Town of Mashpee, Popponesset Bay, & Waquoit Bay East Watersheds

Nitrex^{TM} Technology Scenario Plan

Submitted to:

Town of Mashpee
Sewer Commission
16 Great Neck Road North
Mashpee, MA 02469

***Submitted by*:**

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Town of Mashpee
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Executive Summary

Lombardo Associates, Inc. (LAI) was retained by the Mashpee Sewer Commission to prepare a decentralized wastewater management plan for the Town of Mashpee for the Project Planning Area (PPA) of the East Waquoit and Popponesset Watersheds. The decentralized plan was to achieve the TMDL requirements as specified by the Massachusetts Department of Environmental Protection, and thereby can be compared on an equal basis with the conventional sewering option for nitrogen management.

The Decentralized Scenario Plan includes the options of:

1. Cluster Systems
2. Individual Onsite Nitrex™ Treatment Systems for application as:
   a. Retrofit to properties
   b. New systems
3. Nitrex™ Groundwater Treatment System
   a. Pump and Treat
   b. Permeable Reactive Barrier (PRB)

Individual onsite systems and the groundwater treatment systems are presented for illustrative purposes only. The final proposed decentralized scenario uses only cluster systems.

Per the request of the Mashpee Sewer Commission, LAI also examined Santuit Pond Phosphorus Treatment.

A summary of the costs of the decentralized based Scenarios are presented below.

Table 1. Decentralized Scenario Costs Compared to Centralized WW System

Nitrex™ Technology Scenarios	Capital Cost	Capital Cost / EDU	Capital Cost / (lb/year) N Removed	Capital Cost / (kg/day) N Removed	Capital Cost / (kg/year) N Removed	Nitrex™ Technology Capital Cost as % of Complete WW System w/ Sewers	Nitrex™ Technology Capital Cost as % of Sewers Connected to Existing WWTP & Expansion
Cluster Systems	$300,857,000	$34,777	$20,502	$3,401,417	$9,319	65%	56%
Individual Systems	$259,530,000	$30,000	$17,685	$2,934,184	$8,039	56%	48%
Groundwater Treatment - Pump & Treat	$130,212,000	$15,052	$8,873	$1,472,146	$4,033	28%	24%
Groundwater Treatment - PRB	$239,394,505	$27,672	$18,621	$3,089,342	$8,464	52%	44%
Stearns & Wheler Scenario 4 Proposed Estimates - low end(2,3)	$460,000,000+	$66,000	$22,329	$3,704,618	$10,150		
Stearns & Wheler Scenario 1 Proposed Cost Estimates - high end(2,3)	$540,000,000+	$66,000	$19,021	$3,155,786	$8,646		

(1) MA State Tax Credit of $6,000 may be available to property owners with septic system repair.

(2) The Stearns & Wheler proposed cost estimates in the March 2008 Draft Alternative Scenarios Analysis Report do not include allowances for land acquisition, acquisition of needed WWTPs, and treatment costs at the Falmouth and Barnstable WWTPs.

(3) Ratio of Captial Cost are higher than the per EDU ratio due to the fact that the Stearns & Wheler proposal is to sewer more properties than proposed by LAI.

Table 1b. Decentralized Scenario O&M Costs Per EDU

Nitrex™ Technology Scenarios	Annual O&M Costs / EDU
1. Cluster Systems	$389
2. Individual Systems	$703
3. Groundwater Treatment - Pump & Treat	$135
4. Groundwater Treatment - PRB	$144
5. Conventional Sewerage System	$700 - $1,000[1]

[1]Based on Stearns & Wheler Presentation.

Table 1c. Other Decentralized Technology Options for Specific Areas of PPA

Nitrex™ Technology Scenarios	Capital Cost / (lb/year) N Removed
1. Groundwater Treatment - Pump & Treat	$9,397
2. Groundwater Treatment - PRB	$11,172

It is noted that the TMDLs developed for the PPA require approximately 75-85+/-% of wastewater nitrogen to be removed. The Town may deem it equitable that a portion of the costs be apportioned to those properties whose wastewater is not being treated as they also will be the beneficiaries of the improved water quality.

Massachusetts Estuaries Project (MEP) Unified Database and Model

At the request of the Mashpee Sewer Commission, the Coastal Systems Program (CSP) of the School for Marine Science and Technology (SMAST) at the University of Massachusetts Dartmouth evaluated nitrogen management alternatives for the Town of Mashpee by developing a unified database of land and water-use information and evaluating five (5) wastewater management scenarios using a revised version of the Massachusetts Estuaries Project (MEP) model.

The results were published in the November 13, 2009 MEP Technical Memo on Popponesset Bay Analysis and the December 15, 2009 MEP Technical Memo on Eastern Basins of the Waquoit Bay System (attached as Appendix C).

It is noted that using the nitrogen loads based on the update unified database, Lombardo Associates, Inc. Scenario 3 (Nitrex™) met the threshold values at the sentinel station for restoration of eelgrass in Popponesset Bay and was the only scenario to yield water column TN concentrations within each of the three tributary subembayments that would be restorative of faunal habitat. Of the four (4) conventional scenarios only Scenario #4 met the threshold values in Popponesset Bay.

Of the three East Waquoit watersheds examined, according to MEP, the Lombardo Associates, Inc. Scenario #3 (Nitrex™) did not achieve the TMDL requirements in any of the watersheds. The conventional Scenarios achieved TMDL requirements in 2 of the 3 watersheds.

In response to the MEP Technical Memos on the TMDL model runs, Lombardo Associates, Inc. issued Response Memos to the Mashpee Sewer Commission on December 4, 2009 and December 18, 2009, respectively (attached as Appendix D).

On December 29, 2009, LAI submitted a revised Scenario 3R to MEP for analysis. The revised Scenario 3 did not change any of the cluster assignments or discharge locations in Popponesset Bay. The revisions included were limited in scope in their entirety to the East Waquoit Bay Watershed and the New Seabury area that discharges to the ocean. On February 9, 2010, MEP issued their report on the revised Scenario 3R, in which the analysis showed that the requirements of the TMDL for all subwatersheds within the East Waquoit watershed were met with margin to spare. The report is contained in Appendix C.

Scenario 3R, as evaluated by MEP, utilized dispersal sites that may need revising. Subsequently, the Town of Mashpee has identified a number of prospective dispersal sites that have capacity in excess of what is needed to disperse the treated wastewater. A final optimization of dispersal sites and any associated changes in service areas will be needed to create a final decentralized scenario.

Speed of Implementation & Water Quality Improvement.

The Nitrex™ Technology options can achieve the desired water quality improvements more quickly than treating wastewater because:

1. The Nitrex™ PRB and pump and treat systems can address groundwater just prior to its reaching surface water bodies. Treating wastewater will require the groundwater to cleanse itself after excess nitrogen loadings are reduced.

According to the USGS, this will take 10-20 years **after** the treatment systems are functioning. Conventional sewering may take 10 – 20 years to complete.

In addition to the speed of implementation, these two options have the benefit of treating land use nitrogen loads as well as nitrogen loads from upstream sources. The Nitrex^{TM} on-site and cluster approaches can be implemented quicker and achieve nitrogen loadings faster than conventional sewering.

Nitrogen Load Removal-Based Solutions

Due to data availability, the Nitrex^{TM} Scenario that was most thoroughly developed, and the only one that was evaluated by MEP, was the Cluster System Scenario. This scenario delineates the parcels that need to be treated to achieve the water quality goals for the project planning area. The Onsite Scenario is similar to the Cluster System Scenario, in that the same basic parcels are treated, with minimal adjustments made to account for watersheds that require 100% removal of wastewater nitrogen. The pump and treat and PRB scenarios are presented as alternatives that offer benefits such as significant capital and operational cost savings as well as the speed of implementation and water quality improvement. However, their detailed evaluation requires additional groundwater quality information. The common factor for all scenarios is the required nitrogen removal. The groundwater pump and treat and PRB options require more groundwater flow and quality data than is currently available, as well as specific solute transport data, to accurately locate the systems. Therefore these scenarios are strictly conceptual and for comparison purposes only.

The Watersheds in Popponesset Bay along with the Sub-Watersheds that are most optimal to target, taking into consideration the density and natural attenuation of each, are presented below. The Cluster numbers that are proposed to remove the necessary nitrogen loads are also included.

- Mashpee River Watershed
    - Main Subwatersheds to treat: Upper Mashpee River and Lower Mashpee River
    - Clusters 1, 3, 6, 10, 11, 13 and 16

- Shoestring Bay
    - Subwatersheds to treat: Santuit River and Shoestring Bay
    - Clusters 1, 5, 11-14 and 16

- Ockway Bay
    - Treat all
    - Cluster 3

- Pinquickset Cove

  - No treatment needed
  - Cluster 14 does pick up some parcels in Pinquickset Cove

- Popponesset Bay
  - Subwatersheds to treat: Popponesset Creek and Popponesset Bay
  - Clusters 3 and 14

The Watersheds in East Waquoit Bay along with the Sub-Watersheds that are most optimal to target, taking into consideration the density and natural attenuation of each, are presented below. The Cluster numbers that are proposed to remove the necessary nitrogen loads are also included.

- Quashnet River
  - Subwatersheds to treat: Upper Quashnet River and Johns Pond
  - Clusters 2, 4, 8, 10, and 15

- Hamblin Pond / Red Brook
  - Subwatersheds to treat: Hamblin Pond and Red Brook
  - Clusters 4, 6, and 9

- Jehu Pond / Great River
  - Subwatersheds to treat: Lower Great River and Jehu Pond
  - Clusters 3, 7, 9 and 16

- Sage Lot / Flat Pond
  - No TMDL – No Treatment required
  - Cluster #7 does pick up some parcels in Sage Lot / Flat Pond

Table 2 presents the costs for the cluster systems for the entire PPA. These costs do not include the revisions to the dispersal sites discussed above. It is estimated that relocating dispersal sites would require pump stations and piping that would total approximately $8 million in addition to the costs presented in this report.

Table 3 disaggregates the costs by watershed. As some of the Clusters do overlap into neighboring watersheds, treating one watershed may achieve some treatment in another.

Figures 1 and 2 illustrate the existing attenuated watershed behavior (ATT) and the total wastewater nitrogen contribution as a percentage of the total nitrogen removal required for each of the MEP sub-watersheds (ET). Figure 3 illustrates the treated cluster areas to achieve the nitrogen removal requirements. The Nitrex™ Cluster Scenario database has been submitted to UMass – Dartmouth for determination if the Nitrex™ Scenario achieves the required nitrogen removal for compliance with TMDL requirements.

Table 2. Costs for Cluster Systems in PPA

Planning Area	# of Parcels	Existing Wastewater Flow (gpd)	Total EDUs	Total Capital Cost	Total Capital Cost per EDU	Total O&M	Total O&M per EDU	Total O&M per Parcel	Total Present Worth	Total Present Worth per EDU*	Total Present Worth per Parcel*
			154		154						
Cluster #1	401	37,820	246	$12,014,000	$48,920	$159,169	$648	$397	$10,977,597	$44,700	$44,700
Cluster #2	545	91,268	593	$20,215,000	$34,110	$186,201	$314	$342	$17,445,477	$29,436	$29,436
Cluster #3	631	69,408	451	$19,869,000	$44,085	$178,834	$397	$283	$17,097,665	$37,936	$37,936
Cluster #4	694	86,409	561	$22,833,000	$40,694	$187,893	$335	$271	$19,424,556	$34,619	$34,619
Cluster #5	530	77,492	503	$18,560,000	$36,884	$179,819	$357	$339	$16,130,941	$32,057	$32,057
Cluster #6	353	67,247	437	$13,886,000	$31,800	$170,800	$391	$484	$12,524,544	$28,682	$28,682
Cluster #7	457	59,153	384	$15,258,000	$39,723	$169,927	$442	$372	$13,535,669	$35,239	$35,239
Cluster #8	466	48,516	315	$14,406,000	$45,728	$85,502	$271	$183	$11,841,546	$37,588	$37,588
Cluster #9	467	48,044	312	$14,380,000	$46,093	$165,307	$530	$354	$12,820,094	$41,093	$41,093
Cluster #10	568	132,662	861	$24,728,000	$28,705	$204,866	$238	$361	$21,061,083	$24,449	$24,449
Cluster #11	398	70,710	459	$15,158,000	$33,013	$173,470	$378	$436	$13,499,822	$29,402	$29,402
Cluster #12	206	51,362	334	$9,286,000	$27,843	$160,107	$480	$777	$8,941,283	$26,809	$26,809
Cluster #13	814	92,803	603	$25,948,000	$43,059	$193,752	$322	$238	$21,832,580	$36,230	$36,230
Cluster #14	278	41,497	269	$9,819,000	$36,439	$157,630	$585	$567	$9,313,418	$34,563	$34,563
Cluster #15	491	78,564	510	$17,854,000	$34,997	$179,283	$351	$365	$15,598,257	$30,575	$30,575
Cluster #16	1,352	190,507	1,237	$46,643,000	$37,705	$250,157	$202	$185	$38,030,513	$30,743	$30,743
Totals	*8,651*	*1,243,462*	*8,074*	*$300,857,000*	*$37,260*	*$2,802,717*	*$347*	*$324*	*$260,075,044*	*$32,210*	*$32,210*

*Using 20 year planning period and interest rate of 5%

Table 3. Nitrex™ Scenarios Cost Estimates by Watershed

Planning Area	Existing Sub-Watershed Wastewater Flow in Clusters (gpd)	Total EDUs in Cluster Section in Sub-Watershed	Nitrex™ Solution Range of Total Capital Costs					
			Total Cost			$/EDU		
POPPONESSET BAY WATERSHED								
Mashpee River	394,398	2,561	$39,475,300	-	$89,472,500	$15,500	-	$35,000
Shoestring Bay	274,763	1,784	$25,315,700	-	$66,194,200	$14,200	-	$37,200
Ockway Bay	25,766	167	$2,915,200	-	$7,339,900	$17,500	-	$43,900
Pinquickset Cove	5,584	36	$673,400	-	$1,327,700	$18,600	-	$36,700
Popponesset Bay	38,885	253	$4,404,100	-	$11,048,600	$17,500	-	$43,800
POP TOTAL	*739,395*	*4,801*	*$75,998,900*	-	*$175,382,700*	*$15,900*	-	*$36,600*
EAST WAQUOIT BAY WATERSHED								
Quashnet River	202,140	1,313	$22,924,600	-	$52,300,600	$17,500	-	$39,900
Hamblin Pond / Red Brook	100,630	653	$14,007,700	-	$28,048,400	$21,500	-	$43,000
Jehu Pond / Great River	63,126	410	$7,185,300	-	$16,671,400	$17,600	-	$40,700
Sage Lot / Flat Pond	6,625	43	$635,400	-	$1,704,700	$14,800	-	$39,700
WAQ TOTAL	*372,521*	*2,419*	*$44,803,300*	-	*$97,393,900*	*$18,600*	-	*$40,300*
PPA Total	1,111,916	7,220	$120,802,100	-	$272,776,500	$16,800	-	$37,800

Figure 1. Popponesset Bay – Existing Attenuated Watershed Behavior and Total Wastewater Nitrogen Contribution as % of N Removal Required

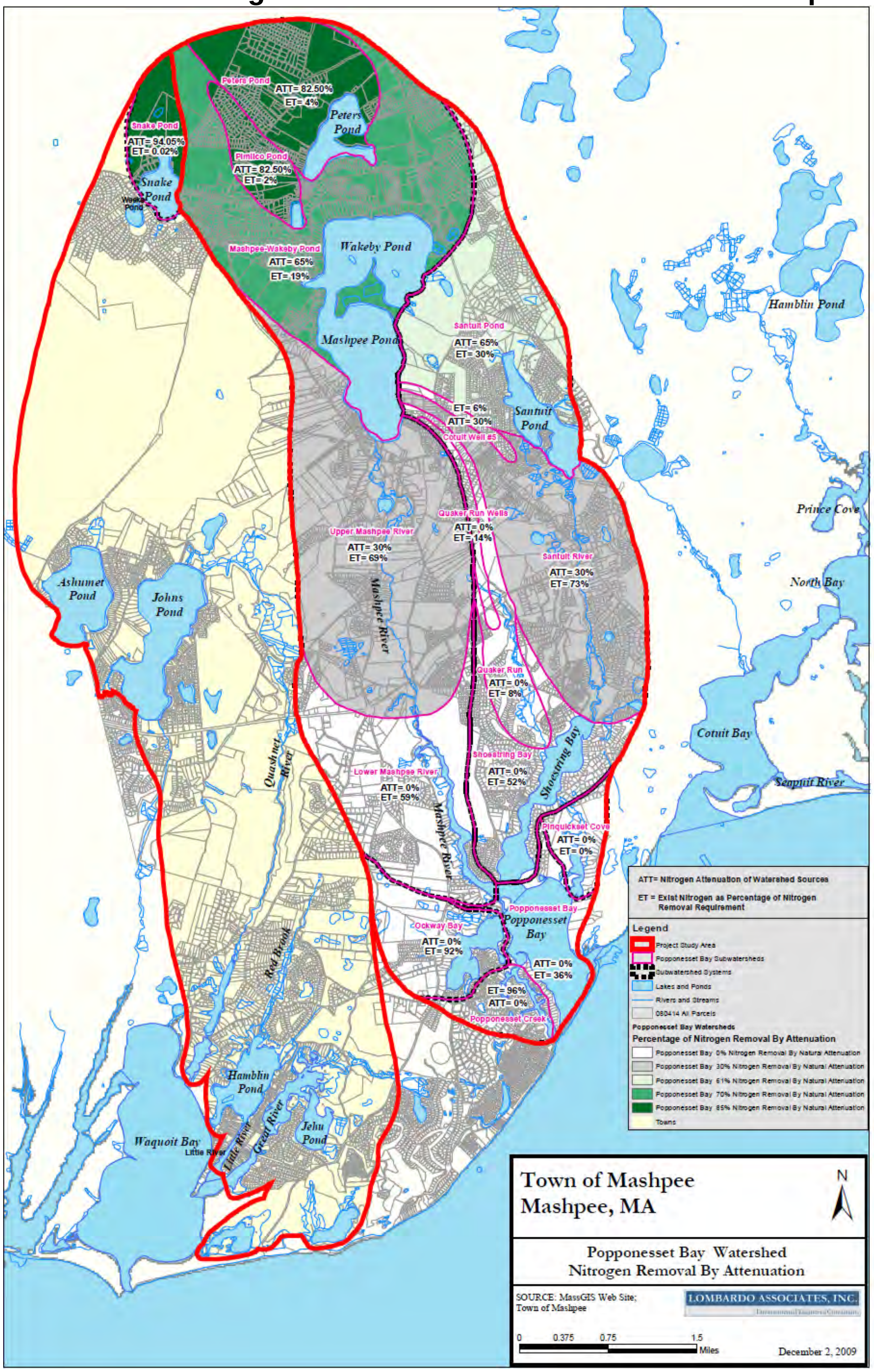


Figure 2. East Waquoit Bay – Existing Attenuated Watershed Behavior and Total Wastewater Nitrogen Contribution as % of N Removal Required

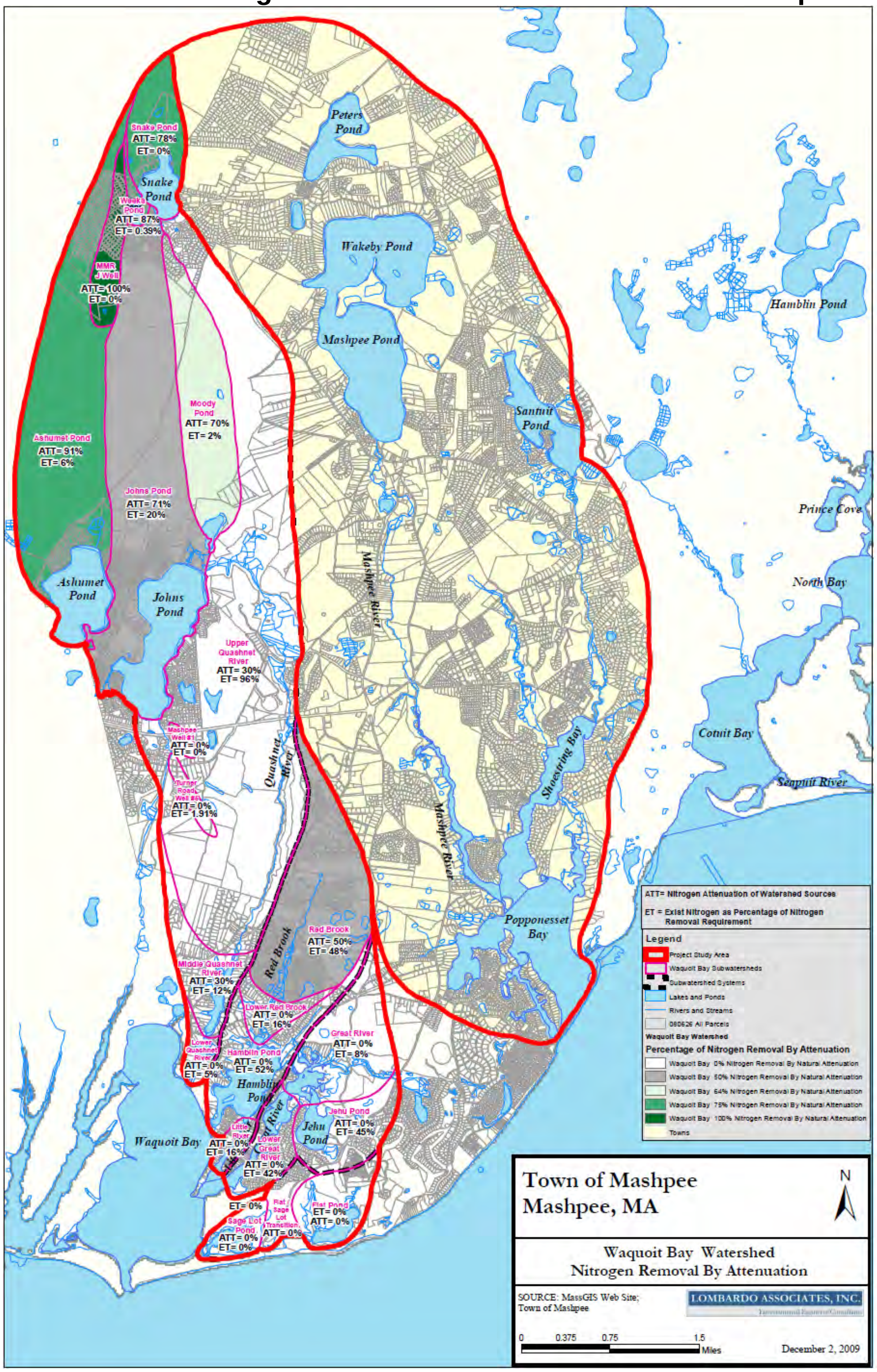
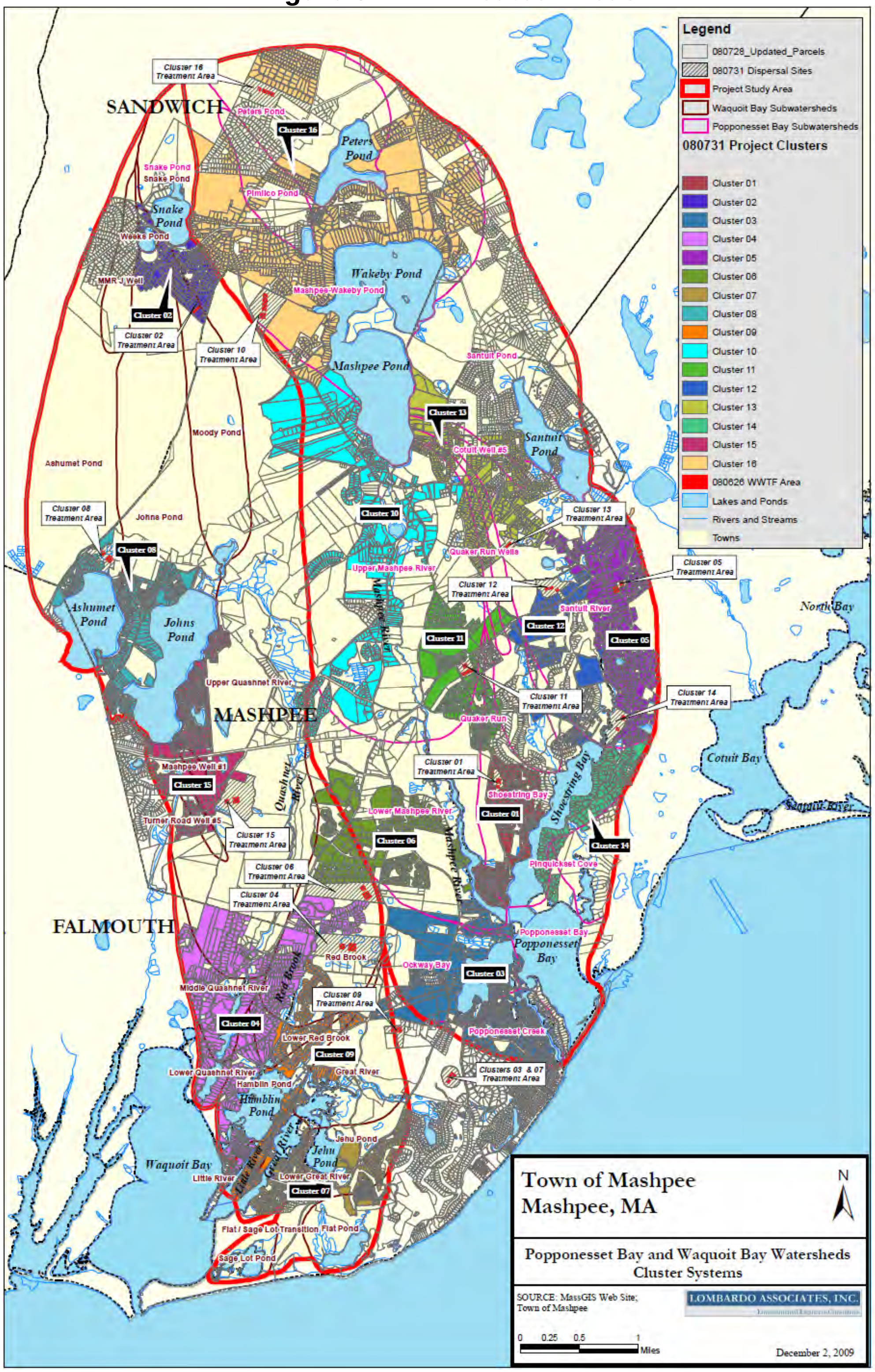


Figure 3. PPA Treated Areas



1 Objective

In accordance with the June 19, 2007 Agreement between the Town of Mashpee Sewer Commission and Lombardo Associates, Inc., Lombardo Associates, Inc. (LAI) has developed a conceptual Decentralized Technology Scenario Plan to achieve compliance with the TMDL reports' nitrogen loading requirements, as well as to address concerns regarding phosphorus overloading in Santuit Pond.

The following Nitrex™ Technology Scenario Plan includes:

1. Cluster Systems
2. Individual Nitrex™ Treatment Systems for application as:
    a. Retrofit to properties
    b. New systems
3. Nitrex™ Groundwater Treatment - PRB
4. Nitrex™ Groundwater Treatment System – Pump and Treat

Scenarios 2, 3 & 4 are presented for illustration purposes. Only the Cluster System scenario (Scenario 1) was developed fully to meet the TMDL requirements. LAI also examined Santuit Pond Phosphorus Treatment.

The purpose of this Report is to provide an environmentally compatible and economically feasible plan for nitrogen reduction, wastewater treatment, and effluent recharge in the Project Planning Area (PPA), utilizing a decentralized approach, as well as addressing phosphorous issues in Santuit Pond. This report is based on the MEP Water Quality Assessment findings and the MADEP TMDL Reports for the watersheds and the Stearns and Wheler, LLC's Final *Town of Mashpee, Popponesset Bay, & Waquoit Bay East Watersheds Needs Assessment* Report (Assessment Report), dated April 2007 and March 2008 Report.

2 Background

Located on Cape Cod, the Town of Mashpee is the fastest growing municipality in the Commonwealth, and felt by its new and old residents to be one of the most gifted with natural beauty. The total area of the Town is 23.48 square miles, with an annual population of 12,946, according to the 2000 census, and a summer population approaching 30,000.

Mashpee is located almost entirely within the watersheds of two shallow, nitrogen-sensitive embayments – Popponesset Bay and Waquoit Bay East. Excessive inputs of nitrogen has been identified as the cause of the degradation of both watersheds.

As stated in the Needs Assessment Report, “The Town of Mashpee’s (Town) Watershed Nitrogen Management Plan (WNMP) project was initiated in 1999 to address the Town’s need for reducing nitrogen impacts to its coastal embayments and to evaluate all options for restoring those embayments.” The Popponesset Bay and the Waquoit Bay East watershed systems, as described in the Massachusetts Estuaries Project (MEP) Reports have been added to the Project Planning Area (PPA).

The PPA includes the following areas:

- The entire town of Mashpee
- The Popponesset Bay watershed that extends into the towns of Barnstable and Sandwich, as defined by MEP
- The Waquoit Bay East watershed that extends into the towns of Falmouth and Sandwich, as defined by MEP

2.1 Wastewater Flows

The existing and future average annual wastewater flows given in the Stearns & Wheler Needs Assessment Report for the entire PPA are presented in Table 2.1.1.

Table 2.1.1. Existing and Future Average Annual Wastewater Flows for Entire PPA

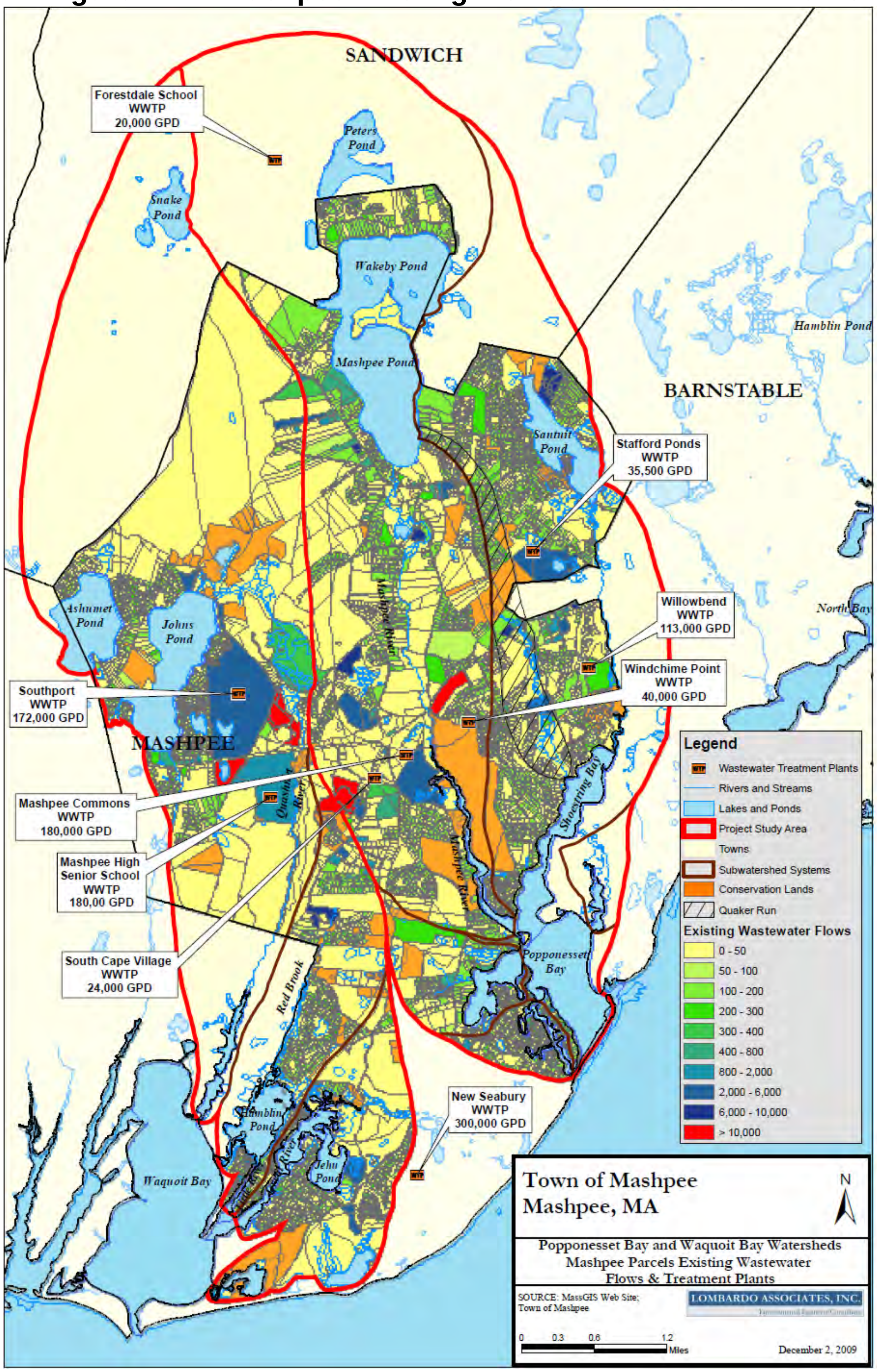
Land Use	Existing Flow (gpd)	Future Flow (gpd)
Multiuse	2,900	4,100
Residential	1,400,000	2,400,000
Commercial	93,000	200,000
Industrial	14,000	72,000
Institutional	15,000	67,000
Total	***1,500,000***	***2,700,000***

Source: Table 7-3 on page 7-5 of the Stearns & Wheler *Needs Assessment Report* , April 2007.

It is noted that the Town’s database state existing wastewater flows are 1,383,780 gpd and future flow 2,353,009 gpd – see Table 3.1.1.

Figure 2.1.1 illustrates the locations of the existing WWTPs in the PPA.

Figure 2.1.1. Mashpee Existing Flows and Treatment Plants



2.2 Hydrogeology

The daily groundwater discharge to each of the sub-embayments in the East Waquoit Bay system and the Popponesset Bay system, as determined from the USGS groundwater model, is presented below in Tables 2.2.1 and 2.2.2, respectively.

The Town of Mashpee had groundwater flow modeling performed in existing and potential effluent discharge locations. These ten (10) modeling results, which show subsurface flow direction and time of travel, are presented on Figures 2.2.1 through 2.2.3.

Table 2.2.1. East Waquoit Bay Groundwater Discharge

Watershed	Discharge		
	ft^3/day	gpd	m^3/day
Great River/Jehu Pond			
Lower Great River	39,070	292,244	1,106
Jehu Pond	65,473	489,738	1,853
Great River	110,631	827,520	3,131
Sage Lot/Flat Pond	92,654	693,052	2,622
SUBTOTAL	**307,828**	**2,302,553**	**8,712**
Little River/Hamblin Pond			
Red Brook	215,913	1,615,029	6,110
Lower Red Brook	31,425	235,059	889
Hamblin Pond	66,615	498,280	1,885
Little River	13,082	97,853	370
SUBTOTAL	**327,035**	**2,446,222**	**9,255**
Quashnet River			
Upper Quashnet River	1,649,859	12,340,945	46,691
Middle Quashnet River	65,937	493,209	1,866
Lower Quashnet River	14,910	111,527	422
SUBTOTAL	**1,730,706**	**12,945,681**	**48,979**
East Waquiot Watershed Total	***2,365,569***	***17,694,456***	***66,946***

Source: MADEP Massachusetts Estuaries Project *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for The Quashnet River, Hamblin Pond, and Jehu Pond, in the Waquoit Bay System of the Towns of Mashpee and Falmouth, Massachusetts* . September 2004.

Table 2.2.2. Popponesset Bay Groundwater Discharge

Watershed	Discharge		
	ft^3/day	gpd	m^3/day
Popponesset Bay			
Popponesset Bay	41,496	310,390	1,174
Popponesset Creek	60,596	453,258	1,715
SUBTOTAL	**102,092**	**763,648**	**2,889**
Ockway Bay			
Ockway Bay	75,887	567,635	2,148
SUBTOTAL	**75,887**	**567,635**	**2,148**
Shoestring Bay			
Shoestring Bay	146,455	1,095,483	4,145
Santuit River	709,625	5,307,995	20,082
Quaker Run	131,724	985,296	3,728
SUBTOTAL	**987,804**	**7,388,774**	**27,955**
Mashpee River			
Upper Mashpee River	1,597,053	11,945,956	45,197
Lower Mashpee River	204,105	1,526,705	5,776
SUBTOTAL	**1,801,158**	**13,472,662**	**50,973**
Pinquickset Cove			
Pinquickset Cove	54,914	410,757	1,554
SUBTOTAL	**54,914**	**410,757**	**1,554**
Popponesset Watershed Total	***3,021,855***	***22,603,475***	***85,518***

Source: MADEP Massachusetts Estuaries Project *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts* . September 2004.

Figure 2.2.1. Mashpee Groundwater Discharge Model Runs 1, 2, 9 & 10

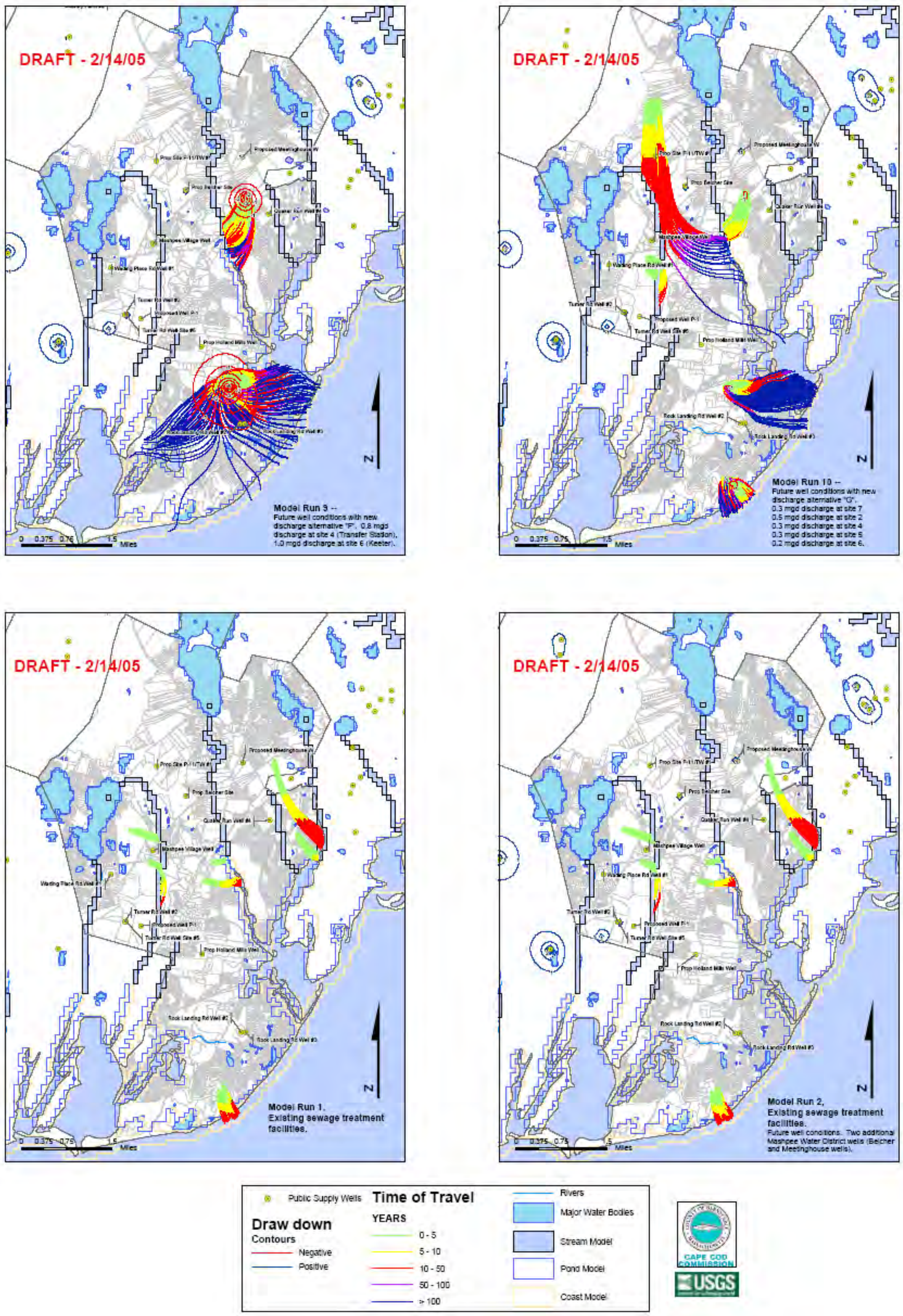


Figure 2.2.2. Mashpee Groundwater Discharge Model Runs 3, 4, 5 & 6

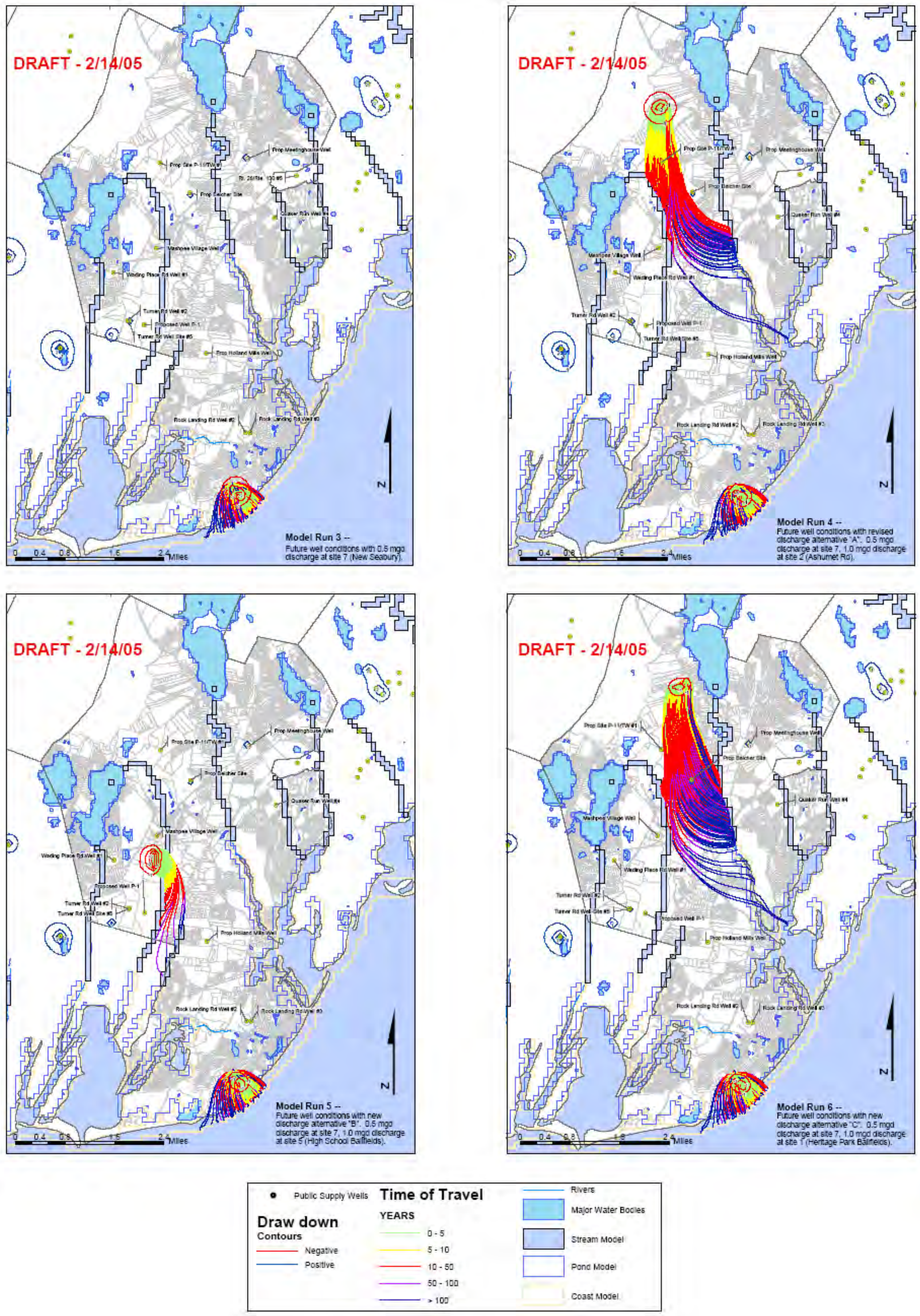


Figure 2.2.3. Mashpee Groundwater Discharge Model Runs 7 & 8

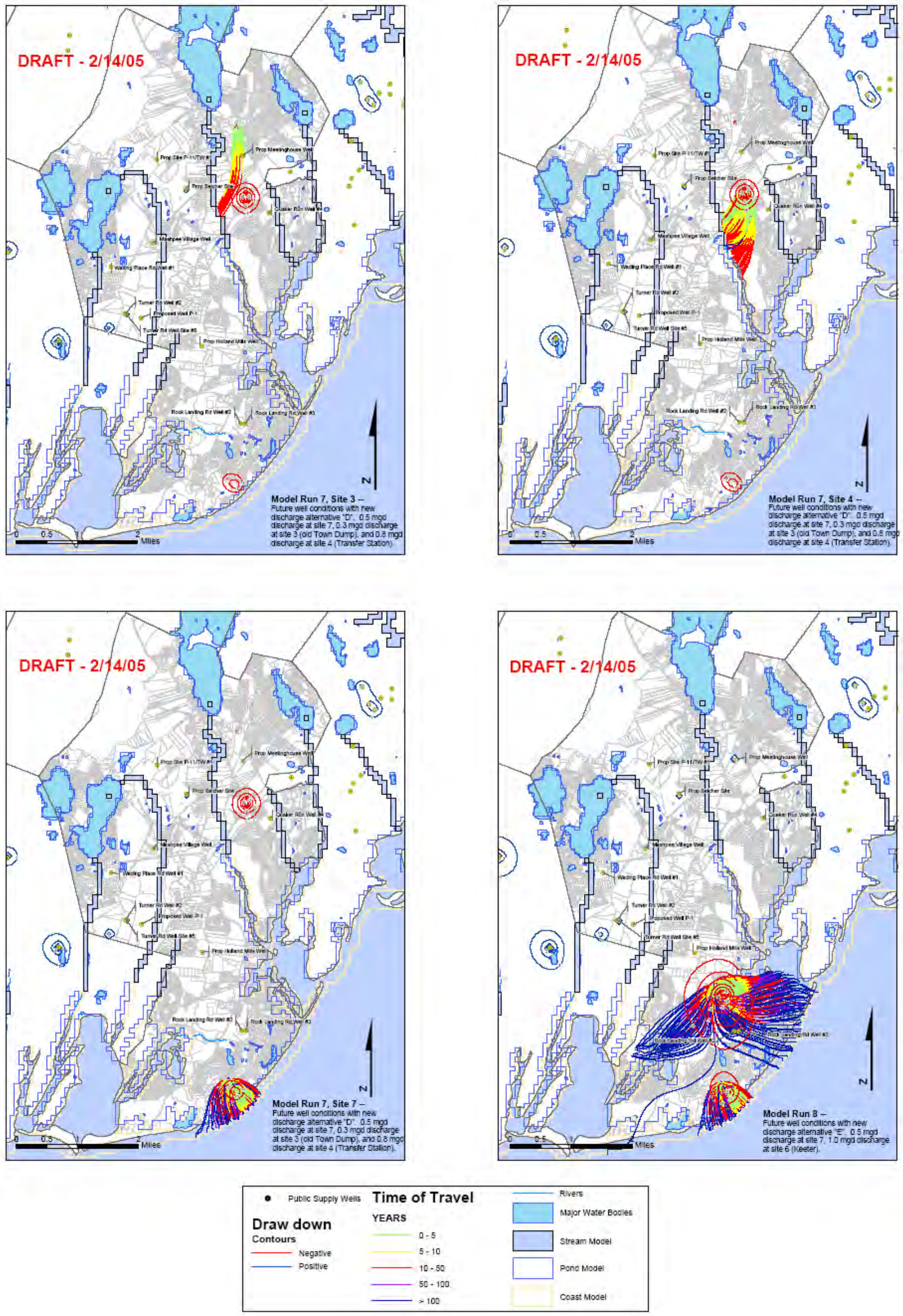


Figure 2.2.4 shows the USGS Groundwater Recharge Areas and Figure 2.2.5 shows the Recharge areas extrapolated to the PPA.

