Town of Barnstable, Massachusetts

Comprehensive Wastewater Management Plan

FY2022 Annual Report

August, 2022

Prepared by: Barnstable Department of Public Works

TABLE OF CONTENTS

LIST OF ATTACHMENTS

LIST OF ELECTRONIC FILES

1.0 BACKGROUND AND PURPOSE

The Town of Barnstable is pleased to prepare this Fiscal Year 2022 Annual Report documenting progress of the Town's Comprehensive Wastewater Management Plan (CWMP) in accordance with the Cape Cod Commission's 208 Plan Consistency Determination for the project, dated April 16, 2021. This document is the first annual report since the approval of the CWMP in the Spring of 2021. This report summarizes progress since the preparation of the final CWMP report (November, 2020) and the end of Fiscal Year 2022 (June 30, 2022). The Town will continue to submit annual reports at the end of each Fiscal Year, which will document the progress and data for the previous Fiscal Year.

After review of the requirements of the annual report as outlined in the 208 Plan Consistency Determinations, this report is arranged in 7 sections that address the stated requirements of the annual report. The 7 Sections are as follows:

1. Background and Purpose: This section summarizes the background and purpose of the annual reports.
2. Implementation Update: This section documents the progress of implementation over the reporting period. This section also addresses any adaptive management changes made during the reporting period. This section is arranged on the basis of project type as identified in the CWMP's Special Review Procedures. The five types of project included in the CWMP are: Sewer System Expansion Project, Treatment Plant Improvements, Effluent Disposal Improvements, Non-Traditional Solutions, and Inter-Municipal Collaboration.
3. Water Quality Monitoring: This section documents the results of the Town's water quality monitoring programs during the reporting period.
4. Outreach and Engagement: This section documents the progress towards public outreach and engagement as relates to the implementation of the CWMP.
5. Financing: This section documents the status of the Town's financing plan for the funding of the implementation of the CWMP.
6. Land Use and Management Controls: This section documents the status of implementation of land use and management controls in order to manage land uses in the community, particularly with the consideration of expanded sewer infrastructure.
7. Date: This section will provide the updated data requested in the 208 Plan Consistency Determination.

2.0 IMPLEMENTATION UPDATE

The Town of Barnstable continues to aggressively implement the Comprehensive Wastewater Management Plan (CWMP). The CWMP is a 30-year plan which will be implemented in three, 10-year phases to address the various wastewater needs of the community. Since 2018, the Town Council has appropriated over $56 Million in support of projects identified in the Plan. In the same time period, over $39 Million has been appropriated for capital improvements to the Water Pollution Control Division's infrastructure (sewer collection system and treatment plant). As outlined in the CWMP's Special Review Procedures, the Plan includes five different types of projects: sewer system expansion projects, treatment plant improvements, effluent disposal improvements, non-traditional solutions and inter-municipal partnerships. This section will provide an update on each type of project, including any changes that have occurred since approval of the CWMP.

2.1 SEWER SYSTEM EXPANSION PROGRAM

2.1.1 PROJECT UPDATES

The Town has commenced implementation of Phase 1 of the sewer system expansion program as identified in the CWMP. The following sections provide a summary of active project updates since approval of the CWMP.

2.1.1.1 Strawberry Hill Road Sewer Expansion Project:

The project involves the construction of approximately 20,500 LF of gravity sewer, 6,400 LF of sewer force main, replacement of approximately 4,000 LF of water main and the installation of one new submersible pump station on a Town-controlled easement at 528 Craigville Beach Road. The infrastructure is being installed along the Vineyard Wind Project upland duct bank route and the project includes new sewers in the following roadways: Craigville Beach Road from Covell's Beach to Strawberry Hill Road; Strawberry Hill Road from Craigville Beach Road to Wequaquet Lane; Wequaquet Lane; Phinney's Lane from Wequaquet Lane to Route 132; and West Main Street from Pleasant Park Avenue to Strawberry Hill Road. The Town has closely coordinated with Vineyard Wind through the design process and now into construction in order to minimize disruption to the community and realize cost savings for the Town. Construction of the project commenced in September of 2021 and the project is on schedule for completion in the Spring of 2023. The project is anticipated to provide sewer service to approximately 240 new properties and remove approximately 4.6 kg/day of nitrogen from the Centerville River Watershed upon completion.

2.1.1.2 Route 28 East Sewer Expansion Project:

The Project will expand sewer westerly along Route 28 to the intersection of Route 28 and Phinneys Lane. The project includes the installation of approximately 11,000 LF of new sewers

within Route 28, Phinney's Lane, and West Main Street. The project also includes the construction of a new pump station to be located at the Town owned property at 1456 Falmouth Road, and approximately 12,000 LF of sewer force mains from the new pump station to the WPCF. The pump station and force mains has been designed to eventually serve the majority of the of the western sewer expansion (more than 7,000 properties). The project also includes modifications at the WPCF to accommodate the new force mains. The Route 28 East project is a critical component of the Town's sewer expansion plan, and will eventually serve more than 7,500 properties as described in the Town's Comprehensive Wastewater Management Plan (CWMP). This project will immediately allow for about 100 properties to connect to the municipal sewer system, removing 1.9 kg/day of nitrogen from the Centerville River Watershed upon completion. Future phases of the sewer expansion plan cannot move forward until the critical infrastructure installed as part of this project are completed.

Design of the project was completed in early 2022 and the project was bid in the spring of 2022. The construction contracts were awarded to the low bidder, Robert B. Our Co. Construction is anticipated to begin in August of 2022. Project completion is estimated in the Winter of 2023/2024.

2.1.1.3 Route 28 West Sewer Expansion Project:

The proposed project combines two projects previously referred to in the CWMP as Route 28 Centerville and Route 28 Marstons Mills. The project will extend municipal sewer on Route 28 from Phinney's Lane to Route 149 in Marstons Mills. Also included in this project would be the decommissioning of the Marstons Mills Wastewater Treatment Plant (MMWWTP) with conveyance of the plants service area back to the WPCF. The project will include the construction of over 25,000 LF of new sewers and an estimated four new sewer pump stations. The project will install critical infrastructure which will facilitate sewer expansion to the western portion of the Town as required by the CWMP. Without the infrastructure to be installed as part of this project, the further western expansion of the municipal sewer system into the Three Bays and Popponesset Bay Watersheds as required in the CWMP cannot be achieved.

The Town Council has appropriated $3,500,000 for the design of the Route 28 West Sewer Expansion Project. Town staff has performed initial conceptual design for the project. In June of 2022, the Town issued an RFP for designer selection and anticipates that selection in August of 2022. Construction is anticipated to begin in FY2025 and be completed in FY2027.

2.1.1.4 Phinney's Lane Sewer Expansion Project:

The project will extend sewer into the residential neighborhoods on the east and west side of Phinney's Lane, which will tie into the sewer infrastructure to be constructed in Phinney's Lane as part of the Strawberry Hill Road and Route 28 East projects. The Phinney's Lane project will also extend sewer to the commercial area along Route 132 between Attucks Lane and Phinney's Lane, leveraging the pump station that was installed through a public private partnership at the Cape Cod Five Headquarters. The project will connect approximately 630 parcels to municipal

sewer, thereby removing 9.7 kg/day of nitrogen from the Centerville River Watershed. Many of these properties are also in close proximity to Wequaquet Lake, and therefore the project is expected to improve water quality in the Lake.

The Town Council has appropriated funding for the project through final design. Survey of the project area is on-going and nearing completion (anticipated in August of 2022). Additionally, Town staff is actively working on the preliminary design of the project. The project will be the first CWMP project to include sewer installation in private roadway (approximately 40 private roadways in the project area). As such, Town staff and leadership are currently engaged in policy discussions relative to sewer installation in private roadways. Construction of the project is currently anticipated to begin in FY2025.

2.1.1.5 Long Pond Sewer Expansion Project:

The project will extend sewer into the residential areas adjacent to Long Pond, Centerville. The project will connect approximately 520 parcels to municipal sewer, thereby removing approximately 9.5 kg/day of nitrogen from the Centerville River Watershed. Many of these properties are also in close proximity to Long Pond, and therefore the project is expected to improve water quality in the Pond.

The Town Council has appropriated funding for the project through final design. Survey of the project area has been completed. Additionally, Town staff is actively working on the preliminary design of the project. Construction of the project is currently anticipated to begin in FY2027.

2.1.1.6 Route 28 and Yarmouth Road Intersection Improvement Project:

The project includes the installation of sewer infrastructure part of MassDOT's Route 28 and Yarmouth Road Intersection Improvement Project. The sewer infrastructure to be installed as part of the project includes gravity sewers within Route 28 from Yarmouth Road to Cedar Street and a force main within Yarmouth Road from Camp Street to Old Yarmouth Road. This infrastructure will remain "dry" until completion of the planned Old Yarmouth Road Sewer Expansion Project, planned for later in Phase 1 of the CWMP. However, this targeted work is being completed as part of the project in order to avoid MassDOT's construction moratorium and to reduce costs. Construction is anticipated to commence in the Fall of 2022.

2.1.1.7 Old Yarmouth Road Sewer Expansion Project:

The project will extend sewer to the north of Route 28 and east of Yarmouth Road providing municipal sewer to businesses and residences on Yarmouth Road, Old Yarmouth Road, Joaquim Road, Bodick Road, and Ferndoc Street. Businesses and residences in this area are completely dependent on on-site solutions to address their wastewater, which has restricted economic growth in the area. The Hyannis Water Systems Maher drinking water wells, which have experienced contamination over the years, are located immediately adjacent to the proposed sewer expansion area. As a result, this project was identified in Phase 1 of the Comprehensive

Wastewater Management Plan (CWMP) to address economic development and drinking water protection. This project will connect approximately 130 properties to municipal sewer and remove approximately 2.2 kg/day of nitrogen from the Lewis Bay Watershed.

In April of 2022, the Town Council appropriated $275,000 for survey and preliminary design of the project. Town staff anticipates issuing a Request for Proposal (RFP) for survey services in the Fall of 2022. Town has developed a preliminary design for the project, which will be refined upon completion of the survey. Construction is anticipated to commence FY2026.

2.1.1.8 Old Craigville Road Sewer Expansion Project:

The project will expand sewer to properties located on Old Craigville Road and adjacent neighborhoods. The properties served will feed to the infrastructure to be installed as part of the Strawberry Hill Road Sewer Expansion Project. The northern portions of the project area have been identified as a needs area for nitrogen removal within the Centerville River Watershed by Massachusetts Estuaries Program (MEP) modeling as well as drinking water well protection (COMM Water supply wells). The southerly portion of the project area has been identified as a needs area for pond protection as residences in this area are located in close proximity to Red Lily Pond and Lake Elizabeth and are completely dependent upon on-site solutions to address their wastewater. This project will connect approximately 440 properties to municipal sewer and remove approximately 4.9 kg/day of nitrogen from the Lewis Bay Watershed.

In April of 2022, the Town Council appropriated $600,000 for survey and preliminary design of the project. Town staff anticipates issuing a RFP for survey services in the Fall of 2022. Town staff will commence preliminary design upon completion of the survey. Construction is anticipated to commence FY2026.

2.1.1.9 Shootflying Hill Road Sewer Expansion Project:

The project will expand sewer to properties located on the residential roadways off of Shootflying Hill Road. Shootflying Hill Road is anticipated to be sewered in coordination with the Park City Wind Project (see Section 2.1.1.11). This project would leverage the infrastructure installed in Shootflying Hill Road to reduce nutrient loading in the Centerville River Watershed as well as to Lake Wequaquet. The southern half of the project area has been identified as a needs area for nitrogen removal within the Centerville River Watershed by Massachusetts Estuaries Program (MEP) modeling. Additionally, many residences in this project area are located in close proximity to Wequaquet Lake and are completely dependent upon on-site solutions to address their wastewater needs. Many properties close to the lake have high groundwater, making replacing on-site septic systems very expensive. In recent years, Lake Wequaquet has experienced declining water quality. As a result, the project area was identified as a needs area for nitrogen removal and pond protection. The project will connect approximately 240 properties to municipal sewer and remove approximately 3.4 kg/day of nitrogen from the Centerville River Watershed.

In April of 2022, the Town Council appropriated $375,000 for survey and preliminary design of the project. Town staff anticipates issuing a RFP for survey services in the Fall of 2022. Town staff will commence preliminary design upon completion of the survey. Construction is anticipated to commence FY2027.

2.1.1.10 Hyannis Avenue Sewer Extension:

The property owner at 10 Hyannis Avenue approached the Town with interest in extending the municipal sewer system in order to service their property which was undergoing a significant renovation. The property owner and the Town entered into an agreement to allow the property owner to construct an approximately 1,250 feet sewer extension at the sole expense of the property owner. After satisfactory completion of the construction, on April 28, 2022, the Town accepted the infrastructure as part of the municipal sewer system. As a result of the project, 17 properties fronting along the infrastructure, which are identified in Phase 2 of the CWMP, now have the ability to connect to the municipal sewer system at their convenience.

2.1.1.11 Park City Wind Route Sewer Expansion:

In May of 2022, the Town entered into a Host Community Agreement with Park City Wind, LLC to allow the project's power cables to ashore at Craigville Beach and be installed within Town roadways in order to connect to the electric grid. Similar to the collaboration of the Strawberry Hill Road Project with the Vineyard Wind Project, the Town will be coordinating with Park City Wind to install sewer infrastructure along the route to minimize construction disruption, coordinate utility corridors and realize significant cost savings. Park City Wind's proposed preferred route and alternate route are both entirely within roadways that are planned to receive sewer expansion as part of the CWMP. The majority of both the preferred route and alternate route are located within roadways that are identified in Phase 1 of the CWMP. However, portions of the routes are located within Phase 2 which will necessitate some adaptive management modifications to the CWMP Phases, which are discussed in Section 2.1.2.1. As of the writing of this report, Park City Wind has not notified the Town of its final route selection.

In December of 2021, the Town Council voted to appropriate $2,750,000 for design of sewer expansion along the selected route. Project design is anticipated to commence in the Summer of 2022. Construction is anticipated to commence in the Fall of 2023.

2.1.2 SEWER EXPANSION PROGRAM ADAPTIVE MANAGEMENT CHANGES

The Town of Barnstable continues to utilize the principle of Adaptive Management as it implements the CWMP in order to allow the Town to respond to opportunities to improve construction efficiency, reduce project costs, react to changing environmental conditions, respond to land use updates, improved technologies, future opportunities and unknowns. Consistent with these principles, the Town has made minor revisions the 30-Year Sewer Expansion Phasing Plan and the Phase 1 Implementation Plan. Table 1 summarizes the updated statistics by Phase and details of each change are described below. An updated Sewer Expansion

Phasing Plan, Phase 1 Implementation Plan and Phase 1 Schedule have been included in Attachments A through C.

Table 1: Sewer Expansion Plan – Revised CWMP Phasing Statistics

	Phase 1 (0-10 Years)	Phase 2 (10-20 Years)	Phase 3 (20-30 Years)	Stages 1-3 (TBD)	Total
WW Captured (gpd)	782,600	827,100	372,900	144,500	**2,127,100**
Load N Removed (kg/day)	78	82	37	14	**211**
Number of Parcels	4,571	3,984	2,377	891	**11,823**
Sewer Road Miles	71	63	39	16	**189**
% of Parcels	39%	34%	20%	7%	**100%**
% of N Removed	37%	39%	17%	7%	**100%**
% of Road Miles	38%	33%	21%	8%	**100%**

Notes:
1. Refer to Tables 5-1 and 5-2 in the CWMP for previous statistics.
2. As of the date of this report, no new sewers have been accepted and no new connections have been completed.

2.1.2.1 Park City Wind Project

The Park City Wind project was not anticipated during the development of the CWMP. Park City Wind proposes to have their power cables come ashore at Craigville Beach and install duct banks within Town Roadway's to convey power to the electric grid via the Oak Street Substation. Similar to the Vineyard Wind Project, the Town will be installing sewers along the route in order to minimize construction disruption, coordinate utility corridors and realize significant cost savings.

Two routes are under consideration by Park City Wind, which are referred to as the "Preferred Route" and the "Alternate Route". Portions of both routes are located within roadways that are identified within Phase 2. As a result, the Town has updated the Phasing Plan to show the entirety of the Preferred Route in Phase 1. If Park City Wind decides to utilize the Alternate Route, a similar change would be made to address this.

Park City Wind plans to commence construction in late 2023. As a result, the Town revisited and modified the Phase 1 Implementation Schedule in order to expedite sewer construction along the proposed corridor.

2.1.2.2 Route 28 West Sewer Expansion Project

The Phase 1 Implementation Plan in the approved CWMP envisioned three Phase 1 projects along the Route 28 corridor to extend sewers along Route 28 from the current termination to

Route 149. Town staff revisited this approach and felt it would be more efficient to achieve this goal within two projects. The first of these projects, the Route 28 East Sewer Expansion Project, will be commencing construction this summer. The second project, now entitled the Route 28 West Sewer Expansion Project, will combine the two projects formerly referred to as Route 28 Centerville and Route 28 Marstons Mills, into a single project which will extend sewer from the end of the Route 28 East project (at Phinneys Lane) to Route 149.

2.1.2.3 Kidd's Hill Area and Marstons Mills Main Street

As a result of the aforementioned need to move portions of Phase 2 into Phase 1, it was determined necessary to move portions of Phase 1 into Phase 2. As a result, the Marstons Mills Main Street and half of the Kidds Hill Area project, have been moved into Phase 2. These two projects were scheduled to be two of the last projects in Phase 1 of the plan, and will now be moved to the beginning of Phase 2, resulting a relatively minor 1-3 year change. The Town recently invested millions of dollars in a streetscape project within the Marstons Mills Main Street project area, and this shift will allow for the infrastructure installed during that investment to have a longer life prior to construction of sewers. The Kidds Hill Area was felt to have two very unique sections; one along the commercial portion of Route 132 and the second along Phinneys Lane and Kidds Hill Road. The Route 132 portion has been moved into the Phinney's Lane Sewer Expansion Project, which is in Phase 1. The second portion of the Kidds Hill Area project is completely undeveloped and was a needs area for development purposes. As such, it was determined this area could be delayed until Phase 2, and revisited sooner if a significant development opportunity arises, potentially in partnership with a future interested developer.

2.2 TREATMENT PLANT IMPROVEMENTS

2.2.1 PROJECT UPDATES

The Town continues to advance planning and implementation of necessary treatment plant improvements as identified in the CWMP. Below is a summary of active project updates since approval of the CWMP:

2.2.1.1 WPCF Solids Processing Upgrade

The solids handling building, built in 1990, is critical to the wastewater treatment process at the WPCF, acting as the "guts" of the wastewater treatment facility by pumping and processing sludge from a variety of sources. The building handles up to 12,000,000 gallons of septage, 1,000,000 gallons of grease, and 11,000,000 gallons of wastewater sludge per year. The purpose of this project is to rehabilitate the solids handling building as outlined in the 2019 Solids Handling Evaluation report. This project involves the demolition and replacement of septic and sludge processing equipment that is at or past the end of its design life. This includes gravity belt thickeners, polymer systems, chemical feed pumps, odor control systems, grit classifiers, sludge tank blowers, septic receiving station, instrumentation, controls, electrical panels, and all

associated piping and valves. The septic waste receiving station will be rehabilitated and a new metering and billing system will be installed. The project addresses several safety and code deficiencies identified within the building. Instrumentation and automation will be updated, allowing for processing to occur for more hours per day which will increase the solids handling capacity of the facility. The project includes structural repairs to the building, including the sludge holding tanks.

The project was bid in the spring of 2021 and WES Construction Corporation was awarded the contract with a contract value of $10,052,296. Construction of the project commenced in August of 2021 and the project is scheduled to be completed in 2023.

2.2.1.2 Nitrogen Removal Improvements

This project involves improvements to the WPCF process in order to reduce the average total nitrogen concentration of the treated effluent discharge from the facility to an average of 3 mg/L or less, as identified in the CWMP. The WPCF is currently permitted to discharge treated effluent at a maximum nitrogen concentration of 10 mg/L. The annual average concentration achieved by the facility is currently 6 mg/L. The intent of this project is to reduce this concentration to an annual average of 3 mg/L or less. Reducing nitrogen concentration in plant effluent will reduce the total nitrogen load to the Lewis Bay watershed and minimize the number of required sewer projects in the Hyannis area to offset the nitrogen load. Additionally, reduced nitrogen concentrations may expand the Town's options for alternative effluent disposal sites.

The Town issued an RFP in the Spring of 2021 for Evaluation of Nutrient Removal Improvements at the WPCF. In the Summer of 2021, the Town selected Wright Pierce to perform the evaluation. The evaluation, which will review technology options and provide a recommended solution, is currently on-going, with the final report anticipated to be delivered to the Town in August of 2022. In the Spring of 2022, the Town Council appropriated $3,000,000 for design and permitting of the nutrient removal improvements. The Town anticipates construction of the project to commence in FY2025.

2.3 EFFLUENT DISPOSAL IMPROVEMENTS

As noted in the CWMP, the Town's Water Pollution Control Facility (WPCF) is currently permitted to treat 4.2 million gallons per day (MGD) max day flows, and dispose of 2.7 MGD max day flows via its adjacent rapid infiltration beds (RIBs). The WPCF, as of the issuing the CWMP, was receiving 1.67 MGD average daily flow, with a measured max daily flow of 2.48 MGD (on July 7, 2017). These existing flows, and the flows that will be added due to the CWMP, equate to approximately 4.5 MGD average daily flow. A disposal solution for the difference between the permitted flows and the expected flows resulting from the 30-year CWMP requires an analysis of alternative disposal methods.

The CWMP identified and discussed five categories of alternative disposal methods. These included:

- Impact Mitigation,
- Land Based Treated Effluent Disposal Options,
- Ocean Outfall Effluent Disposal Options,
- Options outside of the Town of Barnstable, and
- Groundwater extraction and disposal.

This past year the Town has been focusing the majority of its effluent disposal efforts on two of these categories: Groundwater extraction and disposal, and Land Based Treated Effluent Disposal Options. The Town retained a consultant, CDM Smith, to conduct extensive modeling in support of these two methods. Specifically, this work is focusing on two primary tasks:

- Task 1: Optimize the groundwater withdrawal scenario including locating optimal well locations based on a number of criteria to control the mound.
- Task 2: Begin site assessments and determine hydrogeological impacts of effluent disposal at various sites selected by the Town.

The Town and CDM Smith are currently finalizing the optimized effluent withdrawal scenario. Modeling continues to indicate that the Town will be able to control the groundwater mounding caused by increased effluent disposal with strategically placed withdrawal wells. This finding has led to the next point of inquiry; what to do with the withdrawn groundwater.

The Town engaged DEP, EPA water reuse experts, and a water reuse specialty team from CDM Smith to go over the various options and potential treatment requirements for the withdrawn groundwater. At a minimum we are looking at using Task 2 to model impacts of disposing it at various sites in Town. Additionally, we continue to look at other options that could result in a more beneficial use of this resource.

2.4 NON-TRADITIONAL SOLUTIONS

2.4.1 PROJECT UPDATES

In section 2.3.2 of the CWMP, the Town described multiple non-traditional projects that will be completed as part of the CWMP. Over the last year, the Town and its partners continued planning efforts for the following projects:

2.4.1.1 Cranberry Bog Restoration

As noted in the CWMP, the bogs at the head of the Marstons Mills River are considered an important component of the nitrogen management in the Three Bays watershed. The Barnstable Clean Water Coalition (BCWC) has taken the lead on this project and made significant progress in the last year. The BCWC continues to work with the EPA and USGS to perform evaluation of water quality and groundwater movement in these bogs. They received a 5-year federal grant to

support planning, evaluation, design, permitting, and implementation of a cranberry bog restoration project. The BCWC conducted ground penetrating radar surveys to locate the original path of the Marstons Mills River and develop conceptual level designs for the restoration project. Recently, they selected Inter-Fluve as the consultant to perform design and permitting of the project.

2.4.1.2 Mill Pond Dredging

The Town has performed evaluation and outreach efforts as part of this project. The Town has received easements from 3 of the 5 abutting homeowners. The Town is currently working to retain a consultant to advance the project through permitting and final design. The BCWC continues weekly flow and nutrient monitoring at multiple stations within the Marstons Mills River.

2.4.1.3 Warrens Cove

The Town has initiated preliminary surveys of the sediment volume within Warrens Cove and analysis of sediment contaminants within these sediments. This report and data is anticipated to be completed in the Fall of 2022.

2.4.1.4 Innovative/Alternative Septic Systems

The Barnstable Clean Water Coalition has been working with the EPA and USGS to identify an ideal location for assessing enhanced nitrogen reducing I/A septic systems, specifically the NITROe and Layer Cake systems. The project is currently being conducted in the Sand Shores neighborhood near Shubael Pond. The USGS/EPA collected preliminary groundwater data at several wells in the area, while BCWC financed and coordinated the implementation of 14 NITROe systems and 1 Layer Cake system in this neighborhood. All systems are anticipated to be in the ground by fall 2022. As systems come online, the Massachusetts Septic System Test Center (MASSTC) begins performing monthly sampling of the systems to evaluate nitrogen influent and effluent. This data is being compiled and is available upon request from BCWC and MASSTC.

2.5 INTER-MUNICPAL COLLABORATION

As noted in the CWMP, the Town of Barnstable shares watersheds with the Towns of Mashpee, Sandwich, and Yarmouth. Additionally the Town has worked with other entities, such as the Joint Base Cape Cod (JBCC), on wastewater solutions.

2.5.1 SANDWICH

The Town continues to have conversations with the Town of Sandwich. These conversations have focused on three related topics:

1. The best means to address the joint responsibilities regarding the Three Bays Watershed,

2. The potential for a shared facility located in Sandwich that would allow Sandwich to address its wastewater requirements and take wastewater flows from the western section of Barnstable, and
3. The potential to collaborate with the new private entity managing the JBCC wastewater facility.

As noted these discussions are interlinked as one's solution will affect the other concerns. These are ongoing and expected to continue over at least the next reporting period.

2.5.2 MASHPEE

The Town continues to have conversations with the Town of Mashpee regarding the Popponesset Bay Watershed. However, there are no significant updates to report since the approval of the CWMP.

2.5.3 YARMOUTH

The Town continues to have conversations with the Town of Yarmouth regarding the Lewis Bay Watershed. However, there are no significant updates to report since the approval of the CWMP.

2.5.4 JOINT BASE CAPE COD

During this reporting period, the Department of Defense announced its intent to award a utility service contract to Converge Partners. As was noted in the CWMP, the Town of Barnstable partnered with Converge Partners in its application for this utility. As was also previously noted, for JBCC to be an effective option for multiple communities' wastewater, it would need to have its effluent disposal capacity expanded. To this end, the Town of Barnstable joined with the Town of Sandwich in submitting and subsequently receiving a FY'22 Efficiency and Regionalization Grant Application. This grant request will be focused on how best to expand JBCC's disposal capacity, identify the public, private, and non-profit groups that will play a role in this effort, and perform technical work on how this expansion can best be accomplished. Specific tasks included:

- Implementation Plan for Land Acquisition and Environmental Permitting of Effluent Disposal,
- Research and outline land ownership/availability and data needs for land acquisitions and environmental permitting for land-based disposal (RIBs and/or wicks) and for surface water disposal (Cape Cod Canal outfall),
- Arrange for and attend meetings with EPA, USACE, MassDEP, MassCZM, and Environmental Management Commission to advance discussions regarding land ownership/availability and data needs for land acquisitions and environmental permitting,

- Arrange for and attend meetings with non-governmental organizations (e.g., Buzzards Bay Coalition, Conservation Law Foundation) to understand the potential concerns, comment, opposition and/or support for effluent disposal method(s) and location(s), and
- Develop an implementation plan for land acquisition and environmental permitting. Document in a technical memorandum.

Both the above mentioned grant effort and continued conversations with Converge Partners will continue in the next reporting period.

3.0 WATER QUALITY MONITORING

The Town continues to perform robust water quality monitoring programs for embayments, ponds, and lakes. Each program is described below.

3.1 EMBAYMENT MONITORING

The Town of Barnstable, along with the Barnstable Clean Water Coalition and citizen volunteers, completed the 20th year of annual monitoring in 2021. Water quality samples were collected at a total of 85 stations in Barnstable Harbor, Lewis Bay, Halls Creek, Centerville River, and Three Bays. In addition, Barnstable and Yarmouth share Lewis Bay; therefore the Town's coordinate each season to collect samples on the same schedule. Barnstable and Mashpee share the Popponesset Bay estuary; however Mashpee coordinates and conducts the sampling for this shared estuary independently. Each spring the Town schedules water quality training with the Coastal Systems Program at UMass Dartmouth School for Marine Science and Technology (SMAST) to review the sampling protocols. Sample collection occurs four times annually July through September on a mid-ebbing tide between 6am-9am. Water quality samples are collected for nitrogen (DON, PON, NOx, NH4, TN), ortho-phosphate, dissolved oxygen, temperature, salinity, and chlorophyll-a pigments. Water samples are analyzed by the Coastal Systems Analytical Facility at SMAST. The tabulated has been incorporated into a database which will be provided electronically under separate cover.

3.2 PONDS AND LAKES MONITORING

The Town of Barnstable has approximately 180 ponds and lakes, 25 of which are Great Ponds. The Town has two major programs for monitoring water quality in several ponds and lakes throughout the Town, the Ponds and Lakes Stewardship (PALS) Program and Cyanobacteria Monitoring. In addition, the Town has undertaken a program to develop management plans for impaired ponds, with three of these plans currently underway.

3.2.1 PONDS AND LAKES STEWARDSHIP (PALS) PROGRAM

The PALS Program has been ongoing since 2001 and continued through 2021. This program provides an annual snapshot of pond and lake water quality during the late summer (mid-August to mid-September), capturing the worst case scenario for pond and lake water quality. In April 2021, the Town also initiated an effort to perform a PALS snapshot in April to assess pond and lake water quality when the ponds are cold, well oxygenated, and mixed throughout the water column. The spring snapshots will provide a baseline for comparison to the fall water quality conditions to understand the extent of water quality changes that occur from the April to late summer.

In 2021, the Town of Barnstable partnered with several organizations to complete the 2021 PALS spring and fall sampling events. These organizations included:

- Barnstable Clean Water Coalition
- Indian Ponds Association
- Wequaquet Lake Protective Association
- Concerned Citizens of Long Pond Centerville
- Friends of Long Pond Marstons Mills
- Red Lily Pond Protective Association

Samples were collected in the spring and fall at all 25 Barnstable Great Ponds, plus an additional 14 ponds in the fall of 2021. Samples were collected at the deepest location of each pond following the PALS protocol. Water quality samples are sent to the Coastal Systems Program Analytical Facility at the University of Massachusetts Dartmouth School for Marine Science and Technology for analysis. Data is shared with the Cape Cod Commission and Association to Preserve Cape Cod to be compiled into the annual State of the Waters update.

The Town of Barnstable also retained the School for Marine Science and Technology to develop a database and complete a review of all the ponds and lakes water quality data. This report was completed in 2021, providing a database of water quality data for a total of 55 ponds and water quality summaries for a total of 32 ponds, including all 25 Great Ponds in Barnstable. This report has been included as Attachment D and the database will be provided electronically under separate cover.

3.2.2 CYANOBACTERIA MONITORING PROGRAM

The Town of Barnstable Division of Health initiated routine cyanobacteria monitoring for ponds and lakes beginning in 2008. In 2021, the Town of Barnstable contracted with the Association to Preserve Cape Cod (APCC) to continue administering this program and providing weekly reports to the Town regarding the status of cyanobacteria and more importantly harmful cyanobacteria blooms in Barnstable Ponds. Routine sampling and reporting was completed on a weekly to monthly basis at a total of 28 ponds (40 sites in total). Through this monitoring program, the Town of Barnstable Health Division administered Warnings and Pet Advisories following the 2021 Criteria at the ponds listed in Table 2 and Table 3. Table 2 provides a summary of warnings which were posted during the 2021 season. These warnings were based on visible significant scum or estimated microcystin toxin over 8-ppb based on the University of New Hampshire cyanocasting methodology. Table 3 provides a summary of pet advisories which were posted during the 2021 season. These posting were based on estimated microcystin toxin between 4-8-ppb based on the University of New Hampshire cyanocasting methodology.

Table 2: Summary of Warnings

Pond Name	Duration of Warning (weeks)
Long Pond MM	15
Lovells Pond	14
Shubael Pond	6
Muddy Pond	6
Parker Pond	5
Long Pond Centerville	3
Fawcett Pond	2

Table 3: Summary of Pet Advisories

Pond Name	Duration of Pet Advisory (weeks)
Shubael Pond	6
Lovells Pond	4
Long Pond Centerville	3
Long Pond MM	1
Parker Pond	1
Schoolhouse Pond	1

3.2.3 PONDS AND LAKES MANAGEMENT PLAN PROGRAM

The Town of Barnstable has initiated a Ponds and Lakes Monitoring and Management Plan program in an effort to fully identify and remedy issues such as excessive nutrients, low dissolved oxygen, cyanobacteria, and invasive species, that inhibit the use of our freshwater resources. The Monitoring phase includes monitoring for water quality, dissolved oxygen conditions, phytoplankton composition (including cyanobacteria), rooted vegetation survey, mussel survey, stormwater and stream inputs and output monitoring (when applicable), and sediment core collection to determine nutrient regeneration from the sediments. The information is analyzed in junction with a watershed assessment, which provides the groundwater related inputs to the pond. Together, this information is compiled and presented to the Town in a Management Plan Report. Key components of this report include: if the pond is impaired due to phosphorus and/or nitrogen loading, which nutrient sources are contributing the impairment, and a list of management solutions that could be implemented to reduce nutrient inputs and improve water quality conditions. Solution options often include options that can be taken within the watershed (sewers, advanced IA systems, stormwater reduction, etc.) and within the pond (aeration, alum treatment, dredging, etc.) solutions to reduce nutrient inputs and improve water quality.

Once the management plan is received, it will be shared on the Town's web-site and presented to Town stakeholders to decide which solution(s) will be implemented to improve pond water quality. In addition, the Town will share the final management plan reports with the Cape Cod Commission.

The mechanism for deciding which ponds will be selected for management plans and solution implementation has been developed by staff in the Town's Public Works, Conservation, Health, and Natural Resources departments. Inputs from these departments, developed a set of criteria based on water quality history, cyanobacteria history, level of recreational opportunities (how much our public interacts with a particular pond), etc. to prioritize which ponds should be prioritized for a monitoring and management plan. This list will be updated annually based on the most recent information for water quality conditions, determined through the active water quality monitoring programs (PALS, cyanobacteria monitoring, etc.).

The Town has selected one pond per year for development of a management plan starting in 2020. The first three ponds which have been selected for the development of a management plan are: Shubael Pond, Long Pond Marstons Mills, and Lovell's Pond. As of the writing of this report, all three plans are in development.

4.0 OUTREACH AND ENGAGEMENT

The Town of Barnstable undertook a robust outreach effort during the development of the Comprehensive Wastewater Management Plan (CWMP). This outreach effort was successful in explaining the need for the CWMP, and engaging community input in specific design decisions around components such as pump stations. However, it is recognized that ongoing and coordinated engagement is needed to address a range of communications issues associated with financing and implementation of the CWMP.

In 2021 the Town engaged Ridley & Associates to work with DPW and other town departments to develop a communications plan to build broad-based community support needed to finance and implement the CWMP. The communications plan identifies objectives to achieve this goal:

1. Make a compelling case for the need to implement the CWMP and outline the implications of inaction.
2. Develop information to clearly explain the CWMP and how it will be implemented.
3. Ensure that this information is accessible through a variety of formats and platforms, including those accessible to traditionally harder to reach segments of the community.
4. Build broad based support and engage community networks to help convey timely and accurate information about the CWMP.
5. Identify and proactively address questions and concerns about implementation measures.
6. Create effective feedback loops to evaluate and adjust communications.

Many outreach actions recommended in the plan have been initiated or are ongoing. A summary of progress to date and recommended action items is provided below.

4.1 PUBLIC ENGAGEMENT

General education efforts are aimed at informing and engaging all segments of the community about the need to take action to protect water resources and quality of life. Information is designed to:

- Re-enforce the connection between implementing the plan and protecting the health of water resources that are central to quality of life and economic well-being in the community.
- Simplify information about technical aspects including projects and scheduling, the sewer connection process, financial implications for property owners; and other technical issues such as effluent disposal.

- Get ahead of issues that could create confusion or frustration among members of the pubic, including around construction-related traffic management and the sewer connection process.

Multiple public engagement sessions were conducted virtually to discuss a draft Sewer Assessment Ordinance. The sessions were publicized in the local media, via social media, by email and e-newsletters sent directly to civic associations and other community groups and individuals, and on Channel 18. The virtual engagement sessions were conducted via Zoom as a webinar and streamed live on Facebook and aired live on Channel 18 and streamed live on the Town's website. Approximately 150 citizens participated in the live sessions via Zoom and Facebook, and others viewed live on Channel 18. The sessions were recorded and posted to the website where they had more than 2,000 viewings of the three presentations. Feedback from the sessions provided the basis for amendments to the draft and the Town Council ultimately approved the Sewer Assessment Ordinance without opposition in July 2021.

4.2 VARIOUS COMMUNICATION METHODS

A summary of various communications methods being utilized are summarized below.

- The Town launched a dedicated Barnstable Water Resources website to provide one-stop access to current news and information about the CWMP and implementation efforts. Property owners can use the site's "property look-up" tool to find out if their property is included in one of the three sewer expansion phases. An introductory video has been added to the home page to introduce users to the site and explain where they can find information. Separate website landing pages are dedicated to Phase 1 Project Descriptions, Construction Updates including current traffic detours, and a Sewer Service Connection Center, which provides comprehensive information and forms to property owners needing to connect to the sewer service system. The site also provides access to primary documents such as the CWMP, Sewer Assessment Ordinance, and links to significant public presentations.
- A Community Currents e-newsletter is distributed electronically approximately once per month to provide regular updates on the CWMP, construction schedules, Town Council meetings and hearings, and other pertinent news. Website visitors and others are encouraged to sign up for the monthly e-newsletter.
- A CWMP overview brochure was developed to provide concise and accessible overview of Phase 1 implementation, with project-specific information. The brochure is used in mailings, at town events and through door-to-door outreach. The brochure is being translated into Spanish and Portuguese and all three versions will be available in print and posted electronically to the Barnstable Water Resources website.

- The DPW Director provides monthly briefings during regularly scheduled Town Council meetings. The briefings incorporate information about the CWMP overall and the status of individual projects. The presentations are video-taped and aired on Channel 18. Content from the presentations is used in the Community Currents e-newsletter and on social media.
- Media releases are distributed for all public meetings and major project milestones. The Town's media distribution list includes all civic and village, chambers, regional environmental groups, elected officials and other interested stakeholders so that current information is sent directly to groups that can distribute through their established networks.
- The Town Communications Division regularly posts content about the CWMP to the Town's social media accounts (Facebook, Twitter, Instagram). An Instagram page focused on water was added in December 2020 and now has more than 1, 000 followers. The Town of Barnstable YouTube channel, also with a water focus, was also created.
- The Town Council funded a new full-time CWMP Communications Manager position in the FY2023 budget. The Town anticipates filling this position in the Fall of 2022.

