Fresh Pond Reservation

BLACK'S NOOK RESOURCE INVENTORY

FINAL REPORT

Prepared for:

CITY OF CAMBRIDGE WATER DEPARTMENT

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Introduction

1.1 Purpose of this Report

The purpose of the Black's Nook Resource Inventory is to establish a sound ecological basis for habitat restoration and landscape improvement for the Black's Nook study area. This report also affords the opportunity to identify gaps in the existing data that will be filled through future analyses. The contents of this report will inform stakeholders and provide a basis for discussing options for future improvements within the watershed.

The overall objectives of the Resource Inventory were derived from the goals set forth in the Fresh Pond Reservation Master Plan. The Master Plan identifies recommendations for the Black's Nook study area. In particular, it places a "very high priority" on reconstructing and stabilizing the southern and southwestern shoreline of the pond and improvement of visitor access to the water, as well as prioritizing both a limnology and a sediment management study. The Master Plan prioritizes as a "high priority" wetland buffer management and enhancement in the east and southwest as well as flow enhancement and naturalization in the Nook channels. Other high priorities named are entrance and trail improvements, forest management and additional screening along the Concord Avenue entrance and frontage.

Additionally, the Cambridge Water Department (CWD), managing entity for Fresh Pond Reservation, has noted the current conditions in the Black's Nook watershed can benefit from treatments that would: restore water quality in Black's Nook to a Class B level, restore continuity to fragmented landscape types; and improve site circulation while providing new visitor amenities.

1.2 Report Organization

The report is comprised of two main sections: Landscape Character and Water Quality. **Landscape Character** begins with a discussion of previous research documenting the condition of plant communities, habitat usage, and visitor circulation in the Black's Nook study area. The findings are summarized as resource inventory, comprised of a wide range of ecological and cultural factors.

Water Quality describes the existing data on the quality of the water in Black's Nook Pond and how that data relates to established standards for Class B waters. It also includes a discussion of the opportunities for modeling water quality parameters to assess trends in water quality over the long term and concludes with several recommendations aimed at attaining Class B status in Black's Nook Pond.

Deadfall provides wildlife habitat

Compacted shoreline

Canadian geese nest near the 5th green

Landscape Character

2.1 History of Black's Nook Pond

Up until the late 19th Century, Black's Nook was a deep-water cove within Fresh Pond Reservoir. The following timeline describes the events that have resulted in the current physical, chemical and biological state of Black's Nook. In 1880 the Nook was closed off from Fresh Pond to contain pollution caused by dumping into Black's Nook. In 1932 the Thomas P. O'Neill, Jr. Municipal Golf Course was constructed on the west shore (four of the nine tees of the Golf Course are in the Black's Nook Watershed). In 1938 a major hurricane deposited debris into the pond (tree branches, leaves, etc.). By 1963 sanctioned dumping ended. Restoration of the pond through clean up and replanting was initiated by the Cambridge Plant and Garden Club. During the 1980's, the area adjacent to Black's Nook became increasingly forested offering habitat for ducks, grouse, pheasant, songbirds, frogs, muskrats, and turtles.

Presently, the CWD artificially maintains the elevation of Fresh Pond above that of Black's Nook to prevent subsurface migration of contaminated water into Fresh Pond. The surface elevation of Fresh Pond is maintained at16 feet (Cambridge datum).

The physiography of the Black's Nook watershed developed as a result of the geologic and ecological processes that shaped this portion of Cambridge but its development has also been impacted significantly by human use. A revived interest in nature in the city created a focus on Black's Nook as a significant community amenity. This resulted in the development of goals for restoration set forth in the Reservation Master Plan.

Cultural Resources

The Black's Nook watershed is an integral part of Fresh Pond Reservation. Geographically, it links Neville Manor, Maynard Ecology Center, the community gardens, and soccer field to the Cambridge Golf Course. The newly constructed entry point and connector path at Concord Avenue provides improved circulation and access into the Reservation.

The Perimeter Road delineates the southern watershed boundary (see Figure 11). Many visitors use the informal dirt trails to access Black's Nook from the Perimeter Road. These trails bring visitors who want to exercise their dogs, view birds or simply enjoy the setting. Sousa's Rock and the information kiosk are important components of the visitor experience. Black's Nook also contributes to the scenic beauty of the course. Golfers playing the 5th hole enjoy the view of Black's Nook and the wildlife using the pond.

While many visitors come to the Reservation and Black's Nook for recreation, some also come for educational opportunities. The Cambridge Public Schools and the Maynard Ecology Center actively use the Black's Nook area as an outdoor classroom and laboratory. The environment in and around Black's Nook is a fine setting for studying biological diversity, illustrating ecological concepts and practicing field skills.

2.2 Natural Resource Inventory

In order to establish plans to improve the Black's Nook study area, the Cambridge Water Department initiated a resource inventory to quantify many of the natural parameters that define potential restoration measures. Vegetation, soils and slopes were the major components used to best identify these measures. Existing circulation patterns, bank conditions, wildlife, and high litter areas were also mapped as part of the inventory. The opportunities and constraints identified provide the framework for recommendations that will maximize its functionality and value to the community.

Forest Type

The study area around Black's Nook is primarily forested, providing screening from public view and some shade to the water surface. (See Figure 1). Deciduous species generally dominate in both the canopy and in the understory. There is also a stand of white pines (*Pinus strobus*) along the path at the eastern edge of the study area.

The forest community adjacent to the pond is dominated by green ash (*Fraxinus pennsylvanica*) with several very large specimens of weeping willow (*Salix babylonica*). There is a mature stand of white pine (*Pinus strobus*) in the southeast corner of the study area. The tree community west of Stream A is more diverse, with various oak species dominant. There are a large number of locusts (*Robinia pseudoacacia*) along the esker and a small stand of tree-of-heaven (*Allianthus alltissima*) in the depressed area. Additional canopy species include American elm, red maple, basswood, black walnut. Understory species include quaking aspen, black cherry and buckthorn.

Norway maple and buckthorn are not as prevalent as in other sections of the Reservation. This may be due in part to the generally older age class of the tree community. Snags of various size and species are common within the forest matrix; many covered in bittersweet or poison ivy, offering a great habitat resource for insects, birds, and mammals. Snags identified as a potential public safety concern shall be taken down. In general, the tree community is in good health. Aggressive vines such as bittersweet (*Celastrus orbiculatus*) and poison ivy (*Toxicodendron radicans*) threaten the health of some of the larger trees.

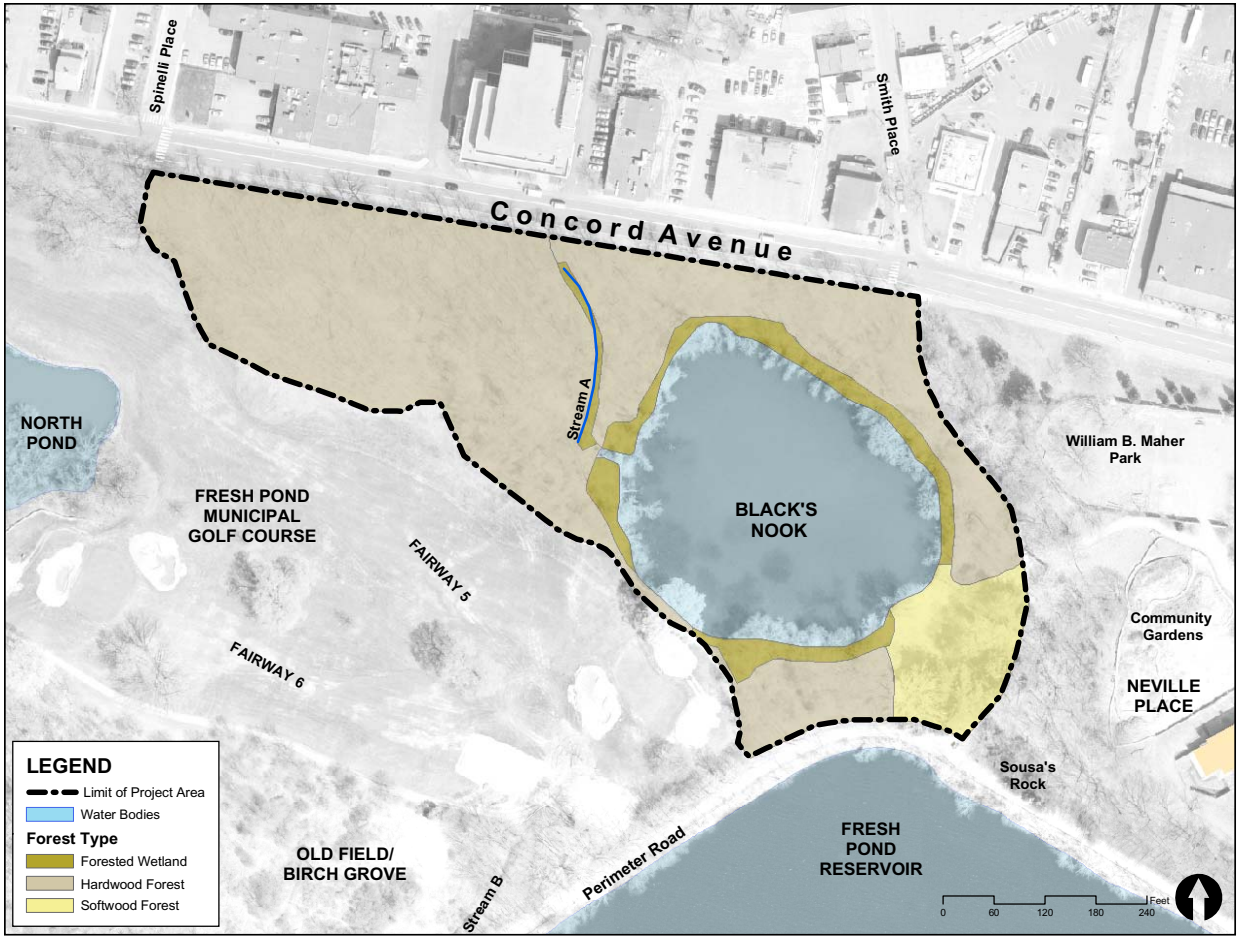


Figure 1 - Forest Type

Typical snag

Upland hardwood forest

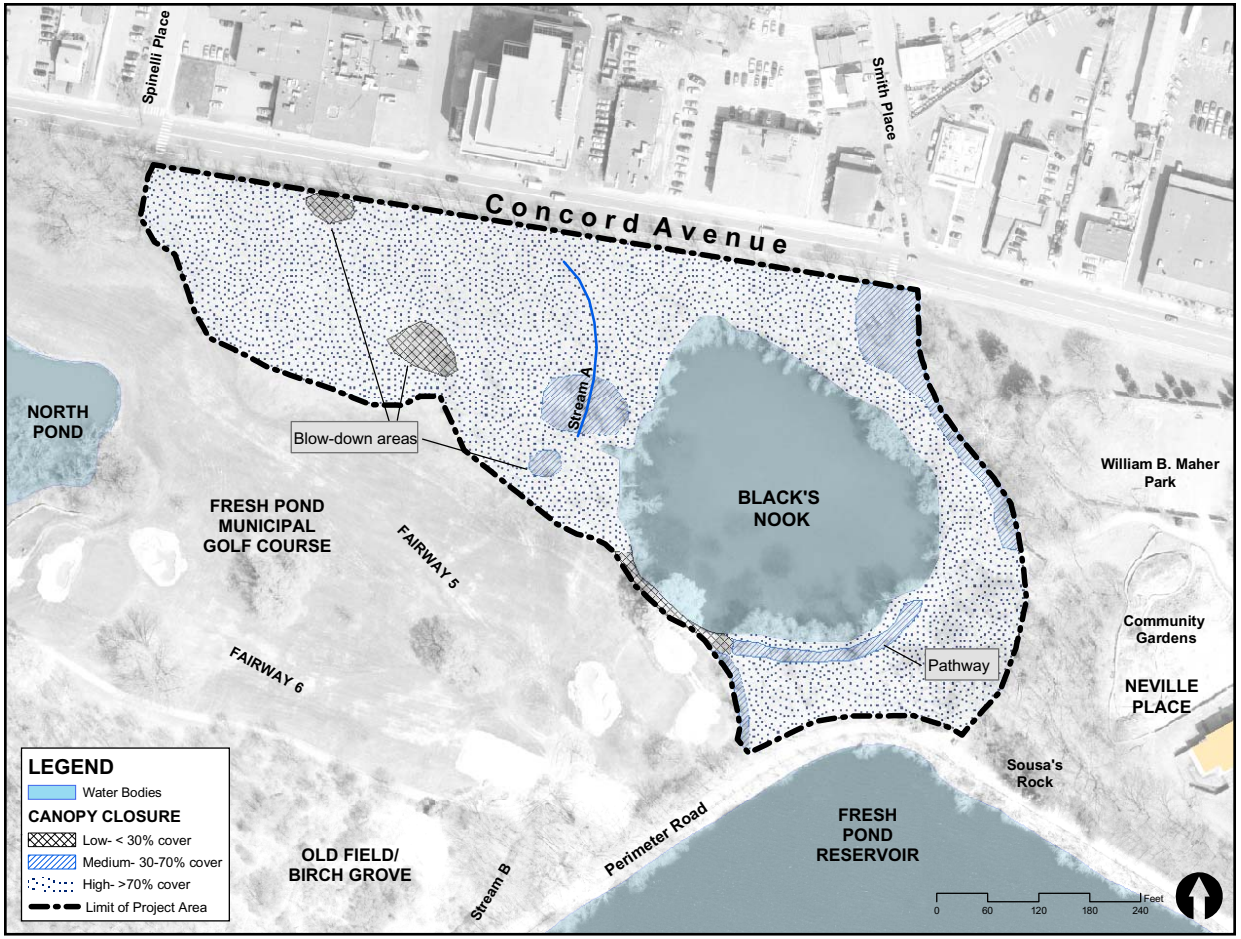


Figure 2 - Canopy Condition

Medium canopy closure

Open canopy near Concord Ave.

