The Future of Coastal Lakes in Monmouth County

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I. Introduction

Herring runs, fyke nets, daysailors, rowing skiffs, gondola and swan boat rides…Monmouth County's coastal lakes have historically provided a variety of commercial and recreational opportunities for area residents and visitors and served as important habitats for fish and wildlife.

Unfortunately, over the past several decades these aquatic ecosystems have become disturbed and degraded from the impacts of the intense development that surrounds them. Unnatural modifications to adjacent shorelines and riparian corridors along their tributaries and the introduction of a variety of pollutants from stormwater and runoff has resulted in degraded water quality, disturbed fish and wildlife habitats, algae blooms, and invasions of nuisance aquatic plants. As a result, the majority of the county's coastal lakes and ponds are now neglected and valued less for the natural resources they support and the recreational opportunities they offer. Instead they are viewed as little more than the terminal receiver of road and overland runoff from storm sewers, algae covered mud holes, and havens for Canada geese.

Further complicating any attempt to manage or restore the coastal lakes and ponds is the fact that with few exceptions, no organization, agency, or governing body has taken responsibility for these waterbodies. Attempts to manage the coastal lakes have tended to follow a disjointed path that has often limited the success and sustainability of restoration efforts. Granted there are groups such as the Deal Lake Commission, Wesley Lake Commission and Fletcher Lake Commission that have been able to rally public support and have been able to make positive improvements in their respective lakes. However, even these well organized groups have faced difficulty in obtaining funding and sustaining the energy needed to achieve all their management and restoration goals.

It is time to change this state of affairs. State, county, and local governments must partner with representatives of civic and community organizations, and local coastal and watershed management groups to develop and implement cost-effectives strategies to restore, protect, and maintain coastal lake ecosystems in Monmouth County

The challenge is to manage coastal lake environments in a manner that provides for the maintenance of their ecological integrity and accommodates active and passive recreational activities. However, this will be no easy task. New resources need to be allocated at the state, county and municipal level, permit processes streamlined, and problems such as dredging and dredged material disposal, aquatic weed control, and stormwater infrastructure improvements addressed on a regional basis.

II. Status of the County's Coastal Lakes and Ponds

In 2000, forty six states, Puerto Rico and the District of Columbia rated lake water quality in their Clean Water Act Section 305(b) reports (USEPA 2000). In total, these states assessed 43% of the lake acreage in the United States. The information reported indicated that 45% of assessed lakes in the U.S. are impaired and partially or totally not supporting one or more of these desirable uses:

- Primary contact recreation (e.g., swimming);
- Secondary contact recreation (e.g., boating, sailing, waterskiing);
- Recreational fishing;
- Fish consumption; and
- Fish, wildlife and aquatic life support.
- Another 8% of the assessed lakes were reported to be threatened for one or more of these uses (EPA 2000).

In 1988-89, a regional study of lakes in Monmouth County was conducted by the Monmouth County Department of Health (MCHD 1990a, MCHD 1990b). This study included an intensive survey of water quality in nine coastal lakes and an analysis of metal contamination in sediments collected from 20 lakes. The water quality investigation characterized physical parameters, nutrients, bacteria, and algal conditions in nine coastal lakes: Takanassee Lake; Deal Lake; Wesley Lake; Fletcher Lake; Sylvan Lake; Silver Lake; Lake Como; Spring Lake; and Wreck Pond. The conclusion of this study was that all of these lakes were experiencing pathogen contamination, algal blooms, aquatic weed overgrowth and eutrophication that was primarily related to inputs of stormwater and runoff from their surrounding watersheds (additional information found at: http://co.monmouth.nj.us/page.aspx?ID=3024). Our collective studies on coastal lakes in the county completed over the last two decades have drawn similar conclusions.

In June 2008, the Monmouth University Urban Coast Institute convened a Future of Coastal Lakes Summit. At the Summit, attendees were asked to rank impairments affecting coastal lakes in Monmouth County. The consensus was that coastal lakes in Monmouth County are all impaired and not fully supporting desirable uses (Table 1).

Table 1. Impairment Ratings for Monmouth County Coastal Lake			
Use	**Good**	**Impaired**	**Severely Impaired**
Swimming	**0 %**	**33 %**	**67 %**
Boating, Sailing, Waterskiing	**0 %**	**67 %**	**33 %**
Fishing	**10 %**	**80 %**	**10 %**
Fish Consumption	**10 %**	**70 %**	**20 %**
Fish, Wildlife, Aquatic Life Support	**10 %**	**50 %**	**40 %**

- **Good = fully supporting the use**
- **Impaired = partially supporting the use**
- **Severely Impaired = not supporting the use**

Note: Results of Ratings by 47 attendees at the *Future of Coastal Lakes Summit,* June 2008 Attendees represented state, county and local government agencies, lake commissions and associations, civic and environmental organizations and citizens living lakeside.

III. An Overview of the Problems Affecting Coastal Lakes and Ponds

According to the USEPA (2000), lakes in the U.S. are being impacted by a number of stressors including excessive nutrients, siltation and infilling, enrichment by organic wastes that deplete oxygen in lake waters, or a combination of several pollutants and processes.

Monmouth County's coastal lakes are no exception. They are no longer primarily recreational features, but instead have become the terminal sinks collecting pollutants from surrounding land uses within their urbanized watersheds via stormwater and runoff. This results in a change from the clear water of a pristine lake that supports desirable wildlife and recreation (Bukata et al.. 1979), to lakes exhibiting impaired water quality, degraded fish and wildlife habitats and use impairments. Impaired water quality in Monmouth County's coastal lakes is primarily related to pathogen contamination, nutrient enrichment, erosion and sedimentation and floatables and debris.

Waterborne pathogens are a major concern in a number of coastal lakes in the county. Once in a waterbody, these disease causing microorganisms can infect humans through contaminated fish and shellfish, skin contact, or ingestion of water (Perdek *et al*. 2003).

The turbid waters of coastal lakes are ideal for the survival and growth of pathogenic microbes. Some of these bacteria and protozoa originate from humans as well as many animal species common in Monmouth County coastal watersheds including wildlife, pets and agricultural animals and are transported to coastal lakes by stormwater and runoff. For example, pathogenic *Eschericia coli* (Somarelli *et al*. 2007), *Salmonella* (Feare 1999), *Campylobacter* (Lillehaug *et al.* 2005) and *Cryptosporidium* (Zhou *et al*. 2004) are found in animal droppings and may be an early indication of future health problems for humans. Waterfowl, such as Canada Geese, are important in this regard and pathogenic bacteria are seen when their feces are examined (Hussong 1979). When water quality drops below levels defined as safe by public health authorities, for example 235 Escherichia coli/100 ml freshwater, restrictions on recreational activities apply (MCPB 2008).

Monmouth County's coastal lakes are eutrophic and are experiencing aquatic weed overgrowth, algal blooms and associated habitat degradation. As a result, they do not support the wildlife we value (Fruh 1967), they are unattractive and they smell of the decay they conceal (Juttner 1984, Preti *et al.* 1993).

Although eutrophication is a natural process that continues slowly under natural conditions, eutrophication can be accelerated from the introduction of excess nutrients, particularly phosphates and nitrates, from nonpoint source pollution. Known as cultural eutrophication, man-made sources of nutrients entering a waterbody cause undesirable ecological changes in lakes and ponds.

Visual effects of eutrophication are commonly observed in the form of peaks of aquatic plant growth such as duckweed (*Lemna*) and watermeal (*Wolfia*) and phytoplankton blooms, especially those associated with cyanobacteria (blue-green algae). These life forms are rich in intensely pigmented chlorophylls and carotenoids. These pigments may become so abundant that they form conspicuous surface water discolorations including green tints and other colors such as red, brown and yellow. Prominent effects of algal and cyanobacterial blooms can also include an intense muddy odor and a foul taste of the water and fish caught therein (Person 1982), musty odors from blue green algae (Sigiura *et al.* 1998) and a sulfurous smell from anaerobic bacteria (Frank and Fielding 2004). In addition, some species of algae produce substances which are toxic for humans and domestic pets (Carvalho *et al.* 2008).

Other less conspicuous effects of eutrophication are elevated ammonium, depleted oxygen, and increased water turbidity. Eutrophication also results in drastic changes in the quality of coastal lake habitats, impairments to fish and wildlife, and impairments to recreational uses.

Eutrophication includes surges of excessive plant growth and eventual decay, depleting oxygen content. Plant pests may be controlled early using pesticides, calculating dose in proportion to water volume but pesticide use must be consistent with activities such as swimming and wildlife conservation. Floating and rooted plants may be harvested using mechanical devices as well. However, there are regulatory issues related to the disposal of harvested weeds that must be addressed. Specifically, as per existing New Jersey Department of Environmental Protection (NJDEP) solid waste disposal regulations, unless a composting facility is licensed for the acceptance of aquatic vegetation, the harvested weeds will not be accepted. This results in the material often having to be transported to conventional landfills or being subject to excessive handling and tipping fees.

In addition, the microbial decay of dead algae and macrophytes generates fine particulate matter that remains in suspension for long periods. This organic turbidity often defies settling causing the impacted lake or pond to appear muddy. While decreasing the aesthetics of the lake, this turbidity also reduces the penetration of light resulting in the shading of native plant growth and facilitating the development of thermal stratification.

Lakes that are over-fertilized and shallow become ideal environments for blooms of nuisance and invasive aquatic weeds. The constant influx and settling of fine grained sediment further increases the viability of the lake to support dense stands of both native and non-native plants with many of the former being highly invasive and difficult to control. It thus is not uncommon for the coastal lakes and ponds to support extremely high densities of such macrophytes as Eurasian water milfoil (*Myriophyllum*), coontail (*Ceratophyllum*), duckweed (*Lemna*), watermeal (*Wolfia*) and spatterdock (*Nuphar*) all of which can reach densities so great as to impede boating, fishing and swimming, decrease circulation and flow and increase sedimentation.

As egregious as the problems arising due to the over-fertilization of the coastal lakes and ponds may be, the problems that have arisen due to the influx of sediment are equally as significant. Erosion throughout Monmouth County results in large amounts of sediment, sand and silt washing into the coastal lakes. This erosion dates back to the early 1900s when land development and farming activities were conducted with little thought to the ramifications of soil disturbance and soil loss. Over the decades that followed, stream banks were denuded, floodplains filled and riparian areas paved, causing more flooding that in turn further exacerbated erosion processes within the tributaries of the coastal lakes. The down cutting and channelization of the stream banks exposed clay deposits (green sands and marl) that once exposed are exceptionally prone to erosion and, due to their acidic nature, difficult to stabilize. These clays are so fine that they are considered colloidal and as such difficult to settle, thereby leading to the muddy appearance so characteristic of many of the coastal lakes. In addition to causing a visual or aesthetic impact, the fine clays can be harmful to wildlife, especially the filter feeding clams, mussels and benthic invertebrates that are important elements of lake and stream environments. Turbidity is particularly distressing to fish and may inhibit their growth (Sigler *et al.* 1984) or cause fatal gill clogging in extreme cases (Lake and Hinch 1999).

The biggest problem with the influx of all this sediment is the eventual infilling that has led to significant water depth loss. Sediment infilling is by far not only one of the biggest problems impacting the coastal lakes and ponds, but the most costly problem to correct. Rates as high as 0.5% reduction in lake volume per year have been recorded by those researching the demise and management of the lakes. Water slows down when it flows from narrow fast streams into wide and relatively quiescent coastal lakes. This gives time for solids to settle before water continues to the sea. The process of sedimentation is natural and usually slow i.e. millimeters per year in pristine lakes (Buynevich and Fitzgerald 2003). However, erosion accelerates sedimentation and the subsequent infilling of lakes (Panayotou *et al.* 2007). Sometimes the rate of accumulation can be so great (Costantini *et al.* 2008) as to render a portion of a lake unusable within a very short time. The transport of this particulate material and sediments into the lakes and ponds may occur directly, with eroded bed and bank sediments being washed in with stream flow, or indirectly, with the runoff collected and subsequently conveyed into the lakes and ponds via the storm water collection system. The control of lake/pond infilling starts with reducing erosion by implementing better stormwater management methods, protecting and restoring riparian buffers, and remediating past erosion problem sites. Eventually, the sediment deposited in the lakes and ponds will need to be removed. As detailed in Section IV, the dredging operations needed to correct the impacts of sediment infilling and reclaim lost water depth and lake volume are expensive and require a significant amount of logistical planning and support. These projects also cannot be conducted without first obtaining a number of NJDEP permits. The complexity of the related regulatory issues associated with dewatering and disposal of dredged sediment can make what appears to be the simplest of dredging projects overwhelming.

Trash, litter and other debris discarded or dumped in Monmouth County's coastal watersheds constitutes another significant problem. These floatables are carried into the lakes and ponds by storm drains, as well as the streams that are tributary to the coastal lakes. Floatables create more than just a trivial aesthetic problem. Floatables also pose a threat to fish and wildlife and are costly to clean up. Discussions centering on stormwater management (Section IV) cannot overlook the need to control this problem. This starts with strong source control measures, requires the renovation, upgrade and retrofit of existing stormwater collection systems, but ultimately needs the support of the public as most of this problem is simply the result of littering and a common disregard for the environment.

With respect to stormwater management, although nutrient and sediment loading related impacts are highlighted, rain water running across parking lots, roads and paved impervious areas will wash hydrocarbons and other oily pollutants into stormwater catch basins. The resulting discharge to the rivers and ultimately the coastal lakes leads to the accumulation of these contaminants (Overstreet and Galt 1995, Conides *et al.* 1996, Conides and Parpoura 1997). Hydrocarbons harm freshwater organisms not only due to their acute toxicity but also by triggering a number of chronic impacts that range from coating water surfaces and gills to preventing the oxygenation of water and gas exchange (Bhattacharyya *et al.* 2003).

Although alluded to above, when discussing the erosion of the tributaries of the coastal lakes and ponds, development and disturbance along the shoreline of the coastal lakes or along the riparian corridors of their feeder streams has also led to the destruction and loss of the important natural functions provided by these areas. At a minimum, natural shorelines provide a buffer between land-based human activities and adjacent waters. Additionally, these areas provide important, but often underappreciated and overlooked natural services and functions critical to a healthy, vibrant aquatic ecosystem. The riparian vegetation growing on the banks of streams prevents erosion and lessens downstream sediment transport. This vegetation also adsorbs and attenuates nutrients as well as the various contaminants contained in stormwater runoff. Vegetated riparian areas and adjacent floodplains also help attenuate flood flows. These areas are also often critical to the successful breeding of many aquatic organisms. Thus a natural riparian area provides hydrologic, water quality, and biological benefits. As often occurs though, critical stream-side riparian areas are cleared, paved and altered, all of which creates problems with the downstream lake ecosystems. Even along a lake's shoreline, one of the first actions taken is to clear away all the native vegetation to increase views or improve access. This native vegetation is most often replaced with lawn cover, which requires fertilizers and pesticide treatments as part of its normal maintenance, or becomes replaced by invasive vegetation that often lacks the soil stabilizing benefits of the native vegetation. Even more pervasive is the construction of bulkheads and the filling of nearshore lake areas. This has a direct negative impact on the lake's wildlife and fishery due to the loss of important littoral zone habitat areas. Thus, as will be discussed in Section IV, part of the long-term restoration of the coastal lakes must include actions implemented to rehabilitate the loss functions and services of disturbed riparian stream corridors and lakefront littoral zones.

Many of the problems discussed above have had measurable negative consequences on the fishery of the coastal lakes. Of particular impact to the lakes' fisheries has been:

- Sediment infilling and loss of important spawning and nursery habitat;
- Bulk heading and filling of lake shoreline littoral areas;
- Colonization of invasive macrophytes, which again impact spawning and nursery habitat, as well as impede predator/prey relationships;
- Degraded water quality related to the influx of contaminants in stormwater runoff;
- Accelerated eutrophication and its negative consequences of trophic shifts in phytoplankton/zooplankton communities;
- Diel oscillations in dissolved oxygen and pH, typically the result of dense summer algae blooms, and
- The establishment of non-native species, especially the common carp (*Cyprinus carpio*) that disrupt habitat and compete with native fish for habitat and food.

Impacts to the lakes' fishery translates to impacts to recreational fishing uses and this further takes away from the viability of the recreational opportunities provided by the coastal lakes and ponds. Correction of many of the problems negatively impacting the fishery of the lakes and ponds are related to the restoration initiatives discussed in Section IV, such as stormwater management, aeration, dredging and the control of invasive weeds and nuisance blooms of algae.

