Natural Resources
Town of Harwich
715 Main Street · P.O. Box 207
Harwich Port, MA 02646
(508) 430-7532 · Fax (508) 430-7535

30 September 2022

To: Harwich Community Preservation Committee (CPC)
From: Heinz Proft, Natural Resources Director

RE: 2023-24 CPC Application Submission for Skinequit Pond Remediation

Members of the Commission:

Enclosed are twelve (12) copies of the CPC application for Skinequit Pond alum treatment to address the preservation, rehabilitation and restoration of Skinequit Pond. Skinequit Pond is the spawning ground for an active herring run originating in the Red River estuary and identified as critical habitat by the Open Space and Recreation Plan. The Comprehensive Waste Management Plan identified Skinequit Pond as "impaired", one of three ponds out of 16 tested that was assigned a "eutrophic" status. The three ponds included Hinckleys Pond, which was subsequently treated with alum in September 2019.

Although this application is being submitted by the Natural Resources Department, the Conservation Agent, Amy Usowski, is well-informed regarding this application. The application has also been reviewed by the Conservation Department, the Conservation Commission, the Health Department Director, the Water Department Director, and the Recreation Department Director. The Skinequit Pond association, Watershed Association of South Harwich (WASH) also supports the application and has contributed to its submission.

Respectfully,

Heinz Proft
Natural Resources Director

Application #_

For Administrative Use

TOWN OF HARWICH - COMMUNITY PRESERVATION COMMITTEE
2022 CPA PROJECT FUNDING REQUEST APPLICATION
FISCAL YEAR 2023-2024

Submission Date: September 30, 2022

APPLICANT INFORMATION

Applicant: Heinz Proft, Natural Resources Director

Town Committee, Board or Organization: Natural Resources

Legal Mailing Address: PO Box 207, Harwichport, MA 02646

Phone: 508-430-7532 Email Address: hproft@town.harwich.ma.us

Project Manager: Heinz Proft, Natural Resources Director

Legal Mailing Address: ____

Phone: ____ Email Address: ____

Second Contact Person: Amy Usowski, Harwich Conservation Administrator

Legal Mailing Address: 732 Main Street, Harwich MA 02645

Phone: (508) 430-7538 Email Address: ausowski@town.harwich.ma.us

PROJECT INFORMATION

PROJECT TITLE: Skinequit Pond Remediation

PROJECT AMOUNT REQUESTED: $92,000

PROJECT DESCRIPTION: ____

In 1998, Skinequit Pond suffered a major toxic algae bloom that resulted in a substantial kill of large and small fish, frogs and tadpoles, mussels, and other inhabitants of the pond. Since then, pond property owners have worked with Town officials to find ways to keep algae blooms at bay and reduce or slow down the eutrophication of the pond. In spite of these efforts, pond water quality has continued to suffer, leading to a 6-week closure in the Summer of 2021 due to a toxic cyanobacteria bloom. The pond abbutters commissioned a study of the pond and review of management options in 2022, subsequently concluding that treatment of the pond with alum is the best option going forward. We are seeking funding for the proposed alum treatment and associated permitting and testing. Please see Appendix A for details.

ESTIMATED START DATE: September 2023

ESTIMATED COMPLETION DATE: December 2025

Three years from the release of funds (July 2023) funds may be rescinded automatically; waivers may be sought.

CPA CATEGORY

APPLICANTS PLEASE TAKE NOTE **please check boxes for all that apply**

- ☐ **Open Space:** This application is for the **"acquisition, preservation, rehabilitation and/or preservation of open space".**
- ☐ **Historic:** This application is for the **"acquisition, preservation, rehabilitation and/or restoration of historic resources". Please provide the date on which the HDHC reviewed and endorsed this application.**
- ☐ **Community Housing:** This application is for the **"acquisition, creation, preservation and/or support of community housing".**
- ✓ **Recreation:** This application is for the **"acquisition, creation, preservation, rehabilitation and/or restoration of land for recreational use".**

How does this project fit into Harwich's Local Comprehensive Plan and/or other Plan?

Please see Appendix A

How does this project benefit the citizens of Harwich? If appropriate, has the application sought public opinion or input? If not, why?

Please see Appendix A

Please list other Commissions/Boards/Committees/Organizations that may have involvement, jurisdiction, partnering:

Commissions/Boards/Committees/Organizations	Please have them initial here after their review
Town administrator	[initials]
Water and Wastewater Department	
Health Department	
Conservation Commission	
Recreation and Youth Commission	
Harwich Conservation Trust	
WASH Member Support	

Describe their response, or provide written comments/input:

Please see letters of support in Appendix C

Please list any documentation to be forthcoming and reason for delay.

Letter of Support from WASH members—to come following review of Oct. 3rd submission.

PROJECT BUDGET: Attach a dated and detailed line item project budget estimate for your funding request. If the request involves a Town-owned asset, provide the project's projected operating expenses, including maintenance.

COST ESTIMATE(S): $92,000
Detail attached in Appendix B

LAND and/or BUILDING ACQUISITION PROJECTS: The following **must** also be submitted, as applicable:

- ☐ Surveys and/or plot plans for the property
- ☐ Appraisals and agreements (if not available then submit by December 1, 2022)
- ☐ Name of present owner and attach copy of deed conveying property unto present owner.
- ☐ Property address, Harwich Assessor's property identification (Map#, Parcel #).
- ☐ For proposed Open Space land purchases, be prepared to discuss public access with the Committee.

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By signing below, the Applicant represents and warrants that all the information included is true and correct to the best of the signer's knowledge and belief. Further, the Applicant acknowledges in the event that the Community Preservation Committee agrees to grant funds to Applicant (and subject to Town Meeting approval), this application together with any Terms and Conditions shall constitute a binding agreement, between the Applicant and the Community Preservation Committee. Further, Applicant acknowledges and agrees to execute any additional grant agreements should the Community Preservation Committee so request.

ATTESTATION: I HEREBY ATTEST THAT THE INFORMATION CONTAINED IN THIS APPLICATION IS TRUE AND ACCURATE TO THE BEST OF MY KNOWLEDGE.

Signature - Chief Executive Officer or Board Chair **Title**

____

Printed Name Heinz Proft **Date** 9-30-2022

APPLICATIONS MUST BE RECEIVED BY OCTOBER 3, 2022 NO LATER THAN 4 PM

Revised: May 16, 2022

APPENDICES

Appendix A: Statement of Application
Appendix B: Breakdown of Estimated Costs of Project
Appendix C: Letters of Support

- Town of Harwich Conservation Commission
- Town of Harwich Water And Wastewater Department
- Town of Harwich Health Department
- Town of Harwich Recreation and Youth Commission
- Harwich Conservation Trust
- Pond Association (WASH) Members

2023-2024 CPC Application for Skinequit Pond Remediation
APPENDIX A

Skinequit Pond Remediation

The Applicant is seeking $92,000 in CPC funds for alum treatment of the pond to address excess nutrient loading and remediate the current eutrophic state of Skinequit Pond. Skinequit Pond is a small freshwater kettle pond located south of Route 28 in South Harwich. The pond is approximately 18 acres, making it the 4th smallest Great Pond in Harwich, and has a maximum depth of around 32 feet, the 4th deepest Great Pond in Harwich behind Long Pond, John Joseph Pond and Seymour Pond.[1] The Town owns approximately 9.8 acres on the northeast edge of the pond, including an old cranberry bog (purchased by the Town in the 1960s), now designated wetlands, and includes approximately 350-400 feet of pond frontage connected to the bog. There is public access to the pond from Ocean Street, which is used by residents of surrounding neighborhoods and fishing afficionados who find the pond on fishing sites. In addition, the Harwich Conservation Trust owns approximately 2.2 acres on Skinequit Road, across the pond and west of the Town land. (See map, Exhibit I). These parcels help filter run-off and provide habitat for a wide variety of species.

Over the past 25 years, pond property owners, along with Town officials, have initiated various projects/programs in an attempt to mitigate the effect of accumulated nutrients in the pond and neutralize algae growth, the most successful of which has been the Solar Bee recirculator. In spite of these efforts, pond water quality has continued to suffer from accumulated nutrient load, leading to toxic algae blooms that forced a six-week closure in 2021. The current eutrophication of the pond is a result of more than a century of nutrient load, much of which can be attributed to the adjacent cranberry bog (now dormant) and watershed runoff (especially from Route 28 which is within 700 feet of the water's edge).[2]

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[1] Comprehensive Wastewater and Management Plan, Town of Harwich, Section 5, Assessment of Freshwater Ponds, CDM Smith, March 2016, Section 5, p. 1.

[2] Comprehensive Wastewater and Management Plan, Town of Harwich, Section 5, Assessment of Freshwater Ponds, CDM Smith, March 2016, Section 5, p. 17.

In 2022, the pond association, Watershed Association of South Harwich (WASH), hired Water Resource Services to evaluate the pond water and sediment and to provide management options for possible remediation (Exhibit II). The study concluded that "(t)here is no way to achieve a desirable P (phosphorus) concentration in Skinequit Pond without addressing the internal load".[3] The proposed management options included dredging, oxygenation, and alum treatment. Of the three options, alum treatment is significantly less expensive than dredging and oxygenation, more proven relative to oxygenation, and less disruptive to the ecology of the pond relative to dredging.

Alum remediation of Skinequit Pond meets goals outlined in the Local Comprehensive Plan and Comprehensive Wastewater Management Plan (detailed below). The project will preserve and enhance the herring spawning grounds for the Red River estuary herring run and improve water quality, and preserve and prevent further degradation of the surrounding critical natural landscape habitat that serves this biodiverse ecosystem. In addition, a healthier pond will reduce public health risks that arise during toxic blooms.

Background

In 1998, Skinequit Pond suffered a major toxic algae bloom that resulted in a substantial kill of large and small fish, frogs and tadpoles, mussels, and other inhabitants of the pond. Although many pond property owners suspected run off from the dormant cranberry bog on town land northeast of the pond, no known cause of the bloom and fish kill was identified at that time.

Since then, pond property owners have worked with Town officials to find ways to keep algae blooms at bay and reduce or slow down the eutrophication of the pond. Along with the Town's Natural Resources and Conservation Officers, several remediation projects were undertaken including:

- oxygenation of the pond through the placement in 2001-2002 of two separate hoses on the northeast and southeast side of the pond, run by compressors on private properties and funded privately.

[3] Skinequit Pond Evaluation and Management Options Review, June 2022, Water Resource Services, p. 26. (See Exhibit II.) Definition of P added.

- the placement of barley bales in 2004 on the north side of the pond in an effort to neutralize algae through production of hydrogen peroxide created by the decomposition of the barley.

- the placement of a Fukui bio cord reactor on the north side of the pond in 2005 intended to attract microbes that would neutralize or slow algae blooms.

- the purchase and installation of the Solar Bee in 2007, which recirculates water to help to mitigate algae growth. Funding for the purchase and installation of the Solar Bee totaled $44,892, of which pond property owners contributed $43, 092 and the Town contributed $1,800; and

- the recent June 2022 study to evaluate the state of the pond and provide management options, funded in full by the property owners.

In 2004, pond property owners created the current pond association, the Watershed Association of South Harwich (WASH), to raise awareness, spread "healthy pond" initiatives to reduce controllable nutrient loads, and raise money to purchase, install, and maintain the SolarBee. Since 2000, pond property owners and WASH members have collected biweekly water samples and data for the pond in the summer (at least five per year). The water samples and data are forwarded to the Town to submit to UMass for analysis as part of the PALS initiative. As mentioned above, WASH also initiated the 2022 Skinequit Pond Evaluation and Management Options analysis by Water Resource Services, funding the full cost of $15,403.

Through WASH, property owners have spent almost $100,000 over the past 20 years (including the cost of the 2022 Water Resource Services study) to enhance pond circulation, improve the health of the pond and mitigate algae blooms (detailed in Exhibit III).

Why Skinequit Pond?

1. *Active Herring Run:* Skinequit Pond is the freshwater spawning grounds for an active herring run, a natural resource that is a Town priority for preservation and restoration. The herring run

originates in the Red River estuary and accesses the pond via a stream that crosses Uncle Venies Road on the southwest area of the pond. Although the Red River/Skinequit Pond herring run is smaller than other Harwich herring runs, it is a crucial link in the food chain for fish and wildlife that includes herons, egrets, osprey, hawks, terns, cormorants, owls, muskrats and otters, foxes and coyotes from around the pond area as well from other critical habitats and wetlands in the surrounding areas.

2. *Existing Damage to Ecosystem:* The Skinequit Pond ecosystem has not yet fully recovered from the 1998 toxic bloom. Historically, the pond was a spawning area for eels in addition to herring and was also the home to freshwater mussels. Although the herring are still active, both the eels and mussels were decimated by the 1998 toxic bloom and perhaps eliminated from the ecosystem; no resident sightings of either have been reported in recent history.

3. *Impaired Waters:* Skinequit Pond's waters are highly eutrophic and threatened by increasingly toxic and sustained algae blooms which ultimately affect the health of pond and its surrounding ecosystem. The June 2022 Water Resource Services report indicated a layer of anoxia of, at times, 9 feet or more at the bottom of the pond. Over 10 years ago, Skinequit Pond water was categorized as "eutrophic" and "impaired" in a freshwater pond assessment conducted by CDM Smith for the Town of Harwich and included in the Town's current Comprehensive Wastewater Management Plan. [4] The study found dissolved oxygen (DO) metrics for Skinequit were below state thresholds in 50% of the 68 DO measurements.[5]

   More recently, in March 2022 the Association to Preserve Cape Cod (APCC)- a non-regulatory non-profit organization that relies on volunteers for water sampling—published a State of the Water

[4] Comprehensive Wastewater Management Plan, Town of Harwich, Section 5, Assessment of Freshwater Ponds, CDM Smith, March 2016, Section 5, Assessment of Freshwater Ponds, pp. 5-21 and 5-23.

[5] Comprehensive Wastewater Management Plan, Town of Harwich, Section 5, Assessment of Freshwater Ponds, CDM Smith, March 2016, Section 5, Assessment of Freshwater Ponds, p. 5-18.

survey of ponds on the Cape which identified Skinequit Pond "Unacceptable/Needs Immediate Protection" based on its eutrophic state and recent cyanobacteria blooms (information provided in Exhibit IV). Testing done by APCC based on water sampling collected by the organization showed that Skinequit Pond's Trophic State Index (TSI) was the second highest (behind Grass Pond) of the eight ponds tested in Harwich.

4. *Biodiverse Ecosystem/Habitat:* The pond 's highly eutrophic state and frequent and lengthy toxic algae blooms threaten the biodiversity of the area, already compromised by the 1998 bloom. In addition to the herring run, Skinequit Pond supports a biodiverse ecosystem of birds, animals, fish, amphibians, reptiles, insects, butterflies and damselflies, and plant life. This includes at-risk species included in the State's list of Species of Greatest Conservation Need, such as alewife herring, American black duck, great egret, snowy egret, black crowned night heron, double breasted cormorant, marsh wren, pine barrens bluet damselfly, herring gull, New England cottontail, and other vertebrates, mammals, invertebrates and plants.[6] Exhibit VI includes a partial list of species observed in and around Skinequit pond by residents and an inventory of tree, shrub and plant species found at Skinequit Pond included in the Harwich Land Management Plan prepared in 2012.[7]

5. *Public Health Risks*: Cyanobacteria blooms are harmful to human and pet health as well, and increasingly pose public health risks. In 2021, Skinequit Pond was closed to swimming for six weeks between mid-July and early September due to toxic cyanobacteria blooms. The Town posts "unacceptable for swimming" notices and WASH forwards the information when notified to its WASH

[6] Identified by Skinequit Pond residents. List of MA Species of Greatest Conservation Need-October 2015, MA State Wildlife Action Plan, https://www.mass.gov/files/documents/2016/11/wi/massachusetts-species-of-greatest-conservation-need.pdf [6] Land Management Plan, prepared by BSC Group, Inc., Town of Harwich, MA, 2012, p. 23.
[7] Town of Harwich Conservation Department website.

email list. However, there is often a time lag between water testing and receipt of results that can expose users to health risks that they are not aware of. In addition, the notices are posted at the public access and are not visible to most of the pond property owners or renters, who are therefore unaware of the health risks to small children and pets. While WASH maintains a list of property owners, properties change hands and/or contact information is not available for some abutters.

6. *Engaged and Supportive Stakeholders:* For more than 25 years, the primary stakeholders—pond property owners—have been engaged and supportive of efforts to inhibit algae growth, reduce man-made nutrient load and support Cape-wide pond water testing. This includes significant investment, as detailed below.

CPA Funding

The applicants believe that this request for alum treatment to remediate Skinequit Pond falls under Section 2 of CPA legislation which permits CPA funds to be spent on the rehabilitation/restoration of recreational areas, including freshwater ponds.

The funding request meets the project selection criteria of the CPC, based on the following considerations:

1. *Consistency with Town plans; Preservation of Threatened Resources; Preservation of Town Assets*

- The 2010 Open Space and Recreation Plan (OSRP, part of the Town of Harwich Local Comprehensive Plan) includes, as a primary goal, the preservation and enhancement of "groundwater and surface water; coastal water and adjacent shoreline areas; inland and coastal wetlands; and wildlife and plant habitats"[8], and specifically called for taking steps to prioritize the prevention of loss or degradation of "critical wildlife and plant habitats such as ….diadromous (e.g. alewife/river herring) fish runs"[9]. The

[8] Town of Harwich Open Space and Recreation Plan, 2010, p.1.
[9] Town of Harwich Open Space and Recreation Plan, 2010, p 64.

OSRP identified the fish run that begins in the Red River estuary and leads to Skinequit Pond herring spawning grounds as a critical habitat.[10] CPA funding for this project will improve water quality and enhance freshwater spawning grounds in Skinequit Pond, and dovetails with the recent Tuttle land grant to the Harwich Conservation Trust, which sought (in part) to preserve the Red River estuary herring run.

- The Comprehensive Wastewater Management Plan categorized Skinequit Pond's water quality as "impaired" and "eutrophic" in its assessment of Harwich freshwater ponds (Exhibit VII) and highlighted Skinequit Pond as a candidate for reducing degradation and/or analysis for possible sewering.[11] (Skinequit is not included in the current Harwich plan for sewering.) This project will improve the trophic state of the pond and help "reset" water quality to a more desirable state.

- The Open Space and Recreation Plan places a priority on preserving and protecting natural habitats, including "critical habitats and natural communities"[12]. In addition to the herring run, acreage abutting the pond (including the Town-owned dormant cranberry bog, now wetlands) has been designated a "Critical Natural Landscape" habitat by the Natural Heritage Endangered Species Program (Exhibit V). Remediation of Skinequit Pond waters will support and likely expand the populations and species in and around the pond, as well as support species in surrounding critical and core habitats and wetlands (also shown in Exhibit V).

2. <u>*Feasibility and Affordability*</u>

    - Of the three management options provided by Water Resource Services, alum treatment is the least expensive and most feasible option to improve water quality and address nutrient load. Alum treatment has a strong track record of success based on treatment of other ponds, both

[10] Town of Harwich Open Space and Recreation Plan, 2010, p. 35.
[11] Comprehensive Wastewater Management Plan, Town of Harwich, CDM Smith, March 2016, Section 5, pp. 3 and 17.

