# Oyster Pond
# Comprehensive Wastewater Management Plan

## Needs Assessment
## (for Oyster Pond and Salt Pond)

## October 2013

## Prepared for the
## Town of Falmouth

by

WRIGHT-PIERCE
Engineering a Better Environment

# Falmouth, Massachusetts
# Oyster Pond
# Comprehensive Wastewater Management Plan

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## October 2013

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# TOWN OF FALMOUTH

# COMPREHENSIVE WASTEWATER MANAGEMENT PLAN

# OYSTER POND & SALT POND

# NEEDS ASSESSMENT REPORT

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# SECTION 1
# INTRODUCTION

## 1.1 PURPOSE

A community generally undertakes a Comprehensive Wastewater Management Plan (CWMP) to address some, or all, of the following issues:

- Addressing public health concerns
- Protection of groundwater and drinking water resources
- Reduction of nutrient loading to surface waters
- Support of sustainable economic development
- Addressing aesthetic and convenience concerns attributable to wastewater issues

The current focus on Cape Cod has been on nutrient removal, particularly nitrogen, which has been causing eutrophication of its coastal embayments and ponds. This issue has been driven by the widespread reliance on on-site septic systems, coupled with significant population growth throughout Cape Cod. Eutrophication of coastal embayments can be reversed, and efforts are underway across Cape Cod to do so. All of the 15 communities on Cape Cod are at some point in the wastewater planning process, each with a particular focus on nitrogen/nutrient removal. This CWMP will identify Falmouth's wastewater management needs for the Oyster Pond and Salt Pond watersheds and will address the wastewater management needs for the Oyster Pond.

## 1.2 CWMP SCOPE

This CWMP is a “targeted plan” focused on the Oyster Pond watershed. The CWMP will be conducted in three phases, as follows:

- Phase 1: Needs Assessment (for both Oyster Pond and Salt Pond watersheds)
- Phase 2: Development and Screening of Alternatives (Oyster Pond)
- Phase 3: Detailed Evaluation of Screened Alternatives & Recommended Plan (Oyster Pond)

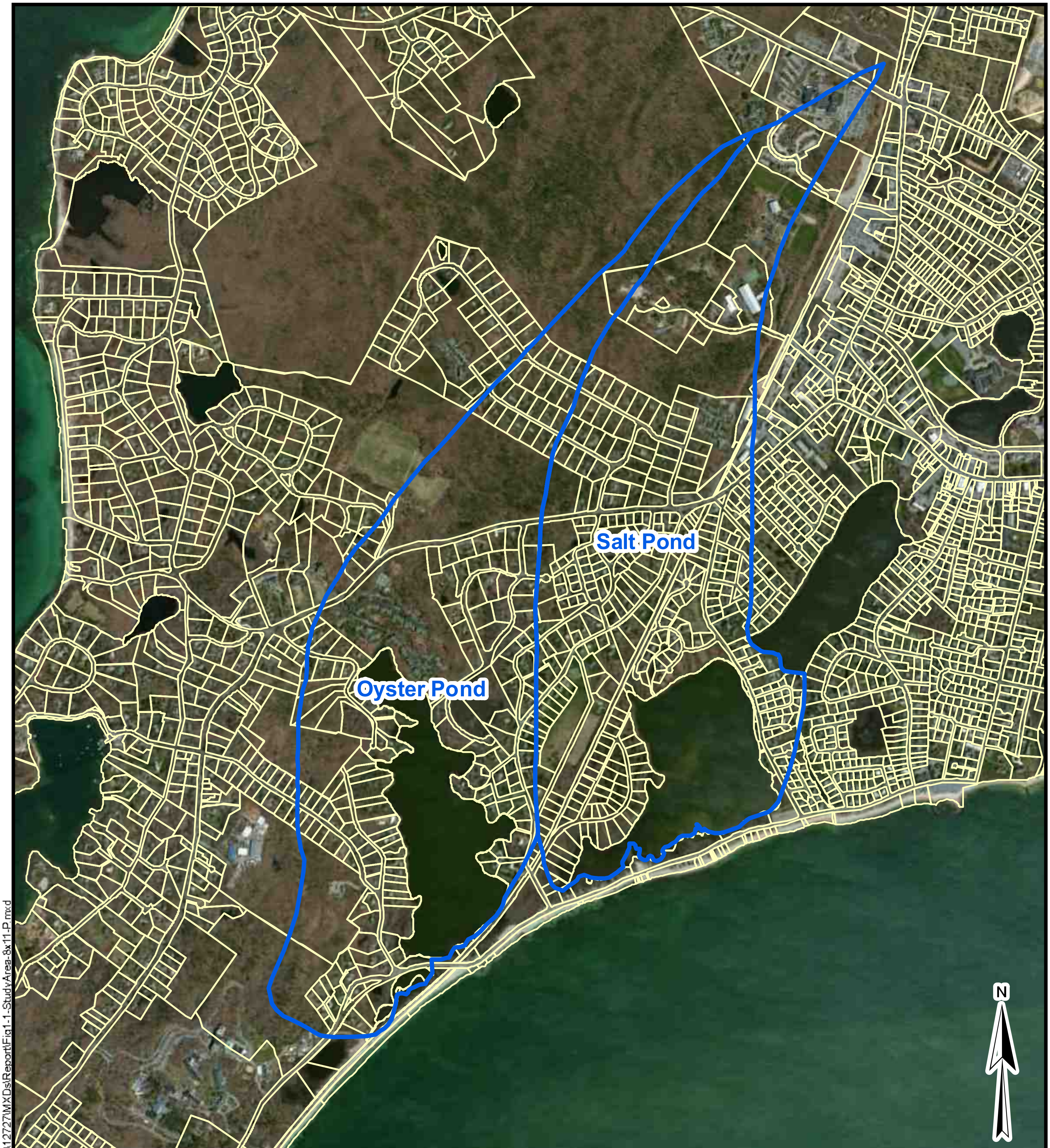
Phase 1, Needs Assessment, began in Spring 2013. Phases 2 and 3 will occur in 2013 and 2014. The study area shown on **Figure 1-1**.

## 1.3 REPORT FORMAT

This Needs Assessment report consists of 4 sections and a number of supporting appendices. Following this Introduction, the report includes these sections:

| | |
|---|---|
| Section 2: | A summary of existing conditions |
| Section 3: | Documentation of water resource management needs |
| Section 4: | A summary of the "next steps" |

This report uses a variety of technical terms, abbreviations and acronyms. **Table 1-1** identifies the most commonly used abbreviations and acronyms.




Watershed Boundary

Base data obtained from
Town of Falmouth (2013),
MassGIS (2009), ESRI (2013)

0 0.3 0.6 Mile

Falmouth
Oyster Pond CWMP

**Study Area**

| PROJ NO: 12727 | DATE: Jul 2013 | FIGURE: 1-1 |
|---|---|---|

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**TABLE 1-1**
**LIST OF COMMONLY USED ACRONYMS AND ABBREVIATIONS**

| | |
|---|---|
| **ACEC** | Area of Critical Environmental Concern |
| **BOH** | Board of Health |
| **BOS** | Board of Selectmen |
| **CCC** | Cape Cod Commission |
| **Current** | Covering the dates 2007 to 2009, applied to population, wastewater flow or nitrogen load conditions |
| **CWMP** | Comprehensive Wastewater Management Plan |
| **DEIR** | Draft Environmental Impact Report |
| **DEP** | Department of Environmental Protection (Massachusetts) |
| **DRI** | Developments of Regional Impact |
| **EIR** | Environmental Impact Report |
| **EENF** | Expanded Environmental Notification Form |
| **EOEEA** | Executive Office of Energy and Environmental Affairs |
| **ESA** | Environmentally Sensitive Area |
| **FEIR** | Final Environmental Impact Report |
| **Future** | Referring to population, wastewater flows or nitrogen loads, expected at Planning Horizon (2040) |
| **GIS** | Geographic Information System |
| **gpd** | Gallons Per Day |
| **gpd/sf** | Gallons Per Day Per Square Foot |
| **I/A** | Innovative and Alternative |
| **I/I** | Infiltration and Inflow |
| **kg/day** | Kilograms Per Day |
| **lb/yr** | Pounds Per Year |
| **MEP** | Massachusetts Estuaries Project |
| **MEPA** | Massachusetts Environmental Policy Act |
| **mgd** | Million Gallons Per Day |
| **mg/l** | Milligrams Per Liter |
| **MMR** | Massachusetts Military Reservation |
| **NHESP** | Natural Heritage and Endangered Species Program |
| **NRCS** | Natural Resources Conservation Service |
| **ORW** | Outstanding Resource Water |
| **PALS** | Pond and Lake Stewards |
| **ppm** | Parts Per Million |
| **SEIR** | Single Environmental Impact Report |
| **SMAST** | School of Marine Science and Technology, University of Massachusetts at Dartmouth |
| **SRF** | State Revolving Fund (administered by Massachusetts Department of Environmental Protection) |
| **TMDL** | Total Maximum Daily Load |
| **USEPA** | U.S. Environmental Protection Agency |
| **USGS** | United States Geologic Survey |
| **WQMC** | Water Quality Management Committee |

# SECTION 2

# EXISTING CONDITIONS

## 2.1 BACKGROUND

A number of previous and on-going planning efforts have been referenced and utilized herein. The efforts utilized most frequently or which are most important are summarized below.

### 2.1.1 Other Wastewater Planning Efforts

There are no previous wastewater planning studies conducted for the Oyster Pond and Salt Pond watersheds. The Town has developed a "*Draft Comprehensive Wastewater Management Plan*" (GHD, July 2012) for the Little Pond, Great Pond, Green Pond, Bournes Pond, Eel Pond and Waquoit Bay watersheds, including recommendations for the West Falmouth Harbor watershed. Some information from that effort has been utilized in the development of this report.

### 2.1.2 Local Comprehensive Plan

The Town's Local Comprehensive Plan Update was last revised in 2005. The Local Comprehensive Plan provides a strategic vision for the community and includes the following subject matter which is relevant to this CWMP effort:

- Land Use and Growth Management;
- Water Resources and Coastal Resources;
- Wetland, Wildlife and Plant Habitat
- Economic Development;
- Capital Facilities and Infrastructure; and
- Open Space and Recreation.

The Local Comprehensive Plan has been referenced in the development of this report.

### 2.1.3 Stormwater Management Plan

The Town of Falmouth owns and operates stormwater infrastructure that collects discharges treated and untreated stormwater to groundwater and surface waters at various locations around the Town. In order to regulate discharges such as these, the Environmental Protection Agency (EPA) issues so-called NPDES Phase II permits to communities that are identified as Municipal Separate Storm Sewer System (MS4) communities. Falmouth will soon be required to secure coverage under the NPDES Phase II program. A major element of this coverage is the requirement to develop and maintain a Stormwater Management Plan. A Stormwater Management Plan will provide an assessment of Falmouth's water bodies, identify areas of concern, and develop Best Management Practices (BMPs) to address those concerns and improve water quality in the community.

### 2.1.4 Massachusetts Estuaries Project

The Massachusetts Estuaries Project (MEP) is being conducted jointly by the Massachusetts Department of Environmental Protection (DEP) and the School of Marine Science and Technology (SMAST) at the University of Massachusetts, Dartmouth. The MEP was initiated to identify resolutions to the problems caused by the anthropogenic nutrient loads delivered to the coastal environment. The MEP has developed and implemented a modeling approach to determine critical nutrient thresholds to the environment. This modeling approach includes simulating nutrient inputs, nutrient outputs, natural attenuation and hydrodynamic conditions and calibrating these factors to measured water quality, hydrologic and hydrogeologic conditions. The output of this effort is called a MEP "technical report" for each watershed under study.

Following completion of the MEP technical reports, DEP develops a Total Maximum Daily Load Report (TMDL) and submits it for review and approval by EPA. A TMDL establishes the threshold pollutant loads below which water quality impairment are not predicted to occur. These TMDLs (which can be written for any combination of pollutants including nutrients, bacteria, atmospheric pollutants, etc.) are the technical documents on which a management or implementation plan (such as this CWMP) is based. The TMDL also forms the regulatory basis for potential enforcement actions for lack of progress toward achieving the specified requirements.

Since this modeling approach will serve as the basis for billions of dollars of infrastructure expenditures across Cape Cod, the Cape Cod Water Protection Collaborative (an agency of Barnstable County) sponsored an independent scientific peer review of the MEP work in order to address questions and concerns from the public. The scientific peer review was conducted in November 2011 by a panel of experts in the fields of estuarine water quality modeling, estuarine hydrodynamic modeling, estuarine biology, groundwater modeling, nitrogen transport in the environment, and TMDL policy and implementation. The Peer Review Panel issued a report of its findings in December 2011 which concluded that the MEP modeling approach is scientifically credible, functionally adequate and appropriate for use as the basis for management planning.

### 2.1.5 Summary of Previous Scientific Studies

Oyster Pond has been studied extensively since the 1960s. Much of the historic study is documented in a book entitled "A Coastal Pond Studied by Oceanographic Methods with Epilogue: Oyster Pond – Three Decades of Change" (Emery, et.al, 1997). The more recent studies are documented in the Massachusetts Estuaries Project report entitled "Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Oyster Pond System, Falmouth, Massachusetts" (Howes, et.al, 2006) as well as on the Oyster Pond Environmental Trust website (www.opet.org).

Oyster Pond is approximately 3,200 feet long and is approximately 1,200 feet wide at its widest point, with a total surface area of approximately 63 acres. It is comprised of three flooded kettle ponds. The ecosystem in Oyster Pond has changed over its history as its outlets have changed and moved. Prior to 3,000 years ago, the kettle holes were freshwater basins. As sea level rose, the kettle holes were filled with saline water. Oyster Pond provided a source of oysters and fish to settlers in the area. In the mid-1700s, longshore drifts and a hurricane (Falmouth Historical Society) formed a baymouth bar which began restricting tidal exchange. The pond outlet location and number varied over time based on natural processes until the railroad and Surf Drive were constructed in the late 1800s (when it was fixed at its present location). Between 1860 and 1960, salinity dropped to the point where oysters and eelgrass could not survive. The earliest recorded salinity measurements (from the 1940s) indicate a salinity of 3 ppt to 5 ppt, as compared to Vineyard Sound salinity of 29 to 32 ppt.

Oyster Pond drains to the Lagoon via a culvert under Surf Drive and ultimately to Vineyard Sound via the Trunk River. Under normal conditions, flow is strictly out of Oyster Pond to Vineyard Sound. During extreme weather and/or tide events, such as the recent Hurricane Sandy, flow from Vineyard Sound pushes up the Trunk River and into the Pond. In the mid-1980s, the Town replaced the Surf Drive culvert with a larger culvert. That allowed more ocean water flow into the pond which increased the salinity from its traditional 2 to 4 ppt up to 13 to 16 ppt. This resulted in a collapse of the Oyster Pond ecosystem. It was discussed at that time if the pond should be allowed to become a saline environment, or try to return it to its historic 2 to 4 ppt. The decision was made to do the latter, and a weir was installed near the culvert in March 1998 in order to control the salt water input to the pond.

In general, water quality in Oyster Pond is homogeneous in the horizontal plane but it can become highly stratified in the vertical plane due to both salinity (density) and water temperature differentials. Once stratified, the bottom waters are isolated from oxygen sources and dissolved oxygen is depleted to very low levels. Anthropogenic nutrient sources in the watershed amplify the dissolved oxygen depletion.

Thermal and density stratification are naturally occurring phenomena in Oyster Pond. Based on data collected by the Falmouth Pond Watchers and the Oyster Pond Environmental Trust (OPET) since 1994, the depth of the naturally occurring stratification is highly variable (i.e., varies between 3 meters and 6 meters depth). The strength and depth of the stratification is strongly influenced by natural weather conditions including: ocean overwash or backflow from intense storms (which increase stratification by increasing salinity of bottom layers when the dense water sinks); rain events (which increase stratification by lowering temperature/salinity/transmittance of surface layers); and wind events (which reduce stratification due to increased wind shear mixing).

The following is a summary of additional relevant findings which are documented in the aforementioned studies (reference and page number noted, findings are paraphrased):

- Hydrogen sulfide and methane gases are present in the water column as well as in sediment samples. Hydrogen sulfide odor is noticeable in the water column. Disturbance of sediment releases gas bubbles. Some bubbles reach surface under calm conditions. Bubble rate peaks in June as temp rises to 15degC than trails off over the following months. Hydrogen sulfide gas is believed to be caused by sulfate-reducing bacteria in bottom sediment and water (Emery, pg. 23).

- Pond level is highly dependent on elevation of Trunk River "sill" (i.e., gravel and sand) (Emery, pg. 54).

- In the studies in the 1960s, benthic animals were found to live only in oxygenated waters of approximately 2 meter depth and shallower (Emery, pg. 63).

- A "pool of ammonium" was found in deep waters with high salinity. The ammonium levels result from the accumulation of remineralized nitrogen from the decay of phytoplankton which settle to the basin sediments. Almost all of the nitrogen is in the form of ammonium, which is readily available for uptake by plants and therefore capable of stimulating algal blooms. The nitrogen levels in this layers [are/were] exceedingly high, >2000 uM or 28 mg/l. Injection of this pool into the surface water layer in a single mixing events would increase the surface water total nitrogen levels from ca. 50 uM to over 400 uM (Emery, pg. 100). *[Based on a review of current OPET data, typical ammonium values range from 0 to 0.5 mg/l; however, peak values in the bottom waters at sample location "OP 1" and "OP 3" range from 1 to 18 mg/l.]*

- An estimated 42 homes were present within 100m of shore prior to 1969. (Emery, pg. 61). Of the approximately 200 dwelling units present prior to 1997 within the watershed, almost two-thirds have been constructed between 1977 and 1997 (Emery, pg. 101). *[Currently there are 225 dwelling units]*

- According to MEP modeling, human activities have increased the total nitrogen load to the watershed by a factor of 5.1 over the past few centuries (i.e., from 0.675 kg/day to 3.493 kg/day). The MEP modeling indicates that this has increased the water column nitrogen concentration from 0.385 mg/l to 0.694 mg/l. MEP reports the "threshold load" and "threshold water column nitrogen concentration" as 1.439 kg/day and 0.548 mg/l, respectively. MEP modeling indicates that the total nitrogen load to the watershed needs to be reduced by 59% in order to achieve the threshold values (Howes, pg. 89-91, 101-107). If this nitrogen load reduction is accomplished solely by elimination of septic system discharges, then 77% of the systems must be eliminated.

## 2.2 LAND USE AND DEMOGRAPHICS

Key land use and demographic data are summarized in **Table 2-1** based on information supplied by the Town's GIS Department. **Figure 2-1** shows the zoning districts and **Figure 2-2** shows current land uses.

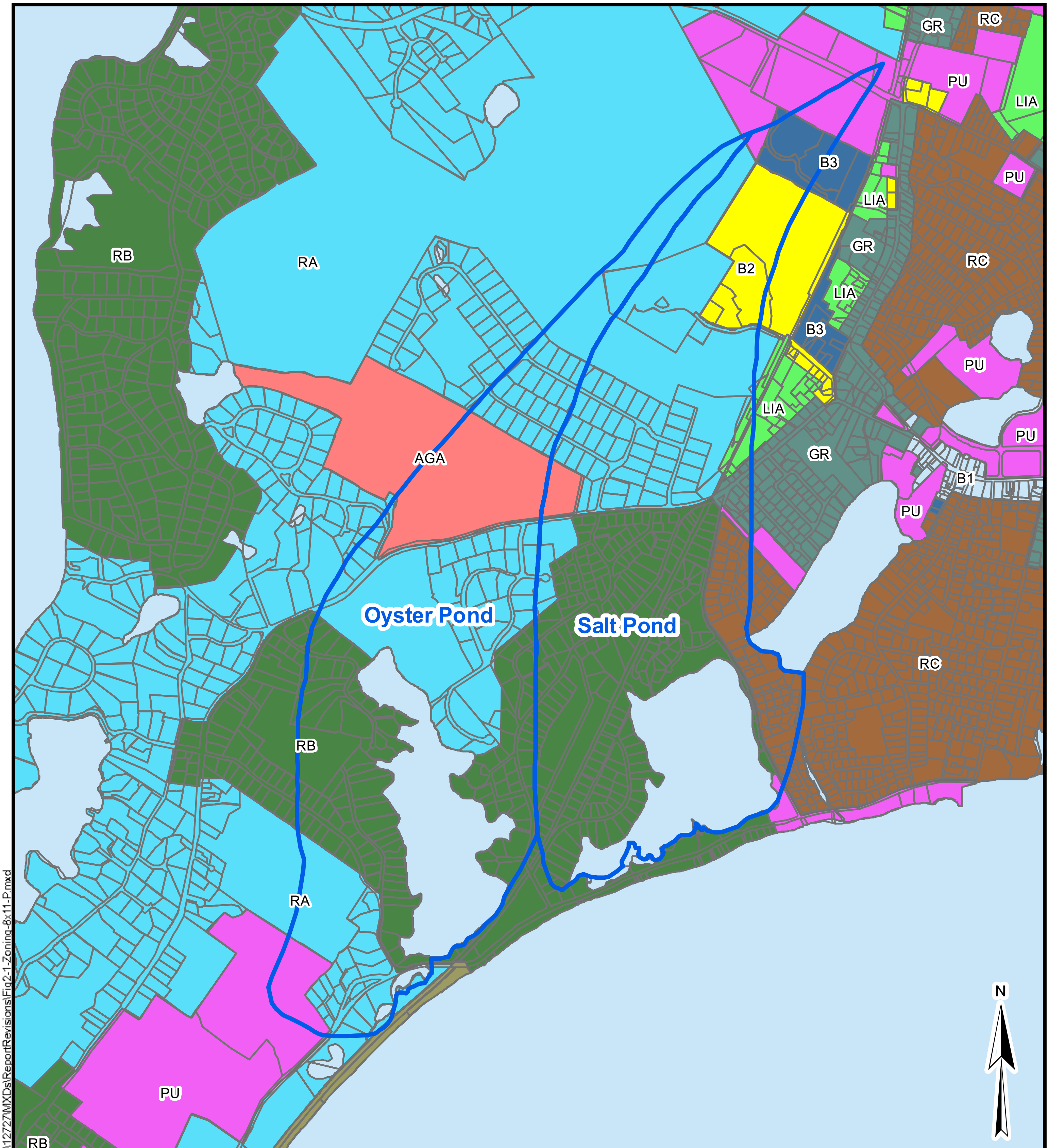
The Oyster Pond watershed is predominantly residential, with a small percentage of parcels dedicated to public service zoning. Approximately 24% of the land in this watershed is dedicated to conservation. There are a total of 211 parcels in this watershed. Of these, approximately: 163 parcels are developed residentially and 3 parcels are developed as public service/exempt. The land in this watershed is substantially developed, with just 8% of the vacant parcels considered developable.

The Salt Pond watershed is predominantly residential, with a small percentage of parcels dedicated to commercial and public service zoning. Approximately 21% of the land in this watershed is dedicated to conservation. There are a total of 381 parcels in this watershed. Of these, approximately: 268 parcels are developed residentially; 9 parcels are developed commercially; 7 parcels are developed as public service/exempt. The land in this watershed is also substantially developed, with less than 3% of the vacant parcels considered developable.

## TABLE 2-1
## SUMMARY OF LAND USE AND DEMOGRAPHIC DATA

| | Oyster Pond | Salt Pond |
|---|---|---|
| **Residential (including multi-family and condo)** | | |
| Parcels - Number Developed | 163 | 268 |
| Parcels - Total Number | 208 | 360 |
| Lot Area - Developed, acres | 173.1 | 155.9 |
| Lot Area - Total, acres | 628.8 | 222.1 |
| Number of Dwelling Units | 225 | 303 |
| Number of Bedrooms | 603 | 956 |
| Avg Size of Developed Lot, acres | 0.74 | 0.58 |
| | | |
| **Commercial** | | |
| Parcels - Number Developed | 0 | 9 |
| Parcels - Total Number | 0 | 12 |
| Lot Area - Developed, acres | 0 | 19.7 |
| Lot Area - Total, acres | 0 | 26.2 |
| | | |
| **Municipal/Exempt** | | |
| Parcels - Number Developed | 3 | 7 |
| Parcels - Total Number | 3 | 9 |
| Lot Area - Developed, acres | 98.5 | 83.5 |
| Lot Area - Total, acres | 98.5 | 87.6 |
| | | |
| **Total** | | |
| Parcels - Number Developed | 166 | 285 |
| Parcels - Total Number | 211 | 381 |
| Lot Area - Developed, acres | 271.6 | 259.0 |
| Lot Area - Total, acres | 727.3 | 335.9 |
| | | |

Source: Falmouth GIS data




Watershed Boundary

**Zoning Districts**

Agricultural A
Business 2
Business 3
General Residence
Light Industrial A
Public Use
Single Residence A
Single Residence AA
Single Residence B
Single Residence C

Base data obtained from Town of Falmouth (2013), MassGIS (2009)

0 0.3 0.6 Mile

Falmouth
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**Zoning**

PROJ NO: 12727 DATE: Aug 2013

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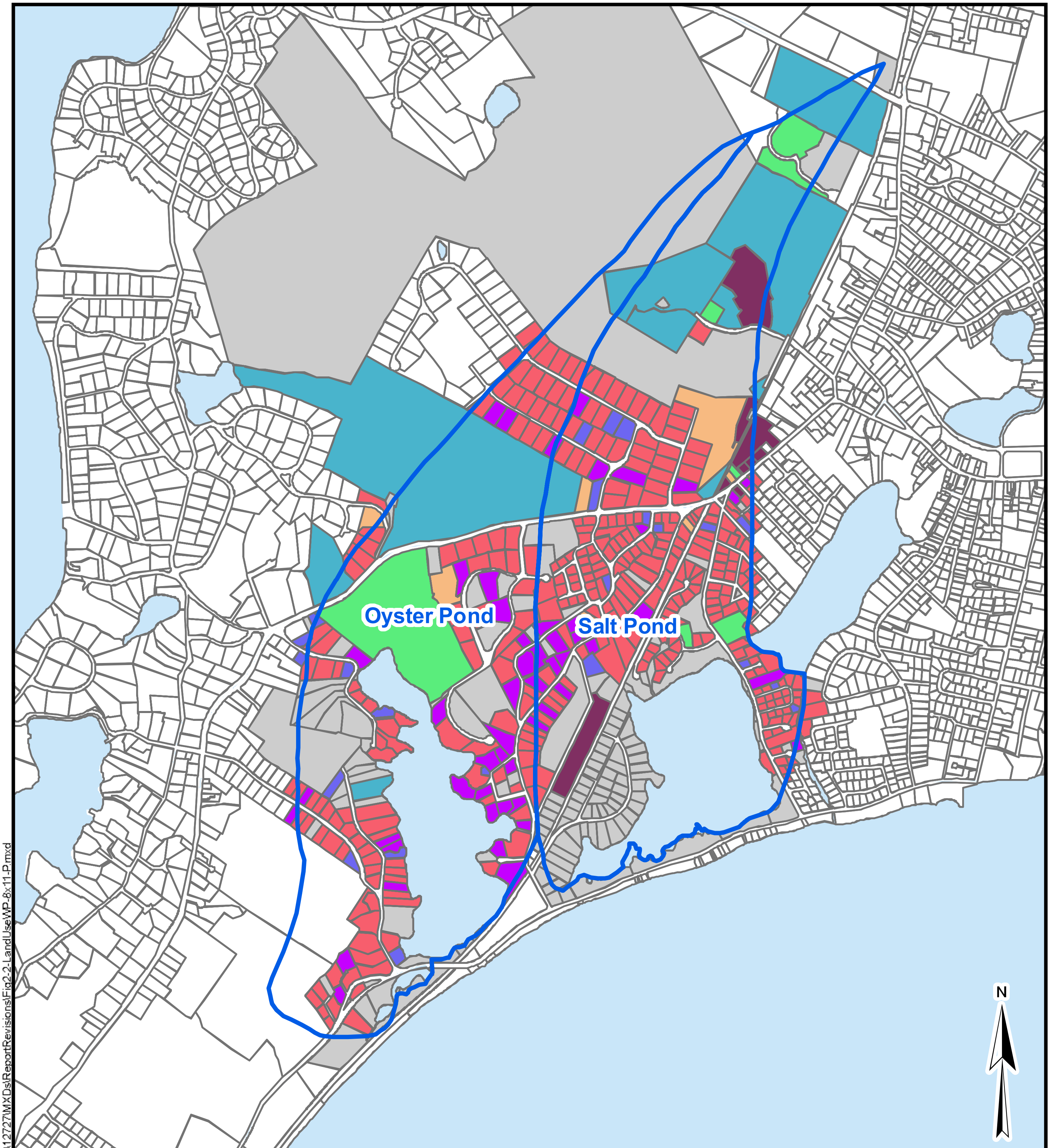
**FIGURE: 2-1**




Watershed Boundary
Commercial
Condo
Multi-Family
Municipal/Exempt
Single Family 1-2 Bedroom
Single Family 3-4 Bedroom
Single Family 5+ Bedroom
Vacant

Base data obtained from Town of Falmouth (2013), MassGIS (2009)

0 0.3 0.6 Mile

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Oyster Pond CWMP

**Land Use**

| PROJ NO: 12727 | DATE: Aug 2013 | FIGURE: 2-2 |
|---|---|---|

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## 2.3 POPULATION

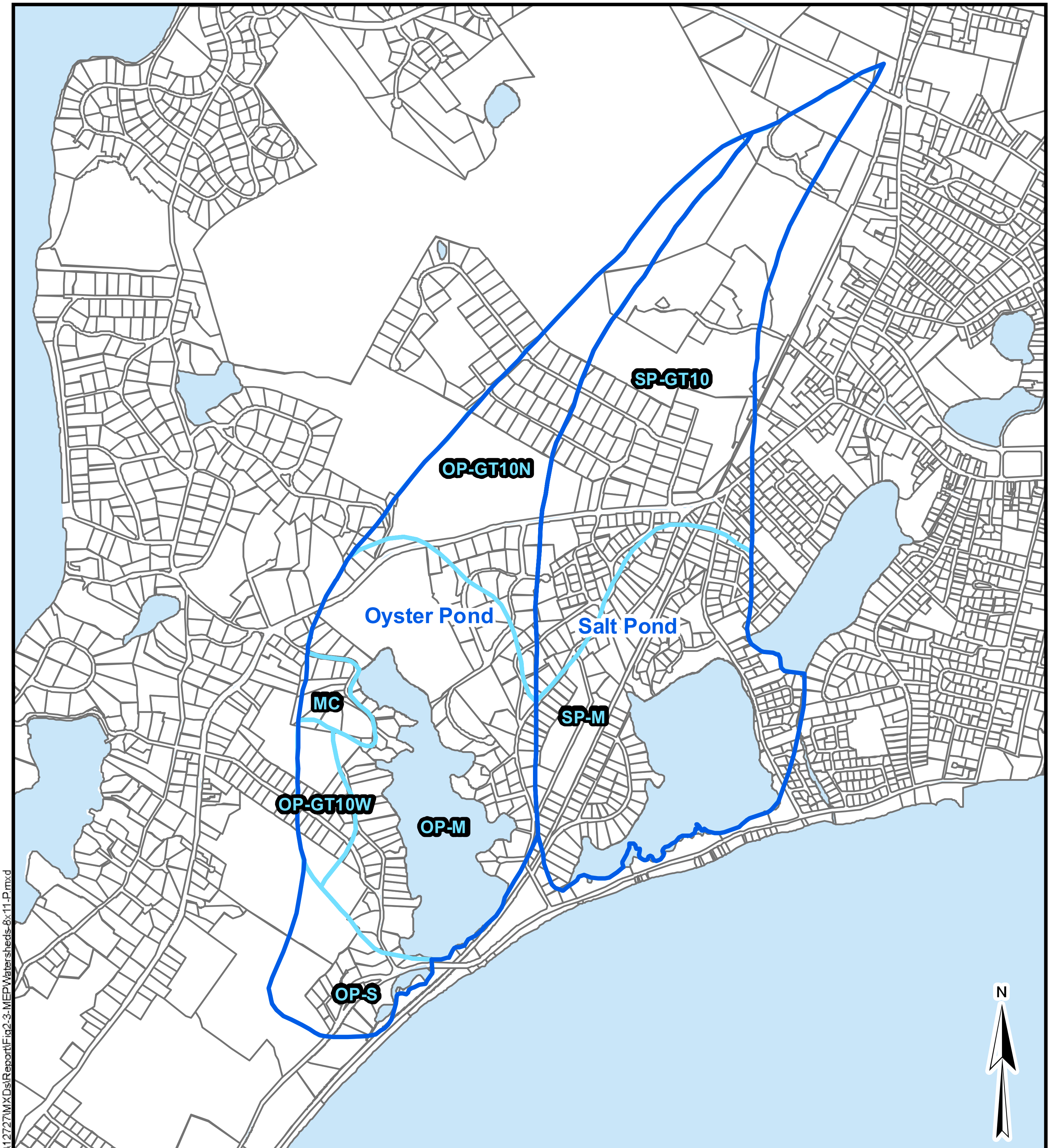
The Local Comprehensive Plan estimates the town-wide population at approximately 32,700 individuals in 2002. For the purposes of wastewater planning, we are interested in "equivalent annual population" as this takes into account seasonal population variation as well as the influence of commercial flows. The Local Comprehensive Plan estimates the "annualized" town-wide population at approximately 49,200 individuals in 2002. The Local Comprehensive Plan estimates that Falmouth's residential parcels are occupied 69% on a year-round basis, 30% on a seasonal basis, while 1% are vacant.

## 2.4 WATERSHEDS

All groundwater recharge in the Oyster Pond and Salt Ponds watershed ultimately flows to Vineyard Sound. Each of these primary watersheds can be further broken down into "subwatersheds", which drain to ponds, stream, wetlands, and coastal waters. The groundwater recharge watershed and subwatershed delineation work is done by the Massachusetts Estuary Project (MEP) as a part of the preparation of their technical reports. The watershed and subwatershed delineations for the watersheds that have completed MEP technical reports are indicated in blue on **Figure 2-3**. The surface watershed has not been delineated; however, OPET has provided preliminary information to the Town for review and analysis.

## 2.5 ENVIRONMENTALLY SENSITIVE AREAS

Environmentally sensitive areas (ESAs) represent significant natural resources in the town. The resources must be recognized when considering existing or potential alternative wastewater management options across town. The following section presents a summary of the ESAs identified for Falmouth based on a review of available Massachusetts Geographic Information System (MassGIS) and Town files, maps, and relevant documents. Information is provided in this section for: 1) freshwater ponds; 2) coastal ponds and embayments; and 3) protected areas.




MEP Watershed Boundary
MEP Subwatershed Boundary

Base data obtained from
Town of Falmouth (2013),
ESRI (2013)

0 0.3 0.6 Mile

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Oyster Pond CWMP

**MEP Watersheds**

| PROJ NO: 12727 | DATE: Jul 2013 | FIGURE: 2-3 |
|---|---|---|

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### 2.5.1 Freshwater Ponds

There are no freshwater ponds within the study area; however, Oyster Pond is brackish with low salinity. Oyster Pond serves as habitat for freshwater and brackish water fish species including herring, white perch, and yellow perch.

### 2.5.2 Coastal Ponds & Embayments

Oyster Pond and Salt Pond are designated coastal ponds. They support a diverse group of species as well as recreational activities like swimming, boating, fishing, and birding. Both ponds are included in the Massachusetts Estuaries Project. The MEP has completed a technical report and a Total Maximum Daily Load (TMDL) Study for Oyster Pond. The MEP has not completed either for Salt Pond. According to published MEP technical reports, residential and commercial development on Cape Cod has negatively impacted estuarine water quality. The contaminant of principal concern for coastal embayments is nitrogen which primarily comes from on-site wastewater disposal, lawn fertilization, stormwater disposal, atmospheric deposition and recycling from bottom sediments. On-site wastewater disposal is by far the largest controllable source of nitrogen to impaired estuaries; therefore, the TMDLs will constitute a significant driving force for wastewater management.

