TOWN OF NANTUCKET GREAT PONDS MANAGEMENT PRINCIPLES

Prepared by the Town of Nantucket Natural Resources Department

Adopted by the Town of Nantucket Select Board

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Chapter 1.

Introduction

Ponds serve as a valuable resource for wildlife by providing an important habitat for animals such as birds, fish, frogs, and turtles. This productive ecosystem also benefits human life by reducing nutrients and serving as a place for recreation, which ultimately has economic impacts for tourism and property values. Nantucket is home to seven great ponds: Hummock, Long, Sesachacha, Miacomet, Coskata, Gibbs and Tom Nevers. Nantucket's ponds vary in geology, chemistry, biology and historic management. Since the 1980s, the Town of Nantucket has actively participated in monitoring four of these seven ponds; Hummock, Long, Sesachacha and Miacomet, whereas the other three systems fall within private lands and are therefore managed privately. Over hundreds of years, the natural progression of pond systems fill in with organic matter from plant decay, animal waste and sediment deposition. This natural progression is greatly accelerated through the influence of human activities. This process is called "eutrophication" and it is part of the natural evolution of closed pond systems, however it is being expedited by population growth and human activities. Overtime Nantucket's ponds' water quality and associated habitats have degraded, and improved management is crucial in restoring these important ecosystems.

The use of synthetic fertilizers in the 20th century has also increased the rate of eutrophication due to increased availability of usable nutrients. Ponds are subjected to nutrient inputs from improperly cited or failed septic systems influencing groundwater nutrient concentrations, fertilizers leaching into groundwater, paved roads, de-watering activities and mowed entry points diverting stormwater towards ponds, and enhanced nutrient concentrations in rain due to the burning of fossil fuels. Nutrient additions to aquatic systems such as ponds cause shifts in biological processes that can result in habitat degradation. The four great ponds managed by the Town have been receiving an excessive amount of nutrients through overland (runoff) and subsurface (beneath earth's surface) flow. These excess nutrients have led to overgrowth of algae and invasive plants, loss of native species, depletion of dissolved oxygen and decreased water clarity. These impacts diminish aesthetic appeal, impact recreational opportunities, and decrease the quality of ecological health both in and around the ponds.

As such, excessive algae and seaweed growth can reduce water clarity and organic matter enrichment in water and sediments. This may lead to increased rates of oxygen consumption and periodic depletion of dissolved oxygen, specifically in bottom waters, as well as limiting the growth of desirable species. The increased organic matter deposition to the sediments generally result in a declining habitat quality for benthic infauna communities (animals living in the sediments). These changes in habitat quality result in a shift from high diversity (deep burrowing animals which include economically important species) to low diversity of organisms (shallow dwelling animals indicative of degraded habitat).

This shift in habitat quality causes degradation of resources and a loss of productivity to shell-fishing, sport-fishing and offshore fisheries. Both the sport-fishery and the offshore fin fishery are dependent upon highly productive coastal salt ponds as a habitat and food resource during migration and various stages of their life cycles. Sea level rise and extreme weather events play an important role in the future management of these pond systems. As over-wash events become more prevalent, coastal infrastructure will continue to be jeopardized as evidenced with Sesachacha Pond washing out part of Polpis Road during the winter of 2018.

Each of Nantucket's ponds have undergone rigorous scientific investigations by a multitude of researchers from the 1970's to present. Hummock, Sesachacha and Long Ponds have had Massachusetts Estuaries Project (MEP) studies conducted which combined habitat assessments, long-term historic water quality data, hydrodynamics and watershed land use to develop threshold nutrient concentrations. The MEP reports and resulting goals (TMDL's: Total Maximum Daily Loads) are nitrogen based, because at the time of the original MEP designations, each of the pond nutrient ratios indicated nitrogen was the limiting nutrient. MEP nitrogen thresholds were developed specifically for each system so that the habitat should recover if the threshold nutrient concentrations were achieved. Given the time elapsed since these studies, changes to zoning and land use should be updated periodically to assess whether historic 'build-out' conditions have since been achieved or surpassed, warranting the need for updated linked-embayment model runs to support nutrient reductions.

Nutrients such as nitrogen are typically released from atmospheric deposition, wastewater, fertilizers, and changes in the freshwater hydrology associated with development (stormwater). Systems with large surface areas are more influenced by atmospheric deposition, due the area subject to deposition (Sesachacha Pond), whereas small systems tend to be influenced less by atmospheric nitrogen deposition (Long Pond). Streams and direct wet and dry deposition from the atmosphere represent natural sources of nutrients, however these are affected by human activities as well, such as proximity to fertilized landscapes, agriculture and failed septic systems.

Phosphorous is the limiting nutrient in freshwater systems and an important driver of harmful algal blooms of cyanobacteria (CyanoHAB). Phosphorous comes from past detergent use, the weathering of rocks, streams, wastewater and fertilizer. Reports indicate co-limitation between nitrogen and phosphorous is likely in brackish coastal water bodies[1]. Due to declining salinity in Hummock Pond and fresh water conditions in Miacomet Pond, Dr. Ken Wagner and Water Resources Services LLC submitted and received a grant from the Massachusetts Department of Environmental Protection (MADEP) to assess the inputs and potential influence of phosphorous in each pond. The project entitled "604b Study of Phosphorous Sources to Hummock and Miacomet Ponds" was a collaboration between the Nantucket Pond Coalition, the Nantucket Land Council and the Town of Nantucket[2]. This study, combined with historic studies provide ample background information on Nantucket's ponds and set the stage for future management decisions.

1.1 Objectives

I. Reduction of human-made inputs to the great ponds.
II. Improve and update pond and watershed data collected and include habitat evaluation to capture ecosystem and environmental health.
III. Investigate and implement the best available measures to improve water quality.
IV. Creat research projects that will not negatively impact any pond habitats or wildlife.
V. Enhance the public's ability to utilize the ponds for recreation without having an adverse impact to the ponds.
VI. Evaluate and implement cost effective in-pond management options.
VII. Provide homeowner's the tools to have a positive impact to the health of the ponds on their property and in their neighborhoods.

The pond management principles were developed in accordance with the "Final Generic Environmental Impact Report: Eutrophication and Aquatic Plant Management in Massachusetts" henceforth referred to as 'the management guide', prepared by the Executive Office of Environmental Affairs, Commonwealth of Massachusetts, 2004[3]. Cost estimates for each management option are provided for comparison however project values may be higher due to permitting requirements, Nantucket's remote location, and the need for equipment and supplies to be shipped from off-island. Long-term watershed management techniques are considered optimal because they eliminate or reduce the source of nutrients and educate the public on their role in nutrient pollution. Many pond systems require in-pond management to control internal nutrient loading, combat pond weeds, and control cyanobacteria blooms, which pose a threat to public health. The Pond Management Principles addresses long-term and short-term management goals related to the Natural Resources Department's mission to "preserve, protect or restore Nantucket's natural resources through responsible active management, research, education and outreach". It is important to keep in mind that projects will require monitoring as part of their permit requirements and maintenance to ensure long-term success and project efficacy. The outline of each pond follows the sections below:

I. Statement of Problem
II. Management Goals
III. Watershed and Pond Characteristics
IV. Review of Past In-pond Management Techniques
V. Review of Existing Watershed Management Techniques
VI. Evaluation of In-pond and Watershed Management Alternatives
VII. Management Recommendations

Pond nutrient management can fall into the following categories[2];

- Non-Point Source Management – control of diffuse nutrient sources from the watershed
- Point Source Management – control of point sources, usually piped discharges
- Hydraulic Controls – diversion, dilution, flushing, and hypolimnetic withdrawal strategies
- Phosphorus Inactivation – chemical binding of phosphorus to limit availability
- Artificial Circulation and Aeration – mixing and oxygen addition
- Dredging – removal of nutrient-laden sediments
- Bacterial Additives – encouraging uptake of nutrients by non-algal microbes
- Removal of Bottom Feeding Fish – elimination of major recyclers of nutrients

Although not discussed in detail within these principles, artificial circulation would require a network of points by which artificial aeration would be necessary. The expense and interference of the application network with recreational and ecological functions is generally intolerable, so this approach is unlikely to be appropriate for these ponds[2]. Bacterial additives are also not likely to produce the desired effect in Nantucket's ponds until nutrients, cyanoHAB and aquatic vegetation are more actively controlled. Therefore, although aeration and bacterial additives represent two nutrient management alternatives, they are less likely to be utilized on Nantucket due to the circulation patterns and current level of nutrient impairment observed.

1.2 Works Cited

1. Conley et al. 2002. *Science*, Vol. 323. Controlling Eutrophication: Nitrogen and Phosphorus.
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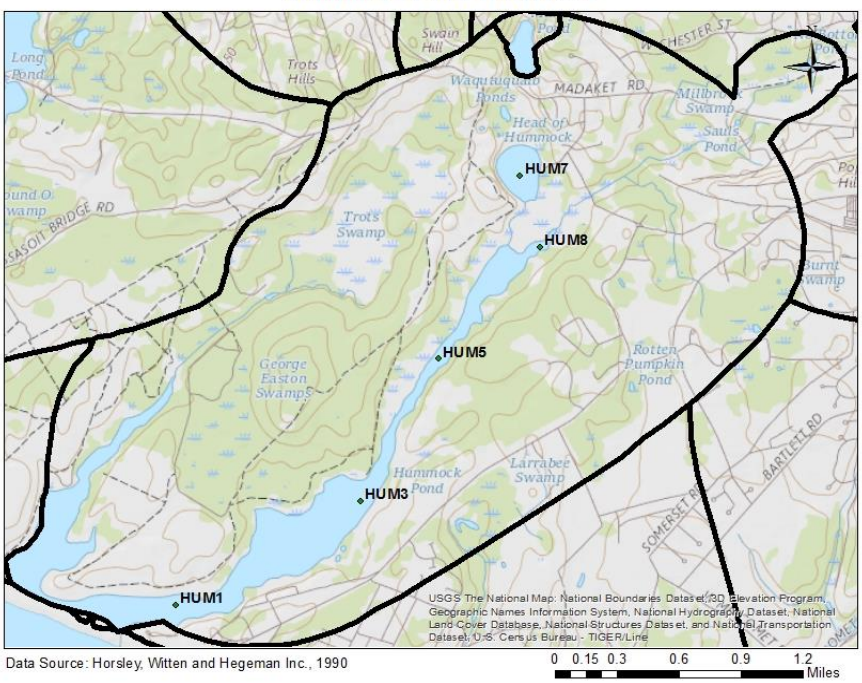
3. Mattson, M.D., P.J. Godfrey, R.A. Barletta and A. Aiello. 2004. Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report. Edited by Kenneth J. Wagner. Department of Environmental Protection and Department of Conservation and Recreation, Executive Office of Environmental Affairs, Commonwealth of Massachusetts.

Chapter 2.

Hummock Pond

Hummock Pond Watershed



Data Source: Horsley, Witten and Hegeman Inc., 1990

Figure 1. Extent of Hummock Pond watershed, as determined by Horsley, Witten and Hegeman in the 1990 Nantucket Water Resources Management Plan. Points indicate location of water quality sites used for Massachusetts Estuaries Project and ongoing sampling.