Canopy Closure

Canopy closure refers to the percentage of ground area shaded by overhead foliage, an indication of a mature forest ecosystem. The dynamics of the canopy are typically associated with disturbances and regeneration. Both natural and human caused disturbances result in environmental heterogeneity. The disturbance and regrowth cycle changes the pattern of light and energy on the forest floor, creating the opportunity of establishment by invasives without management intervention. The various degrees of canopy closure were assessed visually and assigned a low, medium, or high value. This information was then entered into a GIS and is shown in Figure 2.

The canopy cover is quite dense west of Stream A. Three areas were noted where blow-downs have opened the canopy. At the southern end of Stream A, staghorn sumac (*Rhus typhina)*, grape (*Vitis spp.)*, buckthorn (*Frangula alnus)*, blackberry (*Rubus spp.*) and bittersweet have colonized. Further west is a larger plot heavily invaded by buckthorn which is scattered through the understory of nearly the entire study area. Buckthorn saplings have also become established along Concord Avenue.

The canopy coverage north of Black's Nook is relatively consistent with some large willows and green ash providing dense cover. There are also a few healthy beech trees closer to Concord Avenue. The area west of the path entering from Concord Avenue is more open and a more diverse groundcover community is established.

Groundcover

The term “forest structure” refers to the development of vertical strata within the plant community. Forests with well-defined canopy, mid-story, understory, shrub, and groundcover layers will have more habitat niches that can be used by a wide range of wildlife species. With the exception of assessing canopy closure and groundcover density, forest structure was not explicitly recorded but was examined in the field to provide context for describing the forest community.

While the canopy layer around Black’s Nook is rather consistent, the shrub and groundcover layers are much more variable across the study area. Figure 3 shows the approximate distribution and character of groundcover in the Black’s Nook study area. The dominant groundcover west of Stream A is invasive garlic mustard (*Alliaria petiolata*). North of the pond, there are only isolated patches of garlic mustard and much more development of the herbaceous layer. In this area, between the pond and the path to Concord Avenue, there is a mix of nettle (*Urtica dioica*), wild sunflower (*Helianthus spp.*), and jewelweed (*Impatiens capensis*). A stand of invasive Japanese knotweed (*Polygonum datum*) has also established itself north of the pond.

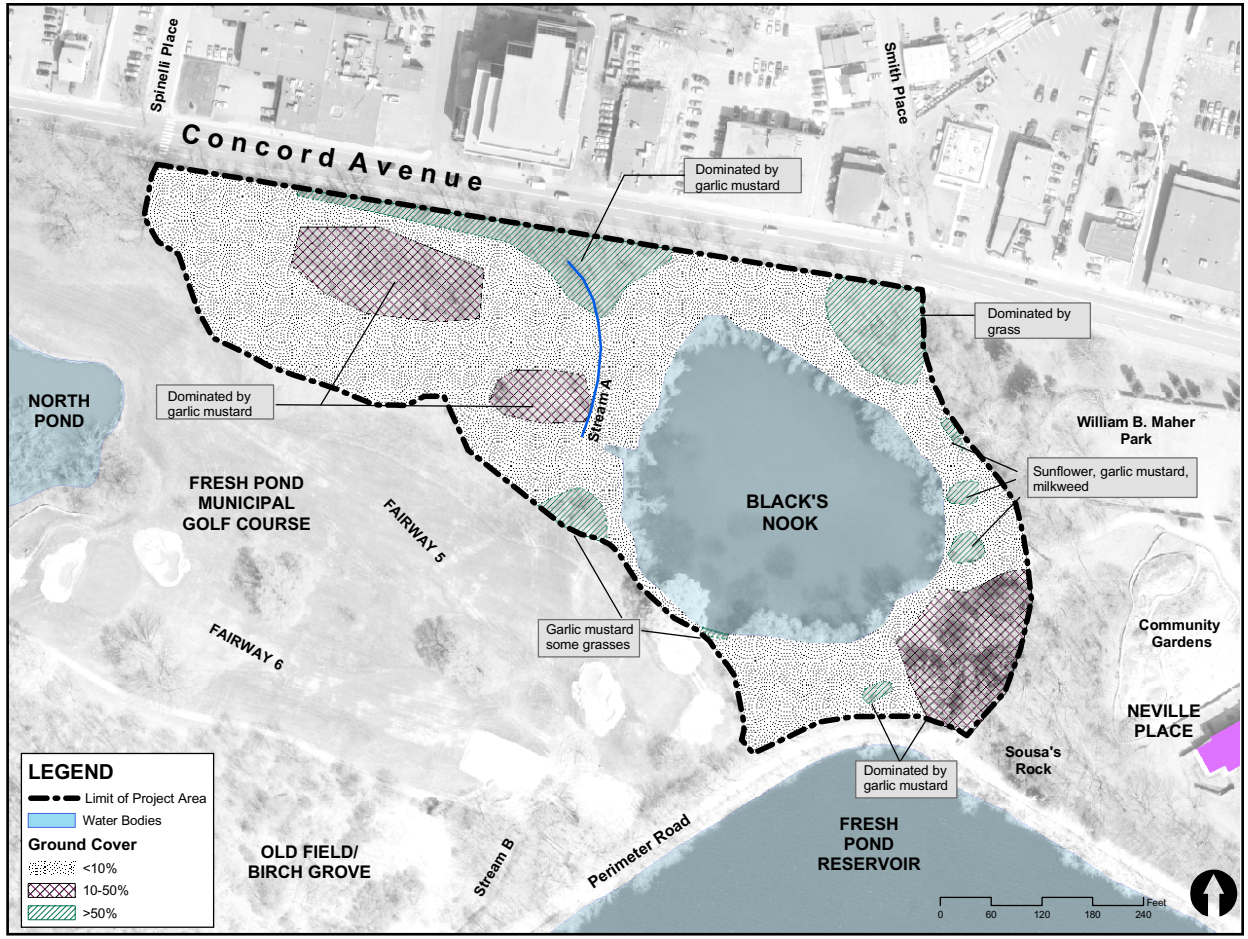


Figure 3 - Groundcover

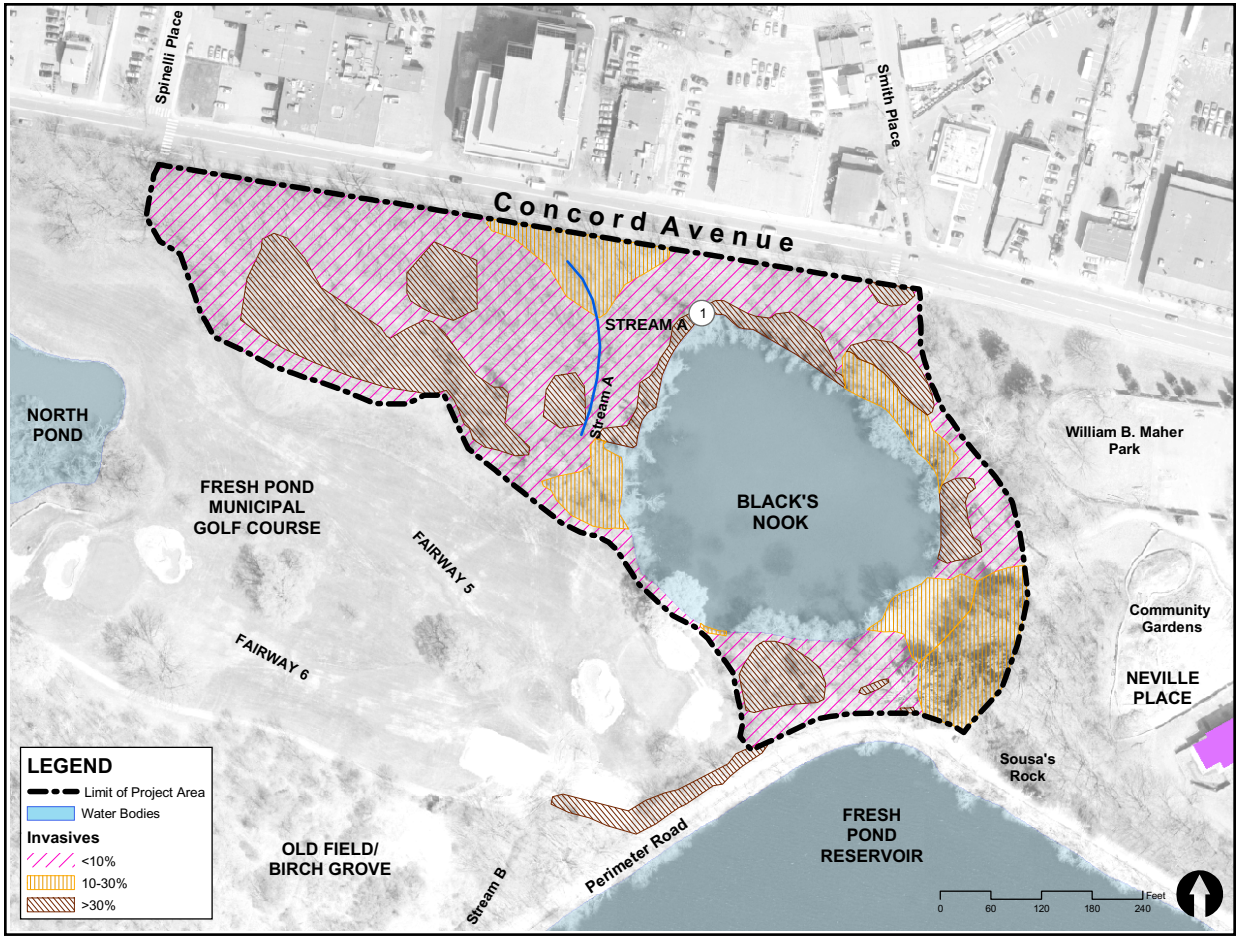


Figure 4 - Invasive Species

Bittersweet vines shade out canopy trees on north side of Black's Nook Pond

Invasive vines in winter

Invasive Species

Much of the understory is comprised of invasive species such as European buckthorn, Norway maple, oriental bittersweet and poison ivy. The approximate percent cover of invasive species is shown in Figure 4. The stand of vegetation east of Black's Nook is overgrown with bittersweet, which has formed dense nets between some of the low branches of the willows and prevented herbaceous or groundcover growth beneath. Management measures in the past have included removal of bittersweet from larger specimen beech and pine trees in the eastern portion of the study area. Recent tree trimming may provide some openness to allow the development of an herbaceous community. However, without establishment of a desirable mix of species and a specific, manual management intervention, it is likely that these places will continue to be invaded by some of the common upland exotics in this part of the Reservation.

Aquatic exotics such as water chestnut (*Trapa natans*) and purple loosestrife (*Lythrum salicaria*) were also present. Several Notices of Intent were filed between 2000 and 2008 to selectively remove water chestnut and purple loosestrife from the Pond and its banks. Roger Frymire, local volunteer, has aided in the removal of water chestnut in Black's Nook Pond. Within the last five years, he estimates the number of water chestnut plants removed was reduced from a high of 65,600 in 2003 to 627 in 2008.

Soils

Soil condition is a critical foundation for ecological restoration. For the purposes of this analysis soils of the study area were organized into four categories: **Upland, Upland Compacted, Upland Erodible, and Wet**. Compaction and erodibility determine the planning possibilities of a site where minimum disturbance is a goal. The properties of soils can be significant constraints on plans to improve the use or habitat quality of that site. Access points and other high traffic areas must be stabilized to prevent erosion, a key issue in any public use setting.

The NRCS soil maps show the study area to be entirely comprised of Scio very fine sandy loam. This soil group is described as moderately well-drained soils of aeolian or lacustrine sediments dominated by silt and very fine sand.

For the purposes of the current resource analysis two overarching categories of soils were identified: upland and wet. Upland soils were further characterized as compacted or erodible and their locations added to the map. **Upland soils** are those that are do not show evidence of saturation or inundation and are not located within low areas where stormwater may collect. **Upland Compacted soils** were determined visually. These soils are those upland soils that show evidence of compaction, mainly by human and animal foot traffic. **Upland Erodible soils** are those that were judged to be relatively unstable due to grain size or lack of vegetative cover.