### 2.5.3 Protected Areas

Environmentally sensitive areas include "protected areas", which receive additional scrutiny by regulatory agencies. These areas include Areas of Critical Environmental Concern (ACECs), Districts of Critical Planning Concern (DCPCs), wetland resource areas, open space and conservation areas, shellfishing areas, outstanding resource waters (ORWs), and protected lands. These areas were identified through mapping available from the Town, MassGIS and the Cape Cod Commission and are described below.

#### *2.5.3.1 Areas of Critical Environmental Concern/ Districts of Critical Planning Concern*

There are no designated Areas of Critical Environmental Concern (ACEC) or Districts of Critical Planning Concern (DCPC) in the study area.

### *2.5.3.2 Wetland Resource Areas*

Wetlands, including marshes, shrub or wooded swamps, wet meadows and bogs, serve a number of vital roles in the natural environment including providing areas of valuable habitat for many species and serving as natural filters and flood management locations. Wetland resource areas also include salt marshes. Vernal pools are temporary pools of water which provide significant seasonal habitat for amphibians during breeding season. Wetlands and vernal pools provide valuable habitat for many species and support recreational activities like bird watching. There are several areas of wetlands and vernal pools in the study area, as shown on **Figure 2-4**.

### *2.5.3.3 Conservation Lands*

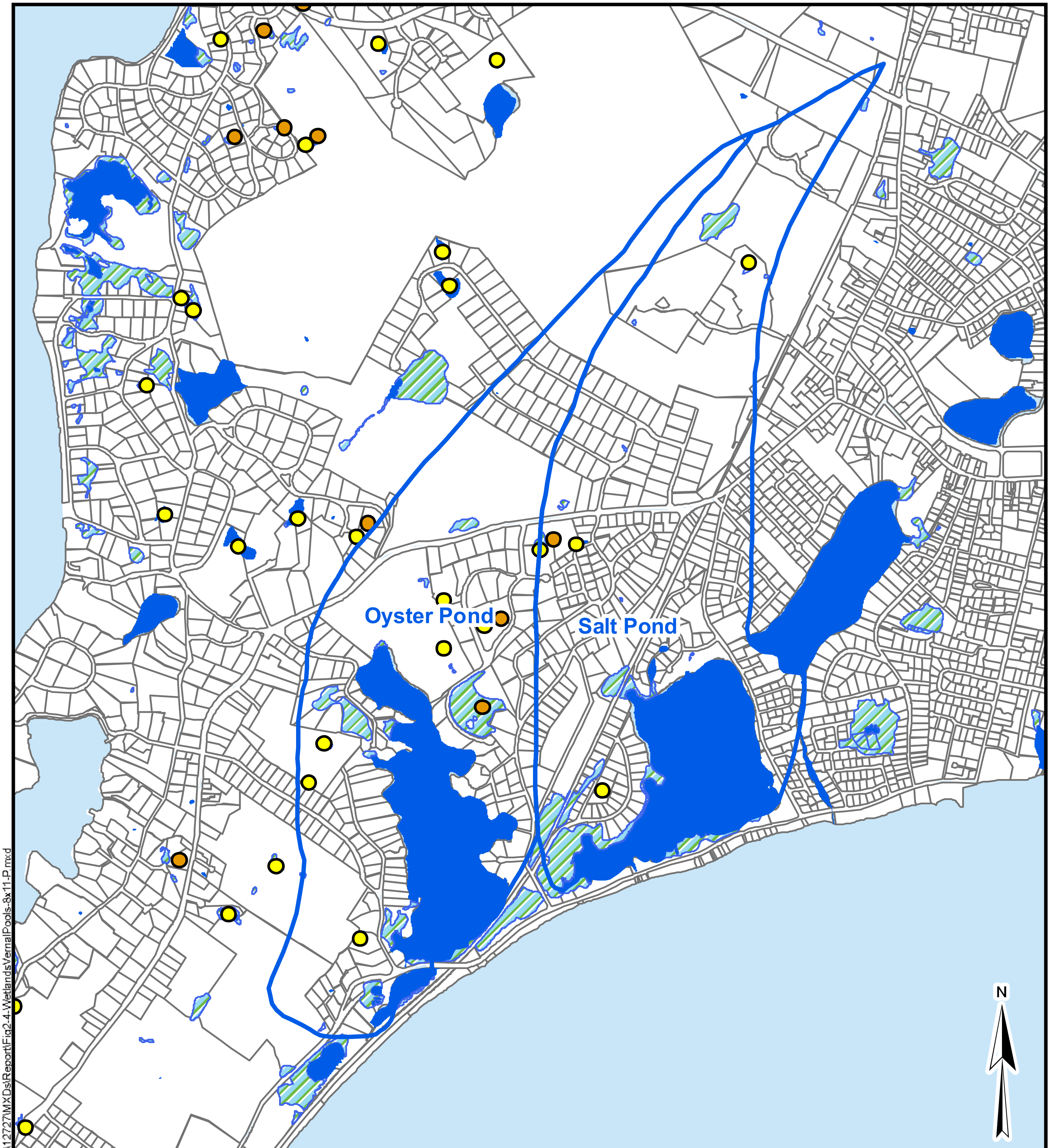
Conservation lands account for approximately 24% of the land area in the Oyster Pond and Salt Pond watersheds. Some of this land is held as privately-owned open space land, including the parcels owned by the Oyster Pond Environmental Trust and the Salt Pond Bird Sanctuaries Inc. Open space and conservation lands are shown on **Figure 2-5**.

### *2.5.3.4 Shellfishing Areas*

MassGIS has an available data layer of designated shellfish growing areas (2009) and shellfish suitability areas (2011). This data layer depicts areas of potential shellfish habitat and their respective harvest classification. According to this information, both Oyster Pond and Salt Pond are classified as "prohibited"; however, a small portion of Salt Pond is identified as potential habitat for the soft-shelled clam. The State stopped sampling Oyster Pond for bacteria in 1999 after the weir was installed and pond salinity was managed to 2-4 ppt. This information is presented on **Figure 2-6**.

### *2.5.3.5 Outstanding Resource Waters*

Outstanding resource waters (ORWs) constitute water bodies, or the watershed of a waterbody, that are designated for protection under Massachusetts surface water quality standards due to high ecological, recreational, or aesthetic values. There are no ORWs in the project area.




MEP Watershed Boundary
Certified Vernal Pool
Potential Vernal Pool
Open Water
Wetland

Base data obtained from
Town of Falmouth (2013),
MassGIS (2000, 2009, 2013),
ESRI (2013)

0 0.3 0.6 Mile

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Oyster Pond CWMP

**Wetlands and Vernal Pools**

| PROJ NO: | DATE: | FIGURE: |
| --- | --- | --- |
| 12727 | Jul 2013 | 2-4 |

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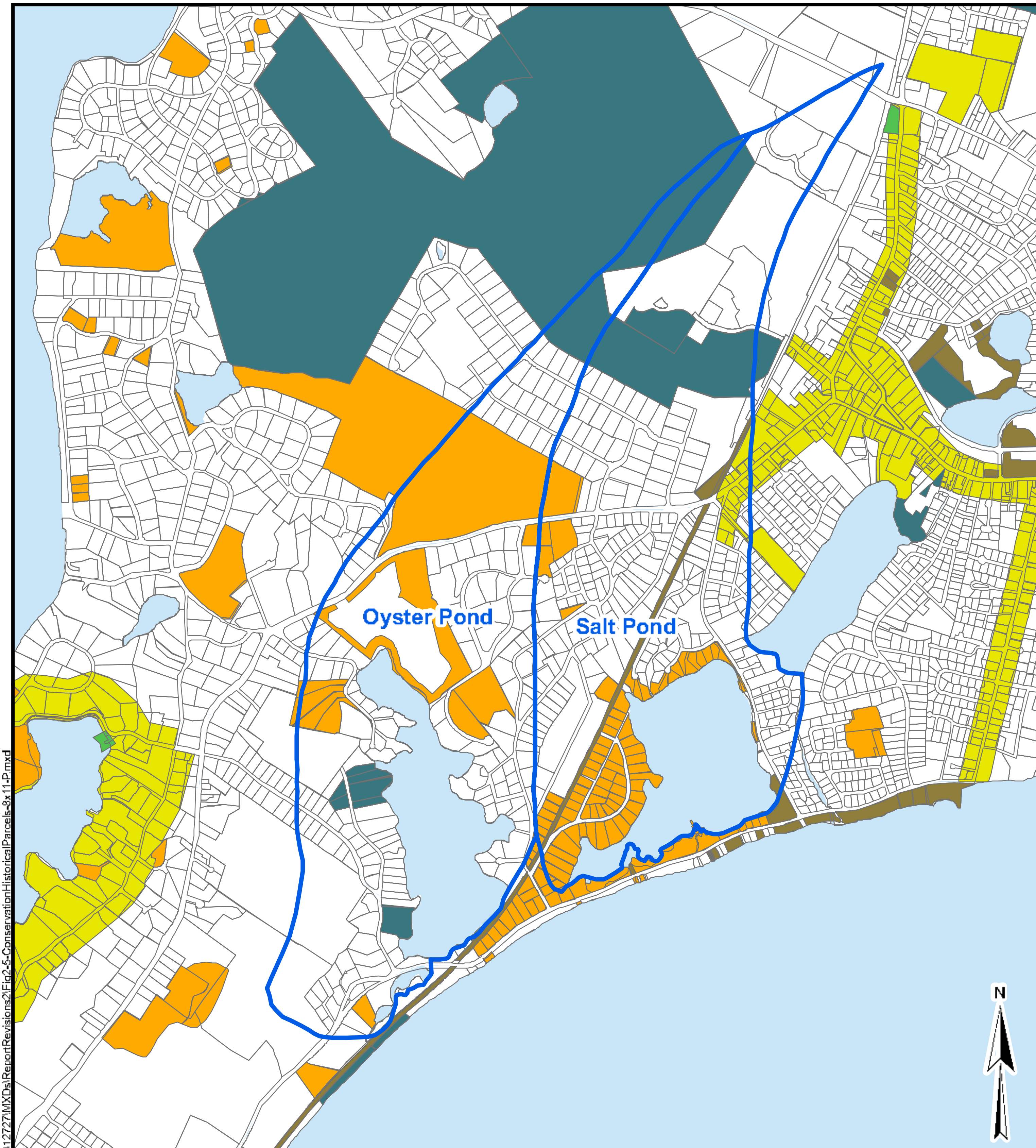


Watershed Boundary
Conservation
Historical/Cultural
Other
Recreation
Recreation and Conservation
Open Water

Base data obtained from Town of Falmouth (2013), MassGIS (2009, 2013)

0 0.3 0.6 Mile

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**Conservation Land**
**Historical Parcels**

PROJ NO: 12727 | DATE: Sep 2013 | **FIGURE: 2-5**

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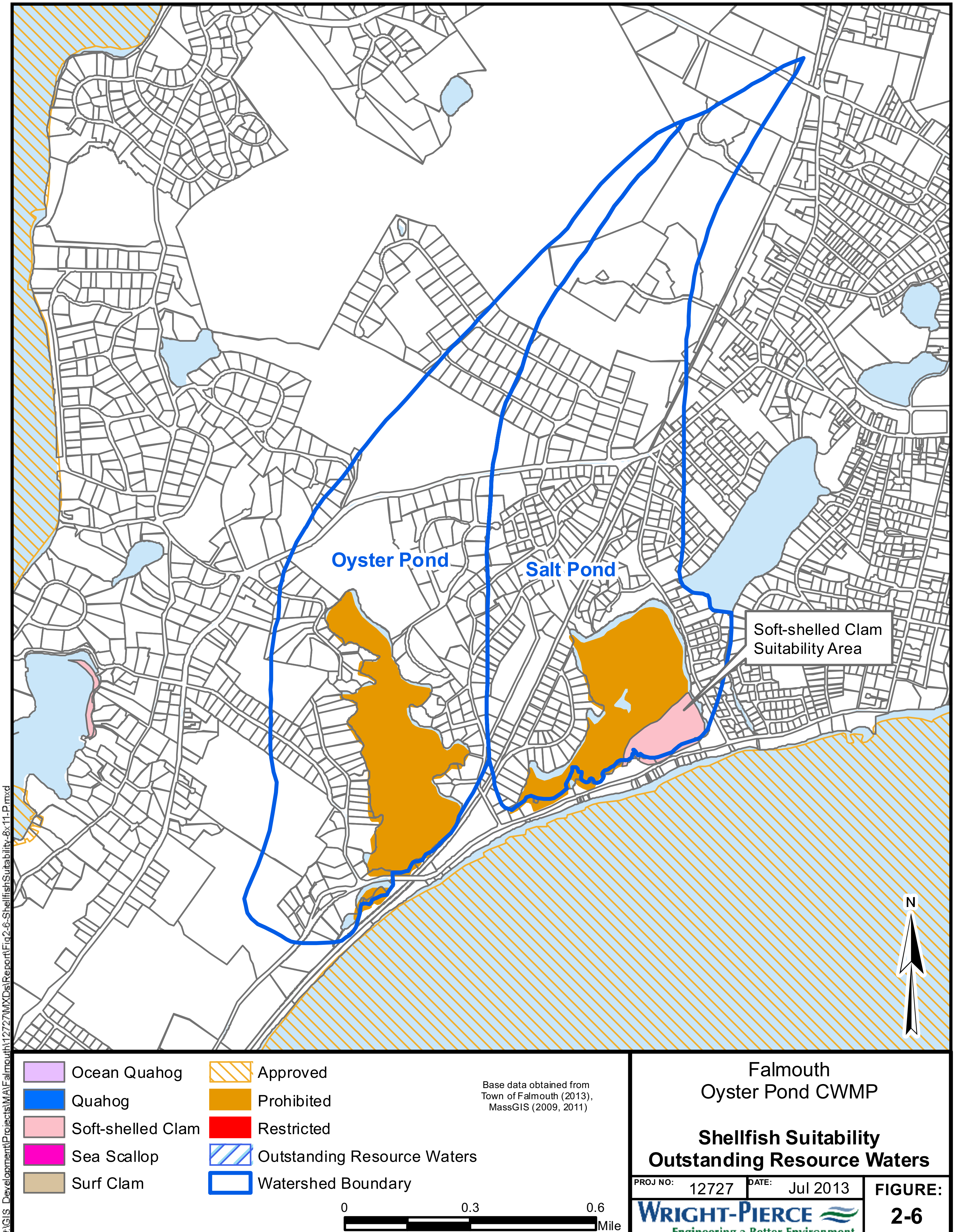


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Oyster Pond CWMP

**Shellfish Suitability**
**Outstanding Resource Waters**

PROJ NO: 12727 | DATE: Jul 2013 | FIGURE: 2-6

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#### *2.5.3.6 Floodplains*

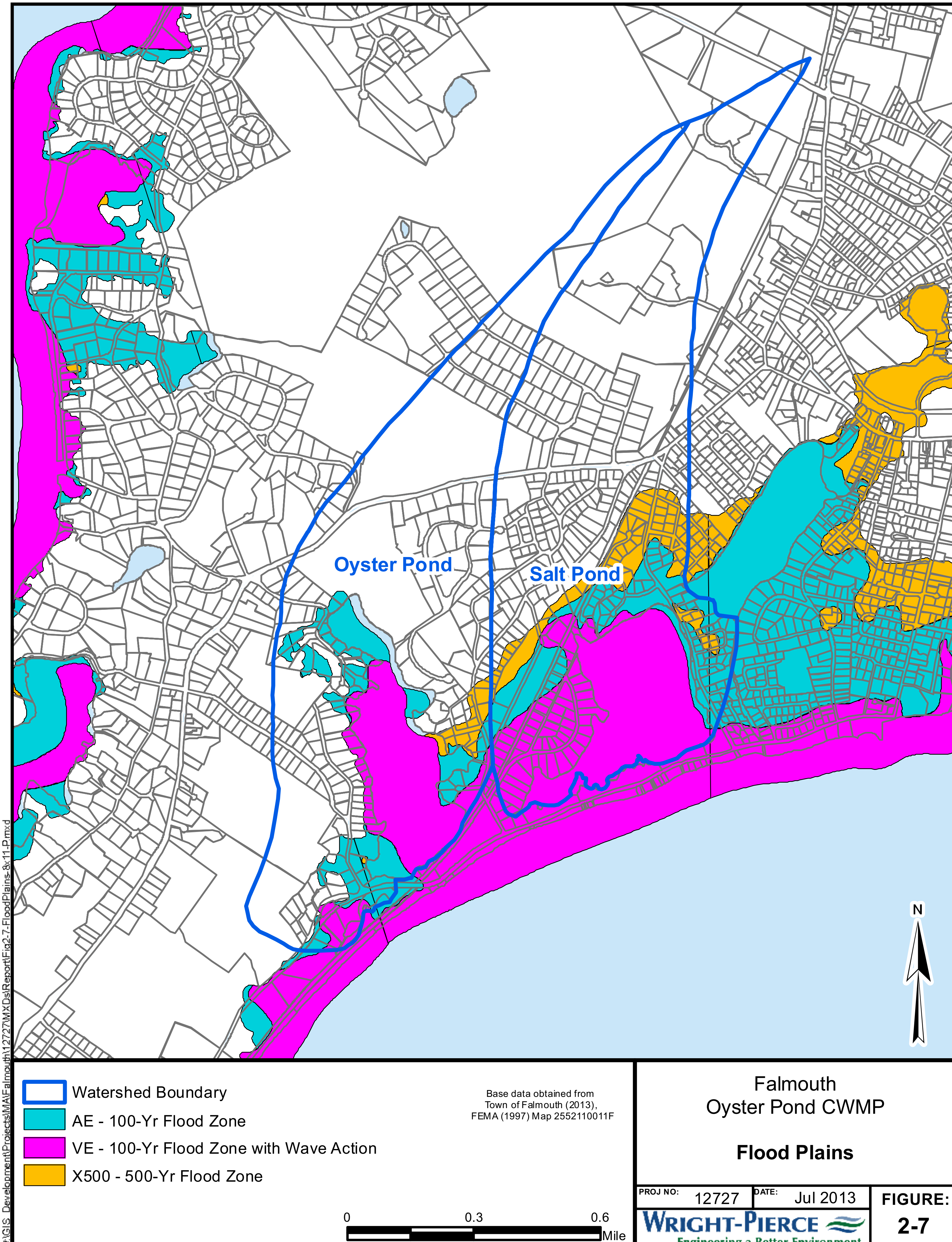
The Federal Emergency Management Agency (FEMA) provide mapping which indicates flood hazard areas based on a statistical 100 year and 500 year flood recurrence intervals. This flood hazard mapping is based on FEMA Flood Insurance Rate Mapping (July 1997) and is depicted on **Figure 2-7**. The extent of floodplains must be taken into consideration in the siting of wastewater infrastructure. FEMA is currently updating the floodplain mapping in Falmouth; however, this data is not yet available.

#### *2.5.3.7 Habitat of Rare and Endangered Species*

The Natural Heritage and Endangered Species Program (NHESP) at the Massachusetts Division Fisheries & Wildlife maintains mapping for priority habitat of rare and endangered species. Numerous species of special concern and endangered species have been identified in the Oyster Pond and Salt Pond watersheds (i.e., Eastern Box Turtle, Common Tern, Least Term and Roseate Tern). NHESP mapping for the study area is presented on **Figure 2-8** (MassGIS, October 2008).

## 2.6 SOILS

Soil conditions are important in selecting sites for treated stormwater disposal, wastewater effluent disposal as well as for sanitary needs screening for Title 5 compliance. The rate at which effluent can percolate through soil directly impacts the size, design, viability and longevity of effluent disposal systems. It also impacts how much "natural treatment" occurs prior to reaching a waterbody. From the standpoint of stormwater and wastewater disposal systems, most of the Cape benefits from sandy soils (i.e. well drained soils). However, the United States Department of Agriculture's Soil Conservation Service characterizes all soils present on Cape Cod as "severe" for the category of septic tank absorption/leaching fields (Soil Survey of Barnstable County MA, March 1993, Table 11) due either to poor percolation or rapid drainage. In the project area, the majority of soil is considered to be “excessively drained” to “well drained”. There are some areas of “poorly drained” soils that are located in lowland areas near wetlands or shore areas. **Figure 2-9** highlights the location of soil type by these three major categories.



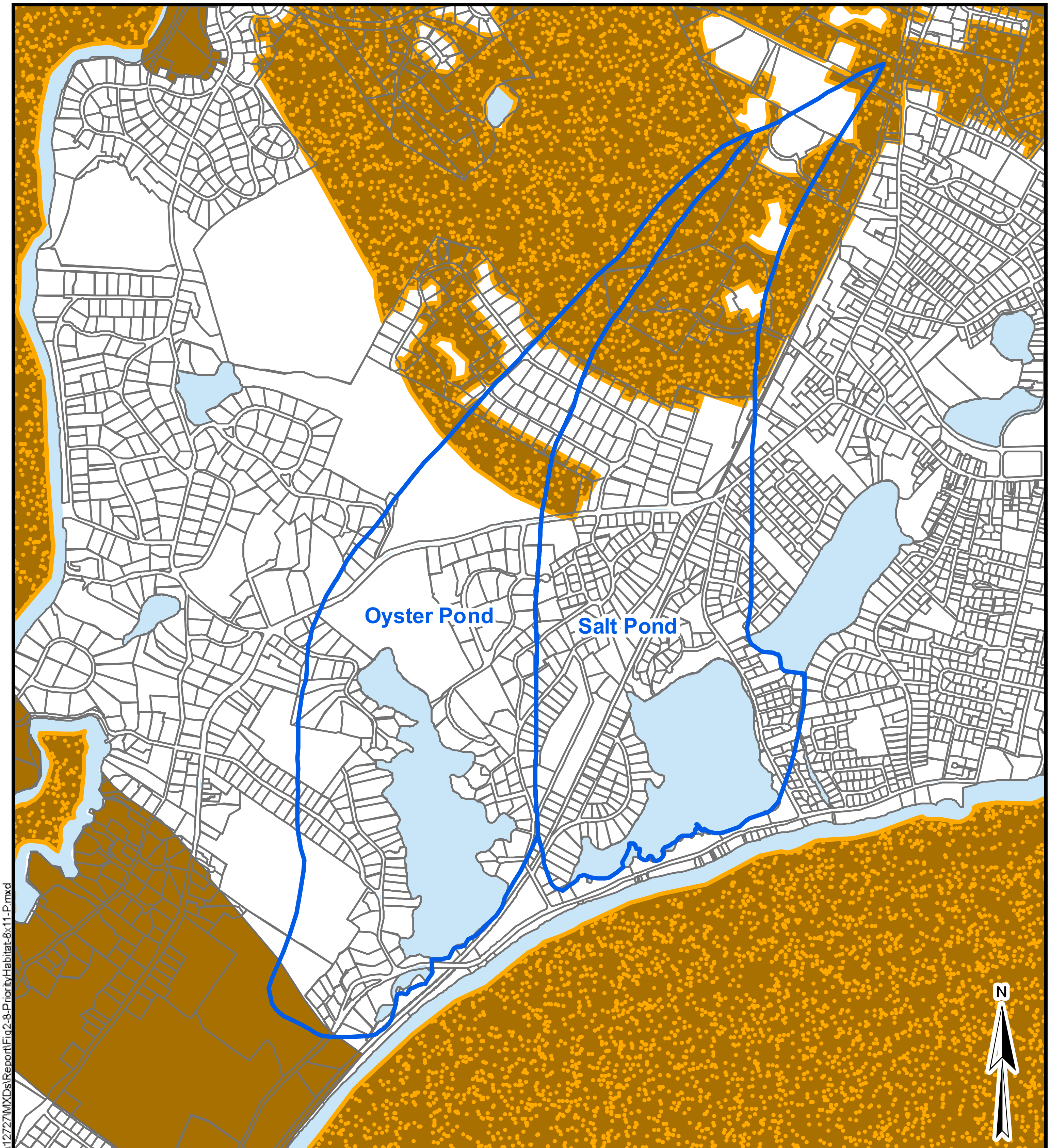

Falmouth
Oyster Pond CWMP

**Flood Plains**

PROJ NO: 12727 | DATE: Jul 2013

WRIGHT-PIERCE
Engineering a Better Environment

FIGURE: 2-7




Watershed Boundary

NHESP Estimated Habitats of Rare Species

NHESP Priority Habitats of Rare Species

Base data obtained from Town of Falmouth (2013), MassGIS (2008, 2009)

0 0.3 0.6 Mile

Falmouth
Oyster Pond CWMP

**Priority Habitat of Rare Species**

| PROJ NO: 12727 | DATE: Jul 2013 | FIGURE: 2-8 |
| --- | --- | --- |

WRIGHT-PIERCE
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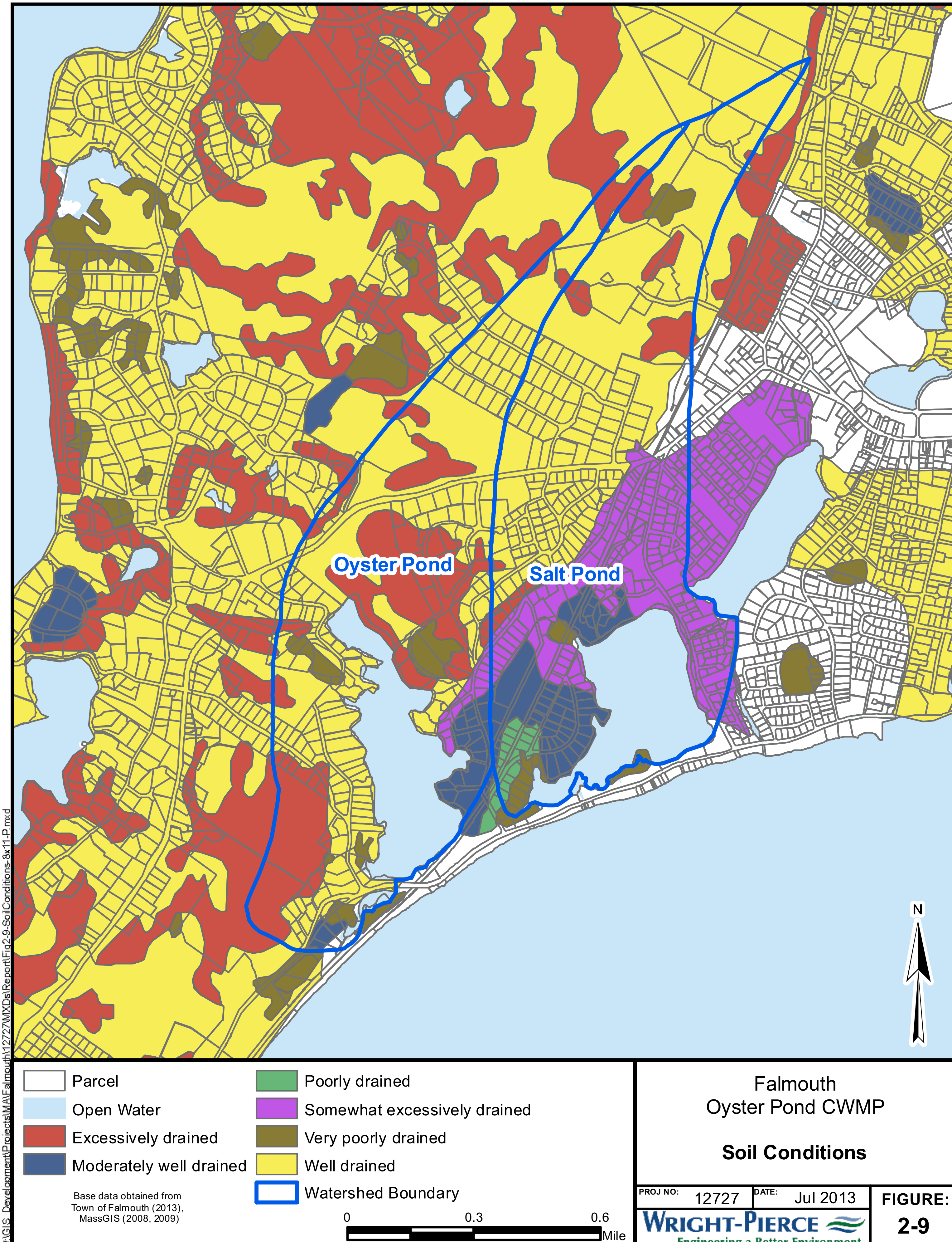



Falmouth
Oyster Pond CWMP

**Soil Conditions**

PROJ NO: 12727 DATE: Jul 2013

FIGURE: 2-9

WRIGHT-PIERCE
Engineering a Better Environment

## 2.7 GROUNDWATER

Groundwater serves as the primary source of drinking water for the Town. Threats to groundwater include septic systems, fuel storage tanks, hazardous materials use and storage. Overall, groundwater contamination has not impeded the Town's ability to meet public drinking water demands.

### 2.7.1 Water Supply Infrastructure

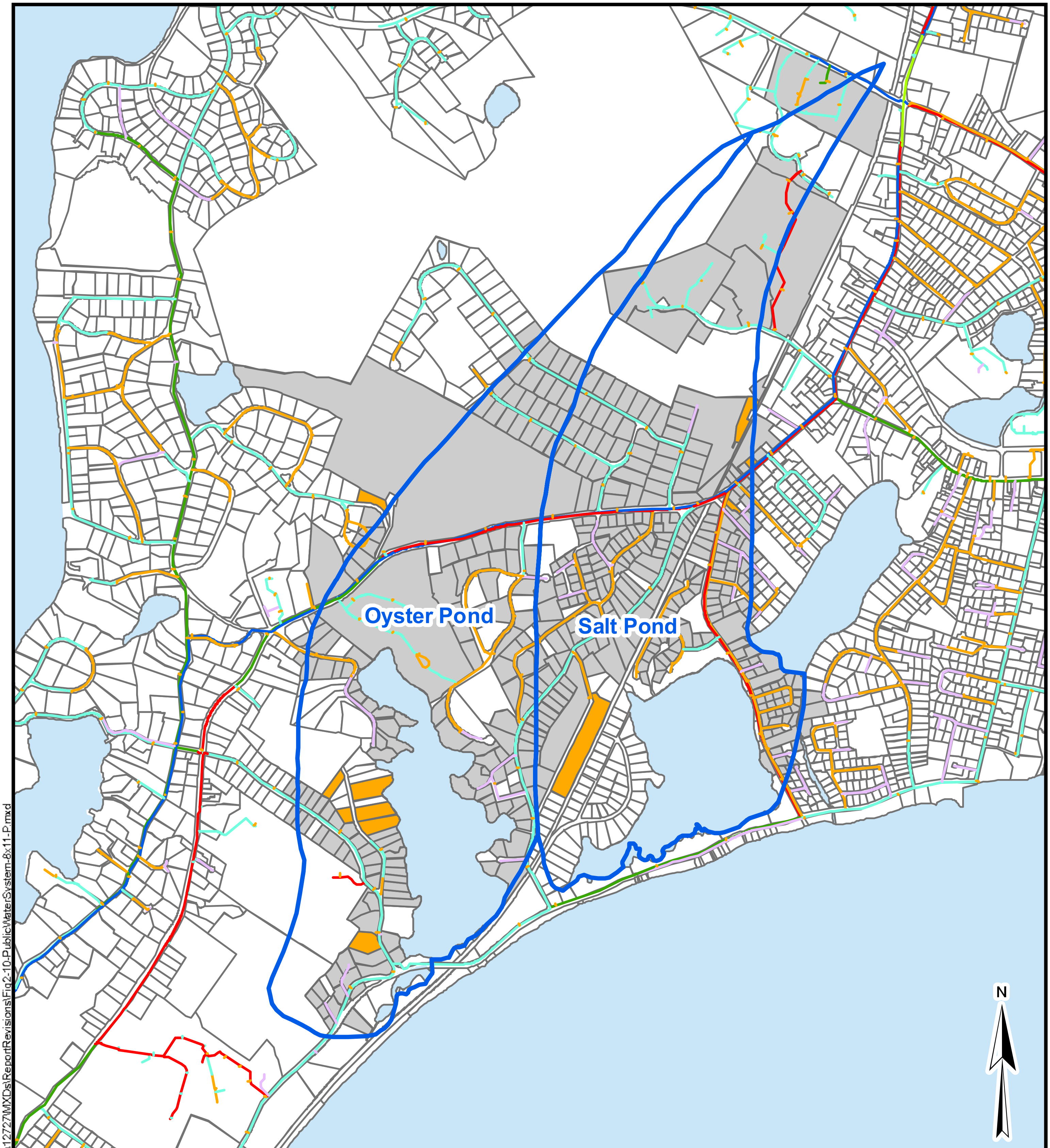
The Town has a public water supply system consisting of groundwater well sources, surface water sources, one water treatment plant, and a water distribution system. Properties which are not served by public water generally have their own private well on site. The properties in the study area which are served by public water as well as by private well are shown on **Figure 2-10**.

### 2.7.2 Wastewater Infrastructure

The Town owns and operates a public wastewater collection treatment system, including sewers, forcemains, pumping stations, and two wastewater treatment facilities (Blacksmith Shop Road and New Silver Beach). These treatment facilities are operated to comply with groundwater discharge permits issued by the Massachusetts Department of Environmental Protection.

No properties in the Oyster Pond watershed are connected to the public sewer system. Thirty eight properties in the northern portion and the southeastern portion of the Salt Pond watershed are connected to the public sewer system. Wastewater flow from these parcels is conveyed to the wastewater treatment facility on Blacksmith Shop Road. Public wastewater infrastructure is shown on **Figure 2-11**.

There are no other public or private wastewater treatment systems serving more than one property in these watersheds. The wastewater flow from all remaining properties is treated and disposed of via on-site systems. Treetops Condominiums has two 4-unit septic systems, twenty seven 2-unit septic systems and a single septic system for the clubhouse. Approximately one-third of the existing on-site systems are Title 5 systems, one-third are cesspools and one-third are septic tanks with leaching pits. There are five denitrifying systems (often called "I/A" or innovative/alternative systems). There are no known “tight tanks” in these watersheds.