2.1 Statement of Problem

Hummock Pond is a brackish coastal pond that is 220 acres and has a 2227 acre watershed. The pond is connected to the north head by a human-made channel. The pond is generally closed to exchange with the Atlantic Ocean except for bi-annual pond openings which occur in the spring and fall to enhance anadromous/diadromous fishery resources. The primary ecological threat to Hummock Pond is degradation due to nutrient enrichment. Although the watershed and the pond have experienced issues related to bacterial contamination in the past, it does not appear to be having large ecosystem-wide impacts. Development in the Hummock Pond watershed is limited compared to other Nantucket ponds, due to its western shore being comprised of conservation land (historically used for agriculture). Hummock Pond and its associated watershed have been greatly altered by human activities over the past ~100 years[1]. As a result, the present nitrogen "overloading" appears to result partly from alterations to its ecological systems. These watershed alterations subsequently affect nitrogen loading within the watershed and influence the degree to which nitrogen loads impact the estuary[1]. Reports dating back to 1989 indicated that the primary bloom forming algae was *Anabaena*. *Anabaena* has since undergone a phylogenic name change to *Dolichospermum*, which is the type of algae that bloomed in Hummock Pond in 2016 and 2017. Due to high chlorophyll-a levels, low dissolved oxygen levels, and water column nitrogen concentrations within Hummock Pond, there is a current lack of eelgrass beds with significantly to moderately degraded benthic infauna habitat quality. Hummock Pond is under seasonal oxygen stress as indicated by dissolved oxygen records, consistent with its significant nitrogen enrichment. [1]

Hummock Pond is currently not attaining uses with regards to swimming, boating and fishing. Swimming standards are not being met due to low water clarity (<1.2m: safe swimming standard), nuisance pond weeds and potentially harmful cyanoHAB. Water quality standards are also not being met due to high Total Phosphorous (TP) and high Total Nitrogen (TN). TN exceeded the goal of 0.50mg/L, with 2017 pond-wide averages of 1.07mg/L. Hummock phosphorous exceeded EPA water quality standards of 0.025mg/L, with pond-wide averages of 0.106 mg/L. Recent 604b work indicated that TP levels >0.02mg/L represent a distinct algae bloom hazard, while 2016 Hummock TP levels were 0.08mg/L. The research conducted as part of the 604b study indicated that sediment provides additional phosphorous for algal blooms and removal may alleviate nutrients capable of inducing blooms, as well as resting algal cysts which lay dormant in the sediment.

Historically algae blooms in Hummock Pond originated in the Head of Hummock and eventually made their way to the main pond basin. However, blooms in 2015 and 2016 began in the main upper portion of the pond and continued throughout the summer season, indicating further degradation of the pond habitat. The chlorophyll data from the Head of Hummock region indicated restriction between the upper main pond and Head of Hummock, as high dissolved oxygen concentrations associated with the algae blooms were observed in 2016, while subsequent bottom oxygen depletion was likely post bloom conditions.

Aesthetic values and boating are limited due to dense submerged aquatic vegetation, cyanoHAB and the invasive wetland grass phragmites. There is a need for defined access and an information kiosk describing bloom possibility and any other pertinent information regarding the pond. Historically the Head of Hummock pond was separate from the main pond basin and there have been discussions with the Massachusetts Department of Environmental Protection (MaDEP) regarding the isolation of the Head of Hummock from the main pond due to concern over the elevated concentrations of sediment derived phosphorous[3].

2.2 Management Goals

Year	**Total Nitrogen**	**Phosph -orous**	**Total Phosphorous**	**Chloro-phyll a**	**Clarity**	**Benthic Infauna**	**Vegetation**	**Phytoplankton**
2016	0.825 mg/L	0.0325 mg/L	0.053	8.99 ug/L	0.713m	Moderate - significant impairment	Dense nuisance pond weed	Periodic blooms in the Head of Hummock; 2016-2017 main pond bloom
2017	1.07 mg/L	0.106 mg/L	N/A	31.66 ug/l	0.74m	Moderate - significant impairment	Dense nuisance pond weed	Periodic blooms in the Head of Hummock; 2016-2017 main pond bloom
Goals	0.50 mg/L	0.015 mg/L	0.015 mg/L	<10 ug/L	>1.2 m	Diversity >3, Evenness >0.7, low # poor health indicator species	Low nuisance pond weed, swimmable fishable	No cyanobacteria blooms, diverse phytoplankton assemblage

2.3 Watershed and Pond Characteristics

According to the Hummock Pond MEP report[1], much of the locally controllable, un-attenuated nitrogen load to Hummock Pond is from wastewater at 81%, while impervious surfaces, farm animals and fertilizer all contribute less than 7% each respectively. Most of the uncontrollable nitrogen load to Hummock Pond is from direct precipitation to the water body surface area at 15%, while natural surfaces in the form of small streams contribute 5%.

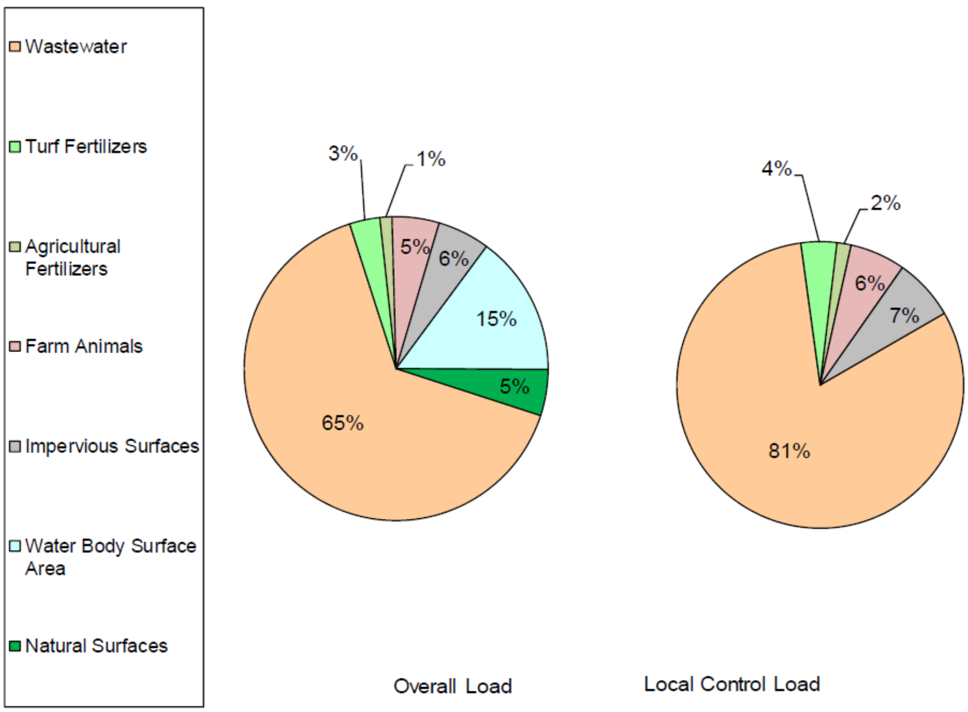


Figure IV-3. Land use-specific unattenuated nitrogen load (by percent) to the overall Hummock Pond System watershed. "Overall Load" is the total nitrogen input within the watershed, while the "Local Control Load" represents those nitrogen sources that could potentially be under local regulatory control.

Pond-wide Total Nitrogen (TN) in 1989 averaged 1.09mg/L while Total Phosphorous (TP) averaged 0.343mg/L[2]. The conductivity averaged 376ms/cm (or <0.2psu salinity) in 1989, 8 years after the 1984 April opening which lasted 3 days. Average pond-wide salinity averaged 6.62ppt in 2016 and is highly dependent on the duration of the pond openings. Currently the pond is highly eutrophic and experiencing significant impairment[1], although present conditions show improvement over 1989 concentrations. In 2016, pond-wide TN averaged 0.825mg/L, elevated concentrations (0.87mg/L) were observed at HUM5 located approximately halfway up the pond. TP measured as part of the pre-pond opening sampling, revealed elevated values of 0.053mg/L, over five times the 'healthy' threshold of 0.01mg/L. Average 2016 summer pond-wide phosphate was 0.0325mg/L, and was greatest in the northernmost channel of the pond.

According to the 604b study[3], phosphorus loading to Hummock Pond was estimated to be 399 kg P/yr, with about 75% from internal loading from sediments. Dr. Wagner concluded that N, P and light are important drivers of phytoplankton growth in Hummock Pond and that available phosphorous concentrations can support cyanobacterial blooms. As the bloom forming alga *Dolichospermum* is capable of fixing nitrogen from the atmosphere, it is likely controlled by phosphorous availability within the pond. The 604b study concludes that, "If internal phosphorous loading could be controlled in Hummock Pond, no further action should be necessary to prevent the frequent and severe cyanobacteria blooms currently experienced during summer. Additional watershed management would be desirable mainly as protection to prolong the benefits of internal load control[3]".

2.4 Review of Past in-pond Management Techniques

Aquatic Vegetation Management

The Nantucket Pond Coalition has facilitated aquatic harvesting of rooted plants from Hummock Pond. According to Dr. Wagner, "harvesting represents the primary alternative strategy, and has already been demonstrated in Hummock Pond in 2015. Mechanical harvesting machines, functionally aquatic lawnmowers, can be used to keep boating, swimming and fishing lanes open, creating a network of channels and open patches that are both ecologically and recreationally beneficial".

- **2015:** The 2015 harvester pilot project in Hummock Pond removed 23,000 lbs. of aquatic vegetation which was re-cycled as fertilizer by Sustainable Nantucket.
- **2017:** Aquatic vegetation removal continued in 2017 and acts to remove the nutrient-rich vegetation and re-cycle those nutrients elsewhere as fertilizer.

Hydraulic Control

Bi-annual pond openings represent a hydraulic management technique and facilitate dilution of high-nutrient pond waters with low-nutrient ocean waters. However, depending on the duration of the openings, this exchange can cause groundwater with elevated nutrients to be drawn into the pond at a faster rate than without the openings. During flooded conditions, the surface area of the pond increases from ~140 acres to approximately 425 acres[1]. Hummock Pond was historically opened to the ocean to enhance fish resources. Hummock was opened again 1984, during which P. Dunwiddle and J. Roe conducted a study on the efficacy of the openings[4]. The finding from this report indicated that the farthest region which experienced lowered water level was Millbrook swamp, there was no change in the mosquito breeding grounds in Trots swamp, salinity increased in the pond but was not measurable at the wells nearby, no saltwater fish were attracted to the opening, there were no impacts to nesting waterfowl, limited shoreline erosion was observed at two summer residences nearby, pond openings limit dune formation and effect aquatic and pond shoreline ecology. These findings are important for the current understanding of the perceived effect that pond openings have on the nearby groundwater table. Unfortunately, historic building practices did not consider the proximity of wetlands and the impact those wetlands would have on flooding in wet spring months.