Figure 2.2.4. USGS Groundwater Recharge Areas

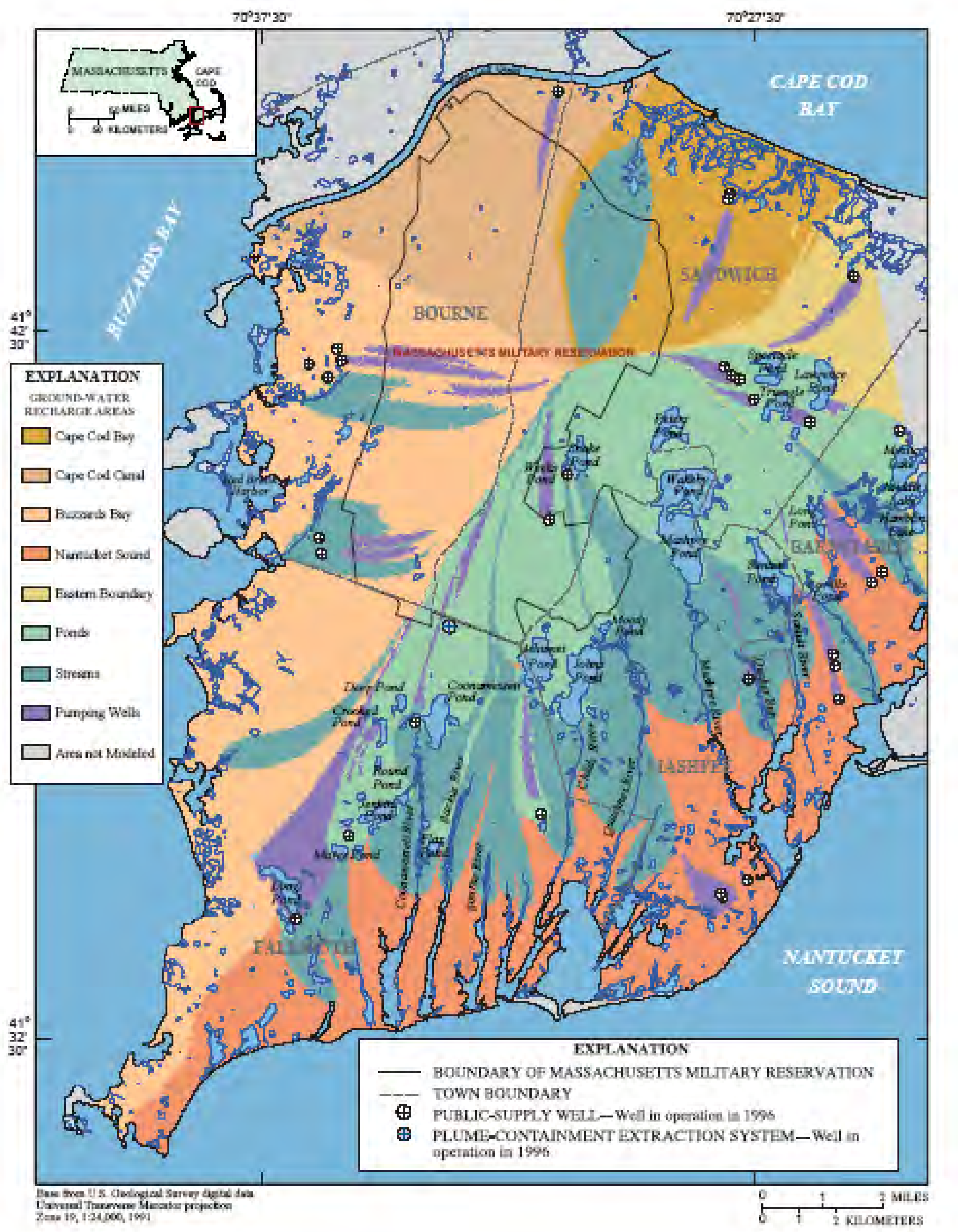
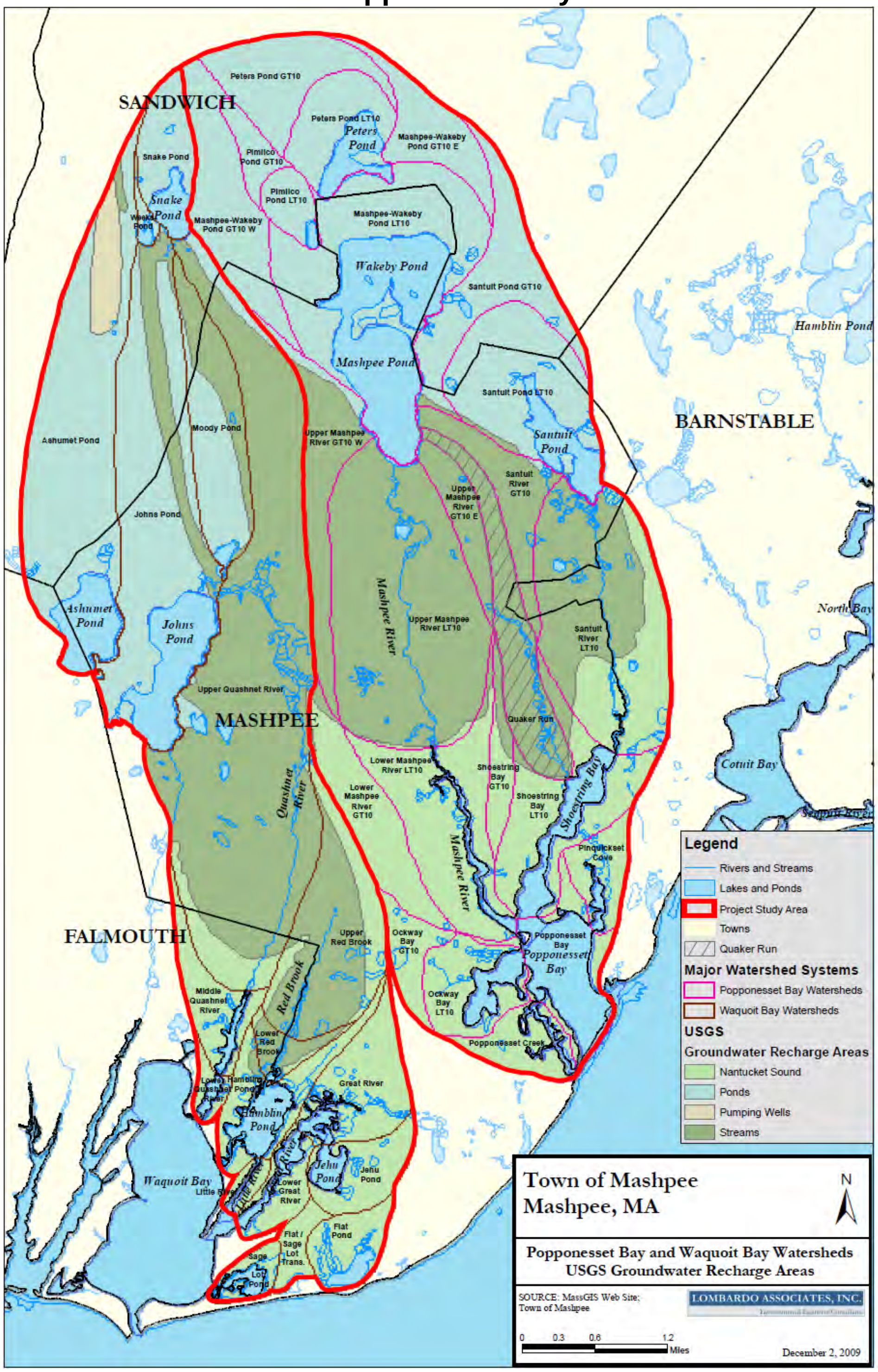


Figure 2.2.5. USGS Groundwater Recharge Areas for Waquoit Bay and Popponesset Bay



3 Needs Definition

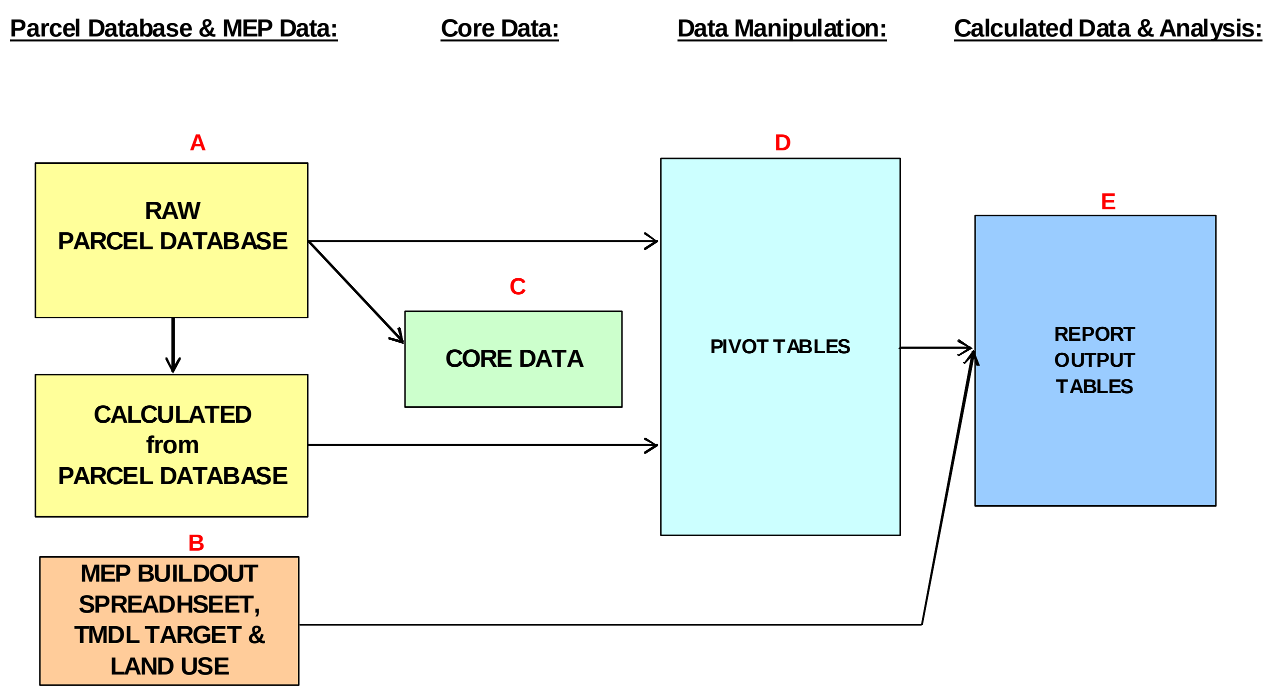
3.1 Data Management - Methodology

A Unified Database was assembled to replace the 5 individual databases that were used in past analyses. The following information was missing from the database furnished to LAI and needed to be extrapolated from other sources:

1. Land use TN loads by parcel or by subwatershed
2. Natural attenuations associated with each subwatershed
3. Pond outflow percentage, used to determine cumulative attenuation for water bodies that are tributary to other water bodies that have natural attenuation.

Figure 3.1 is the flowchart that shows how data sources were used to create summaries for the individual watersheds. The tables in this report were generated using the Unified Database created by SMAST to cover the entire PPA.

Figure 3.1: Database and Output Tables Flowchart



The Waquoit Bay Watershed and Popponesset Bay watershed have been broken down into the following TMDL Subwatersheds, in order to correspond with MEP and TMDL Reports.

Popponesset Bay:

- Popponesset Bay (includes Popponesset Creek)
- Ockway Bay
- Pinkquickset Cove
- Shoestring Bay, with Quaker Run Subwatershed
- Mashpee River

Waquoit Bay:

- Great River / Jehu Pond
- Little River / Hamblin Pond
- Quashnet River

The boundaries of these subwatersheds are presented in Figure 3.2 below. Figures 3.3, 3.4, and 3.5 present the Topographic Relief, the Topographic Relief with Contour Lines, and the USGS Topography Quads respectively.

Figure 3.6 below shows the Title V Setbacks within the PPA, which illustrate the locations of environmentally sensitive areas and setbacks.

The Waquoit Bay and Popponesset Bay subwatersheds are interconnected as illustrated in Figures 3.7 and 3.8, respectively.

Figure 3.2. Subwatersheds in Major Watersheds

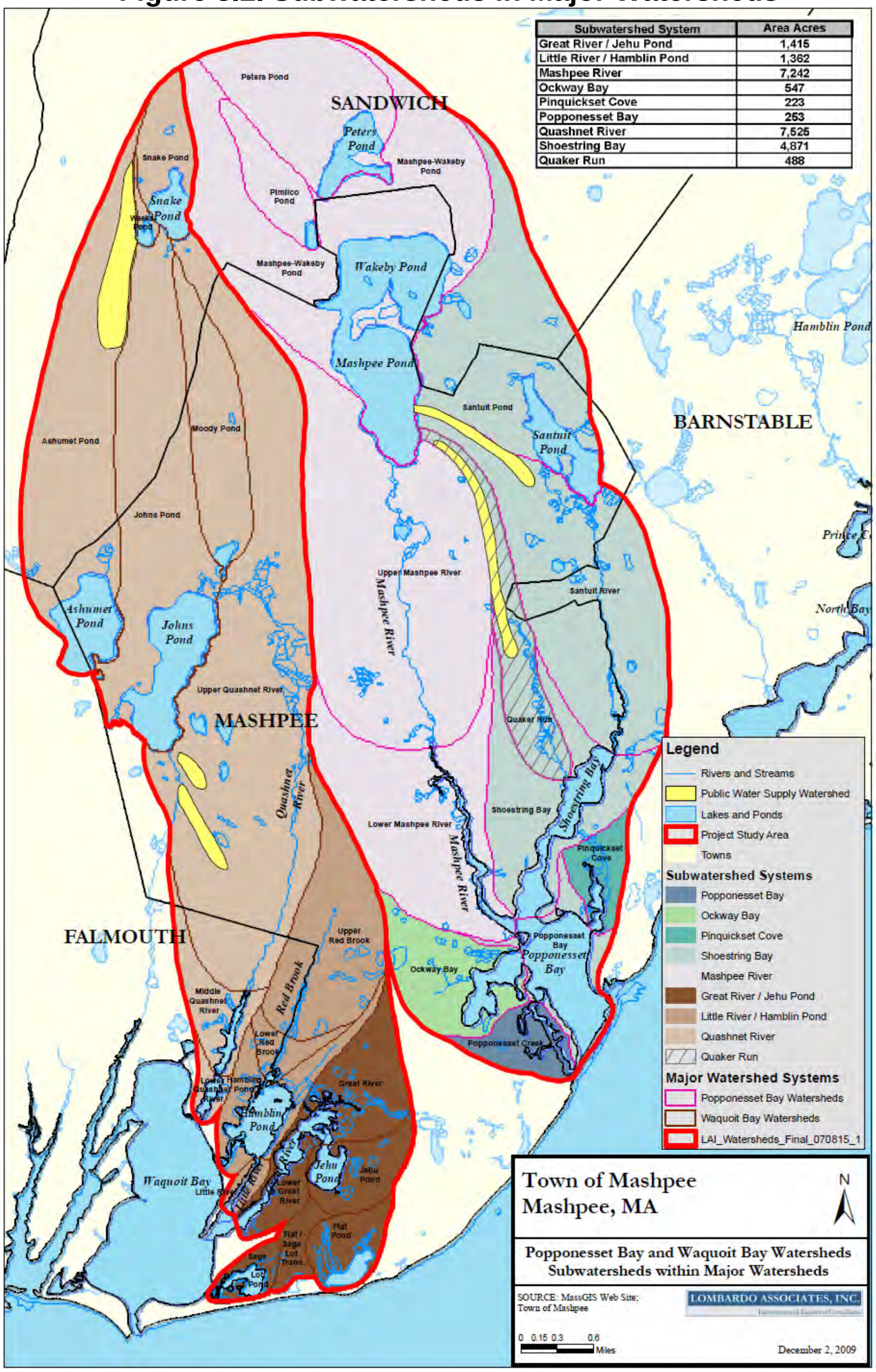


Figure 3.3. Topographic Relief

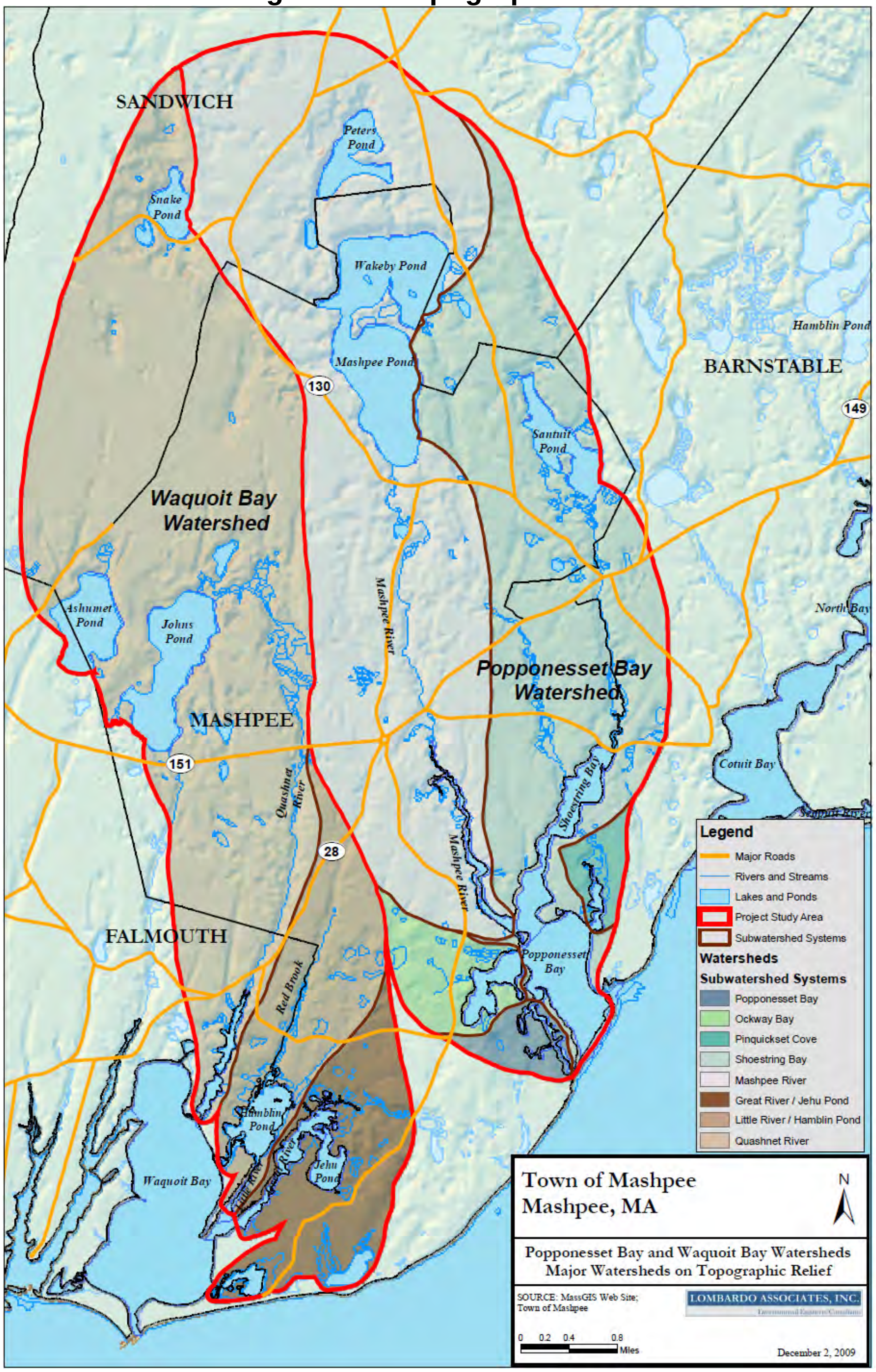


Figure 3.4. Topographic Relief with Groundwater Contour Lines

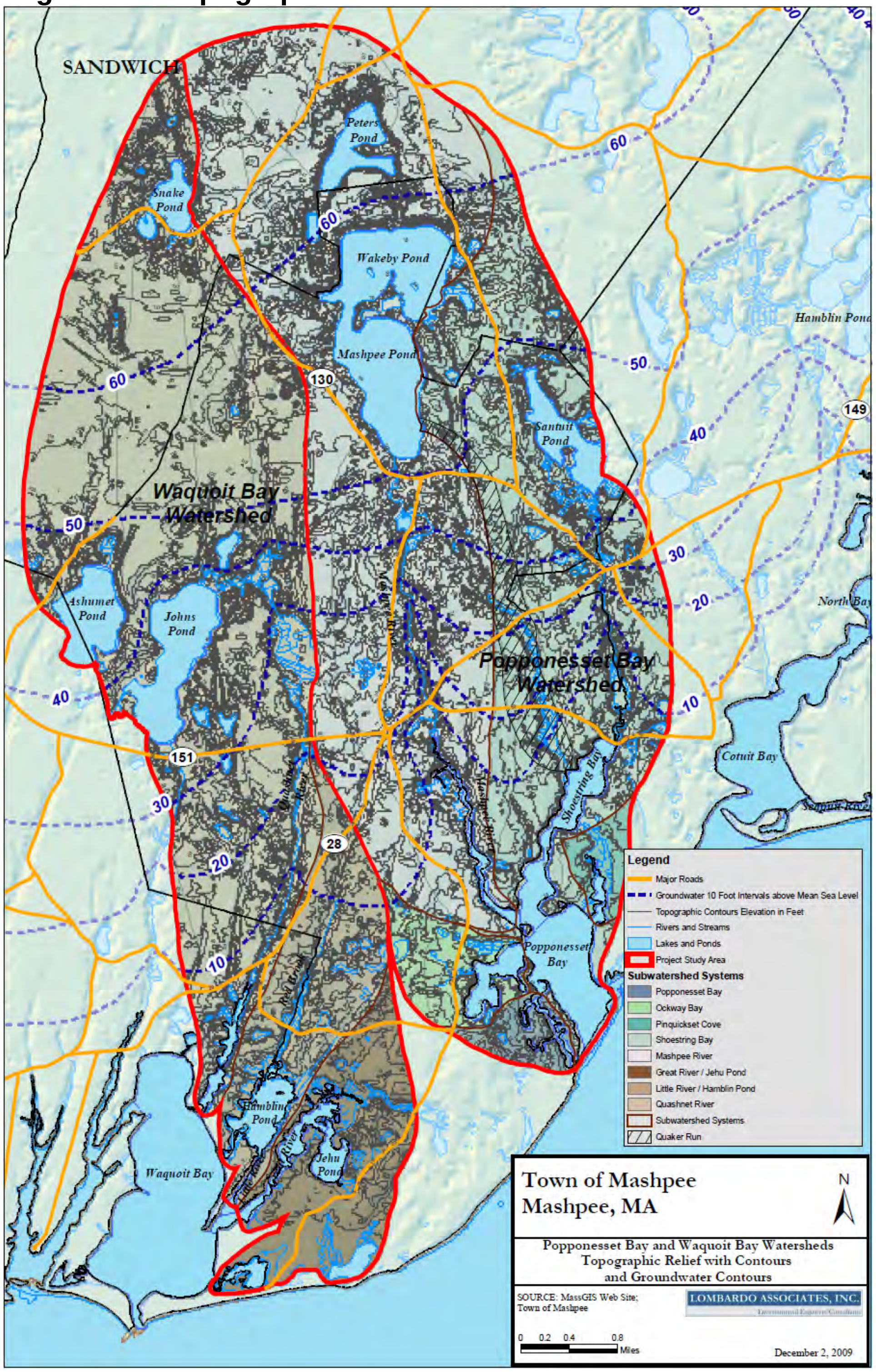


Figure 3.5. USGS Topography Quads

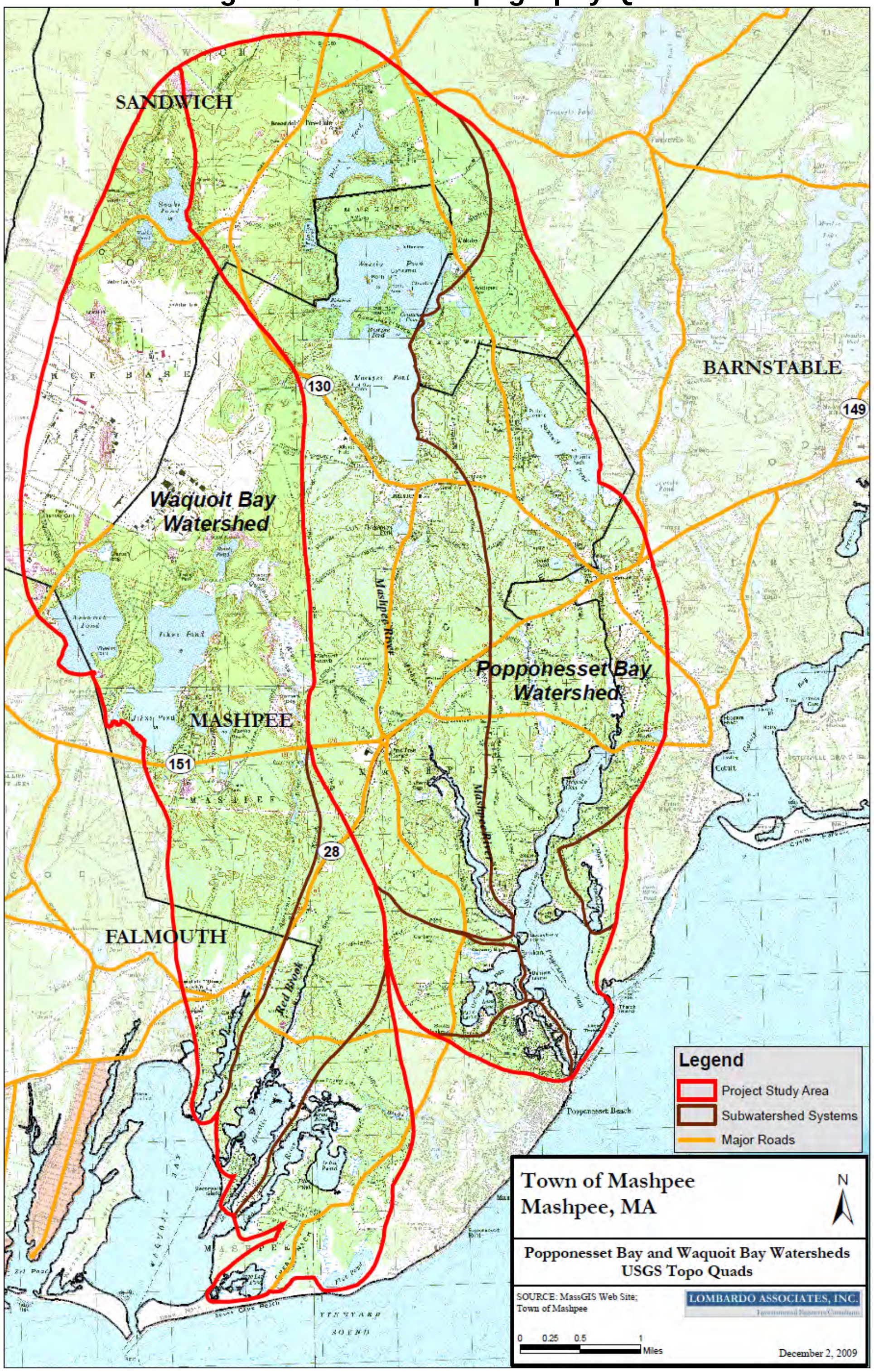


Figure 3.6. Title V Setbacks

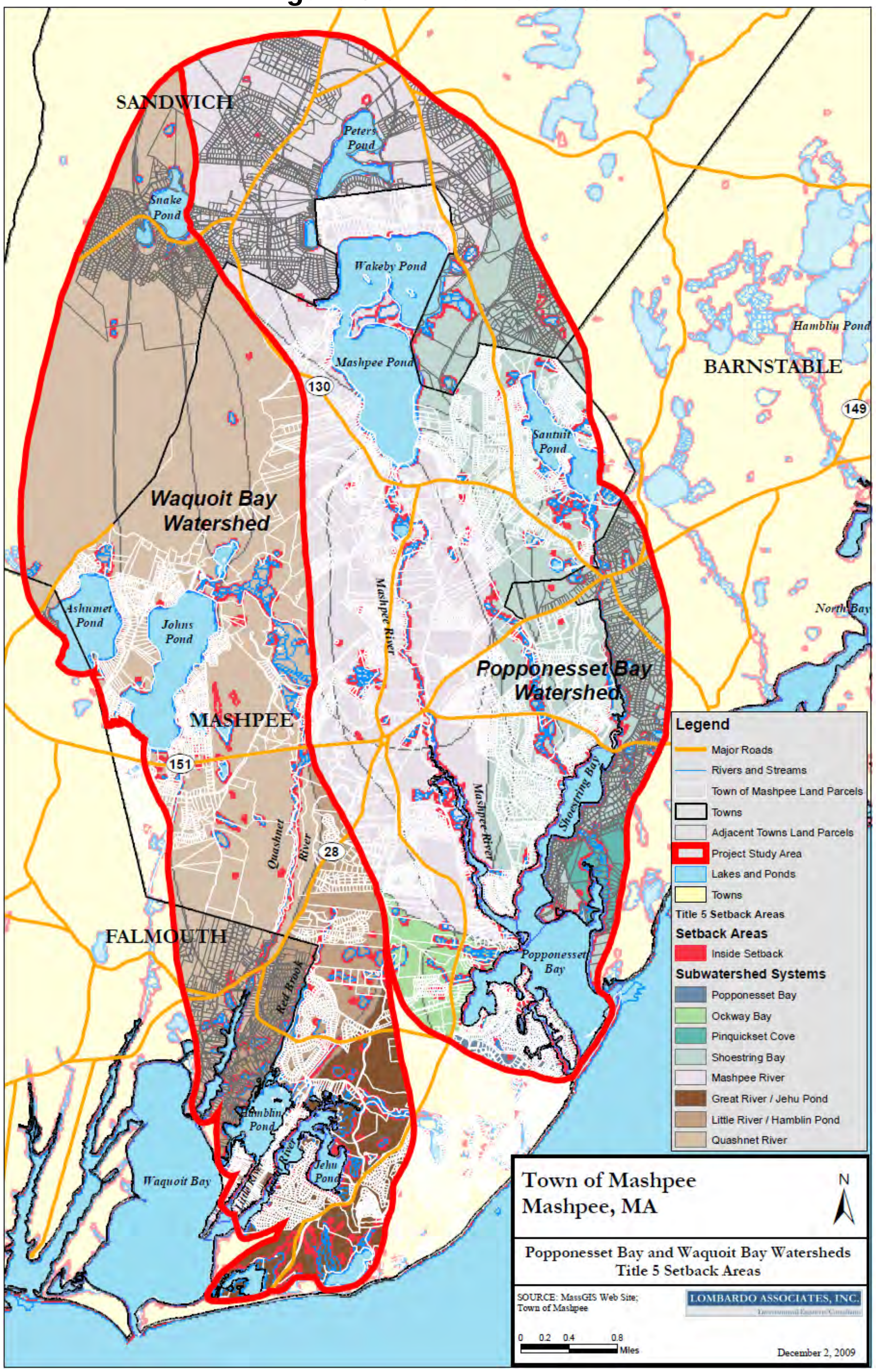


Figure 3.7. Waquoit Bay Surface and Groundwater Flow Diagram

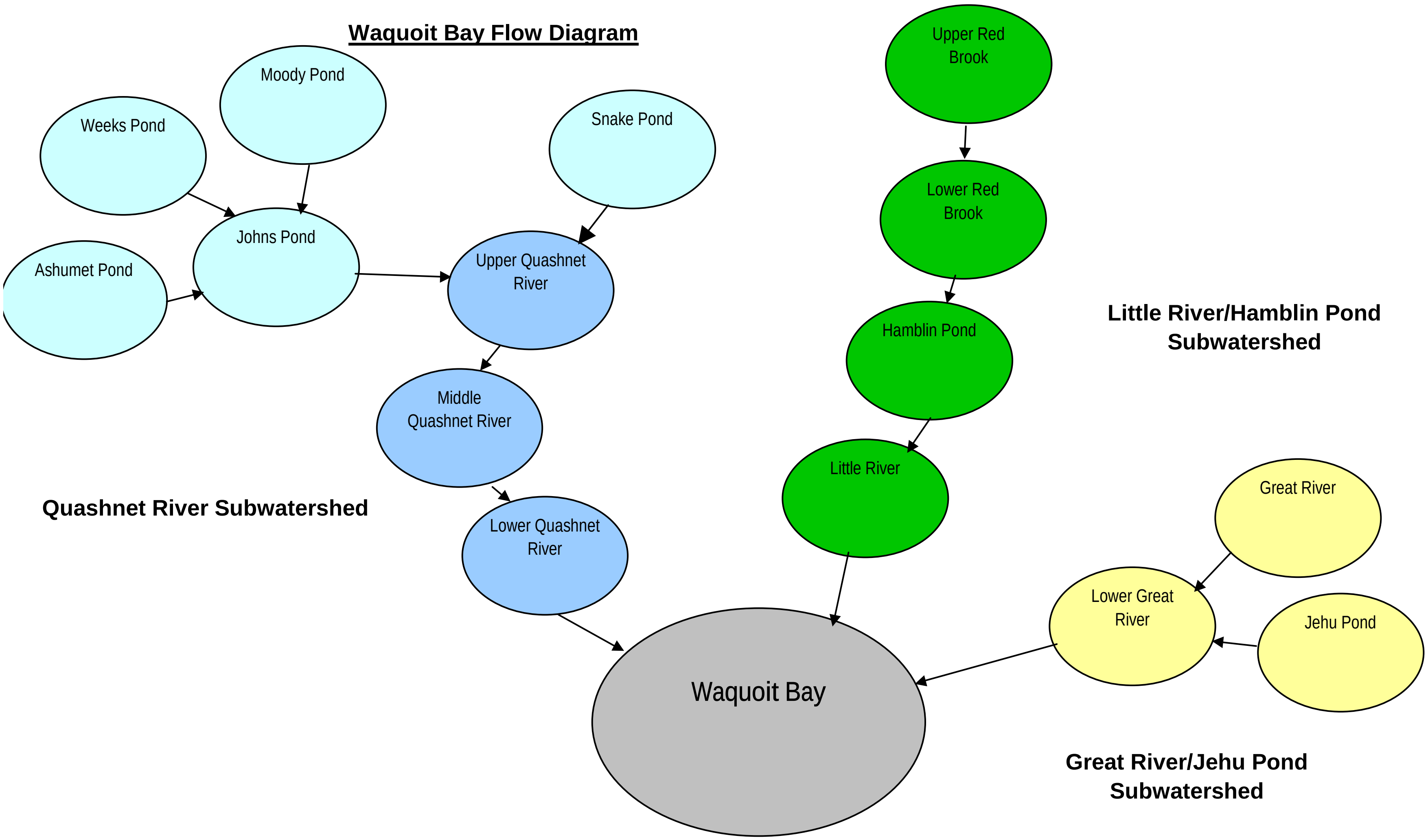
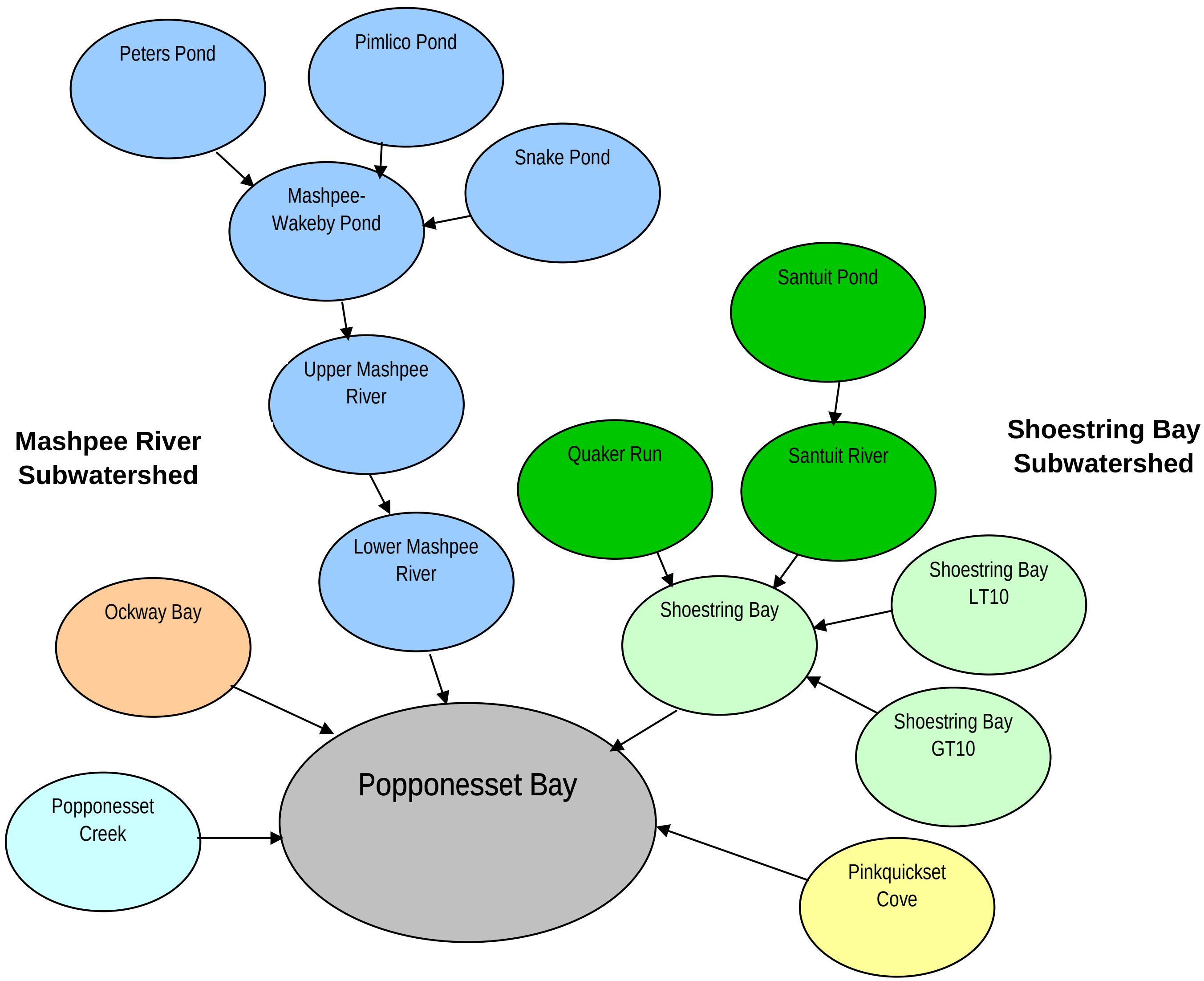


Figure 3.8. Popponesset Bay Surface and Groundwater Flow Diagram



3.2 Planning Area Parcel Summary

The S&W Database total raw Nitrogen Loads and wastewater flow for the Planning area, by town, is presented in Table 3.2.1.

Table 3.2.1. Wastewater Flow & Nitrogen Loading Information by Town

	Existing WW Flow (gpd)	Future WW Flow (gpd)	Existing N Load (kg/day)	Future N Load (kg/day)
Barnstable	118,569	175,958	15.73	23.34
Falmouth	62,157	116,450	8.25	15.45
Mashpee	1,150,537	2,022,918	140.53	225.84
Sandwich	328,772	394,817	43.61	52.37
Total	**1,660,035**	**2,710,144**	**208.12**	**317.00**

Tables 3.2.2 and 3.2.3 show the Waquoit Bay and Popponesset Bay parcel nitrogen loading Information by Subwatershed, respectively.

Table 3.2.2. Waquoit Nitrogen Sources Information by Subwatershed (No Soil or Watershed Attenuation)

MAP _ID	MEP Watersheds	Existing WW Flows (gpd)	Future Seasonal WW Flows (gpd)	Existing WW N Load (kg/day)	Buildout WW TN Load (kg/day)
Quashnet River					
1	Snake Pond	280	280	0.04	0.04
2	Weeks Pond	2,703	3,347	0.36	0.44
3	Ashumet Pond	38,935	47,977	5.16	6.36
4	Johns Pond	51,961	77,409	6.89	10.27
5	Moody Pond	4,802	8,859	0.64	1.18
6	Upper Quashnet River	120,509	383,587	15.84	38.73
7	Middle Quashnet River	20,493	28,867	2.72	3.83
8	Lower Quashnet River	8,456	11,941	1.12	1.58
19	Turner Road Well #5[3]	2,520	3,640	0.33	0.48
20	Mashpee Well #1[3]	2,260	11,306	0.24	1.48
21	MMR J Well[3, 4]	19,338	22,744	2.57	3.02
	Subtotal Quashnet River	**272,257**	**599,957**	**35.91**	**67.41**
Hamblin Pond / Red Brook					
9	Red Brook	52,233	91,418	6.72	11.489
10	Lower Red Brook	8,346	17,419	1.11	2.311
11	Hamblin Pond	31,801	45,243	4.22	6.002
12	Little River	7,968	10,068	1.06	1.335
	SubTotal Hamblin/Red	**100,349**	**164,148**	**13.11**	**21.14**
Jehu Pond / Great River					
13	Great River	4,652	5,912	0.62	0.784
14	Jehu Pond	29,986	41,111	3.98	5.453
15	Lower Great River	24,599	28,221	3.26	3.744
	SubTotal Jehu / Great	**59,236**	**75,244**	**7.86**	**9.98**
Sage Lot / Flat Pond					
16	Flat Pond	10,073	25,487	1.34	2.931
17	Flat / Sage Lot Transition	4,489	5,749	0.60	0.763
18	Sage Lot Pond	0	0	0.00	0.000
	SubTotal Sage Lot / Flat Pond	**14,563**	**31,236**	**1.93**	**3.69**
East Waquoit Bay Totals		***446,405***	***870,586***	***58.80***	***102.22***

Table 3.2.3. Popponesset Bay Parcel Information by Subwatershed (No Soil or Watershed Attenuation)

MEP ID	MEP Watersheds	Existing WW Flows (gpd)	Future Seas. WW Flows (gpd)	Existing WW N Load (kg/day)	Future WW N Load (kg/day)
	Mashpee River				
1	Snake Pond	280	280	0.04	0.04
2	Pimlico Pond	32,241	42,029	4.28	5.58
3	Peters Pond	57,767	64,436	7.66	8.55
4	Mashpee-Wakeby Pond	128,861	193,036	17.09	25.61
6	Upper Mashpee River	79,741	128,738	10.24	16.50
7	Lower Mashpee River	135,129	253,491	19.87	36.11
	Mashpee River SubTotal	**434,019**	**682,009**	**59.18**	**92.38**
	Shoestring Bay				
5	Santuit Pond	124,212	141,778	16.48	18.81
8	Quaker Run	27,900	51,069	1.58	4.19
9	Santuit River	157,573	252,574	20.46	29.55
10	Shoestring Bay	92,268	119,086	10.50	13.37
15	Quaker Run Well[3]	20,431	21,697	2.71	2.88
16	Cotuit Well #5[3]	9,387	10,507	1.25	1.39
	Shoestring Bay SubTotal	**431,771**	**596,711**	**52.97**	**70.19**
12	**Ockway Bay**	**25,626**	**40,746**	**3.40**	**5.40**
11	**Pinquickset Cove**	**6,634**	**9,097**	**0.88**	**1.21**
	Popponesset Bay				
13	Popponesset Creek	40,886	46,066	5.42	5.99
14	Popponesset Bay	17,047	19,533	2.26	2.59
	Popponesset Bay SubTotal	**57,933**	**65,599**	**7.68**	**8.58**
Popponesset Bay Totals		***955,982***	***1,394,161***	***124.12***	***177.76***

3.3 Nitrogen Loading and TMDLs

Table 3.3.1 presents the non-wastewater nitrogen sources design criteria from the MEP technical reports, referenced in the Stearns & Wheler Needs Assessment Report.

Table 3.3.1. Non-Wastewater Nitrogen Sources

Nitrogen Source	Nitrogen Concentration or Load	Recharge Rate
Pavement Runoff	1.5 mg/l	40 in/year
Roof Runoff	0.75 mg/l	40 in/year
Precipitation to Natural Areas	0.072 mg/l	27.25 in/year
Lawn Fertilizer	0.49 kg/lawn[2]	NA

1. MEP used 1.08 lb/lawn. The Nitrogen Load is shown as kg/lawn to correlate with the concentrations in mg/l
2. Source: Stearns & Wheler *Needs Assessment Report* , April 2007.

Nitrogen limits for the Popponesset Bay estuary were determined by MEP in September 2004 and for Waquoit Bay East in January 2005. These nitrogen limits led to the development of TMDLs for these embayments. The TMDLs were issued in April 2006 (Final) and October 2005 (Final Draft), respectively.

3.3.1 Data Overview

There are fundamental differences in how the nitrogen loading data is presented in the TMDL and MEP reports. The first step toward defining the nitrogen removal requirements is to establish the existing and future nitrogen loads and the TMDL in similar units. The following three sources of data were used:

1. Stearns and Wheler provided parcel databases for each Town
2. MEP watershed loadings and delineations
3. TMDL Threshold Watershed Nitrogen Loadings

3.3.1.1 Stearns & Wheler provided Databases

The parcel data contained wastewater flow data for each parcel within the watershed. The Town of Mashpee parcels contained nitrogen loading per parcel, and in the case of parcels that have WWTFs on them, the nitrogen loading reflected the treatment removals. The nitrogen loadings from the database represent raw loads, prior to septic system removal or water body attenuation. The nitrogen concentration for these flows is 35 mg/L.

3.3.1.2 MEP Data

The data presented in the “rainbow” spreadsheets of the MEP reports represent the loadings that the groundwater sees from the septic systems. These numbers reflect the expected removal by the septic systems, assumed to be 25%. The nitrogen concentration for these flows is 26.5 mg/L. Additionally, the following data was furnished by MEP and used in the detailed analysis of the fate of nitrogen following introduction to groundwater in different subwatersheds:

- % of pond outflow to other subwatersheds and outside the PPA
- Existing and buildout land use nitrogen loads
- Buildout septic loads
- Natural attenuation within individual water bodies

The MEP data was used to establish the total existing and future controllable nitrogen load and to determine the cumulative natural nitrogen attenuation for all subwatersheds.

3.3.1.3 TMDL Data

The TMDL data for wastewater loading represents attenuated loads. The attenuation depends on the subwatershed where the nitrogen is introduced. In some cases, where it is introduced prior to a pond that drains to another pond that drains to a river, the natural attenuation can be greater than 75%. For areas that drain directly to the embayment or into a river close to the embayment, there is little to no attenuation beyond the septic system.

3.3.2 Popponesset Bay Nitrogen Removal Requirements

The TMDL report presents a nitrogen loading scenario by subwatershed that will result in meeting the target nitrogen concentration at the sentinel station in Popponesset Bay. The TMDL was developed by separating the controllable loads from the non-controllable loads. A target threshold watershed nitrogen load was developed for the controllable load. When this concentration is added to the non-controllable load, the result is the TMDL. Table 3.3.2 shows the TMDL components for Popponesset Bay. As discussed previously, the TMDL loads are attenuated loads, representing the loads seen in the receiving water body as a result of loadings throughout the watershed.

Table 3.3.2. TMDL Components for Popponesset Bay

Subwatershed Group	Target Threshold Watershed Load - Controllable (kg/day)	Non-Controllable		TMDL (kg/day
		Atmospheric Deposition (kg/day)	Benthic Flux[1] (kg/day)	
Mashpee River	16.2	0.7	9.4	16
Shoestring Bay	19.7	2.2	-8.7	13
Ockway Bay	0.8	1.1	1.1	3
Pinquickset Cove	0.8	0.3	-0.3	1
Popponesset Bay	2.8	4	-5.5	1
Total Popponesset Bay	**40.3**	**8.3**	**-4**	**34**

Source: MADEP December 5, 2006 Report, Final Popponesset Bay Total Maximum Daily Loads for Total Nitrogen

[1]Projected sediment N loadings obtained by reducing the present loading rates proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON.

In order to meet the target threshold watershed load, enough nitrogen must be removed from the existing controllable load to achieve the target. The difference between the current controllable load and the target represents the nitrogen removal requirement. The decentralized scenarios assume that this load must be removed from the wastewater load only, as measures to reduce land use and runoff contributions were not considered, as specified by the Mashpee Sewer Commission. In addition, enough nitrogen must be removed from existing loads to provide capacity for future loads. The controllable load was calculated by adding the land use and runoff contributions, as reported by MEP, to the wastewater loads.

Attenuation varies greatly between subwatersheds, as mentioned previously. For this reason, nitrogen loads from both wastewater and land use / runoff were converted to attenuated loads to illustrate each subwatershed's nitrogen loading contribution to Popponesset Bay. This also helps to identify areas where nitrogen removal will likely be more cost effective. Areas with high levels of natural attenuation are the least cost effective areas for nitrogen removal, and should be included last and only if necessary to meet the target. Table 3.3.3 details the conversion of existing loads to attenuated loads and the subsequent calculation of the nitrogen removal requirement within each of the subwatershed groups listed in Table 3.3.2.

The mass and percent removal calculated in Table 3.3.5 for the subwatershed groups is the basis for selecting parcels to be treated in the decentralized scenarios for Popponesset Bay.