Falmouth
Oyster Pond CWMP

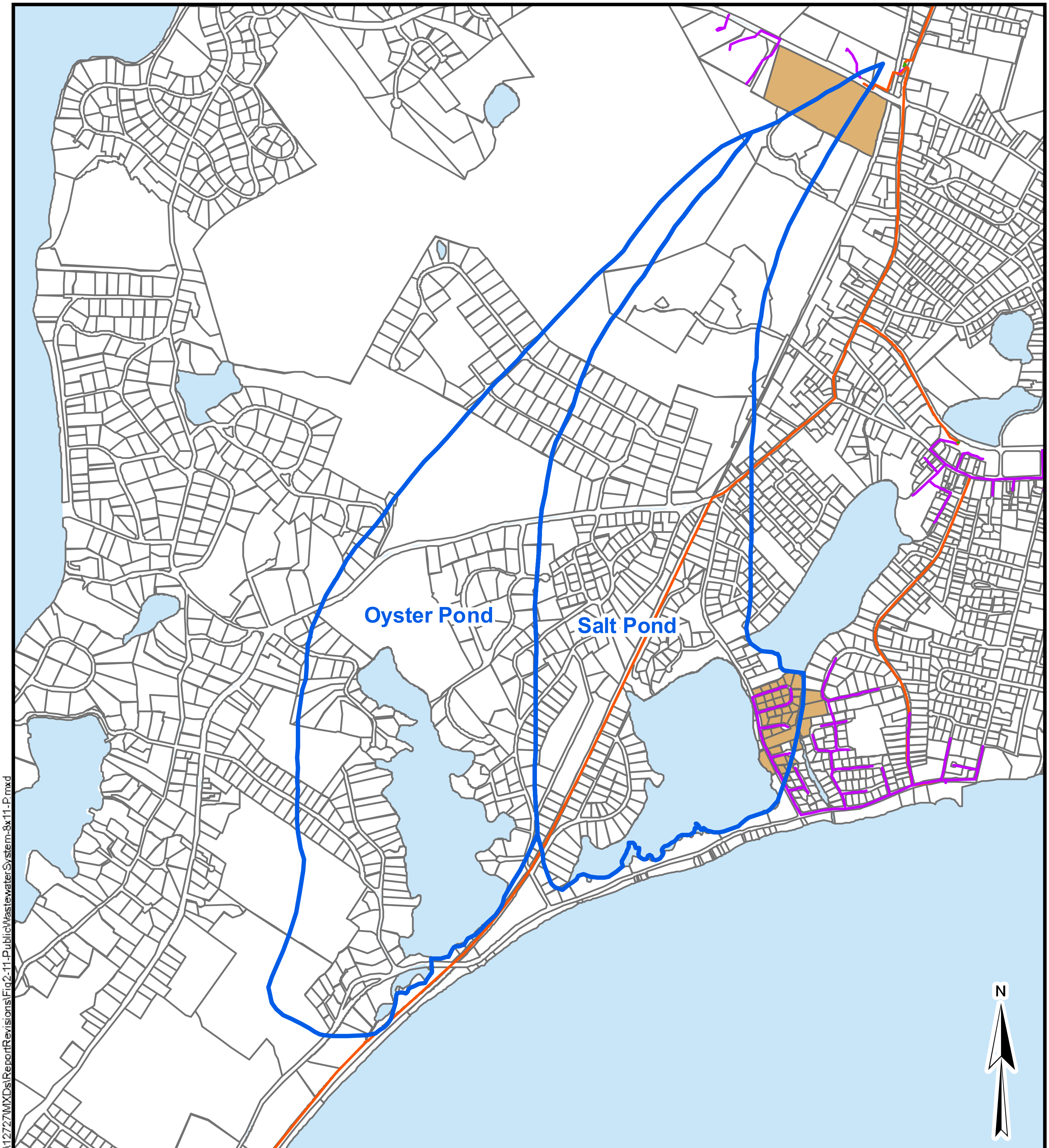
**Public Water System**

PROJ NO: 12727 DATE: Aug 2013

FIGURE: 2-10

WRIGHT-PIERCE
Engineering a Better Environment

W:\GIS_Development\Projects\MA\Falmouth\12727\MXDs\ReportRevisions\Fig2-10-PublicWaterSystem-8x11-P.mxd




Watershed Boundary
Sewer Force Main
Sewer Gravity Main
Other Sewer Main
Watershed Parcels Served by Public Sewer

Base data obtained from Town of Falmouth (2013), MassGIS (2009)

0 0.3 0.6 Mile

Falmouth
Oyster Pond CWMP

**Public Wastewater System**

PROJ NO: 12727 | DATE: Aug 2013 | FIGURE: 2-11

WRIGHT-PIERCE
Engineering a Better Environment

W:\GIS_Development\Projects\MA\Falmouth\12727\MXDs\ReportRevisions\Fig2-11-PublicWastewaterSystem-8x11-P.mxd

## 2.8 SURFACE WATER

The health of surface waters (including streams, rivers, lakes, ponds, wetlands and vernal pools) are affected by numerous factors such as atmospheric deposition, groundwater recharge and storm water runoff. Nutrients and chemicals from industrial processes can be carried in the atmosphere and deposited with rain. Nutrients and chemicals can be conveyed to surface by way of groundwater recharge from wastewater disposal via septic systems. Nutrients and chemicals can also be present on land and carried to these resources in potentially harmful concentrations from stormwater runoff.

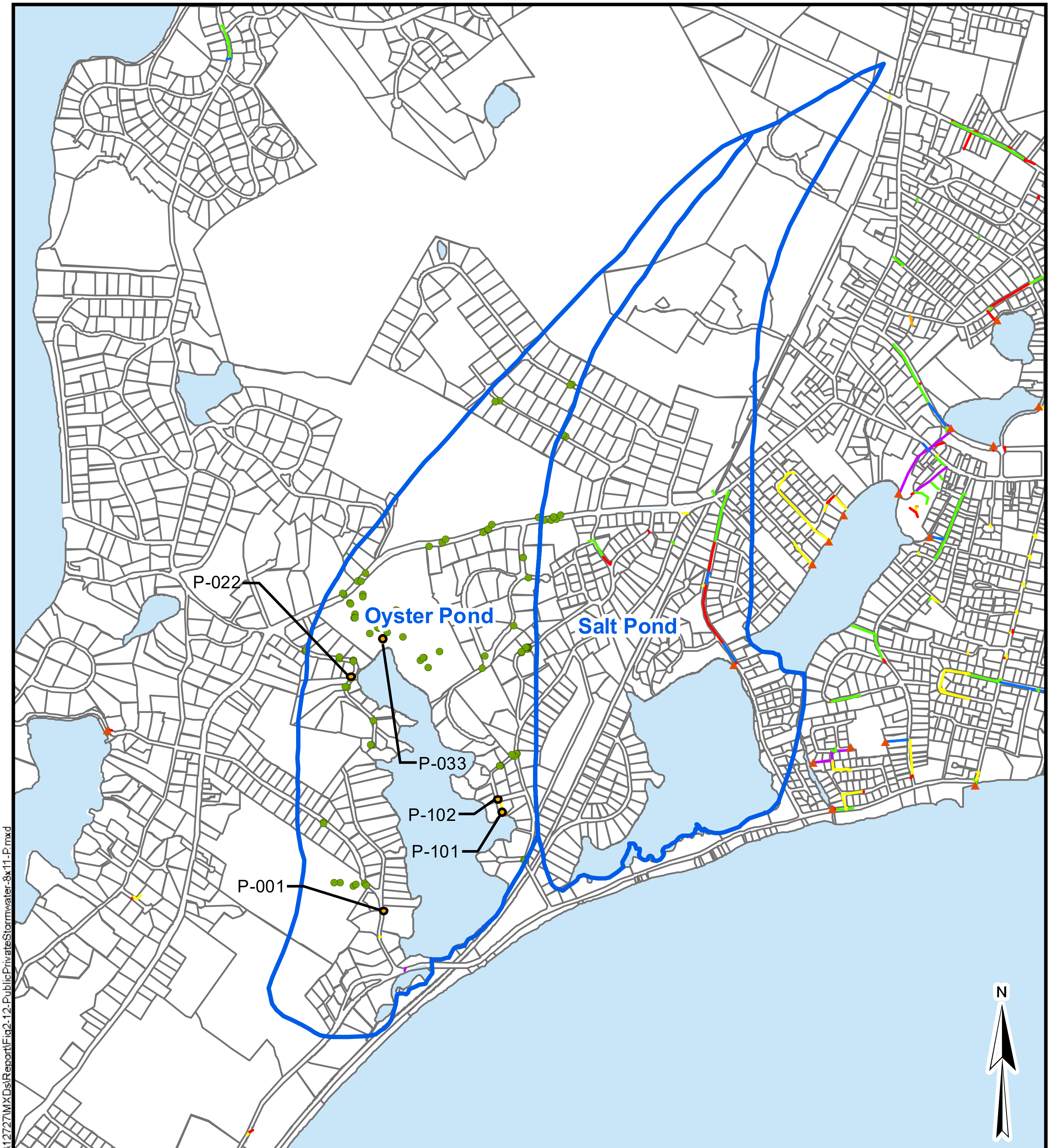
### 2.8.1 Stormwater Infrastructure

The Town owns and operates a public stormwater system consisting of storm drain piping, including catch basins and drain manholes. These stormwater management systems were generally developed as part of the facilities that they serve (e.g., roads, buildings, subdivisions, etc.). A stormwater drainage system site review was conducted on 1 May 2013 by Wright-Pierce and the Falmouth Engineering Department. The purpose of the site review was to locate stormwater drainage system structures in the Oyster Pond watershed and to identify the presence of illicit connections, if any. No evidence of illicit connections was observed during the site review. Wright-Pierce was prepared to collect and analyze samples for: ammonia, nitrate, nitrite, chlorine, e.coli and detergents. No flowing water was observed and no samples were collected.

Based on our site review, we identified numerous drainage system features (e.g., catch basins, drain manholes, pipes, area drains, and curb cuts both in public roads, rights-of-way as well as within private development) which were not previously identified on Town GIS mapping. These drainage system components were located by GPS and were compiled into a GIS shape file (provided to the Town electronically). Of the drainage system features identified, only five features discharged directly to either Oyster Pond or to its adjacent wetlands, as follows:

- P-001: Pipe to the wetland adjacent to Oyster Pond (Oyster Pond Road)
- P-022: Curb cut to Oyster Pond (Ransom Road)
- P-033: Drywell Overflow Pipe to Oyster Pond (TreeTops Landfall Road)
- P-101 and P-102: CB and pipe to Oyster Pond (Quonset Road)

These features will be identified in the Alternatives Analysis phase of the CWMP. The extent of the public and private stormwater management systems are shown on **Figure 2-12**.




Watershed Boundary

Selected Surveyed Structures (W-P)

Surveyed Structures (W-P)

Outfalls

No Diameter

4"; 6"

8"; 10"

12"; 14"

15"; 16"

18" and > 18"

0 0.3 0.6 Mile

Base data obtained from Town of Falmouth (2013), MassGIS (2009)

Falmouth
Oyster Pond CWMP

**Public Stormwater System**

PROJ NO: 12727 DATE: Jul 2013

WRIGHT-PIERCE
Engineering a Better Environment

FIGURE: 2-12

W:\GIS_Development\Projects\MA\Falmouth\12727\MXDs\Report\Fig2-12-PublicPrivateStormwater-8x11-P.mxd

## 2.9 WATER USE AND WASTEWATER FLOWS

### 2.9.1 Town-Wide Water Use

Parcel-specific water use provided by the Town is one of the key building blocks for estimating wastewater flows for the study area. There can be variability from year to year in water use that is influenced by weather or economic conditions. One way to reduce that variability is to compute the average over multiple years of data. For the purposes of this CWMP, data have been obtained for the period of 2007 through 2011. The Town's GIS database serves as the basis for linking water use data to site location and land use.

A summary of town-wide water use data is provided in **Table 2-2**. The town-wide average water use for residential parcels has been documented in previous reports as 153 gpd (2006 Oyster Pond MEP Report, p. 32) and as 154 gpd (2007 Needs Assessment Report, GHD, p. 5-19). For the period 2007 to 2011, the town-wide average water use for residential parcels was 150 gpd (based on residential water billing data provided by the Town).

**TABLE 2-2: SUMMARY OF TOWN-WIDE WATER USE**

| Year | Average Residential Water Use per Account (gpd) | Annual Average (mgd) | Peak Week (mgd) | Peak Day (mgd) |
|---|---|---|---|---|
| 2007 | 159 | 4.54 | 8.96 | 10.70 |
| 2008 | 162 | 4.16 | 8.65 | 9.86 |
| 2009 | 148 | 3.66 | 5.82 | 7.85 |
| 2010 | 126 | 4.19 | 9.98 | 11.46 |
| 2011 | 153 | 4.32 | 7.94 | 9.52 |
| Average | 150 | 4.17 | 8.27 | 9.88 |

Source: Town of Falmouth Water Department Reports

### 2.9.2 Residential Water Use in Oyster Pond and Salt Pond Watersheds

A summary of the single-family residential water use data for each watershed is presented in **Table 2-3** (Oyster Pond) and **Table 2-4** (Salt Pond). An estimate of "seasonal use" was developed using the Town Assessor's data for the parcels identified as having "taxable personal property". This was considered the best available indicator of seasonal use. Based on this indicator, approximately 54% of the single-family properties in the Oyster Pond watershed (counting Treetops as individual unit) are seasonal use and represent 50% of the single-family water use. For the Salt Pond watershed, approximately 40% of the single-family properties are seasonal use and represent 32% of the single-family water use in the watershed. The greater the amount of seasonal use, the higher the peaking factors are for water use. Also, when determining build-out potential, seasonal properties could be converted to year-round properties which would result in greater water use in the future. While the Oyster Pond watershed has a larger percentage of seasonal properties and seasonal water use, the Salt Pond watershed has a larger differential between year-round use and seasonal use.

### 2.9.3 Water Use in Oyster Pond Watershed

The significant majority of the water demand in the Oyster Pond watershed (96%) is met by the Town's public water system, with the remaining coming from 6 private wells. Since water use from private wells is not measured or documented by the Town, it must be estimated. For the purposes of this analysis, the water use on the residential parcels served by private wells was assumed to be equal to the average value of the residential parcels served by the public water system. For the period 2007 to 2011, water use in the Oyster Pond watershed averaged 32,000 gallons per day (gpd). Water use in the Oyster Pond watershed represents approximately 0.8% of the town-wide water use.

**TABLE 2-3**
**SUMMARY OF SINGLE-FAMILY RESIDENTIAL WATER USE - OYSTER POND**

| | Town Water (Year Round) | | | Town Water (Seasonal) | | | Private Well | | | Total Developed Properties | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of | Water Use | | No. of | Water Use | | No. of | Water Use | | No. of | Water Use | |
| | Properties | gpd/parcel | gpd | Properties | gpd/parcel | gpd | Properties | gpd/parcel | gpd | Properties | gpd/parcel | gpd |
| 1-2 Bedroom | | 88 | | | 69 | | | 168 | 168 | 10 | 86 | 864 |
| 3-4 Bedroom | | 169 | | | 135 | | | 168 | 840 | 118 | 154 | 18,197 |
| 5+ Bedroom | | 244 | | | 242 | | | 168 | - | 32 | 243 | 7,762 |
| TOTAL | 78 | 177 | 13,775 | 76 | 158 | 12,040 | 6 | 168 | 1,008 | 160 | 168 | 26,823 |
| | | | | *48%* | | *45%* | | | | | | |

**TABLE 2-4**
**SUMMARY OF SINGLE-FAMILY RESIDENTIAL WATER USE - SALT POND**

| | Town Water (Year Round) | | | Town Water (Seasonal) | | | Private Well | | | Total Developed Properties | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N( | Water Use | | No | Water Use | | No. of | Water Use | | ] | Water Use | |
| | Properties | gpd/parcel | gpd | Properties | gpd/parcel | gpd | Properties | gpd/parcel | gpd | Properties | gpd/parcel | gpd |
| 1-2 Bedroom | | 106 | | | 59 | | | 142 | - | 13 | 81 | 1,049 |
| 3-4 Bedroom | | 154 | | | 113 | | | 142 | 142 | 224 | 138 | 30,987 |
| 5+ Bedroom | | 259 | | | 192 | | | 142 | - | 20 | 228 | 4,568 |
| TOTAL | 154 | 160 | 24,625 | 102 | 116 | 11,838 | 1 | 142 | 142 | 257 | 142 | 36,604 |
| | | | | *40%* | | *32%* | | | | | | |

A summary of current water use for developed parcels in the Oyster Pond watershed is presented in **Table 2-5**. The average and median single-family residential water use values were 168 gpd and 124 gpd. For the purposes of the CWMP, the parcel-specific average values will be utilized (as opposed to median values).

**TABLE 2-5**
**CURRENT WATER USE – OYSTER POND WATERSHED**

| Type of Use | Total Developed Properties | | |
|---|---|---|---|
| | Number of Properties | Est. Water Use, gpd | |
| | | Annual Avg per Property | Annual Total per Category |
| **Residential** | | | |
| Single-Family – Public Water (1) | 154 | 168 | 25,816 |
| Single-Family – Private Well (2) | 6 | 168 | 1,008 |
| Multi-Family | 2 | 208 | 415 |
| Condo (***Note 3***) | 1 | 4,739 | 4,739 |
| **Commercial** | 0 | 0 | 0 |
| **Municipal/Exempt** | 3 | 42 | 125 |
| **TOTAL** | **166** | **193** | **32,103** |

Notes:

1) Source: Falmouth GIS database, 2007 to 2011 water use data.
2) Water use from private wells is assumed to be consistent with water use from public water accounts in the same category (i.e., single-family residential and municipal).
3) This single property is the TreeTops Condominiums which includes 62 residential condo units. The average water use per condo unit is 76 gpd.

It is important to note that there is a fairly large discrepancy between the values reported herein and values utilized in the 2006 Oyster Pond MEP Report. A comparison of the MEP water use analysis versus the CWMP water use analysis is summarized below in **Table 2-6**.

**TABLE 2-6**
**COMPARISON OF WATER USE DATA – MEP ANALYSIS TO CWMP ANALYSIS**

| Category of Use | MEP 2002-2003 gpd | CWMP 2007-2011 gpd |
|---|---|---|
| Residential | 31,924 | 26,824 |
| Multi-family | 3,968 | 415 |
| Condo | 5,410 | 4,739 |
| Commercial | 0 | 0 |
| Municipal/Exempt | 483 | 125 |
| | | |
| **TOTAL** | **41,785** | **32,103** |

Notes:
1) Source: 2006 Oyster Pond MEP Technical Report and data disk, 2002 to 2003 water use data.
2) Source: Falmouth GIS data, 2007 to 2011 water use data.

There are three possible explanations for the discrepancy, as summarized below:

1. Two years of water use data were used for the Oyster Pond MEP report analysis (2002 to 2003) and five years of water use data used for this CWMP (2007 to 2011). These differences are relatively large.
   - The Oyster Pond MEP Report estimated that the single-family residential average water use in the Oyster Pond watershed was 209 gpd. Based on the CWMP analysis, the average water use for single-family residential parcels in the Oyster Pond watershed for the period 2007 to 2011 was 168 gpd. The 15 highest single-family residential water users in the Oyster Pond MEP Report averaged 690 gpd. The 15 highest single-family residential water users in the CWMP averaged 490 gpd.
   - There was one significant outlier value in the Oyster Pond MEP data set. Specifically, Parcel 48-12-002-049 (land use code 109, subwatershed-4) indicated a water use of 3,590 gpd for a single multi-family property. The water use for this same parcel during the 2007 to 2011 period averaged 228 gpd. The owner of this property indicated that the high water use in the early data set was due to a leaking pipe, which was repaired.

2. There could be additional water accounts which are not joined to the assessor's parcel data based on the differences in coding used by the Assessor's Department and the Water Department. These differences are expected to be relatively minor.
3. The parcels assigned to the Oyster Pond watershed do vary slightly between the two efforts. There are more residential parcels in the CWMP analysis (160 vs 153), in part due to 8 new homes having been built in the watershed since the Oyster Pond MEP report. There are fewer municipal/exempt parcels counted in the CWMP analysis (3 vs 6), in part due to the land use, development and water use information contained in the joined database. These differences are relatively minor.

While the water use estimates do vary between the Oyster Pond MEP Report and this CWMP, each analysis is considered complete and separate. For the reasons stated above, the CWMP is based on the "CWMP analysis". The implications of the different values could be assessed via a sensitivity analysis conducted through the MEP process at a later date.

### 2.9.4 Water Use in Salt Pond Watershed

The significant majority of the water demand in the Salt Pond (98%) watershed is met by the Town's public water system, with the remaining coming from 1 private well. Since water use from private wells is not measured or documented by the Town, it must be estimated. For the purposes of this analysis, the water use on the residential parcels served by private wells was assumed to be equal to the average value of the residential parcels served by the public water system. For the period 2007 to 2011, water use in the Salt Pond watershed averaged 96,900 gpd. Water use in the Salt Pond watershed represents approximately 2.3% of the town-wide water use.

A summary of current water use for developed parcels in the Salt Pond watershed is presented in **Table 2-7**. For the Salt Pond watershed, the average and median single-family residential water use values were 142 gpd and 120 gpd, respectively. For the purposes of the CWMP, the parcel-specific average values will be utilized (as opposed to median values).

**TABLE 2-7**
**CURRENT WATER USE – SALT POND WATERSHED**

| Type of Use | Total Developed Properties | | |
|---|---|---|---|
| | Number of Properties | Est. Water Use, gpd | |
| | | Annual Avg per Property | Annual Total per Category |
| **Residential** | | | |
| Single-Family – Public Water (1) | 256 | 142 | 36,462 |
| Single-Family – Private Well (2) | 1 | 142 | 142 |
| Multi-Family | 5 | 780 | 3,902 |
| Condo | 6 | 144 | 868 |
| **Commercial** | 9 | 542 | 4,877 |
| **Municipal/Exempt** | 7 | 6,243 | 43,698 |
| **TOTAL** | **285** | **316** | **89,949** |

Notes:
1) Source: Falmouth GIS database, 2007 to 2011 water use data.
2) Water use from private wells is assumed to be consistent with water use from public water accounts in the same category (i.e., single-family residential and municipal).

### 2.9.5 Wastewater Flows - General

Since wastewater flows are not measured, they need to be estimated from water use data. The difference between water use and wastewater flows is termed "consumptive use" and represents the water use that does not reach the on-site disposal facility (e.g., lawn irrigation, outdoor showers, etc.). Consumptive uses are generally quite low in the winter and reach their peak in the summer months. For this CWMP, consumptive use has been estimated at 10% for all sources on an annual average basis.

### 2.9.6 Wastewater Flows in Oyster Pond Watershed

This analysis leads to the estimate of current wastewater flow of approximately 28,900 gallons per day for the Oyster Pond watershed, expressed as an annual average value. A summary of wastewater flows is presented in **Table 2-8** (by use) and in **Table 2-9 (**by MEP subwatershed).

### 2.9.7 Wastewater Flows in Salt Pond Watershed

This analysis leads to the estimate of current wastewater flow of approximately 87,300 gallons per day for the Salt Pond watershed, expressed as an annual average value. A summary of wastewater flows is presented in **Table 2-10** (by use) and in **Table 2-11 (**by MEP subwatershed).

**TABLE 2-8**
**CURRENT WASTEWATER FLOWS – OYSTER POND WATERSHED**

| **Type of Use** | **Total Developed Properties** | | |
|---|---|---|---|
| | **Number of Properties** | **Est. Wastewater Flow, gpd** | |
| | | **Annual Average per Property** | **Annual Total per Category** |
| **Residential** | | | |
| Single-Family – Public Water (1) | 154 | 151 | 23,234 |
| Single-Family – Private Well (2) | 6 | 151 | 907 |
| Multi-Family | 2 | 187 | 374 |
| Condo (***Note 3***) | 1 | 4,265 | 4,265 |
| **Commercial** | 0 | 0 | 0 |
| **Municipal/Exempt** | 3 | 38 | 113 |
| **TOTAL** | **166** | **174** | **28,893** |

Notes:
1) Source: Falmouth GIS database, 2007 to 2011 water use data.
2) Wastewater flows are estimated from water use..
3) This single property is the TreeTops Condominiums which includes 62 residential units. The average wastewater flow per condo unit is 68 gpd.

**TABLE 2-9**
**CURRENT WASTEWATER FLOWS – OYSTER POND SUBWATERSHEDS**

| **MEP Subwatershed** | **Number of Properties** | **Number of Developed Properties** | **Annual Average Wastewater Flow, gpd** |
|---|---|---|---|
| Oyster Pond, >10 year travel, North | 51 | 46 | 8,128 |
| Oyster Pond, >10 year travel, West | 20 | 16 | 1,239 |
| Mosquito Creek | 10 | 5 | 586 |
| Oyster Pond, Main | 109 | 85 | 16,145 |
| Oyster Pond, South | 21 | 14 | 2,795 |
| **TOTAL** | **211** | **166** | **28,893** |

**TABLE 2-10**
**CURRENT WASTEWATER FLOWS – SALT POND WATERSHED**

| Type of Use | Total Developed Properties | | |
|---|---|---|---|
| | Number of Properties | Est. Wastewater Flow, gpd | |
| | | Annual Average per Property | Annual Total per Category |
| **Residential** | | | |
| Single-Family – Public Water (1) | 256 | 128 | 32,816 |
| Single-Family – Private Well (2) | 1 | 128 | 128 |
| Multi-Family | 5 | 702 | 3,511 |
| Condo | 6 | 130 | 781 |
| **Commercial** | 9 | 488 | 4,389 |
| **Municipal/Exempt** | 7 | 5,617 | 39,329 |
| **TOTAL** | **285** | **284** | **80,954** |

Notes:
1) Source: Falmouth GIS database, 2007 to 2011 water use data.
2) Wastewater flows estimated from water use.

**TABLE 2-11**
**CURRENT WASTEWATER FLOWS – SALT POND SUBWATERSHEDS**

| MEP Subwatershed | Number of Properties | Number of Developed Properties | Annual Average Wastewater Flow, gpd |
|---|---|---|---|
| Salt Pond, >10 year travel, North | 152 | 140 | 26,488 |
| Salt Pond, Main | 190 | 106 | 14,353 |
| Salt Pond, Sewered | 39 | 39 | 40,113 |
| **TOTAL** | **381** | **285** | **80,954** |

### 2.9.8 Wastewater Peaking Factors

All wastewater treatment and disposal systems, whether on-site or off-site, must be sized adequately to handle short-term peak flows (e.g., seasonal maximum month, maximum 2-day flow). According to the Local Comprehensive Plan, approximately 30% of the residential housing stock is considered seasonal use. According to the 2007 Needs Assessment Report (GHD, Table 5-7), the town-wide water supply seasonal peaking factor is 1.8 (i.e., the ratio of maximum month flow to annual average flow). As noted previously, the Oyster Pond and Salt Pond watersheds are "more seasonal" than the town as a whole. Based on our review of Falmouth's water use data as well as our experience with other seasonal populations on Cape Cod, we recommend using utilizing a higher seasonal peaking factor for these two watersheds. For the purposes of this CWMP, we will utilize the following peaking factors:

| | |
|---|---|
| Maximum month: | 2.1 times annual average |
| Maximum week: | 2.3 times annual average |
| Maximum 2-day: | 2.5 times annual average |

The wastewater flow estimates presented herein are based on water use records from the period of 2007 to 2011. These flows are characterized as "current", even though they will represent a time frame prior to the final publication of a completed CWMP.

It is important to note that several residential parcels were constructed after the data collection period for Oyster Pond MEP Report. Specifically, eight residential parcels were constructed between 2004 and 2011. The wastewater flows and loadings from these parcels are included in the CWMP current conditions, but should be considered "future growth" in terms of the Oyster Pond MEP Report.

## 2.10 REGULATORY FRAMEWORK

Major elements of the local, regional and state regulatory framework related to wastewater management and water resource protection are summarized below.

### 2.10.1 Town

**Falmouth Health Regulations** includes numerous supplements to the State Title 5 Environmental Code (FHR-15.0). These regulations specify local requirements for permitting, design and construction of new systems as well as system repairs. These regulations prohibit systems within 100 feet of surface water or wetlands for new construction and outline a procedure for repair or replacement of existing systems within 100 feet of surface water or wetlands.

**Falmouth Coastal Pond Overlay District** identifies the procedure for applicants wishing to develop properties within the watersheds of listed coastal ponds. Applicable development for this overlay district is: subdivisions greater than five lots or five acres; commercial development requiring site plan review; and special permit uses. The intent of the District is to limit the nitrogen loading to a listed coastal pond. Applicable projects in the District shall utilize DEP-approved nitrogen reducing individual or cluster systems, as approved by the Reviewing Board. Applicable coastal ponds (and established critical eutrophic levels) are identified as follows: High Quality Areas (threshold value of 0.32 mg/l annual average total nitrogen); Stabilization Areas (threshold value of 0.52 mg/l annual average total nitrogen); or Intensive Water Activity Areas (threshold value of 0.75 mg/l annual average total nitrogen). Oyster Pond and Salt Pond are both identified in the Stabilization Area list.

**Falmouth Zoning** does not allow off-site private wastewater treatment facilities in any zone. A publicly-owned wastewater treatment facility is allowed as a matter of right in public use districts and in business districts.

### 2.10.2 Department of Environmental Protection

DEP has established a policy that prohibits the issuance of a groundwater discharge permit in a nitrogen-sensitive watershed unless the applicant has already put into effect a project that removes an existing nitrogen load equal to or greater than the load the that proposed project will add to the groundwater. Based on discussions with DEP staff, the nitrogen offset must be in place prior to the start-up of the proposed new WWTF; the applicant cannot merely fund a related study or set money aside for Town use on a future project. A nitrogen-sensitive watershed is one where a draft or final MEP Technical Report indicates that nitrogen-reduction is needed to restore or maintain water quality or one where a TMDL has been issued.

### 2.10.3 Cape Cod Commission

The Cape Cod Commission's Regional Policy Plan (RPP) has numerous elements related to water resource protection, including:

- Nitrate loading from the project must be below 5 parts per million (ppm) for projects in general and below 1 ppm in potential water supply areas, based on the Commission's Technical Bulletin 91-001. The nitrate loading limit reverts to 5 ppm in a potential water supply area if the Town or the Water District signs off. (**MPS WR2.1 and WR2.6**).
- **MPS WR6.1** prohibits a private WWTF if a feasible public option is expected to be constructed within 3 years.
- All WWTFs must meet a 5 ppm total nitrogen limit, either in the effluent or in the groundwater at the downgradient property line. (**MPS 6.2**).
- **MPS WR6.5** requires that projects with private WWTFs give the municipality the opportunity to take ownership when so desired by the municipality.
- No WWTFs are allowed in ACECs or critical wildlife habitat. (**MPS WR6.6**)
- WWTFs larger than 2,000 gpd must participate in an Operation, Maintenance and Compliance Agreement (OMC Agreement) with the Commission and the local BOH. (**MPS WR6.9**), if the effluent limit is lower than would be included in the typical groundwater discharge permit (10 mg/l).

# SECTION 3

# WATER RESOURCE PROTECTION NEEDS

## 3.1 APPROACH

Many communities rely exclusively on private on-site systems for wastewater treatment and disposal. The Commonwealth of Massachusetts sanitary code ("Title 5") provides a thorough regulatory framework for such systems. Under ideal circumstances, on-site systems can provide cost-effective and environmentally-sound wastewater management. Those circumstances include favorable soils, adequate depth to groundwater, reliable and protected water supplies, absence of sensitive downgradient receiving waters, and absence of high-intensity water users. The fundamental question is: ***"On which properties is the on-site wastewater system an adequate means of providing for sanitation and environmental protection, and on which properties is an off-site solution required?"***

One way to answer this question is to identify areas where the above-noted ideal circumstances do not exist. For the purposes of this report, wastewater management needs have been evaluated in the following five categories:

- **Ensuring Sanitary Conditions**--correction or avoidance of unsanitary conditions (that is, public health problems) such as effluent surfacing over a leaching field, inadequate set-back from a private well, or direct discharge of sanitary wastewater to a watercourse.

- **Protecting Private and Public Water Supplies**--preventing contaminants (such as bacteria, viruses, nitrates, pharmaceuticals, and personal care products) from reaching private or public drinking water sources.

- **Protecting Surface Waters from Nutrient Enrichment**--reducing nutrients that can cause accelerated degradation of freshwater ponds (typically phosphorus) or estuarine waters (typically nitrogen).

- **Addressing Convenience and Aesthetic Issues**--avoiding unsightly mounded septic systems or individual treatment systems that may be the only way to achieve compliance with Title 5 if off-site options do not exist, or avoiding frequent septage pumping that creates odor and disruption.

- **Enabling Sustainable Economic Development**--providing wastewater solutions, where necessary, so that wastewater restrictions (such as impermeable soils, shallow groundwater, locations within a Zone II water supply protection area, etc.) are not the limiting factors to economic development.

The overall approach for this needs assessment is to categorize the lots in the Oyster Pond and Salt Pond watersheds according to these five general categories. The specific approach is different for each category, and is presented in the paragraphs that follow. Each category has been evaluated separately, and then the results compiled to address the fact that some lots fall into more than one category of need. Where improved on-site or off-site disposal is necessary, the reasons must be well documented and defensible.

## 3.2 SANITARY NEEDS

Title 5, the state sanitary code, provides regulation to ensure that on-site systems are properly designed to handle sanitary disposal of wastewater. With a few exceptions, a Title 5 wastewater system is both cost-effective and environmentally sound. Systems that are not compliant with Title 5 or were built prior to Title 5, may not adequately protect public health. A failure to protect public health occurs when one of the following happens: 1) sewage backs up into the home; 2) breakout occurs at the surface of the leaching field; or 3) breakout occurs along the sloping edge of the leaching field. Wastewater or septic tank effluent can also cause harm if a septic system was poorly sited and is proximate to wetlands, surface water or to a public or private drinking water supply (these topics will be addressed separately).

In considering which parcels may be best served by an upgraded on-site system or an off-site system, the following information should be considered as direct or indirect indicators of sanitary need:

- Properties that have required significant variances from Title 5 to install or repair an on-site system and/or properties requiring frequent repairs to an on-site system;
- Properties that use a large amount of potable water; and
- Properties near receiving waters where high bacterial counts have been recorded with no other apparent cause.

### 3.2.1 Title 5 Variances

Title 5 is a thorough sanitary code with respect to sanitary issues. If significant variances from Title 5 have been required to allow an on-site system to be constructed or repaired, then there may be benefits to providing that property with other wastewater solutions. Variances fall in two categories: “procedural” and “environmentally significant”. A procedural variance could be granted for a reduction in the setback between a structure and the leach field. An environmentally significant variance could be granted for a reduction in the distance between a leach field and a private drinking water well or a wetland. The latter could have a negative impact on public health, and may not have been granted if an off-site solution had been available. Lots requiring variances may be spread across town, or perhaps may be clustered. Clustered variances could be, for example, the result of small lots, or shallow depth to groundwater. A cluster of variances for these reasons would make a strong case for an off-site solution as the best long-term solution for wastewater management.

The Health Department provided copies of all Title 5 variances granted for the two watersheds. For each variance that was granted, key information was tabulated, such as the name and address of the applicant, and the nature of the variance that was granted. Each variance was reviewed to determine the specific problem that triggered the variance. Points were then assigned to each variance based on the environmental significance of that type of variance. **Table 3-1** summarizes an additive points system for assigning a score to each lot based on the type and severity of the variance granted. Variances that are minor or procedural in nature (e.g., setback from a property line or structure) received a zero-point score. Variances that could significantly impair public or environmental health (e.g., setback to a private water supply) would add 3 to 5 points to a lot's rating. In the case where multiple minor variances have been granted on a single lot, the cumulative impact can be considered, even if each individual variance would be insignificant on its own.

**TABLE 3-1**
**ENVIRONMENTAL SIGNIFICANCE RATING SYSTEM**
**FOR TITLE 5 VARIANCES**

| Nature of Variance | | Points |
|---|---|---|
| 1 | **Setback From Wetlands (100 foot local requirement)** | |
| | Setback greater than 50 feet | **1** |
| | Setback less than 50 feet | **2** |
| 2 | **Setback From Well (100 feet required)** | |
| | **Potable Well** Setback greater than 75 feet | **1** |
| | Setback of 50 to 75 feet | **3** |
| | Setback less than 50 feet | **5** |
| 3 | **Setback From Property Lines** | **0** |
| 4 | **Setback From Structures** | **0** |
| 5 | **Depth to Groundwater (4 feet required)** | |
| | Depth of 3 to 4 feet | **1** |
| | Depth less than 3 feet | **2** |
| 6 | **Thickness of Underlying Pervious Soil** | |
| | Thickness of 3 to 4 feet | **1** |
| | Thickness less than 3 feet | **2** |
| 7 | **Depth of Cover Over Disposal System** | |
| | Depth greater than 3 feet | **0** |
| | Depth less than 3 feet | **1** |
| 8 | **Inadequate Reserve Area** | |
| | Reserve area less than 50% | **1** |
| | No reserve area | **2** |

To convert this scoring process into a rating system for needs assessment, properties were grouped into one of three categories: little or no environmental significance (0 or 1 point); moderate environmental significance (2 points); and major environmental significance (3 points or more). This additive system provides a consistent and graduated method for identifying individual needs, and is central to this assessment of sanitary needs town-wide.

A total of 18 variances were granted for the two watersheds based on records dated back to the late 1980s, as shown on **Figure 3-1**. Variances were granted for 13 parcels in the Oyster Pond watershed (8% of developed parcels) and for 5 parcels in the Salt Pond watershed (2% of developed parcels).

Based on our review of these 18 variances, we find that:

- 40% of the variances are procedural
- 40% of the variances represent “low” environmental significance
- 20% of the variances represent “moderate” environmental significance
- None of the variances represent “major” environmental significance

Properties with variances of major environmental significance are not well suited for on-site disposal. Based on the Board of Health records, there are no parcels that fall in this category.