Public concerns have been voiced over the efficacy of the pond openings, the impact to freshwater species, and the subsequent enhanced groundwater flow that results from the sometimes-long duration pond openings which Hummock Pond experiences. While vigorous flushing of the pond occurs during inlet openings, pond water is continuously discharging to the ocean by pond water seepage through the barrier beach. In addition to historic openings to the ocean, past management activities included dredging a channel from the hyper-eutrophic Head of Hummock region to the main pond basin. Further investigation is required to determine if isolation of the Head of Hummock is permittable, whether pond openings are providing sufficient flushing for in-pond fauna to thrive, and the effect of pond openings on phosphorous availability.

The efficacy and environmental benefit of pond openings has long been debated. The lower pond reveals post opening nutrient improvements, while the upper pond may experience enhanced nutrient loads through groundwater inflows post closure. Given long-term watershed non-point source nutrient management, groundwater derived loads should decline. In addition, connection to town water and sewer systems will inevitably affect the quantity and quality of groundwater over time. Investigations into hydrological enhancements of pond openings revealed that openings should occur a few days prior to the spring tide, during the latter portion of the dropping offshore tidal stage, the hydraulic head differential (difference between ocean height and pond height) must be over 1 meter, preferably 1.5 meters at the time of the pond opening, and the use of offshore predictive wave models (Wavewatch III) will allow for the most successful opening[7]. It is important to note that with increased frequency and duration of extreme weather and sea level rise predicted, Hummock Pond will continue to periodically receive saline waters from the Atlantic Ocean. It has long been recommended through the Hummock Pond MEP and subsequent technical memos that pond openings represent a relatively inexpensive means to improve nutrient-related water quality within the pond[1,5,7]. However, given that sediment derived phosphorous is capable of driving potentially harmful cyanoHAB, periodic pond closures may be warranted to lower salinity and prepare for in-pond management of phosphorous.

Aeration

In response to the Cyanophyte blooms and hyper-eutrophic state of Head of Hummock Pond (HHP), the Nantucket Land Council funded a project whereby Community Preservation Act funding was used to test a SolarBee® long-distance water circulation device to circulate water and disrupt cyanophyte bloom development/ continuation[6]. Findings from the deployment indicated that there was no clear evidence that the SolarBee® long-distance circulation unit had any effect on the 2011 water quality of HHP. Nutrient levels continued to be excessive during the mid-summer and fall and the Cyanophyte blooms continued unabated as in the two previous years with the algal neurotoxin, microcystin, detected in the water column on several occasions. In fact, summaries of water temperature data collected from different levels of the pond provided evidence that long-distance water circulation never became established in the epilimnion of the pond during 2011. It appears that ambient wind blowing across the surface of the pond is sufficient to disrupt the integrity of long-distance water circulation generated by the SolarBee® unit[6].

2.5 Review of Existing Watershed Management Techniques

Nutrient inputs are best managed through active land management aimed at decreasing the quantity of nutrients entering ponds from the watershed. As such the Town of Nantucket has several long-term management techniques currently underway to protect Hummock Pond from land-derived nutrient inputs. State and town-wide strategies for long-term water quality in Nantucket's Great ponds are as follows:

- 2010 Massachusetts General Laws Part 1 Title XIV Chapter 111 Public Health Section 5R Definitions; distribution and sale of household cleansing products containing phosphorus; limitations; violations
- 2012 Massachusetts Legislature: *An Act Relative to the Regulation of Plant Nutrients*
    - Phosphorus-containing fertilizer may only be applied when a soil test indicates that it is needed or when a lawn is being established, patched or renovated.

        - Do not apply plant nutrients to sidewalks or other impervious surfaces. Plant nutrients that land on these surfaces must be swept back onto the grass or cleaned up.
        - No applications of plant nutrients shall be made:
            - between December 1 and March 1;
            - to frozen and/or snow covered soil;
            - to saturated soil, or soils that are frequently flooded;
            - within 20 feet of waterways if using a broadcast method, or 10 feet if using a more targeted application method, such as a drop spreader;
            - within a Zone I of a public water supply well or within 100 feet of surface waters that are used for public drinking water supply

- Non-point Source Management
    - Board of Health Regulations
        - Local Regulation 55.00 Inspection and Upgrading of Substandard Onsite Sewage Disposal Systems within the Hummock Pond Watershed Protection District. September 2010.
        - Local Regulation 56.00 Septic Wastewater Flow Limitations within Hummock Pond Watershed Protection District.
    - Comprehensive Wastewater Management Plan- State approved 20-year plan
        - Hummock Pond South: Design, 2022 Construction, 2023
        - Hummock Pond North: Design, 2025 Construction, 2026
    - Board of Health Local Regulation 75.00 The Content and Application of Fertilizer for Use on Nantucket
    - Best Management Practices for Landscape Fertilizer Use on Nantucket: Limits to the quantity of nitrogen fertilizer applied per year and no phosphorous containing fertilizer may be used unless a soil test indicates a phosphorous deficiency.
        - To provide landscape professionals and homeowners with information for making environmentally sound landscaping decisions that take Nantucket's unique conditions and natural resources into consideration
        - To promote the protection of water resources while maintaining healthy and vibrant ornamental landscapes
        - To reduce the amount of fertilizer use by promoting cultural practices that help reduce nutrient inputs

        - To offer site-planning guidelines and suggestions for ecological restoration that help reduce island-wide fertilizer-dependent landscapes
        - To provide science-based guidance for nutrient management of lawns and gardens on Nantucket

2.6 Evaluation of In-pond and Watershed Management Alternatives

- Update watershed inspection and upgrade timeline until sewer becomes available
- Improve storm-water infiltration in watershed (remove direct sources of runoff from East side pathways/ Bartlett area, enhance infiltration and vegetated buffers).
- Conduct survey of vegetation (follow Miacomet procedure).
- Assess soft sediment quantity through depth survey, following Ken Wagner's protocols.
- Sediment removal to sandy bottom (Rough estimate from Miacomet investigation ~$8.1 million).
    - Pre-assess sediment quality using same procedures used in Miacomet Pond ($2000) for likelihood of disposal.
- Town owned excavation equipment to facilitate pond openings for emergency management and routine clearing of accumulated sediment from opening channel.
- In-pond bottom sediment provides additional phosphorous for algal blooms, 604b recommended phosphorous inactivation due to potentially toxic cyanobacterial blooms.
    - SOLitude estimates provided by The Nantucket Pond Coalition:
        - Low dose treatment= $100,000.
        - High Dose treatment = $525,000.
        - Trial: Head of Hummock only 17 acres= Low $18,500, High $75,000 (depends on area subject to anoxia).
        - Trial: Upper reaches (33 acres) + HOH (17 acres)= Low dose: $55,500. (Propose for Spring 2019).
        - High dose= $225,000 (unlikely due to logistics of this much Aluminum chloride being transported to island).
- Get quote for pumping apparatus and tubing to drain water without opening, in the event of flooding concerns.
- Re-assess load from western shore which previously indicated elevated concentration of inorganic nitrogen (NLC 2018).

- Investigate algaecide utility.
    - Must track the algae composition weekly and apply treatment prior to bloom but as algae is multiplying (PAK27: no water or sediment persistence, Captain XTR: 1-2 day half-life, can lead to low dissolved oxygen levels, toxic to fauna).
    - Permits required: Conservation Commission and BRP WM 04.
- Possibility for Permeable Reactive Barrier (PRB) if load is significant- ~$138,000 or $180/ft^2.
- Pilot project to harvest phragmites.
    - Recent studies in Martha's Vineyard have indicated that harvesting phragmites and pelletizing the harvested material represents a compromise by which both nutrient remediation and view-shed management can be achieved for relatively low costs compared with chemical techniques.

2.7 Management Recommendations

- Add Total Phosphorous (TP) to routine Hummock Pond monitoring program.
- Assess soft sediment quantity through depth survey, following Dr. Wagner's protocols.
- Continued aquatic vegetation harvesting to maintain navigable channels.
- Halt pond opening in Fall 2018 and Spring 2019, to allow water to freshen prior to phosphorous inactivation.
- Contract out Wetland Protection Act permitting for Conservation Commission NOI. (Solitude providing quote)
- Investigate need for further permitting to apply chemicals through DEP, possible need for 401Q Water Quality permit through DEP (Solitude).
- Request review by NHESP (further action required if protected species are present).
- Test treatment: 33 Acres in upper reaches of pond. (Quote requested- Estimate: $18,000 - $45,000 would be sufficient to control nutrients for the season, settle onto sediment and provide further sediment inactivation and reveal efficacy of this treatment option).

2.8 Works Cited

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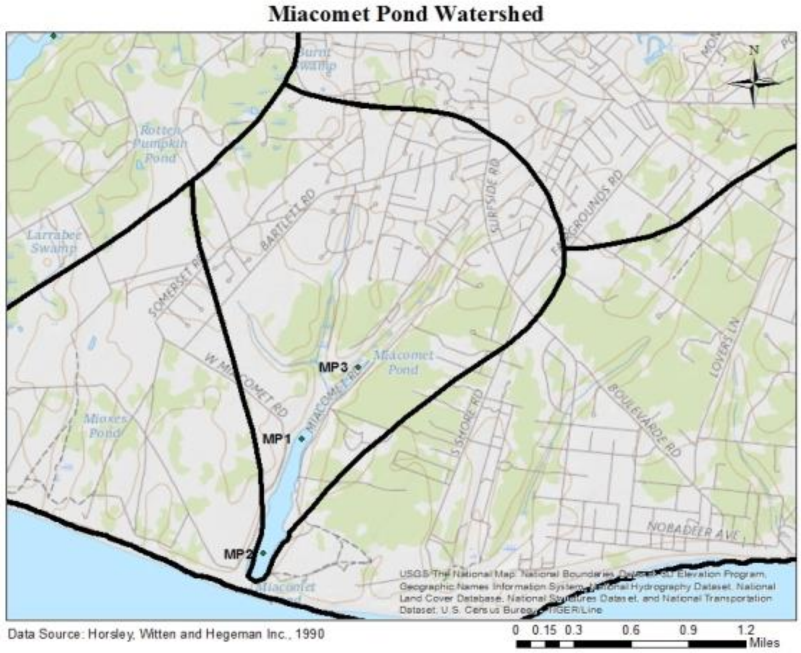
Chapter 3.