[12] Town of Harwich Open Space and Recreation Plan, 2010, Goal VI, Objectives 8 and 9, p.71.

in Harwich, throughout the Cape and beyond. Appendix B breaks down the estimated costs for the project.

3. *Consistency with Recent Town Meeting Actions*

- The project aligns with recent Town Meeting actions, most recently, the funding of alum treatment at Hinckley's Pond, appropriated at the 2018 Annual Town Meeting.

4. *Financial Leverage/Engaged Stakeholders*

- Not included in the CPA request is $15,403 funded by the pond property owners for the 2022 water and sediment study by Water Resource Services (CPC monies were used to fund a similar study for Hinckleys Pond.) When included as part of the overall costs of this project, WASH funding will represent 14.3 % of the total project costs. Pond property owners have a track record of engagement around and financial commitment to the health of the pond. In the past 20 years, pond property owners, through WASH, have spent more than $84,000 to address and slow down the eutrophication of the pond (Exhibit III) and countless hours testing pond waters on behalf of the Town. This total financial support of $100,000 does not include private funds used for the oxygenation project in 2001-2002 or the value of conservation restrictions granted to the Town by a pond property owner relating to a 4.45-acre undeveloped property. Appendix B includes the estimated costs for the project.

5. *Other Considerations*

- *Public Health Risks:* CPA funds will address the public health risks associated with toxic algae blooms and enhance recreational use by pond property owners, abutters, and others in the surrounding area. There are approximately 70 houses directly on the pond, with deeded access, or within a short walking distance of the public access.

- *Public Access:* The Town has committed to improving the current public access to Skinequit Pond by removing poison ivy, trimming back bordering plants, adding clearer signage, and removing a platform that is in the mud below the water.

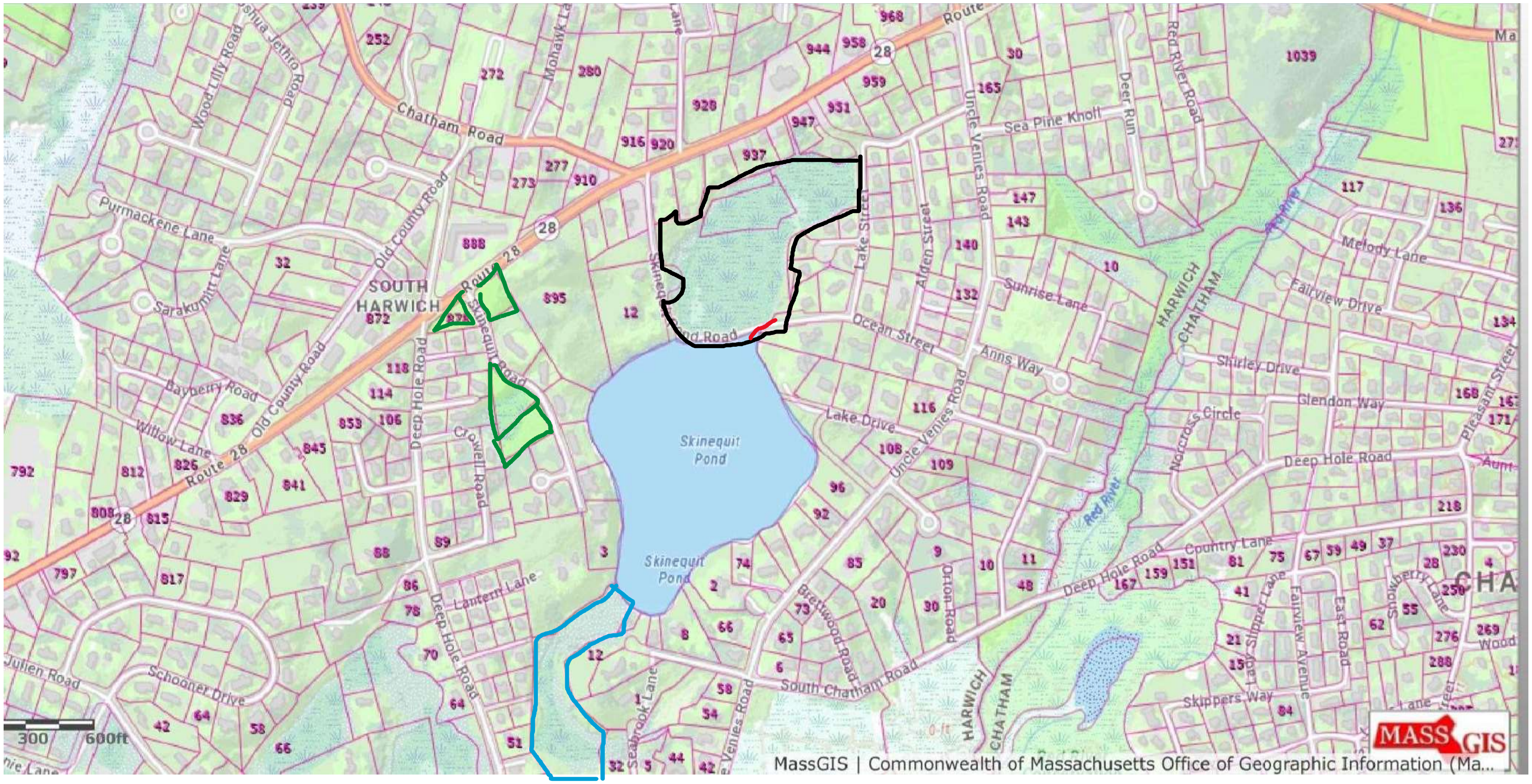
Town-owned land on Skinequit Pond is not conducive to further development or expansion for public trails or recreation, as the land abutting the pond is designated wetlands. The Town's Land Management Plan-- an overview of Town-owned parcels intended to be a living guidance document for making recreation and open space decisions--states that the Skinequit town-owned land "is all within the resource area so no trails or recreational use is recommended".[13] It further states that the site has been "preserved for habitat", other than a small access way to the water off Ocean Street, and no signs, trails, parking, or other structures were proposed for this site at that time.[14]

At the time of the Land Management study, there was a property for sale adjacent to the Town-owned land with a dock. The Land Management Plan proposed that the property could be purchased by the Town, the home removed, and native habitat created for wildlife, with the dock potentially used for recreational purposes. No action was taken, and that property continues to be privately held.

From a practical point of view, there is no room for onsite public parking on Town land. Public access to the pond is not visible from Uncle Venies Road and therefore not easily or practically policeable—both considered informal and practical criteria for recreational areas on or near Town-owned conservation land.

[13] Land Management Plan, prepared by BSC Group, Inc., Town of Harwich, MA, 2012, p. 23.
[14] Land Management Plan, prepared by BSC Group, Inc., Town of Harwich, MA, 2012, p. 24.

Exhibit I: Skinequit Pond Map



*Note: **BLACK** outlined property=Town-owned parcels; **GREEN** outlined property= Harwich Conservation Trust parcels; **BLUE** outlined area= herring run; **RED** line indicates public access.*

Exhibit II: Skinequit Pond Evaluation and Management Options
Water Resource Services
June 2022

Skinequit Pond Evaluation and Management Options Review

Prepared by:
Water Resource Services

JUNE 2022

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Physical Features

Skinequit Pond is in the southeast corner of Harwich, Massachusetts (Figures 1 and 2). The watershed map was generated by WRS from general information on topography and groundwater contours and is approximate. The direct, potential surface drainage area covers 47 acres, mostly northeast of the pond. Land use in this direct drainage area is residential and forested wetland, the latter formed from a cranberry bog that went out of service by the early 1960s. Surface runoff is likely to be a minor source to Skinequit Pond, given sandy soils and limited storm water drainage systems.

The larger groundwater drainage area is mostly north of the pond and is a function of the Monomoy aquifer lens. The groundwater drainage area is largely residential with some undeveloped land. The actual distance groundwater might travel to reach the pond is potentially further, extending all the way up to Rt 6, but the area shown is the subsurface drainage area most likely to have any possible impact on the pond. Even then, many contaminants (including phosphorus but not nitrogen) are removed from groundwater by soil within a few hundred feet of the input point. Some mobility is expected for almost all contaminants, but the process is very slow.

Watershed influence on Skinequit Pond will decrease dramatically with distance from the pond. Of greatest historical concern is the now defunct cranberry bog which operated for decades at a time when environmental controls were limited to absent. The load of organic matter and nutrients to Skinequit Pond was likely large for many years. The likely scenario is that water was pumped from the pond to irrigate and flood the bog. Irrigation water would not have typically returned to the pond, but flood waters would have gone back to the pond with high quantities of organic matter and nutrients. The bog occupied a little over 9 acres, half the area of the pond, so a typical harvest flood event would have involved only about 5-7% of the pond volume, not enough to have a major impact in any one year, but the load mostly winds up in the sediment and that eventually creates a serious oxygen demand and internal phosphorus loading problem. Aside from minor lawn and road runoff and inputs from nearby on-site wastewater disposal systems, there is little in the current watershed that appears to represent a threat to Skinequit Pond. The problems of recent decades appear to be a function of legacy inputs.

Skinequit Pond covers 18 acres with a maximum depth of 32 feet (Figures 3 and 4). Figure 3 is from the 2003 Cape Cod Pond and Lake Atlas while Figure 4 is from an unknown source but was found online. Another map was developed by WASH members and is similar to Figures 3 and 4, just with less smooth contour lines. All bathymetric maps indicate a classic kettle hole, bowl-shaped pond. Maximum depth may be less in 2022, as a consequence of ongoing organic sedimentation in the pond but is likely still at least 30 feet.

The distribution of area and volume over pond depth (Figure 5) indicates a moderately uniform decrease in area as depth increases and a total pond volume of 260 acre-feet (11.3 million cubic feet, 321,000 cubic meters, 85 million gallons). Dividing volume by area, the average depth of Skinequit Pond is 14.5 feet (4.4 m). The pond appears to stratify between 10 and 13 feet of depth (3-4 m), so the upper layer in summer has a volume of about 165 acre-feet (63%) while the bottom layer has a volume of about 95 acre-feet (37%).

Figure 1. Skinequit Pond area of Harwich, MA

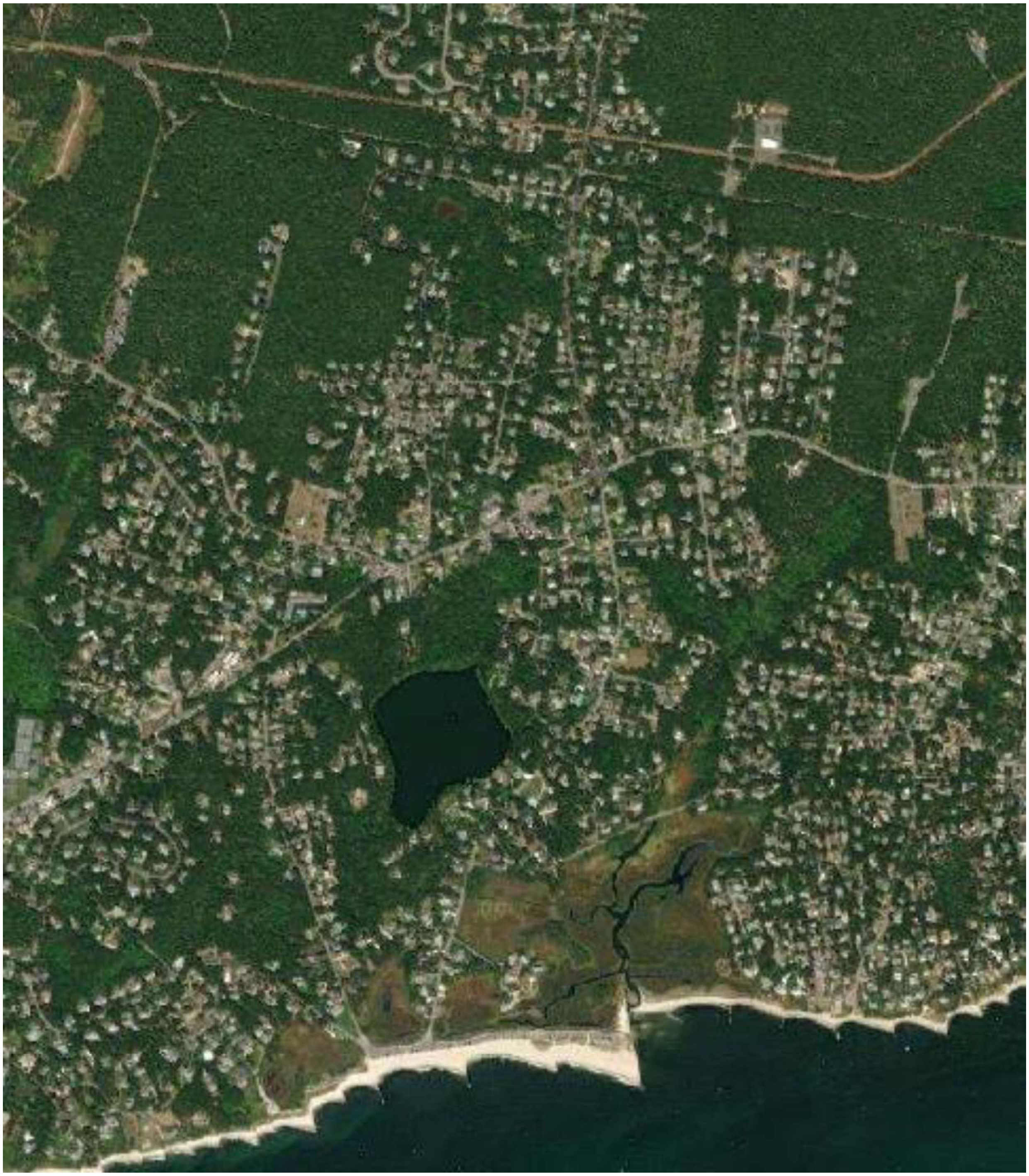


Figure 2. Skinequit Pond and its approximate surface (green) and groundwater (red) drainage areas

Figure 3. Skinequit Pond water depth contours from pre-2003

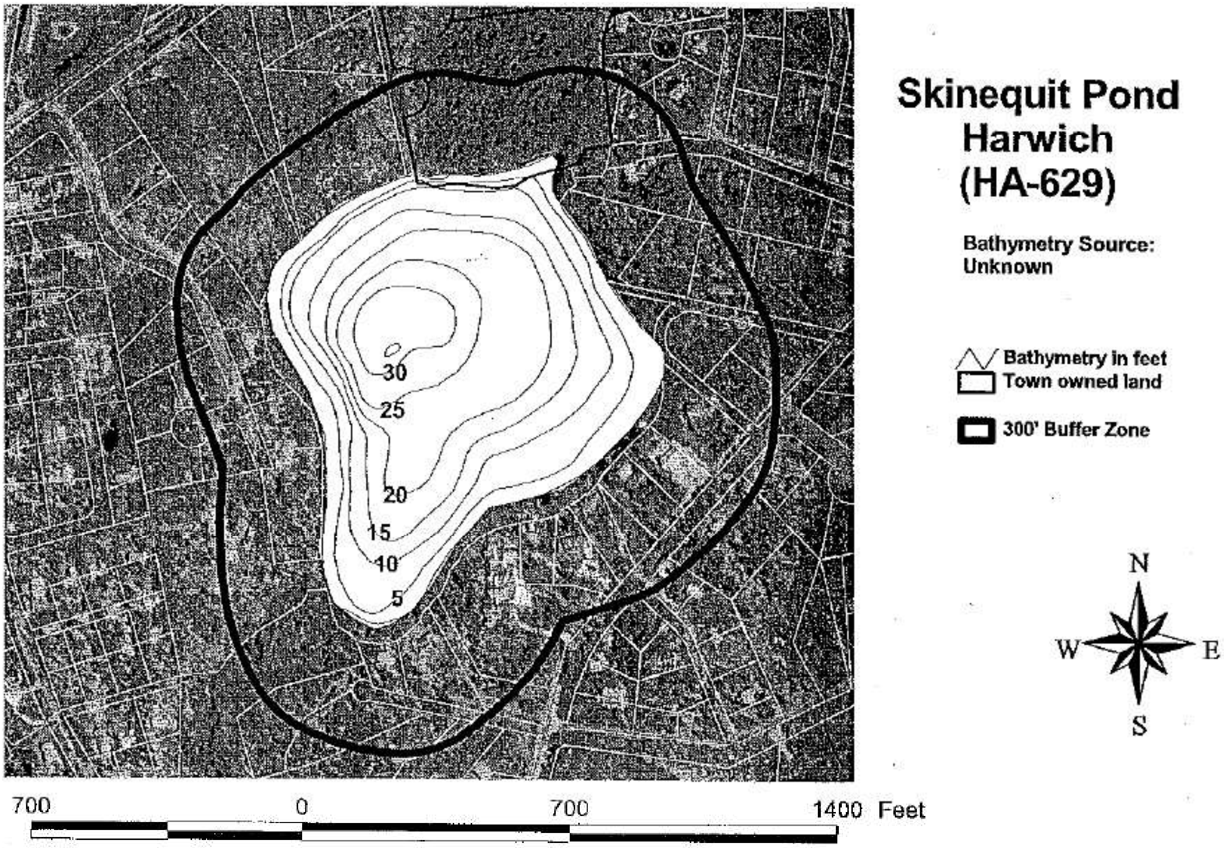
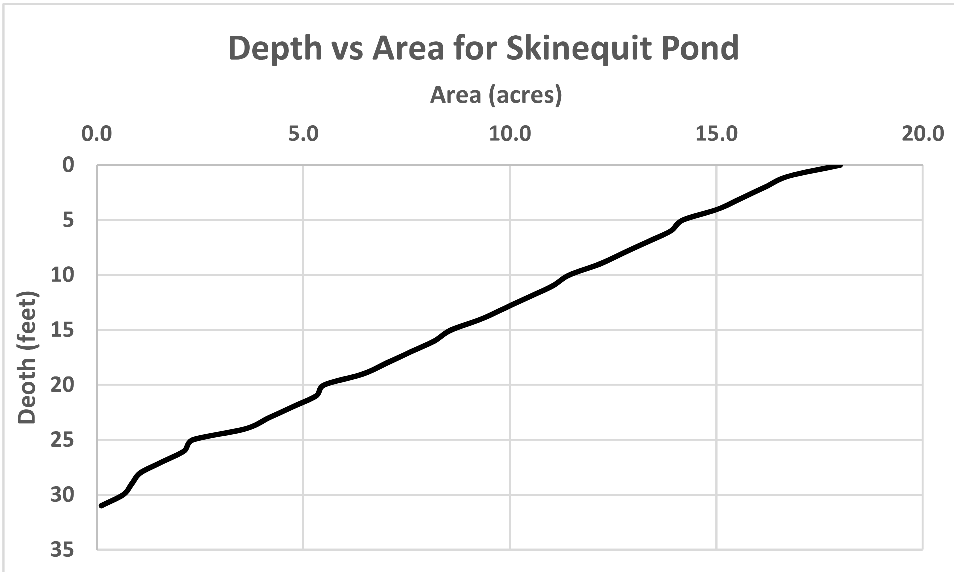
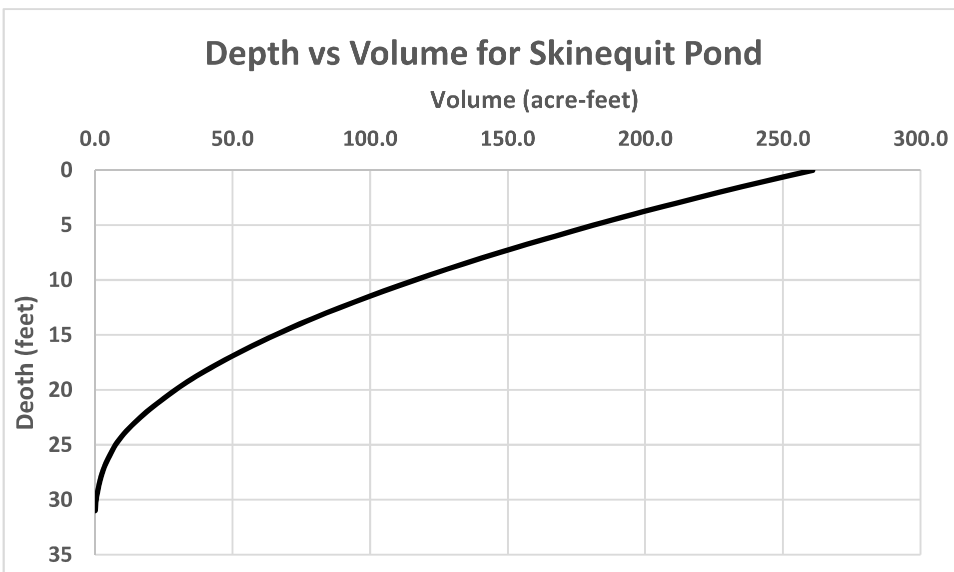


Figure 4. Skinequit Pond water depth contours from an unknown source accessed in 2022

Figure 5. Skinequit Pond depth vs area (upper graph) and volume (lower graph)





Sediment features of Skinequit Pond are likely to be very important to its condition and management. The Cape Cod Pond and Lake Atlas from 2003 notes high organic content of the pond and its sediment but provides no details. With fairly steep slopes, it was expected that organic matter has been focused into deeper water, and that is indeed the case. On the Cape we typically find that soft, organic, oxygen-demanding, P-rich sediment becomes dominant somewhere between 15 and 20 feet of water depth, but it can vary, and site-specific investigation is needed. The quality of the sediment is also important and is unknown for Skinequit Pond. Sediment conditions were examined in early April of 2022.

