LONG ISLAND SOUND STUDY
A Partnership to Restore and Protect the Sound

# LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE

## TECHNICAL SUPPORT FOR COASTAL HABITAT RESTORATION

## Freshwater Wetlands

February 2003

# *LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE*

## *SECTION 2: FRESHWATER WETLANDS*

# *Technical Support for Coastal Habitat Restoration*

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# SECTION 2: FRESHWATER WETLANDS

## DESCRIPTION

The term "freshwater wetlands" is used collectively to describe the diverse range of non-saline ponds, bogs, fens, swamps, and marshes found in the world. The U.S. Fish and Wildlife Service wetland classification system created by Cowardin ***et al.*** (1979) categorizes freshwater wetlands in the United States as palustrine, lacustrine, or riverine systems. The classification system also addresses deep water habitats where the substrate is predominantly non-soil and flooding is permanent, but those types of wetlands are generally not included in the Long Island Sound Study Habitat Restoration Initiative.

Wetlands display a very distinct set of soil characteristics that make it possible to identify even degraded wetlands by the underlying soil profile. These are known as hydric soils. The U.S. Department of Agriculture's Natural Resources Conservation Service, formerly the Soil Conservation Service, has defined hydric soils as saturated, ponded, or flooded for a sufficient time during the growing season to develop anaerobic conditions in the upper part of the soil (Metzler and Tiner, 1992).

Wetland plant species have adapted to grow in these stressful conditions, whereas most upland plants cannot. Non-submersed wetland plants are able to move oxygen from the air above the hydric soil to the root system embedded in the hydric soils. Those wetland plant species that are found exclusively in saturated soil conditions are known as obligate wetland hydrophyte species. Plants that usually grow in saturated soil conditions, but may occasionally be found outside wetlands, are known as facultative wetland plants. It is predominantly these wetland-dependant plant species, along with soil profiles, that are used to identify and delineate wetlands for regulatory purposes at the state and federal level.

It is important to note that the plant communities in wetlands are highly variable even within similar climatic regions. The descriptions of plant communities that appear here are generalized to the Long Island Sound Study Habitat Restoration Initiative project area around Long Island Sound. Typical species associations are emphasized. The reader should consult the inland wetland programs or Natural Heritage Programs in each state for more specific community descriptions in a given location.

Palustrine wetland systems are defined by Cowardin ***et al.*** (1979) as non-tidal wetlands dominated by trees, shrubs, persistent emergents[1], emergent mosses or lichens; or they may be nonvegetated, shallow water areas (less than six feet deep) with no wave formed or exposed bedrock shoreline features. In order to be considered palustrine, these non-vegetated areas must be less than 20 acres in size.

Riverine communities are defined by Cowardin ***et al.*** (1979) as "all wetlands and deep water habitats contained within a channel", except those that are dominated by persistent emergent vegetation, trees or shrubs (palustrine), or have more than 0.5 ppt ocean derived salinity (estuarine, marine). Community types are classified by the rate of water flow which in turn dictates the substrate composition and faunal and vegetation types present. This system also includes tidally influenced

[1] Persistent emergent plants are those that leave all or a visible portion of their foliage above the saturation zone or water surface during the dormant season. Conversely, non-persistent emergents are those plants that leave no portion of their foliage visible during the dormant season.

freshwater non-persistent emergent riverbank vegetation like wild rice. More information on tidally influenced freshwater wetlands can be found in ***Section 1: Tidal Wetlands***.

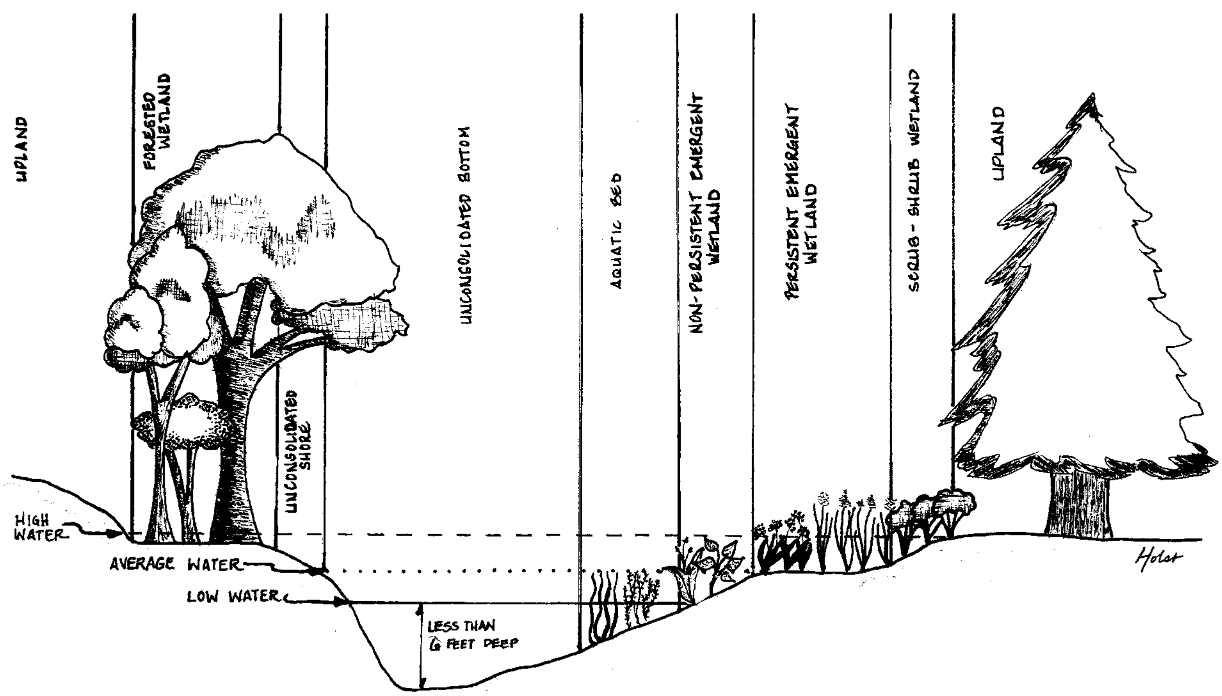
Lacustrine wetlands are wetlands and deep water habitats situated in a topographical depression or dammed river channel; lacking trees, shrubs, persistent emergent vegetation, emergent mosses or lichens with greater than thirty percent areal coverage; and with a total area larger than 20 acres. Certain wetlands smaller than 20 acres may be classified as lacustrine if there are active wave-formed or bedrock shoreline features making up all or part of the boundary, or if the deepest part of the basin exceeds 6.6 feet at low water (Cowardin ***et al.***, 1979). While lacustrine wetlands do occur within the project boundary in Westchester County and in Connecticut, for the purposes of this initiative, restoration will focus on the shorelines of these bodies of water where the classification shifts to palustrine.