Hydric soils were mapped in 2006 as part of a routine wetland determination filed with and approved by the Cambridge Conservation Commission in March of 2006. For the current resource analysis, ecologists dug eight shallow pits (16” deep) throughout the study area to characterize the surface soils and confirm the soil classification by the NRCS Soil Survey for

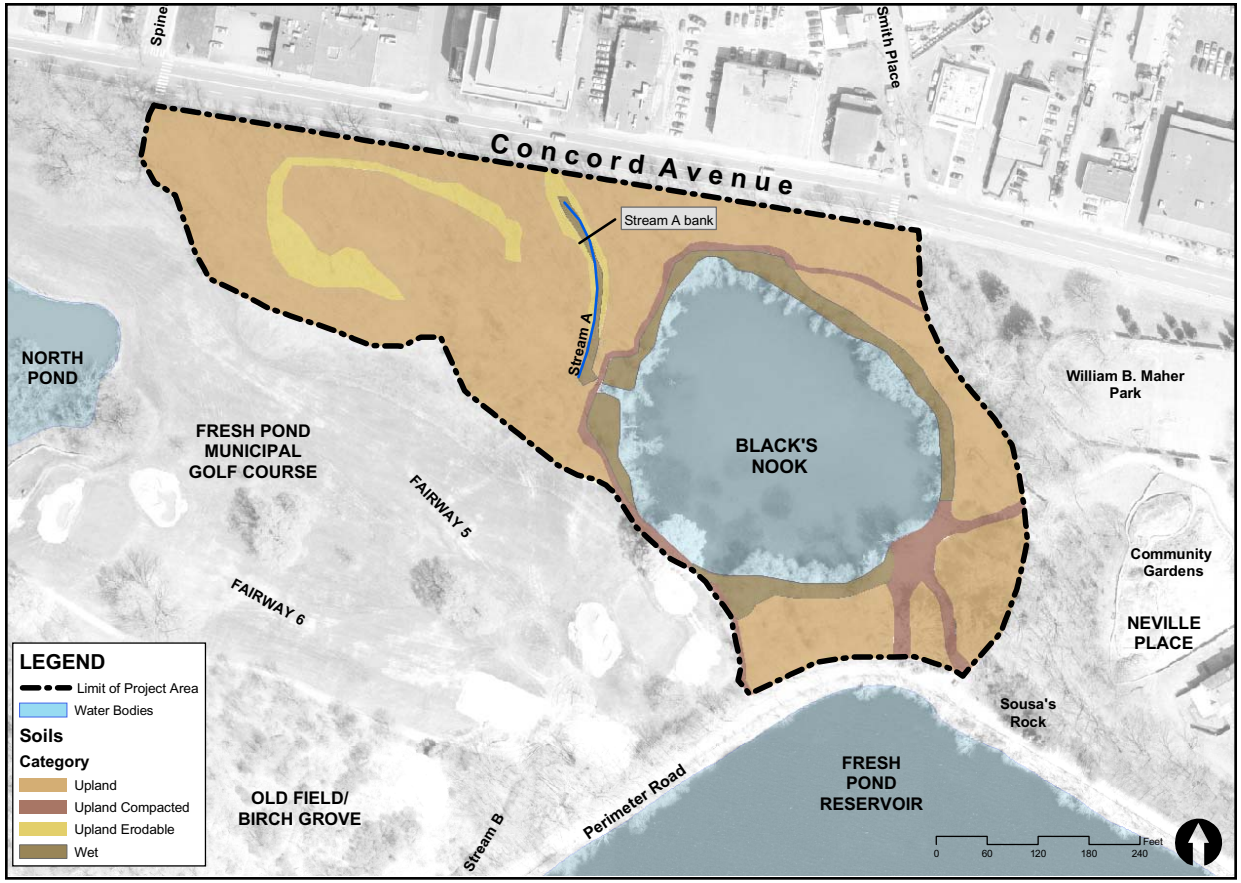


Figure 5 - Soils

Middlesex County. Each pit was examined for texture, density, redoximorphic features and organic content. **Wet soils** meet hydric soil criteria in some but not necessarily all portions of the study area. Wet soils are those that either show hydric soil indicators or are situated where the surface and groundwater hydrology may contribute to periodic saturation. A wet soil represents an opportune situation where a new wetland could be created, without disturbing an existing wetland resource area.

North of Black’s Nook the soil exhibits a deeper rich layer of sandy loam to 10 inches. This topsoil is underlain by a soft yellow sand, likely deposited when this area was the northern shore of Fresh Pond. Constraints to planting in this area are few. South and east of Black’s Nook a thin layer of topsoil (1 to 8 inches) is underlain by dense lacustrine clay extending deeper than 16 inches.

From the east bank of Stream A continuing west, the soils show little development. There is a thin organic layer formed by decayed leaves. Beneath this layer, the soils are dominated by coarse sand and gravel with occasional cobbles up to 3 inches in diameter.

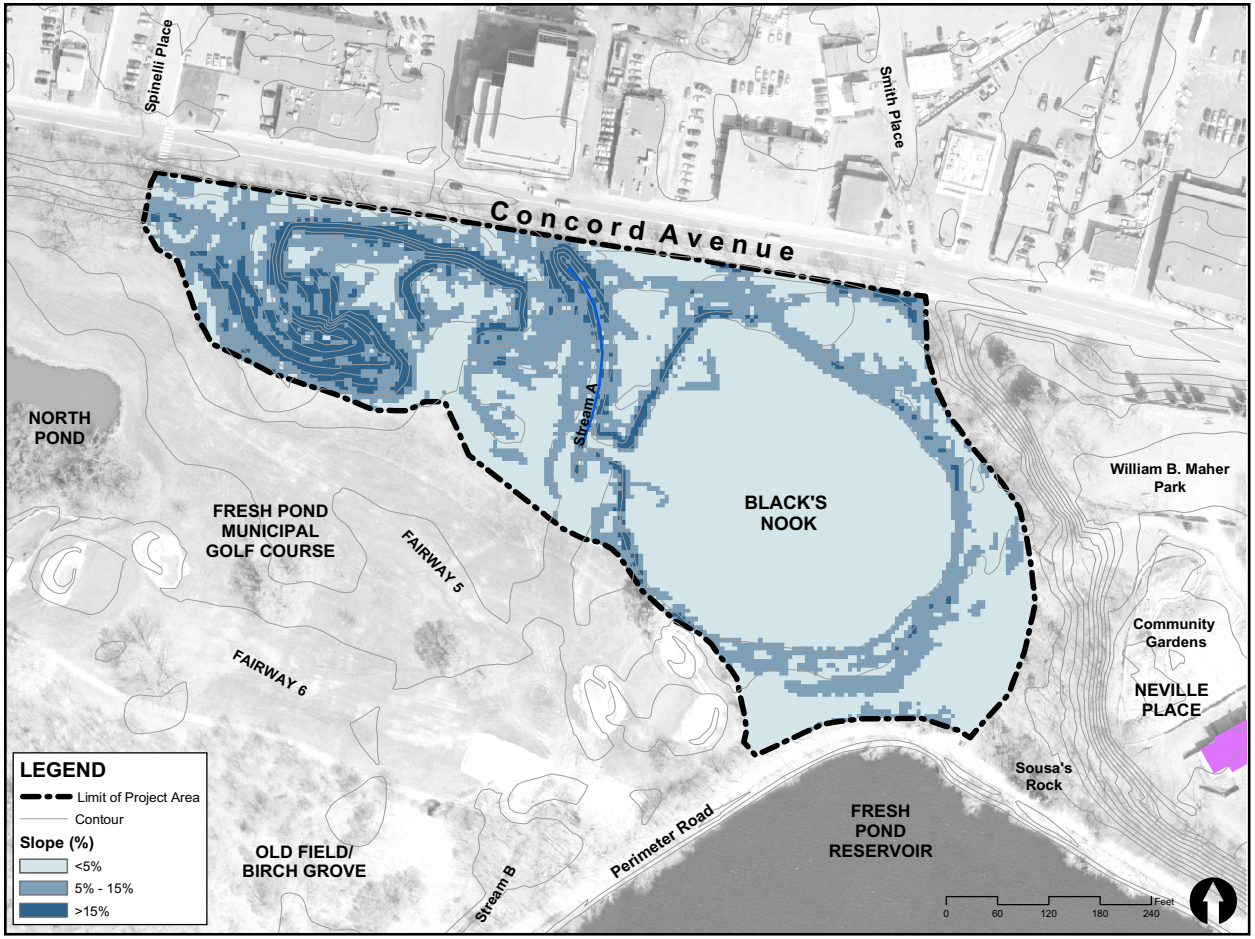


Figure 6 - Slopes

Slopes

Steep slopes are an important constraint to visitor access in any landscape setting. When coupled with erodible soils, they may require stabilization treatments to protect the integrity of the landform. Grades were estimated using topographic survey data and divided into three categories (Figure 6).

In general, the Black's Nook area is characterized by relatively low relief. Steep slopes occur in two key places. The first is along the esker in the western portion of the study area. This glacial feature slopes as steep as 2:1 (50% slope) on the inside and 5:1 (20% slope) on the outside of the esker. The second steep slope area is along the banks of Stream A, particularly at its northern end before the pipe leading under Concord Avenue. The banks of the stream in this area slope at 2: 1. Both areas are at risk for erosion due to the steepness of the slope, the erodibility of the sandy, gravelly soils, and the lack of stabilizing vegetation. Some rill erosion is evident on the inside slope of the esker.

Bare soil erodes and decreases water quality

Many areas around pond's edge show bare soil

Steep slopes, Stream A

Litter

Organic and inorganic debris left by visitors and trespassers can have an effect on the ecological health of the Black's Nook study area. Historical dumping includes urban fill (concrete and brick), asphalt, trees and appliances.

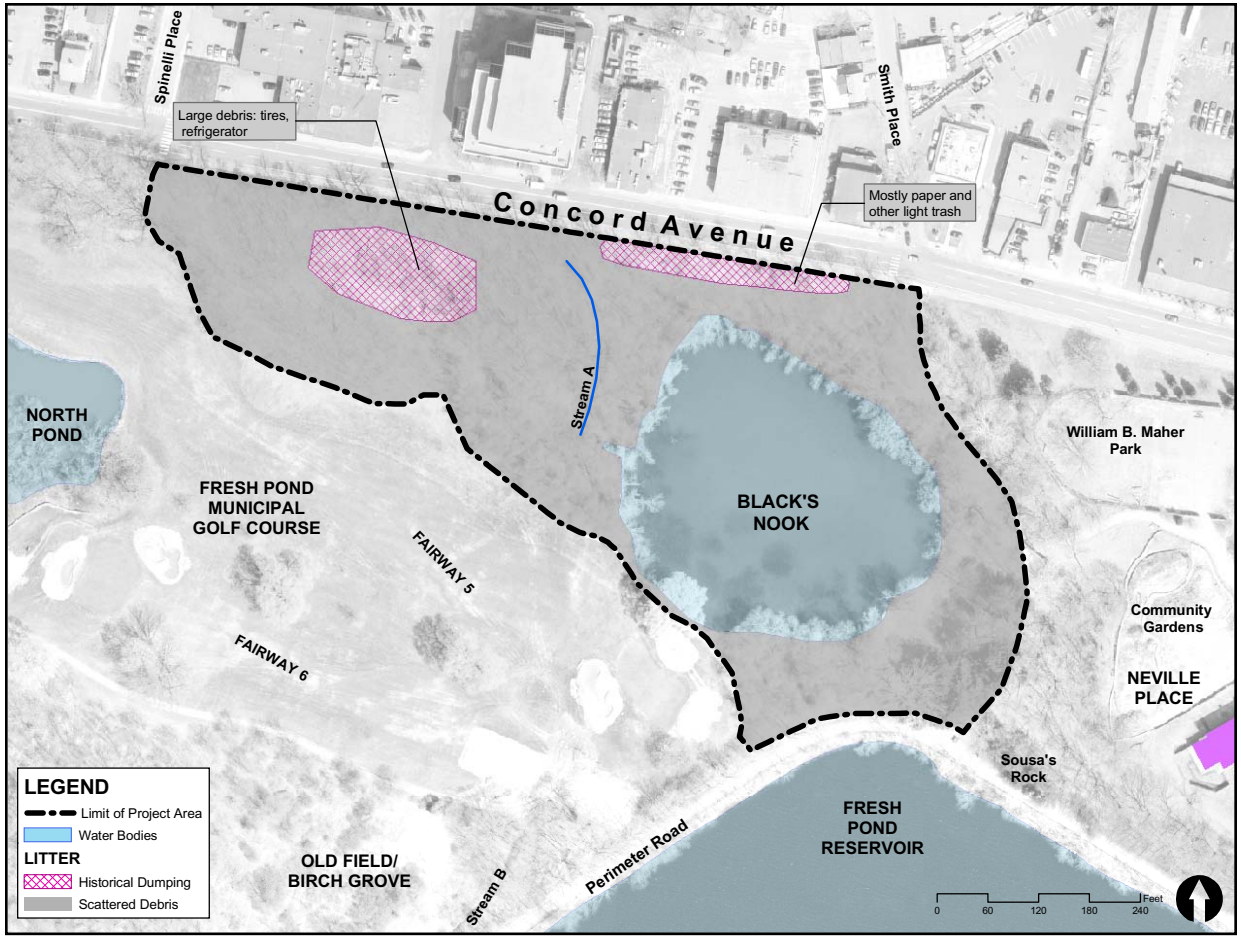


Figure 7- Litter

Historical dumping - granite curbs

Bank Conditions

The condition of the land that relates immediately to a water body has significant impact on the quality of the habitat surrounding it and the water in it. Bank height can be an important factor in locating visitor amenities such as overlooks. Steep banks are generally more prone to erosion than gently sloping banks. Bank conditions, shown in Figure 8, were classified based on height: less than or greater than 12 inches. The banks of Black's Nook are generally quite gentle except for the western side of the pond where the nearly vertical banks are as high as 2 feet. One area that shows significant erosion is on the eastern bank of Black's Nook in the area where dogs enter and exit the pond. This portion of the bank is comprised of compacted mud and has no vegetation.