Visual assessment with an underwater video system and over 60 measurements with a 30 ft metal probe within the pond were performed to determine where the sediment transitioned from sand to organic muck and how deep the organic sediment was. The "muck line", defined here as the point at which organic sediment is consistently >2 inches deep, occurred at 12 to 14 feet of water depth (Figure 6), with 10.5 acres of the pond (58%) covered by organic sediment. The peripheral, shallower area was mostly sand with some gravel and a few rocks.

The area of the pond covered by at least 1 foot of organic sediment was 8.2 acres (Figure 7) and the area covered by at least 2 feet of organic sediment was 6.5 acres (Figure 8). Organic sediment depth increases rapidly at that point, with a depth of >6 feet achieved over 5.7 acres of pond area (Figure 9). It appears that Skinequit Pond was a steeply sloping kettlepond when the stranded ice block that formed it melted, and that it has filled substantially with organic sediment over the last 10,000 years.

Combining data along transects from the N, S, E and W, organic sediment depth profiles are developed (Figure 10). Note that the horizontal scale is not identical in these graphs; the distance from shore at which an organic sediment depth of 6 feet is achieved varies, with the N and W transects dropping off more steeply than the S or E transects. Using the data to calculate the volume of organic sediment (Table 1), the horizontal layers of soft, organic sediment are provided. There are approximately 68,500 cubic yards (cy) of organic sediment down to the point where the sediment thickness is 6 feet. Beyond that depth, the sandy underlayment could not be reached, so we do not know exactly how thick that last layer is, but assuming a thickness of 4 feet, this adds 11,600 cy for a total of more than 80,000 cy. The pond volume is about 420,000 cy, so about 16% of the pond has been filled since it was formed.

Sediment samples were collected from four locations (Figure 11), designated as N, S, E and W, based on the perceived features of the sediment accumulation. Samples were collected to a depth of 10 cm, the maximum depth that typically interacts with the overlying water, Sediment was very dark and loose, with surficial patches of brown to orange iron deposits, indicative of high organic content, high oxygen demand, and substantial P content (Figure 12). The probe sank easily in these sediments to the sandy interface with the softer organic sediment or until the maximum length of the probe (20 feet) was reached.

Figure 6. Skinequit Pond organic sediment depth >2 inches

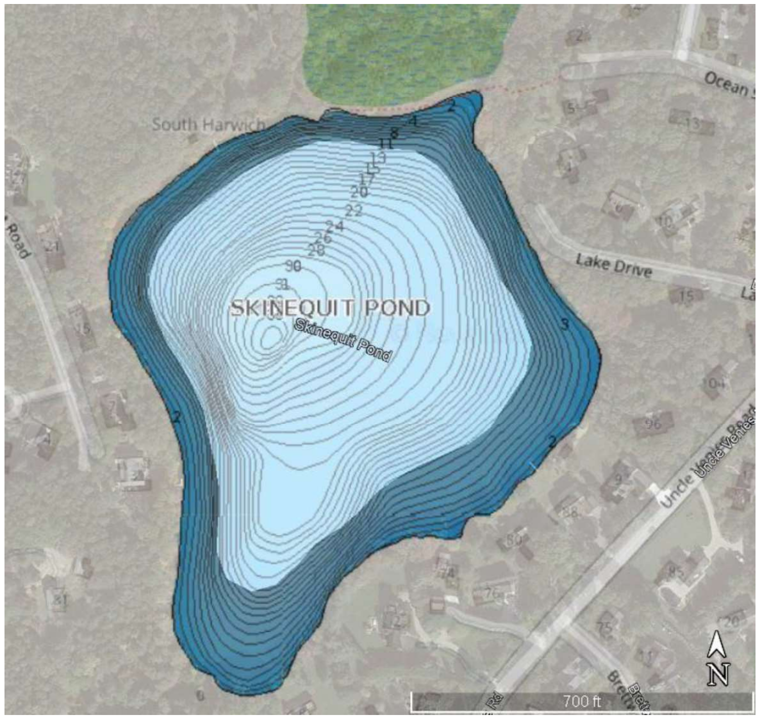


Figure 7. Skinequit Pond organic sediment depth >1 foot

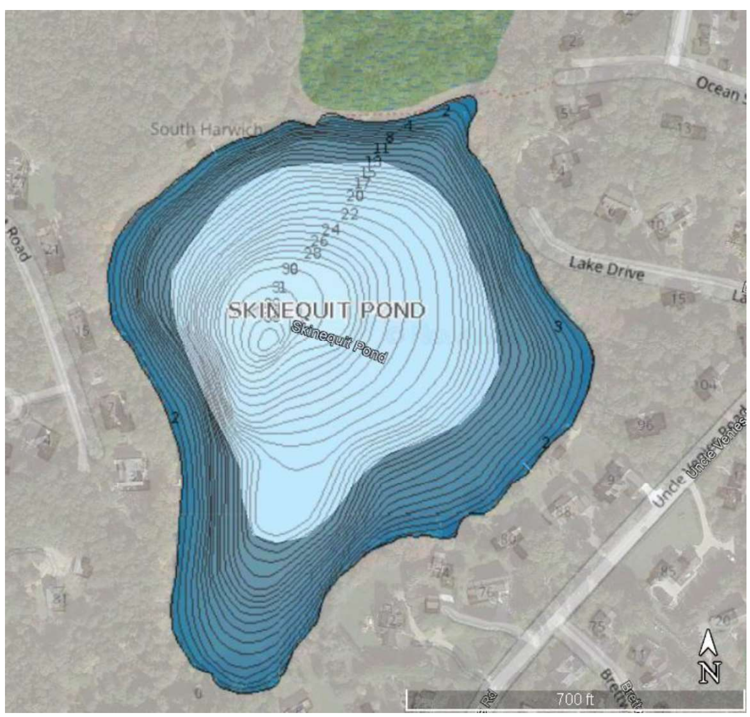


Figure 8. Skinequit Pond organic sediment depth >2 feet

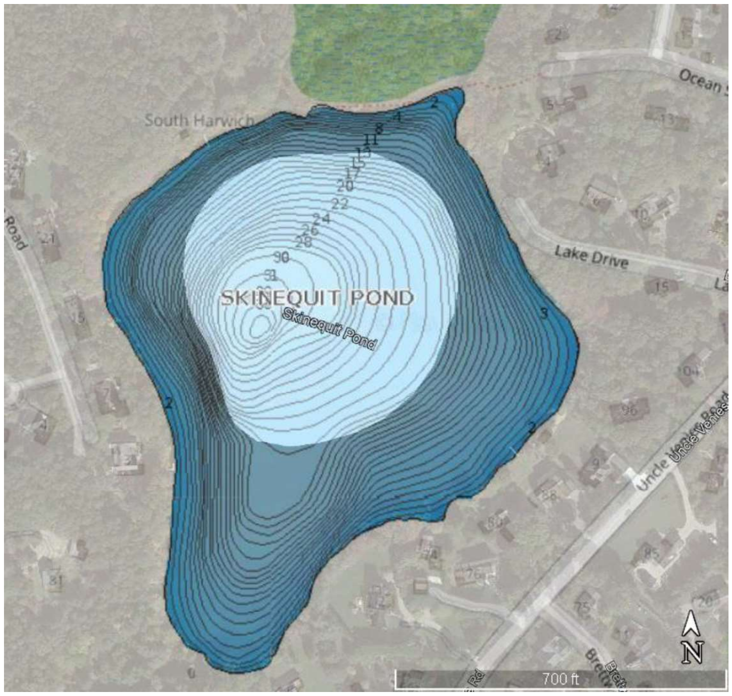


Figure 9. Skinequit Pond organic sediment depth > 6 feet

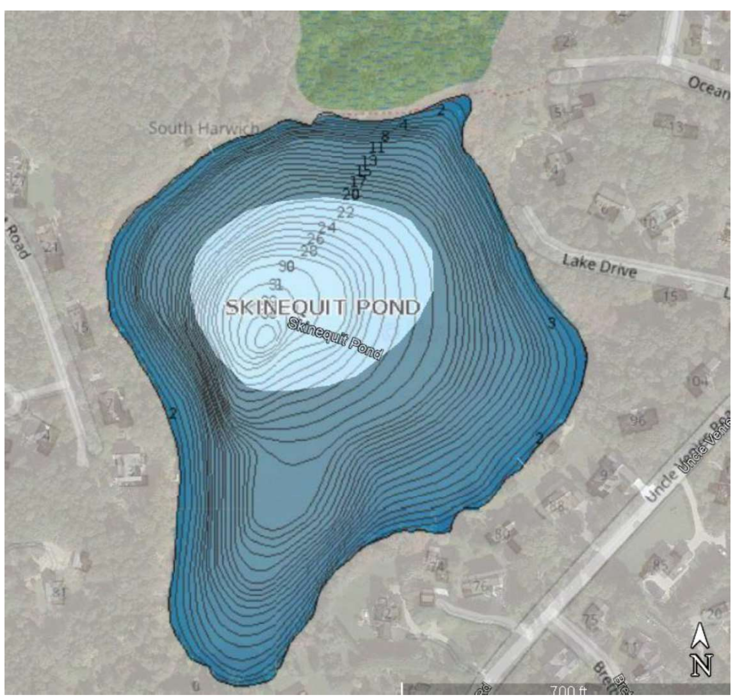
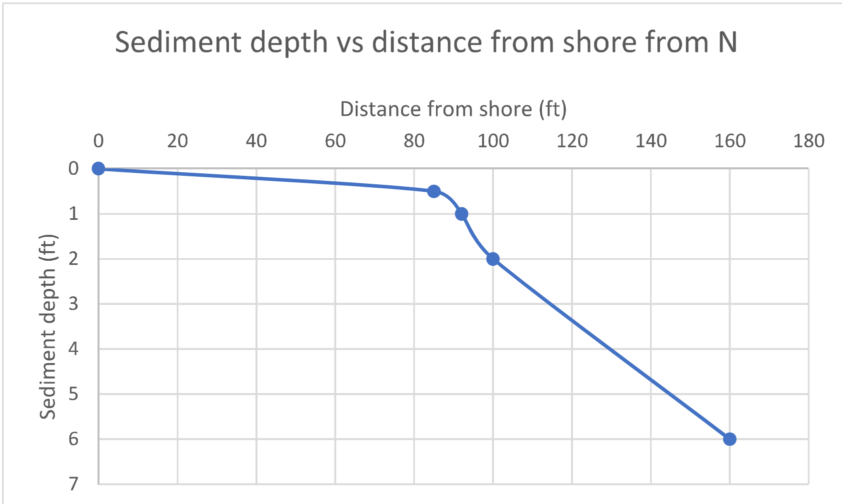
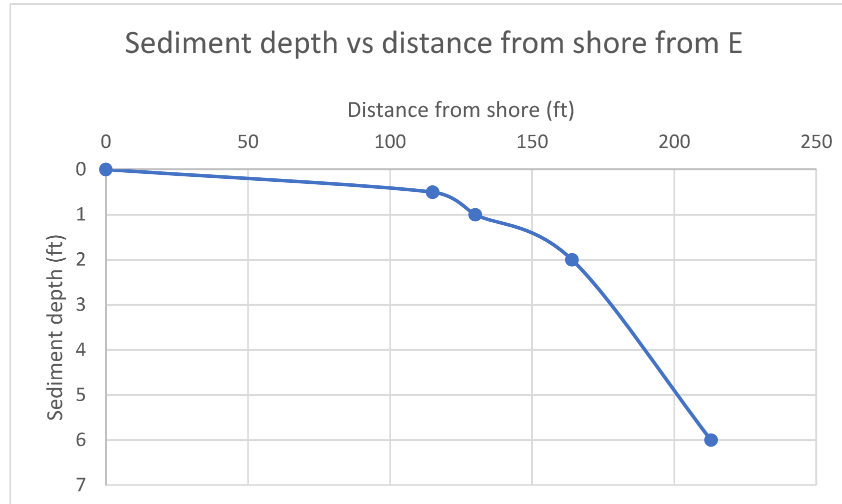
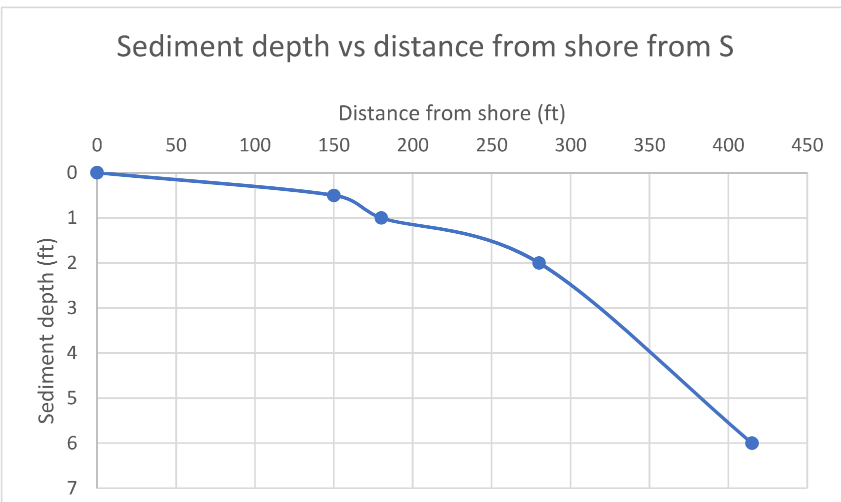


Figure 10. Skinequit Pond organic sediment depth profiles







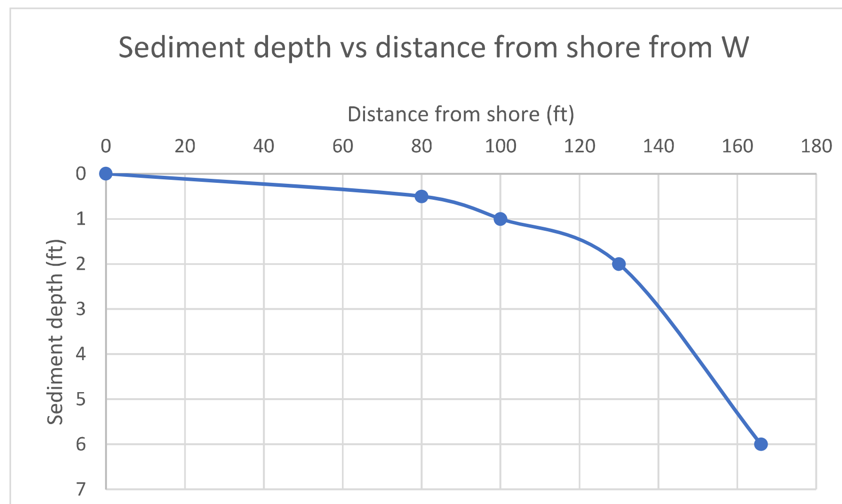
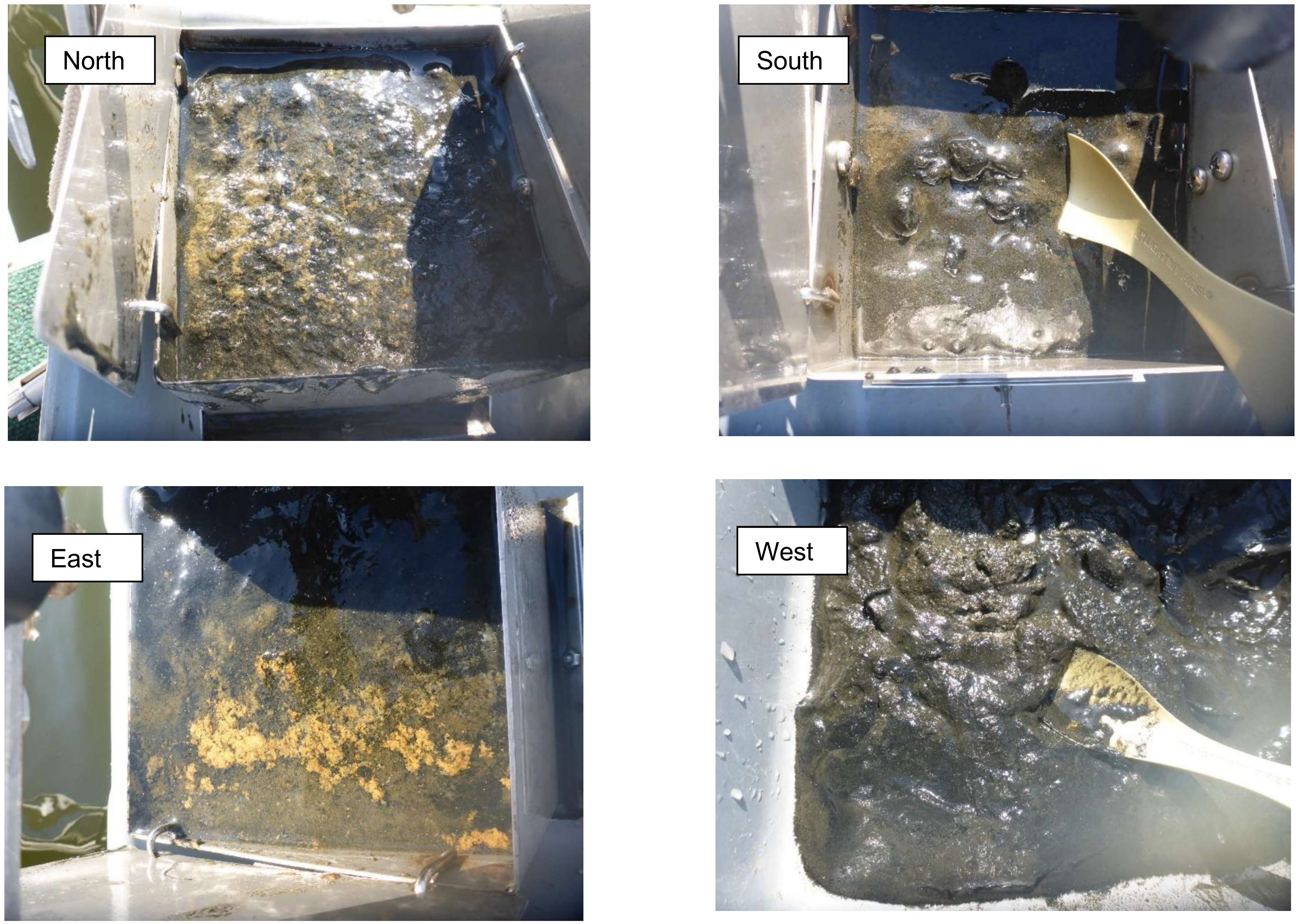