## PALUSTRINE WETLANDS

Palustrine wetland systems are divided into several classes; rock bottom, unconsolidated bottom, aquatic bed, unconsolidated shore, moss-lichen wetland, emergent wetland, scrub-shrub wetland, and forested wetland (see ***Figure 2-1***). There are also subclasses and dominance types used in the classification scheme. With so many defining features, palustrine wetlands are highly variable. The reader should consult the referenced paper by Cowardin ***et al.*** (1979) for the full range of classifications used by the U.S. Fish and Wildlife Service. The community descriptions in this chapter are arranged by plant dominance type.

Palustrine forested wetlands within the project boundary include the coastal plain Atlantic white cedar swamps and red maple-hardwood swamps found in both New York and Connecticut. These swamp areas are dominated by either Atlantic white cedar (***Chamaecyparis thyoides***) or red maple (***Acer rubrum***) which form over 50 percent of the canopy. Both of these communities may have highly variable associations of other plant species. The specific mix of associates is dependant on the soil type, water regime, and historic land use (Metzler and Tiner, 1992).

***Figure 2-1: Typical Cross-Section of Palustrine Marsh Showing Zonation***
Adapted from Cowardin ***et al.***, 1979.



### Atlantic White Cedar Swamps

Atlantic white cedar swamps are considered an extremely rare community by the New York Natural Heritage Program, and are vulnerable to extirpation in New York. Of the statewide occurrences, only two are on mainland New York. The rest are found on Long Island, particularly in the southeastern portion. Atlantic white cedar swamps in Connecticut occur primarily east of the Connecticut River. The soils in these forested wetlands are semi-permanently or seasonally flooded in lowland areas, or saturated.

The Atlantic white cedar may form dense monospecific stands that dominate the tree, shrub, and herb layers of the community (Metzler and Barrett, 1996). If the tree layer is mixed with other species, greater diversity is found in the shrub and herb layer. In some parts of the project area red maple may occur as a co-dominant species in the tree layer. Less common associates in the tree layer include: white pine (***Pinus strobus***), yellow birch (***Betula alleghaniensis***), and eastern hemlock (***Tsuga canadensis***), although a mixed canopy association is reported in some Connecticut occurrences. The shrub layer may include sweet pepperbush (***Clethra alnifolia***), inkberry (***Ilex glabra***), northern bayberry (***Myrica pensylvanica***), and swamp-azalea (***Rhododendron viscosum***). In Connecticut the shrub layer is often dominated by highbush blueberry (***Vaccinium corymbosum***). Herb species may occur in sunny openings; these include cinnamon fern (***Osmundia cinnamomea***), marsh fern (***Thelypteris palustris***), and sundew (***Drosera intermedia***). The ground layer includes several species of ***Sphagnum*** mosses. The Massachusetts fern (***Thelypteris simulata***) and two species of sedges (***Carex atlantica, C. collinsii***) are herbs usually associated with this community throughout New England. While Massachusetts fern is found in Atlantic white cedar swamps within the project area, neither of the sedge species have been reported in New York recently (Metzler and Tiner, 1992; Reschke, 1990; Rozsa, pers. comm.).

### Red Maple-Hardwood Swamps

Red maple-hardwood swamps are the most prevalent of the deciduous forested wetlands in the project area. These wetlands are found in lowland areas, depressions, and on spring-fed slopes. The soils are usually organic silt loam and mucky peat (Metzler and Tiner, 1992). Tree canopy cover is 50 percent or less and dominated by red maple, but there may be one of several species occurring as a codominant. Black ash (***Fraxinus nigra***) and black tupelo (***Nyssa silvatica***) are the most common in the New York portion of the project area. American elm (***Ulmus americana***), swamp white oak (***Quercus bicolor***), butternut (***Juglans cinerea***), and bitternut hickory (***Carya cordiformis***) may also occur in these swamps, but are uncommon to rare within the project area. Characteristic animals associated with red maple swamps are marbled salamanders (***Ambystoma opacum***), red-bellied woodpeckers (***Melanerpes carolinus***), and black-crowned night heron (***Nycticorax nycticorax***). A listing of bird species that commonly nest in forested wetlands is shown in ***Table 2-1***.

***TABLE 2-1. Common Forested Wetland Nesting Bird Species***

| *Common Name* | *Scientific Name* |
|---|---|
| Wood duck | ***Aix sponsa*** |
| Acadian flycatcher | ***Empidonax virescens*** |
| Barred owl | ***Strix varia*** |
| Northern saw-whet owl | ***Aegolius acadicus**** |
| Northern waterthrush | ***Seiurus noveboracensis*** |
| Louisiana waterthrush | ***Seiurus motacilla*** |

**** Species less common in New York***

***From Metzler and Tiner, 1992***

## Flood Plain Forest

An additional forested wetland type that occurs within the project boundary in both states is the flood plain forest community (**Figure 2-2**). These are hardwood forests occurring on mineral soils within the flood plain of rivers or on the river deltas. These areas are flooded in the spring and covered by standing water that usually disappears by summer. Sometimes they will flood again in late summer and early fall due to heavy precipitation associated with tropical storms. The soils are classified as alluvial deposits—soils deposited when river flood waters recede.

Typical dominant trees in this wetland type are silver maple (***Acer saccharinum***), red maple, and sycamore (***Platanus occidentalis***). Cottonwoods (***Populus deltoides***) are found on levees and riverbanks along the perimeters of the flood plain. In Connecticut, another species association has been identified by Metzler (unpub. data) in which the common dominant species are pin oak (***Quercus palustris***) and green ash (***Fraxinus pennsylvanica***). Additional dominant canopy species may include swamp white oak and tupelo (Rozsa, pers. comm.). The shrub layer of flood plain forests may include spicebush (***Lindera benzoin***) and dogwoods (***Cornus spp.***), and a ground layer comprised of Virginia creeper (***Parthenocissus cinquefolia***), jewelweed (***Impatiens capensis***), sensitive fern (***Onoclea sensibilis***), and common poison ivy (***Toxicodendron radicans)***. See **Figure 2-2** for a photograph of forested wetland community.

***Figure 2-2. Skunk Cabbage and Marsh Marigold***

***Skunk cabbage and marsh marigold are shown growing within a stand of red maples along the Nissequogue River floodplain.***

## Scrub-Shrub Wetlands

Palustrine deciduous scrub-shrub wetlands or shrub thickets are also diverse within the project area in both states. The substrate is usually mineral soil or muck with a regular seasonal flooding regime or saturated conditions. These are wetlands dominated by shrubs rather than trees, although stunted trees may be present. One of several shrub species may be dominant: highbush blueberry, buttonbush (***Cephalanthus occidentalis***), swamp azalea (***Rhododendron viscosum***), or black willow (***Salix nigra***). Species like silky willow (***S. sericea***), dogwoods, meadow-sweet (***Spirea latifolia***), swamp rose (***Rosa palustris***), and mountain laurel (***Kalmia latifolia***) may occur in varying densities. Typical animals associated with these wetlands are the green frog (***Rana clamitans***), masked shrew (***Sorex cinerius***), and swamp sparrow (***Melospiza georgiana***).