Miacomet Pond



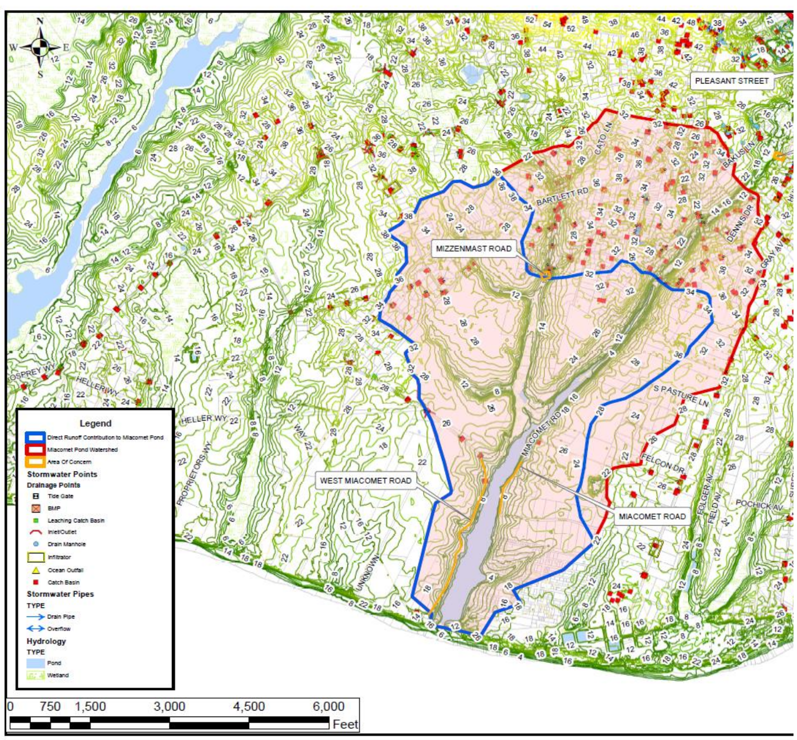


Figure 1. Woodard and Curran (2014) direct surface contribution to Miacomet Pond.

3.1 Statement of Problem

Miacomet Pond is a 43.5 acre freshwater pond located on the southern shore of Nantucket Island, MA which is fed through groundwater and surface water runoff from a 1040 acre watershed of which 653 acres contribute to direct surface runoff[1]. Miacomet Pond has an average depth of 4.0 ft and a maximum depth of 10 ft. Historically the pond was opened yearly to the Atlantic Ocean (1910 report) until it was determined that the pond should be managed as a fresh water body and openings were terminated. The pond periodically receives salt water from the ocean during periods of high sustained winds and was last physically opened, by permit, to the ocean in 2005 due to flooding concerns. The first written records of pond status were from the 1910 Inland Waters reports which included acidity-alkalinity, temperature, light penetration, dissolved oxygen, iron content, fish and vegetation presence.

Miacomet Pond was given a moderate/ poor ecological health score in the report entitled "Overview of Nantucket Fresh Ponds: 1989-1992" due to its extreme salinity fluctuations, oxygen stress and elevated nutrient and phytoplankton concentrations[2]. Since then, several reports have been conducted on Miacomet Pond's watershed, water quality, flora and fauna and hydrodynamics[3,4,5,6,7,8]. Most of the water inputs to the pond are derived from direct surface water runoff (653 acres), while the remaining 387 acres of the watershed contribute to groundwater input through isolated depressions (Figure 1)[3]. As the total area of the Miacomet Pond watershed is 1040 acres, its watershed is nearly 24 times the size of the receiving pond (Miacomet Pond area ~43.5acres), making its inputs predominately freshwater[3]. Miacomet pond has experienced algae blooms in summer, including cyanobacteria at potentially hazardous levels. The ultimate source of P continues in the watershed, however is moved through sandy soils with groundwater and/or release from accumulations in surficial sediments within the pond[8].

3.2 Management Goals

Year	Total Nitrogen	Phosph-orous	Total Phosphorous	Chloro-phyll a	Clarity	Benthic Infauna	Vegetation	Phytoplankton
2016	0.74 mg/L	0.011 mg/L	0.059 mg/L	14.09 ug/L	1.11 m	No data	Dense nuisance pond weed	Strong bloom potential
2017	0.71 mg/L	0.019 mg/L	N/A	14.11 ug/L	1.74 m	No data	Dense nuisance pond weed	Strong bloom potential
Goals	0.60 mg/L (no regulatory threshold developed)	0.015 mg/L	0.015 mg/L	<10 ug/L	>1.2 m	Diversity >3, Evenness >0.7, low # poor health indicator species	Low nuisance pond weed, swimmable fishable	No cyanobacteria blooms, diverse phytoplankton assemblage

3.3 Watershed and Pond Characteristics

According to the 2002 Miacomet study conducted by Applied Science Associates[5], wastewater accounted for 44% (1484kgN/yr) of the total load of nitrogen to the pond. Fertilizer was the second largest contributor at 32% (1080kgN/yr), while atmospheric deposition accounted for 24% (812 kgN/yr). It was estimated that the golf course contributed 23% to the Total Nitrogen load while residential lawns were estimated to contribute 9%[5].

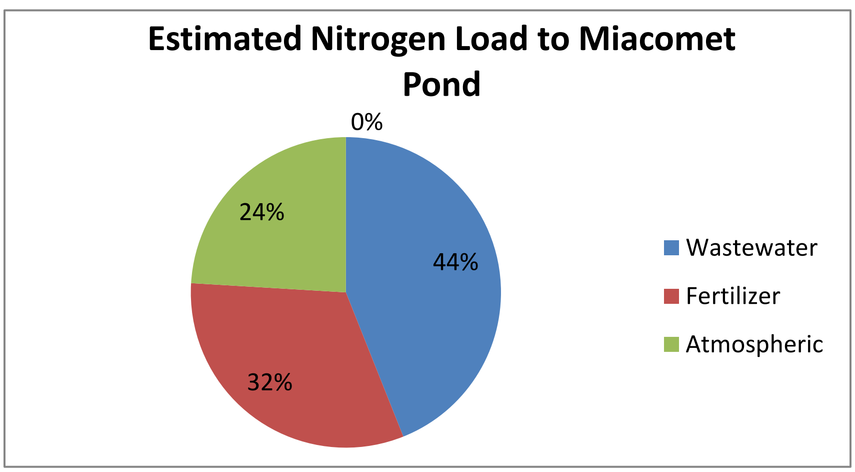


Figure 2. Applied Science Associates (2002) Estimated Nitrogen Load to Miacoment Pond.

Bioactive nitrogen (PON+nitrate+ammonia) in 1989 averaged 0.70mg/L, however only one station located near MP2 was sampled. Phosphorous averaged 0.05mg/L and salinity averaged 0.15ppt in 1989, however increased to 1.44ppt in 1991 after Hurricane Bob. Pond-wide salinity averaged 0.10ppt in 2016 and is highly dependent on the quantity and extent of storm overwash events. Currently the pond is highly eutrophic and experiencing significant impairment[3,4,8] although present conditions show improvement over 1989 concentrations. In 2016 pond-wide TN averaged 0.740mg/L, higher concentrations (0.78mg/L) were observed at sampling site MP3, located at the northern extent of the pond[4]. Total Phosphate (TP), averaged 0.059mg/L in 2016, while average pond-wide phosphate was 0.011mg/L, and was greatest at sampling site MP2, located at the southernmost end of the pond. 2016 TP levels exceeded the EPA Total Phosphorous threshold for this ecoregion of 0.009 mg/L TP by six and a half times in 2016[4].

According to the 604b study[8], phosphorus loading to Miacomet Pond was estimated to be 97 kg P/yr, with internal loading, groundwater and surface water inputs contributing[8]. Dr. Wagner indicated that, "Nutrient limitation appears to fluctuate between P and N, with cyanobacteria blooms seemingly coincident with periods of N limitation. Blooms of golden algae (chrysophytes) are more common when P is limiting, but algae abundance is high most of the summer". The 604b report concludes that "In Miacomet Pond the estimated internal load is the largest source, but both groundwater and possible surface water inputs may be adequate to support blooms if only internal loading is controlled. Some watershed management may be necessary, although the temporal distribution of internal loading (mostly in late spring and summer) makes that source disproportionately important and its control is likely to provide more benefit than a simple annual accounting of loading would indicate"[8].

Miacomet Pond is currently not attaining uses with regards to swimming, boating and fishing. Swimming standards not being met due to low water clarity (<1.2m safe swimming standard), historic and periodic high fecal coliform and blue-green algae blooms. Water quality standards are also not being met due to high Total Phosphorous (TP) and high Total Nitrogen (TN) (values over threshold). Aesthetic values and boating are limited due to dense submerged aquatic vegetation and invasive phragmites[6].

Several other invasive species have been documented in Miacomet Pond that require attention such as pond vegetation likePhragmites and Parrot feather, as well as fishes like Grass Carp and Koi[6]. Parrot feather management has taken place in Burchell Pond by the Land Bank, however regular monitoring of the main pond basin will be required, as there is evidence of infestations in the channel from Burchell Pond to the main pond[6]. Controlling this invasive plant and educating the public on the threats of invasive species is a priority. There is a mercury TMDL for fish tissue in Miacomet Pond due to atmospheric deposition, which is difficult to remediate, due to continued atmospheric deposition. Access to the pond is not well defined, which leads boaters and other pond users to walk over vegetated buffers creating pathways for stormwater to directly enter the pond. There is a need for defined access and an information kiosk describing that fishes should not be consumed, cyanoHAB possibility, and the presence of invasive pond weeds.

There is ongoing discussion about the need to open Miacomet Pond to the ocean due to concerns about basement flooding and to improve water quality. Due to the disproportionate size of the increasingly developed watershed compared to the size of Miacomet pond, groundwater inflow rapidly replaces salt water exchange from pond openings. The Town of Nantucket does not have plans to open Miacomet Pond to the ocean via a man-made channel. This decision is based off many years of historic management documents which indicate opening benefits were quickly overwhelmed by fresh groundwater inflow to the pond. Based on the flora and fauna currently inhabiting the pond, salt water intrusion would negatively impact the freshwater fauna potentially leading to stress and mortality.

3.4 Review of Past In-pond Management Techniques

Hydraulic Control:

- Historically Miacomet Pond was also opened to the Atlantic Ocean, however the pond receives such a high quantity of fresh water from the surrounding developed watershed that any positive influence of openings is quickly diminished as freshwater from the watershed replaces pond water. "Opening of Miacomet Pond to the ocean stopped over a decade ago and there is little reason to resume that practice, but there does appear to be some surface flow to the pond that must be addressed in loading analysis."[8]

- Historic pump systems have also been attempted to drain the pond, however due to the overwhelming quantity of water in this watershed, the pump was unable to operate fast enough to provide a long-term benefit.

- The northern reaches of Miacomet Pond were dredged to create a connection with the main body of the pond as part of a real estate development[8], prior to the Wetlands Protection Act. This activity turned wetlands capable of natural nutrient remediation into a man-made channel which will require routine management to maintain. Costs associated with maintaining this channel should therefore be the responsibility of the individuals interested in such work and not the Town of Nantucket. Permit requests to maintain this region will to be assessed on a case by case basis through the Conservation Commission.