### 3.2.2 Health Department Inspection Reports

Health Department inspections are typically triggered by property sale. While the inspection reports represent a snapshot in time, they do provide good information about the property. Inspection reports were reviewed for the period of 2006 through 2009. A total of 49 records were found for the two watersheds for period in question (approximately 8% of the developed parcels). Based on this limited data set, we find the following:

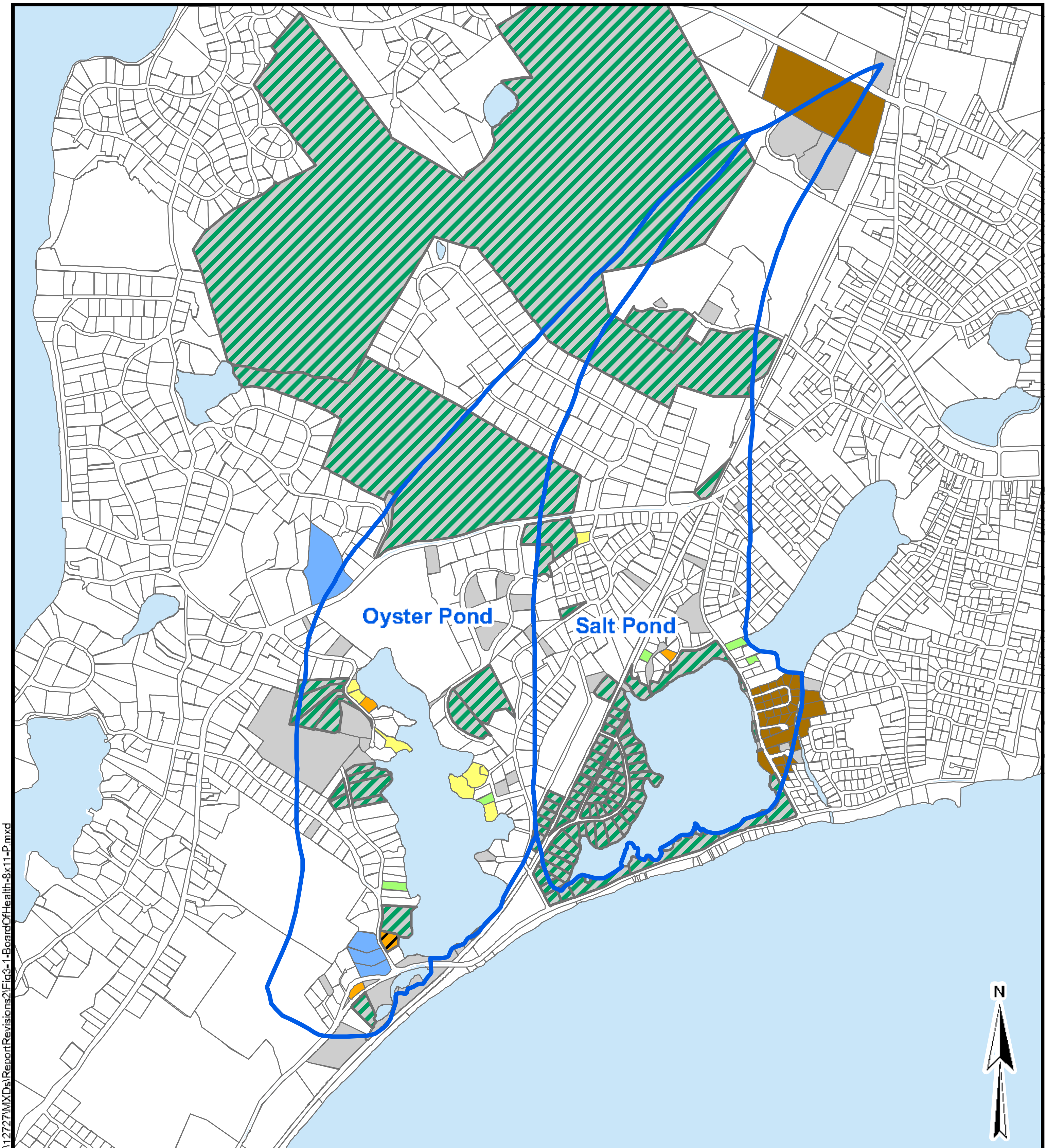
***Oyster Pond***

- 23 records reviewed
- 39% of the systems are cesspools (some single, some multiple units in series)
- 30% of the systems are septic tank with leaching pit (or former cesspool as leaching pit)
- 30% of the systems are septic tanks with leaching fields
- 22% of the systems were noted as “failed” based the Health Agent’s inspection and judgment (all of these were cesspools or septic tanks with leaching pits) (required repair/replacement)
- 57% of the systems were installed in the rear yard.

***Salt Pond***

- 26 records reviewed
- 13% of the systems are cesspools (some single, some multiple units in series)
- 25% of the systems are septic tank with leaching pit (or former cesspool as leaching pit)
- 9% of the systems are septic tanks with leaching fields
- 4% of the systems were noted as “failed” based the Health Agent’s inspection and judgment (all of these were cesspools or septic tanks with leaching pits) (required repair/replacement)
- 29% of the systems were installed in the rear yard.

Since the Town allows for the continued use of non-failing cesspools and septic tanks with leaching pits, the Health Department inspection records will not be utilized as indicators of sanitary need. However, this data is informative and is presented herein for future reference.




I/A System
Title 5 Variance - Procedural
Title 5 Variance w/ Low Environmental Significance
Title 5 Variance w/ Moderate Environmental Significance
Title 5 Variance w/ Moderate Environmental Significance, with I/A System
Watershed Boundary
Sewered
Vacant
Conservation/Recreation

Base data obtained from Town of Falmouth (2013), MassGIS (2009)

0 0.3 0.6 Mile

Falmouth
Oyster Pond CWMP

**Board of Health Records and I/A Systems**

| PROJ NO: 12727 | DATE: Sep 2013 | FIGURE: 3-1 |
| --- | --- | --- |

WRIGHT-PIERCE
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### 3.2.3 Intensive Water Use

Intensive water use is an indirect indicator of parcels which could have potential wastewater disposal problems. The greater the water use intensity, the greater the potential difficulty with on-site wastewater disposal. Title 5 uses a similar approach to determine if a project warrants nitrogen control in the recharge areas of public water supply wells. Parcel size was calculated based on overall property boundaries. Annual average water use values were utilized as described in Section 2.9. For example, a parcel with an annual average water use of 200 gpd and a total lot area of 50,000 sq.ft. has a water use intensity of 40 gpd/10,000 sq.ft. **Figure 3-2** shows the water use intensity for the developed parcels in the watersheds. Whereas this category is an indirect measure of sanitary need, we will utilize this measure to prioritize parcels that may require an off-site solution for other categories of need (e.g., surface water protection).

### 3.2.4 Receiving Water Impacts

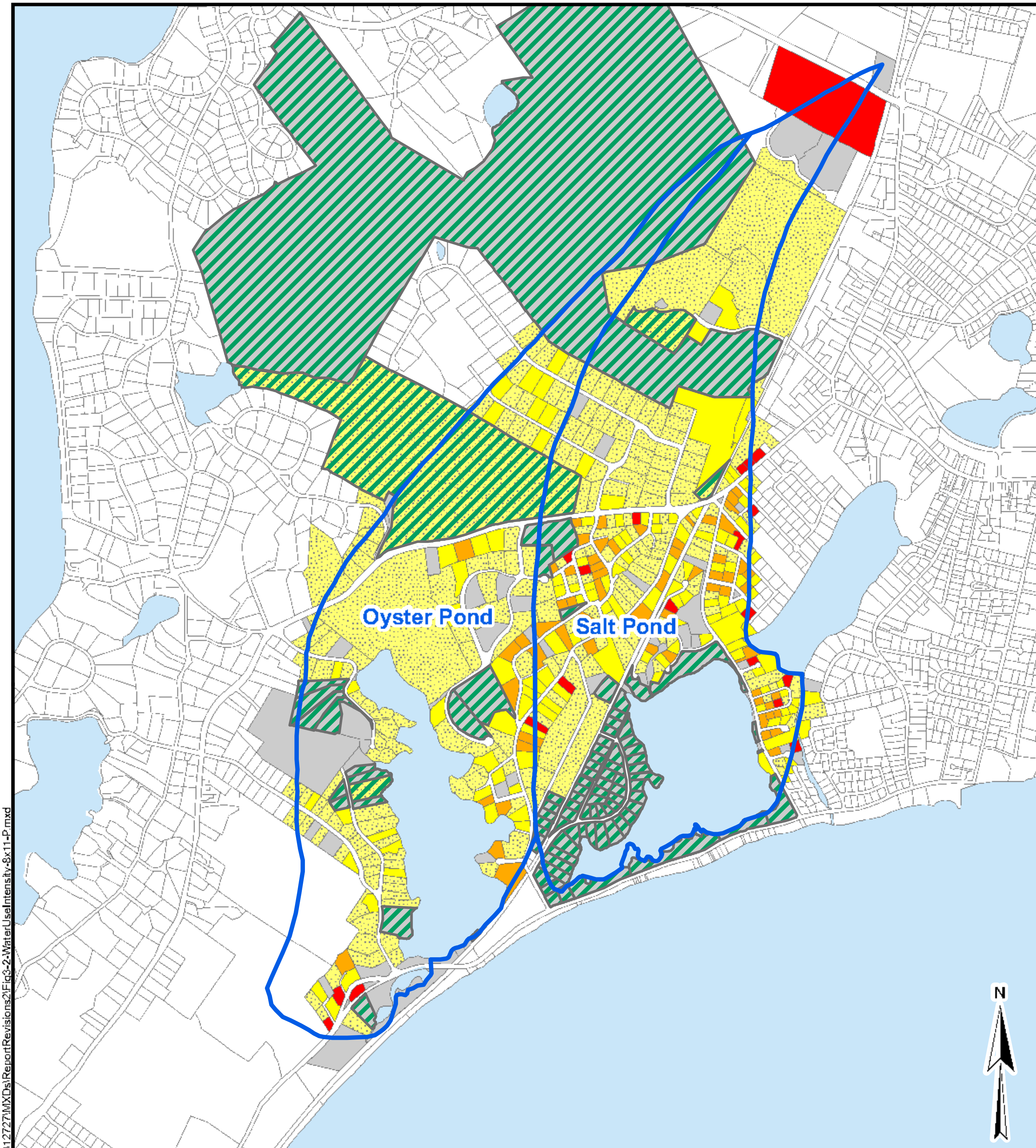
The presence of bacteria in surface waters can have a negative impact on humans or aquatic animals in contact with these waters. Bacterial sources can include road runoff, animal feces (pets, livestock, waterfowl, etc.), or in rare cases, septic tank effluent. In almost all cases, Title 5 systems can be sited such that bacteria in the septic tank effluent are not a threat when the effluent-impacted groundwater reaches nearby surface waters.

While there were documented incidences of human bacteria sources in Oyster Pond in the 1960s, these sources were remedied (Emery, et.al., 1997). Barnstable County Health Department is not aware of any bacteria testing or beach closures at either Oyster Pond or Salt Pond. The Town Health Department is also not aware of any bacteria testing results or beach closures at either pond. Accordingly, no sanitary needs will be attributed to bacteria in surface water. OPET indicates that no bacteria testing has been completed since 1999 after the new weir was installed.

## 3.3 WATER SUPPLY PROTECTION

### 3.3.1 Public Water Supply

The Oyster Pond and Salt Pond watersheds do not include any recharge area for the Town's public water supplies (i.e., groundwater or surface).




Watershed Boundary

**Annual Average GPD per 10,000 SF Lot Area**

- Vacant
- 1 - 54
- 55 - 109
- 110 - 199
- 200+
- Conservation/Recreation

Base data obtained from Town of Falmouth (2013), MassGIS (2009)

0 0.3 0.6 Mile

Falmouth
Oyster Pond CWMP

**Water Use Intensity**

| PROJ NO: 12727 | DATE: Sep 2013 | FIGURE: 3-2 |
|---|---|---|

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### 3.3.2 Private Wells

According to Town records, 6 residential parcels are on private wells in the Oyster Pond watershed and 1 residential parcel is on a private well in the Salt Pond watershed. The Town does not require homeowners to test their wells and is not aware of any water quality issues with these private wells. These homeowners should be encouraged to monitor the water quality in their wells periodically. If nitrate levels are high or are increasing, it would be appropriate to extend public water to these parcels at that time. Each of the residential parcels on private wells could be served with relatively short water main extensions (e.g., Fells Road) or by connection to the public water system at the property line (e.g., Oyster Pond Road, Nonquit Road).

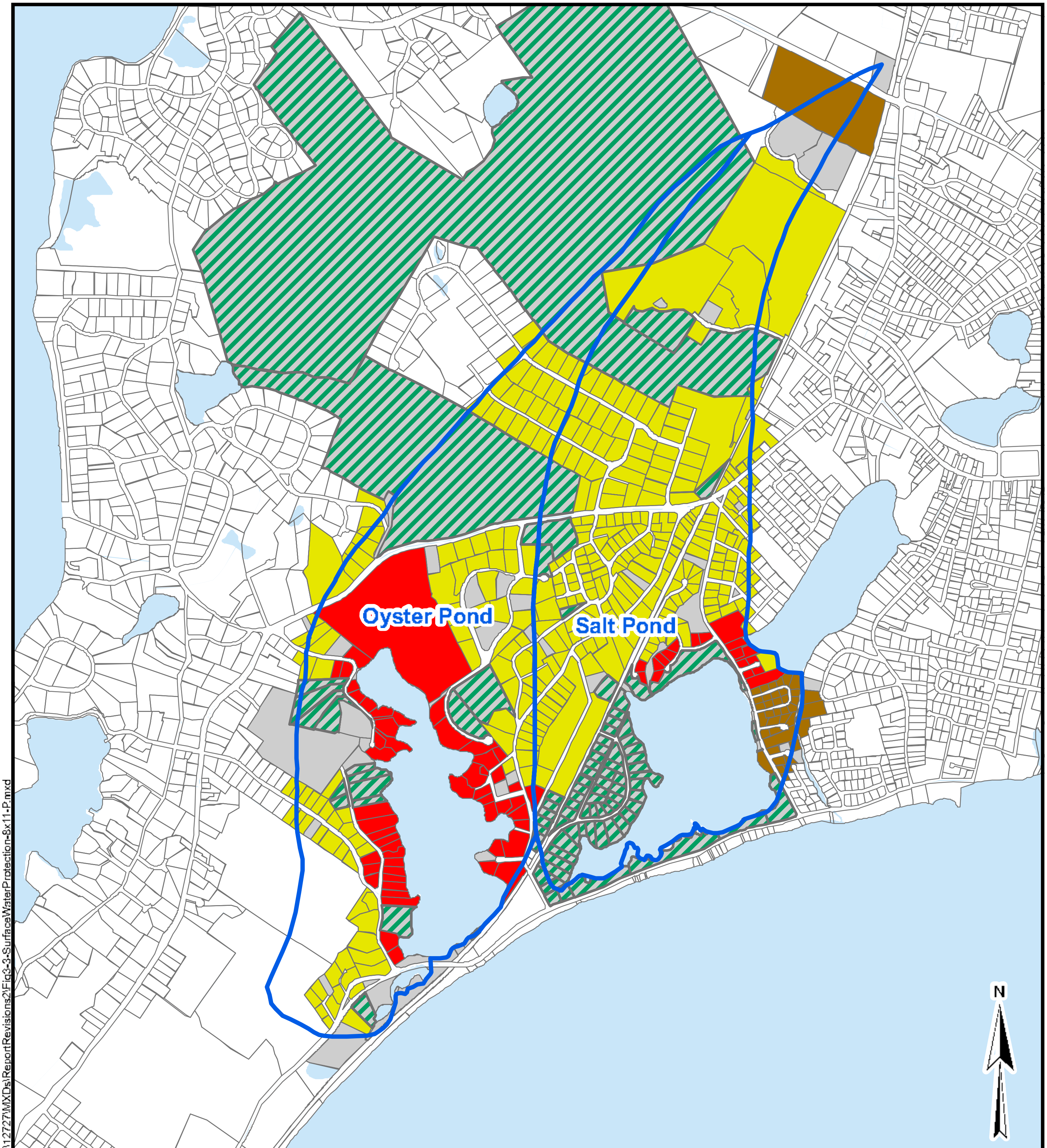
## 3.4 SURFACE WATER PROTECTION

### 3.4.1 Freshwater Ponds

One of the principal causes of water quality degradation in freshwater ponds is phosphorus loading. Phosphorus sources include subsurface wastewater disposal, lawn fertilization, stormwater runoff, and release from bottom sediments. While Oyster Pond (and Salt Pond) are not freshwater ponds, there is some concern that phosphorus sources may contribute to water quality problems in Oyster Pond. Cape Cod Commission guidance suggests that parcels within 300 feet of surface water should be considered for pond protection due to both stormwater runoff (in general and especially from near-shore fertilized lawns) and septic systems (longer-term). We have identified the parcels that are within 300 feet of Oyster Pond and Salt Pond, which are shown on **Figure 3-3**.

For the Oyster Pond watershed, this analysis identified 53 developed parcels within 300 feet of the pond with a current wastewater flow of 10,720 gallons per day (approximately 37% of watershed wastewater flow).

For the Salt Pond watershed, this analysis identified 41 developed parcels within 300 feet of the pond with a current wastewater flow of 4,935 gpd. Of the 41 developed parcels, 22 parcels are currently sewered (2,410 gpd) so wastewater is conveyed out of the watershed to the Town's WWTF. Therefore, only 18 developed parcels with a current wastewater flow of 2,330 gpd fall within the category (approximately 3% of watershed wastewater flow).




Falmouth
Oyster Pond CWMP

**Surface Water Protection Based on Proximity**

| PROJ NO: 12727 | DATE: Sep 2013 | FIGURE: 3-3 |
|---|---|---|

WRIGHT-PIERCE
Engineering a Better Environment

### 3.4.2 Coastal Embayments

Coastal embayments have been the focus of much recent and on-going attention in Falmouth and neighboring towns due to their status as nitrogen-sensitive waters and their functional role in the environment. The Massachusetts Estuaries Project (MEP) includes the study of both the Oyster Pond and Salt Pond watersheds. The Oyster Pond MEP Report was completed in 2006. The Oyster Pond Total Maximum Daily Load (TMDL) Report was completed by DEP in February 2008. The executive summaries from the Oyster Pond MEP Report and TMDL are included in **Appendix A** of this report.

### 3.4.3 TMDL Requirements for Oyster Pond

The MEP Report identifies a variety of nitrogen sources to the Oyster Pond watershed, each with different management approaches. The TMDL specifies the maximum amount of nitrogen which can remain in the watershed in order to restore the ecological balance of the watershed system (the "threshold value"). In this case, the threshold value was set to achieve the Class SA criteria, with a minimum dissolved oxygen value of 6.0 mg/l, in accordance with the State Surface Water Quality Standards set forth in 314 CMR 4.00. The TMDL, which was approved by EPA, identifies the "present watershed load" at 4.474 kg/day and identifies the threshold value for the Oyster Pond watershed at 1.439 kg/day. The TMDL defines present watershed load as the combination of natural background, fertilizer, stormwater runoff and septic system loadings to the watershed at the time of study. A summary of the various nitrogen sources (from the MEP Report) and the threshold value (from the TDML) is presented in **Table 3-2**.

The TMDL does not dictate how the threshold value is to be achieved, so the Town could consider several approaches to achieve the TMDL. For example, the Town could elect to focus more intensively on septic and fertilizer nitrogen sources and ignore stormwater and atmospheric sources. Alternatively, the Town could elect to document reductions in land use/stormwater loads as well as atmospheric sources and focus less intensively on septic and fertilizer nitrogen sources. The former approach is more in line with the expectations identified in the TMDL; whereas the latter approach may require some negotiation and discussion with the regulators.

The primary difference between these two examples in how much *non-septic load reduction* is pursued. To this end, we have identified the following range of non-septic load reduction scenarios to illustrate the importance of these factors:

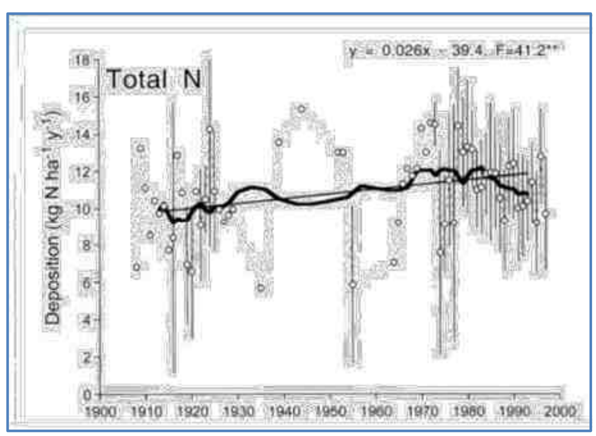
- Scenario 1 assumes that all nitrogen reductions to achieve TMDL-compliance will be accomplished by mitigating septic system loads.
- Scenario 2 assumes that TMDL-compliance credit will be obtained for “small” modifications to nitrogen-loading assumptions for atmospheric deposition to allow for a lesser degree of septic load reduction.
- Scenario 3 assumes that TMDL-compliance credits will be obtained for “medium” modifications to nitrogen-loading assumptions for atmospheric deposition as well as past and future modifications to lawn fertilizer use and stormwater BMPs.
- Scenario 4 assumes that TMDL-compliance credit will be obtained for “large” modifications to nitrogen-loading assumptions for atmospheric deposition as well as past and future modifications to lawn fertilizer use and stormwater BMPs.

These scenarios are presented in **Table 3-3**. Scenario 3 is used in the later tables.

The MEP program has historically treated atmospheric nitrogen deposition as a static value; however, there is a growing body of data which indicates that atmospheric nitrogen deposition is decreasing, especially since the late 1990s when the Clean Air Act and Clean Air Act Amendments were promulgated. Notably, the atmospheric nitrogen deposition concentration used to calibrate the Oyster Pond MEP model is from the late 1990s.

- The Long Island Sound TMDL Report (CTDEP, 2000) included an 18% reduction in atmospheric nitrogen deposition as a part of the required reductions. The CTDEP Long Island Sound Study Work Group is currently re-evaluating the TMDL and expects that atmospheric nitrogen deposition has been reduced more than the 18% value.

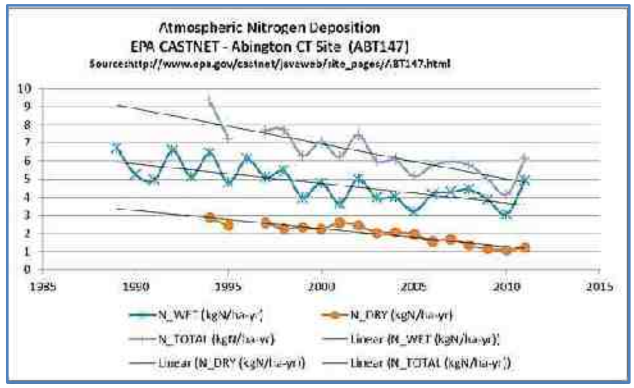
- A paper entitled "Historical Changes in Atmospheric Deposition to Cape Cod", (Bowen, Valiela, 2001) analyzes atmospheric nitrogen deposition trends for the twentieth century in Figure 5 (inset). The conclusions presented in the paper indicate that there was an upward trend through the 20th century; that the data was very variable; and that the upward trend through the 20th century does seem to slow down or even reverse in the last decade. The linear trend in Figure 5 suggests an extrapolated total



nitrogen deposition value of approximately 11 to 12 kg N/ha-yr for the year 2000. This is consistent with the value used by MEP for the Oyster Pond Technical Report (11.1 kgN/ha-yr based on 1.09 mg/1 TN, 40 inches/yr precipitation and 63 acres for Oyster Pond).

- The NHDES "Great Bay Non-Point Source Study" (draft report, May 2013) summarizes the basis for the NHDES nitrogen loading model for the Great Bay Estuary (http:Udes.nh.govIorganization/divisions/water/wmb/coasta1/great-bay-estuarv.htm). Appendix A of the Draft Report summarizes data regarding wet deposition rates, dry deposition rates, NOx emissions estimates and NOx emissions projections through 2020. Referencing EPA estimates, NHDES cites that NOx emissions are expected to decrease by 65% from 2001 to 2020.

- The EPA CASTNET (Clean Air Status and Trends Network) program is a long-term environmental monitoring program. Data collected from selected sites around the country are posted on their website (www.epa.gov/castnet). Data for wet deposition, dry deposition and total deposition for their site in Abington, CT (which is the closest site to Cape Cod) indicate clear trends towards reduced AND (see inset figure). Reductions in total deposition from the late 1990s to 2012 at this site are approximately 20%.




The above data provides a reasonable justification for the use of a 40% reduction in atmospheric nitrogen reduction for the planning period (2000 to 2040), as shown in Scenario 3. For the EPA-approved TMDL, **Table 3-3** indicates that a 77% reduction in the wastewater (septic) nitrogen load must be accomplished if other sources of nitrogen to the watershed are not addressed. By accomplishing and documenting the reductions in non-wastewater sources of nitrogen to the watershed (as shown in **Table 3-3)** over the planning period, the wastewater nitrogen load reduction required will be significantly reduced (i.e., 60% reduction in the wastewater nitrogen load).

The MEP Report and the TMDL identified two alternative dissolved oxygen threshold values (i.e., 5.0 mg/l and 3.8 mg/l). There has been some discussion regarding pursuing these "alternative criteria" and the Town is considering the best course of action for this watershed. If the 3.8 mg/l dissolved oxygen value was determined to be acceptable by DEP and EPA, the reduction in wastewater nitrogen load would be substantially lower than under the EPA-approved TMDL (i.e., a 34% reduction in the wastewater nitrogen load must be accomplished if other sources of nitrogen to the watershed are not addressed and a 17% reduction in the wastewater nitrogen load if accomplishing and documenting reductions in other sources of nitrogen to the watershed). That is, the wastewater load reduction associated with the alternative criteria is only 30% to 40% of that required to meet the EPA-approved TMDL.

Lastly, it is important to understand that the TMDL does not require the same amount of nitrogen removal in each of the subwatersheds. This is because the TMDL indicates that Oyster Pond is over the threshold load, whereas the Lagoon is not. The implications of this factor are presented in **Table 3-4** and **Table 3-5**. Refer to **Figure 2-3** for subwatershed delineations.

**Table 3-4** illustrates the wastewater nitrogen removal requirements, on a subwatershed basis, assuming the EPA-approved TMDL and Scenario 3 non-septic load reductions. This scenario requires that nitrogen from 103 developed properties within the northern subwatersheds (excluding "Oyster Pond South") will need to be removed from the Oyster Pond watershed (i.e., 0 mg/l residual total nitrogen).

**Table 3-5** illustrates the wastewater nitrogen removal requirements, on a subwatershed basis, assuming the EPA-approved TMDL and Scenario 3 non-septic load reductions with *in-watershed effluent disposal*. For this table, we have assumed that a satellite treatment system which is capable of treating to 5 mg/l effluent total nitrogen would be located in an area of the watershed with no natural attenuation. If 5 mg/l residual nitrogen were to remain in the watershed (i.e., a cluster system with in-watershed disposal), a total of 127 developed properties within the northern subwatersheds (again excluding Oyster Pond South) will need to be collected and conveyed to the in-watershed system.

I/A systems which are currently *approved for general use* by DEP cannot meet the TMDL removal requirements, even if every parcel was upgraded. However, there are systems that have *provisional* or *piloting approval* which may achieve the TMDL removal requirements.

**Table 3-2 - Nitrogen Loading to Oyster Pond Watershed based on MEP Report**

| Oyster Pond Embayment | Wastewater (kg/yr) | Lawn Fertilizers (kg/yr) | Impervious Surfaces (kg/yr) | Natural Surfaces (kg/yr) | Present Watershed Load (kg/yr) | Present Watershed Load (kg/day) | Present Atmos. Dep. Load (kg/day) | Benthic Flux (kg/day) | Nitrogen Load-All Sources (kg/day) |
|---|---|---|---|---|---|---|---|---|---|
| Current Conditions | 1364 | 78 | 107 | 60 | 1609 | 4.474 | 0.8 | -1.781 | 3.493 |
| | | | | **EPA-Approved TMDL (SA, Dissolved Oxygen - 6.0 mg/l) >>** | | | | | **1.439** |

**Table 3-3 - Nitrogen Reduction Scenarios for Oyster Pond to meet EPA-Approved TMDL (1.439 kg/day Total Nitrogen)**

| Load Reduction Scenarios | Wastewater (kg/yr) | Lawn Fertilizers (kg/yr) | Impervious Surfaces (kg/yr) | Natural Surfaces (kg/yr) | Watershed Load (kg/yr) | Watershed Load (kg/day) | Atmos. Dep. Load (kg/day) | Benthic Flux (kg/day) | Nitrogen Load-All Sources (kg/day) |
|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 - "None" | **77.0%** | **0%** | **0%** | **0%** | - | - | **0%** | - | - |
| *- Load Remaining* | *314* | *78* | *107* | *60* | *559* | *1.531* | *0.800* | *-0.887* | ***1.44*** |
| Scenario 2 - "Small" | **72.9%** | **0%** | **0%** | **0%** | - | - | **20%** | - | - |
| *- Load Remaining* | *370* | *78* | *107* | *60* | *615* | *1.684* | *0.640* | *-0.887* | ***1.44*** |
| Scenario 3 - "Medium" | **64.2%** | **50%** | **20%** | **0%** | - | - | **40%** | - | - |
| *- Load Remaining* | *488* | *39* | *86* | *60* | *673* | *1.844* | *0.480* | *-0.887* | ***1.44*** |
| Scenario 4 - "Large" | **59.9%** | **50%** | **20%** | **0%** | - | - | **60%** | - | - |
| *- Load Remaining* | *547* | *39* | *86* | *60* | *732* | *2.004* | *0.320* | *-0.887* | ***1.44*** |

**Notes:**

Data from Table IV-4 of MEP Technical Report | Data from Table ES-1 of MEP Technical Report | Data from Table ES-2 of MEP Technical Report

Table IV-4 of the MEP Technical Report indicates a slightly lower present watershed load (1609 kg/yr = 4.408 kg/d) than Table ES-1 of the MEP Technical Report. According to MEP, this is due to a differential between the calculated and measured subwatershed load to Mosquito Creek. The measured subwatershed load to Mosquito Creek is 0.115 kg/d (42 kg/yr), as noted in Table IV-5 of the MEP Technical Report, which was used in the modeling and in Table ES-1 of the MEP Technical Report (4.474 kg/d = 1633 kg/yr).

**Table 3-4 - Septic Nitrogen Removal by Subwatershed for EPA-Approved TMDL with Scenario 3 (out-of-watershed disposal)**

| Oyster Pond Embayment | Wastewater Load, Unatten. (kg/yr) | Removal Req'd to Meet TMDL | Remaining Load, Unatten. (kg/yr) | Natural Atten. | Remaining Load, Atten. (kg/yr) | No. of Developed Parcels | No. of Developed Parcels to be Addressed | No. of Developed Parcels w/in 300-ft Buffer | Additional Parcels Needed Outside Buffer |
|---|---|---|---|---|---|---|---|---|---|
| Current Conditions | **1,364.00** | | | | | 166 | | | |
| 1-Oyster Pond GT10N | 366.46 | 68.2% | 116.53 | 0% | 116.53 | 46 | 31 | - | 31 |
| 2-Oyster Pond GT10W | 43.06 | 68.2% | 13.69 | 0% | 13.69 | 16 | 11 | - | 11 |
| 3-Mosquito Creek Oyster Pond | 10.10 | 68.2% | 3.21 | 30% | 2.25 | 5 | 3 | 3 | - |
| 4-Oyster Pond Main | 860.41 | 68.2% | 273.61 | 0% | 273.61 | 85 | 58 | 48 | 10 |
| 5-Oyster Pond South | 83.85 | 0% | 83.85 | 0% | 83.85 | 14 | - | 2 | - |
| | | | 490.90 | | 489.94 | 166 | 103 | 53 | 52 |
| **Allowable Septic Nitrogen Remaining per Table 3-3, Scenario 3 >>** | | | | | **491.00** | | | | |

**Table 3-5 - Septic Nitrogen Removal by Subwatershed for EPA-Approved TMDL with Scenario 3 (in-watershed disposal with new WWTF)**

| Oyster Pond Embayment | Wastewater Load, Unatten. (kg/yr) | Removal Req'd to Meet TMDL | Remaining Load, Unatten. (kg/yr) | Natural Atten. | Remaining Load, Atten. (kg/yr) | No. of Developed Parcels | No. of Developed Parcels to be Addressed | No. of Developed Parcels w/in 300-ft Buffer | Additional Parcels Needed Outside Buffer |
|---|---|---|---|---|---|---|---|---|---|
| Current Conditions | **1,364.00** | | | | | 166 | | | |
| 1-Oyster Pond GT10N | 366.46 | 84.0% | 58.63 | 0% | 58.63 | 46 | 39 | - | 39 |
| 2-Oyster Pond GT10W | 43.06 | 84.0% | 6.89 | 0% | 6.89 | 16 | 13 | - | 13 |
| 3-Mosquito Creek Oyster Pond | 10.10 | 84.0% | 1.62 | 30% | 1.13 | 5 | 4 | 3 | 1 |
| 4-Oyster Pond Main | 860.41 | 84.0% | 137.66 | 0% | 137.66 | 85 | 71 | 48 | 23 |
| 4A - Hypothetical New WWTF | | | 203.20 | 0% | 203.20 | | | | |
| 5-Oyster Pond South | 83.85 | 0% | 83.85 | 0% | 83.85 | 14 | - | 2 | - |
| | | | 491.86 | | 491.37 | 166 | 127 | 53 | 76 |
| **Allowable Septic Nitrogen Remaining per Table 3-3, Scenario 3 >>** | | | | | **491.00** | | | | |

### 3.4.4 TMDL Requirements – Salt Pond

The MEP is currently working on its study of the Salt Pond watershed; therefore, there is no MEP Report and there are no TMDL requirements for Salt Pond at this time. For the purposes of this needs assessment analysis, we have assumed that the nitrogen removal requirements for Salt Pond will be *similar* to those required for Oyster Pond. Using the Table 3-3/Scenario 3 approach, 65% removal of septic nitrogen load will be utilized as a "placeholder" value. This value will need to be verified when the Salt Pond MEP Report is issued.

### 3.4.5 Summary of Surface Water Protection Needs

Water quality in Oyster Pond and Salt Pond has deteriorated over time based on the increased development that has occurred in both watersheds over the past 50 years. Some modification to wastewater management practices is necessary in order to improve water quality. However, alternative wastewater management practices are costly, and the money spent needs to result in measureable improvement in water quality. The Town should investigate the concept of alternative targets (as described herein) with the DEP. The Town should also quantify the nutrient reduction measures which have been implemented in the watershed since the MEP Report was completed, as they contribute to water quality improvements. The basis for measurement of compliance, particularly with respect to non-septic nitrogen loads will need to be discussed and agreed upon with DEP.

## 3.5 CONVENIENCE AND AESTHETICS

On-site wastewater disposal can be inconvenient and/or aesthetically displeasing to property owners or neighbors under certain circumstances (e.g., mounded systems, I/A system control panels, I/A system enclosures, etc.). These instances can be independent of public health issues or the protection or drinking water or surface waters. Typically, the factors listed below are considered in this category. These factors were discussed with the Town Health Agent, with the results of the discussions indicated in *italics*.