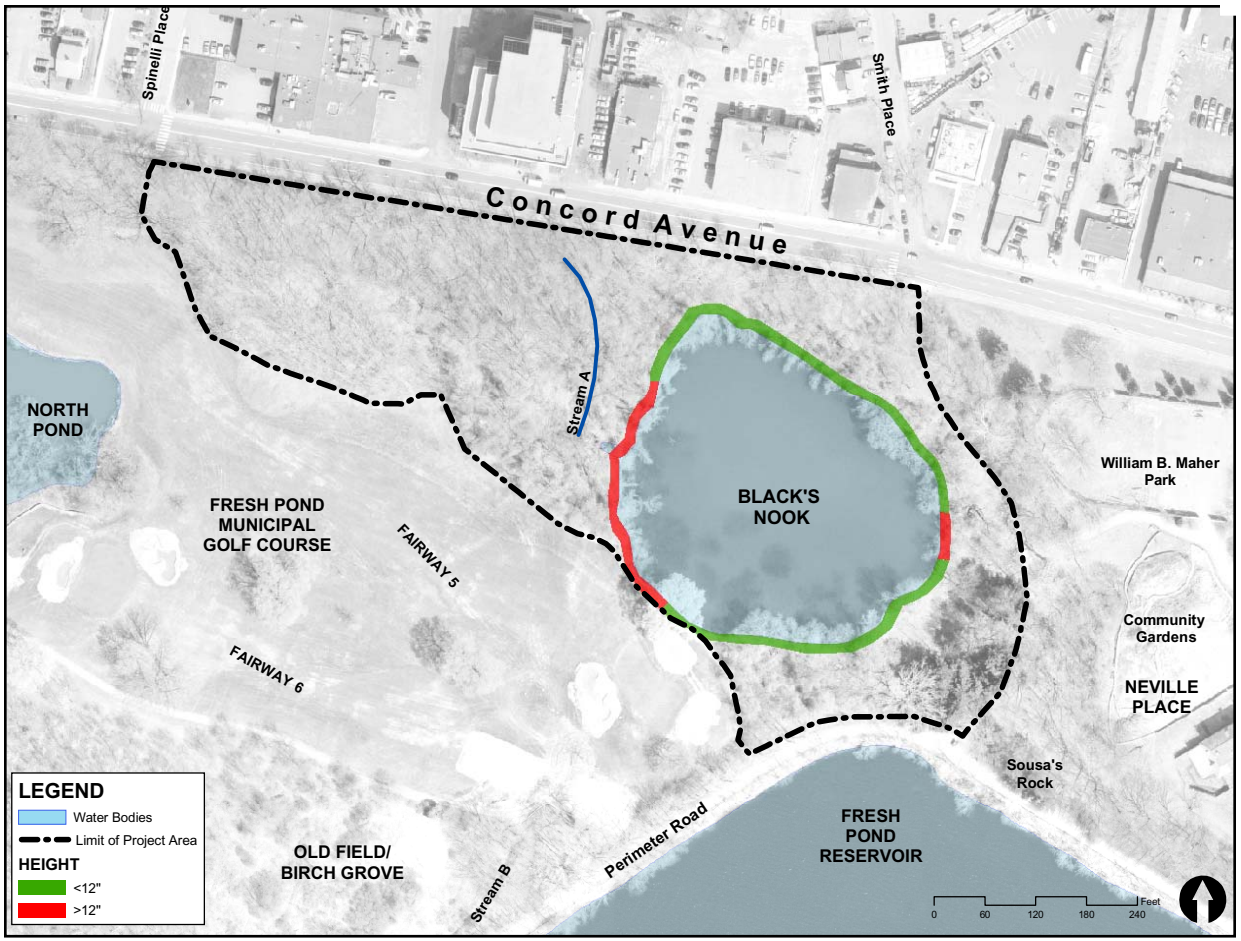


Figure 8 - Bank Conditions

Compacted trail on Eastern bank

Bank height >12"

Bank height <12"

Wildlife

The Black's Nook Pond and its surroundings are home to a variety of wildlife species, including mammals, birds, reptiles, amphibians, fish, microinvertebrates, and plankton. The Maynard Ecology Center in association with the Friends of Fresh Pond Reservation have conducted numerous surveys to document wildlife around Black's Nook.

Based on field observations conducted from 2001 to 2008, the following birds were observed to be nesting in the area:

Canada Goose
Mallard
Green Heron
Mourning Dove
Downy Woodpecker
Northern Flicker
Warbling Vireo
Red-eyed Vireo
Tree Swallow
Black-capped Chickadee
Tufted Titmouse
House Wren
American Robin
Gray Catbird
Yellow Warbler
Northern Cardinal
Common Grackle
Orchard Oriole
Baltimore Oriole

The same study identified the following bird species as being sighted in the area:

Wood Duck
American Wigeon
American Black Duck
Common Goldeneye
Hooded Merganser
Double-crested Cormorant
Great Blue Heron
Black-crowned Night-Heron
Osprey
Red-tailed Hawk
Herring Gull
Belted Kingfisher
Red-bellied Woodpecker
Eastern Wood-Pewee
Eastern Phoebe
Blue Jay
American Crow
Northern Rough-winged Swallow
White-breasted Nuthatch
Golden-crowned Kinglet
Ruby-crowned Kinglet
Blue-gray Gnatcatcher
Hermit Thrush
Northern Mockingbird
European Starling
Cedar Waxwing
Nashville Warbler
Northern Parula
Chestnut-sided Warbler
Magnolia Warbler
Cape May Warbler
Black-throated Blue Warbler
Yellow-rumped Warbler
Black-throated Green Warbler
Blackburnian Warbler
Pine Warbler
Palm Warbler
Blackpoll Warbler
Black-and-white Warbler
American Redstart
Ovenbird
Northern Waterthrush
Mourning Warbler
Common Yellowthroat
Canada Warbler
Wilson's Warbler
Scarlet Tanager
Song Sparrow
Dark-eyed Junco
Red-winged Blackbird
House Finch
American Goldfinch
House Sparrow

The following are some of the other species observed in the study area:

<u>Mammals:</u>
Squirrel
Chipmunk
Woodchuck
Raccoon
Red fox
Opossum

<u>Reptiles:</u>
Red slider turtle
Box turtle
Snapping turtle

<u>Amphibians:</u>
Green frog
Bullfrog

<u>Fish:</u>
Pumpkin seed fish
Perch
Blue gill
Fresh water minnow

<u>Microinvertebrates:</u>
Dragonfly nymph
Damselfly nymph
Caddis fly larvae
Pouch snail
Water scorpion (ranatra)
Leech
Planaria
Hydra
Predacious water beetle
Water boatman
Back strider
Water spider

<u>Phytoplankton:</u>
Pediastrum
Dinobryon
Uroglenopsis
Synura
Peridinium
Schroederia

<u>Zooplankton:</u>
Copepods
Daphnia
Rotifers (Keratella, Synchaeta, Brachionus)

<u>Other:</u>
Bryazoa colony

Trails

The number and distribution of trails is a direct reflection of the degree and nature of human use of the landscape. Trails impact the landscape by causing soil compaction resulting in reduced infiltration and increased erosion. Two types of trails are present in the Black's Nook study area. A recently completed 10' wide asphalt path connects Concord Avenue with the Perimeter Road. Narrower trails of compacted earth and mulch connect the pond edge with the asphalt paths, mainly in the southeast portion of the study area and along the northwest edge of the pond (see Figure 9). No formal trails exist west of Stream A.

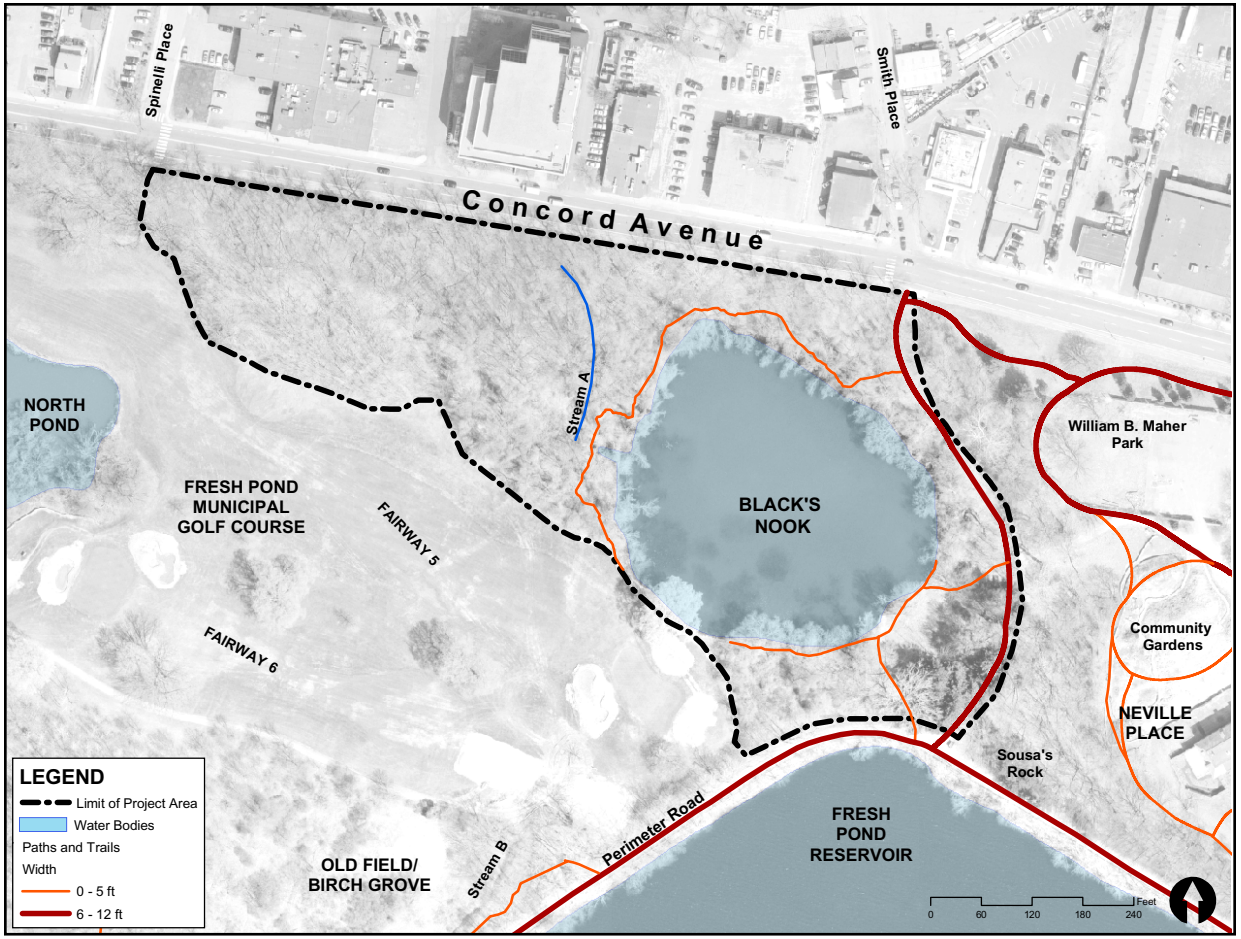


Figure 9 - Trails

Perimeter Road and Sousa's Rock

Connector Path from Concord Ave.

Compacted trail north of Pond

Water Quality

3.1 Evolution of Black's Nook Pond

As a deep-water cove of the Fresh Pond Reservoir, Black's Nook was an integral part of a larger ecosystem that benefited from the internal circulation and dilution potential of a large and carefully managed body of water. The circumstances changed significantly when a fill section was installed in 1880 to support a circumferential road around Fresh Pond that isolated Black's Nook creating, in effect, a highly eutrophic pond in a small watershed with minimal throughflow. Compounding this situation, conversion from forest to managed turf in 1932 that accompanied construction of the Golf Course on approximately 80 percent of its watershed introduced significant concentrations of herbicides, pesticides and nutrients to Black's Nook Pond. In addition, until 1963, Black's Nook Pond was a sink for debris dumping by the City of Cambridge including substantial volumes of organic material such as wood waste, tree branches, leaves, grass cuttings, etc. The dumping over time reduced the Pond's depth from approximately 30 feet to 6 feet, amounting to about 18,000 cubic yards of organically rich and nutrient-laden sediment (Whitman and Howard). The result has been a depletion of water quality, high growth of macrophytes and adverse effects on the aquatic flora and fauna.