Table 3.3.3. Nitrogen Removal Requirements – Popponesset Bay

MEP ID	MEP Watersheds	Existing WW Flows (gpd)	Future Seas. WW Flows (gpd)	Existing WW N Load (kg/day)	Existing WW N Load Septic Effluent (25% Attn.)	Exist. Land Use + Runoff (kg/day)[5]	Total Existing Cont. N Load (kg/day)	Future WW N Load (kg/day)	Future WW N Load Septic Effluent (kg/day)	Other Buildout N Load (kg/day)[7]	Total Buildout Cont. N Load No Trt. (kg/day)	Total Atten. %	Future Septic N Load with Atten. (kg/day)	Future Cont. N Load with Atten. (kg/day)	Buildout Cont. N Load with Atten. (kg/day)	Buildout Non-WW Cont. N Load w/Atten. (kg/day)	Target N Load (kg/day)	N Removal Required (kg/day)	Req'd % Removal from Future Cont.	Req'd % Removal from Future Septic
	Mashpee River																16.17	36.32	69%	**79%**
1	Snake Pond	280	280	0.04	0.03	0.17	0.20	0.04	0.03	0.01	0.20	74%	0.01	0.05	0.05					
2	Pimlico Pond	32,241	42,029	4.28	3.21	0.53	3.74	5.58	4.18	0.13	4.85	83%	0.73	0.85	0.85					
3	Peters Pond	57,767	64,436	7.66	5.79	1.17	6.96	8.55	6.45	0.02	7.64	83%	1.13	1.34	1.34					
4	Mashpee-Wakeby Pond	128,861	193,036	17.09	12.82	2.87	15.69	25.61	19.20	0.03	22.10	65%	6.72	7.74	7.74					
6	Upper Mashpee River	79,741	128,738	10.24	7.69	4.03	11.72	16.50	12.39	0.12	16.54	30%	8.67	11.58	11.58					
7	Lower Mashpee River	135,129	253,491	19.87	15.24	2.35	17.59	36.11	28.45	0.13	30.94	0%	28.45	30.94	30.94					
	Mashpee River SubTotal	**434,019**	**682,009**	**59.18**	**44.77**	**11.13**	**55.91**	**92.38**	**70.71**	**0.44**	**82.27**		**45.72**	**52.49**	**52.49**	**6.77**				
	Shoestring Bay																19.72	25.07	56%	**68%**
5	Santuit Pond	124,212	141,778	16.48	12.36	2.66	15.02	18.81	14.11	0.26	17.02	65%	4.94	5.96	5.96					
8	Quaker Run	27,900	51,069	1.58	1.18	1.39	2.58	4.19	3.14	0.03	4.56	0%	3.14	4.56	4.56					
9	Santuit River	157,573	252,574	20.46	15.82	3.86	19.68	29.55	22.79	0.07	26.72	30%	15.95	18.70	18.70					
10	Shoestring Bay	92,268	119,086	10.50	7.88	2.26	10.14	13.37	10.03	0.04	12.33	0%	10.03	12.33	12.33					
15	Quaker Run Well[3]	20,431	21,697	2.71	2.03	0.21	2.24	2.88	2.16	0.01	2.38	0%	2.16	2.38	2.38					
16	Cotuit Well #5[3]	9,387	10,507	1.25	0.93	0.16	1.10	1.39	1.05	0.02	1.22	30%	0.73	0.86	0.86					
	Shoestring Bay SubTotal	**431,771**	**596,711**	**52.97**	**40.20**	**10.54**	**50.75**	**70.19**	**53.27**	**0.43**	**64.24**		**36.95**	**44.79**	**44.79**	**7.84**				
12	**Ockway Bay**	**25,626**	**40,746**	**3.40**	**2.55**	**0.76**	**3.31**	**5.40**	**4.05**	**0.09**	**4.90**		**4.05**	**4.90**	**4.90**	**0.85**	0.76	4.14	85%	**102%**
11	**Pinquickset Cove**	**6,634**	**9,097**	**0.88**	**0.66**	**0.19**	**0.85**	**1.21**	**0.91**	**0.02**	**1.11**		**0.91**	**1.11**	**1.11**	**0.21**	0.76	0.35	32%	**39%**
	Popponesset Bay																2.77	4.91	64%	**76%**
13	Popponesset Creek	40,886	46,066	5.42	4.07	0.95	5.02	5.99	4.49	0.03	5.48		4.49	5.48	5.48					
14	Popponesset Bay	17,047	19,533	2.26	1.70	0.24	1.94	2.59	1.94	0.01	2.20		1.94	2.20	2.20					
	Popponesset Bay SubTotal	**57,933**	**65,599**	**7.68**	**5.76**	**1.19**	**6.96**	**8.58**	**6.43**	**0.05**	**7.68**		**6.43**	**7.68**	**7.68**	**1.24**				
	Popponesset Bay Totals	***955,982***	***1,394,161***	***124.12***	***93.95***	***23.81***	***117.76***	***177.76***	***135.37***	***1.02***	***160.21***		***94.06***	***110.97***	***110.97***		***40.18***	***70.79***	***64%***	***75%***

[1]All future systems, including commercial and industrial, that are not connecting to an existing WWTF will be required to connect to one of the proposed cluster systems or have their own onsite systems. Nitrogen removal for all future systems is assumed to be 90%

[2]Amount of nitrogen that must be removed from existing septic loads to create capacity for Buildout additional N load.

[3]No credit taken for public water supply well withdrawals

[5]Existing Land Use + Runoff N Loading is the sum of the total Fertilizer, Impervious and Natural Surfaces values taken from Table IV-5 of the January 2005 MEP Report

[6]% of Buildout load from wastewater taken from Figure IV-4 of the January 2005 MEP Report. Future % assumed to be the same as existing.

[7]Other N loading are the total buildout N load minus the septic component. This includes runoff, fertilizer, and all increased loads to existing WWTFs.

3.3.3 East Waquoit Bay Nitrogen Removal Requirements

The TMDL report presents a nitrogen loading scenario by subwatershed that will result in meeting the target nitrogen concentration at the sentinel station in East Waquiot Bay. The TMDL was developed by separating the controllable loads from the non-controllable loads. A target threshold watershed nitrogen load was developed for the controllable load. When this concentration is added to the non-controllable load, the result is the TMDL. Table 3.3.4 shows the TMDL components for East Waquoit Bay. As discussed previously, the TMDL loads are attenuated loads, representing the loads seen in the receiving water body as a result of loadings throughout the watershed.

Table 3.3.4. TMDL Components for East Waquoit Bay

Subwatershed Group	Target Threshold Watershed Load - Controllable (kg/day)	Non-Controllable		TMDL (kg/day
		Atmospheric Deposition (kg/day)	Benthic Flux[1] (kg/day)	
Great River / Jehu Pond	1.88	1.97	21.51	25
Little River / Hamblin Pond	3.83	1.75	-3.44	2
Quashnet River	15.92	0.58	10.62	27
Total East Waquoit Bay	**21.63**	**4.3**	**28.69**	**54**

Source: MADEP October 14, 2005 Report, *Final Draft Quashnet River, Hamblin Pond, Little River, Jehu Pone, and Great River in the Waquoit Bay System Total Maximum Daily Loads for Total Nitrogen*

[1]Projected sediment N loadings obtained by reducing the present loading rates proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON.

In order to meet the target threshold watershed load, enough nitrogen must be removed from the existing controllable load to achieve the target. The difference between the current controllable load and the target represents the nitrogen removal requirement. The decentralized scenarios assume that this load must be removed from the wastewater load only, as measures to reduce land use and runoff contributions were not considered, as specified by the Mashpee Sewer Commission. In addition, enough nitrogen must be removed from existing loads to provide capacity for future loads. The controllable load was calculated by adding the land use and runoff contributions, as reported by MEP, to the wastewater loads.

Attenuation varies greatly between subwatersheds, as mentioned previously. For this reason, nitrogen loads from both wastewater and land use / runoff were converted to attenuated loads to illustrate each subwatershed's nitrogen loading contribution to East Waquoit Bay. This also helps to identify areas where nitrogen removal will likely be more cost effective. Areas with high levels of natural attenuation are the least cost effective areas for nitrogen removal, and should be included last and only if necessary to meet the target. Table 3.3.5 details the conversion of existing loads to attenuated loads and the subsequent calculation of the nitrogen removal requirement within each of the subwatershed groups listed in Table 3.3.4.

The mass and percent removal calculated in Table 3.3.5 for the subwatershed groups is the basis for selecting parcels to be treated in the decentralized scenarios for East Waquoit Bay.

Table 3.3.5. Nitrogen Removal Requirements – East Waquoit Bay

MAP_ID	MEP Watersheds	Number of Parcels Total	Existing Developed	Future Developed	Existing WW Flows (gpd)	Future Seasonal WW Flows (gpd)	% of Watershed Total Flow	Existing WW N Load (kg/day)	Existing WW N Load Septic Effluent (25% Attn.)	Exist. Land Use TN Load (kg/day)[5]	Total Existing Cont. N Load (kg/day)	Buildout WW TN Load (kg/day)	Buildout WW TN Load Septic Effluent (kg/day)	Add'l Buildout Land Use TN Load (kg/day)[7]	Total Buildout Cont. N Load (kg/day)	Total Atten. %	Buildout Septic N Load with Atten.	Buildout Cont. N Load with Atten.	Buildout Non-WW Cont. N Load w/Atten. (kg/day)	Target N Load (kg/day)	N Removal Required (kg/day)	Req'd % Removal from Buildout Cont.	Req'd % Removal from Existing Septic
Quashnet River																				15.92	29.27	65%	**82%**
1	Snake Pond	30	1	1	280	280	0.05%	0.04	0.03	0.17	0.20	0.037	0.028	0.007	0.205	74%	0.007	0.053					
2	Weeks Pond	22	13	16	2,703	3,347	0.56%	0.36	0.27	0.06	0.32	0.444	0.333	0.005	0.394	80%	0.067	0.079					
3	Ashumet Pond	307	224	266	38,935	47,977	8.00%	5.16	3.87	2.66	6.54	6.364	4.773	0.183	7.621	80%	0.955	1.524					
4	Johns Pond	517	391	456	51,961	77,409	12.90%	6.89	5.17	4.95	10.12	10.268	7.701	0.117	12.770	60%	3.081	5.108					
5	Moody Pond	66	23	47	4,802	8,859	1.48%	0.64	0.48	1.45	1.92	1.175	0.881	0.053	2.379	60%	0.353	0.952					
6	Upper Quashnet River	870	576	727	120,509	383,587	63.94%	15.84	11.97	5.80	17.77	38.733	30.033	0.932	36.761	20%	24.026	29.409					
7	Middle Quashnet River	159	93	132	20,493	28,867	4.81%	2.72	2.04	0.36	2.40	3.829	2.872	0.074	3.306	0%	2.872	3.306					
8	Lower Quashnet River	44	31	41	8,456	11,941	1.99%	1.12	0.84	0.22	1.06	1.584	1.188	0.009	1.416	0%	1.188	1.416					
19	Turner Road Well #5[3]	27	18	25	2,520	3,640	0.61%	0.33	0.25	0.03	0.28	0.483	0.362	0.012	0.408	0%	0.362	0.408					
20	Mashpee Well #1[3]	8	5	6	2,260	11,306	1.88%	0.24	0.18	0.07	0.25	1.477	1.108	0.000	1.176	0%	1.108	1.176					
21	MMR J Well[3, 4]	113	97	108	19,338	22,744	3.79%	2.57	1.92	0.34	2.27	3.017	2.263	0.016	2.621	33%	1.516	1.756					
	Subtotal Quashnet River	**2,163**	**1,472**	**1,825**	**272,257**	**599,957**	**100%**	**35.91**	**27.02**	**16.11**	**43.13**	**67.41**	**51.54**	**1.41**	**69.06**		**35.53**	**45.19**	**9.65**				
Hamblin Pond / Red Brook																				3.83	14.62	79%	**92%**
9	Red Brook	520	254	461	52,233	91,418	56%	6.72	5.04	1.28	6.32	11.489	8.616	0.216	10.113	0%	8.616	10.113					
10	Lower Red Brook	126	57	115	8,346	17,419	11%	1.11	0.83	0.28	1.11	2.311	1.733	0.048	2.061	0%	1.733	2.061					
11	Hamblin Pond	311	150	223	31,801	45,243	28%	4.22	3.16	0.48	3.64	6.002	4.501	0.086	5.067	0%	4.501	5.067					
12	Little River	90	71	79	7,968	10,068	6%	1.06	0.79	0.19	0.98	1.335	1.002	0.014	1.205	0%	1.002	1.205					
	SubTotal Hamblin/Red	**1,047**	**532**	**878**	**100,349**	**164,148**	**100%**	**13.11**	**9.83**	**2.23**	**12.06**	**21.14**	**15.85**	**0.36**	**18.45**		**15.85**	**18.45**	**2.59**				
Jehu Pond / Great River																				1.88	7.63	80%	**102%**
13	Great River	84	33	42	4,652	5,912	8%	0.62	0.46	0.32	0.78	0.784	0.588	0.077	0.986	0%	0.588	0.986					
14	Jehu Pond	245	185	208	29,986	41,111	55%	3.98	2.98	0.96	3.94	5.453	4.090	0.034	5.084	0%	4.090	5.084					
15	Lower Great River	285	229	250	24,599	28,221	38%	3.26	2.45	0.60	3.05	3.744	2.808	0.036	3.444	0%	2.808	3.444					
	SubTotal Jehu / Great	**614**	**447**	**500**	**59,236**	**75,244**	**100%**	**7.86**	**5.89**	**1.88**	**7.77**	**9.98**	**7.49**	**0.15**	**9.51**		**7.49**	**9.51**	**2.03**				
Sage Lot / Flat Pond																				NA	NA	NA	**NA**
16	Flat Pond	72	56	58	10,073	25,487	82%	1.34	1.00	0.90	1.90	2.931	2.198	0.000	3.098	0%	2.198	3.098					
17	Flat / Sage Lot Transition	57	45	54	4,489	5,749	18%	0.60	0.45	0.14	0.59	0.763	0.572	0.012	0.724	0%	0.572	0.724					
18	Sage Lot Pond	7	0	0	0	0	0%	0.00	0.00	0.04	0.04	0.000	0.000	0.000	0.040	0%	0.000	0.040					
	SubTotal Sage Lot / Flat Pond	**136**	**101**	**112**	**14,563**	**31,236**	**100%**	**1.93**	**1.45**	**1.08**	**2.53**	**3.69**	**2.77**	0.000	**3.86**		**2.77**	**3.86**	**1.09**				
East Waquoit Bay Totals		***3,960***	***2,552***	***3,315***	***446,405***	***870,586***		***58.80***	***44.20***	***21.30***	***65.49***	***102.22***	***77.65***	***1.92***	***100.88***		***61.64***	***77.01***		***21.63***	***55.38***	***72%***	***90%***

[1]All future systems, including commercial and industrial, that are not connecting to an existing WWTF will be required to connect to one of the proposed cluster systems or have their own onsite systems. Nitrogen removal for all future systems is assumed to be 90%
[2]Amount of nitrogen that must be removed from existing septic loads to create capacity for Buildout additional N load.
[3]No credit taken for public water supply well withdrawals, except for MMR Well
[4]MMR J Well withdrawals discharge outside the watershed. Outflow set to 100% to account for this.
[5]Existing Land Use + Runoff N Loading is the sum of the total Fertilizer, Impervious and Natural Surfaces values taken from Table IV-5 of the January 2005 MEP Report
[6]% of Buildout load from wastewater taken from Figure IV-4 of the January 2005 MEP Report. Future % assumed to be the same as existing.
[7]Other N loading are the total buildout N load minus the septic component. This includes runoff, fertilizer, and all increased loads to existing WWTFs.

3.3.4 Existing PPA Wastewater Treatment Facilities

It is understood that the main source of nitrogen is the sub-surface disposal of domestic wastewater through septic systems or cesspool systems and the migration of the nitrogen in the wastewater to the estuary via groundwater. The other source of wastewater nitrogen loading is the eight (8) small wastewater treatment facilities (WWTFs) in Mashpee and one WWTF in Sandwich.

The following table presents the Nitrogen loads for the Wastewater Treatment Facilities.

Table 3.3.4.1. WWTF Total Nitrogen Concentrations

WWTF	Watershed	Sub-Watershed	TN (mg/l)[1]	Design Flow (gpd)	Average Annual Existing Flow (gpd)	Average Annual Future Flow (gpd)	TN at Existing Flow (kg/day)	TN at Future Flow (kg/day)
Willowbend	Popponesset	Santuit River	7.7	113,000	24,860	59,890	0.172	0.922
Southcape	Popponesset	Mashpee River	9.5	24,000	8,400	15,840	0.012	0.178
Stratford Ponds	Popponesset	Santuit River	11.2	35,500	12,070	21,300	0.302	0.480
Mashpee Commons	Popponesset	Mashpee River	6.3	180,000	19,800	106,200	0.147	1.419
Windchime Point	Popponesset	Mashpee River	6	40,000	10,000	22,000	0.245	0.516
Forestdale School - Sandwich	Popponesset	Sandwich	NA	20,000	1,200	NA	0.085	0.086
Popponesset Subtotal				**412,500**	**76,330**	**225,230**	**0.963**	**3.601**
Southport	Waquoit	Upper Quashnet River	8.4	172,000	29,240	104,920	0.370	1.607
Mashpee Senior High School	Waquoit	Upper Quashnet River	43.5	18,000	2,700	3,600	0.043	0.076
Waquoit Subtotal				**190,000**	**31,940**	**108,520**	**0.413**	**1.683**
New Seabury	Ocean Discharge		2.5	300,000	9,000	69,000	0.000	2.555
		Total		***902,500***	***117,270***	***402,750***	***1.376***	***7.839***

1. Source: Table 7-4 on page 7-7 of the Stearns & Wheler *Needs Assessment Report*, April 2007.

The total nitrogen loading from the treatment plants is 3.70 kg/day, from Table 3.3.4.1. The database values for nitrogen loading from the eight (8) treatment plant in Mashpee is 3.54. This confirms that the database loadings associated with the WWTFs is representative of the treated effluent from these facilities.

Table 3.3.4.2. presents the nitrogen loading reductions associated with adding nitrogen removal facilities to each of the WWTFs. This is presented for discussion purposes only, as no load reduction was assumed from the existing WWTFs.

Table 3.3.4.2. WWTF TN Concentration & Removal to TN = 4 mg/l

WWTF	Watershed	Sub-Watershed	Average Annual Existing Flow (gal/day)	Average Annual Future Flow (gal/day)	TN at Existing Flow (kg/day)	TN at Future Flow (kg/day)	TN at 4 mg/l & Existing Flows (kg/day)	TN at 4 mg/l & Future Flows (kg/day)	Nitrogen Removed from Existing (kg/day)	Nitrogen Removed from Future (kg/day)
Willowbend	Popponesset	Santuit River	24,860	59,890	0.724	1.745	0.376	0.906	0.348	0.838
Southcape	Popponesset	Mashpee River	8,400	15,840	0.302	2.152	0.127	0.240	0.175	1.913
Stratford Ponds	Popponesset	Santuit River	12,070	21,300	0.511	2.537	0.183	0.322	0.329	2.215
Mashpee Commons	Popponesset	Mashpee River	19,800	106,200	0.472	1.427	0.300	1.607	0.172	0.000
Windchime Point	Popponesset	Mashpee River	10,000	22,000	0.227	1.359	0.151	0.333	0.076	1.026
Forestdale School - Sandwich	Popponesset	Sandwich	1,200	NA	NA	NA	NA	NA	NA	NA
Popponesset Subtotal			***76,330***	***225,230***	***2.236***	***9.221***	***1.137***	***3.408***	***1.099***	***5.993***
Southport	Waquoit	Upper Quashnet River	29,240	104,920	0.929	1.903	0.442	1.588	0.487	0.315
Mashpee Senior High School	Waquoit	Upper Quashnet River	2,700	3,600	0.444	9.855	0.041	0.054	0.403	9.801
Waquiot Subtotal			***31,940***	***108,520***	***1.373***	***11.759***	***0.483***	***1.642***	***0.890***	***10.116***
New Seabury	Ocean Discharge		9,000	69,000	0.085	0.566	0.136	1.044	-	-
Total			***117,270***	***402,750***	***3.695***	***21.546***	***1.756***	***6.094***	***1.990***	***16.109***

1. Source: Table 7-4 on page 7-7 of the Stearns & Wheler *Needs Assessment Report* , April

3.3.5 Mashpee Nantucket Sound Discharge

There are Mashpee parcels that fall outside the boundaries of both Waquoit Bay and Popponesset Bay. These parcels, located in the New Seabury area, discharge to Nantucket Sound, and consequently do not impact either the Popponesset Bay or Waquoit Bay Watersheds.

The Nitrogen Loads for these parcels are summarized in Table 3.3.5.1.

Table 3.3.5.1. Mashpee Nantucket Sound Discharge Nitrogen Loads

	Parcel Information								
	Nitrogen Loads			Parcels				Wastewater Flows	
	Present Nitrogen Load (kg/day)	Additional Future Nitrogen Load (kg/day)	Total Future Nitrogen Loads (kg/day)	Total No. of Parcels	Existing Developed	Future Developed	Undeveloped	Present Flow (gpd)	Future Flow (gpd)
Mashpee Parcels Ocean Discharge	66	50	116	1,587	1,253	149	185	176,287	308,635
Totals	229	169	399	9,685	6,568	1,133	1,985	1,061,511	2,011,006

WWTF	TN (mg/l)[1]	Design Flow (gpd)	Average Annual Existing	Average Annual Future	TN at Existing Flow		TN at Future Flow	
					(kg/yr)	(kg/day)	(kg/yr)	(kg/day)
New Seabury	2.5	300,000	9,000	69,000	0.085	0.00023	0.653	0.00179

1. Source: Table 7-4 on page 7-7 of the Stearns & Wheler *Needs Assessment Report* , April 2007.

4 Wastewater Treatment Options & Cost Estimates

The Wastewater Treatment Options for the Town of Mashpee are:

Decentralized Technology Options:

- Cluster Systems
- On-Site Only
- PRB
- Groundwater Treatment via Pump & Treat
- Hybrid of the above

The conventional sewering technology option utilizes sewers with varying service areas and locations. These scenarios and their cost estimates are discussed below.

Examples of installations using these Scenarios are presented in Appendix B. All options are to achieve the MADEP TMDL requirements and to provide capacity for buildout assuming buildout occurs with future wastewater systems removing 90% of its wastewater nitrogen. In other words, 10% of future loadings are removed from existing wastewater sources to create capacity for future buildout.

4.1 Decentralized Scenario 1: Cluster Systems

The Cluster Systems Scenario most resembles conventional sewering and is the highest cost option of all of the decentralized scenarios. The following assumptions were made concerning parcels that will not initially be served by a cluster system:

1. Any non-sewered parcel that has a future expansion in flow, either by developing an undeveloped lot or by expanding an existing development, will either be connected to an existing cluster system or will be required to install an I/A system capable of removing 90% of the influent TN load.
2. Any non-sewered parcel that does not have an increase in future TN load will remain onsite.

The Cluster Scenario consists of:

1. Septic Tanks on individual properties either salvaging the existing septic tank or replacing it with a new septic tank.
2. Septic tank effluent collection system from the served properties to a cluster treatment plant.
3. Cluster Treatment Facility – a wastewater treatment facility that will treat the flows from the collection system.

4. Drainfield Discharge with new facilities – although existing drainfields may be used if feasible.

While the Nitrex™ system offers the potential for capital and operational cost savings, it is not the only treatment system that can be used for cluster treatment. Other systems include MBR's, SBR's and conventional activated sludge treatment systems. Each cluster system should be screened for the optimal technology based on treatment performance, site area constraints and regulatory restrictions. The costs and sizing for this scenario is based on using the Nitrex™ system.

The following assumptions were made for treatment by a cluster system:

1. Influent Nitrogen Concentration – 35 mg/L
2. Effluent Nitrogen Concentration – 5 mg/L
3. Drainfield Discharge Nitrogen Concentration – 3.75 mg/L – after septic system attenuation

This scenario consists of multiple cluster systems located throughout the PPA, treating areas where the density of developed parcels is relatively high and natural attenuation is low. One scenario, using 16 cluster systems has been developed by LAI. This number and their location has been prepared for cluster systems approach feasibility and budgeting purposes only. Figures 4.1.1 and 4.1.2 illustrate the locations of the 16 clusters.

For this planning level study, the delineation of the cluster systems is not as important as the number, type and location of the parcels that they include. Of importance also are the subwatersheds to which the cluster systems discharge treated effluent. Figures 4.1.3 and 4.1.3 illustrate the Decentralized Scenario Plan by Parcel and Development Status. Figure 4.1.5 illustrates one representative layout for a cluster system. Table 4.1.2 details the nitrogen loads removed by the cluster scenario and how this will meet the MADEP TMDL Report Target Threshold Nitrogen Levels. If the target was not met in one subwatershed, additional nitrogen loads were removed from others so that enough nitrogen will be removed from the receiving watershed to ensure that the water quality goal at the sentinel station will be met. The TMDL reports emphasize the fact that those targets are *one* possible combination that will achieve the water quality goals and that there may be others.

Tables 4.1.3 and 4.1.4 present the final nitrogen loadings to the subwatersheds after treatment by the cluster systems. These tables are the basis for input into the MEP model. The nitrogen loadings reported in these tables are septic system effluent values, which do not account for natural attenuation. It is understood that the MEP model uses septic system effluent nitrogen loading as the input values for analysis.

Table 4.1.2. Nitrogen Loads Treated with Cluster Scenario (Includes the Return Loads)

	Popponesset Bay Watershed						East Waquoit Bay Watershed			
	Popponesset Bay	Shoestring Bay	Ockway Bay	Pinquickset Cove	Mashpee River	Sub-Totals	Little River / Hamblin Pond	Great River / Jehu Pond	Quashnet River	Sub-Totals
Total Buildout Cont. N Load (kg/day) with Atten.	7.68	44.79	4.90	1.11	52.49	110.97	18.45	9.51	45.19	73.15
Target Loads	2.77	19.72	0.76	0.76	16.17	40.18	3.83	1.88	15.92	21.63
N Removal Required (kg/day)	4.91	25.07	4.14	0.35	36.32	70.79	14.62	7.63	29.27	51.52
Cluster Number	LAI Removal Loads w/ Atten Consideration					Sub-Totals	LAI Removal Loads w/ Atten Consideration			Sub-Totals
1	-	4.04	-	-	0.59	4.63	-	-	-	-
2	-	-	-	-	-	-	-	-	5.26	5.26
3	4.21	-	4.05	-	0.41	8.67	-	0.13	-	0.13
4	-	-	-	-	-	-	8.50	-	5.90	14.39
5	-	7.15	-	-	-	7.15	-	-	-	-
6	-	-	-	-	9.23	9.23	2.43	-	-	2.43
7	-	-	-	-	-	-	-	6.17	-	6.17
8	-	-	-	-	-	-	-	-	2.66	2.66
9	-	-	-	-	-	-	4.92	1.17	-	6.10
10	-	-	-	-	13.06	13.06	-	-	2.71	2.71
11	-	4.05	-	-	6.93	10.98	-	-	-	-
12	-	6.12	-	-	-	6.12	-	-	-	-
13	-	6.30	-	-	1.06	7.36	-	-	-	-
14	0.78	3.80	-	0.90	-	5.49	-	-	-	-
15	-	-	-	-	-	-	-	-	15.86	15.86
16	-	0.02	-	-	8.10	8.11	-	0.01	-	0.01
Expansion Rmv*	-	-	-	-	-	-	-	-	-	-
Return Loads**	-	3.93	-	-	3.04	6.97	-	-	0.785	0.79
Return Flows**	-	420,720	-	-	660,260	1,080,979	0	0	185,009	185,009
N Loads Removed	4.99	27.56	4.05	0.90	36.33	73.83	15.85	7.49	31.60	54.94
Actual - Required Removal w/ Database Loads	0.09	2.49	-0.09	0.55	0.01	3.04	1.24	-0.15	2.34	3.42
N Loads from Non-Treated Parcels	1.44	3.71	0.00	0.01	0.55	5.71	0.00	0.00	0.00	0.00

*Represents removal from existing N Loads due to expansion related treatement of entire future flow.

**Represents N loads from cluster WWTF's returned to the watershed through dispersal sites

A summary of the capital, O&M costs and present worth for the Cluster System Scenario are presented in Table 4.1.3.

Table 4.1.3. Decentralized Cluster Systems Scenario Cost Estimate

Planning Area	# of Parcels	Existing Wastewater Flow (gpd)	Total EDUs	Total Capital Cost	Total Capital Cost per EDU	Total O&M	Total O&M per EDU	Total O&M per Parcel	Total Present Worth	Total Present Worth per EDU*	Total Present Worth per Parcel*
			154		154						
Cluster #1	401	37,820	246	$12,014,000	$48,920	$159,169	$648	$397	$10,977,597	$44,700	$44,700
Cluster #2	545	91,268	593	$20,215,000	$34,110	$186,201	$314	$342	$17,445,477	$29,436	$29,436
Cluster #3	631	69,408	451	$19,869,000	$44,085	$178,834	$397	$283	$17,097,665	$37,936	$37,936
Cluster #4	694	86,409	561	$22,833,000	$40,694	$187,893	$335	$271	$19,424,556	$34,619	$34,619
Cluster #5	530	77,492	503	$18,560,000	$36,884	$179,819	$357	$339	$16,130,941	$32,057	$32,057
Cluster #6	353	67,247	437	$13,886,000	$31,800	$170,800	$391	$484	$12,524,544	$28,682	$28,682
Cluster #7	457	59,153	384	$15,258,000	$39,723	$169,927	$442	$372	$13,535,669	$35,239	$35,239
Cluster #8	466	48,516	315	$14,406,000	$45,728	$85,502	$271	$183	$11,841,546	$37,588	$37,588
Cluster #9	467	48,044	312	$14,380,000	$46,093	$165,307	$530	$354	$12,820,094	$41,093	$41,093
Cluster #10	568	132,662	861	$24,728,000	$28,705	$204,866	$238	$361	$21,061,083	$24,449	$24,449
Cluster #11	398	70,710	459	$15,158,000	$33,013	$173,470	$378	$436	$13,499,822	$29,402	$29,402
Cluster #12	206	51,362	334	$9,286,000	$27,843	$160,107	$480	$777	$8,941,283	$26,809	$26,809
Cluster #13	814	92,803	603	$25,948,000	$43,059	$193,752	$322	$238	$21,832,580	$36,230	$36,230
Cluster #14	278	41,497	269	$9,819,000	$36,439	$157,630	$585	$567	$9,313,418	$34,563	$34,563
Cluster #15	491	78,564	510	$17,854,000	$34,997	$179,283	$351	$365	$15,598,257	$30,575	$30,575
Cluster #16	1,352	190,507	1,237	$46,643,000	$37,705	$250,157	$202	$185	$38,030,513	$30,743	$30,743
Totals	*8,651*	*1,243,462*	*8,074*	*$300,857,000*	*$37,260*	*$2,802,717*	*$347*	*$324*	*$260,075,044*	*$32,210*	*$32,210*

*Using 20 year planning period and interest rate of 5%

	Cost / EDU	Cost / Parcel
Capital	$37,260	$34,777
Annual O&M	$347	$324
Present Worth	$32,210	$32,210

Table 4.1.4 is the backup for the components that make up the total capital costs. The land acquisition budget is presented for a reasonableness check.

Table 4.1.5 presents a detailed O&M cost breakdown for each cluster system. The Nitrex™ system does not require full time operator attention and the energy costs are associated mostly with pumping requirements.

Table 4.1.4. Capital Cost Breakdown – Decentralized Cluster Systems

Cluster Number	Parcel Information	WW Flow (gpd)			WW Flow / Parcel		Nitrogen Load Removed (kg/day)	Septic Tank Effluent Piping		Septic Tank Effluent Collection Costs	Total Construction Costs	Total Development Costs	Total Capital Cost	Land Acquisition		Total Capital Cost per Existing Parcel	Total Capital Cost per EDU
	Total Parcels	Existing	Additional Future	Total Future	Existing	Total Future	Existing	House Connect ($/ft)	Street Connect ($/ft)					Land Required (ft^2)[1]	Allocated Budget for Land Acquisition ($/acre)		
Unit Cost								$40	$80								
Unit Quantities								100	80					2.3			154
Cluster #1	401	37,820	9,110	46,930	94	117	3.75	$1,604,000	$2,566,400	$5,122,775	$7,393,000	$4,621,000	$12,014,000	107,938	$223,766	$29,960	$49,000
Cluster #2	545	91,268	19,632	110,900	167	203	4.36	$2,180,000	$3,488,000	$6,962,375	$12,440,000	$7,775,000	$20,215,000	255,070	$159,335	$37,092	$35,000
Cluster #3	631	69,408	20,300	89,708	110	142	6.91	$2,524,000	$4,038,400	$8,061,025	$12,227,000	$7,642,000	$19,869,000	206,328	$193,602	$31,488	$45,000
Cluster #4	694	86,409	62,891	149,300	125	215	8.33	$2,776,000	$4,441,600	$8,865,850	$14,051,000	$8,782,000	$22,833,000	343,390	$133,681	$32,901	$41,000
Cluster #5	530	77,492	25,235	102,727	146	194	5.39	$2,120,000	$3,392,000	$6,770,750	$11,421,000	$7,139,000	$18,560,000	236,272	$157,921	$35,019	$37,000
Cluster #6	353	67,247	55,779	123,026	191	349	6.54	$1,412,000	$2,259,200	$4,509,575	$8,545,000	$5,341,000	$13,886,000	282,959	$98,659	$39,337	$32,000
Cluster #7	457	59,153	28,919	88,072	129	193	5.89	$1,828,000	$2,924,800	$5,838,175	$9,389,000	$5,869,000	$15,258,000	202,566	$151,427	$33,387	$40,000
Cluster #8	466	48,516	25,594	74,109	104	159	1.75	$1,864,000	$2,982,400	$5,953,150	$8,865,000	$5,541,000	$14,406,000	170,451	$169,913	$30,914	$46,000
Cluster #9	467	48,044	13,255	61,300	103	131	4.78	$1,868,000	$2,988,800	$5,965,925	$8,849,000	$5,531,000	$14,380,000	140,989	$205,049	$30,792	$47,000
Cluster #10	568	132,662	144,054	276,716	234	487	8.37	$2,272,000	$3,635,200	$7,256,200	$15,217,000	$9,511,000	$24,728,000	636,448	$78,112	$43,535	$29,000
Cluster #11	398	70,710	43,852	114,561	178	288	6.85	$1,592,000	$2,547,200	$5,084,450	$9,328,000	$5,830,000	$15,158,000	263,491	$115,657	$38,085	$34,000
Cluster #12	206	51,362	50,098	101,460	249	493	3.31	$824,000	$1,318,400	$2,631,650	$5,714,000	$3,572,000	$9,286,000	233,357	$79,996	$45,078	$28,000
Cluster #13	814	92,803	21,648	114,450	114	141	6.19	$3,256,000	$5,209,600	$10,398,850	$15,968,000	$9,980,000	$25,948,000	263,236	$198,177	$31,877	$44,000
Cluster #14	278	41,497	13,656	55,153	149	198	4.13	$1,112,000	$1,779,200	$3,551,450	$6,042,000	$3,777,000	$9,819,000	126,852	$155,609	$35,320	$37,000
Cluster #15	491	78,564	117,913	196,477	160	400	6.30	$1,964,000	$3,142,400	$6,272,525	$10,987,000	$6,867,000	$17,854,000	451,898	$79,431	$36,363	$35,000
Cluster #16	1,352	190,507	78,475	268,982	141	199	5.61	$5,408,000	$8,652,800	$17,271,800	$28,703,000	$17,940,000	$46,643,000	618,659	$151,574	$34,499	$38,000
Totals	*8,651*	*1,243,462*	*730,410*	*1,973,872*	*2,394*	*3,909*	*88*	*$34,604,000*	*$55,366,400*	*$110,516,525*	*$185,139,000*	*$115,718,000*	*$300,857,000*	*$4,539,905*	*$133,229*	*$34,777*	*$38,000*
	Total N in PPA (kg/day)																
	Total % Removal from Clusters																

Total Capital Cost	**Total Capital Cost per EDU**	**Total Capital Cost per Parcel**
$300,857,000	**$38,000**	**$34,777**

Nitrogen Removed (kg/day)	**$ / (kg/day) N Removed**	**$ / (kg/year) N Removed**	**$ / (lb/year) N Removed**	**$ / gpd Flow WW Treated**
88	**$3,401,417**	**$9,319**	**$20,502**	**$241.95**

Table 4.1.5. O&M Cost Breakdown – Cluster Systems

Operations & Maintenance													
Cluster #	**Existing Flow (gpd)**	**# of Parcels**	**Contract Operations**	**Annual Sludge Generation**	**Septic Sludge Disposal**	**Electricity**	**Equipment Maintenance**	**Collection System Maintenance**	**Sampling - Lab Costs**	**Administration & Oversight**	**Groundwater Discharge Permit Compliance Fee**	**Annual Misc. O&M Costs**	**Total O&M Costs**
Cluster #1	37,820	401	$80,000	13,804	$1,520	$4,663	$11,346	$10,246	$11,395	$15,000	$15,000	$10,000	$159,169
Cluster #2	91,268	545	$80,000	33,313	$3,670	$9,831	$27,380	$13,925	$11,395	$15,000	$15,000	$10,000	$186,201
Cluster #3	69,408	631	$80,000	25,334	$2,790	$7,704	$20,822	$16,122	$11,395	$15,000	$15,000	$10,000	$178,834
Cluster #4	86,409	694	$80,000	31,539	$3,470	$9,373	$25,923	$17,732	$11,395	$15,000	$15,000	$10,000	$187,893
Cluster #5	77,492	530	$80,000	28,285	$3,120	$8,515	$23,248	$13,542	$11,395	$15,000	$15,000	$10,000	$179,819
Cluster #6	67,247	353	$80,000	24,545	$2,700	$7,512	$20,174	$9,019	$11,395	$15,000	$15,000	$10,000	$170,800
Cluster #7	59,153	457	$80,000	21,591	$2,380	$6,730	$17,746	$11,676	$11,395	$15,000	$15,000	$10,000	$169,927
Cluster #8	48,516	466		17,708	$1,950	$5,696	$14,555	$11,906	$11,395	$15,000	$15,000	$10,000	$85,502
Cluster #9	48,044	467	$80,000	17,536	$1,930	$5,637	$14,413	$11,932	$11,395	$15,000	$15,000	$10,000	$165,307
Cluster #10	132,662	568	$80,000	48,422	$5,330	$13,830	$39,799	$14,512	$11,395	$15,000	$15,000	$10,000	$204,866
Cluster #11	70,710	398	$80,000	25,809	$2,840	$7,853	$21,213	$10,169	$11,395	$15,000	$15,000	$10,000	$173,470
Cluster #12	51,362	206	$80,000	18,747	$2,070	$5,970	$15,408	$5,263	$11,395	$15,000	$15,000	$10,000	$160,107
Cluster #13	92,803	814	$80,000	33,873	$3,730	$9,989	$27,841	$20,798	$11,395	$15,000	$15,000	$10,000	$193,752
Cluster #14	41,497	278	$80,000	15,146	$1,670	$5,013	$12,449	$7,103	$11,395	$15,000	$15,000	$10,000	$157,630
Cluster #15	78,564	491	$80,000	28,676	$3,160	$8,613	$23,569	$12,545	$11,395	$15,000	$15,000	$10,000	$179,283
Cluster #16	190,507	1,352	$80,000	69,535	$7,650	$19,417	$57,152	$34,544	$11,395	$15,000	$15,000	$10,000	$250,157
Totals	**1,243,462**	**8,651**	**$1,200,000**	**$453,864**	**$49,980**	**$136,345**	**$373,039**	**$221,033**	**$182,320**	**$240,000**	**$240,000**	**$160,000**	**$2,802,717**
Average	**77,716**	**541**	**$80,000**		**$3,124**	**$8,522**	**$23,315**	**$13,815**	**$11,395**	**$15,000**	**$15,000**	**$10,000**	**$175,170**

Figure 4.1.1. LAI Cluster Locations

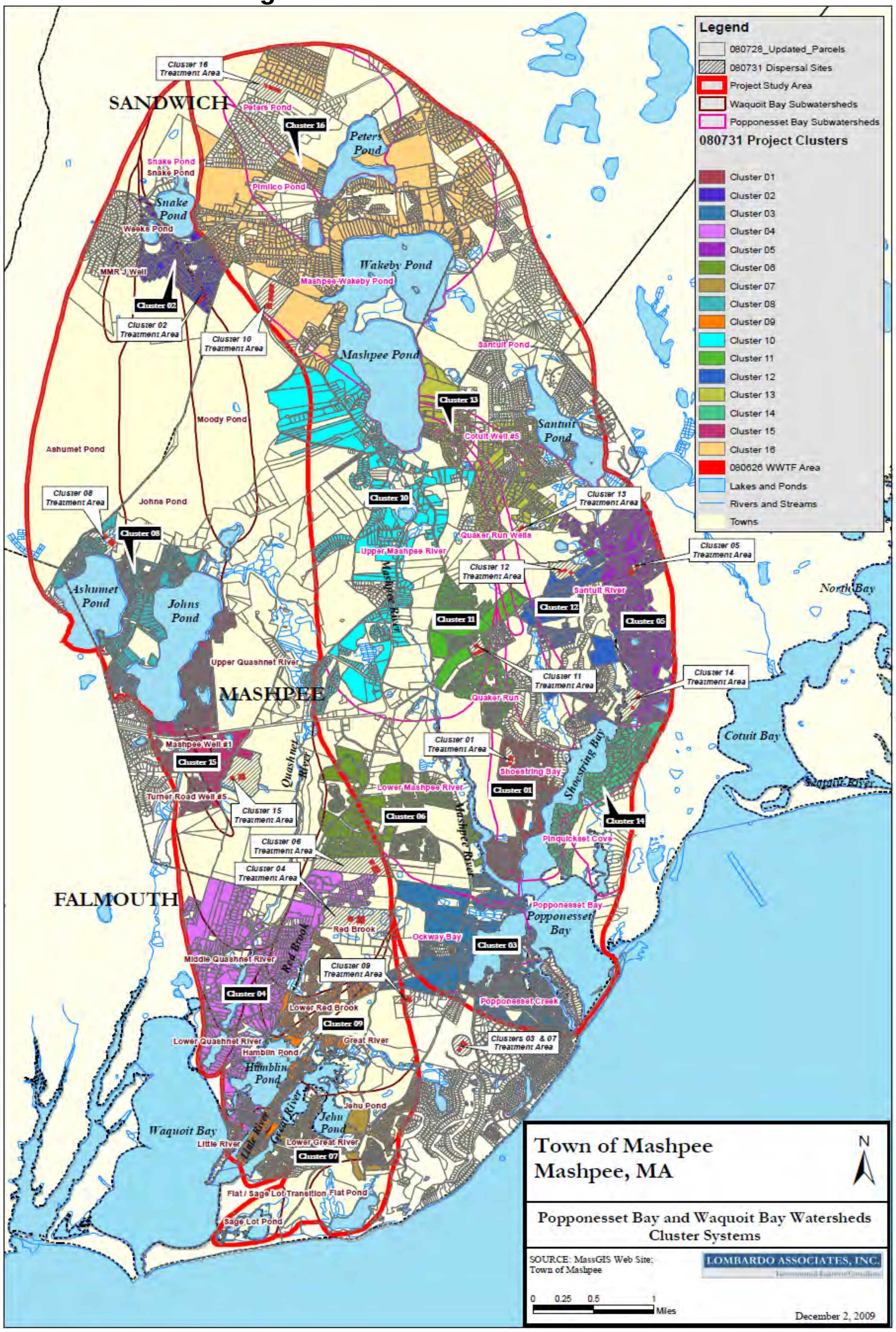


Figure 4.1.2. LAI Cluster Locations on Aerial Photograph

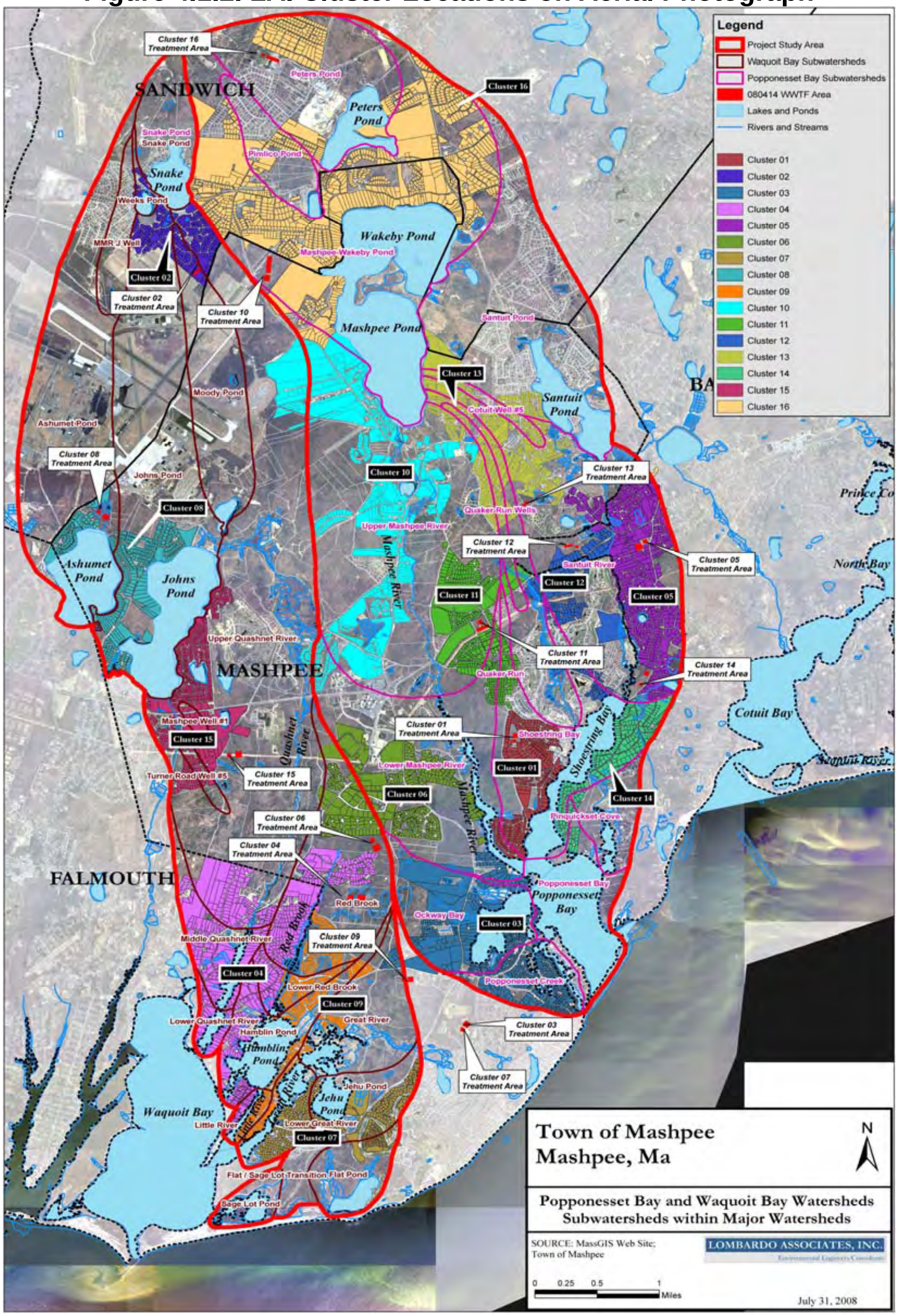
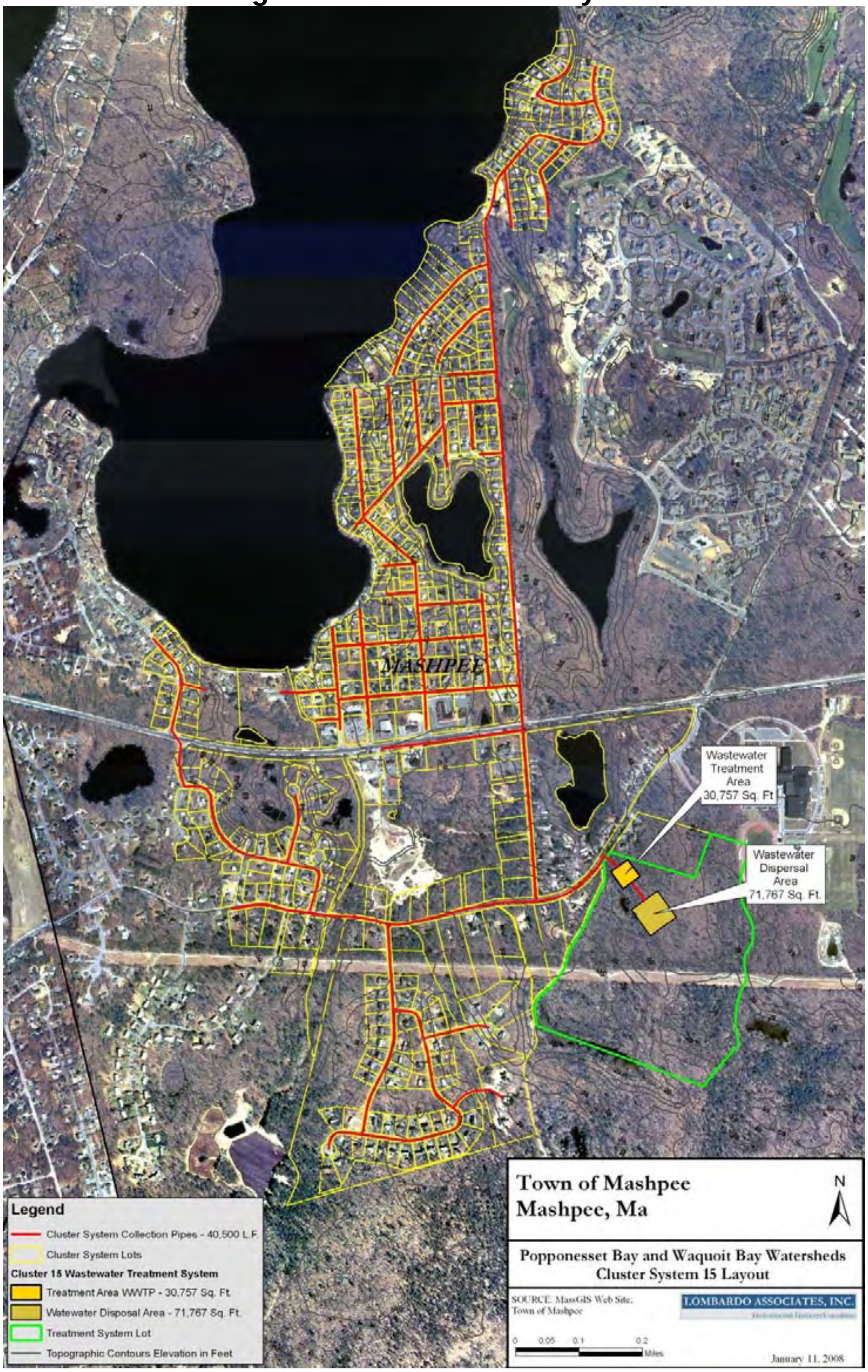


Figure 4.1.5 Cluster 15 Layout



4.2 Decentralized Scenario 2: On-Site Systems Only

Table 4.2.1 summarizes the year built data for the parcels within the Town of Mashpee according to the Mashpee Database provided to LAI on 9/27/07. Half of the existing homes in Mashpee were built after 1985 and 25% after 1995 (the adoption of the current Title V rules), so we have assumed 50% of the septic tanks and drainfields are salvageable.

