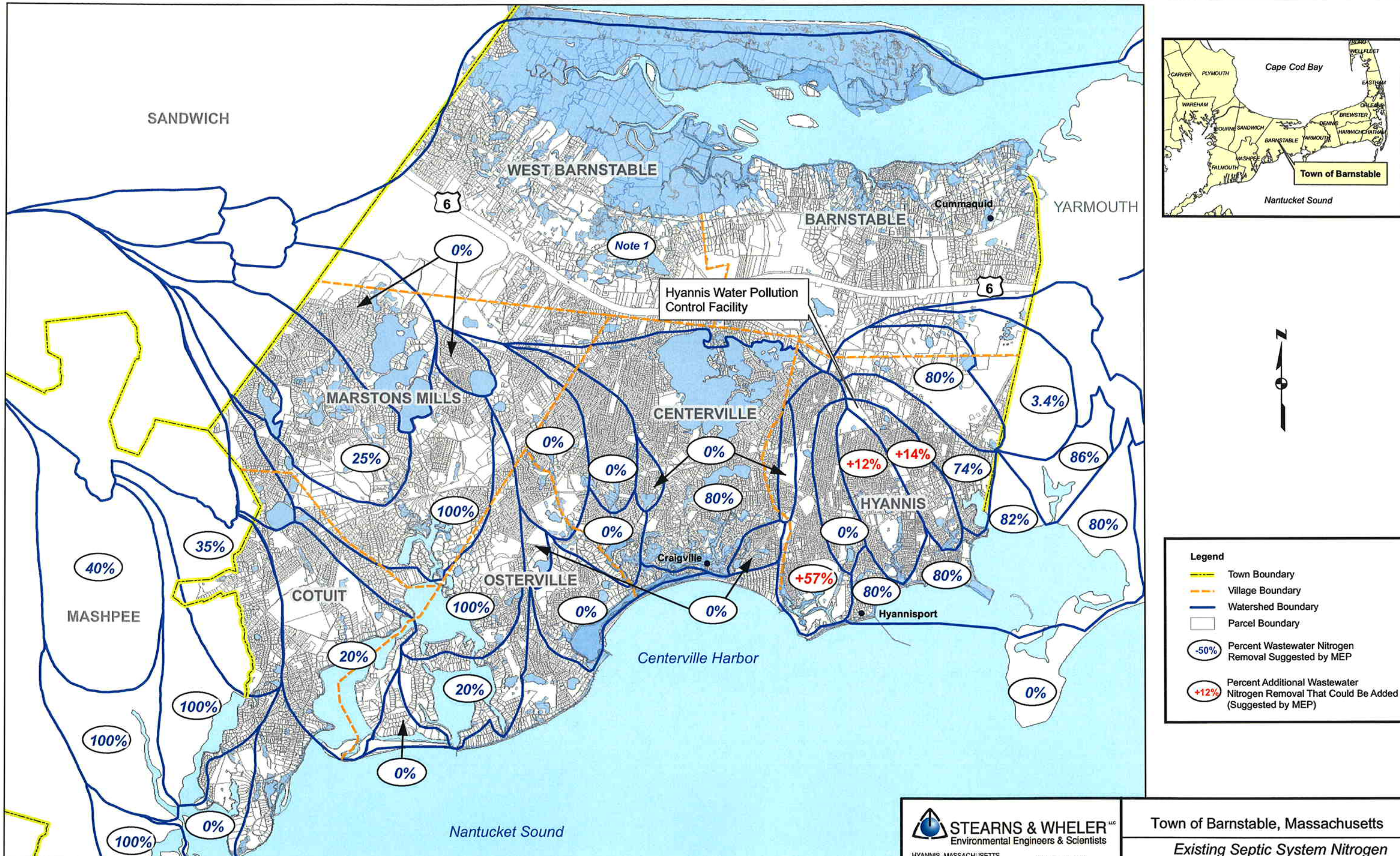
Appendix 5-4

Nitrogen Removal Information Suggested by the Massachusetts Estuaries Project (MEP) on a Subwatershed Basis



Data Source: Mass GIS, Mass Estuaries Project, ESRI

File Location: I:\Jobs\80000\861247400 Barnstable\Figures\Figure 5.1 revisions\Figure N-1.mxd

Notes:
1.) Nitrogen Limits have not been developed as of May 2010
2.) Based on Massachusetts Estuaries Project and MassDEP evaluations and reports.

