green heron	2.0 ft. (60 cm) (Average of 2.5 ft.)

Footnotes:
a. High, medium, and low energy designations were developed by Anchor-QEA in the Wind/Wave Analysis from the Capping and Dredge Area and Depth Technical Document (Parsons, 2009).
b. Selection of modules for specific areas around the lake will consider the presence/occurrence of invasive species.
c. Diversity of species for benthos will be evaluated during the next phase of design.
d. See representative species Tables 4.1 to 4.7 for substrate depth and minimum habitat size information for specific organisms.
e. Structure can be added to any module. Species that would benefit from structure have been noted on the table.
f. A habitat layer will not be required in areas of the Profundal zone that do not have an isolation cap.

TABLE 4.8 (Continued)
HABITAT MODULE CHARACTERISTICS
ONONDAGA LAKE REMEDIAL DESIGN PROGRAM

HABITAT MODULE AREAS[(a) (b) (e)]	REPRESENTATIVE SPECIES/HABITAT						
	Fish	Plants	Benthic Macroinvertebrates[(c)]	Mammals	Reptiles and Amphibians	Birds	Minimum Habitat Layer Thickness[(d)]
8A. Shoreline uplands/riparian Topsoil substrate	None	Successional fields	None	Otter and mink	Leopard frog	Mallard, great blue heron, green heron and red-winged blackbird	1.5 ft. (45 cm) (Average of 2.0 ft.)
8B. Shoreline uplands/riparian Topsoil substrate	None	Scrub-shrub or forested	None	Otter, mink, beaver and Indiana bat	Leopard frog and water snake	Mallard and green heron	1.5 ft. (45 cm) (Average of 2.0 ft.)
9A. Inland wetlands not associated with the lake (saturated soils to pooled water that may be temporary) Topsoil substrate	None	Wet meadow and persistent emergent wetland species, primarily herbaceous	Limited numbers/species, Annelida and Mollusca	Muskrat and mink	Leopard frog, red spotted newt, water snake and green frog	Red-winged blackbird, green heron, great blue heron, spotted sandpiper and bank swallow	2.0 ft. (60 cm) (Average of 2.5
9B. Inland wetlands not associated with the lake (saturated soils to pooled water that may be temporary) Topsoil substrate	None	Forested wetland and scrub-shrub wetland species	Limited numbers/species, Annelida and Mollusca	Mink and beaver	Spotted salamander and wood frog	Red-winged black bird and green heron	2.0 ft. (60 cm) (Average of 2.5

SPECIAL FEATURES/CONSIDERATIONS

Endangered aquatic plants (*Potamogeton strictifolius, Najas guadalupensis* var. muenscheri, or Najas *guadalupensis* var. olivacea)	Potential for these species where submerged aquatic vegetation is targeted. These would most likely fall under Module 3A.
Northern Pike Spawning Wetlands	Provide spawning habitat for northern pike.

Footnotes:
a. High, medium, and low energy designations were developed by Anchor-QEA in the Wind/Wave Analysis from the Capping and Dredge Area and Depth Technical Document (Parsons, 2009).
b. Selection of modules for specific areas around the lake will consider the presence/occurrence of invasive species.
c. Diversity of species for benthos will be evaluated during the next phase of design.
d. See representative species Tables 4.1 to 4.7 for substrate depth and minimum habitat size information for specific organisms.
e. Structure can be added to any module. Species that would benefit from structure have been noted on the table.
f. A habitat layer will not be required in areas of the Profundal zone that do not have an isolation cap.

TABLE 4.9
SUMMARY OF ACREAGES WITHIN THE AREAS OF REMEDIATION

IN-LAKE

	RA-A		RA-B		RA-C		RA-D		RA-D Addendum		RA-E		RA-F		TOTAL	
Habitat Module	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**
1	36.8	35.2	9.5	8.3	14.0	12.8	24.2	26.7	5.6	5.6	41.4	35.0	0.2	0.2	131.6	123.7
2A	23.5	24.4	4.0	4.7	5.2	6.2	30.9	40.6			69.2	45.3	0.1	0.1	132.9	121.3
2B												20.4				20.4
3A	20.8	8.4	1.6	1.4	1.1								0.3	0.3	23.7	10.1
3B					2.9	4.2	38.9	27.3			67.1	70.0			108.9	101.6
4A		4.8														4.8
5A	2.5	4.4	1.1	1.7	0.9										4.5	6.1
5B					1.4	2.3	4.5	2.1			6.9	9.2			12.8	13.6
6A		6.3														6.3
6B						0.0		1.8				4.7				6.5
TOTAL	83.5	83.5	16.1	16.1	25.5	25.5	98.5	98.5	5.6	5.6	184.6	184.6	0.6	0.6	414.4	414.4

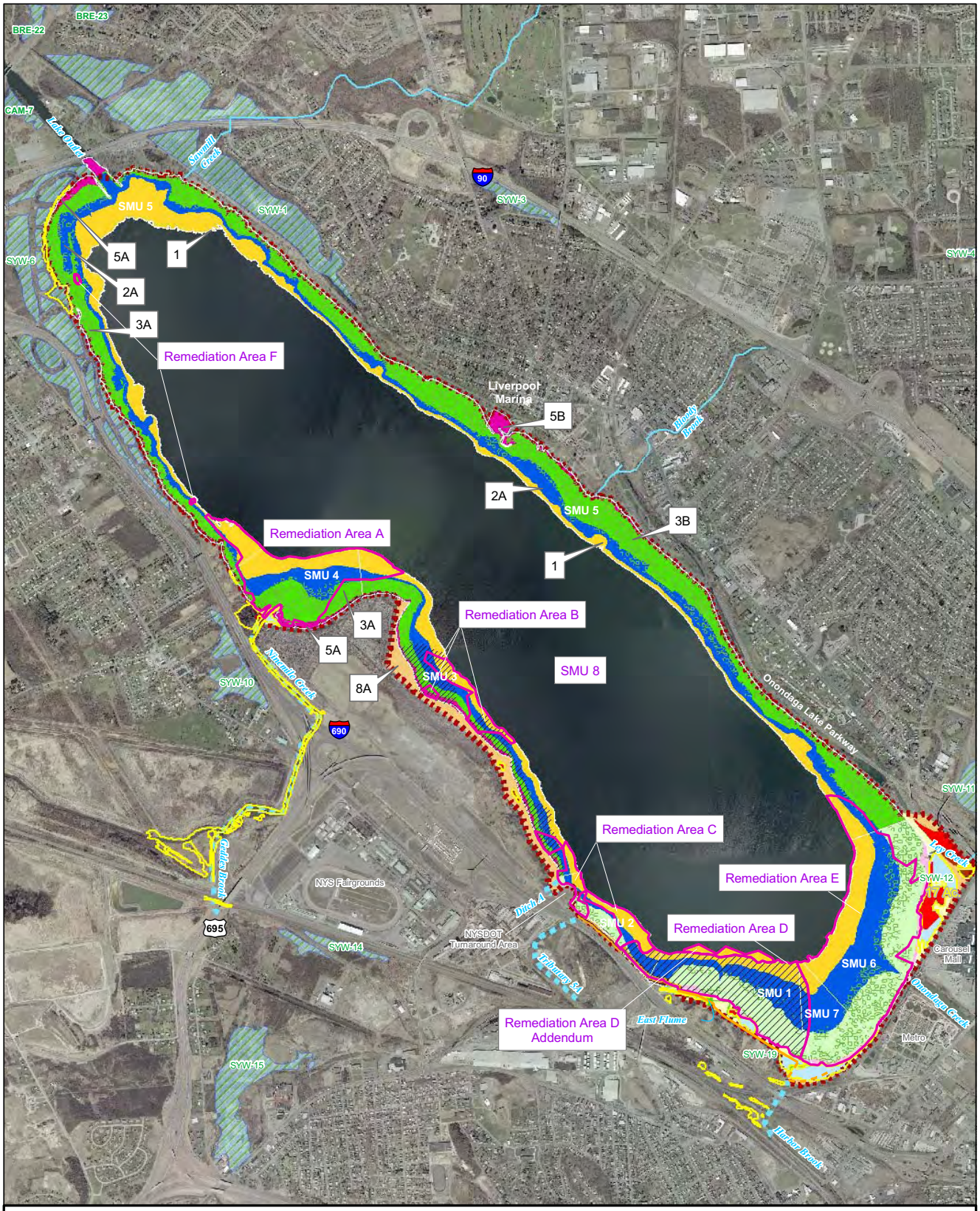
Notes:
(1) TBD - To Be Determined.
(2) Modules with structure have not been broken out separately.

TABLE 4.9 (Continued)
SUMMARY OF ACREAGES WITHIN THE AREAS OF REMEDIATION

LAKESHORE AREA

	WB-B/Harbor Brook		WB 1-8		Mouth of Ninemile Creek		SYW-12		Semet Shoreline		TOTAL	
Habitat Module	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**	**Existing**	**Restored**
3A	2.9										2.9	0.0
3B											0.0	0.0
4A											0.0	0.0
5A											0.0	0.0
5B											0.0	0.0
6A	12.3	14.4		2.3	2.2	1.6	8.8	TBD			23.3	TBD
6B											0.0	0.0
8A	2.4		31.1	24.1			6.3	TBD	1.3		41.0	TBD
8B	6.5	9.9	-				8.5	TBD		1.3	16.3	TBD
9A	0.3		0.7				3.1	TBD			4.1	TBD
9B	1.0	1.2		5.4	0.3	0.9	12.8	TBD			14.1	TBD
TOTAL	25.4	25.4	31.8	31.8	2.5	2.5	39.4	TBD	1.3	1.3	101.6	TBD

Notes:
(1) TBD - To Be Determined.
(2) Modules with structure have not been broken out separately.



Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)

NYSDEC/EPA Approved Wetland Boundaries

NYSDEC Wetland (NYSDEC, 2007)

Sediment Management Unit (SMU) Boundary

Area Containing Solvay Waste or ILWD

Remediation Area Boundary (Parsons, 2009)

Area Covered by Onondaga Lake Remedial Design Elements for Habitat Restoration

Tributary to be remediated by Honeywell

Willis/Semet IRM Barrier Wall

West Wall Portion of the WB-B/HB IRM

Approximate Location of the East Wall Portion of the WB-B/HB IRM

N W E S

New York State Digital Orthoimagery from 2003

980 490 0 980
Feet

Water depth based on lake surface elevation of 362.5' NAVD88.

FIGURE 4.1

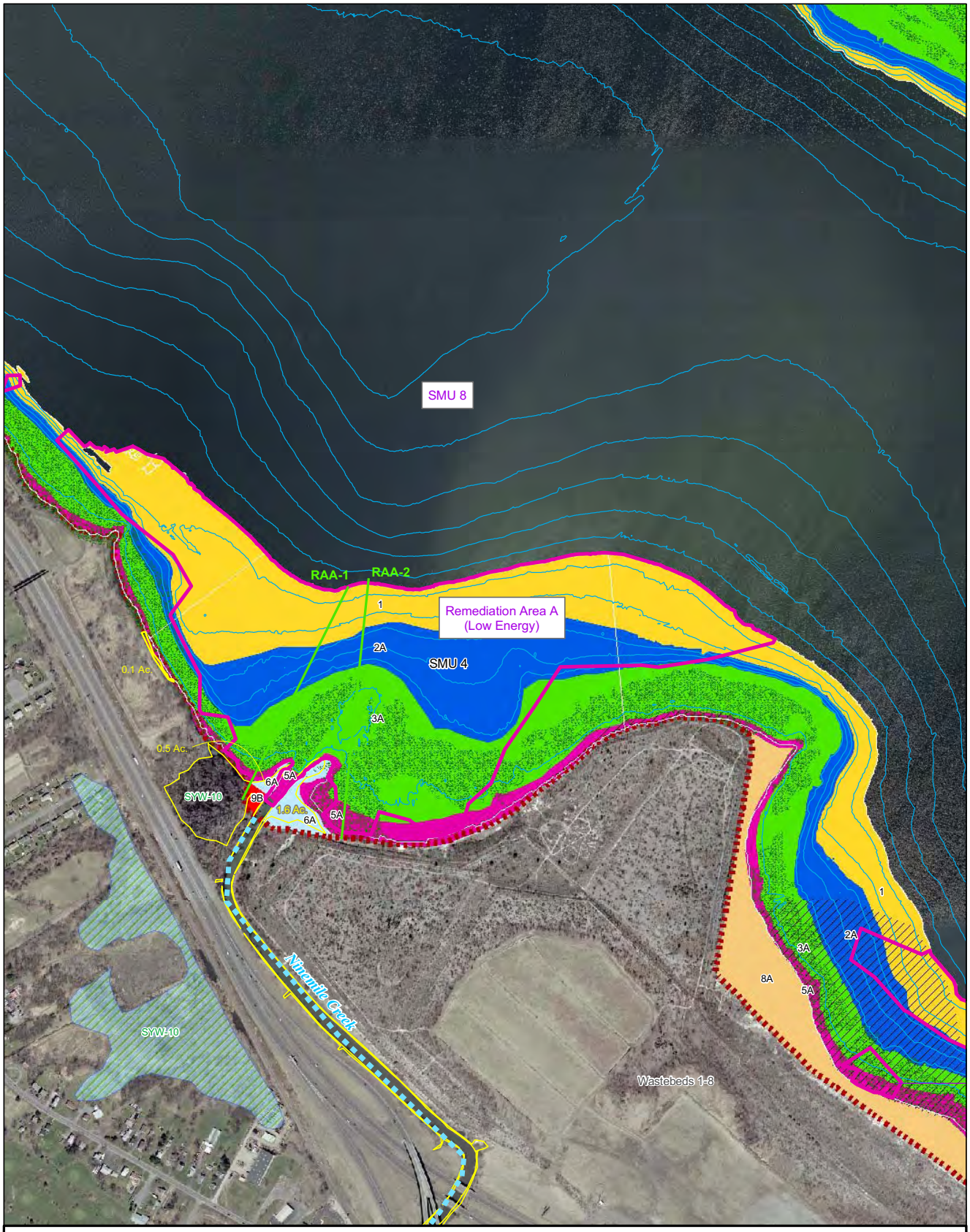
Honeywell

Onondaga Lake
Syracuse, New York

Existing Habitat Modules With The Habitat Plan Boundary

PARSONS

301 PLAINFIELD RD, SUITE 350; SYRACUSE, NY 13212



Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)

NYSDEC/EPA Approved Wetland Boundaries

Sediment Management Unit (SMU) Boundary

NYSDEC Wetland (NYSDEC, 2007)

Area Containing Solvay Waste or ILWD

Remediation Area Boundary (Parsons, 2009)

Cross-section Location and Identification

Area Covered by Onondaga Lake Remedial Design Elements for Habitat Restoration

Tributary to be remediated by Honeywell

N W E S

New York State Digital Orthoimagery from 2003

350 175 0 350
Feet

Water depth based on lake surface elevation of 362.5' NAVD88.

Contour interval = 5'

FIGURE 4.2

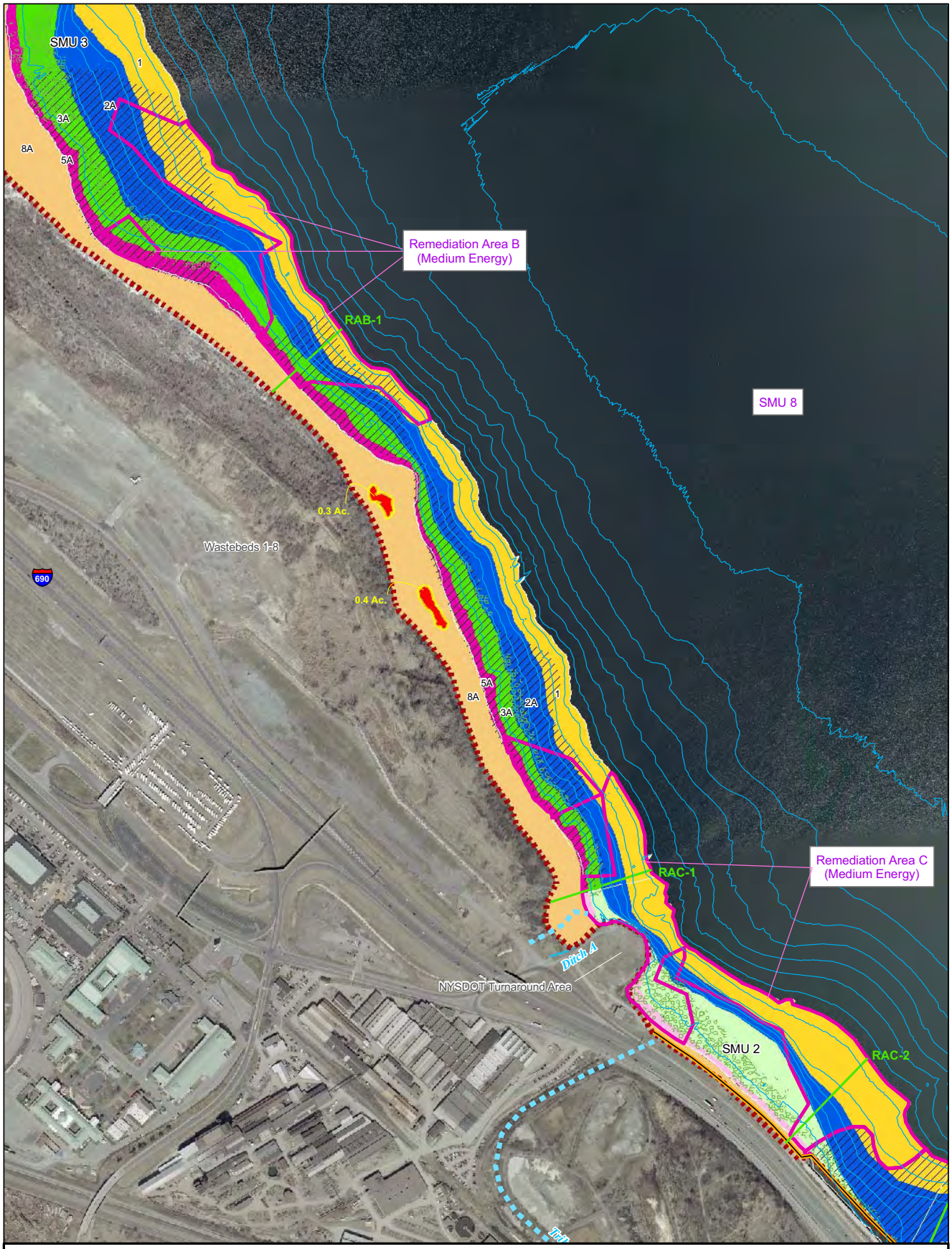
Honeywell

Onondaga Lake
Syracuse, New York

Existing Habitat Modules
Remediation Area A

PARSONS

301 PLAINFIELD RD, SUITE 350; SYRACUSE, NY 13212



Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)

NYSDEC/EPA Approved Wetland Boundaries

Sediment Management Unit (SMU) Boundary

Area Containing Solvay Waste or ILWD

Tributary to be remediated by Honeywell

Remediation Area Boundary (Parsons, 2009)

Area Covered by Onondaga Lake Remedial Design Elements for Habitat Restoration

Willis/Semet IRM Barrier Wall

West Wall Portion of the WB-B/HB IRM

RAB-1 Cross-section Location and Identification

N W E S

New York State Digital Orthoimagery from 2003

350 175 0 350
Feet

Water depth based on lake surface elevation of 362.5' NAVD88.