Numerous studies have been undertaken to document the physical, chemical and biological characteristics of the Pond and assess its character as a healthy and functioning ecosystem (see Appendix B). Conclusions consistently indicate high concentrations of nutrients in untreated runoff entering the Pond, largely from the golf course, combined with in-situ nutrients contained in the sediment that provide an almost continuous supply of dissolved phosphorous. The result is algal blooms and excessive growth of macrophytes (such as smartweed (*Polygonum spp.*), American waterweed (*Elodea canadensis*), pondweed (*Potomageton spp*.), coontail (*Ceratophyllum demersum*), and water chestnut (*Trapa natans*)) that choke the Pond and limit habitat conditions for native aquatic species. High nutrient concentrations are at the root of the problems that place Black's Nook Pond on the 303-d List of Impaired Waters* and precludes its Class B water quality status. Weak thermal stratification, warm water fish species and the presence of high total dissolved solids (TDS) for the bottom of the Pond, particularly fecal coliform bacteria and heavy metals are also reported.

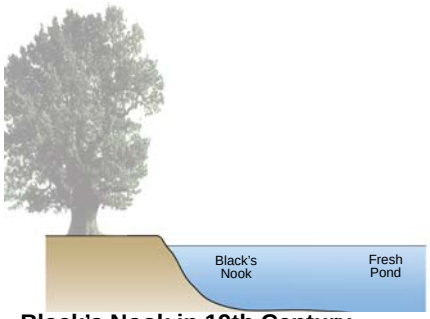
Figure 10 visually depicts the historical and predicted fate of Black's Nook Pond without intervention.

** The 303(d) List of Impaired Waters reports on streams and lakes identified as impaired for one or more pollutants and do not meet one or more water quality standards.*

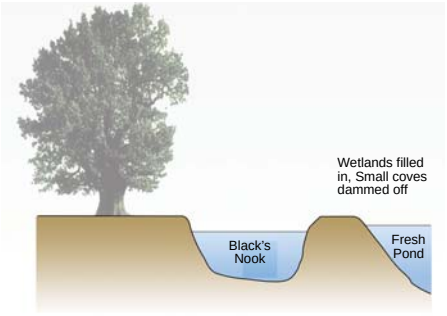
Compacted shoreline, typical

Golf course buffer, 5th fairway

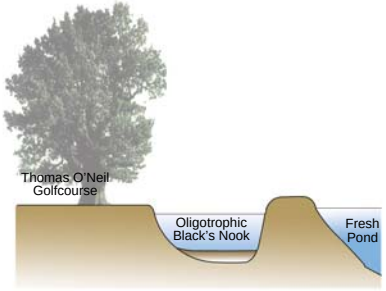
Water chestnut, photo by Jean Baxter



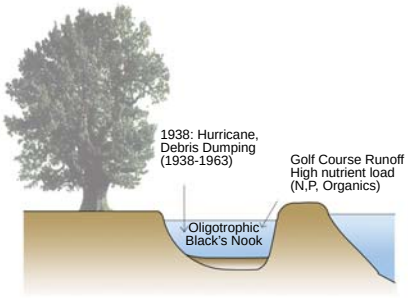
Black's Nook in 19th Century



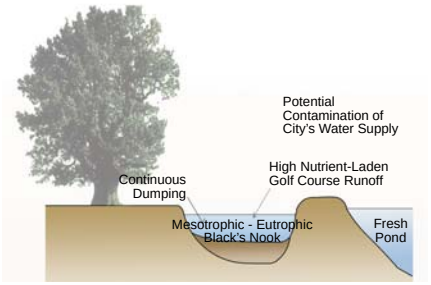
Watershed modifications in 1880



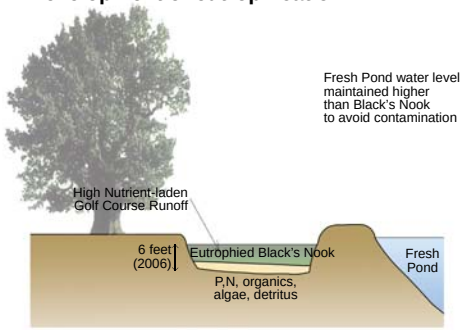
Golf course construction in 1932



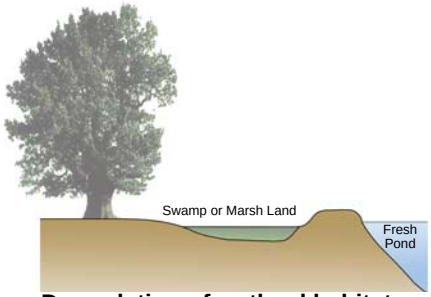
Dumping era from 1938 to 1963



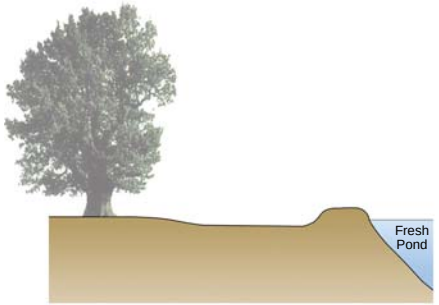
Development of eutrophication



Extreme eutrophication



Degradation of wetland habitat



Loss of wetland habitat

Figure 10: Black's Nook Pond Degradation

3.2 Objectives

The main objectives associated with the water quality analysis include:

- Collect existing data on watershed characteristics, runoff, nutrient loadings and water quality parameters
- Identify and fill data gaps where feasible to enable up-to-date analysis
- Analyze available data to summarize monthly, seasonal and annual trends in water quality, and the related increase in pollutant loadings (1986 to 2006)
- Evaluate the Class "B" surface water quality status of Black's Nook
- Understand the spatial and temporal variation in concentration, as well as fate and transport of nutrients and pollutants
- Assess the applicability of established mathematical models to predict response times, fate and transport of pollutants
- Estimate (qualitatively) water quality dangers faced by Black's Nook in the absence of restoration measures
- Summarize watershed and pond-specific recommendations in order to satisfy the water quality goals outlined in the Fresh Pond Reservation Master Plan

3.3 Watershed Description

Watershed boundaries to the north and southwest were adopted from a 2001 Montgomery, Watson, Harza (MWH) study (See Figure 11). The wetland system surrounding North Pond was added to the watershed area. The boundary on the eastern side (Neville Manor) was updated with the topographic and grading plan from Carol R. Johnson Associates, Inc. (April 2005).

All relevant historical data was consolidated with the most recent water quality data obtained from the CWD to complete the data acquisition process. Appendix A contains tables summarizing the data obtained from 2001 to 2006. The most useful data

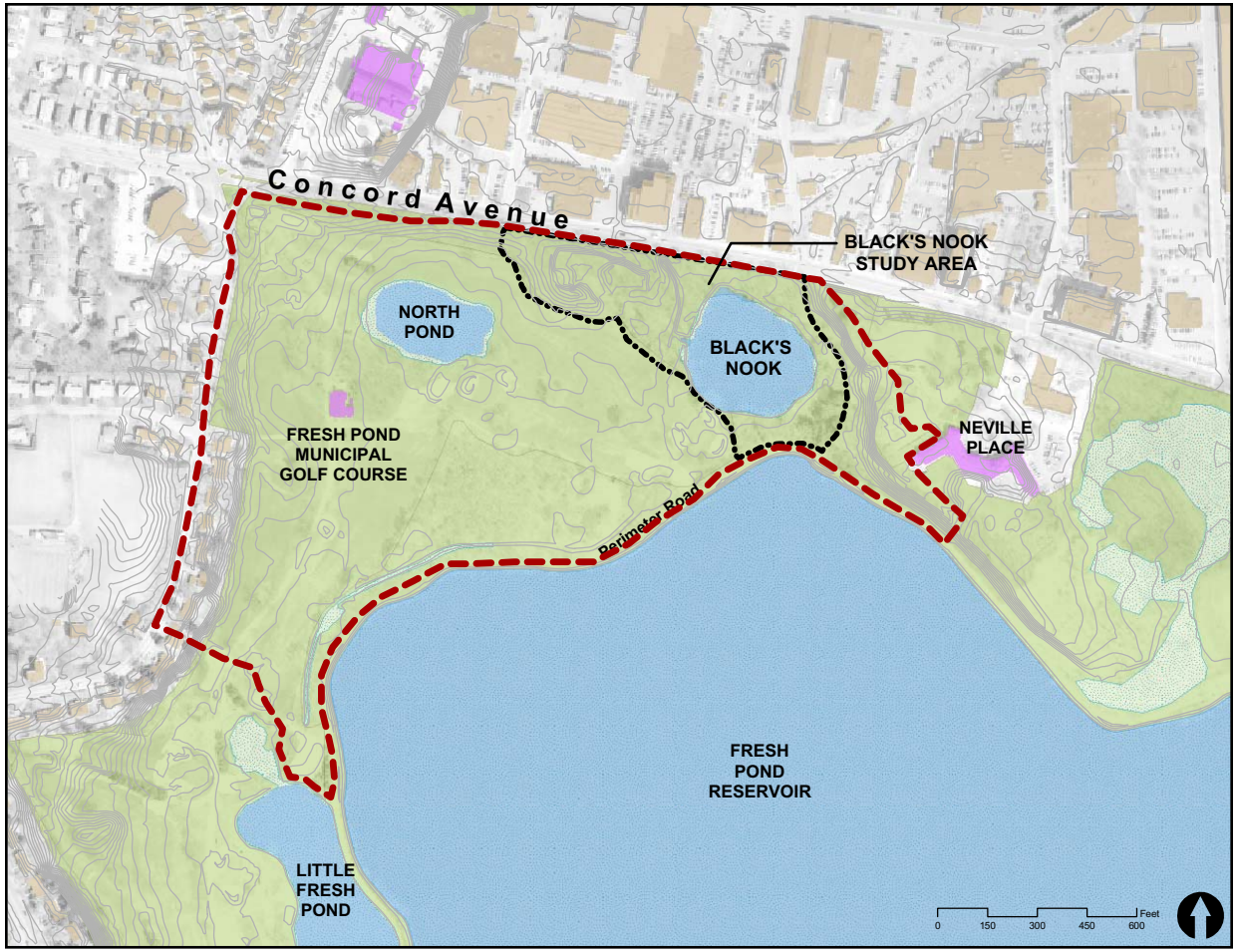


Figure 11: Black's Nook Watershed Boundary

Description	Area (ac)
Total Black's Nook Watershed	46.83
Black's Nook Pond	2.59
North Pond Watershed	11.67
North Pond	1.85

Table 1: Watershed Area in Acres

points for analysis were those collected at the surface (depth = 0 ft). The data deficiencies are described later in this report.

Class "B" Surface Water Quality Status

According to the 314 CMR 4.00: Massachusetts Surface Water Quality Standards, Class "B" waters are, "waters that are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of public water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value."

The following eight factors describe the applicability of the Class B Standards to Black's Nook in light of data collected by the CWD: Dissolved oxygen, temperature, pH, fecal coliform bacteria, solids, color and turbidity, oil and grease, and taste and odor.

Dissolved Oxygen (DO)

> *"DO shall not be less than 6.0 mg/l in cold water fisheries nor less than 5.0 mg/l in warm water fisheries unless background conditions are lower; Natural seasonal and daily variations above these levels shall be maintained; levels shall not be lowered below 75% of saturation in cold-water fisheries nor 60% of saturation in warm water fisheries due to a discharge."*

Based on species observed, Black's Nook can be categorized as a warm water fishery (Whitman and Howard Report, 1986). BioGroup aquatic ecologists confirmed that this is currently the case. The lowest dissolved oxygen values observed were 3.3 mg/l in April 2001, and 3.1 mg/l in February 2004 indicating extreme depletion of dissolved oxygen. This can be attributed to decomposition of detritus and organic matter

(macrophytes and algae) in the water column as well as the sediment. The dissolved oxygen is also utilized by various nitrogen and phosphorus compounds to transform from one form to another. As a result, the hypolimnon is becoming increasingly anaerobic and anoxic at times. This poses a serious threat to the health of the Pond. Dissolved oxygen saturation is a measure of the amount of oxygen that water can hold at a given temperature. The observed range was from 23% (February 2004) to 128% (July 2002 - supersaturation) with an average of 44.17% over the sample collection period (2001-2006). DO saturation should be greater than 60% throughout the year for warm water fisheries. The Dissolved Oxygen Figure in Appendix A shows surface DO levels (at depth = 0 ft) for 2001 – 2006. ***Even the surface water fails to meet the Class "B" criteria during certain parts of the year.*** DO levels were highest in April, May and June; dropped in fall and increased in winter. Evidence for excessive depletion of DO below 5 feet (close to the sediment) confirms algal decomposition and a sediment nutrient transformation phenomenon. Based on both historic information and recent data (up to 2006, additional data has become available since then), Black's Nook does not meet Class "B" surface water quality standards with respect to dissolved oxygen.

The photograph below, taken in 2007, reveals significant eutrophication (varying shades of green show algae populations and different degrees of oxygen depletion). Section 3.5 identifies several strategies for reducing eutrophication in Black's Nook Pond.