IV. Recommendations

IV.1 A History of Impairment

The conditions that impact the quality, ecology, recreational use and aesthetics of the coastal lakes of Monmouth County are directly a function of the degree to which the watersheds of these lakes have become developed. Over time, as the lands surrounding these lakes evolved from farmland to cityscapes, the extent of impervious cover increased and the amount of naturally vegetated lands decreased. The streams that fed many of these lakes became altered as well, with the resulting changes having serious consequences on the quality and conditions of the downstream lake ecosystem. In some cases, this amounted to encroachment of development into the floodplain and riparian areas associated with these streams. This led to increased flooding, stream bank erosion, and increased pollutant transport. In other cases, the streams were actually channelized, or even worse, placed within sub-surface pipes and culverts. The evolution of the watersheds of the coastal lakes increased the rate and volume of runoff conveyed to the lakes reducing water quality and setting the stage for their accelerated eutrophication and sediment infilling. Although once the “crown jewel” of the community as the watershed surrounding each lake became increasingly developed, the lakes became relegated to the role of regional stormwater basins. Currently, though many in name are considered recreational waterbodies, the primary role of most of the coastal lakes is that of receptor of the untreated and unmanaged runoff generated by the surrounding landscape.

Today, the landscape defining the watershed of the coastal lakes is most often characterized by intensive residential and commercial development and large contiguous swaths of impervious cover. Runoff generated from these areas is conveyed to the lakes with little thought given to the management of any of the associated pollutant load, not to mention the loss in recharge and the scour and erosion caused by the increased volume of runoff. As a result, the water quality of almost all of the coastal lakes of Monmouth County has declined. With this has come a loss in the aesthetic attributes and recreational opportunities provided by these waterbodies.

As difficult as it may seem, a balance between watershed development, social needs and expectations, and maintenance of the ecological integrity of the ecosystem of the coastal lakes can be achieved. However, to be successful the long-term management of the causes and impacts of the accelerated eutrophication of these lakes and ponds requires a balance between what is good for the ecosystem and what is good for the user community. This begins with a clear understanding of the ecological and assimilative capacity of the ecosystem in question. This means that before any restoration efforts are initiated a sound water quality database must be established. It also requires formulating a balance between the contradictory goals of continued watershed development and lake restoration.

It is a natural occurrence that people are drawn to water, and it is the positive attributes of the coastal lakes and ponds that resulted in a steady increase in the development of their watersheds. But, as reflected in their current condition, the ecosystem of these lakes and ponds is fragile. Over time the attributes of the coastal lakes that drew the public to Monmouth County in the early 1900s resulted in the alteration and impairment of these waterbodies. With increasing human activity came changes to the ecology of the lakes. Again, as evidenced by the current state of most of the lakes, the resulting water quality changes were not for the good. Although the public cannot easily relate to elevated phosphorus levels or exceedances in total suspended solids, they do relate to the ramifications of algae blooms, nuisance growth of aquatic plants and sediment infilling. As such, emphasis is given in the recommendations following to management measures aimed at correcting the cause of the lakes' degradation while at the same time improving the lakes' ecology, water quality and recreational potential. This will be different for each coastal lake and pond. Additionally, it will require a balance between what is good for the lakes and what is feasible in terms of practicality, cost, environmental regulations and community expectations and needs.

IV.2 The Need for Stormwater Management

When formulating recommendations for the long-term management of the coastal lakes and ponds of Monmouth County, emphasis has to be given to the control of stormwater runoff. This is the key to the sustainable improvement of the County's lakes. Better management of stormwater runoff will:

- Decrease the erosional forces that scour and destabilize tributaries;
- Decrease the mobilization and transport of sediments that fill the lakes;
- Decrease the amount of nutrient loading responsible for the eutrophication of the lakes;
- Decrease pathogen inputs that result in lakes being unfit for swimming and contact recreation; and
- Decrease the influx of floatables and debris carried in from parking lots, roads and other large areas of impervious cover.

While this may be the obvious solution, the successful implementation of measures that can achieve the desired results remains an abitious goal. This is largely due to the extent to which the lakes' watersheds have become developed, the lack of land for regional stormwater management facilities, and an apparent misunderstanding of the direct link between better stormwater management and improved lake conditions.

To achieve measurable, sustainable improvements in lake quality, the management of stormwater must be all encompassing and include provisions that address existing problems and include a framework that protects against future problems. Stormwater management must include both source control and delivery control techniques. As will be discussed in detail herein, source control techniques reduce or prevent the generation of runoff and associated pollutants. Such controls are best exemplified by ordinances and regulations. Delivery control techniques intercept runoff and treat or control it in a manner that reduces the overall volume of runoff and associated influx of pollutants. These techniques are best exemplified by structural best management practices (BMPs) such as bioretention and infiltration basins, but also encompass non-structural stormwater management measures and even land development and re-development techniques.

However, even if it was possible to put in place all of the stormwater management measures needed to reduce exiting impacts to the lakes and prevent their further deterioration, action would still be needed to rectify past impacts and restore these lakes to their full ecological, water quality and recreational potential. Therefore, along with watershed-based management measures there is a need for the implementation of in-lake restoration measures. These are the actions that result in the removal of accumulated silt, management of dense algae blooms, control of aquatic weed growth and the improvement and restoration of aquatic habitats and aquatic communities. In many cases to achieve the desired improvements in lake quality, restoration measures must also be implemented in the lakes' feeder streams and tributaries. Over time these waterbodies have succumbed to the same aforementioned impacts caused by watershed development. This includes poor water quality, as well as severely eroded stream channels, minimal base-flow and loss of ecological services and functions attributable to the filling and alteration of the floodplains, wetlands and riparian areas once associated with these streams.

To achieve long-lasting, significant improvements the restoration and management of the coastal lakes must follow a three pronged plan that:

- Controls, reduces or eliminates existing stormwater related impairments;
- Prevents or correctly mitigates potential future stormwater impairments; and
- Repairs and restores the lost services and functions of the lakes and their tributary streams.

As noted above, this requires a combination of source control, delivery control and restoration measures implemented within the framework of a well-developed, systematic plan. Because many coastal lakes and ponds are located within more than one municipality and are impacted by upstream land uses, a coordinated regional approach and support for restoration and management is warranted.

This is easier said than done given the existing institutional environment and the complexity of State, County and local government interests and regulations affecting the coastal lakes and their watersheds. It is also daunting when one considers the cost associated with the implementing such an effort. Current coastal lake restoration and management efforts in Monmouth County are diffused among governmental agencies, local communities, lake associations and commissions, citizen groups and other NGO groups. These efforts vary substantially being dependent on the capacity and authority of various planning entities and the limited sources and amount of funding available to actually implement the needed management measures. The goal of a regional restoration strategy for Monmouth County's coastal lakes is to provide the framework within which the water quality of the coastal ponds and lakes can be measurably improved. More so, their water quality must consistently exceed the State's minimum standards so that they can be returned to swimmable and fishable conditions. Doing so will enable these lakes and ponds to satisfy desirable ecosystem functions and support community-based, socio-economic values.

IV.3 Achieving Sustainable Improvements in Water Quality

As noted above, the success of any actions implemented to achieve long-term measurable and sustainable improvements in the condition of Monmouth County's coastal lakes and ponds must focus on the control of stormwater. This must involve both the reduction of pollutant loading and the reduction of the volume of runoff. To do this effectively, both source control and delivery control techniques must be implemented. The following paragraphs discuss the recommended stormwater control measures that can reduce stormwater related problems, starting with source control techniques and then followed by delivery control techniques. It should be emphasized that many of the measures discussed below are currently required by State regulations (N.J.A.C. 7:8, et. seq. and 7:15, et. seq.) but are either poorly enforced, or yet to be implemented on a local level.

IV.3.1 Source Controls - Local Ordinances and Regulations

Local ordinances serve as the cornerstone of any source control initiative designed to decrease bacteria, nutrient, sediment and contaminant loading to the lakes. Local ordinances are also a key element of any action taken to control the rate and volume of runoff or to promote its infiltration and recharge. Likewise, local ordinances are key to the implementation of stream-side and riparian corridor buffers intended to protect the lakes' tributaries from further impacts.

The following are examples of regulatory measures that, when consistently implemented throughout a lake's watershed, can greatly alleviate, correct and reduce outstanding water quality problems. As noted above, some of these regulatory controls have already been enacted by some of the coastal municipalities as part of their adopted and NJDEP required municipal stormwater management plan (MSWMP). However, in many cases, though adopted, implementation has been slow and enforcement lacking.

IV.3.1A Nutrient Reduction Strategy - Fertilizer Application Ordinance

Elevated levels of nutrients, particularly phosphorus, have directly led to the eutrophication and degradation of the ecology of the coastal lakes. The eutrophication of the lakes is best illustrated by the excessive and accelerated growth of algae and aquatic plants (weeds) that characterize many of the lakes and degrades their aesthetic and recreational values. When applied improperly, excessively or at the wrong time, runoff of phosphorus containing fertilizer contributes to the eutrophication of the lakes. Most soils in New Jersey contain sufficient amounts of phosphorus to support adequate root growth for established lawns. Although phosphorus replenishment may at times be necessary to sustain a healthy lawn, generally the amount applied far exceeds the amount actually needed. Soil tests can determine the type of fertilizer and fertilizer application rates needed to sustain a healthy lawn. But such tests are rarely performed, and as a result fertilizers are not applied in the most optimal manner, or in a manner consistent with the protection or restoration of the lakes.

A solution to the improper or excessive use of fertilizers is to regulate their use by means of an ordinance. A non-phosphorus fertilizer application ordinance will help protect water quality of the coastal lakes by aiding in the overall decrease in phosphorus loading. The ordinance will have its greatest positive impact when implemented to regulate the use of phosphorus fertilizers on lakeshore lawns. However, its utility and benefit can have watershed-wide benefits. A number of lake communities have implemented non-phosphorus fertilizer ordinances. Such ordinances are in effect in Sparta Township (Sussex County), Borough of Mountain Lakes (Morris County) and the municipalities bordering Lake Hopatcong (Hopatcong, Jefferson, Roxbury and Mt. Arlington). There is also a model lawn fertilizer ordinance promoted by NJDEP as contained in the Tier A Stormwater Management Guidance Manual.

A fundamental element of any fertilizer ordinance must be soil testing. Thus, it is recommended that a coastal lake fertilizer ordinance require a soil test be conducted prior to the selection and application of lawn fertilizers. Additionally, the ordinance should stipulate that only lawn fertilizers that contain no more than 2% phosphorus or other compounds containing phosphorus, such as phosphate, may be applied to all lawns that border any coastal lake and the streams feeding the lake. Allowances can be made for the establishment of new lawns. Additionally, municipalities should work with local businesses to promote low phosphorus products, including retailers of such products and commercial lawn maintenance operations. This has greatly increased the success of such efforts in the Lake Hopatcong and Lake Mohawk watersheds and could serve as a model for the lake communities in Monmouth County.

IV.3.1B Stream Protection Strategies

Riparian areas provide various functions, many of which are a direct benefit to public health and safety. This is best exemplified by the flood attenuation capabilities of riparian areas (floodplains). Ecologically, riparian areas provide critical habitat for many aquatic organisms or organisms that use coastal lakes for foraging, nesting or refuge habitat. Riparian buffers are also important in the maintenance of water quality as they serve to filter runoff, decrease runoff volumes and flows and maintain the physical stability of the banks of streams or lakes. When riparian buffers are undisturbed and in a natural vegetated state, the combined ecological function of the stream and the riparian corridor is maximized. Riparian buffers provide the following ecological functions:

- Provide shade that reduces water temperature;
- Filter sediments and other contaminants;
- Reduce nutrient loads of streams;
- Stabilize stream banks with vegetation;

- Reduce erosion caused by uncontrolled runoff;
- Provide riparian wildlife habitat;
- Provide and protect fish habitat;
- Maintain aquatic food webs;
- Provide a visually appealing greenbelt;
- Provide recreational opportunities; and
- Reduce flooding by absorbing water.

In contrast, as the riparian corridor becomes increasingly denuded of vegetation, and then subsequently colonized by non-native, invasive vegetation or increasingly covered by impervious surfaces, these areas lose their ecological function and their ability to reduce or mitigate the impacts of stormwater runoff. The protection of riparian corridors through the implementation of riparian buffer ordinances is important.

Buffer width is an important factor in maintaining the functional attributes of the riparian corridor, including maintenance of the water quality and ecological function of the associated waterway. Even a small buffer (i.e. 25 feet in width) provides some benefit to the physical stability and ecological services of the stream. However, as recognized by the NJDEP, riparian corridor widths of greater dimension are more likely to substantially reduce polluted runoff, provide an effective habitat for wildlife, ensure flood control and maintain the stability of stream banks and lake shorelines. Currently the NJDEP, through the Flood Hazard Area Rules (N.J.A.C. 7:13), mandates at a minimum a 50 foot riparian buffer along all waters of the State. This buffer width can increase to as much as 300 feet depending on the presence of threatened and endangered species and the classification of the stream or lake as a Category 1 (anti-degradation) waterbody. In the case of the coastal lakes, based largely on the very unstable sandy soils and at times acidic clays that characterize the shoreline of streams and lakes, it is recommended that the minimum riparian buffer be 100 feet as measured from the top of the bank of either a stream or lake/pond. A Riparian Buffer Conservation Ordinance will prevent further degradation of riparian areas and ensure that streams have a functioning riparian buffer. This will aid in reducing the amount of sediment, nutrients and other pollutants entering the coastal lakes.

It is recognized that the lands adjacent to many of the streams, as well as the lake shorelines, are extensively developed. Thus, it could be argued that such a regulation is meaningless. However, disturbances of riparian areas still occur in some communities as part of the redevelopment of lake front lots. With the removal of existing homes and their replacement with larger dwellings comes the desire to clear the natural vegetation and install lawn cover. A riparian buffer ordinance would limit such clearing. Likewise, new development in the more distal reaches of the watershed of some of the coastal lakes is taking place and such an ordinance would protect against expanded stream related impacts. Finally, such an ordinance can come into play even in commercial redevelopment scenarios, where steps can be taken to actually reclaim past impacted riparian areas. Therefore, although arguably of limited value where the riparian areas have been filled over and paved, protection of remaining lakeside or stream-side riparian areas has its place in the overall management and restoration of the coastal lakes.

IV.3.1C Waste Reduction Ordinances

Yard waste (grass clippings and leaves), pet waste and floatables (litter and urban debris) all negatively impact the water quality and aesthetics of the county's coastal lakes. The State's stormwater rules (NJAC 7:8) require municipalities to enact and enforce ordinances to control such pollutants. Most of the communities have entered into programs to label catch basins with "Drains to Lake" stencils or similar markers, or to install "ecogrates" to reduce the passage of debris into catch basins. Yet, even with these measures in place, the public continues to use catch basins as waste receptacles ignoring the consequences their actions have on the quality of their lake. A recent study shows that the phosphorus generated from grass clippings blown into storm drains and catch basins can represent a substantial source of nutrient loading (England and Smith 2009). Yet homeowners and lawn contractors continue to blow or dump grass and leaves down catch basins. The organic material can also increase the biological oxygen demand in the receiving system and trigger declines in dissolved oxygen. In addition to impacting water quality, dumped yard waste can clog stormwater systems and cause localized catch basin flooding that in turn required maintenance at municipal expense. Although the stormwater rules explicitly require the management of yard wastes, recent municipal budget cuts have caused some towns to significantly reduce, and in some case completely eliminate, municipal yard waste collections. This perpetuates the problem and increases the likelihood for curbside dumping. The same can be said for pet waste and litter. Again, although the public has been informed and educated the problem persists. Reduction in loading from these sources will require both ordinances and continued public education.

IV.3.1D Canada Goose Control

Canada geese have created a number of significant problems in the coastal lake and ponds. These waterbodies, due to their setting and history, have become refuges for large numbers of geese. As a result of high year-round densities of these birds, problems such as eroded shorelines, excessive nutrient loading, elevated fecal coliform concentrations, and diminished aesthetics of adjacent lawn areas have been repeatedly documented. Although the public has been informed of the water quality, aesthetic, and health problems attributable to geese, the feeding of Canada geese continues. There is also often wide-spread resistance to the control of geese even though most acknowledge that the nutrients and pathogens associated with the waste material of geese cause algae blooms, unpleasant odors and sanitary problems.

In response, all of the coastal lakes should be encouraged to institute a goose management program as part of their source control efforts. There are a variety of strategies that can be included in such programs. An element of any program should be an ordinance prohibiting the feeding of geese, on at least municipally owned or managed properties. This prohibition will help prevent nutrients, organic pollutants, and pathogens associated with the fecal material of Canada geese from entering the lakes and their tributaries. The control of geese will also help prevent overgrazing of common lawn areas thus avoiding erosion related problems. Supplementing any feeding ordinance should also be an educational program and related outreach materials posted on the municipal websites. Lastly, population control measures should be considered. These can include direct measures like egg addling and indirect measures like shoreline landscaping modifications that remove open grazing areas attractive to geese.