Contour interval = 5'

FIGURE 4.3

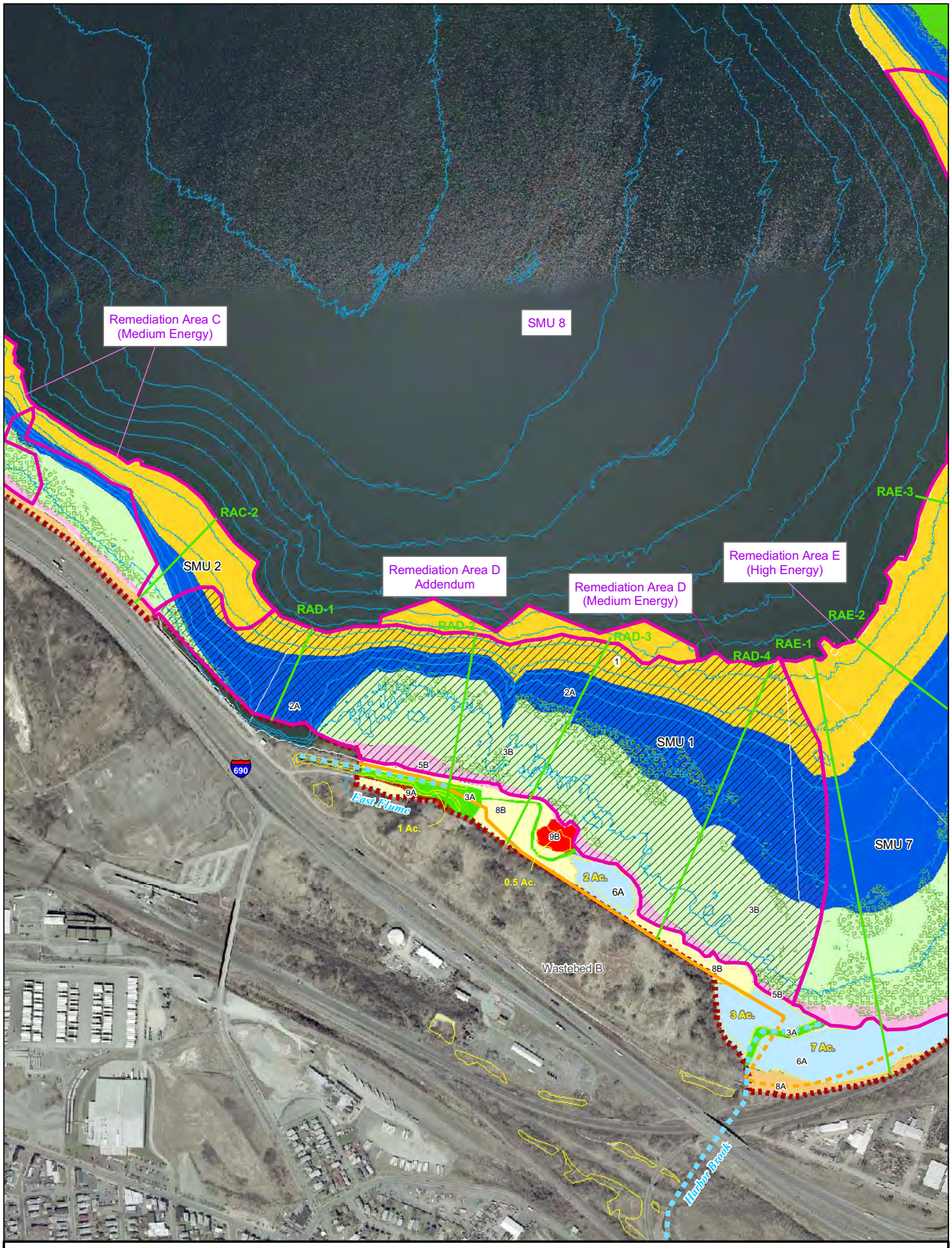
Honeywell

Onondaga Lake
Syracuse, New York

Existing Habitat Modules
Remediation Areas B & C

PARSONS

301 PLAINFIELD RD, SUITE 350; SYRACUSE, NY 13212



Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)

NYSDEC/EPA Approved Wetland Boundaries

Sediment Management Unit (SMU) Boundary

Area Containing Solvay Waste Within the Lake

Remediation Area Boundary (Parsons, 2009)

RAD-1 Cross-section Location and Identification

Area Covered by Onondaga Lake Remedial Design Elements for Habitat Restoration

Tributary to be remediated by Honeywell

Willis/Semet IRM Barrier Wall

West Wall Portion of the WB-B/HB IRM

Approximate Location of the East Wall Portion of the WB-B/HB IRM

N W E S

New York State Digital Orthoimagery from 2003

350 175 0 350
Feet

Water depth based on lake surface elevation of 362.5' NAVD88.

Contour interval = 5'

FIGURE 4.4

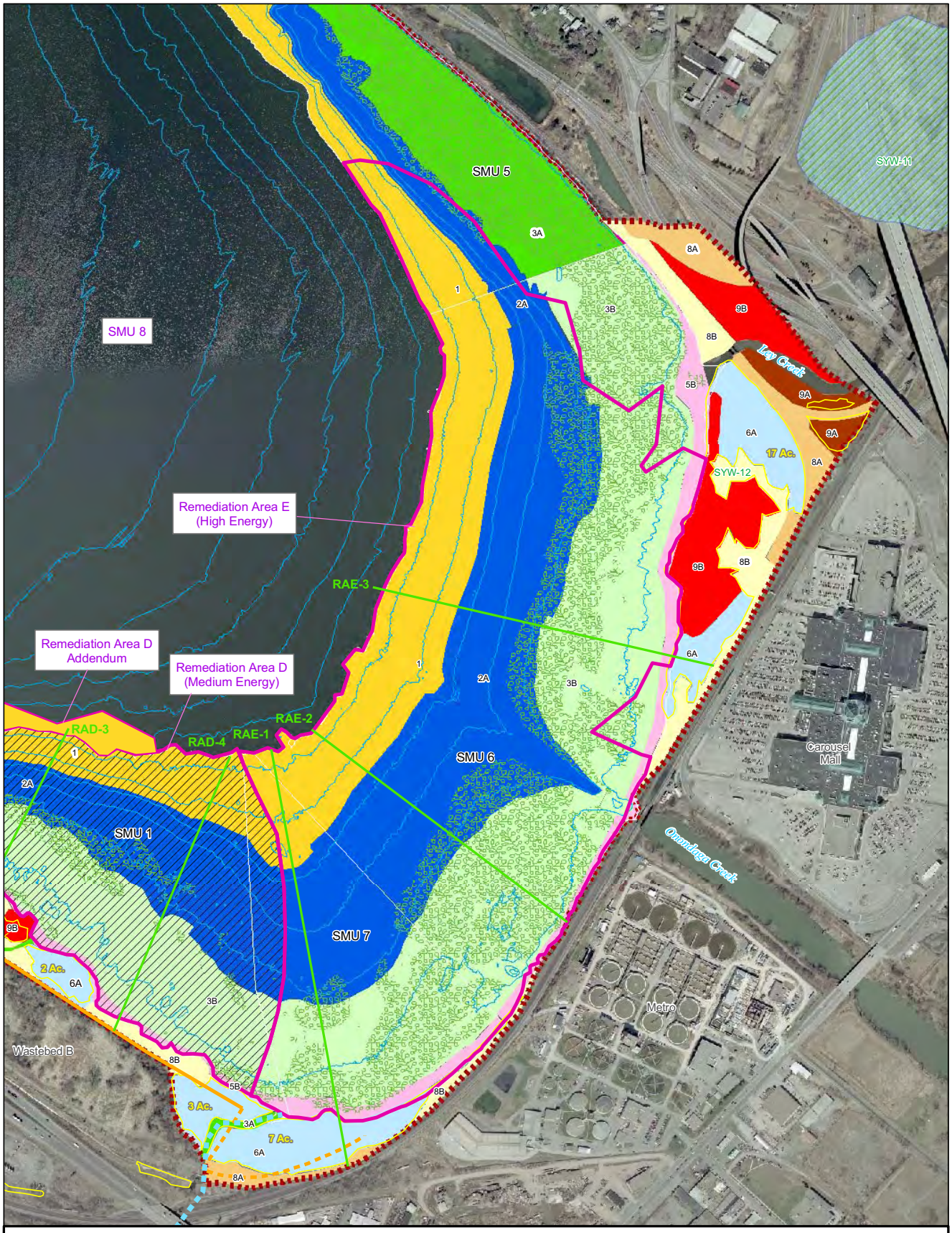
Honeywell

Onondaga Lake
Syracuse, New York

Existing Habitat Modules
Remediation Area D

PARSONS

301 PLAINFIELD RD, SUITE 350; SYRACUSE, NY 13212



Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)

NYSDEC/EPA Approved Wetland Boundaries

Sediment Management Unit (SMU) Boundary

Area Containing Solvay Waste Within the Lake

Remediation Area Boundary (Parsons, 2009)

RAE-1 Cross-section Location and Identification

Area Covered by Onondaga Lake Remedial Design Elements for Habitat Restoration

Tributary to be remediated by Honeywell

Willis/Semet IRM Barrier Wall

West Wall Portion of the WB-B/HB IRM

Approximate Location of the East Wall Portion of the WB-B/HB IRM

N W E S

New York State Digital Orthoimagery from 2003

350 175 0 350
Feet

Water depth based on lake surface elevation of 362.5' NAVD88.

Contour interval = 5'

FIGURE 4.5

Honeywell

Onondaga Lake
Syracuse, New York

Existing Habitat Modules
Remediation Area E

PARSONS

301 PLAINFIELD RD, SUITE 350; SYRACUSE, NY 13212

Section 5: Preliminary Designs for Lakewide Habitat Restoration

One of the top priorities of the Onondaga Lake remedial program is to maintain or improve the habitat conditions that will result after completion of the remediation and restoration efforts. Development of a variety of habitats that will diversify and enhance the lake system is at the forefront of the various design evaluations.

This section of the Habitat Plan describes the approach used to combine the existing and historical information presented in Section 2 with the changes that will occur within the lake as part of remediation described in Section 3 to develop habitat restoration designs that meet the goals and objectives for habitat restoration described in Section 4.

The remedial dredging and capping areas fall within two general categories, those areas within the ILWD and areas outside of the ILWD. Within the ILWD, the ROD required an average depth of removal of 6.5 feet with an additional 3.3 feet of removal in hot spots. As a result, the post-remediation water depths will largely be determined by the dredge and cap designs for the ILWD, as well as considerations for habitat restoration, which are currently in progress. In near shore areas outside of the ILWD, the post-remediation water depths are primarily directed at creating specific conditions suitable for the representative species and habitats. Because the areas outside of the ILWD comprise the majority of remediation acreage, the habitat module approach described in this section provides a unique opportunity to conduct large scale habitat improvements within areas being remediated in Onondaga Lake.

5.1 Generation of Restoration Approach

This Habitat Plan presents the preliminary draft habitat restoration design. These designs are the result of many factors, including the integration of representative species habitat needs with the multiple considerations and constraints associated with the cleanup criteria and design specified in the ROD, the approach specified in the draft Capping and Dredge Area and Depth IDS (Parsons, 2009g), the physical constraints of the site, and the habitat goals and objectives discussed in Section 4.

Specific examples of habitat, dredging, and capping considerations that were integrated into the plan include required isolation cap thickness, habitat layer thickness, cap-induced settlement, ice scour, wind/wave energy, erosion protection requirements, dredging depth, slope stability, and substrate size. These considerations, which can vary depending on the type of remedy and the location in the lake, were then used as guiding assumptions in developing the habitat restoration designs based on the habitat modules.

Due to the iterative nature of integrating habitat, dredging, and capping considerations into the final design for the lake and adjacent shoreline areas, there may be some modification to the application of the

modules. Based on public input, future investigations, studies, and/or remedial decisions, changes to the application of these modules may occur; however, the overall distribution and variety of modules will be consistent with this plan.

One of the key components of the restoration design is the post-remediation water depth. This water depth is important for determining the type and extent of habitat modules, selecting appropriate plant species, designing the erosion protection layer, and potentially controlling invasive species. These issues were evaluated during the development of the habitat modules based on a variety of documents including the Onondaga Lake FS (Parsons, 2004), the ROD (NYSDEC and USEPA, 2005), standards for grain size distribution (ASTM D, 2007), and the draft *Capping and Dredge Area and Depth IDS* (Parsons, 2009g), which includes the cap induced settlement estimates and the wind/wave analysis prepared by AnchorQEA.

A major factor that directly impacts post remediation water depth is the thickness of the habitat material that will be placed after dredging and/or capping is conducted. Habitat materials will be placed in areas that require isolation capping (habitat layer) as well as areas identified for dredging to cleanup criteria (habitat reestablishment material).

The purpose of the habitat layer is to provide a suitable substrate that representative species can utilize while not impacting the chemical isolation layer of the cap. The habitat layer will be placed on top of the isolation layer or erosion protection layer and vary from a minimum of 1.0 feet (average of 1.25 feet) in the deep water to a minimum of 2.0 feet (average of 2.5 feet) in the nearshore areas (Section 5.2 and Table 5.1). These thicknesses were developed based on the specific habitat being created and the types of organisms that will most likely inhabit these areas.

A habitat layer will be placed in the nearshore areas where dredging to cleanup criteria has been proposed and isolation capping is not required. This material will be a minimum of two feet thick and will be consistent with the grain size and habitat modules identified for the nearshore areas (Table 4.8 and Figures 5.1-5.24).

The Habitat TWG evaluated the multiple constraints and established design assumptions with input from other technical teams (e.g. capping) for each of the remediation areas in the lake (Figures 3.1 and 3.2), while meeting each of the habitat goals and objectives. During this process, the group developed a post-remedy surface of the lake bottom that represents the restored lake bottom after the dredging and capping are complete.

The habitat modules were applied to the new lake bottom surface so that the restored module is applied to areas with the appropriate water depth range. The applied modules are conceptual and the boundaries may fluctuate since the lake is a dynamic, natural system. The upland portions adjacent to the lake that fall under the scope of the Habitat Plan have also been included. However, modules for the lower bench of the Wastebeds 1 through 8 site and the SYW-12 site have not been proposed since those sites are still going through the RI/FS process and

remedies have not been established. The status of these areas is further described below under Remediation Area B and E, respectively.

These new lake bottom surfaces were then used to develop cross sections that depict the current water level, the existing bathymetry (water depth), dredge cut, and the restored final lake bottom surface (after dredging and placement of the cap and habitat materials) (Figures 5.2, 5.3, 5.5, 5.7, 5.8, 5.10, 5.11, 5.12, 5.13, 5.15, 5.16, 5.17). Along the bottom of each cross section, the current and restored habitat modules are illustrated as color-coded blocks that correspond to the habitat module table (Table 4.8) introduced in Section 4.

Details regarding the development of the cross sections can be found in Appendix F of the Capping and Dredge Area and Depth IDS (Capping IDS) (Parsons, 2009g).

The cross sections contained in this Habitat Plan are very similar to those found in the Capping IDS; however, there are some slight differences. The Capping IDS includes cross sections that illustrate the elevation of the cap at the *time of placement*. The cross sections contained in this plan show the thickness of the cap (including the habitat/erosion protection lay*er) after the underlying sediment has settled due to the weight of the cap*. These cross sections also illustrate post-remedy bathymetry using the most conservative estimates of overplacement in order to meet the more critical nearshore water depths required for habitat modules 3, 4, and 5.

The amount of settlement was calculated based on the type of existing sediment, the depth of water, geotechnical conditions, rates of compression, etc. These settlement calculations were accounted for in assessing the post-remedy water depths for assigning habitat modules. Details regarding the evaluation and calculation of settlement can be found in the Capping IDS.

Settlement was also taken into consideration when calculating the change in water depth over the areas of remediation between existing conditions and the post-remedy conditions. This change in water depth is shown on Figures 5.20-5.24. Approximately 276 acres will be shallower and 131 acres will be deeper following remediation and restoration.

5.2 Habitat Layer Characteristics and Thickness

The placement of a habitat layer on top of the isolation cap is a key component of the Onondaga Lake remedy. The purpose of the habitat layer is to provide a suitable substrate that representative species (*e.g.*, plants, animals, and fish) can use while remaining isolated from the underlying contaminants. A secondary purpose of the habitat layer is to allow biological activity to occur without affecting the integrity of the underlying isolation cap. As specified in the ROD for Onondaga Lake, the habitat layer will be a minimum of 1 foot thick and will be the top layer of the isolation cap.