Table 4.2.1 Town of Mashpee Year Built Data

Year	Cumulative Existing	Developed within Time Period	Developed		Developed as % of Buildout	
			% of Current Total	Cumulative %	% of Total	Cumulative %
before 1990	12	12	0.15%	0.15%	0.12%	0.12%
1900-1910	28	16	0.20%	0.36%	0.17%	0.29%
1910-1920	32	4	0.05%	0.41%	0.04%	0.33%
1920-1930	73	41	0.52%	0.93%	0.43%	0.76%
1930-1940	135	62	0.79%	1.72%	0.64%	1.40%
1940-1950	285	150	1.91%	3.63%	1.56%	2.96%
1950-1960	747	462	5.88%	10%	4.80%	7.76%
1960-1970	1,476	729	9.28%	19%	7.57%	15%
1970-1980	2,604	1,128	14.36%	33%	12%	27%
1980-1985	3,383	779	9.92%	43%	8%	35%
1985-1990	4,991	1,608	20.48%	64%	17%	52%
1990-1995	5,634	643	8.19%	72%	7%	59%
1995-2000	6,455	821	10.45%	82%	9%	67%
2000	6,753	298	3.79%	86%	3%	70%
2001	7,048	295	3.76%	90%	3%	73%
2002	7,236	188	2.39%	92%	2%	75%
2003	7,384	148	1.88%	94%	2%	77%
2004	7,548	164	2.09%	96%	2%	78%
2005	7,741	193	2.46%	99%	2%	80%
2006	7,853	112	1.43%	100%	1%	82%
Buildable	1,772				18%	100%
Total	**9,625**					

Assuming that each parcel treated will achieve 90% nitrogen removal and 50% of the parcels will require new systems (new septic tanks & drainfields in addition to N removal unit), while the other 50% will use retrofit systems, the following tables present the costs for the On-Site Systems only Scenario.

Table 4.2.2. On-Site Systems Only Cost Estimate

Watershed	Cost	Parcels Treated	Total Capital Cost	Wastewater Flow Treated (gpd)[1]	Total N Removed (kg/day)[2]
Total Planning Area	**$30,000**	**8,651**	**$259,530,000**	**1,243,462**	**88**

1. Assume 154 gpd wastewater flow per parcel
2. Assume each on-site system will remove 0.018 kg/day Nitrogen

	Cost / EDU
Capital	$30,000
Annual O&M	$134
Present Worth	$22,922

Table 4.2.3 presents the O&M Breakdown for each of the four decentralized scenarios.

Table 4.2.3. Decentralized Scenarios O&M Costs

Nitrex™ Technology Scenarios	Annual O&M Costs / EDU
1. Cluster Systems	$315
2. Individual Systems	$561
3. Groundwater Treatment - Pump & Treat	$110
4. Groundwater Treatment - PRB	$120
5. Conventional Sewerage System	$700 - $1,000[1]

[1] *Based on Stearns & Wheler Presentation.*

4.3 Decentralized Scenario 3: Groundwater Treatment, Pump & Treat

The Nitrex™ Technology Groundwater Treatment by pump and treat consists of installing groundwater extraction wells in locations down gradient of drainfields to remove the groundwater where the drainfield plumes are expected to be located at or near surface water discharge locations – based upon LAI's experiences in similar situations. Detailed data collection will be needed for further planning and detailed design purposes. Conservative planning assumptions have been made for this analysis. The extracted groundwater would be treated by a strategically located Nitrex™ unit and treated effluent dispersed back into the groundwater.

A detailed layout was developed for a pump and treat system that would capture Cluster 15 nitrogen contributions. For this example, the entire length of the downgradient side of the cluster was lined with extraction wells. A treatment and dispersal site was selected in a location downgradient of the extraction sites.

Figure 4.3.1 illustrates the layout for this representative Pump and Treat Scenario Application. Table 4.3.1 shows a summary of the costs for all the clusters, if a similar system were installed. Table 4.3.2 presents a comparison of the total costs of the Pump and Treat and the Cluster scenarios. In comparing the two approaches, it is important to note that the Pump and Treat system will not only treat the septic system nitrogen loads, it will treat the land use and runoff nitrogen in the groundwater as well. In addition, the attenuated nitrogen loads of all upgradient subwatersheds that flow through the extraction point will also be treated. A thorough examination of the hydrogeology and nitrogen concentration profile would be required to accurately assess both location and size of extraction wells and the associated nitrogen load treated.

The flow rate required for the Pump and Treat system is not a critical design criteria, as the Nitrex^{TM} system is sized for mass removal. If there is more dilution water than anticipated, then the treatment plant flow will be higher and the nitrogen concentration will be lower. In this case, although the flow rate will increase for the treatment system, the associated size of the Nitrex^{TM} treatment system is not likely to change significantly. For preliminary sizing, the treatment system is assumed to be treating the groundwater equivalent of twice the wastewater flow associated with the parcels in each cluster.

As can be seen in Table 4.3.2, there is significant potential savings using the Pump and Treat option. It is also noted that some areas are much more cost effective than others, and that Pump and Treat may not be applicable in all areas. However, in areas where conditions appear to be favorable, significant saving and additional nitrogen removal can be achieved with the Pump and Treat option.

Figure 4.3.1. Pump and Treat Scenario 1

Table 4.3.1. Pump & Treat Cost Estimate Summary

Planning Area	Existing Wastewater Flow Treated (gpd)	Total EDUs	Existing Nitrogen Load Removed (kg/day)	Total Capital Cost	Total Capital Cost per EDU	Total Annual O&M	Annual O&M per EDU	Annual O&M Per Parcel	Present Worth	Present Worth per EDU	Present Worth Per Parcel
P&T #1	37,680	245	3.75	$4,248,000	$18,000	$56,180	$230	$141	$3,868,127	$15,809	$9,695
P&T #2	40,711	264	2.31	$4,212,000	$16,000	$56,608	$214	$209	$3,857,459	$14,592	$14,234
P&T #3	69,365	450	6.90	$7,848,000	$18,000	$60,735	$135	$97	$6,624,890	$14,708	$10,583
P&T #4	86,129	559	6.72	$10,872,000	$20,000	$63,167	$113	$94	$8,919,197	$15,948	$13,214
P&T #5	80,714	524	5.63	$7,740,000	$15,000	$62,376	$119	$119	$6,567,337	$12,530	$12,557
P&T #6	67,247	437	5.71	$6,894,000	$16,000	$60,444	$138	$171	$5,907,267	$13,528	$16,734
P&T #7	59,123	384	5.88	$6,120,000	$16,000	$59,270	$154	$130	$5,318,640	$13,854	$11,689
P&T #8	47,011	305	1.20	$5,760,000	$19,000	$57,520	$188	$126	$5,026,831	$16,467	$11,048
P&T #9	48,044	312	3.91	$8,226,000	$27,000	$57,657	$185	$123	$6,874,529	$22,035	$14,721
P&T #10	103,480	672	7.07	$10,233,000	$16,000	$65,677	$98	$120	$8,471,482	$12,607	$15,516
P&T #11	70,710	459	5.88	$7,074,000	$16,000	$60,948	$133	$154	$6,053,548	$13,184	$15,325
P&T #12	42,508	276	3.20	$4,698,000	$18,000	$56,866	$206	$343	$4,216,682	$15,276	$25,402
P&T #13	80,025	520	5.72	$7,902,000	$16,000	$62,274	$120	$96	$6,688,069	$12,871	$10,321
P&T #14	35,974	234	3.58	$4,338,000	$19,000	$55,931	$239	$230	$3,935,018	$16,845	$16,193
P&T #15	65,012	422	4.63	$6,912,000	$17,000	$60,109	$142	$127	$5,921,090	$14,026	$12,465
P&T #16	178,324	1,158	5.41	$17,739,000	$16,000	$76,473	$66	$63	$14,232,020	$12,291	$11,666
P&T Totals	*1,112,056*	*7,221*	*77.49*	*$120,816,000*	*$12,067*	*$972,234*	*$135*	*$123*	*$102,482,184*	*$14,192*	*$12,945*

	Cost / EDU	Cost / Parcel
Capital	$12,067	$15,260
Annual O&M	$135	$123
Present Worth	$14,192	$12,945

Table 4.3.3. Pump & Treat O&M Summary

PT #	Existing Flow (gpd)	# of Parcels	Contract Operations	Electricity	Equipment Maintenance	Sampling - Lab Costs	Administration & Oversight	Groundwater Discharge Permit Compliance Fee	Annual Misc. O&M Costs	Total O&M Costs	O&M / Parcel
PT #1	37,680	399	$19,500	$2,017	$3,768	$11,395	$5,000	$7,500	$7,000	$56,180	$141
PT #2	40,711	271	$19,500	$2,142	$4,071	$11,395	$5,000	$7,500	$7,000	$56,608	$209
PT #3	69,365	626	$19,500	$3,403	$6,937	$11,395	$5,000	$7,500	$7,000	$60,735	$97
PT #4	86,129	675	$19,500	$4,159	$8,613	$11,395	$5,000	$7,500	$7,000	$63,167	$94
PT #5	80,714	523	$19,500	$3,909	$8,071	$11,395	$5,000	$7,500	$7,000	$62,376	$119
PT #6	67,247	353	$19,500	$3,324	$6,725	$11,395	$5,000	$7,500	$7,000	$60,444	$171
PT #7	59,123	455	$19,500	$2,963	$5,912	$11,395	$5,000	$7,500	$7,000	$59,270	$130
PT #8	47,011	455	$19,500	$2,424	$4,701	$11,395	$5,000	$7,500	$7,000	$57,520	$126
PT #9	48,044	467	$19,500	$2,457	$4,804	$11,395	$5,000	$7,500	$7,000	$57,657	$123
PT #10	103,480	546	$19,500	$4,934	$10,348	$11,395	$5,000	$7,500	$7,000	$65,677	$120
PT #11	70,710	395	$19,500	$3,482	$7,071	$11,395	$5,000	$7,500	$7,000	$60,948	$154
PT #12	42,508	166	$19,500	$2,221	$4,251	$11,395	$5,000	$7,500	$7,000	$56,866	$343
PT #13	80,025	648	$19,500	$3,876	$8,002	$11,395	$5,000	$7,500	$7,000	$62,274	$96
PT #14	35,974	243	$19,500	$1,938	$3,597	$11,395	$5,000	$7,500	$7,000	$55,931	$230
PT #15	65,012	475	$19,500	$3,213	$6,501	$11,395	$5,000	$7,500	$7,000	$60,109	$127
PT #16	178,324	1,220	$19,500	$8,245	$17,832	$11,395	$5,000	$7,500	$7,000	$76,473	$63
Totals	**1,112,056**	**7,917**	**$312,000**	**$54,708**	**$111,206**	**$182,320**	**$80,000**	**$120,000**	**$112,000**	**$972,234**	
Average	**69,503**	**495**	**$19,500**	**$3,419**	**$6,950**	**$11,395**	**$5,000**	**$7,500**	**$7,000**	**$60,765**	**$123**

Table 4.3.4. Pump & Treat Compared to Cluster System Scenario Costs

Planning Area	Existing Wastewater Flow Treated (gpd)	Existing Nitrogen Load	Total Capital Cost	Total Capital Cost per EDU	Total Annual O&M	Annual O&M per EDU	Annual O&M Per Parcel	Present Worth	Present Worth per EDU	Present Worth Per Parcel
P&T Total	1,112,056	77	120,816,000	12,067	972,234	135	123	102,482,184	14,192	12,945
Cluster Total	1,112,056	77	272,810,000	37,779	2,806,559	389	354	239,125,934	33,115	33,115
% Savings with P&T		*-*	*56%*	*68%*	*65%*	*65%*	*65%*	*57%*	*57%*	*61%*

4.4 Decentralized Scenario 4: Nitrex™ PRB

The Nitrex™ Permeable Reactive Barrier (PRB) Scenario consists of installing the Nitrex™ treatment system in groundwater in strategic locations to remove nitrate from groundwater prior to the groundwater entering surface water bodies. Figure 4.4.1 presents schematic drawings of PRBs. Based upon our analysis, determining the feasibility and costs of the Nitrex™ PRB is challenged by the uncertainty on groundwater flow patterns and nitrogen concentrations. Very importantly, the Nitrex™ PRB Scenario development requires information on groundwater flow paths and expected nitrogen concentrations aerially and with depth. This information is not known to exist to the needed level of detail for a PPA wide analysis. The best available information to our knowledge is the generalized USGS groundwater flow directions as illustrated on Figure 3.4.4. Also, the groundwater flow analysis for dispersal sites on Figures 3.4.3 – 3.4.5 suggest that there are areas where groundwater discharge to surface water is more concentrated. No information has been identified that would describe the vertical extent of nitrogen contamination. Consequently, we are unable to accurately determine the appropriate lengths and locations of Nitrex™ PRBs, their associated costs and expected effectiveness.

Using the watershed boundaries and groundwater contours to assume flow directions, the total barrier length necessary to capture all nitrogen containing flow from each cluster area was generated. These barrier lengths were used to generate representative costs for using the PRB approach to treat the nitrogen from each cluster area. Table 4.4.1 summarizes these results. The costs presented in Table 4.4.1 use worst-case assumptions for PRB depth and a heavy contingency was applied to account for the uncertainty at this level of planning.

The PRB approach offers the lowest lifecycle costs. While there is a great deal of uncertainty as to the exact locations and size of the barriers, given the overwhelming cost savings associated with the PRB approach and the potential for immediate results, this option merits further development. LAI has identified areas condusive to the use of the Nitrex™ PRB.

Figure 4.4.2 illustrates the groundwater nitrogen removal performance of two Nitrex™ PRBs designed and installed by Lombardo Associates, Inc. in Waquoit Bay in 2005 and independently tested by the Woods Hole MBL.

Figure 4.4.1. EPA Schematic of Groundwater Barrier

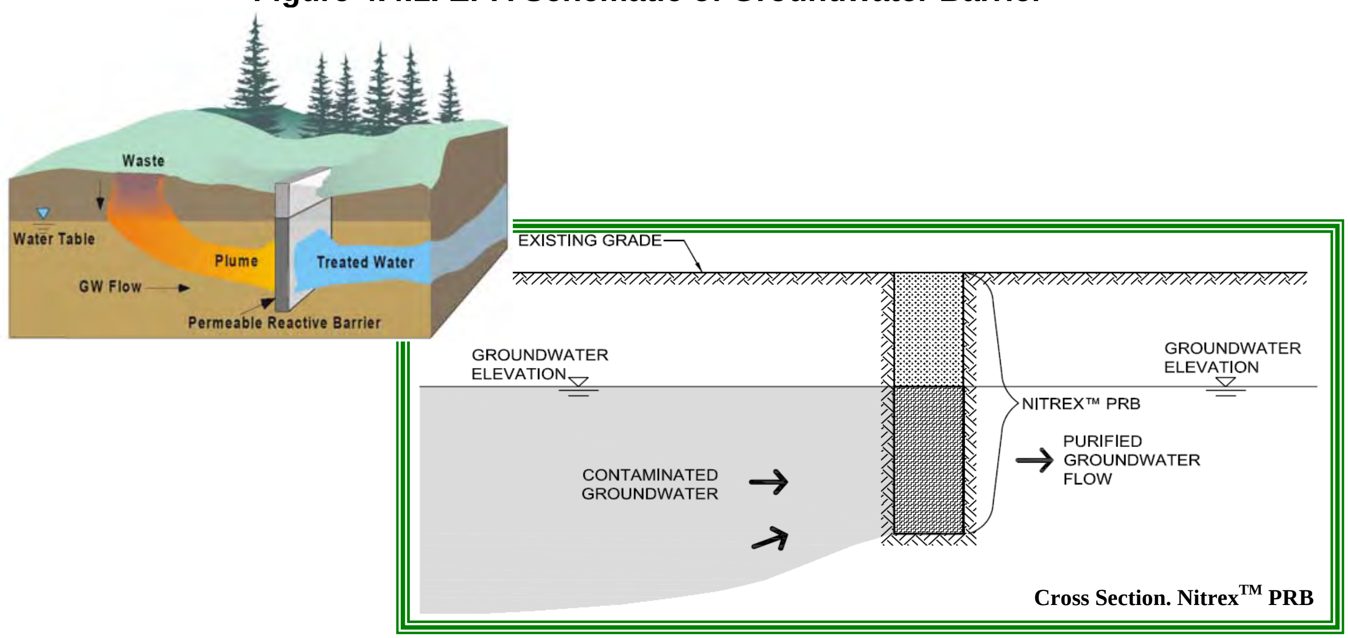
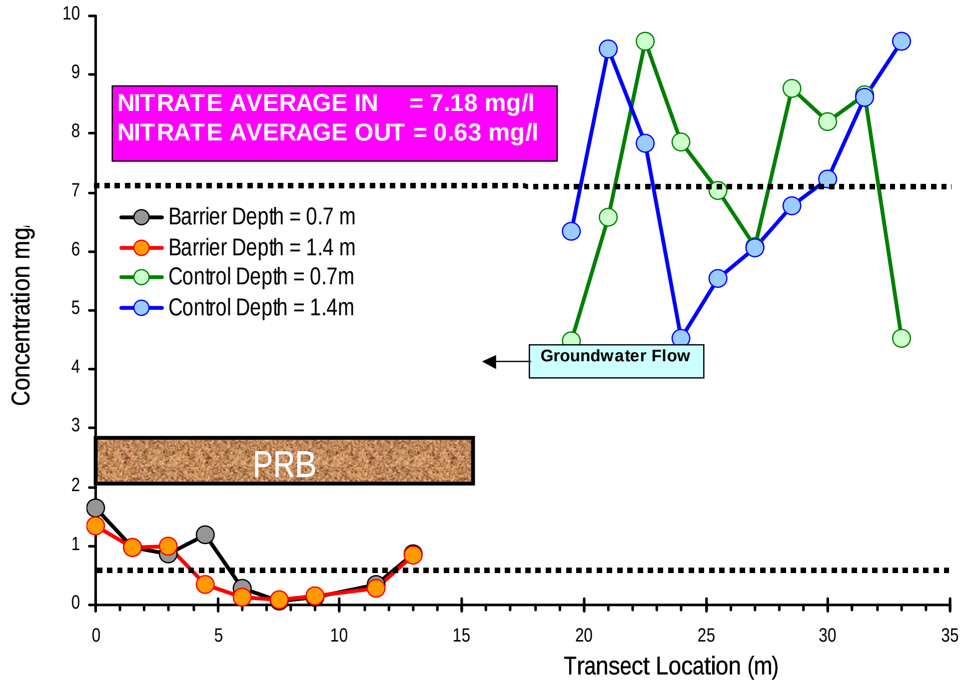


Figure 4.4.2. Groundwater Nitrogen Removal Performance of Nitrex[TM] PRBs in Waquoit Bay



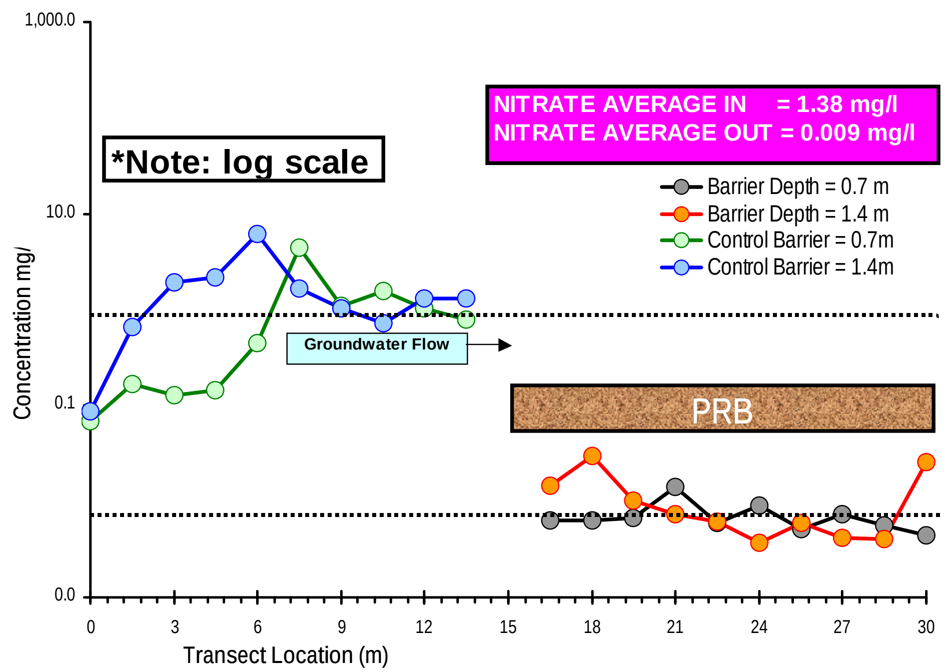


Table 4.4.1. Preliminary Cost Estimates for Nitrex^{TM} PRB Scenario

Planning Area		WW Flow (gpd)			Nitrogen Load Removed (kg/day)	PRB		Total Capital Cost	Total Capital Cost / EDU
	Total Parcels	Existing	Add'l Future	Total Buildout	Existing	PRB Length	PRB Cost		
Cluster #1	399	37,680	8,970	46,650	3.75	10,200	$ 3,060,000	$4,590,000	$18,760
Cluster #2	271	40,711	12,007	52,718	2.31	7,200	$ 2,160,000	$3,240,000	$12,256
Cluster #3	626	69,365	-16,648	52,718	6.90	24,600	$ 7,380,000	$11,070,000	$24,577
Cluster #4	675	86,129	2,556	88,685	6.72	44,400	$ 13,320,000	$19,980,000	$35,725
Cluster #5	523	80,714	22,577	103,291	5.63	13,800	$ 4,140,000	$6,210,000	$11,848
Cluster #6	353	67,247	55,779	123,026	5.71	15,000	$ 4,500,000	$6,750,000	$15,458
Cluster #7	455	59,123	28,779	87,902	5.88	12,600	$ 3,780,000	$5,670,000	$14,769
Cluster #8	455	47,011	25,034	72,044	1.20	18,000	$ 5,400,000	$8,100,000	$26,534
Cluster #9	467	48,044	13,255	61,300	3.91	44,400	$ 13,320,000	$19,980,000	$64,043
Cluster #10	546	103,480	100,264	203,744	7.07	22,500	$ 6,750,000	$10,125,000	$15,068
Cluster #11	395	70,710	36,012	106,721	5.88	13,200	$ 3,960,000	$5,940,000	$12,937
Cluster #12	166	42,508	16,630	59,138	3.20	9,000	$ 2,700,000	$4,050,000	$14,673
Cluster #13	648	80,025	11,152	91,176	5.72	14,400	$ 4,320,000	$6,480,000	$12,470
Cluster #14	243	35,974	10,507	46,481	3.58	10,200	$ 3,060,000	$4,590,000	$19,649
Cluster #15	475	65,012	22,626	87,638	4.63	15,000	$ 4,500,000	$6,750,000	$15,989
Cluster #16	1,220	178,324	68,453	246,777	5.41	44,693	$ 13,407,802	$20,111,703	$17,368
Totals	*7,917*	*1,112,056*	*417,953*	*1,530,009*	*77*	*319,193*	*95,757,802*	*143,636,703*	*$19,891*

	Cost / EDU	Cost / Parcel
Capital	$19,891	$19,891
Annual O&M	$144	$138
Present Worth	$16,671	$15,387

4.5 Decentralized Scenario 5: Hybrid of Scenarios 1-4

A hybrid scenario would consist of a mix of the Decentralized Technology approaches of:

- Cluster
- On-Site
- Groundwater Pump & Treat
- PRB

in an economically optimized manner. The development of optimized hybrid solutions would be the focus of follow – up studies once the technical feasibility and cost – competitiveness of the decentralized approach presented is this report is accepted.

4.6 Scenario 6: Sewering

Stearns & Wheler developed the Sewering Option for the Town of Mashpee. Table 4.6.1 presents their numbers.

Table 4.6.1. Stearns & Wheler Sewer Cost Estimates for the Town of Mashpee

Conventional Sewerage Scenarios	Capital Cost	Capital Cost / EDU
Stearns & Wheler Scenario 4 Proposed Estimates - Low End(1)	$460,000,000+	$66,000
Stearns & Wheler Scenario 1 Proposed Cost Estimates - High End(1)	$540,000,000+	$77,500

(1) The Stearns & Wheler proposed cost estimates in the March 2008 Draft Alternative Scenarios Analysis Report do not include allowances for land acquisition, acquisition of needed WWTPs, and treatment costs at the Falmouth and Barnstable WWTPs.

5 Nitrogen Removal Conclusions

Table 5.1. Nitrex™ Alternatives Cost Comparisons

Nitrex™ Technology Scenarios	Capital Cost	Capital Cost / EDU	Capital Cost / (lb/year) N Removed	Capital Cost / (kg/day) N Removed	Capital Cost / (kg/year) N Removed	Nitrex™ Technology Capital Cost as % of Complete WW System w/ Sewers	Nitrex™ Technology Capital Cost as % of Sewers Connected to Existing WWTP & Expansion
Cluster Systems	$300,857,000	$34,777	$20,502	$3,401,417	$9,319	65%	56%
Individual Systems	$259,530,000	$30,000	$17,685	$2,934,184	$8,039	56%	48%
Groundwater Treatment - Pump & Treat	$130,212,000	$15,052	$8,873	$1,472,146	$4,033	28%	24%
Groundwater Treatment - PRB	$239,394,505	$27,672	$18,621	$3,089,342	$8,464	52%	44%
Stearns & Wheler Scenario 4 Proposed Estimates - low end(2,3)	$460,000,000+	$66,000	$22,329	$3,704,618	$10,150		
Stearns & Wheler Scenario 1 Proposed Cost Estimates - high end(2,3)	$540,000,000+	$66,000	$19,021	$3,155,786	$8,646		

(1) MA State Tax Credit of $6,000 may be available to property owners with septic system repair.
(2) The Stearns & Wheler proposed cost estimates in the March 2008 Draft Alternative Scenarios Analysis Report do not include allowances for land acquisition, acquisition of needed WWTPs, and treatment costs at the Falmouth and Barnstable WWTPs.
(3) Ratio of Captial Cost are higher than the per EDU ratio due to the fact that the Stearns & Wheler proposal is to sewer more properties than proposed by LAI.

Table 5.2. Other Decentralized Options for Specific Areas of PPA

Nitrex™ Technology Scenarios	Capital Cost / (lb/year) N Removed
1. Groundwater Treatment - Pump & Treat	$9,397
2. Groundwater Treatment - PRB	$11,172

6 Santuit Pond Phosphorous Removal

Achieving phosphorus removal for Santuit Pond can be accomplished by:

1. Cluster Wastewater Systems with active chemical feed systems, which will require phosphorus sludge removal.
2. Cluster Wastewater Systems with passive phosphorus mineralization systems, such as the MADEP approved PhosRID™ Technology.
3. Individual On-Site Systems using the PhosRID™ Technology.
4. Groundwater pump and treat using:

   a. Active chemical feed and sludge management.
   b. Passive phosphorus mineralization

5. Groundwater treatment via a permeable reactive barrier.

As LAI is not aware of Pond water quality studies to specify the amount of phosphorus that needs to be removed, along with the sources and mass of phosphorus contributions, it is not possible to develop an explicit phosphorus removal budgets. However, phosphorus removal could be integrated with a nitrogen removal system that would serve wastewater discharges that enter Santuit Pond. A TMDL study of Santuit Pond should be performed so that the optimal phosphorus remediation strategy can be developed.

However, in an attempt to understand the potential magnitude of the situation, Table 6.1 presents the estimated phosphorus loadings to Santuit Pond based upon the Town's database and USGS delineated contributing watershed areas. The significant unknown variable is phosphorus removal by the soils and attenuation prior to reaching Santuit Pond. Assuming the conservative (however, observed on Cape Cod) assumption that phosphorus removal by soils is insignificant, then it is estimated that 90+% removal of wastewater phosphorus is necessary in the watershed to achieve in Pond steady state levels of < 0.03 mg/l, the generally accepted maximum Pond phosphorus concentration to avoid excessive algae growth.

Table 6.2 presents a range of phosphorus removal costs based upon a variety of assumptions in an attempt to bracket this issue. LAI has received MADEP approval for its PhosRID™ phosphorus removal technology, which has been achieving 90+/-% phosphorus removal. A PhosRID™ unit added to a Nitrex™ system would add approximately $5,000 - $10,000 / EDU.

Table 6.1. Santuit Pond Phosphorus Calculation

Santuit Pond Watershed		
Contributing Watershed Area	3,145	acres
Pond Area	697	acres
Total Watershed	3,842	acres
Rainfall Recharge		
Land Contributing Watershed (in/yr)	18	in/yr
Pond (in/yr)	40	in/yr
Rainfall Recharge		
Land Contributing Watershed (gpd)	4,211,226	gpd
Pond (gpd)	2,074,800	gpd
Total recharge	6,286,026	gpd

Parcels	Existing		Add'l Buildout	
Barnstable	0	0%	4	4%
Mashpee	552	61%	56	62%
Sandwich	350	39%	31	34%
Total	902	100%	91	100%

WW Flow	Existing		Add'l Buildout	
Barnstable	-	0%	560	2%
Mashpee	77,905	61%	22736	81%
Sandwich	49,219	39%	4851	17%
Total	127,124	100%	28147	100%

Nitrogen		
Exsiting Wastewater Flow (gpd)	127,124	gpd
Future WW Flow (gpd)	28,147	gpd
Buildout WW Flow (gpd)	155,271	gpd
Existing N Load	15.21	kg/day
Future N Load	3.42	kg/day
Buildout N Load	18.63	kg/day
Existing N Load	31.56	mg/l
Future N Load	32.05	mg/l
Buildout N Load	31.65	mg/l
Calculated Steady State Pond N Conc. Exist Development	0.64	mg/l

Phosphorus 6 mg/l **Wastewater Phosphorus Conc**		
Existing P Load	2.9	kg/day
Future P Load	0.64	kg/day
Buildout P Load	3.5	kg/day
Calculated Steady State Pond P Conc. Exist Development	0.12	mg/l
Target P Lake Concentration	0.03	mg/l
Percent P Required to be Removed by Treatment	75%	
90% P Removal Assumed % P Req'd to be Removed	84%	

Table 6.2. Rough Estimated Phosphorus Removal Costs

Potential Santuit Pond Phosphorus Removal Costs				
Percent P removed by Soils - Attenuation	0%	60%	70%	75%
No Parcels requiring Tr't	754	383	176	11
% of Total Parcels	84%	42%	20%	1%
$/Parcel Tr't	$ 10,000	$ 10,000	$ 10,000	$ 10,000
$/ all Existing Parcels	$ 8,364	$ 4,246	$ 1,951	$ 122
Capital Cost	$ 7,544,000	$ 3,830,000	$ 1,760,000	$ 110,000

	Cost / EDU
Capital	$8,364
Annual O&M	$574
Present Worth	$13,420

7 Management Issues

The Town of Mashpee could establish its own "Wastewater Management Department" to manage the systems or outsource the work. The components of a Management System are:

- Ownership Management
- Program Management for Capital Improvements
- Use Regulation
- Regulatory Compliance Reporting
- Customer Service, Billing, and Collections
- User-Charge System
- Financial Management
- Operations & Maintenance

7.1 Decentralized Cluster Scenario

The management issues with the DecentralizedCluster Scenario are similar to those of any wastewater system with the refinement that the wastewater system begins with the septic tank in each property. Blanket easements are commonly used for access / maintenance of the septic tank and effluent line on each parcel.

7.2 Nitrex™ On-Site Scenario

The Town's On-Site Scenario management requirements are dictated primarily by ownership – whether the on-site systems stay in private ownership or have public ownership. The benefits of private ownership are:

- Maintenance of current practice
- Potential MA Tax Credit
- Barnstable County System currently supports this approach

The key monitoring issue will be the necessary monitoring frequency to validate nitrogen removal requirements.

7.3 Groundwater Treatment

Due to the reduced required treatment facilities, the major management issue will be performance monitoring.

8 Regulatory Issues

8.1 Cluster Scenario

Regulatory requirements will be dictated in large part by MADEP groundwater discharge requirements. Sewer lines and any other construction in jurisdictional areas will require permitting from appropriate agencies, i.e. Conservation Commission, as with any sewer system.

8.2 On-Site Systems

On-Site systems under 10,000 gpd are regulated by Title 5, generally administered by local Board of Health. The Nitrex™ on-site system will need General Use permit, which requires additional performance data for its General Use designation.

8.3 Groundwater Treatment

Groundwater withdrawal and discharge permits will be needed for a pump and treat option.

Due to its uniqueness, a Nitrex™ permeable reactive barrier option will need to be reviewed with MADEP regarding permitting issues in non-jurisdictional (i.e. outside wetland buffer areas) areas.

APPENDIX A – Database Metafile

Category	Sub-Category	Data Point	Description	Units	Source	Field
Unique ID		1	*Unique ID for all parcels*		*Unified Database*	**FID_1**
Location	**Town**	2	*Town each parcel is located in*		*Unified Database*	**TOWN**
	Subwatershed Assignments	3	*Subwatershed Identifier*		*Unified Database*	**MU_ID**
Flows and Loading Information	**Attenuation**	4	*Individual wateshed attenuations*	*%*	*LAI*	**ATT**
	Existing Flows	5	*Existing Flow*	*gpd*	*Unified Database*	**ExistFlow**
	Existing N Loads	6	*Raw Totals*	*kg/yr*	*Unified Database*	**ExistLoad**
	Future Flows	7	*Future Flow for all Parcels (FutFlowS for Mashpee Parcels and FutFlow for all others)*	*gpd*	*LAI*	**FFlowAll**
	Future N Loads	8	*Raw Totals*	*kg/yr*	*Unified Database*	**FutLoad**
Nitrex™ Scenario	**Buildout Nitrogen Load**	9	*Nitrex Scenario Buildout N Load.*		*LAI*	**N_L_NX**
	Cluster Assignment	10	*Cluster Parcel is Assigned to, if any*		*LAI*	**LAI_CLST**
	Dispersal Site	11	*Dispersal Site, if applicable*		*LAI*	**DISPER_SIT**
Parcel Development	**Development Status**	12	*Existing Developed*	*1 = Yes; 0 = No*	*LAI*	**EX_Dev**
		13	*Future Developed*	*1 = Yes; 0 = No*	*LAI*	**FU_Dev**
	Parcel Expansion	14	*Additional Buildout Load*	*kg/yr*	*LAI*	**Buildout**
MEP	**Land Use & Runoff**	15	*Taken from Buildout spreadsheet that contains summaries by subwatershed only.*	*kg/day*	*MEP*	
	Other Buildout Loads	16	*MEP summarized "Other" N Loads by Rain_Shed*	*kg/day*	*MEP*	
	Target TMDL Threshold N-Load	17	*MEP value for Target Threshold N Load*	*kg/day*	*MEP*	

APPENDIX B – Examples of Nitrex^{TM} Technology Projects

Attached are the Performance Summaries for the following Nitrex^{TM} Technology Projects:

- Mashpee, MA
- Eastham, MA
- Malibu, CA
- Otis Test Center, MA
- Groundwater Treatment
- Phosphorus Removal

PROJECT DESCRIPTION – MAIN STREET VILLAGE – MASHPEE, MA

Cluster System Producing Water with Total Nitrogen Average = 3.52 mg/l

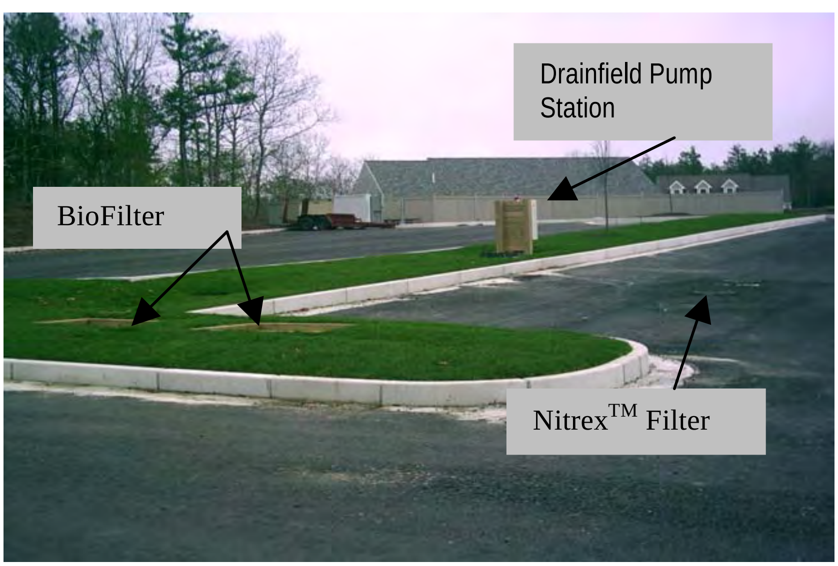
Project: Main Street Village
Mashpee, MA

Design Flow: 5,226 gpd

Wastewater Engineer: Pio Lombardo, P.E.
Lombardo Associates, Inc.
Boston, MA & Malibu, CA
617-964-2924
Pio@LombardoAssociates.com
www.LombardoAssociates.com

The Main Street Village, in Mashpee, Cape Cod, MA, which has 24 housing units and small commercial space, was created with a 5,226 gpd design flow, community-sized wastewater treatment system. The wastewater system is located in a defined nitrogen sensitive area, a Zone II of a public water supply well. Zone II areas are contributing to a water supply well.

The development is served with Town water and the entire Wastewater System includes a wastewater collection system, septic tank, and Recirculating Media Biofilter followed by a Nitrex™ Filter to reduce effluent total nitrogen prior to discharge to a drainfield. Permit effluent requirements are TN must be < 10 mg/l. The Wastewater System became operational in March 2006.



Mashpee, MA Wastewater System at Completion

After the start-up period, wastewater effluent TN levels have generally been < 3 mg/l. Effluent BOD and TSS are typically < 15 mg/l and < 5 mg/l, respectively.

Operations and Maintenance requirements consist of permit required monthly visits for treatment system performance sampling. Daily electrical consumption is approximately 5 KWHr, or $0.75/day with electric costs of $0.15/KWHr. Telephone connection allows remote monitoring of flow and notification of alarm conditions. No chemicals and no other utilities are required.

Environmental Engineers/Consultants
LOMBARDO ASSOCIATES, INC.

The wastewater treatment technology demonstrates that decentralized distributed wastewater systems can be as effective as centralized facilities in achieving the accepted limit of technology of TN < 3 mg/l, and is another tool for wastewater planners and engineers in nitrogen sensitive areas.

The Mashpee project results are similar to independent testing performed in Oregon, Montana, and Massachusetts. The Nitrex™ System is an approved technology in a number of States, with installations in MA, MD, VA, MT, OR, CA and Canada.

Mashpee, MA Performance Summary		
Date	Septic Tank Effluent	Nitrex™ Tank Effluent
	Total Nitrogen (mg/l)	Total Nitrogen (mg/l)
10-May-06	57.6	5.00
16-Jun-06	58.0	<7.00 (1)
26-Jul-06	48.6	2.60
17-Aug-06	75.6	< 3.00
14-Sep-06	67.3	2.15
17-Oct-06	62.3	1.60
20-Nov-06	47.0	2.08
12-Dec-06	51.0	4.10
30-Jan-07	63.0	3.26
28-Feb-07	14.0 (2)	6.27
3-Apr-07	39.0	2.60
26-Apr-07	44.0	2.64
16-May-07	43.0	3.55
26-Jun-07	70.0	3.90
25-Jul-07	73.6	6.05 (1)
12-Sep-07	29.0	2.66
24-Sep-07	45.0	2.50
22-Oct-07	47.0	2.28
24-Jan-08	40.0	4.92
28-Apr-08	64.0	3.73
23-Jul-08	36.0	0.97
24-Oct-08	64.0	0.71
30-Jan-09	26.0	6.10
30-Apr-09	74.0	5.20
19-Aug-09	59.0	2.03
14-Oct-09	67.0	1.46
28-Jan-10	44.0	7.35
Period of Record Avg.	**52.1**	**3.52**
12 Month Rolling Avg.	**54.0**	**4.43**
	% TN Removal	**93.3%**

(1) Due to insufficient nitrification of pretreatment system.

(2) High pH due to inappropriate wastewater discharge caused low total nitrogen.

PROJECT DESCRIPTION – EASTHAM, MA

Cape Cod Residential Development Producing Water with Total Nitrogen <2 mg/l

Project: Brackett Landing, Eastham, MA
40 unit subdivision

Design Flow: 8,310 gpd

Wastewater Engineer: Pio Lombardo, P.E.
Lombardo Associates, Inc.
Boston, MA & Malibu, CA
617-964-2924
Pio@LombardoAssociates.com
www.LombardoAssociates.com

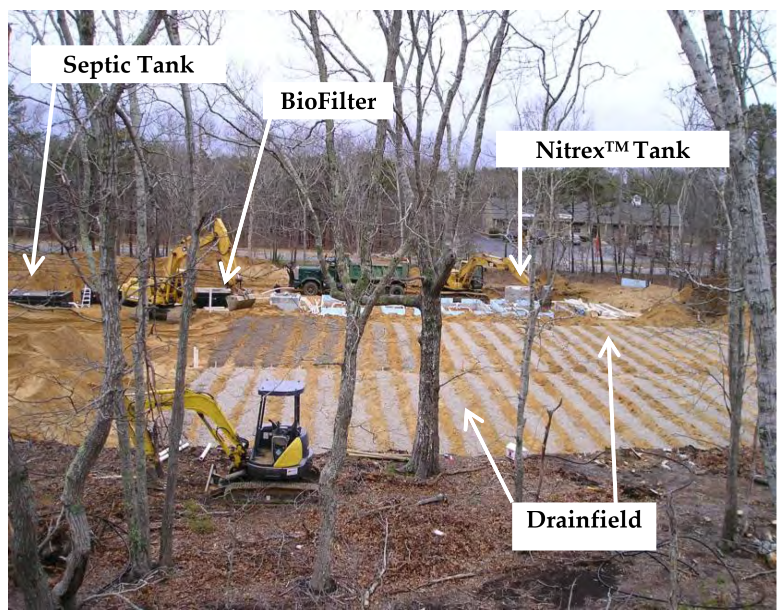
Lombardo Associates, Inc. (LAI) provided design-build-operate services for the wastewater treatment system for the Brackett Landing development in the Town of Eastham on Cape Cod, MA utilizing the Nitrex™ System to achieve nitrogen reduction.

The wastewater system was designed and constructed in accordance with the Town of Eastham Board of Health regulations and the MADEP Title 5 requirements for Total Nitrogen < 10 mg/l. The System has been installed and operational since September 2007, in accordance with the MADEP and Town of Eastham permit requirements.

The performance to date is summarized in the following table:

Date	Septic Tank Effluent	Nitrex™ Effluent
	Total Nitrogen (mg/l)	Total Nitrogen (mg/l)
11/14/2007	10.5	1.56
11/27/2007	15.8	1.61
12/12/2007	24.3	1.64
12/27/2007	17.6	3.67
1/31/2008	22.6	1.74
3/27/2008	25.5	5.45
4/29/2008	22.1	1.80
5/28/2008	26.9	1.75
6/30/2008	15.0	1.87
7/29/2008	56.7	1.60
8/29/2008	19.9	1.05
9/30/2008	19.1	1.03
10/29/2008	16.9	1.12
12/1/2008	36.6	1.15
12/30/2008	14.4	1.35
1/27/2009	133.0	1.56
3/31/2009		1.74
4/30/2009		4.54
5/29/2009		10.3
7/2/2009	21.3	1.57
7/28/2009	44.5	17.6
8/28/2009	16.3	2.47
10/13/2009	48.1	11.5
10/29/2009	57.2	1.96
12/1/2009	12.4	1.05
Average[1]	29.20	1.97
12 month Rolling Average[1]	41.60	1.93
	TN % Removal	**95.3%**

[1] *Not including the 5/29, 7/28 & 10/13/09 sampling event which were the result of power failures.*



Environmental Engineers/Consultants
LOMBARDO ASSOCIATES, INC.
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Portable: (617) 529-4191
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E-mail: pio@LombardoAssociates.com

PROJECT DESCRIPTION – MALIBU CREEK PLAZA, MALIBU, CA

Producing Water Meeting CA Title 22 Unrestricted Water Reuse Standards
Achieving Total Nitrogen <3 mg/l and Turbidity <2 NTU

Project: Malibu Creek Plaza
Shopping Plaza

Design Flow: 16,000 gpd High Strength Equivalent to ~40,000 gpd Residential Strength Wastewater System – approximately 200 homes

Client: Malibu Creek Preservation Co.
c/o Soboroff Partners

Wastewater Engineer: Lombardo Associates, Inc.
Malibu, CA & Boston, MA
www.LombardoAssociates.com

Project Description.

The Malibu Creek Plaza is a shopping plaza consisting of both retail and commercial businesses. It is located in an environmentally sensitive area adjacent to the famous Surfrider Beach in Malibu, California. In 1999 the California Regional Water Quality Control Board (CRWQCB) and the City of Malibu conducted groundwater and surface water sampling at Malibu Creek Plaza and the nearby area and determined that wastewater discharge from the Plaza and other properties using conventional septic systems were causing groundwater pollution, which adversely impacted Malibu Creek and Malibu Lagoon. The CRWQCB required the Plaza to produce the following tertiary quality wastewater effluent:

Lombardo Associates, Inc. (LAI) was retained to engineer a compliant wastewater management system to protect Malibu Lagoon and Surfrider Beach.

The previous system was a conventional system consisting of grease traps, septic tanks and gravel drainfields, which provided insufficient nitrogen and bacteria removal.

LAI designed a cost-effective wastewater management system that employs a septic tank effluent pump (STEP) collection system and treatment system consisting of the Nitrex™ Nitrogen Removal Technology, recirculating media pretreatment of septic tank effluent, and an ozone – UV disinfection system for bacteria removal. Treated effluent is discharged to new high capacity drainfields. The treatment system was designed to treat 16,000 gpd of the high strength wastewater (equivalent to ~40,000 gpd of residential strength wastewater) as 85% of the flow was from the Plaza's popular restaurants.

The Malibu Creek Plaza Wastewater Treatment System has been operational as of July 2007.

The Plaza's wastewater treatment effluent quality is compliant with permit requirements as well as California Title 22 unrestricted water reuse requirements as shown below.

Energy use, 67% of which is for disinfection, of the high strength 16,000 gpd facility (equivalent to 200 - 250 homes) is approximately $7,400 per year (135 kwhr/day @$0.15). Operation & Maintenance requirements are monthly visits.