Table 1. Sediment volume calculations for Skinequit Pond

Organic sediment depth (ft)	Layer area (ac)	Layer thickness (ft)	Layer volume (ac-ft)	Layer volume (cy)
0-0.5	14.45	0.5	7.2	11656
1	9.7	0.75	7.3	11737
1-2	7.55	1	7.6	12181
2-6	5.1	4	20.4	32912
>6	1.8	4	7.2	11616
		up to 6'	42.45	68486
		up to 10 '	49.65	80102

Figure 11. Skinequit Pond sediment sampling sites

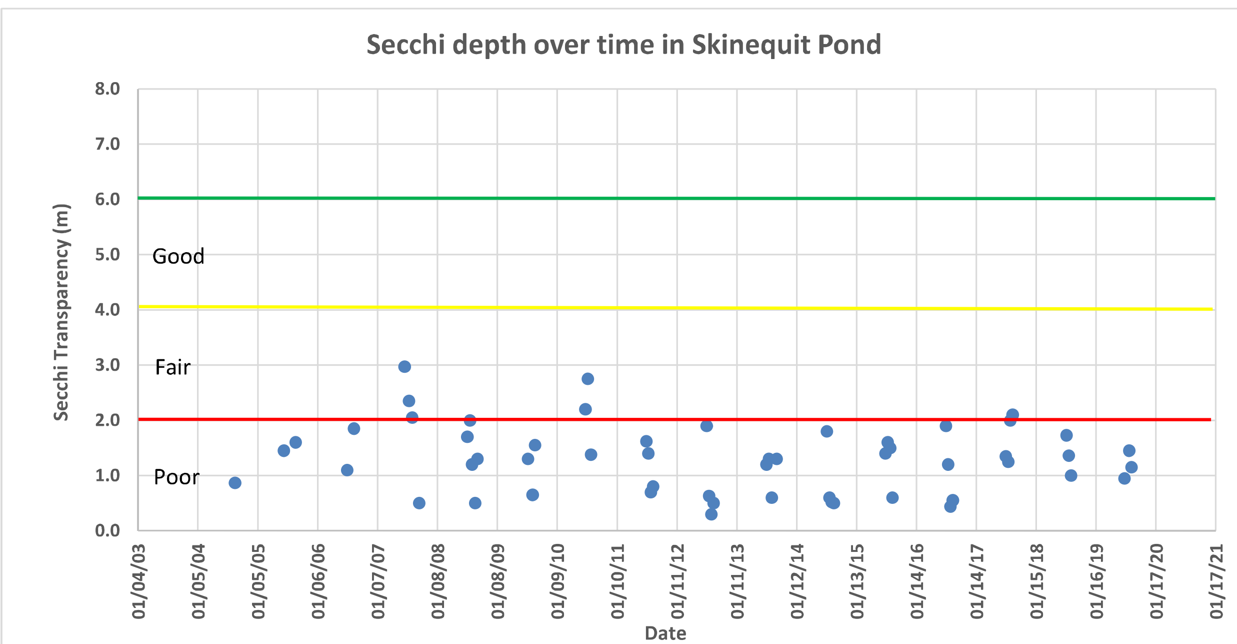
Figure 12. Skinequit Pond sediment photographs



Another key physical feature is often discussed with water quality, but the clarity of the water, usually expressed as Secchi Disk Transparency (SDT) is an integral feature that is affected by physical, chemical, and biological processes and is often what people most easily relate to overall lake quality and utility for various uses. High clarity is prized but can be reduced by many factors, some completely natural and some induced by human influence. Cape Cod ponds rarely have clarity >20 feet (6 m) as a function of natural water color (humic and tannic substances in the water), but without algae blooms Cape Cod ponds typically have SDT readings between 3 and 5 m.

The Cape Cod Pond and Lake Atlas from 2003 reports clarity in Skinequit Pond of 6.6 ft (2 m) from 2001 and notes that a survey in 1989 exhibited similar conditions. The average of all values collected as part of PALS monitoring since 2004 is 4.3 feet (1.3 m) and SDT has routinely fallen into the poor category (Figure 13). Clarity was at its best in 2007 and 2009 but never exceeded 10 ft (3 m). The low clarity has been identified as a function of algae blooms, particularly cyanobacteria. The consistently low clarity of Skinequit Pond is striking and indicates chronically elevated nutrient levels. The solar powered circulator installed in 2007 has not significantly improved clarity based on the available data.

Figure 13. Skinequit Pond Secchi disk transparency



Water Quality

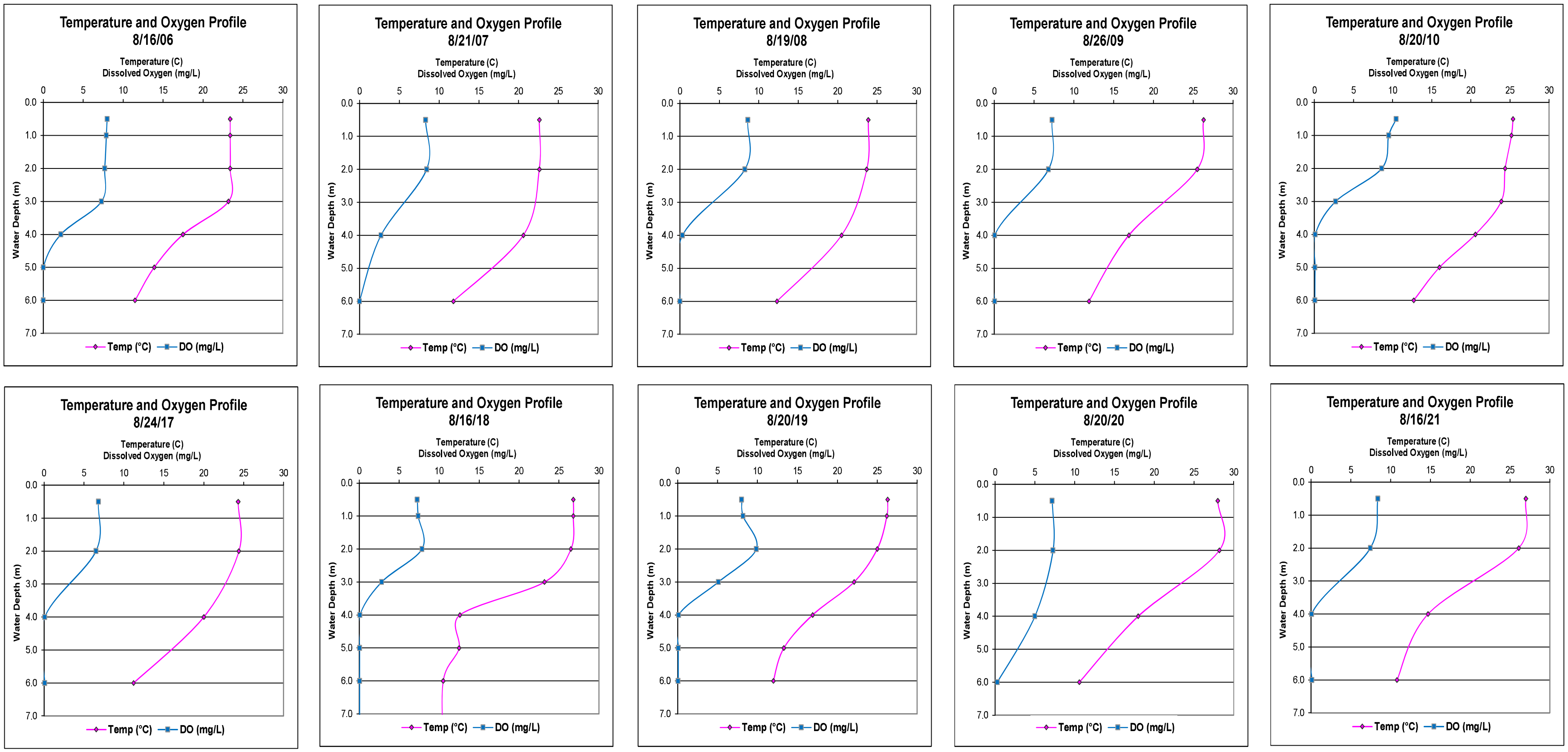
Alkalinity and pH have been routinely assessed in Skinequit Pond during PALS surveys and both are unusually high for a Cape Cod pond. The pH has averaged 7.7 standard units (SU) with a median of 7.3 in surface waters, with bottom water less basic at a mean of 7.0 and a median of 6.7 SU. Alkalinity has average 26 mg/L in surface waters and 65 mg/L in bottom waters. Values for pH and alkalinity are likely to be biologically mediated in Skinequit Pond and not a function of some unusual geology. Excessive algal production raises both pH and alkalinity on a temporary basis. As pH is on a logarithmic scale, such that a 1 SU change represents a tenfold shift in hydrogen ion concentration, the fluctuations in the pond are not conducive to the healthiest aquatic system.

The thermal and oxygen regime of a pond is fundamentally critical to its condition. For ponds deeper than about 20 feet, some thermal stratification is expected during summer, a function of the influence of solar heat input and mixing by the wind. Most ponds stratify between 15 and 20 feet of water depth, although with more algae in the water the light will penetrate less and a shallower depth of stratification is possible. Such appears to be the case for Skinequit Pond, with temperatures declining below about 10 feet of water depth during summer (Figure 14, displaying a selection of August profiles since 2006).

The temperature decline is gradual, so there is not a sharp inflection point that would define the boundary between upper and lower water layers (called the thermocline), but there will be little mixing of water shallower than 10 ft (3 m) with water deeper than 13 ft (4 m) during summer. That stratification breaks down in the fall as the air and water surface cool. Thermal gradient is generally limited over the winter but is re-established in late spring, leading to stratified conditions between sometime in June and sometime in October or even November. The relatively deep maximum depth for the small area of Skinequit Pond limits wind mixing and aids earlier stratification and later destratification.

The thermal stratification isolates the bottom layer (called the hypolimnion) from the upper layer (called the epilimnion). This is important as oxygen enters the pond from the interaction of the surface with air and is mixed throughout the epilimnion by wind. In the hypolimnion the amount of oxygen available at the time of stratification is not augmented by ongoing atmospheric inputs and there is not enough light for rooted plants or algae to photosynthesize and add significant oxygen, but decomposition continues to consume oxygen. In many lakes this imbalance leads to depression or depletion of oxygen in the deeper water layer. Where excess organic matter has been loaded to the lake the oxygen demand will be higher and the probability of oxygen depletion will be greater. Skinequit Pond has suffered oxygen depletion below a depth of 20 feet (6 m) since at least the 1980s and often experiences oxygen depletion at a depth as shallow as 13 feet (4 m) (Figure 14).

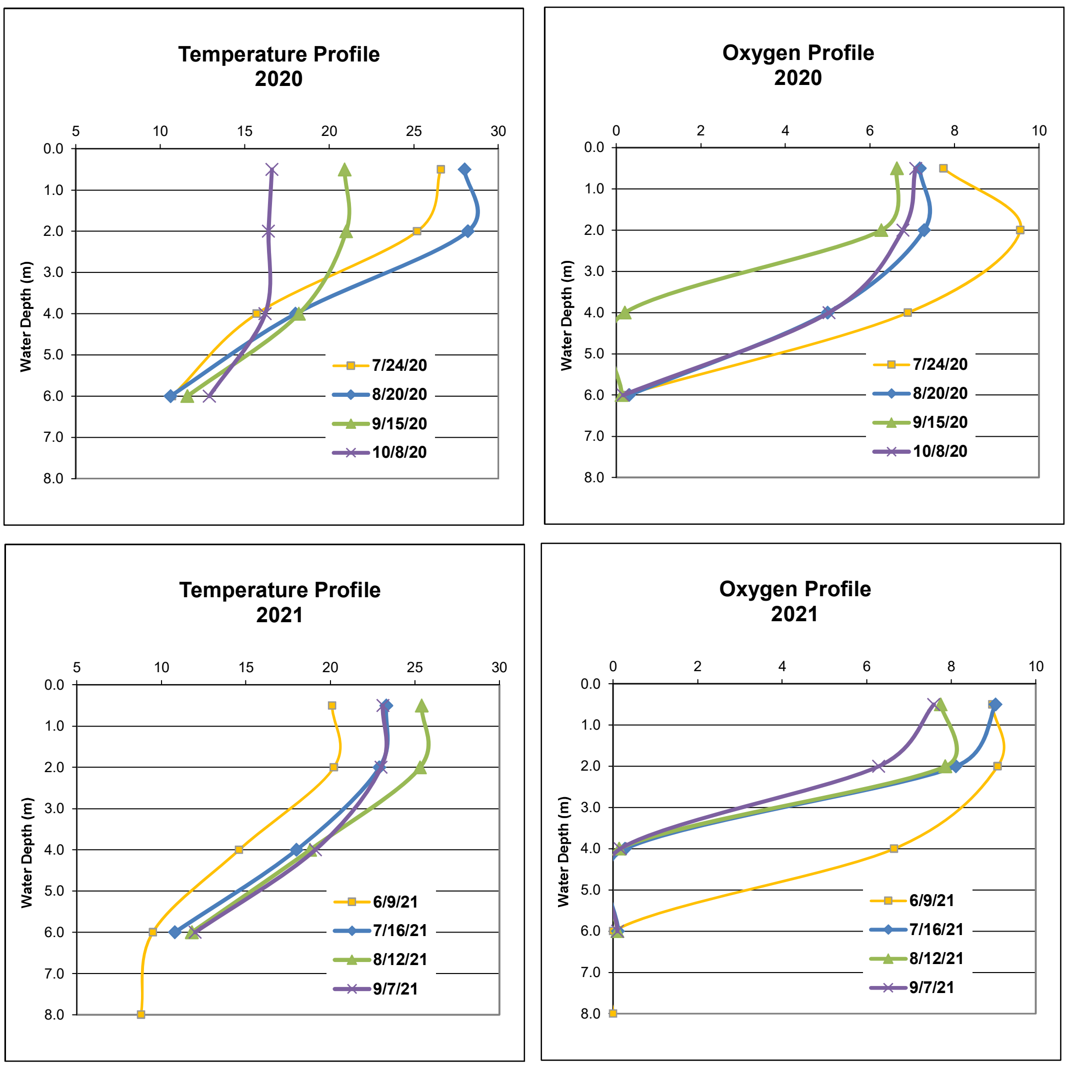
Figure 14. Skinequit Pond temperature and oxygen profiles from August dates.



Considering just the last two years of data (Figure 15), oxygen is depleted at 20 feet (6 m) of water depth in June or July and at 13 feet (4 m) in August or September. Data from 2020 and 2021 appear to capture the overall variability observed in the data since 2003. Despite a range of time over which oxygen depletion (called anoxia) is observed, conditions in the pond have been routinely poor. It does not take too much time without oxygen for many problems to develop.

The volume of Skinequit Pond deeper than 20 feet is 29.3 acre-feet (11% of pond volume) while the volume deeper than 13 feet is 84.1 acre-feet (32% of pond volume). Low oxygen has been observed as shallow as 10 feet (116.2 acre-feet or 45% of pond volume). Anoxia over more than about 10% of the area of a waterbody usually results in water quality issues and greatly increases the probability of algae blooms.

Figure 15. Skinequit Pond oxygen profiles from 2020 and 2021

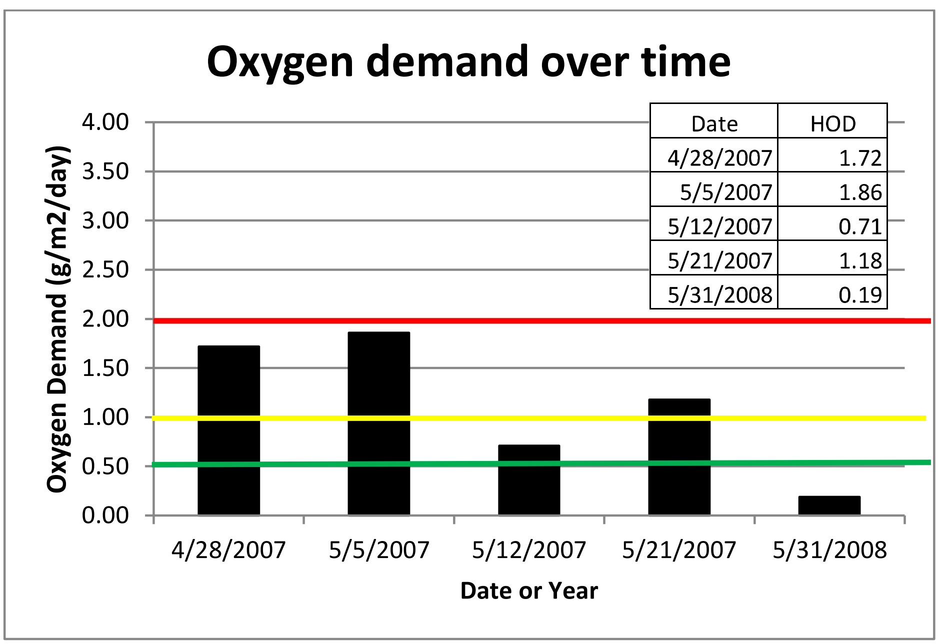


The rate of oxygen loss, or oxygen demand, expressed in the hypolimnion as oxygen is depleted, is a useful measure of the severity of degradation and allows calculation of oxygen needs if that demand is to be satisfied. As the loss of oxygen is not linear at low oxygen levels (it is harder to get that last bit of oxygen out of the water) and cannot decline below 0 mg/L, measurements during summer are not useful in assessing the hypolimnetic oxygen demand (HOD). The easiest way to assess HOD is from spring oxygen data, from a time where oxygen levels are still high but declining in deeper water.