4.3 CONSTRUCTION OUTREACH

There are 17 Phase 1 sewer expansion projects to be implemented over the next 30 years, multiple sewer expansion projects under various stages of construction at any one time. Focused communications strategies are needed to:

- Develop protocols and procedures for outreach to properties on proposed Phase 1 sewer expansion routes, to introduce the project, explain the connection process and address technical issues and questions, and
- Provide accurate and current information about dynamic traffic management conditions in order to minimize disruption and inconvenience to local residents and businesses, as well as schools, emergency services and regional travelers.

4.3.1 PROJECT SPECIFIC OUTREACH

4.3.1.1 Strawberry Hill Road Sewer Expansion Project

- DPW personnel attended multiple meetings of the Centerville Civic Association to present information about a proposed pump station and to share information about the timeline for construction and sewer service connection.
- The Town hosted a Strawberry Hill groundbreaking event (Friday, September 17, 2021) to mark the launch of the first major Phase 1 project and demonstrate momentum in the implementation of the CWMP. Town Council members, town administration, and DPW

personnel were joined at the event by Congressman William Keating, State Senator Julian Cyr, Rep. Kip Diggs, MassDEP Assistant Commissioner Kevin Moran, and Cape Cod Commission Executive Director Kristy Senatori.

- Sewer service connection informational materials were mailed to approximately 300 property owners last July. Materials included links to the Barnstable Water Resources website, sewer connection questionnaires and contact information for DPW personnel to answer questions.
- Door-to-door outreach to the approximately 300 property owners along the Strawberry Hill Road sewer expansion service area began Fall 2021. In addition to providing project information and answering questions, the visits are an opportunity for property owners to subscribe to email alerts and e-newsletters and receive ongoing information.
- DPW personnel take an active role in communicating to affected businesses the coming impact to their customers ahead of a new traffic shift. This has been especially important for medical offices and anywhere that schedules by appointment. The timing of this door-to-door outreach has helped with the accuracy of the information being provided and serves as a refresher from the initial outreach done in fall 2021.

4.3.1.2 Route 28 East Sewer Expansion Project

- In November 2021, the Town conduced a virtual project-related community outreach meeting to explain the Route 28 East sewer expansion project.
- Sewer service connection informational materials were mailed to approximately 90 property owners this summer.
- Door-to-door outreach to properties along the Route 28 East Sewer Expansion route will take place late summer and into the fall.
- Periodic field meetings with property owners are planned.

4.3.2 TRAFFIC MANAGEMENT

- The Town has adopted use of the WAZE mobile application to make current traffic detour information accessible on any mobile device using the WAZE app or Google Maps.
- Updates on traffic information are distributed to the media and community distribution list, distributed via email alert, posted on social media, and posted to the Construction Updates page of the Barnstable Water Resource website.

4.4 SUMMARY OF PRIORITY ACTION ITEMS

Engagement activities in the year ahead will build on the solid foundation achieved in the prior year. Continuing engagement activities will focus on (1) consistent messaging to link the CWMP to quality of life in the community, (2) direct outreach to village and civic associations, other community groups, and property owners on the sewer expansion routes, (3) use of media and social media, particularly efforts to leverage existing community networks, and (4) publication of high quality printed, video and audio materials to support outreach and engagement. Priorities are summarized below.

4.4.1 MESSAGING

- Develop additional messaging to (1) identify the specific watersheds and water bodies that individual projects will protect; (2) raise the profile of the non-traditional nitrogen reduction measures the town may be undertaking; (3) inform the public about complex issues such as effluent disposal and the next steps with the fiscal plan; and (4) relate the CWMP to the community's vision for a clean environment and sustainable economy.

4.4.2 GENERAL OUTREACH

- Complete the Sewer Service Connection Guide and publish in print and electronic format.
- Develop additional print and video "explainers" re: financial implications of sewer connection; sewer connection process; what to expect during construction.
- Continue efforts to reach out to harder-to-reach segments of the community, including youth, young families, and non-English speaking members of the community.
- Publish and distribute the updated overview brochure, including translations into Portuguese and Spanish.
- Continue use of on media and social media to explain the connection between CWMP implementation and protecting water resources that are key to quality of life, and to share project-related news.
- Continue monthly publication of the Community Currents e-newsletter
- Continue to build content on the Barnstable Water Resources website.
- Continue outreach and briefings to village associations and community groups, with a focus on areas where sewer expansion construction activity is underway or soon will begin.
- Consider development of public display materials to create an engaging presence at street fairs and in public venues.

4.4.3 CONSTRUCTION COMMUNICATION

- Identify the likely timing of upcoming public meetings and construction milestones over the next 12 months.
- Codify the standard outreach/communications protocol for all construction projects by building on the outreach applied to the Strawberry Hill Road and Route 28 East sewer expansion projects.
- Continue to develop internal processes to manage and communicate traffic detours and disruptions.
- Complete door-to-door outreach for the Strawberry Hill and Route 28 East Sewer Expansion projects and conduct regular field meetings for property owners affected by those projects as needed.

4.4.3 COORDINATION CAPACITY BUILDING

- Add capacity and protocols for handling incoming public inquiries and troubleshooting.
- Enhance the efficiency of the feedback loop on the internal review of communications materials and recommendations.
- Continue to develop the Google calendar as a planning and tracking tool for communications efforts.

5.0 FINANCIAL PLAN UPDATE

5.1 FUNDING SOURCES

The Town of Barnstable continues to explore various avenues of funding for the CWMP. The initial funding sources are listed below including information on the revenue generated:

5.1.1 MEALS TAX AND ROOMS TAX ON TRADITIONAL LODGING

One-hundred percent (100%) of the Town's local meals tax and one-third (33%) of the local rooms tax on traditional lodging are dedicated to funding the CWMP. These revenue sources performed very well in fiscal year 2022 as post-pandemic activity in the hospitality and tourism industry has improved. Total revenue collected in fiscal year 2022 was $3,017,765 which exceeded any pre-pandemic year.

5.1.2 SHORT-TERM RENTAL TAX

The Barnstable Town Council approved the creation of a Stabilization Fund which dedicates one-hundred percent (100%) of the Town's local rooms tax on short-term rentals for the purpose of Comprehensive Water Management. This can include water and wastewater expenditures. The total amount collected in fiscal year 2022 was $1,729,592; the highest annual amount collected since inception. $318,229 was used for water related funding and $0 for the CWMP.

5.1.3 CAPE COD & ISLANDS WATER PROTECTION FUND (CCIWPF)

The town was awarded contingent commitment for subsidy totaling $11,172,460 for clean water projects listed on the State Department of Environmental Protection's (DEP) 2020 and 2021 Intended Use Plan (IUP). In addition, $1,210,575 was awarded for pre-existing debt on clean water projects. More recently, the town was notified that is was awarded a contingent commitment for subsidy from the CCIWPF totaling $1,385,000 for a project listed on DEP's 2022 IUP.

5.1.4 SEWER ASSESSMENTS

The Barnstable Town Council has adopted a sewer assessment ordinance that went into effect July 1, 2021 (see Attachment E). The sewer assessment is capped at $10,000 per dwelling unit and the amount can be changed annually by the Town Council to recognize a factor for inflation if deemed necessary. The town anticipates issuing its first sewer assessments in fiscal year 2024. The key components of the ordinance are as follows:

- Assessments are initially capped at $10,000 per dwelling unit and can be adjusted annually for inflation by a construction cost index

- A dwelling unit is defined as one or more rooms providing complete living facilities for one family. Living facilities that contain one bedroom or fewer shall be a half dwelling unit.
- A commercial sewer unit shall be the equivalent to 330 gallons of actual or reasonably anticipated daily sewage volume.
- The Uniform Unit Method will be the basis for determining sewer assessments.
- The construction costs of general and special benefit facilities will be considered when determining the sewer assessment per dwelling unit.
- Assessments will not apply to properties that already had the ability to connect to the public sewer system prior to the passage of this ordinance.
- A compensatory Sewer Privilege Fee can be assessed when a change in use or intensity of use occurs on a property.
- Sewer connection costs can be added to the assessment if the Town performs the connection.
- The interest rate on the assessment if apportioned to future tax bills will be 2% above the town's borrowing rate to construct the project.
- Assessments can be apportioned for up to 30 years and added to the annual property tax bills.
- Assessments can be deferred for certain qualified property owners in accordance with MGL Chapter 83, Section 16G.
- An abatement process is provided if a property owner believes they were assessed incorrectly.

5.1.5 SYSTEM DEVELOPMENT CHARGES

No action has been taken to date on implementing such a charge. The most recent conclusion was that this type of charge created too much confusion and was considered unnecessary when revenue to be generated from assessments and property tax contributions can replace any revenue this charge would generate.

5.1.6 DEBT ISSUES

The town continues to seek financing its CWMP capital costs through the MA Clean Water Trust. Several projects listed on the 2020, 2021 and 2022 IUP's will be financed through the Trust. Projects that did not make the IUP list will be lumped together with other borrowing authorizations and financed through the traditional municipal bond market.

5.1.7 FEDERAL AND STATE GRANTS

The Town of Barnstable was awarded a grant of $1,965,219 from Barnstable County as its share of the County's ARPA grant funds. The Town has submitted an application to use these grants funds to offset a portion of its $11 million pump station project at 725 Main St. Hyannis.

5.1.8 PROPERTY TAXES

As part of the Town's Fiscal Year 2023 operating budget development a plan to dedicate $750,000 of the town's property tax growth derived from new development is dedicated for funding the town's capital program including the CWMP. This creates an annual base property tax contribution to the town's capital program that is expected to continue for 5 years. By the fifth year of this plan, an annual total of $3,750,000 will be dedicated to the annual capital budget including the CWMP. Additionally, a recommendation was made to the Town Council to finance any funding gap for implementing the projects listed for the next five years in the CWMP's project list with a debt exclusion. A vote for a debt exclusion will be necessary by the Fall of 2023 (FY24) in order to keep the program moving forward as planned. The estimated annual impact of the debt exclusion on a median assessed value home would be $91 per year.

5.2 FINANCIAL ASSISTANCE FOR LOW INCOME RESIDENTS

The sewer assessment ordinance adopted by the town allows for the apportionment of the assessment to be added to future tax bills for up to 30 years. This minimizes the financial impact on an annual basis for a property owner. In addition, the town adopted the provisions of section 16G of chapter 83 of the General Laws that allow certain eligible property owners to defer payments of sewer assessments.

5.3 OPERATING BUDGET

As part of the town's annual operating budget process, it has established staffing with corresponding operating expense budget support for the implementation of its CWMP. The fiscal year 2023 operating budget includes funding for 16.85 full-time equivalent (FTE) employees which include Project and Construction Inspectors, Construction and Design Engineers, Project and Design Managers, a Communications Manager and a Sewer Assessment Coordinator and Procurement staffing. Operating expenses include funding for legal assistance, hardware and uniforms for professional staff, training, advertising, safety equipment and vehicles.

The approved operating budget for fiscal year 2023 is $3,945,923. This includes over $1.2 million for personnel costs, $240,000 for operating expenses, $2.2 million for debt service on sewer construction related debt and $300,000 for vehicle purchases.

Ultimately 25 FTEs are projected to be needed when the program nears the end of Phase I (first ten years). The operating budget is expected to incrementally increase on an annual basis to

reflect the growth in staffing as well as the loan repayments on bonds issued to fund the expansion of the public sewer system.

5.4 FINANCIAL PROGRAM SUMMARY FOR FY23 TO FY27

- Estimated project costs are $304 million.
- Existing resources dedicated to the program can provide for approximately $165 million of this cost.
- An additional $5.5 million is needed annually to cover the remaining costs within this 5 year period.
- A debt exclusion vote should take place before contracts are awarded for the FY 2025 construction projects.
- A vote by the Fall of 2023 (FY24) would allow for better FY 2025 budget development planning.
- Additional resources will likely be required to fund the next 5 year phase occurring in FY28 – FY32.
- The town will continue to pursue direct grant funding opportunities to offset a portion of these costs.

The most recent review of a system development charge determined this charge would cause undo confusion and was deemed an unnecessary charge based on the revenue to be generated from assessments and property tax contributions.

6.0 LAND USE AND MANAGEMENT CONTROLS

The Town of Barnstable is currently in the process of updating its Local Comprehensive Plan. Last updated in 2010, the Town's current plan establishes strong direction and associated controls to concentrated new growth to areas with existing infrastructure and away from sensitive natural resource areas. An update to the Local Comprehensive Plan will establish a vision, goals, and an action plan to identify appropriate regulatory tools, as well as their advantages, disadvantages, and feasibility. The current plan does not account for the extensive sewer expansion currently underway and planned. It is imperative the Town anticipate and establish controls to prevent sewer induced growth in areas where growth could conflict with natural resources or community character priorities.

The Town continues to pursue financing through the State Revolving Fund (SRF) for wastewater infrastructure projects. As regulations and requirements change, continued planning and analysis will be required to comply. For example, flow neutral regulations will need to limit wastewater flows in compliance with the allowable rates.

7.0 DATA

7.1 GIS-BASED TOOL UPDATE

The Department of Public Works has updated its GIS based planning tool to be utilized for both planning and tracking of implementation of the CWMP. The updated tool, referred to as the "CWMP Implementation" tool is an internal web-based, GIS lite application. A screenshot from the Implementation Tool is provided below in Figure 1. Staff continues to utilize and refine the tool as implementation progresses. Relevant functions of the tool include, but are not limited to:

- Identification of proposed Phase 1 project extents:
    - This function identifies each parcel to be connected to municipal sewer as part of each particular Phase 1 project. Each parcel has dozens of embedded data fields which can be utilized to track project status/effectiveness.
    - Uses of this function include:
        - Graphical representation of the project areas
        - Simplify output of properties within the project area for mailing of notifications to property owners within the project areas.
        - Calculations of sewer assessments.
        - Tracking of connections, nitrogen removal, etc.
- Overlay of schematic sewer design, anticipated flow volume and direction, anticipated pump station locations:
    - This function graphically represents the schematic design of the proposed sewer expansion. This function is utilized by staff for planning purposes.
- Sewer connection permits, tie cards and as-built drawings.
    - Centralized records of all connections and as-built information.
- Environmental conditions, topography, regulatory overlays, flood zones, etc.
    - Utilized by staff for planning purposes.

As sewer connections are completed, parcel status will be updated to allow on demand calculation of estimated wastewater flow captured and nitrogen load removed.

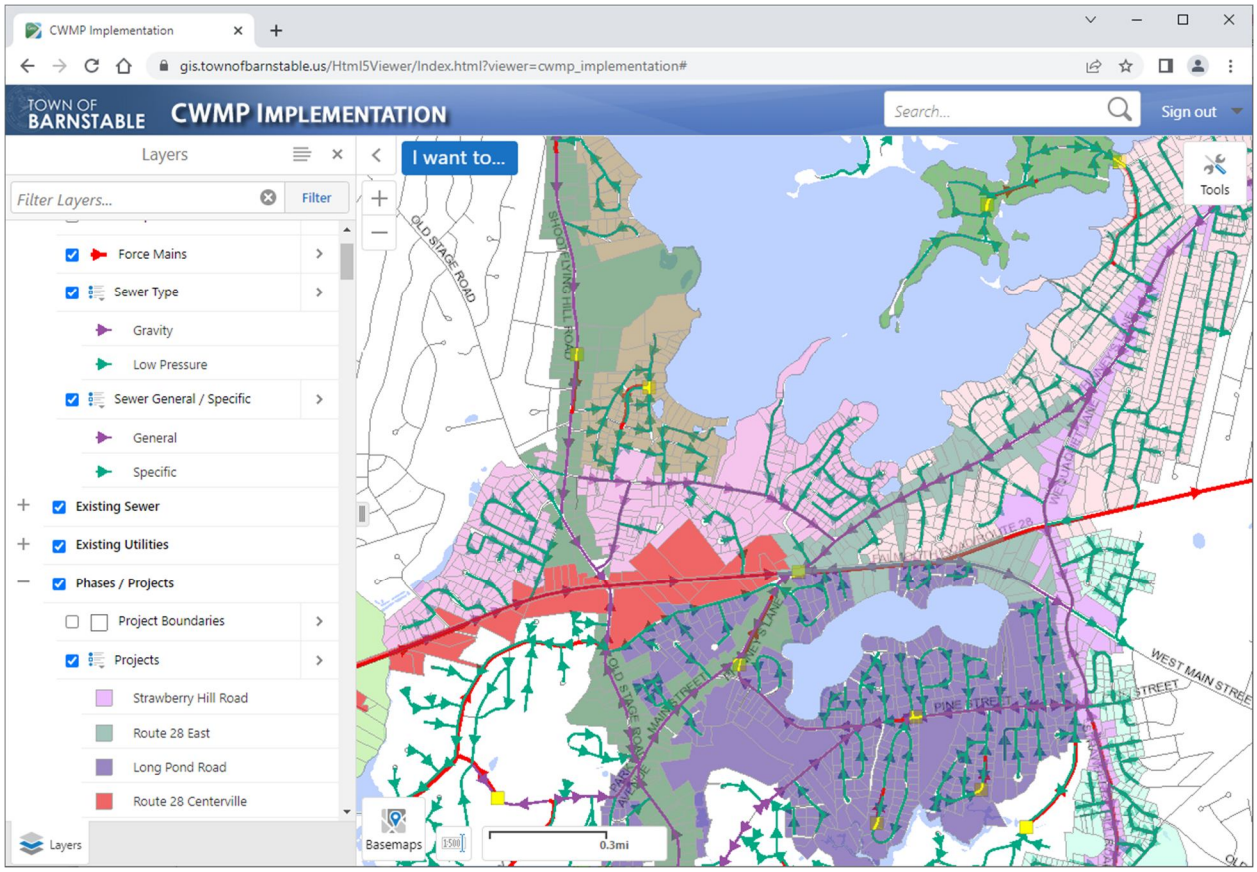


Figure 1: Screenshot from Town's CWMP Implementation GIS Tool

7.2 SEWER CONNECTION DATA

Table 4 provides the list of new sewer connections that were completed from December 29, 2020 to July 1, 2022. All of these connections and disconnections are located within areas where municipal sewer exists prior to the approval of the CWMP. No new sewer connections have been completed within the proposed sewer expansion areas identified in the CWMP as no sewer expansion project has been completed to date.

Table 4: Sewer Connections

Parcel ID	Street Address	Village	Watershed	Use	Date Connected
301/040	30 Commerce Road	Barnstable	BH	Residential	12/29/2020
319/059	69 George Street	Barnstable	BH	Residential	05/27/2021
301/001	145 Salten Point Road	Barnstable	BH	Residential	06/14/2021
274/040/002	6 Aggregate Way	Barnstable	BH	Commercial	06/17/2021
299/061	1680 Hyannis Road	Barnstable	BH	Residential	09/03/2021
298/021/001	1536 Hyannis Road	Hyannis	BH	Residential	12/22/2021
301/045	60 First Way	Barnstable	BH	Residential	03/31/2022
298/021	1526 Hyannis Road	Hyannis	BH	Residential	04/22/2022
250/090	22 Brian Lane	Hyannis	CR	Residential	05/06/2021
269/159	326 West Main Street	Hyannis	Halls Creek	Commercial	02/12/2021
250/036	850 Falmouth Road	Hyannis	Halls Creek	Residential	01/21/2022
306/003	23 Keating Road	Hyannis	Lewis Bay	Residential	11/10/2020
287/120	10 Hyannis Avenue	Hyannis	Lewis Bay	Residential	~12/01/2021
325/122	97 Harbor Bluffs Road	Hyannis	Lewis Bay	Residential	~12/01/2021
307/240	51 Nautical Road	Hyannis	Lewis Bay	Residential	04/12/2021
273/123	1174 Pitcher's Way	Hyannis	Lewis Bay	Commercial	05/14/2021
290/084	27 Betty's Pond Road	Hyannis	Lewis Bay	Commercial	05/26/2021
324/079	28 Folsom Avenue	Hyannis	Lewis Bay	Residential	05/27/2021
290/089	67 Betty's Pond Road	Hyannis	Lewis Bay	Residential	11/11/2021
289/101	65 Greenwood Avenue	Hyannis	Lewis Bay	Residential	12/14/2021
327/068	49 Center Street	Hyannis	Lewis Bay	Commercial	01/24/2022
308/089	39 Pearl Street	Hyannis	Lewis Bay	Residential	~02/01/2022
325/120	125 Harbor Bluffs Road	Hyannis	Lewis Bay	Residential	~02/01/2022
307/031	106 Seabrook Road	Hyannis	Lewis Bay	Residential	03/10/2022
306/249	15 Carl Avenue	Hyannis	Lewis Bay	Residential	03/16/2022
288/148	166 Greenwood Avenue	Hyannis	Lewis Bay	Residential	03/31/2022
324/079	28 Folsom Avenue	Hyannis	Lewis Bay	Residential	03/31/2022
306/224	269 Gosnold Street	Hyannis	Lewis Bay	Residential	04/11/2022

Notes:
1: BH = Barnstable Harbor
2: CR = Centerville River

7.3 TECHNOLOGY PERFORMANCE DATA

There is no technology performance data to report in this annual update.

7.4 BUILDING PERMIT DATA

The Town of Barnstable compiles the building permit data on an annual (calendar year) basis. Building permit data for calendar year 2021 has been provided in Table 5.

Table 5: Sewer Connections

Parcel ID	Street Address	Village	Square Footage Added	Bedrooms Added	Date
139/085	176 Washington Avenue	Osterville	6,633	7	02/02/21
064/055	394 Regency Drive	Marstons Mills	1,850	3	02/16/21
078/013	130 River Road	Marstons Mills	1,320	3	03/22/21
298/021/001	1536 Hyannis Road	Barnstable	2,600	4	04/09/21
142/083	99 Stone Horse Road	Osterville	2,400	3	04/28/21
257/010/002	31 Aberle Way	Barnstable	3,059	3	05/13/21
324/107	33 Circuit Avenue	Hyannis	672	0	05/17/21
193/260	6 Vista Circle	Centerville	960	1	07/12/21
193/259	8 Vista Circle	Centerville	1,536	3	07/15/21
090/008	979 Sea View Avenue	Osterville	2,400	3	08/04/21
070/008/006	591 Grand Island Drive	Osterville	4,207	4	08/25/21
245/090	127 Fifth Avenue	Hyannis	816	0	09/13/21
022/064	51 Ralyn Road	Cotuit	2,600	3	09/21/21
327/133	40 Pleasant Street	Hyannis	3,794	6 DUs	04/12/21
327/134	50 Pleasant Street	Hyannis	10,105	19 DUs	05/16/21

Note: DUs = Dwelling Units

7.5 ASSESSORS DATA

The Town of Barnstable updates the data annually. The data was last updated January 1, 2022. The updated shape file will be provided electronically under separate cover.

7.6 WATER USE DATA

Water use data has been compiled through 2016. We are compiling data through 2021 and anticipate this data compilation to be completed in October. The updated data set and shape file will be provided electronically under separate cover.

7.7 WATER QUALITY DATA

The Town's updated embayment water quality monitoring data and ponds and lakes water quality monitoring data will be provided electronically under separate cover.

ATTACHMENT A

FY2022 SEWER EXPANSION PHASING PLAN UPDATE

TOWN OF BARNSTABLE
COMPREHENSIVE WASTEWATER MANAGEMENT PLAN
FY2022 SEWER EXPANSION PLAN UPDATE

- Existing Sewer
- Phase 1 Sewer: 1-10 years
- Phase 2 Sewer: 11-20 years
- Phase 3 Sewer: 21-30 years
- Stage 1
- Stage 2
- Stage 3

Sandwich
Mashpee
Barnstable Harbor
Yarmouth
Mystic Lake
Middle Pond
Hamblin Pond
Shubael Pond
Lake Wequaquet
Long Pond
North Bay
East Bay
West Bay
Cotuit Bay
Centerville Harbor
Lewis Bay

N
W
E
S

0 0.5 1 2 miles

1 inch = 4,000 feet

ATTACHMENT B

FY2022 PHASE 1 IMPLEMENTATION PLAN UPDATE

- Strawberry Hill Road
- Route 28 East
- Long Pond Area
- Route 28 West
- Great Marsh Road
- Vineyard Wind 2 Route
- Old Craigville Road
- Osterville-West Barnstable Road
- Osterville Woods
- Lumbert Mill
- Marstons Mills Main Street
- Prince Cove
- Shootflying Hill Road
- Kidds Hill Area
- Phinneys Lane
- Long Beach
- Huckins Neck
- Merchants Way
- Old Yarmouth Road
- Conceptual Sewer, Phase 2: 11-20 years
- Conceptual Sewer, Phase 3: 21-30 years

TOWN OF BARNSTABLE
COMPREHENSIVE WASTEWATER MANAGEMENT PLAN
FY2022 PHASE 1 IMPLEMENTATION PLAN UPDATE

N
W E
S

Middle Pond
Shubael Pond
Hamblin Pond
Lovell's Pond
Lake Wequaquet
Long Pond
Yarmouth
North Bay
East Bay
Centerville Harbor
Hyannis Harbor
Lewis Bay

E:\Sewer Expansion Projects\2019-13 Strawberry Hill Road- VW- 2_Sewer Expansion Project\ArcGIS\2020-12-08 VW-Strawberry Hill- GBS and SBS Figure.mxd

1 inch = 3,000 feet

ATTACHMENT C

FY2022 PHASE 1 SEWER EXPANSION PROJECTS
CAPITAL PLAN UPDATE

Sewer Expansion Collection System Projects - Phase 1																
				Phase 1											Phase 2	
Project	**FY19**	**FY20**	**FY21**	**FY22**	**FY23**	**FY24**	**FY25**	**FY26**	**FY27**	**FY28**	**FY29**	**FY30**	**FY31**	**FY32**	***TOTAL***
Merchants Way															***$0***
Strawberry Hill Road		*$835,000*	*$10,600,000*												**$11,435,000**
Route 28 East		*$800,000*		*$22,000,000*											**$22,800,000**
Vineyard Wind 2 Route				$2,500,000		$28,000,000									**$30,500,000**
Phinneys Lane	*$315,000*	*$735,000*					$32,000,000								**$33,050,000**
Route 28 West		*$612,000*		$3,500,000			$35,000,000								**$39,112,000**
Old Yarmouth Road					$275,000	$600,000		$7,150,000							**$8,025,000**
Old Craigville Road					$600,000	$1,400,000		$17,000,000							**$19,000,000**
Long Pond Area	***$402,000***	***$938,000***							$35,000,000						**$36,340,000**
Shootflying Hill Road					$375,000		$875,000		$7,150,000						**$8,400,000**
Long Beach						$300,000	$700,000		$8,000,000						**$9,000,000**
Great Marsh Road							$500,000	$1,200,000		$15,500,000					**$17,200,000**
Osterville Woods							$550,000	$1,250,000		$17,000,000					**$18,800,000**
South County Road								$300,000	$700,000		$13,000,000				**$14,000,000**
Prince Cove									$400,000	$1,000,000		$15,500,000			**$16,900,000**
Huckins Neck									$300,000	$700,000		$9,000,000			**$10,000,000**
Lumbert Mill										$700,000	$1,500,000		$20,225,000		**$22,425,000**
TOTAL COSTS	**$717,000**	**$3,920,000**	**$10,600,000**	**$28,000,000**	**$1,250,000**	**$30,300,000**	**$69,625,000**	**$26,900,000**	**$51,550,000**	**$34,900,000**	**$14,500,000**	**$24,500,000**	**$20,225,000**	**$0**	**$316,987,000**
NEW PARCELS CONNECTED	**0**	**7**	**0**	**0**	**238**	**91**	**0**	**351**	**278**	**1,032**	**441**	**1,352**	**349**	**418**	**4,557**
COMBINED FLOW (GPD)	**1,670,000**	**1,670,000**	**1,670,000**	**1,670,000**	**1,716,500**	**1,732,000**	**1,732,000**	**1,798,000**	**1,870,500**	**2,035,500**	**2,084,500**	**2,320,500**	**2,388,500**	**2,451,000**	**781,000**

FY23 - FY27 Capital Improvement Plan

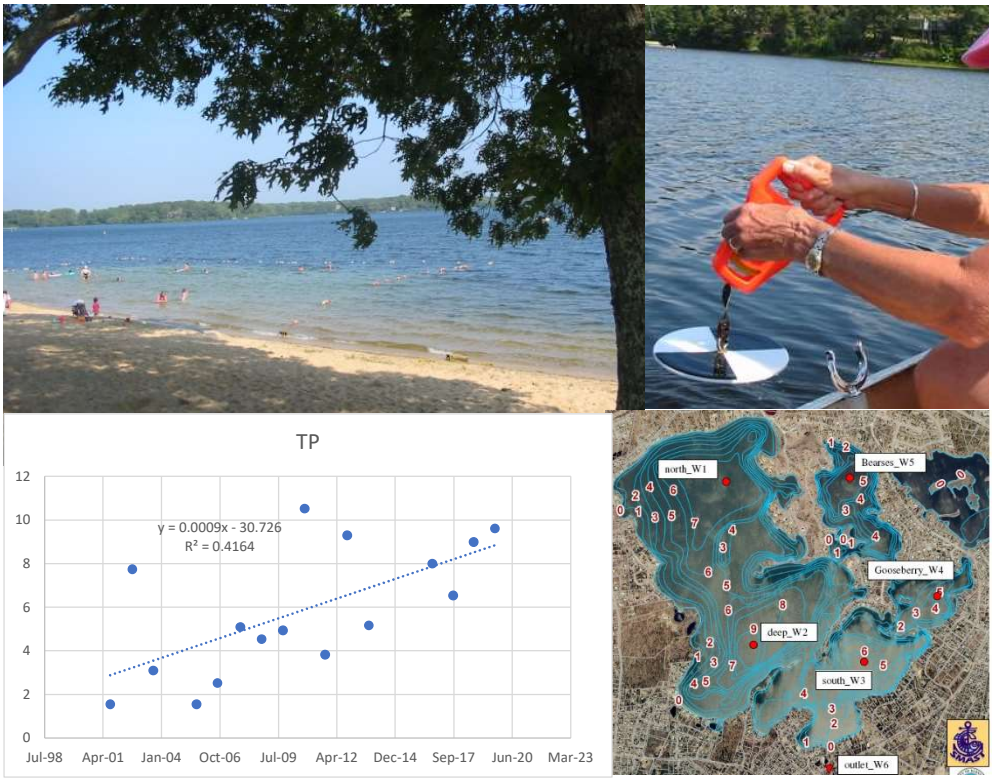
TOWN OF BARNSTABLE
COMPREHENSIVE WASTEWATER MANAGEMENT PLAN
FY2022 PHASE 1 SEWER EXPANSION PROJECTS CAPITAL PLAN UPDATE

ATTACHMENT D

TOWN OF BARNSTABLE FRESHWATER PONDS
DATABASE REPORT, NOVEMBER 2021

Town of Barnstable Freshwater Ponds
2021 Water Quality Monitoring Database: Development and Review

FINAL REPORT
November 2021



Prepared by:

Coastal Systems Group
School for Marine Science and Technology
University of Massachusetts Dartmouth
706 South Rodney French Blvd.
New Bedford, MA 02744-1221

Town of Barnstable Freshwater Ponds
2021 Water Quality Monitoring Database: Development and Review

FINAL REPORT
November 2021

Prepared for

Town of Barnstable
Department of Public Works

Prepared By

Ed Eichner, Principal Water Scientist, TMDL Solutions
Brian Howes, Director/Professor
COASTAL SYSTEMS GROUP
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Acknowledgements:
The authors acknowledge the years of effort and contributions of the many individuals, pond organizations, volunteers, town staff, and boards who have worked for many years for the restoration and protection of the ponds and lakes in the Town of Barnstable. Without these pond stewards and their efforts, this project and all of the collected data would not be possible.

Among these groups, the authors also specifically recognize and applaud the generosity of time and effort spent by past and present PALS Snapshot participants. Among these groups, particular thanks go to Lindsey Counsell (Three Bays Preservation, Inc.), Zee Crocker (Barnstable Clean Water Coalition, Inc.), Emory Anderson (Indian Ponds Association, Inc.), and Gail Maguire (Wequaquet Lake Protective Association, Inc.) for their many years of monitoring and supporting monitors. Special thanks also go Amber Unruh (Barnstable Department of Public Works) and Meg Materne (Barnstable Clean Water Coalition, Inc.) for continuing monitoring in recent years.

In addition to these contributions, project support has been freely and graciously provided by Griffin Beaudoin and Dan Santos of the Barnstable Department of Public Works. Special thanks also to the staff at the Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth for the hours of laboratory analysis and logistics support during the years of Cape Cod PALS Snapshots that provided the majority of the available data in the Town of Barnstable ponds water quality database.

Cover photos (clockwise from lower left): shallow total phosphorus trend in Joshua Pond, Wequaquet Lake public beach, pond volunteer measuring water clarity with a Secchi disk, and water column sampling locations in Wequaquet Lake.

Recommended Citation
Eichner, E. and B. Howes. 2021. Town of Barnstable Freshwater Ponds, 2021 Water Quality Monitoring Database: Development and Review. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 104 pp.

EXECUTIVE SUMMARY

The Town of Barnstable is in the midst of developing and implementing a Comprehensive Wastewater Management Plan (CWMP), largely focused on addressing regulatory Total Maximum Daily Loads (TMDLs) requirements that have been developed for impaired estuaries within the Town. As this effort was underway, the Department of Public Works (DPW) recognized that CWMP implementation should also address pond and lake water quality issues, provide water quality goals that are clearly identified, and management options which adequately address the impairments. To begin this effort, the DPW staff asked the Coastal Systems Program at the School for Marine Science and Technology, University of Massachusetts Dartmouth (CSP/SMAST) to organize and review all available pond and lake water quality monitoring data from Pond and Lake Stewards (PALS) Snapshots and over 40 pond assessment reports into a single database. Additionally, CSP/SMAST was asked to provide an update on individual pond water quality relative to Massachusetts Department of Environmental Protection (MassDEP) regulatory standards and Cape Cod ecoregion thresholds. Finally, they were asked to assess whether there were any water quality trends over time and identify data gaps that would need to be filled for development of pond and lake management plans.

Per the MassDEP state regulations, Barnstable ponds are classified as Class B waters. Class B ponds and lakes are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. As well as, suitable for irrigation, agricultural uses, and compatible for industrial cooling process uses, and have good aesthetic value. MassDEP regulations set standards for dissolved oxygen (DO) based on two categories: cold water fisheries (consistently below 20°C and above 6 mg/L DO) and warm water fisheries (consistently above 20°C and above 5 mg/L DO). In addition, ponds must meet other standards by not exceeding a water temperature of 28.3°C, maintaining a pH between 6.5 to 8.3, and bacteria levels below 61 colonies per 100mL. The MassDEP did not set standards for nutrient levels. Instead, the Cape Cod Commission (CCC) developed nutrient specific thresholds for classifying unimpaired Cape Cod ponds. Unimpaired Cape Cod ponds have total phosphorus less than 10 µg/L, total nitrogen less than 0.31 mg/L, and chlorophyll pigments less than 1.7 µg/L.

This 2021 update represents the first Town wide water quality update since 2009. Preparation of the 2021 Barnstable Pond and Lake Water Quality Database organized over 50,000 water column data inputs into a standardized format for 55 ponds and lakes. Of the 55 ponds with sample data, 32 have at least five samplings and were reviewed in detail. Of the 32 ponds reviewed in detail (Table ES-1): two are significantly impaired, 21 are impaired, one is moderately impaired, six are borderline impaired, one is generally unimpaired, and one is unimpaired based on MassDEP regulations and Cape Cod pond thresholds.

While the Town is taking action to improve water quality in freshwater ponds through stormwater improvements, sewers, and the development of detailed nutrient diagnostic assessments and management plans, it should be recognized that each pond is unique and requires a pond specific management plan to determine specific needs for addressing water quality issues.

Table ES-1. Summary of Ponds reviewed in 2021 Barnstable Pond and Lake Water Quality Database. All ponds greater than 10 acres are Great Ponds under Massachusetts law and publicly owned. Listed maximum depth is based on PALS Snapshots recordings. # of samples varies by constituent. Water quality in all ponds is controlled by phosphorus. Cape Cod Ecoregion total phosphorus (TP) threshold is 10 µg/L. Five additional ponds have data in the database, but were not reviewed because of the limited number of samplings (n≤3).

Pond	Village	Area (acres)	Great Pond	PALS Years	PALS % of overall data	Max depth (m)	# of samples	Avg TP (µg/L)		Overall status
								shallow	deep	
Aunt Bettys	Hyannis	7.1	No	2001-2003, 2008-2013, 2017-2019	97%	1	14 – 21	14	n/a	moderately impaired
Bearse	Centerville	67	Yes	2001-2003, 2005-2015, 2017-2019	36%	6.6	82 – 96	19	29	impaired
Bog	Osterville	7.2	No	2001-2003, 2005-2019	100%	1	33 – 34	26	n/a	significantly impaired
Crocker	Marstons Mills	25	Yes	2001-2003, 2007-2013, 2018-2019	100%	6.1	21 - 22	23	48	significantly impaired
Crystal	Osterville	10	Yes	2001-2003, 2005-2013, 2015-2019	100%	12.2	54 - 57	10	44	impaired
Eagle	Cotuit	8.5	No	2001-2003, 2006-2015, 2017-2018	100%	5.1	28 - 30	10	12	borderline impaired
Elizabeth	Centerville	6.3	No, but Yes if combined with Red Lily	2001-2003, 2008-2013, 2017-2019	80%	4.5[1]	23 - 24	16	52	impaired
Garretts	West Barnstable	28	Yes	2001-2003, 2008-2013, 2017-2019	95%	8.9	11 - 32	12	16	impaired
Gooseberry	Centerville	41	Yes	2001, 2018-2019	36%	5.4	23 – 80	22	24	borderline impaired
Hamblin	Marstons Mills	115	Yes	2001-2019	24%	19.2	106 – 230	9	17[2]	impaired
Hathaway N	Barnstable	21	Yes	2001-2003, 2008-2013, 2017-2019	95%	17.4	11 - 48	10	38	borderline impaired
Hinckley	Barnstable	10	Yes	2001-2003, 2008-2013, 2017-2019	100%	6.9	10 - 11	33	138	impaired
Joshua	Osterville	15	Yes	2001-2003, 2005-2013, 2015- 2019	95%	10.0	39 - 44	6	7	unimpaired

Table ES-1. Summary of Ponds reviewed in 2021 Barnstable Pond and Lake Water Quality Database. All ponds greater than 10 acres are Great Ponds under Massachusetts law and publicly owned. Listed maximum depth is based on PALS Snapshots recordings. # of samples varies by constituent. Water quality in all ponds is controlled by phosphorus. Cape Cod Ecoregion total phosphorus (TP) threshold is 10 µg/L. Five additional ponds have data in the database, but were not reviewed because of the limited number of samplings (n≤3).