3.5 Review of Existing Watershed Management Techniques

Nutrient inputs are best managed through active land management aimed at decreasing the quantity of nutrients entering ponds from the watershed. The Town of Nantucket has several long-term management techniques currently underway to protect Miacomet Pond from land-derived nutrient inputs. State and town-wide strategies for long-term water quality in Nantucket's Great ponds are as follows:

- 2010 Massachusetts General Laws Part 1 Title XIV Chapter 111 Public Health Section 5R Definitions; distribution and sale of household cleansing products containing phosphorus; limitations; violations
- 2012 Massachusetts Legislature: *An Act Relative to the Regulation of Plant Nutrients*-
  - Phosphorus-containing fertilizer may only be applied when a soil test indicates that it is needed or when a lawn is being established, patched or renovated.
  - Do not apply plant nutrients to sidewalks or other impervious surfaces. Plant nutrients that land on these surfaces must be swept back onto the grass or cleaned up.
  - No applications of plant nutrients shall be made:
    - between December 1 and March 1;
    - to frozen and/or snow-covered soil;
    - to saturated soil, or soils that are frequently flooded;
    - within 20 feet of waterways if using a broadcast method, or 10 feet if using a more targeted application method, such as a drop spreader;
    - within a Zone I of a public water supply well or within 100 feet of surface waters that are used for public drinking water supply

- Non-point Source Management
    - Board of Health Regulations
    - Comprehensive Wastewater Management Plan- State approved 20-year plan
        - Miacomet: Design, 2028 Construction, 2029
        - Somerset: Design 2016 Construction, 2017 (delayed)
    - Board of Health Local Regulation 75.00 The Content and Application of Fertilizer for Use on Nantucket
    - Best Management Practices for Landscape Fertilizer Use on Nantucket: Limits to the quantity of nitrogen fertilizer applied per year and no phosphorous containing fertilizer may be used unless a soil test indicates a phosphorous deficiency.
        - To provide landscape professionals and homeowners with information for making environmentally sound landscaping decisions that take Nantucket's unique conditions and natural resources into consideration
        - To promote the protection of water resources while maintaining healthy and vibrant ornamental landscapes
        - To reduce the amount of fertilizer use by promoting cultural practices that help reduce nutrient inputs
        - To offer site-planning guidelines and suggestions for ecological restoration that help reduce island-wide fertilizer-dependent landscapes
        - To provide science-based guidance for nutrient management of lawns and gardens on Nantucket

3.6 Evaluation of In-pond and Watershed Management Alternatives

- Update watershed inspection and upgrade timeline until sewer becomes available.

- Improve storm-water infiltration in watershed and remove direct sources of runoff from various access pathways, enhance infiltration and vegetated buffers.

- Entire pond sediment removal to sandy bottom (Rough estimate from NPC $3,677,640, initial investment of $30,000 for site assessment and testing).

- Town owned excavation equipment to facilitate dredging of accumulated sediment

- Possibility for Permeable Reactive Barrier (PRB) for elevated Nitrogen concentrations from western edge of pond- ~$138,000 or $180/ft^2).

- Re-assess benthic infauna community for improvements associated with nutrient reductions.

- Potential for Town owned harvester to address in-pond accessibility through removal of rooted aquatic vegetation.

- Bottom-fish removal: This option represents an interesting approach for Miacomet Pond given the presence of Carp and Koi. However, the effect of such management techniques would likely be minimal compared with in-pond phosphorous inactivation, dredging or reduction of land-derived inputs. The most common fishing technique to catch Carp is bow-fishing, which represents a potential opportunity to encourage local anglers to catch and discard large carp and koi which are likely adding to the turbidity and nutrient cycling within Miacomet Pond.

- Pilot project to harvest phragmites.

    - Recent studies in Martha's Vineyard have indicated that harvesting phragmites and pelletizing the harvested material represents a compromise by where both nutrient remediation and view-shed management can be achieved for relatively low costs compared with chemical techniques.

3.7 Management Recommendations

- Vegetation control with Aquatic Harvester.
- Work with Nantucket Land Bank to control invasive Parrot Feather emanating from Burchell Pond (NLB 2017, NLB/NRD 2018)
    - Determine if better control of Burchell Pond water could be achieved with barriers.

- In-pond bottom sediment provides additional phosphorous for algal blooms, 604b recommended phosphorous inactivation due to potentially toxic cyanobacterial blooms.

    - SOLitude estimates provided by The Nantucket Pond Coalition:

    - Low dose treatment= $18,050

    - High Dose treatment = $125,000

- Periodic coliform failures (14% exceedance 2003-2016)
    - Watershed Inspections and Upgrade Regulation (BOH)

- Work with Miacomet Golf Course/ Land Bank to determine if BMP to reduce elevated western inputs is necessary, potential for PRB.
- Improve stormwater infiltration in watershed and remove direct sources of runoff from unsanctioned access points/ educational component.
- Provide access and informational kiosk on west side of Pond.
- Identify East shore banks where small-scale restoration could be accomplished to intercept stormwater runoff. Education component required to be successful.
- Assess stream discharges
- Assess groundwater discharges
- Initial assessment of benthic infaunal community.

3.8 Works Cited

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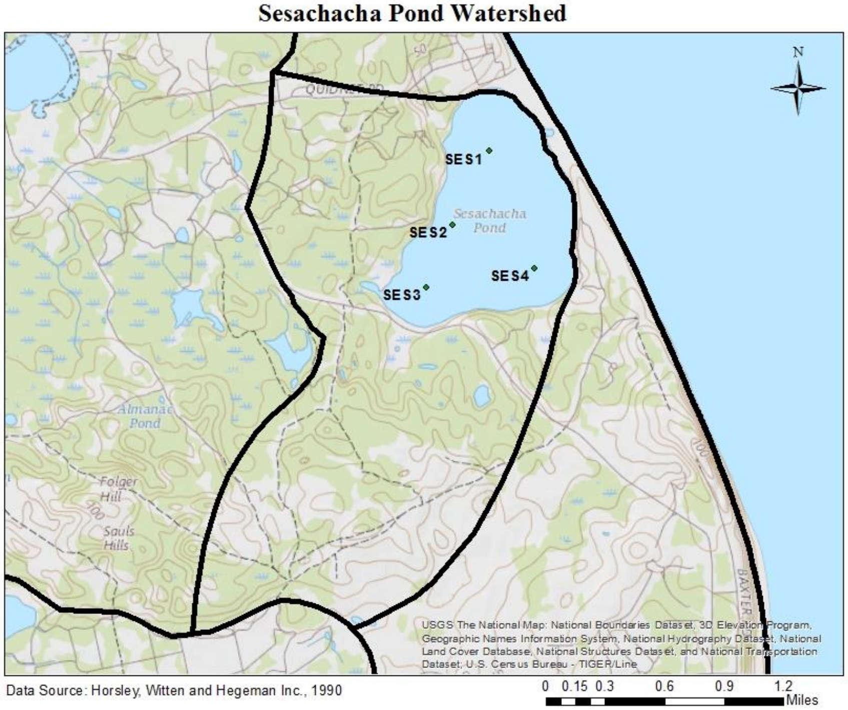
7. Sutherland, J. and S. Oktay. 2010. Miacomet Pond Water Quality 2009: A Summary of Physical, Chemical and Biological Monitoring. For the Nantucket Land Council, Nantucket, MA.
8. Wagner K. Water Resource Services Inc. (2017). 604b Study of phosphorus sources to Hummock and Miacomet Ponds Final Report.

Chapter 4.

Sesachacha Pond

Sesachacha Pond Watershed



Data Source: Horsley, Witten and Hegeman Inc., 1990

Figure 1. Extent of Sesachacha Pond watershed, as determined by Horsley, Witten and Hegeman in 1990 Nantucket Water Resources Management Plan. Location of water quality sites used for Massachusetts Estuaries Project sampling.

4.1 Statement of Problem

Sesachacha Pond is a coastal eutrophic salt pond located on the northeast end of Nantucket Island, MA. Sesachacha Pond was formed by the flooding of a kettle pond as a result of rising sea level following the last glacial period approximately 18,000 years BP[1]. Sesachacha Pond covers 255 acres and consists of two deep areas with a maximum depth of 6.6 meters[1]. The watershed to pond ratio is low (3:1) compared to other Nantucket great ponds. Most of the freshwater input to Sesachacha Pond occurs via groundwater seepage[1]. While direct small stream inputs to Sesachacha occur from Cains Pond, under Polpis Road and from the southeastern end of the pond. Additional storm water inputs from Polpis Road and Sesachacha Road occur during heavy rainfall. The pond is naturally non-tidal and the salinity is maintained by periodic breaching of the barrier beach by the Town. To a lesser degree saline water enters the pond via salt water intrusion through the barrier beach and storm overwash.

Historic pond openings date back to the 1660's, while openings were still commonplace in the 1870's. The northern portion of the pond reveals a Native American site and oyster shell midden, indicating the pond was likely opened by Native Americans to enhance oysters within the pond. In 1981, Sesachacha Pond was opened, however openings were ceased that same year under provisions of the Wetlands Protection Act[2]. In 1983, IEP Inc. was hired by the landowner of the eastern shore (where openings take place) to investigate the impact of pond openings on biological and geological resources. No samples were taken as part of this effort; rather it represented a field reconnaissance, review of pertinent reports and discussions with local experts. The biologic findings of this study were that openings had no perceived effect on mosquito control due to the lack of quantitative data on mosquitoes in the region. Additionally the benefit to the common oyster and soft shell clam seed populations were not significant enough to warrant openings for this reason alone due to the small size of oysters and clams produced. Finally the reason for opening for finfish enhancement actually stunted growth of saltwater species due to low salinities and trapped fish within the pond as well as having potentially negative impacts to nesting birds.

In addition to the impacts on wildlife, geologic findings indicated that openings negatively impacted the dune, and subsequent dune restoration were never conducted. Lowered pond level had a negative effect on groundwater quality through saltwater intrusion and expedited septic effluent seepage as these systems may have been poorly cited close to the pond edge and hence should be relocated and updated to combat loading due to septic influences. The rise in pond level is associated with groundwater inputs and rainwater and it has been suggested that low lying cottages be stilted to combat flooding issues. Sesachacha was not opened legally by the town between 1981 and 1991, although illegal openings did take place during that time[3]. In 1985 the Public Works Department funded a hydrogeologic investigation by Perkins, Jordan Inc to determine the interaction between pond openings, groundwater resources and pond water quality.

Findings from this study indicated that a clay layer exists in the northern region of the pond between elevations 4 and 7 (and may exist under the entire pond) andcontinued closure would decrease the salinity in the pond and surrounding groundwater. Further development in upgradient areas was not expected to have a significant effect on eutrophication, although it was noted that septic systems cited adjacent to the pond should be addressed on a case by case basis. A subsequent EIR in 1989 indicated that periodic tidal exchange, through openings, was required to stabilize the ecology, since storm over wash would lead to salinity cycling within the system. It was hypothesized that the salinity cycling from over wash and storms would result in highly unstable conditions and impairment of habitat quality within the pond. Sesachacha Pond's MEP report was completed in 2006. Sesachacha's in-pond nitrogen declined below historic concentrations in 2010, 2012 and 2013, leading researchers to hypothesize that successful pond openings were responsible for the improvement. Subsequent sediment tests indicated that Sesachacha's habitat-related health was improving along with its nutrient-related water quality[4].