There are very few spring temperature and dissolved oxygen profiles for Skinequit Pond, however. Only five spring profiles were available, and all but two included oxygen values <2 mg/L, the point at which oxygen loss greatly slows and the calculation becomes less valid. Using data from all five available profiles, the range of HOD is 0.19 to 1.86 mg/m^2/day (Figure 16), but only the 1.72 and 1.86 mg/m^2/day values meet the criteria for valid calculation. Further, HOD will increase with temperature and the spring data need to be adjusted to account for higher HOD during summer. HOD in Skinequit Pond is estimated at between 2 and 3 mg/m^2/day.

HOD of >0.5 mg/m^2/day will usually result in some anoxia by late summer, while HOD >1 mg/m^2/day will usually produce anoxia by mid-summer and HOD >2 mg/m^2/day will yield anoxia near the start of summer. Skinequit Pond exhibits late spring to early summer anoxia at >20 feet and full hypolimnetic anoxia by mid- to late summer. This is consistent with a high HOD value. The anoxia caused by oxygen demand at the sediment-water interface has a number of negative consequences, including release of phosphorus bound to iron. The movement of phosphorus into the water column from the sediment supports algae blooms.

Figure 16. Skinequit Pond oxygen demand estimation from spring data

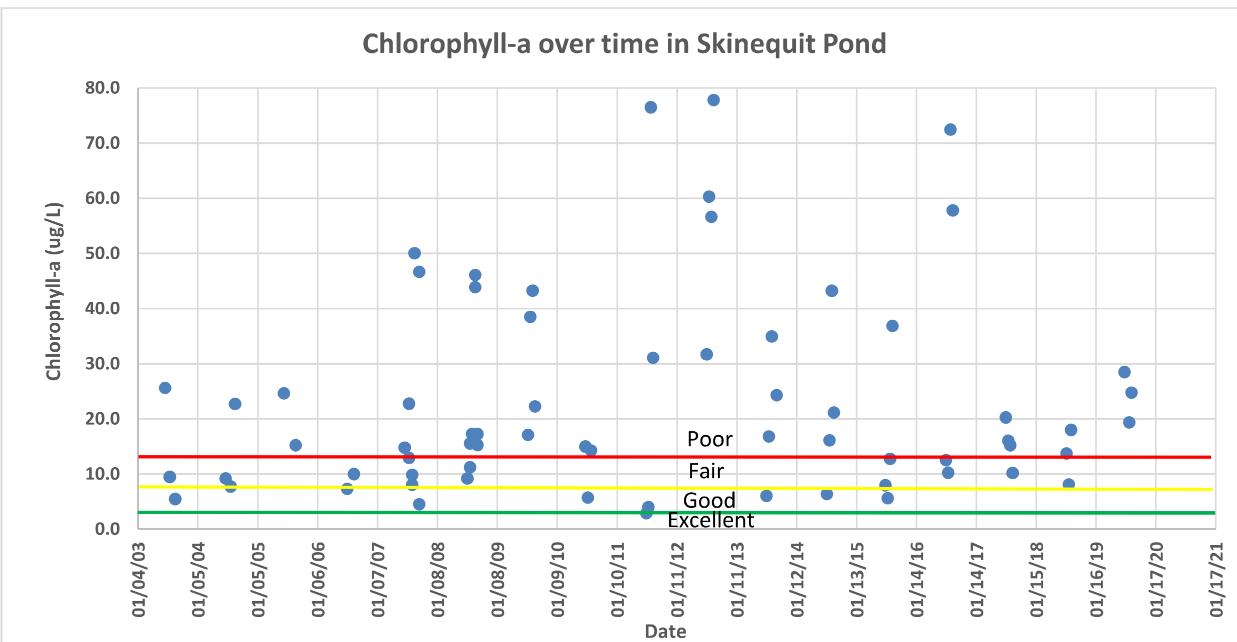


Date	HOD
4/28/2007	1.72
5/5/2007	1.86
5/12/2007	0.71
5/21/2007	1.18
5/31/2008	0.19

The manifestation of elevated phosphorus in the water column is algae blooms that reduce water clarity. Already demonstrated from SDT measurements (Figure 13), the abundance of algae is further documented by chlorophyll-a measurement (Figure 17). Chlorophyll-a is a photosynthetic pigment common to all algae, although the amount per unit of algae biomass varies among algal groups, so it is not a perfect representation of algal mass. Yet values <2 µg/L are considered low, values up to 8 µg/L are rarely problematic, values between 8 and 12 µg/L may produce impairment of uses depending on the types of algae present and values >12 µg/L usually do impair uses.

Most chlorophyll-a values from Skinequit Pond are >12 µg/L and many are quite high. As cyanobacteria tend to be dominant during summer and have the highest biomass to chlorophyll-a ratio among algae, conditions are likely to be worse than the chlorophyll-a data suggest. The data in Figure 10 are just from the upper 3 feet or so of Skinequit Pond; values from deeper water were routinely higher. It is possible that some of the deep water chlorophyll-a was in dying algae or was actually organic matter that can fluoresce at the same wavelength as chlorophyll-a, but either way the organic load on the system is high and the elevated near-surface values are not just a matter of buoyant cyanobacteria being concentrated. Skinequit Pond is extremely productive, to the point where major system imbalances exist and energy flow among trophic levels will be very inefficient. This is not a case of high productivity being desirable for the sake of fish like alewife or water-dependent wildlife like herons.

Figure 17. Chlorophyll-a concentrations in the upper waters of Skinequit Pond from PALS data



Phosphorus and nitrogen are the two most important nutrients for plant life, including algae. Phosphorus tends to determine the quantity of algae that can grow while nitrogen often determines which algae will do best. Many cyanobacteria are able to utilize atmospheric nitrogen gas that is dissolved in pond water, minimizing the importance of nitrate and ammonium, the two inorganic forms of nitrogen taken up by most plants and algae. As a result, cyanobacteria often become dominant at lower ratios of nitrogen (N) to phosphorus (P). On a mass basis, an N:P ratio of <10:1 will favor cyanobacteria while ratios >20:1 will tend to favor other algae, most notably greens (Chlorophyta). In between is a transition zone. Yet as P tends to set the upper limit on algal biomass, it is the concentration of P that warrants the most attention.

P concentrations in Skinequit Pond are usually elevated in the upper water layer (Figure 18) and are extremely high in the lower water layer (Figure 19). Concentrations <10 µg/L are desirable, but concentrations up to about 20 µg/L are usually tolerable without severe algae blooms. Once the concentration exceeds 25 µg/L blooms become far more likely, and once the concentration is >100 µg/L it is unlikely that P will limit productivity. Light often becomes a limiting factor, as dense algae assemblages, especially buoyant cyanobacteria that form surface scums, will restrict light penetration and limit growth beyond the upper few feet of the water column.

The very high P concentrations in the deeper water are not a major problem if that P remains in deeper, darker water. If Skinequit Pond was a lot deeper and there was an oxic zone between the dark, P-rich water and the boundary with the upper water layer, that P would be largely unavailable to algae. But in Skinequit Pond the anoxia extends to the boundary at least in late summer and some mixing is likely to bring deeper water rich in P into the upper water. Even if stratification is strong enough to minimize that mixing, light penetrates to about the boundary and algae can grow there, getting just enough light from above and ample P from below. Further, some cyanobacteria grow at the sediment-water interface at intermediate depths making use of P as it is released from the sediment and getting enough light to grow until they form gas pockets within cells and become buoyant. There are multiple ecological strategies within the algae and having high P in deep water is likely to produce blooms at least some of the time.

Additionally, while some N is released from sediment that is releasing P, the ratio tends to be low (<10:1), thereby favoring cyanobacteria. Most watershed inputs enter with high N:P ratios and lakes with strong and persistent cyanobacteria blooms are justifiably assumed to be subject to substantial internal loading. The N:P ratio in the upper waters of Skinequit Pond averaged 20.5 over the last two decades, seemingly favorable to non-cyanobacteria, but the N:P ratio in the deeper waters averaged about 8, solidly favoring cyanobacteria. Cyanobacteria growing near the thermocline or on sediment at intermediate depth then becoming buoyant and rising to form surface blooms is the likely dominant mechanism of bloom formation in Skinequit Pond.

The P that is being recycled in the pond ultimately came from the watershed, but poor conditions no longer depend on continued watershed inputs. This is why some means to control internal loading is necessary in most lake rehabilitation projects targeting algae, rather than just managing the watershed.

Figure 18. Total phosphorus near the surface of Skinequit Pond from PALS data

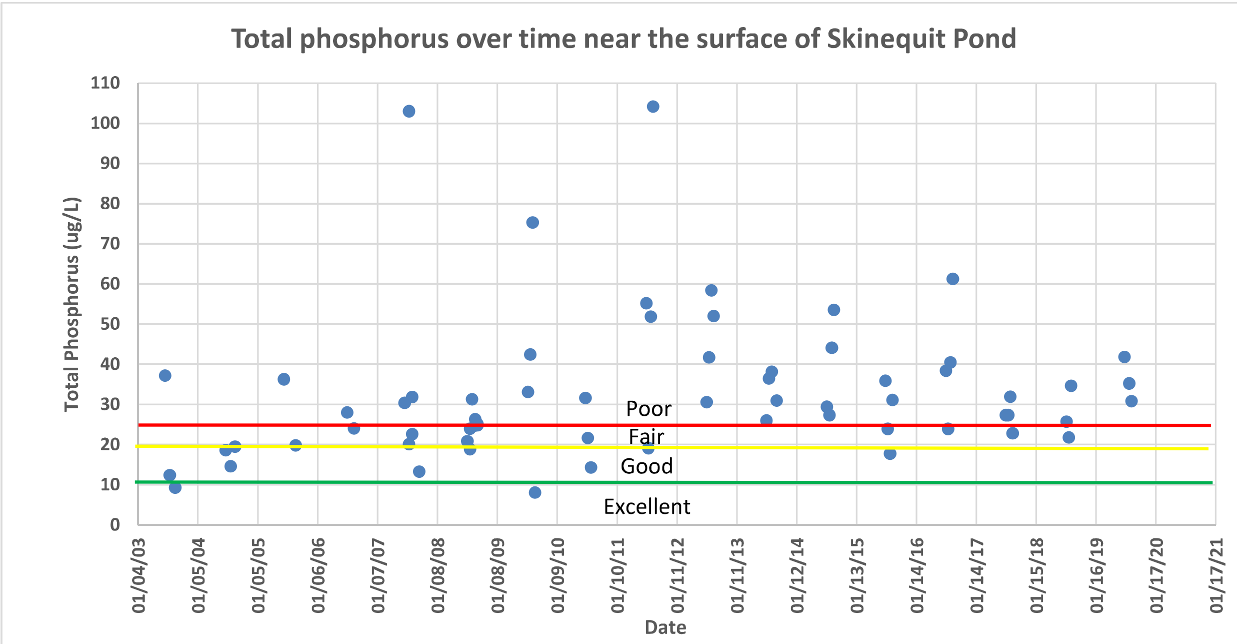
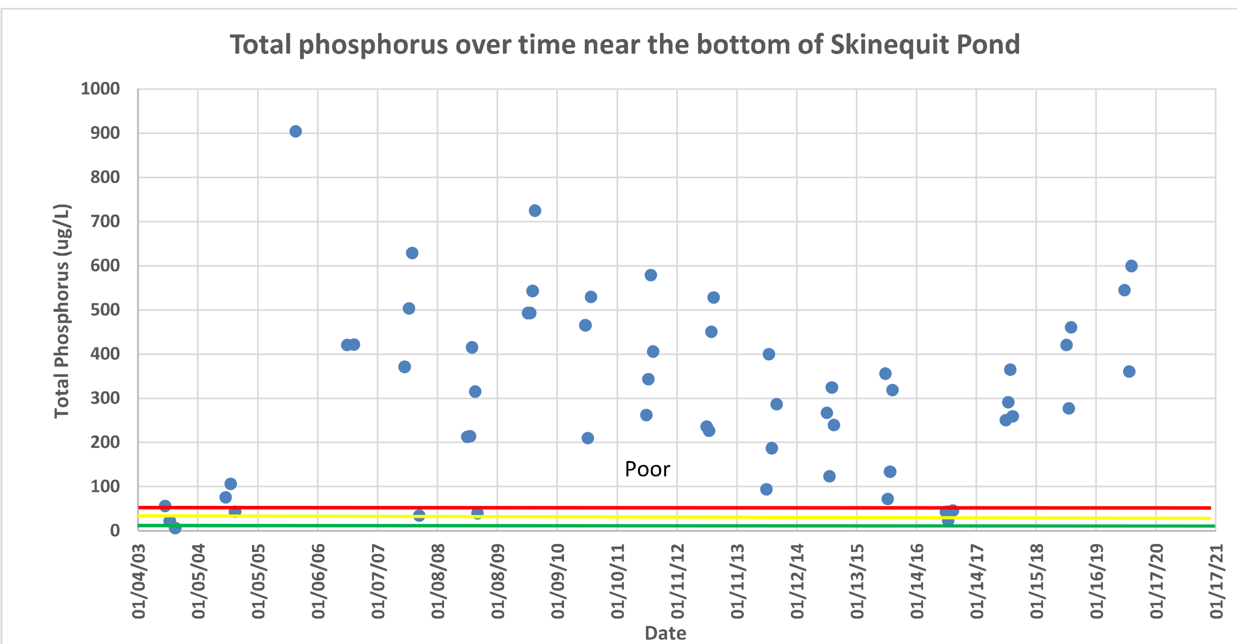


Figure 19. Total phosphorus near the bottom of Skinequit Pond from PALS data



Sediment Quality

The four surficial sediment samples collected in early April were tested in the laboratory for loosely sorbed P (usually a minor component), redox-sensitive P (mostly iron-bound P), P extractable by NaOH (usually a mix of aluminum- and iron-bound P), iron and aluminum in each of those fractions, sediment density, and sediment solids content. These tests allow an assessment of likely internal P loading and facilitate analysis of possible inactivation dosing.

The results of testing (Table 2) indicate low density sediment with very high water content, high levels of iron-bound P, and a very high potential for low oxygen and elevated internal P loading. Loosely sorbed P was minimal, as is typical of Cape Cod sediments; this is P not strongly bound to any other element, and most P is indeed bound to iron, aluminum, or organic matter in these ponds. P associated with iron in the redox-sensitive (BD) fraction is high; values >100 mg/kg are a concern, valued >200 mg/kg are elevated, and values >500 mg/kg are very high. The north and west samples contained very high redox-sensitive P concentrations while the east and south samples had elevated levels, with very little aluminum in the redox-sensitive fraction (also typical).

The NaOH extractable fraction is less sensitive to low oxygen and related redox reactions, but some of the iron-bound P in that fraction may be released, albeit gradually. This fraction usually contains much more aluminum that iron, but in this case the iron levels are not negligible and exceed aluminum in the north and west samples, so some significant release of P is possible from this fraction. Aluminum and iron are the most abundant metals in the crust of the earth, but iron is dominant in the sandy Cape Cod soils. When aluminum is at least three times the iron level, there tends to be little internal P recycling, but when iron is dominant, the potential for release of P from sediment exposed to anoxia is much increased.

Table 2. Sediment quality for Skinequit Pond

	NH4Cl extracts mg/kg dry sediment			BD extracts mg/kg dry sediment			NaOH extracts mg/kg dry sediment				
Sample	P	Al	Fe	P	Al	Fe	P	Al	Fe	Spec. Gravity	% Solids
North	12.48	6.00	271.32	942.6	12.6	11687.4	806.4	427.2	1464.6	1.007	4.8%
South	3.35	1.44	74.19	207.8	0.0	4435.3	261.7	1037.1	427.5	1.037	13.1%
East	3.35	3.53	133.05	262.3	0.6	5330.5	462.3	729.3	607.8	1.024	7.9%
West	6.78	6.48	284.16	876.6	9.6	8298.0	666.0	525.6	924.6	1.032	8.1%

Using these data, the mass of P in the surficial sediment can be calculated (Table 3). Working with just the P that can be released under low oxygen conditions (redox-sensitive P), there is a range of 2.1 to 7.3 g/m^2 over the four samples and corresponding areas. Assuming those values are representative of each defined zone from which the samples were collected and assigning equal area to each (about 2.7 acres), the total mass of redox-sensitive P in the upper 10 cm or organic sediment in the pond is about 185 kg. Including the iron-bound P in the NaOH extractable fraction, the range among samples is 3.8 to 10.9 g/m^2 and the total for the surficial organic sediment in the pond is 287 kg. The iron-bound P in the NaOH extractable fraction is unlikely to be released under low oxygen conditions, so the 185 kg estimate is a more reliable estimate of the P available to be released from sediment exposed to anoxia, but that is still a very high value.

It is uncommon for more than about 10% of the available P in the surficial sediment to be released in any one season of low oxygen (May to September in this pond), suggesting that 18.5 kg of P might be released in late spring and summer. Divided by the volume of the bottom layer of the pond in which P accumulates during the period of stratification, the concentration in that layer would be increased by about 156 µg/L. Divided by the total volume of water in the pond, that would yield a concentration of 58 µg/L, more than enough to support algae blooms. With a low N to P ratio associated with internal loading, cyanobacteria will be favored.

Table 3. Phosphorus mass in surficial sediment of Skinequit Pond

Phosphorus Mass Calculations	Redox sensitive P only					Redox P + Fe NaOH-P				
	LAKE or AREA					LAKE or AREA				
Lake or Area	North	South	East	West	Total	North	South	East	West	Total
Mean Available Sediment P (mg/kg DW)	942.6	207.8	262.3	876.6		1567.0	284.0	472.0	1301.0	
Target Depth of Sediment to be Treated (cm)	10	10	10	10		10	10	10	10	
Volume of Sediment to be Treated per m2 (m3)	0.100	0.100	0.100	0.100		0.100	0.100	0.100	0.100	
Specific Gravity of Sediment	1.007	1.037	1.024	1.032		1.007	1.037	1.024	1.032	
Percent Solids (as a fraction)	0.048	0.131	0.079	0.081		0.048	0.131	0.079	0.081	
Mass of Sediment to be Treated (kg/m2)	4.8	13.6	8.1	8.4		4.8	13.6	8.1	8.4	
Mass of P to be Treated (g/m2)	4.56	2.82	2.12	7.33		7.58	3.86	3.82	10.88	
Target Area (ac)	2.7	2.7	2.7	2.7	10.9	2.7	2.7	2.7	2.7	10.9
Target Area (m2)	10988	10988	10988	10988		10988	10988	10988	10988	
Mass of available P in top 10 cm in defined area	50	31	23	81	185	83	42	42	120	287

Biological Features

Limited biological data have been provided to WRS for review, but there are reports of various pond life, mostly from the WASH website. Previous reports, such as the Cape Cod Pond and Lake Atlas and other correspondence with knowledgeable parties indicate that the summer algae blooms are mostly cyanobacteria. Plankton samples collected in 2009, 2010 and 2011 by WASH and analyzed by GreenWater Labs indicate high concentrations of cyanobacteria, mainly *Aphanizomenon gracile* but also including *Planktothrix agardhii*, both potential toxin-producing species. Cell counts exceeded the MA guidelines for posting waterbodies as potentially hazardous for contact recreation. Green algae (Chlorophyta, with a substantial number of species) were a distant second in terms of abundance. Most other freshwater algae groups (e.g., golden algae, dinoflagellates, euglenoids) were present but not abundant in summer samples.