When the hydrologic regime is extremely wet, the tree canopy may be reduced allowing willows (***Salix spp.***) to dominate the shrub layer. Moderate hydrological conditions favor low shrub layers of alders (***Alnus spp.***) and dogwoods. Other shrub species typically include spicebush, winterberry (***Ilex verticillata***), and highbush blueberry, among others. The herb layer may be dominated by several species of ferns like cinnamon fern, royal fern (***Osmundia regalis***), sensitive fern, crested wood-fern (***Dryopteris cristata***), and toothed wood-fern (***D. carthusiana***). Other herbaceous species characteristically present include skunk cabbage (***Symplocarpus foetidus***), sedges (***Carex spp.***), jewelweed, and skullcaps (***Scutellaria spp.***).

Black willow and buttonbush/silky willow communities are associated with areas of moving water. Black willow communities are found along riverbanks between the herbaceous bank vegetation and the low flood plain. There may be diverse annual vegetation associates in the ground layer, but usually fall panicum (***Panicum dichotomiflorum***), barnyard grass (***Echinochloa crusgalli***), beggar's ticks (***Bidens spp.***), and smartweeds (***Polygonum spp.***) can be found from year to year. A similar community dominated by buttonbush and silky willow are found on gentle slopes and fed by ground water. The hydrologic regime is very wet and the water table seldom drops below the soil surface. The herb layer usually includes ditch stonecrop (***Penthorum sedoides***), marsh fern, marsh purselane (***Ludwigia palustris***), and tussock sedge (***Carex stricta***).

Standing-water deciduous shrub thickets are dominated by either highbush blueberry or buttonbush. Swamp azalea is a common associate in both dominance types. The hydrologic regime is extremely wet with standing water above the substrate in spring and dropping slightly below the substrate by late summer. The soils are highly organic silt loams or muck. More acidic and undrained conditions such as perched water tables will favor highbush blueberry and swamp azalea. Herbaceous species and mosses are more sparse, generally appearing when the water table is lower.

Evergreen shrub thickets within the project area are dominated by leatherleaf (***Chamaedaphne calyculata***), with black spruce (***Picea mariana***) or sedge (***Carex utriculata***) as an associate. Black spruce will be the associate in glacial kettle holes and on the margins of oligotrophic ponds. Trees are rare, but white pine, swamp azalea, sheep laurel (***Kalmia angustifolia***), and highbush blueberry occur in the shrub layer. The herb layer usually contains small cranberry (***Vaccinium oxycoccos***) and pitcher plant (***Sarracenia purpurea***). Mosses may also be present.

### Bogs

Sedge is found with leatherleaf in nutrient-poor minerotrophic basins and wet depressions called leatherleaf bogs. The herb layer covers up to 80 percent of the total wetland area. A few red maples and highbush blueberries may form a scattered shrub layer, if present. Herbs include three-way sedge (***Dulichium arundinaceum***), white beakrush (***Rhynchospora alba***), and tawny cotton-grass (***Eriophorum virginicum***). Mosses also cover 80 to 100 percent of the ground layer; of these, ***Sphagnum papillosum*** and ***S. fallax*** are the most common.

A variant description of this community described by the New York portion of the project area is the coastal plain poor fen. These wetlands are extremely rare in New York with only one occurrence within the project area on Long Island (New York State Dept. of Environmental Conservation, unpublished data). Coastal plain poor fens are dominated by ***Sphagnum*** mosses, but may include scattered shrubs, sedges, and stunted Atlantic white cedars and red maples. The waters supporting fens are slightly acidic and weakly mineralized. Characteristic shrubs include sweet pepperbush, water willow (***Decodon verticillatus***), leatherleaf, and sweet gale (***Myrica gale***). Typical herb dominants include swamp loosestrife (***Lysimachia terrestris***), fibrous bladderwort (***Utricularia fibrosa***), rose pogonia (***Pogonia ophioglossoides***), marsh St. John's-wort (***Triadenum virginicum***), and white water-lily (***Nymphaea odorata***) (Reschke, 1990).

### Emergent Marshes

Freshwater emergent marshes are dominated by a variety of herbaceous plants; genera of grasses like ***Typha***, ***Panicum***, ***Cladium***, ***Carex***, ***Cyperus***, and ***Sagittaria sp***.; and floating aquatic herbs like ***Nymphaea***. These plants comprise hundreds of individual species that may occur in the freshwater marshes of the temperate Atlantic region (Mitsch and Gosselink, 1993). Dominant herbs vary according to the depth of the water above the substrate. In areas that are semi-permanently saturated (up to two yards deep), emergent aquatics like yellow pond-lily (***Nuphar luteum***), white water-lily (***Nymphaea odorata***), cattails (***Typha spp.***), bulrushes (***Scirpus spp.***), arrow arum (***Peltandra virginica***), and wild rice (***Zizania aquatica***) are typical.

In areas where the substrate is slightly better drained, but still saturated and only seasonally flooded, a different assemblage of plant species is found. The dominant species at these slightly higher elevations include bluejoint grass (***Calamagrostis canadensis***), reed canary grass (***Phalaris arundacea***), rice cutgrass (***Leersia oryzoides***), mannagrass (***Glyceria canadensis***), sedges, and bulrushes. These two emergent marsh communities are often found in intergrading patches covering large stretches of pond shore or riverbank. Both emergent marshes and shrub-dominated wetlands are home to the Eastern cottontail (***Sylvilagus floridanus***) and muskrat (***Ondatra zibethicus***).

The sand plain pond shore community is found at the margins of ponds and small lakes in sandy and gravelly glacial deposits along the Atlantic coast. The water level fluctuates both annually and seasonally, but the mucky soils of the drawdown areas are always saturated. These plant communities contain a high percentage of traditionally southern species. This is because the ocean moderates temperatures along the Connecticut coast sufficiently to enable survival of less hardy species at the Sound's northern latitude (Rozsa, pers. comm.).

The specific assemblages of plants in the coastal plain pond shore are quite different in Connecticut than in New York. The Connecticut community is dominated by wing-stem meadow-pitcher (***Rhexia virginica***), yellow hedge-hyssop (***Gratiola aurea***), and false pimpernel (***Lindernia dubia***). Other common species of this community in Connecticut include spatulate-leaved sundew (***Drosera intermedia***), rush (***Juncus pelocarpus***), common yellow-eyed grass (***Xyris difformis***), and spikerush (***Eleocharis flavescens*** var. ***olivacea***). The Long Island community, on the other hand, is dominated by pipewart (***Eriocaulon aquaticum***), sedge (***Carex walteriana***), horned rush (***Rhynchospora macrostachya***), panic grasses (***Panicum spp.***), spatulate-leaved sundew, and pink tickseed (***Coreopsis rosea***).

### *Palustrine Aquatic Beds*

Palustrine aquatic beds are also highly variable within the project area. Shallow open water areas may support hydromorphic forbs. These are plants, either rooted or floating, which are structurally supported by the water column. Yellow pond lilies (***Nuphar variegatum***) and white waterlilies are floating plants found in association with one another where water depths are six feet or less. They occur in ponds, bogs, and fens with a wide range of pH values. If the lilies are not densely occurring, other submersed species may also be present. These include pondweeds (***Potamogeton spp.***), watershield (***Brasenia schreberi***), and little floating heart (***Nymphoides cordata***).