Pond	Village	Area (acres)	Great Pond	PALS Years	PALS % of overall data	Max depth (m)	# of samples	Avg TP (µg/L)		Overall status
								shallow	deep	
Lewis	Cotuit	4.6	No	2001-2003, 2005-2006, 2008-2015, 2017-2018	95%	4.2	28 - 29	15	32	Impaired
Little	Marstons Mills	9.7	No	2001-2002, 2005-2013, 2015-2019	100%	1.2	13 - 29	17	n/a	Impaired
Long	Centerville	53	Yes	2001-2003, 2005-2008[3]	53%	7.2	9 - 61	11	86	Impaired
Long	Marstons Mills	56	Yes	2008, 2011, 2013, 2018-2019[3]	88%	6.2	9 - 10	11	61	Impaired
Lovells	Cotuit	55	Yes	2001-2003, 2005-2006, 2008-2015, 2017-2018	40%	11.4	54 - 122	16	35[4]	Impaired
Lumbert	Centerville	9.7 or 12.7[5]	No	2001-2003, 2007-2013, 2017-2019	100%	1.6	13 - 18	11	26	Impaired
Mary Dunn	Hyannis	18	Yes	2001, 2003, 2008-2013, 2017-2019	100%	2.1	11 - 17	11	n/a	borderline impaired
Micah	Osterville	16	Yes	2001-2003, 2005-2013, 2015- 2019	95%	12.4	17 - 60	8	14	generally unimpaired
Middle	Marstons Mills	105	Yes	2001-2019	51%	10.3	39 – 142	11	22	Impaired
Mill	Marstons Mills	6.0	No	2002-2003, 2005-2019	93%	1.4	14 – 35	35	93	Impaired
Mystic	Marstons Mills	148	Yes	2001-2019	40%	14.6	60 – 246	17	214[6]	Impaired
Neck	Osterville	14	Yes	2001-2003, 2005-2013, 2015- 2019	100%	11.5	17 - 61	7	17	borderline impaired
Parker	Osterville	12	Yes	2001-2003, 2005-2013, 2015-2019	100%	6.4	15 - 40	16	44	Impaired

Table ES-1. Summary of Ponds reviewed in 2021 Barnstable Pond and Lake Water Quality Database. All ponds greater than 10 acres are Great Ponds under Massachusetts law and publicly owned. Listed maximum depth is based on PALS Snapshots recordings. # of samples varies by constituent. Water quality in all ponds is controlled by phosphorus. Cape Cod Ecoregion total phosphorus (TP) threshold is 10 µg/L. Five additional ponds have data in the database, but were not reviewed because of the limited number of samplings (n≤3).

Pond	Village	Area (acres)	Great Pond	PALS Years	PALS % of overall data	Max depth (m)	# of samples	Avg TP (µg/L)		Overall status
								shallow	deep	
Red Lily	Centerville	4.5	No, but Yes if combined with Elizabeth	2001-2003, 2008-2013, 2018, 2019	74%	1.2	13 - 35	16	n/a	Impaired
Round	Marstons Mills	9.8	maybe	2001-2003, 2005, 2007-2013, 2017-2019	100%	4.8	14 - 27	19	29	Impaired
Schoolhouse	Hyannis	3.6	No	2001-2003, 2007-2013, 2017-2019	100%	2.2	13 - 26	116	70	impaired
Shallow	Centerville	78	Yes	2001-2003, 2008-2013, 2017-2018	70%	2.5	12 - 40	13	16	borderline impaired
Shubael	Marstons Mills	55	Yes	2001-2003, 2007-2013, 2017-2019	85%	13.4	14 - 59	10	30	Impaired
Wequaquet	Centerville	661[7]	Yes	2002-2003, 2005-2015, 2017-2018	36%	9.8	35 – 104	19	29[8]	Impaired

NOTES:

1. Depth entries for Red Lily Pond appear to include readings in feet, but original PALS sampling sheets (pre-2018) have not been secured as of the writing of this report. Statistical analysis of total depth readings do not identify any statistical outliers.
2. Hamblin Pond TP concentrations since 2015 (post-alum treatment)
3. There are 3 potential additional PALS years that could be Long Pond Centerville or Long Pond Marstons Mills; original PALS datasheets have not been secured.
4. Lovells Pond TP concentrations since 2014 (post-alum treatment)
5. Lumbert Pond area is 9.7 acres based on the primary water surface, while the town parcel is 12.7 acres and includes a stream connected to the pond
6. Mystic Pond TP concentrations since 2010 (post-alum treatment)
7. Wequaquet Lake surface area includes connected basins of Bearse Pond and Gooseberry Pond
8. Wequaquet Lake TP concentrations since 2001 and at the deep location in the main basin only

Table of Contents

Town of Barnstable Freshwater Ponds
2021 Water Quality Monitoring Database: Development and Review

List of Figures

Town of Barnstable Freshwater Ponds
2021 Water Quality Monitoring Database: Development and Review

List of Tables

Town of Barnstable Freshwater Ponds
2021 Water Quality Monitoring Database: Development and Review

I. Introduction

The Town of Barnstable has numerous ponds and lakes scattered throughout the town. According to the Cape Cod Pond and Lake Atlas, Barnstable has over 180 ponds covering a total area of nearly 1,900 acres (Figure I-1).[1] Of these ponds, 25 are greater than 10 acres and 78 are greater than one acre. Management of these resources has been guided by a mix of municipal activities and citizen advocacy, typically through lake associations.[2] Prior to 2001, water quality monitoring of these resources was generally focused on individual ponds through pond assessments completed by consultants rather than long-term tracking of changes in water quality conditions and data based prioritization.

In 2001, the Cape Cod Commission (CCC), the Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth (CSP/SMAST), numerous local and state agencies, and hundreds of citizen volunteers began the Cape Cod Pond and Lake Stewards (PALS) program, which included a regular annual pond and lake water quality snapshot sampling throughout Cape Cod. This sampling was and continues to be supported by laboratory analysis provided by the CSP/SMAST at no cost to the towns, volunteers, or the CCC.

Annual water quality snapshots were part of PALS activities, which also included the production of the Cape Cod Pond and Lake Atlas, which contained the first complete list of all ponds on Cape Cod (nearly 1,000 ponds), and a review of the first PALS water quality snapshot results.[3] For most of the sampled ponds and lakes, the annual PALS Snapshot sampling was the first water quality measurements ever collected. The PALS Snapshot concept was designed by CCC and CSP/SMAST to provide reliable water quality data at a time that pond water quality should be at its worst (late summer) and use that data as a prioritization tool for targeting the development of more refined, diagnostic assessments, and pond and lake management plans. It was also thought that the PALS program and snapshots would enhance the visibility of pond and lake water quality and stewardship issues throughout the region.

CSP/SMAST has continued to support the annual PALS Snapshot for over 20 years and now directly coordinates the sampling with towns, lake and pond associations, and volunteers. As more water column data has been collected, local concerns about algal blooms, fish kills, and impacts of changing land uses have all been raised and nascent discussions have begun about how to develop town-wide pond management strategies. As this report is being written, water quality samples have been collected from 55 ponds and lakes in the Town of Barnstable.

In 2020, the Town of Barnstable, through the Department of Public Works, and CSP/SMAST began discussing options to begin the process of integrating pond management into an overall comprehensive water quality management strategy. Although pond and lake water quality were organized and reviewed in 2009,[4] it was thought that as the town moved forward it would be prudent to compile all available pond and lake data and use this information to prioritize future activities. This report summarizes the results of organizing all available pond water quality data

[1] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

[2] *e.g.*, the Indian Ponds Association, the Wequaquet Lake Protective Association, etc.

[3] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.

[4] Eichner, E. 2009. Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities. School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 79 pp.

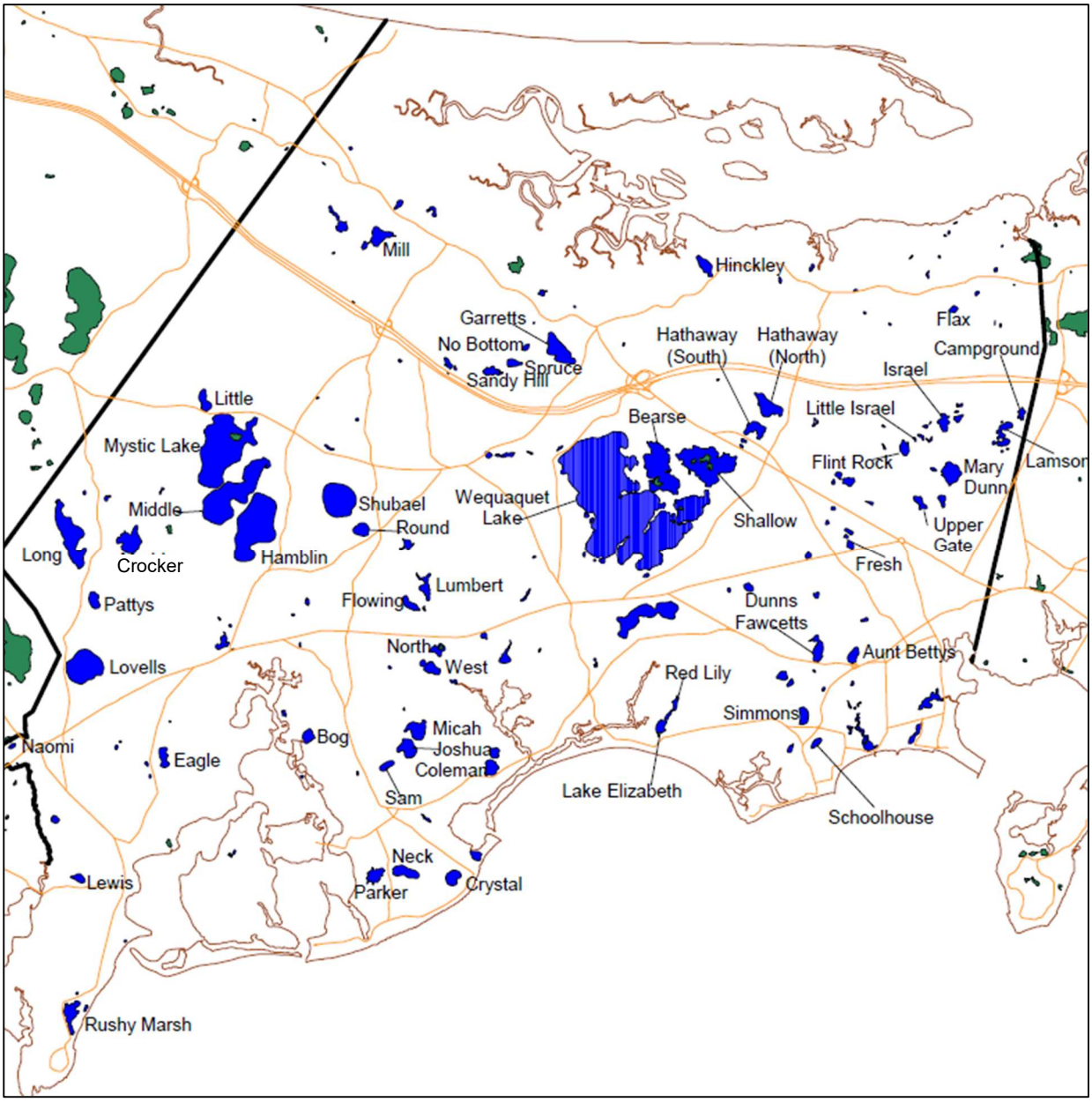

Figure I-1. Town of Barnstable Ponds and Lakes. According to the 2003 Cape Cod Pond and Lake Atlas, there are 180 ponds and lakes covering a total area of nearly 1,900 acres within the Town of Barnstable. Of these ponds, 25 are publicly-owned Great Ponds under Massachusetts law (*i.e.*, greater than 10 acres) and 78 are greater than one acre. The Massachusetts Department of Environmental Protection has listed 12 of the ponds and lakes in the latest integrated list of all surfaces waters within the Commonwealth and determined that five of them have impaired water quality compared to state surface water standards and, thus, require TMDLs. According to the review of data organized for this report, water quality data has been collected from 55 of the ponds. Figure is modified from Pond Atlas figure.

for Barnstable ponds and lakes and reviews how this data can be used as guidance for prioritizing individual pond management efforts and as part of individual pond assessments.

I.1. Overview of the Cape Cod Ponds and Lakes Formation History

Cape Cod was formed during the last continental glaciation approximately 15,000 years ago and the topography of the Cape reflects how the glaciers moved, deposited materials, and how water levels changed as the glaciers retreated. Portions of the Town of Barnstable south of Route 6 are generally made of well-sorted sands deposited by glacial meltwaters in braided streams.[5] Route 6 generally travels along the Sandwich Moraine that formed as the glaciers advanced south during a cooler period and piled up previously deposited materials. Ponds and lakes tend to be depressions in the land surface that formed after large blocks of ice were left behind by the main glacier, surrounded and buried by meltwater sands, and then eventually melted, with the sands collapsing to form depressions. As the glaciers retreated north, released their water, and sea levels rose, these depressions gradually filled with groundwater and formed the lakes and ponds that are seen today. Because they are part of the groundwater system, the ponds and lakes on the Cape tend to be exposed portions of the top of the groundwater system and are occasionally referred to as "windows on the aquifer."

Because of this direct connection between the ponds and the groundwater, their watersheds are defined by the area of groundwater upgradient of the pond that flows through it rather than the land surface topography. Water added within this capture area by rain, road runoff, or septic system effluent eventually flows into the pond. Pond water flows out of the pond and back into the groundwater system along a downgradient, usually opposite, shoreline. Water flows in individual ponds can become complicated by stream inputs or outputs, stormwater discharge due to runoff collection systems, and/or agricultural withdrawals or additions (*e.g.*, cranberry bogs).

Since Cape Cod is mostly composed of sands, there is little carbonate in the aquifer system to balance the natural acidity in rain and, thus, the ponds and lakes tend to be naturally acidic (*i.e.*, pH less than 7). The sandy soils also mean that prior to human development, rainwater (either directly on the surface or through runoff from surrounding lands) was the primary source of major nutrients (*i.e.*, nitrogen and phosphorus). Human development within pond watersheds has added additional nutrient sources through wastewater disposal (*e.g.*, septic systems) and piped or channeled stormwater runoff from impervious surfaces (*i.e.*, roads and roofs).

Cape Cod ponds and lakes, like all wetlands, tend to function as natural traps for nutrients. These nutrients are used for plant and animal growth. Nutrients are captured by the plants (both microscopic phytoplankton and rooted plants) and stored in the pond bottom sediments as ponds cycle through seasons of varying growth (*e.g.*, summer vs. winter). If excessive nutrients enter the pond, the sediments can become a meaningful additional nutrient source as nutrients are regenerated from the sediments into the water column.

Impaired water quality in lakes and ponds is usually defined by excessive nutrient concentrations, loss of clarity, excessive plant growth, and anoxic bottom waters. Cape Cod ponds and lakes tend to have low nutrient levels, which typically means low phytoplankton levels and sparse rooted plants within the ponds. Excessive nutrients usually cause more plant

[5] Oldale, R.N. 1992. *Cape Cod and the Islands: The Geologic Story.* Parnassus Imprints. East Orleans, MA. 208 pp.

growth either through more phytoplankton growth with accompanying loss of water clarity or more emergent or submerged plants on the pond bottom. Since Cape Cod has relatively strong ambient winds, especially during the summer, most unimpaired shallow ponds tend to have dissolved oxygen levels that match atmospheric saturation throughout their water column. Excessive nutrients cause significant oxygen demand in the sediments and reduced dissolved oxygen concentrations. The chemical changes caused by loss of oxygen in the sediments lead to nutrient regeneration from the sediments to the water column. Restoring ponds to acceptable water quality usually means determining whether the primary source of nutrients measured in the water column is watershed sources or internal sediment regeneration and figuring out the best management options to reduce those nutrient inputs.

I.2. Overview of Cape Cod Pond and Lake Management History

Assessment and management of Cape Cod pond and lake resources has evolved slowly, but has recently become more focused as federal, state, and local water quality protection interests have begun to converge. Any ponds greater than 10 acres are classified as "Great Ponds" under Massachusetts law and are publicly-owned waters of the Commonwealth.[6] This concept was developed prior to the creation of the United States, during the governance of the Massachusetts Bay Colony.[7] In contrast, management of ponds less than 10 acres is usually based on private landowner concerns, but can vary depending on the ownership of the land under the water.

Federal laws protecting pond and lake water and habitat quality were reaffirmed and strengthened in 1972 with the passage of the Clean Water Act.[8] The Clean Water Act created provisions linking state laws and regulations with water quality assessments. A key provision in the Act was the concept of determining acceptable contaminant loads, otherwise known as Total Maximum Daily Loads (TMDLs), for individual water bodies or groups of similar surface waters that are not attaining state water quality standards. The Act states that waters not attaining state standards shall be classified as "impaired" and all impaired water bodies must have a TMDL for each contaminant causing impairment. The Act required each state to produce an integrated list of all surface waters every two years that included identification of all impaired waters requiring TMDLs.[9] The Town of Barnstable currently has five ponds listed as impaired in the latest Massachusetts integrated list.

Massachusetts regulations include water quality standards for surface waters.[10] These standards are organized based on the use of the pond and its natural temperature characteristics. The standards are mostly descriptive, but include selected key numeric standards for temperature, pH, dissolved oxygen (DO), and bacteria. The regulations also include provisions for natural fluctuations outside of the listed numeric ranges, which is important for the low pH values typically found in Cape Cod ponds and lakes.

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[6] MGL c. 91 § 35

[7] H.J. Wilson, The Public Trust Doctrine in Massachusetts Land Law, 11 B.C. Envtl. Aff. L. Rev. 839 (1984), http://lawdigitalcommons.bc.edu/ealr/vol11/iss4/6 (accessed 12/15/20).

[8] 33 U.S.C. §1251 *et seq*.

[9] The latest MassDEP list is: Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

[10] 314 CMR 4

Under the state regulations, Cape Cod ponds are classified as Class B waters.[11] Class B waters are described as "designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. Where designated in 314 CMR 4.06, they shall be suitable as a source of public water supply with appropriate treatment ("Treated Water Supply"). Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value."[12]

Temperature provisions in the Massachusetts regulatory standards stress whether the pond has suitable habitat for cold water fish species, such as trout, or warm water species, such as bass. Under these regulations, a cold water fishery lake or pond must have a portion of the water column that has temperatures consistently less than 20°C. Since higher DO concentrations are required to sustain salmonid populations, such as trout, cold water fisheries must maintain a minimum DO concentration of 6 mg/L. Warm water fisheries (*i.e.*, ponds with temperatures consistently above 20°C) must maintain DO concentrations above 5 mg/L. Other numeric standards in Massachusetts water quality regulations are:

a) temperature shall not exceed 83°F (28.3°C),
b) pH shall be in the range of 6.5 to 8.3, and
c) bacteria (*Enterococci*) shall not exceed 61 colonies per 100 ml at bathing beaches (with variations available for multiple samples or use of different indicator species).

Although Massachusetts regulations do not have numeric nutrient standards, the CCC assessed potential nutrient standards for Cape Cod using the results of the initial 2001 PALS Snapshot.[13] The initial PALS Snapshot collected water quality samples from 195 ponds and lakes between August 15 and September 30. CCC staff reviewed the data using an USEPA method for setting nutrient criteria[14] and proposed provisional Cape Cod-specific nutrient standards.[15] The PALS effort was originally part of a regionally integrated water quality management strategy that included all water resources including, public water supplies, estuaries, and ponds and lakes.[16] The PALS program portion of the strategy was to develop reliable data and use the data to prioritize development of individual pond assessments and management plans.

As PALS has continued, including the continuous and on-going commitment of CSP/SMAST to support the PALS Snapshots, many of the Cape towns have begun to implement some of the integrated water quality assessment and management tasks originally envisioned when PALS was started. PALS Snapshot data has been used as meaningful data in individual pond

[11] Class A waters are used as drinking water sources.

[12] 314 CMR 4.05(3)(b)

[13] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.

[14] U.S. Environmental Protection Agency. 2000. Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs. First Edition. EPA-822-B00-001. US Environmental Protection Agency, Office of Water, Office of Science and Technology. Washington, DC.

[15] See Table 5 in Cape Cod Pond and Lake Atlas.

[16] Eichner, EM. 1993. Watershed protection: A Cape Cod perspective on national efforts. *Environmental Science and Technology* 27, no. 9: 1736—1740.

assessments, including some in Barnstable (*e.g.*, Wequaquet Lake[17], Mystic Lake[18]). Some Cape Cod towns have reviewed cumulative PALS data in order to prioritize the development of individual pond management plans and provide feedback to volunteer monitors, while incorporating the results of these efforts into comprehensive wastewater planning (*e.g.*, Orleans[19] and Brewster). PALS concepts of developing reliable data to ensure effective pond and lake water quality management has also been begun in the Town of Plymouth.[20]

I.3. Overview of Barnstable Pond Management History

The Town of Barnstable is in the midst of developing and implementing a comprehensive wastewater management plan (CWMP).[21] While much of the focus of the CWMP is on meeting TMDLs that have been developed for impaired estuaries within the Town, town DPW staff have also recognized that CWMP implementation should also address pond and lake water quality issues where possible, provided that individual pond water quality impairments are understood, water quality goals are clearly identified, and management options adequately address the impairments.

Historic assessment and management of ponds within the Town of Barnstable has generally been on an *ad hoc* basis for individual ponds. Selected ponds have had multiple water quality assessments, while others have water quality sampling limited to occasional PALS Snapshots. In addition, selected ponds have had various treatments (*e.g.*, herbicide applications) generally focused on management of one portion of the pond ecosystem (*e.g.*, herring, invasive plants, etc.) rather than the overall pond. This historic management approach is relatively common for ponds and lakes on the Cape, but may lead to water quality management issues as the rest of the ecosystem adjusts to changes in one part of the ecosystem.

Based on pond surface areas, the Town of Barnstable has 25 Great Ponds (Table I-1), although this number may fluctuate depending on how linked basins are counted.[22] As mentioned above, these ponds are publicly-owned ponds with potential state regulatory and management responsibilities. Integration of management activities run by multiple departments in the Town, such as invasive species treatments, and state departments, such as herring runs managed by the Massachusetts Division of Marine Fisheries and the Town, will be important for water quality and overall pond ecosystem management. Water quality data has been collected from 23 of the listed Great Ponds and 55 ponds and lakes overall (Table I-2).

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[17] Eichner, E. 2008. Lake Wequaquet Water Quality Assessment. Completed for the Town of Barnstable and the Cape Cod Commission. Coastal Systems Program, School of Marine Science and Technology, University of Massachusetts Dartmouth. 81 p.

[18] WRS, Inc. 2011. Internal Phosphorus Load Inactivation in Mystic Lake, Barnstable, MA. 120 pp.

[19] Eichner, E and B. Howes. 2017. Town of Orleans Freshwater Ponds, Water Quality Monitoring Database: Development and Review. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 216 pp.

[20] Eichner, E.M., B.L. Howes, and S. Horvet. 2015. Town of Plymouth Pond and Lake Atlas. Town of Plymouth, Massachusetts. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 138 pp.

[21] Barnstable Department of Public Works, Presentation to Town Council, January 3, 2019. https://town.barnstable.ma.us/Departments/PublicWorks/Office_Resources_and_Updates/Wastewater-Update-Presentation---Town-Council.pdf

[22] The count of ponds in Barnstable varies depending on whether separate basins in Lake Wequaquet are counted as separate ponds and whether Lake Elizabeth and Red Lily Pond are treated as separate ponds.

As mentioned above, each of the Great Ponds and those listed as impaired has the potential for MassDEP regulatory focus and, as such, may have to be addressed in town CWMP strategies. MassDEP included 11 Barnstable ponds on the latest Integrated List approved by EPA (see Table I-2).[23] Five of these listed ponds are identified as impaired: Hamblin, Lovells, Middle, Mystic, and Red Lily. Note that two Great Ponds do not have any water quality data in the 2021 Database: Fawcetts Pond and Lamson Pond.

Management of smaller ponds (<10 acres) using Town funding is more complicated because the land under the pond water is usually privately owned. Town management priorities for smaller ponds, such as Red Lily Pond, which is not a Great Pond,[24] but is on the Integrated List as an impaired water body may also need to be addressed. The Town should consider seeking guidance from MassDEP to clarify the status of individual smaller ponds included on the Integrated List.

The last review of available pond water quality data in Barnstable was completed in 2008.[25] The 2008 review gathered water quality results from 38 ponds, including PALS Snapshots from 2001 to 2006 and available individual diagnostic pond assessments completed at eight ponds. Diagnostic assessments typically include refined surveys of pond ecosystem components, including water quality measurements, but also rooted plant and phytoplankton surveys, bathymetric measurements, and sediments surveys. The 2008 Ponds Report included a number of recommendations that the Town has begun implementing, including: 1) development of an integrated long-term monitoring program, 2) prioritization of individual pond assessments, and 3) development of Town-wide pond physical data (*e.g.*, bathymetry) for the ponds the town wanted to manage.

As the Town moved forward with integrating pond management into the CWMP development, the Town has taken a number of steps. In 2016, the Town asked CSP/SMAST to develop bathymetric data for 23 ponds that previously had not been surveyed.[26] During the 2020 summer, the Town also coordinated with town volunteer monitoring groups to ensure that all selected ponds, including all Great Ponds, were sampled during the 2020 PALS Snapshot and has sampled most of these ponds again during the Spring 2021. In addition, the Town has recently asked CSP/SMAST to develop a diagnostic assessment/management plan for Shubael Pond and will be reviewing the database associated with this report for insights on prioritizing management plans for other ponds.

Pond and lake management plans typically contain a gathering of all available data on a selected pond, synthesis of that data through a diagnostic assessment to establish a reasonable understanding of how the ecosystem in the individual pond functions and identify any ecosystem

[23] Massachusetts DEP. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing.

[24] But is on some state lists as a combined Red Lily/Lake Elizabeth Great Pond

[25] Eichner, E. 2008. Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities. School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 79 pp.

[26] Schlezinger, D., B. Howes, and S. Sampieri Horvet. 2017. Pond Water Quality Assessment of 23 Ponds in the Town of Barnstable using Pond and Lake Stewardship (PALS) Protocols. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 38 pp.

impairments, a review of applicable management options to address the impairments or projected future impairments, and a recommended plan/strategy to implement the best management options.[27] Gathering of all available data for the diagnostic assessment typically includes reviews of the pond watershed and its inputs, sediment interactions with the pond water column, phytoplankton population changes (including blue-green cyanobacteria), the extent of freshwater mussels, herring counts, rooted plant extent and density, and all available water quality data.

The current project summarized in this report collected available pond and lake water column monitoring data, including PALS data, and reviewed this data to evaluate the status of the monitored ponds and what data gaps will need to be addressed if the Town chooses to develop individual pond management plans. Identification of the data gaps and findings from the review of the available data can help the Town understand what is known about individual ponds and to prioritize pond management activities, such as pond management plans, stormwater mitigation, and watershed sewer activities through the CWMP.

[27] *e.g.*, Eichner, E., B. Howes, and D. Schlezinger. 2019. Pilgrim Lake Management Plan and Diagnostic Assessment. Town of Orleans, Massachusetts. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 114 pp.

Table I-1. Great Ponds within the Town of Barnstable. Under Massachusetts law, any pond with an area greater than 10 acres is a "Great Pond" and is publicly owned. There are a few additional ponds in town that are also close to the 10 acre threshold that may have 10 acres of water during high groundwater conditions (*e.g.*, Little, Lumbert, Round). Under the federal Clean Water Act, MassDEP is required to produce a listing of all surface waters and their water quality status every two years. The latest MassDEP list includes 11 Barnstable Ponds. Three of the listed ponds are in Category 3 ("No Uses Assessed"), two are in Category 4a ("TMDL is completed"), one is in Category 4c ("Impairment not caused by a pollutant – TMDL not required") and five are in Category 5 (Impaired waters - "Waters requiring a TMDL"). PALS# shown here are the unique identifiers assigned to each Cape Cod pond during the development of the Cape Cod Pond and Lake Atlas (2003). Notes: 1) Gooseberry and Bearses are parts of Wequaquet Lake; Bearses is listed separately by MassDEP, but Gooseberry is not; 2) Red Lily and Lake Elizabeth combined are greater than 10 acres, but separately are not. Some MassDEP listings combine them, others do not.

Pond	PALS #	Village	Area (acres)	MassDEP Integrated List (Yes or No)	MassDEP Integrated List Classification
Bearse	BA-617	Centerville	66.8	Yes	4a (Mercury in fish)
Crocker	BA-694	Marstons Mills	24.6	No	
Crystal	BA-878	Osterville	10.1	No	
Fawcetts	BA-748	Hyannis	11.9	No	
Garretts	BA-510	West Barnstable	27.9	No	
Gooseberry	BA-605	Centerville	41.0	No	
Hamblin	BA-668	Marstons Mills	115.4	Yes	
Hathaway N	BA-565	Barnstable	20.9	No	
Hathaway S	BA-594	Barnstable	12.6	No	
Hinckley	BA-411	Barnstable	10.3	No	
Joshua	BA-807	Osterville	14.7	No	
Lamson	BA-596	Barnstable	12.3	No	
Long	BA-737	Centerville	51.0	Yes	4c (Non-Native Aquatic Plants)
Long	BA-675	Marstons Mills	54.8	No	
Lovells	BA-759	Cotuit	55.5	Yes	5
Mary Dunn	BA-646	Hyannis	18.0	No	
Micah	BA-797	Osterville	16.0	No	
Middle	BA-640	Marstons Mills	104.6	Yes	5
Mill	BA-391	West Barnstable	16.7	No	
Mystic	BA-640	Marstons Mills	148.4	Yes	5
Neck	BA-874	Osterville	13.6	No	
Parker	BA-875	Osterville	10.9	No	
Shallow	BA-626	Centerville	78.4	Yes	3
Shubael	BA-664	Marstons Mills	55.1	Yes	3
Wequaquet	BA-605	Centerville	554.3	Yes	4a (Mercury in fish)

Table I-2. List of Ponds included in the 2021 Barnstable Pond and Lake Water Quality Database. Ponds with water quality assessments and PALS Snapshots data are listed, as well as ponds with more limited sampling projects (*i.e.,* "Other"). Bearses and Gooseberry areas are portions of Wequaquet and are listed separately in the database.

Pond	PALS #	Village	Area	MassDEP Category	2021 Database Sources		
			Acres		PALS	Assessment	Other
286	BA-799	Hyannis	4.3				X
3 Pond	BA-636	Centerville	2.2				X
Aunt Bettys	BA-756	Hyannis	7.1		X		X
Bearse	BA-617	Centerville	66.1	4a	X	X	X
Bens	BA-771	Hyannis	4.5				X
Bog	BA-802	Osterville	7.2		X		
Campground	BA-574	Barnstable	3.5				X
Coleman	BA-819	Osterville	9.9		X		
Crocker	BA-694	Marstons Mills	24.6		X		
Crystal	BA-878	Osterville	10.1		X		
Darica Way Bog	BA-382	West Barnstable	4.7				X
Duck	BA-708	Hyannis	0.9		X		
Dunns	BA-723	Hyannis	3.6		X		
Eagle	BA-815	Cotuit	8.5		X		
Elizabeth	BA-795	Centerville	6.3	3	X	X	
Fawcetts	BA-748	Hyannis	8.0				X
Filends	BA-750	Centerville	4.3				X
Flax	BA-473	Barnstable	2.0				X
Flintrock	BA-614	Barnstable	6.1				X
Flowing	BA-733	Centerville	7.7				X
Fresh Hole	BA-662	Hyannis	4.3				X
Garretts	BA-510	West Barnstable	27.9		X		X
Gooseberry	BA-605	Centerville	41.0		X	X	X
Hamblin	BA-668	Marstons Mills	115.4	5	X	X	X
Hathaway N	BA-565	Barnstable	20.9		X		X
Hinckley	BA-411	Barnstable	10.3		X		
Israel	BA-585	Barnstable	8.2				X
Joshua	BA-807	Osterville	14.7		X		X
Lamson	BA-596	Barnstable	12.4				X
Lewis	BA-881	Cotuit	4.6		X		
Little	BA-564	Marstons Mills	9.3		X		
Long	BA-737	Centerville	51.0	4c	X	X	X
Long	BA-675	Marstons Mills	54.8		X		X
Lovells	BA-759	Cotuit	55.5	5	X	X	
Lumbert	BA-719	Centerville	9.7		X		
Mary Dunn	BA-646	Hyannis	18.0		X		
Micah	BA-797	Osterville	16.0		X		X
Middle	BA-640	Marstons Mills	104.6	5	X	X	X

Table I-2 (continued). List of Ponds included in the 2021 Barnstable Pond and Lake Water Quality Database. Ponds with water quality assessments and PALS Snapshots data are listed, as well as ponds with more limited sampling projects (*i.e.,* "Other"). Bearses and Gooseberry areas are portions of Wequaquet and are listed separately in the database.

Pond	PALS #	Village	Area	MassDEP Category	2021 Database Sources		
			Acres		PALS	Assessment	Other
Mill	BA-746	Marstons Mills	6.0		X		X
Mill	BA-391	West Barnstable	16.7		X		X
Mystic	BA-584	Marstons Mills	148.4	5	X	X	X
Neck	BA-874	Osterville	13.6		X		
No Bottom	BA-523	West Barnstable	1.8		X		
North	BA-816	Osterville	4.3				X
Parker	BA-875	Osterville	10.9		X		
Pattys	BA-731	Marstons Mills	7.5				X
Red Lily	BA-782	Centerville	4.5	5	X	X	
Round	BA-691	Marstons Mills	9.8		X		
Sam	BA-820	Osterville	4.8				X
Schoolhouse	BA-806	Hyannis	3.6		X		
Shallow	BA-626	Centerville	78.4	3	X	X	X
Shubael	BA-664	Marstons Mills	55.1	3	X		X
Simmons	BA-789	Hyannis	7.5				X
Weathervane	BA-699	Marstons Mills	4.5				X
Wequaquet	BA-605	Centerville	554.3	4a	X	X	X

II. Pond Data Sources

In order to develop the 2021 Barnstable Pond and Lake Water Quality Database, project staff collected and organized available pond water quality data from various sources and years (Table II-1). PALS Snapshot data from 2001 to 2019[28] is the largest source of data and was consistently collected for most of the Great Ponds. This data is limited to the PALS collection window: August 15 to the end of September (based on previously completed data reviews, the current PAL window was adjusted to August 15 to September 15). The remainder of the available data is generally either Town staff sampling conducted as part of an in-lake treatment follow-up (*e.g.*, the alum treatment of Mystic Lake[29]) or data collected by consultants or volunteers during the course of individual pond assessments or diagnostic/feasibility studies (*e.g.*, Wequaquet Lake[30]).

The database focuses only on water column data and chemical parameters of collected samples. Most of the individual pond assessments include important, complementary data that would be required for a diagnostic/feasibility assessment portion of a management plan. This complementary data includes phytoplankton populations and species, sediment assays, streamflows, bathymetry, and continuous automated data collection (such as DO and temperature), but organization and review of these more complex datasets is best accomplished in the process of developing individual pond and lake assessments or management plans.

The consistency of PALS Snapshot sampling and sample handling protocols and the use of the same laboratory assay procedures provide a reliability that allows long-term data comparisons and trend analysis. Water quality samples analyzed at the CSP/SMAST Analytical Facility, including PALS samples, used the same analysis and sampling procedures in the MassDEP-approved SMAST Coastal Systems Analytical Facility Laboratory Quality Assurance Plan (2003). These lab procedures utilized consistent detection limits and standard laboratory checks, such as laboratory and field sample duplicates, blind performance evaluation samples, and inter-lab comparisons. The use of these procedures and consistent detection limits for surface waters provides reliable data for interannual comparisons and trend analysis. These are the same procedures utilized for coastal estuary water quality assays, including those completed for the Massachusetts Estuaries Project (MEP), modified to account for salinity. MEP estuary water quality results were the basis for the estuary nitrogen TMDLs that provide guidance to the Town CWMP strategies. Use of these assay procedures for pond samples have been approved by MassDEP in a number of pond sampling Quality Assurance Project Plans.[31]

In contrast, many of the pond water quality assessments, especially the pre-2001 assessments, utilized a variety of labs and chemical assay procedures. Many of the assay procedures utilized detection limits that were designed for wastewater analysis and were often too high for lake and pond samples, so comparisons between older and newer sampling results should be done carefully and with an understanding of the procedures and associated detection limits. Since this is a complex effort, requiring reviews of lab reporting sheets and assay methods, it should be

[28] 2020 PALS water samples were collected, but assay results were not available.

[29] WRS. 2011.

[30] Eichner, E. 2008. Lake Wequaquet Water Quality Assessment.

[31] *e.g.*, Town of Orleans Ponds and Lakes Monitoring Program, Quality Assurance Project Plan, 2018-2020. 2018. Approved by MassDEP, August 2018. Prepared by Town of Orleans, Marine and Fresh Water Quality Committee and Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. 48 pp.

done within the context of a lake or pond water quality assessment. For the purposes of the 2021 Barnstable Pond and Lake Water Quality Database, water quality results are listed with the lab that completed the assays and the document where the data was reported. PALS and CSP/SMAST water quality lab results were listed separately from data from other labs.

Data included in the 2021 Barnstable Pond and Lake Water Quality Database is listed by the depth where the water quality sample or reading was recorded. PALS Snapshot protocols call for collection of samples based on the depth of the pond at the sampling station. PALS protocols require each pond to have a minimum of two samples collected.[32] Shallow ponds less than 1.5 m deep have two samples collected just below the surface (0.5 m depth). Ponds up to 9 m deep have a shallow sample collected at 0.5 m depth and a deep sample 1 m above the bottom. Ponds greater than 10 m deep have four samples collected: 0.5 m, 3 m, 9 m, and one meter above the bottom. Water samples are collected as whole water, stored at 4°C, and transferred to the CSP/SMAST lab and processed within 24 hours. In addition to the collection of water samples, measurements of dissolved oxygen (DO), temperature, clarity/Secchi depth, and station depth are recorded at the pond station. Temperature and DO profiles are generally recorded at 1 m increments after the 0.5 m measurement (*i.e.*, recorded at 0.5 m, 1 m, 2 m, etc.). Profile recordings in ponds shallower than 3 m are recommended at 0.5 m increments. Volunteers are trained/briefed by local PALS "captains" who have been trained in sampling techniques and have extensive PALS Snapshot experience. These PALS captains organize the town volunteers, oversee sharing of equipment, ensure timely transfer of samples, etc. In Barnstable, the various advocacy groups [*e.g.*, Barnstable Clean Water (née Three Bays Preservation), Indian Ponds Association, Wequaquet Lake Protective Association, etc.] worked to ensure their volunteers followed PALS sampling protocols.