Floating leaved plants, mainly water lilies, are found around the pond perimeter, but few growths at depths more than about 4 feet are expected due to low light. Older reports of possibly excessive vegetation may not be reliable, but if there were problems with rooted vascular plants, that suggests that clarity has been reduced and algae blooms have become more frequent and severe over the last three decades. At this point Skinequit Pond is dominated by algae, with cyanobacteria blooms common during the summer into autumn.

No data on invertebrates was provided and we are unaware of any studies of insect larvae, mussels, snails, crayfish or other invertebrate life in Skinequit Pond. However, mussels, dragonflies, mayflies, beetles and water striders have been reported from the pond. Zooplankton, tiny animals in the water column that eat algae, form an important link in the food chain but no data appear available. The strong anoxia at depths as shallow as 13 feet will be a limiting factor for benthic invertebrates, but many species could inhabit the shallower waters of the pond.

Skinequit Pond contains a variety of warmwater fish species, including white and yellow perch, sunfish and catfish, although no survey data have been provided. The pond is known to host an alewife run in the spring and acts as a nursery for juvenile alewife for the summer. Data for numbers of adult alewife entering to spawn or juveniles leaving in the autumn have not been provided. It is believed that the stream leading from the ocean to the pond was constructed or at least altered to foster access. This is a valuable function, given the elimination of access to many ancestral ponds by damming, greatly reducing alewife production in coastal New England. However, alewife juveniles consume nearly all the zooplankton in a pond while present, limiting food resources for other fish that depend on zooplankton. Alewife provide an ample food resource for larger fish, but recruitment of gamefish in an alewife pond may be limited. The low oxygen in water deeper than 13 feet for some of the summer may also impact fish resources.

Skinequit Pond is known to host many species of water-dependent birds, including gulls, cormorants, ducks, geese, ospreys, herons, and kingfishers. Reptiles known from the pond include snapping and painted turtles. Amphibians reportedly include green and bull frogs. No census data have been provided, but these are all wildlife that would be expected in a pond like this one.

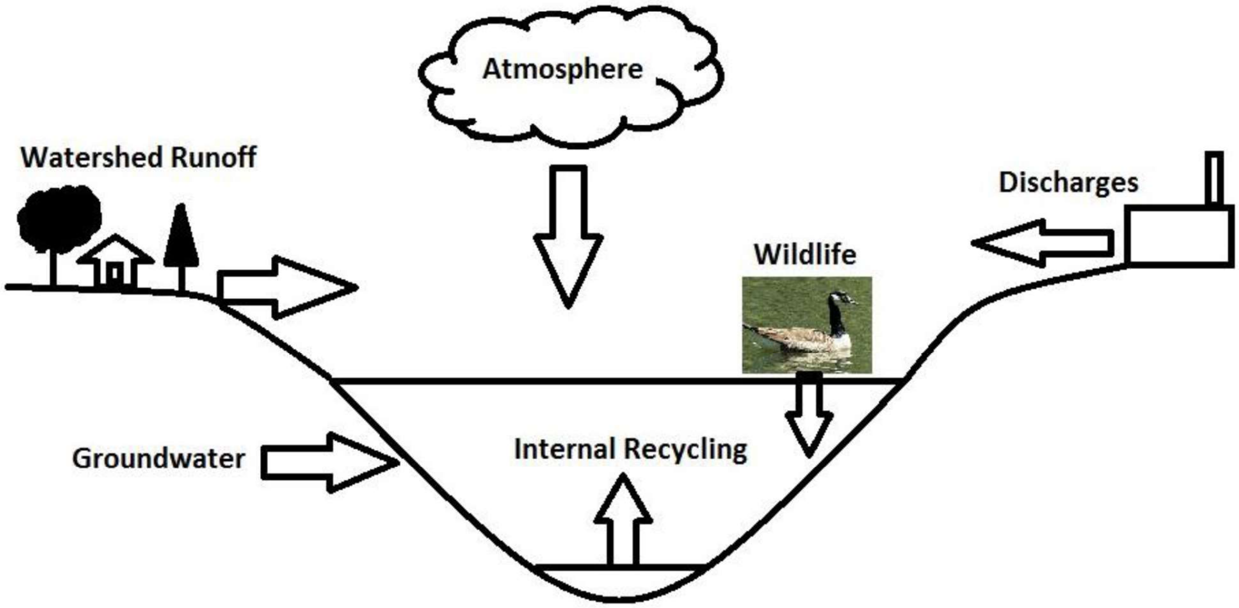
Examination of online records from the Natural Heritage and Endangered Species Program revealed no Priority or Estimated Habitat for protected species and no other indication of any biological resources present that would complicate management efforts. Regulatory agencies often impose time restrictions on activities when alewife are present, but actions are not usually prevented, just limited to certain seasons.

Phosphorus Loading Analysis

No loading analysis appears available for Skinequit Pond. A simple analysis is provided here to provide a rough estimate of loading from potential sources and facilitate comparison of the magnitude of each. There are six potentially major sources of contaminants to lakes (Figure 20). For Skinequit Pond, the best available estimate for each is provided as follows:

- Discharges - No permitted discharges are known for Skinequit Pond.
- Wildlife - No data on wildlife resources have been provided, but if we assume the equivalent of 10 birds (ducks, gulls, etc.) present all the time (more likely 20 present half the time) at a typical input of 0.2 kg P per year, the total P input would be about 2 kg/yr. Some of this will be particulate matter that settles and becomes part of the internal load, possibly resulting in an overestimate of total loading, but it is a minor source overall.
- Atmospheric inputs – Deposition is typically estimated at 20 µg/L in the total volume of rainfall falling directly on the target waterbody. At about 44 inches of rainfall on an 18-acre lake, that represents 82 million liters of water or about 1.6 kg P/yr. Some of this will be particulate matter

Figure 20. Sources of contaminants to lakes



that will settle and become part of the internal load, resulting in a possible overestimate of total loading, but it is a minor and generally uncontrollable source.

- Groundwater – Inputs of P via seepage should be nominal, but some movement of P into the pond with groundwater is possible. We don't know the seepage rate, but the north side of the pond represent the primary groundwater interface area and is about 800 feet long. If we assume the sediment is sandy for at least 100 feet offshore, allowing inseepage, that is a seepage area of 80,000 square feet or a little under 2 acres. A high seepage rate, even for the Cape, would be 20 L/m^2/day, so the roughly 7500 m^2 area times 20 L/day for 365 days per year equals 55 million L/yr per year. At a concentration of no more than 25 µg/L in groundwater that equates to 1.4 kg P/yr. Much of that P would come with high iron and precipitate out in the presence of oxygen, becoming part of the potential internal load and resulting in overestimation of the total load.
- Watershed runoff – The sandy soils in the area limit runoff, but there are roads and lawns that may generate some runoff during significant storms. There are no permanent tributaries, but there was at least one storm drain historically and the drainage from the former bog has a channel of sorts, so some runoff will reach the pond. The generation of P from low density residential areas is typically between 0.3 and 0.5 kg/ha/yr. With a watershed of 47 acres, or 18.8 hectares, that suggests an overland watershed P load of 5.6 to 9.4 kg P/yr. A more detailed analysis would be needed to support watershed management activities, but this range is suitable for general evaluation purposes, and an average of 7.5 kg/yr is offered. Much of this input may be in particulate forms that settle to the bottom rapidly and do not directly impact surface water

quality until transformed by in-lake processes and becoming part of the internal load. Again, some overestimation of total P loading may result.

- Internal loading – There is a lack of multiple samplings over the course of one or more summers to evaluate the accumulation of P in the pond by direct measurement, but the available data do provide some insight. A typical upper water column P concentration would be between 10 and 20 µg/L in this area. The average for upper waters of Skinequit Pond is 55 µg/L, but there are several very high values that skew the average and the median at 30 µg/L is a better representation of P in the upper part of the pond. The extra 10-20 µg/L are probably a result of deep water P getting into upper waters, so a range of 10-30 µg/L could be assumed to be the base P level in Skinequit Pond. The average deep water P concentration is 301 µg/L with a median of 289 µg/L, so either is a reasonable representation of typical deep water P. That deep water P, usually measured in late summer, is the result of P release from sediment exposed to anoxia. If we assume 300 µg/L minus a 20 µg/L base level, the concentration in the bottom of the pond increased by up to 280 µg/L over the period of anoxia. As the measures are made near the bottom and will decline as one moves upward in the water column, the actual average deep water concentration of P is probably about half the difference, or about 140 µg/L. The bottom layer represents about 95 acre-feet of water, or 118 million L. This suggests that the release of P from sediment exposed to anoxia is about 16.6 kg P/yr. The period of anoxia extends well beyond the time at which P was measured in virtually all years, so could be an underestimate, but algae are also settling from above and may increase the P concentration without release from sediment. An estimate of 16.6 kg/yr is suitable for a general evaluation. Note also that this input is all in the summer period, making it more important than other sources spread out over the entire year.

Summing up these rough calculations, an approximate P loading tally can be generated (Table 4).

Table 4. Estimated phosphorus load to Skinequit Pond

Source	P (kg/yr)	%
Direct Precipitation	1.6	5.5%
Groundwater	1.4	4.8%
Overland drainage	7.5	25.8%
Wildlife	2.0	6.9%
Internal Release	16.6	57.0%
Total	29.1	100.0%

While there can be considerable variation in each of these values, it is apparent that internal P loading is the largest source and is even more important by virtue of all being added during the summer and early autumn, the primary period of interest for controlling algae blooms.

There are a series of empirical models that WRS has melded into a larger modeling approach to assessing inputs and concentrations of P. Application of this approach suggests that to get the P concentration observed in the surface waters of Skinequit Pond, the P load would have to be about

25 kg/yr. This is slightly lower than the estimate in Table 4 but recall the issue with overestimation due to several itemized sources contributing to the internal load, resulting in possible double counting of some loads. Without more detailed information on P concentrations at more depths on a more frequent basis there is no easy way to more accurately evaluate loading, but it is apparent that the load is high relative to what the pond can handle, and it is more than half internal P load.

Using the modeling approach to determine what magnitude of loading would have to be achieved to reach an in-lake concentration of 20 µg/L, a load of about 11 kg/yr is derived. While the estimates are all approximate, it is apparent that the internal load would have to be much reduced to achieve the goal. No other source provides enough P to make a major difference and the internal load can be addressed several ways, all practical albeit potentially expensive.

Given the apparent importance of the internal P load, refining that estimate is worthwhile. Another way to evaluate the internal load is through sediment P assessment, which was conducted in spring of 2022. About 10% of the iron-bound P reserves of the upper 10 cm are expected to be released in any given summer of anoxic exposure. By measuring iron-bound P in the surficial sediment, an estimate of internal loading was independently derived.

Based on just the mass of redox-sensitive P in the upper 10 cm of sediment over the 10 to 11 acres covered by organic sediment, and assuming that 10% of that P is released in a summer, the internal load would be about 18.5 kg/yr, a reasonable match for the estimate of 16.6 kg/yr from deep water concentration change over the summer. Dividing the 18.5 kg by the volume of the lower water layer in which it accumulates, the concentration in that lower layer would be increased by about 156 µg/L, a reasonable match for the 140 µg/L estimate derived from water quality data. The estimated internal P load of 16.6 kg/yr derived from water quality data may be slightly low but is still the dominant source in the pond. There is no way to achieve a desirable P concentration in Skinequit Pond without addressing the internal load.

Management Options

Overview

The primary issue facing Skinequit Pond is high internal P loading with subsequent algae blooms supported by the released P. Addressing the watershed load may be warranted, but the internal load must be addressed to minimize algae blooms and could achieve the desired conditions by itself. There are four ways to minimize internal loading:

- Dredge the organic, P-rich sediment from the pond – While technically the truly restorative approach, this is a highly disruptive, expensive technique that is difficult to permit in MA. It is worth consideration with an estimate of the quantity of sediment that must be removed but may not be affordable or feasible.
- Selective withdrawal – By removing high-P water the P reserves in the pond can be eventually depleted. This has been attempted with some success in just a few lakes in New England and has required >20 years of enhanced withdrawal by either drawdown or pumping in those cases where improvement has been observed. In no case, however, was a P concentration <20 µg/L achieved and while cyanobacteria blooms were reduced, they were not minimized to the degree desired. With no way to draw Skinequit Pond down, the cost of pumping, and possible interference with alewife, this does not seem to be an appropriate approach for Skinequit Pond.
- Oxygenate the pond to minimize P release from sediment – By keeping oxygen at >2 mg/L the iron will not release P and much of the current internal load can be prevented. However, with adequate oxygen there will be more decay of organic matter containing P, so some internal loading by that mode is to be expected. This would still represent a major reduction in P concentration in the pond and would greatly enhance habitat for fish and other aquatic life. There are two categories of oxygenation that can be considered:
    - Circulate the entire water column – by preventing stratification and continually mixing the water in the pond the oxygen concentration can be kept high enough near the sediment-water interface to limit P release due to anoxia. The current circulator is moving water from a depth of only 8 ft and has no effect on the bottom water layer during stratification. A much deeper intake with more water moved would be necessary with the current approach. An alternative system in which surface water is pushed down is philosophically preferable, sending algae and oxygenated water to the bottom, but the risk of stirring up the bottom must be mitigated. The use of air to mix water by rising bubbles is actually the oldest and most reliable approach and could be applied. The downside of this approach is that whatever P is still in the water will be more available to algae. Destratifying circulation sometimes minimizes cyanobacteria blooms but does not result in especially clear water, as other algae that prefer mixed conditions can dominate.
    - Add oxygen to the deeper water layer without mixing the entire pond – This can be done several ways, the easiest being to release fine bubbles of pure oxygen near the bottom and have those bubbles be absorbed before they reach the thermocline and cause mixing. This requires about a 20-foot vertical run for the bubbles, which is not available in much of Skinequit Pond. The alternatives all involve some kind of chamber in which water is oxygenated and distributed back into the hypolimnion. The simplest of the chambered approaches involves a shore-based oxygenator that is currently being tested in Orleans,

MA. If developed to a successful degree, this would probably be the best choice for oxygenating Skinequit Pond.

- P inactivation – By adding a binder that will hold P in the sediment despite low oxygen, the internal loading can be strongly curtailed. Aluminum is the most common binder applied and has been used in multiple Cape Cod ponds. Getting the right dose is critical and has not been easy to estimate, but there are now sediment tests that can be run to improve that process. Alternative binders such as calcium are not effective in low pH water and Phoslock with its active ingredient lanthanum is not yet approved for use in MA, so aluminum would be the logical choice for Skinequit Pond. Toxicity to aquatic life can be an issue during application, but with proper treatment that can be avoided; there have been no fishkills from aluminum treatments in New England in over two decades.

Dredging

There is no practical way to lower the water in Skinequit Pond, and in fact the pond would have to be drained entirely to conduct "dry" dredging, so the logical approach to sediment removal in this case is hydraulic dredging. A barge with an augur at the end of an intake pipe would stir up sediment that would be sucked into the pipe with pond water, creating a slurry that would be transferred to a containment area where the sediment would settle and the water would be returned to the pond. The key factors in assessing dredging feasibility are the quantity and quality of sediment to be removed.

The quantity has been estimated as greater than 68,500 cy and probably around 80,100 cy, about what can be hydraulically dredged in one season. The sediment is highly organic with a low specific gravity and a very high water content. It can be expected to dry to a much lower volume, probably not more than 30,000 cy. If a containment area was built on 5 acres, one of which would be mostly berm to hold material in place, the remaining 4 acres of storage area would have to have sediment piled 12 to 13 feet high during the dredging process. That material would dry and compact down to <5 feet thick. A larger containment area would result in lesser depths of sediment. Finding an appropriate location close enough to the pond to allow pumping without multiple booster stations would be ideal. The former cranberry bog may offer some options, but as much of that area is now considered wetland, use as a containment area may not be allowable. Containment and final disposal areas would be a task for a proper dredging feasibility study.

The quality of the sediment is a major factor in ultimate disposal. Massachusetts has stringent standards for handling of contaminated soil and sediment, and extensive testing must be conducted to determine if standards are met for any possible disposal proposal. The average concentration of several metals and hydrocarbons in Massachusetts lakes and ponds exceeds the unrestricted use standards, so dredged material may either have to be covered by clean soil or taken to an approved disposal facility, both increasing the cost of dredging. Testing usually involves one sample per 1000 cy of dredged material at a cost of about $1000 per sample for all required testing. If we assume that 80,000 cy of sediment would be removed, the lab cost alone would be $80,000 just to find out how expensive disposal will be. Sampling, engineering, and permitting can be expected to add another $100,000 or more, so a dredging project will cost on the order of $200,000 before a dredge is ever operating in the pond.

The actual cost of dredging will vary with disposal options, including the distance material must travel for temporary and final disposal. A low end cost of $30/cy is typical in Massachusetts, with contaminated sediment often costing closer to $100/cy. For the 80,000 cy estimate of sediment to be removed, this suggests a dredging cost of $2.4 to 8 million, a rather expensive endeavor. Partial dredging may be an option if remaining sediment exposed by dredging has a lower P content. Only the upper 10 cm of sediment was assessed in this survey, and there does tend to be a decline in available P with sediment depth, but considerable additional sediment testing from core samples would be needed to determine if there is a sediment depth at which further removal is not necessary. This would also be part of a dredging feasibility study, during which core samples would be collected for testing. It is unlikely, however, that partial dredging at less than the total sediment in areas with <2 feet of sediment would provide adequate removal of P reserves. That suggests a sediment volume of about 36,000 cy and a dredging cost of $1.1 to 3.6 million, still a very expensive approach.

Oxygenation

WASH and the Town of Harwich have had a SolarBee circulator in place for 15 years now and the pond has not improved to the desired extent. Some shift in algal types appears to have occurred, but the phytoplankton are still dominated by potentially toxic cyanobacteria much of the summer and P concentrations are still excessive. Circulation of the entire water column has some limited potential to improve pond conditions, but circulation of just the upper water column is not expected to solve the problem and has not after 15 years of use. It is hard to admit failure when a group has spent considerable money on an approach, but the data simply do not support any conclusion of success from the circulation approach applied. There is a growing base of literature that has found similar results elsewhere, and a review of 16 upward pumping circulator approaches and projects (Wagner 2015) found that 2 met water quality goals, 6 did not, and 8 provided partial achievement of goals. The Skinequit Pond SolarBee effort may fall into the partial achievement category but has not achieved the stated goals.

As described above, circulation of the entire water column offers greater potential for success but also carries greater risk of worsening conditions if the circulation does not result in adequate oxygen near the bottom throughout the period of stratification. It is very difficult for whole lake circulation systems to maintain mixed conditions as the summer proceeds, as the water gets warmer and warmer (not that heat is not dissipated by circulation, just mixed evenly when successful) and the energy required to mix warmer water is higher than that required to mix colder water. As a result, most circulation systems fail or at least do not provide complete mixing by late summer, unless considerably more power (bigger pumps, more air, more overall mixing capacity) is designed into the system at much greater capital cost. To circulate Skinequit Pond with SolarBees, the intake would need to be set near the bottom in up to 30 feet of water and at least five units would be needed, probably more. Aside from the cost, the aesthetics of that many units on the pond may be an issue.