The uppermost layer of soil/substrate specified in each module is dedicated habitat material and will consist of either finer material (silts and sands) or coarser material (gravel and cobble) depending upon desired habitat in that area. The specific grain sizes that will be used are designed to allow movement under the dynamic conditions of the lake and are not intended to be stable during storm events like the erosion protection layer. The grain size of the habitat material can affect the suitability of the module for plant and animal species. In some instances, the grain size may be a disadvantage for certain species or species groups, but an advantage to others. For example, coarse substrates may tend to reduce or limit the suitability of an area for plants to root, while at the same time it may increase or enhance the area for certain fish species and groups of benthic macroinvertebrates. These suitability differences are presented in the habitat module table (Table 4.8) and discussed in Section 4.6.

For the wetland habitat modules and modules specified for onshore areas, the uppermost portion of the habitat layer will be topsoil with a specified minimum organic content. The specifications for the different types of soil/substrate are presented in Section 5.5. The grain sizes for the different types of soil/substrate are presented in Section 5.5.

The need for organic content in each of the modules will be determined as part of subsequent design submittals.

The last column on Table 4.8 identifies the habitat layer thickness considered appropriate for each habitat module. These habitat layer thicknesses were developed by a group of technical staff from the USEPA; USFWS; NYSDEC; NYSDEC Division of Fish, Wildlife, and Marine Services; and national and local habitat experts from SUNY ESF, Mississippi State University, Parsons, O'Brien and Gere, TES, AnchorQEA, and the University of Louisiana at Lafayette. This process involved multiple meetings and extensive discussions to evaluate the biological factors that dictate the appropriate thickness of the habitat layer. Specifically, information on plant rooting depth, animal burrowing depth, depth of fish nests and bioturbation were reviewed from the scientific literature, guidance documents on subaqueous cap design, and site-specific data and observations from Onondaga Lake and adjacent areas.

While each of these biological factors was determined to be important, the group's review and professional experience identified plant rooting depth and animal burrowing depth as the critical factors. In general these factors result in the need for thicker habitat layers in shallower areas where plants root deeper and along the shoreline where animals may burrow. The depth of plant roots in shallow water wetlands and near shore environments is a function of several factors, but is primarily determined by the characteristics of a species and how the hydrology and substrate in the area affect the duration and depth of anaerobic conditions. Under flooded conditions, plant species have shallower root systems. In wetlands dominated by woody species, roots are typically confined to the upper 1 to 1.5 feet of substrates, or generally above the water table. The roots need oxygen and do not survive in the saturated zone where water forces out the oxygen. An emergent wetland of

herbaceous species typically has water levels near the sediment/soil surface and the majority of the roots in the top 0.5 to 1 feet of material. In deeper waters where submerged and floating aquatic vegetation may be present, the rooting depth is largely determined by nutrient availability, since water is readily available. Nutrients do not percolate into the sediment, but are deposited from the overlying water column. This typically results in the highest nutrient concentrations near the sediment/water interface (0 to 0.5 feet) where the root systems of submerged and floating plants are found (Mitsch and Gosselink, 2003; Service Engineering Group, 2002; Spencer and Ksander, 2005; Thiebaut, 2005; Lehmann *et al*., 1997; Wigand *et al*., 1997).

In addition to the review of biological factors, there were also extensive discussions regarding the operational considerations of how the cap and habitat material will be placed in the lake. The way in which the contractor will place the material and the requirements stated in the contract are important factors that ultimately affect the thickness of each layer. The contract requirements may specify that the contractor will need to place a minimum thickness for each layer. The most effective and efficient means that contractors have to be certain they have met the required minimum thickness is to place *more* material than is needed for that layer, which is called "over placement." For each specific layer (e.g. chemical isolation, erosion protection, and habitat) the contract documents may specify the minimum thickness and the allowable amount of over placement. The typical end result of this approach is that the final thickness of each layer is more than the specified minimum thickness in each area.

Based on the biological and operational considerations noted above, as well as the 1-foot minimum thickness specified in the Onondaga Lake ROD, and the need to keep biota and from contacting the underlying isolation cap, the technical team has developed habitat layer thicknesses for the littoral zone in Onondaga Lake as summarized below:

Water Depth	Minimum Habitat Layer Thickness
7 ft to 30 ft	1 ft (Estimated 1.25 ft average)
3 ft to 7 ft	1.5 ft (Estimated 2 ft average)
+1 foot to 3 ft	2 ft (Estimated 2.5 ft average)

Based on recommendations of the NYSDEC and discussions with the TWG, it was determined that the materials of the habitat layer should be finer grained and allowed to move, unlike the erosion protection layer. This finer grained material will be placed following completion of the isolation layers in various portions of the lake. Due to the dynamic nature of the physical processes present in the Onondaga Lake system, measurements of the habitat layer will be made once placement of the material is completed to ensure the minimum thicknesses noted above are met. Some movement of substrate within the habitat layer is

expected following confirmation of the thicknesses noted above due to the dynamic nature of the lake system and a new equilibrium being reached following restoration. The details of the acceptable levels of movement and maintenance requirements for the habitat layer will be included in subsequent design submittals. Additional details on the monitoring program are noted in Section 5.5.2.

5.3 Application of Habitat Modules to Remediation Areas

The most challenging step in the restoration of habitats is selecting what specific habitat type (or in this instance, habitat module) should be targeted in each area. Applying these modules provides an opportunity to diversify and improve the terrestrial and aquatic habitat of the lake system. Such improvement can occur by creating new habitats that do not currently exist or were historically present (*e.g.* wetland fringe habitats), or by enhancing existing habitats (*e.g.* by providing different water depth/substrate types or eliminating invasive species).

Mudflats are covered under Habitat Module 7 and may exist in fringe areas following restoration.

Each of the habitat modules presented on Table 4.8 was applied at some location within a remediation area. Presently, mudflats (Module 7) have not been included due to the lack of control over fluctuating water levels required to keep the mudflat area unvegetated, the presence of the canal system that controls water levels in the lake, and the high potential for colonization by the invasive *Phragmites*. However, shorelines and shallow water areas that are exposed during periods of low lake level will provide shorebird habitat similar to that of mudflats.

The application of habitat modules is shown in the cross sections and plan views presented on Figures 5.1, 5.4, 5.6, 5.9, and 5.14. These figures depict an approach that accounts for the various physical constraints and considerations noted in the ROD and the Capping Area and Dredge Depth Technical Document (Parsons, 2009b). The deep water portion of the lake (SMU 8) may require some active remediation (*i.e.* thin layer capping); however, habitat designs have not yet been developed for these areas as the final location for these areas are still undefined.

Remediation is required in the portions of the lake where contaminants exceed the criteria specified in the ROD. Remediation efforts are required in the portion of the lake from near the mouth of Ninemile Creek southeast along the lake to the mouth of Harbor Brook and the southern portion of the lake to near the mouth of Ley Creek. With a few minor exceptions, active remediation will not be required in the eastern, northern, or northwestern portions of the lake. The remedy for each of the remediation areas in the lake requires isolation capping, dredging to cleanup criteria or a combination of dredging and isolation capping (Figures 3.1 and 3.2).

Although the remediation areas are defined by the lake shoreline, the habitat modules within the additional shoreline areas covered by the Habitat Plan (dashed red line on figures) are also shown. The restored

habitat for each remediation area is fully discussed in the following section.

Table 4.9 offers a summary of the changes in area for the existing and restored habitat modules in the areas of the lake requiring remediation and in the adjacent upland Lakeshore Area.

5.3.1 Remediation Area A (SMU 4) and Mouth of Ninemile Creek

As indicated on Figure 1.2, Remediation Area A is the lake area located at the mouth of Ninemile Creek. This remediation area includes a cap area in deeper water and a dredge and cap area closer to shore. Habitat restoration in this area includes the remediation area and the on-shore areas up to the red line habitat plan limit.

The location, distribution, and extent of the restored habitat modules, as well as the cap areas are shown on Figure 5.1. Two cross-sections (Sections RAA-1 and RAA-2) each showing existing and restored habitats are shown on Figures 5.2 and 5.3, respectively. This presentation allows comparison of the restored habitat modules to existing habitats. The cross section also shows the restored substrate type in each portion of the habitat module.

Overview of Habitat Restoration in Area A

The primary consideration in developing a restoration plan for Remediation Area A included the following concepts: recognized area of low wave energy environment, importance of the Ninemile Creek tributary, importance of connection between lake and Ninemile Creek, bird and waterfowl use of the area, and adjacent on-shore habitats.

The restoration approach for this area includes a broad, shallow shelf (Module 6A) to help reduce wave energy on the sensitive near shore environments in this remediation area and provides the only shallow water lower energy environment in the areas specified for remediation. This is significant because low energy is beneficial for the development of non-persistent emergent wetlands (Habitat Module 5A) and necessary for the floating aquatic wetlands (Habitat Module 4A) in this area.

The mouth of Ninemile Creek and the shoreline wetlands are part of the restoration activities in the Habitat Plan.

Maintaining the connectivity between Ninemile Creek and the lake is an important part of the habitat designs.

The nearshore area east of Ninemile Creek will be dredged to create a deeper channel for floating aquatic species in the low energy area along the shoreline (Module 4A). The shallow water module offshore of this area (Module 6A) will support persistent emergent vegetation. The deeper water nearshore also will help reduce the ability of *Phragmites* to spread out into the floating aquatic vegetation and emergent wetlands near the lakeshore. A shallow channel is also planned to further reduce the threat of *Phragmites* spreading into the restored emergent wetlands. The channel will be 2 to 3 feet deep and 20 to 30 feet wide to limit habitat suitability for *Phragmites* (USEPA, 2008).

The importance of maintaining a significant connection between the lake and Ninemile Creek is recognized in the habitat restoration plan for this area by the provision of a deeper channel (Module 3A, 2 to 7 foot water

depths) at the creek mouth to maintain fish passage and recreational boat access.

The approach for Remediation Area A provides for a natural transition from the lake to the forested and emergent wetlands and upland areas immediately adjacent to this area. These wetland and upland areas are part of the Geddes Brook/Ninemile Creek site. Module 9 (forested wetlands) will also be present along the shore on either side of Ninemile Creek where it joins the lake to help maintain the existing forested wetland in the area and also to reduce *Phragmites* along the edges. The shade created by the trees will reduce the suitability of the area for this invasive species.

5.3.2 Remediation Area B (SMU 3)

Remediation Area B is located along the base of Wastebeds 1 through 8 in a medium energy environment (Figure 5.4). The remedy for this area consists of dredging and capping of select areas, and habitat enhancement along the shoreline as specified in the ROD (p. 75). The total acreage for this area is minor compared to the adjacent areas. A cross-section through one of the restored remediation areas is presented on Figure 5.5.

This Habitat Plan also covers the shoreline area of Wastebeds 1-8, which is adjacent to Remediation Area B.

Overview of Habitat Restoration in Area B

Shoreline stabilization will be integrated with the remedy for Wastebeds 1 through 8 to reduce resuspension and turbidity along the shoreline of SMU 3. The shoreline stabilization will use a combination of various bioengineering techniques to develop a natural shoreline area that provides a transition zone from the low-lying area of Wastebeds 1 through 8 to SMU 3. Details of the shoreline stabilization enhancement are presented in Section 5.3.3.

Other objectives that are addressed by the restored habitat in this area include increasing water depth in nearshore areas by dredging and maintaining a steep offshore shelf to create topographic heterogeneity. The restored habitat modules attempt to maximize the area suitable for submerged aquatic plants and maintaining mid-water depth modules (*e.g.* Module 2A) in areas with sufficient oxygen.

Most of the remediation work in this area is in the deeper water depths. As a result, Habitat Modules 1 and 2 have been applied to this area. Areas of remediation work within the submerged aquatic vegetation water depth will be restored in-kind with Habitat Module 3.

The low-lying bench of Wastebeds 1 through 8 has been included within the boundary of the Habitat Plan due to the low elevation of this area and proximity to the lakeshore. The RI/FS is currently ongoing for this site and a proposed plan for remediation and restoration, if necessary, has not been established. The potential to create wetlands in this area will be further evaluated as the RI/FS progresses. A portion of the low-lying bench area has modules assigned for the purposes of wetland and open water mitigation, and the shoreline stabilization areas for the Remediation Area B shoreline will be integrated with the habitat modules for this area.

5.3.3 Habitat Enhancement (SMU 3 Shoreline)

The ROD identified two specific locations where habitat enhancement activities would be applied-- the areas are along an estimated 1.5 miles (2.4 km) of shoreline (SMU 3) and over approximately 23 acres (SMU 5) to stabilize calcite deposits and oncolites and promote submerged aquatic plant growth. The status of the habitat enhancement activities for SMU 5 is described in Section 5.3.9. The following section describes the habitat enhancement activities planned to stabilize the SMU 3 shoreline.

This exposed Solvay Waste along the shoreline of Wastebeds 1-8 will be addressed as part of the habitat enhancement activities discussed in this section.

The shoreline stabilization is designed to reduce resuspension and turbidity along the shoreline of SMU 3 and will ultimately be integrated with the remedy for Wastebeds 1 through 8. It is anticipated that the shoreline stabilization will use a combination of bioengineering techniques to provide a natural shoreline area to provide transition zones from the low lying area or Wastebeds1 through 8 and SMU 3. However, the feasibility study has not been completed and no remedial approach has been identified for Wastebeds 1 through 8. As such, the shoreline stabilization described in this section is specific to the shallow water portion of SMU 3 up to an elevation of approximately 365 feet (NAVD 88), which is close to the highest high water mark for Onondaga Lake (*i.e.*, 95% of all recorded water surface elevations are at or below 365 feet [NAVD 88]). Stabilization measures for the shoreline areas above the 365 feet (NAVD 88) elevation will be developed once the remedial approach for WB 1 through 8 has been determined.

Approach

As discussed in the Onondaga Lake FS, the shoreline of SMU 3 has the potential to erode during wind/wave events. Stabilization of the shoreline would minimize the potential for resuspension of nearshore and shoreline material due to frequent wave events, reducing erosion and potentially improving water quality conditions in the nearshore littoral zone for submerged aquatic plant growth. The approach for stabilizing the calcite deposits along the SMU 3 shoreline will use bioengineering techniques to the greatest extent possible to minimize hardening of the shoreline and provide a transition between the Wastebeds1 through 8 remediation and in-lake remediation in SMU3. These bioengineering techniques may include the use of a live crib wall, live fascines (woody vegetation bundles such as *Salix spp*.) and vegetative mattresses (brush material buried in trenches). The majority of bioengineering techniques incorporate larger sized stone near the toe of the slope which corresponds with the surf zone of SMU 3. The larger sized stone will be used to stabilize substrate and reduce resuspension. If possible, non-angular graded gravel will be used for habitat enhancement, but in areas where erosion protection is necessary, the preferred material may be angular. This angular material has more stability than rounded material and may better withstand erosive forces.

The results of the wind/wave analysis completed for Onondaga Lake were used to determine the extent of the surf zone and the size of stone needed to stabilize the substrate (Parsons, 2009b). The surf zone

associated with the 10-year storm event period was selected as the basis of design for defining the treatment area. This is essentially the area with a 10% probability of receiving a large storm with 2.5 ft waves in any year. Based on the wind/wave analysis, the surf zone (and corresponding wave height) extends to a water depth of approximately 2.5 feet for waves associated with the 10-year return period. The treatment area for stabilizing the substrate will be set at the 2.5 feet contour within SMU 3, for a total treatment area of 16.2 acres.

The design event for determining the stable particle size should be the same as the design event used to define the surf zone so that the material placed within the surf zone will be stable. However, the design event should not be so conservative as to require unnecessarily large stone sizes that could limit the habitat suitability of the material. As a result, the 10-year return period was used as the basis of design for determining the stable particle size to balance between stability and particle size. Based on this analysis, graded gravel with a median particle size of 0.08 to 0.1 feet will be placed within the surf zone to stabilize the substrate to reduce resuspension and at the toe of the slope where bioengineering treatments are anticipated. This material will be placed along the entire SMU 3 shoreline to a water depth of 2.5 feet, coincident with the depth that demarks the shallow edge of Module 3 and will extend partially into SMU 4 towards the mouth of Ninemile Creek. As such, there is no overlap of the shoreline stabilization areas with the limited area of Module 3 or deeper water modules planned for Remediation Area B.

Substrate type

As previously stated, the substrate type that will be placed within the surf zone and along the toe of the slope will be graded gravel with a D_{50} (median stone size) of 0.08 to 0.1 feet. The gravel will be placed on top of a fabric that will support the gravel and keep the Solvay waste from working up through the material. Ongoing work on Wastebeds 12 through 15 will be used to determine the types of soil amendments that may be needed to support vegetation within the bioengineering treatments that will be applied as part of the Wastebeds 1 through 8 site remediation. The need to place soil amendments in other portions of Wastebeds 1 through 8, including areas adjacent to the shoreline stabilization treatments, will be evaluated once the remedy for that area has been determined.

Substrate thickness

Graded gravel 0.5 feet thick will be placed to a water depth of 2.5 feet to stabilize the substrate along the SMU 3 shoreline, which will reduce the turbidity during wind/wave events in this area.

In the area between the average lake elevation (362.5 feet) and the highest elevation for the habitat enhancement treatment (365 feet), the gravel will be 1 foot thick, mixed with topsoil. In addition, vegetation (including live stakes, shrubs, and riparian seeds for example) will be planted in the area.

5.3.4 Low-lying Portion of Wastebeds 1 through 8 (adjacent to Remediation Area B [SMU 3])

The low-lying portion of Wastebeds 1 through 8 is immediately adjacent to the shoreline stabilization area and Remediation Area B. The area is currently under investigation as part of a focused feasibility study and comprehensive feasibility study. Habitat restoration designs will be dependent on the final remedy for the site and have not been identified at this time.

The low-lying portion of the shoreline of Wastebeds 1-8 is addressed by this Habitat Plan.

There are certain habitat restoration activities that are expected to occur in this area as part of the mitigation to offset impacts associated with remedial activities in other portions of the lake. Impacts associated with the installation of a portion of the barrier wall along Willis Avenue resulted in the loss of approximately 2.3 acres of lake surface area. Wetland areas near the mouth of Harbor Brook will also be affected by the installation of a barrier wall and other remediation activities. These impacts will be offset through the creation of a wetland/open water complex on the low lying portion of Wastebeds 1-8 along the southern shoreline of Onondaga Lake. The mitigation will consist of creating aquatic habitat and wetlands adjacent to the lake. The current design provides for 5.4 acres of inland wetland and 2.3 acres of connected wetlands (Figure 3.7). The specific size and location of this wetland / open water complex and type of wetland system will be determined during intermediate design.