- A record of frequent septage pumping – *records not maintained by the Town;*
- A tight tank – *None identified in the Oyster Pond or Salt Pond watersheds;*

- A mounded septic system – *None identified in the Oyster Pond or Salt Pond watersheds;*
- Septic systems with a high replacement cost – *Kettle Hole Road/Two Ponds Road/Riddle Hill Road neighborhood (approximately 90 parcels in Oyster Pond, Salt Pond and the "direct discharge" watershed to the west of Oyster Pond watershed).*

The use of enhanced (I/A) treatment systems allow for improved nitrogen removal but, in some cases, the above-ground portions of I/A systems may be objectionable to the owner and/or to neighbors. I/A also cost much more to operate on an annual basis than a typical septic system. A list of the locations of I/A systems within the watersheds was obtained from the Barnstable County Department of Health and Environment. Five systems were identified in Oyster Pond watershed and none in the Salt Pond watershed. Of the five Oyster Pond systems, three are located in the Oyster Pond South subwatershed and two are located in the Oyster Pond Main subwatershed (see **Figure 3-1**).

The convenience and aesthetics category will be considered "not applicable" for the Oyster Pond and Salt Pond watersheds because it involves a relatively small number of properties and because the Town considers I/A systems to be an appropriate nutrient management strategy.

## 3.6 SUSTAINABLE ECONOMIC DEVELOPMENT

Wastewater management planning must address both current and future needs. Wastewater flows will increase as vacant lots are developed, as seasonal homes are converted to year-round use (or are occupied a greater percentage of the year), and as commercial development expands to serve the larger population. For "future conditions", the following terms will be used:

- *New Flow.* In wastewater terms, it is appropriate to characterize growth as the difference between "current" conditions and "future" conditions and call it "new" flow.

- *Theoretical Build-Out.* The residential and commercial/industrial/institutional activity associated with the ultimate development to the fullest extent possible under current zoning and other regulations (including Title 5).

- *Practical Build-Out.* The residential and commercial/industrial/institutional activity associated with more realistic assumptions on the extent of build-out, factoring in such concerns as economic realities, other limitations on growth (such as infrastructure capacity), land protection efforts, and retention of estate properties.

- *Planning Horizon.* The residential and commercial/industrial/institutional activity, and its associated wastewater flow, that will be the basis for analyzing wastewater management options and for the design of whatever infrastructure may be recommended. This value could be less than, or equal to, the level of development anticipated at Practical Build-Out. We recommend a planning horizon of 20 to 30 years into the future and suggest a planning horizon for this study is 2040.

Once the build-out conditions are determined, wastewater flow estimates are calculated. The projection of future wastewater quantities are in the form of annual average flow values. The following sections summarize the results of previous build-out assessments for the study area, as well as the build-out assessment which will form the basis for the CWMP.

### 3.6.1 Mass. Estuaries Project Build-Out Assessment

As a part of the 2006 Oyster Pond MEP Report, SMAST estimated residential growth for the Oyster Pond watershed as summarized below. These parcels are identified on the attached **Figure 3-4** (Figure IV-3 from the Oyster Pond MEP Report).

- Miscellaneous development of single-family homes on vacant parcels (16 units).
- Significant subdivision development on one existing parcel partially located in the watershed at Parcel 48 10 009 000C – 7 units (Woods Hole Oceanographic Institute).
- MEP does not typically include “redevelopment” flows in its build-out projections.

Based on the Oyster Pond MEP projections, build-out in this watershed will result in a 11% increase in annual average wastewater flows and loads over current conditions. Since 2004 (after the MEP water use analysis was completed), eight residential units have been constructed in the watershed, leaving 14 units (of the estimated 23 units) remaining to be built. MEP has not completed its analysis of the Salt Pond watershed.

**FIGURE 3-4 – PARCELS IDENTIFIED FOR BUILD-OUT IN OYSTER POND MEP REPORT**

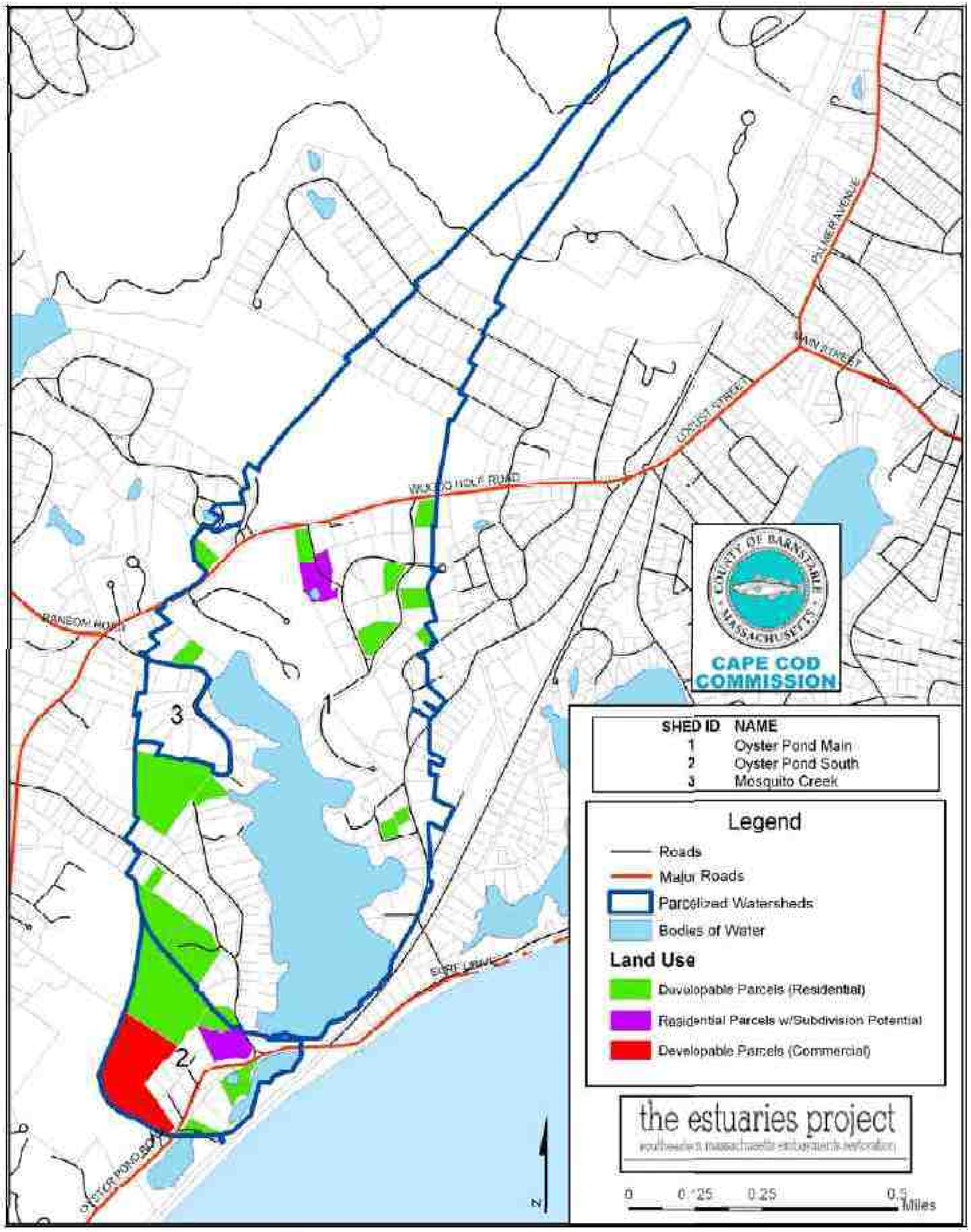



Figure IV-3. Parcels, Parcelized Watersheds, and Developable Parcels in the Oyster Pond watersheds. The Developable Commercial Parcel is owned by WHOI.

### 3.6.2 Cape Cod Commission Build-Out Assessment

As a part of its on-going regional wastewater management planning efforts, the Cape Cod Commission (CCC) estimated potential future residential and commercial development for all of Cape Cod (CCC, July 31, 2012). The CCC estimates of future development within the Oyster Pond and Salt Pond watersheds are summarized below. The build-out parcels identified by the CCC are identified on the attached **Figure 3-5** (residential) and **Figure 3-6** (commercial).

#### 3.6.2.1 Oyster Pond Watershed

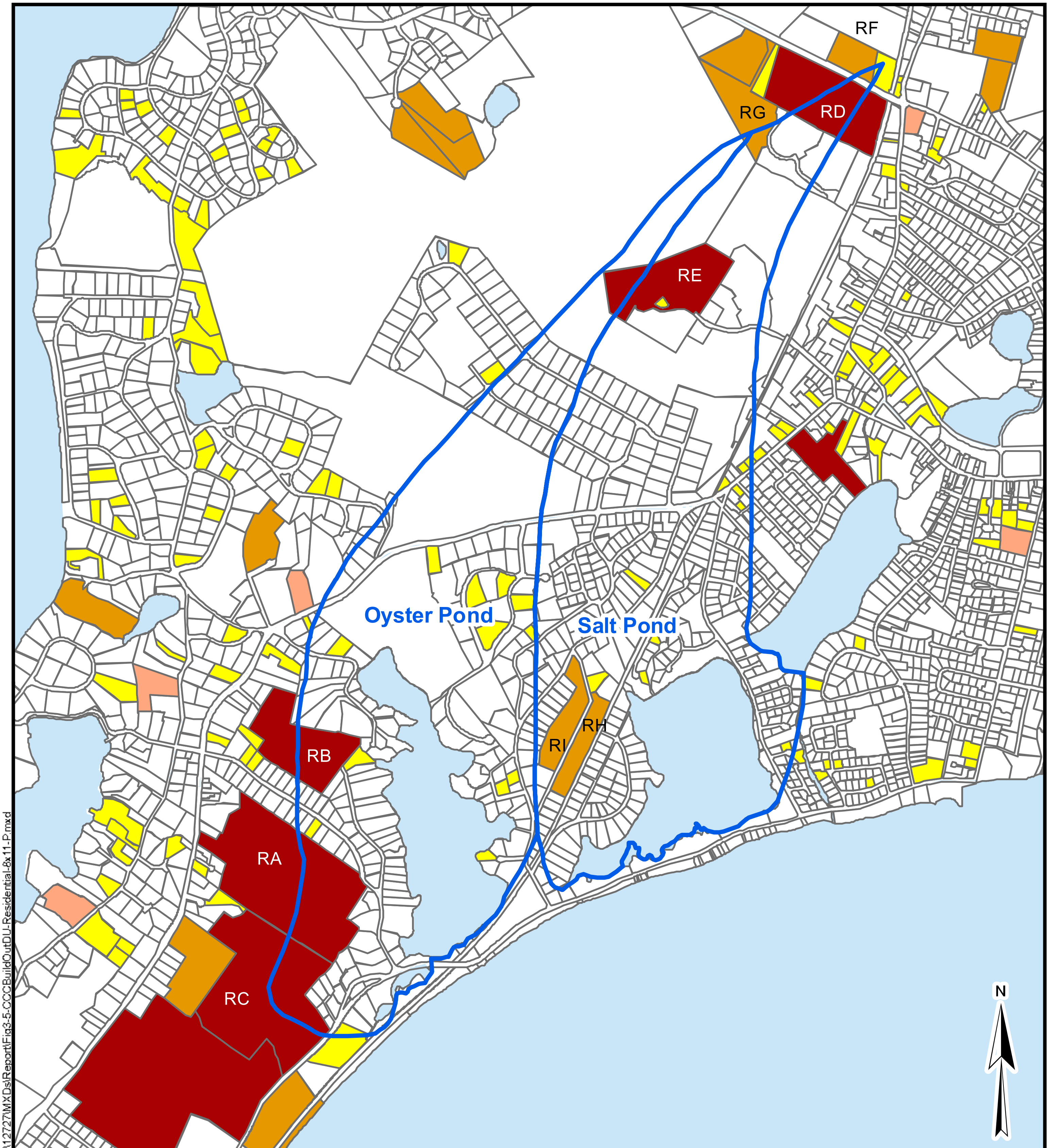
- Miscellaneous development of single family homes on vacant parcels (14 units).
- Significant subdivision development on the following existing parcels partially located in the Oyster Pond watershed as follows. Where indicated, parcels were excluded by Wright-Pierce because the parcel centroid is outside the watershed and development is assumed to occur in the adjacent watershed.

| Key** | Map | Owner | Dwelling Units | Excluded from Analysis |
|---|---|---|---|---|
| RA | 48 09 002 003 | Woods Hole Oceanographic Institute | 39 | X |
| RB | 48 10 009 000C | Woods Hole Oceanographic Institute | 15 | |
| RC | 50 06 009 000A | Woods Hole Oceanographic Institute | 36 | X |

** Note "Key" is a tag for parcel reference and is not intended to be a zoning designation.

- No commercial development.

The future development estimated by the CCC is significantly higher than that estimated by the MEP (i.e., 104 residential units vs 23 residential units) and includes development of some commercially zoned parcels as residential dwelling units. Based on the CCC projections, build-out in this watershed will result in a 40% increase in annual average wastewater flows over current conditions.




Watershed Boundary

**Build-Out Dwelling Units**

0

1

2

3 - 10

> 10

Base data obtained from Town of Falmouth (2013), Cape Cod Commission (2013) MassGIS (2009)

0 0.3 0.6 Mile

Falmouth
Oyster Pond CWMP

**Residential Build-Out CCC Analysis**

| PROJ NO: 12727 | DATE: Jul 2013 | FIGURE: 3-5 |
|---|---|---|

WRIGHT-PIERCE
Engineering a Better Environment

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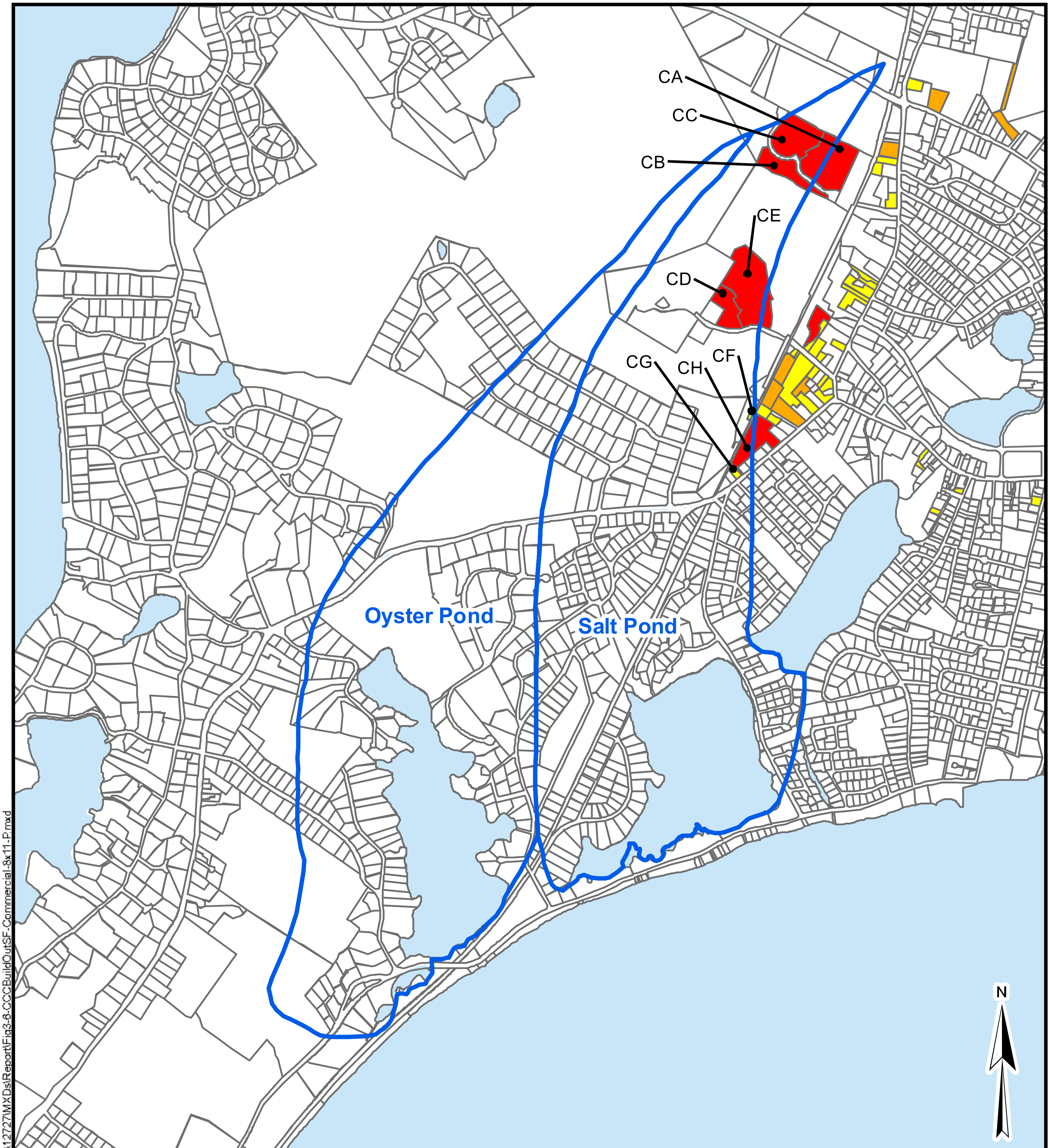


Watershed Boundary

**Build-Out (Sq. Ft.)**

- 1 - 5,000
- 5,000 - 10,000
- > 10,000

Base data obtained from
Town of Falmouth (2013),
Cape Cod Commission (2013)
MassGIS (2009)

0 0.3 0.6
Mile

Falmouth
Oyster Pond CWMP

**Commercial Build-Out**
**CCC Analysis**

PROJ NO: 12727
DATE: Jul 2013

**FIGURE:**
**3-6**

WRIGHT-PIERCE
Engineering a Better Environment

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#### 3.6.2.2 Salt Pond Watershed

- Miscellaneous development of single family homes on vacant parcels (15 units).
- Significant subdivision development on the following existing parcels partially located in the Salt Pond watershed as follows. Where indicated, parcels were excluded by Wright-Pierce because the parcel centroid is outside the watershed and development is assumed to occur in the adjacent watershed.

| Key | Map | Owner | Dwelling Units | Excluded from Analysis |
|---|---|---|---|---|
| RD | 38 01 009A 004 | Falmouth Hospital Assoc. | 19 | Connected to Sewer |
| RE | 38 01 015 000F | Cape Cod Conservatory | 16 | |
| RF | 38 01 008 002 | Visiting Nursing Assoc. | 4 | X |
| RG | 38 01 009 003 | Falmouth Assisted Living | 8 | X |
| RH | 47 01 024 229 | Falmouth Assoc. | 4 | |
| RI | 48 14 037 242 | Falmouth Assoc. | 6 | |

- Miscellaneous commercial development, as follows. All parcels were included in the analysis because the parcel centroid was inside the watershed.

| Key | Map | Owner | Developed Square Feet | Notes |
|---|---|---|---|---|
| CA | 38 01 010 002A | Falmouth Hospital Assoc. | 66,280 sf | Connected to Sewer |
| CB | 38 01 010 003 | Bramblebush Condo Owners | 23,140 sf | |
| CC | 38 01 010B 001A | Bramblebush Condo Owners | 27,470 sf | |
| CD | 38 01 011A 001 | Cape Cod Curling Club | 11,150 sf | |
| CE | 38 01 011B 003 | DMCP Corp. | 24,095 sf | |
| CF | 38 01 014 000 | Wood Lumber Co. | 1,110 sf | |
| CG | 47A 01 049 001A | Locust Street Condo Owners | 870 sf | |
| CH | 47A 01 051 000 | Wood Lumber Co. | 17,680 sf | |
| | | TOTAL | 171,795 sf | |

### 3.6.3 CWMP Build-Out Assessment

The MEP and CCC build-out analyses provided a baseline for the Town to complete its own estimate of future development in these two watersheds for the CWMP. The Town Planner, Town Wastewater Superintendent and Wright-Pierce reviewed the MEP and CCC build-out assessments. It was agreed that the MEP values appear to be a reasonable representation of "practical build-out" and that the values calculated by CCC appear to be a reasonable representation of the "theoretical build-out" condition.

In addition, the Town Planner, Town Wastewater Superintendent and Wright-Pierce reviewed the development potential associated with the following categories: conversion of seasonal homes to year-round homes; addition of accessory apartments in residential zones; addition of apartments over commercial establishments; conversion of commercial properties to residential units; changes to more intensive commercial uses; and conversion to affordable housing (Chapter 40B). The results of this analysis are presented in **Table 3-6**.

**TABLE 3-6: SUMMARY OF REDEVELOPMENT CRITERIA FOR PRACTICAL BUILD-OUT**

| | Oyster Pond | Salt Pond |
|---|---|---|
| Conversion of seasonal homes to year-round homes | Allowance 10% of existing flow | Allowance 10% of existing flow |
| Addition of accessory apartments in residential zones | 0 units | 0 units |
| Addition of apartments over commercial establishments | 0 units | 0 units |
| Conversion of commercial properties to residential units | 0 units | 0 units |
| Conversion of commercial properties to more intensive commercial uses | 0 units | Allowance 30% of commercial growth at an increased flow of 50 gpd/thousand sf |
| Conversion to affordable housing (Chapter 40B) | 0 units | 0 units |

Lastly, the Town Planner, Town Wastewater Superintendent and Wright-Pierce reviewed the ratio of development at practical build-out versus that at theoretical build-out. Based on this review, the Town elected to set the planning horizon for this study at practical build-out. The build-out assessment to be utilized for the CWMP is summarized on **Table 3-7** (Oyster Pond) and **Table 3-8** (Salt Pond).

**TABLE 3-7**

**CWMP BUILD-OUT FOR OYSTER POND WATERSHED**

| Wastewater Flows, gpd | **Oyster Pond Watershed** | | | | | |
|---|---|---|---|---|---|---|
| | Planning Horizon | | Practical Build-out | | Theoretical Build-out | |
| | Flow, gpd | Notes | Flow, gpd | Notes | Flow, gpd | Notes |
| **Current Flows** | | | | | | |
| Residential | 28,780 | | 28,780 | | 28,780 | |
| Commercial | 0 | | 0 | | 0 | |
| Municipal | 113 | | 113 | | 113 | |
| Total | **28,893** | | **28,893** | | **28,893** | |
| **Increases in Flows** | | | | | | |
| Seasonal conversion and home expansion | | | 2,880 | *10% of Ex.* | 7,200 | *25%* |
| Undeveloped but Developable Lots | | | | *18 lots* | | *18 lots* |
| New dwellings and apartments | | | | | | |
| New homes on existing vacant lots | | | 1,590 | *75% of TBO* | 2,114 | *14 du* |
| New homes on new lots | | | 1,130 | *50% of TBO* | 2,265 | *15 du* |
| Accessory apts in residential zones | | | 0 | *n/a* | 0 | *0 apt* |
| Apts. over commercial | | | 0 | *n/a* | 0 | *n/a* |
| Comm. conversion to Residential | | | 0 | *n/a* | 0 | *n/a* |
| Subtotal | | | 2,720 | | 4,379 | |
| Commercial | | | | | | |
| New comm. space on vacant land | | | 0 | *n/a* | 0 | *n/a* |
| Expansion of existing comm. uses | | | 0 | *n/a* | 0 | *n/a* |
| Change to more intensive comm. use | | | 0 | *n/a* | 0 | *n/a* |
| Conversion to 40B housing | | | 0 | *n/a* | 0 | *n/a* |
| Comm. conversion to Residential | | | 0 | *n/a* | 0 | *n/a* |
| Subtotal | | | 0 | *n/a* | 0 | *n/a* |
| Total increase | **5,600** | *100%* | **5,600** | | **11,579** | |
| **Future Flows** | **34,493** | | **34,493** | | **40,472** | |
| *Percentage Increase over Current Conditions* | *19%* | | *19%* | | *40%* | |

# TABLE 3-8

# CWMP BUILD-OUT FOR SALT POND WATERSHED

| Wastewater Flows, gpd | Salt Pond Watershed | | | | | |
|---|---|---|---|---|---|---|
| | Planning Horizon | | Practical Build-out | | Theoretical Build-out | |
| | Flow, gpd | Notes | Flow, gpd | Notes | Flow, gpd | Notes |
| **Current Flows** | | | | | | |
| Residential | 37,236 | | 37,236 | | 37,236 | |
| Commercial | 4,389 | | 4,389 | | 4,389 | |
| Municipal | 39,329 | | 39,329 | | 39,329 | |
| Total | **80,954** | | **80,954** | | **80,954** | |
| **Increases in Flows** | | | | | | |
| Seasonal conversion and home expansion | | | 3,720 | *10% of Ex.* | 9,310 | *25%* |
| Undeveloped but Developable Lots | | | | *11 lots* | | *11 lots* |
| New dwellings and apartments | | | | | | |
| New homes on existing vacant lots | | | 1,430 | *75% of TBO* | 1,905 | *15 du* |
| New homes on new lots (sewered) | | | 1,210 | *50% of TBO* | 2,413 | *19 du* |
| New homes on new lots (unsewered) | | | 1,650 | *50% of TBO* | 3,302 | *26 du* |
| Accessory apts in residential zones | | | 0 | *n/a* | 0 | *0 apt* |
| Apts. over commercial | | | 0 | *n/a* | 0 | *0 apt* |
| Comm. conversion to Residential | | | 0 | *n/a* | 0 | *n/a* |
| Subtotal | | | 4,290 | | 7,620 | |
| Commercial | | | | | | |
| New comm. space on vacant land | | | 3,310 | *50%* | 6,628 | *66,280 sf* |
| Expansion of existing comm. uses | | | 5,290 | *50%* | 10,572 | *105,720 sf* |
| Change to more intensive comm. use | | | 1,250 | *50%* | 2,500 | *50,000 sf* |
| Conversion to 40B housing | | | 0 | *n/a* | 0 | *n/a* |
| Comm. conversion to Residential | | | 0 | *n/a* | 0 | *n/a* |
| Subtotal | | | 9,850 | | 19,700 | |
| Total increase | **17,860** | *100%* | **17,860** | | **36,630** | |
| **Future Flows** | **98,814** | | **98,814** | | **117,584** | |
| *Percentage Increase over Current Conditions* | *22%* | | *22%* | | *45%* | |

### 3.6.4 Summary of CWMP Build-Out Assessment

The build-out assessment to be utilized for this CWMP is summarized on **Table 3-7** and **Table 3-8**. The Town has elected to set the planning horizon for this evaluation at practical build-out.

For Oyster Pond, based on the assumptions described herein, the annual average wastewater flows have been estimated to increase by 19% through the planning horizon. Practical build-out represents approximately 50% of theoretical build-out. Redevelopment (i.e., as opposed to new development on vacant land) represents approximately 51% of new wastewater flows at practical build-out.

For Salt Pond, based on the assumptions described herein, the annual average wastewater flows have been estimated to increase by 22% through the planning horizon. Practical build-out represents approximately 50% of theoretical build-out. Redevelopment represents approximately 57% of new wastewater flows at practical build-out.

Lastly, it is our determination that the CWMP build-out assessment presented herein is flow-neutral. The CWMP build-out assessment does not allow for more wastewater flow than would be allowed under Title 5 and other Town zoning, land use, ordinances and by-laws.

## 3.7 AGGREGATED NEEDS

The single largest need for the Oyster Pond and Salt Pond watersheds is protection of surface waters from nutrient enrichment based on the findings of the 2006 MEP Report and the 2008 TMDL. While there are numerous on-site wastewater systems which will require upgrades during the planning period, the vast majority of these systems can be upgraded on-site. That is, this need can be satisfied by owner-implemented replacement of the existing system with a Title 5 compliant system and, therefore, does not represent a municipal need. While it is important to characterize wastewater needs in these separate categories, it is also important to recognize that numerous properties could fall into more than one category of need. However, in the case of Oyster Pond and Salt Pond, the only needs are surface water protection.

It is possible (and necessary) to identify specific parcels for alternative wastewater management when sanitary conditions or water supply protection are involved. In case of coastal embayment surface water protection, the specific lot identity is less important. Lots will need to be prioritized (if possible) based on their proximity to the surface water (restoration will occur faster if near-shore septic systems are eliminated), water use (proportional to the wastewater volume), density of development, and occupancy status (typically year-round homes produce more nitrogen than seasonal homes). Parcels with the follow attributes were prioritized for alternative wastewater management:

- Parcels within 300 ft of the ponds
- Parcels with previous Title 5 variances
- Parcels with water use greater than 200,000 gallons per year
- Parcels with higher density development (less frontage)
- Parcels within the 10-year time of travel zone defined by MEP
- Parcels with CWMP build-out development on vacant lots

**Figure 3-7** was prepared to illustrate the magnitude of parcels which will be impacted in order to address the aggregated needs based on Scenario 3 ("medium") described earlier in this section. Watershed parcels that are within 300 feet of surface water are indicated in red. The additional parcels needing alternative wastewater management to achieve "alternate criteria" are indicated in yellow. Next, the additional parcels needing alternative wastewater management to achieve the EPA-approved TMDL under *current conditions* are indicated in green. Lastly, the additional parcels needing alternative wastewater management to achieve the EPA-approved TMDL under *future conditions* are indicated in blue. In-watershed effluent disposal will increase the number of parcels requiring alternative wastewater management. The aggregated needs for Oyster Pond are presented in **Table 3-9** and the aggregated needs for Salt Pond are presented in **Table 3-10**.

Since Oyster Pond is largely residential, the percentage of current *developed lots* requiring alternative wastewater management (63%) is relatively close to the percentage of current *wastewater flows* requiring alternative management (65%). Since the watershed nitrogen loading already exceeds the TMDL threshold load, <u>all</u> new flow in the watershed requires alternative wastewater management.

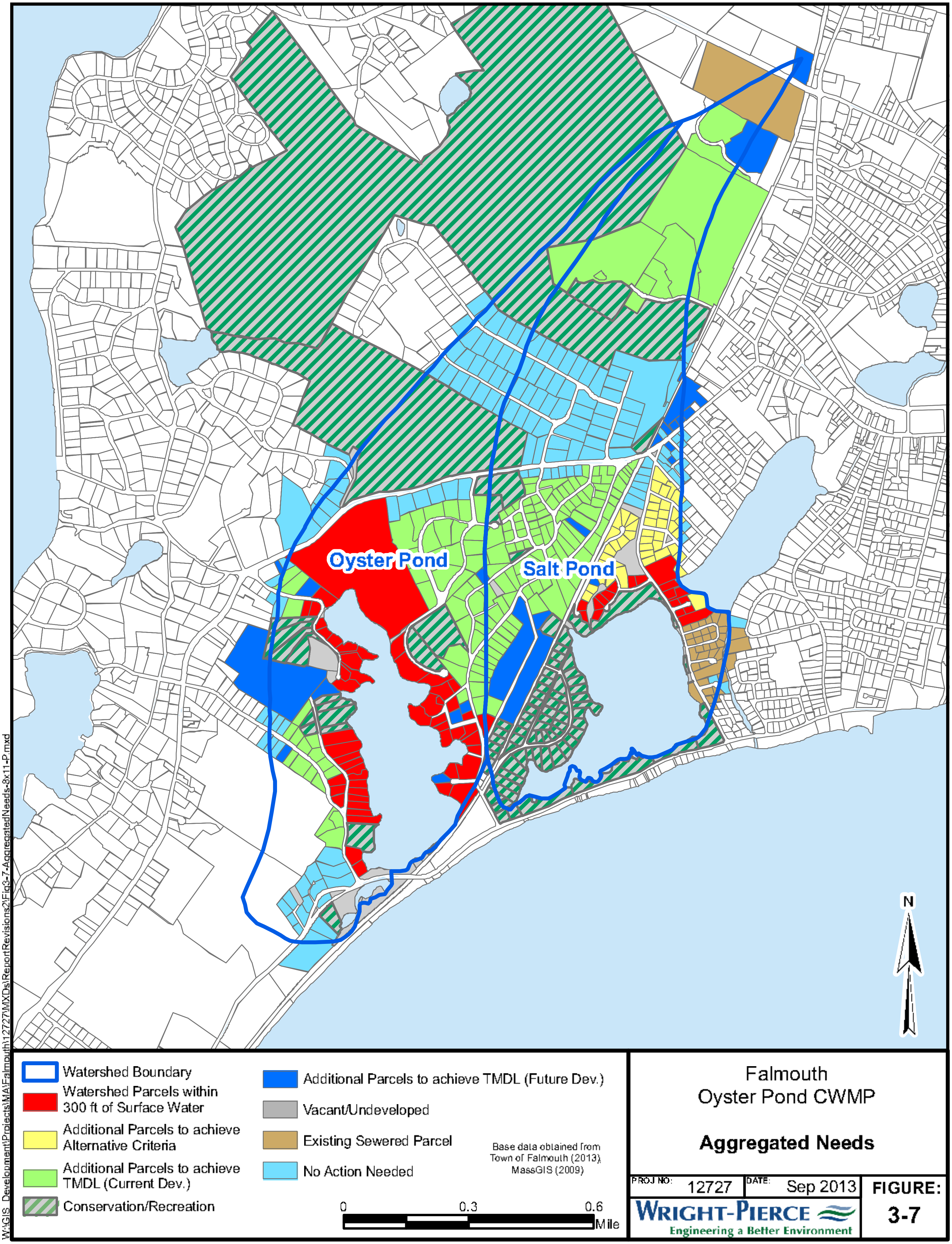


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**Table 3-9 - Wastewater Management Needs for Oyster Pond (out-of watershed disposal)**

| | Current | | Increase at Plan. Horizon | |
|---|---|---|---|---|
| | Parcels | Wastewater Flow (gpd) | New Units | Wastewater Flow (gpd) |
| **Sanitary** | 0 | 0 | 0 | 0 |
| **Water Supply Protection** | 0 | 0 | 0 | 0 |
| **Surface Water Protection** | | | | |
| Within 300' of Surface Water | 53 | 10,720 | 0 | 0 |
| Additional Needed for "Alternate Criteria" | 0 | 0 | 0 | 0 |
| Additional Needed for EPA-Approved TMDL | 52 | 8,200 | 0 | 0 |
| Seasonal Conversions (Note 1) | 0 | 0 | 0 | 2,880 |
| Dev. on Vacant/New Lots - Residential | 0 | 0 | 18 | 2,720 |
| **Convenience & Aesthetics** | 0 | 0 | 0 | 0 |
| **Economic Development beyond Flow Neutral** | 0 | 0 | 0 | 0 |
| **TOTAL** | 105 | 18,920 | 18 | 5,600 |
| *% of Total Developed Parcels* | *63%* | - | - | - |
| *% of Total Current Flow in Watershed* | - | *65%* | - | - |
| *% of Total New Flow in Watershed* | - | - | - | *100%* |

*Note 1) Not parcel-specific.*

**Table 3-10 - Wastewater Management Needs for Salt Pond (out-of watershed disposal)**

| | Current | | Increase at Plan. Horizon | |
|---|---|---|---|---|
| | Parcels | Wastewater Flow (gpd) | New Units | Wastewater Flow (gpd) |
| **Sanitary** | 0 | 0 | 0 | 0 |
| **Water Supply Protection** | 0 | 0 | 0 | 0 |
| **Surface Water Protection** | | | | |
| Within 300' of Surface Water | 18 | 2,330 | 0 | 0 |
| Additional Needed for "Alternate Criteria" (21%) | 45 | 6,090 | 0 | 0 |
| Additional Needed for EPA-Approved TMDL (65%) | 102 | 18,050 | 0 | 0 |
| Seasonal Conversions (Note 1) | 0 | 0 | 0 | 3,720 |
| Dev. on Vacant/New Lots - Residential | 0 | 0 | 24 | 3,080 |
| Dev. on Vacant Lots - Commercial (Note 2) | 0 | 0 | 0 | 3,310 |
| Redevelopment - Commercial (Note 3) | 0 | 0 | 7 | 5,290 |
| Redevelopment - Commercial (Notes 1, 4) | 0 | 0 | 0 | 1,250 |
| **Convenience & Aesthetics** | 0 | 0 | 0 | 0 |
| **Economic Development beyond Flow Neutral** | 0 | 0 | 0 | 0 |
| **TOTAL** | 165 | 26,470 | 31 | 16,650 |
| *% of Total Developed Parcels* | *58%* | - | - | - |
| *% of Total Current Flow in Watershed (Note 5)* | - | *65%* | - | - |
| *% of Total New Flow in Watershed (Note 5)* | - | - | - | *100%* |

*Notes: 1) Not parcel-specific.*
*2) Parcel connected to existing sewer (Hospital).*
*3) 86,000 sf.*
*4) 25,000 sf.*
*5) Excluding flow from existing sewered parcels (Table 2-11).*

Since Salt Pond has several commercial and institutional users with high water use, the percentage of developed lots requiring alternative wastewater management (58%) is several points lower than the percentage of current wastewater flows requiring alternative management (65%). Similarly, since the watershed nitrogen loading already exceeds the presumed TMDL threshold load, all new flow in the watershed requires alternative wastewater management.