IV3.1E Zero Silt Runoff Requirement

A unique element of the Regional Stormwater Management Plan developed for Deal Lake is a proposed Zero Silt Runoff Ordinance. Given that watershed-based sediment loading is a major problem for most of the coastal lakes and that most of the lakes and ponds are impacted by accumulated silt and are in need of dredging, any measure that reduces the influx of sediment is a positive. Even with the passage of the new stormwater regulations, new development and the redevelopment of previously developed properties continues with minimal effort to control sediment loading. The NJ Soil Erosion and Sediment Control Standards apply to all new construction disturbing greater than 5,000 square feet. The Deal Lake Regional Stormwater Management Plan (RSWMP) calls for the imposition of the State's erosion control standards on all new construction and redevelopment related activities occurring within 500' of the lake or any of its tributaries that disturbs greater than 1,000 square feet. Projects determined to be subject to the Zero Silt Runoff requirements will first develop and submit for the review and approval by the Deal Lake Commission (DLC) the proposed erosion and sediment control plan before submitting it to the Freehold Soil Conservation District. The plan must identify in detail the measures that will be implemented to avoid soil disturbance and mitigate any such disturbance so that at any time over the course of the subject project no silt is conveyed into the lake, its tributaries or a stormwater collection system that discharges to the lake or its tributaries. The erosion and sediment control plan must include access approval for the DLC or its representative to inspect all erosion and sediment control practices proposed for a project over the life of the project. The DLC or its representatives will be allowed access to the site for routine inspection at a minimum weekly and following every significant rain event. In addition to the standard erosion and sediment control techniques and materials (e.g., hay bales and silt fencing), developers will be encouraged to use additional runoff management techniques such as:

- Ultra-Inlet Guard®
  http://www.spillcontainment.com/inlet-guard
- IPP Inlet Filter http://www.blocksom.com/sedimenterosioncontrol_moreinfo.htm
- Ultra-Drain Guard®
  http://www.spillcontainment.com/drain-guard-ultimate-model

For construction or disturbed sites where extreme conditions exist (e.g., slopes > 15%, located within 100 feet of the lake, etc.) the DLC will encourage developers to use advanced soil erosion control practices including polymers, erosion control blankets, fiber matrices and bioengineering soil stabilization techniques. The Zero Silt Runoff

Ordinance would also require developers to follow a regular schedule for the maintenance of approved soil erosion control, sediment trapping devices, or other measures implemented to retain soils on the project site. Inspections of active construction sites would be conducted by trained professionals identified and hired by the developer, and supplemented by periodic independent inspections of the project sites conducted by municipal or Deal Lake Commission personnel.

Given the pervasive nature of sediment loading to the coastal lakes, it is recommended that all the coastal lake communities consider adopting an ordinance or regulation similar to the Deal Lake Commission's Zero Silt Runoff element of the Deal Lake RSWMP. If such an effort was implemented county-wide, each and every construction site, whether a new or re-development project, would be required to adhere to the more aggressive erosion control strategy outlined above. This would have a positive impact on the lakes and add to the longevity of any dredging or sediment removal project.

IV.3.2 Delivery Control Techniques

Delivery control techniques, also referred to as structural best management practice (BMPs), are used to control the rate of flow, decrease the volume of runoff and especially, reduce the pollutant load conveyed with stormwater runoff. Within the next sub-sections of this report a variety of delivery control techniques that are suitable for use in the management of the coastal lakes are reviewed. All of the highlighted BMPs are designed to treat stormwater runoff passively; there are no pumps, moving parts, or mechanical devices used to control or treat the runoff. Most rely on detention, infiltration, settling and simple filtration to manage the collected runoff. This makes these devices easy to maintain. Additionally, the majority of the stormwater BMPs highlighted below are particularly well suited for use in the highly urbanized watersheds that characterize the coastal lakes of Monmouth County in that they can be readily integrated into existing stormwater collection and conveyance systems. Thus, their installation does not require a lot of (or in most cases any) land. The technologies are also recognize by NJDEP as suitable BMP approaches to the management of runoff and all are consistent with the requirements set forth in the stormwater management rules, the performance and design standards of the NJDEP BMP manual and the Tier A stormwater management guidance manual.

It is stressed that there are numerous additional BMPs other than the delivery control techniques presented below that would be suitable and would work well for the coastal lakes. Therefore, other stormwater management options should not be dismissed. As will be discussed at the close of this section, it may in fact be possible as part of redevelopment projects to construct large basins that could be used to manage runoff regionally. The same could potentially be accomplished through large-scale stormwater efforts funded under the NJDEP 319(h) program. Therefore, although this section of the report focuses largely on basic infrastructure retrofit delivery control techniques, it should not be viewed as the only approach for the management of stormwater problems for the coastal lakes. Consideration on a case-by-case basis should also be given to delivery control techniques including recharge basins, drywells, regional bioretention basins, green roofs, and created wetlands.

IV.3.2A Manufactured Treatment Devices and Retrofit Solutions

As discussed at the beginning of Section IV, improperly managed stormwater runoff is responsible for most of the problems impacting the county's coastal lakes and ponds. The most effective way to deal with the pollutants and erosion related problems caused by runoff is to intercept it and treat it before it enters the lakes. However, the age, design and capacity of the existing storm water infrastructure associated with most of the coastal lakes makes this difficult to accomplish. Additionally, the lack or cost of available land greatly precludes opportunities for the construction of large surface BMPs such as regional basins. Faced with these limitations one of the more feasible options is the retrofit or upgrade of existing stormwater infrastructure using manufactured treatment devices (MTDs). This section of the report focuses on the utility and application of such devices.

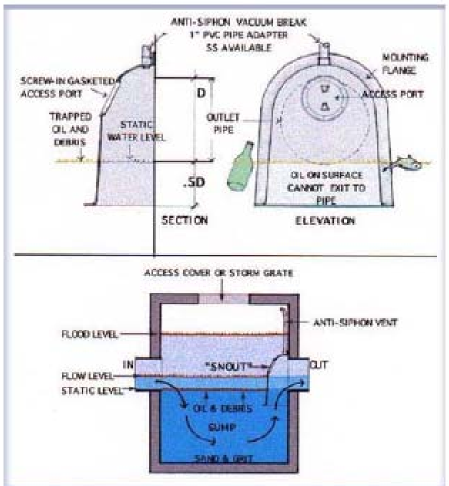
Stormwater retrofits are essentially modifications or enhancements of an existing stormwater conveyance system to improve the system's pollutant reduction capacity. The advantages to retrofits are that they require substantially smaller amounts of space for installation than do the construction of at-surface basins and related BMPs. They are also typically less expensive to implement. A list of some stormwater retrofits that would be applicable for the coastal lakes is provided below. Illustrations of examples of each of these BMPs are also provided. The installation of each retrofit is dependent upon site specific conditions that need to be assessed.

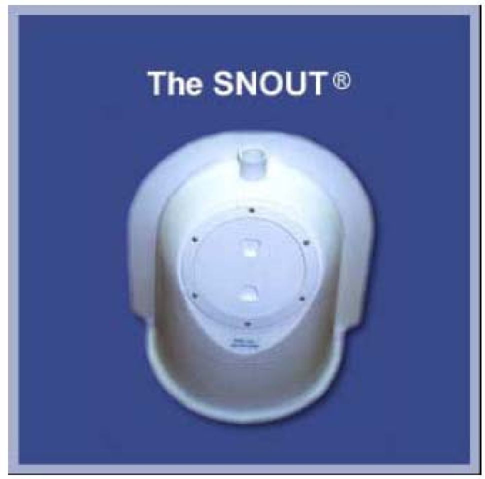
- ***SNOUT Oil-Water-Debris Separator*** - Converts an existing catch basin into a water quality inlet. Primarily for oils, particulate material and trash. Not overly effective, but inexpensive and at least capable of decreasing the transport of sediment into the lake. Requires very little modification of the existing catch basin structure. Typical cost including installation $500 to $1,500.

- ***Water Quality Inlets*** – Filter inserts, baffle systems or sumps that slow and/or passively filter the incoming stormwater thereby removing sediment and particulates. The sumped basins should infiltrate the retained stormwater into the ground, thus consideration needs to be given to depth to groundwater or bedrock. These easy to implement and relatively inexpensive retrofits can effectively reduce floatables, particulate pollutants and pollutants adsorbed on sediment particles (e.g. phosphorus). Typical cost with installation, $1,500 to $3,000.

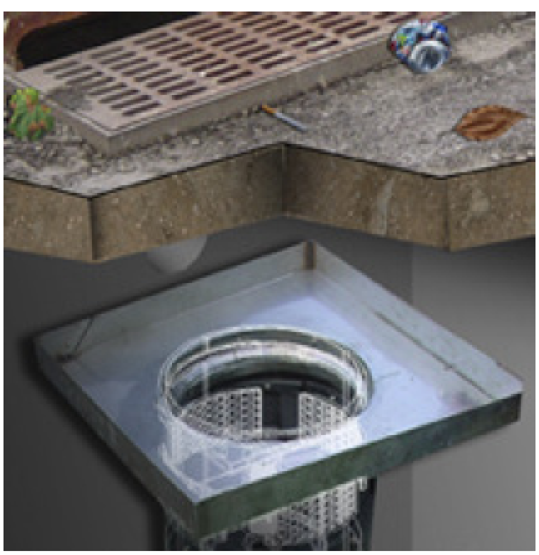
- ***Manufactured Treatment Devices (MTDs)*** - Available through a variety of manufactures (e.g., Stormceptor, BaySaver, SunTree, Vortechs, etc). These larger and more sophisticated MTDs use various types of hydraulic techniques to separate sediments and particulate material from the stormwater stream. These devices yield at least 50% Total Suspended Solids (TSS) removal and some can decrease nutrient and pathogen loads as well. Typical cost with installation $60,000 - $150,000.

Snout Catch Basin Insert Device





Catch Basin Inlet Filter



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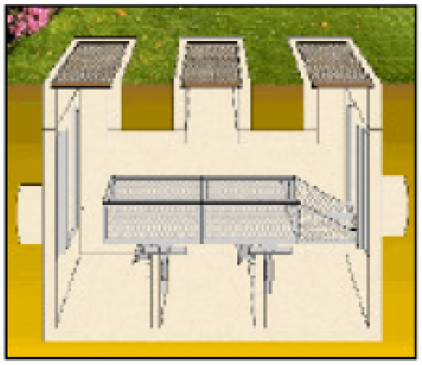
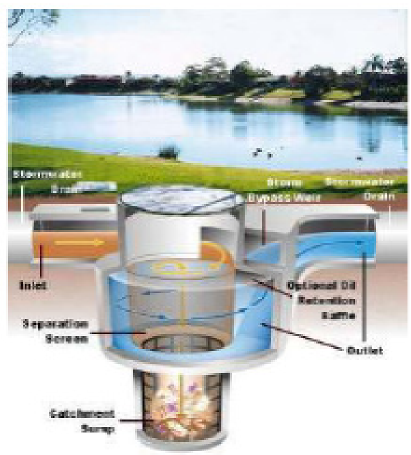
<tr><td colspan="2"> </td></tr>
<tr><td></td><td>
</td></tr>
</table>

Illustrations courtesy of:
Baysaver Technologies http://www.baysaver.com
Suntree Technologies http://www.suntreetech.com
Stormceptor http://www.stormceptor.com
Best Management Products, Inc. http://www.bmpinc.com
Aquashield, Inc. http://www.aquashieldinc.com

Prior to implementing any stormwater retrofit project it will be necessary to accurately map and detail the existing stormwater conveyance system. This information is critical in properly sizing and even in selecting the appropriate BMP.

The types of retrofits discussed and illustrated above have been used to manage the runoff in New Jersey lake communities that share many of the same land-limited and development issues as the coastal lake communities. For example, using 319(h) funds, these types of MTDs have been used to successfully correct runoff related problems in the Lake Hopatcong and Greenwood Lake watersheds.

IV.3.2B Bioretention Swales and Basins

Although there may be limited opportunity for the construction of new regional stormwater basins, it may be possible to retrofit an existing basin to increase its pollutant removal and sediment trapping efficiency. Such opportunities often arise as part of a redevelopment project on commercial or retail sites, or may be possible using NJDEP funding to improve existing municipally-owned and operated basins. Biotreatment techniques make use of vegetation and special amended soils to maximize the removal of pollutants by the introduced plants. This is accomplished via filtering, settling or assimilation processes. The basins may also be designed to promote the recharge of the collected runoff, thus decreasing the volume of water discharged downstream of the basin.

Bioretention BMPs typically fall into two broad categories: swales or basins. A swale is a wide, man-made shallow ditch used to temporarily store, route or filter runoff. Swales are often used in rural areas in place of a conventional curb and gutter to collect and convey stormwater, but can be used in urbanized areas as well. When properly designed and used in combination with other structural stormwater measures, bioretention swales can substantially improve the quality of stormwater. This is accomplished in two ways. First, the vegetation present in the swale will reduce runoff velocity. The extent to which this occurs is dependent on the length, depth and gradient of the swale, as well as the density of the vegetation. As the runoff is slowed, sediment particles begin to settle out of the stormwater stream. Second, a portion of the runoff discharged to the swale will infiltrate into the soil, reducing the volume of runoff. The extent to which this occurs is dependent on soil moisture conditions, the gradient of the swale, the properties of the underlying soils, and the velocity of the runoff.

Bioretention basins are relatively large excavated depressions into which runoff is conveyed and detained for treatment and renovation using specific types of plants. These BMPs have high pollutant removal efficiencies, on the order of 90% Total Suspended Solids (TSS) removal, and as much as 75% Total Phosphorus (TP) removal. The biggest drawback with conventional bioretention basins is the amount of land needed for their construction. However, as noted above, most conventional detention basins (the standard type of stormwater BMP constructed starting from the mid-1980s) can be easily and effectively renovated to function as a bioretention BMP. In addition to swales and basins, small bioretention systems are being used more frequently in highly urbanized areas. These so-called pocket BMPs, or small scaled versions of bioretention basins include the rain gardens and streetscape treatment systems as illustrated below. These applications are especially well suited for small catchment areas and existing developed neighborhoods.

http://www.filterra.com/index.php/product/

http://www.rainkc.com/

As with any BMP, even a simple retrofit will require maintenance to optimize their long-term operation and effectiveness. The frequency of maintenance for the basin inserts and filters is greater than that needed for larger BMPs. This is a function of their limited size and high trap efficiency. The need for maintenance increases during particularly wet years when loading increases. The sediment, debris and leaf litter collected by the inserts and sump type BMP retrofits usually needs to be removed twice per year. This can be accomplished using a vac-all, hand labor or a small clam shell. The bioretention basins normally need to be mowed once per year and perhaps the accumulated sediment removed once every 2-5 years. The stormwater retrofits discussed above are very cost effective delivery control solutions and will reduce the nutrient and sediment loads (i.e. phosphorus and suspended solids) entering the coastal lakes via stormwater runoff.

IV.3.3 Stream Bank Stabilization

As noted earlier, a major problem that has arisen due to improper or inadequate stormwater management is the erosion and de-stabilization of the banks of the tributary streams of the coastal lakes. The sediment present in the beds of the streams represents a type of legacy load that is continually replenished by the failing banks and subsequently pushed down stream into the lakes by each storm event. The erosion of the streams is exacerbated by the sandy nature of the county's predominant soils. Over time as the stream banks become exposed, denuded of vegetation and subsequently eroded, bands of clays have also become exposed. The clay lenses tend to be acidic and difficult to revegetate or stabilize. Stream bank erosion is itself the most significant underlying cause of the sediment infilling of many of the lakes, and unless corrected will continue to plague the quality of the affected lakes and ponds. As is the case with any remedial action, before money and time is spent in correcting stream erosion problems a comprehensive reconnaissance of the streams draining to the coastal lakes must be conducted, engineering plans prepared, projects ranked and prioritized and all the required NJDEP permits obtained.

Depending on site-specific conditions stream bank stabilization projects can involve the implementation of standard structural engineering techniques (i.e. rip-rap, gabions), soil bioengineering techniques (i.e. biologs, installation of vegetation) or a combination of both. Stream bank stabilization costs are highly variable and dependent on a number of factors, but tend to range from $50.00 and $175.00 per linear foot. The price per linear foot can be decreased if municipalities provide the needed equipment and some of the labor. Another means of reducing the costs is to have volunteers assist with the planting when the solution entails the implementation of soil bioengineering techniques. Volunteer assistance may include boy or girl scouts, middle or high school students, concerned local citizens, civic groups or Americorp personnel.