Water Quality Data – Nitrex™ Wastewater System – Malibu Creek Plaza, Malibu, CA

Constituent		Average Flow	pH	TSS	BOD_5	Turbidity	Total Coliform	Fecal Coliform	Enterococcus	Oil & Grease	TDS	Chloride	Boron	Sulfate	TN
Units		gpd		mg/l	mg/l	NTU	MPN/100 ml	MPN/100 ml	MPN/100 ml	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Malibu Creek Plaza	Avg			30	30	10.0		-	24	-	-	-		-	10.00
Effluent Standards	Max			45	45	15.0		200	104	15	2,000	500		500.0	10.00
Title 22	Avg					2.0	2.2								10.0
Unrestricted Reuse	Max					10.0	23								10.0
Sept. 2007		11,778	6.6	3.2	4.9	1.76	<2	<2	<1	<5	596	241		66	5.79
Oct. 2007		11,950	6.3	<5	6.9	1.08	<2	1	<1	<5	432	165		90	4.71
Nov. 2007		11,692	6.9							<5	540	212	0.31	59	3.23
Dec. 2007		11,692	6.2	9.0	12.0	1.80	8	2	<1	<5	688	270	0.24	62	3.57
Jan. 2008		9,680	6.4	<5	6.0	1.10	50	<2	<1	<5	604	162	0.21	50	4.73
Feb. 2009		9,893	6.2	<5	<5	5.40	<2	<2	<1	<5	684	226	0.23	68	5.61
Mar. 2008		9,808	6.5	<5	<5	1.90	<2	<2	<1	<5	720	213	0.27	98	6.72
Apr. 2008		10,238	6.4	7.0	<5	2.60	23	23	1	<5	660	205	0.34	87	9.17
May 2008		9,475	6.6	<5	<5	1.80	1600 *	350 *	46	<5	748	235	0.26	81	7.88
June 2008		9,996	6.7	8.0	<5	1.40	22	11	11	<5	776	296	0.32	132	15.91
July 2008		11,057	6.8	6.0	<5	1.40	<2	<2	<2	<5	652	167	0.44	82	9.46
Aug. 2008		10,255	6.9	<5	5.3	1.73	533	140	<1	<5	620	149	0.27	110	6.22
Sept. 2008		9,086	6.9	<5	5.0	4.50	<2	<2	1	<5	760	224	0.33	85	6.50
Oct. 2008		9,193	6.8	<5	<5	1.00	30	<2	<1	<5	776	297	0.00	151	3.17
Nov. 2008		9,734	6.9	<5	<5	3.70	<2	<2	<1	<5	772	296	0.34	81	3.74
Dec. 2008		9,153	6.8	<5	<5	0.20	<2	<2	1	<5	736	308	0.44	81	3.54
Jan. 2009		8,094	6.6	6.0	<5	0.20	23	<2	<1	7.00	752	330	0.43	97	2.68
Feb. 2009		6,216	6.9	<5	<5	1.45	<2	<2	<1	<5	884	360	0.47	93	2.84
Mar. 2009		6,429	7.0	<5	<5	0.46	4	3	<1	<5	896	290	0.43	115	2.11
Apr. 2009 **		5,649	6.7	12.5	14.4	11.28	813	806	1	<5	1,012	365	0.52	146	10.12
May. 2009		5,258	7.0	6.3	<5	1.78	63	<2	2	<5	1,030	1,240	0.58	384	3.22
June 2009		7,139	7.0	<5	<5	0.78	<2	<2	<1	4.63	916	325	0.53	101	1.95
July 2009		6,372	7.6	<5	<5	0.38	<2	<2	1	<5	744	275	0.54	126	1.33
August 2009		6,986	6.9	3.7	<5	0.30	<2	<2	<1	<5	778	230	0.55	86	1.09
September 2009		6,938	6.9	<5	7.3	0.23	<2	<2	<1	<5	756	241	0.54	98	1.42
October 2009		6,178	6.9	3.0	7.1	0.60	<2	<2	1	<5	744	225	0.97	97	0.96
November 2009		5,247	6.8	<5	5.4	0.45	2.8	<2	1	<5	692	227	0.80	83	1.29
December 2009		5,289	6.7	6.9	<5	0.28	<2	<2	92	<5	776	244	0.90	72	0.82
January 2010		5,799	7.0	<5	<5	0.55	13.0	<2	<1	<5	736	385	0.89	82	1.33
February 2010		8,697	7.2	3.7	3.8	1.75	106.5	59	4	2.7	836	352	0.86	100	3.64
Average from 9/1/07		8,499	6.8	3.7	3.8	1.75	106	59	4.0	2.7	744	292	0.46	102	3.64
Average from 10/1/08 after Equipment Repairs		6,963	6.9	3.9	3.9	1.41	56	82	6.1	2.9	814	352	0.58	117	2.47
Average from 10/1/08 excluding Operator error data		6,963	6.9	3.5	3.2	0.77	9	1.2	6.0	2.9	814	352	0.58	117	1.89

Notes: (*)Electrical equipment malfunction (**) Operator Error

An additional 125 chemicals are analyzed on a monthly basis. All are within permit requirements. All contaminants of concern are below Detection Limits, typically 5 ppb.

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Independent Testing at MASSTC

NITREX™ COMES OUT ON TOP AT MASSTC TESTING FOR NITROGEN REMOVAL

Project Description

The Nitrex™ system is one of a number of alternative septic systems technologies being assessed at the Massachusetts Septic System Test Center.

Project Application Data

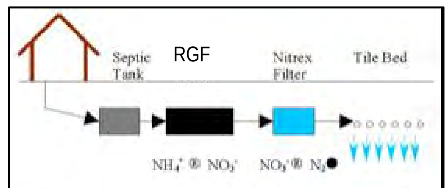
- <u>Location</u>: Otis Air Force Base, Massachusetts
- <u>Site Application</u>: Massachusetts Alternative Septic System Test Center
- <u>Installation Date</u>: October 4, 2001

Design Profile

- Design Wastewater Flow: 330 gpd
- Wastewater Treatment Process: Septic Tank – Recirculating Gravel Filter (RGF) – Nitrex™

Nitrex™ Treatment Performance

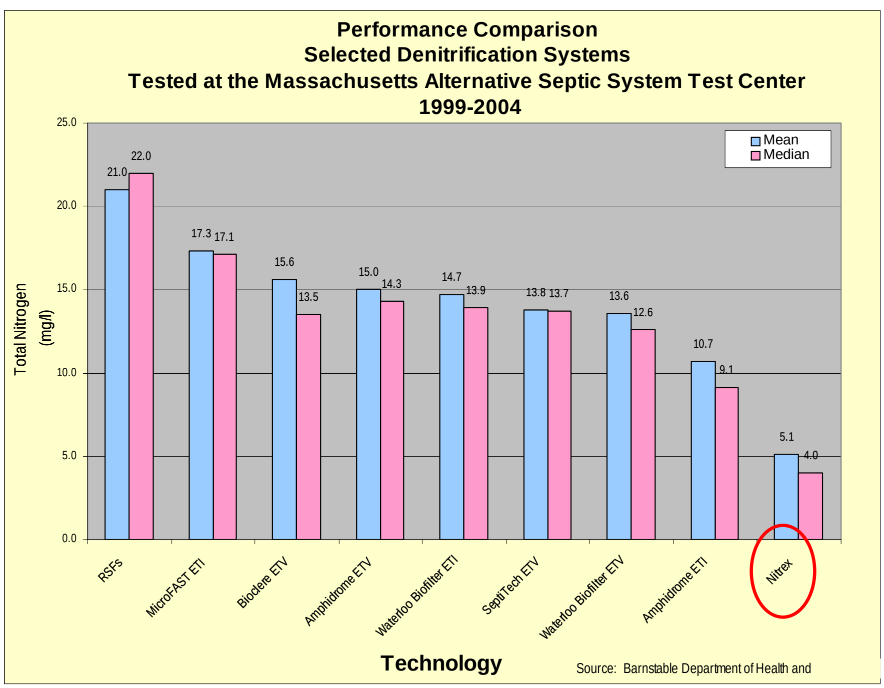
The Nitrex™ filter installed at Otis Air Force base has reduced nitrogen in the effluent by an average of 74.1% over the two years that it has been in operation. The following figures illustrate the nitrate in the effluent and % of nitrate removed from the effluent due to the Nitrex™ filter. The Table provides the actual data measured by an independent laboratory. The lower winter 2003 wastewater temperature from the RGF reduced the performance of the Nitrex™ filter.



NITREX module in a septic system

Nitrex™ System Performance Summary

	Total Nitrogen Median (mg/l)	
	Nitrex™ Influent	Effluent
Otis, MA	19.7	4.5



Date	Discharge Temp (o F)	Influent TN (mg/l)	Influent TKN	Effluent TN (mg/l)	Nitrite	Nitrate	NH4 (mg/l)	TKN	CBOD	TSS
10/24/01		19		3.1	0.4	0.1	1.3	2.6		
11/07/01		19		3.8	0.1	1.9	1.1	1.8		
11/20/01		19		2.2	0.1	0.1	0.9	2		
12/04/01		19		2.2	0.2	0.1	0.2	1.9		
12/19/01		19		2.5	0.1	0.1	0.4	2.3		
01/03/02		19		1.6	0.1	0.1	0.2	1.4		
01/16/02		19		1.7	0.1	0.1	0.2	1.5		
02/13/02		19		2.1	0.1	0.1	0.9	1.9		
03/13/02		19		2.8	0.1	0.6	1.2	2.1		
04/10/02		19		2.4	0.1	0.8	0.2	1.5		
05/08/02		19		3	0.1	0.1	0.6	2.8		
05/22/02		14.8	2.5	2	0.1	0.1	0.3	1.8		
06/12/02		16.7	3	2.5	0.1	0.1	0.2	2.3		
07/10/02		13.6	3.6	3.4	0.1	0.1	2.2	3.2		
08/14/02	77.4	15.8	1.3	2.7	0.1	0.1	1.1	2.5		
09/11/02	73.8	20.5	1.3	2.1	0.1	0.1	0.8	1.9		
10/09/02	68	15.5	0.3	2	0.1	0.3	1.4	1.6		
11/13/02	56.5	18.9	1.3	6.7	0.2	1.8	0.2	4.7		
12/11/02	44.8	18.7	0.5	6.1	0.3	4.3	0.4	1.5		
01/08/03	41.5	11.2	4.2	8	0.3	4.4	2.7	3.3		
02/12/03	37.6	18.2	7.8	13.1	0.3	5.4	6.2	7.4		
03/12/03	36.9	16.9	9.8	12.6	0.1	2.8	7.9	9.7		
04/09/03	41.5	17.9	4.7	8.9	0.1	4	4.2	4.8		
05/14/03		11.7	3.2	6	0.1	2.1	0.9	3.8		
06/11/03	60.3	10.23		7.2	0.05	0.1				
06/25/03	61.7									
07/09/03	72									
10/15/03	18.1	21.76	0.5	5.71	0.06	0.05	3.2	5.6	11	32
11/12/03	12.2	25.1	1.6	4.8	0.1	3.3	0.5	1.4	1	2
12/10/03	6.2	14.76	0.5	5.11	0.21	3.6	0.6	1.3	1	0.5
01/07/04	6	13.1	4.1	3.93	0.07	0.86	1.8	3	2.9	1
03/11/04	2.3	24.82	11	18.15	0.05	0.1	13	18	10	5.5
12/01/04	10.2	21.83	0.8	10.33	0.03	7.7	0.8	2.6	4	2.5
12/08/04	9.4	23.13	3.1	8.73	0.03	6.6	0.3	2.1	8	2.5
12/15/04	8.5	22.43	3.4	11.53	0.03	8.3	0.5	3.2	4	2.5
12/22/04	6.7	20.28	0.25	11.23	0.03	9.7	0.5	1.5	1	2.5
01/05/05	7.3	19.73	3.7	10.19	0.19	8.2	0.3	1.8	11	2.5
01/12/05	5.8	17.83	3.8	6.03	0.03	4.1	0.1	1.9	6	2.5
01/19/05	5.3	19.93	1.9	10.23	0.03	8.5	0.5	1.7	11	2.5
02/02/05	3.3	20.73	0.7	11.28	0.03	11	0.3	0.25	14	2.5
02/09/05		40.63	1.6	16.43	0.03	15	0.4	1.4	4	2.5
02/16/05	4.1	25.33	1.3	12.33	0.03	10	0.3	2.3	1	2.5
02/23/05	3.3	20.23	1.2	11.23	0.03	9.8	0.3	1.4	4	2.5
03/04/05	2.5	28.28	0.25	17.03	0.03	16	0.3	1	5	2.5
03/11/05	2.7	20.83	2.8	10.03	0.03	7.6	0.2	2.4	5	2.5
03/18/05	3.6	22.93	2.9	8.23	0.03	6.4	0.4	1.8	5	2.5
03/25/05	3.9	18.73	2.7	6.63	0.03	4.3	0.5	2.3	3	2.5
04/08/05	7.9	23.49	1.9	8.33	0.03	6.1	0.4	2.2	3	2.5
04/15/05	7.7	23.35	0.25	8.13	0.03	6.4	3	1.7	4	2.5
04/22/05		25.68	1.9	9.23	0.03	7.2	0.5	2	4	2.5
05/13/05	11.4	16.63	1.2	3.23	0.03	1.3	0.4	1.9	3	5.4
05/20/05	11.5	16.23	2.2	1.08	0.03	0.05	0.1	1	8	5
05/27/05	11.1	11.93	4.1	3.23	0.03	1.3	0.3	1.9	5	2.5
06/03/05		20.55	0.9	3.73	0.03	2	0.1	1.7	5	2.5
06/10/05		24	1.3	5.33	0.03	3.5	0.3	1.8	3	2.5
06/17/05	17.8	14.79	2.9	3.97	0.17	1.8	0.1	2	7	2.5
06/24/05		16.33	3.3	2.82	0.03	0.99	0.6	1.8	4	2.5
07/01/05	19.3	16.43	2.4	3.73	0.03	1.1	1.4	2.6	6	2.5
07/08/05		20.48	2.7	3.73	0.03	1.7	0.7	2	6	2.5
07/15/05	20.7	21.75	1.4	3.83	0.03	1.8	0.5	2	5	2.5
07/22/05	22.7	22.3	0.25	3.35	1.5	0.15	0.6	1.7	5	2.5
07/29/05	22.5	28.33	1.3	4.93	0.03	2.2	0.5	2.7	5	2.5
08/03/05	22.6	28.65	0.25	4.73	0.03	2.6	0.7	2.1	4	2.5
08/10/05	23.4	23.31	0.9	4.03	0.03	2	0.6	2	4	2.5
08/17/05		26.61	0.25	5.53	0.03	3.3	0.3	2.2	4	2.5
08/24/05	23.2	31.83	3.8	3.73	0.03	1.8	0.2	1.9	30	2.5
08/31/05	23.5	28.13	1.9	4.43	0.03	2.4	0.4	2	6	2.5
09/14/05	22.7	26.28	0.25	4.53	0.03	2.6	0.4	1.9	11	2.5
09/21/05	22.4	24.15	0.7	2.76	0.06	1.2	0.8	1.5	7	2.5
09/28/05	21.5	23.86	2.5	3.63	0.13	2	0.3	1.5	2.2	2.5
10/05/05	19.9	19.74	0.25	3.59	0.09	2.1	0.1	1.4	1	2.5
Average	23.0	20.4	2.3	6.0	0.1	3.3	1.1	2.5	5.8	3.3
Median	18.1	19.7	1.9	4.5	0.1	2.0	0.5	2.0	5.0	2.5
St Dev	21.4	5.1	2.2	4.0	0.2	3.7	2.0	2.4	4.8	4.5

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Passive Groundwater Treatment for Nitrogen, Phosphorus & Perchlorate Removal

Nitrate Nitrogen < 0.1 -0.6 mg/l
Total Phosphorus < 0.1 mg/l
Total Perchlorate < 0.2 ug/l

Project: Permeable Reactive Barrier (PRB) Passive Groundwater Treatment Nitrogen Removal

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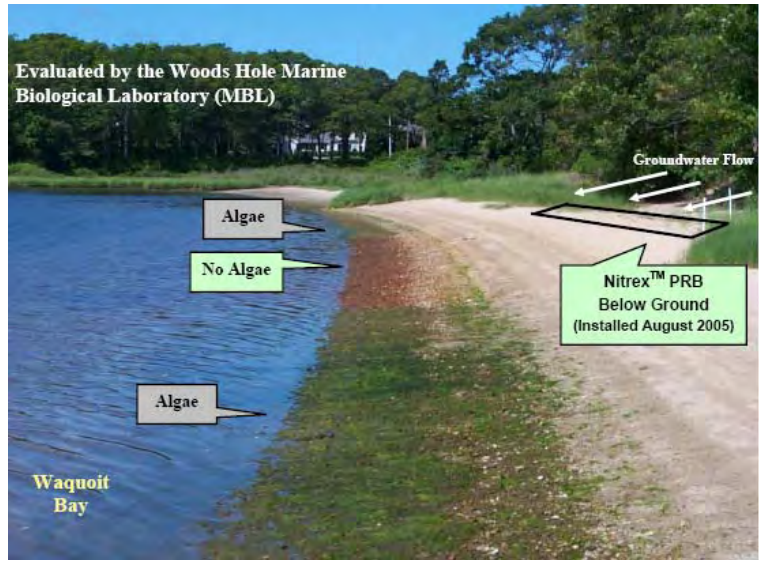
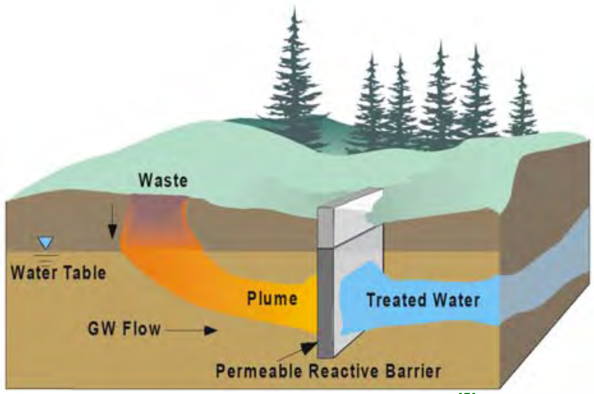


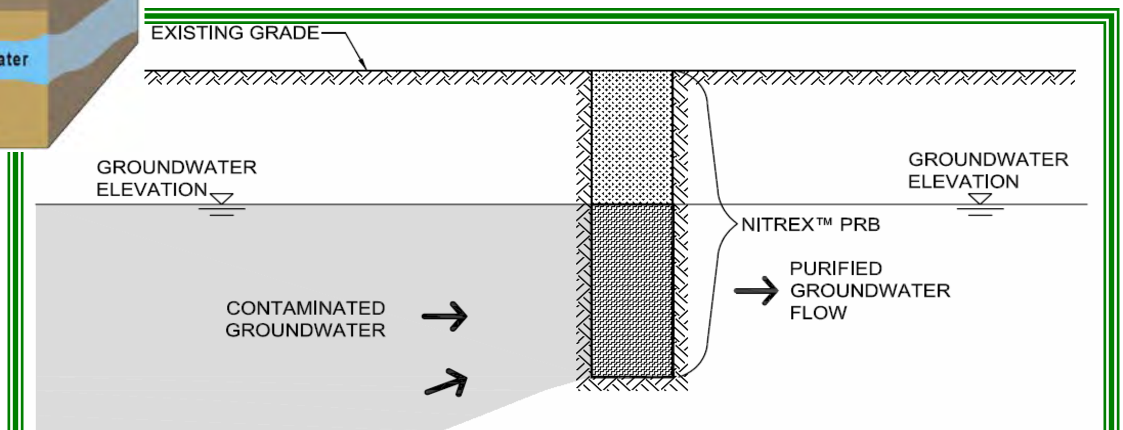
Site 1 – Nitrogen Removal – Cape Cod, MA

As part of a Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) funded demonstrated project, the Woods Hole Marine Biological Lab (MBL) retained Lombardo Associates, Inc. (LAI) for installation of the patented Nitrex™ groundwater nitrogen removal technology at two locations on Cape Cod, MA in the Waquoit Bay watershed. The above photograph illustrates the dramatic water quality improvement with the installation.

Performance

Site	Influent Nitrate – N (mg/l)	Effluent Nitrate – N (mg/l)
Waquoit Bay, MA	1.74	0.007
Childs River, MA	7.19	0.568





Cross Section. Nitrex™ PRB

Site 2 – Nitrogen Removal – Southern New England

Two Nitrex™ PRBs were installed in a Rhode Island coastal watershed. Upstream and downstream concentrations of nitrate, ammonia, and dissolved organic nitrogen in the groundwater were monitored over two annual cycles. The dissolved inorganic nitrogen (DIN) levels are presented below.

Site	Influent DIN (mg/l)	Effluent DIN (mg/l)
Coastal Site #1	3.9	0.2
Coastal Site #2	3.7	0.1

DIN = Dissolved Inorganic Nitrogen = Ammonium + Nitrate + Nitrite

Site 3 – Perchlorate and Nitrogen Removal – Ontario, Canada

Ontario, Canada Site	Nitrate - N (mg/l)	Perchlorate (ug/l)
Influent	50	50
Effluent	<0.1	<0.2

Site 4 – Phosphorus Removal –Massachusetts Site

Massachusetts Site	Influent Phosphorus (mg/l)	Effluent Phosphorus (mg/l)
Site #1	1.7	0.1

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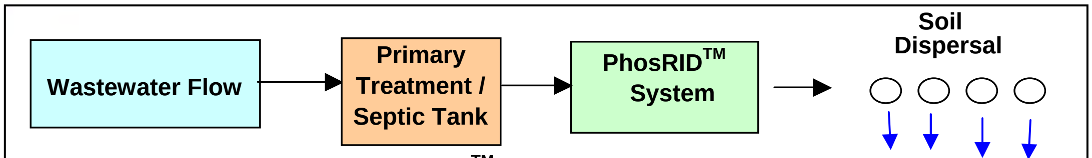
PhosRID™ Passive Phosphorus Wastewater Removal System



PhosRID™ Module in a Wastewater System

The PhosRID™ system removes phosphorus from water through reductive iron dissolution and mineralization of phosphorus.

Septic System Test Center, MA Project

Project Description

Lombardo Associates, Inc. (LAI) and the University of Waterloo installed a demonstration PhosRID™ phosphorus removal system at the Massachusetts Septic System Test Center. Data collection and analysis was performed by the Barnstable County Health Department.

Project Application Data

- Location: Otis Air Force Base, MA
- Site Application: Massachusetts Septic System Test Center (MASSTC)
- Installation Date: August 2002

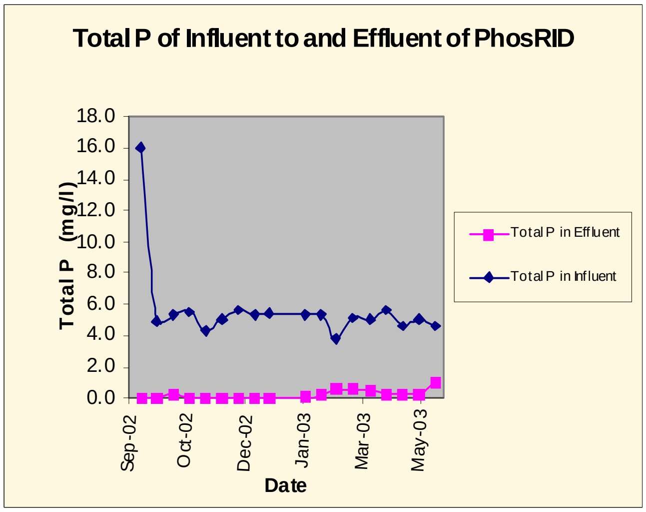
Design Profile

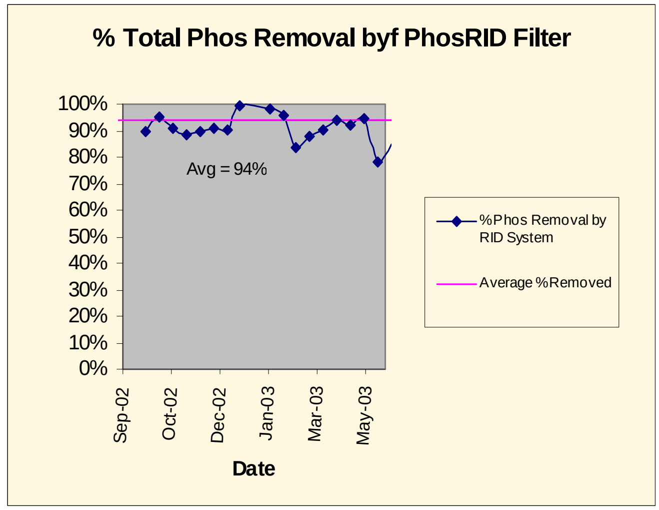
- Design Wastewater Flow: 330 gpd
- Wastewater Treatment Process: Septic Tank – PhosRID™ - Media Filter - Leaching Trench

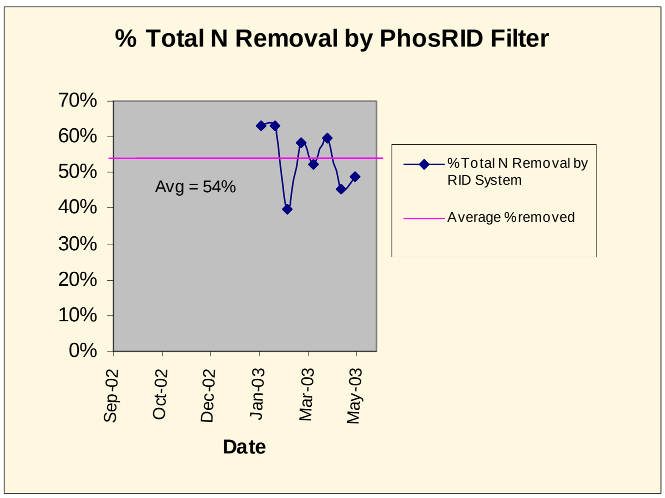
PhosRid™ Treatment Performance

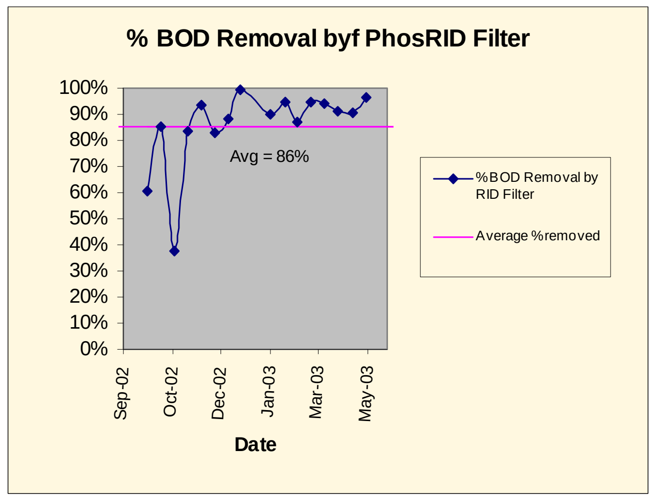
The PhosRID™ installed at the Massachusetts Septic System Test Center has reduced phosphorus in the effluent by an average of 94% over the one year that it has been in operation. In addition, the PhosRID™ has reduced the Total Nitrogen by 54% and BOD in the effluent by 86%.

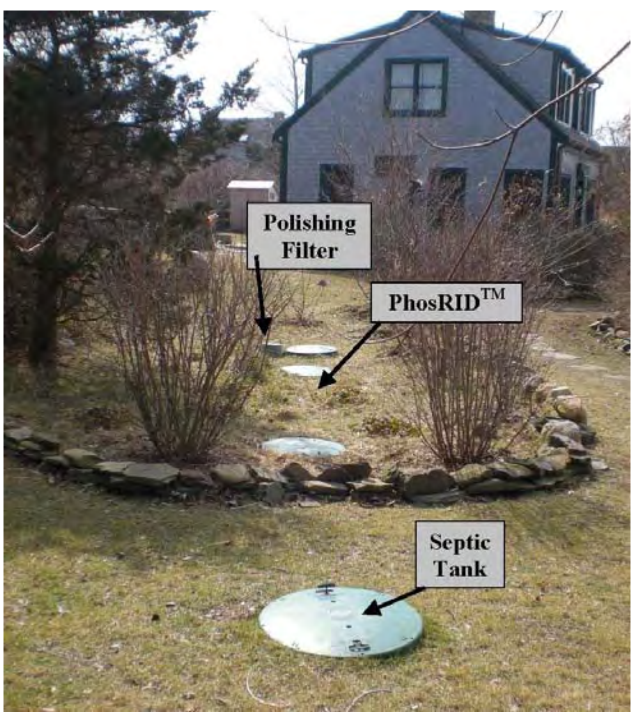
Result	Influent to RID					RID Filter			
	PO4 -3 (mg-P/L)	BOD_5 (mg/L)	Total P (mg/L)	TSS (mg/L)	TN (mg/L)	Total P (mg/L)	% P Removal	% BOD Removal	% N Removal
Average (mean)	4.2	150.0	5.7	23.2	33.3	0.4	94%	86%	54%
Standard Deviation	0.6	67.9	2.6	7.3	3.9	0.3	7%	15%	9%
MIN	3.1	46.0	3.8	4.4	26.2	0.0	79%	37%	40%
MAX	5.5	277.0	16.0	40.7	37.2	1.0	100%	99%	63%











Reference:
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Barnstable County Department of Health
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Barnstable, MA 02630
(508) 375-6616

Nantucket, MA Projects

Lombardo Associates, Inc. (LAI) designed PhosRID™ system components to be integrated with the property's septic tank and soil absorption system. The design flows is 440 gpd for Sites 1 and 2 and 330 gpd for Site 3.

The PhosRID™ technology has proven extremely effective at removing phosphorus from septic tank effluent. In addition, PhosRID™ also provides nitrogen reduction, BOD reduction and reduction in the total suspended solids.

The Nantucket, MA sites performance summary is presented below:

	Site #1 56 Meadow View Drive					Site #2 11 Columbus Ave					Site #3 76 Millbrook				
Date	Average Monthly Flow (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l)			Average Monthly Flow (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l)			Average Monthly Flow[1] (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l)		
			TP	BOD	TSS			TP	BOD	TSS			TP	BOD	TSS
7/5/2007		1.83	0.12			130.9	1.30	<0.02							
8/9/2007		9.5	0.1			144.9	4.10	0.08							
9/11/2007		9.5	0.11	<4		35.2	5.00	0.04	<4						
12/17/2007		8	0.07	<4	<2	17.7	6.30	<0.02	<4	<2					
3/26/2008						1.6	9.50	0.03	<4	<2	180.6				
5/14/2008						57.9						2.4	0.11	<4	6.0
6/25/2008						96.6	4.10	<0.02	12.0	5.0	103.3	2.8	<0.02	<4	<4
7/31/2008						307.1					105.0	2.7	<0.02	<4	<2
9/30/2008						50.3	8.00	0.03	44.0	17.0					
10/30/2008						5.1					68.2	4.2	<0.02	<4	<2
1/28/2009						0.7	8.70	<0.02	<12	4.0	99.0	5.3	<0.02	<4	<2
4/30/2009											50.3	6.5	0.07		
7/22/2009						11.2	4.95	0.03	16.0	<2					
9/10/2009							5.70	0.18	<4	10.0					
9/24/2009											89.3	3.9	0.01	<4	14
12/23/2009												4.2	<0.01	<4	17
Average		***7.21***	***0.10***	***<4***	***<2***	***81.1***	***5.77***	***0.05***	***10.8***	***5.6***	***111.2***	***4.00***	***0.03***	***<4***	***<3***
Percent P Removal			**98.6%**					**99.1%**					**99.3%**		

Lombardo Associates, Inc. (LAI) has been Engineer of Record for over $200 million of wastewater management projects, including numerous wastewater treatment facilities utilizing a wide variety of on-site and decentralized systems. LAI provides a wide range of services, including engineering feasibility studies, traditional engineering services of planning, design and construction engineering, and the turnkey services of designing, building, owning/financing, and operating wastewater and water facilities. Among our areas of nationally recognized expertise are the planning and implementation of on-site and decentralized wastewater systems and innovative nitrogen and phosphorus removal technologies.

LAI is a recipient of the prestigious American Consulting Engineer's Council Engineering Excellence Award for its innovative wastewater project. Pio Lombardo was an *Engineering News Record* Construction Man of the Year candidate.

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APPENDIX C – MEP Technical Memos

1. Report on Unified Database and Requested MEP Scenarios (November 13, 2009)

2. Report on Unified Database and Requested MEP Scenarios (December 15, 2009)

3. Brian Howes Email Re: CSP/SMAST East Waquoit Bay Memo (December 18, 2009)

4. Report on Unified Database and Requested MEP Scenarios (February 9, 2010)

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MEP Technical Memo

To: Tom Fudala, Chair, Mashpee Sewer Commission

From: Ed Eichner, Brian Howes CSP/SMAST
Sean Kelley, John Ramsey ACRE

Date: November 13, 2009

Re: Report on Unified Database and Requested MEP Scenarios

At the request of Mashpee Sewer Commission, two tasks were undertaken relative to evaluating nitrogen management alternatives for the Town of Mashpee: 1) develop a unified database of the land and water-use information in the Popponesset and East Waquoit Bay watersheds and 2) evaluate five (5) wastewater management scenarios, related to each estuarine system, using the unified database with a revised version of the Massachusetts Estuaries Project (MEP) linked model. Each of these tasks and a summary of their results are described below.

Unified Database Timeline

In order to provide a better context for why these tasks were completed, it is useful to review the timeline of MEP Technical Team involvement in assessments of Popponesset and East Waquoit Bay. In September 2004, the MEP Technical Team released the Popponesset Bay Technical Report[1] and in January 2005, the East Waquoit Bay Technical Report[2] was released. The nitrogen thresholds in these Technical Reports eventually were approved as Total Maximum Daily Load (TMDL) limits by the US Environmental Protection Agency.[3,4]

Both Final MEP Technical Reports were released along with MEP Data Disks containing the watershed nitrogen loading models and the underlying GIS land use, parcel, and build-out information. Collectively, the loading models relied on town-supplied information based on the following:

Mashpee land use 2001, water use 1997 through 1999
Sandwich land use 2000, water use 1998 through 2000
Barnstable land use 2000, water use 1998 through 2000
Falmouth land use 2001, water use 2000
Build-out information reviewed and approved by respective town planners

In 2006, the Popponesset Bay MEP model was used by MEP Technical Team to evaluate five (5) watershed nitrogen management scenarios, which were funded by the MassDEP.[5] Two scenarios with complete removal of wastewater N from selected subwatersheds were completed; both of these scenarios, which were based on existing watershed conditions, met the threshold concentrations/TMDLs. Two additional scenarios, using build-out assumptions, were completed assuming installation of denitrifying septic systems throughout the watershed with N removal rates of 25% and 45%. For these model runs, nitrogen removal rates were set by MassDEP with consideration of the monitoring results from the Cape Cod denitrifying septic system database maintained by the Barnstable County Department of Health and the Environment. Neither of these build-out scenarios met the threshold concentrations/TMDLs. The fifth scenario was an evaluation of potential natural nitrogen reductions if portions of the Santuit River were routed old cranberry bogs south of Santuit Pond. Monitoring associated with this scenario showed that under current conditions ~20% of the nitrogen load entering the bogs is removed. After completing a more detailed characterization of the bogs, their volumes and the flows that exchange nitrogen among the bogs, SMAST scientists estimated that reworking of flowpaths could raise this removal rate by twofold or more.

The current effort described in this Technical Memo began in mid-2007: the Sewer Commission selected five watershed wastewater scenarios to be assessed using both the Popponesset Bay and East Waquoit MEP models (*i.e.*, a total of 10 model runs). In early 2008, the nitrogen loads for these scenarios were publicly presented and, in April 2008, were forwarded to the MEP Technical Team for review prior to modeling.

The nitrogen loads from the five selected scenarios included updated land use and water use databases supplied by Stearns and Wheler (S&W) in consultation with the Sewer Commission. Land use and water use databases were updated for the Town of Mashpee, Town of Falmouth, and Town of Barnstable, but no changes were made to the MEP Town of Sandwich databases. All five scenarios are based on build-out conditions. Four of the scenarios are described in detail in the S&W Alternatives Analysis[6] and the fifth scenario (or third as listed below) was developed by Lombardo Associates, Inc. (LAI).[7]

In brief, these scenarios are characterized by the following:

- Scenario 1 – S&W: No expansion of existing wastewater treatment facilities (WWTFs);
  4 new WWTFs with 3 ppm total nitrogen (TN) effluent and 5 effluent discharge sites;
  ~380 new innovative/alternative (I/A) septic systems with 10 ppm TN effluent
- Scenario 2 – S&W: Upgrade and expansion of existing facilities to a practical extent with effluent discharge of 3 ppm TN;
  4 new WWTFs with 3 ppm TN effluent and 4 effluent discharge sites
- Scenario 3 – LAI: Nitrex™- based decentralized approach with 16 WWTFs with 3.75 ppm TN effluent and 16 discharge sites;
  all new and expanded on-site septic system flow treated with on-site Nitrex™ with 3.75 ppm TN effluent
- Scenario 4 – S&W: Fair Share based on facilitated discussions:
  3 new WWTFs with 3 ppm TN effluent and 3 effluent discharge sites;
  ~130 new innovative/alternative (I/A) septic systems with 10 ppm TN effluent

• Scenario 5 – S&W: Centralized approach:
2 new WWTFs (one in Mashpee, one in Sandwich) with 3 ppm TN effluent and 5 effluent discharge sites;
conversion of existing private WWTFs in Mashpee (except New Seabury) to pumping stations connected to the primary Mashpee WWTF

In July 2008, MEP Technical Team reported to the Sewer Commission, S&W and LAI on the April 2008 scenario data. Technical Team analysis found significant differences between the land use/water use databases and the presented nitrogen loads from both firms. These differences created difficulties, not only in using the MEP models, but also in comparing the results between scenarios from the two firms. In order to resolve these differences, SMAST indicated that a single unified database was required to properly configure the scenarios to support the modeling effort by the MEP Technical Team. Following discussions with all parties, it was agreed that SMAST would create the required unified database.

In November 2008, MEP Technical Team reported to the Sewer Commission that in the course of reconstructing the database, differences in the underlying database were found to be more extensive than just the land-use and build-out classifications and included mis-assignment of parcels to subwatersheds. In February 2009, a supplemental agreement between SMAST and Sewer Commission was approved to correct the databases and create a cleaned up, unified database. Cape Cod Commission agreed to provide GIS services in support of this effort. In July 2009, the updated unified database was transferred to S&W and LAI for review. By late October 2009, the wastewater flows and effluent treatment nitrogen concentrations determined by SMAST for both S&W and LAI scenarios had been approved by their respective firms. The resulting nitrogen loads were used by the MEP Technical Team to complete the scenario runs that are discussed in this memo.

<u>Unified Database Nitrogen Loads</u>

As mentioned, the updated unified database for the Popponesset Bay and East Waquoit Bay watersheds includes updates to the build-out estimates for Mashpee, Falmouth, and Barnstable land uses. The Sandwich estimates are the same as those used in the original MEP analyses of these systems. The included Mashpee parcel analysis update includes comments about development potential of most non-residential properties.

One notable change in the updated unified database that impacts nitrogen loads is an assumption by S&W that all newly developed or residential properties using private wells in either watershed are assumed to have a water use of 140 gallons per day (gpd). This is 9% lower than the 154 gpd used in the MEP analyses. The MEP water use is based on the average water use of all single family residences in Mashpee.

Since the updated unified database changed the number of parcels from the original MEP build-out estimate, revised nitrogen loads from residential lawns, roof areas, and driveway areas, revised counts of residential parcels at build-out were developed using the updated unified database. Road, cranberry bog, and golf course areas were not changed from MEP calculations. All these loads from these sources are consistent across all five Sewer Commission scenarios.

During the development of the updated unified database, SMAST staff identified parcels that are not proposed to be connected to either a WWTF or an I/A septic system in any of the five scenarios. Wastewater from these parcels or others with standard Title 5 septic systems is assigned the standard MEP septic system loading factors.

Table 1 provides a summary of the wastewater flows and effluent TN concentration by treatment technology for each of the scenarios. Table 2 provides the attenuated watershed nitrogen loads by subembayment for each of the scenarios based on the updated unified database.

MEP Scenario Results and Discussion

Scenario Results: Comparison to Threshold Nitrogen Concentrations

Using the nitrogen loads based on the update unified database, Scenarios 3 and 4 meet the threshold values at the sentinel station for restoration of eelgrass in Popponesset Bay. Of these, only Scenario 3 yields water column TN concentrations within each of the three tributary sub-embayments that would be restorative of infaunal habitat (Table 3), although Scenario 4 is very close.

In should also be noted that all of the scenarios yield water column TN concentrations restorative of infaunal habitat in Ockway and Shoestring Bays, but all but Scenario 3 (and possibly 4) leave excess TN levels in the Mashpee River. This finding suggests that the collective wastewater treatment in the Ockway and Shoestring Bay watersheds may exceed what is necessary, but that the collective wastewater treatment in the Mashpee River watershed is insufficient in Scenarios 1, 2, 4 and 5. It should be noted that no other alternative nitrogen reduction approaches other than improved wastewater treatment were considered in these scenarios.

Related to these findings, it is also worth noting that Scenario 5 (Centralized approach) has the lowest nitrogen load to the lower Mashpee River (see Table 2), but the highest load to the freshwater portion of the Mashpee River. This result suggests that selection of effluent discharge locations in more optimal positions in the watershed may allow this and other scenarios to meet the threshold concentrations.

Use of Alternative Septic Systems

Review of Table 1 shows that there are significant differences among the scenarios regarding how alternative on-site septic systems are used. Scenario 3 assumes that 306,825 gallons per day (gpd) of wastewater flow in the combined Popponesset Bay/East Waquoit Bay study area is treated with alternative on-site septic systems. By contrast, Scenario 1 uses alternative on-site septic systems for 41,311 gpd of wastewater flow, Scenario 4 uses these systems for 5,621 gpd, and Scenarios 2 and 5 do not use alternative on-site septic systems.

Effluent Concentration Assumptions in Scenarios

Another issue that the Sewer Commission should consider is the effluent discharge concentrations assigned to the various wastewater treatment technologies in the scenarios. As indicated in Table 1, standard Title 5 septic systems are assigned an effective effluent total nitrogen (TN) concentration of 23.63 mg/L in MEP analyses. This concentration is based on an effluent TN concentration of 26.25 mg/L and, since water use is used as a proxy for wastewater generation, a 0.9 factor to account for consumptive use. This effective concentration has been approved in consultation with MassDEP.

Most Ground Water Discharge Permits (GWDPs) granted by MassDEP for private WWTFs are assigned an effluent TN concentration of 10 mg/L. For larger municipal WWTFs (typically with flows greater than 1 million gallons per day), MassDEP has approved effluent TN concentrations as low as 3 mg/L. Average effluent concentrations for the existing WWTFs in Mashpee range between 2.4 and 9 mg/L; these concentrations are used in the MEP modeling of existing conditions in the Popponesset and East Waquoit Technical Reports.

Twelve alternative on-site septic systems currently have provisional use approval from MassDEP for nitrogen reduction.[8] The provisional use permits limit the installation of these technologies to 50 units with the thought that monitoring results will be used to guide regulatory standards for a general use installation permit. Generally, these use permits have nitrogen effluent limits of 19 mg/l for residential uses and 25 mg/l for commercial uses. In the scenarios discussed in this memo, S&W used 10 mg/l TN for alternative septic systems, while LAI used 3.75 mg/l TN.

Since the assigned wastewater effluent concentrations are the key to determining the wastewater nitrogen loads, care should be taken to ensure that these concentrations are appropriate based on the performance of these technologies and how they are likely to be permitted in regulatory settings. This step will allow the Sewer Commission to have confidence that remediation goals in Popponesset and East Waquoit Bays will be attained.

Endnotes

1. Howes, B., Kelley, S., Ramsey, J., Samimy, R., Eichner, E., Schlezinger, D., and Wood, J. 2004. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts. Commonwealth of Massachusetts, Department of Environmental Protection, Massachusetts Estuaries Project, 138 pp. + Executive Summary, 10 pp. http://www.oceanscience.net/estuaries/Popponesset.htm

2. Howes B., S.W. Kelley, J.S. Ramsey, R. Samimy, D. Schlezinger, T. Ruthven, E. Eichner. 2005. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Quashnet River, Hamblin Pond, and Jehu Pond, in the Waquoit Bay System in the Towns of Mashpee and Falmouth, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. http://www.oceanscience.net/estuaries/Quashnet.htm

3. Approval of Quashnet River, Hamblin Pond, Little River, Jehu Pond, and Great River in the Waquoit Bay System TMDLs for Total Nitrogen. November 7, 2007. Letter from Stephen S. Perkins, Director, Office of Ecosystem Protection, US Environmental Protection Agency, Region 1 to Laurie Burt, Commissioner, Massachusetts Department of Environmental Protection. http://www.epa.gov/NE/eco/tmdl/pdfs/ma/waquoitbay.pdf

4. Approval of Popponesset Bay System Total Maximum Daily Loads For Total Nitrogen. January 22, 2008. Letter from Stephen S. Perkins, Director, Office of Ecosystem Protection, US Environmental Protection Agency, Region 1 to Laurie Burt, Commissioner, Massachusetts Department of Environmental Protection.

5. Popponesset Bay: Results Pilots Modeling Scenarios. March 31, 2006 MEP Technical Memorandum from Brian Howes, Roland Samimy, SMAST, Ed Eichner, Cape Cod Commission and Sean Kelley, Applied Coastal Research & Engineering to Claire Barker, MassDEP and Popponesset Bay Committee Members. http://www.oceanscience.net/estuaries/Centerville.htm

6. Watershed Nitrogen Management Plan, Alternative Scenarios Analysis and Site Evaluation Report, Town of Mashpee, Popponesset Bay & Waquoit Bay East Watersheds. March 2008. Stearns & Wheler, LLC. Hyannis, MA.

7. Nitrex™ Technology Scenario Plan - Draft. 2008. Town of Mashpee, Popponesset Bay, & Waquoit Bay East Watersheds. Lombardo Associates, Inc. Newton, MA. *This scenario was revised in subsequent discussions with LAI to include one additional collection and treatment cluster added to the 15 described in the draft.*

8. Massachusetts Department of Environmental Protection Title 5 Innovative/Alternative Technology Approvals website: http://www.mass.gov/dep/water/wastewater/iatechs.htm

Table 1. Wastewater flows and effluent total nitrogen concentrations for each of the scenarios.
All flows are based on the updated unified land use and water use database prepared by MEP Technical Team. Updated unified database has revised land use, water use, and build-out information for Mashpee, Falmouth, and Barnstable parcels within both the Popponesset Bay and East Waquoit Bay MEP watersheds. Parcels within the Town of Sandwich have the same information as contained in the respective MEP watershed nitrogen loading models. Existing WWTF flows are flows assigned at build-out to WWTF that are already constructed and/or are already permitted.

Scenario	Firm	TOTAL Standard Title 5 Septic System Flow	Septic System Effluent Total Nitrogen Concentration	TOTAL Innovative/ Alternative Septic System Flow	I/A Effluent Total Nitrogen Concentration	TOTAL Existing Wastewater Treatment Facility Flow	WWTF Existing Effluent Total Nitrogen Concentration	TOTAL New Wastewater Treatment Facility Flow	WWTF New Effluent Total Nitrogen Concentration
		gpd	mg/L (ppm)	gpd	mg/L (ppm)	gpd	mg/L (ppm)	gpd	mg/L (ppm)
1	S&W	135,016	23.63	41,311	10	345,928	10	1,403,799	3
2	S&W	355,995	23.63	0	-	774,411	3	913,570	3
3	LAI	236,835	23.63	306,825	3.75	345,928	3.75	1,378,852	3.75
4	S&W	344,874	23.63	5,621	10	512,598	3	836,242	3
5	S&W	453,143	23.63	0	-	1,000	3	1,332,295	3

NOTES:

1. Total wastewater flows for each scenario will not be equal. Within each of the scenarios, varying portions of the flows within the two watersheds are discharged to locations outside of the watersheds (*e.g.*, New Seabury).
2. The total nitrogen concentration assigned to Title 5 on-site septic systems is the standard factor used in MEP nitrogen loading analyses and includes a 10% factor for water consumption.
3. The assumed I/A effluent concentrations are less than MassDEP approved concentrations for residential uses. Currently, MassDEP has approved reduced effluent concentrations for 12 I/A systems, including the Nitrex^{TM} system, under the provisional category. The lowest effluent total nitrogen concentration assigned to any of these systems is 19 mg/l.