Given that wastewater management needs related to nitrogen control to achieve the TMDL are not parcel-specific, there is significant flexibility in how the TMDL will be attained. There may be some parcels which are in need of an upgraded or replacement system; clearly, these parcels would be good candidates. This information should be solicited from property owners.

### 3.8 SUMMARY OF WOODS HOLE GROUP REVIEW

Woods Hole Group (WHG) was retained to perform a scientific review of: 1) the water quality data collected since the MEP Technical Report was published; and 2) the MEP methodology as it pertains to assessing compliance with the model inputs and outputs. The WHG report is included as **Appendix C**. A brief summary of the WHG findings is provided below:

- The water quality data indicates a highly variable system. This variability is a function of watershed inputs and of the natural phenomena described above. A rigid TMDL framework does not provide flexibility to address the natural variability in this system.

- Maintenance dredging of the Trunk River sill is an important aspect to allowing freshwater (and nutrient) outflow from Oyster Pond.

- The MEP report provides all data in terms of "total nitrogen" and does not provide a breakdown of the fractionation (or types) of nitrogen. The water quality data collected by OPET since 2004 does not include all the components necessary to determine total nitrogen (i.e., particulate organic nitrogen, or PON, is excluded from the OPET data set). *Unfortunately, this does not allow for direct comparison of the two data sets unless or until the MEP fractionation is made available*. That said, limited historic fractionation data from the Falmouth Pond Watchers allows for estimation of total nitrogen for the OPET data. Based on this estimation, it appears that the water column total nitrogen concentrations have decreased since the MEP report was published. This apparent reduction is consistent with efforts made by residents in the watershed to reduce the watershed nitrogen load (refer to Table 3 in Appendix C) as well as with reduction in atmospheric NOx concentrations resulting from EPA air pollution reduction regulations. Further data review should be performed if/when MEP data can be obtained.

- The MEP modeling approach uses a set of conservative assumptions and conditions to model a static condition aimed at meeting the State water quality classification criteria (*e.g., "what reduction in water column nitrogen concentration is required to increase the minimum dissolved oxygen concentration from 2.0 mg/l to 6.0 mg/l at a salinity of 2 ppt and a temperature of 25degC at a depth of 4 meters assuming a [inverse] linear relationship between dissolved oxygen concentration and water column nitrogen concentration"*). This approach is not flexible enough to address the natural factors which control the Oyster Pond system; however, additional modeling is not recommended. Rather, a probabilistic approach to assessing compliance with the TMDL criteria, which appropriately recognizes the unique characteristics and natural factors associated with Oyster Pond, needs to be incorporated into the monitoring program. Ideally, this approach would allow for temporal variation in dissolved oxygen concentration similar to the approach utilized by EPA for the Chesapeake Bay ("Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll *a* for the Chesapeake Bay and its Tidal Tributaries", 2003).

- Based on a review of the Oyster Pond data, phosphorus appears to be a limiting nutrient under certain conditions and certain times of year. This phenomena has also been observed in the Gulf of Mexico at the eastern periphery of the Mississippi River/Gulf of Mexico confluence ("Evaluation of the Role of Nitrogen and Phosphorus in Causing or Contributing to Hypoxia in the Northern Gulf", EPA, 2004). This means that phosphorus management also needs to be included in the alternatives analysis.

- Given its location and elevation, Oyster Pond will be sensitive to the impacts of sea level rise, climate change and storm intensity. The Trunk River sill elevation will likely require more intensive management based on increased storm intensity and/or frequency and changes in long shore drift. Pond water levels will likely rise as sea level rises. Density and thermal stratification patterns will be modified based on more intense storms and/or more frequent backflow or overwash. Benthic and finfish habitat could be impacted by changes in the frequency and duration of thermal stress events, including low dissolved oxygen concentrations related to temperature.

## 3.9 IMPLICATIONS OF NO ACTION

It is standard practice in wastewater management planning to consider the implications of taking no action. For the Oyster Pond and Salt Pond watersheds, taking no action would result in the continued use of traditional on-site wastewater systems (except for those limited areas in Salt Pond where sewers are currently in place). Since most categories of need have been ruled out (i.e., ensuring sanitary conditions; protection of public and private drinking water supplies; addressing convenience and aesthetic issues; and enabling sustainable economic development), the only category of need that would be "un-addressed" is surface water protection.

Taking no action will result in watershed nutrient loadings which will remain above the threshold criteria established in the EPA-approved TMDL. Surface water quality will not improve and will likely be continually degraded. Algae blooms (including the associated odor issues, reduction in water clarity or poor habitat conditions) will continue to vary on a periodic and unpredictable frequency. Further, taking no action could subject the Town to eventual enforcement action by DEP for non-compliance with TMDL Report requirements.

It is important to recognize that, because the water column nitrogen concentration is relatively insensitive to increases or reductions in watershed nitrogen loading, significant nitrogen removal will be required before the water column nitrogen concentration is reduced. This factor, in conjunction with the significant natural variability in the Oyster Pond system, may require longer time frames to achieve TMDL criteria and consistent water quality improvement. Lastly, even with watershed nitrogen reduction, the seasonal turnover of the pond when thermal and/or density stratification "sets up" or "breaks down" will result in intermittent reductions in water quality.

# SECTION 4

# NEXT STEPS

This section presents the "next steps" for the Town in the CWMP process:

1. Circulate the Draft Report to the WQMC and meet with the WQMC. Once approved by the WQMC, make the Draft Report available to the interested public and potentially to DEP and CCC.

2. Decide whether to proceed with establishing “alternate criteria”. This approach would involve first developing documentation for review by DEP and then subsequently meeting with DEP. This process could likely be a difficult technical and legal endeavor.

3. Quantify the nutrient reduction effectiveness of the measures which have been implemented since the MEP Report was completed when MEP data is made available. Specifically:
   a. How much “credit” can be accrued for physical improvements made in the watershed (e.g., fertilizer reductions, stormwater infrastructure modifications) since the MEP data set was collected (late 1990s to 2003).
   b. How much credit can be accrued for reduction in atmospheric sources of nitrogen related to EPA air pollution control regulations which have been in-force since the late 1990s.
   c. How much credit can be accrued for water quality improvements based on the OPET monitoring data collected since 2005.

4. Request additional MEP model runs for the following:
   a. Update the MEP model based on current water quality data, implemented measures and a non-linear relationship between nitrogen and dissolved oxygen. Update to inputs for Mosquito Creek watershed based on new data.

5. Begin to collect the following data for the purposes of developing a long-term record:
    a. Establish a rain gauge sample location (either an existing installation or a new installation) to collect rain water for periodic laboratory analysis for NOx. Develop a sampling program to establish a long-term, local record for atmospheric deposition.
    b. Deploy a sonde at OP3 set at the 4m interval to collect continuous data record for salinity, temperature and dissolved oxygen. This data collection would serve to establish baseline information for eventually assessing TMDL compliance, including the variability in the density/thermal stratification layer over time.
    c. Establish an "algae bloom report form". This form would be used to record the pond conditions and weather conditions during an algae bloom event.

6. Initiate the Identification and Evaluation of Alternatives phase of the CWMP.

7. Consider adding attribute fields to the Assessor's database to indicate the type of wastewater disposal system, age of system and whether there are any environmentally significant Title 5 variances. The Town should also consider scanning the paper copy records maintained by the Health Department and Board of Health for data security purposes. These efforts would be labor intensive, but would make this valuable information more readily available to Health Department and Wastewater Department staff.

# APPENDIX A
## Executive Summaries
## of Relevant Mass. Estuaries Project Technical Reports

University of Massachusetts Dartmouth
The School for Marine Science and Technology

Massachusetts Department of Environmental Protection

# Massachusetts Estuaries Project

# Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Oyster Pond Falmouth, Massachusetts

# Executive Summary

## 1. Background

This report presents the results generated from the implementation of the Massachusetts Estuaries Project's Linked Watershed-Embayment Approach to the Oyster Pond embayment system, a coastal embayment within the Town of Falmouth, Massachusetts. Analyses of the Oyster Pond embayment system was performed to assist the Town with up-coming nitrogen management decisions associated with the Towns' current and future wastewater planning efforts, as well as wetland restoration, anadromous fish runs, shell fishery, open-space, and harbor maintenance programs. As part of the MEP approach, habitat assessment was conducted on the embayment based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. Nitrogen loading thresholds for use as goals for watershed nitrogen management are the major product of the MEP effort. In this way, the MEP offers a science-based management approach to support the Town of Falmouth resource planning and decision-making process. The primary products of this effort are: (1) a current quantitative assessment of the nutrient related health of the Oyster Pond embayment, (2) identification of all nitrogen sources (and their respective N loads) to embayment waters, (3) nitrogen threshold levels for maintaining Massachusetts Water Quality Standards within embayment waters, (4) analysis of watershed nitrogen loading reduction to achieve the N threshold concentrations in embayment waters, and (5) a functional calibrated and validated Linked Watershed-Embayment modeling tool that can be readily used for evaluation of nitrogen management alternatives (to be developed by the Town) for the restoration of the Oyster Pond embayment system.

***Wastewater Planning:*** As increasing numbers of people occupy coastal watersheds, the associated coastal waters receive increasing pollutant loads. Coastal embayments throughout the Commonwealth of Massachusetts (and along the U.S. eastern seaboard) are becoming nutrient enriched. The elevated nutrients levels are primarily related to the land use impacts associated with the increasing population within the coastal zone over the past half-century.

The regional effects of both nutrient loading and bacterial contamination span the spectrum from environmental to socio-economic impacts and have direct consequences to the culture, economy, and tax base of Massachusetts's coastal communities. The primary nutrient causing the increasing impairment of our coastal embayments is nitrogen, with its primary sources being wastewater disposal, and nonpoint source runoff that carries nitrogen (e.g. fertilizers) from a range of other sources. Nitrogen related water quality decline represents one of the most serious threats to the ecological health of the nearshore coastal waters. Coastal embayments, because of their shallow nature and large shoreline area, are generally the first coastal systems to show the effect of nutrient pollution from terrestrial sources.

In particular, the Oyster Pond embayment system within the Town of Falmouth is at risk of eutrophication (over enrichment) from enhanced nitrogen loads entering through groundwater and surface water from the increasingly developed watersheds to these coastal salt ponds. Eutrophication is a process that occurs naturally and gradually over a period of tens or hundreds of years. However, human-related (anthropogenic) sources of nitrogen may be introduced into ecosystems at an accelerated rate that cannot be easily absorbed, resulting in a phenomenon known as cultural eutrophication. In both marine and freshwater systems, cultural eutrophication results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources.

The Town of Falmouth has recognized the severity of the problem of eutrophication and the need for watershed nutrient management and is currently developing a Comprehensive Wastewater Management Plan, which it plans to rapidly implement. The Town of Falmouth has also completed and implemented wastewater planning in other regions of the Town not associated with the Oyster Pond embayment system. The Town has nutrient management activities related to their tidal embayments, which have been associated with the MEP effort in Great/Perch Pond, Green Pond and Bournes Pond embayment systems as well as other embayments in the Town of Falmouth such as Little Pond and West Falmouth Harbor. The Town of Falmouth and work groups have recognized that a rigorous scientific approach yielding site-specific nitrogen loading targets was required for decision-making and alternatives analysis. The completion of this multi-step process has taken place under the programmatic umbrella of the Massachusetts Estuaries Project, which is a partnership effort between all MEP collaborators and the Town. The modeling tools developed as part of this program provide the quantitative information necessary for the Towns' nutrient management groups to predict the impacts on water quality from a variety of proposed management scenarios.

***Nitrogen Loading Thresholds and Watershed Nitrogen Management:*** Realizing the need for scientifically defensible management tools has resulted in a focus on determining the aquatic system's assimilative capacity for nitrogen. The highest-level approach is to directly link the watershed nitrogen inputs with embayment hydrodynamics to produce water quality results that can be validated by water quality monitoring programs. This approach when linked to state-of-the-art habitat assessments yields accurate determination of the "allowable N concentration increase" or "threshold nitrogen concentration". These determined nitrogen concentrations are then directly relatable to the watershed nitrogen loading, which also accounts for the spatial distribution of the nitrogen sources, not just the total load. As such, changes in nitrogen load from differing parts of the embayment watershed can be evaluated relative to the degree to which those load changes drive embayment water column nitrogen concentrations toward the "threshold" for the embayment system. To increase certainty, the "Linked" Model is independently calibrated and validated for each embayment.

***Massachusetts Estuaries Project Approach:*** The Massachusetts Department of Environmental Protection (DEP), the University of Massachusetts – Dartmouth School of Marine Science and Technology (SMAST), and others including the Cape Cod Commission (CCC) have undertaken the task of providing a quantitative tool to communities throughout southeastern Massachusetts (the Linked Watershed-Embayment Management Model) for nutrient management in their coastal embayment systems. Ultimately, use of the Linked Watershed-Embayment Management Model tool by municipalities in the region results in effective screening of nitrogen reduction approaches and eventual restoration and protection of valuable coastal resources. The MEP provides technical guidance in support of policies on nitrogen loading to embayments, wastewater management decisions, and establishment of nitrogen Total Maximum Daily Loads (TMDLs). A TMDL represents the greatest amount of a pollutant that a waterbody can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation and fishing. The MEP modeling approach assesses available options for meeting selected nitrogen goals that are protective of embayment health and achieve water quality standards.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach, which links watershed inputs with embayment circulation and nitrogen characteristics.

The Linked Model builds on well-accepted basic watershed nitrogen loading approaches such as those used in the Buzzards Bay Project, the CCC models, and other relevant models. However, the Linked Model differs from other nitrogen management models in that it:

- requires site-specific measurements within each watershed and embayment;
- uses realistic “best-estimates” of nitrogen loads from each land-use (as opposed to loads with built-in “safety factors” like Title 5 design loads);
- spatially distributes the watershed nitrogen loading to the embayment;
- accounts for nitrogen attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes nitrogen regenerated within the embayment;
- is validated by both independent hydrodynamic, nitrogen concentration, and ecological data;
- is calibrated and validated with field data prior to generation of “what if” scenarios.

The Linked Model Approach’s greatest assets are its ability to be clearly calibrated and validated, and its utility as a management tool for testing “what if” scenarios for evaluating watershed nitrogen management options.

For a comprehensive description of the Linked Model, please refer to the *Full Report: Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. A more basic discussion of the Linked Model is also provided in Appendix F of the *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. The Linked Model suggests which management solutions will adequately protect or restore embayment water quality by enabling towns to test specific management scenarios and weigh the resulting water quality impact against the cost of that approach. In addition to the management scenarios modeled for this report, the Linked Model can be used to evaluate additional management scenarios and may be updated to reflect future changes in land-use within an embayment watershed or changing embayment characteristics. In addition, since the Model uses a holistic approach (the entire watershed, embayment and tidal source waters), it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries. Unlike many approaches, the Linked Model accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics and accommodates the spatial distribution of these processes. For an overview of several management scenarios that may be employed to restore embayment water quality, see *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm.

***Application of MEP Approach:*** The Linked Model was applied to the Oyster Pond embayment system by using site-specific data collected by the MEP and water quality data from the Falmouth PondWatch Program (see Chapter 2). Evaluation of upland nitrogen loading was conducted by the MEP, data was provided by the Town of Falmouth Planning Department, and watershed boundaries delineated by USGS. This land-use data was used to determine watershed nitrogen loads within the Oyster Pond embayment system and each systems sub-embayments as appropriate (current and build-out loads are summarized in Table IV-3). Water quality within a sub-embayment is the integration of nitrogen loads with the site-specific estuarine circulation. Therefore, water quality modeling of this controlled estuary included a thorough evaluation of the hydrodynamics of the estuarine system. Estuarine hydrodynamics control a variety of coastal processes including tidal flushing, pollutant dispersion, tidal currents, sedimentation, erosion, and water levels. In Oyster Pond, the hydrodynamic regime is dominated by freshwater inputs to the system from groundwater recharge, surface flow run-off from the watershed, and direct precipitation to the pond's surface. Though tides in Vineyard Sound are only occasionally high enough to cause seawater flows into the pond, tidal flushing is still important to the stability and health of this estuary, mostly by its effect on salinity in the pond. Once the hydrodynamics of the system was quantified, transport of nitrogen was evaluated from current information developed by the numerical models.

A two-dimensional depth-averaged hydrodynamic model based upon the tidal currents and water elevations was employed for the Oyster Pond embayment system. The hydrodynamic modeling effort for Oyster Pond was similar to other estuarine systems modeled as part of the MEP, though the tidally restricted nature of this system required modifications to the modeling and analysis techniques that have been applied to simpler embayments. From the perspective of hydrodynamics, the most important difference between the Oyster Pond system and other estuaries in Falmouth is the adjustable salinity control/fish weir in the inlet channel to the Pond.

Once the hydrodynamic properties of the estuarine system were computed, two-dimensional water quality model simulations were used to predict the dispersion of the nitrogen at current loading rates. Using standard dispersion relationships for estuarine systems of this type, the water quality model and the hydrodynamic model was then integrated in order to generate estimates regarding the spread of total nitrogen from the site-specific hydrodynamic properties. The distributions of nitrogen loads from watershed sources were determined from land-use analysis while nitrogen entering Falmouth's coastal embayment was quantified by direct measurement of stream nutrient concentrations and freshwater flow, predominantly groundwater, in streams discharging directly to the embayment. Boundary nutrient concentrations in Vineyard Sound source waters were taken from water quality monitoring data. Measurements of current salinity distributions throughout the estuarine waters of the Oyster Pond embayment system was used to calibrate the water quality model, with validation using measured nitrogen concentrations (under existing loading conditions). The underlying hydrodynamic model was calibrated and validated independently using water elevations measured in time series throughout the embayments.

***MEP Nitrogen Thresholds Analysis:*** The approach for determining nitrogen loading rates, which will maintain acceptable habitat quality throughout an embayment system, is to first identify a sentinel location within the embayment and second, to determine the nitrogen concentration within the water column which will restore that location to the desired habitat quality. The sentinel location is selected such that the restoration of that one site will necessarily bring the other regions of the system to acceptable habitat quality levels. Once the sentinel site and its target nitrogen level are determined, the Linked Watershed-Embayment Model is used to sequentially adjust nitrogen loads until the targeted nitrogen concentration is achieved.

Oyster Pond differs from most other estuaries in its lack of horizontal gradients in salinity, nitrogen, and nitrogen related parameters (chlorophyll a, D.O., transparency, etc.). Therefore, selection of the sentinel station was not based on horizontal gradients and their response to changing nitrogen loads. Instead, the sentinel station was selected to best capture the overall conditions of the Pond waters.

The nitrogen thresholds developed in Section VIII-2 were used to determine the amount of total nitrogen mass loading reduction required for restoration of Oyster Pond to a series of dissolved oxygen values. Due to the existing salinity levels in the Pond (historically between 0 and 4 ppt), eelgrass cannot be established within this brackish water body. Instead, development of an appropriate threshold to restore infaunal habitat was based on minimum dissolved oxygen within the lower basin of Oyster Pond. It was determined that a linear relationship was appropriate to assess the expected changes in dissolved oxygen relative to total nitrogen for the site-specific conditions within the main basin of the Pond. Minimum dissolved oxygen thresholds derived in Section VIII.1 were used to adjust the calibrated constituent transport model developed in Section VI. It is important to note that load reductions can be produced by reduction of any or all sources or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment. The load reductions presented in the report represent only one of a suite of potential reduction approaches that need to be evaluated by the community. The presentation in this report of load reductions aims to establish the general degree and spatial pattern of reduction that will be required for restoration of this nitrogen impaired embayment.

The Massachusetts Estuaries Project's thresholds analysis, as presented in this technical report, provides the site-specific nitrogen reduction guidelines for nitrogen management of the Oyster Pond embayment system in the Town of Falmouth. Future water quality modeling scenarios should be run which incorporate the spectrum of strategies that result in nitrogen loading reduction to the embayment. The MEP analysis has initially focused upon nitrogen loads from on-site septic systems as a test of the potential for achieving the level of total nitrogen reduction for restoration of each embayment system. The concept was that since septic system nitrogen loads generally represent 75%-85% of the watershed load to the Oyster Pond embayment system and are more manageable than other of the nitrogen sources, the ability to achieve needed reductions through this source is a good gauge of the feasibility for restoration of these systems.

## 2. Problem Assessment (Current Conditions)

A habitat assessment was conducted throughout Oyster Pond based upon available water quality monitoring data, macroalgae distribution, time-series water column oxygen measurements, and benthic community structure. At present the bulk of the Oyster Pond is showing moderately to significantly impaired habitat quality. All of the indicators show a consistent pattern of moderate to significant impairment throughout the basins of Oyster Pond. While the Pond does not show strong gradients in salinity or water quality parameters, the enclosed nature of the northern basin appears to increase the duration of stratification and subsequent hypoxia. The deep southern basin (~6 m) is salinity stratified for months to years at a time and is generally anoxic as a result of this natural process. Based primarily on the infaunal communities and the bottom water hypoxia, it was concluded that Oyster Pond habitat is presently moderately to significantly impaired. Since the ultimate cause of the low dissolved oxygen ($\leq$4m) results from nitrogen enrichment, it can also be concluded that the system is nitrogen overloaded at present.

The following is a brief synopsis of the present habitat quality within the salt pond. The underlying quantitative data is presented on nitrogen (Section VI.1.3), oxygen and chlorophyll *a* (Section VII.2), eelgrass (Section VII.3), and benthic infauna (Section VII.4).

The effect of nitrogen enrichment is to cause oxygen depletion; however, with increased phytoplankton (or epibenthic algae) production, oxygen levels will rise in daylight to above atmospheric equilibration levels in shallow systems (generally ~7-8 mg $L^{-1}$ at the mooring sites). The clear evidence of oxygen levels above atmospheric equilibration indicates that the upper tidal reach of the Oyster Pond System is eutrophic.

Unlike many of the other embayments in southeastern Massachusetts, Oyster Pond showed a relatively consistent pattern of low oxygen in its bottom waters throughout its basins. The deep, southern basin (6 meters) is consistently anoxic during summer months due to its salinity stratification which persists for months to years. However, this represents only ~10% of the pond bottom. The remaining areas, $\leq$4 meters depth are only periodically anoxic or hypoxic. The northern basin was periodically anoxic between1998-2004. However, this basin is enclosed and this anoxia is driven mainly by stratification. The majority of the sediments in the pond (~80%) are represented by the oxygen levels observed in the upper and lower main basin (OP-2 3.25 m, OP-3 4 m). These regions are more open to wind-driven mixing and showed oxygen levels 3 mg/L or above in 96% of samplings and 2 mg/L as a minimum level. Restoration of this system will require an improvement of oxygen levels in this lower basin, which represents most of the benthic habitat and which does not appear to support long periods of stratification shallower than 4 meters depth (as opposed to the northern basin)..

The low salinity waters of Oyster Pond are not supportive of eelgrass bed formation. The DEP Eelgrass Mapping Program has conducted no surveys in Oyster Pond. However, observations have been made by PondWatch from 1987 to present which support the lack of eelgrass in this system. Similarly, a complete system data collection and analysis effort conducted in the 1960's throughout the main basin of Oyster Pond did not indicate the presence of eelgrass (Emery, 1997). This latter effort included a census of submerged aquatic vegetation, which did not indicate eelgrass, but did indicate that the dominant SAV in 2004, *Ceratophyllum demersum*, was also dominant in the 1960's. Therefore, the most likely reason for the absence of eelgrass in the main basin of Oyster Pond is the low salinity. This indicates that eelgrass cannot be used as a habitat restoration indicator for this system.

The Benthic Infaunal Study indicated that Oyster Pond is not presently supportive of either diverse (H' 0-1.12, mean 0.65) or evenly distributed (mean E = 0.46) benthic infauna. More telling is the low number of species (0-6, mean=3) compared to nearby healthy estuarine areas (~30 species per sample). Due to its brackish waters, Oyster Pond sediments supported both freshwater and estuarine invertebrate populations. The freshwater species were generally insect larvae and these tended to dominate the community. Also notable was that almost half of the samples (5 of 11) had only 0-84 individuals, indicative of an impoverished community. Although the remaining samples had dense populations, they were distributed among a very few species, 6 or less, indicating a stressed community. Overall, the infauna community was consistent with the low dissolved oxygen and organic matter deposition observed in this relatively closed estuarine basin.

## 3. Conclusions of the Analysis

The threshold nitrogen level for an embayment represents the average watercolumn concentration of nitrogen that will support the habitat quality or dissolved oxygen conditions being sought. The watercolumn nitrogen level is ultimately controlled by the integration of the watershed nitrogen load, the nitrogen concentration in the inflowing tidal waters (boundary condition) and dilution due to ground or surface water flows and (in the case of Oyster pond limited flushing via tidal flows. The water column nitrogen concentration is modified by the extent of sediment regeneration and by direct atmospheric deposition.

The nitrogen threshold for Oyster Pond is based upon restoring benthic habitat for infaunal animals. Given the natural stratification of Pond waters, sediments < 4 meters depth representing ~80% of the pond bottom were targeted. This depth is based upon the depth distribution of the bottom and the depth of the mixed layer. Since the present nitrogen levels result in periodic hypoxia at 4 meters depth, the nitrogen threshold was set to improve and maintain oxygen levels $\geq$6 mg/L at 4 meters depth in the main basin (OP-3). At present, the minimum dissolved oxygen at this station is most likely 3 mg/L, although a single reading of 2 mg/L was recorded. Given the uncertainties in determining minimum D.O. in any estuary, the nitrogen threshold was set using 2 mg/L as the current minimum D.O. level.

Watershed nitrogen loads (Tables ES-1 and ES-2) for the Town of Falmouth Oyster Pond embayment system was comprised primarily of wastewater nitrogen. Land-use and wastewater analysis found that generally about 75%-85% of the watershed nitrogen load to the embayment was from wastewater.

The threshold nitrogen levels for the Oyster Pond embayment system in Falmouth were determined as follows:

***Oyster Pond Threshold Criteria***

- Since at summer temperatures (25$^{o}$C) and salinities (2 ppt), dissolved oxygen saturation is 8.2 mg/L and current oxygen minimum is 2 mg/L then raising the minimum oxygen level to 6 mg/L would require 4/6.2 or 65% reduction in the rate of oxygen uptake during stratification. This assumes that the present duration and frequency of stratification of waters overlying sediments 4 meters or less deep will remain as at present. This is a safe assumption as long as the management plan does not allow the pond salinity levels to climb above target 2-4 ppt range. Given the link between nitrogen load and oxygen uptake rate, this 65% reduction in oxygen uptake would require a 65% reduction in nitrogen loading to Oyster Pond. Using a similar analysis, raising the periodic minimum dissolved oxygen to 3.8 mg/L (Chesapeake Bay value) or the SB criteria of 5 mg/L would require reductions in nitrogen **loading** of 29% and 48%, respectively.

- As shown in Table VIII-2, the nitrogen load reductions within the system necessary to achieve the threshold dissolved oxygen concentrations were higher for higher minimum dissolved oxygen levels. Since the nitrogen concentrations are generally uniform across the entire surface of Oyster Pond (i.e. there is virtually no spatial gradient in nitrogen concentration), the nitrogen load was removed uniformly. Distributions of tidally-averaged nitrogen concentrations associated with the threshold analysis are shown in Section VIII.

- To achieve the threshold dissolved oxygen concentrations at the sentinel stations, a reduction in TN **concentration** of approximately 9%, 15%, and 21% is required for dissolved oxygen concentrations of 3.8 mg/l (based on the EPA's Chesapeake Bay limit), 5.0 mg/l (Massachusetts SB waters), and 6.0 mg/l (Massachusetts SA waters), respectively. Although the above modeling results provide one manner of achieving the selected threshold levels within the Oyster Pond system, the specific examples do not represent the only method for achieving this goal. However, the thresholds analysis provides general guidelines needed for the nitrogen management of this embayment

It is important to note that the analysis of future nitrogen loading to the Oyster Pond estuarine systems focuses upon additional shifts in land-use from forest/grasslands to residential and commercial development. However, the MEP analysis indicates that significant increases in nitrogen loading can occur under present land-uses, due to shifts in occupancy, shifts from seasonal to year-round usage and increasing use of fertilizers (presently less than half of the parcels use lawn fertilizers). Therefore, watershed-estuarine nitrogen management must include management approaches to prevent increased nitrogen loading from both shifts in land-uses (new sources) and from loading increases of current land-uses. The overarching conclusion of the MEP analysis of the Oyster Pond estuarine system is that restoration will necessitate a reduction in the present (2002) nitrogen inputs and management options to negate additional future nitrogen inputs.

Table ES-1. Existing total and sub-embayment nitrogen loads to the estuarine waters of the Oyster Pond system, observed nitrogen concentrations, and sentinel system threshold nitrogen concentrations. Loads to estuarine waters of Oyster Pond include both upper watershed regions contributing to the major surface water inputs (Mosquito Creek).

| Sub-embayments | Natural Background Watershed Load [1] (kg/day) | Present Land Use Load [2] (kg/day) | Present Septic System Load (kg/day) | Present WWTF Load [3] (kg/day) | Present Watershed Load [4] (kg/day) | Direct Atmospheric Deposition [5] (kg/day) | Present Net Benthic Flux (kg/day) | Present Total Load [6] (kg/day) | Observed TN Conc. [7] (mg/L) | Threshold TN Conc. (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| ***OYSTER POND SYSTEM*** | | | | | | | | | | |
| Oyster Pond[a] | 0.490 | 1.367 | 3.587 | 0.00 | 4.181 | 0.773 | -1.733 | 3.220 | 0.67-0.71 | -- |
| Oyster Pond Lagoon | 0.047 | 0.090 | 0.023 | 0.00 | 0.293 | 0.027 | -0.048 | 0.273 | | – |
| **Oyster Pond System Total** | 0.537 | 1.457 | 3.610 | 0.000 | 4.474 | 0.800 | -1.781 | 3.493 | 0.67-0.71 | **0.633[8]** |

1 assumes entire watershed is forested (i.e., no anthropogenic sources)
2 composed of non-wastewater loads, e.g. fertilizer and runoff and natural surfaces and atmospheric deposition to lakes
3 existing wastewater treatment facility discharges to groundwater
4 composed of combined natural background, fertilizer, runoff, and septic system loadings
5 atmospheric deposition to embayment surface only
6 composed of natural background, fertilizer, runoff, septic system atmospheric deposition and benthic flux loadings
7 average of 1997 – 2004 data, ranges show the upper to lower regions (highest-lowest) of an sub-embayment.
8 Threshold loading for Oyster Pond is based upon removal required to achieve 3.8, 5.0 or 6.0 mg/L DO concentration in the deepest basin of the Pond. Resulting TN concentrations in the lower Pond basin for these three scenarios are 0.633, 0.588 an d0.548 mg/L, respectively.
a Include loads from surface water sources (i.e., Mosquito Creek).

Table ES-2. Present Watershed Loads, Thresholds Loads, and the percent reductions necessary to achieve the Thresholds Loads for the Oyster Pond system, Town of Falmouth, Massachusetts. Threshold loading for Oyster Pond is based upon removal required to achieve 3.8, 5.0 or 6.0 mg/L DO concentration in the deepest basin of the Pond.

| Sub-embayments | Present Watershed Load [1] (kg/day) | Target Threshold Watershed Load [2] (kg/day) | Direct Atmospheric Deposition (kg/day) | Benthic Flux Net [3] (kg/day) | TMDL [4] (kg/day) | Percent watershed reductions needed to achieve threshold load levels |
|---|---|---|---|---|---|---|
| ***GREAT POND SYSTEM*** | | | | | | |
| Oyster Pond | 4.181 | *DO 3.8:* 2.855<br>*DO 5.0:* 1.967<br>*DO 6.0:* 1.233 | 0.773 | *DO 3.8:* -1.342<br>*DO 5.0:* -1.080<br>*DO 6.0:* -0.863 | *DO 3.8:* 2.286<br>*DO 5.0:* 1.660<br>*DO 6.0:* 1.143 | *DO 3.8:* -31.7%<br>*DO 5.0:* -53.0%<br>*DO 6.0:* -70.5% |
| Oyster Pond Lagoon | 0.293 | 0.293 | 0.027 | *DO 3.8:* -0.037<br>*DO 5.0:* -0.030<br>*DO 6.0:* -0.024 | *DO 3.8:* 0.283<br>*DO 5.0:* 0.290<br>*DO 6.0:* 0.296 | *DO 3.8:* 0.0<br>*DO 5.0:* 0.0<br>*DO 6.0:* 0.0 |
| **Oyster Pond System Total** | 4.474 | *DO 3.8:* 3.148<br>*DO 5.0:* 2.260<br>*DO 6.0:* 1.526 | 0.800 | *DO 3.8:* -1.379<br>*DO 5.0:* -1.110<br>*DO 6.0:* -0.887 | *DO 3.8:* 2.569<br>*DO 5.0:* 1.950<br>*DO 6.0:* 1.439 | *DO 3.8:* -29.6%<br>*DO 5.0:* -49.5%<br>*DO 6.0:* -65.9% |

(1) Composed of combined natural background, fertilizer, runoff, and septic system loadings.
(2) Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentration identified in Table ES-1.
(3) Projected future flux (present rates reduced approximately proportional to watershed load reductions).
(4) Sum of target threshold watershed load, atmospheric deposition load, and benthic flux load.

# APPENDIX B
## Technical Memorandum – LEC Environmental Consultants

# MEMORANDUM

**DATE:** May 29, 2013

**TO:** Ed Leonard (Wright Pierce)

**FROM:** Brian Madden (LEC)

**Re:** Oyster Pond Comprehensive Wastewater Management Plan
Falmouth, MA

**PROJECT #:** WP\13-089.01

---

LEC has prepared this Memo to review potential state-listed rare species regulatory implications associated with preliminary planning of the Oyster Pond Comprehensive Wastewater Management Plan (CWMP).

According to the 13th edition of the *Massachusetts Natural Heritage Atlas* (effective October 1, 2008) published by the Massachusetts Natural Heritage and Endangered Species Program (NHESP), portions of the Oyster Pond Watershed are located within a Priority Habitat of Rare Species and/or Estimated Habitat of Rare Wildlife (see 4/8/13 Aerial Orthophoto and Figure 2-10). In response to a MESA Information Request, NHESP confirmed that northern portion of the Watershed extends into Priority Habitat 15 (PH 15)/Estimated Habitat 115 (EH 115), mapped for the presence of the Eastern Box Turtle (*Terrapene carolina*). The southwesterly tip of the Watershed also minimally extends into PH 385, mapped for the Common Tern (*Sterna hirundo*), Least Tern (*Sterna antillarum*), and Roseate Tern (*Sterna dougallii*). Roseate Tern is protected as an "Endangered" species under the *Massachusetts Endangered Species Act* (MESA, M.G.L. c. 131A) and its implementing *Regulations* (321 CMR 10.00), while the three (3) remaining are species of "Special Concern". The Roseate Tern is also protected under the federal Endangered Species Act (16 U.S.C. 1531-1544, 87 Stat. 884), as amended.

LEC understands that following a review of Baseline Conditions and a Needs Assessment, alternative traditional and non-traditional technologies and approaches will be explored. Technology options may include traditional and nontraditional sewer systems (e.g. gravity, vacuum, low pressure, step/steg), as well as transport to existing conveyance systems and the main wastewater treatment plant. On-site technologies, such as denitrifying systems and cluster systems will also be evaluated. The goal of the project is a CWMP that demonstrates a detailed analysis of the most cost effective and environmentally sound means of meeting the nitrogen reduction requirements of the Total Maximum Daily Load (TMDL) required by the MA DEP.