A palustrine submersed species association described in the Connecticut portion of the project area is formed by pondweeds, tapegrass (***Vallisneria americana***), and the naiad ***Najas flexilis***. There may also be free-floating forms present like bladderworts (***Utricularia spp.***) and hornwort (***Ceratophyllum demersum***) (CTDEP, 1982).

## *RIVERINE WETLANDS*

There are four subsystems identified by Cowardin ***et al.*** (1979) that make up the riverine system; tidal, lower perennial, upper perennial, and intermittent. As mentioned earlier, tidally influenced freshwater systems have been covered in ***Section 1: Tidal Wetlands*** and will not be described here. Each subsystem is divided into seven classes; rock bottom, unconsolidated bottom, aquatic bed, rocky shore, unconsolidated shore, and non-persistent emergent wetland. Riverine wetlands within the project area may have all the subsystems and several of these classes over the entire run of the stream or river. Since the vegetation defines only the aquatic bed and non-persistent emergent wetland classes, the focus will be on these and the subsystem descriptions. Riparian areas and riverine systems as a whole are more fully covered in the Riverine Migratory Corridors volume of this series.

Marsh headwater streams are characterized by slow-flowing, cool water. These streams cut through a marsh, fen, or swamp prior to channelization of the flow. Typical submersed macrophytes in this type of stream include water milfoil (***Myriophyllum heterophyllum***), hornwort (***Ceratophyllum demersum***), pondweeds, duckweed (***Lemna minor***), waterweed (***Elodea nuttali***), and water stargrass (***Heteranthera dubia***). The overall substrate is gravel or sand, with silt, muck, peat, or marl deposits along the shoreline (Reschke, 1990). There may be springs present and deposition is minimal. The faunal community consists of small forage fish like the golden shiner (***Notemigonus crysoleucas***).

In the rocky portions of Westchester county and western Connecticut, the rocky headwater stream may be found. Here, the water is cold, flowing over eroded bedrock in a moderate to steep gradient channel. There may be alternating riffle and pool sections[2], and waterfalls and springs. The stream is usually well shaded by bordering trees that reduce primary production. The main source of nutrients to the stream is terrestrial in the form of leaf litter and other organic input. The resident faunal community may include creek chub (***Semotilus atromaculatus***), sculpins (***Cottus spp.***), or introduced salmonids like brown trout (***Salmo trutta***) and rainbow trout (***S. gairdneri***). Typically there will be mosses present along the stream bank, these may include ***Brachythecium rivulare***, ***B. plumosum***, and ***Hygroamblystegium tenax***.

Further along in the development of the waterway is the midreach stream. This is a section of the stream that has a well-defined series of alternating pools, riffles, and runs. There may also be springs and waterfalls providing other habitat features. The resident finfish species include pumpkinseed (***Lepomis gibbosus***) and shiners (***Notropis spp.***) occurring in pools. The riffle sections are home to sculpins and darters (***Etheostoma spp.***). Minnows (***Cyprinidae***) and suckers (***Catostomus spp.***) are typically found in run sections. Submersed vegetation includes waterweed and pondweeds.

Coastal plain streams are found along the coastal plain portions of the project area in Connecticut and Long Island. These streams are sluggish and often darkly stained from leaf litter. Submersed vegetation may be abundant, including species such as pondweeds, waterweeds (***Elodea spp.***), naiads (***Najas spp.***), bladderwort, duckweed, and the introduced watercress (***Nasturtium officianale***). Finfish species include the American eel (***Anguilla rostrata***), redfin pickerel (***Esox americanus americanus***), pumpkinseed, and swamp darter (***Etheostoma fusiforme***).

# VALUES AND FUNCTIONS

The functions of wetlands in general have been defined hydrogeomorphically by the U.S. Army Corps of Engineers Waterways Experiment Station (***Table 2-2***). By utilizing these parameters, the relative "value" of a wetland or wetland system may be objectively quantified. It should be noted that this evaluation system is not based on the ecological assessment of wetlands, but by strictly functional attributes defined by physical parameters. As the term hydrogeomorphic indicates, the ability of a wetland or wetland system to perform any or all of these functions depends on the geological features in and around the wetland, the wetland shape and form, and the local hydrology. Wetlands have the potential to perform all of the hydrogeomorphic functions; however, not all wetlands do. The ability of an individual wetland to

***Table 2-2. Functions of Freshwater Wetlands***

- Modification of Ground Water Discharge
- Modification of Ground Water Recharge
- Storage of Flood and Storm Water
- Shoreline protection
- Hydrologic support
- Sediment and Particulate Retention
- Atmospheric Coupling
- Nutrient and Contaminant Retention
- Chemical and Detrital Export
- Maintenance of Characteristic Wildlife Communities

***From Brinson, 1993***

[2] ***Pool*** : Part of a stream with reduced velocity, commonly with deeper water than surrounding areas.
***Riffle*** : Part of a stream where water flows swiftly over completely or partially submerged obstructions producing increased surface agitation.
***Run*** : A slow moving relatively shallow body of water with moderately low velocities and minimal surface agitation.

perform a function may be precluded by natural or anthropogenic factors. The fact that wetlands are highly variable in their functions is part of what makes individual wetlands difficult or impossible to replace.

Modification of water quality by wetlands is extremely important in the watershed of the Sound. Wetlands are capable of trapping particulate matter in the vegetation or allowing it to settle in basins. They absorb and transform excess nutrients during the growing season. These nutrients are utilized by the wetland plant communities for growth and then transformed to other food sources like detritus. This transformation helps reduce nutrient enrichment in nearby lakes, ponds, and downstream water bodies, including the Long Island Sound. Metals and organic chemical compounds like hydrocarbons can be metabolized or transformed into less harmful components by the bacterial community within the wetland. Wetland plants are also involved in the uptake of metals, but little transformation takes place. Instead, the metals are simply sequestered in the plant material until it decays, which slows the exposure of biota to the metals.

Wetlands can modify groundwater discharges in two ways. They can sequester and transform chemical pollutants, and absorb and transform nutrients. Groundwater may contain nitrates, phosphates, and other nutrients, as well as trace metals like iron, and organic chemical contaminants. Wetland plant communities are able to modify groundwater recharge similarly, in that they sequester and transform surface pollutants before the water seeps into the underground aquifers. The layer of organic matter and fine sediments slows the recharge as well. This allows for more purification to take place than normally would on the sandy glacial soils of the project area. In many portions of the project area road runoff is required to be directed to constructed earthen recharge basins. Road runoff carries a heavy pollutant load that can be at least partially removed through filtration. The retention of precipitation and stream flow in pooled areas of surface water also helps to ensure areas of standing water in times of reduced precipitation.

Similarly, wetlands aid greatly in storage of flood and storm water. Wetlands can hold a significantly larger amount of flood water than an equal area of developed land. The flood water is then released slowly over a long period of time, which reduces flooding damage to surrounding properties. During times of heavy rainfall, storm water collected from streets and directed to vegetated and nonvegetated recharge basins is prevented from flowing directly into the Sound. Direct discharge of storm water is a nonpoint pollution source for the Sound (Long Island Sound Study, 1994).