IV.4 In-Lake Restoration

In-lake restoration measures are the actions taken to remediate the impacts of watershed development. These are the actions that the public typically want implemented first as they are designed to decrease or correct the impacts of watershed development. When done correctly, these measures can dramatically improve the quality, aesthetics and recreational potential of a lake. But, unless backed by watershed management measures that control the causes of lake eutrophication, infilling and other impairments, the results may be short lived. Additionally, some of these measures (such as those geared at controlling the growth of algae and weeds) should be viewed more as maintenance as opposed to management actions as they will definitely need to be repeated both intra- and inter-annually. The following provides an overview of some of the more typically implemented in-lake restoration measures, all of which have some merit in the management of the county's coastal lakes and ponds. Again, it must be stressed that implementation of any of these measures is part of long-term management plan developed from a robust database that has accurately established the root-causes of the lake's problems and has identified the proposed measures as a correct "fix". In the following section, in-lake restoration options are divided into five main categories:

- Algae control;
- Macrophyte (aquatic weed) control;
- Dredging;
- Alum treatments; and
- Aeration.

IV.4.1 Algae Control

A variety of products can be used to control nuisance algae blooms. These include biological products, conventional algaecides, non-conventional algaecides and even physical methods of control. Although the following is not comprehensive it does cover all of the most commonly used products and techniques. Each has its limitations. In particular, copper based algaecides must always be applied carefully and in a manner cognizant of their potential negative consequences. Any type of control or treatment should only proceed after the offending algae species has been correctly identified. The treatment program should also call for some monitoring of lake water quality (pH, dissolved oxygen and alkalinity) to ensure the treatment will not trigger a negative impact on the lake's fisheries. In all cases the product should be used in moderation and as part of a program that also reduces the influx or availability of nutrients.

IV.4.1A Algaecides

The most commonly implemented technique used to control algae blooms involves the application of some form of algaecide; a chemical that specifically kills algae. These products are licensed for use in the aquatic environment by both the U.S. Environmental Protection Agency (USEPA) and the NJDEP and are effective in the control of both mat (filamentous) and planktonic forms of algae. The filamentous forms of algae are those that create dense mats. These mats initially form on the bottom of the lake or pond, but eventually rise to the surface creating the appearance of cotton candy or a floating blanket. The planktonic or phytoplankton forms are microscopic and remain suspended in the water column, although some will accumulate as scum at the surface. These algae encompass a broad range of species and groups ranging from diatoms to cyanophytes (blue-green algae). Not all planktonic algae, such as the diatoms, are considered problematic, but some groups, such as the cyanophytes, routinely form dense blooms. Most of the coastal lake algae related problems are due to mat algae or cyanophyte blooms. The blooms typically intensify in the middle of the summer and can render a lake unfit for recreational use. Although an algaecide application is typically very effective in eliminating or controlling these blooms, as noted below these products must be used cautiously and conservatively.

The most frequently utilized algaecides contain some form of copper, typically copper sulfate ($CuSO_4$). Copper based algaecides provide an extremely effective means of quickly killing large amounts of algae for a small amount of money. As is the case with all aquatic pesticides, there are no pre-emergent products, meaning an algaecide application must occur after some amount of algae growth has developed in the lake. Additionally, the control of the algae is brief (2-4 weeks) meaning that repeat algaecide applications will be required. This is because these treatments only control a symptom of the lake's eutrophication problems (excessive densities of algae) and not the cause of the bloom (excessive nutrient inputs, inadequate flushing or circulation, etc.). The key to effective algae control using algaecides is to time the treatment before the bloom peaks and use as little product as possible. Doing so results in suitable control without creating some of the various problems associated with large-scale, high concentration applications of copper-based algaecides. These problems are detailed below. It must also be stressed that all algaecide treatments conducted in New Jersey must be done by a NJDEP Category V licensed pesticide applicator, and will require a permit from the NJDEP Pesticide Control Program and be implemented in accordance with the limits and stipulations of the NJDEP issued treatment permit.

Several undesirable environmental impacts are known to be associated with excessive or improper use of copper-based algaecide treatments. Negative impacts include fish and zooplankton toxicity, the depletion of dissolved oxygen, copper accumulation in the sediments, increased internal nutrient recycling and increased tolerance to copper by some nuisance species of blue-green algae. Zooplankton is planktonic organisms that feed on phytoplankton, bacteria and other microscopic organisms. They are a lake's natural means of controlling excessive algal growth. In sufficient numbers, zooplankton can, on their own, limit the development of algal blooms. Zooplankton is known to be more sensitive to copper than algae. In fact, copper sulfate is approximately ten times more toxic to zooplankton then it is to phytoplankton. In addition, the generation time of zooplankton is substantially longer than algae. Therefore, these organisms require a longer amount of time to recover from copper treatments relative to algae. While the phytoplankton community can recover from a copper treatment within 1-2 weeks, recovery of the zooplankton community may take several weeks. Thus, the phytoplankton tends to rebound quicker than other aquatic organisms from copper treatments. If copper treatments cause a decline in zooplankton densities, a perturbation of the lake's food web will be experienced, resulting in the loss of the natural control of algal densities. Miniminal use of copper based products will allow the zooplankton to proliferate and, in turn, graze on the algae.

There are other negative side effects of frequent copper treatments. After copper sulfate kills algae, and possibly other non-target organisms, in-lake rates of bacterial decomposition will substantially increase. Such elevated rates of bacterial decomposition will consume dissolved oxygen (DO). If bacterial respiration is too high, in-lake DO concentrations may decline rapidly to levels that trigger a fish kill. This is especially true during the summer months.

There are some alternatives to copper based algaecides. These products may not always be as effective, as quick or as cheap. However, when used properly they can control algae growth and avoid obnoxious blooms. These alternative products fall into three main categories:

- Oxidizing agents;
- Dyes; and
- Microbial products.

IV.4.1B Oxidizing Agents

All of the oxidizing agents require a permit for use and application similar to the copper-based products, as will some of the dyes, depending on how they are labeled. The microbial products on the other hand do not. The following provides a brief overview of how these products work.

As is the case with the copper-based algaecides, the oxidizing agents also kill algae. They also disrupt the cell wall, but do so using a peroxide-based chemical that causes an oxidizing reaction. These products tend to be far more costly than copper based algaecides but do not create the depressed DO conditions. As such, they tend to be safer for use when sensitive fish are present in the lake or pond. Additionally, there is no chemical residual as is the case with the copper based algaecides.

IV.4.1C Dyes

The dyes work by decreasing the penetration of light. Less light results in less photosynthesis, which in turn translates to less algae growth. There are a variety of dye products on the market. As noted above, some are labeled as an algaecide and require a NJDEP permit for their use. The impact of the dye will largely be a function of the lake or pond's flushing rate. The more water exchange or flushing that is occurring, the more frequently the dye will need to be reapplied. Normally, dye applications are limited to small lakes and ponds. These products can be used in concert with copper based algaecides and oxidizers to increase the longevity of the algaecide application. A jar test on the product should be conducted in advance of a dye treatment to ensure that the dye will not create too artificial a color or bind to suspended sediments, which can result in off color or a reduction in effectiveness.

IV.4.1D Microbial Products

Microbial inoculants are available as solid (granular) or liquid products. These products are essentially concentrated, common soil bacteria (*Nitrosomonus* and *Nitrobacter*) that are used to reduce the availability of nutrients for assimilation by algae. These bacteria are already present in lake and pond water, but not at concentrations high enough to control algae growth effectively. This is basically accomplished through nutrient competition by the bacteria. Theoretically, due to the quicker growth rates and turnover time of the bacteria, they should be able to reduce the availability of nutrients for assimilation by algae (mostly planktonic forms). It is important to note that the effect of these products is considered to be algaestatic (preventing new growth of algae) as opposed to algaecidal (killing existing algae). Hence, use of these products does not require a NJDEP permit. However, it should be noted that since these products do not kill algae, they need to be used in a proactive manner to inhibit growth, as opposed to being used to control or eliminate an existing bloom.

The effectiveness of these products is highly variable, with them working best for small, shallow ponds that flush infrequently and have moderate pH (7-8.5). The utility of these products is therefore largely limited with respect to the management of any of the larger coastal lakes (> 5 acres) or lakes that flush frequently which is the case for the majority of the coastal lakes and ponds. Typically a number of treatments are required throughout the growing season. The initial introduction of the inoculant is conducted in early spring before algae growth is substantial and continues with the reapplication of the product every 2-3 weeks over the entire course of the growing season (through September).

Barley straw is another type of product that falls under the microbial product heading. A significant amount of research has been conducted on the efficacy and mode of action of barley straw, with most of this work having been originally conducted in Great Britain by Dr. Brian Moss, but more recently by Purdue University, University of Nebraska and Iowa State University. Although results can be variable, the straw tends to be useful in controlling algae growth. The research suggests that the algae control capabilities of the barely straw are the result of one of two factors. First, as it decomposes the straw produces compounds including liganes, oxidized polyphenolics and hydrogen peroxide that inhibit or reduce algal growth (primarily planktonic forms). These products may either be exuded from the barley straw itself or created as a by-product of the metabolic processes of the bacteria and fungi actively breaking down the straw as it sits on the bottom of the lake or pond. The second mode of control may result from the uptake of nutrients by the bacteria and fungi actively breaking down the straw, with the control being similar in effect to that associated with the aforementioned bacterial inoculants. As is the case with the bacterial inoculants, barley straw is considered to have algaestatic as opposed to algaecidal properties.

Thus, to be effective the barley straw must be introduced before any substantial algae growth has occurred. This again means initiating any such program in the spring. The typical application rate is approximately 225 pounds of straw per acre of lake/pond. The bales are usually staked to the lake bottom. It is recommended that the bales be placed in some type of mesh or wire basket to prevent loose straw from floating and accumulating on the shoreline. Over the course of the growing season the bales may need to be replaced 2-3 times. Additional information and guidance on the use of barley straw is available through the Lake Water Quality Extension Program, University of Nebraska, the Centre for Aquatic Plant Management (http://www.exit109.com/~gosta/pondstrw.sht), and the North American Lake Management Society (www.NALMS.org). The utility of barley straw in the control of algae blooms in the coastal lakes may be hampered by two factors, the typically quick flushing rate of these systems (which could flush out the beneficial chemical products or bacteria) and their typical turbid nature (sediment settling on the straw may inhibit bacteria and fungi activity).

IV.4.2 Macrophyte Control

Weed or macrophyte control options suitable for the coastal lakes include a wide variety of physical, chemical and biological options. Each option has its advantages and disadvantages. Also, it is possible to utilize a combination of these measures to manage weeds in a single lake. The following provides an overview of these options beginning with the physical measures and ending with the biological control measures. To aid those seeking to properly manage invasive macrophytes, a brief primer is provided as Appendix A, to this report which touches on the life history and key biological attributes of some of the more commonly encountered weed species found in the county's coastal lakes and ponds.

IV.4.2A Mechanical Weed Harvesting

Mechanical control techniques involve the use of specialized machinery to cut, harvest, dislodge or uproot aquatic weeds. The machinery used in these operations tend to be paddle-wheel propelled, pontoon supported barges that both cut and collect aquatic weeds. This is one of the most common methods of aquatic vegetation control used in New Jersey, especially for the larger lakes. When correctly conducted, weed harvesting will not only reduce the density of nuisance aquatic weeds, but can effectively remove significant amounts of organic material and nutrients (Souza, et al.., 1988).

Weed harvesting is generally considered a non-selective weed management technique because all plants that come into contact with the cutting bar are cut and removed. However, through proper planning and operator training it is possible to limit cutting in prime fish spawning or nursery areas, or in areas where non-invasive plants are dominant. It is also possible through altering the depth of the cutter head to maintain a bottom “carpet” of plants. This can be advantageous in decreasing the propensity for benthic algal mat formation. It can also increase the efficiency of the operation, but may require multiple or repeat harvesting of the same areas over the course of the growing season. As such, selectivity can be increased through pre-harvesting surveys and directing the harvesting effort to areas where monoculture plant beds exist.

Mechanical harvesting is often viewed as a cosmetic or short-term measure for aquatic plant control. Although it provides immediate benefits in the area subject to harvesting, the effect may be temporary as plant growth is expected to continue. However the technique does, have the ability to quickly provide relief from surface canopies and dense underwater growth of nuisance plants. The tops of the aquatic plants are cut, removing the growing leaves, seed heads and nutlets and flowering parts of strongly rooted plants. Weakly rooted plants may be uprooted. For aquatic plants that propagate primarily from seed banks or nutlets, such as water chestnut, removing the top of the plant (which usually carries the seeds) prior to the maturation of the seeds can eliminate the following year of growth. Multiple years of harvesting may gradually deplete the bank of seeds in the sediments. It is recognized that fragments and “floaters” constitute a big problem with any harvesting operation. Harvester operators must therefore recognize this and be especially careful to collect and control the spread of plant fragments. This is important for a number of reasons. First, the resulting fragments can regenerate and create new plant growth in other areas of the lake. Second, the floaters will tend to pile up in windward areas creating a major aesthetic problem. Third, the retrieval of the wind concentrated floaters can result in a waste in operational time, money and resources.

Largely due to the capital investment (for the purchase of the equipment) or operational costs (to run and maintain the harvester or contract with a vendor for harvesting services), weed harvesting is an expensive proposition. Mechanical weed harvesting costs approximately $300 to $800/acre, and depending on the setting and density of weeds, most units can cut and remove weeds from 2-5 acres per day. The actual amount cut and harvested per day will be influenced by a number of factors ranging from the experience of the operator to the weather conditions. One of the biggest factors controlling productivity is the distance from the harvesting area to the disposal site. Essentially the harvesting operation becomes less efficient as the time involved in transporting cut weeds to shore increases. Docks, piers, stumps, hanging trees, irregular shorelines and rocks and obstacles will all impact operations and decrease the overall effectiveness of the harvester. Also certain plants, such as *Vallisneria* and the stalked algae (*Nitella*) may be more difficult to harvest. Areas where dense plant growth has occurred, although easier to harvest may require more time simply due to the frequency of off-loading.

In addition many of the coastal lakes and ponds lack an adequate launch area for these machines. Although they can be placed in the lake by cranes, this greatly adds to the overall cost of the operation. As noted above, harvesting will be impeded in areas with a high density of subsurface obstructions (stumps, rocks, etc.) or numerous piers, docks and other structures. For example, harvesting in Deal Lake is complicated by the numerous low bridges and causeways that span the lake's arms making these areas basically inaccessible to the larger machines. Finally, the utility of weed harvesting can further be impeded if the lake or pond is too shallow (<18"). Unfortunately, it is often these shallow areas that become the most impacted by weed growth.

Weed harvesters can also be purchased. The price of a medium-sized unit is in the $125,000 - $175,000 range. Along with the harvester a trailer and conveyor are also needed. These additional pieces of equipment may add approximately $75,000 - $100,000 to the overall purchase cost. In addition to the cost of the harvesters, there are operational and maintenance costs and additional labor associated with the transport and disposal of the cut weeds. Typical operational costs, based on the review of actual data compiled for Lake Hopatcong and Sodus Bay, NY are approximately $300 - 500 per day per harvester. These estimates include wages, insurance, unemployment, workman's compensation parts, maintenance, fuel, etc.

Although for a number of reasons one could conclude that weed harvesting is not a very well suited operation for the coastal lakes, the applicability and utility of this approach could be improved. First, weed harvesting operations should be conducted by smaller units (5' cutting swath). The machines are easier to launch, often have a collapsible bridge (thus enabling to pass under low causeways), and are much more nimble than the larger units. Second, rather than contract harvest of the lakes, a single harvester and related support equipment (conveyor and trailer) could be purchased by the county and through an inter-local agreement be used to manage weed growth using municipal personnel in each of the coastal lakes. This shared services approach would reduce overall costs of operation and maintenance and eliminate any downtime of the machine.

IV.4.2B Drawdown

Drawdown entails the temporary lowering of a lake for the purpose of exposing the lake bottom to achieve some degree of weed control. Typically conducted in the winter, a lake drawdown capitalizes on exposure, freezing and desiccation to kill plant seeds or destroy roots and rhizomes. Most drawdowns are conducted in the winter. Lowering of the lake is achieved by diverting inflow or opening a valve, gate or other type of control device at the lake's dam or outfall. The lake may be fully or partially drained, allowing the littoral zone to become fully exposed to the elements. Once lowered, the lake is left in this lowered and exposed state over at least a two-month period during the middle of the winter. Exposure of the hydrosoils within the littoral zone and any remaining plant biomass facilitates the freezing of the plants and seeds.