It is likely that elements of potential CWMP work activities within Priority Habitat will be exempt from MESA Project Review. Potential applicable exempt activities under 321 CMR 10.14 may include:

*(6) construction, repair, replacement or maintenance of septic systems, private sewage treatment facilities, utility lines, sewer lines, or residential water supply wells within existing paved areas and lawfully developed and maintained lawns or landscaped areas, provided there is no expansion of such existing paved, lawn and landscaped areas;*

*(7) repair, replacement or maintenance of existing, properly maintained stormwater detention basins or other stormwater management systems;*

*(8) construction of new stormwater management systems that are designed to improve stormwater management at previously developed sites, provided that the plans for the system are submitted to the Division for prior review, and the Division makes a written determination that such systems will not have an adverse impact on state-listed species or their habitats;*

*(9) repair, replacement or maintenance of existing, properly maintained dry hydrant pipe systems;* or

*(10) installation, repair, replacement, and maintenance of utility lines (gas, water, sewer, phone, electrical) for which all associated work is within ten feet from the edge of existing paved roads, and the repair and maintenance of overhead utility lines (phone, electrical) for which all associated work is within ten feet from the edge of existing unpaved roads, provided, however, that unpaved utility access roads associated with exempt activities under 321 CMR 10.14(11) shall be addressed in and subject to the Division-approved operation and maintenance plan required thereunder;*

Any non-exempt CWMP work activities within Priority Habitat require MESA Project Review. NHESP always recommends that rare species habitat concerns be addressed during the preliminary project design phase prior to submission of a formal filing, as avoidance and minimization of impacts to rare species and their habitats is likely to expedite endangered species regulatory review under MESA.

Potential CWMP work activities within PH 385 are unlikely to materially impact potential *Sterna* spp. habitat. PH 385 is essentially mapped as a potential *Sterna* spp. flyover between Vineyard Sound (south) and Quissett Harbor/Buzzards Bay (north). Nevertheless, non-exempt CWMP work activities within PH 385 will require MESA Project Review.

Non-exempt CWMP work activities within PH 15/ EH 115 will be evaluated in the context of potential impacts to Eastern Box Turtle habitat that may rise to the level of a "take" of the state-listed species. A "take", in reference to animals, means to "harass, harm, pursue, hunt, shoot, hound, kill, trap, capture, collect, process, disrupt the nesting, breeding, feeding or migratory activity or attempt to engage in any such conduct, or to assist such conduct". Activities resulting in Eastern Box Turtle habitat modification, degradation, or destruction may result in the disruption of nesting, breeding, feeding or migratory activity, thus constituting a "take".

NHESP's positive determinations may come in three forms:

1) No "take"; the project is approved as proposed.

2) Conditional no "take"; the project is approved as proposed along with specific conditions (e.g., work timing considerations, construction protection measures, restrictive covenants—Declaration of Restrictions or Conservation Restrictions, etc.)

3) Permitted "take"; the Applicant has avoided, minimized, and mitigated impacts to state-listed species, exhausted all viable alternatives, the project results in an insignificant impact to the local population, and the Applicant provides a long-term net benefit to the state-listed species. NHESP will issue a Conservation & Management Permit for an authorized "take". Additionally, if a "take" occurs on a project site of 2 or more areas within a Priority Habitat, an Applicant will need to file with MEPA.

Please note that potential CWMP work activities within EH 115 that require submission of a Notice of Intent to the Falmouth Conservation Commissions and DEP, also necessitate NHESP review under the *Massachusetts Wetlands Protection Act* (WPA, M.G.L. c. 131, § 40) and its implementing Regulations (310 CMR 10.00).

LEC is pleased to provide this preliminary overview of potential state-listed rare species regulatory implications associated with the CWMP and we look forward to further review as the Needs Assessment and Alternatives Analysis are evaluated. Should you have any immediate questions or comments, feel free to contact me at 508-746-9491 or ______________________.

May 07, 2013

Brian Madden
LEC Environmental Consultants, Inc
12 Resnik Road, Suite 1
Plymouth MA 02360

RE: Project Location: Oyster Pond Watershed Area
Town: FALMOUTH
**NHESP Tracking No.: 13-32156**

To Whom It May Concern:

Thank you for contacting the Natural Heritage and Endangered Species Program of the MA Division of Fisheries & Wildlife (the "Division") for information regarding state-listed rare species in the vicinity of the above referenced site. Based on the information provided, this project site, or a portion thereof, is located **within** *Priority Habitat 15 & 385* (PH 15 & 385) and *Estimated Habitat 115* (EH 115) as indicated in the *Massachusetts Natural Heritage Atlas* (13th Edition). Our database indicates that the following state-listed rare species have been found in the vicinity of the site:

*Priority Habitat 15* (PH 15) and *Estimated Habitat 115* (EH 115):

| Scientific name | Common Name | Taxonomic Group | State Status |
|---|---|---|---|
| *Terrapene carolina* | Eastern Box Turtle | Reptile | Special Concern |

*Priority Habitat 385* (PH 385):

| Scientific name | Common Name | Taxonomic Group | State Status |
|---|---|---|---|
| *Sterna hirundo* | Common Tern | Bird | Special Concern |
| *Sternula antillarum* | Least Tern | Bird | Special Concern |
| *Sterna dougallii* | Roseate Tern | Bird | Endangered |

The species listed above are protected under the Massachusetts Endangered Species Act (MESA) (M.G.L. c. 131A) and its implementing regulations (321 CMR 10.00). State-listed wildlife are also protected under the state's Wetlands Protection Act (WPA) (M.G.L. c. 131, s. 40) and its implementing regulations (310 CMR 10.00). Fact sheets for most state-listed rare species can be found on our website (www.nhesp.org).

Please note that projects and activities located within Priority and/or Estimated Habitat **must** be reviewed by the Division for compliance with the state-listed rare species protection provisions of MESA (321 CMR 10.00) and/or the WPA (310 CMR 10.00).

## Wetlands Protection Act (WPA)

If the project site is within Estimated Habitat and a Notice of Intent (NOI) is required, then a copy of the NOI must be submitted to the Division so that it is received at the same time as the local conservation commission. If the Division determines that the proposed project will adversely affect the actual Resource Area habitat of state-protected wildlife, then the proposed project may not be permitted (310



Division of Fisheries and Wildlife
*Temporary Correspondence*: 100 Hartwell Street, Suite 230, West Boylston, MA 01583
*Permanent:* Field Headquarters, North Drive, Westborough, MA 01581 (508) 389-6300 Fax (508) 389-7890
*An Agency of the Department of Fish and Game*

CMR 10.37, 10.58(4)(b) & 10.59). In such a case, the project proponent may request a consultation with the Division to discuss potential project design modifications that would avoid adverse effects to rare wildlife habitat.

A streamlined joint MESA/WPA review process is available. When filing a Notice of Intent (NOI), the applicant may file concurrently under the MESA on the same NOI form and qualify for a 30-day streamlined joint review. For a copy of the NOI form, please visit the MA Department of Environmental Protection's website: http://www.mass.gov/dep/water/approvals/wpaform3.doc.

**MA Endangered Species Act (MESA)**

If the proposed project is located within Priority Habitat and is not exempt from review (see 321 CMR 10.14), then project plans, a fee, and other required materials must be sent to Natural Heritage Regulatory Review to determine whether a probable "take" under the MA Endangered Species Act would occur (321 CMR 10.18). Please note that all proposed and anticipated development must be disclosed, as MESA does not allow project segmentation (321 CMR 10.16). For a MESA filing checklist and additional information please see our website: www.nhesp.org ("Regulatory Review" tab).

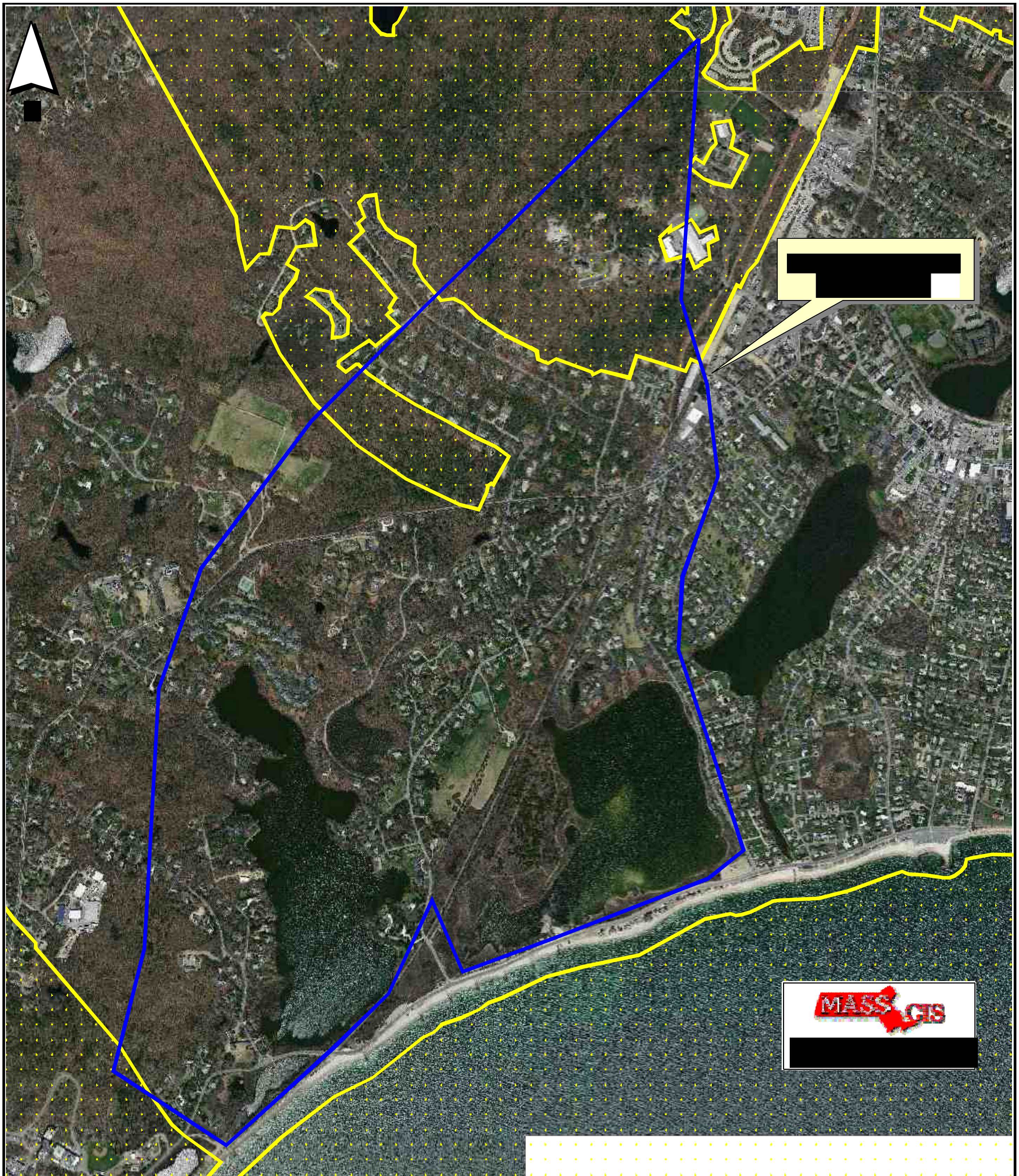
We recommend that rare species habitat concerns be addressed during the project design phase prior to submission of a formal MESA filing, as avoidance and minimization of impacts to rare species and their habitats is likely to expedite endangered species regulatory review.

This evaluation is based on the most recent information available in the Natural Heritage database, which is constantly being expanded and updated through ongoing research and inventory. If you have any questions regarding this letter please contact Amy Coman-Hoenig, Endangered Species Review Assistant, at (508) 389-6364.

Sincerely,

Thomas W. French

Thomas W. French, Ph.D.
Assistant Director




LEC

[redacted]

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[redacted]

# APPENDIX C
## Technical Memorandum – Woods Hole Group

# Oyster Pond Review

**Prepared For:**
Wright- Pierce
40 Shattuck Way, Suite 305
Andover, MA 01810

**Prepared By:**
Woods Hole Group, Inc.
81 Technology Park Drive
East Falmouth, MA 02536

July 2013

# Oyster Pond Review

**July 2013**


**Prepared for:**
Wright- Pierce
40 Shattuck Way, Suite 305
Andover, MA 01810

**Prepared by:**
Woods Hole Group
81 Technology Park Drive
East Falmouth MA  02536
(508) 540-8080

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## 1.0 INTRODUCTION/BACKGROUND

The purpose of this technical memo is to summarize changes in the conditions of water quality, or other environmental conditions, in Oyster Pond (Falmouth, MA) since the baseline studies were conducted and reported by UMASS Dartmouth's School of Marine Science and Technology (SMAST) in 2006. The monitoring work that supported the associated Massachusetts Estuary Project (MEP) report, and subsequent Oyster Pond Total Maximum Daily Load (TMDL), took place from 1997 through 2004. The monitoring effort was a combination of long-term monitoring through the Falmouth Pond Watchers organization, a non-profit community group with ties to Woods Hole Sea Grant, and the SMAST department of UMASS Dartmouth.

Oyster Pond is unique in character due to its physical and hydrodynamic setting. Physical characteristics include two distinct bathymetric features located in both the northern and southern portions of the pond. These are composed of two deep basins that contribute to the commonly observed stratified condition in the pond where roughly 3 to 4 meters of the surface water "floats" over the remaining bottom water (at between 3 to 6 meters depth) and exchange between the two layers is only periodic when temperature and wind conditions allow mixing. These deep basins typically hold cooler, saltier water that is not significantly mixed through tidal action or wind.

The nature of tidal communication with Vineyard Sound water is limited through a constructed water control system at its connection with a small tidal lagoon. There is a relatively small outlet, the Trunk River that connects this lagoon to Vineyard Sound. Seawater from Vineyard Sound is delivered to the pond from occasional wash over events during storms and periodic extreme astronomical tides.

These physical characteristics have resulted in the pond's surface waters having salinities typically between 2 and 4 parts per thousand (ppt). The bottom waters (about 20% of total pond volume) are typically more saline (4 ppt to 13 ppt) and, as described above, only mix with surface waters on a periodic basis.

The MEP report concluded that Oyster Pond is impaired from excessive nutrient loads from its contributing watershed. The nutrient of importance is nitrogen (determined through nutrient limitation studies). Unlike most other south Cape estuarine systems studied under the MEP, Oyster Pond does not support eelgrass (*Zostera marina*) habitat due to low salinities within the photic zone. Therefore, dissolved oxygen (DO) was selected as the ecological endpoint to base nitrogen load reductions on in order to support Oyster Pond's benthic community. The target reduction was associated with sustaining a minimum DO concentration of 6.0 mg/l at the base of the surface water column layer (4.0 m depth) where salinity ranges between 2 to 4 ppt. The load reduction was calculated as a linear (1:1) relationship with the percent increase in minimum DO concentrations required to get to the target concentration of 6.0 mg/l.

The Falmouth Pond Watchers have continued to monitor water quality in Oyster Pond since the MEP report was released in 2006. This memo summarizes these subsequent data (2005 through 2012) in context with the historical conditions described by SMAST in the MEP report. Oyster Pond is a unique estuarine system and the job of determining critical nitrogen loads is certainly challenging given the physical nature of this system. The additional Pond Watcher data, along with the documentation of changes in the watershed and Trunk River allow further study of the system's variability and current water quality and ecological conditions.

# 2.0 OYSTER POND

## 2.1 OYSTER POND CHANGE SUMMARY

This section provides a summary of important changes in conditions within Oyster Pond since the MEP field assessment was completed (data applied from 1997 through 2004).

### Nitrogen Data Review

The MEP process involves a two-step modeling approach to establish nitrogen reductions (from watershed sources) necessary to achieve a specified condition at points that are identified as "sentinel" stations. Watershed loads to Oyster Pond are based on a watershed loading model that uses inputs from land use and land parcel data to derive estimates of total nitrogen (TN) that Oyster Pond receives on an annual basis. Field monitoring for a minimum period of 3 years produces data to (1) characterize existing conditions and (2) help calibrate (tune) a hydrodynamic/water quality model. The hydrodynamic model is used to simulate physical flushing within the estuary and the expected mean TN concentrations at various sections of the system. Typically, the MEP process is to average the observed TN data, calibrate the hydrodynamic model to fit these observed data (by station) through changing some physical parameters within the model (e.g., dispersion coefficient). Once calibrated, the model is used to predict the TN loading rate from the watershed (while recognizing the tidal flux of offshore nitrogen) that corresponds to a TN target concentration.

This process was conducted on Oyster Pond using field data collected from 1997 through 2004. Although the raw data have not been made available for this review exercise, the TN concentrations are summarized, by station, in the MEP report. The following is a summary of findings.

The MEP report used measured TN concentrations from 3 sampling stations[1]: OP1, OP2, and OP3 (Figure 1). The concentrations are summarized and compared to modeled concentrations in Table VI-1 on page 82 of the MEP report (Table 1, below). The report shows TN concentrations in the surface layer (<4 m depth) ranging very little from 0.70 mg/l. The model was calibrated to within a very small difference of reported mean TN values.

[1] Additional stations were monitored by Falmouth Pond Watchers; however, these three stations form the basis of model calibration and the subsequent TMDL.

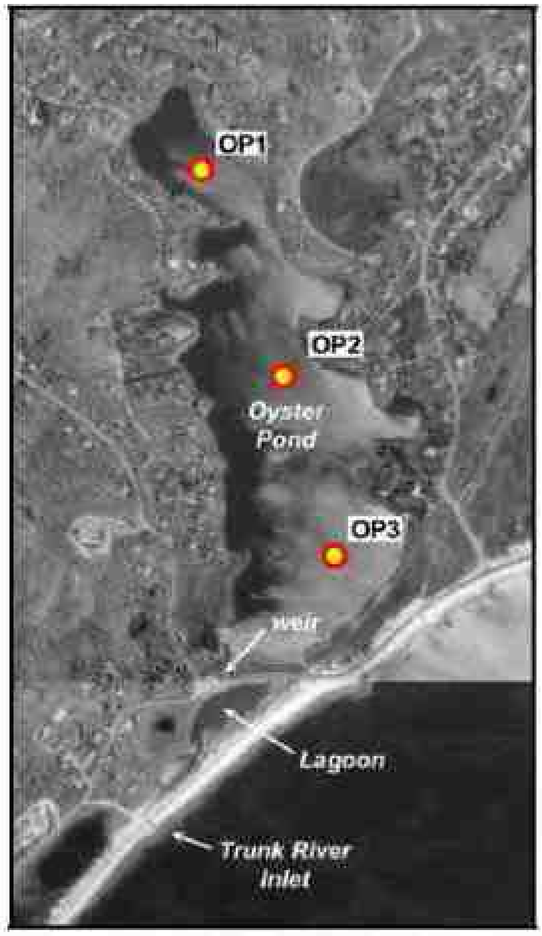


**Figure 1. Oyster Pond MEP sampling locations.**

**Table 1. Oyster Pond MEP summary of TN concentrations and model performance.**

Table VI-1. Falmouth PondWatch measured data, and modeled Nitrogen concentrations for the Oyster Pond system used in the model calibration plots of Figure VI-2. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means.

| Sub-Embayment | monitoring station | data mean | s.d. all data | N | model min | Model max | model average |
|---|---|---|---|---|---|---|---|
| Oyster Pond - Head | OP1 | 0.695 | 0.026 | 50 | 0.646 | 0.747 | 0.696 |
| Oyster Pond - Mid | OP2 | 0.669 | 0.018 | 81 | 0.644 | 0.746 | 0.694 |
| Oyster Pond – Lower, deep basin | OP3 | 0.705 | 0.157 | 84 | 0.641 | 0.746 | 0.693 |
| Vineyard Sound | VS | 0.280 | 0.065 | 196 | - | - | 0.280 |

The number of samples shown in Table 1 corresponds to a collection period of 1997 through 2004; however, at this time we do not have access to the raw data so the timing and frequency of sampling within this period is unknown. It is assumed that sampling occurred on at least a monthly basis from April through October, with occasional winter sampling, each year. The MEP report states that the model was calibrated with average summer season TN concentrations.

The results of subsequent OPET sampling depict inter-annual variability in total dissolved nitrogen (TDN) trends in Oyster Pond. The difference between TN and TDN is the amount of particulate organic nitrogen (PON) present in the water. Therefore, the OPET data cannot be directly compared with the TN summary of means that have been reported in the MEP report. Having the full suite of water quality data that supported the MEP work would offer the possibility for comparisons of TDN and specific species of N ($NO_3$, $NH_4$, and dissolved organic N). In a review of limited historical data published in the 1998 annual Pond Watchers summary report of 1997 data, PON composed between 12% and 43% of TN. At the old site OP3, PON comprised 16% of TN. At this time information is insufficient to accurately characterize the relationship between TN and TDN in Oyster Pond. Furthermore, without the entire suite of water quality data associated with the MEP report, and subsequent TMDL, it is difficult to assess the extent to which changes in TDN and subspecies of nitrogen have occurred since the period covering the MEP assessment. However, the following is a summary of the OPET data covering the period 2005 through 2012.

Figure 2 shows the average surface mixed layer (OP1, OP2, and OP3) TDN concentrations throughout the entire Falmouth Pond Watcher monitoring program from 2005 through 2012. The summer values of TDN are consistently lower than the means reported by the MEP (Figure 1, Table 1) which is due to the omission of PON in these surveys.

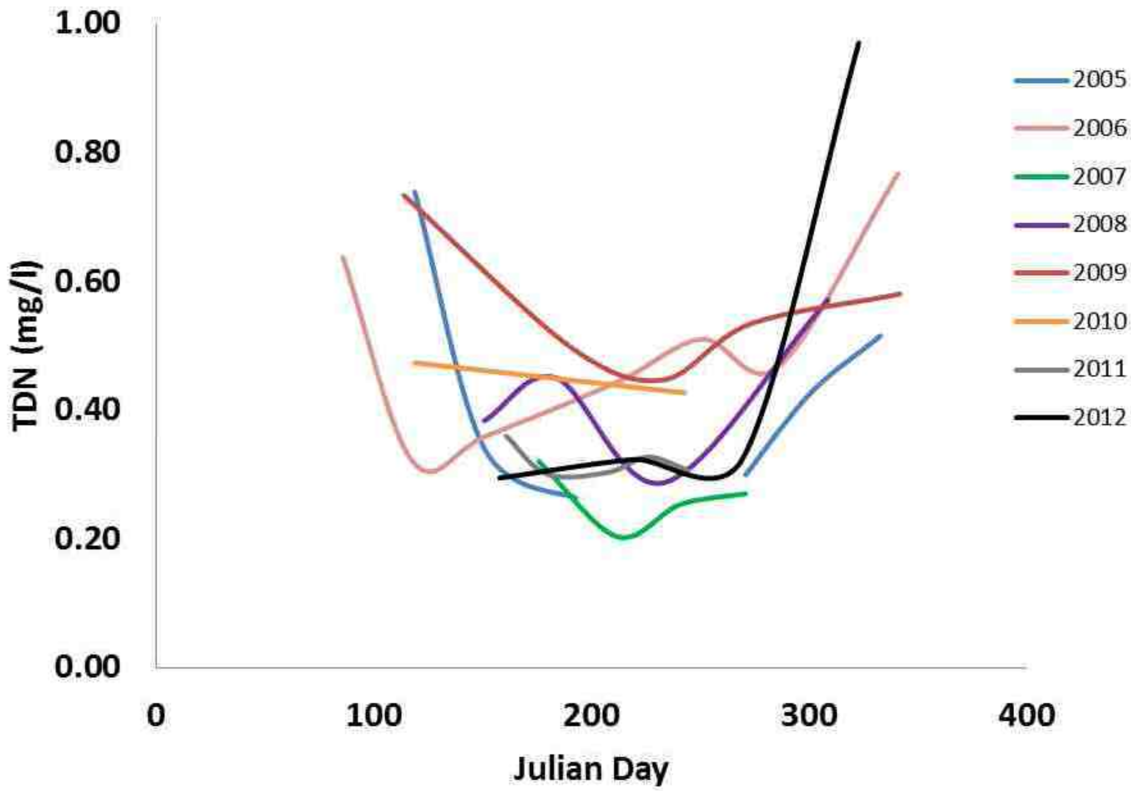


**Figure 2.** **Average surface mixed layer total dissolved nitrogen concentrations in Oyster Pond from 2005 through 2012. Average of surface observations from stations OP1, OP2, and OP3.**

For comparison, Figure 3 shows the summer, or growing season, averaged TDN concentrations for all 7 years of the recent monitoring period (2005 through 2012). Corresponding values (mean and standard deviation) are shown in Table 2 and compared with the MEP values.

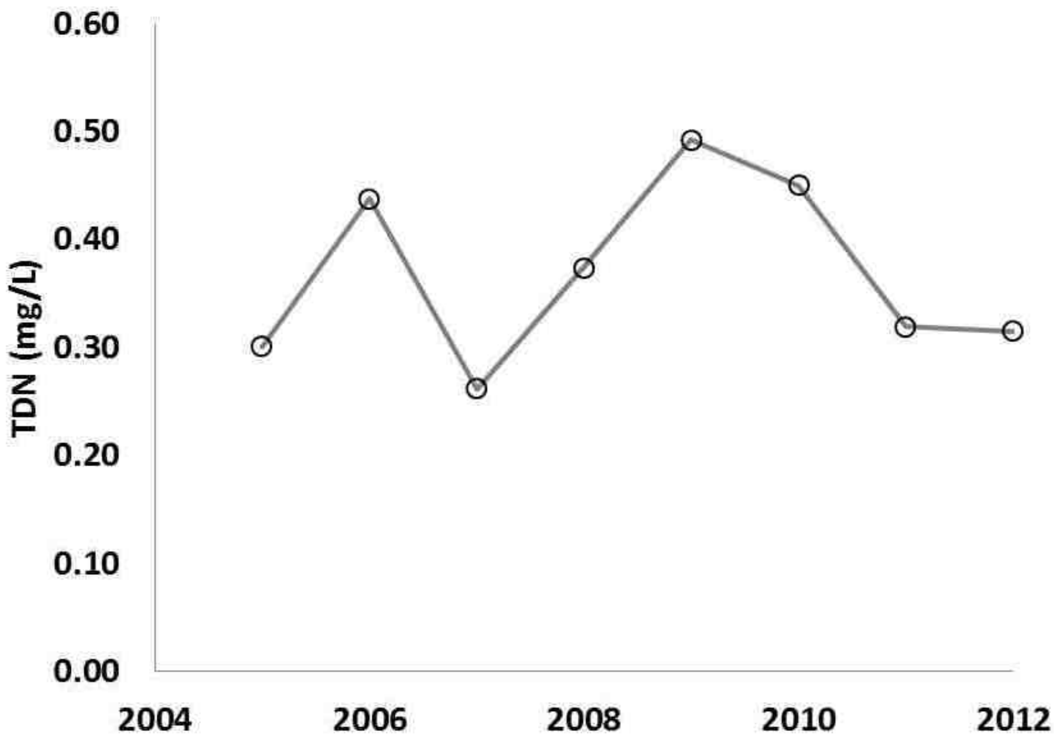


**Figure 3. Mean summer (May through September) surface layer TDN concentrations for Oyster Pond sampling stations OP1, OP2, and OP3.**

**Table 2. Summary and comparison of TDN and estimated TN concentration data from two different sampling periods. Estimated TN values for 2005 through 2012 shown in parentheses.**

| Monitoring Station | 2005 – 2012 mean | s.d. | N | 1997 – 2004 mean | s.d. | N |
|---|---|---|---|---|---|---|
| OP1 | 0.360 (0.537) | 0.087 | 25 | 0.695 | 0.026 | 50 |
| OP2 | 0.353 (0.527) | 0.101 | 25 | 0.669 | 0.018 | 81 |
| OP3 | 0.347 (0.518) | 0.103 | 25 | 0.705 | 0.157 | 84 |
| All Combined | 0.35 (n/a) | 0.09 | 75 | - | - | 215 |

The MEP TN means are not directly comparable to the OPET TDN data because PON is not accounted for. The limited historical data show a range of 12% and 43% of PON in TN and a review of other pond data (Little Pond, Green Pond) resulted in a mean of 33% PON in TN. A graphical summary of nitrogen species within the water column in K.O. Emery's *A Coastal Pond* reports PON as approximately 35% of the pond's surface water TN concentration. The estimate that PON is 33% of TN applied to the values shown in

Table 12 suggest a possible improvement in water quality since the MEP report data set (shown in parentheses). Historically, there was a trend of decreasing TN at OP2 where it dropped from about 1.2 to 0.6 mg/l in the 1990s (Figure 4). The Pond Watchers report attributes this to the successful restoration of the salinity structure of the pond (surface maintained at 2 to 4 ppt) – a condition that allows the separation of the surface and bottom layers of water and the maintenance of higher water quality in the surface mixed layer.

There have also been documented changes to the Oyster Pond watershed and the Trunk River inlet throughout this more recent time frame. These are summarized in Table 3. Note that tidal exchange was more frequently maintained throughout this period (1998 through 2012) despite some significant storm events that temporarily closed the inlet or resulted in overwash.

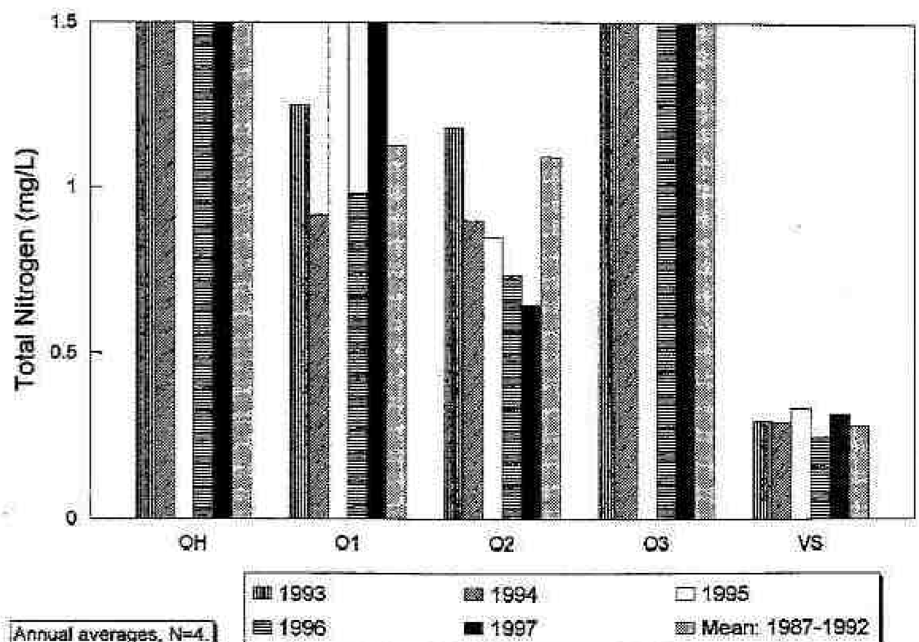


Figure 8. Oyster Pond average bottom water oxygen (Top) and total nitrogen (Bottom) levels during 1997. The freshening of the pond, 1995-1997 (Fig. 7), has resulted in a decrease in summer stratification such that the mid-basin has been oxygenated since the fall of 1994 and nitrogen levels have declined. The depth of the top of the hydrogen sulfide-high nitrogen zone of the deep basin has also declined from 4 m to 6 m over this same period (not shown).

**Figure 4. From the 1998 annual Falmouth Pond Watchers report: summary of TN concentrations in Oyster Pond from 1993 through 1997.**

**Table 3. Relevant changes to Oyster Pond and environs (1979 through 2012). Source: OPET.**

| Date/Year | Relevant Changes to Oyster Pond and Environs |
|---|---|
| 1979-1980 | Treetops built |
| 1987 – Present | Pond Watchers monitoring of Oyster Pond. |
| 1989/1990 | Culvert collapses and forms blockage for several months. |
| 1990 | Culvert replaced roughly 3 times larger than previous one. |
| TBD | Woods Hole Rd. stormwater improvements. |
| 1998 | Weir is constructed to control the amount of sea water entering the pond. |
| 2001 | Trunk River dredged, the bottom lined, and jetties repaired and rebuilt. |
| 2004 | Trunk River dredged due to severe algal growth in the lagoon. |
| 2005, 2006, 2007 | Additional hand dredging of Trunk River to maintain outflow. |
| 2005 | OPET initiates independent water quality sampling program. |
| 2010 | Major dredging of Trunk River and lagoon. |
| 2010 | A second major dredging of Trunk river after storm event. |
| 2010 | Ransom Rd. drainage and paving completed. |
| 2010 | Final drain adjustments made to Ransom Rd. improvements. |
| 2011 | Treetops Condos begins transition to an organic landscaping regime. |
| 2011 | More dredging of lagoon by OPET due to buildup of dead eelgrass. |
| 2011 | Tropical Storm Irene. (August 2011) |
| 2012 | Hurricane Sandy. (October 2012) |

The activities associated with increasing drainage from the pond, stabilizing the salinity regime, and controlling stormwater and fertilizer delivery to the pond appear to have contributed to lower nitrogen concentrations that have been observed in Oyster Pond since the late 1990s.

**Phosphorus Data Review**

OPET includes phosphorus in their monitoring program. Initially, total phosphorus (TP) was reported from 2005 through April 2006. From April 2006 to the present OPET reports total dissolved phosphorus (TDP) and/or dissolved inorganic phosphorus (DIP, reported as phosphate) at varying frequencies (i.e., sometimes one or the other, or both).

Trends of TP, TDP, and phosphate ($PO_4$) concentrations in the surface waters of Oyster Pond are shown in Figures 5, 6, and 7.