Table 2. Scenario Watershed Nitrogen Loads: Popponesset Bay

Attenuated total nitrogen loads by subembayment and surface water input to Popponesset Bay are presented for each Mashpee Sewer Commission scenario. Scenarios 1, 2, 4, and 5 were developed by Stearns and Wheler, while Scenario 3 was developed by Lombardo Associates. All scenarios loads are based on build-out nitrogen loading conditions using the updated SMAST unified database; MEP build-out loads are presented for comparison (a build-out load for the unified database was not a requested scenario). Loads do not include atmospheric deposition onto the sub-embayment surface or benthic flux loading terms. "Threshold" load is from the scenario used in the MEP technical report to meet the N threshold levels in the Bay.

sub-embayment	MEP Build-out load (kg/day)	threshold (kg/day)	threshold % change	Scenario 1: S&W		Scenario 2: S&W		Scenario 4: S&W		Scenario 5: S&W		Scenario 3: LAI	
				BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change
Popponesset Bay	1.98	1.819	-8.1%	1.07	-46.0%	1.61	-18.7%	1.91	-3.5%	1.61	-18.7%	1.01	-49.0%
Popponesset Creek	5.35	0.953	-82.2%	1.56	-70.9%	2.16	-59.7%	2.41	-55.0%	2.16	-59.7%	1.72	-67.9%
Pinquickset Cove	0.98	0.764	-22.4%	0.73	-25.8%	0.73	-25.8%	1.03	4.7%	0.73	-25.8%	0.57	-42.1%
Ockway Bay	3.16	0.757	-76.0%	0.94	-70.2%	1.00	-68.3%	1.00	-68.3%	1.00	-68.3%	0.89	-71.8%
Mashpee River	17.13	2.500	-85.4%	8.54	-50.2%	6.32	-63.1%	4.94	-71.2%	2.95	-82.8%	4.97	-71.0%
Shoestring Bay	9.76	2.260	-76.9%	4.25	-56.5%	4.25	-56.5%	5.98	-38.7%	4.25	-56.5%	3.74	-61.7%
Surface Water Sources													
Mashpee River	30.31	13.668	-54.9%	19.76	-34.8%	19.02	-37.2%	16.92	-44.2%	23.15	-23.6%	13.07	-56.9%
Santuit River	20.55	11.474	-44.2%	8.13	-60.4%	8.38	-59.2%	8.02	-61.0%	7.32	-64.4%	11.65	-43.3%
Quaker Run River	6.62	5.983	-9.6%	2.01	-69.6%	2.01	-69.6%	2.01	-69.6%	2.01	-69.6%	3.30	-50.1%
TOTAL	**95.84**	**40.179**	-58.1%	**46.984**	-51.0%	**45.468**	-52.6%	**44.211**	-53.9%	**45.175**	-52.9%	**40.932**	-57.3%

Table 3. Threshold Comparison Results for Mashpee Sewer Commission Scenarios

Comparison of TN concentrations for present conditions, threshold loading, and five modeled build-out loading scenarios for the Popponesset Bay system. MEP threshold concentrations for Popponesset Bay are 0.380 mg/L TN for eelgrass (primary), and between 0.400 and 0.500 mg/L TN for infauna (secondary). The TMDL for all components of the Popponesset Bay system is 0.38 mg/l total nitrogen.[6]

	threshold	Present	MEP Threshold	Scenario 1 S&W	Scenario 2 S&W	Scenario 4 S&W	Scenario 5 S&W	Scenario 3 LAI
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Popponesset Bay - head	eelgrass	0.464	0.38	0.394	0.386	0.378	0.389	0.372
Mashpee River – mid to lower	infauna	0.712	0.4 - 0.5	0.601	0.570	0.529	0.596	0.472
Shoestring Bay - upper to lower	infauna	0.631	0.4 – 0.5	0.472	0.462	0.449	0.461	0.461
Ockway Bay – upper	infauna	0.567	0.4 – 0.5	0.457	0.449	0.438	0.453	0.421

Note: shaded cells indicate Scenarios that meet MEP thresholds for eelgrass/TMDL or infauna

Appendix A

Nitrogen Loading Tables relative to Mashpee Sewer Commission Scenarios 1, 2, 3, 4, and 5

Table A-1. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Present loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.819	4.005	-5.039
Popponesset Creek	4.940	-	-0.639
Pinquickset Cove	0.764	0.290	-0.326
Ockway Bay - lower	-	-	-1.596
Ockway Bay - upper	3.151	1.093	3.372
Mashpee River	12.107	0.663	15.339
Shoestring Bay	9.208	2.233	-11.854
Surface Water Sources			
Mashpee River	21.888	-	-
Santuit River (Shoestring Bay)	15.584	-	-
Quaker Run River (Shoestring Bay)	5.984	-	-
TOTAL	75.444	8.285	-0.743

Table A-2. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **threshold loading conditions** for the listed sub-embayments. These loads represent the sub-watershed loading conditions for the scenario used in the MEP technical report to meet N threshold level.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.819	4.005	-4.915
Popponesset Creek	0.953	-	-0.624
Pinquickset Cove	0.764	0.290	-0.318
Ockway Bay - lower	-	-	-1.132
Ockway Bay - upper	0.757	1.093	2.249
Mashpee River	2.500	0.663	9.430
Shoestring Bay	2.260	2.233	-8.735
Surface Water Sources			
Mashpee River	13.668	-	-
Santuit River (Shoestring Bay)	11.474	-	-
Quaker Run River (Shoestring Bay)	5.983	-	-
TOTAL	**40.179**	**8.285**	**-4.044**

Table A-3. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-1 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.068	4.005	-4.952
Popponesset Creek	1.559	-	-0.628
Pinquickset Cove	0.726	0.290	-0.320
Ockway Bay - lower	-	-	-1.171
Ockway Bay - upper	0.942	1.093	2.340
Mashpee River	8.540	0.663	13.047
Shoestring Bay	4.252	2.233	-7.383
Surface Water Sources			
Mashpee River	19.756	-	-
Santuit River (Shoestring Bay)	8.134	-	-
Quaker Run River (Shoestring Bay)	2.005	-	-
TOTAL	46.984	8.285	0.933

Table A-4. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-2 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.611	4.005	-4.940
Popponesset Creek	2.162	-	-0.627
Pinquickset Cove	0.726	0.290	-0.319
Ockway Bay - lower	-	-	-1.185
Ockway Bay - upper	0.997	1.093	2.362
Mashpee River	6.318	0.663	12.170
Shoestring Bay	4.252	2.233	-7.444
Surface Water Sources			
Mashpee River	19.022	-	-
Santuit River (Shoestring Bay)	8.375	-	-
Quaker Run River (Shoestring Bay)	2.005	-	-
TOTAL	45.468	8.285	0.017

Table A-5. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-3 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.910	4.005	-4.940
Popponesset Creek	2.405	-	-0.627
Pinquickset Cove	1.030	0.290	-0.319
Ockway Bay - lower	-	-	-1.185
Ockway Bay - upper	0.997	1.093	2.362
Mashpee River	4.937	0.663	11.148
Shoestring Bay	5.981	2.233	-7.767
Surface Water Sources			
Mashpee River	16.923	-	-
Santuit River (Shoestring Bay)	8.022	-	-
Quaker Run River (Shoestring Bay)	2.005	-	-
TOTAL	44.211	8.285	-1.328

Table A-6. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-4 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.611	4.005	-4.940
Popponesset Creek	2.162	-	-0.627
Pinquickset Cove	0.726	0.290	-0.319
Ockway Bay - lower	-	-	-1.185
Ockway Bay - upper	0.997	1.093	2.362
Mashpee River	2.948	0.663	12.376
Shoestring Bay	4.252	2.233	-7.199
Surface Water Sources			
Mashpee River	23.153	-	-
Santuit River (Shoestring Bay)	7.321	-	-
Quaker Run River (Shoestring Bay)	2.005	-	-
TOTAL	45.175	8.285	0.469

Table A-7. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario LAI-3 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.005	4.005	-2.885
Popponesset Creek	1.721	-	-0.366
Pinquickset Cove	0.573	0.290	-0.187
Ockway Bay - lower	-	-	-0.822
Ockway Bay - upper	0.893	1.093	1.766
Mashpee River	4.970	0.663	8.433
Shoestring Bay	3.737	2.233	-7.537
Surface Water Sources			
Mashpee River	13.074	-	-
Santuit River (Shoestring Bay)	11.655	-	-
Quaker Run River (Shoestring Bay)	3.304	-	-
TOTAL	40.932	8.285	-1.597

Coastal Systems Program
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MEP Technical Memo

To: Tom Fudala, Chair, Mashpee Sewer Commission

From: Ed Eichner, CSP/SMAST
Brian Howes, CSP/SMAST
Sean Kelley, ACRE
John Ramsey, ACRE

Date: December 15, 2009

Re: Report on Unified Database and Requested MEP Scenarios for the:
(a) Popponesset Bay Estuary and (b) Eastern Basins of the Waquoit Bay System

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At the request of Mashpee Sewer Commission, two tasks were undertaken relative to evaluating nitrogen management alternatives for the Town of Mashpee:

1) Develop a unified database of the land and water-use information in the Popponesset and East Waquoit Bay watersheds, including the towns of Mashpee, Falmouth, Sandwich, and Barnstable, and

2) Evaluate five (5) wastewater management scenarios using the unified database and revised versions of the Massachusetts Estuaries Project (MEP) linked models for Mashpee's estuarine systems: Popponesset Bay and the 3 tributary basins to eastern Waquoit Bay.

Each of these tasks and a summary of their results are described below.

Unified Database Timeline

As a context to the present effort, it is useful to review the timeline of MEP Technical Team involvement in assessments of Popponesset and Eastern Waquoit Bay. In September 2004, the MEP Technical Team released the Popponesset Bay Technical Report[1] and in January 2005, the Eastern Waquoit Bay Technical Report[2] was released. The nitrogen thresholds in these Technical Reports eventually were approved as Total Maximum Daily Load (TMDL) limits by the US Environmental Protection Agency.[3,4]

Both Final MEP Technical Reports were released along with MEP Data Disks containing the watershed nitrogen loading models and the underlying GIS land use, parcel, and build-out information. Collectively, the loading models relied on town-supplied information based on the following:

Mashpee land use 2001, water use 1997 through 1999
Sandwich land use 2000, water use 1998 through 2000
Barnstable land use 2000, water use 1998 through 2000
Falmouth land use 2001, water use 2000
Build-out information reviewed and approved by respective town planners

In 2006, the Popponesset Bay MEP model was used by MEP Technical Team to evaluate five (5) watershed nitrogen management scenarios, which were funded by the MassDEP.[5] Two scenarios with complete removal of wastewater nitrogen from selected subwatersheds were completed; both of these scenarios, which were based on existing watershed conditions, met the threshold concentrations/TMDLs.

Two additional scenarios, using build-out assumptions, were completed assuming installation of denitrifying septic systems throughout the watershed with nitrogen removal rates of 25% (~19.7 ppm nitrogen) and 45% (~14.4 ppm). For these model runs, nitrogen removal rates were set by MassDEP with consideration of the monitoring results from the Cape Cod denitrifying septic system database maintained by the Barnstable County Department of Health and the Environment. Neither of these build-out scenarios met the threshold concentrations/TMDLs.

The fifth scenario was an evaluation of potential natural nitrogen reductions if portions of the Santuit River were routed old cranberry bogs south of Santuit Pond. Monitoring associated with this scenario showed that under current conditions ~20% of the nitrogen load entering the bogs is removed. After completing a more detailed characterization of the bogs, their volumes and the flows that exchange nitrogen among the bogs, SMAST scientists estimated that reworking of flowpaths could raise this removal rate to 40-50% or more.

The current effort described in this Technical Memo began in mid-2007: the Sewer Commission selected five watershed wastewater scenarios to be assessed using both the Popponesset Bay and East Waquoit MEP models (*i.e.*, a total of at least 10 model runs). In early 2008, the nitrogen loads for these scenarios were publicly presented by the wastewater consulting firms and, in April 2008, were forwarded to the MEP Technical Team for review prior to modeling.

The nitrogen loads from the five selected scenarios included updated land use and water use databases supplied by Stearns and Wheler (S&W) in consultation with the Sewer Commission. Land use and water use databases were updated for the Town of Mashpee, Town of Falmouth, and Town of Barnstable, but no changes were made to the MEP Town of Sandwich databases. All five scenarios are based on build-out conditions. Four of the scenarios are described in detail in the S&W Alternatives Analysis[6] and the fifth scenario (or third as listed below) was developed by Lombardo Associates, Inc. (LAI).[7]

In brief, these scenarios are characterized by the following:
• Scenario 1 – S&W: No expansion of existing wastewater treatment facilities (WWTFs);
4 new WWTFs with 3 ppm total nitrogen (TN) effluent and 5 effluent discharge sites;
~380 new innovative/alternative (I/A) septic systems with 10 ppm TN effluent

- Scenario 2 – S&W: Upgrade and expansion of existing facilities to a practical extent with effluent discharge of 3 ppm TN;
  4 new WWTFs with 3 ppm TN effluent and 4 effluent discharge sites
- Scenario 3 – LAI: Nitrex™- based approach with 16 WWTFs with 3.75 ppm TN effluent and 16 discharge sites;
  all new and expanded on-site septic system flow treated with on-site Nitrex™ with 3.75 ppm TN effluent
- Scenario 4 – S&W: 3 new WWTFs with 3 ppm TN effluent and 3 effluent discharge sites;
  ~130 new innovative/alternative (I/A) septic systems with 10 ppm TN effluent
- Scenario 5 – S&W: Centralized approach:
  2 new WWTFs (one in Mashpee, one in Sandwich) with 3 ppm TN effluent and 5 effluent discharge sites;
  conversion of existing private WWTFs in Mashpee (except New Seabury) to pumping stations connected to the primary Mashpee WWTF

In July 2008, MEP Technical Team reported to the Sewer Commission, S&W and LAI on the April 2008 scenario data. Technical Team analysis found significant differences between the land use/water use databases and the nitrogen loads presented by both firms. These differences created difficulties, not only in using the MEP models, but also in comparing the results between scenarios from the two firms. In order to resolve these differences, SMAST indicated that a single unified database was required to properly configure the scenarios to support the modeling effort by the MEP Technical Team. Following discussions with all parties, it was agreed that SMAST would create the required unified database.

In November 2008, MEP Technical Team reported to the Sewer Commission that in the course of reconstructing the database, differences in the underlying database were found to be more extensive than just the land-use and build-out classifications and included mis-assignment of parcels to subwatersheds. In February 2009, a supplemental agreement between SMAST and Sewer Commission was approved to correct the databases and create a cleaned up, unified database. Cape Cod Commission agreed to provide GIS services in support of this effort. In July 2009, the updated unified database was transferred to S&W and LAI for review. By late October 2009, the wastewater flows and effluent treatment nitrogen concentrations determined by SMAST for both S&W and LAI scenarios had been approved by their respective firms. The resulting nitrogen loads were used by the MEP Technical Team to complete the scenario runs that are discussed in this memo.

Unified Database Nitrogen Loads

As mentioned, the updated unified database for the Popponesset Bay and Eastern Waquoit Bay watersheds includes updates to the build-out estimates for Mashpee, Falmouth, and Barnstable land uses. The Sandwich estimates are the same as those used in the original MEP analyses of these systems. The included Mashpee parcel analysis update includes comments about development potential of most non-residential properties.

One notable change in the updated unified database that impacts nitrogen loads is an assumption by S&W that all newly developed or residential properties using private wells in either watershed are assumed to have a water use of 140 gallons per day (gpd). This is 9% lower than the 154 gpd used in the MEP analyses and may lead to an overestimate of consumptive use since the MEP model includes a 10% reduction to adjust water use to wastewater flows. The MEP water use flow is based on the average water use of all single family residences in Mashpee.

Since the updated unified database changed the number of parcels from the original MEP build-out estimate, revised nitrogen loads from residential lawns, roof areas, and driveway areas, revised counts of residential parcels at build-out were developed using the updated unified database. Road, cranberry bog, and golf course areas were not changed from MEP calculations. All these loads from these sources are consistent across all five Sewer Commission wastewater scenarios.

During the development of the updated unified database, SMAST staff identified parcels that are not proposed to be connected to either a WWTF or an I/A septic system in any of the five scenarios. Wastewater from these parcels or others with standard Title 5 septic systems is assigned the standard MEP septic system loading factors.

Table 1 provides a summary of the wastewater flows and effluent TN concentration by treatment technology for each of the five scenarios. Table 2 provides the attenuated watershed nitrogen loads for each of the scenarios based on the updated unified database for each Popponesset Bay subembayment, while Tables 3 and 4 provide the same information for each East Waquoit Bay subembayment (Jehu/Hamblin Ponds and Quashnet River, respectively).

MEP Scenario Results and Discussion

Popponesset Bay Scenario Results: Comparison to Threshold Nitrogen Concentrations

Using the nitrogen loads based on the update unified database, Scenarios 3 and 4 meet the threshold values at the sentinel station for restoration of eelgrass in Popponesset Bay. Of these, only Scenario 3 yields water column TN concentrations within each of the three tributary sub-embayments that would be restorative of infaunal habitat (Table 5), although Scenario 4 is very close.

It should also be noted that all of the scenarios yield water column TN concentrations restorative of infaunal habitat in Ockway and Shoestring Bays, but all but Scenario 3 (and possibly 4) leave excess TN levels in the Mashpee River. This finding suggests that the collective wastewater treatment in the Ockway and Shoestring Bay watersheds may exceed what is necessary, but that the collective wastewater treatment in the Mashpee River watershed is insufficient in Scenarios 1, 2, 4 and 5. It should be noted that no other alternative nitrogen reduction strategies other than improved wastewater treatment were considered in these scenarios.

Related to these findings, it is also worth noting that Scenario 5 (Centralized approach) has the lowest nitrogen load to the lower Mashpee River (see Table 2), but the highest load to the freshwater portion of the Mashpee River. This result suggests that selection of effluent discharge locations in more optimal positions in the watershed may allow this and other scenarios to meet the threshold concentrations.

Eastern Waquoit Bay Scenario Results: Comparison to Threshold Nitrogen Concentrations
Using the nitrogen loads based on the updated unified land-use database and the MEP hydrodynamic and water quality models, Scenarios 1, 2, 4 and 5 meet the threshold values at the sentinel station for restoration of eelgrass in Hamblin and Jehu Ponds (Table 6). Scenario 3 did not meet the threshold for either Hamblin or Jehu Pond. In addition, none of the scenarios (1-5) had sufficient nitrogen source reduction to meet the Quashnet River water column TN concentration threshold necessary to restore infaunal habitat, although Scenario 4 may be sufficiently close for planning purposes (0.523 mg L^{-1} versus 0.520 mg L^{-1}). Consultation with MassDEP is recommended on interpretation and compliance with TMDLs and nitrogen threshold issues; this normally occurs during the CWMP process.

It should also be noted that Scenarios 1, 2, 4 and 5 yield water column TN concentrations that are significantly less than the threshold concentrations in Hamblin and Jehu Ponds. This finding suggests that the collective wastewater treatment in the Hamblin Pond and Jehu Pond watersheds may exceed what is necessary for estuarine restoration. It is also important to note that no other alternative nitrogen reduction strategies other than improved wastewater treatment were considered in these scenarios.

Scenario Terms and Assumptions to Consider:

Use of Alternative Septic Systems
Review of Table 1 shows that there are significant differences among the scenarios regarding how alternative on-site septic systems are used. Scenario 3 assumes that 306,825 gallons per day (gpd) of wastewater flow in the combined Popponesset Bay/East Waquoit Bay study area is treated with alternative on-site septic systems. By contrast, Scenario 1 uses alternative on-site septic systems for 41,311 gpd of wastewater flow, Scenario 4 uses these systems for 5,621 gpd, and Scenarios 2 and 5 do not use alternative on-site septic systems.

Effluent Concentration Assumptions in Scenarios
Another issue that the Sewer Commission should consider is the effluent discharge concentrations assigned to the various wastewater treatment technologies in the scenarios. As indicated in Table 1, standard Title 5 septic systems are assigned an effective effluent total nitrogen (TN) concentration of 23.63 mg/L in MEP analyses. This concentration is based on an effluent TN concentration of 26.25 mg/L and, since water use is used as a proxy for wastewater generation, a 0.9 factor to account for consumptive use. This effective concentration has been approved in consultation with MassDEP.

Most Ground Water Discharge Permits (GWDPs) granted by MassDEP for private WWTFs are assigned an effluent TN concentration of 10 mg/L. For larger municipal WWTFs (typically with flows greater than 1 million gallons per day), MassDEP has approved effluent TN concentrations as low as 3 mg/L. Average effluent concentrations for the existing WWTFs in Mashpee range between 2.4 and 9 mg/L; these concentrations are used in the MEP modeling of existing conditions in the Popponesset and East Waquoit Technical Reports.

Twelve alternative on-site septic systems currently have provisional use approval from MassDEP for nitrogen reduction.[8] The provisional use permits limit the installation of these technologies to 50 units with the thought that monitoring results will be used to guide regulatory standards for a general use installation permit. Generally, these use permits have nitrogen effluent limits of 19 mg/l for residential uses and 25 mg/l for commercial uses. In the scenarios discussed in this memo, S&W used 10 mg/l TN for alternative septic systems, while LAI used 3.75 mg/l TN. Assigning a MassDEP-approved effluent concentration for alternative septic systems for use in all scenarios would have altered some the results.

Since the assigned wastewater effluent concentrations are the key to determining the wastewater nitrogen loads, care should be taken to ensure that these concentrations are appropriate based on the performance of these technologies and how they are likely to be permitted in regulatory settings. This step will allow the Sewer Commission to have confidence going forward that remediation goals in Popponesset and Eastern Waquoit Bays will be attained.

Endnotes

1. Howes, B., Kelley, S., Ramsey, J., Samimy, R., Eichner, E., Schlezinger, D., and Wood, J. 2004. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts. Commonwealth of Massachusetts, Department of Environmental Protection, Massachusetts Estuaries Project, 138 pp. + Executive Summary, 10 pp. http://www.oceanscience.net/estuaries/Popponesset.htm

2. Howes B., S.W. Kelley, J.S. Ramsey, R. Samimy, D. Schlezinger, T. Ruthven, E. Eichner. 2005. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Quashnet River, Hamblin Pond, and Jehu Pond, in the Waquoit Bay System in the Towns of Mashpee and Falmouth, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. http://www.oceanscience.net/estuaries/Quashnet.htm

3. Approval of Quashnet River, Hamblin Pond, Little River, Jehu Pond, and Great River in the Waquoit Bay System TMDLs for Total Nitrogen. November 7, 2007. Letter from Stephen S. Perkins, Director, Office of Ecosystem Protection, US Environmental Protection Agency, Region 1 to Laurie Burt, Commissioner, Massachusetts Department of Environmental Protection. http://www.epa.gov/NE/eco/tmdl/pdfs/ma/waquoitbay.pdf

4. Approval of Popponesset Bay System Total Maximum Daily Loads For Total Nitrogen. January 22, 2008. Letter from Stephen S. Perkins, Director, Office of Ecosystem Protection, US Environmental Protection Agency, Region 1 to Laurie Burt, Commissioner, Massachusetts Department of Environmental Protection.

5. Popponesset Bay: Results Pilots Modeling Scenarios. March 31, 2006 MEP Technical Memorandum from Brian Howes, Roland Samimy, SMAST, Ed Eichner, Cape Cod Commission and Sean Kelley, Applied Coastal Research & Engineering to Claire Barker, MassDEP and Popponesset Bay Committee Members.

6. Watershed Nitrogen Management Plan, Alternative Scenarios Analysis and Site Evaluation Report, Town of Mashpee, Popponesset Bay & Waquoit Bay East Watersheds. March 2008. Stearns & Wheler, LLC. Hyannis, MA.

7. Nitrex™ Technology Scenario Plan - Draft. 2008. Town of Mashpee, Popponesset Bay, & Waquoit Bay East Watersheds. Lombardo Associates, Inc. Newton, MA. *This scenario was revised in subsequent discussions with LAI to include one additional collection and treatment cluster added to the 15 described in the draft*.

8. Massachusetts Department of Environmental Protection Title 5 Innovative/Alternative Technology Approvals website: http://www.mass.gov/dep/water/wastewater/iatechs.htm

Table 1. Wastewater flows and effluent total nitrogen concentrations for each of the scenarios.
All flows are based on the updated unified land use and water use database prepared by MEP Technical Team. Updated unified database has revised land use, water use, and build-out information for Mashpee, Falmouth, and Barnstable parcels within both the Popponesset Bay and East Waquoit Bay MEP watersheds. Parcels within the Town of Sandwich have the same information as contained in the respective MEP watershed nitrogen loading models. Existing WWTF flows are flows assigned at build-out to WWTF that are already constructed and/or are already permitted.

Scenario	Firm	TOTAL Standard Title 5 Septic System Flow	Septic System Effluent Total Nitrogen Concentration	TOTAL Innovative/ Alternative Septic System Flow	I/A Effluent Total Nitrogen Concentration	TOTAL Existing Wastewater Treatment Facility Flow	WWTF Existing Effluent Total Nitrogen Concentration	TOTAL New Wastewater Treatment Facility Flow	WWTF New Effluent Total Nitrogen Concentration
		gpd	mg/L (ppm)	gpd	mg/L (ppm)	gpd	mg/L (ppm)	gpd	mg/L (ppm)
1	S&W	135,016	23.63	41,311	10	345,928	10	1,403,799	3
2	S&W	355,995	23.63	0	-	774,411	3	913,570	3
3	LAI	236,835	23.63	306,825	3.75	345,928	3.75	1,378,852	3.75
4	S&W	344,874	23.63	5,621	10	512,598	3	836,242	3
5	S&W	453,143	23.63	0	-	1,000	3	1,332,295	3

NOTES:
1. Total wastewater flows for each scenario will not be equal. Within each of the scenarios, varying portions of the flows within the two watersheds are discharged to locations outside of the watersheds (*e.g.*, New Seabury).
2. The total nitrogen concentration assigned to Title 5 on-site septic systems is the standard factor used in MEP nitrogen loading analyses and includes a 10% factor for water consumption.
3. The assumed I/A effluent concentrations are less than MassDEP approved concentrations for residential uses. Currently, MassDEP has approved reduced effluent concentrations for 12 I/A systems, including the Nitrex^{TM} system, under the provisional category. The lowest effluent total nitrogen concentration assigned to any of these systems is 19 mg/l.

Table 2. Scenario Watershed Nitrogen Loads: Popponesset Bay

Attenuated total nitrogen loads by subembayment and surface water input to Popponesset Bay are presented for each Mashpee Sewer Commission scenario. Scenarios 1, 2, 4, and 5 were developed by Stearns and Wheler, while Scenario 3 was developed by Lombardo Associates. All scenarios loads are based on build-out nitrogen loading conditions using the updated SMAST unified database; MEP build-out loads are presented for comparison (a build-out load for the unified database was not a requested scenario). Loads do not include atmospheric deposition onto the sub-embayment surface or benthic flux loading terms. "Threshold" load is from the scenario used in the MEP technical report to meet the N threshold levels in the Bay.

sub-embayment	MEP Build-out load (kg/day)	threshold (kg/day)	threshold % change	Scenario 1: S&W		Scenario 2: S&W		Scenario 4: S&W		Scenario 5: S&W		Scenario 3: LAI	
				BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change
Popponesset Bay	1.98	1.819	-8.1%	1.07	-46.0%	1.61	-18.7%	1.91	-3.5%	1.61	-18.7%	1.01	-49.0%
Popponesset Creek	5.35	0.953	-82.2%	1.56	-70.9%	2.16	-59.7%	2.41	-55.0%	2.16	-59.7%	1.72	-67.9%
Pinquickset Cove	0.98	0.764	-22.4%	0.73	-25.8%	0.73	-25.8%	1.03	4.7%	0.73	-25.8%	0.57	-42.1%
Ockway Bay	3.16	0.757	-76.0%	0.94	-70.2%	1.00	-68.3%	1.00	-68.3%	1.00	-68.3%	0.89	-71.8%
Mashpee River	17.13	2.500	-85.4%	8.54	-50.2%	6.32	-63.1%	4.94	-71.2%	2.95	-82.8%	4.97	-71.0%
Shoestring Bay	9.76	2.260	-76.9%	4.25	-56.5%	4.25	-56.5%	5.98	-38.7%	4.25	-56.5%	3.74	-61.7%
Surface Water Sources													
Mashpee River	30.31	13.668	-54.9%	19.76	-34.8%	19.02	-37.2%	16.92	-44.2%	23.15	-23.6%	13.07	-56.9%
Santuit River	20.55	11.474	-44.2%	8.13	-60.4%	8.38	-59.2%	8.02	-61.0%	7.32	-64.4%	11.65	-43.3%
Quaker Run River	6.62	5.983	-9.6%	2.01	-69.6%	2.01	-69.6%	2.01	-69.6%	2.01	-69.6%	3.30	-50.1%
TOTAL	**95.84**	**40.179**	-58.1%	**46.984**	-51.0%	**45.468**	-52.6%	**44.211**	-53.9%	**45.175**	-52.9%	**40.932**	-57.3%

Table 3. Scenario Watershed Nitrogen Loads: East Waquoit Bay (Jehu and Hamblin Ponds)
Attenuated total nitrogen loads by subembayment and surface water input to the Jehu and Hamblin Ponds portions of East Waquoit Bay are presented for each Mashpee Sewer Commission scenario. Scenarios 1, 2, 4, and 5 were developed by Stearns and Wheler, while Scenario 3 was developed by Lombardo Associates. All scenarios loads are based on build-out nitrogen loading conditions using the updated SMAST unified database; MEP build-out loads are presented for comparison (a build-out load for the unified database was not a requested scenario). Loads do not include atmospheric deposition onto the sub-embayment surface or benthic flux loading terms. "Threshold" load is from the scenario used in the MEP technical report to meet the N threshold levels in the Bay, which is based on a 0.35 mg/L boundary condition in Waquoit Bay.

sub-embayment	MEP Build-out load (kg/day)	threshold (kg/day)	threshold % change	Scenario 1: S&W		Scenario 2: S&W		Scenario 4: S&W		Scenario 5: S&W		Scenario 3: LAI	
				BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change
Hamblin Pond	4.84	1.347	-72.2%	0.899	-81.4%	1.249	-74.2%	0.899	-81.4%	0.641	-86.8%	0.641	-86.8%
Upper Hamblin Pond	2.10	0.609	-71.0%	0.361	-82.8%	0.367	-82.5%	0.367	-82.5%	0.367	-82.5%	0.361	-82.8%
Little River	1.27	0.429	-66.1%	0.605	-52.2%	0.895	-29.3%	0.605	-52.2%	0.394	-68.9%	0.388	-69.3%
Lower Great River	3.37	0.600	-82.2%	0.688	-79.6%	0.688	-79.6%	0.688	-79.6%	0.688	-79.6%	0.688	-79.6%
Upper Great River	1.58	0.320	-79.8%	0.359	-77.3%	0.359	-77.3%	0.359	-77.3%	0.359	-77.3%	0.359	-77.3%
Jehu Pond	4.01	0.960	-76.0%	1.153	-71.2%	1.293	-67.7%	1.293	-67.7%	1.293	-67.7%	1.058	-73.6%
Surface Water Sources													
Red Brook	7.29	1.451	-62.6%	0.775	-80.0%	0.775	-80.0%	0.885	-77.2%	0.775	-80.0%	2.688	-30.8%
TOTAL	24.45	**5.717**	-67.5%	**4.840**	-72.5%	**5.627**	-68.0%	**5.095**	-71.1%	**4.517**	-74.3%	**6.183**	**-**64.9%

Table 4. Scenario Watershed Nitrogen Loads: Eastern Waquoit Bay (Quashnet River)

Attenuated total nitrogen loads by subembayment and surface water input to the Quashnet River portion of East Waquoit Bay are presented for each Mashpee Sewer Commission scenario. Scenarios 1, 2, 4, and 5 were developed by Stearns and Wheler, while Scenario 3 was developed by Lombardo Associates. All scenarios loads are based on build-out nitrogen loading conditions using the updated SMAST unified database; MEP build-out loads are presented for comparison (a build-out load for the unified database was not a requested scenario). Loads do not include atmospheric deposition onto the sub-embayment surface or benthic flux loading terms. "Threshold" load is from the scenario used in the MEP technical report to meet the N threshold levels in the Bay, which is based on a 0.35 mg/L boundary condition in Waquoit Bay.

sub-embayment	MEP Build-out load (kg/day)	threshold (kg/day)	threshold % change	Scenario 1: S&W		Scenario 2: S&W		Scenario 4: S&W		Scenario 5: S&W		Scenario 3: LAI	
				BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change	BO Load (kg/day)	% change
Lower Quashnet	0.89	0.480	-46.0%	0.123	-86.2%	0.123	-86.2%	0.123	-86.2%	0.123	-86.2%	0.123	-86.2%
Upper Quashnet	3.02	1.073	-64.5%	0.529	-82.5%	0.529	-82.5%	0.529	-82.5%	0.529	-82.5%	0.545	-82.0%
Surface Water Sources													
Moonakiss River	46.82	10.406	-77.8%	16.186	-65.4%	16.699	-64.3%	15.896	-66.0%	17.225	-63.2%	18.093	-61.4%
TOTAL	50.73	**11.960**	-76.4%	**16.838**	-66.8%	**17.351**	-65.8%	**16.548**	-67.4%	**17.877**	-64.8%	**18.762**	-63.0%

Table 5. Threshold Comparison Results for Mashpee Sewer Commission Scenarios: Popponesset Bay

Comparison of TN concentrations for present conditions, threshold loading, and five modeled build-out loading scenarios for the Popponesset Bay system. MEP threshold concentrations for Popponesset Bay are 0.380 mg/L TN for eelgrass (primary), and between 0.400 and 0.500 mg/L TN for infauna (secondary). The TMDL for all components of the Popponesset Bay system is 0.38 mg/l total nitrogen.[4]

	Habitat threshold	Present	MEP Threshold	Scenario 1 S&W	Scenario 2 S&W	Scenario 4 S&W	Scenario 5 S&W	Scenario 3 LAI
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Popponesset Bay - head	eelgrass	0.464	0.38	0.394	0.386	0.378	0.389	0.372
Mashpee River – mid to lower	infauna	0.712	0.4 - 0.5	0.601	0.570	0.529	0.596	0.472
Shoestring Bay - upper to lower	infauna	0.631	0.4 – 0.5	0.472	0.462	0.449	0.461	0.461
Ockway Bay – upper	infauna	0.567	0.4 – 0.5	0.457	0.449	0.438	0.453	0.421

Note: shaded cells indicate Scenarios that meet MEP thresholds for eelgrass/TMDL or infauna.

Table 6. Threshold Comparison Results for Mashpee Sewer Commission Scenarios: East Waquoit Bay

Comparison of TN concentrations for present conditions, threshold loading, and five modeled build-out loading scenarios for the East Waquoit Bay system. Threshold concentrations are 0.446 mg/L TN for Jehu Pond (eelgrass), 0.380 mg/L TN for Hamblin Pond (eelgrass), and less than 0.520 mg/L TN for average of the upper- and mid-river monitoring stations of the Quashnet River (infauna).[2]

	Habitat Threshold	Present	MEP Threshold	Scenario 1 S&W	Scenario 2 S&W	Scenario 4 S&W	Scenario 5 S&W	Scenario 3 LAI
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Jehu Pond	eelgrass	0.603	0.446	0.429	0.435	0.437	0.434	0.472
Hamblin Pond	eelgrass	0.528	0.380	0.252	0.253	0.260	0.252	0.400
Quashnet River	infauna	0.781	0.520	0.536	0.547	0.523	0.559	0.584

Note: shaded cells indicate Scenarios that meet threshold concentrations to support eelgrass or infaunal habitat (TMDL).

Appendix A

Popponesset Bay
Nitrogen Loading Tables relative to
Mashpee Sewer Commission Scenarios
1, 2, 3, 4, and 5

Table A-1. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Present loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.819	4.005	-5.039
Popponesset Creek	4.940	-	-0.639
Pinquickset Cove	0.764	0.290	-0.326
Ockway Bay - lower	-	-	-1.596
Ockway Bay - upper	3.151	1.093	3.372
Mashpee River	12.107	0.663	15.339
Shoestring Bay	9.208	2.233	-11.854
Surface Water Sources			
Mashpee River	21.888	-	-
Santuit River (Shoestring Bay)	15.584	-	-
Quaker Run River (Shoestring Bay)	5.984	-	-
TOTAL	75.444	8.285	-0.743

Table A-2. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **threshold loading conditions** for the listed sub-embayments. These loads represent the sub-watershed loading conditions for the scenario used in the MEP technical report to meet N threshold level.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.819	4.005	-4.915
Popponesset Creek	0.953	-	-0.624
Pinquickset Cove	0.764	0.290	-0.318
Ockway Bay - lower	-	-	-1.132
Ockway Bay - upper	0.757	1.093	2.249
Mashpee River	2.500	0.663	9.430
Shoestring Bay	2.260	2.233	-8.735
Surface Water Sources			
Mashpee River	13.668	-	-
Santuit River (Shoestring Bay)	11.474	-	-
Quaker Run River (Shoestring Bay)	5.983	-	-
TOTAL	**40.179**	**8.285**	**-4.044**

Table A-3. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-1 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.068	4.005	-4.952
Popponesset Creek	1.559	-	-0.628
Pinquickset Cove	0.726	0.290	-0.320
Ockway Bay - lower	-	-	-1.171
Ockway Bay - upper	0.942	1.093	2.340
Mashpee River	8.540	0.663	13.047
Shoestring Bay	4.252	2.233	-7.383
Surface Water Sources			
Mashpee River	19.756	-	-
Santuit River (Shoestring Bay)	8.134	-	-
Quaker Run River (Shoestring Bay)	2.005	-	-
TOTAL	46.984	8.285	0.933

Table A-4. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-2 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.611	4.005	-4.940
Popponesset Creek	2.162	-	-0.627
Pinquickset Cove	0.726	0.290	-0.319
Ockway Bay - lower	-	-	-1.185
Ockway Bay - upper	0.997	1.093	2.362
Mashpee River	6.318	0.663	12.170
Shoestring Bay	4.252	2.233	-7.444
Surface Water Sources			
Mashpee River	19.022	-	-
Santuit River (Shoestring Bay)	8.375	-	-
Quaker Run River (Shoestring Bay)	2.005	-	-
TOTAL	45.468	8.285	0.017

Table A-5. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-4 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.910	4.005	-4.940
Popponesset Creek	2.405	-	-0.627
Pinquickset Cove	1.030	0.290	-0.319
Ockway Bay - lower	-	-	-1.185
Ockway Bay - upper	0.997	1.093	2.362
Mashpee River	4.937	0.663	11.148
Shoestring Bay	5.981	2.233	-7.767
Surface Water Sources			
Mashpee River	16.923	-	-
Santuit River (Shoestring Bay)	8.022	-	-
Quaker Run River (Shoestring Bay)	2.005	-	-
TOTAL	44.211	8.285	-1.328

Table A-6. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-5 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.611	4.005	-4.940
Popponesset Creek	2.162	-	-0.627
Pinquickset Cove	0.726	0.290	-0.319
Ockway Bay - lower	-	-	-1.185
Ockway Bay - upper	0.997	1.093	2.362
Mashpee River	2.948	0.663	12.376
Shoestring Bay	4.252	2.233	-7.199
Surface Water Sources			
Mashpee River	23.153	-	-
Santuit River (Shoestring Bay)	7.321	-	-
Quaker Run River (Shoestring Bay)	2.005	-	-
TOTAL	45.175	8.285	0.469

Table A-7. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario LAI-3 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.005	4.005	-2.885
Popponesset Creek	1.721	-	-0.366
Pinquickset Cove	0.573	0.290	-0.187
Ockway Bay - lower	-	-	-0.822
Ockway Bay - upper	0.893	1.093	1.766
Mashpee River	4.970	0.663	8.433
Shoestring Bay	3.737	2.233	-7.537
Surface Water Sources			
Mashpee River	13.074	-	-
Santuit River (Shoestring Bay)	11.655	-	-
Quaker Run River (Shoestring Bay)	3.304	-	-
TOTAL	40.932	8.285	-1.597

Appendix B

Eastern Tributary Basins to Waquoit Bay: Hamblin and Jehu Ponds subembayments Nitrogen Loading Tables relative to Mashpee Sewer Commission Scenarios 1, 2, 3, 4, and 5

Table B-1. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent present loading conditions for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	Direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	3.84	1.53	-5.54
Hamblin Pond Cut	-	-	2.06
Upper Hamblin Pond	1.54	0.06	-4.98
Little River	1.11	0.16	3.53
Lower Great River	2.95	0.75	10.06
Upper Great River	0.68	0.55	9.55
Jehu Pond	3.61	0.67	10.43
Surface Water Sources			
Red Brook	3.88	-	-

Table B-2. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent MEP Threshold loading conditions (original threshold scenario B) for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	Direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	1.34	1.53	-4.04
Hamblin Pond Cut	-	-	1.50
Upper Hamblin Pond	0.61	0.06	-3.63
Little River	0.43	0.16	2.73
Lower Great River	0.60	0.75	7.12
Upper Great River	0.32	0.55	6.75
Jehu Pond	0.96	0.67	7.64
Surface Water Sources			
Red Brook	1.45	-	-

Table B-3. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-1 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	Direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	0.899	1.529	-3.553
Hamblin Pond Cut	-	-	1.321
Upper Hamblin Pond	0.361	0.055	-3.191
Little River	0.605	0.157	2.472
Lower Great River	0.688	0.753	6.929
Upper Great River	0.359	0.553	6.586
Jehu Pond	1.153	0.674	7.438
Surface Water Sources			
Red Brook	0.775	-	-

Table B-4. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-2 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	Direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	1.249	1.529	-3.687
Hamblin Pond Cut	-	-	1.366
Upper Hamblin Pond	0.367	0.055	-3.312
Little River	0.895	0.157	2.535
Lower Great River	0.688	0.753	6.992
Upper Great River	0.359	0.553	6.642
Jehu Pond	1.293	0.674	7.498
Surface Water Sources			
Red Brook	0.775	-	-

Table B-5. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-4 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	Direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	0.899	1.529	-3.579
Hamblin Pond Cut	-	-	1.329
Upper Hamblin Pond	0.367	0.055	-3.215
Little River	0.605	0.157	2.485
Lower Great River	0.688	0.753	6.992
Upper Great River	0.359	0.553	6.642
Jehu Pond	1.293	0.674	7.498
Surface Water Sources			
Red Brook	0.885	-	-

Table B-6. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario S&W-5 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	Direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	0.641	1.529	-3.472
Hamblin Pond Cut	-	-	1.290
Upper Hamblin Pond	0.367	0.055	-3.118
Little River	0.394	0.157	2.434
Lower Great River	0.688	0.753	6.992
Upper Great River	0.359	0.553	6.642
Jehu Pond	1.293	0.674	7.498
Surface Water Sources			
Red Brook	0.775	-	-

Table B-7. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **Scenario LAI-3 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	Direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	0.641	1.529	-3.822
Hamblin Pond Cut	-	-	1.422
Upper Hamblin Pond	0.361	0.055	-3.433
Little River	0.388	0.157	2.624
Lower Great River	0.688	0.753	6.882
Upper Great River	0.359	0.553	6.530
Jehu Pond	1.058	0.674	7.397
Surface Water Sources			
Red Brook	2.688	-	-

Appendix C

Eastern Tributary Basin to Waquoit Bay: Quashnet River subembayment Nitrogen Loading Tables relative to Mashpee Sewer Commission Scenarios 1, 2, 3, 4, and 5

Table C-1. Sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **present loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg N/day)	Direct atmospheric deposition (kg N/day)	benthic flux (kg N/day)
Upper Quashnet River	0.789	0.252	4.782
Middle Quashnet River	-	-	1.496
Lower Quashnet River	2.162	0.334	8.553
Surface Water Sources			
Moonakis River	23.00	-	-

Table C-2. Modeling **Scenario B** sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River Estuary within the Waquoit Bay System, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg N/day)	Direct atmospheric deposition (kg N/day)	benthic flux (kg N/day)
Upper Quashnet River	0.480	0.252	3.581
Middle Quashnet River	-	-	1.046
Lower Quashnet River	1.073	0.334	5.989
Surface Water Sources			
Moonakis River	10.41	-	-

Table C-3. Modeling **Scenario S&W-1** sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River Estuary within the Waquoit Bay System, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg N/day)	Direct atmospheric deposition (kg N/day)	benthic flux (kg N/day)
Upper Quashnet River	0.123	0.252	3.321
Middle Quashnet River	-	-	0.950
Lower Quashnet River	0.529	0.334	5.441
Surface Water Sources			
Moonakis River	16.19	-	-

Table C-4. Modeling **Scenario S&W-2** sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River Estuary within the Waquoit Bay System, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg N/day)	Direct atmospheric deposition (kg N/day)	benthic flux (kg N/day)
Upper Quashnet River	0.123	0.252	3.370
Middle Quashnet River	-	-	0.970
Lower Quashnet River	0.529	0.334	5.553
Surface Water Sources			
Moonakis River	16.70	-	-

Table C-5. Modeling **Scenario S&W-4** sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River Estuary within the Waquoit Bay System, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg N/day)	Direct atmospheric deposition (kg N/day)	benthic flux (kg N/day)
Upper Quashnet River	0.123	0.252	3.297
Middle Quashnet River	-	-	0.940
Lower Quashnet River	0.529	0.334	5.384
Surface Water Sources			
Moonakis River	15.90	-	-

Table C-6. Modeling **Scenario S&W-5** sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River Estuary within the Waquoit Bay System, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg N/day)	Direct atmospheric deposition (kg N/day)	benthic flux (kg N/day)
Upper Quashnet River	0.123	0.252	3.427
Middle Quashnet River	-	-	0.989
Lower Quashnet River	0.529	0.334	5.663
Surface Water Sources			
Moonakis River	17.22	-	-

Table C-7. Modeling **Scenario LAI-3** sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River Estuary within the Waquoit Bay System, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg N/day)	Direct atmospheric deposition (kg N/day)	benthic flux (kg N/day)
Upper Quashnet River	0.123	0.252	3.508
Middle Quashnet River	-	-	1.022
Lower Quashnet River	0.545	0.334	5.850
Surface Water Sources			
Moonakis River	18.09	-	-

From: Brian Howes [mailto:bhowes@umassd.edu]
Sent: Friday, December 18, 2009 02:06
To: Pio Lombardo; townplanner@ci.mashpee.ma.us; mberrelli@hotmail.com
Cc: brian.dudley@state.ma.us; eichner@comcast.net; donald.desmarais@town.barnstable.ma.us
Subject: Re: MEP East Waquopit Bay Memo - LAI Response

Pio,

Let's see if we can save some time.

Question #1:

Re: Jehu Pond Watershed

- ***How, given that Scenario 3 removes MORE TN and has a lower buildout TN load than the other four scenarios, it is the only one that does not meet the target.***

Jehu Pond and Hamblin Pond do not act as independent systems (they join via the confluence of the Great and Little Rivers). So while Scenario 3 Jehu Pond has 86 kg/yr less than the highest of the other scenarios, the Hamblin Pond watershed load for Scenario 3 has 289-684 kg more load than the other scenarios. Scenario 3 for the combined Jehu/Hamblin watershed load has 203-608 kg more load than the other scenarios. Also note that it did lower the TN concentration from 0.603 to 0.472 mg/L and 0.528 to 0.400 mg/L approaching the desired threshold values.

Question #2:

Re: Quashnet River Watershed

The target threshold watershed TN load appears to have been lowered from 15.92 kg/day published in the 2005 TMDL report to 11.96 kg/day in the December 15, 2009 MEP Technical Memo. What is the basis?

You are correct on this. The MEP Final Report has a load of 15.92 kg/day for the Threshold watershed load for Scenario B. This is also what is in the TMDL. It is not what is in Table 4 or Appendix Table C-2. Checking, it is clear that there was a copying error in the preparation of the tables and they need to be fixed. HOWEVER, these tables (Table 4 and Append Table C-2) in the Tech Memo are provided only for reference for the reader and are not used in any of the analysis. In addition, the Threshold load is only 1 example of how one might meet the target concentration, so a management plan can have very different numbers and still work. So, while I thank you for catching this, the threshold load has not been changed, nor does the copy error affect the results or interpretation in any way.

Hope everyone has a Happy Holiday and keeps warm.

Best, Brian Howes

----- Original Message -----
From: Pio Lombardo
To: townplanner@ci.mashpee.ma.us ; mberrelli@hotmail.com
Cc: brian.dudley@state.ma.us ; eichner@comcast.net ; bhowes@umassd.edu ; donald.desmarais@town.barnstable.ma.us

Sent: Friday, December 18, 2009 9:10 AM
Subject: RE: MEP East Waquopit Bay Memo - LAI Response

Commissioners,

It is requested that MEP be directed to explain

Re: Jehu Pond Watershed

- ***How, given that Scenario 3 removes MORE TN and has a lower buildout TN load than the other four scenarios, it is the only one that does not meet the target.***

Re: Quashnet River Watershed

The target threshold watershed TN load appears to have been lowered from 15.92 kg/day published in the 2005 TMDL report to 11.96 kg/day in the December 15, 2009 MEP Technical Memo. What is the basis?

Thank you

Pio

Pio Lombardo, P.E. | Lombardo Associates, Inc. | Environmental Engineers Consultants | Tel: 617-964-2924 | Cell: 617-529-4191| Fax: 617-332-5477
Email: Pio@LombardoAssociates.com | www.LombardoAssociates.com

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

MEP Technical Memo

To: Pio Lombardo, Lombardo Associates Inc.
Tom Fudala, Chair, Mashpee Sewer Commission

From: Ed Eichner, CSP/SMAST
Brian Howes, CSP/SMAST
Sean Kelley, ACRE
John Ramsey, ACRE

Date: February 9, 2010

Re: Report on Revised MEP Scenario 3 for Eastern Basins of the Waquoit Bay System

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At the request of Lombardo Associates, Inc. (LAI), the Massachusetts Estuaries Project (MEP) Technical Team completed a revised scenario run for the Eastern Basins of the Waquoit Bay System. The previous December 18, 2009 MEP Technical Memo[1] detailed the water quality impacts on the Eastern Basins of the Waquoit Bay System of a wastewater-based scenario developed by LAI. The LAI scenario in the previous memo, labeled Scenario 3, did not attain the MEP Threshold Nitrogen concentrations for the Eastern Basins of Waquoit Bay: Jehu Pond, Hamblin Pond, and the Quashnet River estuary (Figure 1).