5.3.5 Remediation Area C (SMU 2)

Remediation Area C (SMU 2 and a small portion of the southern end of SMU 3) is located in the southwestern portion of the lake just south of the State Fair parking lot (Figure 3-4). I-690 is adjacent to Remediation Area C, with an exit from I-690 and a gravel parking lot and a NYSDOT turnaround area just west of the lakeshore. This gravel parking lot provides a place for viewing wildlife on the lake and there is also an unimproved boat launch for boat access to the lake. Existing and future recreational use and access are important aspects of this area. Ditch A, a small tributary that drains from the State Fair parking lot, enters the lake just north of the gravel parking lot.

NYSDOT turnaround area off of I-690 and adjacent to Remediation Area C.

Remediation Area C is a medium energy environment. The remedy for this area consists of limited removals along the shoreline followed by capping throughout the majority of the littoral zone. The remedy for this area is also directly affected by the Willis/Semet IRM barrier wall, which stops contaminated groundwater from discharging to Onondaga Lake.

Overview of Habitat Restoration in Area C

Habitat modules for this area are shown on Figure 5.6, and two cross-sections that show existing and future bathymetry and substrates are shown on Figures 5.7 and 5.8. A boat launch may be constructed along the shoreline in this area in the future, which could be located along the south side of the gravel parking lot.

The habitat modules are designed to maintain deep water nearshore for fishing access and public use (Module 2A), as well as placing coarse grained material along the shoreline to support fish spawning and limit invasive species (Modules 3B and 5B). These considerations will help increase the recreational use of the Remediation Area C shoreline in the future and are consistent with the habitat priorities and goals.

5.3.6 Remediation Area D (SMU 1)

Remediation Area D (SMU 1 and small portions of SMUs 2 and 7) is located in the southwestern portion of the lake. This remediation area is currently characterized by a large area of ILWD, which has created shallow water and poor quality substrates throughout this remediation area.

Remediation Area D is also characterized by the existing and proposed segments of the onshore barrier wall, and extensive restoration (primarily wetland habitat modules) will be conducted between the barrier wall and the current lake shoreline (Figure 5.9). Recreational use potential, especially in the northern end of this remediation area, also influences the habitat restoration plans. The Wastebed B area provides undeveloped habitat that separates the barrier wall from I-690.

Remediation Area D is located adjacent to the Wastebed B/Harbor Brook site.

The dredging approach required in Remediation Area D to satisfy the ROD requirements (*i.e.* removal depth equal to an average of 6.6 feet [2 meters] over the current boundary of the ILWD and the additional removal in hot-spot areas) is still being developed. The current remedy for this area includes dredging and capping with deeper excavation in hot-spot areas.

An addendum has been added to Remediation Area D to cover a small area within SMU 8 adjacent to Remediation Area D. This area is approximately 5.6 acres in size and has elevated Mean PECQ levels and will require an isolation cap and habitat layer (Figure 5.9).

Overview of Habitat Restoration in Area D

Habitat modules for Restoration Area D and adjacent onshore areas are shown on Figure 5.9. Cross sections through this area are illustrated on Figures 5.10, 5.11, 5.12, and 5.13. In-lake areas of Remediation Area D include Habitat Modules 1 and 2, with an extensive area of deeper water (Module 2) close to shore in the northern area of this remediation area. The Remediation Area D Addendum area will also consist of additional Module 1 in this small portion of SMU 8. The design noted above creates significant fishing opportunities from the shore for an extensive reach. Water depths in the shallow ILWD areas will be increased by the application of Habitat Module 3 and a clean, more suitable substrate provided, which will support many aquatic plants and animals. Areas of hot-spot removal will create a diversity of water depths within the Module 3 area, and a deep pocket of Module 2. These features will provide additional habitat opportunities for aquatic species.

Nearshore areas of Remediation Area D will be restored with shallower depth modules, which will act as a wave break, reduce the wave energy, and protect the on-shore wetlands, which are described in Section 5.3.8.

5.3.7 Remediation Area E (SMUs 6 and 7)

Remediation Area E (SMU 6 and 7) is located between Harbor Brook and Ley Creek on the eastern shoreline of the lake.

Remediation Area E is a fairly extensive area located at the very southern end of Onondaga Lake. It is an area of high wave energy due to the long fetch of the lake. Onondaga Creek, the primary tributary to the lake, and Harbor Brook discharge into the lake in this area. Emergent wetlands, currently degraded by the presence of waste material and the prevalence of *Phragmites*, occur around the lower reach of Harbor Brook. The barrier wall is also proposed to extend into portions of this wetland complex.

Two other considerations in the restoration of this area are the presence of the discharge from the Syracuse Metro wastewater facility, and the navigational concerns at the mouth of Onondaga Creek. Channel depth at the mouth of Onondaga Creek must be sufficient to accommodate commercial boat traffic that uses Onondaga Creek and the Inner Harbor, and water depth must be sufficient enough to keep Metro discharge from collecting at the end of the lake.

Overview of Habitat Restoration in Area E

Habitat restoration plans for Remediation Area E are shown on Figure 5.14. Cross-sections for this area are shown on Figures 5.15, 5.16, and 5.17. For the Harbor Brook area, details of restoration efforts are shown on Figures 5.18 and 5.19.

The habitat modules in Remediation Area E were designed to account for the high energy in this area, consistent with NYSDEC priority 2, and accommodate the flow of Onondaga Creek and the discharge from the Metro facility into the lake. The restoration approach specifically incorporates several NYSDEC priorities for this remediation area, including shallow shelves to break high energy waves outboard of the shoreline and Wetland SYW-12; deeper water nearshore by removal of impacted material (dredging to cleanup criteria); and creation of a deep water for boat access to Onondaga Creek and the Inner Harbor.

Habitat restoration in the deeper water portions of this area (Modules 1 and 2) will provide water depths similar to current conditions, but with a clean sand and fine gravel substrate.

A large area of Habitat Module 3B is present across this remediation area. Water depths vary in this model and it is intended to reduce some of the wave energy that would reach the shore. Restored substrates are coarse gravel because of the high energy environment. Although these substrates will limit submerged aquatic vegetation establishment, they will benefit certain fish species and benthic organisms.

Near the Harbor Brook area a shallower water area of Habitat Modules 5B and 6B has been included. This area is intended to provide a wave break to protect the wetland habitats around the lower reach of Harbor Brook. Those portions of Habitat Module 6B that are above the lake level at times will provide mudflat habitat beneficial to resident and migratory shorebirds.

5.3.8 Harbor Brook Wetland Complex (On-shore Region Straddling Remediation Areas D and E)

On shore areas between the barrier wall and existing shoreline will be restored to wetlands that will enhance the habitat function and value in this area. Most of the area will be persistent emergent wetland (Habitat Module 6), with a small portion of forested wetland (Habitat Module 9). Good quality emergent wetlands are a noticeably missing habitat around the lake and these areas will enhance and diversify the lake system for aquatic and terrestrial organisms.

As with other persistent emergent wetlands around the lake, the encroachment of *Phragmites* is a concern. For this reason, a *Phragmites* control channel will be constructed along the landward edge of the emergent wetland. This deeper channel is designed to limit the invasion of *Phragmites*, but it will also be good habitat for floating aquatic (Module 4) and non-persistent wetland species (Module 5). As a result, it will be part of the overall wetland complex.

The area of forested wetland (Habitat Module 9) for the on shore area is designed to replace some wooded wetlands, diversify the restored habitats, and to provide some shelter for the adjacent emergent wetlands in the area. The shape of this wetland should create a protected cove in its lee on the southeast side.

During periods of high lake water levels (at or over an elevation of 363.5 feet [NAVD 88]), the creation of these shoreline wetlands will actually provide more lake water area, while providing for interspersed islands for waterfowl nesting. At these lake levels, the lake area will increase as the shoreline will actually be along the toe-of-slope from the barrier wall. Fringing wetlands are commonly flooded during seasonal high water events, increasing lake surface area.

Restoration of the upland habitat areas between the landward edge of the wetlands and the top of the barrier wall and uplands landward of the barrier wall will also be conducted. Module 8B is proposed in those areas and will allow for the use of shade trees and shrubs in this area.

Currently, the lower portion of Harbor Brook is a channelized reach surrounded by a wetland composed of a monoculture of *Phragmites*. It is degraded by the presence of waste material and the prevalence of *Phragmites* with limited value to terrestrial and aquatic organisms.

Significant habitat restoration efforts are planned for this area within and adjacent to Harbor Brook. These efforts will greatly enhance and diversify the habitats in this area and provide benefits to a diverse array of aquatic and terrestrial species.

An overview of the restoration for the Harbor Brook area is shown on Figure 5.9. More detailed plans are presented on Figures 5.18 and 5.19.

The habitat restoration approach for this area includes the reconfiguration of Harbor Brook into a braided stream wetland complex

(Figures 5.18 and 5.19). The reconfiguration of Harbor Brook would allow for increased stream stability, development of improved habitats suitable for a variety of species, and improvement of the connectivity of wetlands with the lake habitats. The wetlands restoration will include a persistent emergent wetland complex (Module 6A) that is specifically designed with shallow channels to enhance the area for northern pike spawning. Slightly higher mounds have been included to provide areas for waterfowl nesting.

The barrier wall extends into the Harbor Brook area. Upland habitat modules (Modules 8A and 8B) will be restored to transition from the wetlands up to the wall, and to restore the areas on the landward edge of the wall. Wetlands and side slopes, open fields, and scrub-shrub habitat landward of the wall will benefit a variety of wildlife species.

SYW-12 Area

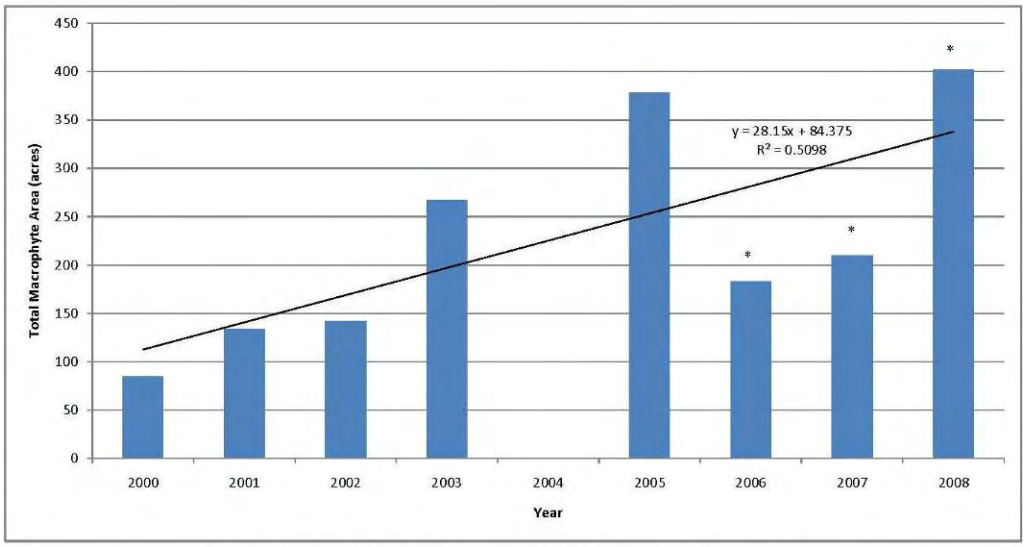
The SYW-12 area is currently under investigation to determine the nature and extent of contamination in this area. Once these data have been fully evaluated, an approach for remediation and restoration of SYW-12 wetland and adjacent area will be addressed through the RI/FS process for the Wastebed B/Harbor Brook site.

5.3.9 Remediation Area F

Based on additional data collected as part of the pre-design investigation since the issuance of the ROD, the area requiring active remediation is Remediation Area F has been updated (Figure 3.1). In two small isolated areas (S-95 and S-111) that total less than 1 acre of area, 1 foot of sediment will be dredged to cleanup criteria to remove the contamination in these areas.

5.3.10 Habitat Enhancement (SMU 5)

As described in the ROD, habitat enhancement was planned to occur over approximately 23 acres in Remediation Area F (SMU 5) to stabilize calcite deposits and oncolites and promote submerged aquatic plant growth (NYSDEC and USEPA, 2005). The approach described in the ROD was based on stabilizing the oncolitic sediments to allow plant colonization. The target of 23 acres was based on increasing the percent cover of the littoral zone to provide optimal habitat for the largemouth bass (Stuber et al. 1982a). The information used in the ROD was based on 2000 plant surveys, which documented a total of 17.8 acres in Remediation Area F (SMU5) (EcoLogic, 2001) within the optimal water depth for plants.



TOTAL PLANT COVER IN ONONDAGA LAKE: 2000 to 2008

Notes: Plant cover was not determined in 2004.
** Plant cover was determined in June during 2000-2005, but could not be photographed until August during 2006-2008 due to water clarity issues in early summer .*

Since that time, the area covered by plants has increased significantly, largely due to water quality improvements associated with the upgrades to the Metro facility. Based on the most recent 2008 survey, there were approximately 314 acres of plants mapped in the lake and approximately 160 acres in Remediation Area F within the optimal water depth for plants (personal communication, Dave Synder, Onondaga County). As such, there is significantly more acreage covered by aquatic plants than would have occurred resulted from implementation of the 23 acres of habitat enhancement. In fact, the majority of the treatment areas identified in the Onondaga Lake FS for habitat enhancement have been naturally colonized by aquatic plants. Therefore, the habitat enhancement activities, which were designed to increase aquatic plant cover to provide optimal habitat for the largemouth bass, may not be necessary to meet the objectives noted in the ROD.

SMU 8 is located in the center of the lake in greater than 30 feet of water.

5.3.11 Profundal Zone (thin-layer capping - SMU 8)

As specified in the ROD, thin layer capping may be required in areas of the profundal zone that exceed the remedial criteria. The profundal zone is defined as the portion of the lake where water depths exceed 30 feet (SMU 8). This section describes the thin layer capping that may be completed in portions of the profundal zone.

Approach

Thin layer capping is intended to provide an immediate decrease in surface sediment concentrations by adding a layer of clean material that

would then be incorporated into the surface sediments through natural processes such as bioturbation and sedimentation. The Remedial Action Objective for SMU 8 is to "eliminate or reduce, to the extent practicable, releases of mercury from profundal sediments." The basis of design for selecting the areas to cap and the thickness of the cap was determined based on surface sediment concentrations of mercury and exceedances of the mean PECQ of 1, as well as the bioaccumulation-based sediment quality value (BSQV) for mercury of 0.8 mg/kg on an area-weighted basis.

Application

A half foot of sand will be placed in areas meeting the requirements for thin layer capping as described above. Since the profundal zone is not exposed to wind or wave action, there is no need for an erosion protection layer in addition to the 0.5 feet of sand. Since the remedy will not change oxygen availability in the hypolimnion during summer stratification, use of the profundal zone by organisms, including the reference species, is not likely to change following remediation. If oxygenation is used to reduce mercury methylation, oxygen concentrations, although greater than under nitrate addition, may not be sufficient to sustain fish or aerobic benthic macroinvertebrates. If nitrate addition is used to reduce mercury methylation, there still will be periods of anoxia during the summer.

5.4 Suitability of Remediation Areas for Representative Species

The TWG evaluated the suitability of the habitat modules in the remediation areas for the representative species within each major species group to determine how these species may use each area following the restoration. See Table 5.2 for a summary of potential locations for the representative species described in this section.

5.4.1 Fish

Lake sturgeon use deep water habitats.

Suitable habitat for fish will be provided in each remediation area. Northern pike spawning and rearing habitat will be provided in Remediation Area A, Remediation Area B, and in the Harbor Brook area adjacent Remediation Area E. Specific habitat designs were incorporated into the Harbor Brook restoration to promote northern pike spawning. Adult northern pike habitat will be provided in Remediation Areas A, B, C, D, and E. Deeper water modules will also provide habitat for the northern pike in Remediation Area E. Habitat for walleye will also be provided primarily by the deeper water modules. Adult walleye habitat will be provided in Remediation Area A, B, C, D and E. Juvenile walleye habitat will be provided in Remediation Area C. The habitat suitability for walleye in these areas would be improved with the addition of structure.

The two deepest water modules (i.e., 1 and 2) will provide habitat for the lake sturgeon in Remediation Areas A, B, C, D, and E. Habitat for the emerald shiner and brown trout will also be provided by the deeper

water modules in all remediation areas. Golden shiners prefer weedy, quiet, shallow waters, and the best habitat will be provided in Remediation A. The submerged aquatic vegetation in Remediation Areas B and C will also provide habitat for the golden shiner.

Largemouth and smallmouth bass habitat will be provided in both deeper water modules (for adults) and the shallower water modules (for spawning and juveniles) in each remediation area. The suitability of the shallow water modules (i.e., areas of wetlands and submerged aquatic vegetation) for both the large and smallmouth bass would be improved with the addition of structure. Pumpkinseed habitat would be provided in these same areas.

The application of the habitat modules also takes into account the fact that there are limited fishing opportunities on the western shore of the lake, particularly areas where fish characteristic of deeper water habitats can be reached using shore fishing techniques. As such, deeper water areas have been applied along the shore in Remediation Area D to provide access for fishing.

A more detailed discussion on the suitability of each Remediation Area for the representative fish species is provided in Appendix D.

5.4.2 Plants

The sandy substrate in the shallow water portions of Remediation Areas A and B will be suitable habitat for representative submerged aquatic vegetation species such as coontail, sago pondweed, tapegrass, and elodea (*Elodea canadensis*), as well as other pond weeds and submerged aquatic plants common in the lake. Submerged aquatic vegetation habitat will also be provided in Remediation Areas C, D, and E. However, because of the wave energy in these locations, the use of coarse substrate for the habitat layer will be required and it may take longer for these areas to support the same level of submerged aquatic plants as in other Remediation Areas.

Plants such as cattail will be used to replace invasive species like Phragmites.