Wetlands can also modify stream flow. This makes the in-water area more hospitable to fish and wildlife species. The wetland plants slow water currents and provide cover for juvenile finfish, invertebrates, and amphibians. These vegetated areas also curtail the rate of erosion caused by flowing water.

Wetlands contribute to the abundance and diversity of wetland fauna. Freshwater wetlands are "oases" of potable water for wildlife in an area dominated by salt water. Wildlife utilizing the Sound's resources must still have access to fresh water for survival. If these waters are inaccessible, polluted or destroyed, many fish and wildlife species will be forced to move out of the area to survive. Coastal development may exacerbate existing freshwater shortages by blocking coastal land and limiting animals’ access to inland water supplies.

The use of the Long Island Sound area freshwater wetlands by migratory birds lends international significance to the health of these resources. The Long Island Sound watershed lies in the flight pathways of several neotropical migrant bird species during their semiannual move between the temperate and neotropical regions. Impairment of their resting and feeding areas affects the bird population of the entire hemisphere. Many bird species are already experiencing stress due, in part, to deforestation in Central and South America. If there is further loss of habitats in North America as well, existing impacts in southern latitudes will be compounded.

Amphibian species are directly affected by the impairment of freshwater wetlands. They must reproduce in fresh water, and the juvenile life stage is spent in shallow pools and among wetland plants. Without access to fresh water, therefore, frogs, salamanders, and toads will be unable to maintain populations within the project area. There are currently four species of amphibians listed as endangered, threatened, or of special concern within the project area in New York and Connecticut. The tiger salamander (***Ambystoma tigrinum***) is listed as endangered by NewYork State Department of Environmental Conservation (NYSDEC). Amphibian species of special concern in the New York project area are the southern leopard frog (***Rana utricularia***), Eastern spadefoot toad (***Scaphiopus holbrooki)***, blue-spotted salamander (***Ambystoma laterale***), and spotted salamander (***A. maculatum***). The blue-spotted salamander is also listed as a species of special concern in Connecticut.

Amphibians are considered excellent indicators of environmental stressors and their relative abundance can help to determine the health of an ecosystem. Amphibians respire through their skin, making them particularly sensitive to toxic substances and changes in water quality. Their absence or illnesses may indicate that a problem exists long before it manifests itself in mammals (including humans), fish, or birds. Additionally, amphibians and their eggs are an important food source for many other fish and wildlife species. Largemouth bass (***Micropterus salmoides***) and snapping turtles (***Chelydra serpentina***) eat frogs and tadpoles, as do the kingfisher (***Megaceryle alcyon***) and other wading and diving birds. The Eastern hognose snake (***Heterodon platyrhinos***), a species of special concern in both New York and Connecticut, eats primarily Fowler's toads (***Bufo woodhousii***). Without that critical food source, Eastern hognose snakes will continue to decline in this region (Breisch, pers. comm.). Of the 290 animal species listed as federally endangered in 1986, one half were dependent on wetlands for all or part of their life cycles (Mitsch and Gosselink, 1993).

Freshwater finfish species also depend on wetlands for primary production, forage area, breeding and nursery habitat, refuge from predators, and resting areas. Many of these species form the basis of a healthy sportfish industry within the project area. The stream areas that connect with the Sound, in particular, support a diverse assemblage of species from the estuarine portions at the interface with the Sound to fresh headwaters miles inland. The Riverine Migratory Corridors volume discusses this aspect in more detail.

Wetlands contribute greatly to the diversity of plant species. Wetland communities like freshwater emergent marshes and riparian forests are highly diverse communities (Mitsch and Gosselink, 1993) containing hundreds of plant species within the project area. Because of the unique adaptations many wetland plants have made to survive in the saturated anaerobic conditions, they are not found outside of wetland systems. The disappearance of wetlands will cause the loss of these plant species and the support they provide to the animals that depend on them. In addition, approximately 43 percent of the plants statewide that appear on the New York State listing of endangered, threatened, and special concern species are found in wetlands (Young, pers. comm.).

An additional function that freshwater wetlands perform is the cycling of nutrients and atmospheric gases. Wetland plant species utilize carbon dioxide in the air and release oxygen into the soil layer surrounding the roots. Wetland plants and plants in other stressed environments display a metabolic adaptation that allows them to utilize carbon dioxide much more efficiently than their terrestrial counterparts. Carbon dioxide uptake is directly proportional to the rate of photosynthesis in the plant. In some cases the wetland plants display a photosynthetic rate five times greater than plants that have conventional metabolic processes (Mitsch and Gosselink, 1993).

Bacteria in the soils of freshwater wetlands are able to fix various forms of nitrogen into nitrate that is then cycled into the food web by primary producers. The combination of oxygenated soil and near neutral pH in freshwater emergent marshes allows for relatively rapid decomposition of plant material into detritus by bacterial decomposers.

# STATUS AND TRENDS

Historically, Bronx and Queens counties had extensive areas of rich and productive farmland, far removed from the crowding and pollution of Manhattan. Vast coastal meadows with clear running freshwater streams were bordered by Long Island Sound on one side and dense upland forest on the other. As the boundaries of New York City expanded, both counties underwent major transformations to densely-developed urban extensions of the city.

Flushing Meadows-Corona Park in Queens County is best known today as the home of the U.S. Open tennis championships and one of the largest urban parks in the country. At the time of the Dutch settlement of New York, however, Flushing Meadows was thousands of acres of tidally-flushed and freshwater spring-fed wet meadows. During the construction of the 1939-40 World's Fair grounds, the vast majority of these wetlands were filled with material excavated from building foundations in surrounding areas of New York City.

The rivers of the Bronx have been channelized and used to support the industry along the southern waterfront. Failing bulkheads allow debris to fall into the waterway and cannot attenuate runoff containing industrial contaminants. These rivers have now become pollutant conduits into the Sound. Some natural areas remain in the upper Bronx River within the boundaries of the Bronx Zoological Park and the Botanical Garden, and restoration efforts are underway further downstream as part of the Bronx River Restoration project. The Hutchinson River has become degraded by storm water inputs from roads and the routing of the Hutchinson River Parkway through its floodplain.

Nassau and Suffolk counties have also been heavily developed, though not to the densities found in the boroughs of New York City. The freshwater seeps and artesian springs that gave Cold Spring Harbor its name have all but disappeared, and the major tributary stream of that harbor was first dammed in the 1700s. The Nissequogue River was also dammed for mill operation and almost every shoreline town on the Sound has a "Mill Pond" indicating the location of a dammed tributary stream. Mill Creek that flows into Port Jefferson Harbor is now channelized into roadside drainage ditches and the stream delta wetlands have been filled. The creek has also been contaminated by industrial solvents in the creek’s groundwater source.

In the past, large tracts of Connecticut’s wetlands were drained for agriculture, or altered to produce cranberry and blueberry bogs. According to Metzler and Tiner (1992), a large portion of the agricultural properties have been abandoned and the opportunity for restoration exists. Dahl (1990) estimates that 53 percent of the Nation’s wetlands were lost between approximately 1780 and 1983. The States of Connecticut and New York are thought to have lost 74 and 60 percent, respectively, of their wetlands from about 1780 to the time of the National Wetlands Inventory in 1983. Metzler and Tiner (1992) disputed Dahl's 1990 estimate for the loss of wetlands in Connecticut and offered a more conservative estimate of 40 to 50 percent loss for freshwater wetlands.