Temperature

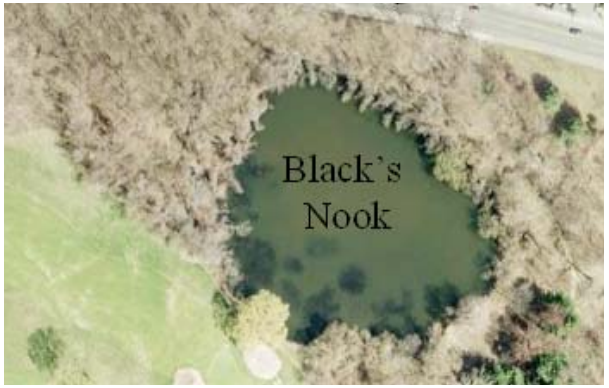
> *"Shall not exceed 68°F (20°C) in cold water fisheries nor 83°F (28.3°C) in warm water fisheries, and the rise in temperature due to a discharge shall not exceed 3°F (1.7°C) in rivers and streams designated as cold water fisheries nor 5°F (2.8°C) in rivers and streams designated as warm water fisheries (based on the minimum expected flow for the month); in lakes and ponds the rise shall not exceed 3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperature)"*

Water temperature decreased with depth (see Surface Temperature Figure, Appendix A) for most of the available data collection period. Surface water temperatures were higher than 314 CMR 4.00 Class "B" criteria on two days in 2002. Temperature drop with depth was observed (30 C drop in 6 feet) but the data does not indicate distinct stratification.

pH

> *"pH shall be in the range of 6.5 through 8.3 standard units and not more than 0.5 units outside of the background range. There shall be no change from background conditions that would impair any use assigned to this Class."*

As shown in Surface pH Figure, Appendix A, the lowest pH was recorded on February 20th 2004 (3.04) and highest pH recorded was on July 10th 2002 (9.09). Discounting these two deviations, pH does not seem to pose any serious water quality problems.



Aerial View of Eutrophication

Fecal Coliform Bacteria

> *"Shall not exceed a geometric mean of 200 organisms per 100 ml in any representative set of samples nor shall more than 10% of the samples exceed 400 organisms per 100 ml. This criterion may be applied on a seasonal basis at the discretion of the Department."*

Fecal coliform data was collected by the CWD only for surface waters (depth = 0 ft). On May 8, 2002 and June 22, 2006, fecal coliform levels were almost twice that of the required limits, which indicates serious organic contamination in the Pond (see Surface Fecal Coliform Figure, Appendix A).

Overflow from Stream A (Black's Nook Channel) backing up into Black's Nook Pond (April 2008)

Additional data collected in a systematic and periodic manner is required to accurately characterize the organic contamination in Black's Nook. Chlorophyll a concentration, which is a measure of algal biomass ranged from 0.79 to 110 mg/l (average = 21.57 mg/l). More data is required to accurately estimate the spatial distribution.

Solids

> *"These waters shall be free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom."*

Solids concentrations were not measured by the CWD. However, historical data on Total Dissolved Solids (Whitman and Howard, 1986) indicates eutrophication issues in Black's Nook Pond. A correlation between solids and turbidity (for which data is available) is described below.

Color and Turbidity

"These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class."

Turbidity in Black's Nook ranged between 0.5 NTU to 611.2 NTU (Nephelometric Turbidity Units). High turbidity values can be correlated to the presence of solids (suspended and dissolved colloidal) as well as debris. Though there are not any specified standards, visual observation suggests Black's Nook is turbid. The greenish color of the water during growth season indicates a high degree of eutrophication.

Oil and Grease

> *"These waters shall be free from oil, grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of aquatic life, coat the banks or bottom of the water course, or are deleterious or become toxic to aquatic life."*

There is no evidence of oil or grease contamination in Black's Nook Pond.

Taste and Odor

> *"None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this Class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life."*

These are primarily qualitative standards. Taste testing was not performed anytime and there are no known odor issues in and around Black's Nook.

Nitrogen

Ammonia concentrations ranged between 0.04 mg/l to 1.75 mg/l (average = 0.35 mg/l); organic Nitrogen between 0.13 mg/l to 3.35 mg/l (average = 0.75 mg/l); TKN (Total Kjeldahl N = Organic-N + Ammonia-N) ranged between 0.17 mg/l to 5.10 mg/l (average = 1.1 mg/l). The high values of nitrogenous compounds indicate nutrient loadings from the golf course runoff laden with fertilizers. The data set, though representative, is highly discontinuous.

Phosphorus

Total phosphorus concentrations in the water column must be lower than 0.03 mg/l to maintain the health of Black's Nook. Recent data shows more than twice the acceptable levels of total phosphorus in the water column. Past studies have further indicated high levels of phosphorus in the sediment (736 mg/l to 1,118 mg/l) exceed Class B water quality thresholds, especially during the summer months.

Metals

CWD analyzed the samples collected from Black's Nook Pond in 2006. The following table summarizes the concentration ranges of inorganic contaminants in the Pond.

Date	Al (mg/l)	Ca (mg/l)	Fe (mg/l)	Mn (mg/l)
1/19/06	0.34	24.2	1.7	0.22
6/22/06	0.059	23.7	0.785	0.109
8/10/06	0.12	27	1.27	0.189

Table 2: 2006 Metals Data

3.4 Water Quality Modeling

Modeling Approach and Alternatives

Previous studies have included hydrological analysis and water budget calculations. Future studies for predicting water quality should be consistent with goals and objectives set by the Water Department. Some potential studies include:

- Contaminant fate and transport
- Response time to restore pollutant concentrations to dry weather conditions (addresses primary and secondary point contact and recreational aspects)
- Eutrophication modeling to evaluate existing conditions and make mathematically valid recommendations to reduce contaminant levels.

Data Issues

The available data set had the following constraints making quantitative modeling impractical in the resource assessment:

- bathymetric data acquisition insufficient
- different data points for sampling locations
- Data collected at random depths, making spatial predictions impossible
- Nonidentical data sets for the study interval (sampling done on an "as needed" basis)
- No clear evidence of thermal stratification
- Insufficient data to accurately characterize

and quantify point and non point source pollutant loading
- Variation of nutrient concentrations unavailable (depth and spatial variation)
- Physical information on vertical sections (required for WASP6 modeling) unavailable

A monitoring plan should be established to enable setting up and calibrating the selected model. Subsequent monitoring for wet and dry weather conditions needs to be carried out on a regular basis at all chosen locations for all the nutrients to confirm the validity of the model in simulating field results accurately. **A systematic monitoring plan will help modify and retrofit restoration alternatives on a priority basis**.

The following predictions can be made based on available water quality data:

- Concentrations of soluble phosphorus increase linearly because there are no consumers
- Sediment pool increases the concentration of soluble phosphorus due to remineralization of sediment, supplying a constant amount of dissolved phosphorus
- Phytoplankton and detritus phosphorus decrease due to sedimentation processes
- An algal bloom is represented by a peak in soluble phosphorus in the water column
- Increase in phosphorus concentrations and transformation between its various forms (soluble, organic, algal and sediment) will make the waters highly productive where many clear water species would cease to survive – a hypereutrophic state
- Uncontrolled increase in organic and biological (fecal coliform, algae and E. coli) contaminants will result in extreme deterioration of water quality in the Pond, requiring labor and capital-intensive remediation efforts
- Frequent (high) loadings of nutrients in varying forms from golf course runoff and other sources are slowly converting the pond into a marsh/swamp system.

Figure 10 shows the progression of changes in the absence of any restoration measures.

3.5 Recommendations for Improving Water Quality

The Water Quality Enhancement Diagram (Page 19) identifies how the water quality objectives for Black's Nook Pond can be achieved through the use of USEPA's preferred hierarchy for pollution prevention model.

A schematic-level Site Improvement Plan developed by BioGoup in 2006 identified a watershed-based solution for improving water quality within Black's Nook Pond and improvements to Streams A (Black's Nook Channel) and B. This plan proposed to deepen the Pond by removing sediments and constructing a weir to help maintain surface elevations. Stream B would be daylit at its northern end and connected to Black's Nook Pond to restore water circulation and provide for periodic flushing. Sediment removed from the Pond would be used to line the newly constructed wetlands along Stream B. Golf course drainage would be diverted into the constructed wetlands for initial treatment.

The options listed below illustrate the range of techniques that may be drawn upon when selecting actions for the Landscape Restoration Plan. Restoration, which can improve the water quality of Black's Nook if engineered and applied wisely, may also reduce the costs currently incurred in maintaining the reservoir levels. A natural systems-based approach calls for a synergistic implementation of active management strategies including **source reduction, dilution, enhancement, and sediment removal**.

Source Reduction

Runoff from the golf course and the other parts of the watershed is a significant source of nutrients for the aquatic weeds and macrophytes. Hence, implementing "source reduction" options are the highest priority from a restoration perspective. Fertilizers are being used extensively as part of golf course maintenance activities, which contribute to high loadings of N, P, K, organic compounds, and trace elements to the surface runoff. The recommended source reduction options are:

- Minimizing fertilizer usage to the maximum possible extent
- Material substitution (using alternate fertilizers)

Dilution

Black's Nook Pond has been isolated from Fresh Pond for over a century, creating a sink for pollutants. Its small watershed provides minimal impact to maintain adequate flushing of the water column. Connecting Black's Nook Pond to Little Fresh Pond's overflow system (via Stream B) would provide a periodic pulse of water to dilute and flush the contaminated water. The remaining water, however, would require treatment. The use of wetlands to treat contaminated water is further outlined in this section.

Nonstructural BMP's

Nonstructural BMP's such as sweeping impervious areas draining into the Pond, or debris and leaf pick-up can be effective ways to contain the nutrient loading in stormwater runoff at source. De-weeding, debris clearance, and harvesting of algae and aquatic weeds along the Pond's shoreline will reduce the nutrient content and flux in Black's Nook. Disposal of the harvested aquatic weeds to landfills or suitable restoration sites are the final step of this process. The near-term benefits of harvesting include

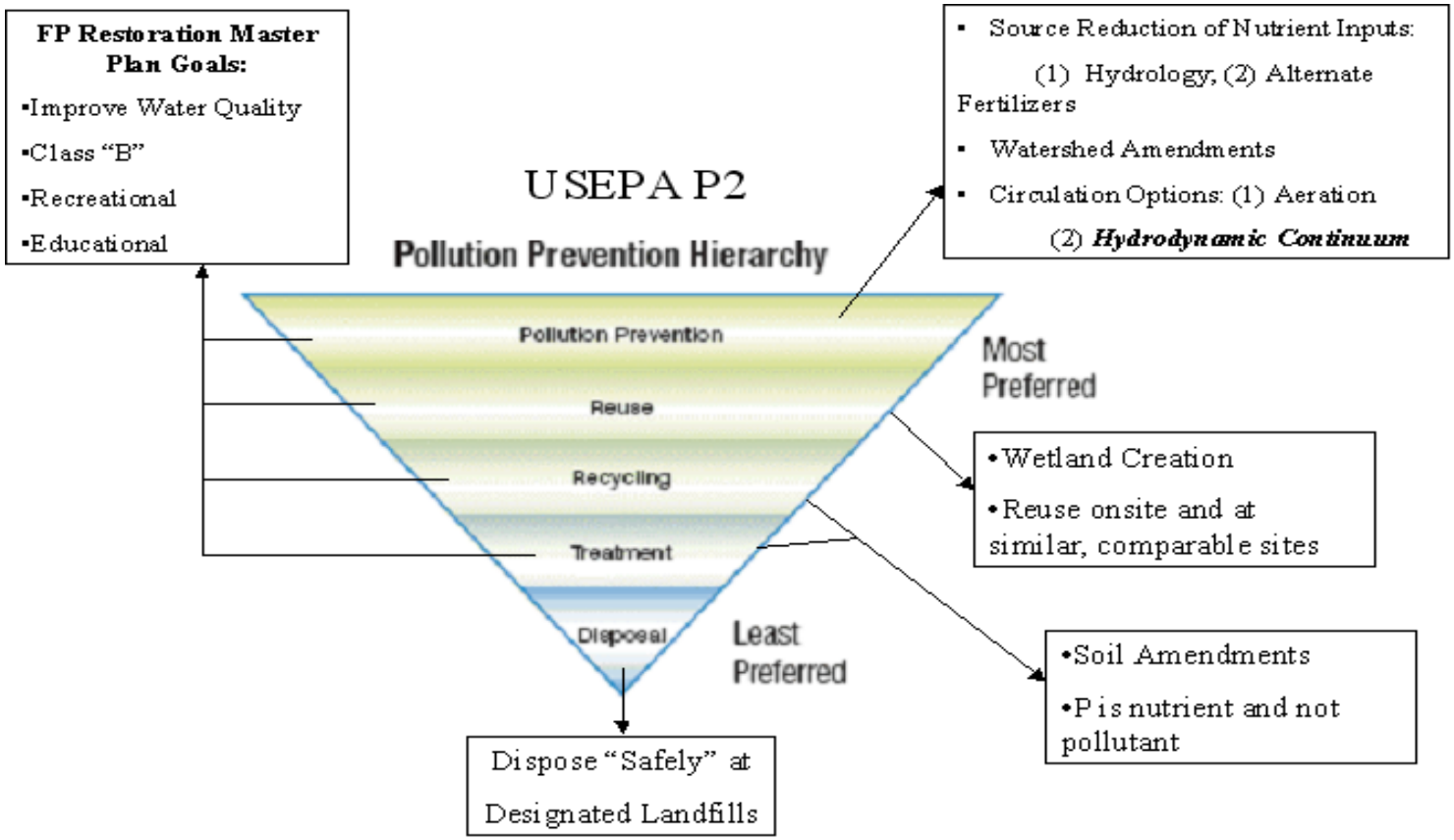


Figure 12: Water Quality Enhancement Diagram

improved opportunity for fishing in Black's Nook Pond.