While PALS Snapshot data is reliable, it is, by design, limited to late summer samples and conditions. The PALS Snapshot was originally designed to collect samples during the period when water quality is likely to be at its worst. This period was initially targeted as a way to find out which ponds were most likely to have impaired water quality and use that information to guide collection of more refined supplementary data, including sampling throughout the summer management period, and to prioritize the development of management options. The Town will be implementing April/May 2021 sampling using the same PALS protocols as a way to provide a better context for each year's late summer PALS sampling results and, over time, a sense whether conditions measured during the PALS Snapshots occur throughout the summer or only develop in the late summer. Individual pond assessments generally collected water column samples throughout the key summer management period (usually April to September), but also in some cases during the winter. All available data was incorporated into the database if it was provided in numeric form in assessment reports. Some of the available reports only had data available in graphs and staff did not attempt to extrapolate numbers from graphs to include in the database.

Aside from differing laboratory analytical procedures, organization of the available data also strived to provide a consistent format for reported concentrations and pond names, as well as correcting clear data input errors. For example, some reports included data transpositions (*e.g.*, dissolved oxygen and temperature profiles transposed) or incorrect input values in summary

[32] this provides a built-in field duplicate procedure for the collective annual PALS Snapshot effort

tables (these were corrected from original datasheets or laboratory reports included in report appendices). Project staff also tried to ensure consistent pond names or sampling stations; for example, laboratory reporting for samples from Wequaquet Lake included the following names: "Waquaquet", "Lake Wequaquet", "W2", and "Wequaquet Main"). Additional data corrections were found during the statistical reviews of the data and incorporated into the unified database. All available data was brought into a consistent format for later review and analysis and to make the database more user friendly for the Town.

Table II-1. Source and Years when pond and lake water quality data was collected in the Town of Barnstable. Separate studies prior to 2001 tend to be diagnostic/feasibility studies for individual ponds funded through the federal Clean Lake Program, whereas studies after 2001 tend to be Town funded studies more narrowly focused on identified management issues. Town monitoring tends to be follow-up monitoring after alum treatments. *PALS 2020 data has been collected, but was not available at the time the database was prepared.

year	Separate studies	PALS	Town monitoring
1948	X		
1975	X		
1978	X		
1979	X		
1980	X		X
1985	X		
1992	X		
1995			X
1996			X
1997			X
1998			X
1999			X
2000	X		X
2001	X	X	
2002		X	
2003		X	
2004	X	X	
2005	X	X	
2006		X	
2007	X	X	
2008		X	
2009		X	
2010	X	X	X
2011	X	X	X
2012	X	X	X
2013	X	X	
2014	X		
2015	X	X	
2016		X	
2017		X	
2018		X	
2019		X	
2020	X	*	

Note: All PALS samples (collected between August 15 and September 30) were assayed at CSP/SMAST.

III. Review of Individual Ponds

Part of organizing the available water quality data was also completing a review of the collected data. Project staff focused on comparison of the data to available MassDEP regulatory surface water standards[33] (*e.g.*, the state regulatory basis for whether a water body is classified as impaired) and ecoregion guidance levels for total phosphorus, total nitrogen, and chlorophyll a established for Cape Cod ponds.[34] Project staff also completed statistical review of average concentrations[35] at shallow and deep depths to gauge potential sediment regeneration of nutrients. In addition, in ponds where data were collected relatively consistently between 2001 and 2019 (*i.e.*, only missing one or two years), project staff reviewed potential trends in the water quality data and identified those that were statistically significant over the past 20 years.[36]

The database includes identification of statistical outliers. These outliers are data points that are greater than two standard deviations more or less than the mean. The outlier analysis identified outliers by review of data points from the same depth (*e.g.*, shallow or deep). This approach generally works for shallow samples, but generally has some issues in deeper samples where the depth of the sampling often varied because samplers did not find the deepest point in the pond (*e.g.*, the deepest sample was at 7 m one year and 9 m the next). Statistical outliers were identified, but not removed from the database because some of these data points are outliers only because the majority of the available sampling was completed in August and September, so a May sample is not expected to be consistent with most of the available data.

The individual pond reviews were completed for 33 ponds. There are data from other ponds included in the 2021 Barnstable Pond and Lake Water Quality Database that were not reviewed because they only have a few readings. Some ponds in database have only a few readings (*e.g.*, Duck, Dunn, etc.). Selected ponds have extensive datasets with data from multiple sampling points distributed throughout the pond (*e.g.*, Wequaquet); all of the available data is included in the Database, but the individual pond reviews in this report focused only on the sampling conducted over the deepest point.

All of the data in the 2021 Barnstable Pond and Lake Water Quality Database is water column measurements. These measurements provide insights into the conditions within the pond, but not their underlying causes. Diagnostic assessments typically have the detailed surveys to determine the underlying causes of the measurements in the water column. These surveys typically include measurement of sediment phosphorus, phytoplankton populations and how they change during the summer, watershed nitrogen, phosphorus, and water inputs (including septic systems, stormwater runoff, etc.), and continuous measurements of dissolved oxygen, temperature, and chlorophyll a. The extent and number of surveys required will depend on the individual characteristics of the pond (*e.g.*, its depth and area) and its characteristics (*e.g.*, does it have a stream outflow or inflow). Results from these types of surveys combined with water column measurements provide the necessary basis for understanding how the water column measurements develop, how the pond ecosystem functions, and how those ecosystem functions can be managed if there are water quality impairments. Once this understanding is reliable, management options can be developed, typically through a management plan, to identify those that have the lowest cost and highest reliability to attain the water quality and ecosystem goals for a given pond.

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[33] 314 CMR 4.00 (CMR = Code of Massachusetts Regulations)

[34] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.

[35] Simple t-test using 0.05 as a basis for statistically significant difference (*i.e.*, a 95% chance that the averages are different).

[36] F-statistic using 0.05 as a basis for statistically significant trend (*i.e.*, a 95% chance that the measure is changing with time)

III.1. Aunt Bettys Pond

Aunt Bettys Pond (PALS# BA-756) is a 7.1-acre pond located north of the West End rotary in Hyannis (see Figure I-1). It does not have an available bathymetric map to indicate depths throughout the pond. The average depth of where PALS Snapshot sampling occurred, which is supposed to occur over the deepest location in the pond, was 0.82 m with a maximum depth of 0.95 m. The pond has a stream outflow at North Street that flows into Stewarts Creek and stream inflows from a wetland system north of Mitchells Way and an abandoned historic cranberry bog on the west side. The pond is within the Stewarts Creek subwatershed delineated in the Lewis Bay Massachusetts Estuaries Project (MEP) assessment, but does not have a separate pond watershed delineation.[37] A recent review of pond features by the Town DPW showed it did not have a public access point and it has approximately 40 buildings around it.[38] Given that it has a surface area less than 10 acres, the pond is not a Great Pond and it is not included in the most recent MassDEP Integrated List.[39]

Pond Summary			
Pond	Aunt Bettys		
Village	Hyannis		
Area (acres)	7.1		
Great Pond	No		
Management Plan	No		
Max Depth (m)	1		
Streams	2 in, 1 out		
Temperature stratified	No		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2008-2013, 2017-2019		
Total # of samples (including duplicates)	14 – 21 (depending on constituent)		
PALS % of WQ data	97%		
Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	14	n/a	10
TN (mg/L)	1.0	n/a	0.31
Chlorophyll a (µg/L)	2.6	n/a	1.7

Available sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database is almost exclusively PALS Snapshot data (97% is PALS data), so almost all samples were collected in August and September. PALS Snapshot samplings occurred in 2001-2003, 2008-2013, and 2017-2019. Review of available data did not indicate any notable or significant water quality trends. Review of public databases show that no diagnostic assessment or management plan of Aunt Bettys Pond has been completed.

Available PALS clarity data showed that during most PALS Snapshots the Secchi disk could be seen on the bottom (*i.e.*, 100% Secchi readings and clarity to the pond bottom). As a very shallow pond with light throughout the water column, it would be expected that dissolved oxygen concentrations would be close to 100% saturation (*i.e.*, in equilibrium with the atmospheric concentration), however, average % saturation was 82% with a range of 36% to

[37] Howes B., H. Ruthven, E. Eichner, J. Ramsey, R. Samimy, D. Schlezinger. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Lewis Bay System, Towns of Barnstable and Yarmouth, MA. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 253 pp.

[38] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee (2016).

[39] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

104%. Among the available DO concentrations, 85% were above the MassDEP minimum of 5 mg/L. Most (85%) of the pH readings were above the MassDEP minimum of 6.5, but the average pH (6.8) was elevated for average Cape Cod ponds, which average 6.3.[40] Higher than average pH readings are typically associated with a high phytoplankton population; photosynthesis causes pH levels to increase as carbon dioxide is incorporated into organic matter.

Nutrient levels in Aunt Bettys Pond were relatively high. Average total phosphorus was elevated (14 µg/L) with 76% of the available readings exceeding the 10 µg/L Cape Cod Ecoregion threshold.[41] The average total nitrogen was notably high (1 mg/L) with all 21 of the available readings above the 0.31 mg/L Cape Cod Ecoregion threshold. Average chlorophyll concentration was also elevated (2.6 µg/L) with 75% exceeding the 1.7 µg/L Cape Cod Ecoregion threshold; not surprising given the high nutrient levels. Comparison of nitrogen and phosphorus concentrations show that phosphorus is the nutrient determining water quality conditions within Aunt Bettys Pond.

Overall, Aunt Bettys Pond presents as a moderately impaired system, largely based on the high nutrient and chlorophyll readings. Determining the source(s) of these high water column nutrient levels would require reviewing watershed inputs, measurement of direct stormwater inputs (the most recent town-wide stormwater system review showed one direct outfall discharge[42]), measurement of the streamflows and nutrient concentrations in and out, measurement of the sediment nutrient contributions, measurement of water column readings and phytoplankton populations throughout the summer.

[40] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.
[41] *Ibid*.
[42] Comprehensive Environmental Inc. 2019. Illicit Discharge Detection and Elimination (IDDE) Plan, Barnstable, MA. 368 pp.

III.2. Bearse Pond

Bearse Pond (PALS# BA-617) is a 67-acre Great Pond in Centerville, that is sub-basin to Wequaquet Lake (PALS# BA-605). Bearse Pond is located west of Huckins Neck Road and east of Nyes Neck Road and has an approximately 20 m wide connection to the main basin of Wequaquet Lake (see Figure I-1). The pond has had numerous studies and summer-long measurements collected, including a 1989 diagnostic/feasibility assessment,[43] a 2009 water quality assessment,[44] continuous water column recordings in 2014[45] and 2015 (with incubation of sediment cores),[46] and a 2013 profiling and long-term management plan.[47] Management activities at the pond have include herbicide applications and suction dredging to control fanwort[48] and the herring run that connects Wequaquet Lake and Long Pond to the Centerville River estuary.

Bearse Pond is mostly within the Wequaquet Lake/Shallow Pond subwatershed delineated in the Centerville River Massachusetts Estuaries Project (MEP) assessment, but does not have a separate watershed delineation.[49] The US Geological Survey groundwater modeling

Pond Summary			
Pond	Bearse (part of Wequaquet Lake)		
Village	Centerville		
Area (acres)	67		
Great Pond	Yes (listed separately by MassDEP)		
Management Plan	Last completed in 1989		
Max Depth (m)	6.6		
Streams	none		
Temperature stratified	Temporary stratification measured (2 -3 days)		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2005-2015, 2017-2019		
Total # of samples (including duplicates)	82 – 96 (depending on constituent)		
PALS % of WQ data	36%		
Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	19	29	10
TN (mg/L)	0.43	0.50	0.31
Chlorophyll a (µg/L)	5.1	8.2	1.7

[43] IEP, Inc. and K-V Associates, Inc. 1989. Diagnostic/Feasibility Study of Wequaquet Lake, Bearse, and Long Pond. Prepared for Town of Barnstable Conservation Commission. 150 pp.

[44] Eichner, E. 2009. Lake Wequaquet Water Quality Assessment. Completed for the Town of Barnstable and the Cape Cod Commission. Coastal Systems Program, School of Marine Science and Technology, University of Massachusetts Dartmouth. 81 pp.

[45] CSP/SMAST Technical Memorandum. February 3, 2015. Summary of Continuous Monitoring at two stations in Lake Wequaquet, Main Basin (Station #2) and Bearses Pond (Station #5), between August 15 and October 7, 2014. From: E. Eichner, B. Howes, and D. Schlezinger. To: R. Gatewood, Town of Barnstable Conservation Administrator, P. Canniff, President, Wequaquet Lake Protective Association, and G. Maguire, Vice President, Wequaquet Lake Protective Association. 24 pp.

[46] CSP/SMAST Technical Memorandum. March 22, 2016. Continuous Monitoring at Main Basin and Bearses Pond (Station #5), Bearses Pond sediment cores, and Bearses Pond Management Options. From: E. Eichner, B. Howes, and D. Schlezinger. To: D. Karle, Town of Barnstable Conservation Administrator, P. Canniff, President, Wequaquet Lake Protective Association, and G. Maguire, Vice President, Wequaquet Lake Protective Association. 22 pp.

[47] Woods Hole Group, Inc. 2013. Wequaquet Lake Profiling and Long-Term Management Plan. 126 pp.

[48] Solitude Lake Management. 2020. Barnstable Ponds Report: Wequaquet Lake. Shrewsbury, MA. 9 pp.

[49] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

completed for the MEP also shows that a portion of downgradient flow out of Bearse Pond flows toward Barnstable Great Marshes along its northern shoreline; this means that Bearse Pond is situated along the regional groundwater divide between Cape Cod Bay and Vineyard Sound. Previous work by the Town DPW showed it does not have a public access point and approximately 60 buildings surrounded it.[50] Bearse Pond is listed and categorized as a 4a water body in the most recent MassDEP Integrated List.[51] Category 4a in the Integrated List is "TMDL is completed"; the approved TMDL is for mercury in fish tissue in Bearse Pond and Wequaquet Lake based on MassDEP sampling in 2001-2004.[52] An assessment of nutrient water quality conditions in Bearse Pond is not included in the most recent MassDEP Integrated List.

In a 2015 CSP/SMAST Technical Memo, project staff noted that Bearse Pond water quality conditions were impaired compared to both MassDEP regulatory standards and Cape Cod ecoregion standards.[53] Review of collected data at the time, including PALS Snapshot data, showed that summer water column conditions in Bearse Pond had relatively consistent annual bottom hypoxia, high chlorophyll concentrations, and release of phosphorus from the sediments. The late summer 2014 continuous water column monitoring showed that Bearse Pond had occasional, temporary (2-3 days) temperature stratification events that created a significant decrease in DO and accompanying significant increase in chlorophyll a (likely from phosphorus being released from the sediments by the DO decrease). Measurements from collected sediment cores in 2015 confirmed that the onset of low oxygen prompted significant release of phosphorus from Bearse Pond sediments.[54] The 2016 Technical Memorandum recommended that the Town pursue either an aeration system or an alum treatment to ensure acceptable water quality in Bearse Pond. Preliminary cost estimates showed that the alum treatment was less expensive. It was also recommended by the project team that whatever management activity was pursued in Bearse Pond that it be accompanied by monitoring in the rest of Wequaquet Lake since changes in Bearse Pond are likely to impact the Main Basin of the Lake at a minimum. It was further suggested that development of a system-wide, Wequaquet Lake management plan would be an appropriate tool to organize public discussion of management options and potential costs.

PALS Snapshot data is the predominant source (36%) of water column data for Bearse Pond in the 2021 Barnstable Pond and Lake Water Quality Database with the 2008 Water Quality Assessment (22%) and 1989 Diagnostic/Feasibility Study as the next largest sources (12%). PALS Snapshot samplings occurred in 2001-2003, 2005-2015 and 2017-2019. Reflecting these available sources, August and September sampling dates are 60% of available readings; only two of the 53 sampling dates occurred in April or May. Outlier analysis found that many of the outliers in the overall averages were in the May or June readings, which suggests that they are not outliers, but reflective of high frequency of late summer readings in the overall dataset.

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[50] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[51] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

[52] Massachusetts Department of Environmental Protection. 2006. Massachusetts Fish Tissue Mercury Studies: Long-Term Monitoring Results, 1999-2004. 48 pp.

[53] CSP/SMAST Technical Memorandum. February 3, 2015. Summary of Continuous Monitoring at two stations in Lake Wequaquet, Main Basin (Station #2) and Bearses Pond (Station #5), between August 15 and October 7, 2014.

[54] CSP/SMAST Technical Memorandum. March 22, 2016. Continuous Monitoring at Main Basin and Bearses Pond (Station #5), Bearses Pond sediment cores, and Bearses Pond Management Options.

Review of the available data also noted that older and more recent data had significant differences. Review of PALS data showed statistically significant ($\rho<0.05$) differences between many of the shallow and deep averages, but none of the average readings from assessments prior to PALS in 2001 showed similar differences. Part of this may be due to changes in the system, but some may also be due to changes in laboratory assay methods; the average TP concentration in shallow pre-2001 data was 30.8 µg/L, while it was 18.7 µg/L in data collected after 2001. This difference suggests that data from SMAST and older data should be kept separate during future reviews; better understanding of the source of this difference could be resolved during the development of a management plan. For the purposes of developing average conditions, project staff relied on data generated after 2001.

Past review of water column data showed that Bearse Pond has impaired conditions during the summer and the continuous water column monitoring showed that these conditions occasionally become even more impaired. Defining average conditions with this kind of pattern needs to understand that results that might be statistical outliers generally should be regarded as outside of average conditions, but still accurate measurements. Given this finding and that the majority of the readings were PALS Snapshot data, project staff focused the database water quality review of average conditions and trend analysis exclusively on August and September data.

Review of the data collected for the 2021 Barnstable Pond and Lake Water Quality Database generally confirmed past finding indicating that Bearse Pond has impaired water quality. Greater than 90% of August and September shallow concentrations for total phosphorus, total nitrogen, and chlorophyll a were greater than their respective Cape Cod regional thresholds. Only 23% of pH readings were below the MassDEP minimum, which is consistent with large phytoplankton populations raising the pH. Trend analysis did not show significant trends for shallow nutrients, pigments, or clarity, but deep TP concentrations did show a significant ($\rho<0.05$) increasing trend in August/September readings between 2001 and 2019. Increasing trends were also noted in deep pigments, likely due to changes in the phytoplankton population and/or changes in particle settling patterns. The increasing trend in deep TP concentrations would seem suggest greater frequency and/or duration of low oxygen/temporary stratification events over years of available sampling. Also of note is a significant increasing trend in alkalinity in both shallow and deep samples. Alkalinity in Cape Cod waters is usually significantly influenced by photosynthesis changes, but this may be due to other changes, such as pH buffering for drinking water imported into the watershed or hydrologic changes in water flows in and out of the pond. More refined evaluation of these changes could be resolved in a diagnostic feasibility assessment and management plan.

Overall, Bearse Pond presents as an impaired system, largely based on the high nutrient and chlorophyll readings, regular anoxic events, and water quality data that show regular sediment release of phosphorus to the water column. Monitoring results and sediment characterization in the 2015 and 2016 CSP/SMAST Technical Memos showed that water quality impairments are enhanced when the pond has temporary temperature stratification and recommended that the Town consider installing an aeration system or conducting an alum treatment to prevent the temporary, but significant, release of sediment phosphorus. It was further suggested that a

management plan could help focus all management concerns, identify all underlying causes, [55] and create community agreement on the preferred management options. It is important to track the apparent temporal trend of increasing TP in bottom waters as this will potentially increase impairment of surface waters when periodic mixing occurs. An updated diagnostic assessment and management plan for Bearse Pond has not been completed since 1989.

[55] Including stormwater inputs. 2019 Town review of stormwater infrastructure noted a stormwater outfall on the eastern shoreline of Bearses Pond (Comprehensive Environmental Inc. 2019).

III.3. Bog Pond

Bog Pond (PALS# BA-802) is a 7.2-acre pond in Osterville. Bog Pond is south of Ice Valley Road and west of Bunker Hill Road. It does not have an available bathymetric map to indicate depths throughout the pond. The average depth of where PALS Snapshot sampling occurred, which is supposed to occur over the deepest location in the pond, was 0.58 m with a maximum depth of 1.0 m. Based on review of aerial photographs, the pond has a stream outflow into Dam Pond, though it is likely that there is a weir or flapper valve at the connection point that prevents tidal flow into Bog Pond. The pond has a watershed delineation completed through the Three Bays Massachusetts Estuaries Project (MEP) assessment.[56] A recent review of pond features by the Town DPW showed it did not have a public access point and has approximately 12 buildings around it.[57] Review of Town GIS property maps does not have any assigned ownership attributes for the pond parcel.[58] Given that it has a surface area less than 10 acres, the pond is not a Great Pond and it is not included in the most recent MassDEP Integrated List.[59]

Pond Summary		
Pond	Bog	
Village	Osterville	
Area (acres)	7.2	
Great Pond	No	
Management Plan	No	
Max Depth (m)	1.0	
Streams	1 out	
Water Column Monitoring Summary		
PALS Years	2001-2003, 2005-2019	
Total # of samples (including duplicates)	33 – 34 (depending on constituent)	
PALS % of WQ data	100%	
Average concentrations		
assay	Shallow	Cape Cod threshold
TP (µg/L)	26	10
TN (mg/L)	0.73	0.31
Chlorophyll a (µg/L)	5.3	1.7

Available sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database is exclusively PALS Snapshot data, so all samples were collected in August and September. PALS Snapshot samplings occurred in 2001-2003 and 2005-2019. Trend analysis showed that all of the available measures had modest, but statistically insignificant, trends. Most of the primary regulatory limits (*e.g.*, DO) and Cape Cod thresholds (*e.g.*, TP) showed no meaningful change between 2001 and 2019. Review of public databases show that no diagnostic assessment or management plan of Bog Pond has been completed.

Available PALS clarity data showed that during most PALS Snapshots the Secchi disk could be seen on the bottom (*i.e.*, 100% Secchi readings and clarity to the pond bottom). As a very shallow pond with light throughout the water column, it would be expected that dissolved oxygen concentrations would be close to 100% saturation (*i.e.*, in equilibrium with the atmospheric concentration), and the average among available readings was 93% with a range of 66% to 114%. All measured DO concentrations (except one reading) were above the MassDEP

[56] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 183 pp.

[57] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee (2016).

[58] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 4/15/21).

[59] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

minimum of 5 mg/L. Similarly, all but one of the 18 pH readings were above the MassDEP minimum of 6.5 with the average pH (7.0) was elevated for average Cape Cod ponds, which average 6.3.[60] Higher than average pH readings are typically associated with a high phytoplankton population; photosynthesis causes pH levels to increase as carbon dioxide is incorporated into organic matter.

PALS Snapshot nutrient levels were high. Average total phosphorus was high (26 µg/L) with 94% of the available readings exceeding the 10 µg/L Cape Cod Ecoregion threshold.[61] The average total nitrogen was also high (0.73 mg/L) with all 18 of the available readings above the 0.31 mg/L Cape Cod Ecoregion threshold. As would be expected from the high nutrient levels, the average chlorophyll concentration was also elevated (5.3 µg/L) with all readings exceeding the 1.7 µg/L Cape Cod Ecoregion threshold. Comparison of nitrogen and phosphorus concentrations show that phosphorus is the nutrient determining water quality conditions within Bog Pond (N:P ratios averaged 66).

Overall, available data presents Bog Pond as a significantly impaired system, largely based on the high nutrient and chlorophyll readings. Trend analysis suggested that these readings have been relatively consistent between 2001 and 2019, but since no measurements are available in any months other than August and September, it is not known whether measured conditions persist throughout the summer or whether conditions outside of the sampled months have changed between 2001 and 2019.

Determining the source(s) of the high water column nutrient levels in Bog Pond would require reviewing watershed inputs, measurement of the stream outflow, measurement of the sediment nutrient contributions, measurement of water column readings and phytoplankton populations throughout the summer.[62] This type of assessment is typically completed through a management plan. A management plan would include quantification of the relative contributions of phosphorus from the sediments and the watershed, a review all applicable options to address the water quality impairments, and cost estimates for all applicable options.

[60] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.
[61] *Ibid*.
[62] No stormwater outfalls were noted around Bog Pond in 2019 Town review of stormwater infrastructure (Comprehensive Environmental Inc. 2019).

III.4. Crocker Pond

Crocker Pond (PALS# BA-694) is a 24.6-acre pond in Marstons Mills that was formerly named Muddy Pond (see **Figure I-1**). Crocker Pond is west of River Road and north of Olde Homestead Road. It has historic stream inputs from three adjacent cranberry bogs; review of aerial photographs showed that at least two of the connections are still utilized. Crocker Pond is within the watershed to the Three Bays estuary watershed and had its watershed delineated as part of the Three Bays Massachusetts Estuaries Project (MEP) assessment.[63] It has a bathymetric map with 5 ft contours included in the Cape Cod Pond and Lake Atlas,[64] which indicates a maximum depth of approximately 15 ft (4.6 m). The average depth of where PALS Snapshot sampling occurred, which is supposed to occur over the deepest location in the pond, was 3.81 m with range of 1.8 to 6.1 m. A recent review of pond features by the Town DPW showed it did not have a public access point and has approximately 7 buildings around it.[65] Given that it has a surface area greater than 10 acres, Crocker Pond is a Great Pond. It is not included in the most recent MassDEP Integrated List.[66]

Pond Summary			
Pond	Crocker (née Muddy)		
Village	Marstons Mills		
Area (acres)	24.6		
Great Pond	Yes		
Management Plan	No		
Max Depth (m)	6.1		
Streams	3 in from cranberry bogs		
Temperature stratified	no		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2007-2013, 2018-2019		
Total # of samples (including duplicates)	21 - 22 (depending on constituent)		
PALS % of WQ data	100%		
Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	23	48	10
TN (mg/L)	0.55	0.79	0.31
Chlorophyll a (µg/L)	7.8	11.1	1.7

Available sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database is exclusively PALS snapshot data, so all samples were collected in August and September. PALS Snapshot samplings occurred in 2001-2003, 2007-2013, and 2018-2019. Trend analysis of available data is unreliable given the multi-year gaps (*i.e.*, 2004-2006 and 2014-2017). Statistical review of the primary regulatory (*e.g.*, DO) and Cape Cod thresholds (*e.g.*, TP) showed no significant change between 2001 and 2019. Review of public databases show that no diagnostic assessment or management plan of Crocker Pond has been completed.

Average August/September PALS Snapshot data show impaired water quality conditions in Crocker Pond. Clarity data showed notably diminished light penetration within the water

[63] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 183 pp.

[64] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.

[65] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee (2016).

[66] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

column, approximately half (57%) of the water column has light; average Secchi depth was 2.09 m (range = 1.08 m to 3.13 m). Dissolved oxygen (DO) concentrations averaged 70% of saturation (100% saturation would be at atmospheric equilibrium). Average shallow and deep DO concentrations were statistically significant different ($\rho<0.05$). Average deep DO (4.28 mg/L) was less than the MassDEP minimum (5 mg/l) and individual readings were occasionally anoxic (<1 mg/L). Available pH readings, however, had an average (6.23) comparable to the average of all Cape Cod ponds and lakes (6.3).[67]

PALS Snapshot water column nutrient levels were high with differences between shallow and deep averages indicating summer nutrient regeneration from the sediment. Average shallow total phosphorus (TP) was high (23 µg/L) with 92% of individual shallow TP readings exceeding the 10 µg/L Cape Cod Ecoregion threshold.[68] Deep TP averaged (48 µg/L) slightly more than double the shallow average with all readings exceeding the Cape Cod threshold. The average shallow total nitrogen (TN) was also high (0.55 mg/L) with all 12 of the available readings above the 0.31 mg/L Cape Cod Ecoregion threshold. Deep TN averaged 0.79 mg/L. As would be expected from the high nutrient levels, average shallow chlorophyll concentration was also elevated (7.8 µg/L) with 75% of readings exceeding the 1.7 µg/L Cape Cod Ecoregion threshold. Comparison of nitrogen and phosphorus concentrations show that phosphorus is the nutrient determining water quality conditions within Crocker Pond (N:P ratios averaged 47).

Overall, available data presents Crocker Pond as a significantly impaired system based on the high nutrient and chlorophyll readings, diminished clarity, and low, and occasionally anoxic, DO concentrations. All available data was collected through PALS Snapshots. Trend analysis is unreliable given the multi-year gaps in collected data. Since no measurements are available in any months other than August and September, it is not known whether measured conditions persist throughout the summer or whether conditions outside of the sampled months have changed between 2001 and 2019.

Determining the relative source(s) of the high water column nutrient levels in Crocker Pond would require reviewing watershed inputs, measurement of the stream inflows, measurement of the sediment nutrient contributions, measurement of water column readings and phytoplankton populations throughout the summer.[69] This type of assessment is typically completed through a management plan. A management plan would include quantification of the relative contributions of phosphorus from the sediments and the watershed, a review all applicable options to address the water quality impairments, and cost estimates for all applicable options.

[67] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.
[68] *Ibid*.
[69] No stormwater outfalls were noted around Crocker Pond in 2019 Town review of stormwater infrastructure (Comprehensive Environmental Inc. 2019).

III.5. Crystal Lake

Crystal Lake (PALS# BA-878) is a 10.1-acre pond in Osterville (see **Figure I-1**). Crystal Lake is west of Wianno Avenue, south of Crystal Lake Road, and approximately 240 m north of Vineyard Sound. Review of available aerial photographs showed that the lake has no stream inflows or outflows. Crystal Lake is located between the estuary watersheds to Three Bays and Centerville River/East Bay assessed through the Massachusetts Estuaries Project (MEP) assessment, so it does not have a watershed delineation completed. It does not have an available bathymetric map to indicate depths throughout the pond. The average depth of where PALS Snapshot sampling occurred, which is supposed to occur over the deepest location in the pond, was 9.76 m with range of 5.8 to 12.2 m. A recent review of pond features by the Town DPW showed it did not have a public access point and had approximately 15 buildings around it.[70] Review of Barnstable GIS parcels shows two small parcels extending from the road rights-of-ways off East Avenue and Wianno Avenue to the pond.[71] Given that it has a surface area greater than 10 acres, Crystal Lake is a Great Pond. It is not included in the most recent MassDEP Integrated List.[72]

Pond Summary			
Pond	Crystal		
Village	Osterville		
Area (acres)	10.1		
Great Pond	Yes		
Management Plan	No		
Max Depth (m)	12.2		
Streams	none		
Temperature stratified	yes		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2005-2013, 2015-2019		
Total # of samples (including duplicates)	54 - 57 (depending on constituent)		
PALS % of WQ data	100%		
Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	10	44	10
TN (mg/L)	0.39	0.83	0.31
Chlorophyll a (µg/L)	2.3	2.3	1.7

Available sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database is exclusively PALS Snapshot data, so all samples were collected in August and September. PALS Snapshot samplings occurred in 2001-2003, 2005-2013, and 2015-2019. Review of data shows that most measures did not change notably with time and there are some notable data gaps in some of the individual water column profile readings (*i.e.*, recording of DO in profiles often stopped at 7 to 8 m depth once DO concentrations were below 1 mg/L). Trend analysis of clarity and shallow temperature, DO, pH, and TN did not show significant trends, but shallow TP did have a statistically significant ($\rho<0.05$) increasing trend from 2001 to 2019. No significant trends were noted among the deep samples, although deep TP did have an increasing trend at the $\rho<0.08$ level. Increasing TP is likely due to increased watershed phosphorus transfer from the surrounding houses, but this needs to be confirmed by reviewing the ages of the houses and their septic system leachfields. Review of public databases show that no diagnostic assessment or management plan of Crystal Lake has been completed.

[70] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee (2016).

[71] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 4/15/21).

[72] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

Average August/September PALS data show impaired water quality conditions in Crystal Lake. Available PALS clarity data showed notably diminished light penetration within the water column, half of the water column has light; average Secchi depth was 4.5 m (range = 3.2 m to 6.8 m). Surface DO concentrations averaged 85% of saturation (100% saturation would be at atmospheric equilibrium). Average shallow and deep DO concentrations were significantly different ($\rho<0.05$). Average deep DO (3.28 mg/L) was less than the MassDEP minimum (5 mg/l) and individual readings were occasionally anoxic (<1 mg/L) even with many DO profiles that did not extend to the deepest depth. Among available individual deep DO readings, 44% are less than the MassDEP minimum. Available pH readings also showed a significant difference between shallow and deep averages and, overall, 44% of all pH readings were less than the MassDEP minimum.

Available PALS water column nutrient levels were high with differences between shallow and deep averages indicating summer nutrient regeneration from the sediments. Average shallow total phosphorus (TP) was at the regional 10 µg/L Cape Cod Ecoregion threshold.[73] Deep TP averaged (44 µg/L) slightly more than 4X the shallow average with all but one of individual readings exceeding the Cape Cod threshold. Average shallow total nitrogen (TN) was moderately high (0.39 mg/L) with 88% of the available individual readings above the 0.31 mg/L Cape Cod Ecoregion threshold. Deep TN averaged 0.83 mg/L, again confirming regular sediment release accompanying deep anoxic conditions. Average shallow chlorophyll concentration was slightly elevated (2.2 µg/L) with 59% of readings exceeding the 1.7 µg/L Cape Cod Ecoregion threshold. Comparison of nitrogen and phosphorus concentrations show that phosphorus is the nutrient determining water quality conditions within Crystal Lake (shallow N:P ratios averaged 87).

Overall, available data presents Crystal Lake as an impaired system with relatively acceptable shallow conditions, but significantly impaired deep conditions. All available data was collected through PALS Snapshots. Trend analysis shows that TP concentrations, which are controlling growth and the impairments, have increased between 2001 and 2019 and have not reached a steady state. Since no measurements are available in any months other than August and September, it is not known whether measured conditions persist throughout the summer or whether conditions outside of the sampled months have changed between 2001 and 2019.

Determining the relative source(s) of the high water column nutrient levels in Crystal Lake would require reviewing watershed inputs, measurement of the sediment nutrient contributions and potential future contributions, measurement of water column readings and phytoplankton populations throughout the summer.[74] This type of assessment is typically completed through a management plan. A management plan would include quantification of the relative contributions of phosphorus from the sediments and the watershed, a review all applicable options to address the water quality impairments, and cost estimates for all applicable options.

[73] *Ibid*.

[74] No stormwater outfalls were noted around Crystal Lake in 2019 Town review of stormwater infrastructure (Comprehensive Environmental Inc. 2019).

III.6. Eagle Pond

Eagle Pond (PALS# BA-815) is an 8.5-acre pond in Cotuit (see **Figure I-1**). Eagle Pond is east of Putnam Avenue and west of Cordwood Road. Review of Town GIS parcels showed that the pond is completely enclosed within a Barnstable Land Trust (BLT) parcel and the pond does not have a separate parcel delineation within the Trust parcel.[75] Review of available aerial photographs showed that the pond has no stream inflows or outflows.

Pond Summary			
Pond	Eagle		
Village	Cotuit		
Area (acres)	8.5		
Great Pond	No		
Management Plan	No		
Max Depth (m)	5.1		
Streams	none		
Temperature stratified	no		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2006-2015, 2017-2018		
Total # of samples (including duplicates)	28 - 30 (depending on constituent)		
PALS % of WQ data	100%		
Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	10	12	10
TN (mg/L)	0.59	0.57	0.31
Chlorophyll a (µg/L)	2.4	2.5	1.7

Eagle Pond is within the watershed to the Three Bays estuary and had its watershed delineated as part of the Three Bays Massachusetts Estuaries Project (MEP) assessment.[76] It has a bathymetric map included in the Cape Cod Pond and Lake Atlas, [77] but the contour depths appear to be mislabeled given the sampling depths measured in PALS Snapshots. PALS Snapshot sampling protocols require sampling over the deepest point in the pond and the average depth of all PALS Snapshot sampling of Eagle Pond was 4.33 m with range of 3.8 to 5.1 m. A recent review of pond features by the Town DPW showed it did not have a publicly-owned access point, but did have public access through a number of BLT trails on the property.[78] The pond has no buildings around it.[79] Given that it has a surface area less than 10 acres, Eagle Pond is not a Great Pond. It is not included in the most recent MassDEP Integrated List.[80]

Available sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database is exclusively PALS Snapshot data, so all samples were collected in August and September. Review of data shows that most did not change significantly with time. PALS Snapshot samplings occurred in 2001-2003, 2006-2015, and 2017-2018. Trend analysis of PALS clarity and shallow temperature, DO, pH, TP and TN data did not show statistically significant trends,

[75] Town on-line GIS (accessed 1/14/21) shows that the parcel containing Eagle Pond is owned by Barnstable Land Trust.

[76] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 183 pp.

[77] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.

[78] https://static1.squarespace.com/static/5e52e8cbc3edc625cc000211/t/5e7a6bf34b2bc27f3691b38d/1585081335059/EaglePondTrailMap.pdf (BLT Eagle Pond Trail Map; accessed 4/15/21).

[79] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee (2016).

[80] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

but nutrients did increase with time likely due to upgradient development within the watershed that has generally occurred since the 1970's. N:P ratios also did not have significant trends, but shallow ratios increased consistent with watershed nitrogen additions likely associated with increased N loading from in septic systems within the watershed. Deep ratios decreased which would be consistent with additional sediment retention and regeneration of phosphorus. Review of public databases show that no diagnostic assessment or management plan of Eagle Pond has been completed.

Average August/September PALS data show a mix of impaired measures and acceptable conditions in Eagle Pond. Available PALS clarity data showed only slightly diminished light penetration within the water column, 80% of the water column has light; average Secchi depth was 3.4 m (range = 2.1 m to 4.2 m). Shallow dissolved oxygen concentrations averaged 87% of saturation (100% saturation would be at atmospheric equilibrium) with all individual readings greater than the MassDEP minimum (5 mg/l). However, the average deep DO concentration was significantly ($\rho<0.05$) lower than the average shallow concentration and 25% of the deepest individual readings were less than the MassDEP minimum. It is notable that this DO loss occurs even with no significant temperature difference between shallow and deep readings; lack of significant temperature difference means the water column should be able to reliably mix with available winds and sediment oxygen demand causing low deep DO concentrations should be addressed by replenishment from the atmosphere and water column mixing. Sustained water column oxygen loss means the sediments have significant oxygen demand, which is usually a symptom of excessive phosphorus additions. Nutrient concentrations show that 71% of individual shallow and deep TP concentrations and all of the individual shallow and deep TN concentrations were greater than their respective Cape Cod Ecoregion thresholds.[81] N:P ratios show that phosphorus is the nutrient controlling water quality in Eagle Pond.

Overall, available data presents Eagle Pond as a borderline impaired system. No statistically significant trends were noted in the data except of increasing alkalinity. All available data was collected through PALS Snapshots. Since no measurements are available in any months other than August and September, it is not known whether measured impairments persist throughout the summer or whether conditions outside of the sampled months have changed between 2001 and 2019. The lack of development around the pond should prevent significant new additions of phosphorus, but it is likely that phosphorus travel time from development outside of the undeveloped parcel is currently reaching the pond and causing the measured water column nutrients.