According to the literature, the success of such efforts are marginal with some plants being impacted and other plants actually becoming more robust or at a minimum showing no ill effect. Milfoil (*Myriophyllum* sp.) and Lilies (*Nuphar* sp. and *Nymphaea* sp.) tend to be negatively affected, but pond weed (*Potamogeton* sp.) may actually exploit such conditions and expand its coverage after a drawdown. This is especially true for curly leaf pondweed (*Potamogeton crispus*). This plant reproduces, in part, by the spread of turions, specialized reproductive seedpods. The leathery nature of the pods increases their resilience to exposure, desiccation and freezing. The resilient nature of the turions allows the curly leaf pondweed to expand its coverage into areas where other plants have been weakened or eliminated. Thus, the observation of increased densities of this plant is not uncommon following a winter drawdown.

A large negative factor of drawdown is the impact it can have on a lake's fishery. When a shallow lake is appreciably lowered for a long period of time, all overwintering habitat used by the lake's fish could be eliminated. This could lead to a major die-off of the lake's fishery.

In addition to weed harvesting, drawdown is often used to facilitate dredging operations. Typically, sediment removal can proceed more quickly, less expensively and with less secondary impacts when the sediments are removed dry. Obviously any large scale drawdown will impact a lake's fishery, as noted above. However, extended drawdown will allow the sediments to dewater in place, thus reducing the volume of material that needs to be handled or exported. Dry dredging" the lake will also allow the use of conventional construction equipment, which normally speeds up the overall operation and lowers the overall costs as compared to dredging involving hydraulic equipment. The lake's fishery could then be reestablished following the completion of the dredging operation by means of stocking specific game and predatory fish. Dredging and its role in the restoration of the coastal lakes is discussed in greater detail in a subsequent sub-section of this report.

IV.4.2C Hand Harvesting

Hand harvesting and related manual weed control measures are best suited for small areas due to cost, application and labor intensiveness. Private beaches, docking areas, and areas around bulkheads and piers are the ideal locations for the more commonly employed manual measures (hand pulling, diver assisted hand pulling, benthic mats, etc.). None of these measures are regulated by the NJDEP, and thus can be conducted without any permits.

Hand harvesting involves grasping the plant material as close to the sediment layer as possible, even digging into the sediment to grab the root crown, and pulling the intact plant out of the bottom sediment. Plants should be removed slowly to minimize fragmentation, and if possible the entire root system should be removed from the sediment along with the stalk or stem of the weed. Hand removal methods can be a preferred technique for sensitive environments that harbor threatened native plants, have intermixed community of desirable and nuisance plants or are important fish spawning areas (Cook 1993, Sutherland, 1990). Although limited by scope and the degree of effort, hand pulling can be an effective means of controlling unwanted weed growth.

In some cases, the removal of the weeds is conducted by divers who use suction equipment to transport the pulled weed to the lake surface. The one significant positive attribute of hand pulling of weeds, especially when it is done without the use of suction equipment or divers, is that it is relatively cheap. However, it is very labor intensive. Furthermore, the effectiveness of hand harvesting and hand pulling techniques are often dependent on sediment types. The soft, silty sediments that characterize most of the coastal lakes are ideal for hand harvesting operations, but their waters can become quickly turbid as a result of the disturbance of fine silts and organic materials. This decreases visibility, slows down the overall process and impacts the effectiveness of weed removal.

In general, the majority of reports dealing with hand harvesting and hand pulling of invasive plants conclude that it is most appropriate for small-scale weed control projects or for use in highly sensitive areas, where the invasive plants are growing intermixed with desirable native plants. A project of this nature coordinated by a local stakeholder group would be a terrific opportunity to increase public support for larger, more intensive and costly weed control options or to generate support for the watershed initiatives needed to control the causes of the lake’s eutrophication. Thus, although the applicability of this technique may be limited due to the scope of such projects, it has its place in the management of the county’s coastal lakes and ponds.

IV.4.2D Benthic Barriers

Benthic barriers, sometimes called benthic mats, benthic screens or bottom barriers, prevent plant growth by blocking out the light required for growth. All aquatic plants require sunlight. By inhibiting light penetration, the mats or barriers reduce photosynthesis ultimately leading to the die-off or control of all plants present underneath the barrier. Obviously this is a non-selective control strategy, meaning both desirable and invasive macrophytes will be impacted. However, while benthic barriers do not selectively control the underlying plants, the placement of the mats can be limited to areas dominated by a combination of invasive plants or areas where a monoculture of a particular invasive or nuisance plant occurs.

Many materials have been used as benthic barriers, including sheets or screens of organic, inorganic and synthetic materials, sediments such as dredge sediment, sand, silt or clay, fly ash, and combinations of the above (Cooke 1980b; Nichols 1974; Perkins 1984; Truelson 1984). The problem with using the non-screen or sheet techniques (aside from potential impact associated with the sediment material) is that new plants establish on top of the added layer (Engel and Nichols 1984). The problem with synthetic sheeting is that the gases released from decomposing plants and normal bacterial activities collect under the barrier, lifting it (Gunnison and Barko 1992).

The common element associated with the bulk of the more commonly used textile type products is that they are made of a negatively buoyant, gas permeable material. Such benthic barriers, in order to be fully effective should have the following characteristics: sufficiently opaque to block photosynthetically active radiation; durable enough to withstand physical abuse (foot traffic, scrapping by boat hulls, boat trailer traffic); be negatively buoyant; and allow for the escape of gases. It is also desirable for the material to possess a smooth upper surface to inhibit fragment rooting (Cooke, 1993). The material, which can run in sizes of 100' x 25-50' or even greater sizes, are typically laid down on the lake bottom early during the growing season in advance of the establishment of extensive plant growth. There is the need to anchor the material in place. The anchoring system can be readily available materials such as re-bar or concrete blocks, or product specific anchoring equipment that is slipped through the material into the underlying sediments, much similar to a tent stake.

In addition to limiting growth through the reduction in sunlight penetration, the barriers also provide a physical barrier to growth. The tightly weaved, open cell material will control plant growth by reducing the space available for expansion and physically limiting the development of the plant stem and leaves. In some cases, the mat can be placed over actively growing plants. Most aquatic plants present under the screen will be controlled within 30 days (Perkins *et al.* 1980). Unless the material is gas permeable, the resulting gas generated through the biological decomposition of the plant material can buoy the mat off of the bottom. For small applications, such as along docks and private beaches, the average cost appears to be in the range of approximately $1.10 per square foot installed. A typical installation (15' X 100') should be in the range of $1,500 to $2,000. The ability to reuse the material over multiple years will help to decrease the overall costs. This technique has a significant level of practicality for implementation in the coastal lakes, given that most are relatively shallow and have extensive littoral areas where weeds develop and grow quite easily. For the most part, benthic mats can be set in place and anchored by volunteers or private lake users after only minimal training. Applications in difficult sites, for example where water depths drop off quickly or where there are a lot of underwater obstructions or areas where heavy plant growth already exists, professional installation may be required. This obviously increases the cost. Most of the larger installations will require the use of scuba divers not only to set the material in place but also to anchor it to the sediments. The Army Corps of Engineers (USACOE) Vicksburg Experimental Laboratory offers the following recommendations and cautions concerning the use of benthic mats:

> *"…Covering sediments that normally exchange gases with the water column will trap gases. Covering clay or sand substrates where this type of gas generation is not extensive will limit that type of problem. Covering highly organic sediments will require that the operator consider this and develops a maintenance program to deal with it. In addition, if the barrier is placed over actively growing weeds, those plants will die and decompose under the mat. This will also create gas problems in the short term. Gas buildup can be dealt with fairly easily. The operator should have divers periodically inspect the mats and push gas bubbles*

to the edge of the mat, where they are released. Divers can also cut small slits in the material to vent this gas. Pinning the material to the bottom will also help."

IV.4.2.E Lake Sweepers

Lake sweepers are electric powered devices used to control weed growth in small areas, usually around bulkheads and docks. The repetitive, gentle disturbance of the sediment surface by the roller as it sweeps back and forth over the sediments impedes plant growth both as a result of the mechanical damage to the plants or the constant agitation of the sediments. The device can be free standing and anchored to a post centered within the control area, although most are designed for attachment to a permanent fixture such as a dock or pier piling. Operation of these devices requires a lake-side electrical power source. Depending on the product, weed growth in an area up to a 42-foot radius around the anchoring device can be controlled.

For the coastal lakes and ponds, lake sweepers are a very practical solution for the control of weed growth around private docks, piers and bulkheads. It is best to install and start operating these devices in the spring before plants begin actively growing. If they are operated after plants have grown, plants could be uprooted or detached from the sediment. In such cases, the detached plants should be removed from the water with a rake or gathered by hand. Once the plants are cleared from the area, the lake sweeper may only need to be used as little as one day per week or less to keep plants from re-colonizing the area. Therefore, it is highly likely that one unit could be shared by three to four lake front property owners. Little maintenance is required, but these units must be removed from the water in winter in areas where lakes are expected to freeze, as they will be subject to damage by ice flows. Cost varies between products, with some of the cheaper, more basic units starting at approximately $1,000 but the majority being in the $4,000 to $5,000 price range. The electrical costs associated with the operation of these units must be added to the overall costs, but this should be far less than $100 per year. Factors that may limit the practicality and utility of these units include the presence of large rocks, stumps and similar underwater obstacles, steep slopes and uneven bottom terrain. Obviously, their application is also limited to areas where electrical service can be provided (typically 110 volt, 8 amps).

IV.4.2F Hydroraking and Rotovating

Although rotovating and hydroraking have similar applications they are very different with the former creating a greater amount of bottom disturbance than the latter. However, rotovating usually achieves a longer period of weed control because of the extent to which the lake bottom is disturbed and the amount of seed stock and biomat removed as part of the process.

Rotovating and hydroraking can equally be used to control either weakly rooted plants such as Eurasian water milfoil and stone wort or densely rooted plants such as water lilies or reeds (*Phragmites)*. Each of these techniques can be used as an alternative or a compliment to standard mechanical harvesting (IV.4.2A). The machines used for either rotovating or hydroraking consist of a barge mounted cutter head, rototiller or deep tine rake that cuts and/or dislocates aquatic plants and their roots from the sediment. As with harvesting, the cut or dislocated plant material is removed from the lake.

As noted above, rotovators work in a manner somewhat similar to a rototiller operating on dry land. The blades of the cutter head, which may extend seven to nine inches below the sediment-water interface, disrupt the sediments and in the process dislodge and remove the plants including their roots. The dislodged plant and root material wraps around the cutter device. The material is then freed from the cutter head by reversing the rotation and dumped in a helper barge or a standard weed harvesting barge. In those cases where the dislodged plants are freed to float in the water column they will need to be removed with a conventional harvester.

The hydrorake essentially drags the rake’s long tines through the sediment in the process raking up rooted weeds, benthic algae and non-rooted weed masses. The material that collects on the rake is, as with the case of the rotovator, dumped into a helper barge or conventional weed harvesters. As with the rotovator, floaters and other freed material will need to be collected at the end of each day’s operation with a weed harvester.

Since hydroraking and rotovating removes the roots as well as the plant, the process is typically considered more effective than mechanical harvesting as they have the potential for providing a longer period of weed control. It has been demonstrated, because of its mode of action and the disturbance of the sediments, to be capable of maintaining low levels of weed growth for several seasons. For example, there are a number of studies showing this technique controlling Eurasian water milfoil growth (a plant with a weak root system) for as long as two years. As such, these techniques provide immediate relief. Depending on the size of the rotovator, the types of targeted plant material and site logistics they may work either faster or slower on per unit area than large scale harvesting operations. This method of plant removal also tends to be most efficient when the plants are shorter since longer plants tend to wrap around the spinning blades and may damage the equipment. However, it must be recognized that because most aquatic plants are annuals, new plant growth can easily occur if seeds have already dispersed.

A typical rotovator barge is approximately as large as a large (8’ cutter head) harvester. They tend to draft little water and thus may be able to operate in water as shallow as 18” – 24”. Given the size of the equipment, rotovators are typically limited to use in large waterbodies. Hydrorakes, by comparison are somewhat smaller, typically the size of a small to medium sized weed harvester. In some cases, due to their size and added maneuverability, hydrorakes are a better choice for working around docks and piers or in tight quarters. As with the rotovators, these units draft very little water. With respect to either unit, there may be the need to use a crane to transfer the unit into the lake. However, most of the more recently designed units can self-deploy much in the same manner as a typical weed harvester.

One of the most significant disadvantages of either technique is the turbidity that results due the disturbance of the sediments. In addition to creating turbidity problems, this can also lead to the release nutrients into the water column, create short-term oxygen demand problems and impact benthic organisms and fish. Most of these impacts can be avoided by erecting sediment curtains or turbidity barriers. Again, this adds to the cost of the operation. Due to their disturbance of the sediments and creation of turbidity, hydroraking and rotovating may also severely impact habitat critical to fish spawning.

The capital costs for rotovating and hydroraking machines are generally equivalent to the capital costs for mechanical harvesting, with machines ranging in price from $100,000 to $200,000. Operating costs are generally on the order of $200-300 per acre, with only about 1-3 acres per day being hydroraked or rotovated. If contracted out, the approximate cost of these techniques is on the order of $1,500 per acre (as based on our actual experience with sub-contracting such work). These costs and time estimates do not consider retrieval and disposal of the removed plants or the need to use a weed harvester in tandem with the rotovator/hydrorake to transport weeds to disposal areas. It should be noted that neither technique is selective, thus the operation will impact native, beneficial non-targeted plants growing in the same areas as the invasive weed species. Furthermore, rotovators, even more so than hydrorakes, cannot be easily maneuvered, making their use in cramped areas or areas with numerous obstructions difficult. Finally, neither type of machine should be used in areas having significant amount of underwater obstructions, such as rocks and logs, as large submerged debris can damage the equipment.

Overall, we feel that hydroraking in particular could successfully be used to control weed growth or remove accumulated organic debris from the coastal lakes. However, as is the case with the weed harvesters, deployment of the equipment will pose a challenge. Therefore, it is important to conduct a detailed survey of the lake or specific lake-area targeted for control. The survey should be used to establish the homogeneity of the targeted weed stand and the presence of any submerged obstructions that could impact the operation of either type of unit. To protect the lakes' fishery resources, we recommend that operations of this nature be conducted either in the late summer or early fall.

IV.4.2G Chemical Weed Control

Chemical weed control involves the application of specially formulated and approved herbicides by NJDEP licensed applicators operating under a permit issued by the NJDEP Pesticide Control Program. Chemical weed control is the most common technique used to control aquatic weeds in New Jersey's lakes, ponds and reservoirs. There are two basic types of aquatic herbicides: contact and systemic forms.

As the name implies, a contact herbicide kills plants through direct contact with the plant's surface tissue. In doing so, the product penetrates the cell wall and causes the cells to lyse or disintegrate. To be effective, contact herbicides need to be introduced only after weed densities have started to peak. Because of their mode of action, these products initially need to be added at least twice over the course of the growing season to control first the early growing plants and then control the plants that grow later in the summer. In some cases, depending on local climatic conditions and the nuisance species targeted for control, three or more treatments may be annually required through the course of one growing season. Each treatment, especially when conducted later in the growing season, increases the opportunity for phosphorus liberated from decomposing weeds to be channeled into algae biomass.

Contact aquatic herbicides function similarly to copper-based algaecides; that is they provide immediate, short-term control of excessive densities of nuisance aquatic plants. Thus, contact herbicides have many of the advantages and disadvantages associated with copper-based algaecides. The advantages include a fairly immediate (days to weeks) reduction in nuisance plant densities and relatively low associated costs. The disadvantages to the treatment of the lake in total with a contact herbicide include potential impacts to non-target, desirable macrophytes, a depletion of DO as a result of the bacterial decomposition of the dead organic matter, and the recycling of nutrients back into the water column that would otherwise be bound in plant biomass. In fact, many algae, especially cyanobacteria (blue-green algae) can effectively assimilate the organic phosphorus liberated from the decomposing weeds. As a result algae blooms may develop within 3-5 days of large scale contact herbicide applications.