Restrictions due to protected habitat, narrow permit windows, tide and wind considerations, sand deposition on the inner portion of the barrier beach and coordination between excavation contractors have unfortunately led to the pond's further eutrophic conditions since sufficient exchange has not been maintained in recent years. Research has indicated that Sesachacha water quality is closely tied to successful pond openings however the goal salinity levels (22ppt) have only been achieved eight times in the past 50 years. Despite planning the openings during the most favorable conditions, changes in wind speed and direction close the pond prematurely. Reports from the 1990's indicated that 75% of the nitrogen available for water column plant growth originates from pond sediment. This finding combined with the high MEP sediment flux values indicates a potential need for sediment remediation. Currently additional work is being planned for Sesachacha Pond to identify the main sources of nutrients to the pond, ascertain whether nutrient threshold goals are attainable and whether pond openings are providing sufficient flushing for in-pond shellfish and fish species to thrive. This study will lead to the development of a restoration and/or management plan aimed at improving pond health.

Sesachacha Pond is currently not attaining uses with regards to swimming. Swimming standards not being met due to low water clarity (<1.2m safe swimming standard), nuisance pond weeds and the potential for harmful blue-green algae blooms. Recreational boating in Sesachacha Pond is currently unaffected. Sesachacha Pond is closed to shellfishing due to historic bacterial concerns. Water quality standards are also not being met due to high Total Phosphorous (TP) and high Total Nitrogen (TN). Sesachacha TN exceeded the TMDL of 0.60mg/L, with 2016 pond-wide averages of 0.978mg/L. Sesachacha Pond's phosphorous level far exceeded EPA water quality standards of 0.025mg/L, with pond-wide averages of 0.208mg/L. High TN, TP and iron content entering the system through small streams, represent a distinct concern with regards to phosphorous availability, given the dynamics between iron, salt water intrusion (sulfate availability) and phosphorous release. High phosphorous concentrations, over eight times the EPA water quality standard, pose a distinct blue-green algae bloom threat if salinity levels drop below the primarily freshwater algae salinity tolerances.

There is a need for defined access and an information kiosk describing cyanobacteria bloom possibility and any other pertinent information to the pond. There are ongoing discussions about the efficacy and environmental benefit of the Sesachacha pond openings and the need for longer duration openings or alternative management techniques. Currently water quality within the pond is tied to successful openings which drain the pond of its high nutrient levels and allow ocean water to enter the pond. This dilution does not represent a sustainable option for pond management, as it does not address the root cause of the high nutrient concentrations, nor does it remediate the inputs. A more complete understanding of the fish species present in Sesachacha Pond will enable better management of the pond as an anadromous/catadromous fish resource. Although soft shell clams, oysters, herring, striped bass and eels have been observed in Sesachacha Pond, the salinities presently are not sufficient to allow for these species to grow to marketable size. A more thorough understanding of the fish and shellfish species present and their health must be conducted prior to any changes in management of this pond.

4.2 Management Goals

Year	Total Nitrogen	Phosph-orous	Total Phosphorous	Chloro-phyll a	Clarity	Benthic Infauna	Vegetation	Phytoplankton
2016	0.978 mg/L	0.208 mg/L	N/A	7.29 ug/L	0.77m	From 2012 1.56 Diversity 0.713 Evenness From 2002 0.99, 0.566	No data (or very old)	Strong bloom potential
2017	0.884 mg/L	0.251 mg/L	N/A	10.62 ug/L	0.923m	N/A		Strong bloom potential
Goals	0.60 mg/L	0.015 mg/L	0.015 mg/L	<10 ug/L	>1.2 m	Diversity >3, Evenness >0.7, low # poor health indicator species	Low nuisance pond weed, swimmable fishable	No cyanobacteria blooms, diverse phytoplankton assemblage

4.3 Watershed and Pond Characteristics

According to MEP research and models, most of the locally uncontrollable, un-attenuated nitrogen load to Sesachacha Pond is from direct wet and dry precipitation of nitrogen on the water body surface, with natural surface inputs being the second largest uncontrollable load. Impervious surfaces such as roads direct stormwater towards the pond and represent the greatest contribution to controllable nitrogen inputs at 65% of the total nitrogen load; wastewater from septic systems contributes 25%; fertilizers contribute 10%[1]. Sediment incubations indicated that the shallow regions of Sesachacha Pond were releasing nitrogen to the water column while the deeper basins represented a sink. Overall, there was a net release of nitrogen to the water column, which substantiates the 1991 finding that ~75% of the water column nitrogen is derived from the sediments[1].

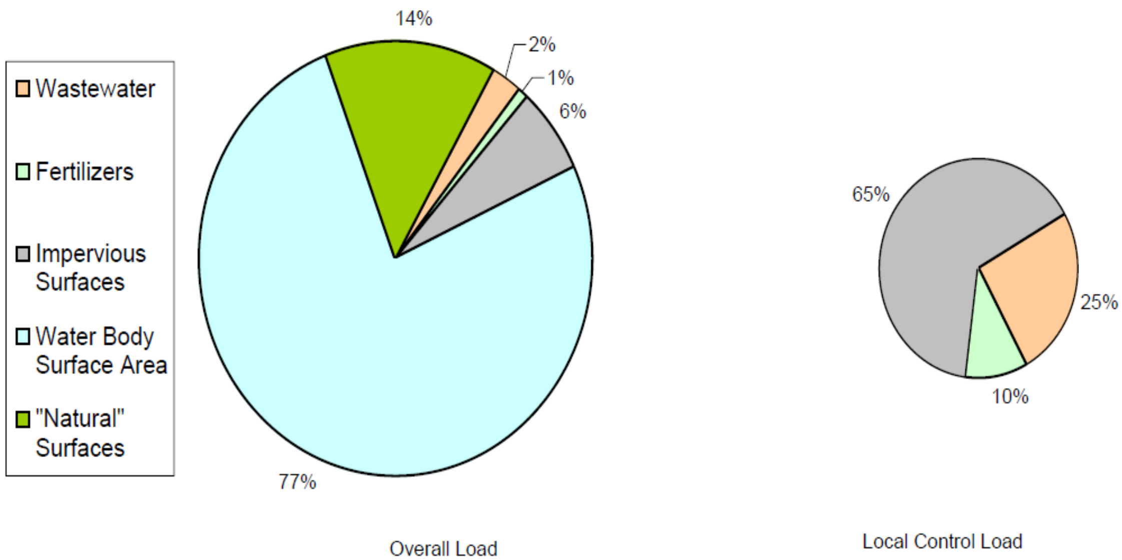


Figure IV-4. Land use-specific unattenuated nitrogen load (by percent) to the Sesachacha Pond System watershed. "Overall Load" is the total nitrogen input within the watershed, while the "Local Control Load" represents only those nitrogen sources that could potentially be under local regulatory control.

Pond Total Nitrogen (TN) in 1985 averaged 0.46mg/L and was greatest at Station 1 (0.665mg/L), located in the northernmost portion of the pond closest to Quidnet village[1]. Total Phosphorous (TP) averaged 0.475mg/L and was greatest at Station 5, located in the middle of the pond (0.560mg/L)[1]. The salinity averaged 5.675ppt in 1985, 4 years after the 1981 opening[3,4]. Currently the pond is highly eutrophic and experiencing significant impairment[2,6]. In 2016, pond wide TN averaged 0.978mg/L, over two times the concentrations observed 30 years ago[6]. Total Phosphate (TP) is not currently measured in Sesachacha Pond, however 2016 average pond wide phosphate values were 0.208mg/L, and were greatest in the southwest corner of the pond, near Cains Pond. The phosphate values measured in Sesachacha were the highest pond phosphate values observed in 2016 and ranged from 7-20 times higher than the phosphate of other Nantucket great ponds. Due to the observed levels of phosphate and nitrogen, there is a strong algae bloom potential for this system. In 2016 average pond wide salinity was 11.52 ppt which may prevent cyanobacteria species from forming blooms.

Sesachacha Pond receives freshwater from groundwater, however small streams and Cains Pond also contribute freshwater to the pond. Elevated iron content in inputs are of concern for phosphorus dynamics. The phosphorous load to Sesachacha Pond is exacerbated by the high iron content in the inputs. High iron paired with saltwater intrusion into groundwater, leads to phosphorous release (due to iron binding to sulfate in seawater, thereby releasing phosphorous). This scenario favors cyanobacteria blooms, due to the availability of phosphorous, which is limiting to growth. The current salinity of Sesachacha may be protecting it from cyanobacterial blooms. The 2005 MEP report indicated that the linear increase in total nitrogen concentration is directly related to the rate of net nitrogen release from the sediments, integrated over the entire pond[2]. This rate of nitrogen increase in pond waters was used to calculate a rate of nitrogen increase per square meter across the entire pond per day, from the water volume and bottom area measurements. It was determined that the estimated daily input from Sesachacha sediments during the summer was approximately 18.0 mg N/ m^2/day. This benthic nitrogen flux is similar to Head of Hummock Pond and slightly higher than Long Pond[2].

4.4 Review of Past In-pond Management Techniques

Hydraulic Control

The MEP report on Sesachacha Pond indicated that achieving a salinity of 22 psu would facilitate improved water quality within the pond. In the past 50 years, Sesachacha Pond has only achieved a salinity >22 psu 8 times. Recently, 2012 was the last time that salinity >22 psu was achieved in the pond. The opening in 2012 increased the salinity within the pond and lead the Town to investigate the effects that increased salinity and improved water quality had on the benthic infauna of the pond[6]. Samples revealed that the benthic infauna were responding to improved water quality conditions through increased diversity and evenness metrics. However subsequent openings have not achieved the desired salinity, likely due to sand accumulation and pond opening constraints dealing with time of year restrictions and wind speed/direction changes.

In the Spring of 2016, the Natural Resources Department began measuring water quality parameters pre and post pond openings to ascertain the effect of openings on pond water quality. Both nitrogen and phosphorous increased steadily throughout the summer sampling season. The Spring 2016 opening duration was three days and resulted in a 0.2 mg/L decline in TN and a slight decline in phosphate, although levels were very low (<0.005 mg/L) even before the opening took place. A slight decline in Total Phosphorous also occurred. TN and phosphorous again showed a consistent increase throughout the summer, yet began to decline post Fall opening. The Fall 2016 opening duration was 1.5 days and resulted in a large TP and phosphorous decline post closure. TN increased slightly post closure in the Fall. The Spring 2017 opening duration was seven days in total and required re-opening due to a premature closure from winds. The Spring opening resulted in a 0.2 mg/L decline in TN, and already low levels of phosphorous declined further post pond closure, whereas TP showed a moderate increase post closure. The pond opening water quality measurements indicate that openings can reduce TN levels, especially during the Spring openings, however in-pond TN levels quickly increase to elevated levels during the summer post pond closure. The September TN levels in 2016 were ~0.2 mg/L greater than

2015, indicating that pond openings do not produce a sustained benefit in terms of decreasing in-pond TN levels. May TN levels were nearly 0.2 mg/L higher in 2016 than 2015. Both May and September TN levels were ~0.2 mg/L greater in 2016 than 2015. Seasonal phosphorous trends indicate that depletion naturally occurs during the winter months, leaving very low levels prior to the Spring opening. This seasonal trend is also evident in the Fall when phosphorous concentrations begin to decline prior to the pond being opened. The benefit of Fall openings to phosphorous concentrations is unclear, as it appears seasonal phosphorous cycling has already begun to decrease the phosphorous content prior to the opening.