Loss of wetlands in this country appears to have hit a peak between 1954 and 1974 (Mitsch and Gosselink, 1993). Within the project area this is most likely due to the post-World War II housing boom. With the advent of mass construction techniques pioneered in places like Levittown on Long Island, housing in the suburbs of the New York metropolitan area expanded at an unprecedented rate. At that time, the prevailing attitude towards wetlands was one of exploitation or elimination. The highly organic soils of wetlands made fertile farm fields when drained. Areas that could not be exploited for lumber or farming were often filled. Wetlands in general were viewed as sources of disease and unhealthy atmosphere.

Sportsmen and hunters were among the first wetland preservationists. They valued wetland for waterfowl habitat. In 1934 the first federal "duck stamps" were issued to generate revenues for wetland preservation. Scientific research, interest by sportsmen and hunters, and popular support of the environmentalist movement in the United States caused a groundswell of support for wetland conservation in the early 1970s. Statistics have shown that as public awareness of the values of wetlands has increased, the rate of wetland loss nationally has decreased. Unfortunately, the rate of natural wetland formation and restoration efforts by agencies like U.S. Fish and Wildlife Service has not been able to keep pace with the overall losses (Dahl, 1990).

***TABLE 2-3. Mapped Palustrine Wetlands of the Connecticut Project Area by County***

| *County* | *Acres* |
|---|---|
| Fairfield | 14,563 |
| Middlesex | 12,031 |
| New Haven | 12,258 |
| New London | 30,770 |

The U.S. government passed the Clean Water Act in 1972. Section 401 of the Act ensures that federally permitted activities comply with the protective measures of the Act and water quality standards enacted by states. Section 404 of the Act regulates the discharge of dredged or fill material into the waters of the United States, including wetlands. Since the enactment of Federal legislation protecting and regulating wetlands, the national loss rate of all wetlands has been cut in half (Mitsch and Gosselink, 1993). A study by Dahl and Johnson (1991) indicates that between the mid-1970s and mid-1980s nationwide palustrine emergent marsh area showed a net increase of 0.9 percent.

***TABLE 2-4. Mapped Freshwater Wetlands of New York Project Area by County***

| *County* | *Acres* |
|---|---|
| Bronx | 3 |
| Nassau | 729 |
| Queens | 167 |
| Suffolk | 2403 |
| Westchester | 7572 |

The Connecticut State Legislature passed the Inland Wetlands and Waterways Protection Act in 1972. The goal of this law is to balance wetland preservation with compatible economic growth of the state, yet it has been estimated that 200 acres of wetlands are still annually encroached upon or filled (Council on Environmental Quality, 2001). According to the National Wetlands Inventory Maps completed in 1982, 69,622 acres of palustrine wetland were mapped within the project area of Connecticut. ***Table 2-3*** presents the acreage by county.

New York State passed Article 24, the Freshwater Wetlands Act, in 1974. This part of the Environmental Conservation Law regulates the alteration of non-tidal freshwater wetlands 12.4 acres or larger and their adjacent areas. Smaller wetlands may be included if they are deemed locally significant. These smaller wetlands have been included in Nassau and Suffolk counties. There is currently a permitted loss rate of less than one acre per year. New York State has currently mapped 10,874 acres of freshwater wetlands of all types within the project area. ***Table 2-4*** displays the acreage by county.

New York State also regulates wetlands to some extent under Article 15 of the Environmental Conservation Law, the Protection of Waters Act. This law provides for the regulation of activities like construction and maintenance of dams and impoundments, construction of docks and bulkheads, and dredging and filling in the waters of the state.

There are other programs that indirectly protect freshwater wetlands. The North American Waterfowl Management Plan provides for the management and restoration of waterfowl habitats in the U.S. and Canada. Preservation of endangered species and their habitats is mandated under federal and state laws. Many wetland plants and animals are on the federal and state listings of endangered species. Both New York and Connecticut have programs to manage the habitats of fish and wildlife species. Both states also have a Natural Heritage Program that identifies significant habitats for management, restoration and enhancement. New York State's Wild, Scenic, and Recreational Rivers program was developed to protect and preserve those rivers of the state which possess outstanding natural, scenic, historical, ecological, and recreational values. The Nissequogue River in Smithtown, New York has been designated as a Wild, Scenic, and Recreational River under this program. Connecticut also has a Rivers Management Program that protects and preserves critical riverine resources and provides for comprehensive river management plans.

# DEGRADED WETLANDS AND RESTORATION METHODS

The major cause of wetland degradation is the alteration of the hydrology in the wetland system. This alteration may be caused by a number of activities such as draining, filling, and impounding. Other degradation may be caused by chemical inputs to wetlands, or invasion by exotic species. While degradation is caused by unique combinations of circumstances in each affected wetland, some general causes and restoration methods can be outlined.

## DRAINED MARSHES

Freshwater wetlands were drained in the past for a variety of reasons. One of the most common uses for drained freshwater wetlands nationwide was agriculture. The highly organic soils of the wetlands are suitable for growing crops without the need for costly fertilizers. In other cases, wetlands were drained for development of homes, as in the densely populated suburbs of New York City.

Drainage of standing water in the wetland by digging channels causes a shift in seasonal as well as instantaneous hydrology. The vegetative community moves away from submergent and emergent obligate wetland plant species to facultative wetland species and upland plants tolerant of wet conditions. In extreme cases the plant community may shift entirely to upland species as the wetland soils are exposed to air and become oxygenated.

Wetland drainage may be an unintentional side effect of other activities by people. Groundwater-fed wetlands may suffer degradation due to the presence of water supply wells nearby. The extraction of groundwater from shallow aquifers for human consumption may eventually cause the aquifer to shrink, reducing the seepage to wetlands on the surface. The same may happen with deeper aquifers. The wetland hydrology shifts depending on the surface water and precipitation input, but in most cases the wetland shrinks in size and may become intermittent. The vegetation will reflect the infrequent flooding, and upland plants will begin to colonize the former wetland area.

In the past, surface water supplies to wetlands have been diverted for drinking water reservoirs, flood control projects, cooling of industrial plants, and irrigation of crops. Wetlands that are dependent upon surface water to maintain their water budget will suffer degradation from this loss.

### Restoration Methods:

① The simplest way to reverse the drainage of wetlands is to fill or plug the ends of the drainage ditches and allow them to fill naturally. The former area of wetland should refill with water.

Once the hydrology is stabilized, the seed bank contained within the soil will naturally recolonize the site. The restored wetland's plant distribution may be different once it is re-flooded due to compaction and subsidence of the soils while it was drained. Once the wetland is drained the saturated soils become exposed to air and decomposition of organic matter takes place. If this has happened, the proportion of open water to emergent marsh may be greater than in the previously undisturbed wetland. This should be taken into consideration when setting restoration goals for the site and when measuring restoration success.