In general, the representative lakeshore wetland plant species prefer lower wave energy environment, shallow water depths, and fine substrates for Remediation Area A, B, D, and the Harbor Brook area adjacent to Remediation Area E. Remediation Area A is the only area in the lake that will provide suitable habitat for floating aquatic vegetation which includes white water lily, yellow pond lily, American pondweed, and potentially free-floating duckweeds. The planned wetlands in Remediation Areas A, B, D, and the Harbor Brook area adjacent to Remediation Area E will provide habitat for representative non-persistent and persistent emergent species. Non-persistent emergent species include pickerel weed, arrow arum, arrowhead, water plantain, and water smartweed.

Persistent emergent wetland species include cattail, soft-stem bulrush, river bulrush, burreed, willow-weed, water-willow, and sedge. A deeper water trench will also be created along the shoreline in Remediation Areas A and E to limit *Phragmites* encroachment into the wetland areas. These areas will provide habitat for non-persistent emergent species. Wetlands are also planned for Remediation Area E. However, the wave

energy in this area will require the use of coarse substrate which could limit the density of wetland plants.

Forested wetland habitat is planned adjacent to Remediation A and Remediation Area D. Habitat for silver maple, American elm, and black willow, which are common in the existing forested wetland near Remediation Area A, will be provided in these areas.

A more detailed discussion on the suitability of each Remediation Area for the representative plant species is provided in Appendix D.

Appendix E includes a master list of plants suitable for the restored habitat areas.

5.4.3 Benthic Macroinvertebrates

Habitat for benthic macroinvertebrates will be provided in each remediation area, primarily due to the placement of clean substrate. The addition of structure will increase habitat diversity and provide additional habitat for some species, especially crayfish, in the shallow waters of each Remediation Area. The shallow waters of each remediation area will support diverse and suitable habitat for lentic species of all the representative invertebrate orders. The deeper waters of each remediation area will provide suitable habitat for amphipods and true flies.

A more detailed discussion on the suitability of each Remediation Area for the representative benthic macroinvertebrate species is provided in Appendix D.

Remediation Area A is one of the best locations for mammals within Onondaga Lake.

5.4.4 Mammals

The combination of habitat requirements for the representative species (*e.g.*, low energy areas, emergent vegetation, trees or other cover along the shoreline) makes Remediation Area A the best location within the lake for the creation of suitable habitat for beaver, mink, muskrat and otter. The proximity to Ninemile Creek further enhances the suitability of these areas for mink and otter which can use the tributary as a travel corridor. In addition, the current and planned forested areas near the mouth of the creek could potentially provide habitat for the Indiana bat.

Remediation Areas B, D, and E will also provide habitat for beaver, mink, muskrat and otter. In general, the shallower portion of these remediation areas will provide habitat for all four species, while deeper waters would provide habitat for the otter, mink and beaver. The inland wetland areas located outside the boundaries of the remediation area and adjacent to Remediation Area D will provide suitable habitat for mink and beaver and potentially Indiana bat. The large wetland complex adjacent to Remediation Area D will provide suitable habitat for mink, otter, beaver, and in particular, muskrat. The realigned Harbor Brook and associated wetland complex adjacent to Remediation Area E will provide suitable habitat for mink, otter, beaver, and muskrat. Muskrats should be significantly favored by these habitat changes.

A more detailed discussion on the suitability of each Remediation Area for the representative mammals is provided in Appendix D.

5.4.5 Reptiles and Amphibians

The representative reptile species, musk turtle, painted turtle, snapping turtle, and northern water snake prefer lower energy environments with shallow water and access to cover or some type of structure. Habitat for the reptile species will be provided in the shallow water portions of Remediation Areas A, B, D, and the Harbor Brook area adjacent to Remediation Area E. Specifically, the shallow water areas would provide suitable habitat for hibernation and feeding for the four representative reptile species. The wetland, submerged aquatic and floating aquatic (Remediation Area A only) vegetation would provide areas of cover for escape and feeding for the painted turtle and northern water snake as well as nesting areas for musk turtle. Musk turtle also may find suitable nesting habitat in the wetland areas. Snapping turtle would use the natural transition from emergent wetlands in the lake to upland areas in Remediation Area A, Remediation Area B, and Remediation Area E. The vegetated cover Remediation Area C would provide cover for species such as the snapping turtle, painted turtle, and northern water snake.

Restored wetlands will support a variety of species including this painted turtle.

The representative amphibian species (red spotted newt, mudpuppy, spotted salamander, green frog (*Rana clamitans melanota)*, leopard frog (*Rana pipiens-s. utricularius*), and wood frog generally prefer shallow water environments. Mudpuppy will also use deeper areas, but will nest in water less than 3 feet deep. The wetlands planned in Remediation Area A, B, C, D, and the Harbor Brook area adjacent to Remediation Area E will provide suitable habitat for all of the representative amphibian species, and provide a transition from the lake to terrestrial areas. The fine substrate that will be used in Remediation Area A, B, and Harbor Brook area adjacent to Remediation Area E would also provide suitable foraging and hibernating areas for red-spotted newt, green frog, leopard frog, and wood frog. Mudpuppy habitat would be provided by the wetlands and by Harbor Brook during the cooler spring and fall months. The wetlands would also provide suitable habitat for concealment and foraging for the red-spotted newt, leopard frog, and wood frog.

Sediments composed of finer grain sizes and organic matter would provide vegetation important for concealment and egg deposition, as well as providing a gradual transition to persistent emergent wetlands for cover and foraging. The seasonal temporary pools that will be created as part of the inland wetland complex located outside the boundaries of the remediation area will provide suitable breeding habitat for the wood frog and would provide sufficient shallow areas for tadpole survival. In addition, the waterfowl nesting mounds included in this complex will provide habitat for the green frog and leopard frog.

Red-spotted newt and spotted salamander spend their adult stages terrestrially and the habitats planned adjacent to Remediation Area A and E would provide cover and suitable habitat. The deeper water portions of all Remediation Areas would provide habitat for the

mudpuppy, particularly with the addition of structure. Snapping turtles may also use these areas.

A more detailed discussion on the suitability of each Remediation Area for the representative reptiles and amphibians is provided in Appendix D.

5.4.6 Birds

The deeper water portions of the littoral zone will provide suitable foraging and feeding habitat for mallard, common goldeneye, common tern osprey, bank swallow and the belted kingfisher. The vegetated shoreline areas transitioning from wetlands to submerged aquatic plants will provide foraging habitat for great blue heron, green heron, and sandpipers in Remediation Area A, Remediation Area B, and the Harbor Brook area adjacent to Remediation Area E. These same areas would provide suitable habitat for mallards to forage and provide access to adjacent terrestrial locations for nesting, and also provide an invertebrate food base for species such as the spotted sandpiper and semi-palmated sandpiper.

Common Goldeneye is a species that would be suitable for several remediation areas.

Currently, the steep banks adjacent to Remediation Areas A and B will provide nesting habitat for bank swallows and belted kingfisher. The forested wetlands in Remediation Area A and D will provide perching structures for osprey, red-winged blackbird, and green heron and cover for nesting in bushes, thickets, and small trees for the green heron, red-winged blackbird, common goldeneye, and mallard.

Areas where herbaceous cover is planned in Remediation Areas B, C, and D and the Harbor Brook area adjacent to Remediation Area E, will provide suitable nesting areas for the common tern and red-winged blackbird. Habitat for shorebirds, such as the spotted sandpiper and semi-palmated sandpiper, will be provided from the coarser, rockier areas along the shoreline of Remediation Area C.

The shallow water wetland and banks of Harbor Brook in the area adjacent to Remediation Area E would provide foraging areas for the great blue heron, green heron, belted kingfisher, red-winged blackbird, spotted sandpiper, and the semi-palmated sandpiper. The waterfowl nesting mounds would provide ideal habitat for nesting for the mallard, as well as protection of nests from terrestrial predators. Insect production of the wetland will provide foraging opportunities for bank swallows.

A more detailed discussion on the suitability of each Remediation Area for the representative birds is provided in Appendix D.

5.5 General Specifications for Habitat Restoration

5.5.1 Substrate Types

References to substrate types in this section are based on the Unified Soil Classification System (USCS). Substrate type is usually

Many types of substrate will be used in the habitat restoration design.

categorized based on grain size, and those sizes are listed below. Soils seldom exist in nature separately as sand, gravel, or any other single component. They are usually found as mixtures with varying proportions of particles of different sizes; each component part contributes its characteristics to the soil mixture. Soils are primarily identified as coarse grained, fine grained, and highly organic. If possible, rounded material will be used in the habitat layer design. Likewise, angular material may be more suitable for the erosion protection layer. Detailed specifications for substrate (including grain size distribution, appropriate source material, and organic content)will be provided in subsequent design submittals.

Component	Size
Cobbles	Above 3 inches
Gravel	0.167 inch to 3 inches
Coarse	0.75 inch to 3 inches
Fine	0.167 inch to 0.75 inch
Sand	0.003 inch to 0.167 inch
Coarse	0.167 inch to 0.0787 inch
Medium	0.0787 inch to 0.0167 inch
Fine	0.0167 inch to 0.003 inch
Fines (silt or clay)	Less than 0.003 inches (no minimum)

In the text of Section 5, coarse substrates are those shown in the previous table as coarse gravel and cobble, and fine substrates have particle sizes of fine gravel and smaller. Figures 5.25 – 5.29 illustrate the substrate material associated with the restored habitat in each of the remediation areas.

5.5.2 Monitoring Requirements

Comparisons to baseline conditions, threshold values, or reference conditions are methods that can be used to complete an assessment of the overall performance of the habitat restoration. There are currently numerous programs on the lake and tributaries being conducted by Onondaga County, Upstate Freshwater Institute (UFI), SUNY-ESF, and Honeywell. These studies include data collection on water quality, sediment characterization, macrophytes, fish populations and community structure, benthic community, and wetland delineations.

As a part of the Operations, Maintenance and Monitoring (OM&M) plan, a monitoring program will be developed to assess the performance of the habitat restoration/enhancement actions and evaluate whether the objectives outlined in this plan are being met by comparing to baseline conditions, threshold values or reference conditions. Monitoring will also provide information that can improve the implementation and performance of any maintenance activities (*e.g.*, corrective actions).

The monitoring program will begin immediately after completion of the habitat restoration/enhancement activities. Specifically, the monitoring program will 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.

The specific elements and the duration of the monitoring program will be dictated by the final habitat restoration/enhancement designs. Monitoring will occur annually and include:

- assessment of the areal extent of each habitat module;
- assessment of substrate suitability and placement;
- list of plant species and percent cover of dominant plants in each planted habitat module;
- assessment of percent survival of installed plant material (submerged aquatic plants, emergent vegetation, shrubs, trees);
- percent cover of invasive species; and
- assessment of the use of restored/enhanced habitats by biological organisms.

Additional monitoring metrics may be warranted based on the final habitat restoration designs. Collected data will be compared to success criteria that will also be established as part of the final designs. The success criteria will include specific measures that must be met for the project to be considered successful. For example, for wetland restoration areas, one criterion would be to achieve a specific percent cover (e.g., 85%) after a specific period of time (e.g., 5 years). The success criteria will also take into consideration that the water depth limits of the habitat modules are not discrete boundaries. There will be a transition or overlap zone from one module to the next and one habitat type to the next. For example, submerged aquatic vegetation (primarily associated with Module 3) will occur at the deeper limit of the floating aquatic wetland (Module 4), and non-persistent emergent wetland vegetation (associated with Module 5) can occur at the shallow end of the floating aquatic wetland module. In addition, the success criteria will be focused on providing suitable habitat for the representative species (i.e., the successful implementation of the habitat modules) rather than the occurrence of the representative species. The status of certain species which are rare (e.g., lake sturgeon) or are not currently present (e.g. mudpuppy) in the lake may be related to factors other than habitat suitability. As such, the successful implementation of the habitat modules may not change their status.

The site-specific monitoring program will be developed based on the final habitat restoration designs. This information will be provided in an Operations, Maintenance and Monitoring Plan to be submitted as part of the final designs.

5.5.3 Maintenance Requirements

The monitoring program will be designed to provide data necessary to identify and correct potential concerns within an adaptive maintenance program. For example, if the vegetative cover has not met the desired percent cover, bare areas may be reseeded or replanted. Additional measures to control invasive species (*e.g.*, *Phragmites*, Eurasian watermilfoil) or herbivory within the restored areas may also be warranted, if indicated by the monitoring data.

Maintenance actions to correct deficiencies identified during monitoring would be undertaken at the time the condition is observed or within the appropriate seasonal (*e.g.*, planting) window and may potentially include the following.

- Control of invasive species in restored areas by physical, mechanical or chemical methods. Any use of chemical control would require further evaluation for compliance with ARARs.
- Targeted plantings to increase percent cover and/or replace missing or dead plant material. This maintenance activity would not include complete replanting of an area unless the cause(s) for the initial failure of the plantings has been identified and corrected/controlled.
- Maintenance of structures included in the habitat restoration designs, consistent with design specifications.

The site-specific monitoring and maintenance program will be developed based on the final habitat restoration designs. This information will be provided in an Operations, Maintenance and Monitoring Plan to be submitted as part of the final designs.

5.5.4 Design Details for Habitat Restoration

This conceptual level document is intended to convey the approach for habitat restoration in the remedial areas within the lake and select shoreline areas adjacent to the lake. In accordance with standard designs procedures, additional details for each of the concepts presented in this plan (e.g. types and size of structure or material specifications) will be further developed and documented in subsequent design submittals. Additional details will be provided in those design submittals for items such as the following:

- thin layer cap details;
- habitat layer material specifications, performance and maintenance;
- design details for mitigation areas;
- microtopography, structure, other habitat features (*e.g.,* turtle nesting) within wetland complexes;
- placement and types of structure;

Onondaga Lake

- substrate composition, grain-size distribution, organic content, source;
- plants considered for seeding or planting;
- techniques for establishment of microtopography within habitat modules;
- tolerances for placement of habitat layer;
- success criteria;
- monitoring program; and
- maintenance requirements.

5.6 Summary of Habitat Restoration Design

Honeywell has placed habitat considerations at the forefront of the restoration designs for Onondaga Lake, and habitat restoration will continue to play a key role as the remedial activities are advanced. A sustainable habitat that allows for public access has been, and will continue to be, an integral part of the approach for restoring Onondaga Lake and returning this key resource to the people of central New York.

The Habitat Restoration Plan is the result of almost two years of effort by the TWG, which consisted of local and national experts from the Honeywell team and several state and federal agencies. During the preparation of this plan the Onondaga Nation and local interest groups provided several suggestions for specific habitat considerations for Onondaga Lake.

Many different considerations were involved in the design of the Habitat Restoration Plan. Critical among these considerations were historical and current habitat conditions in the lake; established goals, objectives, and priorities of the habitat restoration; numerous remedial design elements; location of adjacent tributary systems; and adjacent shoreline land uses and habitats.

Establishing existing and historical habitat conditions and the collection of information available for the lake was important in the development of this plan. Representative plant and animal species were selected from different groups of organisms and their habitat requirements were assessed to help direct the habitat restoration efforts. Habitat modules were established to represent habitat areas defined by the basic elements of water depth, substrate type, and wave energy. The application of these modules was used to define the restored habitat in each area specified for remediation.

The habitat designs described in this plan were developed using many different criteria, including the integration of habitat needs for representative species with the requirements associated with the dredging and capping design specified in the Onondaga Lake Bottom Record of Decision, the physical conditions of the site, and the habitat goals and objectives. The holistic approach for integrating multiple remedial considerations from the related lake and shoreline areas will result in improved conditions for a wide variety of species in these areas.

TABLE 5.1
SUMMARY OF PARAMETERS FOR ONONDAGA LAKE CAP DESIGN

Remediation Area	Water Depth (ft)	Minimum Mixing and Chemical Isolation Thickness (ft)	Total Erosion Protection/Habitat Layer Thickness (ft)	Habitat Grainsize	Minimum Cap Thickness (ft)	Assumed Maximum Cap Thickness with Over Placements (ft)	Calculated Average Settlement at 2 years (ft)
RA-A (Cap Model Areas A-1 and A-2)	0 - 3	1.25	2	medium sand	3.25	5.0	1.4
	3 - 7		1.5	fine gravel	2.75	4.25	1.3
	7 - 20		1	medium sand	2.25	2.75	1.1
	20 - 30	0.75	1		1.75	2.25	1.0
RA-B	0 - 3	1.5	2	fine gravel	3.5	5.7	1.9
	3 - 7		1.5		3.0	5.2	1.9
	7 - 10		1	coarse sand	2.5	4.0	1.8
	10 - 30		1	medium sand	2.5	3.5	1.6
RA-C	0 - 3	1.75	2	fine gravel	3.75	5.5	1.1
	3 - 7		1.5		3.25	5.0	1.2
	7 - 10		1		2.75	3.75	1.1
	10 - 30		1	medium sand	2.75	3.25	1.1
RA-D	0 - 3	1.5	2	medium sand	3.5	5.7	NA[5]
	3 - 7		1.5		3.0	5.2	NA[5]
	7 - 10		1		2.5	4.0	NA[5]
	10 - 30		1		2.5	3.5	NA[5]
RA-D Addendum	30+	1.5	1	medium sand	2.5	3.5	n/a
RA-E (Cap Model Areas E-1 and E-2)	0 - 3	1.25	2	coarse gravel	3.25	5.25	1.5
	3 - 7		1.5		2.75	4.75	1.7
	7 - 10		1		2.25	4.75	1.7
	10 - 20		1	fine gravel	2.25	3.25	2.0
	20 - 30	0.75	1	coarse sand	1.75	2.25	1.6

Notes:

1. See Capping and Dredge Area and Depth IDS (Parsons, 2009) for details and assumptions.
2. Both cap model areas in Remediation Area A and E have the same cap-design thickness.
3. Minimum combined erosion protection/habitat and additional habitat layer material. Average total habitat thickness will be greater due to estimated over placements allowed for operational considerations of cap placement.
4. 50% safety buffer is included in the chemical isolation thickness for RA-C. Cap modeling has shown that it can be included in the habitat layer for all other model areas.
5. Due to the complexities associated with the ILWD removal approach (average 2 meters plus hot spots), settlement calculations have not been estimated in Remediation Area D for this conceptual design.