In contrast to contact herbicides, a systemic herbicide affects the targeted plant internally instead of externally. That is, uptake of the chemical disrupts biochemical functions thereby killing the plant. Sonar^{R} (fluridone) and 2,4-D are two of the more commonly used systemic aquatic herbicides. Systemic herbicides are designed to be assimilated by the plant and then disrupt a biological process of the plant leading to its death. They are usually applied early in the growing season, before significant plant biomass has developed, but while the plants are in their highly active growth phase. Once absorbed and assimilated by the plants it will begin to disrupt the plant's metabolic activities. In the case of fluridone this results in a disruption of the production of chlorophyll pigments, which are used in photosynthesis. This effectively prevents the plants from successfully photosynthesizing, eventually leading to the plant's death. This mode of action is in sharp contrast to contact herbicides that burn the plant tissue from the outside.

There are a number of advantages to using systemic herbicides relative to contact herbicides. First, contact herbicides typically require multiple applications, between two and four treatments, through the course of one growing season to obtain an acceptable level of control. In contrast, if properly timed and executed, one systemic herbicide treatment application can result in an entire year of control. Second, while contact herbicides need to be applied to lakes when plant biomass is peaking, fluridone is typically applied in the spring when seasonal growth rates are high, but before the plants have achieved maximum biomass. This treatment strategy effectively eliminates the depletion of DO and the possibility of fish kills; a potential secondary impact associated with large contact herbicide treatments. In addition, because the systemic herbicide treatment is conducted before the presence of a large amount of aquatic plant biomass, the liberation of phosphorus from dead and decomposing plants is far less than that experienced following a typical contact herbicide treatment. This decreases the likelihood of post-treatment spurred algal blooms (Souza and Lubnow, 2000).

There are also some disadvantages associated with the use of systemic herbicides. The primary disadvantage is relatively high cost of these products as compared to most contact herbicides. For example, although the volume of fluridone, a systemic herbicide, needed to control nuisance aquatic species is low (on average 20 ppb), the typical unit cost is over an order of magnitude greater than that of contact herbicides. Another disadvantage of many systemic herbicides, especially fluridone, is that due to its mode of action, it is a slow acting herbicide, taking a minimum of 30 days to manifest some observable degree of plant control. As such, targeted control concentrations need to be sustained over the course of at least a month. This means outflow from the lake needs to be minimal during the period of treatment and the product may need to be introduced in a series of splits. This increases the opportunity for improper introduction of the herbicide and sub-optimal control. Finally, some of the systemic herbicides have use restrictions that limit their application in drinking water reservoirs or ponds/lakes used for the irrigation of turf, ornamentals or agricultural crops.

For the coastal lakes, well planned and implemented herbicide treatments, whether using contact or systemic products, present probably the most effective and cost-efficient mode of weed control. Unlike mechanical harvesting or hydroraking, chemical control programs can be used even in the shallowest lakes and in areas with numerous docks and other obstructions. A well timed program can result in season long control with only one or two applications of the product. Again, a well designed program can greatly diminish the likelihood of any impacts to fish, avoid secondary algae blooms and avoid DO related problems. Selection of the correct product can also result in some degree of selectivity, thus enabling the invasive species to be controlled while having limited or no impact on desirable species. The cost of chemical control treatments varies greatly with the area of the lake impacted by the weed infestation, the type(s) of weeds requiring control, and especially the type of product being used (contact or systemic). As such, it is not feasible to provide an average price per acre or even a price range for a chemical control program.

IV.4.2H Biomanipulation

Biomanipulation refers to a series of modifications made to the biota of lakes and of their habitats to facilitate certain interactions and results leading to the control of problematic algae and/or invasive aquatic weed. When discussing the management of the coastal lakes, biomanipulation would most likely be used to re-structure the aquatic food web to favor the growth of beneficial algae, minimize the density of blue-green algae, and limit the density or spread of non-native invasive plants. For example, an increase in piscivorous (fish eating) fish biomass could result in a decrease in planktivorous fish (smaller forage fish) biomass, with this in turn reducing grazing pressure on the zooplankton. If successful, this would lead to increased zooplankton biomass and a decrease in phytoplankton biomass. These conditions ultimately produce an increase in water clarity and quality. Because of the complexities associated with most biomanipulation projects, such techniques generally should not be considered until a detailed biological and chemical database has been developed for the lake or pond.

However, one type of biomanipulation though that could be used even with the collection of only a limited amount of data is biological control of nuisance aquatic plant species through the stocking of “weed eating” fish, specifically the Asian grass carp (*Ctenopharangyedon idella*). However, it must be stressed that this is a regulated activity, requiring a permit from the NJDEP. Before such a permit can be issued and the fish stocked a fair amount of information must be supplied to the NJDEP. Additionally, the NJDEP imposes significant restrictions on the stocking of grass carp. First, the fish must be produced by a NJDEP certified hatchery and the stocking of the fish must occur under the supervision of NJDEP Fish and Wildlife following the receipt of the aforementioned permit. Second, the fish cannot be stocked in lakes larger than 10 acres. Third, it must be shown that the problem weeds are actually among those preferred and eaten by these fish. And finally, it must be demonstrated that the problem weeds must cover or impact at least 40% of the lake’s total area.

IV.4.3 Alum Treatments

During periods of anoxia (depletion of dissolved oxygen) phosphorus becomes liberated from the sediments of lakes and ponds at very high rates, typically 10-100 fold greater than under oxic conditions. This liberated phosphorus can then be assimilated by algae leading in many cases to algae blooms. Although the phenomena of internal phosphorus release and recycling occurs more commonly in deep (>10 feet) lakes, it can occur with a high degree of frequency in even shallow lakes and ponds.

Control of this internal phosphorus load is usually achieved by means of aeration or the application of alum. The former is used to keep the lake’s water column destratified (fully mixed) and well oxygenated (oxic), while the latter is used to bind and make unavailable any of the released phosphorus. This section of the report addresses the applicability of alum in the management of the coastal lakes. Although there are a number of alum surrogates that can be used in a similar manner (e.g., PAC, ferric chloride, various polymers), alum (Al2(SO4)3, aluminum sulfate) is the most commonly employed product. While alum treatments are not regulated by the NJDEP, and hence do not require a permit, the use of this product in the management of the coastal lakes and ponds must be done carefully as alum can cause negative side effects. The three main ways that alum has been used in the management of lakes are as follows:

- Sediment sealing or blanket applications of alum involve the introduction of large volumes of alum (typically on the order of 150-500 gallons/acre). The material is dispensed over the surface of the lake, but the resulting alum floc coagulates and slowly settles to the lake bottom. The flock then becomes incorporated into the sediments. Phosphorus released from the sediments, either during aerobic or anaerobic conditions, is in turn bound by the alum present in the sediments. This effectively reduces the liberation of phosphorus into the water column thereby decreasing the magnitude of the internal load. This form of alum treatment has been used for well over two decades in the management of lakes, and for the most part lakes deeper than 10-15'. This technique has limited utility with respect to the management of the coastal lakes owing to their typical shallow depth and high flushing rates.

- Stormwater injection applications of alum involve the introduction of alum to stormwater before or a it is discharged into a lake. This involves the construction and operation of an injection system that is programmed to release a specified amount of alum over the course of a storm event. While a practical technique in the management of the coastal lakes, these systems tend to be expensive and require a considerable amount of water quality and engineering data to design and operate. However, these systems have been used very successfully in ultra-urban setting and established lake communities as part stormwater retrofit solutions. Currently there are two such units in operation in New Jersey, both at Lake Mohawk, in Sparta, Sussex County. While the remaining discussion in this sub-section of the report does not deal with stormwater injection systems, there is a place for the use of this technique in the management of the coastal lakes.

- Water column stripping entails the application of relatively high concentrations of alum. In this case the objective of the operation is to have suspended material and dissolved phosphorus bind to the alum floc. As the alum floc settles it then clarifies the water column through a stripping action. Alum has been used in this manner for decades in water treatment plants. Water column stripping is used in the management of both deep and shallow lakes, and is the focus of this sub-section as it is the most practical means by which alum can be used in the restoration and management of the coastal lakes.

Before contemplating the use of alum, a considerable amount of work needs to be conducted and a significant amount of data needs to be collected First, the lake's bathymetry must be profiled as accurate depth and volume data is needed to properly compute the required alum dose. Second, the lake's flushing rate and hydrologic budget will need to be computed. Again, these data are key input parameters in the computation of the alum dose, and will also be needed to project the longevity of each alum application. Third, the in-lake phosphorus concentrations must be accurately measured along with the lake's alkalinity and pH. Finally, a bench test will need to be conducted to arrive at the required and safe alum dosing rates. This is extremely important as alum can induce negative environmental effects, namely fish kills. This occurs due to the solubilization of aluminum, which is triggered as pH levels drop below 5.5. Alum, due to its acidic nature and the acidic reaction it causes in the water column, will temporarily depress or lower the treated lake's pH. As such, it is critical to understand how the lake will respond to the alum during the treatment. This is the purpose of the bench test.

The treatment process is rather straight forward with the alum usually being applied in a liquid form to the surface of the lake. Upon contact with the water, the alum is chemically converted into aluminum hydroxide, Al(OH)3. This chemical reaction results in the formation of a floc that causes the lake to take on a milky appearance. This is a very short term effect, lasting a few hours during the time that the floc is binding with particulate material and dissolved phosphorus. Once the floc settles the lake becomes clear and the concentration of dissolved phosphorus is typically undetectable or very low.

As noted above, alum treatments need to be conducted with care and may not be suitable for all of the coastal lakes. A considerable amount of research has been conducted concerning the safe use of alum (Freeman and Everhart 1971, Cooke et al., 1978, Kennedy and Cooke 1982). Given the high alkalinity and basic pH of most of the coastal lakes, it should be possible to conduct alum treatments with little environmental consequence. The key is to ensure that the application does not depress the pH below 5.5, and this can be determined through the aforementioned bench test. The longevity of the treatment will be largely a function of the lake's hydrology, with the technique less feasible for lakes and ponds with high flushing rates.

IV.4.4 Aeration

In New Jersey, most lakes greater than 6 feet in depth become thermally stratified to some extent over the course of the summer. Stratification is caused by the heating of the water's surface due to the increased intensity and duration of the summer sun. Stratification refers to the thermal and density layering of the lake whereby a warm water layer forms and subsequently sits over a cool water layer. The differences in density between the warm and cool waters can become great enough to impede the vertical mixing of the water column thus creating a stratified condition. The extent, duration and frequency of thermal stratification is dependent on a number of factors including water depth, clarity, color, but especially flushing rate (the rate of water in-flow and discharge from the lake). Slow flushing lakes will be more prone to stratification than will fast flushing systems. Waterbodies that stratify in the summer are subject to the formation of zones of lowered oxygen levels, typically close to the bottom of the pond or lake. These zones can quickly become devoid of oxygen (anoxic). Not only will fish and other biota be unable to live in the anoxic zone of the lake, but also because of resulting changes in sediment redox properties, large amounts of phosphorus will be released from the sediments. As discussed elsewhere throughout this report, this internally recycled phosphorus can stimulate algae blooms. Typically, any lake greater than six feet in depth is subject to stratification and its associated problems. However, even shallower lakes, especially those having limited through-flow or wind mixing, can stratify. Although the degree of stratification is usually weaker than that observed in deeper lakes, it can be intense enough, and of sufficient duration, to trigger all of the above noted impacts.

Thermal stratification and its related problems can be corrected using a properly designed and operated aeration system. Aeration systems are typically used to accomplish one of three objectives:

1. Introduce additional dissolved oxygen into the water column for the improvement of a lake's fishery;
2. Vertically mix a lake to keep it thermally destratified state; and
3. Reduce the occurrence of anoxia to control the release of phosphorus, minerals and metals from the sediments.

Different aeration applications are suited for each of the above purposes. However, for the coastal lakes, due to their shallow depth, the most effective aeration technique to combat thermal stratification is one that uses diffused, compressed air. Called destratification systems, these aeration applications are designed to destratify and maintain a lake in a mixed state. This is accomplished by introducing compressed air into the lake via a series of diffusers placed on the lake bottom. The air released from the diffusers form very fine bubble patches that rise to the lake surface, in the process creating an upwelling convection current that effectively breaks down the thermal and density layering. Operation of these units typically begins in the spring before the onset of stratification and continues until the fall when the lake becomes cooled in concert with declining air temperatures. Destratification aeration systems range in price from $5,000 to well over $100,000 depending on the size and morphometry of the lake.

IV.4.5 Dredging - Removal of Unconsolidated Sediments

Dredging is by far the in-lake restoration measure that has stimulated the greatest amount of discussion and interest for the coastal lakes and ponds of Monmouth County. This is because the majority of these waterbodies are impacted to some extent by the silt and sediment that has accumulated over time as a result of improper stormwater management, stream bank erosion and inadequate sediment control at construction sites. Reclamation of most of the coastal lakes and ponds thus requires some degree of dredging to improve recreational use and restore natural flow and circulation patterns. It must be stressed that dredging should not be considered in itself as a weed control measure. Although the removal of sediment will help address weed growth in especially shallow areas, dredging is by far too expensive to be used for weed control. Although a reduction in weed densities will be realized in the dredged areas, the benefits will be short lived as it will not be possible or practical to deepen the lake to the point where light cannot penetrate to the bottom of most of the lake. Any of the previously discussed weed control techniques, especially the chemical control, weed harvesting or hydroraking options, provide a far more cost effective means of controlling weeds than does dredging.

When designing a dredging project all of the following must be taken into consideration:

- Access to and operation within the targeted dredging area;

- The chemical and physical quality and characteristics of the sediments;
- The dredging method that will employed;
- The location and size of temporary sediment stockpiling areas;
- The location and size of the final disposal area;
- Ecological issues and conflicts; and
- Permit application requirements and limitations.

Before any dredging operation is even contemplated sediment samples must be obtained from the lake or the targeted location within the lake. The testing of the lake's sediments is required by NJDEP as part of the permit review process, and will likely be mandated by the owner or operator of any off-site facility or property where the dredged material will be ultimately disposed. The testing is very comprehensive and therefore expensive. It typically entails at least the following laboratory analyses as specified by NJDEP (http://www.state.nj.us/dep/srp/regs/sediment/):

- Volatile Organics
- Organics
- (Semi-Volatiles, PAHs)
- Pesticides/Herbicides
- PCBs
- Heavy Metals

Additionally the physical properties of the sediments must be analyzed for the following characteristics and parameters:

- Water Content
- Percent Solids
- Grain Size Distribution
- Plasticity
- Organic Content
- Bulking Factors
- pH

Basic site logistics must be considered due to traffic, noise, dust and possibly odor problems. This includes how the project is to be staged and how equipment is to be scheduled and then moved throughout the project site as the dredging operation proceeds. For example, it may be necessary to create a temporary haul road for the dump trucks, strategically locate temporary sediment stock pile areas, and establish processes for the diversion of inflow to prevent the dredging area from becoming re-flooded or to prevent any environmental impact to adjacent areas or down stream ecosystems. An important, but often overlooked element of any dredging operation pertains to traffic control. Given the number of trucks that are needed to haul the dredged material off-site (which is typically the case), truck traffic can create significant problems for any moderately sized dredging project.

The removal of lake sediments is accomplished using one of three techniques:

- Hydraulic dredging;
- “Dry” dredging; or
- A hybrid of the two.

Hydraulic dredges remove the material using an auger/suction type device that cuts the sediments, liquefies it, and then pumps the slurry into a holding basin for settling and dewatering. Typically hydraulic dredging is feasible only if a large disposal site is available in an upland area located relatively close to the lake. With this technique the lake is not lowered or dewatered. Rather, a dredging barge operates within the lake, moving by means of spuds set into the sediments or a cable system strung from shore-to-shore. The process tends to be slow but can be fairly cost-effective, especially if the dredged material can be left on-site within the dewatering basin(s). The major drawback with hydraulic dredging is that the sediment slurry pumped from the lake will have a very high water content. Thus large sediment containment and dewatering basins are needed, and for the coastal lakes there is little available land to use in the construction of such basins. Additionally, if the dewatered dredged material must be transported off-site for final disposal the overall cost of the project will greatly increase, due to the additional handling and transport of the sediment.

In contrast to hydraulic dredging, dry dredging requires the lowering of the lake’s water level. The lake’s sediments are exposed to the air, thus facilitating their in-place dewatering. Once the sediments are reasonably dry, conventional construction equipment (i.e. backhoe, trackhoe, dragline bucket, bull dozers) can be used to remove the material. To minimize impacts to recreational use, fish and other aquatic life, most dry dredging projects are conducted in the fall/winter. Once the lake is drawn down, the sediments should remain exposed for approximately 1 to 2 months to facilitate dewatering. Even so, it still may be necessary during the dredging process to temporarily stock pile sediments within or adjacent to the dredging area for a few days to further promote their dewatering. Once sufficiently dewatered, the sediments are loaded on trucks and transported to the disposal site. To minimize transportation costs, the disposal site should preferably be located within 1 mile of the project area as transportation costs alone can greatly escalate total project costs. For example, the trucking cost alone is approximately $150,000 for the disposal of 25,000 yd^3 of sediments to a disposal site requiring a 5 mile round trip. If the disposal site requires a 25 mile round trip, the trucking costs for the same amount of dredged material increases to approximately $400,000. Another issue that needs to be anticipated in a dry dredging project is how to keep the project site from flooding over the course of the sediment removal operation. This usually entails the construction of earthen berms to segregate work areas. These berms are also used as haul roads for the dump trucks or as staging areas for the track hoe used in the removal of the sediment.