② In wetlands where the surface water has been diverted, replacement of that flow is the best method of restoration. If the original source of flow cannot be restored, an alternate source of water may be considered in its place. For example, diverted cooling water may be channeled back to the wetland, groundwater may be pumped into the wetland or stream to provide a surface flow, or the wetland deepened to intercept shallow groundwater pockets. In each of these methods, the hydrologic budget of the wetland must be carefully calculated to ensure adequate flow and/or saturation of the hydric soils. As with drained wetlands, the remaining seed bank in the soil may be sufficient to revegetate the site.

③ It is possible to help alleviate groundwater withdrawal related wetland degradation by redirecting storm water and sewage treatment plant effluent into recharge basins or by direct groundwater injection. This course of action is not to be taken lightly. It involves a great deal of engineering and construction, as well as multiple permits. Recharge basins are often a required component of new subdivisions and other types of construction. The complexity of the issue does not lend itself to detailed discussion here. State and municipal permitting authorities can provide further information about this topic.

## FILLED MARSHES

Filling of wetlands with additional soils or garbage increases the elevation of the wetland and causes the plant community to disappear due to burial. This type of degradation was common until legislation outlawed siting of structures and municipal landfills on wetlands. A slower form of filling may occur due to silt runoff from disturbed upland areas. Gradually the wetland becomes shallower until it is converted to upland. Storm water from roads directed to wetlands with no treatment can also cause this problem.

### Restoration Methods:

Restoration can be achieved by excavation of the fill materials to the level of the pre-existing peat or organic soils. Once the former elevations are restored, the hydrology should eventually reach equilibrium, provided that water budget calculations are accurate. The existing seed bank is then left to revegetate the wetland naturally. If the organic soil horizon has been disturbed, the area should ideally be reflooded early in the growing season. Since destruction of the organic soil horizon will have also disturbed the seed bank, recolonization will be somewhat slower. The area may have to be colonized by nearby wetlands. To compensate for this, annual emergents like wild rice may be seeded to stabilize the substrate until the natural colonization occurs. Alternatively, planting of permanent resident shrubs and other perennials may be done immediately. Shrubs and trees are slow to return to wetland areas, and if the habitat values they provide are desired, planting will ensure these values in the short term. Immediate planting or seeding of herbaceous species is also advisable in areas where invasion by purple loosestrife is likely.

## IMPOUNDMENTS

Rather than hydrology modifications that result in a loss of water, wetlands may be degraded by influx of too much water. This type of degradation has been extensive on Long Island riverine wetlands and was reported as having been a regular practice in colonial times (State of New York, 1939).

Impoundments and dams increase the area of permanently flooded wetland, which results in a shift in vegetative cover. In areas where riverine wetland vegetation is dominant, the fringing vegetation becomes flooded. Impoundments and dams have traditionally been placed to provide power for hydroelectric plants and mills, and to provide artificial lakes for recreation.

### Restoration Methods:

Lowering of the impoundment structure profile in order to reduce the flooded area may result in rapid recolonization by fringing wetland plants. The impoundment structure may be removed entirely, if feasible. Otherwise, installation of weir boards to allow for drawdown during wet seasons is a viable alternative when concerns of downstream flooding are present.

Replanting in these areas is seldom necessary. The lowering of the water level allows emergent vegetation to recolonize the newly drained area quickly from the remaining seed bank, or new seeds from adjacent populations. However, if invasive species are present on the project site, it is advisable to plant the desired species in densities sufficient to provide a competitive advantage over invasive species.

## EXOTIC SPECIES INVASION

Throughout the northeastern United States, purple loosestrife (***Lythrum salicaria***) has become a pervasive invader of freshwater wetland systems. This plant is native to Europe and has flourished in the United States due to the absence of natural predators. Purple loosestrife is virtually uncontrollable without intense, hands-on management. Once it invades, purple loosestrife spreads quickly, forming dense monotypic stands. It reduces the diversity of the wetland plant community and provides reduced ecological value to the biota of the wetland. Fortunately, Long Island has not been invaded to the same extent as upstate New York, but control of any populations occurring there is vital to halting its spread within the project area.

A similar type of degradation is seen with the invasion of wetlands by the common reed (***Phragmites australis***). While common reed is a native plant, under some circumstances it too may form dense monotypic stands that reduce the vegetational diversity. The thick woody stems are less desirable for nesting to many animal species than other emergent wetland plants like cattails and bulrushes. The woody nature of the plant also makes it decay more slowly in the marsh, reducing its detrital export value. In areas where other degradation has already taken place, common reed can become invasive. Like purple loosestrife, it provides reduced food and cover value to the wetland biota.

### Restoration Methods:

① Purple loosestrife and common reed are both difficult plants to remove from wetlands. Mechanical removal through mowing and excavation are labor intensive and often have limited success since remaining stands of the plants are quick to recolonize cleared areas. The restoration practitioner must be vigilant and remove all above and below-ground portions of the plants. The mechanical disturbance also has the potential to cause damage to the remaining wetland area. The excavation may cause increased turbidity of standing water areas in the wetland that can cause shading of submerged aquatic vegetation or reduce dissolved oxygen required by fishes.

② Herbicide application in wetlands is a somewhat controversial method of exotic species control. While there are herbicides that are designed to become inert when mixed in water, extreme care must be exercised when applying herbicides. Hand application is necessary to ensure that the herbicide kills only the target species. Some herbicides are toxic to juvenile stages of finfish, crustaceans, and other invertebrates and should not be used in or near wetlands. Persons involved in wetland restoration in areas with invasive species should familiarize themselves with the variety of herbicides used by restoration ecologists and learn the ecological impacts of each prior to undertaking this restoration method. When used properly, herbicide application has proven successful as a restoration and management tool. This is especially true in cases where mechanical removal may require several disruptive treatments over time.

③ Another method to control purple loosestrife is the introduction of insects to help reduce spread of the plant. There are three species of beetles that have been introduced in areas of the Hudson River, a project funded by New York's Clean Air/Clean Water Bond Act. These insects are a root-boring beetle (***Hylobius transversovittatus***), and two species of leafeating beetles (***Galerucella calamariensis***, and ***G. pusilla***). In Connecticut, releases of the two leaf-eating beetle species began in 1996, followed by releases of a flower-feeding ***weevil (Nonophyes marmoratus***) in 1998. In the Montezuma Wetlands in western New York, and in Connecticut release sites, initial introductions of these insects appear to be successful. The insects show high host fidelity, meaning that they are not eating plants other than the target species. If proven successful, this method of purple loosestrife control may be appropriate in the project area. This may prove particularly useful as a control on Long Island where purple loosestrife is less common than in wetlands of upstate New York and Connecticut and there is still opportunity to control its spread.

## CHEMICAL CONTAMINATION

Some wetlands can become contaminated by pesticides like those used in controlling mosquitoes, by chemically contaminated groundwater, or by petroleum products and metals carried in stormwater runoff. A crucial first step in restoring the wetland is tracking down the source of contamination and abating it. If the contamination is severe enough, it may require specially trained personnel working under state and federal guidelines to protect the safety of the public, workers, and fish and wildlife species. Often disposal of the contaminated soils and water must occur at a specially licensed facility, and can be quite expensive.