TABLE 5.2

SUMMARY OF POTENTIAL LOCATIONS FOR REPRESENTATIVE SPECIES WITHIN REMEDIATION AREAS OF ONONDAGA LAKE

Remediation Area (1)(2)	REPRESENTATIVE SPECIES					
	Fish	Plants	Benthic Macroinvertebrates	Mammals	Reptiles / Amphibians	Birds
Remediation Area A (SMU 4)	• Brown trout • Lake sturgeon • Emerald shiner • Large and smallmouth bass • Walleye • Pumpkinseed • Northern pike • Golden shiner	• Submerged aquatic vegetation • Floating aquatic vegetation • Non-persistent emergent vegetation • Persistent emergent vegetation	• Scud • True Flies • Mayfly • Dragonfly/Damselfly • Caddisfly • Crayfish	• Otter • Mink • Muskrat • Beaver	• Snapping turtle • Painted turtle • Musk turtle • Northern water snake • Red spotted newt • Green frog • Leopard frog • Mudpuppy • Spotted salamander • Wood frog	• Common goldeneye • Mallard • Osprey • Bank swallow • Common tern • Belted Kingfisher • Great blue heron • Green heron • Spotted sandpiper • Semi-palmated sandpiper • Red-winged blackbird

NOTES:
TBD – To Be Determined
1) Representative species noted for each area indicates that habitat conditions will be suitable for these species following remedial activities. Every species may not populate all specified locations in the future.
2) Remediation Area F has not been included since it is less than one acre. Species would be similar to the deep water portion of Remediation Area A.

TABLE 5.2 (continued)
SUMMARY OF POTENTIAL LOCATIONS FOR REPRESENTATIVE SPECIES WITHIN REMEDIATION AREAS OF ONONDAGA LAKE

Remediation Area [(1)(2)]	REPRESENTATIVE SPECIES					
	Fish	Plants	Benthic Macroinvertebrates	Mammals	Reptiles / Amphibians	Birds
Remediation Area B (SMU 3)	• Brown trout • Lake sturgeon • Emerald shiner • Large and smallmouth bass • Adult walleye • Pumpkinseed • Northern pike • Golden shiner	• Submerged aquatic vegetation • Non-persistent emergent vegetation	• Scud • True Flies • Mayfly • Dragonfly/Damselfly • Caddisfly • Crayfish	• Otter • Mink • Muskrat • Beaver	• Snapping turtle • Painted turtle • Musk turtle • Northern water snake • Red-spotted newt • Green frog • Mudpuppy	• Common goldeneye • Mallard • Osprey • Bank swallow • Common tern • Belted Kingfisher • Great blue heron • Green heron • Sandpipers • Red-winged Blackbird

NOTES:
TBD – To Be Determined
1) Representative species noted for each area indicates that habitat conditions will be suitable for these species following remedial activities. Every species may not populate all specified locations in the future.
2) Remediation Area F has not been included since it is less than one acre. Species would be similar to the deep water portion of Remediation Area A.

TABLE 5.2 (continued)
SUMMARY OF POTENTIAL LOCATIONS FOR REPRESENTATIVE SPECIES WITHIN REMEDIATION AREAS OF ONONDAGA LAKE

Remediation Area [(1)(2)]	REPRESENTATIVE SPECIES					
	Fish	Plants	Benthic Macroinvertebrates	Mammals	Reptiles / Amphibians	Birds
Remediation Area C (SMU 2)	• Brown trout • Lake sturgeon • Emerald shiner • Large & small-mouth bass • Walleye • Pumpkinseed • Lake sturgeon • Northern pike • Golden shiner	• Submerged aquatic vegetation	• Scud • True Flies • Mayfly • Dragonfly/Damselfly • Caddisfly • Crayfish	• Otter • Mink • Muskrat • Beaver	• Snapping turtle • Northern water snake • Mudpuppy	• Common goldeneye • Mallard • Osprey • Common tern • Belted Kingfisher • Great blue heron • Green heron

NOTES:
TBD – To Be Determined
1) Representative species noted for each area indicates that habitat conditions will be suitable for these species following remedial activities. Every species may not populate all specified locations in the future.
2) Remediation Area F has not been included since it is less than one acre. Species would be similar to the deep water portion of Remediation Area A.

TABLE 5.2 (continued)
SUMMARY OF POTENTIAL LOCATIONS FOR REPRESENTATIVE SPECIES WITHIN REMEDIATION AREAS OF ONONDAGA LAKE

Remediation Area (1)(2)	REPRESENTATIVE SPECIES					
	Fish	Plants	Benthic Macroinvertebrates	Mammals	Reptiles / Amphibians	Birds
Remediation Area D (SMU 1)	• Brown trout • Lake sturgeon • Emerald shiner • Large and smallmouth bass • Pumpkinseed • Walleye • Northern pike • Golden shiner	• Submerged aquatic vegetation	• Scud • True Flies • Mayfly • Dragonfly/Damselfly • Caddisfly	• Otter • Mink • Muskrat • Beaver	• Snapping turtle • Northern water snake • Mudpuppy	• Common goldeneye • Osprey • Mallard • Common tern • Belted Kingfisher • Great blue heron • Green heron • Spotted sandpiper • Semi-palmated sandpiper

NOTES:
TBD – To Be Determined
1) Representative species noted for each area indicates that habitat conditions will be suitable for these species following remedial activities. Every species may not populate all specified locations in the future.
2) Remediation Area F has not been included since it is less than one acre. Species would be similar to the deep water portion of Remediation Area A.

TABLE 5.2 (continued)
SUMMARY OF POTENTIAL LOCATIONS FOR REPRESENTATIVE SPECIES WITHIN REMEDIATION AREAS OF ONONDAGA LAKE

Remediation Area (1)(2)	REPRESENTATIVE SPECIES					
	Fish	Plants	Benthic Macroinvertebrates	Mammals	Reptiles / Amphibians	Birds
Remediation Area E (SMU 6/7)	• Brown trout • Lake sturgeon • Emerald shiner • Large and smallmouth bass • Walleye • Pumpkinseed • Northern pike • Golden shiner	• Submerged aquatic vegetation	• Scud • True Flies • Mayfly • Dragonfly/Damselfly • Caddisfly • Crayfish	• Otter • Mink • Muskrat • Beaver • Indiana Bat	• Snapping turtle • Northern water snake • Mudpuppy	• Common goldeneye • Mallard • Osprey • Common tern • Belted Kingfisher • Great blue heron • Green heron • Spotted sandpiper • Semi-palmated sandpiper
SMU 8	• Brown trout • Lake sturgeon • Emerald shiner • Large and smallmouth bass • Walleye • Pumpkinseed	Not Applicable	• Scud • True Flies	• Not Applicable	• Not Applicable	• Common goldeneye • Mallard • Osprey

NOTES:
TBD – To Be Determined
1) Representative species noted for each area indicates that habitat conditions will be suitable for these species following remedial activities. Every species may not populate all specified locations in the future.
2) Remediation Area F has not been included since it is less than one acre. Species would be similar to the deep water portion of Remediation Area A.

TABLE 5.2 (continued)
SUMMARY OF POTENTIAL LOCATIONS FOR REPRESENTATIVE SPECIES WITHIN REMEDIATION AREAS OF ONONDAGA LAKE

Remediation Area (1)(2)	REPRESENTATIVE SPECIES					
	Fish	Plants	Benthic Macroinvertebrates	Mammals	Reptiles / Amphibians	Birds
Wetlands at Mouth of Ninemile Creek	• Northern Pike spawning • Young of year for various species	• Persistent emergent vegetation • Forested wetland and scrub-shrub wetland species	• Caddisfly • True Flies • Dragonfly/Damselfly • Crayfish	• Otter • Mink • Muskrat • Beaver • Indiana Bat	• Snapping turtle • Painted turtle • Musk turtle • Northern water snake • Red-spotted newt • Leopard frog • Green frog • Spotted salamander • Wood frog	• Mallard • Spotted sandpiper • Semi-palmated sandpiper • Red-winged blackbird • Great blue heron • Green heron • Common tern

NOTES:
TBD – To Be Determined
1) Representative species noted for each area indicates that habitat conditions will be suitable for these species following remedial activities. Every species may not populate all specified locations in the future.
2) Remediation Area F has not been included since it is less than one acre. Species would be similar to the deep water portion of Remediation Area A.

TABLE 5.2 (continued)
SUMMARY OF POTENTIAL LOCATIONS FOR REPRESENTATIVE SPECIES WITHIN REMEDIATION AREAS OF ONONDAGA LAKE

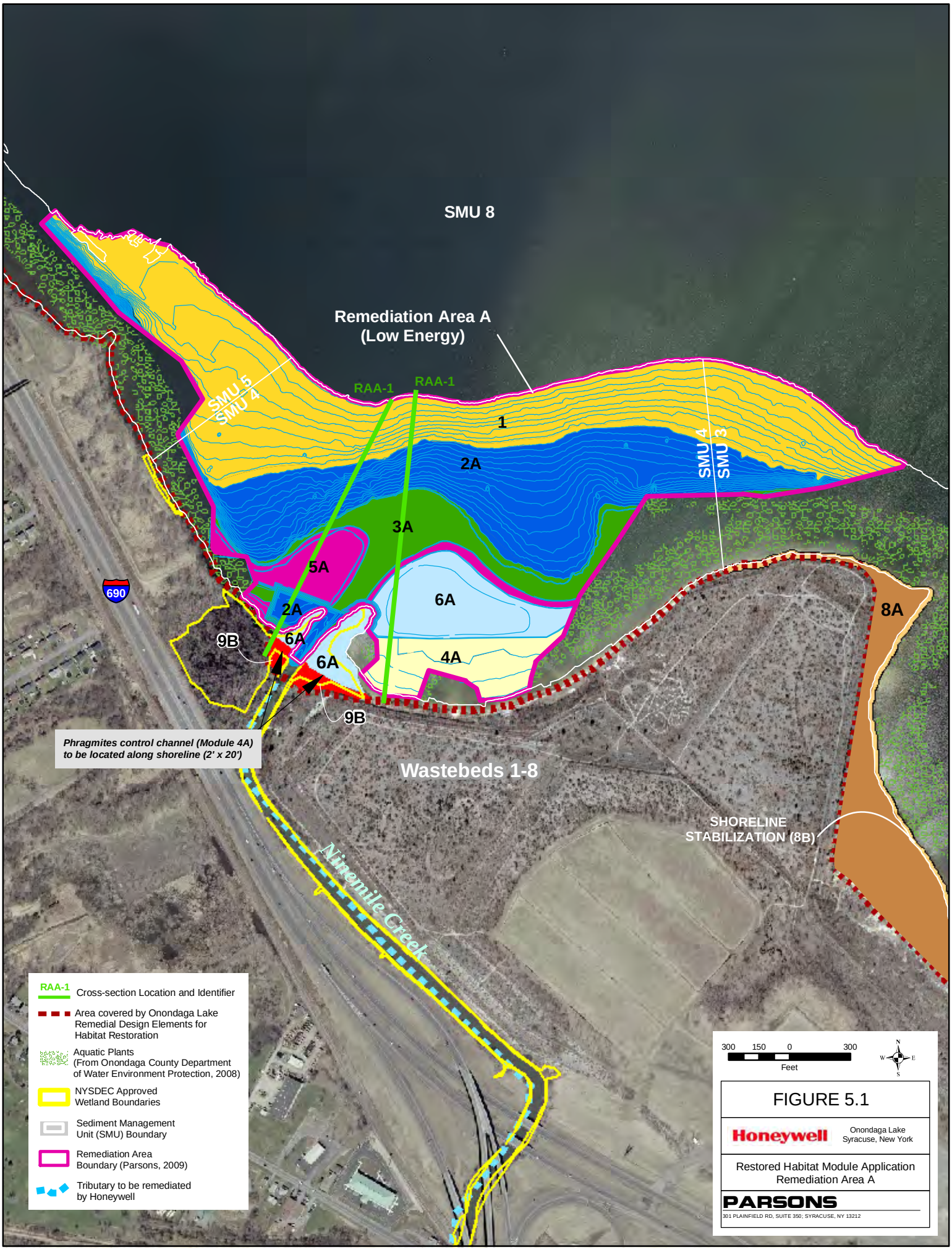
Remediation Area (1)(2)	REPRESENTATIVE SPECIES					
	Fish	Plants	Benthic Macroinvertebrates	Mammals	Reptiles / Amphibians	Birds
Low Lying Area of Wastebeds 1-8	• Northern Pike spawning • Young of Year for various species	• Persistent emergent vegetation • Scrub-shrub vegetation • Floating Aquatic vegetation • Non-persistent emergent vegetation • Open Fields	• True Flies • Mayfly • Dragonfly/Damselfly • Caddisfly • Crayfish	• Otter • Mink • Muskrat • Beaver • Indiana Bat	• Snapping turtle • Painted turtle • Musk turtle • Water snake • Red-spotted newt • Leopard frog • Green frog • Spotted salamander • Wood frog • Mudpuppy	• Osprey • Common Goldeneye • Belted Kingfisher • Bank Swallow • Mallard • Spotted sandpiper • Semi-palmated sandpiper • Red-winged blackbird • Great blue heron • Green heron • Common tern

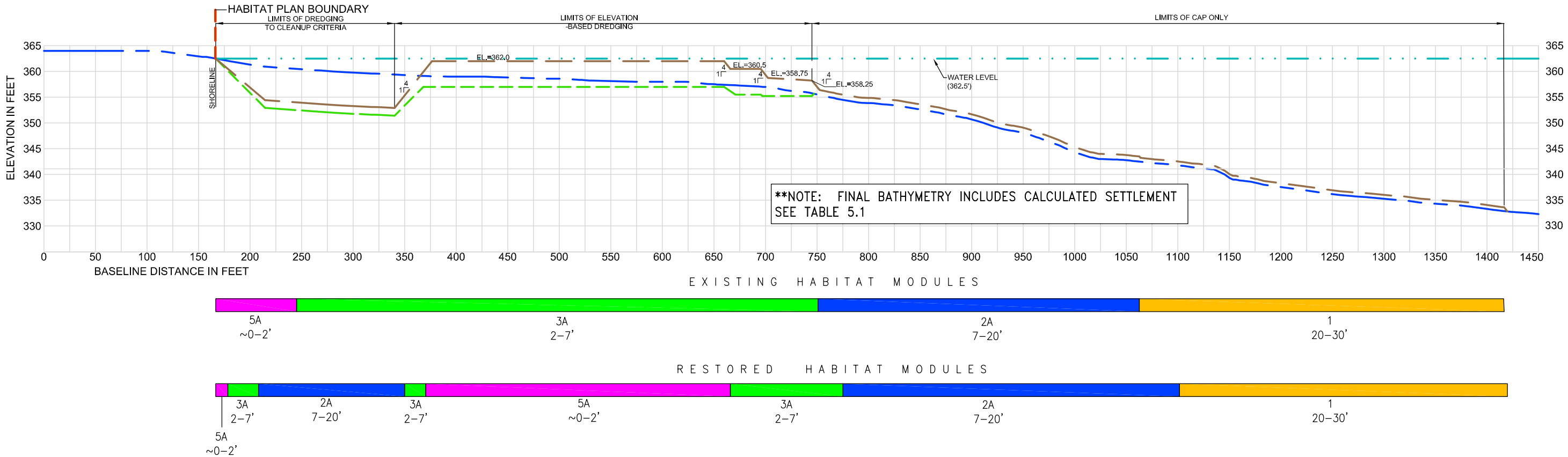
NOTES:
TBD – To Be Determined
1) Representative species noted for each area indicates that habitat conditions will be suitable for these species following remedial activities. Every species may not populate all specified locations in the future.
2) Remediation Area F has not been included since it is less than one acre. Species would be similar to the deep water portion of Remediation Area A.

TABLE 5.2 (continued)
SUMMARY OF POTENTIAL LOCATIONS FOR REPRESENTATIVE SPECIES WITHIN REMEDIATION AREAS OF ONONDAGA LAKE

Remediation Area (1)(2)	REPRESENTATIVE SPECIES					
	Fish	Plants	Benthic Macroinvertebrates	Mammals	Reptiles / Amphibians	Birds
Wastebed B / Harbor Brook Wetland Area	• Northern Pike spawning • Young of Year for various species	• Persistent emergent vegetation • Scrub-shrub vegetation • Forested wetland • Floating Aquatic vegetation • Non-persistent emergent vegetation	• True Flies • Mayfly • Dragonfly/Damselfly • Caddisfly • Crayfish	• Otter • Mink • Muskrat • Beaver • Indiana Bat	• Snapping turtle • Painted turtle • Musk turtle • Water snake • Red-spotted newt • Leopard frog • Green frog • Spotted salamander • Wood frog • Mudpuppy	• Osprey • Common Goldeneye • Belted Kingfisher • Bank Swallow • Mallard • Spotted sandpiper • Semi-palmated sandpiper • Red-winged blackbird • Great blue heron • Green heron • Common tern
Wetland SYW-12	TBD	TBD	TBD	TBD	TBD	TBD

NOTES:
TBD – To Be Determined
1) Representative species noted for each area indicates that habitat conditions will be suitable for these species following remedial activities. Every species may not populate all specified locations in the future.
2) Remediation Area F has not been included since it is less than one acre. Species would be similar to the deep water portion of Remediation Area A.