Hybrid units used in the dredging of lakes include the aforementioned hydrorake equipped with a bucket loader. Most of these hybrid machines are basically a floating excavator or clamshell. They are best suited for use in very small projects (<1,000 yds^3) or as a supplement to either a hydraulic or dry dredge operation with the machines used in areas where access may be difficult or where water levels never adequately retreat.

Given the cost of any large dredging project, stakeholders may wish to implement the project in a series of phases over a number of years. Such a strategy may be easier to implement in terms of project logistics and budgetary constraints. Similarly, certain highly impacted areas of a lake may be prioritized and the remainder of the lake left alone. For the majority of the coastal lakes, a selective or spot dredging approach may be the most feasible approach, especially in terms of cost control. For example, such dredging can be used to target the removal of the sediment deltas at the discharge point of streams or major storm sewers.

The feasibility of dredging all the accumulated sediment present in any of the coastal lakes or ponds is low due primarily to the overall cost of such an operation. The current per cubic yard cost for lake dredging (including all engineering and disposal costs) range from $45-$75. The presence of any significant amount of contaminants will drive the cost even higher. As such, it is unlikely that any of the lakes, with the exception of the smaller coastal ponds, could be dredged in-total. Additionally, because the NJDEP regulations (NJAC 7:7A, GP13) prohibit the deepening or expansion of the dimensions of a lake or pond beyond its original contours, the extensive deepening of the lakes, even if fiscally possible, would be prohibited by the regulations.

IV.4.6 The Role of Public Education In Managing the Coastal Lakes

Coastal lake communities interested in developing and implementing lake and/or watershed management projects must first begin with development of a lake restoration plan. As illustrated in the earlier sub-sections, lake restoration and watershed management is not a simple process. The success of a restoration program is predicated on decisions and actions developed on the basis of a technically sound, robust dataset that accurately characterizes the lake and its watershed. The plan must also focus on correcting the causes and not just the symptoms of the lake's problems. That is, although it must seek to restore the lake through the correction of problems such as dense weed growth and algae blooms or sediment in-filling, it must be focused on correcting the underlying causes of these problems. As noted above, to the public and the lake's users the actions needed to correct these problems are not always obviously linked to problems themselves. Source control efforts stressing phosphorus reduction initiatives through yard waste management or better stormwater controls are not as direct as weed and algae control efforts. Conversely, while the correction of the factors responsible for lake's problems needs to be the focus of the plan, to be successful the plan must also take into account the immediate needs and concerns of the lake community and lake stakeholders. Therefore, having and following a detailed lake management plan is critical to achieving the long-term, successful restoration of the coastal lakes.

It is clear that a detailed, comprehensive lake and watershed management plan consists of a number of integrated actions all linked to a common goal. However, putting a complex plan in action requires a considerable amount of support, especially when the need for some of the required actions may not be as obvious as are actions geared toward weed or algae control. Thus it becomes important during the implementation phase of any lake restoration plan to inform and educate the public, the lake users and the lake/watershed stakeholders of the "whats, whys and hows" of the plan. This is where a well developed public education and outreach program becomes valuable. Public education and awareness programs can lead to a more highly educated and involved lake community. This is particularly advantageous when developing or sustaining the support for long-term or costly efforts that may not yield obvious or immediately measurable improvements, such as many of the source control initiatives discussed previously. As such, any public education program created as part of a lake restoration program should encompass the following:

- A well defined, clear action plan;
- A data-supported decision tree;
- Easily defined objectives and goals that can be used to measure success and report back to the community; and
- Key project milestones.

Additionally, the plan must stress patience. It is neither possible nor realistic to expect that a lake's problems, which typically have evolved over a considerable amount of time, can be fully corrected in a short amount of time.

Public education and outreach efforts also increase the opportunity for creating or strengthening cooperative partnerships amongst stakeholders. For example, a project could involve the integration of State regulatory personnel, County DPW, lake management consultant, and local environmental commission.

During the course of creation and implementation of a lake restoration program, or even during the implementation of a single objective of the plan, the community and stakeholders can be kept informed using such outlets as:

- Local website
- Blogs
- Email posts
- Newsletters
- Brochures
- Meetings
- Public Access TV & Radio

All of these outreach mechanisms provide the means of keeping the public appraised of what is being done while at the same time maintaining public input and involvement.

IV.4.7 Funding Opportunities and Sources

Before any discussion of lake restoration funding is initiated, it must be emphasized that the competition for all of the sources noted below is significant and that any one funding source may not be able to provide all of the monies required to restore a lake or adequately manage its watershed. Also, the following should not be considered an exhaustive investigation of potential sources of funding that could be sought to support various types of lake restoration and watershed management activities. Rather, the following is provided as a starting point.

Unfortunately, for any lake in New Jersey, whether it be coastal or in-land, there are no ear-marked funding sources specifically available at the State or Federal level for use in lake restoration. Also, there are no NJDEP grant programs specifically designed to cover the expenses of lake dredging. Additionally, State and Federal funding cannot be used to support any macrophyte or algae control project based on the use of chemicals (algaecides or herbicides). Therefore, there are no easy sources of funding to support any of the lake restoration projects most needed by the coastal lakes, whether that be dredging or the control of algae blooms. This means that funding opportunities for coastal lake restoration projects are scant and when they do become available either do not provide ample amount to fully restore a lake or may not cover the restoration activities most needed by the lake.

The best program for stormwater related funding is the NJDEP's 319(h) program. These funds are provided by the federal government (USEPA) but administered state-wide by the NJDEP. This source of funding is routinely used for the implementation of stormwater management corrective measures. This can include the purchase and installation of manufactured treatment devices (MTDs), construction of rain gardens and the construction of bioretention stormwater basin. These funds can also potentially be used to cover restoration costs for the correction of eroded stream corridors, the reestablishment or revegetation of riparian areas and even the restoration of an eroding lake's shoreline. However, currently for a lake to qualify for these funds it must have or be part of an NJDEP approved Watershed Management or Watershed Protection Plan. Of the numerous coastal lakes in Monmouth County, as of January 2009 the only one having such plans is Deal Lake. One of the major benefits of NJDEP 319 funding is that the State requires no set matching funds; that it is, a grant receipt is not obliged to provide a certain percentage of funding as match for the money obtained through this program. However, to demonstrate both commitment and support of the project for which funding is sought, most recipients will provide some amount of in-kind match. Normally this amounts to volunteered services associated with the execution or management of project tasks or services (for example, lake cleanups) that are beneficial to the project's overall goal.

The 604 (b) grant program is another source of funding available through the NJDEP. Each year, the State of New Jersey receives funds from the Federal government under

Section 604(b) of the Clean Water Act to carry out planning under Sections 205(j) and 303(e) of the Act. These grants are specifically ear-marked for use in developing management plans for onsite wastewater treatment systems (septic systems). Because of the limited use of onsite wastewater systems to manage wastewater in the watersheds of the coastal lakes, the applicability of these grants may be very limited, but still should not be overlooked, especially for the larger lakes or the lakes with large watersheds that encompass less extensively developed lands.

Another potential State source of watershed management related funding is the State's Environmental Infrastructure Financing Program. This is not a grant program, but rather a low-interest loan program. This funding has been used to facilitate the implementation of various types of clean water projects. Funding from this source is often used by municipalities to implement water quality protection measures such as the installation of the MTDs. These low-cost loans (0% - to market rate interest, 20-year payback) are obtained through either the NJDEP or the New Jersey Environmental Infrastructure Trust. There are some conditions associated with the application of these funds. In addition, incentives exist for stormwater projects for certain urban areas in the form of the Smart Growth Financing Package.

Besides funding available through the NJDEP there are a variety of other funding opportunities available through various federal agencies. It should be noted that for the most part the various federal grants have a 25% - 50% cash match requirement. Some of the most commonly sought funds for lake and watershed are obtained through the USEPA, the US Army Corps of Engineers or the US Geological Survey, US Fish and Wildlife Service and the USDA Natural Resource Conservation Service. Since each funding agency has very specific parameters for the types of projects that meet their funding requirements, details of each are not provided in this report. However, any of the following links will provide information about the funding opportunities available through each of the above noted sources.

- http://www.epa.gov/owow/lakes/
- http://www.usgs.gov/
- http://www.nrcs.usda.gov/
- http://www.usace.army.mil/

A somewhat unique source of funding that some of the lake associations representing the lake communities of Monmouth County may qualify for are the Environmental Justice grants available through the USEPA[1] . These funds are provided through the USEPA to eligible organizations working on or planning to work on projects to address local environmental and/or public health issues in their communities. To be eligible for these funds the applicant must be either: a 501(c)(3) non-profit organization or a recognized non-profit organization. As such, these funds are not available to a

[1] (http://www.epa.gov/compliance/environmentaljustice/grants/index.html).

municipal entity. The funding is used primarily to build the capacity of community-based organizations to address environmental and/or public health issues at the local level.

Finally, there are a number of private funding sources including foundations, fishing interest groups and other lake or environmental advocacy or stewardship programs that will provide lake associations and municipalities with funding to implement specific lake-related projects. An example of such a funding source is the conservation grants available through the Fish America Foundation.

Legislative allocations, commonly referred to as ear-marks, have been used in the past to channel funding to lakes in Monmouth County for the implementation of specific projects, including dredging. These types of funding opportunities are increasingly difficult to obtain and may require an extensive amount of lobbying regardless of whether the funding is coming from a state or federal legislative source. However, in the case of the coastal lakes this may be a very likely source of funding at the state or county levels if a number of lakes could be packaged together and the projects demonstrated to have regional or event national significance.

Finally, lake communities should not overlook the positives that can be achieved through the forging of inter-local agreements for shared services, or to create joint funding opportunities for projects of regional significance. Many of the coastal lakes can (and many have) benefit from such arrangements, especially as it pertains to the pooling of funds or the sharing of resources. In some cases such inter-local agreements are a requirement for eligibility for the various state and federal funding opportunities discussed above.

Two examples of inter-local agreements that could be created for the county's coastal lakes are the Coastal Lakes Management Initiative and the Coastal Lakes Dredging Initiative. With respect to the Coastal Lakes Management Initiative, in order to better disseminate lake and watershed management information, learn about new technologies, educate municipal employees, and create opportunities for roundtable discussions about the issues facing the County's coastal lakes, a Coastal Lakes Management Committee should be formed. This committee could be composed of members of the various county-wide lake commissions and associations, municipal representatives, Monmouth County Planning and Engineering, Monmouth County Mosquito Commission, Monmouth University Urban Coast Institute, Rutgers Cooperative Extension and other interested groups that manage stormwater in the coastal region of New Jersey. The committee would have four key purposes:

- Serve as a clearing house for information on the management and restoration of lakes and their watershed;
- Form and oversee partnerships among the committee's stakeholders;
- Facilitate links between funding sources and prioritized projects, emphasizing projects of regional significance or projects that could benefit multiple lakes or lake communities; and
- Serve as a uniform voice when dealing with legislators and regulators.

Along the same lines, a Coastal Lakes Dredging Committee should be formed. This could be accomplished through an inter-local agreement that would forge the partnerships needed to implement dredging projects. Such a committee would have four key purposes:

- Bring together coastal lake communities having dredging needs with dredging related resources (e.g., Monmouth County Mosquito Extermination Commission);
- Function as a clearinghouse on dredging related information,
- Aid communities in the preparation of dredging permit related material, and
- Maximize the dredging efforts of lake communities by linking projects and using other means to reduce overall costs.

With respect to the last item, a key element of a Coastal Lakes Dredging Initiative should be the identification of multiple county-wide locations for the disposal of dredged sediments. The lack of a suitably located and sized area where dredged materials could be disposed of at no cost, has proven to be one of the biggest hurdles faced by the coastal lakes. Having a number of such sites located in the county would address this issue and decrease to some extent the cost of dredging.

The above two initiatives are excellent examples of the types of partnerships that could come about through inter-local agreements among the coastal lake communities. Other types of shared services directly related to the management and restoration of the coastal lakes that would benefit from such agreements include sharing of equipment used in the maintenance of stormwater management structures, development of unified ordinances (non-phosphorus fertilizer, waste management, goose feeding, etc.), the authoring and circulation of educational materials and the coordination and staging of public outreach efforts.

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Glossary of Frequently Used Terms

- Acidity - The state of being acid that is of being capable of transferring a hydrogen ion in solution; solution that has a pH value lower than 7.

- Alkalinity - The capacity of water for neutralizing an acid solution. Alkalinity of natural waters is due primarily to the presence of hydroxides, bicarbonates, carbonates and occasionally borates, silicates and phosphates. It is expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate) or as microequivalents per liter (µeq/l) 20 µeq/l = 1 mg/l of $CaCO_3$. A solution having a pH below 4.5 contains no alkalinity. Low alkalinity is the main indicator of susceptibility to acid rain. Increasing alkalinity is often related to increased algal productivity. Lakes with watersheds having a sedimentary carbonate rocks geology then to be high in dissolved carbonates (hard-water lakes), whereas those in a watershed with a granitic or igneous geology tend to be low in dissolved carbonates (soft water lakes).

- Anthropogenic activities – Impacted by, created by or resulting from human activities.

- Aeration - A process which promotes biological degradation of organic matter in water. The process may be passive (as when waste is exposed to air), or active (as when a mixing or bubbling device introduces the air).

- Algae - Microscopic plants which contain chlorophyll and live floating or suspended in water. They also may be attached to structures, rocks or other submerged surfaces. They are food for fish and small aquatic animals. Excess algal growths can impart tastes and odors to potable water. Algae produce oxygen during sunlight hours and use oxygen during the night hours. They can affect water quality adversely by lowering the dissolved oxygen in the water.

- Alum Treatment - Process of introducing granular or liquid alum (*Aluminum sulfate*) into the lake water, to create a precipitate or floc that is used to strip the water column of fine particles and algae or used to treat the bottom sediment for the purpose of limiting the internal recycling of phosphorus.

- Ammonia - A colorless gaseous alkaline compound that is very soluble in water, has a characteristic pungent odor, is lighter than air, and is formed as a result of the decomposition of most nitrogenous organic material.

- Bathymetry - The measurement and mapping of water depths and bottom contours.

- Best Management Practices - Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include but are not limited to treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or wastewater disposal, or drainage from raw material storage. Practices or structures designed to reduce the quantities of pollutants -- such as sediment, nitrogen, phosphorus, and animal wastes that are washed by rain and snow melt from farms into surface or ground waters.

- Chlorophyll *a* - A green pigment found in photosynthetic organisms; used as an indicator of algal biomass.

- Clarity - The transparency of a water column. Commonly measured with a Secchi disk

- Composite water quality sample - A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the rate of flow when the sample was collected The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

- Detritus - Organic detritus is material produced directly from the decomposition of dead organic remains. Detritus also refers to the debris (organic and inorganic) on the bottom of lakes that is partially integrated with the sediments.

- Dissolved oxygen - The amount of oxygen dissolved in a stream, river or lake is an indication of the degree of health of the stream and its ability to support a balanced aquatic ecosystem. The oxygen comes from the atmosphere by solution and from photosynthesis of water plants. The maximum amount of oxygen that can be held in solution in a stream is termed the saturation concentration and, as it is a function of temperature, the greater the temperature, the less the saturation amount. The discharge of an organic waste to a stream imposes an oxygen demand on the stream. If there is an excessive amount of organic matter, the oxidation of waste by microorganisms will consume oxygen more rapidly than it can be replenished. When this happens, the dissolved oxygen is depleted and results in the death of the higher forms of life.

- Dredging - Removal of sediment from the bottom of a water body.

- Epilimnion- The upper layer of water in a thermally stratified lake or reservoir. This layer consists of the warmest water and has a fairly uniform (constant) temperature. The layer is readily mixed by wind action.

- Eutrophication - A process that occurs when a lake becomes overly rich in plant nutrients, leading to the excessive growth and development of algae and aquatic plants. Eutrophication is a natural process often accelerated by cultural process , especially land development and agriculture. Not all eutrophic waterbodies are problematic, as slightly or moderately eutrophic waterbodies support a complex web of plant and animal life and have acceptable water quality characteristics.