Circulation in general is not ideal for the Skinequit Pond situation, given the high oxygen demand of the sediment and its high redox-sensitive P concentration. Algae may grow at the sediment-water interface then float up to form blooms even if there is adequate oxygen above. Oxygen must be high enough at the sediment-water interface to drive the anoxic zone into the sediment where light is inadequate for algae growth. This is a rare occurrence with any circulation system.

The alternative, as noted previously, is a sidestream saturation system, or oxygen saturation technology, in which deep water is removed, oxygenated to a high degree, and put back into the deep zone. The chamber for oxygenation is on shore with a pump pulling water from the target zone and a gravity feed pipe sending oxygenated water back. The oxygenated water will move laterally at a fast pace, so a blanket of oxygenated water can be placed over the pond bottom to minimize P release. This is the system currently in place in Sarah's Pond in Orleans. An earlier system, involving nanobubbles, did not provide acceptable results over a two-year run. The current system experienced operational issues last year, but with some adjustments has run well so far in 2022. Target oxygen levels have been maintained, but it remains to be seen if this will be enough to prevent cyanobacteria blooms. If it performs acceptably, this could be an appropriate approach for Skinequit Pond.

The Sarah's Pond unit is handling a smaller area with lower oxygen demand and would have to be scaled up for Skinequit Pond. A similar pond on Long Island has been considering an oxygen saturation approach, and the estimated capital cost is between $150,000 and $200,000. Annual operational cost is expected to be on the order of $20,000 to $30,000.

An alternative costing approach is to consider the mass of oxygen that needs to be supplied. The oxygen demand estimated from available data was high, at 2-3 $g/m^2/d$. Over the roughly 11 acres with oxygen-demanding organic sediment cover, that translates into an oxygen mass need of between 90 and 134 kg/d. At about $1200/kg, a capital cost of $110,000 to 161,000 is suggested. Operational cost of about $40,000 is estimated. As the details of any oxygenation installation are highly site-specific (e.g., availability of access and power, length of pipe needed, location of oxygenator), getting estimates from qualified vendors is advisable, but it seems likely that an appropriate system could be installed for <$200,000. Operational cost, mostly a function of power needs to supply oxygen, will decline, as oxygen demand should decrease over time, but there will always be a need to counter the oxygen demand, so the system is expected to run throughout the period of stratification.

Phosphorus Inactivation

The addition of aluminum to replace iron as the main P binder in surficial sediments subject to anoxia has been practiced for over four decades, but much has been learned over the last decade that has improved results and minimized unintended impacts. At least a dozen lakes have been treated on Cape Cod with varying degrees of success (Wagner et al. 2017). Where results were less than what was desired, the problem is traceable to inadequate dose, sometimes a function of limited data and sometimes a restriction imposed by permits. Aluminum does not release P when exposed to low oxygen, so it can prevent the internal loading experience with iron-bound P.

Aluminum can be added in several forms, and where higher doses for inactivation of sediment P are involved, it is typical to add aluminum sulfate and sodium aluminate simultaneously (but not pre-mixed) to provide enough aluminum while maintaining the pH in the desired range. The dose at any one time is usually limited to no more than 5 mg/L, with sequential doses as needed to apply enough aluminum to inactivate the targeted sediment P. Doses are expressed in g/m^2, with back-calculation of the temporary water column concentration by division by the depth of the mixing zone during application.

For Skinequit Pond there appear to be two discrete zones with different inactivation needs. The north and west areas have a higher redox-sensitive P content than the east and the south areas. This makes sense if the cranberry bog was the main source, as the P would have entered mostly as particulate material, would have settled in the north area and been focused into the deeper west area by normal lake processes. The P content is different enough to warrant different doses in these areas. The calculation of dose can be done stoichiometrically or by a lab assay. The stoichiometric calculation involves providing 10 to 20 aluminum atoms for each targeted P atom. As the atomic weights of Al and P are similar, this can be addressed similarly on a mass basis. The calculation of P mass is provided in Table 3 and suggests that the east and south areas can be combined for treatment calculations. The north and west areas may be sufficiently different to warrant separate doses, but with a twofold range of Al:P ratio and a fairly high expected dose, these might also be treated as one areal unit for purposes of treatment.

With high oxygen demand and very loose sediment that allows potentially greater interaction with overlying water, the higher end of the Al:P ratio (20:1) would be preferred in the stoichiometric approach. This yields a dose estimate of 147 g/m^2 for the north area, 91 g/m^2 for the west area, 42 g/m^2 for the east area, and 56 g/m^2 for the south area. Doses above 100 g/m^2 are less efficient when added at once and are generally split in half and applied several years apart. The potential error with only a single sample from each area does not suggest that the east and south area doses are significantly different. It could be concluded that the north and west areas would be treated at 100 g/m^2 and the east and south areas would be treated at about 50 g/m^2.

The alternative lab assay method of dose calculation involves adding varied doses of aluminum to small amounts of suspended sediment in the lab and testing for residual redox-sensitive P after reactions have occurred. A graph of the results shows the curvilinear decline in available P with sequentially higher Al doses and allows determination of optimum dose based on amount of P inactivated and the diminishing returns of greater Al addition. This testing was not conducted in this first level assessment, given both cost and the smaller size of the pond; refinement of dose is not likely to make a great difference in overall cost of treatment in this case but the assays could be conducted if WASH will fund them.

The duration of results is largely determined by the rate at which P is replaced from the watershed (expected to be very slow currently) and how long it takes for P that is not inactivated by the treatment (deeper than 10 cm) to migrate upward with the concentration gradient and reach the sediment surface (usually the dominant means for internal load resumption). For stratified lakes, Huser et al. (2015) found an average of 21 years of benefits, and the only retreated lakes on Cape Cod got 14 and 17 years of benefit before re-treatment was necessary, and both had initially received doses lower than the maximum recommended. There is nothing magic about the 10 cm sediment depth; there is likely to be plenty of redox-sensitive P below that depth, but most treatments do not penetrate deeper than 10 cm and the primary source of P in internal loading scenarios is from the upper 1-2 cm. Consequently, the first 10-20 g/m^2 of Al added provides great benefit and additional Al is simply extending the duration of those benefits, inactivating more and deeper P. One could perform smaller treatments every few years or one larger treatment every decade or two, but in the end it is still a maintenance operation to some degree, at least until all available P is exhausted. With several feet of apparently P-rich organic substrate in Skinequit Pond, P reserves will not be exhausted for many decades.

The cost of aluminum treatment is a function of dose and area treated. The simplest estimate is about \$50 per g/m^2 per acre treated. For Skinequit Pond there are two defined areas of about 5.4 acres each, one with a suggested dose of 100 g/m^2 and the other with 50 g/m^2. A cost of about \$40,500. Adding in permitting and monitoring costs, this is about a \$50,000 project. It would be conducted using a boat with tanks in it for the aluminum product, not a larger barge, but access is still an issue for Skinequit Pond and some extra cost may be incurred to restore an area used to get the boat and aluminum product to the pond.

The primary concern with aluminum addition is toxicity, as the active aluminum in applied compounds can be toxic to aquatic life if the aluminum concentration is high enough (about 10 mg/L) and the pH is outside the range of about 6 to 8 standard units. Fish kills have resulted from treatments that did not manage the aluminum concentration or pH adequately, including one on Hamblin Pond in Marstons Mills in 1995 and another in a Connecticut lake in 2000, but since that time the application of aluminum products has become more informed and controlled, and no toxic events have been recorded over more than 50 treatments in New England over the last 20 years.

Concerns over human health issues with aluminum are based on older literature that has been discredited or explained by alternative factors. Aluminum has been found to accumulate in nerve synapses and was thought by some to be a factor in neurological diseases like Alzheimer’s or Lou Gehrig’s disease, but it is now understood that the aluminum is a byproduct of the condition, not a causative agent. Still, people are uneasy about putting any chemical in water with which they come in contact, despite the use of aluminum in the vast majority of potable water treatment systems and high use of medicines, bath products, and other “chemicals” that are ingested or applied to skin. Yet it is not possible to argue that there is no risk or that a non-chemical alternative might pose less risk. Ultimately it is a trade-off between risk and reward, and decisions need to be made collectively with the best possible information provided to all involved parties.

Combination Approaches

None of the three applicable approaches to internal P loading control is mutually exclusive. If a thorough dredging project was undertaken, there would not likely be any need for oxygenation or

P inactivation. Partial dredging followed by either oxygenation or P inactivation could be implemented, but a well-designed oxygenation or P inactivation project would sufficiently limit internal P recycling and minimize the need for more expensive dredging.

The more applicable combination approach is oxygenation and P inactivation, as each provides benefits to a greater degree than the other. P inactivation will depress internal P loading more than oxygenation, as the presence of oxygen in deeper water will aid decomposition and release of P by that process. Some improvement in deep water oxygen may be garnered from P inactivation, as there will be less algae produced that will later decay and consume oxygen, but the demand already expressed by the sediment will remain high and will cause low oxygen in at least the deepest water.

However, the magnitude of the P reserves suggests that the typical combination of oxygenation and P inactivation, which would involve injecting smaller quantities of aluminum or another P binder (iron will work if oxygen is maintained above about 2 mg/L) into a circulation system (SolarBee technology might work if the intake was extended to the deepest zone and capacity was adequate to mix the whole pond), will not be adequate to provide the desired benefits from the start. A much larger initial P inactivation treatment or a more complete oxygenation project is needed to address the legacy P reserves currently in the surficial sediment. Combination oxygenation/P inactivation systems tend to work best to counter ongoing, uncontrolled inputs from the watershed (e.g., stormwater runoff, large waterfowl population).

Deciding What to Do

There is no watershed technique that will rehabilitate Skinequit Pond. Reducing inputs to the pond from the watershed is always a good idea, but the pond is like a boat that has been leaky for a long time. We can patch the leaks, but the boat is still full of water and won't be useable until the water is removed. No amount of watershed management will improve the condition of Skinequit Pond now; the internal load must be addressed.

Among the choices for reducing internal P loading, dredging is the most thorough and will provide the greatest overall benefit for the longest time, but the cost is very high and the permitting process is long and arduous. Oxygenation with a sidestream saturation system could be effective at a capital cost of <$200,000 and an annual operating cost <$40,000, but the track record for such systems is not yet extensive enough to guarantee results. Observing the results at nearby Sarah's Pond in Orleans may be worthwhile to see if such a system is successful there. P inactivation, almost certainly with aluminum based on current product approvals for use in Massachusetts, represents the lowest cost alternative at about $50,000. Such treatments have been conducted with minimal non-target impacts for over 20 years in Massachusetts, with over a dozen projects on Cape Cod. While all cases have resulted in improvement of pond conditions, not all have achieved the goal of eliminating cyanobacteria blooms entirely. An aluminum treatment should provide benefits for at least a decade and possibly for two decades but would eventually have to be re-done.

Lake management is like a three-legged stool with legs representing science, economics, and institutions. The stool is only functional if all three legs are solid. This report has focused on the science and provides economic information that allows some prediction of likely cost. The institutional side, which includes state and local government, related permitting processes, quasi-governmental groups operating on Cape Cod, and the Watershed Association of South Harwich with its preferences, is the most difficult leg to firm up. Opinions count, although they should not be considered more reliable than data and unbiased analysis. All involved parties need to discuss goals for the pond, the options for attaining those goals, and the costs for implementing those options. Considerably more data collection will be needed if dredging is to be pursued, and some input from qualified vendors is advisable if oxygenation is preferred. The data in hand are sufficient to plan a P inactivation treatment, and that appears to be the least cost alternative. It is now up to WASH to discern a path forward.

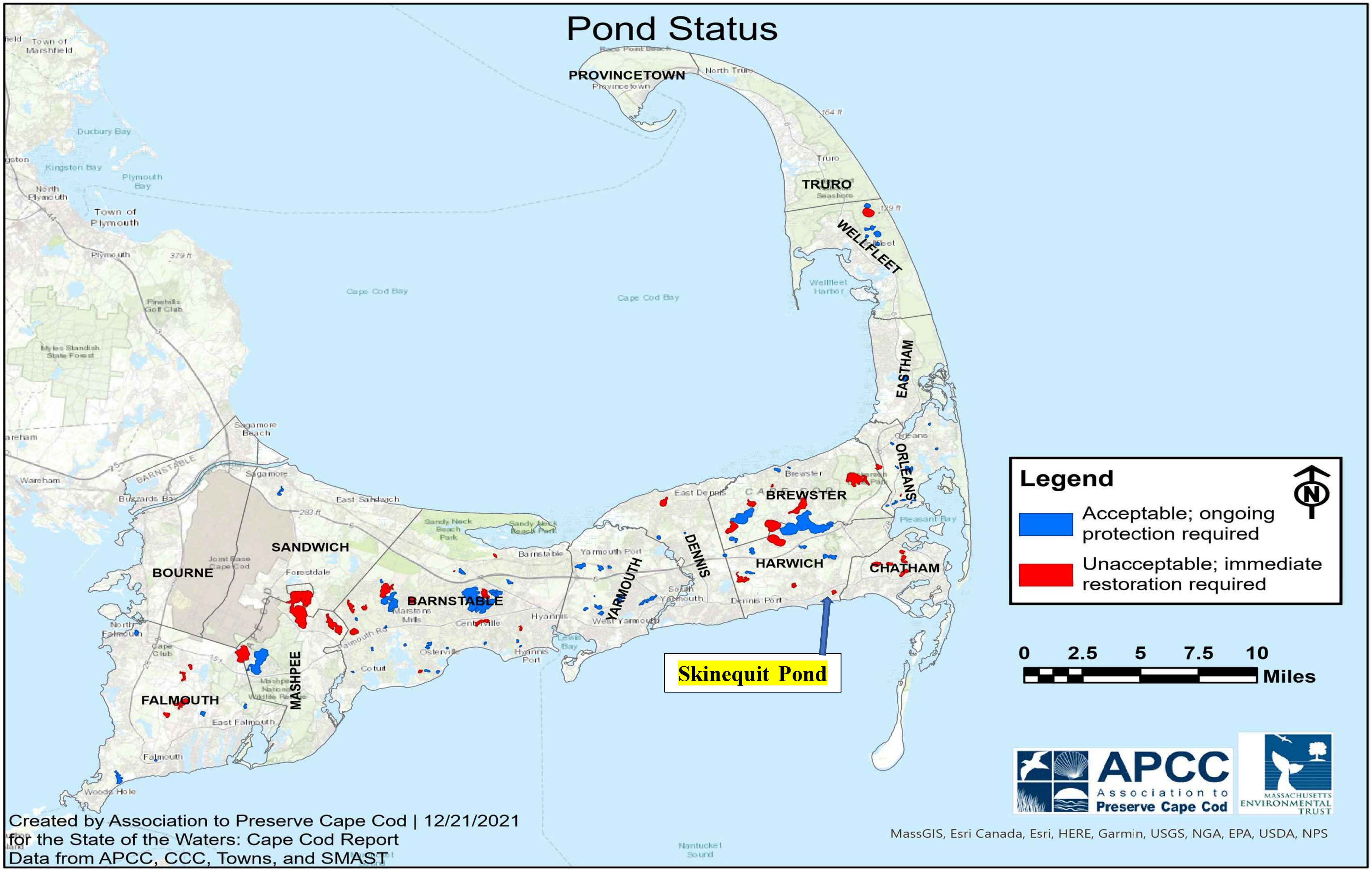
Exhibit III: Private Funds Used for Skinequit Pond Remediation, 2007-2022

WASH Skinequit Pond Remediation Expenditures

Expenditures	Date	Amount
Solar Bee Purchase and Installation	2007	$43, 092
Annual Solar Bee Maintenance Fees	2007-2022	$40,900
2022 Water Resource Services Pond Evaluation	2022	$15,403
Total		**$99,395**

Note: Does not include privately funded power costs for oxygenation in 2001-2002, in-kind pond water testing provided to the Town, or association filing and other fees.

Exhibit IV: APCC Pond Status Map



Source: State of the Waters: Cape Cod 2021, Pond Status Map, Association for the Preservation of Cape Cod (APCC), March 2022. Highlighting added.

Exhibit IV (Continued): APCC Pond Data Used for 2021 Pond Status Map

Pond Name	Most Recent Year Tested	Years Covered	Trophic State Index (TSI) Average	Carlson Eutrophic Grade (CTI)	CTI Change 2020-21	Cyano Tier	Final Grade
Aunt Edies	2020	2016-2020	48.5	Acceptable	2.8	Low	Acceptable; ongoing protection required
Bucks	2019	2016-2019	41.4	Acceptable	0.2		Acceptable; ongoing protection required
Grass	2019	2016-2019	58.9	Unacceptable	-2.3		Unacceptable; immediate restoration required
Hinckleys*	2020	2016-2020	52.9	Unacceptable	-6.8	Low	Unacceptable; immediate restoration required
John Josephs	2019	2016-2019	39.4	Acceptable	-1.4		Acceptable; ongoing protection required
Robbins	2020	2016-2018	42.8	Acceptable	1.6	Low	Acceptable; ongoing protection required
Sand	2019	2016-2019	42.5	Acceptable	-4.4		Acceptable; ongoing protection required
Skinequit	2020	2016-2020	56.4	Unacceptable	-5.6	High	Unacceptable; immediate restoration required
West Reservoir	2020	2020	N/A	N/A	N/A	High	Unacceptable; immediate restoration required