Water Quality Enhancement Options

Nutrient Immobilization

Phosphorus can be removed from the water column and deposited (precipitated) in the sediments by adding salts of aluminum and iron to the Pond. The proper chemical dosages and frequency of treatment are critical to achieve desired results.

Phytoremediation

Mn, Al, Ca and Fe compounds were observed in the water column of Black's Nook Pond (CWD Data, 2006). These inorganic contaminants, with the exception of Ca, can be extracted directly from the water column or sediments using certain plant species. Phytoremediation is the strategy wherein particular plant species are chosen to accumulate, concentrate and transform organic and inorganic toxins directly from the water column or sediments using solar energy to drive the process. Currently, research is being carried out to demonstrate phytoremediation as a viable option to reduce Ca levels in the water column. Since there are other proven ways to mitigate Ca levels, phytoremediation could be considered as an option to bio-augment the other three metals (Mn, Al and Fe) and reduce their levels. The following mechanisms could be employed in a phytoremediation strategy to assimilate metals and other contaminants:

- Phytoextraction: concentration of metals from the soil into the harvestable portions of roots and shoots
- Rhizofiltration: absorption, precipitation, and concentration of metals from the water column by the root system
- Phytostabilization: immobilization of metals by special tolerant plants, in order to avoid movement through erosion

Control of Macrophytes

Steps were taken in the past to physically remove invasive aquatic plants from within the Pond. Harvesting is an important tool related to nutrient management within Black's Nook and should be monitored and managed annually.

Chemical control of macrophytes is not being considered due to the proximity of Black's Nook to the Reservoir.

Planting native aquatic plant species that can competitively inhibit the growth of macrophytes can be cost-effective and safe. Certain viruses can also be used to control blue-green algal blooms.

Water Level Management

Water-level manipulation will control rooted aquatic plants. During winter months, a combination of lowering water levels and freezing will reduce the plant population via dehydration and dessication. Care should be taken in order to avoid increased release of N and P compounds during extreme lowering. Additionally, impacts to the water level at Little Fresh Pond shall be measured and approved by the Water Department before any action takes place.

Aeration

Aeration can be effectively used to maintain the hydrodynamic nature of Black's Nook Pond (see *Black's Nook Pond Water Quality Analysis and Management Recommendations*, Snow, 2004). Aeration results in release of phosphorus from the sediment under aerobic conditions. Mixing and destratification can be ensured by the use of compressed air or pumps.

Aeration operations must be planned and implemented in a way not to disturb the seasonal thermocline in the Pond. Any thermocline is expected to develop during the growth season and is a strong barrier to nutrient transport from the sediment into the water. However, current data does not indicate significant stratification or thermocline. If thermal stratification can be established by more data gathering, it would be wise to aerate only the hypolimnion layer without destratification. If Black's Nook is sufficiently deepened and allowed to develop a stable thermocline, more concentration of nitrogen and phosphorus can be accumulated in the hypolimnetic (lower) layer than in the epilimnetic (upper) layer. The source of these high concentrations under such anaerobic conditions is the nutrient pool in the sediment of the Pond. Hypolimnetic withdrawal of water will provide higher nutrient flux out of the Pond than epilimnetic removal of pond water. Release of H2S under anoxic conditions in the hypolimnion should be considered and controlled. Costs of the aeration operations will determine the applicability of this solution. Past studies have focused on aeration opportunities but do not present many opportunities to achieve circulation of the nutrients and contaminants.

Wetland Creation

Flushing can be effective in controlling pollutant levels in Black's Nook Pond if large volumes of treated water are made available throughout the year. Minimizing stagnation would develop a more dynamic environment in the Pond while achieving the required flushing by directing the periodic overflow from Little Fresh Pond through Stream B (see summary, proposed Site Improvement Plan, 2006), This approach can help to (a) maintain Class B Standards, (b) enhance habitat values and (c) decrease the frequency and severity of algal blooms.

Sediment Removal and Re-use

The high phosphorus loading in the sediment can be removed in order to take it out of circulation. The study by Whitman and Howard (1986)

indicated that approximately 18,000 cubic yards of sediment is contained in the Pond. Dredging plans have been proposed in the past as part of restoration strategies. As stated previously, a load of phosphorus exists in the water column as well as in the sediment. Based on the dissolved oxygen content and other physiochemical parameters, phosphorus gets transformed between the three states: soluble P, algal P and sediment P. A two-step process that reduces phosphorus levels in the water and within the sediment is recommended.

Nutrient and organic-rich sediment could be used to construct a Stream B wetland complex, but would require an integrated phytoremediation strategy. Measures to physically and chemically immobilize nutrients would require careful planning, design and ongoing maintenance. High ecological value and reduced costs associated with off-site disposal could be obtained using this approach.

3.6 Summary and Conclusion

Black's Nook Pond does not meet Class "B" Surface Water Quality standards throughout the year. It has also been listed as an Impaired Water Body on the Massachusetts Section 303(d) list since 1998 as a Category 5 water body, requiring TMDL analysis (Total Maximum Daily Load).

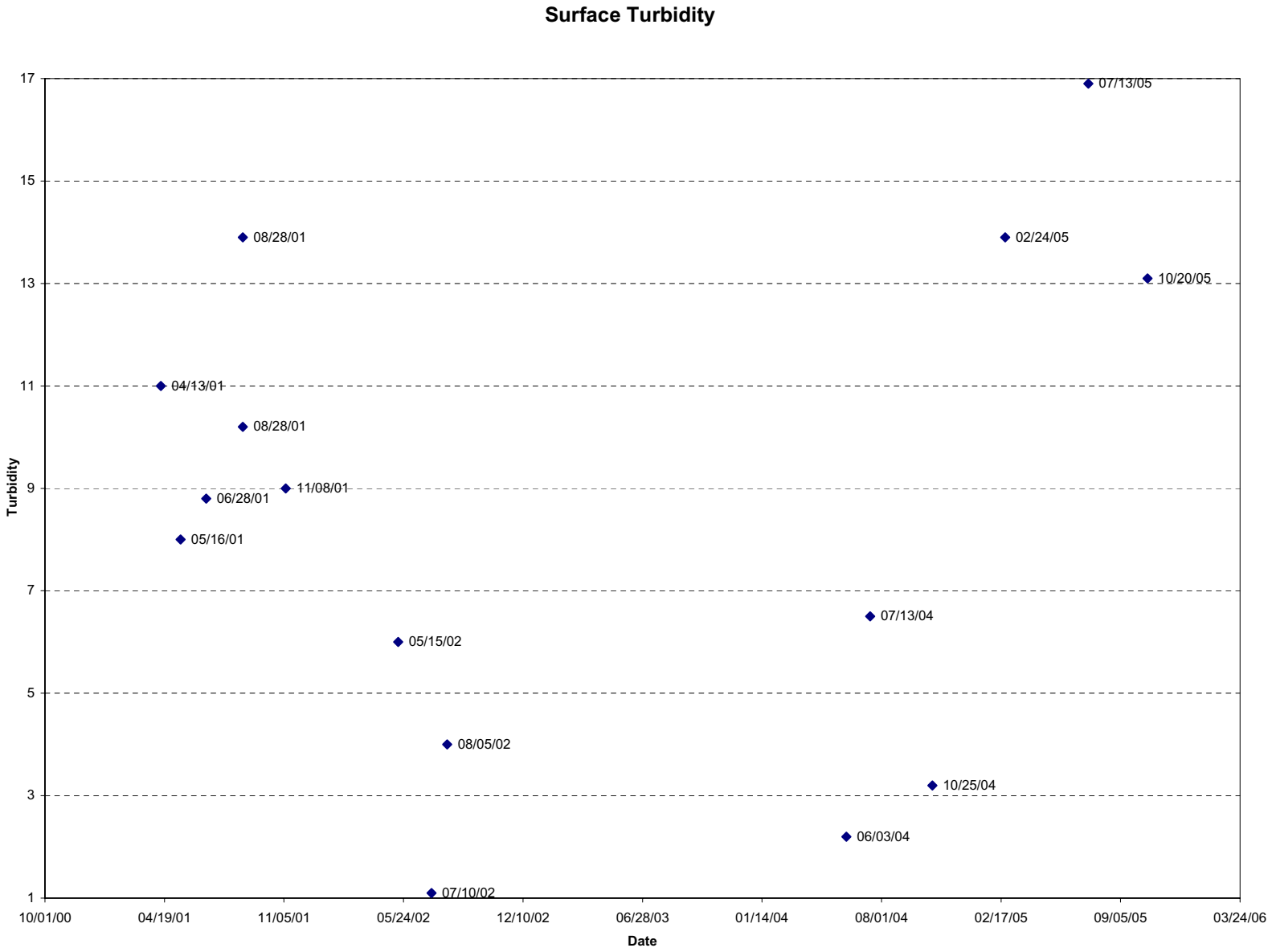
The problems that exist in Black's Nook Pond will not be corrected until the excessive nutrients entering the water column from runoff and the enriched sediment are addressed. Since it is not possible nor advisable to eliminate runoff that enters the Pond from within its watershed it will be necessary to reduce the concentrations of nutrients, pesticides and herbicides used on the golf course to an absolute minimum. In addition all runoff should be treated with BMPs prior to entering Black's Nook Pond. A constructed wetland associated with an expansion of Stream B that is connected to periodic overflow of Little Fresh Pond could provide a significant improvement in water quality as well as additional flood storage. This approach could capture and treat the majority of Golf Course runoff and provide dilution and flushing within the Pond that has been absent since Black's Nook was isolated from Fresh Pond in 1888. Overflow from Black's Nook would flow toward the Concord Avenue storm drain system via Stream A. This approach would require coordination with the City of Cambridge DPW to model the hydrological impacts on a watershed- level scale.

Creating a wetland complex would require an infusion of high organic soils that could be supplied by the Black's Nook sediments. This would provide a synergistic effect since removal of the sediments from the Pond is the second major action required to eliminate the nutrients that migrate into the water column. Surveys have indicated the presence of organic and inorganic contaminants in the pond sediments. These can be managed through dilution, by mixing sediments with additional soil amendments, and phytoremediation within the wetland complex.

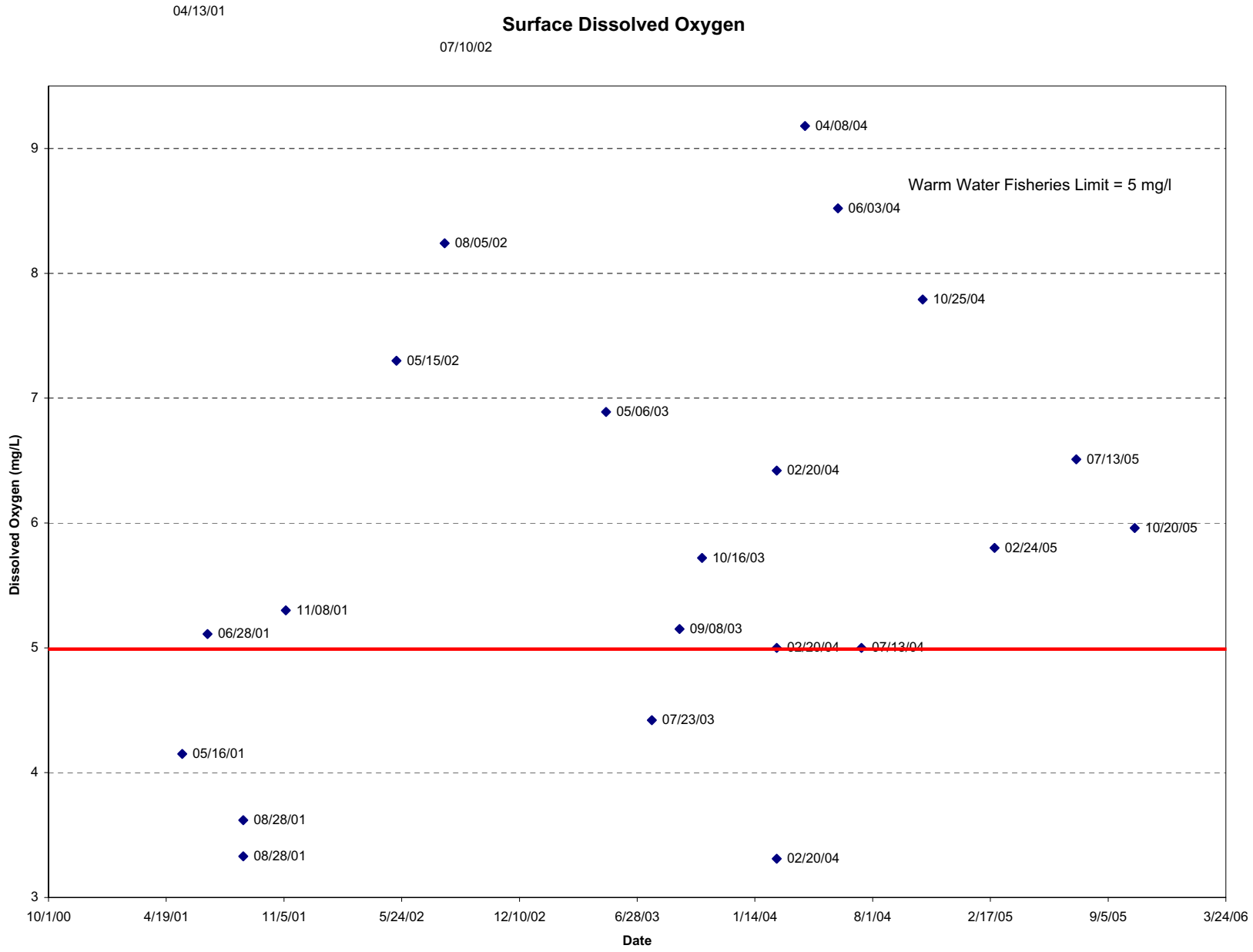
In order to accurately determine the current water quality status and pollutant loadings entering Black's Nook Pond, systematic data collection is recommended. Analysis of the water quality (through suitable models), watershed hydrology, water and sediment budget need to be performed to reflect current conditions, in particular, and the Reservation in general. These analyses will help assign ranks to different water quality parameters, in a way similar to the landscape and ecological parameters as indicated in this report. The above activities are critical to complete the water quality enhancement and landscape restoration study, and to achieve the goals set forth in the Fresh Pond Reservation Master Plan.