Determining the relative source(s) of the high water column nutrient levels in Eagle Pond would require reviewing watershed inputs, measurement of the sediment nutrient contributions and potential future contributions, measurement of water column readings and phytoplankton populations throughout the summer.[82] This type of assessment is typically completed through a management plan. A management plan would include quantification of the relative contributions of phosphorus from the sediments and the watershed, a review all applicable options to address the water quality impairments, and cost estimates for all applicable options.

[81] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.

[82] No stormwater outfalls were noted around Eagle Pond in 2019 Town review of stormwater infrastructure (Comprehensive Environmental Inc. 2019).

III.7. Lake Elizabeth

Lake Elizabeth (PALS# BA-795) is a 6.3-acre pond in Centerville and is hydrologically connected to Red Lily Pond (PALS#BA-782) through a culvert under Centerville Avenue. Lake Elizabeth is located east of Lake Elizabeth Drive and north of Craigville Beach Road (see **Figure I-1**). Aside from the connection to Red Lily Pond, it has an outflow stream connected to the Centerville River estuary and a surface water input from a small wetland to the east. The pond has had numerous measurements, studies, and one complete year of monthly water quality measurements collected in 1985 as part of a diagnostic/feasibility assessment that was completed for the combined Lake Elizabeth/Red Lily Pond system.[83] The bathymetric map in the 1988 diagnostic/feasibility study has 1 ft contours and a maximum depth of 3.9 ft (1.2 m). The pond system has had numerous management activities implemented including installation of a cluster septic system (1994), stormwater treatment (1998), subsidence dredging and reverse layering of bottom sediments (2000-2001), sand relayering (2003), and hydroraking (2011). Total cost of implementing management options between 1996 and 2005 (including local match and in-kind services) was $686,000.[84] Other management activities at the pond have also included a herring run that connects Red Lily Pond and Lake Elizabeth to the Centerville River estuary.

Pond Summary			
Pond	Elizabeth		
Village	Centerville		
Area (acres)	6.3		
Great Pond	No		
Management Plan	Last completed in 1988		
Max Depth (m)	4.5		
Streams	2 inflows (1 from Red Lily Pond and 1 from wetland to east), 1 stream outflow		
Temperature stratified	no		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2008-2013, 2017-2019		
Total # of samples (including duplicates)	23 - 24 (depending on constituent)		
PALS % of WQ data	80%		
Average PALS concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	16	52	10
TN (mg/L)	0.63	0.83	0.31
Chlorophyll a (µg/L)	3.6	13.9	1.7

Lake Elizabeth is within a Lake Elizabeth/Red Lily Pond subwatershed delineated in the Centerville River Massachusetts Estuaries Project (MEP) assessment, but the lake does not have a separate watershed delineation.[85] Previous work by the Town DPW showed it did not have a public access point and has approximately 20 buildings around it.[86] Review of Town GIS parcels showed that the pond has its own parcel, but the pond surface area is also part of an adjacent private parcel and no ownership information is attached to the pond parcel.[87] Lake Elizabeth is listed separately from

[83] K-V Associates, Inc. and IEP, Inc. 1988. Red Lily Pond Diagnostic/Feasibility Study. Prepared for Town of Barnstable. 260 pp.

[84] ENSR Technical Review. February 1, 2008. Third Party Peer Review of Proposal entitled "Feasibility Study for Restoration of Water and Sediments at Red Lily Pond; Craigville, Massachusetts." From D. Mitchell. To: D. Saad, Special Project Manager, Town of Barnstable Department of Public Works. 50 pp.

[85] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

[86] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[87] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 4/15/21).

Red Lily Pond in the most recent MassDEP Integrated List and is assigned to Category 3.[88] Category 3 in the Integrated List is "No Uses Assessed"; Red Lily Pond is assigned to Category 5, which is impaired "waters requiring a TMDL." If Lake Elizabeth and Red Lily Pond are treated as parts of the same pond, the combined area is greater than 10 acres and it would be considered a Great Pond. The separate treatment of the ponds in the Integrated List suggests that MassDEP regards them as separate ponds; from this perspective, Lake Elizabeth is not a Great Pond.

Among the available water column sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database, 80% of the available data is PALS Snapshot data, so the majority of data were collected in August and September. Review of available data shows that most did not change significantly with time, but any conclusions from the trend analysis must be tempered by the multi-year gaps in the available data (*e.g.*, PALS Snapshots were collected between 2001 and 2003, 2008 to 2013, and 2017 to 2019). Trend analysis of PALS clarity and shallow temperature, pH, and TN did not show statistically significant trends, but shallow TP and DO did decrease with time. These decreases suggest that the causes of water column concentrations likely involve complex interactions between the watershed, sediments, flow from Red Lily Pond, and the rooted plants in the pond. Given the shallowness of the lake, deep measurements tended to change in the same way as shallow measurements. N:P ratios showed that phosphorus was the key nutrient for determining water quality conditions in Lake Elizabeth.

Average August/September PALS Snapshot data generally showed impaired conditions in Lake Elizabeth. Available PALS clarity data showed diminished light penetration within the water column, 62% of the water column has light; average Secchi depth was 1.9 m (range = 1.4 m to 2.5 m). Available shallow DO concentrations were all above the MassDEP minimum (5 mg/l) consistent with high plant growth, but the deep average DO concentration (3.3 mg/L) was less than the MassDEP minimum. It is notable that this DO loss occurs in a shallow pond with a residence time estimated in 1988 at 10 days.[89] Sustained water column oxygen loss in a pond with a short residence time means the sediments have significant oxygen demand, which is usually a symptom of excessive phosphorus additions. Nutrient concentrations show that 83% of both the shallow and deep TP concentrations and most (96%) of the shallow and deep TN concentrations were greater than their respective Cape Cod Ecoregion thresholds.[90]

Overall, available data presents Lake Elizabeth as an impaired system. The temporal gaps where the pond was not sampled make it difficult to discern how the pond has changed since the implementation of management actions; some of the available data shows trends that would benefit from forensic review of both the management actions and the water quality results. Most of the recent available data was collected through PALS Snapshots. Since measurements outside of the PALS sampling window (August and September) are limited, it is not known whether current measured conditions persist throughout the summer or whether conditions outside of the sampled months have changed between 2001 and 2019.

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[88] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

[89] K-V Associates, Inc. and IEP, Inc. 1988. Red Lily Pond Diagnostic/Feasibility Study.

[90] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.

Determining the relative source(s) of the high water column nutrient levels in Lake Elizabeth would require an updated review of watershed inputs, measurement of the sediment nutrient contributions and potential future contributions, measurement of stream inputs and outflows, potential stormwater inputs,[91] characterization of the rooted plant community, measurement of water column readings and phytoplankton populations throughout the summer. This type of assessment is typically completed through a management plan. A management plan would include quantification of the relative contributions of phosphorus from the sediments and the watershed and the role of plants, a review all applicable options to address the water quality impairments, and cost estimates for all applicable options.

[91] No stormwater outfalls were noted around Lake Elizabeth in 2019 Town review of stormwater infrastructure (Comprehensive Environmental Inc. 2019), but the roads adjacent to the pond may have overland flow to the lake that was not noted.

III.8. Garretts Pond

Garretts Pond (PALS# BA-510) is a 27.9-acre Great Pond in West Barnstable and is located west of Oak Street and south of Route 6A (see **Figure I-1**). Review of aerial maps and historical US Geological Survey topographic maps showed a stream inflow from a wetland system along the western shoreline and a stream outflow to Barnstable Great Marshes at its northernmost extent. Garretts Pond has a bathymetric map included in the Cape Cod Pond and Lake Atlas, which shows a maximum depth of approximately 25 ft (7.6 m).[92] The average depth of where PALS Snapshot sampling occurred, which is supposed to occur over the deepest location in the pond, was 8.4 m with range of 7.9 to 8.9 m.

Pond Summary			
Pond	Garretts		
Village	West Barnstable		
Area (acres)	27.9		
Great Pond	Yes		
Management Plan	none		
Max Depth (m)	8.9		
Streams	1 inflow and 1 stream outflow		
Temperature stratified	Occasional, very deep		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2008-2013, 2017-2019		
Total # of samples (including duplicates)	11 - 32 (depending on constituent)		
PALS % of WQ data	95%		
Average PALS concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	12	16	10
TN (mg/L)	0.28	0.31	0.31
Chlorophyll a (µg/L)	2.3	6.9	1.7

Garretts Pond is within the watershed to the Barnstable Great Marshes estuary and had its watershed delineated as part of the Barnstable Great Marshes-Bass Hole Massachusetts Estuaries Project (MEP) assessment.[93] In the MEP assessment, the stream outflow (Brickyard Creek) had a gauge, but it did not have measurable flow during the deployment.[94]

A recent review of pond features by the Town DPW showed there is public access to the pond off Oak Street and had 35 buildings around it.[95] Given that it has a surface area greater than 10 acres, Garretts Pond is a Great Pond. Classification as a Great Pond means that state regulatory provisions would need to be addressed in management decisions. Garretts Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[96]

Among the available water column sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database, 95% of the available data is PALS Snapshot data, so the most of data were collected in August and September. Since there were a number of years where PALS

[92] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.

[93] Howes B., E. Eichner, S. Kelley, R. Samimy, J. S. Ramsey, D. Schlezinger, P. Detjens. 2017. Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Barnstable Great Marshes - Bass Hole Estuarine System, Town of Barnstable and Dennis, Massachusetts, Massachusetts Department of Environmental Protection. Boston, MA. 213 pp.

[94] Figure IV-7 in Barnstable Great Marshes – Bass Hole MEP report.

[95] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee (2016).

[96] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

Snapshot data was not collected (2004-2007, 2014-2016), trend analysis needs to be approached with these gaps in mind. Review of public databases show that no diagnostic assessment or management plan of Garretts Pond has been completed.

Review of data shows that most parameters did not change significantly with time. Trend analysis of PALS Snapshot clarity and shallow temperature, DO, pH, TP and TN readings did not show statistically significant trends. Deep readings of these factors also did not have statistically significant trends except for TP, which significantly increased in the available data. This increase in deep TP suggests more frequent and/or longer duration anoxic events causing more sediment TP regeneration, but data outside of August/September is not available to evaluate this theory. Shallow N:P ratios did not have significant trends and consistently showed that phosphorus control is the key to water quality management of this pond. Deep N:P ratios decreased significantly caused by the increasing deep TP concentrations.

Average August/September PALS data show impaired measures throughout the water column in Garretts Pond. Available PALS Snapshot clarity data showed diminished light penetration (average 51% of water column); average Secchi depth was 4.4 m (range = 3.2 m to 5.2 m). Shallow DO concentrations averaged 93% of saturation (100% saturation would be at atmospheric equilibrium) with all readings greater than the MassDEP minimum (5 mg/L). However, the average deep DO concentration was significantly ($\rho<0.05$) lower than the average shallow concentration and 82% of the individual deep readings were less than the MassDEP minimum. Average shallow and deep temperature readings were also significantly different suggesting some occasional temperature stratification (*i.e.*, thermal layering) during the summer in the deepest portions of the pond. Sustained deep water column oxygen loss means the sediments have significant oxygen demand, which is usually a symptom of excessive phosphorus additions. Nutrient concentrations show that 75% and 67% of the individual shallow and deep TP readings, respectively, were greater than the Cape Cod Ecoregion threshold (*i.e.*, 10 µg/L).[97] TN concentrations, on the other hand, were comparatively lower with no significant difference between shallow and deep average concentrations and only 28% of all individual readings exceeded the Cape Cod Ecoregion TN threshold.[98] This relative difference between TP and TN concentrations suggest internal phosphorus loading from the sediments is the key to management of Garretts Pond water quality, but further confirmation would be necessary through measurement of sediment and stream nutrient levels and evaluation of watershed phosphorus sources. These types of measurements are typically included in the diagnostic assessment portion of a pond management plan.

Overall, available data presents Garretts Pond as an impaired system. All available data was collected through PALS Snapshots. Since no measurements are available in any months other than August and September, it is not known whether measured conditions persist throughout the summer or whether conditions outside of the sampled months have changed between 2001 and 2019. Given that most of the land around the pond is developed,[99] water quality conditions will tend to become more impaired as the pond retains more phosphorus, but the pace of this change is difficult to predict from the available data.

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[97] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas.
[98] *Ibid*.
[99] Review of Town of Barnstable online GIS shows buildings on most properties around the pond.

Determining the relative source(s) of the high water column nutrient levels and the other impairments in Garretts Pond would require reviewing watershed inputs, measurement of the sediment nutrient contributions and potential future contributions, measurement of water column readings including continuous dissolved oxygen and phytoplankton populations throughout the summer.[100] This type of assessment is typically completed as part of the development of a management plan. A management plan would include quantification of the relative contributions of phosphorus from the sediments and the watershed, a review all applicable options to address the water quality impairments, and cost estimates for all applicable options.

[100] No stormwater outfalls were noted around Garretts Pond in 2019 Town review of stormwater infrastructure (Comprehensive Environmental Inc. 2019).

III.9. Gooseberry Pond

Gooseberry Pond is a 41 acre linked basin of Wequaquet Lake (PALS# BA-605) and does not have a separate PALS number. Gooseberry Pond is located west of Huckins Neck Road and north of Phinneys Lane and has two (<30 m wide) connections to the southern basin of Wequaquet (see **Figure I-1**). As part of Wequaquet Lake, the pond has had numerous studies and summer-long measurements collected, including a 1989 diagnostic/feasibility assessment[101] and a 2009 water quality assessment.[102] Management activities at the pond have include herbicide applications and suction dredging to control fanwort[103] and the herring run that connects Wequaquet Lake and Long Pond to the Centerville River estuary.

Pond Summary			
Pond	Gooseberry (part of Wequaquet Lake)		
Village	Centerville		
Area (acres)	41		
Great Pond	Not separately, part of Wequaquet		
Management Plan	Last completed in 1989		
Max Depth (m)	5.4		
Streams	none		
Temperature stratified	no		
Water Column Monitoring Summary			
PALS Years	2001, 2018-2019		
Total # of samples (including duplicates)	23 – 80 (depending on constituent)		
PALS % of WQ data	36%		
Average concentrations (since 2001)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	22	24	10
TN (mg/L)	0.46	0.50	0.31
Chlorophyll a (µg/L)	3.8	4.3	1.7

Watershed delineations in the area have generally shown the Gooseberry Pond watershed as part of the Wequaquet Lake/Shallow Pond watershed. The most recent watershed delineations in the Centerville River Massachusetts Estuaries Project (MEP) assessment included Gooseberry Pond was part of a combined Wequaquet Lake/Bearses Pond/Shallow Pond watershed.[104] The 2009 water quality assessment delineated watersheds to each of the basins of Wequaquet Lake and the Gooseberry Pond watershed was mostly properties directly adjacent to the Pond.[105] Previous work by the Town DPW showed the pond has public access across a beach off Huckins Neck Road and approximately 40 buildings around it.[106]

Gooseberry Pond is not listed separately in the most recent MassDEP Integrated List, which assigns Wequaquet Lake to Category 4a.[107] Category 4a in the Integrated List is "TMDL is

[101] IEP, Inc. and K-V Associates, Inc. 1989. Diagnostic/Feasibility Study of Wequaquet Lake, Bearse, and Long Pond. Prepared for Town of Barnstable Conservation Commission. 150 pp.

[102] Eichner, E. 2009. Lake Wequaquet Water Quality Assessment. Completed for the Town of Barnstable and the Cape Cod Commission. Coastal Systems Program, School of Marine Science and Technology, University of Massachusetts Dartmouth. 81 pp.

[103] Solitude Lake Management. 2020. Barnstable Ponds Report: Wequaquet Lake. Shrewsbury, MA. 9 pp.

[104] Howes B., H. Ruthven, E. Eichner, J. Ramsey, R. Samimy, D. Schlezinger. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Lewis Bay System, Towns of Barnstable and Yarmouth, MA. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 253 pp

[105] Eichner, E. 2009. Lake Wequaquet Water Quality Assessment.

[106] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[107] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

completed" and the approved TMDL is for mercury in fish tissue in Gooseberry Pond and Wequaquet Lake based on MassDEP sampling in 2001-2004.[108] An assessment of nutrient water quality conditions in Gooseberry Pond is not included in the most recent MassDEP Integrated List.

In the most recent 2009 review of Gooseberry Pond water quality data, pond clarity had decreased significantly and nutrient concentrations (both N and P) had increased significantly since mid-1980's.[109] DO and temperature profiles collected in 2007 showed that the water column was generally isothermic (and well mixed) and all DO concentrations were above the MassDEP regulatory minimum (5 mg/L) with some slight decrease in DO during the summer. This same assessment also noted that a late September phytoplankton samples had blue-green algae/cyanobacteria as the primary cell type, but the cell count (148 cells/ml) was significantly less than the MassDPH 70,000 cells/ml cyanobacteria threshold established as a blue-green direct contact advisory level. Sediment samples collected in 2007 showed that the pond sediments had significantly more phosphorus (>100X) than in 1986. At the time, project staff recommended that the Town develop an overall Wequaquet Lake management plan (including Gooseberry Pond) to address the water quality findings and particularly the temporal trends, as well as other management issues such as water level and water sheet management.[110]

PALS Snapshot data is a relatively minor source (12%) of water column data for Gooseberry Pond in the 2021 Barnstable Pond and Lake Water Quality Database. Monitoring for the 2009 Wequaquet Lake assessment is the largest source (34%), followed by Town samplings (23%), the 1989 study (22%), and 2010 monitoring by CSP/SMAST.[111] August and September are 44% of available readings with 78% of the available readings collected between June and September . Overall, water quality samples and/or field data (*i.e.,* DO and temperature profiles and Secchi disk water clarity readings) have been collected from Gooseberry Pond on 43 dates from 1985 to 2019.

Review of the available data in the 2021 Barnstable Pond and Lake Water Quality Database generally matched with the well-mixed water column profile information: none of the parameters had significant differences between shallow and deep averages. Average late summer (August/September) shallow and deep TP concentrations (19 µg/L and 22 µg/L) were both greater than the Cape Cod ecoregion threshold (10 µg/L). Review of N:P ratio showed that phosphorus controls the water quality conditions in Gooseberry Pond.

It should also be noted that older and more recent data in the 2021 Barnstable Pond and Lake Water Quality Database had significant differences. TP concentrations in older data had higher concentrations than data collected from the PALS Snapshots and other post-2001 data. These higher concentrations seem to be inconsistent with other measures (*e.g.*, land use, sediments, etc.), but some may also be due to changes in laboratory analytical methods. TN, chlorophyll a concentrations are generally higher in the more recent data, as would be expected, so this

[108] Massachusetts Department of Environmental Protection. 2006. Massachusetts Fish Tissue Mercury Studies: Long-Term Monitoring Results, 1999-2004. 48 pp.

[109] Eichner, E. 2009. Lake Wequaquet Water Quality Assessment.

[110] *Ibid.*

[111] CSP/SMAST Technical Memorandum: Lake Wequaquet 2010 water quality monitoring. March 23, 2011. From: Eichner, E. and B. Howes. To: Rob Gatewood, Conservation Administrator, Town of Barnstable. 11 pp.

difference may be only with TP assays. These differences suggests that data from SMAST and older data should be kept separate during future reviews and as the pond water quality database is sustained; this difference could be resolved during the development of a management plan as more refined and detailed data evaluation is conducted. For the purposes of developing average conditions, project staff relied on data generated after 2001.

Overall, Gooseberry Pond presents as a borderline impaired system, largely based on the high nutrient and chlorophyll readings and loss of clarity in the summer, while maintaining acceptable DO concentrations throughout the water column. As noted, it was recommended in 2009 that the town develop a management plan for the overall Wequaquet Lake system. There are some data gaps that should be resolved in developing such a plan, but, as noted, extensive snapshot data has been collected and baseline data from the 1980s has been compiled for comparison. An updated diagnostic assessment and management plan for Gooseberry Pond has not been completed since 1989.

III.10. Hamblin Pond

Hamblin Pond (PALS# BA-668) is a 115 acre Great Pond located in Marstons Mills. Hamblin Pond is located west of Cotuit Road/Route 149 and north of River Road. It is one of the three ponds addressed through the Indians Ponds Association along with Mystic Lake and Middle Pond. Hamblin Pond has a maximum measured depth of approximately 19 m, which nearly matches maximum depth in an available bathymetric map.[112] It is also one of three deep ponds in Barnstable that clearly meet the MassDEP cold water fishery criteria.[113] Hamblin Pond had an alum application in May 1995 and another in June 2015 following blue-green algal blooms in 2013 and 2014.[114] Two other assessments of Hamblin Pond have also been completed: a 1993 diagnostic/ feasibility study[115] and a 2006 water quality assessment.[116] Other management activities at the pond have also included Massachusetts Division of Fisheries and Wildlife stocking of the pond with various trout species.[117]

Pond Summary			
Pond	Hamblin		
Village	Marstons Mills		
Area (acres)	115		
Great Pond	Yes		
Management Plan	Last completed in 1993		
Max Depth (m)	19.2		
Streams	none		
Temperature stratified	Yes		
Water Column Monitoring Summary			
PALS Years	2001-2019		
Total # of samples (including duplicates)	106 – 230 (depending on constituent)		
PALS % of WQ data	24%		
Average concentrations (since 2015)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	9	17	10
TN (mg/L)	0.27	0.41	0.31
Chlorophyll a (µg/L)	1.2	6.4	1.7

The latest Hamblin Pond watershed delineation was completed as part of the Three Bays Massachusetts Estuaries Project (MEP) assessment.[118] The Hamblin Pond watershed includes watersheds to Mystic Lake and Middle Pond. Previous work by the Town DPW showed the pond has three public access points, including a public beach and a separate boat landing both off Cotuit Road, and approximately 33 buildings around it.[119]

[112] Eichner, E. 2008. Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities. School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 79 pp.

[113] The other two are Hathaway Pond and Mystic Lake.

[114] Water Resources Services, Inc. 2017. Phosphorus Inactivation Project for Hamblin Pond, Barnstable, Massachusetts. 68 pp.

[115] Baystate Environmental Consultants. 1993. Diagnostic/feasibility study of Hamblin Pond, Barnstable, Massachusetts. East Longmeadow, MA.

[116] Eichner, E., S. Michaud, and T. Cambareri. 2006. First Order Assessment of the Indian Ponds: Mystic Lake, Middle Pond, and Hamblin Pond. Cape Cod Commission. Barnstable, MA. 71 pp.

[117] https://www.mass.gov/service-details/trout-stocking-report (accessed 8/12/21)

[118] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts. Department of Environmental Protection. Boston, MA. 183 pp.

[119] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

Hamblin Pond is assigned to Category 5 in the most recent MassDEP Integrated List of surface waters in Massachusetts.[120] Category 5 waters in the Integrated List are impaired waters requiring a TMDL. A TMDL would address the contaminant causing the impairment. Impairments listed for Hamblin Pond are dissolved oxygen and harmful algal blooms. Hamblin Pond has a completed TMDL for mercury in fish tissue based on MassDEP sampling in 2001-2004.[121]

Hamblin Pond has had water quality samples and/or DO and temperature profiles collected on over 100 dates. Among these, 16 were collected prior to the 1995 alum treatment and another 30 were collected after the treatment. On these 1995 dates, DO and temperature profiles were collected along with water quality samples assayed for a limited number of water quality parameters (*i.e.*, shallow and deep samples for TP, pH, alkalinity, and TKN+nitrate-N). Another 10 dates were associated with the 2015 alum treatment (three prior and nine after the treatment), often with profiles collected at two or three locations in the pond. Other sampling dates were mostly those associated with the 2006 water quality assessment and PALS Snapshot samplings.

Water quality improved following each alum treatment. Water clarity prior to the 1995 alum treatment was generally less than 4 m with minima of less than 1 m. Clarity was much improved until 2013 when the pre-1995 conditions returned. Water clarity after the 2015 alum treatment was generally greater than after the 1995 treatment. Shallow and deep TP concentrations decreased following each alum treatment, although laboratory assays were only made annually after more intensive monitoring in the year following the treatments. Late summer PALS DO profile measurements in 2017, 2018, and 2019 showed that deep water anoxia continues to be an impairment in Hamblin Pond.

Overall, Hamblin Pond presents as an impaired system with improved conditions following both the 1995 and 2015 alum treatments. Generally, the pond has acceptable shallow water quality and significantly impaired deep waters, largely based on the regular seasonal deep anoxia and high nutrient concentrations. The alum treatments have sustained improved Secchi clarity readings, although longer term monitoring is still warranted. If the Town considers a diagnostic assessment and management plan for Hamblin Pond in the future, it should include updated land use analysis and water and nutrient budgets.

[120] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

[121] Massachusetts Department of Environmental Protection. 2006. Massachusetts Fish Tissue Mercury Studies: Long-Term Monitoring Results, 1999-2004. 48 pp.

III.11. Hathaway Pond North

Hathaway Pond North (PALS# BA-565) is a 21 acre Great Pond located in Barnstable Village. It is one of two Hathaway Ponds (Hathaway Pond South, BA-594, is the other) and both are located west of Phinneys Lane and north of Old Route 132. Hathaway Pond North has a maximum measured depth of approximately 17 m, which matches the maximum depth in an available bathymetric map.[122] Hathaway Pond North is also one of three deep ponds in Barnstable that clearly meet the MassDEP cold water fishery criteria.[123] Review of public databases does not show that Hathaway Pond North has had a diagnostic/feasibility study or a water quality assessment. Other management activities at the pond have also included Massachusetts Division of Fisheries and Wildlife stocking of the pond with various trout species.[124]

Pond Summary			
Pond	Hathaway North		
Village	Barnstable		
Area (acres)	21		
Great Pond	Yes		
Management Plan	none		
Max Depth (m)	17.4		
Streams	none		
Temperature stratified	Yes		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2008-2013, 2017-2019		
Total # of samples (including duplicates)	11 - 48 (depending on constituent)		
PALS % of WQ data	95%		
Average concentrations			
Assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	10	38	10
TN (mg/L)	0.24	0.50	0.31
Chlorophyll a (µg/L)	1.7	2.0	1.7

The latest Hathaway Pond North watershed delineation was completed as part of the Barnstable Great Marshes Massachusetts Estuaries Project (MEP) assessment.[125] The area around the ponds is town-owned conservation land and Barnstable Fire District water supply areas. The pond is a true kettle hole pond with no streams flowing into or out of it. Previous work by the Town DPW showed the pond has public access through a town beach, which includes a parking lot, and has no buildings surrounding it.[126] Given that it has a surface area greater than 10 acres, Hathaway Pond North is a Great Pond and, therefore, publicly owned. It is not included in the most recent MassDEP Integrated List of surface waters in Massachusetts.[127]

Among the available water column data included in the 2021 Barnstable Pond and Lake Water Quality Database, 95% of the available data is PALS Snapshot data and majority of data (87%)

[122] Eichner, E. 2008. Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities. School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 79 pp.

[123] The other two are Hamblin Pond and Mystic Lake.

[124] https://www.mass.gov/service-details/trout-stocking-report (accessed 8/12/21)

[125] Howes B., E. Eichner, S. Kelley, R. Samimy, J. S. Ramsey, D. Schlezinger, P. Detjens. 2017. Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Barnstable Great Marshes - Bass Hole Estuarine System, Town of Barnstable and Dennis, Massachusetts, Massachusetts Department of Environmental Protection. Boston, MA. 213 pp.

[126] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[127] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

were collected in September. Since there were a number of years where PALS Snapshot data was not collected (2004-2007, 2014-2016), trend analysis needs to be approached with these temporal gaps in mind.

Review of the available data shows that Hathaway Pond North was always temperature stratified when it was sampled in late summer with hypoxic or anoxic conditions in the deep, cold layer. Review of shallow, 3 m, 9 m, and deep TP concentrations showed that the average shallow concentration was less than the ecoregion threshold (*i.e.,* 10 µg/L TP), but the average deep concentration was approximately 4X the shallow concentrations, which is indicative of sediment regeneration of TP. TN concentrations followed a similar pattern, but deep concentrations were 2X the shallow average. Trend analysis of clarity and shallow temperature, DO, pH, TP and TN did not show statistically significant trends. Water clarity averaged 7 m and 45% of the overall pond depth. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Hathaway Pond North.

Overall, available data presents Hathaway Pond North as a borderline impaired system with acceptable shallow water quality and impaired deep waters, largely based on the regular consistent deep anoxia and high nutrient concentrations. Since available water quality data has only been collected during September, it is not known whether the deep impaired conditions are sustained throughout the summer or if the deep water high nutrient concentrations are ever mixed into the upper waters. Collection of water quality data and key complementary data, such as phytoplankton species and cell counts, throughout a summer would provide insights into whether the measured late summer conditions are representative of conditions throughout the summer. Consistent annual regular sampling (spring and late summer) would also provide data for trend analysis, including whether nutrient levels are increasing over time.

III.12. Hinckley Pond

Hinckley Pond (PALS# BA-411) is a 10 acre Great Pond located in Barnstable Village. It is located north of Route 6A and west of Scudder Lane. It is also approximate 100 m south of coastal marshes fringing the Barnstable Great Marsh system. The pond has a maximum depth of approximately 7 m; review of available data sources did not find a bathymetric map. Review of public databases also did not find a Hinckley Pond diagnostic/feasibility study or a water quality assessment.

The latest Hinckley Pond watershed delineation was completed as part of the Barnstable Great Marshes Massachusetts Estuaries Project (MEP) assessment.[128] Previous work by the Town DPW showed the pond has no public access and approximately 11 buildings around it.[129]

Given that it has a surface area greater than 10 acres, Hinckley Pond is a Great Pond and, therefore, publicly owned. It is not included in the most recent MassDEP Integrated List of surface waters in Massachusetts.[130]

Pond Summary			
Pond	Hinckley		
Village	Barnstable		
Area (acres)	10		
Great Pond	Yes		
Management Plan	none		
Max Depth (m)	6.9		
Streams	May have a small intermittent outflow		
Temperature stratified	Yes		
Water Column Monitoring Summary			
PALS Years	2003, 2006-2013, 2016-2017, 2019		
Total # of samples (including duplicates)	10 - 11 (depending on constituent)		
PALS % of WQ data	100%		
Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	33	138	10
TN (mg/L)	0.75	2.96	0.31
Chlorophyll a (µg/L)	13.2	32.0	1.7

Among the available water column sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database, all of the available data is PALS Snapshot data and all of the data were collected in September. Sampling through the PALS Snapshots has been somewhat sporadic and a number of years (2010, 2016, 2017, and 2019) did not follow PALS protocols; overall PALS Snapshot sampling occurred in 2003, 2006-2013, 2016, 2017, and 2019.

Review of the available data in the 2021 Barnstable Pond and Lake Water Quality Database shows that Hinckley Pond was always temperature stratified in September when it was sampled with the upper portion of the water column (≤4 m) relatively isothermic and a notable decrease in temperature in readings 5 m or deeper. This type of temperature profile is relatively novel for shallow ponds on Cape Cod, but has been measured in a number of ponds on the northern shore

[128] Howes B., E. Eichner, S. Kelley, R. Samimy, J. S. Ramsey, D. Schlezinger, P. Detjens. 2017. Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Barnstable Great Marshes - Bass Hole Estuarine System, Town of Barnstable and Dennis, Massachusetts, Massachusetts Department of Environmental Protection. Boston, MA. 213 pp.

[129] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[130] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

along Cape Cod Bay and relatively close to the coastline or marsh systems.[131] This configuration is likely due to deep groundwater discharge. In Hinckley Pond, anoxia was consistently measured in its deep waters during each of the PALS Snapshots; the average deep DO concentration was 0.3 mg/L and all deep readings were less the MassDEP regulatory minimum (5 mg/L). Review of shallow and deep TP and TN concentrations show all individual readings were above the Cape Cod ecoregion thresholds and there were notable differences between shallow and deep averages consistent with sediment nutrient regeneration. Water clarity averaged 1.6 m and 47% of the overall pond depth. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Hinckley Pond.

Overall, available data presents Hinckley Pond as an impaired system, largely based on the regular deep water anoxia, high nutrient concentrations, and diminished clarity. Since available water quality data has only been collected during September, it is not known whether these impaired conditions are sustained throughout the summer or if these conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as complete phytoplankton species (not just blue-greens) and cell counts throughout the summer and sediment nutrient release rates would provide insights into how impaired conditions develop and are sustained. This information could then be combined with watershed information to complete a diagnostic assessment of the relative sources of the nutrients and then an evaluation of management options to restore acceptable water quality in Hinckley Pond.

[131] *e.g.*, Boland Pond in Orleans

III.13. Joshua Pond

Joshua Pond (PALS# BA-807) is a 15 acre Great Pond located in Osterville. It is located east of Pond Street and west of Old Mill Road. It is part of a cluster of ponds, also including Micah Pond and Sam Pond, between Scudder Bay and North Bay. The pond has a measured maximum depth of approximately 10 m, although available bathymetric maps show its maximum depth of 7.6 m.[132] Review of public databases does not show that Joshua Pond has had a diagnostic/feasibility study or a water quality assessment.

Pond Summary	
Pond	Joshua
Village	Osterville
Area (acres)	15
Great Pond	Yes
Management Plan	None
Max Depth (m)	10
Streams	None
Temperature stratified	Generally, no, but data show infrequent stratification
Water Column Monitoring Summary	
PALS Years	2001-2003, 2005-2013, 2015- 2019
Total # of samples (including duplicates)	39 - 44 (depending on constituent)
PALS % of WQ data	95%

Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	6	7	10
TN (mg/L)	0.18	0.20	0.31
Chlorophyll a (µg/L)	1.0	1.1	1.7

The latest Joshua Pond watershed delineation was completed as part of the Centerville River Massachusetts Estuaries Project (MEP) assessment.[133] The watershed includes portions of Micah Pond and portions of the Joshua Pond shoreline discharge to the Three Bays watershed. Previous work by the Town DPW showed the pond has public access through a town beach on the southwest side and approximately four buildings around it.[134] The majority of the land around Joshua Pond is owned by the Town of Barnstable. Joshua Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[135]

Among the available water column sampling data for Joshua Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, 17 of the 18 sampling dates were from PALS Snapshot samplings data and 95% of the data were collected in August or September. PALS Snapshot sampling missed a few years, but have been relatively consistent; PALS Snapshot sampling occurred in 2001-2003, 2005-2013, and 2015-2019.

Review of the available data shows that the water column in Joshua Pond was generally isothermic from the surface to the bottom with infrequent stratification (only two of 18 profiles

[132] Eichner, E. 2008. Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities. School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 79 pp.

[133] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

[134] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[135] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

had temperature stratification of warm, shallow waters and cold, deep waters). Comparison of shallow and deep pH, alkalinity, chlorophyll a, TP, and TN average concentrations reflected this well-mixed water column with no significant differences in shallow and deep average concentrations. Most of the water quality parameters show unimpaired conditions: a) only one of 141 DO concentrations were less than the MassDEP regulatory minimum (5 mg/L), b) only one shallow TP, TN, or chlorophyll-a measurement exceeded the respective Cape Cod ecoregion thresholds, and c) deep TP and TN concentrations exceeded the respective Cape Cod ecoregion thresholds in only 27% and 13% of the available readings, respectively. Deep readings showed occasional sediment TP regeneration, but the average deep TP concentration (7.3 µg/L) was less than the ecoregion threshold (10 µg/L). Water clarity averaged 7.6 m and 90% of the overall pond depth. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Joshua Pond.

Review of water quality trends shows that shallow TP concentrations in Joshua Pond are increasing with time. Shallow TP concentrations have a significant ($\rho<0.05$) increasing trend (+0.3 µg/L per year). Review of the shallow TN concentrations also showed increasing concentrations, but the trend is not statistically significant. The difference between the shallow TP and TN trends suggests that Joshua Pond is retaining more P than N, which would be consistent with the N:P ratios. Given that average shallow and deep TP concentrations are similar, the increasing shallow TP concentrations are likely due to adjacent TP sources built during the last few decades finally discharging to the pond after decades of soil P retention. Evaluation of watershed sources and their ages could help to further clarify why there is an increasing TP trend.

Overall, available data presents Joshua Pond as a largely unimpaired system that could be an example of a reference Cape Cod pond for its depth and size. Since available water quality data has only been collected during August and September, it is not known whether the available data are representative of conditions throughout the summer or if these conditions only develop in late summer. Although the water quality is unimpaired, the Town may want to consider developing some baseline measurements of other management factors, such as submerged aquatic vegetation and phytoplankton, as well as reviewing potential phosphorus sources to understand the increasing trend in shallow TP concentrations. Baseline measurements would provide insights for any future changes, as well as providing guidance on management for other ponds and lakes in Town.

III.14. Lewis Pond

Lewis Pond (PALS# BA-881) is a 4.6 acre pond located in Cotuit. It is located west of Highland Avenue and east of Santuit Road. It is also approximately 350 m west of the Santuit River portion of Shoestring Bay. The pond has a maximum recorded depth of 4.2 m and a bathymetric map was not found in a search of available databases. Review of public databases also did not find a Lewis Pond diagnostic/feasibility study or a water quality assessment. Lewis Pond also does not have a recent watershed delineation.

Pond Summary	
Pond	Lewis
Village	Cotuit
Area (acres)	4.6
Great Pond	No
Management Plan	none
Max Depth (m)	4.2
Streams	unclear
Temperature stratified	Generally, no, but data shows some occasional stratification
Water Column Monitoring Summary	
PALS Years	2001-2003, 2005-2006, 2008-2015, 2017-2018
Total # of samples (including duplicates)	28 - 29 (depending on constituent)
PALS % of WQ data	95%

Average concentrations			
Assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	15	32	10
TN (mg/L)	0.51	0.68	0.31
Chlorophyll a (µg/L)	15.6	31.9	1.7

Since Lewis Pond is less than 10 acres, it is not a Great Pond. Review of Town GIS parcels show that the pond area is part of the road right-of-way for Lewis Pond Road.[136] Previous work by the Town DPW showed the pond has public access through the ROW connection on the north side off Lewis Bay Road and the pond has approximately 23 buildings around it.[137] Lewis Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[138]

All of the available water column data for Lewis Pond in the 2021 Barnstable Pond and Lake Water Quality Database (15 sampling dates) were from PALS Snapshot samplings, so all of the data were collected in August or September. PALS Snapshot sampling missed a few years, but have been relatively consistent; PALS Snapshot sampling occurred in 2001-2003, 2005-2006, 2008-2015, and 2017-2018.

Review of the available data shows that the Lewis Pond water column was isothermic in six of the 15 profiles and had a colder, thermally isolated layer on the bottom of approximately 1 m thickness in the other 9 available profiles. When the pond had the isolated deep layer, that layer was always anoxic (DO <1 mg/L), but the deep waters were also often hypoxic or anoxic on sampling dates when the water column was isothermic. Average deep DO was 1.5 mg/L and 90% of individual deep DO readings were less than the MassDEP regulatory minimum (5 mg/L). None of the shallow DO concentrations were less than 5 mg/L. Comparison of average shallow and deep pH, phytoplankton pigments, TP, and TN concentrations showed significant differences consistent with notable deep sediment oxygen demand. All average shallow and deep TP, TN,

[136] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 3/18/21).