***NOTE: Hinkleys Pond has been treated with alum since the most recent year tested in this presentation**.*

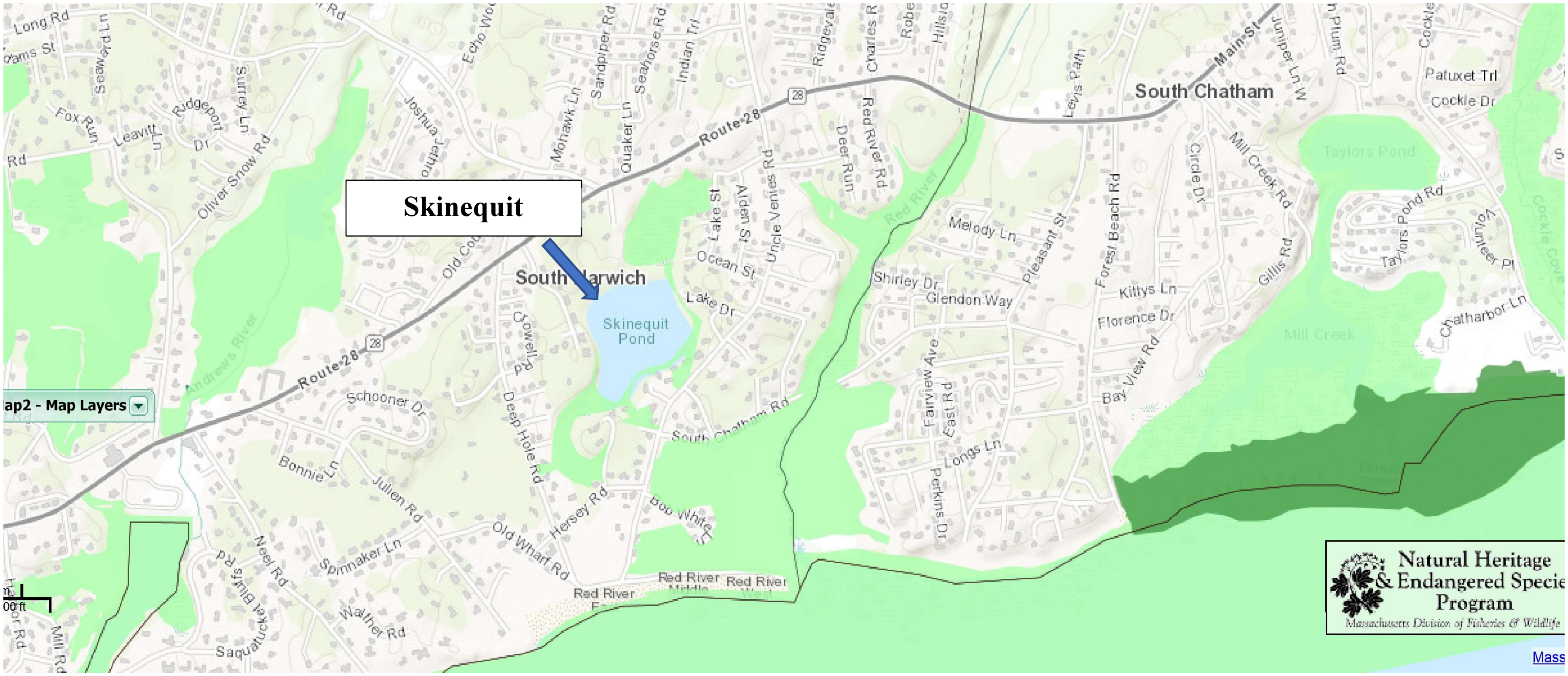
APCC Combined Pond Grading System

APCC's combined pond grading system combines available Carlson Trophic Index (CTI) grades and cyanobacteria grades, as described below and updated with more recent data and revised cyanobacteria grading system:

1. *Carlson Trophic Index scores and grades for ponds were calculated only for ponds where more recent water quality data from 2016 on was available, and where at least three years of data were available.*
2. *2) Cyanobacteria monitoring data from 2020 were used to grade ponds using APCC's revised tiered cyanobacteria system:*
   a. *Ponds in the "High" and "Moderate" cyanobacteria tiers were graded as "Unacceptable: requires immediate restoration"*
   b. *Ponds in the "Low" cyanobacteria tier were graded as "Acceptable: requires ongoing protection."*
3. ***If a pond had both Carlson Trophic Index grades and Cyanobacteria grades:***
   a. *The pond was graded as **"Acceptable: requires ongoing protection" only if both grades were Acceptable.***
   b. *The pond was graded as **"Unacceptable: requires immediate restoration" if at least one of the grades was Unacceptable.***
4. ***If a pond had only one grade (i.e., Carlson Trophic Index grade or Cyanobacteria grade), that grade was used as the sole determinant of the overall pond grade.***

Source: State of the Waters: Cape Cod 2021, Pond Status Map, Association for the Preservation of Cape Cod (APCC). APCC chart; description of grading system consolidated for clarity and presentation. Highlighting and bolding added.

Exhibit V: NHESP BioMap2 Core Habitat and Critical Natural Landscape



Light Green= Natural Heritage Endangered Species Program (NHESP) Critical Natural Landscape
Dark Green= Natural Heritage Endangered Species Program (NHESP) Core Habitat

Source: Core Habitat and Critical Natural Landscape, BioMap2, Harwich, MA, Natural Heritage & Endangered Species Program (NHESP). Identification added.

Exhibit VI: Partial List of Animal, Bird and Other Sightings on and around Skinequit Pond

(Identified by Pond Residents)

Birds

Osprey	Barn Owl
Red-Tailed Hawk	Screech Owl
Cooper's Hawk	Baltimore Oriole
Great Blue Heron (has nested on the pond)	Northern Cardinal
Black Crowned Night Heron	Unidentified Vireo
Yellow Crowned Night Heron (possible breeding ground)	Blue Jay
Great Blue Heron (has nested on the pond)	American Crow
Green Heron	Tufted Titmouse
Great Egret	Black-capped Chickadee
Snowy White Egret	American Robin
Belted Kingfisher	American Goldfinch
Double Crested Cormorant	Mourning Dove
Black Duck	Marsh Wren
Mallard Duck	House Sparrow
Bufflehead Duck	Dark-eyed Junco
Common Merganser Duck	Warblers
Canadian Geese	Sparrows
Mute Swan	Other unidentified migratory birds
Common Tern	
Wild Turkey	
Herring Gull	
Seagulls of all types	
Yellow-bellied Sapsucker	
Downy Woodpecker	
Northern Flicker	

Butterflies and Moths

Canadian Tiger Swallowtail	Viceroy
Monarch	Cabbage White
Red Admiral	

Dragonflies/Damselflies

Northern Bluet Damselfly	Unidentified Emerald Dragonfly
Unidentified Blue Dragonfly	Eastern Amberwing Dragonfly
Pine Barrens Bluet Damselfly	

Animals

Muskrat (nesting/breeding ground)	Cottontail Rabbit
Otter	Skunk
Racoon	Red Fox
Coyote	
Opossum	

Reptiles/Amphibians

Bullfrog	Snapping turtle (Breeding grounds)
Green frog	Painted turtle

Fish

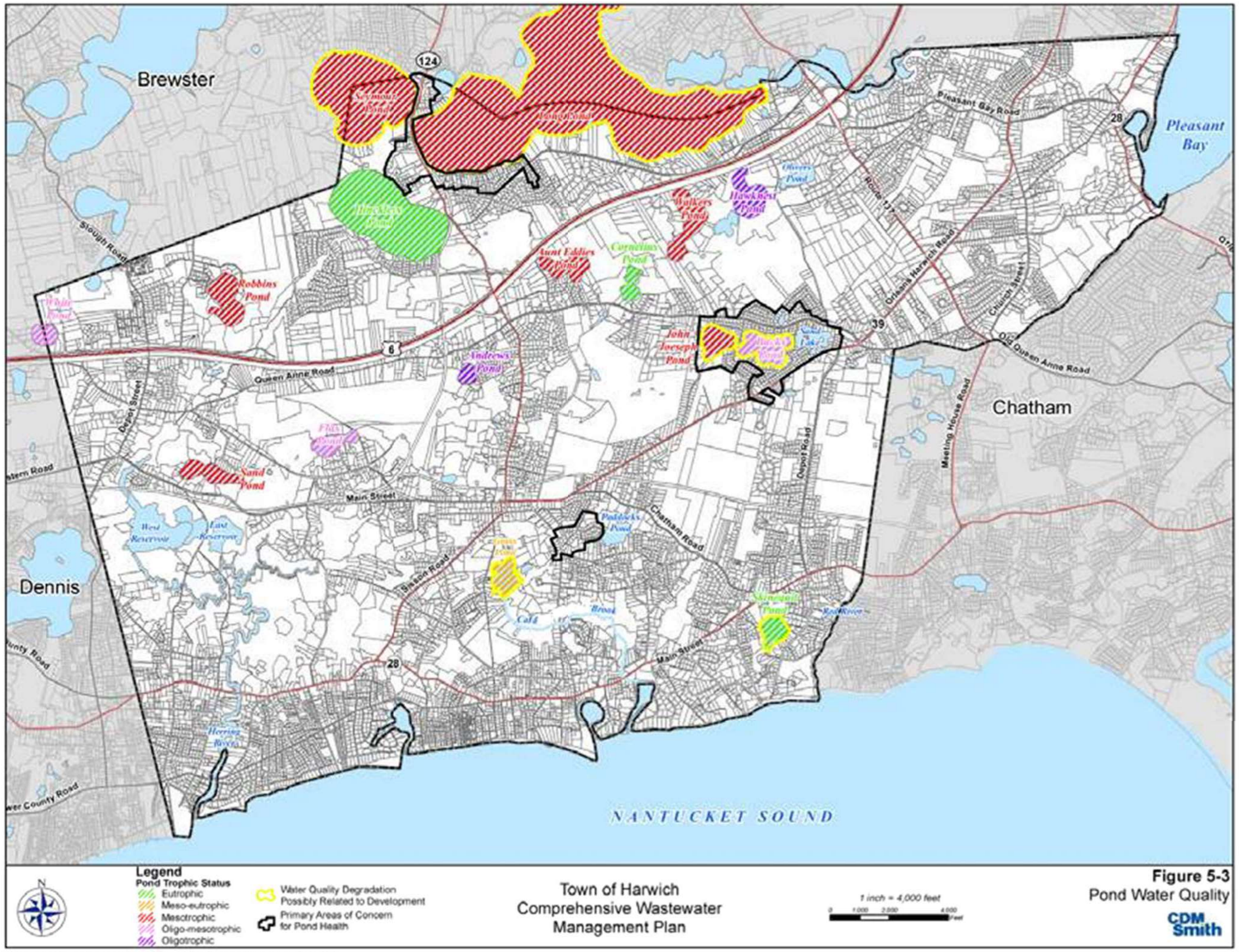
Sunfish	White and yellow perch
Catfish	Alewife herring

Invertebrates

American Bumble Bee	Water bugs
Honeybee	Pond skaters
Yellow Banded Bumblebee	Dragonfly and damselfly larvae
Carpenter Bees	Mayflies
Water beetles	

Source: Pond property owners' observations.

Exhibit VII
Comprehensive Wastewater Management Plan Assessment of Ponds



Note: Light green areas are identified as eutrophic, yellow orange as meso-eutrophic, red as mesotrophic, light purple as olio-mesotrophic, dark purple as oligotrophic. A separate map (Fig. 5-2 on p. 5-3) identifies the waters of Hinckleys Pond, John Joseph Pond, Bucks Pond, Long Pond and Seymour Pond as "impaired".

Source: Comprehensive Wastewater Management Plan, Town of Harwich, CDM Smith, 2016, Section 5, p.23.

Exhibit VII (Continued)
Comprehensive Wastewater Management Plan Assessment of Ponds

Name	Pond Trophic Status	Shoreline Development
Andrews Pond	Oligotrophic	Low
Aunt Edies Pond	Mesotrophic	Low
Bucks Pond	Oligo-mesotrophic	Med. to High
Cornelius Pond	Eutrophic	Low
Flax Pond	Oligo-mesotrophic	Low
Grass Pond	Meso-eutrophic	Low
Hawksnest Pond	Oligotrophic	Low
Hinckleys Pond	Eutrophic	Med. to High
Island Pond	*	*
John Joseph Pond	Mesotrophic	Med. to High
Littlefields Pond	*	*
Long Pond	Mesotrophic	Med. to High
Oilvers Pond	*	*
Okers Pond	*	*
Paddocks Pond	*	*
Robbins Pond	Mesotrophic	Low
Sand Pond	Mesotrophic	Low
Seymour Pond	Mesotrophic	Med. to High
Skinequit Pond	Eutrophic	Med. to High
Walkers Pond	Mesotrophic	Low
West Reservoir	*	*
White Pond	Oligo-mesotrophic	Low

Note: (*) No data available. Red Fields indicate impaired water quality.

Source: Comprehensive Wastewater Management Plan, Town of Harwich, CDM Smith, 2016, Section 5, p.21. Highlighting added.

2023-2024 CPC Application for Skinequit Pond Remediation
APPENDIX B

Estimated Costs for Alum Treatment to Skinequit Pond

Category	Amount	Source/Comments
Alum Treatment	$50,000	Estimates from Solitude Lake Management and Water and Wetland LLC
Pre- and Post- Treatment Testing	$10,000	WRI estimate
Initial 2-year Monitoring and Report	$20,000	WRI estimate
Permitting	$0	Town to handle, no NHESP requirement
Ongoing monitoring	$0	WASH and Town through PALs program?
Subtotal	**$80,000**	
Contingency	$12,000	15% contingency
Total CPC Request	**$92,000**	
Pre-Treatment Water and Sediment Study	$15,403	Funded by WASH
Total Project Costs	**$107,403**	Funded by CPC and WASH

Letters Of Support
APPENDIX C

- Town of Harwich Conservation Commission
- Town of Harwich Water And Wastewater Department
- Town of Harwich Health Department
- Town of Harwich Recreation and Youth Commission
- Harwich Conservation Trust
- Pond Association (WASH) Members

732 Main Street
Harwich, MA 02645
CONSERVATION COMMISSION
CONSERVATION COMMISSION **(508)-430-7538 FAX (508)430-7531**

September 23, 2022

To: Heinz Proft, Director of Natural Resources
From: Amy Usowski, Conservation Administrator

RE: Skinequit Pond CPC Application

At their September 21, 2022 public meeting, the Harwich Conservation Commission voted 5:0 in support of the submittal of a Community Preservation Committee Application Town of Harwich Natural Resources Department to treat Skinequit Pond with alum.

Skinequit Pond has had a history of poor water quality, and the Commission recognized the efforts of the Town and the Watershed Association of South Harwich (WASH) over the past twenty of so years to improve it. Last year, Skinequit Pond had a toxic cyanobacteria bloom that lasted for six weeks. Not only does this affect public usage of the pond, but also is harmful to the environment, causing decreased oxygen levels that stress the organisms that live in the pond.

This letter is in support of submitting the CPC application. The Conservation Commission will need to formally review and vote on the project at a public hearing under the Massachusetts Wetlands Protection Act and Harwich Wetlands Bylaw sometime this winter or early spring.

Town of Harwich Water & Wastewater Department
196 Chatham Road, Harwich, MA 02645 USA | www.harwichwater.com
P. 508-432-0304 | F. 888-774-3557 | Dpelletier@harwichwater.com

September 28, 2022

Community Preservation Committee, Town of Harwich
David Nixon, Chair
732 Main Street
Harwich, MA 02645

Subject: Letter of Support – Skinequit Pond Remediation Project

Please accept this letter of support for the Skinequit Pond Remediation Project application for CPC funds by the Watershed Association of South Harwich. The elevated nutrient levels in Skinequit Pond have been the cause for numerous water quality issues for many years. Where the nutrients are in-solution intervention is a necessary step to restore water quality and mitigate further degradation. The Association has made significant investments to restore/maintain water quality with waning success. The proposed alum treatment would have an immediate impact on water quality as it acts by pulling the nutrients out-of-solution where they then settle out on the pond floor. That said, alum is not a permanent solution as it does not address the source of the nutrients which will need to be addressed with either conventional sewers, I/A septic systems, or other technology. The evaluation of Harwich's ponds along with proposed remediation strategies have been incorporated into the Town's CWMP revisions project. In my opinion, the proposed Skinequit Pond Remediation Project is a great first step to improving the ponds health and will also help maintain water quality while a solution to address the nutrient source is developed. I would like to thank the Community Preservation Committee for your careful consideration and recommend your approval of this project

.

Respectfully,

Dan Pelletier
Superintendent of Water & Wastewater

T o w n o f H a r w i c h

Health Department

732 Main Street Harwich, MA 02645
508-430-7509 – Fax 508-430-7531
E-mail: health@town.harwich.ma.us

September 23, 2022

Dear CPC Members;

Please accept this letter of support for the Skinequit Pond CPC Application submitted by Natural Resources Director, Heinz Proft, and Conservation Administrator, Amy Usowski. Local public health officials recognize that cyanobacteria is an area of concern for residents and visitors alike, and have been meeting regularly to determine a proactive multi-agency approach for dealing with this complex issue, which requires attention from both a public health and environmental standpoint.

Cape Cod has seen an increase in algal blooms due to human activities. The primary causes are both improper use of fertilization, and faulty septic systems. These activities have introduced an overabundance of nutrients into the environment, which leads to an ecologically unhealthy condition called eutrophication. Eutrophication is the process by which a water body becomes enriched in dissolved nutrients such as phosphates and nitrogen. The greater the nutrient availability, the more fuel is created for cyanobacteria to grow and thrive.

Alum reduces the growth of algae by trapping phosphorus, and binding it to sediments that sink, making it unusable as a nutrient source to algae. Alum is both a safe, and effective method to mitigate excess phosphorus.

I fully support this application to improve the overall health of this pond and the area. Please do not hesitate to reach out to me with any further questions.

Best Regards,

Kathleen A. O'Neill

Kathleen A. O'Neill, Sc.D., R.S.
Harwich Health Director

To Whom It May Concern,

At a meeting of the Recreation and Youth Commission on Tuesday September 27,2022 the Recreation and Youth Commission unanimously voted to support the Community Preservation Article Request from Natural Resources for funding for the treatment for Skinequit Pond Remediation.

The Commission supports the remediation of this Town of Harwich jurisdiction property and it's resource to the town.

This project will meet the goals of the Local Comprehensive Plan and have positive effects on the environment of the pond and it's surroundings.

We highly encourage the approval of the request for $92,000 to the Community Preservation Committee.

Thank you for your attention to this matter.

Eric Beebe

Director-Harwich Recreation Department

P.O. Box 101, South Harwich, MA 02661
Ph. 508-432-3997 ● E-mail: info@harwichconservationtrust.org
www.harwichconservationtrust.org

Town of Harwich Community Preservation Committee (CPC): Sept. 27, 2022
David Nixon, Chair, Recreation and Youth Commission Representative
Kathy Green, Vice Chair, Real Estate and Open Space Committee Representative
Mary Maslowski, Planning Board Representative
John Ketchum, Conservation Commission Representative
Robert Doane, Historic District Representative
Joseph McParland, Housing Committee Representative
Elizabeth Harder, Housing Authority Representative
Carole Ridley, Select Board's Representative
Kelly Barber, Select Board's Representative

Dear Members of the Community Preservation Committee:

On behalf of the HCT Board of Trustees, I am writing in support of the application to CPC for Skinequit Pond alum treatment remediation. Skinequit Pond is of particular interest to HCT because it is within the watershed area that includes a number of HCT parcels, including four parcels located on Skinequit Road totaling 2.2 acres.

The pond could experience water quality improvements similar to Hinckleys Pond, the focus of a similar project reviewed and recommended by CPC and ultimately approved by Town Meeting voters. The Town Natural Resource Dept. has a growing working knowledge and measurable data from the Hinckleys Pond project that will help inform this new project.

HCT support of this project is in line with our focus on protecting and improving pond health and preserving wildlife habitats. The project will improve the water quality of Skinequit Pond, which directly affects the ecosystems in and around the pond. This is particularly important because of the following:

- The pond is an active and important spawning ground for an active herring run that originates in the Red River estuary as fish swim from the Sound upstream. In 2020, the Tuttle family gifted seven acres of Red River salt marsh to HCT in part to protect the Red River herring run. The Tuttle land gift directly connects to the herring run into Skinequit Pond. Improved water quality in the pond is important for the preservation of the herring run and, hopefully, an increase in herring population over time.

- Both the tract of conservation land on the northern side of the pond owned by the Town and the herring run from the Red River estuary are designated Critical Natural Landscape by the National Heritage Endangered Species Program (NHESP). The term Critical Natural Landscape identifies and prioritizes intact landscapes that are better able to support ecological processes and a wide array of species and habitats over long periods of time.

The HCT Board of Trustees recommends your favorable review of the project to protect the health of Skinequit Pond.

Respectfully,

Thomas M. Evans
President