- Erosion- The wearing away of land surface by wind or water. Erosion occurs naturally but farming, residential or industrial development, mining, or timber-cutting can increase the rate and severity of erosion.

- Fecal contamination - The presence in water bodies of living organisms (bacteria and viruses) or agents attributable to waste material. Such contaminated waters can cause negative human health effects. Fecal contamination may be a result of wildlife, livestock, pet, waterfowl or septic and sewage discharges. The presence of fecal contaminants typically measured and quantified using an indicator bacteria such as fecal coliform or E. coli.

- Herbicides - A compound, usually a man-made organic chemical, used to kill or control plant growth.

- Hydrology – Having to do with water and water budget. Data related to the occurrence, circulation, distribution, and properties of the waters of the earth, and their reaction with the environment. For lakes this is usually associated with the quantification of the water flow into and out of the system and the study of pollutant transport that occurs in concert with the inflow.

- Hypolimnion - Bottom waters of a thermally stratified lake. This layer consists of colder, more dense water. Its water temperatures remain relatively constant year around and it may experience little or no mixing with the upper warmer layers of the water body. The hypolimnion of a eutrophic lake is usually low or lacking in oxygen.

- Hypereutrophic - A lake characterized by excessive nutrient concentrations resulting in extremely high productivity. Such waters are often impacted by dense algal blooms and periods of oxygen deficiency.

- *In- situ* water quality parameters - in place; in situ measurements consist of measurements of water quality parameters in the field, rather than in a laboratory.

- Invasive species - A species whose presence in the environment causes economic or environmental harm or harm to human health. Invasive species may be a native or exotic.

- Limnology - The study of fresh water ecosystems, in particular lakes and ponds, focusing on the integration of the waterbody’s physical, chemical, hydrological, and biological attributes.

- Littoral zone - 1. That portion of a body of fresh water extending from the shoreline lake ward to the limit at which rooted plants can grow. 2. A strip of land along the shoreline between the high and low water levels.

- Land Use/Land Cover (LU/LC) - The arrangement of land units into a variety of categories based on the properties of the land or its suitability for a particular purpose. Used to characterize, model and quantify land development patterns of a watershed.

- Macroinvertebrates - An organism that lacks a backbone and can be seen with the naked eye. Typically used in reference to clams, mussels, snails, worms and aquatic insects.

- Macrophyte - A large macroscopic plant, specifically aquatic forms such as a the rooted, floating, and submerged plant life occurring in lakes and ponds.

- Mesotrophic – Lakes with moderate quantities of nutrients and moderate productivity in terms of aquatic animal and plant life.

- Nitrogen - An essential nutrient in the food supply of plants and the diets of animals.

- Non Point Source Pollution - Water pollution that can not be traced to a specific source. Human-made or human-induced pollution caused by diffuse, indefinable sources that are not regulated as point sources, resulting in the alteration of the chemical, physical, biological, and/or radiological integrity of the water.

- Oligotrophic - Lakes that have a low supply of nutrients and thus contain little organic matter. Such lakes are typically deep, natural lakes characterized by high water transparency and high dissolved oxygen.

- pH - A measure of the acidity or alkalinity of a material, liquid or solid. pH is represented on a scale of 0 to 14 with 7 representing a neutral state, 0 representing the most acid and 14, the most alkaline.

- Periphyton - Microscopic underwater plants and animals that are firmly attached to solid surfaces such as rocks, logs, and pilings.

- Phosphorus - An essential nutrient for the food supply of plants. Tends to be the nutrient most responsible for the eutrophication of lakes.

- Photosynthesis - The process by which plants transform carbon dioxide and water into carbohydrates and other compounds, using energy from the sun captured by chlorophyll in the plant. Oxygen is a by-product of the process. Photosynthesis is the essence of all plant life (autotrophic production) and hence of all animal life (heterotrophic production).

- Phytoplankton - Microscopic, plants free floating in the water column of ponds and lakes. Phytoplankton tend to accumulate near surface of the water column where sunlight intensity is maximal for growth. The accumulation of phytoplankton at the surface can lead to the formation of obnoxious scums, referred to as blooms. Phytoplankton form the basis for all aquatic food chains.

- Point Source Pollution - Source of water pollution emanating from discrete point of origin such as the discharge pipe from a factory, sewage treatment plant, or specific location or use.

- Pollutant Loading - The amount of polluting material that is transported into a lake over a given period of time. Pollutant loading is expressed as Lbs or Kg/year.

- Secchi Disc Transparency – The clarity of a lake as measured using a flat, white/black approximately 9" diameter disc that is lowered into the water until it is just barely visible. At this point, the depth of the disc from the water surface is the recorded Secchi disc transparency. This depth is approximately equal to the 10% of the incident light as measured at the surface of the lake. It is also representative of the depth at which there is no longer enough light to support algal or phytoplankton photosynthesis.

- Sedimentation - Process of deposition of waterborne or windborne sediment or other material; also refers to the infilling of bottom substrate in a waterbody by sediment (siltation) as when soil particles (sediment) settle to the bottom of a lake.

- Specific Conductance - A rapid method of estimating the dissolved-solids content of a water supply. The measurement indicates the capacity of a sample of water to carry an electrical current, which is related to the concentration of ionized substances in the water. Also called conductance.

- Stormwater Runoff - Stormwater runoff, snow melt runoff, and surface runoff and drainage; rainfall that does not infiltrate the ground or evaporate because of impervious land surfaces but instead flows onto adjacent land or watercourses or is routed into drain/sewer systems.

- Stratification - Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with lighter water overlaying heavier and denser water. The tendency in deep water bodies for distinct density layers of water to form as a result of a vertical change in water temperature. During stratification, dissolved oxygen, nutrients, and other water chemistry parameters do not mix well between layers, resulting in chemical as well as thermal gradients.

- Submerged Aquatic Macrophytes – (Also see macrophytes) Aquatic vegetation that lives at or below the water surface. Often referred to as aquatic "weeds", macrophytes include both native and non-native species. Although macrophytes may create user related impacts when growing too dense, aquatic plants are essential for a healthy lake environment as they provide among other things important habitat for young fish and other aquatic organisms.

- Total Suspended Solids - Solids that either float on the surface or are suspended in water, and which are largely removable by laboratory filtering. 2) The quantity of material removed from water in a laboratory test, as prescribed in standard methods for the examination of water and wastewater.

- Thermocline - The depth in a thermally stratified lake or reservoir at which an abrupt change in water temperature and density is measured over a short increase in depth.

- Turbidity - A cloudy condition in water due to suspended silt or organic matter often attributable to algae blooms or increased sediment loads.

- Water Quality - The biological, chemical, and physical conditions of a waterbody. Maybe used to define or measure of a waterbody's ability to support beneficial uses.

- Watershed management - A holistic approach applied within an area defined by hydrological, not political, boundaries, integrating the water quality impacts from both point and nonpoint sources. Watershed management has a premise that many water quality and ecosystem problems are better solved at the watershed scale rather than by examining the individual waterbodies or dischargers. Use, regulation and treatment of water and land resources of a watershed to accomplish stated objectives.

- Weed harvesting – A mechanical means of controlling the growth of aquatic macrophytes. Involves both the cutting and removal of macrophyte biomass. Can be implemented on large scale using floating barge like machines or a small localized scale using hand tools.

- Zooplankton - Microscopic, floating and free swimming aquatic animals. Zooplankton generally feed upon bacteria, suspended detrital material, phytoplankton and each other.

Appendix A: Overview of Commonly Occurring Macrophytes

Fundamental to the management of the aquatic “weeds” impacting the coastal lakes and ponds of Monmouth County is an understanding about the nature, origin and basic life history of the more commonly encountered invasive species. Although some of these macrophytes are native, most of the problem weeds are invasive exotic plants. The following is intended to provide an overview of the most commonly encountered aquatic weed species. Focus is placed on the submerged plant species, as these are usually the most problematic. Not included below, but recognized as at times being problematic, are the floating plants such as spatterdock or yellow water lily (*Nuphar*), the white and pink water lily (*Nymphaea*), duckweed (*Lemna*) and watermeal (*Wolfia*). For additional information concerning these species refer to North American Lake Management Society (www.NALMS.org), the University of Florida Center for Invasive and Exotic Plants (http://aquat1.ifas.ufl.edu/), and the Northeast Aquatic Plant Management Society (http://www.NEAPMS.net).

1. **Eurasian Water Milfoil,** Scientific Name: *Myriophyllum spicatum*

Source: Robert Johnson, Cornell University. Ruthanna Hawkins Cayuga Lake Watershed Network

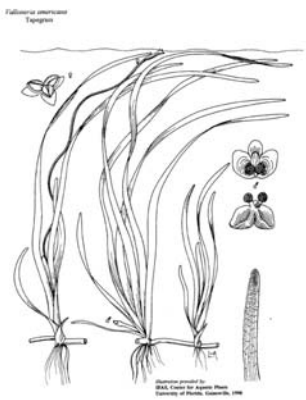
Origin: Eurasia (Exotic)

Identification: Eurasian Water Milfoil is a submerged, rooted, perennial aquatic plant characterized by slender reddish-green stems often 6-20 feet in length. The leaves are feather like, olive green in color and deeply divided. Each leaf consists of a central axis with 14-24 very slender leaflets on either side.

Distribution: Milfoil is extremely tolerant of varying light, temperature, and salinity conditions and has invaded waterbodies throughout North America. Milfoil is the *most comon invasive species* occurring in the coastal lakes and ponds. Current research is evaluating bio controls using the Milfoil weevil (*Euhrychiopsis lecontei*) and moth (*Acentria ephemerella*).

2. Eel Grass / Tape Grass, Scientific Name: *Vallisneria americana*

Source: University of Florida at Gainesville

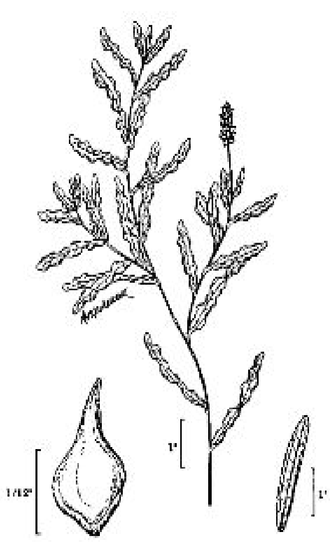


Origin: Eastern North America

Identification: Tapegrass is a submerged perennial aquatic monocot. The most prominent feature of tapegrass are its long, slender, green, ribbon like leaves that often grow to the waters surface. This plant holds to the substrate through extensive fibrous roots, which extend from horizontal rhizomes. A distinct feature of tapegrass is the long cylindrical stalks that coil following pollination.

Distribution: Found throughout the entire United States. Tapegrass is prominent throughout the bay, and grows in water depths up to 12 ft, in dense monotypic stands.

3. Curly Leaf Pondweed, Scientific Name: *Potamogeton crispus*



Origin: Eurasia

Identification: Oblong, stiff, translucent leaves have distinctly wavy edges with fine teeth and 3 main veins. Sheaths (stipules) are free of the leaf base and disintegrate as they age. Stems are branched and flattened. Flowers are produced in spikes on stalks up to 7 cm long. Curly leaf pondweed produces many sharp angled turions, which fall to the lake bed by mid-summer.

Notable Characteristics: Curly leaf pondweed is able to tolerate cool water. Due to its over-wintering it is often the first plant species to grow in the early spring and often dies back by the fourth of July. It reproduces via spiraled turions deposited onto the sediment.

Distribution: Found throughout the entire United States.

Source: plants.usda.gov

4. Coontail, Scientific Name: *Ceratophyllum desmersum*

Source: University of Florida at Gainesville

Origin: Unknown

Identification: The serrated, forked leaves of coontail are arranged on the stems in whorls, with usually 5-12 leaves in each whorl. It is generally a dark, olive green color, and rough to the feel. Lacking true roots, coontail acquires most of its nutrients through the water column. When growing close to the sediment coontail may develop modified leaves or "holdfasts" which are used to anchor to the sediment.

Distribution: Found throughout the entire United States.

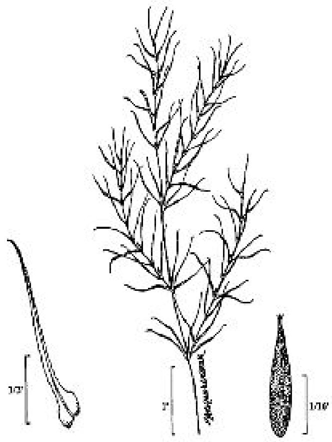
5. Water Stargrass, Scientific Name: *Zosterella dubia*

Origin: Unknown

Identification: The long, grass like leaves of water stargrass are similar to those of eel grass. Water stargrass may be recognized by its narrow, parallel-sided leaves with many fine veins, but lacking a central mid-vein. Leaves are alternate, stipitate, linear, obtuse to rounded, or apicate at the tip. The base of the leaves is jointed to a tubular sheath, which is wrapped around the stem. Stems of water stargrass are slender, elongate, and freely branched.

Distribution: Found throughout the United States.

6. Slender Naiad, Scientific Name: *Najas flexilis*



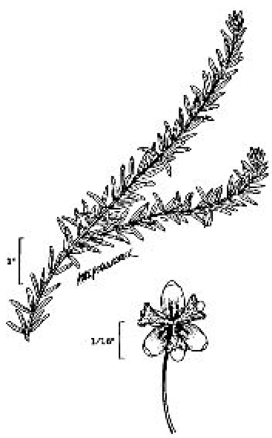
Origin: North America

Identification: Leafs are glossy, green, and finely toothed and are oppositely arranged. Stems are very thin, green, and easily broken and fragmented.

Notable Characteristics: Slender Naiad is an extremely valuable food for duck's.

Distribution: Found throughout the north and western United States. For the coastal lakes this species typically do not reach nuisance proportions until the latter part of the summer.

7. Elodea, Scientific Name: *Elodea canadensis*



Origin: North America

Identification: Leaves are small, green and lanced shaped. Leaves attach directly to the stem in a whorl of three leaves. Whorls density becomes greatest the closer to the apex of the stem. Stems are long and slender. Female plants produce tiny, white flowers with three petals that float on the waters surface.

Distribution: Found throughout the United States except for Texas, Louisiana, and Georgia. As this plant often remains close to the lake bottom, it rarely becomes a nuisance plant.

8. Water Chestnut, Scientific Name: *Trapa natans*

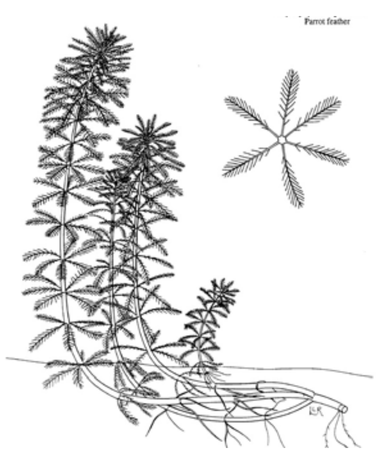
Source: University of Florida

<u>*Origin*</u>: Asia (Exotic)

<u>*Identification:*</u> Water Chestnut is an annual aquatic plant with a submerged flexuous stem and a floating rosette of leaves. The stems possess long petioles with certain portions capable of inflation, which can suspend the leaves on the waters surface. Reproductive nuts have 4 sharp spines that are hazardous to swimmers. These seeds may remain viable in the sediments for up to twelve (12) years.

<u>*Distribution:*</u> Invasive plant found in waters from Virginia to upstate New York. The plant forms dense, monotypic stands that preclude passage of canoes. The water chestnut reproduces exponentially and 1 acre may produce enough offspring to cover 100 acres the following year. Although not yet identified in any of the coastal lakes, it is becoming increasingly common in New Jersey and is creating major impacts to fishing, boating and swimming in lakes in Mercer, Morris, Hunterdon and Sussex counties.

9. Parrot Feather, Scientific Name: *Myriophyllum aquaticum*



Source: University of Florida

<u>*Origin*</u>*:* South America (Exotic)

<u>*Identification*</u>*:* oblong, deeply cut and feathery looking leaves with bright blue-green color. Leaves are arranged in whorls of four to six about the stem. Stems trail along the ground or water surface, becoming erect and leafy at the ends.

<u>*Distribution:*</u> Occurring northward from Florida. This invasive plant occurs in numerous lakes throughout New Jersey and is routinely encountered in Monmouth County. Often confused with Eurasian water milfoil, this species is much brighter in color and lacks the pronounced “bushy” and dark red terminus at the end of the stem characteristic of *M. spicatum.*