SMU 8
Remediation Area A
(Low Energy)
RAA-1
RAA-1
SMU 5
SMU 4
1
2A
SMU 4
SMU 3
3A
5A
6A
2A
6A
9B
6A
4A
9B
8A
690
Phragmites control channel (Module 4A)
to be located along shoreline (2' x 20')
Wastebeds 1-8
SHORELINE
STABILIZATION (8B)
Ninemile Creek
RAA-1 Cross-section Location and Identifier
Area covered by Onondaga Lake Remedial Design Elements for Habitat Restoration
Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)
NYSDEC Approved Wetland Boundaries
Sediment Management Unit (SMU) Boundary
Remediation Area Boundary (Parsons, 2009)
Tributary to be remediated by Honeywell
300 150 0 300
Feet
N
W
E
S
FIGURE 5.1
Honeywell
Onondaga Lake
Syracuse, New York
Restored Habitat Module Application
Remediation Area A
PARSONS
301 PLAINFIELD RD, SUITE 350; SYRACUSE, NY 13212



REMEDIATION AREA A – SECTION RAA-1

Vertical: 1"=20'-0"
Horizontal: 1"-100'-0"

**NOTE
1. DETAILED ASSUMPTIONS FOR CAP THICKNESS AND SETTLEMENT ARE CONSISTENT WITH THOSE SPECIFIED IN THE CAPPING AND DREDGE AREA AND DEPTH IDS
2. CROSS SECTION IS CONSISTENT WITH SECTION 2/D-2 FROM CAPPING AND DREDGE AREA AND DEPTH IDS

LEGEND:
- WATERLINE (362.5 NAVD 88) (GROWING SEASON)
- EXISTING GRADE
- DREDGE GRADE
- CAP GRADE

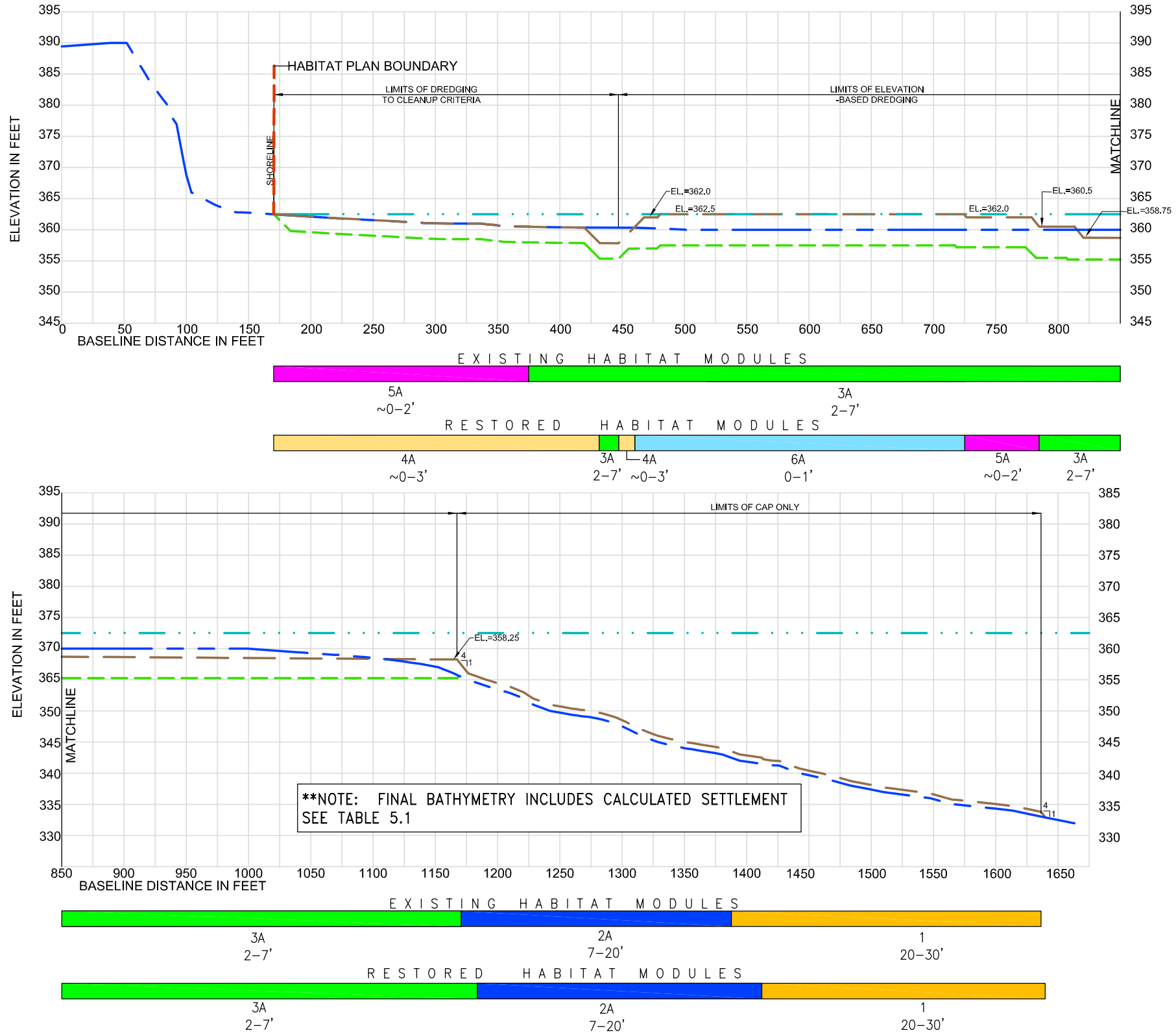
FIGURE 5.2

Honeywell

CONCEPTUAL CROSS SECTION
REMEDIATION AREA A (SMU 4)
SECTION RAA-1

PARSONS
310 PLAINFIELD ROAD ▪ SUITE 350 ▪ SYRACUSE, NY 13212 ▪ 315/451-9560
OFFICES IN PRINCIPAL CITIES

FILE NAME: P:\HONEYWELL -SYR\444284 – HABITAT AND CPP II\10 TECHNICAL CATEGORIES\10.1 CAD\FROM ANCHOR QEA\HABITAT 11-09 XSEC5.DWG
PLOT DATE: 12/14/2009 9:39 AM PLOTTED BY: NEUMANN, JEREMY



LEGEND:

- WATERLINE (362.5 NAVD 88) (GROWING SEASON)
- EXISTING GRADE
- DREDGE GRADE
- CAP GRADE

**NOTE

1. DETAILED ASSUMPTIONS FOR CAP THICKNESS AND SETTLEMENT ARE CONSISTENT WITH THOSE SPECIFIED IN THE CAPPING AND DREDGE AREA AND DEPTH IDS
2. CROSS SECTION IS CONSISTENT WITH SECTION 4/D-12 FROM CAPPING AND DREDGE AREA AND DEPTH IDS

REMEDIATION AREA A – SECTION RAA-2

Vertical: 1"=20'-0"
Horizontal: 1"-100'-0"

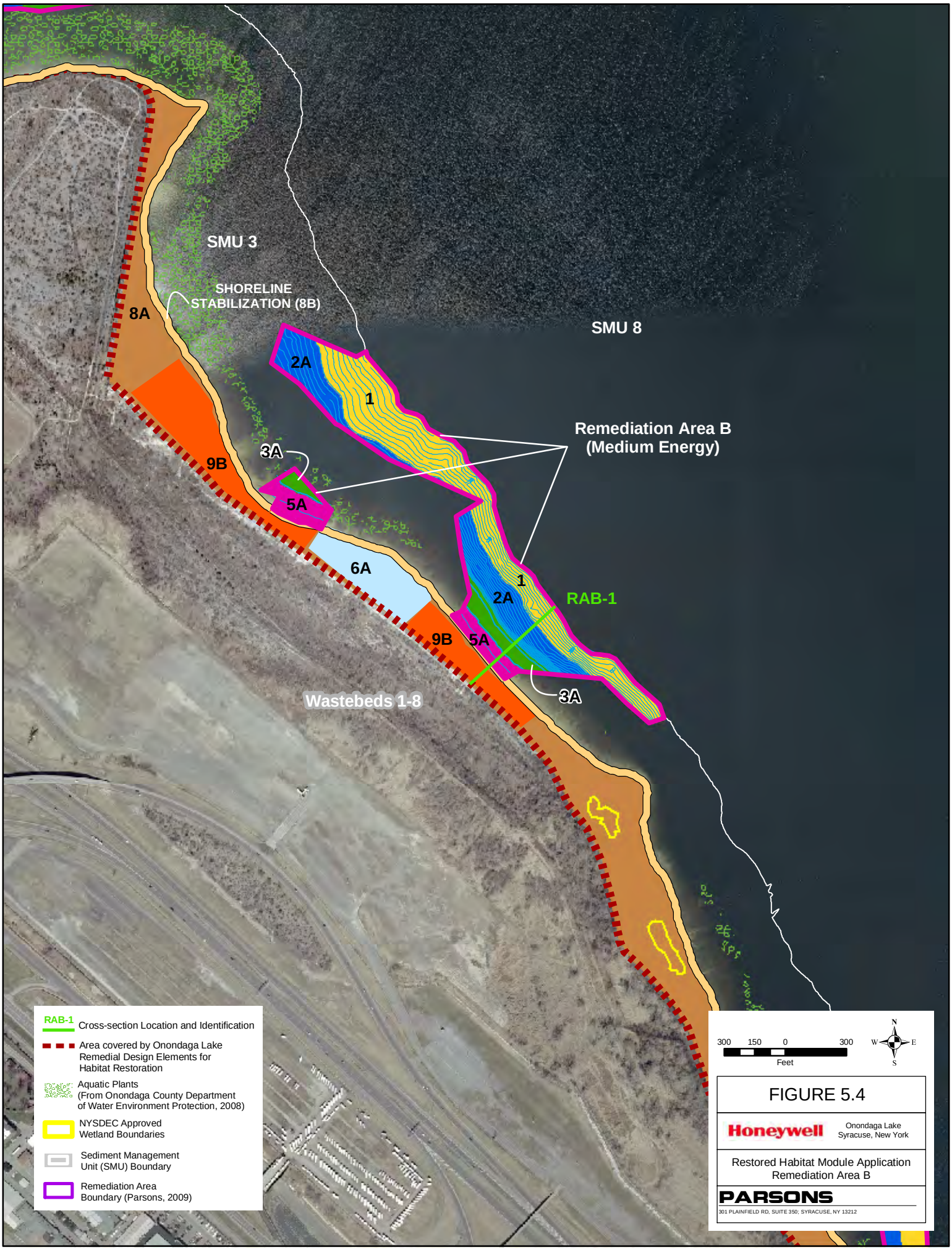
FIGURE 5.3

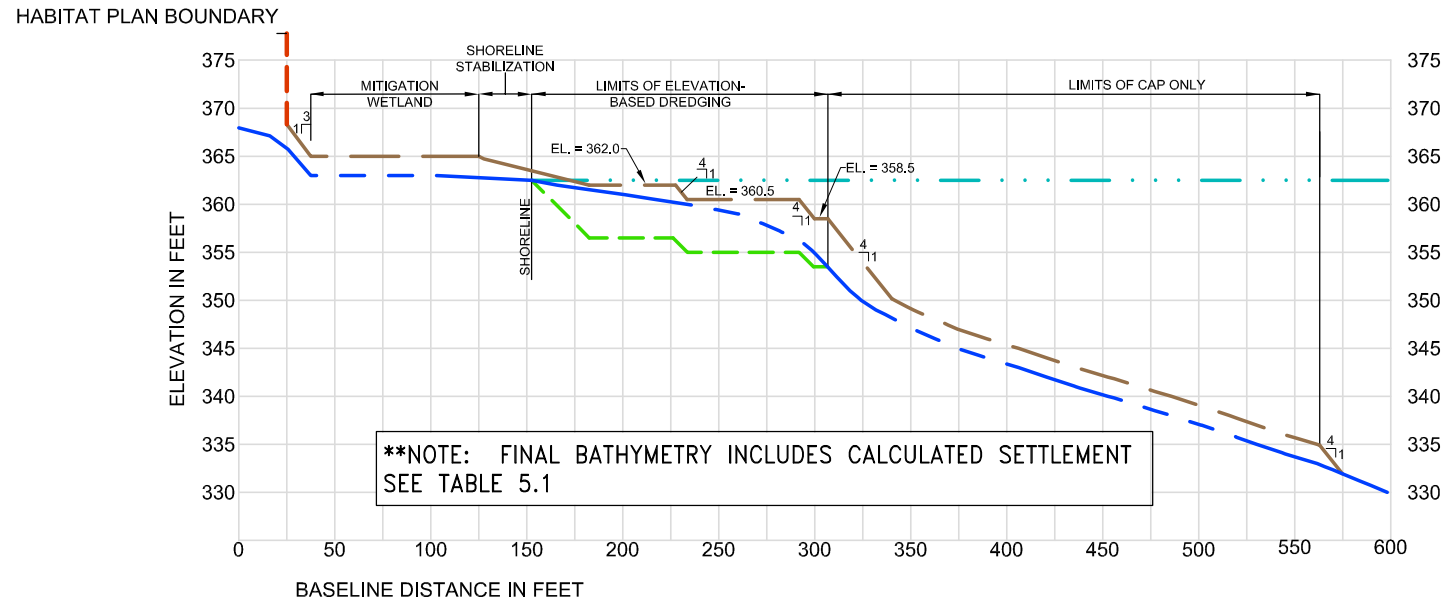
Honeywell

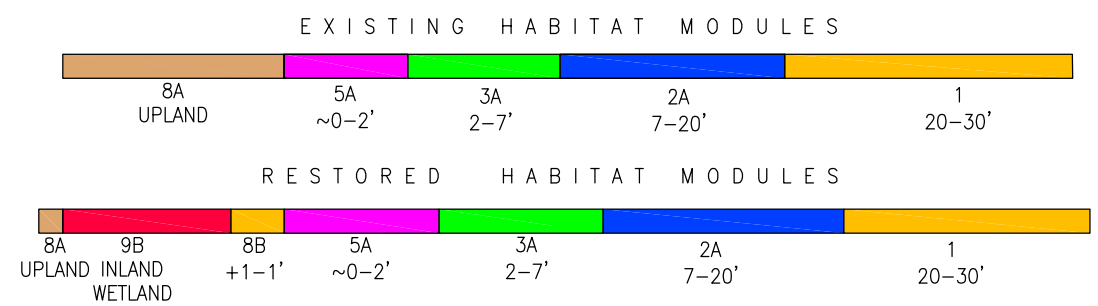
CONCEPTUAL CROSS SECTION
REMEDIATION AREA A (SMU 4)
SECTION RAA-2

PARSONS
310 PLAINFIELD ROAD ▪ SUITE 350 ▪ SYRACUSE, NY 13212 ▪ 315/451-9560
OFFICES IN PRINCIPAL CITIES

FILE NAME: P:\HONEYWELL -SYR\444284 – HABITAT AND CPP II\10 TECHNICAL CATEGORIES\10.1 CAD\FROM ANCHOR QEA\HABITAT 11-09 XSEC5.DWG
PLOT DATE: 12/14/2009 9:36 AM PLOTTED BY: NEUMANN, JEREMY


SMU 3
SHORELINE STABILIZATION (8B)
8A
SMU 8
2A
1
Remediation Area B
(Medium Energy)
3A
9B
5A
6A
1
2A
RAB-1
9B
5A
3A
Wastebeds 1-8
RAB-1 Cross-section Location and Identification
Area covered by Onondaga Lake Remedial Design Elements for Habitat Restoration
Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)
NYSDEC Approved Wetland Boundaries
Sediment Management Unit (SMU) Boundary
Remediation Area Boundary (Parsons, 2009)
300 150 0 300
Feet
N
W
E
S
FIGURE 5.4
Honeywell
Onondaga Lake
Syracuse, New York
Restored Habitat Module Application
Remediation Area B
PARSONS
301 PLAINFIELD RD, SUITE 350, SYRACUSE, NY 13212





REMEDIATION AREA B – SECTION RAB–1

Vertical: 1"=20'–0"
Horizontal: 1"–100'–0"

**NOTE
1. DETAILED ASSUMPTIONS FOR CAP THICKNESS AND SETTLEMENT ARE CONSISTENT WITH THOSE SPECIFIED IN THE CAPPING AND DREDGE AREA AND DEPTH IDS
2. CROSS SECTION IS CONSISTENT WITH SECTION 9/D–14 FROM CAPPING AND DREDGE AREA AND DEPTH IDS