4.5 Review of Existing Watershed Management Techniques

Nutrient inputs are best managed through active land management aimed at decreasing the quantity of nutrients entering ponds from the watershed. The Town of Nantucket has a number of long-term management techniques currently underway to protect Sesachacha Pond from land-derived nutrient inputs. State and town-wide strategies for long-term water quality in Nantucket's Great ponds are as follows:

- 2010 Massachusetts General Laws Part 1 Title XIV Chapter 111 Public Health Section 5R Definitions; distribution and sale of household cleansing products containing phosphorus; limitations; violations
- 2012 Massachusetts Legislature: *An Act Relative to the Regulation of Plant Nutrients*-
    - Phosphorus-containing fertilizer may only be applied when a soil test indicates that it is needed or when a lawn is being established, patched or renovated.
    - Do not apply plant nutrients to sidewalks or other impervious surfaces. Plant nutrients that land on these surfaces must be swept back onto the grass or cleaned up.
    - No applications of plant nutrients shall be made:
        - between December 1 and March 1;
        - to frozen and/or snow covered soil;
        - to saturated soil, or soils that are frequently flooded;
        - within 20 feet of waterways if using a broadcast method, or 10 feet if using a more targeted application method, such as a drop spreader;
        - within a Zone I of a public water supply well or within 100 feet of surface waters that are used for public drinking water supply

- Non-point Source Management
    - Board of Health Local Regulation 75.00 The Content and Application of Fertilizer for Use on Nantucket
    - Best Management Practices for Landscape Fertilizer Use on Nantucket: Limits to the quantity of nitrogen fertilizer applied per year and no phosphorous containing fertilizer may be used unless a soil test indicates a phosphorous deficiency.
        - To provide landscape professionals and homeowners with information for making environmentally sound landscaping decisions that take Nantucket's unique conditions and natural resources into consideration
        - To promote the protection of water resources while maintaining healthy and vibrant ornamental landscapes
        - To reduce the amount of fertilizer use by promoting cultural practices that help reduce nutrient inputs
        - To offer site-planning guidelines and suggestions for ecological restoration that help reduce island-wide fertilizer-dependent landscapes
        - To provide science-based guidance for nutrient management of lawns and gardens on Nantucket

4.6 Evaluation of In-pond and Watershed Management Alternatives

- Town owned excavation equipment to facilitate pond openings for emergency management and routine clearing of accumulated sediment from opening channel.
    - Sediment testing for common limits to dredge disposal.
    - Contract out permitting required for dredge/ channel maintenance
    - Feasibility/ alternatives analysis for openings.
    - Investigate feasibility/ benefit of mid-summer opening potential in future.

- Re-assess benthic infauna community for improvements associated with nutrient reductions (NRD, report due April 2018).

- Cost estimate for Town owned harvester to address in-pond accessibility (TBD- NPC).

4.7 Management Recommendations

- Add Total Phosphorous (TP) to routine Sesachacha monitoring program (NRD 2018).
- Quidnet Squam Association resident funded investigation into restoration potential for nutrient remediation in Sesachacha Pond (NRD/ Horsley Witten 2018).
- Biologic surveys of vegetation, phytoplankton, fish, shellfish and benthic infauna.
- Apply for Coastal Resilience Grant Program, Coastal Zone Management funding for Natural Storm-Damage Protection Techniques.
    - Pond opening equipment.
    - Funds to do living shoreline/oyster castle remediation project (Dependent on results from Spring 2018 Horsley Witten site visit and associated work).
- Re-assessment of Sesachacha watershed using current techniques.
    - Finalize Sesachacha on-site septic system inspection and upgrade program.
- Decrease stormwater inputs through active management of roads and impervious surfaces.
    - Redirect stormwater from roads back to natural wetland system to the south of Polpis Road
    - Redirect stormwater from Sesachacha rd. to wetlands to the northwest of Quidnet village.
- Research study to determine if pond openings can outweigh the eutrophication due to benthic regenerated nutrients.

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Chapter 5.

Long Pond

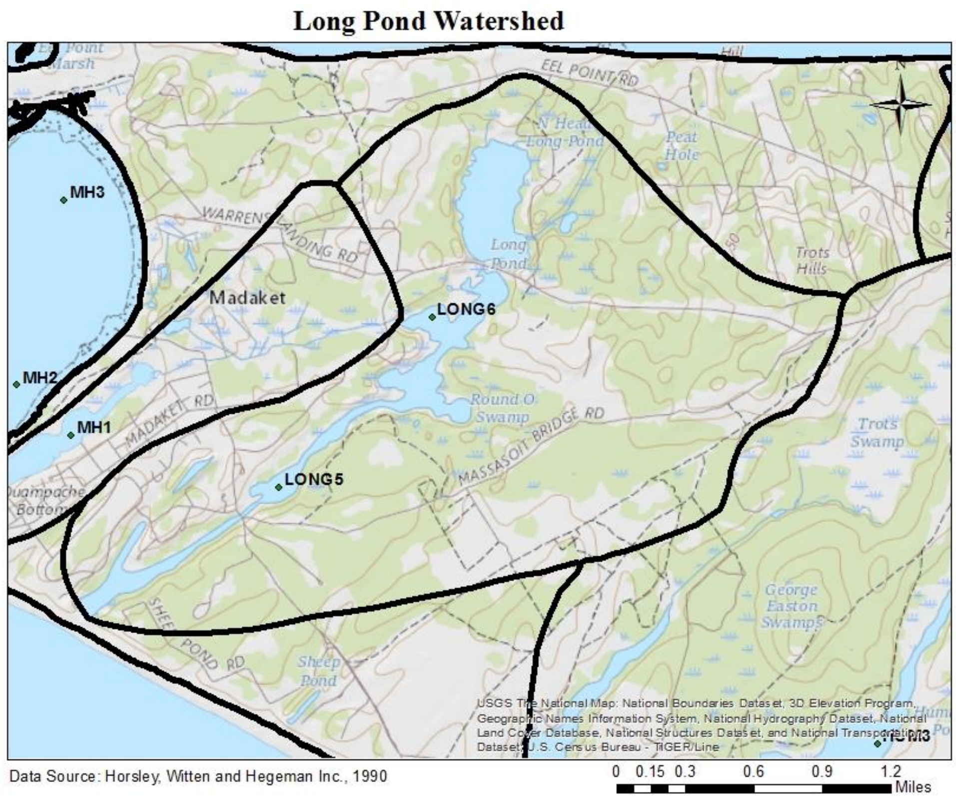

Figure 1. Extent of Long Pond watershed, as determined by Horlsey, Witten and Hegeman in 1990 Nantucket Water Resources Management Plan. Location of water quality sites used for Massachusetts Estuaries Project sampling.

5.1 Statement of Problem

As Long Pond and North Head of Long Pond are brackish water basins with significant wetland influence, these basins are naturally nutrient and organic matter enriched. Generally, brackish basins support productive benthic animal communities. Long Pond has a high number of benthic animal individuals, however has low species numbers, diversity and Evenness. Due to observed hypoxic conditions and elevated chlorophyll, there are low numbers of total species and overall diversity which indicate an impaired habitat. The North Head of Long Pond is similar to Long Pond in that it also supports a lower numbers of individuals, however the community is dominated by amphipods rather than oligochaeta worms, which indicate a productive organic rich habitat and are consistent with the observed oxygen levels in this basin[3].

Water quality standards are currently being met as 2016 represents the second year that the entire pond average TN has been below the secondary TMDL goal of 0.800 mg/L. Phosphorous was below the EPA water quality criteria for lakes and reservoirs of 0.025 mg/L, with a pond-wide average of 0.01 mg/L in 2016. Long Pond is currently not attaining uses with regards to swimming, boating and fishing. Swimming standards are also not being met due to low water clarity (<1.2m safe swimming standard), historic high fecal coliform and periodic algae blooms. Aesthetic values and boating are limited due to submerged aquatic vegetation and invasive phragmites. Access to the pond is not well defined, which makes boat access difficult for water quality sampling as well as other boat uses. There is a need for defined access and an information kiosk describing that fishes should not be consumed and that toxic algal blooms are a possibility. The culverts connecting Long Pond to the Madaket ditches are undersized and need to be cleaned out/resized. Very little is known about the aquatic fauna in Long Pond.

5.2 Management Goals

Year	Total Nitrogen	Phosph-orous	Total Phosphorous	Chloro-phyll a	Clarity	Benthic Infauna	Vegetation	Phytoplankton
2016	0.64 mg/L	0.01 mg/L	N/A	5.82 ug/L	0.73	1.19 Diversity 0.6 Evenness	Widgeon Grass	Euglena, green algae (indicative of organic matter inputs)
2017	0.79 mg/L	0.023 mg/L	N/A	18.56 ug/L	0.78	N/A	Widgeon Grass	Euglena, green algae (indicative of organic matter inputs)
Goals	0.80 mg/L (second-ary TMDL)	0.015 mg/L	0.015 mg/L	<10 ug/L	>1.2 m	Diversity >3, Evenness >0.7, low # poor health indicator species	Low nuisance pond weed, swimmable fishable	No cyanobacteria blooms, diverse phytoplankton assemblage

5.3 Watershed and Pond Characteristics

Long Pond is a 132 acre tidally restricted brackish pond dominated by fringing wetlands, located to the east of Hither Creek on the western side of Nantucket Island, MA. Long Pond is surrounded by several closely settled residential lots with septic systems and private wells, and the town Landfill is located on the eastern shore. A significant amount of conservation land surrounds the pond, buffering some of the potential land use impacts. According to the Massachusetts Estuaries Project report, the primary locally controllable load to Long Pond comes from the landfill at 78%, while wastewater represents 12%, impervious surfaces 8% and fertilizers 2%. Natural surface inputs represent 15% of the uncontrollable total load[1].

Pond-wide bioactive nitrogen (PON+nitrate+ammonia) in 1989 averaged 0.58 mg/L and was greatest at the innermost pond site (near current site LP5)[2]. Pond-wide phosphate averaged 0.21 mg/L in 1989 and was greatest near present day site LP6. The salinity averaged 4.00 ppt in 1989, yet likely fluctuated with the tidal cycle, due to the connection to Hither Creek via the Madaket Ditch[2]. Pond-wide salinity averaged 12.865 psu in 2016 and continues to fluctuate tidally through the connection with Hither Creek via Madaket Ditch[4]. In 2016 pond-wide TN averaged 0.640mg/L, with higher concentrations occurring further from the ditch connection, at LP5. Phosphorous was below the EPA water quality criteria for lakes and reservoirs of 0.025mg/L, with a pond-wide average of 0.01mg/L in 2016[4].

An investigation into the Nantucket's landfill nutrient data was conducted in response to the hypothesis that capping and mining activities at the landfill are responsible for the improved nutrient-related water quality health at the water quality monitoring station adjacent to the landfill in Long Pond. Total Nitrogen (TN) levels at this site indicate an improvement, with TN falling below the secondary nutrient goal (Goal= 0.800mg/L) for that site for four consecutive years (Figure 2). Sampling station Long 6 is located East of second bridge, directly to the West of MW5 and to the Northwest of MW4. Historically, the Western edge of the landfill site had been used for animal carcass disposal, which may have contributed to elevated nutrient loads as the carcasses decomposed. There is no way to validate the historic inputs to the pond, however we can gage whether the habitat is improving because of lowered in-pond nutrient concentrations. In the Fall of 2017, habitat related water quality health was assessed through sediment sampling. The animals that live in the sediment (benthic infauna) were compared to historic data to determine if habitat improvement was occurring in conjunction with the TN reductions. The final report of this work will be available in the Spring of 2019.