Based upon the modeling results, LAI revised the collection and discharge of wastewater within the Eastern Waquoit Bay subwatersheds and requested another, scenario run, labeled Scenario 3R (3 Revised). LAI's revisions in 3R primarily focused on the expansion of Cluster 2 (Figure 2) and Cluster 15 (Figure 3), as well as increased discharge of wastewater effluent outside of the watershed (Table 1). As a result of these revisions, less than 0.4% of the watershed wastewater flow is treated by on-site septic systems. Wastewater loads by subwatershed for Scenario 3R are presented in Table 2.

MEP Scenario Results and Discussion

Eastern Waquoit Bay Scenario 3R Results: Comparison to Threshold N Concentrations

Using the nitrogen loads based on the updated unified land-use database and the MEP hydrodynamic and water quality models, Scenario 3R meets the threshold values at the sentinel station for restoration of eelgrass in Hamblin and Jehu Ponds and the restoration of infaunal habitat in the Quashnet River (Table 3).

It should be noted that Scenario 3R produces water column TN concentrations that are significantly lower than required to meet the threshold concentrations in Hamblin and Jehu

Ponds and the Quashnet River. *This finding indicates that the collective wastewater treatment in these watersheds exceeds what is necessary for estuarine restoration.* It is also important to note that no other alternative nitrogen reduction strategies other than improved wastewater treatment were considered in these scenarios.

It should also be noted that both LAI Scenarios 3R and 3, assume that all treated wastewater achieves an effluent concentration of 3.75 ppm total nitrogen except for flows treated by standard Title 5 septic systems. Since the assigned wastewater effluent concentrations are the key to determining the wastewater nitrogen loads for these scenarios, the Sewer Commission should ensure that this concentration is appropriate based on the performance of all the proposed treatment technologies and how they are likely to be permitted in regulatory settings.

Endnotes

1. Report on Unified Database and Requested MEP Scenarios for the: (a) Popponesset Bay Estuary and (b) Eastern Basins of the Waquoit Bay System. December 18, 2009 MEP Technical Memorandum from Ed Eichner, Brian Howes, SMAST and Sean Kelley, John Ramsey, ACRE to Tom Fudala, Chair, Mashpee Sewer Commission.

2. Howes B., S.W. Kelley, J.S. Ramsey, R. Samimy, D. Schlezinger, T. Ruthven, E. Eichner. 2005. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Quashnet River, Hamblin Pond, and Jehu Pond, in the Waquoit Bay System in the Towns of Mashpee and Falmouth, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. http://www.oceanscience.net/estuaries/Quashnet.htm

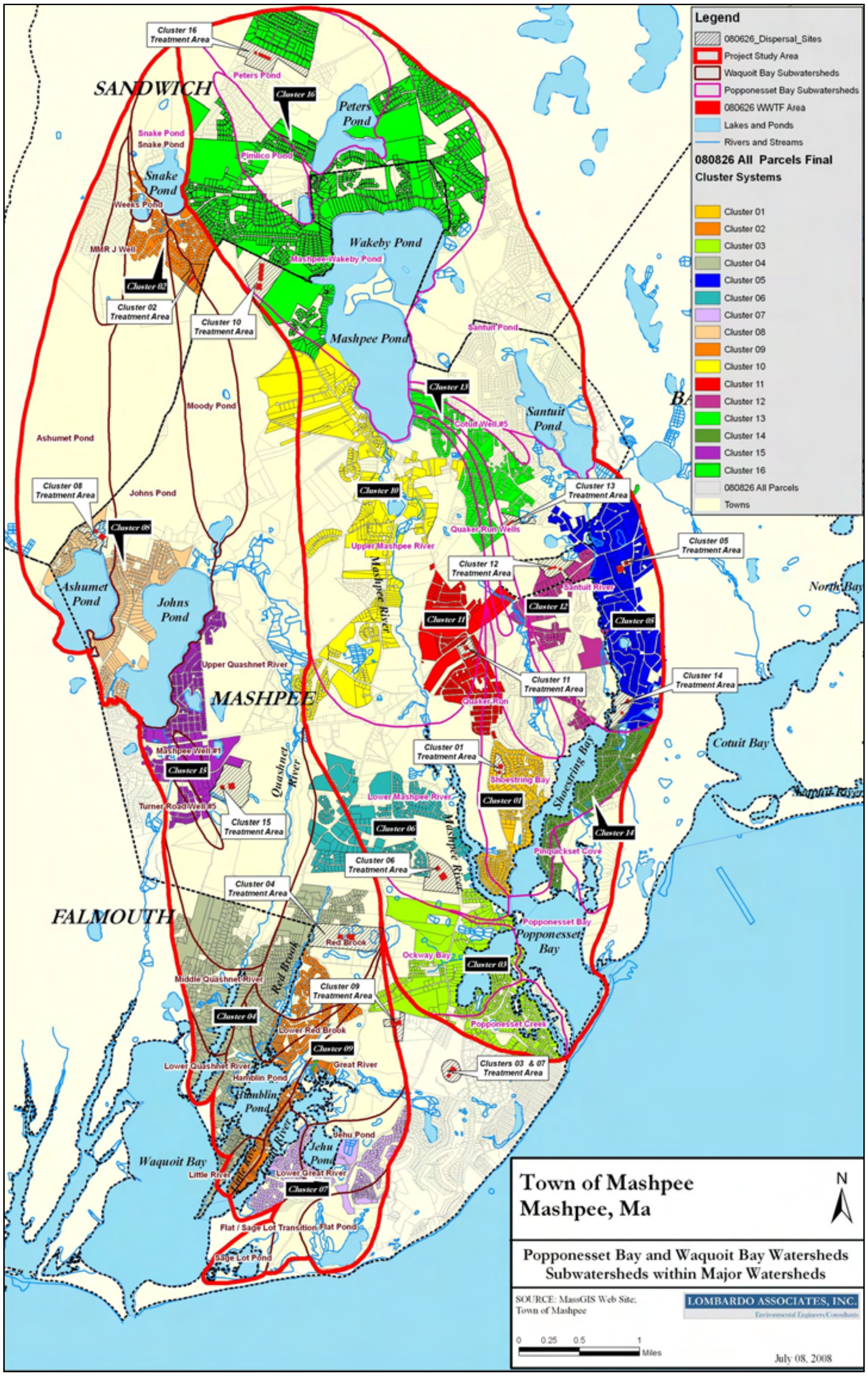


Figure 1. LAI Proposed Wastewater Collection Clusters and Treatment and Discharge Sites in both the Popponesset Bay and Eastern Waquoit Bay watersheds. These clusters and discharge sites were used by the MEP Technical Team to complete scenario runs comparing the impact of the wastewater treatment improvements to the respective MEP Nitrogen Threshold Concentrations. The results of the scenario runs are documented in a December 18, 2009 MEP Technical Memo to the Mashpee Sewer Commission.

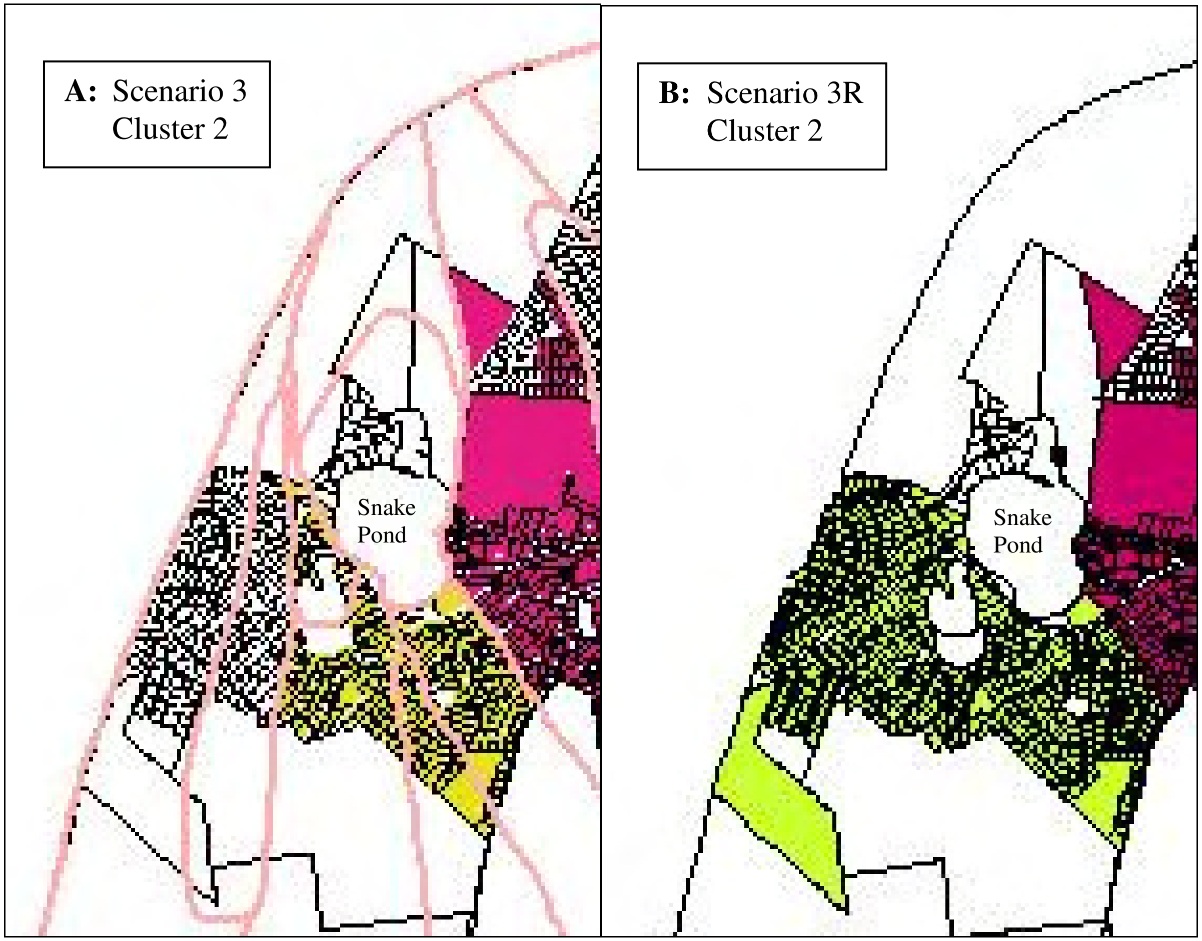


Figure 2: Scenario 3R Expansion of LAI Cluster 2

The Scenario 3 Cluster 2 wastewater collection area (shown in yellow in A) is expanded under Scenario 3R to include most of the parcels to the west of Snake Pond (shown in light green in B). Based on the wastewater flows in the Unified Wastewater Database, the flow from Cluster 2 increases from 52,438 gallons per day (gpd) in Scenario 3 to 110,900 gpd in Scenario 3R. Treated wastewater effluent from Cluster 2 is discharged within the watershed to Moody Pond in both versions of Scenario 3.

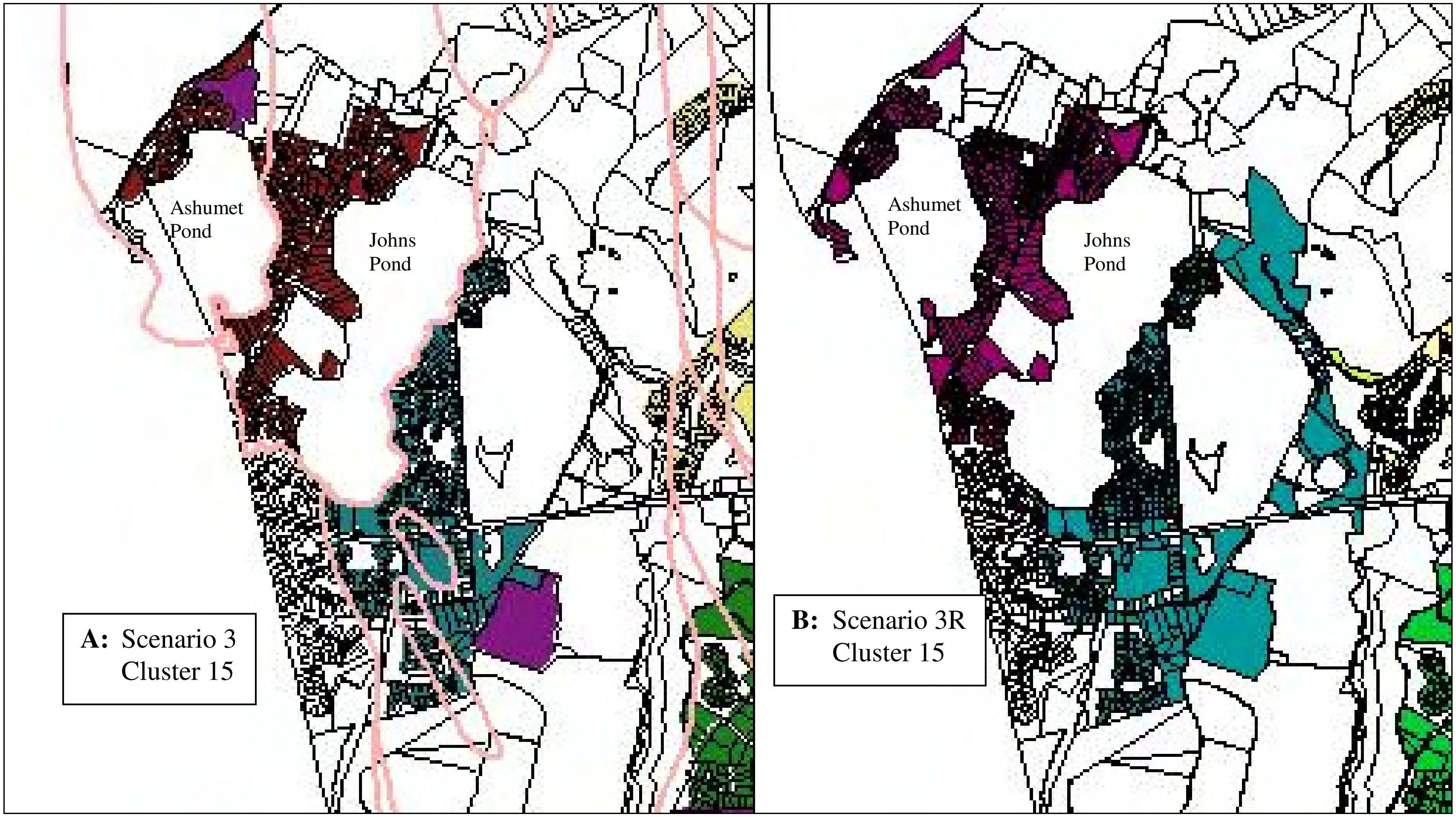


Figure 3: Scenario 3R Expansion of LAI Cluster 15

The Scenario 3 Cluster 15 wastewater collection area (shown in blue in A) is expanded under Scenario 3R to include most of the parcels to the east of Johns Pond (shown in blue in B). Based on the wastewater flows in the Unified Wastewater Database, the flow from Cluster 15 increases from 87,638 gallons per day (gpd) in Scenario 3 to 196,477 gpd in Scenario 3R. Treated wastewater effluent from Cluster 15 is discharged within the watershed to the Quashnet River in Scenario 3 and is discharged at the New Seabury discharge site (outside of the Waquoit watershed) in Scenario 3R.

Table 1. Wastewater flows to each LAI cluster in Scenarios 3 and 3R. Wastewater flows in gallons per day (gpd) are shown for each LAI wastewater collection cluster under Scenario 3 and the revised Scenario 3R. Scenario 3R collects 161,325 gpd more flow into clusters than Scenario 3. Also shown are the wastewater effluent discharge/dispersal areas for the clusters or collection of clusters. Scenario 3R proposes to discharge more wastewater effluent outside of the Eastern Waquoit watershed at the Rock Landing Well/New Seabury location than proposed in Scenario 3. Wastewater flows in both versions of the Scenario are from the Unified Database described in the MEP Technical Memo of December 18, 2009.

Cluster	Scenario 3R gpd	Scenario 3 gpd	change gpd	Dispersal area watershed in Scenario 3R	Dispersal area watershed in Scenario 3
1	46,650	46,650	0	Shoestring Bay	Shoestring Bay
2	110,900	52,438	58,462	Moody Pond	Moody Pond
3	88,685	88,685	0	Rock Landing Wells/outside	Rock Landing Wells/outside
4	149,300	146,388	2,913	Rock Landing Wells/outside	Red Brook
5	101,331	101,331	0	Santuit River	Santuit River
6	123,026	123,026	0	Rock Landing Wells/outside	Red Brook
7	88,072	87,902	170	Rock Landing Wells/outside	Rock Landing Wells/outside
8	74,109	72,044	2,065	Ashumet Pond	Ashumet Pond
9	61,300	61,300	0	Rock Landing Wells/outside	Rock Landing Wells/outside
10	200,926	203,744	-2,818	Mashpee-Wakeby Pond	Mashpee-Wakeby Pond
11	106,721	106,721	0	Mashpee River	Mashpee River
12	59,224	66,281	-7,057	Santuit River	Santuit River
13	91,176	91,176	0	Santuit River	Santuit River
14	46,362	46,362	0	Santuit River	Santuit River
15	196,477	87,638	108,839	Rock Landing Wells/outside	Quashnet River
16	244,969	246,219	-1,250	Peters Pond	Peters Pond
TOTAL (clusters)	1,789,229	1,627,905	161,325		

Table 2. Scenario Watershed Nitrogen Loads: Eastern Waquoit Bay (Hamblin and Jehu Ponds and Quashnet River)

Attenuated total nitrogen loads by subembayment and surface water input to the Hamblin and Jehu Ponds and Quashnet River portions of East Waquoit Bay are presented for Lombardo Associates, Inc. Scenario 3 and Scenario 3R. Both scenarios loads are based on build-out nitrogen loading conditions using the updated SMAST unified database; MEP build-out loads are presented for comparison (a build-out load for the unified database was not a requested scenario). Loads do not include atmospheric deposition onto the sub-embayment surface or benthic flux loading terms. "Threshold" load is from the scenario used in the MEP technical report to meet the N threshold levels in the Bay, which is based on a 0.35 mg/L boundary condition in Waquoit Bay.

sub-embayment	MEP Build-out load (kg/day)	threshold (kg/day)	threshold % change	Scenario LAI-3		Scenario LAI-3R	
				(kg/day)	% change	(kg/day)	% change
Hamblin Pond	4.84	1.347	-72.2%	0.641	-86.8%	0.641	-86.8%
Upper Hamblin Pond	2.10	0.609	-71.0%	0.361	-82.8%	0.356	-83.0%
Little River	1.27	0.429	-66.1%	0.388	-69.3%	0.388	-69.3%
Lower Great River	3.37	0.600	-82.2%	0.688	-79.6%	0.688	-79.6%
Upper Great River	1.58	0.320	-79.8%	0.359	-77.3%	0.359	-77.3%
Jehu Pond	4.01	0.960	-76.0%	1.058	-73.6%	1.052	-73.8%
Surface Water Sources							
Red Brook	7.29	1.451	-80.0%	2.688	-63.1%	0.775	-89.4%
Jehu/Hamblin TOTAL	24.45	**5.717**	-67.5%	**6.183**	-64.9%	**4.259**	-75.8%
Upper Quashnet	0.89	0.41	-53.9%	0.123	-86.2%	0.123	-86.2%
Lower Quashnet	3.02	0.95	-68.6%	0.545	-82.0%	0.529	-82.5%
Surface Water Sources							
Moonakiss River	46.82	14.56	-68.9%	18.093	-61.4%	13.55	-71.1%
Quashnet River TOTAL	50.73	**15.92**	-68.6%	**18.762**	-63.0%	**14.205**	-72.4%

Table 3. Threshold Comparison Results for Mashpee Sewer Commission Scenarios: East Waquoit Bay

Comparison of TN concentrations for present conditions, threshold loading, and five modeled build-out loading scenarios for the East Waquoit Bay system. Threshold concentrations are 0.446 mg/L TN for Jehu Pond (eelgrass), 0.380 mg/L TN for Hamblin Pond (eelgrass), and less than 0.520 mg/L TN for average of the upper- and mid-river monitoring stations of the Quashnet River (infauna).[2]

	Habitat Threshold	Present	MEP Threshold	Scenario 1 S&W	Scenario 2 S&W	Scenario 4 S&W	Scenario 5 S&W	Scenario 3 LAI	Scenario 3R LAI
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Jehu Pond	eelgrass	0.603	0.446	0.429	0.435	0.437	0.434	0.472	0.429
Hamblin Pond	eelgrass	0.528	0.380	0.252	0.253	0.260	0.252	0.400	0.251
Quashnet River	infauna	0.781	0.520	0.536	0.547	0.523	0.559	0.584	0.460

Note: shaded cells indicate Scenarios that meet threshold concentrations to support eelgrass or infaunal habitat (TMDL).

Appendix A

Eastern Tributary Basins to Waquoit Bay:
Hamblin and Jehu Ponds and Quashnet River subembayments

Nitrogen Loading Tables relative to
Mashpee Sewer Commission
Scenario 3R

Table A-1. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **present loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	3.84	1.53	-5.54
Hamblin Pond Cut	-	-	2.06
Upper Hamblin Pond	1.54	0.06	-4.98
Little River	1.11	0.16	3.53
Lower Great River	2.95	0.75	10.06
Upper Great River	0.68	0.55	9.55
Jehu Pond	3.61	0.67	10.43
Surface Water Sources			
Red Brook	3.88	-	-

Table A-2. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **MEP Threshold loading conditions** (original threshold scenario B) for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	1.34	1.53	-4.04
Hamblin Pond Cut	-	-	1.50
Upper Hamblin Pond	0.61	0.06	-3.63
Little River	0.43	0.16	2.73
Lower Great River	0.60	0.75	7.12
Upper Great River	0.32	0.55	6.75
Jehu Pond	0.96	0.67	7.64
Surface Water Sources			
Red Brook	1.45	-	-

Table A-3. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **LOADING SCENARIO LAI-3** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	0.641	1.529	-3.822
Hamblin Pond Cut	-	-	1.422
Upper Hamblin Pond	0.361	0.055	-3.433
Little River	0.388	0.157	2.624
Lower Great River	0.688	0.753	6.882
Upper Great River	0.359	0.553	6.530
Jehu Pond	1.058	0.674	7.397
Surface Water Sources			
Red Brook	2.688	-	-

Table A-4. Sub-embayment and surface water loads used for total nitrogen modeling of the Hamblin Pond/Jehu Pond system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **LOADING SCENARIO LAI-3R** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Hamblin Pond	0.641	1.529	-3.472
Hamblin Pond Cut	-	-	1.287
Upper Hamblin Pond	0.356	0.055	-3.118
Little River	0.388	0.157	2.434
Lower Great River	0.688	0.753	6.882
Upper Great River	0.359	0.553	6.530
Jehu Pond	1.052	0.674	7.397
Surface Water Sources			
Red Brook	0.775	-	-

Table A-5. Sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **present loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg N/day)	direct atmospheric deposition (kg/day)	benthic flux (kg N/day)
Upper Quashnet River	0.789	0.252	4.782
Middle Quashnet River	-	-	1.496
Lower Quashnet River	2.162	0.334	8.553
Surface Water Sources			
Moonakis River	23.00	-	-

Table A-6. Sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **MEP Threshold loading conditions** (original threshold scenario B) for the listed sub-embayments.

sub-embayment	watershed load (kg N/day)	direct atmospheric deposition (kg/day)	benthic flux (kg N/day)
Upper Quashnet River	0.480	0.252	3.581
Middle Quashnet River	-	-	1.046
Lower Quashnet River	1.073	0.334	5.989
Surface Water Sources			
Moonakis River	10.41	-	-

Table A-7. Modeling **Scenario LAI-3** sub-embayment and surface water loads used for total nitrogen modeling of the Quashnet River Estuary within the Waquoit Bay System, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg N/day)	direct atmospheric deposition (kg/day)	benthic flux (kg N/day)
Upper Quashnet River	0.123	0.252	3.508
Middle Quashnet River	-	-	1.022
Lower Quashnet River	0.545	0.334	5.850
Surface Water Sources			
Moonakis River	18.09	-	-

APPENDIX D – Lombardo Associates, Inc. Memos

1. Response to 091113 Report on Unified Database and Requested MEP Scenarios (December 4, 2009)

2. Report on 091115 Unified Database and Requested MEP Scenarios (December 17, 2009)

3. Pio Lombardo's Response to Brian Howes Email Re: CSP/SMAST East Waquoit Bay Memo (December 18, 2009)

4. Pio Lombardo's Email to Brian Howes Re: LAI Revised Scenario 3 to Achieve TMDL Compliance in the East Waquoit Bay (December 29, 2009)

5. Response to MEP Technical Memo on Popponesset Bay Analysis (January 21, 2010)

Memorandum

Date: December 4, 2009

To: Tom Fudala, Don Desmarais, Matthew Berrelli

CC: Gary Rubenstein, Brian Howes, Ed Eichner

From: Pio Lombardo

Re: Response to MEP Technical Memo on Popponesset Bay Analysis

OVERVIEW

On November 13, 2009, MEP issued a memorandum of the results of the model run for the Lombardo Associates, Inc. (LAI) decentralized wastewater management scenario (Scenario 3) along with results of 4 other scenarios ran, using conventional wastewater technology, developed for the Town. The following issues have been raised with respect to Scenario 3:

1. Effluent concentration assigned to cluster systems and I/A systems treating future flows
2. Total I/A flows were reported to be 306,825 gallons per day (gpd) across both the E. Waquoit and Popponesset Bay watersheds
3. Costs associated with treating future flows not associated with cluster systems
4. Costs for treating for emerging contaminants
5. Treatment Technology

This Memo clarifies these issues with respect to assumptions associated with the LAI Decentralized Scenario.

1. CLUSTER SYSTEM EFFLUENT NITROGEN LIMITS

Scenario 3 assumes that the cluster systems will discharge treated effluent to groundwater at a concentration of 3.75 mg/L. Questions were raised concerning any drainfield attenuation of nitrogen. LAI is proposing treatment facilities that will discharge 3.75 mg/L from the treatment process and is not relying on any drainfield attenuation. Attached is treatment performance for our Mashpee, Eastham and MASSTC installation along with installations in Malibu, CA that demonstrate routinely achieving these performance levels.

2. TOTAL I/A SYSTEM FLOW

The following assumptions are integral to Scenario 3:

1. Any parcel that is not included in a cluster and does NOT have a future nitrogen load that is greater than the existing nitrogen load will remain “as-is”.
2. Any parcel that is not included in a cluster AND has a future increase in nitrogen load will be required to either connect to one of the cluster systems, being part of a future cluster, or be fitted with an I/A system capable of producing an effluent nitrogen concentration of 3.75 mg/L.

The MEP Technical Memo presented a table that assigned a total I/A system flow, across both the E. Waquoit and Popponesset Bay watersheds, of 306,825 gpd. This number was supposed to represent the total future flow for all parcels that meet the following conditions, based on the above assumptions:

1. Future Nitrogen Load > Existing N Load
2. Not included in a proposed cluster system
3. Not a WWTF

The attached map illustrates the parcels in both watersheds that meet these criteria. As can be seen, there are very few parcels that are not clustered and are expected to expand their existing nitrogen load. LAI summarized the flows from these parcels by watershed, and the results are as follows:

- Popponesset Bay - 26,818 gpd
- E. Waquoit Bay - 29,323 gpd

The result is a combined total I/A flow of 56,140 gpd. This is vastly different from the analysis that was presented in the MEP (whom we have notified) Technical Memo, and this flow is similar to the 41,311 gpd associated with Scenario 1. In addition, as can be seen on the map, there are very few if any parcels that are not close to one of the proposed cluster systems. It is unlikely that a significant portion of the 56,140 gpd will ultimately be fitted with an individual I/A system. Most of these parcels will simply connect to existing cluster systems. Consequently, for all practical purposes Scenario 3 relies entirely on MADEP Groundwater Discharge Systems.

3. COSTS FOR TREATING FUTURE FLOWS

One of the advantages of Scenario 3 is the ability to build what is needed now and add facilities later if/when they are needed. The cost for treating Build-out flow is estimated at $30-40 million, proposed to be expended when and if needed.

4. COSTS FOR TREATING FOR EMERGING CONTAMINANTS

The cost for the additional treatment for emerging contaminants at all the cluster systems is estimated at $5-10 million.

5. TREATMENT TECHNOLOGY

It is noted that no decisions or proposals have been made on which specific treatment technologies would be used, as sitting issues are a significant factor in the selection. Candidate technologies include membrane bioreactors (MBR), recirculating media filters (i.e. modern day trickling filters), etc. – all with denitrification filters to achieve TN of 3.75 mg/l. The Nitrex™ Filter may or may not be proposed as the denitrification filter – again as sitting and specific cost-effectiveness issues need to be addressed at the next level of analysis. Should the Nitrex™ Filter be proposed, to the extent required by MA DEP, provisions would be made for a substitute conventional chemical feed –denitrification filter with financial assurances provided for the change – should the Nitrex™ Filter not meet design requirements – which has never occurred in any of the numerous installations throughout the US. It is noted that a conventional chemical feed – denitrification filter is less expensive from a capital cost, however its operational cost and management requirements are much higher than the Nitrex™ Filter. Furthermore, the denitrification component represents less than 5% of the overall cluster system cost – so it does not materially affect the overall LAI Decentralized Plan – which is technically and economically viable with or without Nitrex™ Filter.

The other nitrogen management tools using Nitrex™ technology are for:

- Groundwater treatment;
- Title 5 cluster wastewater systems < 10,000 gpd; and
- Title 5 individual wastewater systems

would be examined in the next phase to determine cost saving opportunities associated with the decentralized Plan and an adaptive management plan that addressed risks and permitting issues for their integration with the Plan would be developed.

LIST OF ATTACHMENTS

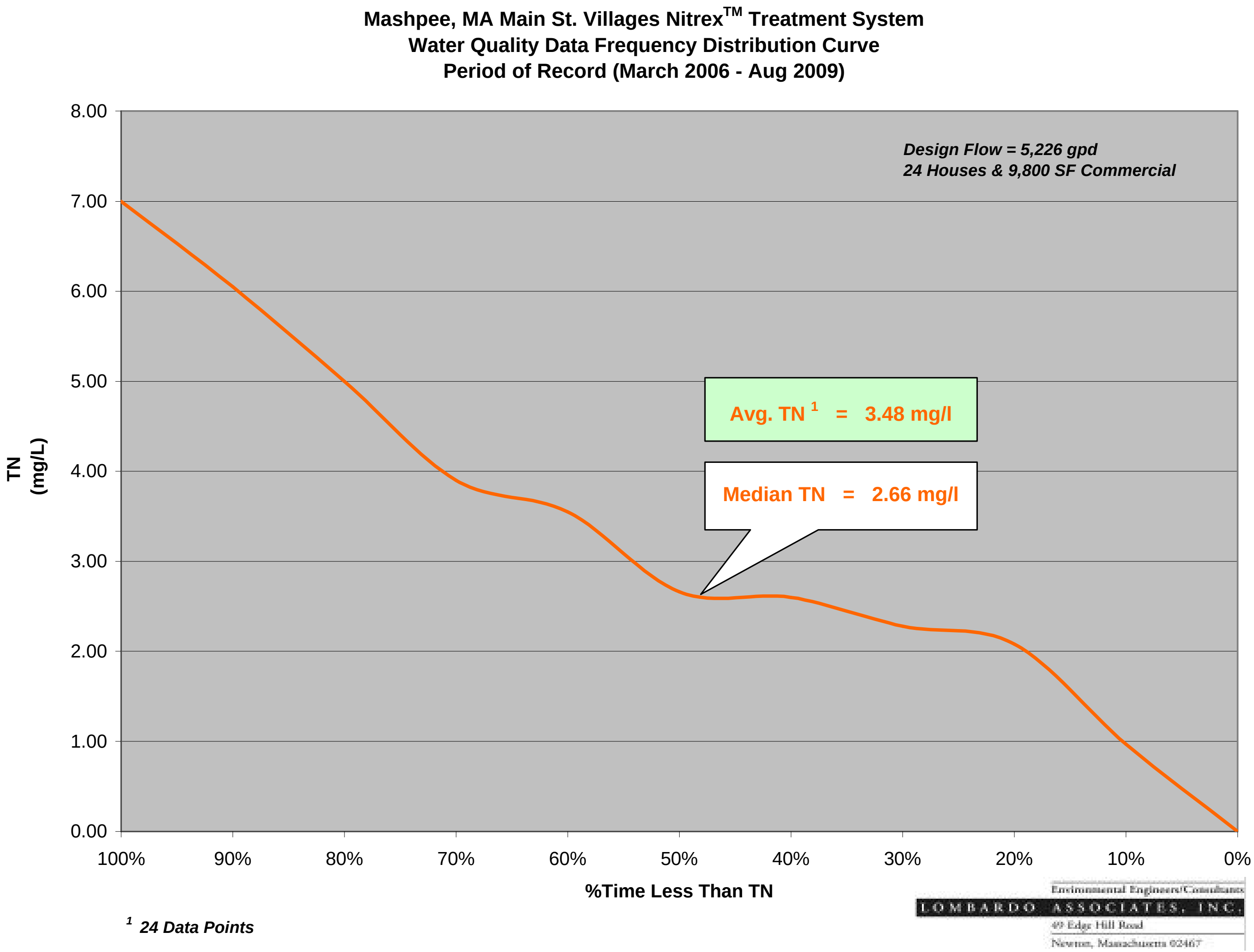
- Main Street Villages, Mashpee, MA
- Eastham, MA
- MASSTC Installation
- Malibu, CA Installations
- Waquoit Bay Estuarine Research Center Groundwater Treatment

MAIN STREET VILLAGES, MASHPEE, MA

Mashpee, MA Performance Summary				
Date	Septic Tank Effluent Total Nitrogen (mg/l)	Nitrex™ Tank Effluent Total Nitrogen (mg/l)	BOD (mg/l)	TSS (mg/l)
10-May-06	57.6	5.00	130	16
16-Jun-06	58.0	<7.00(1)	160	14
26-Jul-06	48.6	2.60	49	2
17-Aug-06	75.6	< 3.00	27	9
14-Sep-06	67.3	2.15	24	3
17-Oct-06	62.3	1.60	10	1
20-Nov-06	47.0	2.08	7	1
12-Dec-06	51.0	4.10	7	2
30-Jan-07	63.0	3.26	8.2	3
28-Feb-07	14.0(2)	6.27	7	1
3-Apr-07	39.0	2.60	23.6	6
26-Apr-07	44.0	2.64	13.3	1
16-May-07	43.0	3.55	13.1	4
26-Jun-07	70.0	3.90	8.9	4.5
25-Jul-07	73.6	6.05(1)	9.4	1
12-Sep-07	29.0	2.66	9	2
24-Sep-07	45.0	2.50	12.2	1
22-Oct-07	47.0	2.28	<7	<1
24-Jan-08	40.0	4.92	<7	<1
28-Apr-08	64.0	3.73	9.2	3
23-Jul-08	36.0	0.97	10.4	3
24-Oct-08	64.0	0.71	<7	<2
30-Jan-09	26.0	6.10	<7	<3
30-Apr-09	74.0	5.20	<7	<2
19-Aug-09	59.0	2.03	<7	<1
14-Oct-09	67.0	1.46	8.3	3
Period of Record Avg.	**52.7**	**3.25**	**18.1**	**3.07**
12 Month Rolling Avg.	**58.0**	**3.10**	**4.7**	**1.50**
% TN Removal		**93.8%**		

(1) Due to insufficient nitrification of pretreatment system.

(2) High pH due to inappropriate wastewater discharge caused low total nitrogen.

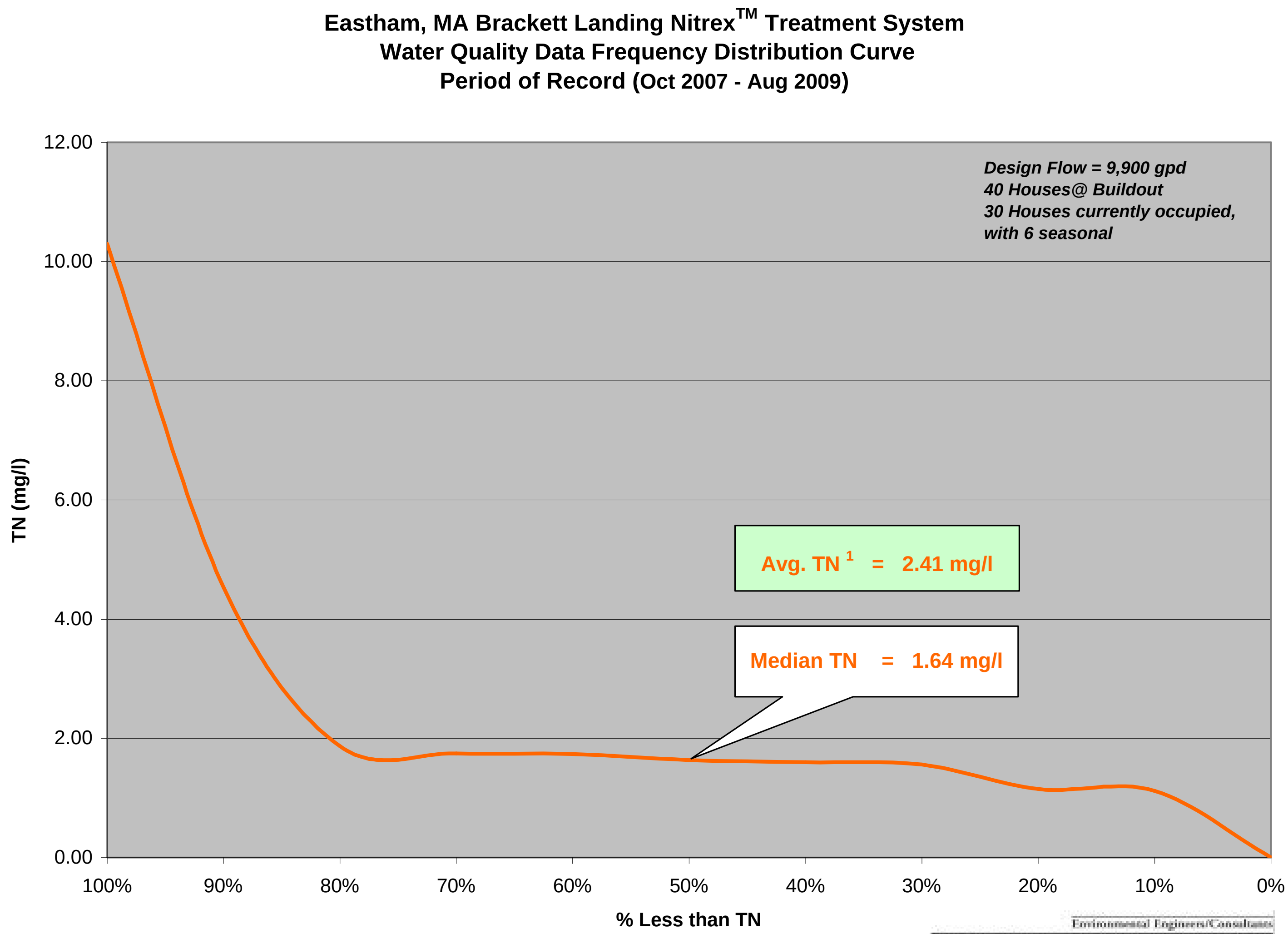

Mashpee, MA Main St. Villages Nitrex™ Treatment System
Water Quality Data Frequency Distribution Curve
Period of Record (March 2006 - Aug 2009)
Design Flow = 5,226 gpd
24 Houses & 9,800 SF Commercial
Avg. TN 1 = 3.48 mg/l
Median TN = 2.66 mg/l
TN (mg/L)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
%Time Less Than TN
1 24 Data Points
Environmental Engineers/Consultants
LOMBARDO ASSOCIATES, INC.
49 Edge Hill Road
Newton, Massachusetts 02467

EASTHAM, MA

Brackett Landing, Eastham, MA Nitrex™ Treatment System				
Date	Septic Tank Effluent	Nitrex™ Effluent		
	Total Nitrogen (mg/l)	Total Nitrogen (mg/l)	BOD [2] (mg/l)	TSS (mg/l)
10/2/2007	23.3	3.01	100	140
10/23/2007	24.2	1.70	44.8	7
11/14/2007	10.5	1.56	29.4	6.5
11/27/2007	15.8	1.61	26.8	5
12/12/2007	24.3	1.64	28.1	5.5
12/27/2007	17.6	3.67	28.8	13
1/31/2008	22.6	1.74	15.1	4
3/27/2008	25.5	5.45	7.3	4
4/29/2008	22.1	1.80	39.5	10
5/28/2008	26.9	1.75	41.6	11.5
6/30/2008	15.0	1.87	25.6	12.5
7/29/2008	56.7	1.60	19.2	10.5
8/29/2008	19.9	1.05	15.8	5
9/30/2008	19.1	1.03	10.4	4
10/29/2008	16.9	1.12	8.8	<4.0
12/1/2008	36.6	1.15	4.2	<4.0
12/30/2008	14.4	1.35	4.9	<4.0
1/27/2009	133.0	1.56	<4.0	<4.0
3/31/2009		1.74	4	<4.0
4/30/2009		4.54	<4.0	<4.0
5/29/2009		10.3	5.6	<4.0
7/2/2009	21.3	1.57	6.2	<4.0
7/28/2009	44.5	17.6	4.4	<4.0
8/28/2009	16.3	2.47	7.5	<4.0
Average[1]	**28.09**	**2.40**	**22.40**	**17.04**
12 month Rolling Average[1]	**39.75**	**2.87**	**9.92**	**8.00**
TN % Removal		**94.0%**		

[1] Not including the 7/28/09 sampling event which was the result of power failure.

[2] BOD and Alkalinity were omitted from the 11/14/07 data and were tested on 11/26/07.



[1] *22 Data Points; excluding 07/28/09 data resulting from power failure.*

Environmental Engineers/Consultants
LOMBARDO ASSOCIATES, INC.

MASSTC INSTALLATION

PROJECT DESCRIPTION

The Nitrex^{TM} system is one of a number of alternative septic systems technologies being assessed at the Massachusetts Septic System Test Center.

PROJECT APPLICATION DATA

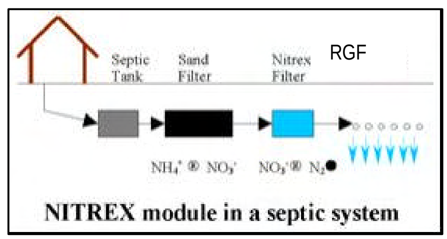
- Location: Otis Air Force Base, Massachusetts
- Site Application: Massachusetts Alternative Septic System Test Center
- Installation Date: October 4, 2001

Design Profile

- Design Wastewater Flow: 330 gpd
- Wastewater Treatment Process: Septic Tank – Recirculating Gravel Filter (RGF) – Nitrex^{TM}

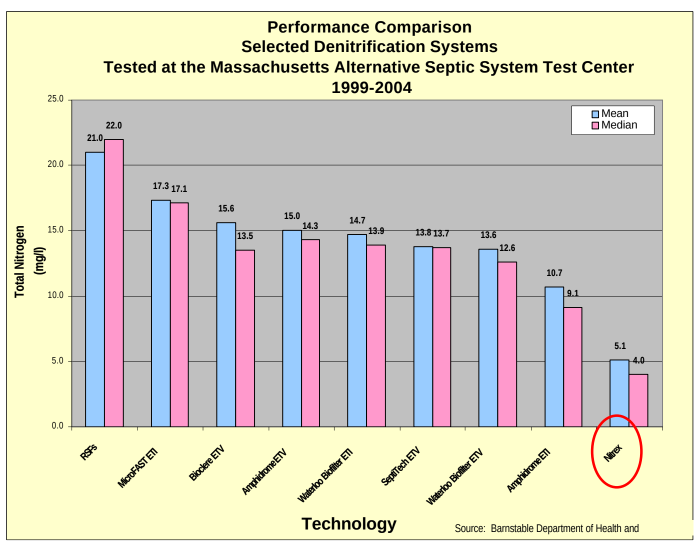
NITREX^{TM} TREATMENT PERFORMANCE

The Nitrex^{TM} filter installed at Otis Air Force base has reduced nitrogen in the effluent by an average of 74.1% over the two years that it has been in operation. The following figures illustrate the nitrate in the effluent and % of nitrate removed from the effluent due to the Nitrex^{TM} filter. The Table provides the actual data measured by an independent laboratory. The lower winter 2003 wastewater temperature from the RGF reduced the performance of the Nitrex^{TM} filter.