- In some cases it may be possible to remove the contaminants contained in wetland sediments and plant material. Dredging the contaminated sediments and disposing of them properly will remediate the contamination. Vegetation should be replaced where necessary. Depending on the depth of excavation, the sediments may have to be replaced with clean material to prevent alteration of the plant and animal communities.

- In areas where excavation of the contamination is too costly or otherwise inappropriate, it may be possible to "cap" the contamination with clean material. This solution should be reserved for situations where the contamination poses an acute threat to wildlife and/or people since it will result in altering the depth of the wetland.

- In some places heavily contaminated wetland sites have been planted with species capable of not only tolerating the contaminated soils and water, but of extracting the hazardous substances and sequestering them. This practice is known as bioremediation. In many places around the country, plants have successfully been used to extract heavy metals from wetlands contaminated by mine tailings. Some plants possess this ability naturally, in other cases the plants have been specifically engineered to serve the purpose. Once the plants have extracted contaminants during the growing season, the foliage may be harvested and taken to a disposal facility that handles contaminated materials. This restoration option is fairly complex and will require the restoration project manager to engage in further investigation with state and federal authorities.

All of the above restoration methods require the restoration practitioner to do quite a bit of homework. Part of this homework is investigating what permits may be required of state, federal, and local agencies to engage in wetland restoration activities. It is also important to research the plant and animal communities found in the wetland prior to the disturbance that degraded it.

## SPECIFIC RESTORATION OBJECTIVES

In setting restoration goals for freshwater wetlands, it is prudent to examine the body of scientific literature on the subject. As mentioned in the previous section, there is a wealth of information on successful techniques of emergent marsh and stream restoration, but very little is known about restoration techniques for other wetland types. By looking at historical records of lands that are still conducive to restoration efforts, the acreage available for restoration will become clear. Publicly owned parcels are desirable for restoration because their future use is more readily controlled. Alternatively, conservation easements, land donation, and outright purchase are potential mechanisms to pursue long-term restoration on private property.

Each of the hydrogeomorphic functions of wetlands should be considered when evaluating potential wetland restoration projects. Restoration projects should attempt to restore as many of the wetland's original functions as possible.

In addition, the restoration should be completed with the context of the habitats surrounding the wetland addressed to help correct fragmentation that has already occurred. For example, along with their need for wetlands in which to reproduce, amphibians require upland habitats adjacent to those wetlands as part of their adult habitat range. New York State's Article 24 provides a 100-foot regulated wetland adjacent area, however, the habitat range of the amphibians may extend up to 300 feet from the wetland. This makes amphibians particularly sensitive to habitat fragmentation. Restoration of buffer areas and corridors between freshwater wetlands and complementary upland habitats should be included as part of a freshwater wetland restoration. The restoration of upland buffers will benefit other fish and wildlife species as well.

The stabilization and restoration of stream bank buffer zones will contribute greatly to down stream water quality while, at the same time, providing improved wildlife habitat. River and stream corridors are important migratory pathways for many different fish and wildlife species. Using river and stream corridors to connect adjacent habitat types is an efficient means to reduce habitat fragmentation.

## RESTORATION SUCCESS AND MONITORING

The measurement of the success in the restoration of freshwater wetlands should be based upon the functions that are designed to be returned to the restoration site. This may include measuring the pre- and post-restoration diversity and density of plant communities, level of use by fish and wildlife species, the appearance of endangered or threatened species in the restoration site, chemical and hydrological cycling, and persistence of the restored community. Often when restoration is performed for regulatory reasons, like correction of illegal filling, the regulatory agency involved only requires single parameter measurement of success. This is usually a requirement of a certain percentage of plant survival over a few growing seasons. For in-stream habitats, monitoring of finfish diversity, submersed vegetation, insect community, stream velocity, and temperature are all important. Little long-term monitoring has taken place for any of these parameters within the project area. Each restoration site is unique and a long-term monitoring plan should be developed that is site-specific.

Long-term monitoring is also pertinent when dealing with varying weather conditions such as droughts and floods. A drought or flood can drastically affect the presence of plant and animal species in a wetland, causing them to temporarily disappear or shift their zonation. In wetlands dominated by annual plants, a single drought or flood event can decimate the vegetation for that growing season.

The plants may take years to return to their former abundance. Similarly, the animal species dependant on that wetland and its plant community may be forced to relocate, or become stressed. Stress on the animals may negatively affect reproductive success, or even cause death. Therefore, animal populations may fluctuate as well as the plant communities. A wetland restoration judged solely on the basis of a single growing season will result in an unreliable conclusion.

In order to measure success of the project, it is necessary to set specific and measurable goals for the project. The first step in restoring the wetland should be an examination of the lost functions at the restoration site. Based on this information, the restoration planner needs to evaluate the possibility of returning all of those lost functions to the wetland. Most critical is an examination of the site hydrology. In many areas on Long Island, the shallow aquifers have been drawn down to provide drinking water and irrigation. If the draw down has been severe, there may not be a high enough water table to support the desired size wetland. A water budget must be calculated for the site.

In planning for the wetland restoration, it is also necessary to gather information about the soils on the restoration site. If the former wetland soils are in place, the project will have a higher likelihood of success. If the soil profile has been disturbed, then appropriate soils may need to be brought to the site, or project time frames lengthened to allow proper soil chemistry to become established. In the case of filled emergent marsh areas it will be useful to obtain soil borings. The borings will indicate where old marsh peat layers may reside under the current fill. The borings will also provide insight into the nature of the fill, grain size, and likelihood of contamination.

Measurements of success must be based on project goals. Selecting which functions of the degraded wetland can be restored under the current conditions is of primary importance. Progress toward these goals is the basic framework on which to base measurements of success. Useful measures may include vegetational diversity, biomass, and species richness, and animal community composition. Seasonal changes in both the plant and animal communities should be taken into account while developing the monitoring plan for the restoration site. Pre-construction baseline and post-construction follow-up measurements should, at a minimum, measure vegetation survival across five growing seasons utilizing the assumption that structure creates function. Vegetation forms the structure of the habitat, allowing it to perform the functions of animal habitat. Measurement methods can include aerial and ground-based photography, and transect and quadrant surveys.

Ideally, animal surveys and primary production should be included in determining the success of the restoration project. All of these measures should be compared to a nearby reference site that displays the functions and characteristics desired in the restoration site. While there are no "magic number" targets to shoot for, the comparison of the two sites as a start and an end point should allow the restoration planner to measure progress toward the desired end point. Published values of primary productivity and accounts of animal and plant community descriptions are available for both states. The U.S. Environmental Protection Agency and other federal programs are making monitoring data from completed restoration projects available on the World Wide Web.

As stated in the introduction to this document, the state Habitat Restoration Initiative staff and all the Habitat Restoration Workgroup members are available to provide guidance and technical advice with project planning, financing, permitting, and monitoring. It is highly advisable to contact them at the beginning of the restoration planning process to learn what resources are available to assist with any project.

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