[137] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[138] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

and chlorophyll concentrations were significantly higher than their respective Cape Cod ecoregion thresholds. All of the individual chlorophyll a and TN concentration readings, both shallow and deep, were greater than their respective Cape Cod ecoregion thresholds. Most of the individual shallow (73%) and deep (93%) TP readings were greater than the TP ecoregion threshold (10 µg/L). Water clarity averaged 1.1 m and 29% of the overall pond depth. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Lewis Pond.

Review of water quality results with time showed that clarity has been increasing, while shallow TN has been decreasing and shallow TP has had no notable change. Review of other factors, such as N:P ratios and total pigments, show somewhat fewer notable changes. These time-series results would require some additional complementary data and surveys (such as rooted plant, phytoplankton, and freshwater mussel surveys) to help understand the water column results and sources of nutrients. If these types of surveys are pursued, additional analysis, such as a watershed review, measurement of sediment nutrient contributions, and development of nitrogen and phosphorus budgets would provide a fuller context.

Overall, available data presents Lewis Pond as an impaired system, largely based on the regular deep water hypoxia, high nutrient concentrations, and significant differences between shallow and deep average concentrations. Since available water quality data has only been collected during August and September, it is not known whether these impaired conditions are sustained throughout the summer or if these conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as complete phytoplankton species (not just blue-greens) and cell counts throughout the summer and sediment nutrient release rates would provide insights into how impaired conditions develop and are sustained. This information could then be combined with watershed information to complete a diagnostic assessment of the relative sources of the nutrients and then an evaluation of management options to restore acceptable water quality in Lewis Pond.

III.15. Little Pond

Little Pond (PALS# BA-881) is a 9.7 acre pond located in Marstons Mills. It is also known as Stoney Pond or Little Stoney Pond. It is located north of Race Lane and approximately 140 m northwest of Mystic Lake. The pond is very shallow with a maximum recorded depth of 1.2 m; a bathymetric map was not found in a search of available databases. Review of public databases also did not find a Little Pond diagnostic/feasibility study or a water quality assessment.

Pond Summary	
Pond	Little
Village	Marstons Mills
Area (acres)	9.7
Great Pond	No
Management Plan	none
Max Depth (m)	1.2
Streams	none
Temperature stratified	No
Water Column Monitoring Summary	
PALS Years	2001-2002, 2005-2013, 2015-2019
Total # of samples (including duplicates)	13 - 29 (depending on constituent)
PALS % of WQ data	100%

Average concentrations			
Assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	17	n/a	10
TN (mg/L)	0.58	n/a	0.31
Chlorophyll a (µg/L)	4.8	n/a	1.7

Little Pond is included in the Mystic Lake watershed delineated as part of the Three Bays Massachusetts Estuaries Project (MEP) assessment, but does not have a separate watershed delineation.[139] Previous work by the Town DPW showed the pond has a town way to water off Little Pond Road and approximately six buildings around it.[140] Review of aerial photographs and historic USGS quads show that the wetland system to the north of the pond has been wetland, and not a cranberry bog, since at least 1943.

The area of Little Pond is close to the 10 acre Great Pond threshold. Project staff review of the surface area of the pond in available aerial photos during high and low groundwater conditions and even during high groundwater condition when it is clear that the surface area expands, the area still remains less than 10 acres and this suggests that Little Pond should not be classified as a Great Pond. This review also showed that the water surface of the pond notably decreases during periods of low groundwater conditions. Review of Town GIS parcels show that the pond area is a separate parcel without any ownership attributes.[141] Little Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[142]

Among the available water column sampling data for Little Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, all 16 of water quality sampling dates were from PALS Snapshot samplings, so all of the data were collected in August or September. PALS Snapshot

[139] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts. Department of Environmental Protection. Boston, MA. 183 pp.

[140] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[141] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 3/18/21).

[142] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

sampling missed a few years, but has been relatively consistent; PALS Snapshot sampling occurred in 2001-2002, 2005-2013, and 2015-2019.

Because Little Pond is so shallow, many of the collected samples were either duplicates at the same depth or samples at two similar depths (*i.e.*, 0.5 m and 1.0 m). Review of all available data showed that light always reaches the bottom of the pond, but DO occasionally was impaired; 22% of the individual DO readings were less than the MassDEP regulatory minimum (5 mg/L). Average nutrient concentrations were greater than Cape Cod ecoregion thresholds and 70% and 93% of individual TP and TN readings, respectively, were greater than their respective ecoregion thresholds. About half of the individual chlorophyll a concentrations (48%) were above the chlorophyll a Cape Cod ecoregion threshold, but review of aerial photographs suggest that submerged aquatic plants and phytoplankton are likely competing for available phosphorus in the overall pond ecosystem. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Little Pond. As would be expected in a very shallow pond, TP, TN, and clarity do not have any notable trends.

Overall, available data presents Little Pond as an impaired system, largely based on the occasional hypoxia and high nutrient concentrations. However, given its very shallow depth and changeable water surface area due to groundwater fluctuations, this pond may function closer to other types of wetlands, like fens or bogs. Defining the goals for this wetland would help to inform appropriate management options, including water and habitat quality management options.

III.16. Long Pond (Centerville)

Long Pond (PALS# BA-737) is a 53 acre Great Pond located in Centerville. It is located south of Route 28 and north of Pine Street. It has a stream inflow from Wequaquet Lake and a stream outflow to the Centerville River estuary. The Long Pond bathymetric map in the Cape Cod Pond and Lake Atlas[143] shows a maximum depth contour of 6 m, while PALS sampling has recorded a maximum depth of 7.2 m. Long Pond was part of a 1989 combined system diagnostic/feasibility study that also included Wequaquet Lake and Bearses Pond.[144] An updated diagnostic/feasibility study has not been completed, but Long Pond has had a number of herbicide applications[145] due to the presence of *hydrilla verticillata*, an invasive aquatic plant that typically displaces native species if not controlled and is part of a herring run that connects Wequaquet Lake and Long Pond to the Centerville River estuary..

Pond Summary	
Pond	Long
Village	Centerville
Area (acres)	53
Great Pond	Yes
Management Plan	none
Max Depth (m)	7.2
Streams	One inflow, one outflow
Temperature stratified	no
Water Column Monitoring Summary	
PALS Years	2001-2003, 2005-2008 (3 potential additional years that could also be Long Marstons Mills)
Total # of samples (including duplicates)	9 - 61 (depending on constituent)
PALS % of WQ data	53%

Average concentrations (PALS only)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	11	86	10
TN (mg/L)	0.55	0.54	0.31
Chlorophyll a (µg/L)	10.7	22.2	1.7

The latest Long Pond watershed delineation was completed as part of the Centerville River Massachusetts Estuaries Project (MEP) assessment, which also included a whole year of stream outflow monitoring.[146] Previous work by the Town DPW showed the pond has public access through three locations: off Childs Street, off Piney Point Drive, and off Horatio Lane. This work also showed that the pond has approximately 76 buildings around it.[147]

Given that it has a surface area greater than 10 acres, Long Pond is a Great Pond and, therefore, publicly owned. In the most recent MassDEP Integrated List of the surface waters of Massachusetts, Long Pond is listed in Category 4c, which is for waters classified as impaired, but the impairment is not caused by a pollutant and, therefore, a TMDL not required.[148] The

[143] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

[144] IEP, Inc. and K-V Associates, Inc. 1989. Diagnostic/Feasibility Study of Wequaquet Lake, Bearse, and Long Pond. Prepared for Town of Barnstable Conservation Commission. 150 pp.

[145] *e.g.*, Aquatic Control Technology. February 2014. Project Completion Report for 2013 Hydrilla Management Performed at Long Pond & Mystic Lake – Barnstable, MA. 10 pp.

[146] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

[147] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[148] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

impairment of Long Pond is listed as "non-native aquatic plants." An assessment of nutrient water quality conditions in Long Pond is not included in the most recent MassDEP Integrated List.

Among the available water column sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database, 53% is PALS Snapshot data, 33% is from the 1989 diagnostic/feasibility study, and the remainder is from monitoring associated with the hydrilla treatments. The majority of the data (73%) was collected in August or September. PALS Snapshot data was collected in 2001-2003 and 2005-2008. There is also PALS Snapshot data collected for "Long Pond" in 2009, 2010, and 2012 that is included in the 2021 Barnstable Pond and Lake Water Quality Database, but it is unclear whether this is for Long Pond in Centerville or Long Pond in Marstons Mills. It is hoped that at some point, the original datasheets will be recovered to clarify to which Long Pond was sampled in these years.

Review of the available data shows that the water column in Long Pond was relatively isothermic with most individual water column profiles showing a ~2°C difference between surface and deep temperature readings. Most of the available profiles have reduced DO concentrations in the deepest readings, which is indicative of notable sediment oxygen demand, and 70% of the individual deep water concentrations were less than the MassDEP regulatory minimum (5 mg/L) and two of the deep readings were anoxic (<1 mg/L DO). However, comparison of average shallow and deep pH, phytoplankton pigments, TP, and TN concentrations since 2001 showed no significant differences suggesting that diminished DO concentrations were not present of long enough to trigger statistically significant changes in the deeper water nutrient concentrations. All average TP, TN, and chlorophyll concentrations since 2001 were notably higher than their respective Cape Cod ecoregion thresholds. All of the individual chlorophyll a and TN concentration readings, both shallow and deep, were greater than their respective Cape Cod ecoregion thresholds. Most of the individual shallow (57%) and deep (83%) TP readings were greater than the TP ecoregion threshold (10 µg/L). Water clarity averaged 3.0 m and 39% of the overall pond depth. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Long Pond.

Overall, available data presents Long Pond as an impaired system, largely based on the high nutrient and chlorophyll concentrations and deep water hypoxia. Although the hydrilla treatments are controlling the growth of hydrilla, the water quality data shows that other water quality impairments also exist. Since available water quality data outside of August and September is limited after the completion of the 1989 diagnostic/feasibility study, it is not known whether the impaired conditions are sustained throughout the summer or if these conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as complete phytoplankton species (not just blue-greens) and cell counts throughout the summer and sediment nutrient release rates would provide insights into how impaired conditions develop and are sustained. This information could be combined with the regular submerged aquatic vegetation mapping that supports the hydrilla treatments to present a more comprehensive review of the overall plant community and water quality in Long Pond. The water quality and plant information could then be combined with watershed information to complete a diagnostic assessment of the relative sources of the impairments and then an evaluation of management options to restore acceptable water quality in Long Pond.

III.17. Long Pond (Marstons Mills)

Long Pond (PALS# BA-675) is a 56 acre Great Pond located in Marstons Mills. It is located west of Santuit-Newtown Road and north of Wakeby Road. The Long Pond bathymetric map in the Cape Cod Pond and Lake Atlas[149] shows two basins, each with a maximum depth contour of 15 ft (4.6 m), while PALS sampling has recorded a maximum depth of 6.2 m. Review of public databases did not find a Long Pond diagnostic/feasibility study or a water quality assessment.

The latest Long Pond watershed delineation was completed as part of the Three Bays Massachusetts Estuaries Project (MEP) assessment.[150] Previous work by the Town DPW showed the pond has public access through two locations: off Long Pond Road and through conservation land off Santuit-Newtown Road. This work also showed that the pond has approximately 49 buildings around it.[151]

Given that it has a surface area greater than 10 acres, Long Pond is a Great Pond and, therefore, publicly owned. Long Pond is not listed in the most recent MassDEP Integrated List of the surface waters of Massachusetts.[152]

Pond Summary			
Pond	Long		
Village	Marstons Mills		
Area (acres)	56		
Great Pond	Yes		
Management Plan	None		
Max Depth (m)	6.2		
Streams	None		
Temperature stratified	No		
Water Column Monitoring Summary			
PALS Years	2008, 2011, 2013, 2018-2019 (3 potential additional years that could also be Long Centerville)		
Total # of samples (including duplicates)	9 - 10 (depending on constituent)		
PALS % of WQ data	88%		
Average concentrations (PALS only)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	11	61	10
TN (mg/L)	0.63	0.69	0.31
Chlorophyll a (µg/L)	4.9	22.6	1.7

Available water column sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database is limited to five PALS Snapshot samplings (2008, 2011, 2013, 2018, and 2019) and one 1948 profile. All readings were collected in August or September. There is additional PALS Snapshot data collected for "Long Pond" in 2009, 2010, and 2012 that is included in the Barnstable Pond and Lake Water Quality Database, but it is unclear whether this is for Long Pond in Centerville or Long Pond in Marstons Mills. It is hoped that at some point, the original PALS datasheets will be recovered and clarify to which Long Pond was sampled in these years.

[149] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

[150] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 183 pp.

[151] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[152] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

Review of the available data shows that the water column in Long Pond was relatively isothermic with most profiles showing a ~2°C difference between surface and deep temperature readings. A couple of the available water column profiles have reduced dissolved oxygen concentrations in the deepest depths, indicative of sediment oxygen demand, but most have little difference between surface and deep concentrations. Only one of the individual deep DO readings was less than the MassDEP regulatory minimum (5 mg/L). As would be expected in a pond with a well-mixed water column, surface and deep average concentrations for pH, phytoplankton pigments, TP, and TN concentrations showed no significant differences. However, all average TP, TN, and chlorophyll concentrations at both shallow and deep depths were notably higher than their respective Cape Cod ecoregion thresholds. Among individual readings, 90% of the TP and chlorophyll concentrations exceeded their respective Cape Cod ecoregion thresholds and all of the TN concentrations were greater than the TN ecoregion threshold. PALS Snapshot water clarity averaged 2.1 m and 36% of the overall pond depth. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Long Pond.

Overall, available data in the 2021 Barnstable Pond and Lake Water Quality Database presents Long Pond as an impaired system, largely based on the high nutrient and chlorophyll concentrations. Since available water quality data is limited to only August and September readings, it is not known whether the impaired conditions are sustained throughout the summer or if these conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as complete phytoplankton species (not just blue-greens) and cell counts throughout the summer, rooted plant and bathymetric surveys, and measurement of sediment nutrient release rates would provide insights into how impaired conditions develop and are sustained. This information could be combined watershed information to complete a diagnostic assessment of the relative sources of the impairments and then an evaluation of management options to restore acceptable water quality in Long Pond.

III.18. Lovells Pond

Lovells Pond (PALS# BA-675) is a 55 acre Great Pond located in Cotuit. It is located east of Santuit-Newtown Road and north of Route 28. The Lovells Pond bathymetric map in the 2014 water quality review listed a maximum depth of 37.5 ft (11.4 m),[153] while PALS sampling has confirmed this depth with a recorded maximum depth of 11.4 m. Lovells Pond has had a number of assessments, an aeration system in operation during the summers of 2010 through 2012, and an alum treatment in June 2014.[154] Other management activities at the pond have also included Massachusetts Division of Fisheries and Wildlife stocking of the pond with various trout species.[155]

Pond Summary			
Pond	Lovells		
Village	Cotuit		
Area (acres)	55		
Great Pond	Yes		
Management Plan	None, but has had a number of water quality assessments, an aeration system (since discontinued) and a 2014 alum treatment		
Max Depth (m)	11.4		
Streams	Inflow and outflow though they may be intermittent or blocked		
Temperature stratified	yes		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2005-2006, 2008-2015, 2017-2018		
Total # of samples (including duplicates)	54 - 122 (depending on constituent)		
PALS % of WQ data	40%		
Average concentrations (post-alum, PALS only)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	16	35	10
TN (mg/L)	0.36	1.82	0.31
Chlorophyll a (µg/L)	2.3	13.4	1.7

The latest Lovells Pond watershed delineation was completed as part of the Three Bays Massachusetts Estuaries Project (MEP) assessment.[156] The watershed includes portions of three towns: Barnstable, Mashpee, and Sandwich. Lovells Pond has historic connections to surrounding cranberry bogs, none of which appear to be currently active based on review of aerial photographs. Historic USGS topographic maps also show an outflow to Little River, which flows into Cotuit Bay. Previous work by the Town DPW showed the pond has public access at two locations: a boat ramp and a beach both off Santuit-Newtown Road. This work also showed that the pond has approximately 22 buildings around it.[157]

Given that it has a surface area greater than 10 acres, Lovells Pond is a Great Pond and, therefore, publicly owned. Lovells Pond is listed in the most recent MassDEP

[153] Water Resources Services, Inc. 2014. Investigation of Algal Blooms and Possible Controls for Lovell's Pond, Barnstable, Massachusetts, 2013. 90 pp.

[154] Water Resources Services, Inc. 2015. Phosphorus Inactivation Project for Lovell's Pond, Barnstable, Massachusetts. 46 pp.

[155] https://www.mass.gov/service-details/trout-stocking-report (accessed 8/12/21)

[156] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 183 pp.

[157] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

Integrated List of waters of Massachusetts as having impairments due to high chlorophyll-a, low dissolved oxygen, harmful algal blooms, total phosphorus, clarity, and turbidity. Because it is classified as impaired, it is assigned to Category 5 in the Integrated List and requires a TMDL.[158]

Since water quality in Lovells Pond has been evaluated a number of times, it has a number of different datasets, some of which are available and were included in the 2021 Barnstable Pond and Lake Water Quality Database. Other datasets had portions that were unavailable since the data was only presented in graphical form, laboratory results without sample collections depths, etc. Among the available data, 40% is PALS Snapshot data and the remaining 60% are 2013 to 2015 data collected by WRS. There is additional data in the WRS assessments (*e.g.*, DO and temperature profiles), as well as data in the 1997 Ambient diagnostic/feasibility study.[159] More in-depth review and organization of historic data could be task if an updated diagnostic/feasibility study is completed.

Recent water column readings (since the 2014 alum treatment) generally show a well-mixed, isothermic shallow surface layer of 5 to 6 m with a gradual or sharp interface to colder, deeper waters (the sharpest interface is typically in September). DO profiles initially after the alum treatment showed acceptable DO concentrations below the interface, but 2017 and 2018 PALS profiles showed concentrations less than the MassDEP regulatory minimum (5 mg/L) throughout the cold layer. Shallow TP, TN, and chlorophyll a average concentrations still exceed their respective Cape Cod ecoregion thresholds, but they are all notably lower than their pre-alum averages. Average clarity has also improved (+1.3 m) since the alum treatment. Average deep TP concentrations still show evidence of sediment regeneration, but the average concentration has decreased by over 100 µg/L since the alum treatment. No significant change was noted in deep chlorophyll or TN average concentrations. N:P ratios continue to show that phosphorus is the key nutrient determining water quality conditions in Lovells Pond.

Overall, available data presents Lovells Pond as an impaired, but much improved, system following the 2014 alum treatment. Impairments continue to be low deep water DO, diminished clarity, and high average concentrations of phosphorus, nitrogen, and chlorophyll. Phytoplankton sampling completed in 2015 continued to show cyanobacteria as a large component of the algal biomass late in the summer, which suggests some additional phosphorus reductions should be considered. As with other readings, the post-alum treatment phytoplankton population was better balanced and the biomass concentration was notably reduced from pre-alum treatment readings. Further phosphorus reductions would likely need to come from watershed sources and the Town may want to consider an updated evaluation of watershed sources as part of current CWMP activities.

[158] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

[159] Ambient Engineering, Inc. 1997. Diagnostic/Feasibility Study, Lovell's Pond, Barnstable, Massachusetts. 78 pp.

III.19. Lumbert Pond

Lumbert Pond (PALS# BA-719) is a 9.7 acre pond located in Centerville. It is located north and east of Lumber Mill Road and west of Nye Road. The pond is very shallow with a maximum recorded depth of 1.6 m in PALS Snapshots. A bathymetric map was not found in a search of available databases. It is part of the Skunknett River wetland corridor that includes West Pond, the former North Pond, and the Skunknett River Wildlife Sanctuary. Review of public databases also did not find a Lumbert Pond diagnostic/feasibility study or a water quality assessment.

Pond Summary	
Pond	Lumbert
Village	Centerville
Area (acres)	9.7 or 12.7
Great Pond	Unclear
Management Plan	none
Max Depth (m)	1.6
Streams	One inflow, one outflow
Temperature stratified	No
Water Column Monitoring Summary	
PALS Years	2001-2003, 2007-2013, 2017-2019
Total # of samples (including duplicates)	13 - 18 (depending on constituent)
PALS % of WQ data	100%

Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	11	26	10
TN (mg/L)	1.41	2.01	0.31
Chlorophyll a (µg/L)	2.8	14.1	1.7

Lumbert Pond is included in the North Pond watershed delineated as part of the Centerville River/East Bay Massachusetts Estuaries Project (MEP) assessment, but does not have a separate watershed delineation.[160] Public access to the pond is via Town conservation land off Nye Road. Previous work by the Town DPW showed the pond has a town way to water off Little Pond Road and approximately 14 buildings around it.[161]

Deciding whether Lumbert Pond is a Great Pond is complex because of its regularly changeable surface area. The Town parcel map shows that it is a 12.7 acre parcel with a thin arm that follows a stream inflow to an unnamed pond north of Lumbert Pond. Review of historic aerial photos shows that the open water area of the pond changes with seasons, as well as on a multi-year cycle. All of the surface area changes were likely due to groundwater fluctuations. In addition, MassDMF identified the outlet from the pond under Lumbert Mill Road as a stream obstruction, which means the surface area of the pond would likely be smaller if water flowed out freely under the road.[162] Classification as a Great Pond means that state regulatory provisions would need to be addressed in management decisions. Lumbert Pond is not listed in the most recent MassDEP Integrated List of waters of Massachusetts.[163]

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[160] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

[161] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[162] Reback, K.E., P.D. Brady, K.D. McLaughlin, and C.G. Milliken. 2004. A Survey of Anadromous Fish Passage in Coastal Massachusetts, Part 2: Cape Cod and the Islands. Massachusetts Division of Marine Fisheries Technical Report TR-16. 153 pp.

[163] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

Among the water column sampling data for Lumbert Pond included in the 2021 Barnstable Pond and Lake Water Quality Database are 13 sampling events, all of which are from PALS Snapshot samplings, so most of the data were collected in August or September (one sampling was in October). Because Lumbert Pond is so shallow, many of the collected PALS Snapshot samples were either duplicates at the same depth or samples at two similar depths (*i.e.*, 0.5 m and 1.0 m). PALS Snapshot sampling occurred in 2001-2003, 2007-2013, and 2017-2019.

Review of the data found that there were no statistically significant differences in average shallow and deep concentrations among the PALS constituents, but deep water average concentrations for a number of constituents were notably greater than shallow averages (*i.e.*, TN, TP, chlorophyll a) and this may indicate some sediment contributions to the water column measurements. Review of all available data showed that light usually reached the bottom of the pond (*i.e.*, 9 of 13 Secchi readings had the disc on the bottom). Surface DO concentrations were always greater than the MassDEP regulatory minimum (5 mg/L), but percent saturation levels showed a wide range and included high levels that would be consistent with regular algal blooms (*i.e.*, % saturation >110%) and deeper concentrations were mostly less than 100% saturation. Average surface TP and TN concentrations were greater than Cape Cod ecoregion thresholds and 70% and 93% of individual TP and TN readings, respectively, were greater than the thresholds. Among all of the available individual readings, all of the TN concentrations and 67% of both the individual concentrations of TP and chlorophyll a were greater than their respective Cape Cod ecoregion thresholds. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Lumbert Pond. As would be expected in a very shallow pond with very changeable conditions, TP, TN, and clarity do not have any notable temporal trends. Review of aerial photographs suggest that submerged aquatic plants are likely to be an important part of the overall plant community, so water column chlorophyll a concentrations would need to be reconsidered once the submerged aquatic plant community has been characterized.

Overall, available data presents Lumbert Pond as an impaired system, largely based on the high nutrient and chlorophyll a concentrations. However, given its very shallow depth and changeable water surface area due to groundwater fluctuations, management of this pond may indicate that higher concentrations are acceptable and this pond may function closer to other types of wetlands that have significant submerged aquatic plant communities. Defining the goals for this pond would help to inform appropriate management options, including water quality management options.

III.20. Mary Dunn Pond

Mary Dunn Pond (PALS# BA-646) is an 18 acre Great Pond located in Hyannis. It is located east of Mary Dunn Road and north of Hyannis Airport. There are a number of ponds in the area, including Lamson Pond, Flintrock Pond, and Israel Pond, that are often collectively referred to as the Hyannis Coastal Plains Ponds Complex. All of these ponds are very shallow and, as such, are impacted by natural fluctuations in groundwater levels. The plant community around these ponds have adapted to these water level fluctuations and a number of species are regionally or globally rare, including the Plymouth gentian (*Sabatia kennedyana*). These natural groundwater level fluctuations are also impacted by a number of public water supply wells in the area and a number of studies have focused on relationships in groundwater fluctuations caused by well pumping.[164] Most management discussions for these ponds have focused on plant species and water level fluctuations. Review of public databases did not find a Mary Dunn Pond diagnostic/feasibility study or a water quality assessment.

Pond Summary			
Pond	Mary Dunn		
Village	Hyannis		
Area (acres)	18		
Great Pond	Yes		
Management Plan	none		
Max Depth (m)	2.1		
Streams	none		
Temperature stratified	No		
Water Column Monitoring Summary			
PALS Years	2001, 2003, 2008-2013, 2017-2019		
Total # of samples (including duplicates)	11 - 17 (depending on constituent)		
PALS % of WQ data	100%		
Average concentrations			
Assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	11	n/a	10
TN (mg/L)	0.41	n/a	0.31
Chlorophyll a (µg/L)	2.4	n/a	1.7

Mary Dunn Pond has a separate watershed delineation included in the Lewis Bay Massachusetts Estuaries Project (MEP) assessment.[165] The Town does not have a listed public access point and the pond does not have a separate parcel within the Town parcel coverage (it is part of a number of Town-owned parcels). Previous work by the Town DPW showed the pond has approximately six buildings around it.[166]

Given that it has a surface area greater than 10 acres, Mary Dunn Pond is a Great Pond and, therefore, publicly owned. Maximum recorded depth for Mary Dunn Pond among PALS Snapshot samplings was 2.1 m. There is no bathymetric map of this pond at present. Mary Dunn Pond is not listed in the most recent MassDEP Integrated List of waters of Massachusetts.[167]

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[164] *e.g.*, McHorney, R. 1997. Hydrologic Report: Hyannis Ponds Project. The Nature Conservancy. 71 pp.

[165] Howes B., H. Ruthven, E. Eichner, J. Ramsey, R. Samimy, D. Schlezinger. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Lewis Bay System, Towns of Barnstable and Yarmouth, MA. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 253 pp.

[166] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[167] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

Among the available water column sampling data for Mary Dunn Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, are 11 water quality samplings, all from PALS Snapshot samplings, so all of the data were collected in August or September. Because Mary Dunn Pond is so shallow, many of the collected PALS Snapshot samples were either duplicates at the same depth or samples at two similar depths (*i.e.*, 0.5 m and 0.7 m). PALS Snapshot sampling occurred in 2001, 2003, 2008-2013, and 2017-2019.

Review of all available data showed a mix of water quality conditions. Available clarity readings showed that light reached the bottom of the pond during each of the PALS Snapshot sampling dates (*i.e.*, all Secchi readings had the disc on the bottom). All DO concentrations were greater than the MassDEP regulatory minimum (5 mg/L), but percent saturation levels averaged 87%, which is indicative of some sediment oxygen demand. Average TP, TN, and chlorophyll a concentrations were greater than the respective Cape Cod ecoregion thresholds and 65%, 88%, and 59% of individual TP, TN, and chlorophyll a readings were greater than their respective thresholds. Since aerial photos show that submerged aquatic plants are dispersed throughout the pond and chlorophyll a readings are relatively high, it suggests that there is a complex relationship between rooted plants and water column plants (*i.e.*, phytoplankton). N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Mary Dunn Pond. There are no discernable temporal trends in TP, TN, or chlorophyll a concentrations.

Overall, available data presents Mary Dunn Pond as borderline impaired system, largely based on water column DO loss and nutrient and chlorophyll a concentrations exceeding Cape Cod ecoregion standards. However, given its very shallow depth and the extreme fluctuations in water surface area that occur (*e.g.*, the pond has become completely dry in the last 30 years), water quality management of this pond may indicate that higher concentrations are acceptable and this pond may function closer to other types of shallow wetlands that have significant submerged aquatic plant communities. Defining the water quality goals for this pond would help to inform development of appropriate management options.

III.21. Micah Pond

Micah Pond (PALS# BA-807) is a 16 acre Great Pond located in Osterville. It is located east of Pond Street and west of Old Mill Road. It is part of a cluster of ponds, including Joshua Pond and Sam Pond, between Scudder Bay and North Bay. The pond has a maximum measured depth among PALS Snapshot samplings of 12.4 m, although available bathymetric maps show its maximum depth of 9.1 m.[168] Review of public databases does not show that Micah Pond has had a diagnostic/feasibility study or a water quality assessment.

Pond Summary	
Pond	Micah
Village	Osterville
Area (acres)	16
Great Pond	Yes
Management Plan	none
Max Depth (m)	12.4
Streams	none
Temperature stratified	Generally no, but data shows infrequent stratification
Water Column Monitoring Summary	
PALS Years	2001-2003, 2005-2013, 2015- 2019
Total # of samples (including duplicates)	17 - 60 (depending on constituent)
PALS % of WQ data	95%

Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	8	14	10
TN (mg/L)	0.25	0.29	0.31
Chlorophyll a (µg/L)	1.1	1.4	1.7

The latest Micah Pond watershed delineation was completed as part of the Centerville River Massachusetts Estuaries Project (MEP) assessment.[169] Previous work by the Town DPW showed the pond has public access through town-owned land off Pond Street and has approximately two buildings around it.[170] The majority of the land around Micah Pond is owned by the Town of Barnstable. Micah Pond is not listed in the most recent MassDEP Integrated List of waters of Massachusetts.[171]

Among the available water column sampling data for Micah Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, are 17 water quality sampling dates of which 16 were from PALS Snapshot samplings. Most (94%) of the data were collected in August or September. PALS Snapshot sampling missed a few years, but have been relatively consistent overall; PALS Snapshot sampling occurred in 2001-2003, 2005-2013, and 2015-2019.

Available data has some issues with consistency that limit some of the conclusions that can be drawn from the water quality results. For example, many of the DO profiles did not include readings to within one meter of the bottom; readings often stopped 2 to 3 m above the bottom and missed low oxygen conditions that were occasionally measured in profiles that reached to

[168] Eichner, E. 2008. Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities. School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 79 pp.

[169] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

[170] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[171] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

within 1 m of the bottom (as specified in PALS Snapshot protocols). Because this deep DO data was not consistently collected, it is not known how often these low oxygen/impaired conditions exist during the late summer. Deep water quality samples were often collected at a depth specified by PALS Snapshot sampling protocols, but without accompanying DO and temperature readings.

Review of the available data shows that the water column in Micah Pond was often isothermic from the surface to the bottom, but occasionally had strong thermal stratification (3 of the 17 profiles had large differences between warm shallow waters and cold deeper waters). Strong stratification may be a regular summer occurrence, but the depth of the transition between warm and cold waters may vary and often occur in the deeper waters, below the deep where many of the DO and temperature profiles stopped. Average shallow and deep phytoplankton pigments and TP concentrations were significantly different, suggesting some regular deep hypoxia and sediment TP regeneration.

Among the seven profiles where deep DO readings were appropriately collected, four were less than the 5 mg/L DO MassDEP regulatory minimum. Average shallow TP, TN, and chlorophyll readings, however, were all less than their respective Cape Cod ecoregion thresholds and individual readings only exceed the respective Cape Cod ecoregion thresholds in only 40%, 27% and 7% of the available readings. Review of the shallow TP and TN concentrations do not show any notable trends, but they do show high variability suggesting that there are intermittent additions from a relatively large source (*e.g.*, the bottom regeneration or the adjacent inactive cranberry bog that appears to have a hydroconnection to the pond). Water clarity averaged 6.8 m and 65% of the overall pond depth, consistent with the low pigment levels. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Micah Pond.

Overall, available data presents Micah Pond as a generally unimpaired system with some concerns over bottom water quality. The available data have some limitations that could be addressed through regular sampling that completely follows PALS Snapshot protocols. In addition, since available water quality data has only been collected during August and September, it is not known whether the available data are representative of conditions throughout the summer or if these conditions only develop in late summer. Although the water quality is generally unimpaired, the Town may want to consider developing some baseline measurements of other management factors, such as submerged aquatic vegetation and phytoplankton, as well as reviewing potential phosphorus sources to understand the fluctuations in shallow TP and TN concentrations. Establishing proper baseline measurements would support a full assessment and provide insights for any future changes.

III.22. Middle Pond

Middle Pond (PALS# BA-640) is a 105 acre Great Pond located in Marstons Mills. Middle Pond is located west of Cotuit Road/Route 149 and north of River Road. It is one of the three ponds addressed through the Indians Ponds Association along with Mystic Lake and Hamblin Pond. The pond has a maximum recorded depth among PALS Snapshot samplings of 10.3 m, which is consistent with available bathymetric maps that show a maximum contour of 30 ft (9.1 m).[172] Middle Pond has had a number of assessments focused on management issues also identified for Mystic Lake and Hamblin Pond, including a freshwater mussel survey,[173] a submerged aquatic plant survey,[174] and numerous annual monitoring efforts, including phytoplankton and zooplankton sampling.[175] Management activities at the pond have also included herbicide treatments and a herring run that connects Middle Pond and Mill Pond to the Three Bays estuary.

Pond Summary			
Pond	Middle		
Village	Marstons Mills		
Area (acres)	105		
Great Pond	Yes		
Management Plan	None		
Max Depth (m)	10.3		
Streams	1 inflow, 1 outflow		
Temperature stratified	occasional		
Water Column Monitoring Summary			
PALS Years	2001-2019		
Total # of samples (including duplicates)	39 – 142 (depending on constituent)		
PALS % of WQ data	51%		
Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	11	22	10
TN (mg/L)	0.29	0.38	0.31
Chlorophyll a (µg/L)	1.8	7.1	1.7

The latest Middle Pond watershed delineation was completed as part of the Three Bays Massachusetts Estuaries Project (MEP) assessment.[176] The Middle Pond watershed includes the watershed to Mystic Lake. Previous work by the Town DPW showed the pond has one public access point, including a beach off Flume Avenue, and has approximately 39 buildings around it.[177]

Middle Pond is assigned to Category 5 in the most recent MassDEP Integrated List of surface waters in Massachusetts.[178] Category 5 waters in the Integrated List are impaired waters

[172] Eichner, E. 2008. Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities. School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 79 pp.

[173] Biodrawversity LLC. 2018. Freshwater Mussel Surveys in Mystic Lake and Middle Pond: 2007-2017 (Barnstable, Massachusetts). Leverett, MA. 14 pp.

[174] Solitude Lake Management. 2017. Barnstable Ponds: Long Pond, Mystic Lake & Middle Pond. Hydrilla Management Program. Shrewsbury, MA. 12 pp.

[175] Water Resources Services, Inc. 2018. Monitoring of Mystic Lake and Middle Pond in Barnstable, Massachusetts in 2017. 42 pp.

[176] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts. Department of Environmental Protection. Boston, MA. 183 pp.

[177] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[178] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

requiring a TMDL. Impairments listed for Middle Pond are low dissolved oxygen and harmful algal blooms.

The 2021 Barnstable Pond and Lake Water Quality Database includes water quality readings or samples on over 40 dates from Middle Pond; water quality samples were collected on 33 dates. PALS Snapshots represent 51% of the available data, the 2006 Cape Cod Commission assessment[179] was 33% and WRS monitoring was 15%. Most of the collected readings (72%) were in August and September.

Review of Middle Pond water quality data shows that average shallow concentrations are generally acceptable, but deep concentrations show some impairments and trend analysis of shallow TP reading suggest some long-term concerns. Available deep DO concentrations average 1.7 mg/L, which is less than the MassDEP regulatory minimum concentration of 5 mg/L. In contrast, average shallow TP and chlorophyll readings were only slightly above their respective Cape Cod ecoregion thresholds (11 µg/L and 1.8 µg/L, respectively) with 48% and 50% of the individual readings greater than the thresholds. These comparisons suggest that the deep impairments are not impacting the shallow conditions, but trend analysis of the shallow TP concentrations show they have a statistically significant (ρ=0.01) increasing trend between 2001 and 2019. Review of clarity does not show a similar trend. Additional management issues include potential spillover of Mystic Lake alum treatment impacts and mussel population fluctuations (along with their filtering capacity). Late summer PALS DO profile measurements in 2017, 2018, and 2019 showed that deep water anoxia continues to be an impairment in Middle Pond.

Overall, Middle Pond presents as an impaired system, but most of the impairments are its deep waters. Continued monitoring and integration of the water quality and other ecosystem measures is warranted to track how the bottom water impairments may be impacting surface waters. If the Town considers a diagnostic assessment and management plan for Middle Pond in the future, it should include updated land use analysis and water and nutrient budgets.

[179] Eichner, E., S. Michaud, and T. Cambareri. 2006. First Order Assessment of the Indian Ponds (Mystic Lake, Middle Pond, and Hamblin Pond). Cape Cod Commission. Barnstable, MA. 71 pp.

III.23. Mill Pond – Marstons Mills

Mill Pond (PALS# BA-746) is a six acre pond located in Marstons Mills.[180] It is located north of Route 28 and west of Route 149. The pond is located near the terminus of the Marstons Mills River and just above its discharge into Prince Cove. The pond is very shallow with a maximum recorded depth of 1.4 m. Bathymetric and sediment thickness measurements suggest that the pond has gradually filled with sediments over the past three centuries (with sediment thickness of 7 ft in a 2000 assessment).[181] Review of public databases also did not find a Mill Pond diagnostic/feasibility study or a water quality assessment, although nitrogen loads into and out of the pond were extensively measured as part of the part of the Three Bays Massachusetts Estuaries Project (MEP) assessment [182] and two CSP/SMAST evaluations of sediment nitrogen contributions.[183] Management activities at the pond have included the herring run that connects Middle Pond and Mill Pond to the Three Bays estuary.

Pond Summary	
Pond	Mill
Village	Marstons Mills
Area (acres)	6
Great Pond	No
Management Plan	None
Max Depth (m)	1.4 m (2002)
Streams	1 inflow, 2 outflow
Temperature stratified	No
Water Column Monitoring Summary	
PALS Years	2002-2003, 2005-2019
Total # of samples (including duplicates)	14 – 35 (depending on constituent)
PALS % of WQ data	93%

Average concentrations (PALS only; Deep n=3)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	35	93	10
TN (mg/L)	0.67	0.84	0.31
Chlorophyll a (µg/L)	2.5	6.0	1.7

The latest Mill Pond watershed delineation was also completed as part of the Three Bays MEP assessment. The Mill Pond watershed includes the portions of watershed to Mystic Lake, Middle Pond, Hamblin Pond, Long Pond, and Muddy Pond. Previous work by the Town DPW showed the pond does not have a readily accessible public access point except through the fish ladder property at the intersection of Routes 28 and 149 and the pond has approximately 9 buildings around it.[184] Given its area, Mill Pond is not a Great Pond and review of the on-line Town GIS does not have any ownership assigned to the parcel that contains the pond.[185] Mill Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[186]

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[180] There is another Mill Pond in Barnstable: Mill Pond in West Barnstable (PALS# BA-391) is 17 acres.