LEGEND:
- WATERLINE (362.5 NAVD 88) (GROWING SEASON)
- EXISTING GRADE
- DREDGE GRADE
- CAP GRADE

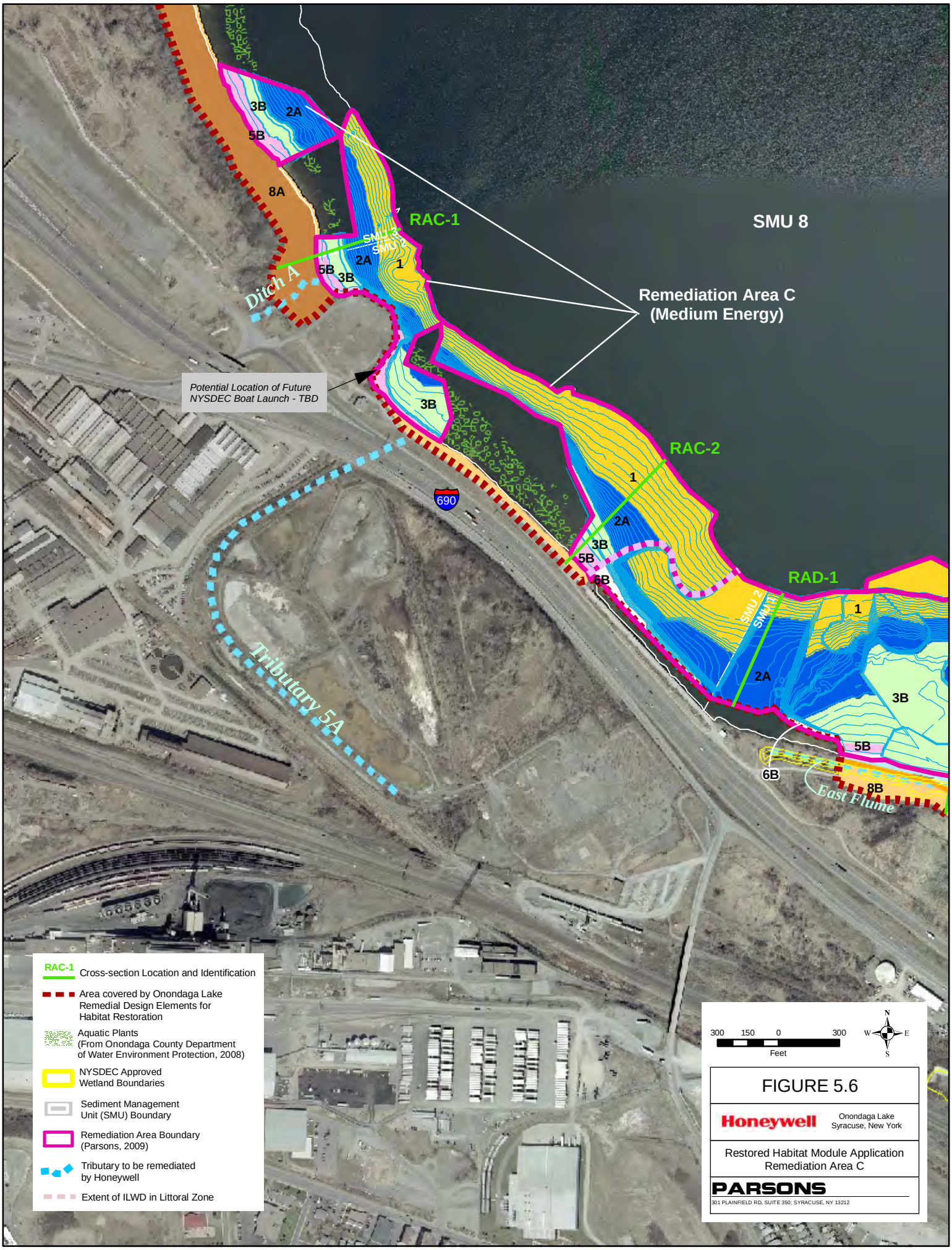
FIGURE 5.5

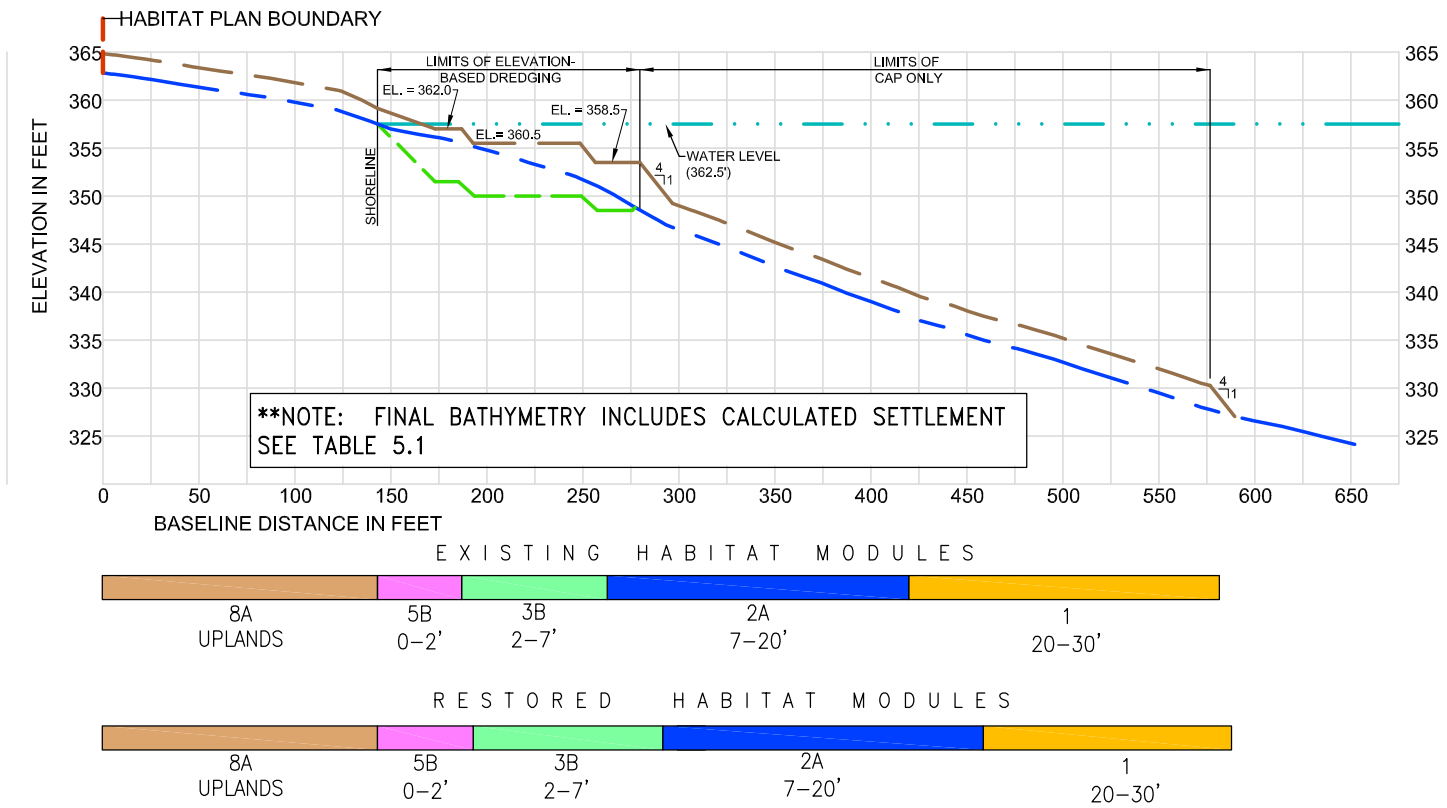
Honeywell

CONCEPTUAL CROSS SECTION
REMEDIATION AREA B (SMU 3)
SECTION RAB–1

PARSONS
310 PLAINFIELD ROAD • SUITE 350 • SYRACUSE, NY 13212 • 315/451-9560
OFFICES IN PRINCIPAL CITIES

FILE NAME: P:\HONEYWELL –SYR\444284 – HABITAT AND CPP II\10 TECHNICAL CATEGORIES\10.1 CAD\FROM ANCHOR QEA\HABITAT 11–09 XSEC5.DWG
PLOT DATE: 12/14/2009 9:34 AM PLOTTED BY: NEUMANN, JEREMY


SMU 8
Remediation Area C
(Medium Energy)
RAC-1
RAC-2
RAD-1
SMU 2
SMU 1
Ditch A
Tributary 5A
East Flume
Potential Location of Future
NYSDEC Boat Launch - TBD
690
3B
2A
5B
8A
1
6B
8B
RAC-1 Cross-section Location and Identification
Area covered by Onondaga Lake Remedial Design Elements for Habitat Restoration
Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)
NYSDEC Approved Wetland Boundaries
Sediment Management Unit (SMU) Boundary
Remediation Area Boundary (Parsons, 2009)
Tributary to be remediated by Honeywell
Extent of ILWD in Littoral Zone
300 150 0 300
Feet
N
W
E
S
FIGURE 5.6
Honeywell
Onondaga Lake
Syracuse, New York
Restored Habitat Module Application
Remediation Area C
PARSONS
301 PLAINFIELD RD, SUITE 350; SYRACUSE, NY 13212



REMEDIATION AREA C – SECTION RAC–1

Vertical: 1"=20'–0"
Horizontal: 1"–100'–0"

**NOTE
1. DETAILED ASSUMPTIONS FOR CAP THICKNESS AND SETTLEMENT ARE CONSISTENT WITH THOSE SPECIFIED IN THE CAPPING AND DREDGE AREA AND DEPTH IDS
2. CROSS SECTION IS CONSISTENT WITH SECTION 11/D–15 FROM CAPPING AND DREDGE AREA AND DEPTH IDS

LEGEND:

- WATERLINE (362.5 NAVD 88) (GROWING SEASON)
- EXISTING GRADE
- DREDGE GRADE
- CAP GRADE

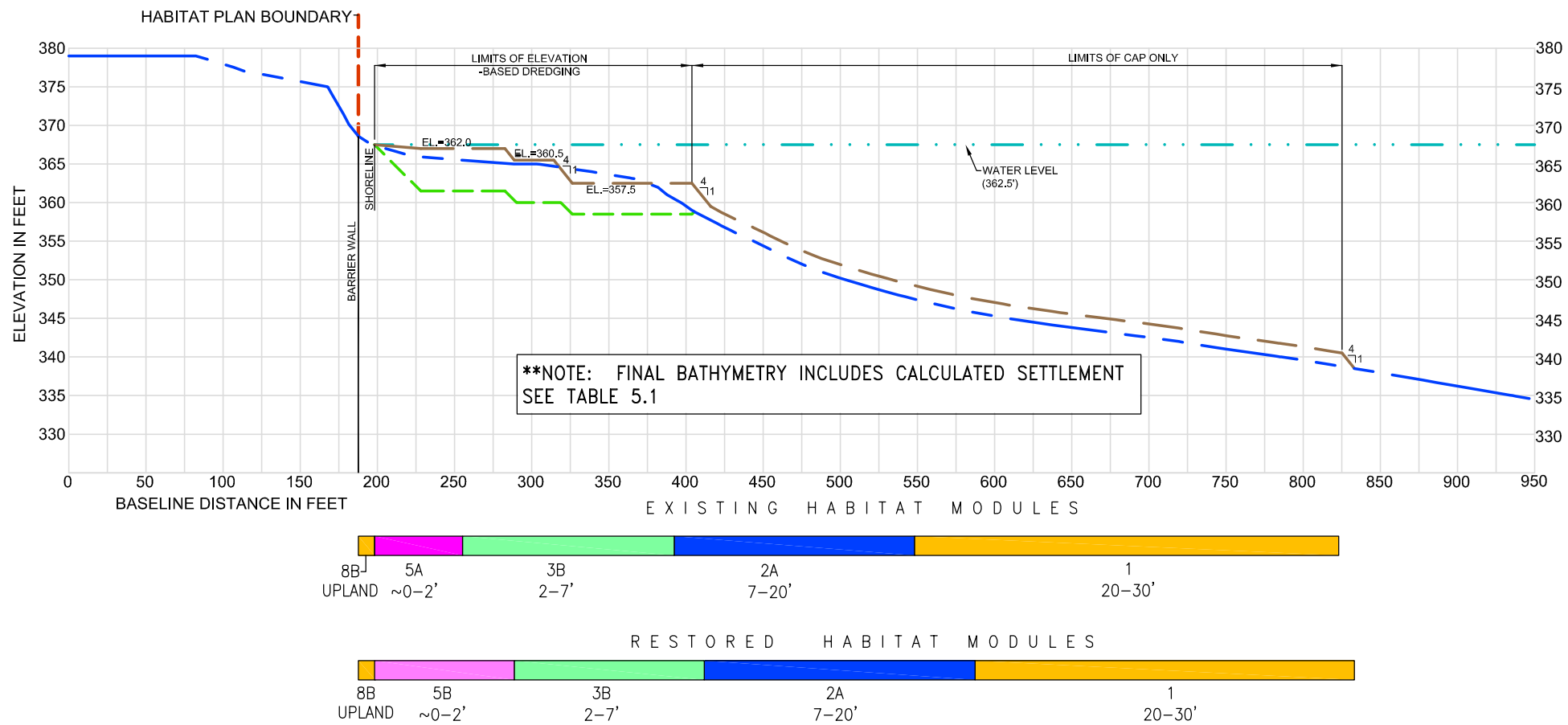
FIGURE 5.7

Honeywell

CONCEPTUAL CROSS SECTION
REMEDIATION AREA C (SMU 2)
SECTION RAC–1

PARSONS
310 PLAINFIELD ROAD • SUITE 350 • SYRACUSE, NY 13212 • 315/451-9560
OFFICES IN PRINCIPAL CITIES

FILE NAME: P:\HONEYWELL –SYR\444284 – HABITAT AND CPP II\10 TECHNICAL CATEGORIES\10.1 CAD\FROM ANCHOR QEA\HABITAT 11–09 XSEC5.DWG
PLOT DATE: 12/14/2009 9:31 AM PLOTTED BY: NEUMANN, JEREMY



REMEDIATION AREA C – SECTION RAC-2

Vertical: 1"=20'-0"
Horizontal: 1"-100'-0"

**NOTE
1. DETAILED ASSUMPTIONS FOR CAP THICKNESS AND SETTLEMENT ARE CONSISTENT WITH THOSE SPECIFIED IN THE CAPPING AND DREDGE AREA AND DEPTH IDS
2. CROSS SECTION IS CONSISTENT WITH SECTION 14/D-16 FROM CAPPING AND DREDGE AREA AND DEPTH IDS

LEGEND:
- WATERLINE (362.5 NAVD 88) (GROWING SEASON)
- EXISTING GRADE
- DREDGE GRADE
- CAP GRADE

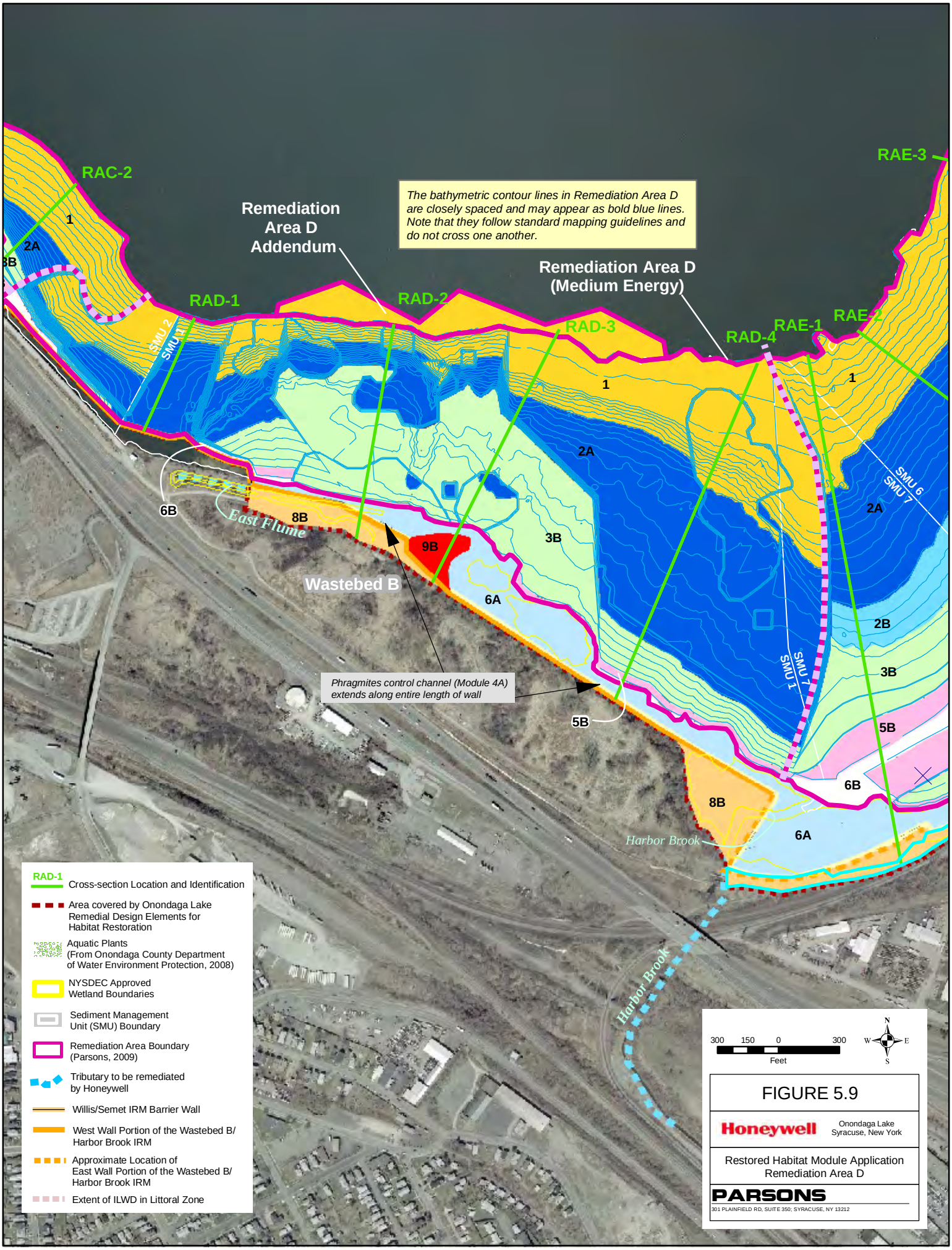
FIGURE 5.8

Honeywell

CONCEPTUAL CROSS SECTION
REMEDIATION AREA C (SMU 2)
SECTION RAC-2

PARSONS
310 PLAINFIELD ROAD ▪ SUITE 350 ▪ SYRACUSE, NY 13212 ▪ 315/451-9560
OFFICES IN PRINCIPAL CITIES

FILE NAME: P:\HONEYWELL -SYR\444284 - HABITAT AND CPP II\10 TECHNICAL CATEGORIES\10.1 CAD\FROM ANCHOR QEA\HABITAT 11-09 XSEC5.DWG
PLOT DATE: 12/14/2009 9:29 AM PLOTTED BY: NEUMANN, JEREMY


RAC-2
RAE-3
Remediation Area D Addendum
The bathymetric contour lines in Remediation Area D are closely spaced and may appear as bold blue lines. Note that they follow standard mapping guidelines and do not cross one another.
Remediation Area D (Medium Energy)
RAD-1
RAD-2
RAD-3
RAD-4
RAE-1
RAE-2
SMU 2
SMU 1
SMU 6
SMU 7
East Flume
Wastebed B
Phragmites control channel (Module 4A) extends along entire length of wall
Harbor Brook
1
2A
2B
3B
5B
6A
6B
8B
9B
RAD-1 Cross-section Location and Identification
Area covered by Onondaga Lake Remedial Design Elements for Habitat Restoration
Aquatic Plants (From Onondaga County Department of Water Environment Protection, 2008)
NYSDEC Approved Wetland Boundaries
Sediment Management Unit (SMU) Boundary
Remediation Area Boundary (Parsons, 2009)
Tributary to be remediated by Honeywell
Willis/Semet IRM Barrier Wall
West Wall Portion of the Wastebed B/ Harbor Brook IRM
Approximate Location of East Wall Portion of the Wastebed B/ Harbor Brook IRM
Extent of ILWD in Littoral Zone
300 150 0 300
Feet
N
W
E
S
FIGURE 5.9
Honeywell
Onondaga Lake
Syracuse, New York
Restored Habitat Module Application
Remediation Area D
PARSONS
301 PLAINFIELD RD, SUITE 350; SYRACUSE, NY 13212