Appendix A

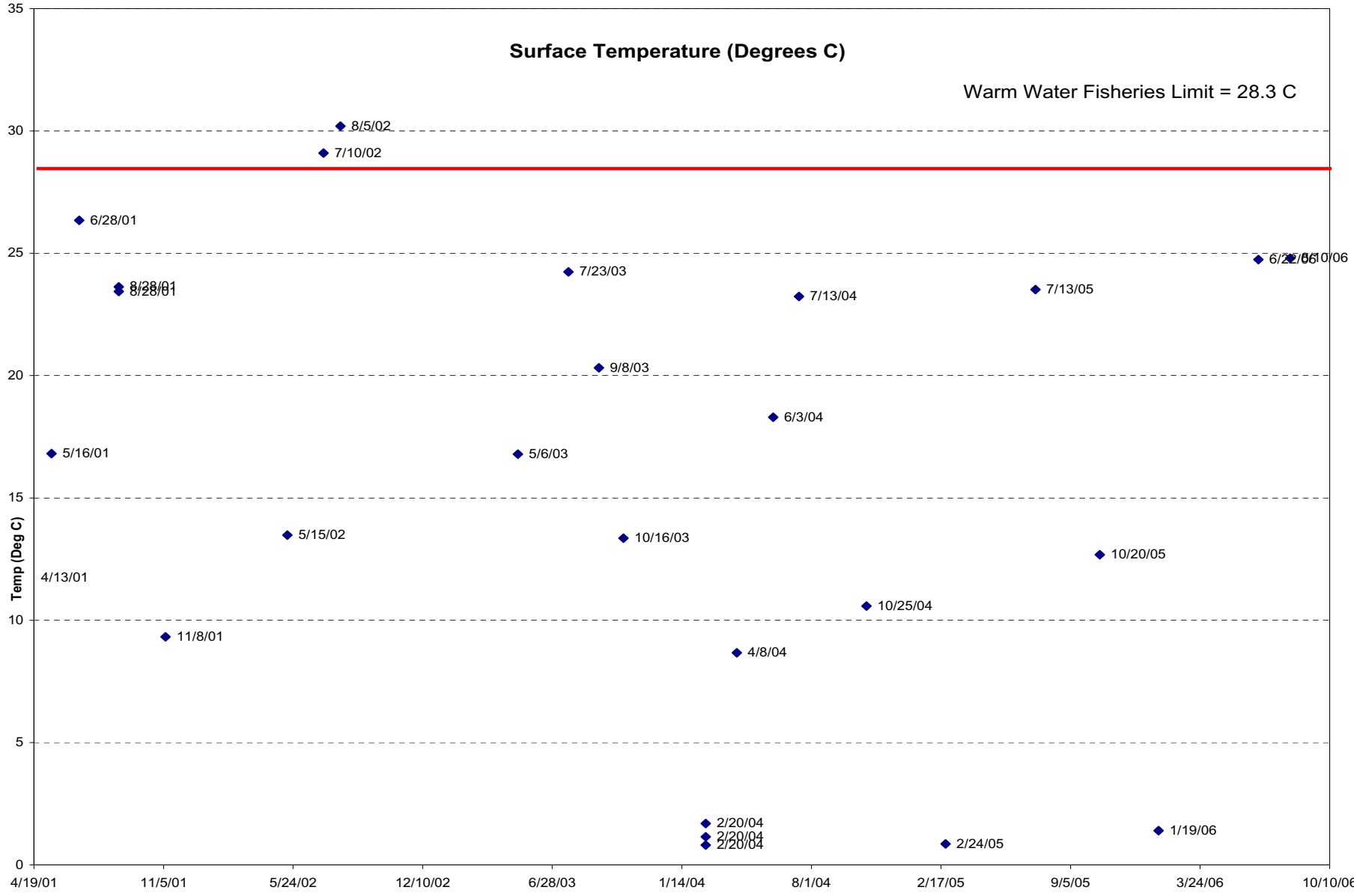
Expanded Figures



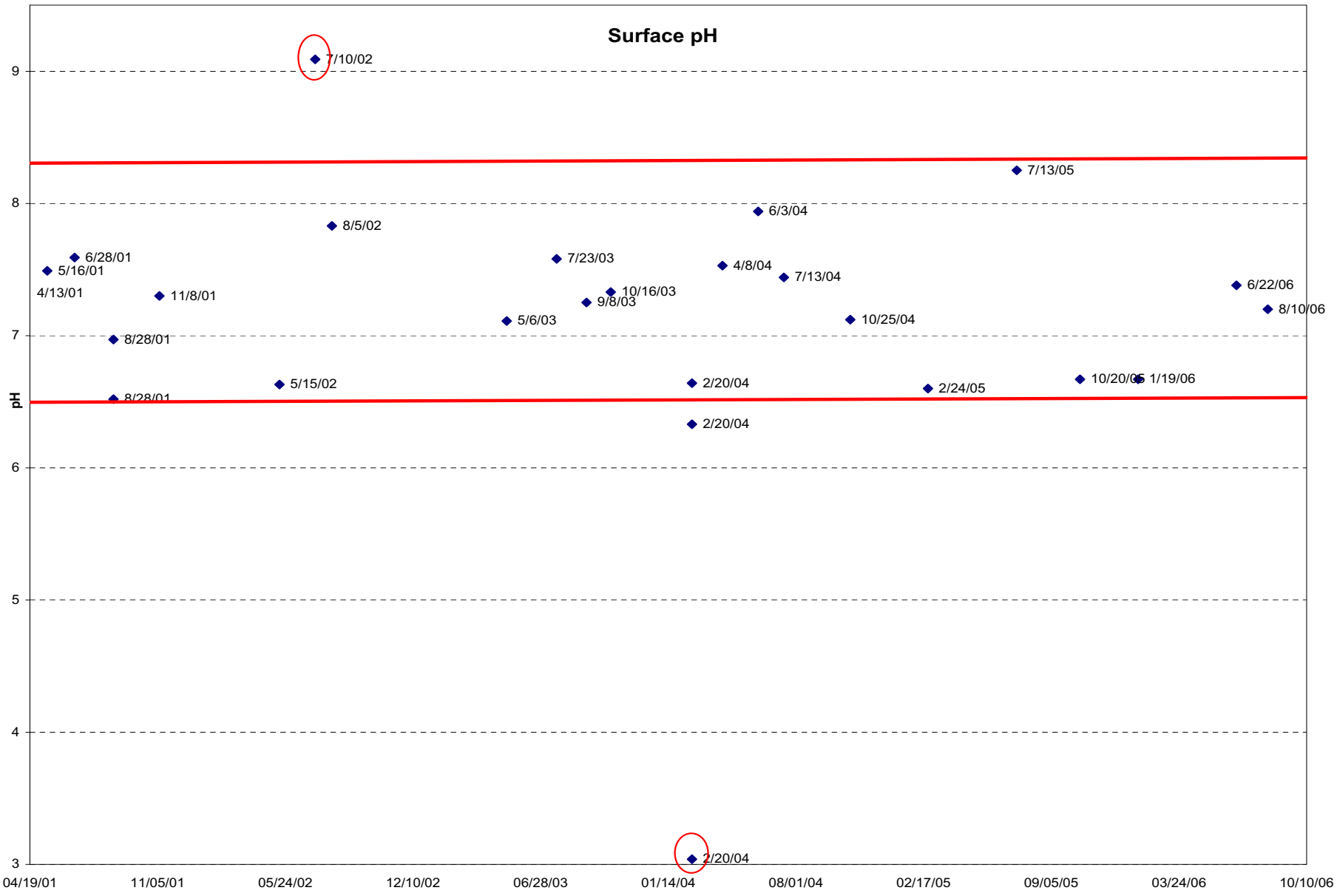
Color and Turbidity, in Nephelometric Turbidity Units



Surface Dissolved Oxygen Levels



Surface Temperatures


Surface pH
pH
9
8
7
6
5
4
3
04/19/01
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01/14/04
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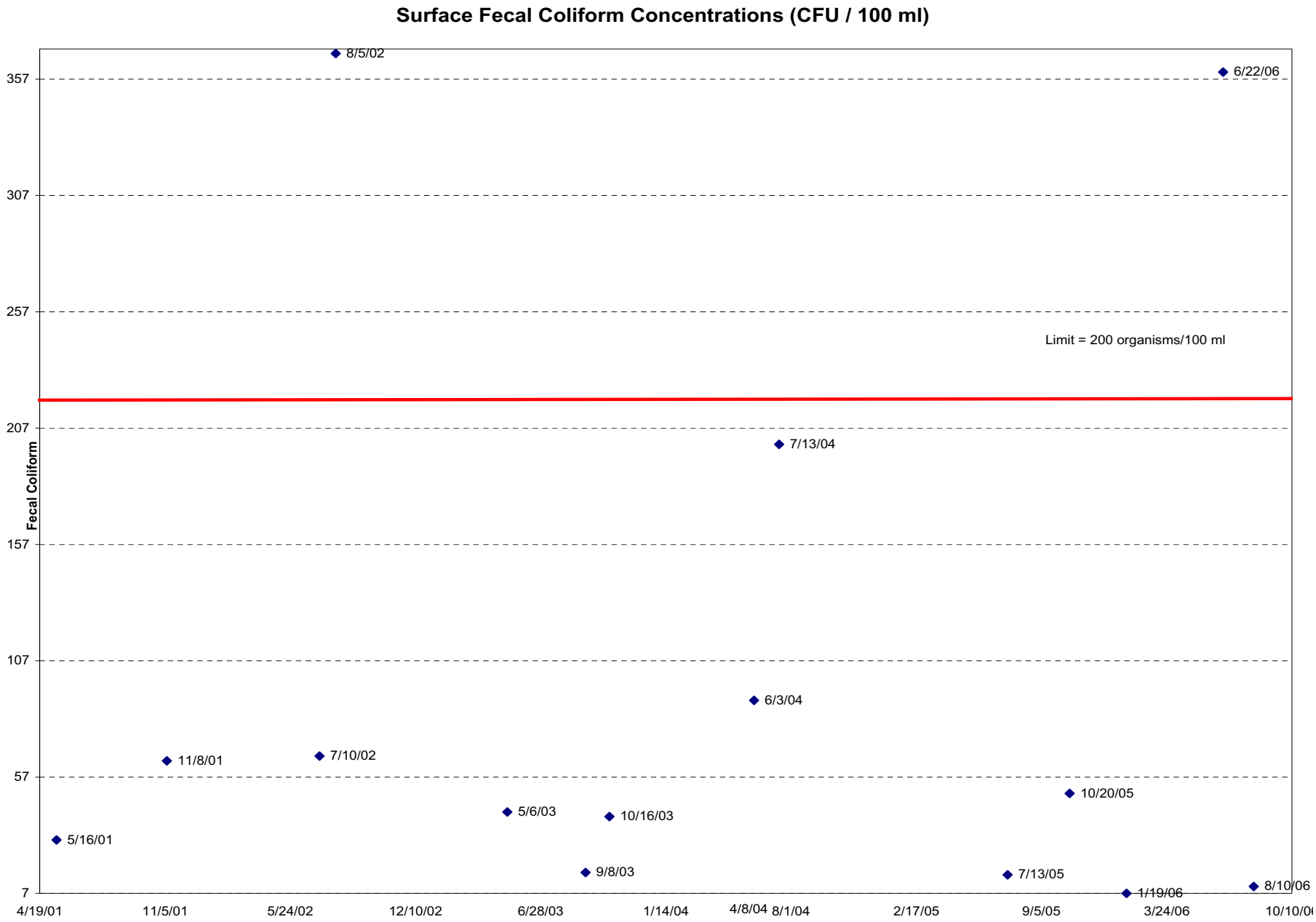
Surface pH



Fecal Coliform Bacteria

Appendix B

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