[181] Lycott Associates, Inc. 2000. Recommendation for Treatment for the Elimination of Rampant Aquatic Macrophyte Growth at Mill Pond, Marstons Mills. Southbridge, MA. 62 pp.

[182] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts. Department of Environmental Protection. Boston, MA. 183 pp.

[183] Howes, B.L. D. Schlezinger, and R. Samimy. 2017. Fresh Pond Restoration and Management: Benthic Nutrient Flux of Mill Pond, Town of Barnstable. School of Marine Science and Technology, University of Massachusetts Dartmouth. 8 pp.

[184] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[185] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 4/5/21).

[186] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

Management discussions of Mill Pond have generally focused on dredging the pond as a way to partially restore its historic depth and to increase its residence time; increasing its volume would increase its capacity to attenuate or decrease watershed nitrogen on its way to the Three Bays estuary. Previous efforts have included a MEPA ENF filing to dredge the pond that was subsequently withdrawn[187] and identification of the pond as a Priority Habitat for Bridle Shiner, which is a species of special concern in Massachusetts.[188] Previous work also identified extensive wetlands surrounding the pond, especially where the river discharges into the pond, and review of available aerial photographs suggest that these northern wetland areas have expanded and changed over the last 20 years.

Among the available water column sampling data for Mill Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, 17 of the 20 samplings were PALS Snapshots and 95% of the collected data was in August or September. Because Mill Pond is so shallow, many of the collected PALS Snapshot samples were either duplicates at the same depth or samples at two similar depths (*i.e.*, 0.5 m and 1.0 m). PALS Snapshot sampling occurred in 2002-2003 and 2005-2019.

Review of the available data found that there were no statistically significant differences in average shallow and deep concentrations among the PALS constituents, but deep average concentrations for a number of constituents were notable greater than shallow averages (*i.e.*, TN, TP, chlorophyll a) and this may indicate some sediment contributions to the water column measurements. Review of all available data showed that light usually reaches the bottom of the pond (*i.e.*, 14 of 15 available Secchi readings had the disc on the bottom). Surface DO concentrations were almost always greater than the MassDEP regulatory minimum (5 mg/L), but percent saturation levels generally showed the impact of sediment oxygen demand (*e.g.*, 69% of surface DO concentrations were less than 85% saturation). Average surface TP and TN concentrations were notably greater than Cape Cod ecoregion thresholds (35 µg/L an 0.67 mg/L, respectively) and all individual TP and TN readings were greater than the ecoregion thresholds. Most of the individual surface chlorophyll a concentrations (69%) were greater than the respective ecoregion threshold. Review of surface concentrations with time showed that only TP concentrations had a significantly increasing trend ($\rho<0.05$), which appears to be consistent with noted differences in the 2008 and 2016 sediment core incubations, which showed P uptake in 2008 and P release in 2016.[189] N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Mill Pond.

Overall, available water quality data presents Mill Pond as an impaired system, largely based on the high nutrient and chlorophyll a concentrations. Much of the focus of its management to date has been on ways to restore its water depth that has shallowed from sedimentation over the years to increase nitrogen removal and help restore the Three Bays estuary. Defining the goals for this pond would help to inform appropriate management options, including water quality management options.

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[187] Horsley Witten Group. 2012. Environmental Notification Form: Mill Pond Improvement Project, Barnstable, MA. Prepared for the Town of Barnstable. Sandwich, MA. 96 pp.

[188] Letter from Thomas French, Assistant Director, MassDFW to Town of Barnstable Conservation Division. December 23, 2009. RE: Dredge approximately 10 feet of sediment from the bottom of Mill Pond. 2 pp.

[189] Howes, B.L. D. Schlezinger, and R. Samimy. 2017. Fresh Pond Restoration and Management: Benthic Nutrient Flux of Mill Pond, Town of Barnstable.

III.24. Mystic Lake

Mystic Lake (PALS# BA-584) is a 148 acre Great Pond located in Marstons Mills. Mystic Lake Pond is located south of Race Lane and east of Old Mill Road. It is one of the three ponds addressed through the Indians Ponds Association along with Hamblin Pond and Middle Pond. It is also one of three deep ponds in Barnstable that clearly meet the MassDEP cold water fishery criteria.[190] Due to water quality impairments especially those deep in the pond, an alum treatment was proposed in 2008, but was rejected by the Massachusetts Natural Heritage and Endangered Species Program (NHESP) over concern of potential impacts on the freshwater mussel community that included a number of state-listed species. In 2009, the deep water quality impairments reached shallower areas of the pond, a cyanobacteria bloom occurred, and it was estimated that 99.8% of the key NHESP-listed mussel species (tidewater mucket) died.[191] In 2010, the pond had an alum application in September/October.[192] Mystic Lake has had a number of monitoring efforts focused on its management, both before[193] and after the 2010 alum treatment.[194] Management activities at the pond have also included hand pulling and herbicide treatments to address invasive *hydrilla* and a herring run that connects Middle Pond, Mystic Lake and Mill Pond to the Three Bays estuary.

Pond Summary			
Pond	Mystic		
Village	Marstons Mills		
Area (acres)	148		
Great Pond	Yes		
Management Plan	none		
Max Depth (m)	14.6		
Streams	1 outflow		
Temperature stratified	Yes		
Water Column Monitoring Summary			
PALS Years	2001-2019		
Total # of samples (including duplicates)	60 – 246 (depending on constituent)		
PALS % of WQ data	40%		
Average PALS concentrations (since Oct 2010 alum treatment)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	17	214	10
TN (mg/L)	0.30	2.68	0.31
Chlorophyll a (µg/L)	3.0	2.1	1.7

The latest Mystic Lake watershed delineation was completed as part of the Three Bays Massachusetts Estuaries Project (MEP) assessment.[195] The Mystic Lake watershed extends into Sandwich and includes portions of the watersheds to Triangle Pond and Lawrence Pond. Mystic Lake is upgradient of and part of the watersheds to Middle Pond and Hamblin Pond. Previous work by the Town DPW showed the pond has two public access points, one off Race Lane and another through the Danforth Recreation Area and approximately 51 buildings around it.[196]

[190] The other two are Hathaway Pond and Hamblin Pond.

[191] Biodrawversity LLC. 2018. Freshwater Mussel Surveys in Mystic Lake and Middle Pond: 2007-2017 (Barnstable, Massachusetts). Leverett, MA. 14 pp.

[192] Water Resources Services. 2011. Internal Phosphorus Load Inactivation in Mystic Lake, Barnstable, Massachusetts, 2010. 120 pp.

[193] Eichner, E., S. Michaud, and T. Cambareri. 2006. First Order Assessment of the Indian Ponds: Mystic Lake, Middle Pond, and Hamblin Pond. Cape Cod Commission. Barnstable, MA. 71 pp.

[194] Water Resources Services. 2020. Mystic Lake Status Update. 29 pp.

[195] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts. Department of Environmental Protection. Boston, MA. 183 pp.

[196] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

Mystic Lake was assigned to Category 5 in the most recent MassDEP Integrated List of surface waters in Massachusetts.[197] Category 5 waters are impaired waters requiring a TMDL to address the causes of the listed impairments. Impairments listed for Mystic Lake are low dissolved oxygen and non-native aquatic plants.

The 2021 Barnstable Pond and Lake Water Quality Database includes 47 sampling dates for Mystic Lake. Among the dates are 24 additional water column samplings at locations in the lake other than the deepest point, mostly completed in support of pre- or post-alum treatment monitoring. PALS Snapshot sampling data is 40% of the available data, while WRS sampling is 33% and sampling associated with the 2006 Cape Cod Commission sampling is 26%. It should also be noted that there is more extensive supplemental monitoring data (*e.g.*, phytoplankton, zooplankton, mussel populations) that has been collected and should be considered in any comprehensive assessment of Mystic Lake. PALS Snapshot sampling occurred every year from 2001 to 2019.

Water quality improved immediately following the 2010 alum treatment, but longer term comparisons of pre- and post-alum water quality measures present a mixed assessment of the water quality status of Mystic Lake. PALS Snapshot TP average concentrations at shallow and deep stations pre- and post-alum treatment were not significantly different ($\rho<0.05$), but clarity was significantly deeper and surface chlorophyll a averages were significantly lower post-alum. It should be noted, however, that the post-alum surface chlorophyll a and TP averages (3.0 µg/L and 17 µg/L) were still higher than the respective Cape Cod ecoregion thresholds. In addition, all of the available DO readings a 9 m depth and deeper both before and after the alum treatment were less than the MassDEP minimum (6 mg/L) and average DO concentrations at 9 m and deeper were anoxic (<1 mg/L).

Overall, Mystic Lake presents as an impaired system. Water quality improved immediately following the 2010 alum treatment, but those improvements have not been sustained and have not had the longevity usually seen in other alum treatments (*e.g.*, Hamblin Pond). Deep DO concentrations continue to be significantly less than the MassDEP regulatory minimum and shallow TP and chlorophyll a concentrations exceed Cape Cod ecoregion thresholds. If the Town considers a diagnostic assessment and management plan for Mystic Lake in the future, it should include updated land use analysis and water and nutrient budgets.

[197] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

III.25. Neck Pond

Neck Pond (PALS# BA-874) is a 14 acre Great Pond located in Osterville. It is located east of Parker Road and west of West Street. It is part of a cluster of ponds, including Parker Pond and Crystal Lake, between East Bay and West Bay. The pond has a maximum recorded depth among PALS Snapshot samplings of 11.5 m; review of public databases did not find a bathymetric map. Review of public databases also did not show that Neck Pond has had a diagnostic/feasibility study or a water quality assessment.

Public databases also did not find a Neck Pond watershed delineation. The pond is located between the Massachusetts Estuaries Project (MEP) watersheds to the Centerville River/East Bay and Three Bays estuaries. Previous work by the Town DPW showed the pond has approximately 18 buildings around it[198] and no public access, although review of town parcel maps appears to show a portion of the Scudder Road right-of-way extends to the pond.[199] The majority of the land around Neck Pond is owned by the Town of Barnstable. Neck Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[200]

Pond Summary			
Pond	Neck		
Village	Osterville		
Area (acres)	14		
Great Pond	Yes		
Management Plan	none		
Max Depth (m)	11.5		
Streams	none		
Temperature stratified	Some data shows deep stratification; unclear if it is sustained		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2005-2013, 2015- 2019		
Total # of samples (including duplicates)	17 - 61 (depending on constituent)		
PALS % of WQ data	100%		
Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	7	17	10
TN (mg/L)	0.37	0.51	0.31
Chlorophyll a (µg/L)	1.2	1.5	1.7

All of the available water column sampling data for Neck Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, is from PALS Snapshots (17 dates) and 93% of the data were collected in August or September. PALS Snapshot sampling missed a few years, but have been relatively consistent; PALS Snapshot sampling occurred in 2001-2003, 2005-2013, and 2015-2019.

Available datasets have some issues with consistency that limit some of the conclusions that can be drawn from the water quality results. For example, many of the DO profiles did not include readings to within one meter of the bottom; readings often stopped 1 to 2 m above the bottom missing low oxygen conditions that were sometimes measured at 8 m and deeper. The most recent (2018 and 2019) monitoring has shown anoxic conditions in these deep waters, but because this data was not consistently collected, it is not known how frequently these conditions occur or if they have only recently developed.

[198] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[199] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 4/6/21).

[200] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

Review of the available data shows that the water column in Neck Pond was generally isothermic to 7 or 8 m depth with occasional transition to colder temperatures in deep water with differences significant enough to establish temperature stratification. Average DO concentrations were above MassDEP minimum (5 mg/L) except for the deepest readings, which averaged 4.1 mg/L with a couple of anoxic readings (<1 mg/L) in 2019. Average surface TP and chlorophyll a concentrations were less than their respective ecoregion thresholds. Average deep TP and TN concentrations were significantly higher ($\rho<0.05$) than the shallow averages, which would be consistent with stratification and enhanced sediment regeneration caused by anoxia. Total pigments also showed this pattern suggesting that the phytoplankton population was relatively significant, but may peak earlier in the summer than the PALS Snapshot period. Clarity readings were consistent with a moderate phytoplankton population (*e.g.*, average clarity was 6.4 m or 64% of the water column). Review of the shallow TP and TN concentrations do not show any notable temporal trends, but they do show high variability perhaps due to occasional release of sediment regenerated nutrients mixing into the upper water column. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Neck Pond.

Overall, available data presents Neck Pond as an impaired system with generally acceptable shallow conditions and regular deep water impairments. The available data have some limitations that could be addressed through regular sampling that follows PALS Snapshot protocols. In addition, since available water quality data has only been collected during August and September, it is not known whether the available data are representative of average conditions throughout the summer or if measured conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as complete phytoplankton species (not just blue-greens) and cell counts throughout the summer and sediment nutrient release rates would provide insights into how the impaired conditions develop and are sustained. This information could then be combined with watershed information to complete a diagnostic assessment of the relative sources of the nutrients and then an evaluation of management options to ensure acceptable water quality throughout the Neck Pond water column.

III.26. Parker Pond

Parker Pond (PALS# BA-875) is a 12 acre Great Pond located in Osterville. It is located west of Parker Road and east of Eel River Road. It is part of a cluster of ponds, including Neck Pond and Crystal Lake, between East Bay and West Bay and is approximately 0.15 km from the eastern lobe of West Bay. The pond has a maximum recorded depth among PALS Snapshot samplings of 6.4 m; review of public databases did not find a bathymetric map. Review of public databases also did not show that Parker Pond has had a diagnostic/feasibility study or a water quality assessment.

Pond Summary	
Pond	Parker
Village	Osterville
Area (acres)	12
Great Pond	Yes
Management Plan	none
Max Depth (m)	6.4
Streams	none
Temperature stratified	Data shows deep stratification; unclear if it is sustained
Water Column Monitoring Summary	
PALS Years	2001-2003, 2005-2013, 2015-2019
Total # of samples (including duplicates)	15 - 40 (depending on constituent)
PALS % of WQ data	100%

Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	16	44	10
TN (mg/L)	0.74	2.39	0.31
Chlorophyll a (µg/L)	7.0	46.2	1.7

Public databases also did not find a Parker Pond watershed delineation. Parker Pond is included in the West Bay watershed delineated as part of Three Bays Massachusetts Estuaries Project (MEP) assessment, but does not have a separate watershed delineation.[201] Previous work by the Town DPW showed the pond has approximately five buildings around it and no public access to the pond.[202] The majority of the land around Parker Pond is owned by either the Wianno Club or Barnstable Land Trust.[203] Parker Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[204]

All of the available water column sampling data for Parker Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, is from 17 PALS Snapshot samplings and 94% of the data were collected in August or September. PALS Snapshot sampling missed a few years, but have been relatively consistent; PALS Snapshot sampling occurred in 2001-2003, 2005-2013, and 2015-2019.

Review of the available data shows that the water column in Parker Pond generally was cold enough at 5 m depth to be thermally stratified. This temperature stratification led to regular anoxia in deep waters; average deep DO was 0.3 mg/L (n=17). Many of the available profiles

[201] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts. Department of Environmental Protection. Boston, MA. 183 pp.

[202] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[203] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 4/20/21).

[204] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

showed low DO conditions at shallower depths as well, often related to depth where the temperature transition to colder, deeper water began. Hypoxic DO concentrations were regularly measured at the 4 m depth and occasionally at 3 m depth. Average shallow TP, TN, and chlorophyll a concentrations were all greater than their respective Cape Cod ecoregion thresholds and all individual TP, TN, and chlorophyll a concentrations were also greater than the thresholds. Average deep TP and TN concentrations were significantly higher ($\rho<0.05$) than the shallow averages, which would be consistent with enhanced sediment regeneration caused by anoxia. Chlorophyll a and total pigments also showed this pattern suggesting that the phytoplankton population was significant. Clarity readings were notably limited with an average of only 1.3 m or 23% of the water column visible. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Parker Pond.

Review of the shallow TP and TN concentrations show significant temporal trends ($\rho<0.05$), although in different directions. Shallow TP concentrations were increasing between 2001 and 2019, while shallow TN concentrations were decreasing. This difference is likely due to changes in internal P regeneration from the sediments and decreases in watershed occupancy rates, respectively, but further evaluations would be necessary to clarify why these trends are occurring.

Overall, available data presents Parker Pond as an impaired system, largely based on the high nutrient and chlorophyll a concentrations and regular bottom water anoxia. Since available water quality data have only been collected during PALS Snapshots, it is not known whether the available data are representative of average conditions throughout the summer or if these conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as complete phytoplankton species (not just blue-greens) and cell counts throughout the summer and sediment nutrient release rates would provide insights into how the impaired conditions develop and are sustained. This information could then be combined with watershed information to complete a diagnostic assessment of the relative sources of the nutrients and then an evaluation of management options to ensure acceptable water quality throughout the Parker Pond water column.

III.27. Red Lily Pond

Red Lily Pond (PALS# BA-782) is a 4.5-acre pond in Centerville and is linked to Lake Elizabeth (PALS# BA-795) through a culvert under Centerville Avenue. Red Lily Pond is located west of Old Craigville Road and east of Lake Elizabeth Drive. Aside from the connection to Lake Elizabeth, it has two small inflow streams from adjacent wetlands at the north and west sides of the main basin.[205] The pond has had numerous measurements, studies, and one complete year of monthly water quality measurements collected in 1985 as part of a diagnostic/feasibility assessment that was completed for the combined Red Lily Pond/Lake Elizabeth system.[206] The bathymetric map in the 1988 diagnostic/feasibility study has 1 ft contours and a maximum depth contour of 4 ft located close to Centerville Avenue. Maximum depth among the PALS Snapshot samplings was 1.17 m (3.8 ft). The combined pond system has had numerous management options implemented including installation of a cluster septic system (1994), stormwater treatment (1998), subsidence dredging and reverse layering of sediments (2000-2001), sand relayering (2003), and hydroraking (2011). Total cost of implementing management options between 1996 and 2005 (including local match and in-kind services) was $686,000.[207] Other management activities at the pond have also included a herring run that connects Red Lily Pond and Lake Elizabeth to the Centerville River estuary.

Pond Summary			
Pond	Red Lily		
Village	Centerville		
Area (acres)	4.5		
Great Pond	No		
Management Plan	Last completed in 1988		
Max Depth (m)	1.2		
Streams	2 inflows (from wetlands), 1 outflow to Lake Elizabeth		
Temperature stratified	no		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2008-2013, 2018, 2019		
Total # of samples (including duplicates)	13 - 35 (depending on constituent)		
PALS % of WQ data	74%		
Average PALS concentrations (since 2003 relayering)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	16	n/a	10
TN (mg/L)	1.43	n/a	0.31
Chlorophyll a (µg/L)	9.2	n/a	1.7

Red Lily Pond is within a Lake Elizabeth/Red Lily Pond subwatershed delineated in the Centerville River Massachusetts Estuaries Project (MEP) assessment, but the Red Lily Pond does not have a separate watershed delineation.[208] Previous work by the Town DPW showed it did not have a public access point and approximately 22 buildings surrounded it.[209]

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[205] K-V Associates, Inc. and IEP, Inc. 1988. Red Lily Pond Diagnostic/Feasibility Study. Prepared for Town of Barnstable. 260 pp.

[206] *Ibid.*

[207] ENSR Technical Review. February 1, 2008. Third Party Peer Review of Proposal entitled "Feasibility Study for Restoration of Water and Sediments at Red Lily Pond; Craigville, Massachusetts." From D. Mitchell. To: D. Saad, Special Project Manager, Town of Barnstable Department of Public Works. 50 pp.

[208] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

[209] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

Red Lily Pond is listed separately from Lake Elizabeth in the most recent MassDEP Integrated List of surface waters of Massachusetts and is assigned to Category 5.[210] Category 5 waters in the Integrated List are impaired waters requiring a TMDL to address the listed impairments. Impairments listed for Red Lily Pond are high fecal coliform, nutrient/eutrophication biological indicators and aquatic plants (macrophytes). If Red Lily Pond and Lake Elizabeth are treated as a composite pond, the combined area is greater than 10 acres and it would be considered a Great Pond. The separate treatment of the ponds in the Integrated List suggests that MassDEP regards them as separate ponds; from this perspective, Red Lily Pond is not a Great Pond and therefore is not state owned.

Among the available water column sampling data included in the 2021 Barnstable Pond and Lake Water Quality Database, 74% of the available data is PALS Snapshot data, so the majority of data were collected in August and September. Most of the collected readings were collected at shallow depth (0.5 m); only two sampling runs have water quality samples collected at a depth of 0.8 or deeper. Average TP, TN, and chlorophyll a concentrations since the 2003 relayering exceed their respective Cape Cod ecoregion standards and show no statistically significant differences from results collected in 1985 during diagnostic/feasibility study. All of the individual TN readings and 75% of the TP readings since 2003 exceed their respective Cape Cod ecoregion thresholds. PALS Snapshot data was not collected consistently between 2001 and 2019, so trend analysis is not available. PALS Snapshot data was collected 2001-2003, 2008-2013, 2018, and 2019. N:P ratios showed that phosphorus was the key nutrient for determining water quality conditions in Red Lily Pond.

Although there were no statistically significant differences between 1985 and post-2003 readings, there were some notable differences that should guide future management activities. Deep DO readings (readings at 0.8 m or greater) averaged less than the MassDEP minimum (5 mg/L) and two of the six deep readings were anoxic (DO <1 mg/L), which is unusual in very shallow ponds. Anoxic conditions could facilitate sediment regeneration of phosphorus and prompt additional phytoplankton growth if these conditions are sustained for a sufficient period during the summer. Only two deep water quality samples have been collected since 2003 (in 2018 and 2019), so it is unclear whether significant sediment P regeneration is regularly occurring.

Overall, available data presents Red Lily Pond as an impaired system. Impairment is based on high TP, TN, and chlorophyll concentrations and occasional deep water anoxia. Available data suggests that there is no significant water quality difference between current water quality conditions and the water quality prior to the 2003 reverse layering. More definitive and comprehensive assessment data including aquatic plant populations (both rooted and phytoplankton) and water quality results throughout a summer would be necessary to fully assess how or if the system has changed significantly. Most of the available data was collected through PALS Snapshots. Determining the relative source(s) of the high water column nutrient levels in Red Lily Pond would require an updated review of watershed inputs, measurement of sediment nutrient contributions, measurement of stream inputs and outflows, potential stormwater

[210] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

inputs,[211] characterization of the rooted plant community, measurement of water column readings and phytoplankton populations throughout the summer. This type of assessment is typically completed through a management plan. A management plan would include quantification of the relative contributions of phosphorus from the sediments and the watershed, a review all applicable options to address the water quality impairments, and cost estimates for all applicable options.

[211] No stormwater outfalls were noted around Red Lily Pond in 2019 Town review of stormwater infrastructure (Comprehensive Environmental Inc. 2019), but the roads adjacent to the pond may have overland flow to the lake that was not noted.

III.28. Round Pond

Round Pond (PALS# BA-691) is a 9.8 acre pond located in Marstons Mills. It is located north of Old Falmouth Road and east of Flint Street. It is approximately 0.1 miles south of Shubael Pond. The pond has a maximum recorded depth among PALS Snapshot samplings of 4.8 m; review of public databases did not find a bathymetric map. Review of public databases also did not show that Round Pond has had a diagnostic/feasibility study or a water quality assessment.

Pond Summary	
Pond	Round
Village	Marstons Mills
Area (acres)	9.8
Great Pond	maybe
Management Plan	none
Max Depth (m)	4.8
Streams	none
Temperature stratified	no
Water Column Monitoring Summary	
PALS Years	2001-2003, 2005, 2007-2013, 2017-2019
Total # of samples (including duplicates)	14 - 27 (depending on constituent)
PALS % of WQ data	100%

Average concentrations			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	19	29	10
TN (mg/L)	0.46	0.52	0.31
Chlorophyll a (µg/L)	8.2	13.9	1.7

Public database review also did not find a Round Pond watershed delineation. Round Pond is included in the Skunknet River/Skunknet Pond watershed delineated as part of Centerville River Massachusetts Estuaries Project (MEP) assessment, but the pond does not have a separate watershed delineation.[212] Previous work by the Town DPW showed the pond has approximately 14 buildings around it and public access at a landing off Old Falmouth Road.[213] Round Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[214]

All of the available water column sampling data for Round Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, is from 14 PALS Snapshot samplings and all of the data were collected in August or September. PALS Snapshot sampling occurred in 2001-2003, 2005, 2007-2013, and 2017-2019.

The area of Round Pond is very close to the 10 acre Great Pond threshold. Review of historic aerial photos show that it is difficult to accurately measure the pond surface area due to overhanging trees along the shoreline. A 2017 Massachusetts Great Pond list produced by the state for Chapter 91 enforcement includes Round Pond.[215]

Review of the available data shows that the water column in Round Pond was generally isothermic with no significant differences in temperature throughout the water column. DO readings, however, showed statistically significant differences ($\rho<0.05$) between average shallow

[212] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

[213] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[214] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

[215] https://www.mass.gov/doc/massachusetts-great-ponds-list/download (accessed 4/8/21).

and deep water concentrations with deepest waters averaging less than the MassDEP minimum (5 mg/L) and anoxia in 44% of the deepest readings (n=9). Average surface TP, TN, and chlorophyll a concentrations were all much greater than their respective Cape Cod ecoregion thresholds and 85%, 100%, and 86% of the individual shallow concentrations were also greater than the respective thresholds. Average deep TP, TN, and chlorophyll a concentrations were all higher than shallow averages, but were not significantly higher ($\rho<0.05$). Clarity readings averaged 2.4 m or 54% of the water column visible. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Round Pond.

Review of the shallow TP, TN, and chlorophyll a concentrations do not show any notable temporal trends, but do show a large amount of variability. This variability is likely related to the deep anoxia that was occasionally measured. If anoxia persists long enough, the pond sediments can become a significant additional source of phosphorus causing a rapid rise in phosphorus concentrations and prompt phytoplankton growth (*i.e.*, high chlorophyll a concentrations). The lack of significant differences between shallow and deep average concentrations suggest the deep anoxia is an occasional occurrence, but more frequent monitoring would be necessary to confirm whether anoxia is occurring more frequently or for longer periods in recent years.

Overall, available data presents Round Pond as an impaired system, largely based on the high nutrient and chlorophyll a concentrations and occasional bottom water anoxia. Since available water quality data have only been collected during the PALS Snapshots, it is not known whether the available data are representative of average conditions throughout the summer or if these conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as continuous measures of deep water DO concentrations, characterization of phytoplankton species throughout the summer (not just blue-greens and including cell counts), a submerged aquatic plant survey, and sediment nutrient release rates would provide insights into how the impaired conditions develop and are sustained. This information could then be combined with watershed information to complete a diagnostic assessment of the relative sources of the nutrients and then an evaluation of management options to ensure acceptable water quality throughout the Round Pond water column.

III.29. Schoolhouse Pond

Schoolhouse Pond (PALS# BA-806) is a 3.6 acre pond located in Hyannis. It is located east of Scudder Avenue and south of Marston Avenue. The pond has a maximum recorded depth among PALS Snapshot samplings of 2.2 m; review of public databases did not find a bathymetric map. Review of public databases also did not show that Schoolhouse Pond has had a diagnostic/feasibility study or a water quality assessment.

Pond Summary	
Pond	Schoolhouse
Village	Hyannis
Area (acres)	3.6
Great Pond	no
Management Plan	none
Max Depth (m)	2.2
Streams	1 inflow from wetland to east
Temperature stratified	no
Water Column Monitoring Summary	
PALS Years	2001-2003, 2007-2013, 2017-2019
Total # of samples (including duplicates)	13 - 26 (depending on constituent)
PALS % of WQ data	100%

Average concentrations (deep 1.5 m samples not consistently collected; n=4)

assay	Shallow	1.5 m	Cape Cod threshold
TP (µg/L)	116	70	10
TN (mg/L)	1.45	1.21	0.31
Chlorophyll a (µg/L)	50.6	27.1	1.7

Review of public databases also did not find a Schoolhouse Pond watershed delineation. Schoolhouse Pond is included in the Hyannis Harbor West watershed delineated as part of Lewis Bay Massachusetts Estuaries Project (MEP) assessment, but does not have a separate watershed delineation.[216] Previous work by the Town DPW showed the pond has approximately 17 buildings around it and no public access,[217] although review of town parcel maps seems to show a portion of the Prospect Avenue right-of-way extends to the pond.[218] Schoolhouse Pond is not listed in the most recent MassDEP Integrated List of surface waters of Massachusetts.[219]

All of the available water column sampling data for Schoolhouse Pond included in the Barnstable Pond and Lake Water Quality Database is from 13 PALS Snapshot samplings and all of the data were collected in August or September. PALS Snapshot sampling occurred in 2001-2003, 2007-2013, and 2017-2019.

Review of the available data shows that the water column in Schoolhouse Pond was generally isothermic with most column measurements having less than 1 to 2°C difference between shallow and deep readings, but occasionally having 4 to 5°C differences. DO readings, however, showed statistically significant differences ($\rho<0.05$) between average shallow and deep (>1.5 m) concentrations. Overall, 64% of the 14 deep readings were less than the MassDEP regulatory minimum (5 mg/L) and 29% were anoxic. Average surface water TP, TN, and chlorophyll a

[216] Howes B., H. Ruthven, E. Eichner, J. Ramsey, R. Samimy, D. Schlezinger. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Lewis Bay System, Towns of Barnstable and Yarmouth, MA. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 253 pp

[217] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[218] https://gis.townofbarnstable.us/Html5Viewer/Index.html?viewer=propertymaps (accessed 4/8/21).

[219] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

concentrations were all significantly greater than their respective Cape Cod ecoregion thresholds and all of the individual shallow concentrations were also greater than the respective thresholds. Average TP, TN, and chlorophyll a deep water concentrations were not significantly different from the surface averages. Clarity readings averaged 0.9 or 45% of the water column, which is consistent with high nutrient and chlorophyll a concentrations; Secchi readings in 2 m deep ponds with lower nutrient concentrations typically show light reaching the pond bottom (*i.e.*, seeing the disc on the bottom of the pond). N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Schoolhouse Pond.

Review of the shallow TP, TN, and chlorophyll a concentrations do not show any notable temporal trends, but do show a large amount of variability. This variability is likely related to the occasional deep anoxia that has been measured; DO readings at depth between 1.9 and 2.5 m (n=5) averaged 2.9 mg/L with two anoxic readings (*i.e.*, <1 mg/L). If anoxia persists for long enough, pond sediments can become a significant additional source of phosphorus causing a rapid rise in water column phosphorus concentrations which would prompt phytoplankton growth (*i.e.*, high chlorophyll a concentrations). High variability would also occur if phytoplankton populations bloom and then senesce to the bottom or if there is periodic water column mixing.

Overall, available data presents Schoolhouse Pond as an impaired system, largely based on the high nutrient and chlorophyll a concentrations and occasional bottom water anoxia. Since available water quality data have only mostly been collected during the PALS Snapshots, it is not known whether the available data are representative of average conditions throughout the summer or if these conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as continuous measures of deep DO concentrations, characterization of phytoplankton species throughout the summer (not just blue-greens and including cell counts), a submerged aquatic plant survey, and sediment nutrient release rates would provide insights into how the impaired conditions develop and are sustained. This information could then be combined with watershed information to complete a diagnostic assessment of the relative sources of the nutrients and then an evaluation of management options to ensure acceptable water quality throughout the Schoolhouse Pond water column.

III.30. Shallow Pond

Shallow Pond (PALS# BA-626) is a 78 acre Great Pond located in Centerville. It is located east of Huckins Neck Road and west of Route 132. The pond has a maximum recorded depth among PALS Snapshot samplings of 2.5 m. A bathymetric map in a 1991 diagnostic/feasibility study showed a maximum contour of 2 m;[220] this study appears to be the most recent water quality assessment of Shallow Pond.

Pond Summary	
Pond	Shallow
Village	Centerville
Area (acres)	78
Great Pond	Yes
Management Plan	Yes (1991)
Max Depth (m)	2.5
Streams	none
Temperature stratified	no
Water Column Monitoring Summary	
PALS Years	2001-2003, 2008-2013, 2017-2018
Total # of samples (including duplicates)	12 - 40 (depending on constituent)
PALS % of WQ data	70%

Average concentrations (since 2001)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	13	16	10
TN (mg/L)	0.46	0.48	0.31
Chlorophyll a (µg/L)	4.5	11.5	1.7

Shallow Pond is positioned close to the regional groundwater divide between Cape Cod Bay and Vineyard Sound. Watershed delineations and groundwater flow in this area is complicated because of the divide and the high density of large ponds in a relatively small area. The watershed delineations in the Centerville River Massachusetts Estuaries Project (MEP) assessment did not have a separate Shallow Pond watershed; Shallow Pond was part of a combined Wequaquet Lake/Bearses Pond/Shallow Pond watershed.[221] A 2009 water quality assessment delineated watersheds to Shallow Pond and each of the basins of Wequaquet Lake.[222] This delineation had outflow from the pond along most of its shoreline and only a small watershed along its eastern shoreline. Previous work by the Town DPW showed the pond has approximately 39 buildings around it and public access off Huckins Neck Road.[223] Shallow Pond is assigned to Category 3 ("no uses assessed") in the most recent MassDEP Integrated List of surface waters of Massachusetts.[224]

Water column sampling data for Shallow Pond included in the 2021 Barnstable Pond and Lake Water Quality Database is from the 1991 diagnostic/feasibility study and 11 PALS Snapshot samplings. Diagnostic/feasibility sampling occurred on 19 dates in 1985-1986; additional data included in the 1991 assessment include phytoplankton and fish sampling, sediment analysis and

[220] K-V Associates, Inc. and IEP, Inc. 1991. Shallow Pond Diagnostic-Feasibility Study. Clean Lakes Program, Massachusetts Department of Environmental Protection. Falmouth, MA and Barnstable, MA. 298 pp.

[221] Howes B., H. Ruthven, E. Eichner, J. Ramsey, R. Samimy, D. Schlezinger. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Lewis Bay System, Towns of Barnstable and Yarmouth, MA. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 253 pp

[222] Eichner, E. 2008. Lake Wequaquet Water Quality Assessment. Completed for the Town of Barnstable and the Cape Cod Commission. Coastal Systems Program, School of Marine Science and Technology, University of Massachusetts Dartmouth. 81 pp.

[223] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[224] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

stormwater runoff measurements. PALS Snapshot data was the only available sampling data since the completion of the diagnostic/feasibility study. PALS Snapshot sampling occurred in 2001-2003, 2008-2013, and 2017-2018.

Review of the available PALS data since 2001 shows that the water column in Shallow Pond is generally isothermic with less than 1°C average difference between shallow and deep readings. Average shallow DO is slightly greater than the average deep water concentration, but only 2 of the 11 individual deep readings were less than the MassDEP regulatory minimum (5 mg/L) and none were anoxic. Average shallow TP, TN, and chlorophyll a concentrations were all greater than their respective Cape Cod ecoregion thresholds and there was no significant difference between shallow and deep average concentrations for TP, TN, or chlorophyll a. All of the individual shallow and deep TN and chlorophyll a concentrations were greater than the respective Cape Cod ecoregion thresholds, while 75% of the shallow and deep TP concentrations were greater than the TP ecoregion threshold. Clarity readings averaged 99% of the water column with 82% of the readings having light reaching the bottom (*i.e.*, 100% of the water column). Review of the shallow TP and chlorophyll a concentrations since 2001 show increasing concentrations, but these trends are not significant largely due to high variability in the concentrations from year to year. TN concentrations do not show any change with time. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Shallow Pond.

Overall, available data presents Shallow Pond as having borderline impaired conditions that could be acceptable depending on management objectives. DO concentrations were generally greater than MassDEP regulatory minimum and clarity has been generally excellent with light penetration extending to the bottom in most readings. Average shallow and deep TP concentrations are greater than the respective Cape Cod ecoregion thresholds, but not exceptionally greater. Average TN and chlorophyll concentrations are much higher, but they may be acceptable in the context of a shallow pond. In addition, since all of readings since 2001 are PALS Snapshot samples collected during August and September, the measured conditions should represent the worst water quality conditions of each year. With all that in mind, other management concerns that are not addressed through the available data are whether submerged aquatic plants are restricting uses of the pond. Review of available historic photographs do not show any notable changes in submerged aquatic plants over the past 15 years, but further review and discussions with users of the pond may provide guidance on management concerns.

If the Town decides to purse an update of the diagnostic/feasibility study, key complementary data will be needed to definitively resolve whether other aspects of the system are as acceptable as the water column sampling results. These complementary data should include characterization of phytoplankton species throughout the summer (not just blue-greens and including cell counts), a submerged aquatic plant survey, stormwater sampling, and collection of sediment cores to measure sediment nutrient release rates. This information could then be combined with watershed information to complete a diagnostic assessment and this could then be used to inform discussion of management goals and options for Shallow Pond.

III.31. Shubael Pond

Shubael Pond (PALS# BA-664) is a 55 acre Great Pond located in Marstons Mills. It is located east of Route 149 and south of Race Lane. The pond has a maximum recorded depth among PALS Snapshot samplings of 13.4 m, which is consistent with the maximum 40 ft (12.2 m) contour in the MassDFW bathymetric map included in the Cape Cod Pond and Lake Atlas.[225] Review of public databases did not show that Shubael Pond has had a diagnostic/feasibility study or a water quality assessment, although the Town has recently asked CSP/SMAST to collect data for such an assessment. Other management activities at the pond have also included Massachusetts Division of Fisheries and Wildlife stocking of the pond with various trout species.[226]

Pond Summary			
Pond	Shubael		
Village	Marstons Mills		
Area (acres)	55		
Great Pond	Yes		
Management Plan	No, but planned for 2021		
Max Depth (m)	13.4		
Streams	none		
Temperature stratified	yes		
Water Column Monitoring Summary			
PALS Years	2001-2003, 2007-2013, 2017-2019		
Total # of samples (including duplicates)	14 - 59 (depending on constituent)		
PALS % of WQ data	85%		
Average concentrations (since 2001)			
Assay	Shubael	Deep	Cape Cod threshold
TP (µg/L)	10	30	10
TN (mg/L)	0.37	0.75	0.31
Chlorophyll a (µg/L)	2.5	1.7	1.7

Shubael Pond watershed was delineated as part of the Centerville River Massachusetts Estuaries Project (MEP) assessment.[227] This watershed, which is based on US Geological Survey groundwater modeling,[228] showed that flow out of the pond is divided between the Centerville River and Three Bays estuaries. Previous work by the Town DPW showed the pond has approximately 22 buildings around it and two public access points: 1) a boat ramp at the end of Willimantic Drive and 2) at the end of a right-of-way called Shubael Pond Road.[229] Shubael Pond is assigned to Category 3 ("no uses assessed") in the most recent MassDEP Integrated List of surface waters of Massachusetts.[230]

Among the available water column sampling data for Shubael Pond included in the 2021 Barnstable Pond and Lake Water Quality Database, 13 of the 27 of the sampling dates were from PALS Snapshots and 95% of the available data were collected in August or September. Among

[225] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

[226] https://www.mass.gov/service-details/trout-stocking-report (accessed 8/12/21)

[227] Howes B., H. Ruthven, E. Eichner, J. Ramsey, R. Samimy, D. Schlezinger. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Lewis Bay System, Towns of Barnstable and Yarmouth, MA. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 253 pp

[228] Walter, D.A. and A. Whealan. 2004. Simulated Water Sources and Effects of Pumping on Surface and Ground Water, Sagamore and Monomoy Flow Lenses, Cape Cod, Massachusetts. USGS Scientific Investigations Report 2004-5181. 92 pp.