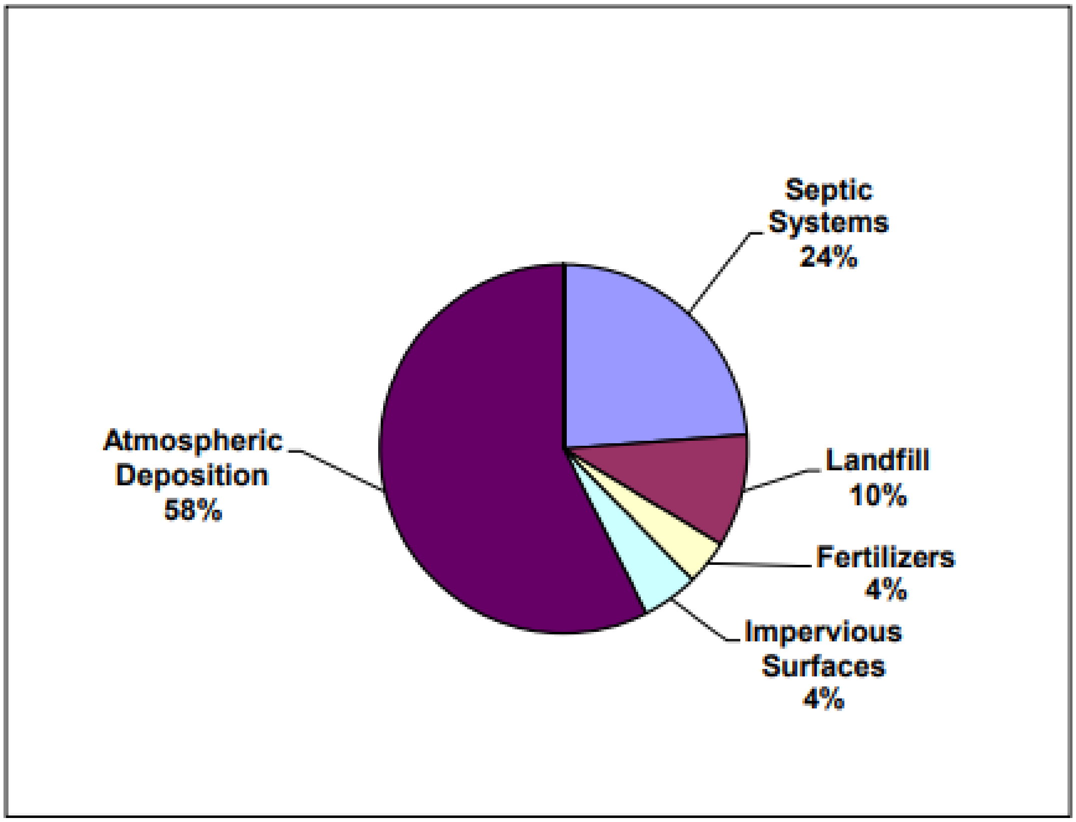

Figure 2. Percent contributions of all nitrogen sources to the Madaket Harbor and Long Pond Estuarine System (Madaket Harbor and Long Pond Estuarine System Total Maximum Daily Loads for Total Nitrogren 2015).

5.4 Review of Past In-pond Management Techniques

- **Hydraulic Control**: Long Pond connects to Hither Creek and Madaket Harbor by a ditch dug in 1665 through a cooperative agreement between the island's early European settlers and the Native American Wampanoag Tribe who sought an efficient method of harvesting Blueback herring and American eels spawning and living in the pond, respectively[2].
    - There is no need to manually open the southern portion of Long Pond to the Atlantic Ocean as enhanced flushing can be achieved through maintenance of the Madaket Ditch.
- **Invasive Species Management:** The Nantucket Pond Coalition has facilitated several Phragmites eradication projects in the Long Pond watershed.
    - **2015-2017 Massasoit Bridge Phragmites Pilot Project:** Madaket Residents Association financed.
    - **2016-2017 White Goose Cove:** CPC Financed.
    - **2017 Southwest shore of Long Pond:** Resident/abutter financed.
    - **2018 Northwest shore of Long Pond:** Resident/abutter financed.

5.5 Review of Existing Watershed Management Techniques

Nutrient inputs are best managed through active land management aimed at decreasing the quantity of nutrients entering ponds from the watershed. The Town of Nantucket has long-term management techniques currently underway to protect Long Pond from land-derived nutrient inputs. State and town-wide strategies for long-term water quality in Nantucket's Great ponds are as follows:

- 2010 Massachusetts General Laws Part 1 Title XIV Chapter 111 Public Health Section 5R Definitions; distribution and sale of household cleansing products containing phosphorus; limitations; violations
- 2012 Massachusetts Legislature: *An Act Relative to the Regulation of Plant Nutrients*-
    - Phosphorus-containing fertilizer may only be applied when a soil test indicates that it is needed or when a lawn is being established, patched or renovated.
    - Do not apply plant nutrients to sidewalks or other impervious surfaces. Plant nutrients that land on these surfaces must be swept back onto the grass or cleaned up.
    - No applications of plant nutrients shall be made:
        - between December 1 and March 1;

            - to frozen and/or snow-covered soil;
            - to saturated soil, or soils that are frequently flooded;
            - within 20 feet of waterways if using a broadcast method, or 10 feet if using a more targeted application method, such as a drop spreader;
            - within a Zone I of a public water supply well or within 100 feet of surface waters that are used for public drinking water supply

- Non-point Source Management
    - Board of Health Regulations
        - Local Regulation 53.00: Inspection and upgrading of substandard onsite sewage disposal systems within the Madaket Harbor Watershed
        - Local Regulation 49.00 Madaket Tight Tank Policy
        - Local Regulation 51.00 Town of Nantucket Board of Health Regulations Affecting Madaket.
    - Board of Health Local Regulation 75.00 The Content and Application of Fertilizer for Use on Nantucket
    - Best Management Practices for Landscape Fertilizer Use on Nantucket: Limits to the quantity of nitrogen fertilizer applied per year and no phosphorous containing fertilizer may be used unless a soil test indicates a phosphorous deficiency.
        - To provide landscape professionals and homeowners with information for making environmentally sound landscaping decisions that take Nantucket's unique conditions and natural resources into consideration
        - To promote the protection of water resources while maintaining healthy and vibrant ornamental landscapes
        - To reduce the amount of fertilizer use by promoting cultural practices that help reduce nutrient inputs
        - To offer site-planning guidelines and suggestions for ecological restoration that help reduce island-wide fertilizer-dependent landscapes
        - To provide science-based guidance for nutrient management of lawns and gardens on Nantucket
    - Ongoing landfill capping and mining: With the current mining operation of the landfill, material in the existing unlined cell is removed, sorted, portions passed through a digester and/or recycled. Some materials that cannot be recycled are then shipped off Island and what cannot be recycled or reused are then placed in lined cells, which are then capped preventing contamination to the groundwater.

- This process reduces the potential for nitrogen loading to the groundwater that ultimately flows into the watershed via Long Pond, Madaket Ditch, Hither Creek and ultimately Madaket Harbor. As this process continues, nitrogen loading is further reduced to the overall watershed. The Town's Annual Water Quality testing shows preliminary results that this mining is reducing the Nitrogen load to Long Pond and together with the removal of on-site wastewater is the solution to meet the TMDL in this embayment area.

5.6 Evaluation of In-pond and Watershed Management Alternatives

- Landfill capping, mining and additional nutrient testing of wells.
  - Comprehensive Wastewater Management Plan- State approved 20-year plan. The East side of Long Pond falls within the Madaket sewer need area, whilst the entirety of Long Pond falls within the Madaket Water Protection District, as such it has been recommended for sewer service since the 1980's.
    - "In contrast to Madaket Harbor, Long Pond and Hither Creek are well beyond their respective abilities to assimilate additional nutrient loading without impacting ecological health. Nitrogen levels are elevated in these areas with eelgrass beds totally lost from Hither Creek. The result is a need for nitrogen management in the overall system in order to restore the resources and limit future nitrogen loading in the watershed".
  - The ACO provides property owners with failing on-site systems the ability to defer major repairs as long as their property is located within an approved Needs Area and sewer is proposed in the near future. At the time of this development, Madaket Needs Area was approved to utilize the ACO, which saves the owner from having the expense of designing and installing a major repair/replacement system and then having to pay for sewer. The Board of Health will work with the property owner to find a temporary solution until such time as sewer is available.
  - Local regulation I/A clause if sewer not passed, effective July 2019.
- Determine seepage of groundwater from Eastern shore. Assess future PRB possibility- must be cited outside of saltwater intrusion zone.

- Undersized culverts connecting Hither Creek to Long Pond via Madaket Ditch (scope of work and cost associated TBD through Madaket Water Quality Improvement Project 2017-2019).
- Sediment testing for common limits to dredge disposal
- Re-assess benthic infauna community for improvements associated with nutrient reductions.

5.7 Management Recommendations

- Add Total Phosphorous (TP) to routine Long Pond monitoring program (NRD 2018).
- Additional samples to assess landfill nutrient inputs to Long Pond (2017) indicate lower loads than previously estimated
- Continue monitoring for Total Nitrogen, Total Phosphorous, landfill area and groundwater movement to track further reductions (CDM/ DPW).
- Landfill loads should be updated using the new landfill area and new groundwater flow data (CDM/ DPW).
- Linked-embayment models should be updated to reflect landfill management activities and ascertain current land management requirements to achieve TMDL goal in Hither Creek sentinel station (SMAST/ Applied Coastal scope pending: April 2018) (NRD).
- Aquatic flora and fauna surveys (NRD/NLC).
- Herring/diadromous fishery assessment (NRD/ NLC).
- Continue with Long Pond Phragmites work (NPC).

5.8 Works Cited

1. 1989 Pond Report, no author.
2. Howes B, and D. Goehringer. 1993. Overview of Nantucket Fresh Ponds 1989-1992. WHOI
3. Howes B.L., J. S. Ramsey, E.M. Eichner, R.I. Samimy, R. Acker, D.R. Schlezinger (2010). Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Madaket Harbor and Long Pond Estuarine System, Nantucket, Massachusetts. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.
4. Howes B., S. Sampieri, M. Bartlett, R. Samimy, D. Schlezinger (2017). Water Quality Monitoring and Assessment of the Nantucket Island-Wide Estuaries and Salt Ponds Update 2016.
5. Commonwealth of Massachusetts, Office of Energy and Environmental Affair, Massachusetts Department of Environmental Protection, Bureau of Water Resources (2015). Madaket Harbor and Long Pond Estuarine System Total Maximum Daily Loads for Total Nitrogen.