Nitrex^{TM} System Performance Summary:

	Total Nitrogen Median (mg/l)	
	Nitrex^{TM} Influent	Effluent
Otis, MA	**19.7**	**4.5**



		Influent		Effluent						
Date	Discharge Temp (o F)	TN (mg/l)	TKN	TN (mg/l)	Nitrite	Nitrate	NH4 (mg/l)	TKN	CBOD	TSS
10/24/01		19		3.1	0.4	0.1	1.3	2.6		
11/07/01		19		3.8	0.1	1.9	1.1	1.8		
11/20/01		19		2.2	0.1	0.1	0.9	2		
12/04/01		19		2.2	0.2	0.1	0.2	1.9		
12/19/01		19		2.5	0.1	0.1	0.4	2.3		
01/03/02		19		1.6	0.1	0.1	0.2	1.4		
01/16/02		19		1.7	0.1	0.1	0.2	1.5		
02/13/02		19		2.1	0.1	0.1	0.9	1.9		
03/13/02		19		2.8	0.1	0.6	1.2	2.1		
04/10/02		19		2.4	0.1	0.8	0.2	1.5		
05/08/02		19		3	0.1	0.1	0.6	2.8		
05/22/02		14.8	2.5	2	0.1	0.1	0.3	1.8		
06/12/02		16.7	3	2.5	0.1	0.1	0.2	2.3		
07/10/02		13.6	3.6	3.4	0.1	0.1	2.2	3.2		
08/14/02	77.4	15.8	1.3	2.7	0.1	0.1	1.1	2.5		
09/11/02	73.8	20.5	1.3	2.1	0.1	0.1	0.8	1.9		
10/09/02	68	15.5	0.3	2	0.1	0.3	1.4	1.6		
11/13/02	56.5	18.9	1.3	6.7	0.2	1.8	0.2	4.7		
12/11/02	44.8	18.7	0.5	6.1	0.3	4.3	0.4	1.5		
01/08/03	41.5	11.2	4.2	8	0.3	4.4	2.7	3.3		
02/12/03	37.6	18.2	7.8	13.1	0.3	5.4	6.2	7.4		
03/12/03	36.9	16.9	9.8	12.6	0.1	2.8	7.9	9.7		
04/09/03	41.5	17.9	4.7	8.9	0.1	4	4.2	4.8		
05/14/03		11.7	3.2	6	0.1	2.1	0.9	3.8		
06/11/03	60.3	10.23		7.2	0.05	0.1				
06/25/03	61.7									
07/09/03	72									
10/15/03	18.1	21.76	0.5	5.71	0.06	0.05	3.2	5.6	11	32
11/12/03	12.2	25.1	1.6	4.8	0.1	3.3	0.5	1.4	1	2
12/10/03	6.2	14.76	0.5	5.11	0.21	3.6	0.6	1.3	1	0.5
01/07/04	6	13.1	4.1	3.93	0.07	0.86	1.8	3	2.9	1
03/11/04	2.3	24.82	11	18.15	0.05	0.1	13	18	10	5.5
12/01/04	10.2	21.83	0.8	10.33	0.03	7.7	0.8	2.6	4	2.5
12/08/04	9.4	23.13	3.1	8.73	0.03	6.6	0.3	2.1	8	2.5
12/15/04	8.5	22.43	3.4	11.53	0.03	8.3	0.5	3.2	4	2.5
12/22/04	6.7	20.28	0.25	11.23	0.03	9.7	0.5	1.5	1	2.5
01/05/05	7.3	19.73	3.7	10.19	0.19	8.2	0.3	1.8	11	2.5
01/12/05	5.8	17.83	3.8	6.03	0.03	4.1	0.1	1.9	6	2.5
01/19/05	5.3	19.93	1.9	10.23	0.03	8.5	0.5	1.7	11	2.5
02/02/05	3.3	20.73	0.7	11.28	0.03	11	0.3	0.25	14	2.5
02/09/05		40.63	1.6	16.43	0.03	15	0.4	1.4	4	2.5
02/16/05	4.1	25.33	1.3	12.33	0.03	10	0.3	2.3	1	2.5
02/23/05	3.3	20.23	1.2	11.23	0.03	9.8	0.3	1.4	4	2.5
03/04/05	2.5	28.28	0.25	17.03	0.03	16	0.3	1	5	2.5
03/11/05	2.7	20.83	2.8	10.03	0.03	7.6	0.2	2.4	5	2.5
03/18/05	3.6	22.93	2.9	8.23	0.03	6.4	0.4	1.8	5	2.5
03/25/05	3.9	18.73	2.7	6.63	0.03	4.3	0.5	2.3	3	2.5
04/08/05	7.9	23.49	1.9	8.33	0.03	6.1	0.4	2.2	3	2.5
04/15/05	7.7	23.35	0.25	8.13	0.03	6.4	3	1.7	4	2.5
04/22/05		25.68	1.9	9.23	0.03	7.2	0.5	2	4	2.5
05/13/05	11.4	16.63	1.2	3.23	0.03	1.3	0.4	1.9	3	5.4
05/20/05	11.5	16.23	2.2	1.08	0.03	0.05	0.1	1	8	5
05/27/05	11.1	11.93	4.1	3.23	0.03	1.3	0.3	1.9	5	2.5
06/03/05		20.55	0.9	3.73	0.03	2	0.1	1.7	5	2.5
06/10/05		24	1.3	5.33	0.03	3.5	0.3	1.8	3	2.5
06/17/05	17.8	14.79	2.9	3.97	0.17	1.8	0.1	2	7	2.5
06/24/05		16.33	3.3	2.82	0.03	0.99	0.6	1.8	4	2.5
07/01/05	19.3	16.43	2.4	3.73	0.03	1.1	1.4	2.6	6	2.5
07/08/05		20.48	2.7	3.73	0.03	1.7	0.7	2	6	2.5
07/15/05	20.7	21.75	1.4	3.83	0.03	1.8	0.5	2	5	2.5
07/22/05	22.7	22.3	0.25	3.35	1.5	0.15	0.6	1.7	5	2.5
07/29/05	22.5	28.33	1.3	4.93	0.03	2.2	0.5	2.7	5	2.5
08/03/05	22.6	28.65	0.25	4.73	0.03	2.6	0.7	2.1	4	2.5
08/10/05	23.4	23.31	0.9	4.03	0.03	2	0.6	2	4	2.5
08/17/05		26.61	0.25	5.53	0.03	3.3	0.3	2.2	4	2.5
08/24/05	23.2	31.83	3.8	3.73	0.03	1.8	0.2	1.9	30	2.5
08/31/05	23.5	28.13	1.9	4.43	0.03	2.4	0.4	2	6	2.5
09/14/05	22.7	26.28	0.25	4.53	0.03	2.6	0.4	1.9	11	2.5
09/21/05	22.4	24.15	0.7	2.76	0.06	1.2	0.8	1.5	7	2.5
09/28/05	21.5	23.86	2.5	3.63	0.13	2	0.3	1.5	2.2	2.5
10/05/05	19.9	19.74	0.25	3.59	0.09	2.1	0.1	1.4	1	2.5
Average	**23.0**	**20.4**	**2.3**	**6.0**	**0.1**	**3.3**	**1.1**	**2.5**	**5.8**	**3.3**
Median	**18.1**	**19.7**	**1.9**	**4.5**	**0.1**	**2.0**	**0.5**	**2.0**	**5.0**	**2.5**
St Dev	**21.4**	**5.1**	**2.2**	**4.0**	**0.2**	**3.7**	**2.0**	**2.4**	**4.8**	**4.5**

MALIBU, CA INSTALLATION

Malibu Creek Plaza Effluent Water Quality Data					Nitrex™ Treatment System								
	Constituent	BOD_5	Total Suspended Solids	Turbidity	Oil & Grease	TDS	Sulfate	Chloride	Total Nitrogen	Enterococcus (b)	Total Coliform	Flow @ Sampling Date	Average Monthly Flow
	Units	mg/l	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	MPN/ 100 ml	MPN/ 100 ml	gpd	gpd
Malibu Creek Plaza	Average	30.00	30.00	10.00	-	-	-	-	-	24.00			
Effluent Standards	Max	45.00	45.00	15.00	15.00	2,000	500	500	10.00	104.00			
Title 22 Unrestricted	Average			2.00							2		
Reuse Requirements	Max			10.00							23		
Sampling Location	Date												
DF-1	07/16/07											16,643	21,982
DF-1	07/26/07	164.00	36.00	18.60	9.00	620	6	189	11.47			12,215	21,982
DF-1	08/09/07	137.00	10.00	48.70					4.07			15,476	15,244
DD-1	08/16/07	70.00	10.00	11.80	<5	940	23	228	3.39			13,395	15,244
DF-1	08/23/07	57.00	37.00	38.20					6.49			11,325	15,244
DD-1	08/30/07	19.00	35.00	3.50					3.00			10,825	15,244
DD-1	09/04/07	11.00	6.00	3.00					4.13			11,234	11,778
DD-1	09/07/07	<5	<5	2.10					9.95			9,849	11,778
DD-1	09/11/07	<5	<5	1.70					4.96			10,930	11,778
DD-1	09/18/07	6.00	<5	1.00	<5	596	66	241	5.29	<1	<2	12,009	11,778
DD-1	09/25/07	<5	<5	1.00		584			4.60	<1	<2	10,668	11,778
DD-1	10/02/07	6.00	<5	1.50		644			3.99			13,531	11,950
DD-1	10/11/07	12.00	<5	1.80		636			4.14			10,266	11,950
DD-1	10/16/07	8.00	<5	0.40		652			3.87	<1	<2	13,386	11,950
DD-1	10/25/07	6.00	<5	1.20	<5	432	90	90	7.80	<1	2	11,713	11,950
DD-1	10/30/07	<5	<5	0.50		496			3.75	<1	<2	16,160	11,950
DD-1	11/01/07	<5	<5	1.00		512			3.31			10,936	11,692
DD-1	11/15/07	<5	<5	0.70	<5	540	59	212	3.14			14,014	11,692
DD-1	12/06/07	12.00	9.00	1.80	<5	688	62	270	3.57	<1	8	10,834	11,692
DD-1	01/17/08	6.00	<5	1.10	<5	604	50	162	4.73	<1	50	9,982	9,680
DD-1	02/14/08	<5	<5	5.40	<5	684	68	226	5.61	<1	<2	10,133	9,893
DD-1	03/12/08	<5	<5	1.90	<5	720	98	213	6.72	<1	<2	8,729	9,808
DD-1	04/17/08	<5	7.00	2.60	<5	660	87	205	9.17	<1	23	9,605	10,238
DD-1	05/07/08	<5	<5	1.80	<5	748	81	235	7.88	<1	1,600	8,355	9,475
DD-1	06/25/08	<5	8.00	1.40	<5	776	132	296	7.88	11.00	22	10,474	9,996
DD-1	07/24/08	<5	6.00	1.40	<5	652	82	167	9.46	<1	<2	11,200	11,057
DD-1	08/07/08	<5	<5	2.30	<5	604	76	193	7.20	<1	<2	9,413	10,255
DD-1	08/14/08		<5	0.70	<5	560	127	163	5.25	<1	<2	4,541	10,255
DD-1	08/22/08	8.00	<5	2.20	<5	620	110	149	5.03	<1	1,600	10,307	10,255
DD-1	08/29/08								7.41			10,524	10,255
DD-1	09/11/08								7.15			7,867	9,086
DD-1	09/19/08	5.00	<5	4.50	<5	760	85	224	7.52	1.00	<2	11,359	9,086
DD-1	09/26/08								4.83			9,498	9,086
DD-1	10/02/08								3.75			9,740	9,193
DD-1	10/09/08								4.28			10,591	9,193
DD-1	10/24/08								3.00			10,710	9,193
DD-1	10/30/08	<5	<5	1.00	<5	776	151	297	1.64	<1	30	11,359	9,193
DD-1	11/07/08	0.00	0.00	0.00	0.00	0	0	0	3.47	0.00	0	10,597	9,734
DD-1	11/20/08	<5	<5	3.70	<5	772	81	296	3.84	<1	<2	9,239	9,734
DD-1	11/26/08	0.00	0.00	0.00	0.00	0	0	0	3.90	0.00	0	10,444	9,734
DD-1	12/18/08	<5	<5	0.20	<5	736	81	308	3.54	1.00	<2	7,551	9,153
DD-1	01/28/09	<5	6.00	0.20	7.00	752	97	330	2.68	<1	23	7,817	8,094
DD-1	02/09/09								2.51			6,086	6,216
DD-1	02/19/09	<5	<5	0.90	<5	884	93	360	3.70	<1	<2	7,817	6,216
DD-1	02/26/09	<5	5.00	2.00	<5				2.32	<1	<2	6,039	6,216

Malibu Creek Plaza Effluent Water Quality Data					Nitrex™ Treatment System								
	Constituent	BOD_5	Total Suspended Solids	Turbidity	Oil & Grease	TDS	Sulfate	Chloride	Total Nitrogen	Enterococcus (b)	Total Coliform	Flow @ Sampling Date	Average Monthly Flow
	Units	mg/l	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	MPN/ 100 ml	MPN/ 100 ml	gpd	gpd
Malibu Creek Plaza Effluent Standards	Average	30.00	30.00	10.00	-	-	-	-	-	24.00			
	Max	45.00	45.00	15.00	15.00	2,000	500	500	10.00	104.00			
Title 22 Unrestricted Reuse Requirements	Average			2.00							2		
	Max			10.00							23		
Sampling Location	**Date**												
DD-1	03/05/09	<5	<5	0.70	<5				1.98	<1	<2	6,894	6,429
DD-1	03/12/09	<5	<5	0.40	<5				1.95	1.00	14	6,509	6,429
DD-1	03/19/09	<5	<5	<0.1	<5	896	115	290	2.33	<1	<2	6,144	6,429
DD-1	03/26/09	<5	<5	0.70	<5				2.19	<1	<2	6,959	6,429
DD-1	04/09/09	<5	6.00	0.30	<5				0.81	<1	<2	4,640	5,649
DD-1	04/16/09	50.00	39.00	35.40	<5				22.45	<1	1,600	4,634	5,649
DD-1	04/28/09	<5	<5	4.30	<5				9.81	3.10	1,600	4,255	5,649
DD-1	04/30/09	<5	<5	5.10	<5	1,012	146	365	7.42	<1	50	5,161	5,649
DD-1	05/07/09	<5	<5	2.60	<5				4.07	4.00	8	5,797	5,258
DD-1	05/14/09	<5	12.00	1.10	<5				3.39	<1	<2	5,785	5,258
DD-1	05/21/09	<5	8.00	3.00	<5	1,030	384	1,240	3.26	2.00	240	8	5,258
DD-1	05/28/09	<5	<5	0.40	<5				2.16	<1	<2	6,255	5,258
DD-1	06/04/09	<5	<5	0.90	11.00				2.29	<1	<2	6,997	7,139
DD-1	06/11/09	<5	<5	0.80	<5				2.00	<1	<2	6,916	7,139
DD-1	06/18/09	<5	<5	0.90	<5	916	101	325	1.60	<1	<2	8,992	7,139
DD-1	06/25/09	<5	<5	0.50	<5				1.92	<1	<2	6,923	7,139
DD-1	07/02/09	<5	<5	0.40	<5				1.55	<1	<2	6,570	6,372
DD-1	07/09/09	<5	<5	0.20	<5				1.60	1.00	<2	7,050	6,372
DD-1	07/15/09	<5	<5	0.60	<5				0.95	<1	<2	5,852	6,372
DD-1	07/22/09	<5	<5	0.30	<5	744	126	275	1.23	<1	<2	5,982	6,372
DD-1	08/06/09	<5	6.00	0.20	<5				1.21	<1	<2	6,193	6,986
DD-1	08/20/09	<5	<5	0.20	<5	778	86	230	0.67	<1	<2	9,899	6,986
DD-1	08/26/09	<5	<5	0.50	<5				1.38	<1	<2	7,255	6,986
DD-1	09/03/09	<5	<5	0.30	<5				1.92	<1	<2	6,779	6,938
DD-1	09/10/09	<5	<5	0.20	<5				1.13	<1	<2	5,754	6,938
DD-1	09/17/09	12	<5	0.20	<5	756	98	241	1.32	<1	<2	6,377	6,938
DD-1	09/24/09	12	<5	0.20	<5				1.31	<1	<2	6,844	6,938
DD-1	10/01/09	13.00	<5	0.30	<5				1.00	<1	<2	6,921	6,178
DD-1	10/07/09	<5	5.00	1.10	<5				1.06	1.00	<2	7,662	6,178
DD-1	10/14/09	15.00	<5	0.40	<5				1.13	<1	<2	6,116	6,178
DD-1	10/22/09	<5	<5	0.60	<5	744	97	225	0.85	<1	<2	5,550	6,178
DD-1	10/29/09	<5	<5	0.60	<5				0.75	<1	<2	4,852	6,178
DD-1	11/05/09	14.00	<5	0.10	<5				1.34	<1	<2	5,198	5,247
DD-1	11/13/09	<5	<5	1.20	<5				1.30	<1	<2	5,768	5,247
DD-1	11/19/09	<5	<5	0.30	<5	692	83	227	1.46	<1	8	5,251	5,247
DD-1	11/24/09	<5	<5	0.20	<5				1.04	4.10	<2	5,036	5,247

Malibu Creek Plaza Effluent Water Quality Data				Nitrex[TM] Treatment System									
	Constituent	BOD_5	Total Suspended Solids	Turbidity	Oil & Grease	TDS	Sulfate	Chloride	Total Nitrogen	Enterococcus (b)	Total Coliform	Flow @ Sampling Date	Average Monthly Flow
	Units	mg/l	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	MPN/ 100 ml	MPN/ 100 ml	gpd	gpd
Malibu Creek Plaza Effluent Standards	Average	30.00	30.00	10.00	-	-	-	-	-	24.00			
	Max	45.00	45.00	15.00	15.00	2,000	500	500	10.00	104.00			
Title 22 Unrestricted Reuse Requirements	Average			2.00							2		
	Max			10.00							23		
Sampling Location	**Date**												
July 2007 Avg.		164	36	19	9	620	6	189	11.47			14,429	21,982
Aug. 2007 Avg.		70.75	23.00	25.55	<5	940	23	228	4.24			12,755	15,244
Sept. 2007 Avg. [1]		4.90	3.20	1.76	<5	590	66	241	5.79	<1	<2	10,938	11,778
Oct. 2007 Avg [2]		6.90	<5	1.08	<5	572	90	90	4.71	<1	<2	13,011	11,950
Nov. 2007 Avg.		<5	<5	0.85	<5	526	59	212	3.23			12,475	11,692
Dec. 2007 Avg.		12.00	9.00	1.80	<5	688	62	270	3.57	<1	8	10,834	11,692
Jan. 2008 Avg.		6.00	<5	1.10	<5	604	50	162	4.73	<1	50	9,982	9,680
Feb. 2008 Avg.		<5	<5	5.40	<5	684	68	226	5.61	<1	<2	10,133	9,893
Mar. 2008 Avg.		<5	<5	1.90	<5	720	98	213	6.72	<1	<2	8,729	9,808
Apr. 2008 Avg.		<5	7.00	2.60	<5	660	87	205	9.17	<1	23	9,605	10,238
May 2008 Avg.		<5	<5	1.80	<5	748	81	235	7.88	<1	1,600	8,355	9,475
June 2008 Avg.		<5	8.00	1.40	<5	776	132	296	7.88	11.00	22	10,474	9,996
July 2008 Avg.		<5	6.00	1.40	<5	652	82	167	9.46	<1	<2	11,200	11,057
August 2008 Avg.		5.25	<5	1.73	<5	595	104	168	6.22	<1	533	8,696	10,255
September 2008 Avg.		5.00	<5	4.50	<5	760	85	224	6.50	1.00	<2	9,575	9,086
October 2008 Avg.		<5	<5	1.00	<5	776	151	297	3.17	<1	30	10,600	9,193
November 2008 Avg.		<5	<5	3.70	<5	772	81	296	3.74	<1	<2	10,093	9,734
December 2008 Avg.		<5	<5	0.20	<5	736	81	308	3.54	1.00	<2	7,551	9,153
January 2009 Avg.		<5	6.00	0.20	7.00	752	97	330	2.68	<1	23	7,817	8,094
February 2009 Avg.		<5	<5	1.45	<5	884	93	360	2.84	<1	<2	6,647	6,216
March 2009 Avg.		<5	<5	0.46	<5	896	115	290	2.11	<1	4	6,627	6,429
April 2009 Avg.		14.38	12.50	11.28	<5	1,012	146	365	10.12	1.15	813	4,673	5,649
May 2009 Avg.		<5	6.25	1.78	<5	1,030	384	1,240	3.22	1.75	63	4,461	5,258
June 2009 Avg.		<5	<5	0.78	4.63	916	101	325	1.95	<1	<2	7,457	7,139
July 2009 Avg.		<5	<5	0.38	<5	744	126	275	1.33	0.63	<2	6,363	6,372
August 2009 Avg.		<5	3.67	0.30	<5	778	86	230	1.09	<1	<2	7,782	6,986
September 2009 Avg.		7.25	<5	0.23	<5	756	98	241	1.42	<1	<2	6,439	6,938
October 2009 Avg.		7.1	3.00	0.60	<5	744	97	225	0.96	0.60	<2	7,292	6,178
November 2009 Avg.		5.4	<5	0.45	<5	692	83	227	1.29	1.4	2.8	5,313	5,247
Average from 9/1/07		3.97	3.73	1.90	2.75	754	105	290	4.50	1.06	118	8,861	9,037
Average from 10/1/08		4.22	3.85	1.63	2.97	821	124	358	2.82	0.75	67.4	7,290	7,232
Average from 10/1/08 excluding Operator error data		3.37	3.39	0.84	2.97	806	122	357	2.15	0.71	9.4	7,431	7,272

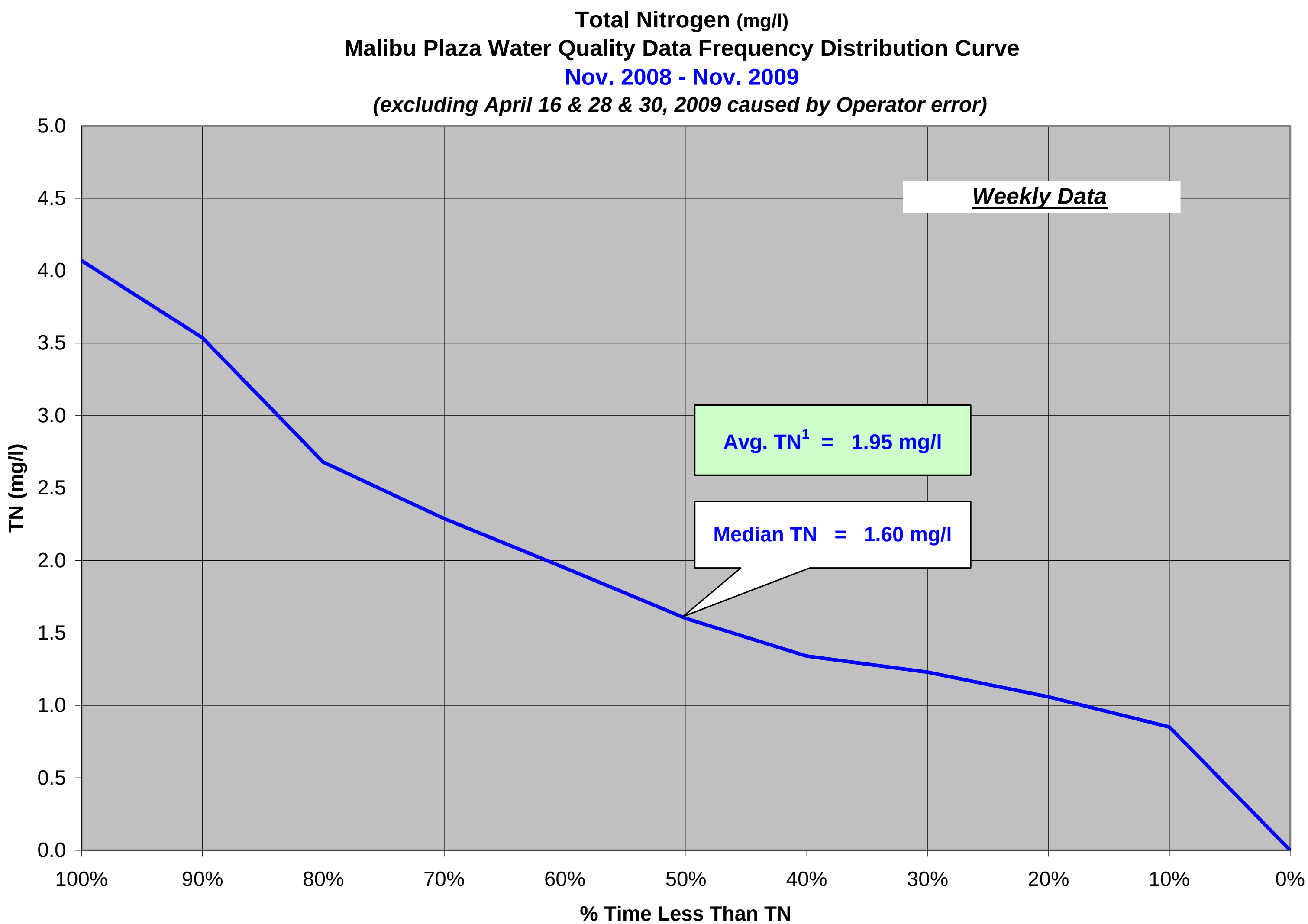
[1]The Sept TN Average does not include the September 7 sampling data, as the TN for this date was high due to start-up conditions.

[2]The Oct TN Average does not include the October 25 sampling data, as the TN for this date was high due to Operational Issues.

(a) The limits for coliform shall apply, prior to discharge of the effluent into the leach fields.

(b) The enterococcus limit is geometric mean of at least 5 equally spaced samples in any 30-day period.

DD-1 = Drainfield Discharge DF-1 = Disinfection Feed



[1] *41 Data Points*

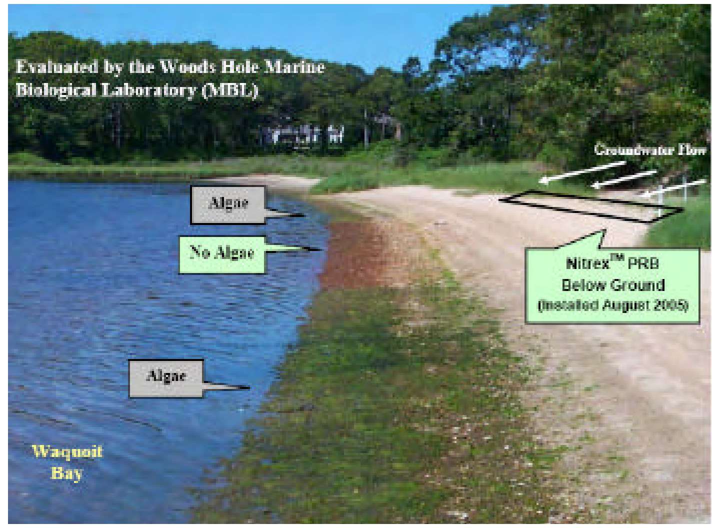
Environmental Engineers/Consultants
LOMBARDO ASSOCIATES, INC.

Environmental Engineers/Consultants
LOMBARDO ASSOCIATES, INC.

WAQUOIT BAY ESTUARINE RESEARCH CENTER GROUNDWATER TREATMENT

Project: Permeable Reactive Barrier (PRB)
Passive Groundwater Treatment
Nitrogen Removal

Wastewater Engineer: Pio Lombardo, P.E.
Lombardo Associates, Inc.
Boston, MA & Malibu, CA
617-964-2924
Pio@LombardoAssociates.com
www.LombardoAssociates.com

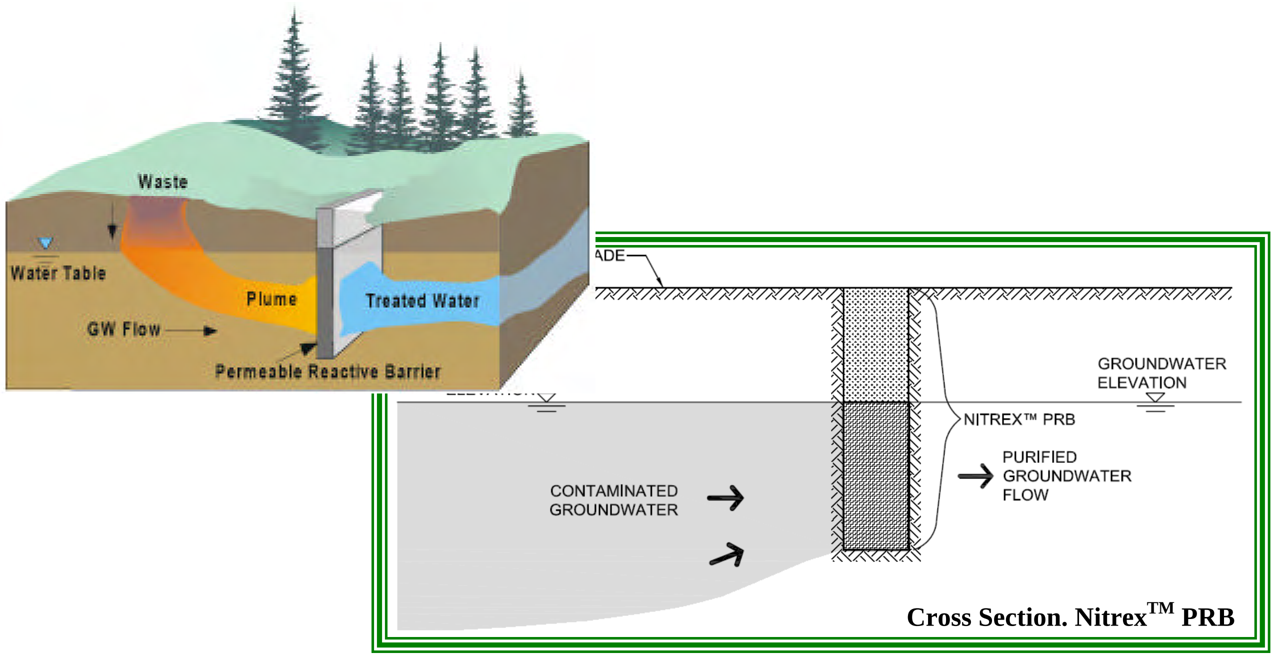


Site 1 – Nitrogen Removal – Cape Cod, MA

As part of a Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) funded demonstrated project, the Woods Hole Marine Biological Lab (MBL) retained Lombardo Associates, Inc. (LAI) for installation of the patented Nitrex™ groundwater nitrogen removal technology at two locations on Cape Cod, MA in the Waquoit Bay watershed.

Performance

Site	Influent Nitrate – N (mg/l)	Effluent Nitrate – N (mg/l)
Waquoit Bay, MA	1.74	0.007
Childs River, MA	7.19	0.568



Cross Section. Nitrex™ PRB

Site 2 – Nitrogen Removal – Southern New England

Two Nitrex™ PRBs were installed in a Rhode Island coastal watershed. Upstream and downstream concentrations of nitrate, ammonia, and dissolved organic nitrogen in the groundwater were monitored over two annual cycles. The dissolved inorganic nitrogen (DIN) levels are presented below.

Site	Influent DIN (mg/l)	Effluent DIN (mg/l)
Coastal Site #1	3.9	0.2
Coastal Site #2	3.7	0.1

DIN = Dissolved Inorganic Nitrogen = Ammonium + Nitrate + Nitrite

Site 3 – Perchlorate and Nitrogen Removal – Ontario, Canada

Ontario, Canada Site	Nitrate - N (mg/l)	Perchlorate (ug/l)
Influent	50	50
Effluent	<0.1	<0.2

Site 4 – Phosphorus Removal –Massachusetts Site

Massachusetts Site	Influent Phosphorus (mg/l)	Effluent Phosphorus (mg/l)
Site #1	1.7	0.1

Environmental Engineers/Consultants
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E-mail: pio@LombardoAssociates.com

MEMORANDUM

To: Tom Fudala, Town of Mashpee
Matthew Berrelli, Town of Mashpee
Don Desmarais, Town of Mashpee

Date: December 17, 2009

cc: Brian Howes, CSP/ SMAST
Ed Eichner, CSP/ SMAST
Gary Rubenstein, LAI
Brian Dudley, MADEP

From: Pio Lombardo, P.E.
Lombardo Associates, Inc. (LAI)

Re: Response to MEP Technical Memo on Popponesset Bay Analysis

1. Overview

Lombardo Associates, Inc. (LAI) was retained by the Mashpee Sewer Commission to prepare a Nitrex™ Technology based wastewater management plan for the Town of Mashpee for the Project Planning Area (PPA) of the East Waquoit and Popponesset Watersheds. The Nitrex™ Technology based plan was to achieve the TMDL requirements as specified by the Massachusetts Department of Environmental Protection, and thereby could be compared on an equal basis with the conventional sewering option for nitrogen management.

This memo is constructed in response to the MEP Technical Memo "Report on Unified Database and Requested MEP Scenarios" issued December 15, 2009.

2. Executive Summary

In response to the attached UMass Dartmouth December 15, 2009 memo on the TMDL model runs, Lombardo Associates, Inc. is submitting this memo to the Mashpee Sewer Commission. Following are summary comments/observations for your consideration.

Of the three East Waquoit watersheds examined, according to MEP, our Scenario # 3 did not achieve the TMDL requirements in any of the watersheds. The conventional Scenarios achieved TMDL requirements in 2 of the 3 watersheds.

In the **Hamblin Pond watershed** in Scenario 3, data quality control and management challenges - exacerbated by the numerous required iterations due to data quality issues and restricted budget - resulted in our having two drainfields in this watershed that need to be moved, with an estimated additional project capital cost of $1 - $ 2 million. This adjustment should result in TMDL compliance, as 100% of the buildout wastewater flow for Scenario 3 is proposed to be sewered with dispersal outside the watershed. Dispersal is proposed in a nearby watershed in which available land exists and there are no TMDL restrictions due to ocean draining hydrogeology.

In the **Jehu Pond watershed**, TMDL requirements are greater than wastewater N contributions so solely sewering will not achieve TMDL requirements for any Scenario. The LAI Scenario removed more nitrogen than the other Scenarios **so the results that the other Scenarios achieved TMDL compliance are very puzzling. Something is off**. The LAI Scenario removed 100% of the wastewater nitrogen. It is unclear how, given that Scenario 3 removes MORE TN and has a lower buildout TN load than the other four scenarios, it is the only one that does not meet the target.

In the **Quashnet River watershed**, of which no Scenario achieved TMDL requirements, it appears that our understandings (derived form the MEP Reports) of watershed natural attentuation and interbasin transfers - **for which we have not received from MEP requested confirmation of our estimates** - may be the cause of Scenario 3 non-attainment of TMDL requirement. Regardless, few properties (as only a few in the watershed have not been proposed to be sewered) will need to be sewered to achieve the additional required N removal. The cost for the additional N removal by sewering would be ~$6 million

All in all the additional costs for addressing the MEP identified issues would be an additional project costs of $8+/- million

Scenario 3 only examined the use of cluster systems. The next step was to identify where groundwater treatment would be used to lower costs and reduce sewering needs

In reference to further analysis and ongoing compliance certification, it is recommended that the Town either:

1. obtain the MEP model, or
2. obtain (i.e. have created) a complex or simplified input-output computer program that mimics sufficiently for planning purposes what the MEP model does

in order that optimization of the Town's Nitrogen Management Plan can be an ongoing activity to assist adaptive management that is expeditiously performed

It is noted that the existing modeling analysis is based on data that is 10+/- years old, the current method is not user friendly and is a very inefficient consumer of user resources. As a point of reference, Lombardo Associates, Inc. has extensive experience on water quality modeling, as author and user of the nationally used US EPA water quality model.

3. Jehu Pond Analysis

- In Scenario #3, **81.4%** of the parcels in the Jehu Pond / Great River subwatershed are sewered, capturing **99.8%** of the wastewater flow. The remaining 0.2% is a single parcel that for this area would most efficiently be connected to the existing cluster system.

Table 1. Jehu Pond and Great River Parcel & Wastewater Flow Summary

Category	# Parcels	Buildout WW Flow (gpd)	% Total
Cluster Systems	500	75,074	99.8%
Future I/A Systems	1	140	0.2%
Subtotal	501	75,214	100%
Existing Title V Systems that will Remain On-site [1]	1	30	0.0%
Undeveloped / Undevelopable	112	0	0.0%
Total	614	75,244	100.0%

[1] Data values are from Unified Database. We suspect this is a seasonally used parcel.

- The Jehu Pond subwatershed does not have any contributory watersheds, however it is connected to the Great River, and for analytical purposes, was grouped with the Great River subwatersheds in the TMDL report.
- A Target Threshold Nitrogen Load was taken from the TMDL and used by LAI to determine the required TN load reduction for the combined subwatersheds.
- Even with 100% sewering of all existing and future parcels, the target threshold subwatershed TMDL requirements can not be met.
- All parcels within these three subwatersheds are being served by cluster systems that discharge outside the subwatersheds, resulting in a 100% removal of existing and future septic TN loads for Scenario 3.
- This exceeds the TN removal in any of the other four scenarios.
- Table 2 compares the percent removal and the buildout TN load for the centralized Scenario 1 (which has the lowest Jehu Pond modeled TN concentration) and Scenario 3.

- ***It is unclear how, given that Scenario 3 removes MORE TN and has a lower buildout TN load than the other four scenarios, it is the only one that does not meet the target.***

Table 2. MEP Model Results for Scenarios 1 and 3*

East Waquoit Bay Subembayment	MEP Buildout Load (kg/day)	Threshold (kg/day)	Threshold % Change	Scenario 1: S&W		Scenario 3: LAI	
				BO Load (kg/day)	% Change	BO Load (kg/day)	% Change
Lower Great River	3.37	0.600	-82.2%	0.688	-79.6%	0.688	-79.6%
Upper Great River	1.58	0.320	-79.8%	0.359	-77.3%	0.359	-77.3%
Jehu Pond	4.01	0.960	-76.0%	1.153	-71.2%	1.058	-73.6%
Total	8.96	1.880	79.0%	2.200	75.4%	2.105	76.5%

** Values taken from Table 3 of the December 15, 2009 MEP Technical Memo*

4. Hamblin Pond Analysis

- In Scenario #3, **83.6%** of the parcels in the Hamblin Pond subwatershed are sewered, capturing **99.5%** of the wastewater flow.
- The remaining 0.5% is all buildout flow which will be treated either with an I/A system or by connection to the cluster system.

Table 3. Hamblin Pond Parcel & Wastewater Flow Summary

Category	# Parcels	Buildout WW Flow (gpd)	% Total
Cluster Systems	875	163,308	99.5%
Future I/A Systems	6	840	0.5%
Subtotal	881	164,148	100%
Existing Title V Systems that will Remain On-site	0	0	0.0%
Undeveloped / Undevelopable	166	0	0.0%
Total	1,047	164,148	100.0%

- The following four subwatersheds were combined into one for analytical purposes in the TMDL report:
    1. Red Brook
    2. Upper Hamblin
    3. Hamblin Pond
    4. Little River
- The target threshold TN contribution was taken from the TMDL report and LAI concluded that 79% of the existing septic loads would need to be removed to meet the target threshold concentration.
- Scenario 3 sewers 100% of the parcels in these combined subwatersheds, however the effluent from two cluster systems, Cluster #4 and Cluster #6, is discharged into the Red Brook subwatershed.
- The result exceeded the target threshold TN load associated with the combined watersheds.
- ***Given that 100% of the parcels are sewered, the only way to reduce TN concentrations is to move the discharge locations outside of the watershed.***
- Moving the discharge location would involve approximately 1,800 ft of force main to transport effluent flows from Cluster 4 and Cluster 6 to a new site.

5. Quashnet River Analysis

- In Scenario #3, **69.8%** of the parcels in the Quashnet River subwatershed are sewered, capturing **65.1%** of the wastewater flow.

Table 4. Quashnet River Parcel & Wastewater Flow Summary

Category	# Parcels	Buildout WW Flow (gpd)	% Total
Cluster Systems	1509	320,091	65.1%
Future I/A Systems	128	125,930	25.6%
Subtotal	1,637	446,021	90.8%
Existing Title V Systems that will Remain On-site	188	45,397	9.2%
Undeveloped / Undevelopable	336	0	0.0%
Total	2,161	491,417	100.0%

- LAI's analysis of the required removal was heavily dependent on natural attenuation and pond outflow percentage assumptions derived from MEP reports and spreadsheets. LAI requested but never received the individual watershed attenuations and pond outflow percentages that are critical in determining the required TN removal from each subwatershed.
- **The target threshold watershed TN load appears to have been lowered from 15.92 kg/day published in the 2005 TMDL report to 11.96 kg/day in the December 15, 2009 MEP Technical Memo.**
- LAI calculated a final Scenario 3 watershed TN load of 11.3 kg/day for the Quashnet River subwatershed. The MEP analysis reports the Scenario 3 TN load at 18.762. As mentioned above, this analysis is heavily dependent on natural attenuations and pond outflow percentage assumptions that LAI requested validation on and never received.

6. <u>Lombardo Associates, Inc. (LAI) Sewered Parcel Analysis</u>

Table 6 illustrates the Lombardo Associates, Inc. Scenario sewered parcel analysis for the Project Planning Area (PPA), which consists of the East Waquoit Bay and Popponesset Bay Watersheds.

Table 5. Scenario 3 Summary

Category	# Parcels	Buildout WW Flow (gpd)	% Total
Cluster Systems	7843	1,590,513	74.4%
Future I/A Systems	440	216,372	10.1%
Subtotal	8,283	1,806,885	84.5%
Existing Title V Systems that will Remain On-site	1444	332,140	15.5%
Undeveloped / Undevelopable	1786	0	0.0%
Total	11,513	2,139,025	100.0%

- **85% of the wastewater flow is proposed to be treated.**

Flow Discrepancies

On November 13, 2009, MEP issued a memorandum summarizing the results of the model run for the Lombardo Associates, Inc. (LAI) decentralized wastewater management scenario (Scenario 3) along with results of four (4) other scenarios, using conventional wastewater technology, developed for the Town. In LAI's December 4, 2009 Response Memo, the following discrepancy was reported with respect to I/A system flows:

- MEP Report – 306,825 gpd
- LAI Scenario – 56,140 gpd

In addition, two separate emails to Ed Eichner, dated 11/30/09 and 12/04/09, restated the discrepancy and requested clarification on the issue as well as information on the basis of their flow numbers. To date, LAI has not received any response. The December 15, 2009 MEP Technical Memo published the same I/A flows with no mention of the publicized discrepancy.

Data management issues were discovered that accounted for approximately two thirds of the discrepancy, however in summarizing total flows associated with Cluster, Future I/A and Title V parcels additional discrepancies were discovered. As seen in Table 5, future I/A systems represent 216,372 gpd across the entire study area. This is still significantly different than the 306,825 gpd from the MEP Technical Memos. In addition, the Title V and Cluster System flows are also inconsistent. LAI's wastewater flows are summaries taken directly from the version of the Unified Database that was furnished by SMAST and are not affected by discharge location.

7. Issue of Flow Balance Analysis

Figure 3 illustrates the following parcel designations for the PPA:

- Title 5 Properties that will Remain Onsite
- Cluster Sewers
- I/A Systems
- Undeveloped Parcels/Public Land

Table 6 summarizes the parcel and wastewater flow information for the East Waquoit Bay PPA.

Table 6. Parcel Analysis for the East Waquoit Bay PPA

Category	# Parcels	Buildout WW Flow (gpd)	% Total
Cluster Systems	2884	558,473	76.4%
Future I/A Systems	135	126,910	17.4%
Subtotal	3,019	685,383	93.8%
Existing Title V Systems that will Remain On-site	189	45,427	6.2%
Undeveloped / Undevelopable	614	0	0.0%
Total	3,822	730,810	100.0%

8. Recommendations

It is recommended that the Town either:

1. obtain the MEP model, or
2. obtain (i.e. have created) a complex or simplified input-output computer program that mimics sufficiently for planning purposes what the MEP model does

in order that optimization of the Town's Nitrogen Management Plan can be an ongoing activity to assist adaptive management that is expeditiously performed

It is noted that the existing modeling analysis is based on data that is 10+/- years old and the current method is not user friendly and is a very inefficient consumer of user resources. As a point of reference, Lombardo Associates, Inc. has extensive experience on water quality modeling, as author and user of the nationally used US EPA water quality model.

Lastly, Scenario 3 only examined the use of cluster systems. The next step was to identify where groundwater treatment would be used to lower costs and reduce sewering needs.

Pio Lombardo

From: Pio Lombardo
Sent: Tuesday, December 29, 2009 06:22 PM
To: 'Brian Howes'
Cc: 'eichner@comcast.net'; 'townplanner@ci.mashpee.ma.us'; 'mberrelli@hotmail.com'; 'donald.desmarais@town.barnstable.ma.us'; Gary Rubenstein; ''Ed Eichner'; Jerid Grandinetti
Subject: MEP East Waquoit Bay Memo - Scenario 3 Addendum
Attachments: 091229 E Waquoit attentuation factors.xls; 091228 Reference Documents Combined.pdf; 091229 Letter to MEP Eichner Revised Scenario 3.pdf

Brian

Based upon detailed further analysis, it _appears_ to Lombardo Associates, Inc. that causes for Scenario 3 not achieving TMDL compliance in the East Waquoit Bay watersheds are described below. We look forward to receiving your comments on these matters.

I. Scenario # 3 Causes for non TMDL Compliance

1. Little River/Hamblin Pond & Great River/Jehu Pond Watersheds

Rainbow Spreadsheet attenuation of 50% for Red Brook as stated in the MEP Report appears to be different from what is used in the model and we have deduced that 0% should be used. (Reference Table IV-5 on page 37 of the MEP Linked Watershed Embayment Model- Waquoit Bay Final Report, Jan. 2005 - copy attached)
Please advise/confirm.

2. Quashnet River Watershed

LAI's understanding of Attenuation Factors, Pond Outflow Apportionment and Updated Land Use contributions need revision.

Attached are the Quashnet River Watershed Attenuation Factors and Pond Outflow Apportionment that we have used and summarized on Table 3.3.5 on page 38 of the LAI Final Technology Scenario Plan (August 2008), and discussed in Ed Eichner's email response (May 2008) re: Quashnet River attenuation and LAI Memo to Tom Fudala (May 2008) re: Nitrogen Loadings - copies attached. ***Please advise of any needed attenuation modifications as something is off***

Based upon the above and the December 15, 2009 memo, we have deduced that the following revisions are necessary for Scenario 3 TMDL compliance

II. Deduced Scenario # 3 Needed Revision

1. Little River/Hamblin Pond & Great River/Jehu Pond Watersheds

Table 3 of the MEP December 15, 2009 memo suggests 0.466 kg/day N removal is required for Scenario # 3 to be TMDL compliant for these watersheds. ***Please confirm as well as provide proper attenuation for Red Brook.***

2. Quashnet River Watershed

Table 4 of the MEP December 15, 2009 memo suggests 2.2 kg/day attenuated N removal is required for Scenario # 3 to be TMDL compliant. ***Please confirm as well as provide proper attenuation for Quashnet subwatersheds or confirm what we are using is correct***

We propose to achieve those revisions as follows

III. Proposed Scenario # 3R Revisions

1. Little River/Hamblin Pond & Great River/Jehu Pond Watersheds

Move clusters # 4 & 6 drainfield discharges to adjacent, nearby ocean discharge watershed. This removes > 0.5 kg/day of N from watersheds. Assuming attenuation of 0% for Red Brook, this removes 3.5 kg/day, or with attenuation of 50% for Red Brook this removes 1.75 kg/day

2. Quashnet River Watershed

The attenuation factors are needed for us to properly make the optimal determination, as there are a number of additional N removal options available. However pending receipt of the correct Attenuation Factors, Pond Outflow Apportionment and Updated Land Use contributions, we are proposing:

- a. moving cluster # 15 drainfield discharge to adjacent, nearby ocean discharge watershed. This removes 0.8 +/- kg/day of attenuated N from watershed.
- b. Sewering Title 5 and I/A systems which removes net 2.5 +/- kg/day of attenuated N from watershed

The shapefiles and database with this Scenario #3 R have been sent FedEx on a CD with the attached transmittal letter to Ed Eichner. You will note that no changes were made to Popponesset Bay watershed parcels.

Pio

Pio Lombardo, P.E. | Lombardo Associates, Inc. | Environmental Engineers Consultants | Tel: 617-964-2924 | Cell: 617-529-4191| Fax: 617-332-5477
Email: Pio@LombardoAssociates.com | www.LombardoAssociates.com

From: Brian Howes [mailto:bhowes@umassd.edu]
Sent: Friday, December 18, 2009 02:06
To: Pio Lombardo; townplanner@ci.mashpee.ma.us; mberrelli@hotmail.com
Cc: brian.dudley@state.ma.us; eichner@comcast.net; donald.desmarais@town.barnstable.ma.us
Subject: Re: MEP East Waquopit Bay Memo - LAI Response

Pio,

Let's see if we can save some time.

Question #1:

Re: Jehu Pond Watershed

- ***How, given that Scenario 3 removes MORE TN and has a lower buildout TN load than the other four scenarios, it is the only one that does not meet the target.***

Jehu Pond and Hamblin Pond do not act as independent systems (they join via the confluence of the Great and Little Rivers). So while Scenario 3 Jehu Pond has 86 kg/yr less than the highest of the other scenarios, the Hamblin Pond watershed load for Scenario 3 has 289-684 kg more load than the other scenarios. Scenario 3 for the combined Jehu/Hamblin watershed load has 203-608 kg more load than the other scenarios. Also note that it did lower the TN concentration from 0.603 to 0.472 mg/L and 0.528 to 0.400 mg/L approaching the desired threshold values.

Question #2:

Re: Quashnet River Watershed

The target threshold watershed TN load appears to have been lowered from 15.92 kg/day published in the 2005 TMDL report to 11.96 kg/day in the December 15, 2009 MEP Technical Memo. What is the basis?

You are correct on this. The MEP Final Report has a load of 15.92 kg/day for the Threshold watershed load for Scenario B. This is also what is in the TMDL. It is not what is in Table 4 or Appendix Table C-2. Checking, it is clear that there was a copying error in the preparation of the tables and they need to be fixed. HOWEVER, these tables (Table 4 and Append Table C-2) in the Tech Memo are provided only for reference for the reader and are not used in any of the analysis. In addition, the Threshold load is only 1 example of how one might meet the target concentration, so a management plan can have very different numbers and still work. So, while I thank you for catching this, the threshold load has not been changed, nor does the copy error affect the results or interpretation in any way.

Hope everyone has a Happy Holiday and keeps warm.

Best, Brian Howes

----- Original Message -----
From: Pio Lombardo
To: townplanner@ci.mashpee.ma.us ; mberrelli@hotmail.com
Cc: brian.dudley@state.ma.us ; eichner@comcast.net ; bhowes@umassd.edu ; donald.desmarais@town.barnstable.ma.us

Sent: Friday, December 18, 2009 9:10 AM
Subject: RE: MEP East Waquopit Bay Memo - LAI Response

Commissioners,

It is requested that MEP be directed to explain

Re: Jehu Pond Watershed

- ***How, given that Scenario 3 removes MORE TN and has a lower buildout TN load than the other four scenarios, it is the only one that does not meet the target.***

Re: Quashnet River Watershed

The target threshold watershed TN load appears to have been lowered from 15.92 kg/day published in the 2005 TMDL report to 11.96 kg/day in the December 15, 2009 MEP Technical Memo. What is the basis?

Thank you

Pio

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MEMORANDUM

To: Tom Fudala, Town of Mashpee
Matthew Berrelli, Town of Mashpee
Don Desmarais, Town of Mashpee

Date: January 21, 2009

From: Pio Lombardo, P.E.
Lombardo Associates, Inc. (LAI)

cc: Brian Howes, CSP / SMAST
Ed Eichner, CSP / SMAST
Gary Rubenstein, LAI

Re: Response to MEP Technical Memo on Popponesset Bay Analysis

1. Overview

On November 13, 2009, MEP issued a memorandum of the results of the model run for the Lombardo Associates, Inc. (LAI) decentralized wastewater management scenario (Scenario 3) along with results of 4 other scenarios, using conventional wastewater technology, developed for the Town.

Due to its relative insignificance on the project and to address the question of the proper Title 5 I/A effluent quality that can be assumed for TMDL purposes, Lombardo Associates, Inc. has removed the Title 5 I/A system option for demonstrating TMDL compliance in the Nitrex based Scenario 3, which relies solely on cluster systems for existing and buildout wastewater Nitrogen removal.

As stated in the 29 December 2009 email and transmittal package, all I/A parcels in the East Waquoit Bay watershed have been added to existing clusters and included in the December 29, 2009 Scenario 3R documents

For the Popponesset Bay watershed, the parcels with proposed I/A treatment have been added to existing clusters or designated as a conventional Title 5 system, hereinafter referred to as Scenario 3R2

2. Scenario 3R2 – Change to No I/A systems in Popponesset Watershed

Lombardo Associates, Inc. (LAI) used the following method in producing the revised Popponesset Bay Scenario 3R2 to eliminate any parcels being treated by I/A systems:

- Assign I/A parcels within proximity to an existing cluster to that cluster, or otherwise to a Title 5 system category.

- Add sufficient Title 5 parcels to clusters to remove the equivalent nitrogen load contributed by the redesignated I/A parcels in each subwatershed.
- The shapefiles and database have been created that reflect these changes in the Popponesset Bay watershed. No changes from the Scenario 3R were made in the East Waquoit Bay watershed in Scenario 3R2.

3. Transmittal & Verification

The revised Scenario 3R2 has been submitted to MEP for determination that it achieves TMDL compliance in the Popponesset watershed and that no changes were made to the East Waquoit watershed from the Scenario 3R vesrion.