[229] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[230] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

the data are also readings from a 1992 Living Lakes, Inc report that includes 11 sampling dates between 1986 and 1991, where water column readings and samples were mostly collected from one or two depths.[231] PALS Snapshot sampling occurred in 2001-2003, 2007-2013, and 2017-2019.

Review of the available data collected since 2001 shows that the water column in Shubael Pond in late summer was generally thermally stratified with a warm, well-mixed, upper layer of 6 to 8 m, a 1 to 2 m transition zone, and cold water below the transition zone. Average DO concentrations in the warmer upper layer were near atmospheric equilibrium (*i.e.*, 100% DO saturation), while waters deeper than the transition layer (usually 9 m and deeper) were hypoxic (average = 1.2 mg/L DO; n=17). Average shallow TP concentration since 2001 was slightly less than the 10 µg/L TP Cape Cod ecoregion threshold, however, average TP concentrations at 3 m, 9 m, and the deepest readings were all greater than the ecoregion threshold. Average TP concentrations at 9 m and deeper depths were both significantly greater ($\rho<0.05$) than the shallow and 3 m averages. The average deep water TP concentration was nearly 3X the average shallow TP concentration. Average TN and chlorophyll a concentrations at shallow, 3 m, 9 m, and deep sampling depths were all greater than their respective Cape Cod ecoregion thresholds. Clarity readings averaged 4.4 m or 38% of the water column. Review of the Shubael Pond shallow PALS TP concentrations showed a significant increasing ($\rho<0.05$) temporal trend, but shallow TN did not, suggesting that the TP increase is likely related to internal sediment regeneration rather than watershed inputs. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Shubael Pond.

Overall, available data presents Shubael Pond as having borderline impaired water quality in its shallow waters, but significantly impaired conditions in the deeper bottom waters based on low DO concentrations and high TP, TN, and chlorophyll a concentrations. The increasing trend in shallow TP levels since 2001 suggests that water quality conditions will worsen with time. Since available water quality data since 2001 have been mainly collected during PALS Snapshots in August and September, it is not known whether the available data are representative of average conditions throughout the summer or if these conditions only develop in late summer. Collection of summer-long water quality data and key complementary data, such as continuous measures of deep water DO concentrations, characterization of phytoplankton species throughout the summer (not just blue-greens and including cell counts), a submerged aquatic plant survey, and measurement of sediment nutrient release rates would provide insights into how the impaired conditions develop and are sustained. Data collection of these parameters and additional surveys, such as an updated bathymetric map, are currently being completed by CSP/SMAST through a project with the Town DPW. This information will be combined with watershed information to complete a diagnostic assessment of the relative sources of the nutrients and then an evaluation of management options to ensure acceptable water quality throughout the Shubael Pond water column. If funding is approved, a draft diagnostic assessment/management plan of Shubael Pond will be completed in November 2021.

[231] This data was included in the 2008 Barnstable Pond Status Report (Eichner, 2008), but the Living Lakes report was not available for re-review in the current project.

III.32. Wequaquet Lake

Wequaquet Lake (PALS# BA-605) is a 661-acre Great Pond in Centerville. The total surface area of the Lake includes two named ponds: Bearse Pond (PALS# BA-617) and Gooseberry Pond. Wequaquet Lake is located east and south of Shootflying Hill Road and west of Huckins Neck Road. The Lake has five deep basins with two in the main portion of the pond (426 acre surface area) and then one each in Gooseberry Pond, Bearse Pond, and a 21 acre south basin. A stream outflow from the south basin at Phinneys Lane flows under Route 28 and into Long Pond. The pond has had numerous studies and summer-long measurements collected, including a 1989 diagnostic/feasibility assessment,[232] a 2009 water quality assessment,[233] continuous water column recordings in 2014[234] and 2015 (with incubation of sediment cores for measuring nutrient release)[235], and a 2013 profiling and long-term management plan.[236] Management activities at the pond have included herbicide applications and suction dredging to control fanwort[237] and the herring run that connects Wequaquet Lake and Long Pond to the Centerville River estuary.

Pond Summary			
Pond	Wequaquet		
Village	Centerville		
Area (acres)	661 (including Bearse Pond and Gooseberry Pond)		
Great Pond	Yes		
Management Plan	2013		
Max Depth (m)	9.8		
Streams	1 outflow		
Temperature stratified	Temporary stratification measured in 2015 continuous recording		
Water Column Monitoring Summary			
PALS Years	2002-2003, 2005-2015, 2017-2018		
Total # of samples (including duplicates)	35 – 104 (depending on constituent)		
PALS % of WQ data	36%		
Average concentrations (since 2001)			
assay	Shallow	Deep	Cape Cod threshold
TP (µg/L)	19	29	10
TN (mg/L)	0.43	0.48	0.31
Chlorophyll a (µg/L)	4.4	3.9	1.7

Wequaquet Lake is part of a combined Wequaquet Lake/Shallow Pond subwatershed delineated in the Centerville River Massachusetts Estuaries Project (MEP) assessment, but does not have a

[232] IEP, Inc. and K-V Associates, Inc. 1989. Diagnostic/Feasibility Study of Wequaquet Lake, Bearse, and Long Pond. Prepared for Town of Barnstable Conservation Commission. 150 pp.

[233] Eichner, E. 2009. Lake Wequaquet Water Quality Assessment. Completed for the Town of Barnstable and the Cape Cod Commission. Coastal Systems Program, School of Marine Science and Technology, University of Massachusetts Dartmouth. 81 pp.

[234] CSP/SMAST Technical Memorandum. February 3, 2015. Summary of Continuous Monitoring at two stations in Lake Wequaquet, Main Basin (Station #2) and Bearses Pond (Station #5), between August 15 and October 7, 2014. From: E. Eichner, B. Howes, and D. Schlezinger. To: R. Gatewood, Town of Barnstable Conservation Administrator, P. Canniff, President, Wequaquet Lake Protective Association, and G. Maguire, Vice President, Wequaquet Lake Protective Association. 24 pp.

[235] CSP/SMAST Technical Memorandum. March 22, 2016. Continuous Monitoring at Main Basin and Bearses Pond (Station #5), Bearses Pond sediment cores, and Bearses Pond Management Options. From: E. Eichner, B. Howes, and D. Schlezinger. To: D. Karle, Town of Barnstable Conservation Administrator, P. Canniff, President, Wequaquet Lake Protective Association, and G. Maguire, Vice President, Wequaquet Lake Protective Association. 22 pp.

[236] Woods Hole Group, Inc. 2013. Wequaquet Lake Profiling and Long-Term Management Plan. 126 pp.

[237] Solitude Lake Management. 2020. Barnstable Ponds Report: Wequaquet Lake. Shrewsbury, MA. 9 pp.

separate watershed delineation.[238] The US Geological Survey groundwater modeling completed for the MEP also shows that a portion of downgradient flow out of Wequaquet Lake flows toward Barnstable Great Marshes along a portion of its northern shoreline; this means that Wequaquet Lake is situated along the regional groundwater divide between Cape Cod Bay and Vineyard Sound. A 1998 hydrology study of the area showed that the lake generally dampens the effects of groundwater fluctuations in the area, but lake levels can increase significantly if seasonal precipitation rates are exceptionally high.[239] Previous work by the Town DPW showed the lake has a public access at a beach and boat ramp off Shootflying Hill Road and approximately 232 buildings around it.[240] Wequaquet Lake is a Great Pond and is listed and categorized as a 4a water body in the most recent MassDEP Integrated List of surface waters in Massachusetts.[241] Category 4a in the Integrated List is "TMDL is completed" and the approved TMDL is for mercury in fish tissue in Wequaquet Lake and is based on MassDEP sampling in 2001-2004.[242] An assessment of nutrient-related water quality conditions in Wequaquet Lake is not included in the most recent MassDEP Integrated List.

Recent reviews of Wequaquet Lake water quality show that it varies from year to year and that it can be notably impaired. In a 2016 CSP/SMAST Technical Memo, project staff reviewed results from installation of continuous DO monitors in 2014 and 2015.[243] In 2014, no anoxia was noted at depth in the main basin, but in 2015, anoxic conditions were sustained throughout August and DO concentrations were consistently less than the MassDEP minimum into September. Water quality sampling confirmed that deep pond sediments were adding TP to the water column when anoxia was occurring. In a 2015 CSP/SMAST Technical Memo, project staff recommended that the Town consider implementing an aeration or alum treatment in the clearly impaired Bearses Pond sub-basin and that parallel, complementary monitoring in the main basin of Wequaquet Lake be conducted to assess the impacts on water quality from implementation of management options in the connected basin.[244]

PALS Snapshot data is the main source (36%) of water column data for Wequaquet Lake in the 2021 Barnstable Pond and Lake Water Quality Database. Other database sources are: the various CSP/SMAST projects (2009, 2014, and 2015) (accounting for 34% of the available data), Town monitoring efforts (22%), and the 1989 diagnostic/feasibility study (10%). Most of the available studies have additional data that was not included in the database (*e.g.,* phytoplankton sampling, continuous monitoring, etc.) that should be reviewed if a more comprehensive

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[238] Howes B., H.E. Ruthven, J. S. Ramsey, R. Samimy, D. Schlezinger, J. Wood, E. Eichner. 2006. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 pp.

[239] Eichner, E.M., T.C. Cambareri, V. Morrill, and B. Smith. 1998. Lake Wequaquet Water Level Study. Cape Cod Commission. Barnstable, MA. 44 pp.

[240] Town GIS analysis completed by the Town DPW staff for the Water Resources Advisory Committee

[241] Massachusetts Department of Environmental Protection. December 2019. Massachusetts Year 2016 Integrated List of Waters. Final Listing. Massachusetts Division of Watershed Management, Watershed Planning Program. CN: 470.1. Worcester, MA. 375 pp.

[242] Massachusetts Department of Environmental Protection. 2006. Massachusetts Fish Tissue Mercury Studies: Long-Term Monitoring Results, 1999-2004. 48 pp.

[243] CSP/SMAST Technical Memorandum. March 22, 2016. Continuous Monitoring at Main Basin and Bearses Pond (Station #5), Bearses Pond sediment cores, and Bearses Pond Management Options.

[244] CSP/SMAST Technical Memorandum. February 3, 2015. Summary of Continuous Monitoring at two stations in Lake Wequaquet, Main Basin (Station #2) and Bearses Pond (Station #5), between August 15 and October 7, 2014.

assessment of Wequaquet Lake is planned. August and September samplings represent 52% of available readings with 76% of the available readings collected in summer months (June to September). Outlier analysis found that many of the outliers in the overall 2021 database averages were in the May or October readings, which suggests that they are not outliers, but reflective of the high frequency of late summer in the overall dataset.

Review of data collected since 2001 showed that the main basin of Wequaquet Lake generally is isothermic with similar temperatures (within 1 to 2°C) at the surface and bottom.[245] This condition means the water column in the Lake is generally vertically well mixed by wind blowing across its surface. As would be expected, parallel DO measurements were generally acceptable with only 25% of the deep readings less than the MassDEP minimum (5 mg/L[246]). However, the occurrence of regular anoxia in the 2015 continuous recordings show that annual or monthly snapshot sampling may miss ecologically important events. The significant algal blooms in 2012 and 2013 were likely the result of sustained low oxygen in bottom waters causing phosphorus regeneration from the sediments that was significant enough to prompt blooms when the enhanced deep P concentrations were mixed into the upper water column.

Average shallow water TP, TN, and chlorophyll a concentrations since 2001 were all notably greater than their respective Cape Cod ecoregion thresholds. Deep water average TP concentration was significantly higher ($\rho<0.05$) than the shallow water average, while deep TN and chlorophyll a concentrations were higher than their respective shallow averages, the differences were not statistically significant. Almost all of the individual shallow and deep TP, TN, and chlorophyll a concentrations were greater than the respective Cape Cod ecoregion thresholds (83 to 96% of individual readings). Clarity readings averaged 3.0 m or 33% of the water column. N:P ratios showed that phosphorus was the key nutrient determining water quality conditions in Wequaquet Lake.

Trend analysis generally confirms that water quality in Wequaquet Lake has been declining since 2001. Wequaquet Lake main basin had a statistically significant ($\rho<0.02$) increasing trend in shallow TP concentrations, while water clarity had a matching decreasing trend ($\rho<0.0008$). Total N data shows a slight increase over the same period but the trend is not statistically significant. This analysis shows that more TP is in the water column than in the past and TP levels continue to increase. This finding is consistent with an increasing frequency of low oxygen conditions in the main basin accompanied by increased internal TP additions (*i.e.*, sediment regeneration). More comprehensive review of the available data with accompanying assessments (*e.g.*, watershed reviews) could help to clarify why conditions are changing in Wequaquet Lake.

Review of the available data also noted that older and more recent data had some differences that are likely related to differences in procedures and detection limits among the multiple labs. Review of PALS data showed statistically significant ($\rho<0.05$) differences between many of the shallow and deep parameter averages, but none of the average readings from assessments prior to

[245] Water quality data has been collected at five stations in Wequaquet Lake, including Bearses Pond, Gooseberry Pond, south basin, and two stations in the main basin (north and deep). Data discussed here focusses on the main deep station. All available data is included in the Barnstable Pond and Lake Water Quality Database.

[246] 314 CMR 4.05

PALS in 2001 showed similar differences. Part of this may be due to changes in the Wequaquet Lake, but some may also be due to changes in laboratory assay methods; for example, the TP detection limit used in much of the 1989 diagnostic/feasibility study was 10 µg/L compared to the 3.1 µg/L typically used PALS Snapshot assays. For this reason, SMAST and older data were kept separate in the 2021 Barnstable Pond and Lake Water Quality Database and likely should be kept separate in future reviews until laboratory procedures are closely reviewed. These types of differences could be resolved during the development of a management plan. For the purposes of developing current average conditions, project staff relied on data generated after 2001.

Overall, Wequaquet Lake presents as an impaired system, largely based on the high nutrient and chlorophyll readings, diminished clarity, and occasional anoxic events. The trend analysis further shows that TP concentrations have significantly increased between 2001 and 2018. Review of TP and TN concentrations show that TP determines the water quality in Wequaquet Lake. In the 2014 CSP/SMAST Technical Memo, it was suggested that the Town consider water quality management in Bearses Pond accompanied by monitoring in the Main Basin of Wequaquet Lake to better understand the relationship between the two basins and begin to restore the clearly impaired conditions in Bearses Pond. The 2015 CSP/SMAST Technical Memo showed that the sediments in Bearses Pond have high phosphorus concentrations and when periodic low DO conditions occur, significant sediment phosphorus is released into the water column. At the time, CSP/SMAST staff suggested that aeration or an alum treatment in Bearses Pond would likely represent the lowest cost options to address these impairments. This recommendation was paired with another recommendation that the Town develop a management plan for the whole Wequaquet Lake system to understand the relative contributions of phosphorus from the sediments and the watershed, review all applicable options to address the water quality impairments, and develop cost estimates for all applicable options. An updated diagnostic assessment and management plan for Wequaquet Lake has not been completed since 1989.

IV. Conclusions

Organization of available pond water quality data for the Town of Barnstable revealed some findings that should be incorporated into current and future monitoring protocols and data reviews and pond and lake management planning:

a. Most of the monitored ponds have impaired water quality

Project staff reviewed water quality data from 32 of the 55 ponds included in the 2021 Barnstable Pond and Lake Water Quality Database. Most of these ponds had water quality impairments associated with nutrient enrichment, including associated high phytoplankton levels, low water clarity and bottom water hypoxia. Impairment was defined by comparing the results to MassDEP regulatory standards (314 CMR 4) and Cape Cod Ecoregion thresholds defined in the Cape Cod Pond and Lake Atlas.

b. All water column data needs additional context

The 2021 Barnstable Pond and Lake Water Quality Database is a collection of water column data, including PALS Snapshot results, town monitoring data, and data from various pond water quality assessments. Although water column data provides useful insights into pond health, management of the water quality in these ponds requires developing an understanding of what causes the water column concentrations and conditions, including defining the sources of nutrients and why conditions change over time.

c. Each pond is unique, but data gaps are similar

Data gap surveys of key pond ecosystem features are needed to provide the additional context for understanding the causes of water quality conditions. The review of the 2021 Database data found each pond had unique characteristics based on its depth, area, surface water flows (in or out), number of houses around it, etc. But the data gap information needed to understand how the measured water quality in the pond developed was fairly similar from pond to pond: watershed delineation, watershed land use, measurement of stormwater inputs, measurement of sediment regeneration of nutrients, measurement of surface water flows and nutrient loads, measurement (biomass, cell counts, etc.) and speciation of phytoplankton populations throughout the summer, etc. Addressing these data gaps will provide the information necessary to understand how water column constituent levels develop and change. Once this understanding is sufficient, water quality management options to address water quality impairments can be reliably developed, compared, and implemented.

d. Pond water quality management will require a pond-by-pond approach

Developing sufficient understanding of pond ecosystem functions and options to restore acceptable water quality is typically addressed through an individual pond management plan. Since each pond has individual characteristics, management plans typically focus on individual ponds. Management of pond water quality will have to involve community discussions about goals, including regulatory standards and ecoregion thresholds, but also use of the pond (*e.g.*, boating, swimming, fishing, public access) and natural resource concerns (*e.g.*, herring runs, plant coverage). Since the range of these issues will also differ slightly from pond to pond, this reinforces the unique nature of each pond and the need to address management for each individual pond in a focused way.

V. Recommendations

Based on the preparation of the 2021 Barnstable Pond and Lake Water Quality Database and review of the collected water quality data, project staff has a number of recommendations:

1. **Consider a tiered data review process with annual and 3 year reviews**
   The PALS Snapshot program is an effort largely run by volunteers with donations of time and materials provided by professional staff and CSP/SMAST. There is no funding to regularly compare water quality results to past results or review and clarify monitoring missteps (*e.g.*, DO collected as % saturation, switching the labels on shallow and deep sample bottles, deep samples that likely hit the bottom, etc.). Some of these missteps are caught and clarified so they do not occur the following year, but some persist for a number of years. It is recommended that the Town consider a tiered data review approach that completes a limited review of PALS Snapshot data each year to check for any issues/questions that should be resolved prior to the next year by comparing results (both field and lab) to ranges available in this 2021 Database. This annual limited data review would then be linked to a regular three year overall review similar to the review in this project that looks at updated averages and trends, provides regular feedback to volunteer monitors.

2. **Consider a commitment to completion of pond management plans for all Great Ponds**
   Great Ponds are publicly-owned waters of the Commonwealth of Massachusetts. As such, they have associated regulatory standing and concerns, including potential for inclusion in the Massachusetts Integrated List and TMDLs and incorporation into town Comprehensive Wastewater Management Plans (CWMPs). The Town of Barnstable has 25 Great Ponds based on the pond surface areas identified in this project. Development of pond management plans for these public resources would allow the Town to proactively address TMDL concerns, identify ways that implementation of the current CWMP could address pond water quality concerns, and identify those ponds where management should be focused on internal sediment nutrient loading and/or watershed nutrient sources. Management plans would also help pond residents and the town understand all management concerns, including lake uses, and develop potential strategies to address those concerns. The Town could use the 2021 Database results to help prioritize the management plans.

3. **Consider the development of Town of Barnstable pond and lake QAPP**
   Acceptance of monitoring data by MassDEP for regulatory decisions, including Integrated List review, often requires demonstration of the sampling techniques used, the sampling handling and transfer procedures, and laboratory assays methods. A Quality Assurance Project Plan (QAPP) for Town of Barnstable ponds and lakes could document all pond monitoring, including volunteer monitoring and data gap monitoring for pond management plans. A QAPP would ensure that minimum detection limits are used in laboratory procedures and applicable techniques are used to guide pond management decisions, as well as providing a boilerplate for what information should be provided in a management plan, while also providing MassDEP acceptance of results prior to submittal for Integrated Listing, TMDL development and/or CWMP compliance.

4. **Continue April and late summer pond and lake snapshot monitoring**
   The original Cape Cod PALS Snapshot was developed as a way to assess water quality in ponds and lakes during late summer, which was likely to be when the worst water quality conditions existed. As data was developed, it was clear that there was variation from year to year and it would be useful to provide an annual starting point for the late summer conditions by sampling in the spring when water quality conditions would be largely unimpacted by summer temperatures. The Town has recently begun sampling ponds and lakes in April and then again during the late summer PALS Snapshot. Development of this data while pursuing individual pond management plans will provide key information for the management plans, as well as assistance in prioritizing which order ponds are selected for plans.

5. **Individual pond sampling locations should be standardized**
   The PALS approach has relied on volunteers identifying the deepest location from either local knowledge or review of available bathymetric maps. It was anticipated that this approach would have some variability, including variability associated with groundwater level fluctuations. Review of the 2021 database results shows some variability built into the PALS Snapshot structure, but also years where the deepest sampling location was completely missed. In order to remove some of the data uncertainties and lost opportunity created by this variability, it is recommended that GPS coordinates be established for sampling points and tools be provided to volunteers to ensure that the same site is located during each future sampling event.

6. **Changes in laboratories or data equipment should be carefully considered**
   Review of the ponds water quality database showed a variety of laboratory detection limits and methods, especially in older water quality assessments. Generally, these were not substantial obstacles to considering all assay results from different labs, but there were some circumstances where samples were collected and results were not reliable (often due to TP detection limits that were too high or a DO cable that was too short to reach the bottom). It is recommended that the Town assess any potential data usage limitations when water quality samples are assayed by different laboratories or monitoring equipment is changed/updated.

7. **Try to integrate/coordinate pond management objectives across all Town efforts**
   Review of the various pond water quality reports showed that some of the data collection and pond management activities were through the Town Conservation Commission (ConComm), while others were through the Town Department of Public Works (DPW). It appears that the separation of these activities is largely based on whether the activities are in a pond watershed (DPW) or within the pond water body (ConComm). Since most pond water quality management is a combination of watershed and in-pond activities, it is recommended that overall Town pond management ensure coordination throughout assessment and management plan activities.

Project staff are available to discuss all conclusions and recommendations, as well as continuing to assist the Town of Barnstable with reliable and cost-effective pond and lake water quality management.

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ATTACHMENT E

SEWER ASSESSMENT ORDINANCE

Town of Barnstable

Office of Town Clerk

367 Main Street, Hyannis MA 02601

Office: 508-862-4044
Fax: 508-790-6326

Ann M. Quirk, CMC/CMMC/MMC
Town Clerk

July 21, 2021

To whom it may concern:

Please be advised that the following is a true copy of an item duly passed by the Barnstable Town Council on July 1, 2021:

2021-139 ORDER AMENDING CHAPTER 184 SEWERS AND WATER OF THE GENERAL ORDINANCES INTRO: 04/15/2021, 05/20/2021, 07/01/2021

Upon a motion duly made and seconded it was

ORDERED: That Chapter 184 General Ordinances of the Code of the Town of Barnstable be amended by inserting the following new Article II, Sewer Assessments, as presented to the Town Council on April 15, 2021, and as amended by the Town Council at its meeting of May 20, 2021, and renumbering the current Articles II and III as Articles III and IV:

"ARTICLE II
SEWER ASSESSMENTS

Section 1: Purpose and Authorization

The purpose of this Article II is to assess all properties receiving benefit or advantage from public sewerage construction within a limited and determinable area, including, but not limited to, as set forth in the Comprehensive Wastewater Management Plan approved by vote of the Town Council on November 7, 2019, and in accordance with Section 1 of Chapter 83 of the General Laws, any other applicable section of said Chapter 83 and any other applicable general or special law.

Section 2: Definitions

For the purpose of this Article II, the following words shall be considered to have the following meanings:

(1) Commercial Use: Occupancy of premises for financial gain including profit such as business and industrial uses.

(2) Commercial Sewer Unit: Shall be equivalent to 330 gallons of actual or reasonably anticipated daily sewage volume, as determined by the Director of the Department of Public Works based on Title 5 of the State Environmental Code, 310 CMR 15.203, System Sewage Flow Design Criteria. For purposes of determining the number of Commercial Sewer Units to be assessed, volume in an amount up to and including 330 gallons shall be deemed one Commercial Sewer Unit. An additional Commercial Sewer Unit shall be assessed for each additional 330 gallons of volume.

(3) Compensatory Sewer Privilege Fee: A fee that is assessed in lieu of a sewer assessment to reflect the increased use of a property in situations where: (a) a sewer assessment has been assessed to an undeveloped property based on the number of potential Sewer Units and said property is ultimately developed to accommodate a greater number of Sewer Units than that originally assessed; or (b) a sewer assessment has been assessed to a developed parcel and subsequently the use of that parcel has changed or intensified to accommodate a greater number of Sewer Units than that originally assessed; or (c) no sewer assessment was assessed to an Unbuildable Lot and that lot subsequently is issued a building permit.

(4) Dwelling Unit: One or more rooms providing complete living facilities for one family, including equipment for cooking, or provisions for the same, and including room or rooms for living, sleeping, and eating; provided that, solely for the purposes of this Article II, such complete living facilities that contain one bedroom or fewer shall be a Half Dwelling Unit.

(5) Force Main: A line without access from individual properties providing access from pumping station to pumping station or to trunk and sewer main.

(6) General Benefit Facilities: Improvements, such as pumping stations, trunk and force mains, acquisition of land or interests in land, which will provide benefit or advantage to an area exceeding that served by the Special Benefit Facilities. Ordinarily, General Benefit Facilities will serve a major part of a Pumping District.

(7) Lateral Line: Sewer conduit from a house to a street.

(8) Pumping District: An area, as identified by the Department of Public Works, which consists of a collection of sewer mains that connect to generally used infrastructure, such as pump stations, trunk mains and force mains that moves sewage from said collection of sewer mains to a treatment facility.

(9) Residential Sewer Units: Shall be equivalent to the number of existing Dwelling Units, including, but not limited to, Accessory Dwelling Units, affordable accessory apartments and family apartments as defined by the Zoning Ordinance, and the number of potential Dwelling Units on the property as permitted under the Zoning Ordinance for the district in

which the property is located; provided that any Accessory Dwelling Unit, affordable accessory apartment or family apartment that did not exist at the time of assessment shall be assessed a Compensatory Sewer Privilege Fee in accordance with Section 4F hereof; provided further, that a Half Dwelling Unit shall be assessed as one half of one Sewer Unit.

(10) Semi-public Use: Occupancy of premises by private non-profit organizations, including without limitation private schools, hospitals, and religious institutions.

(11) Sewer Main: The line serving as a conduit for sanitary sewerage from the lateral lines from each individual property.

(12) Special Benefit Facilities: The sewer main to which a lateral line from an individual abutting property can be connected, acquisition of land or interests in land, pumping stations that are required to service a specific project area and any other costs of improvements required to service a specific project area.

(13) Trunk Main: The line serving as a conduit for sanitary sewerage from a number of sewer mains and lateral lines. Trunk mains shall be considered as those lines ten (10) inches and over in diameter.

(14) Unbuildable Lot: At the time at which a sewer assessment would have been imposed, a lot, as determined by the assessors of the Town, on which there is no apparent legal way to build a legal residence or commercial building because the lot does not conform to the Town's building regulations or Zoning Ordinance.

(15) Uniform Unit Method: A means by which sewerage construction costs shall be equally divided between the total number of existing and potential Sewer Units to be served after having proportioned the costs resulting from the construction of Special and General Benefit Facilities.

(16) Zoning Ordinance: The Zoning Ordinance in effect in the Town of Barnstable at the time the sewerage assessment is levied.

Section 3: Basic Requirements

The Town Manager shall assess sewerage construction costs to all properties receiving benefit or advantage on the basis of the Uniform Unit Method. The Town Manager shall separate the costs of the General Benefit Facilities from those of the Special Benefit Facilities. The proportional cost of the Special and General Benefit Facilities shall be assessed in accordance with Section 5 hereof.

Section 4: Determination of Sewer Units

Section 4A: Each parcel of land in a Pumping District shall be converted into permanent Residential or Commercial Sewer Units, as defined herein, by the DPW for the purpose of proportionally dividing the construction costs equitably among such parcels of land.

Section 4B: Developed Residential Lots

A residential lot that contains one Dwelling Unit shall be assessed as one Sewer Unit. If such residential lot contains more than one Dwelling Unit, the number of assessed Residential Sewer Units shall equal the number of Dwelling Units. Single family dwellings shall comprise one Residential Sewer Unit; single family dwellings which have an Accessory Dwelling Unit, affordable accessory apartment or family apartment as defined by the Zoning Ordinance within the single family residence or in a detached building on the same lot shall comprise two Residential Sewer Units; duplex dwellings shall comprise two Residential Sewer Units; three-family dwellings shall comprise three Residential Sewer Units; four-family dwellings shall comprise four Residential Sewer Units; and multiple family dwellings (in excess of four dwelling units) shall comprise one Residential Sewer Unit for each apartment in a rental property and one Residential Sewer Unit for each dwelling unit in a condominium complex; provided that the number of Residential Sewer Units in the foregoing list shall be adjusted accordingly for Half Dwelling Units. A Dwelling Unit that occupies two residential lots in such a way that only one Dwelling Unit is allowed shall be assessed as one Residential Sewer Unit.

Section 4C: Lots Capable of Division or Sub-Division

1. Residential Lots Capable of Division or Sub-Division
Residentially zoned land which is capable of being divided or sub-divided according to the Zoning Ordinance shall be assessed as currently used plus one additional Sewer Unit for each lot which could be created in accordance with the Zoning Ordinance. At the property owner's request, the time for payment of such additional assessment may be extended until such time as the land is built upon, provided that interest at the annual rate of 4% shall be paid annually upon the assessment from the time it was made, and the assessment shall be paid in full within three months after such land is built upon.

2. Commercial, Industrial, Business and Semi-public Lots Capable of Division or Sub-Division
Commercial, industrial, business, and semi-public lots which could be divided or sub-divided according to the Zoning Ordinance shall be assessed as currently used plus one additional Commercial Sewer Unit for each additional 330 gallons of reasonably anticipated daily sewage volume which could be generated from the use in accordance with the Zoning Ordinance. At the property owner's request, the time for payment of such additional assessment may be extended until such time as the land is built upon, provided that interest at the annual rate of 4% shall be paid annually upon the assessment from the time it was made, and the assessment shall be paid in full within three months after such land is built upon.

Section 4D: Improved Commercial, Industrial, Business, and Semi-public Lots and Uses

Improved commercial, industrial, business, and semi-public lots and uses shall be assessed according to the reasonably anticipated sewage volume to be generated from the use. 330 gallons of actual or anticipated daily sewage volume shall equal one Commercial Sewer Unit.

Section 4E: Unbuildable Lots

An Unbuildable Lot shall not be assessed any Sewer Units, provided that upon the issuance of a building permit, said lot shall be assessed a Compensatory Sewer Privilege Fee in accordance with Section 4F below.

Section 4F: Changes in Use or Intensity of Use

In the event that existing uses on a parcel of land are changed or intensified under any circumstance, including without limitation issuance of a building permit for what had been classified as an Unbuildable Lot at the time a sewer assessment otherwise would have been imposed, changes in zoning, variance from the Zoning Ordinance, new construction and changes in use or reconfiguration, resulting in greater actual or potential sewage output than that established at the time of the original assessment or at the time the decision was made not to assess, the Town Manager or his or her designee shall assess a Compensatory Sewer Privilege Fee to reflect the new or increased use. The Compensatory Sewer Privilege Fee shall be computed based on the number of Sewer Units attributable to the new or increased use; provided that the amount of the fee for each such Sewer Unit shall be no greater than the initial maximum amount, as adjusted and most recently in effect, in accordance with Section 5A hereof. The Compensatory Sewer Privilege Fee shall be levied either at the time of connection of new or additional flow to the public sewer or upon Town of Barnstable approval of the change in use. Payment of the Compensatory Sewer Privilege Fee shall be made in accordance with the process for payment of assessments set forth in Section 8 hereof; provided that if the property owner chooses to apportion the payments, the Town will apply the same interest rate as that which would have been imposed for a sewer assessment on the property. Compensatory Sewer Privilege Fees collected by the Town shall be placed into a Sewer Privilege Fee Fund to be established by the Town and such monies shall be used to pay costs associated with the operation and maintenance costs of the Town's sewer system and wastewater treatment facility.

Section 5: Cost Determination and Apportionment Using the Uniform Unit Method

Section 5A: Sewer Cost Determination and Apportionment for Residential Land and Uses

Sewer assessments shall be based on one hundred percent (100%) of the cost of Special and General Benefit Facilities, as determined in accordance with the formulas set forth below. The actual assessment per Residential or Commercial Sewer Unit shall be the allocated cost or Ten Thousand Dollars ($10,000.00) (the "initial maximum amount"), whichever is lower. This initial maximum amount will remain in effect until June 30 of the

year following the calendar year in which the first sewer assessments are made. Thereafter, the initial maximum amount may be adjusted annually as of July 1 of each year by the percentage change in the construction cost index as calculated by the Gordian Company for the immediately preceding year ending June 30, as determined by the Town Manager, subject to approval by the Town Council. In the event that Gordian ceases to publish such index, the Department of Public Works will select an index which most closely resembles the Gordian index and the substitute index shall then be used for so long as the Director of the Department of Public Works determines that the substitute index accurately reflects market conditions.

Section 5B: Cost and Assessment of General Benefit Facilities

1. The cost of General Benefit Facilities and of Special Benefit Facilities shall be determined separately from each other.
2. The cost of General Benefit Facilities for a Pumping District shall be divided by the number of Sewer Units in such Pumping District. The result of such calculation shall be the General Benefit Facility Unit Cost.
    a. The General Benefit Facility Unit Cost shall be assessed to Sewer Units which abut existing streets and have the capability to connect to the sewer system so that the property will receive a direct benefit and advantage upon connection to the sewer system.
    b. The General Benefit Facility Unit Cost shall not be assessed to Sewer Units that do not currently abut existing streets to be sewered but shall be assessed at such later time as such Sewer Units shall have the capability to connect to the sewer system and directly benefit from the General Benefit Facilities.

Section 5C: Cost and Assessment of Special Benefit Facilities

1. The cost of Special Benefit Facilities for a Pumping District shall be divided by the number of Sewer Units in such Pumping District. The result of such calculation shall be the Special Benefit Facility Unit Cost.
    a. The Special Benefit Facility Unit Cost shall be assessed to Sewer Units which abut existing streets and have the capability to connect to the sewer system so that the property will receive a direct benefit and advantage upon connection to the sewer system.
    b. The Special Benefit Facility Unit Cost shall not be assessed to Sewer Units that do not currently abut existing streets to be sewered but shall be assessed at such later time as such Sewer Units shall have the capability to connect to the sewer system and directly benefit from the Special Benefit Facilities.

Section 6: Estimated Assessments

The Town may assess and collect estimated sewer assessments in connection with the construction of water pollution collection, pumping, treatment and disposal facilities. The

total amount of such estimated sewer assessments shall not exceed the lesser of: (i) one-half of the Town's liability under all contracts it has entered into for the construction of such facilities or (ii) the amount of any cap on sewer assessments as determined under Section 5 multiplied by the total number of Residential and Commercial Sewer Units. The total of such estimated assessments shall be determined by the same method to be used for the determination of the actual assessments upon the completion of the work. When the final costs of construction of the facilities have been determined, the Town may assess and collect actual sewer assessments for the balance owed. The interest rate on estimated sewer assessments will be the rate as determined under Section 8.

Section 7: Sewer Connection Costs

The cost of connecting the abutter to the completed section of sewer will be assessed back to the property abutter at one hundred percent (100%) of the cost. Property abutters may elect to pay the entire cost of connection upon completion or may choose to have it added to their sewer assessment. Alternatively, property abutters may elect to privately arrange and pay for the connection to the completed section of sewer.

Section 8: Interest Rate on Apportioned Sewer Assessments

Section 8A. At the time of assessment, the property owner will have the option to pay the full amount of the assessment within thirty (30) days, or to make a partial payment on the assessment and apportion the unpaid balance over future tax bills for a period of their choosing, up to 30 years, or to apportion the full assessment over future tax bills for a period of their choosing, up to 30 years. The Town will apply an interest rate to the sewer assessment at an annual fixed rate of two percent (2.0%) above the borrowing costs the Town incurs on the loan. If multiple loans are issued, a blended rate will be used to calculate the Town's borrowing cost. The property owner may pay the total remaining principal amount due at any time without a prepayment penalty.

Section 8B. The provisions of section 15D of Chapter 83 of the General Laws, with respect to the apportionment of payments of the assessment over a 30 year period, are hereby accepted by reference as a part of the general ordinances of the Town.

Section 9: Deferral of Charges

Section 9A. In accordance with and subject to the provisions of Section 16G of Chapter 83 of the General Laws, the Department of Public Works shall, upon application of the owner of real property served by the common sewers, if such owner is receiving an exemption from property taxes under clause Forty-first A of Section 5 of Chapter 59 of the General Laws with respect to such property, defer charges for said use of the common sewers. An application for deferral may be filed with the Department of Public Works within the time limit established for the filing of an application for exemption under said clause Forty-first A.

Section 9B. The provisions of section 16G of Chapter 83 of the General Laws, with respect to the ability of certain eligible property owners to defer payments of sewer assessments, are hereby accepted by reference as a part of the general ordinances of the Town.

Section 10: Abatements

A property owner aggrieved by a sewer assessment imposed under this Article II may apply for abatement thereof by filing a request for abatement with the Town Manager on a form provided by the Department of Public Works within six months of the date of notice of such Assessment. The Town Manager shall make a final ruling on the application within 45 days from the date of filing. The filing of the application does not stay the payment of the sewer assessment, which must be paid as assessed. If the abatement request is allowed, the appropriate refund will be made by the Town. A property owner who is aggrieved by the refusal of the Town Manager to abate an assessment in whole or in part may within thirty days after notice of the decision of the Town Manager appeal therefrom by filing a petition for the abatement of such assessment in the superior court in accordance with Section 7 of Chapter 80 of the General Laws."

VOTE: PASSES 11 YES Roll Call: Atsalis, Bogan, Clark Cullum, Rapp Grassetti, Hebert, Levesque, Neary, Schnepp, Shaughnessy, Steinhilber I NO Starr

Sincerely,

Ann M. Quirk
Town Clerk/Town of Barnstable