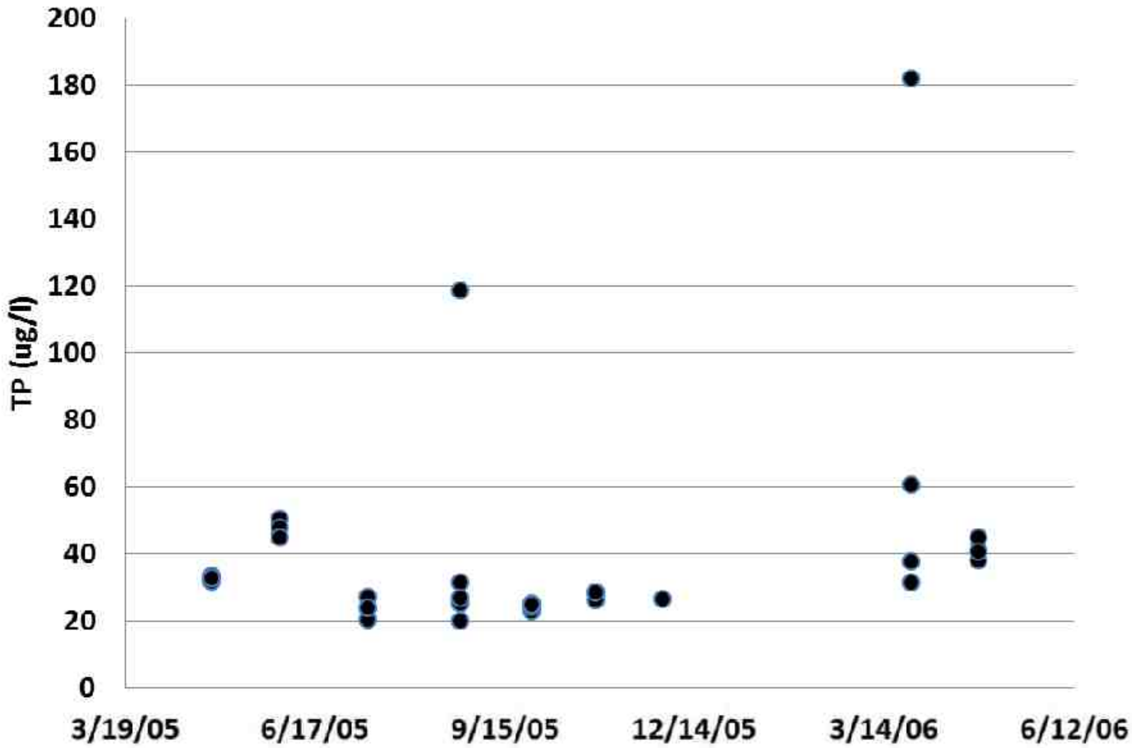


**Figure 5. Total phosphorus (TP) concentrations in the surface layer of Oyster Pond.**

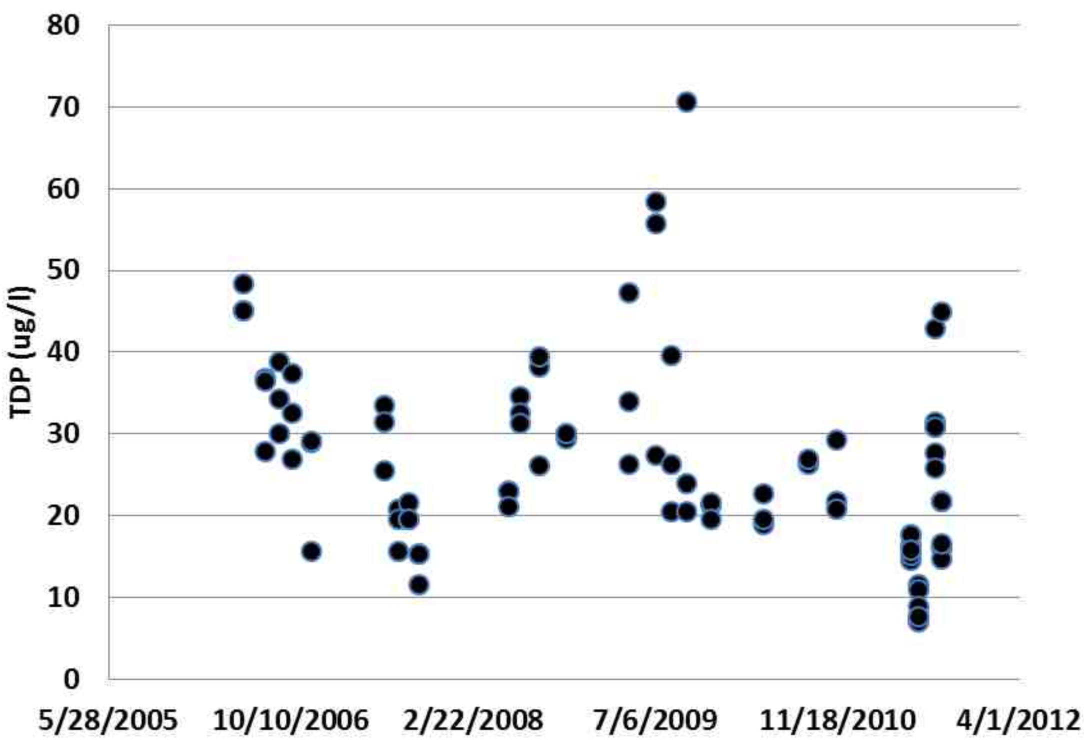

**Figure 6. Total dissolved phosphorus (TDP) concentrations in the surface layer of Oyster Pond.**

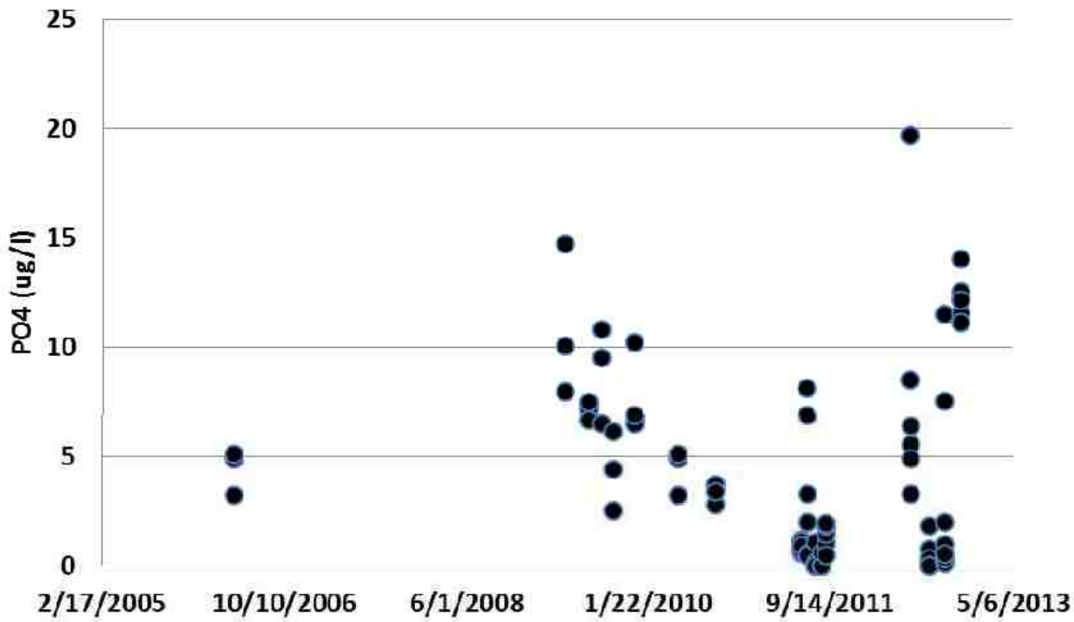


**Figure 7. Phosphate ($PO_4$) concentrations in the surface layer of Oyster Pond.**

**N:P and Nutrient Limitation**

The phosphorus concentration in the surface layer (to 4 meters in depth) is important with regard to determining which nutrient, N or P, limits growth of algae and macrophytes within Oyster Pond. In general, marine systems are nitrogen limited and freshwater systems are phosphorus limited. This has to do, primarily, with the nature of how phosphorus is cycled within each type of environment. Typically, when the N:P falls below 10 then nitrogen is considered limiting. If N:P is greater than 17 then phosphorus is considered limiting. Previous unpublished studies on Oyster Pond have suggested that both N and P limit phytoplankton production. In an enrichment study conducted by Erlitz et al. (unpublished) the results suggested that phytoplankton growth increased with the addition of both N and P rather than from either one alone. The authors cite Dixon et al. (2002) as reporting that the "current" N:P ratio in Oyster Pond is 6:1. A review of the OPET nutrient data suggest that nutrient limitation can shift from nitrogen to phosphorus and can be considered equally limited (N:P between 10 and 17) (Figure 8)

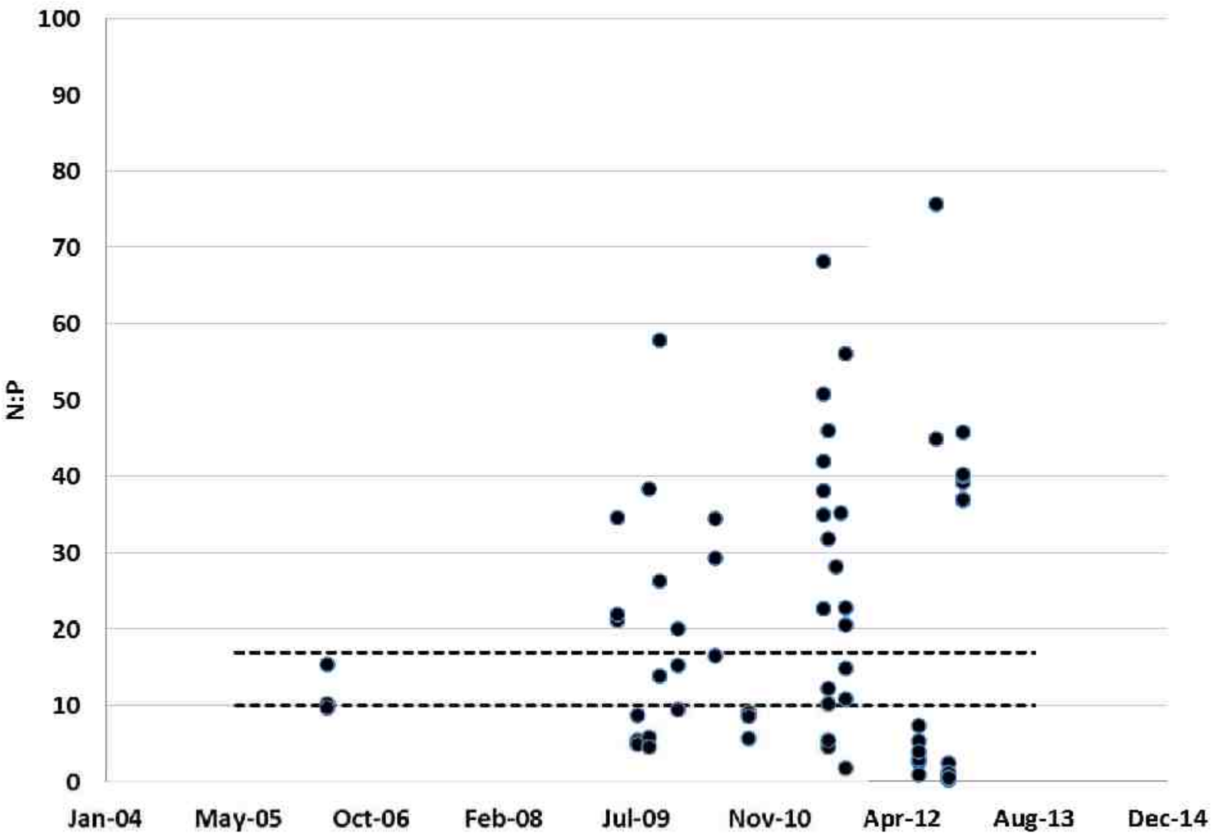


**Figure 8. N:P ratio in Oyster Pond's surface layers. Dashed lines indicate approximate limitation thresholds (10 and 17) for nitrogen and phosphorus, respectively.**

The mean and median values of N:P in Oyster Ponds surface layer, not including three extremely high values reported in the data set[2], are 22 and 15, respectively. This suggests that the pond may be more limited by phosphorus than nitrogen at times. Therefore, management of both nutrients is warranted.

**Dissolved Oxygen and Stratification**

As described above, the MEP report concluded that a desired sustainable target of at least 6.0 mg/l DO concentration at 4 m depth at sampling station OP3 would serve to improve water quality to the extent that the surface mixed layer would be relatively healthy and support a healthy benthic habitat. The nitrogen load reduction necessary to achieve this, based on MEP modeling, was estimated with the application of the following equation:

*%N Reduction = (Target DO – Min. Observed DO)/(Max. Saturation – Min. Obs. DO) *100*

[2] Values were 392, 2,468, and 1,507.

According to the MEP (p. 102): *"Since the present nitrogen levels result in periodic hypoxia at 4 meters depth, the nitrogen threshold was set to improve and maintain oxygen levels >6 mg/L at 4 meters depth in the main basin (OP-3). At present, the minimum dissolved oxygen at this station is most likely 3 mg/L, although a single reading of 2 mg/L was recorded. Given the uncertainties in determining minimum D.O. in any estuary, the nitrogen threshold was set using 2 mg/L as the current minimum D.O. level. This adds a level of safety to the analysis."*

According to the resulting reduction calculations, the selection of 2 mg/l rather than 3 mg/l for the existing minimum observed DO accounts for a 65% reduction vs. a 58% reduction associated with a 3 mg/l minimum. It should be noted that these calculations are assuming temporally consistent, or static, salinity and temperature conditions (2 ppt at 25C).

There are several considerations associated with this load reduction scenario:

- Current DO and salinity conditions
- Variability of water column salinity and DO concentrations
- Benthic-pelagic exchanges of DO and nutrients
- Change in nutrient loadings

In the more recent years, the minimum observed DO concentration at station OP3 at the 4 m depth was 0.06 mg/l (August 7, 2012) and there are several others that are below the 2.0 mg/l minimum reported by MEP. Therefore, based on the MEP approach to determine the nitrogen threshold, the MEP load reductions would be an underestimate based on more recent data associated with the 4 m depth. But there are a few things to consider about the MEP approach. It assumes a static condition in the water column; that the 4 m depth is characteristic of the location of the pond's summer time pycnocline (the zone within the water column that separates less dense, lower salinity surface water from deeper, denser higher salinity water). However, the data do not necessarily support this. The observed 0.06 mg/l minimum corresponds to an observed salinity of 7.2 ppt which is not considered indicative of the 2-4 ppt mixed surface layer. A review of data from 2005 through 2012 reveals that the summertime pyncnocline varies in depth from 3 to 6 m (Figure 9).

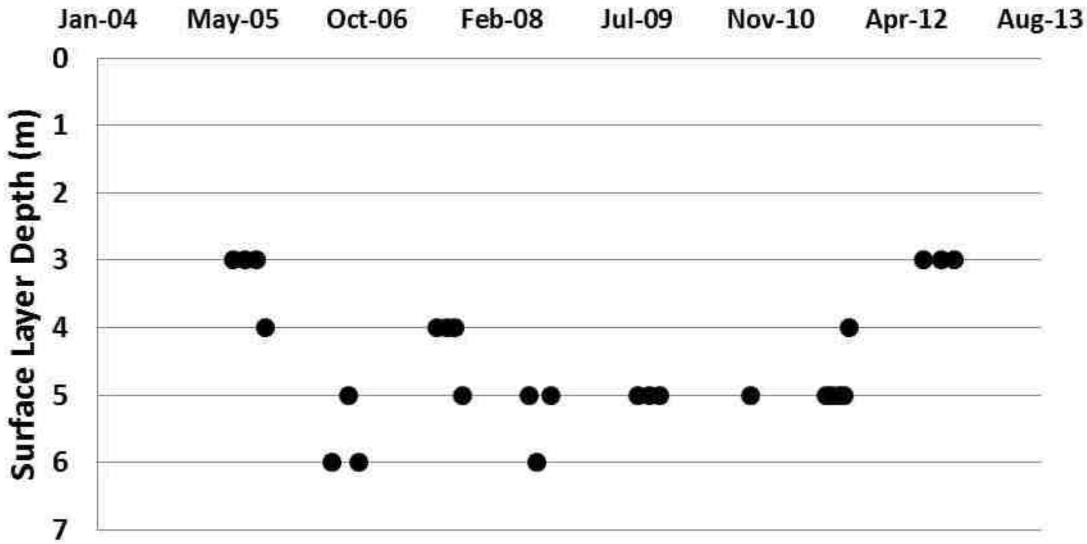


**Figure 9. Depths of summer pyncnoclines at station OP3 between 2005 and 2012 (defined as depth where salinity< 4 ppt).**

The data reveal that DO concentrations do vary with salinity and that the depth of the division between the pond's surface and bottom layers can vary significantly. This suggests that the variability of the location of the pyncnocline and corresponding DO concentrations should be more closely evaluated in the attempt to characterize the ability to (1) determine nitrogen concentration thresholds and (2) sufficiently determine the degree of compliance to these thresholds. In other words, without a probabilistic approach that integrates observed variability, there is a chance that low DO events could occur at the 4 m depth at any rate of nitrogen loading. Figure 6 shows the relationship between the location of the 4 ppt salinity pyncnocline and the corresponding observed DO values. It suggests that DO concentrations decline with depth of the 4 ppt salinity boundary and that DO varies widely at each boundary depth.

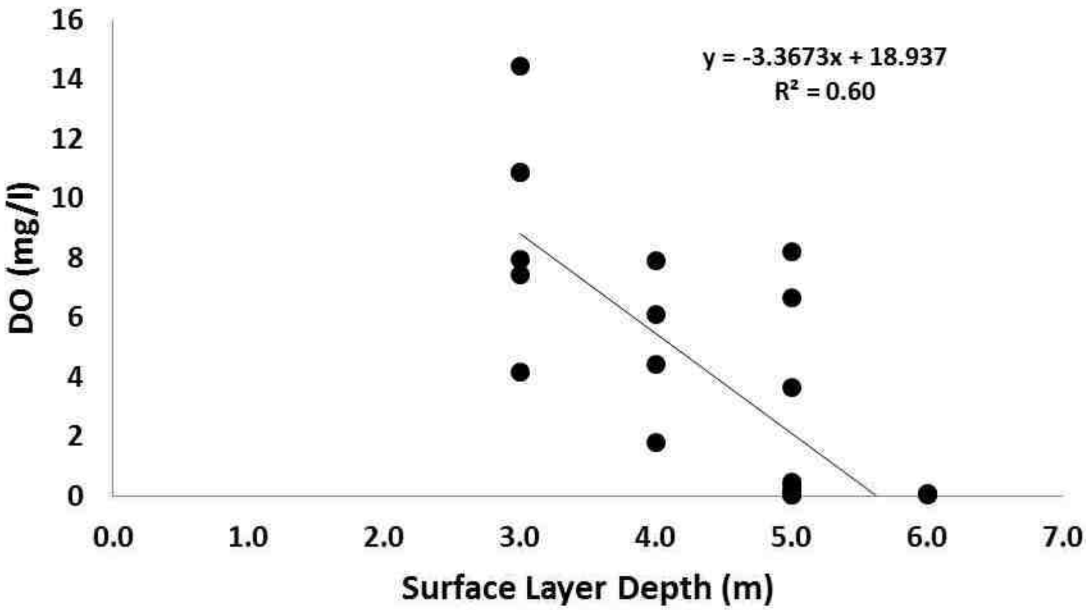


**Figure 10. The relationship between Oyster Pond surface layer depth (4 ppt salinity) and corresponding DO concentrations.**

The mean summertime DO value at 4 m depth from this period is 5.07 mg/l. The Massachusetts regulations are based on a minimum value, not the mean, which makes the timing of monitoring very important in determining whether Oyster Pond is below the Class SA designated use threshold of 6.0 mg/L. Oyster Pond, like most coastal aquatic systems, exhibits variability in DO concentrations. Figure 10 provides one example of the variability in DO concentrations based on discrete samplings. DO can also vary considerably throughout the daily (diel) period; very low DO can occur just before sunrise while supersaturating conditions can occur during the mid-afternoon. Although the MEP report does not report diel DO conditions in the pond, recent continuous measurements in the surface layer of Salt Pond depict this characteristic cycle (Figure 11). Therefore, the timing of sampling can have a significant impact on the understanding of DO dynamics in Oyster Pond. Certainly, with enough samples over the years it is possible that the mean conditions can be determined with some level of certainty. However, this should be demonstrated in Oyster Pond and the variability of DO in this water body should be better understood toward assessing the level of ecological impairment and the subsequent development of management plans.

Other states have integrated time-dependent variability in developing ecological thresholds associated with DO levels. For example, the DO criteria for Chesapeake Bay are based on five separate designated uses that are associated with defined geographical and bathymetrical features. The criteria also integrate frequency and duration such that variability in DO is accounted for. They also have temporal periods (e.g., migratory fish spawning periods) that are protective of specific ecological endpoints (Figure 12).

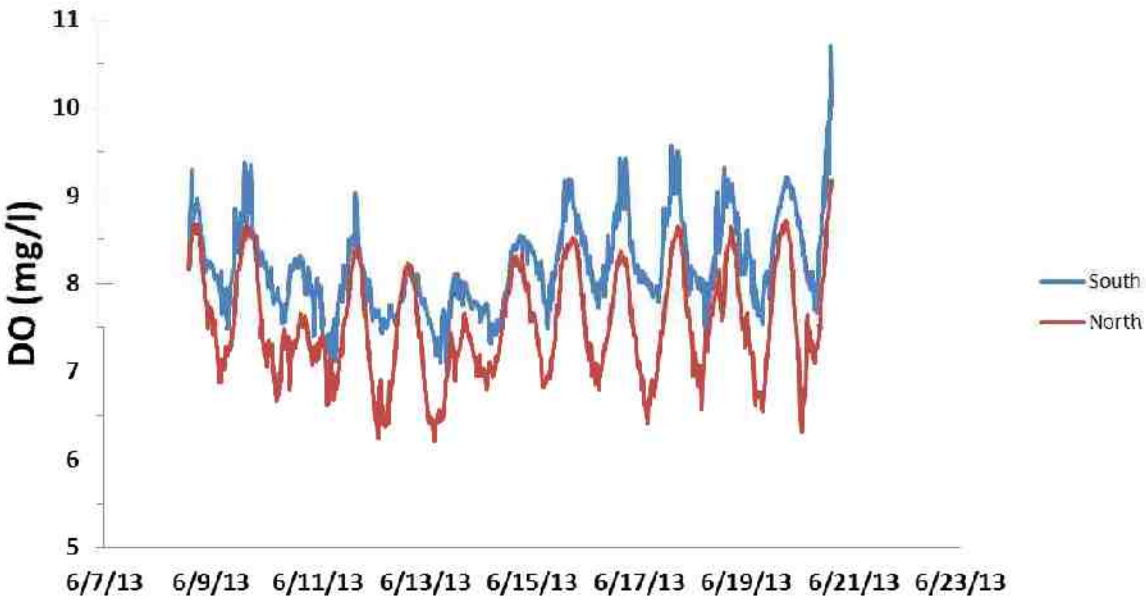


**Figure 11. Diel DO values at two shallow locations in Salt Pond, Falmouth. These are continuous observations (every 15 minutes) for a period of about 10 days in June 2013.**

Some measure of system variability should be considered with DO rather than random discrete values. DO concentrations can vary rapidly over time a space (on an hourly scale). This suggests that an approach to integrate frequency and duration of low DO events should be considered, such as a percentile approach. The effective boundary of the surface water layer in Oyster Pond varies vertically and, therefore, directly influences its horizontal (areal) extent.

| Designated Use | Criteria Concentration/Duration | Protection Provided | Temporal Application |
|---|---|---|---|
| Migratory fish spawning and nursery use | 7-day mean ≥ 6 mg liter$^{1}$ (tidal habitats with 0-0.5 ppt salinity) | Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species. | February 1 - May 31 |
| | Instantaneous minimum ≥ 5 mg liter$^{1}$ | Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species. | |
| | Open-water fish and shellfish designated use criteria apply | | June 1 - January 31 |
| Shallow-water bay grass use | Open-water fish and shellfish designated use criteria apply | | Year-round |
| Open-water fish and shellfish use | 30-day mean ≥ 5.5 mg liter$^{1}$ (tidal habitats with 0-0.5 ppt salinity) | Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species. | Year-round |
| | 30-day mean ≥ 5 mg liter$^{1}$ (tidal habitats with >0.5 ppt salinity) | Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species. | |
| | 7-day mean ≥ 4 mg liter$^{1}$ | Survival of open-water fish larvae. | |
| | Instantaneous minimum ≥ 3.2 mg liter$^{1}$ | Survival of threatened/endangered sturgeon species.[1] | |
| Deep-water seasonal fish and shellfish use | 30-day mean ≥ 3 mg liter$^{1}$ | Survival and recruitment of bay anchovy eggs and larvae. | June 1 - September 30 |
| | 1-day mean ≥ 2.3 mg liter$^{1}$ | Survival of open-water juvenile and adult fish. | |
| | Instantaneous minimum ≥ 1.7 mg liter$^{1}$ | Survival of bay anchovy eggs and larvae. | |
| | Open-water fish and shellfish designated-use criteria apply | | October 1 - May 31 |
| Deep-channel seasonal refuge use | Instantaneous minimum ≥ 1 mg liter$^{1}$ | Survival of bottom-dwelling worms and clams. | June 1 - September 30 |
| | Open-water fish and shellfish designated use criteria apply | | October 1 - May 31 |

[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter$^{1}$ will protect survival of this listed sturgeon species.

**Figure 12. Chesapeake Bay dissolved oxygen criteria.**

The mathematical relationship between mean DO and surface layer depth at station OP-3 is shown in Figure 13. Class SA and SB thresholds are shown for comparative purposes. The relatively steep slope of the curve suggests that mean DO is very sensitive (drops rapidly) with depth and that the 3.0 m value exceeds the threshold by a large margin (only one observation was below 6 mg/L, see Figure 10 above). Based on the variability in the summer salinity profile shown in Figure 9, it may be worthwhile for decision makers to consider a probabilistic approach to managing nitrogen load reductions. This could result in a more definitive and consistent approach to determining compliance of future load reductions to TMDL targets and overall water quality goals.

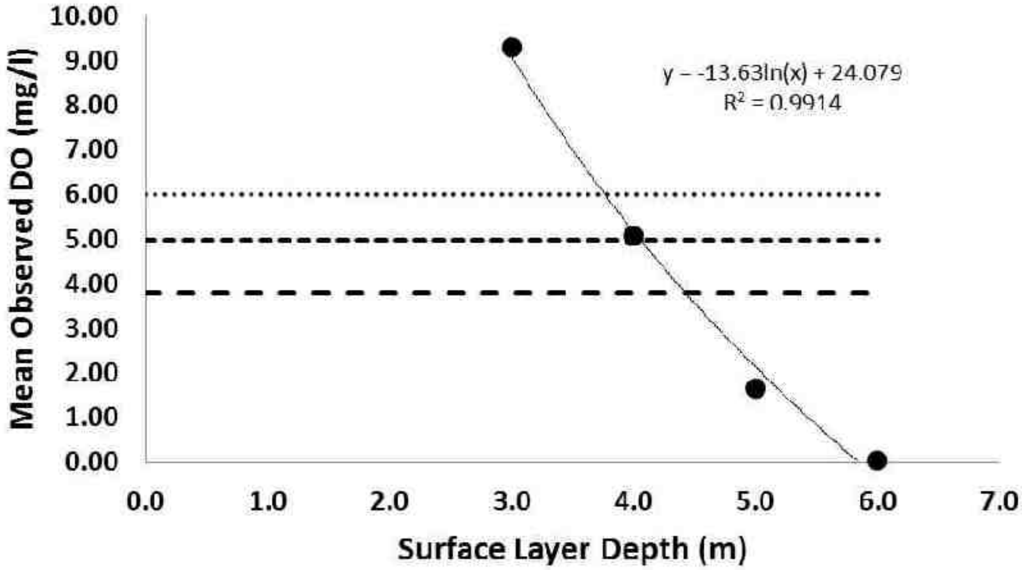


**Figure 13. The relationship between surface layer depth (4 m) and mean observed summer DO concentrations (mg/l) from 2005 through 2012 data. Dashed lines indicate DO thresholds for Chesapeake Bay (3.8), SB (5.0), and SA (6.0). Logarithmic trend is also shown.**

## 2.2 MEP CONCLUSION SUMMARY

The MEP report on Oyster Pond provides a summary of conditions observed 1997 through 2004. Based on the data collected and modeling work applied to the pond, the MEP calculated the nitrogen load reductions necessary to restore water quality to the surface mixed layer of the pond. The reductions were based on the following assumptions:

- The salinity regime will remain near-constant in the surface layer (at about 2-4 ppt).
- That station OP-3 is the best representative for basing TMDL compliance.
- The depth of 4 meters (at station OP-3) is the point where TMDL compliance should be met to assure water quality improvement throughout the entire pond.
- The SA classified designated use category, and criteria, should be applied to station OP-3 at depth of 4 m (DO maintained at or above 6 mg/L).
- Assumed that the nitrogen load reduction is a linear 1:1 relationship between percent increase in DO necessary for compliance and nitrogen load.
- The percent DO increase necessary to maintain 6 mg/L at 4 m depth at station OP-3 is based on a relationship between the minimum observed value of DO (assumed 2 mg/L), mean summer water temperature of 25C, and salinity of 2 ppt.
- DO consumption in the water column was assumed to be directly proportional to the amount of organic matter in Oyster Pond which was assumed to be proportional to nitrogen load.

- The final percent reduction of nitrogen load (65%) was based on the assumption that mean summer conditions would remain constant in the future due to the controlled salinity regime in the pond.

The nature of Oyster Pond certainly provides a challenge to ecological modelers because of the unique features of its bathymetry and stratification. However, the data collected by OPET in the years subsequent to the MEP work provides an insight to the natural variability of salinity and DO at depth and this variability would certainly affect the application of the model results.

## 2.3 CLIMATE CHANGE AND SLR

The predictions associated with are ripe with uncertainty. The benthic habitat of Oyster Pond may encounter changes in the frequency and duration of thermal stress events, including low DO that can be associated with increased temperature. The fauna may also respond to milder winters with fewer freezing events through changes in competition among existing fauna and the introduction and sustainability of non-native species. Sea level is maintained by the weir above the lagoon. However, the frequency and duration of flood events could increase as a result of sea level rise, especially during periodic increases in sea level that already naturally occur (Figures 14 and 15).

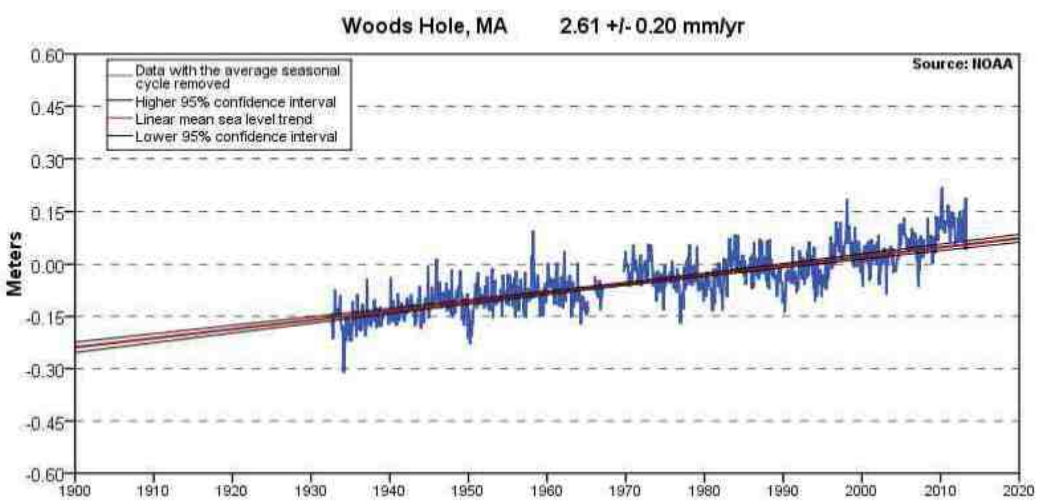


**Figure 14. The mean sea level trend is 2.61 millimeters/year with a 95% confidence interval of +/- 0.20 mm/yr based on monthly mean sea level data from 1932 to 2006 which is equivalent to a change of 0.86 feet in 100 years.**

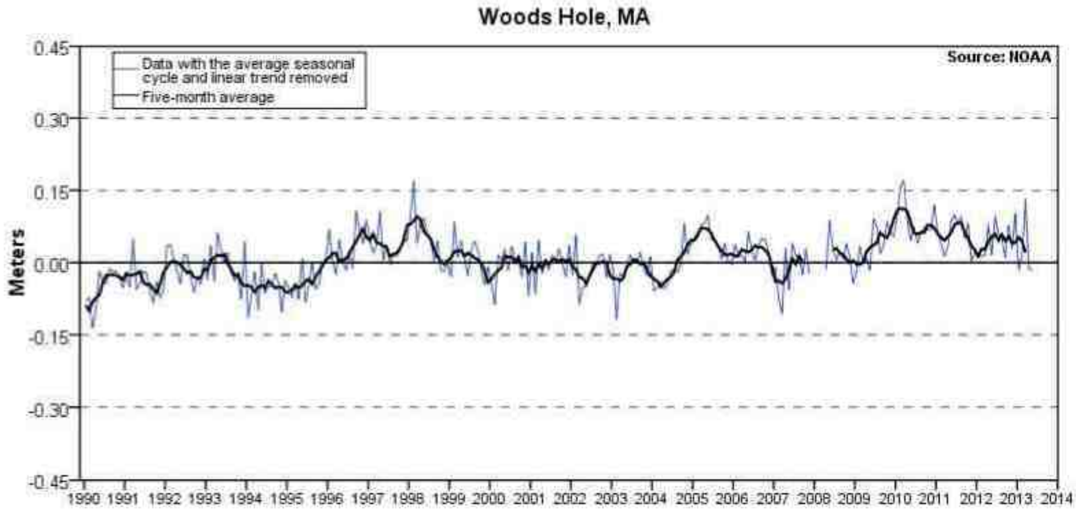


**Figure 15. The interannual variation of monthly mean sea level and the 5-month running average. The average seasonal cycle and linear sea level trend have been removed. Interannual variation is caused by irregular fluctuations in coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The interannual variation for some stations is closely related to the** El Niño Southern Oscillation (ENSO)**.**

The management of thermal stress and related ecological changes is somewhat limited because it is due to external environmental conditions. Increasing the flushing rate of Oyster Pond could ameliorate thermal stress events, but this would also alter the salinity of the surface waters and be contrary to current management of the pond. Sea level rise can be managed through engineering solutions (barrier dunes, reconstruction of the weir) to some extent and preparations for these types of responses could be explored now.

## 2.4 THERMAL AND DENSITY-INDUCED STRATIFICATION

The current conditions of summer stratification effectively segregates Oyster Pond's water column into two classes: relatively good surface water and organic-rich hypoxic and anoxic bottom waters. The margin between the surface and bottom can vary significantly (based on a review of OPET data) and each layer may influence each other depending upon their extent of physical or diffusive exchange. The current management of the pond allows for the preservation of the surface layer habitat (across up to 80% of the pond) at the cost of enhancing deleterious effects within the bottom layer. Preserving this salinity regime, as much as possible, will limit the exchange of hypoxic and anoxic bottom waters from the deeper regions of the pond to the surface. However, periodic turnovers or exchange events may result in temporary summer and seasonal declines in Oyster Pond's surface layer water quality. The nitrogen load reductions necessary to achieve improved water quality in the pond's surface waters will always depend upon the frequency and extent of surface and bottom mixing (note that ammonium concentration in the deeper regions of the pond can be quite high). Load reductions should also be practical to avoid unnecessary capital projects. To avoid this, a probabilistic approach that incorporates natural variability, pond-specific designated uses, and monitoring sufficient to have some acceptable level of confidence in the pond's conditions is recommended.

### 2.5 MONITORING METHODS

The monitoring methods employed by the MEP and OPET work are sufficient to characterize mean conditions and some of the variability along depth intervals in the pond. If dissolved oxygen continues to be the indicator of water quality, and benthic habitat quality, then continuous logging of DO should be applied to understand and quantify diel and event-driven influences on DO. Continued monitoring at the designated stations will allow comparisons to historical data and trends. The OPET database doesn't included PON which is an important nitrogen constituent in the MEP work. The dissolved nitrogen data from the MEP work, if made available, could be compared to the more recent OPET data in, perhaps, a more effective effort to track changes in the pond.

### 2.6 CONSEQUENCES OF NO ACTION FOR OYSTER POND

The consequences of not abating nutrient inputs to Oyster Pond likely include the continuation of good, but marginal, water quality. Benthic habitat will be marginal and may decrease over time with the accumulation of organic matter. Periodic nuisance macroalgal blooms are likely to continue due to the existing level of nutrient enrichment in the pond's surface waters. The bottom waters will continue to exhibit hypoxic and anoxic conditions even with modest to significant nutrient reductions due to the nature of this unique system. This persistent condition, due to the stratification of the water column, will continue to support periodic enrichment events because the pyncnocline is variable by nature and some exchange along the boundary of surface and bottom waters is likely.

### 2.7 SUGGESTED MONITORING PROGRAM

The monitoring program should be based on one or more hypotheses and planned through a rigorous statistical approach. In recent work in Little Pond, the Town has been encouraged to determine the minimum level of samples to collect over time to sufficiently determine whether the data will detect significant changes in water quality (e.g., TN concentration). Inter-annual differences in TN (and other important water quality indicators) occur frequently (see Figures 2, 3, and 4). The confidence in detecting independent and measurable changes in water quality is dependent upon the number of samples from Oyster Pond, and other environmental data (meteorological). This can be done by analyzing the variability in the MEP and OPET data. This requires the raw data such as reported online by OPET.

WRIGHT-PIERCE

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