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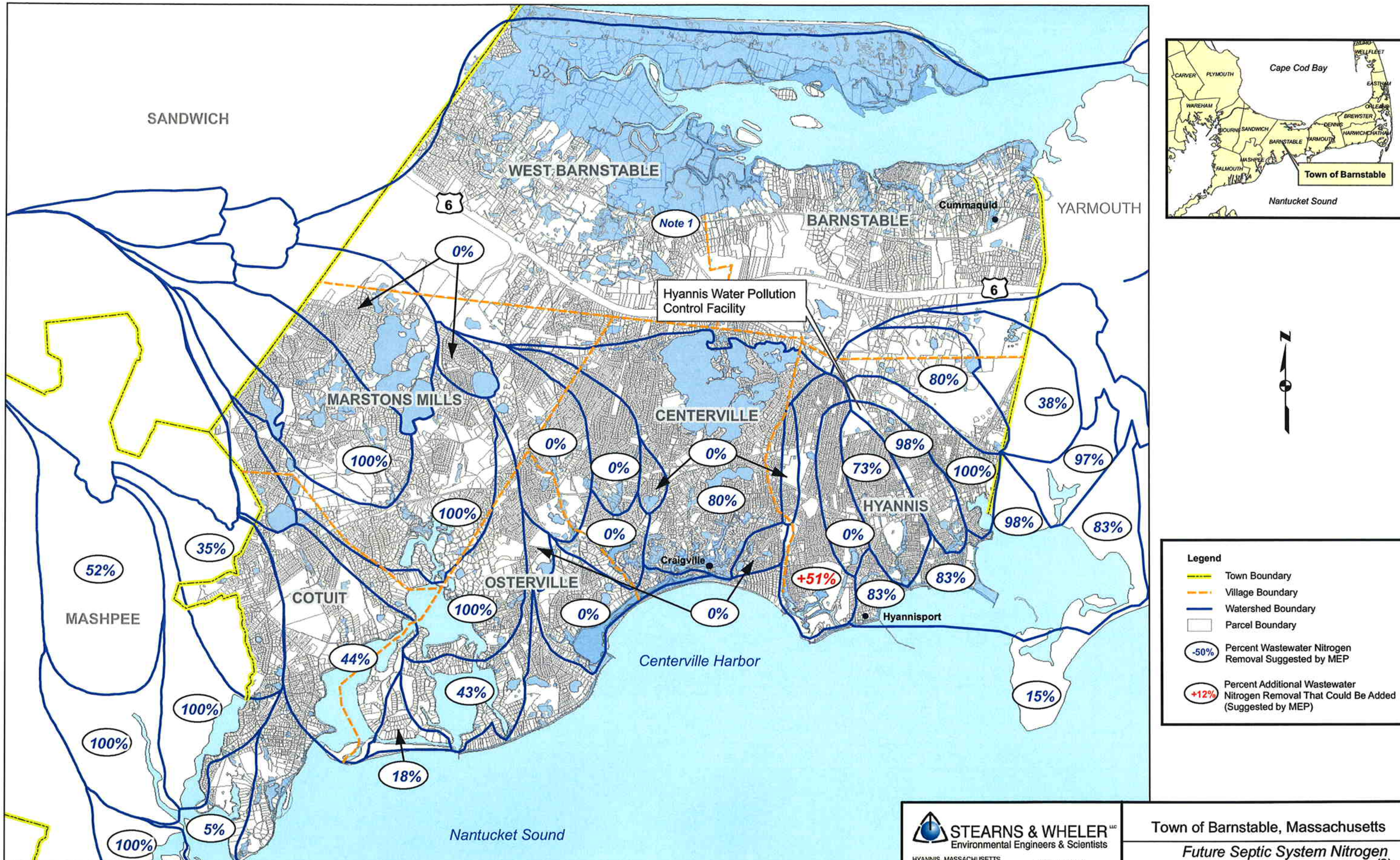
Date: 4/29/2010

Town of Barnstable, Massachusetts

Existing Septic System Nitrogen Removals to Meet TMDLs (2)

FIGURE N-1



Data Source: Mass GIS, Mass Estuaries Project, ESRI

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Barnstable SRF\Figures\Nutrient Management March 2010\Figure N-2 .mxd

Notes:
1.) Nitrogen Limits have not been developed as of May 2010
2.) Based on Massachusetts Estuaries Project and MassDEP evaluations and Reports.

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Town of Barnstable, Massachusetts

Future Septic System Nitrogen Removals to Meet TMDLs (2)

FIGURE N-2

PB-1

Map #	Sub-Embayment Name
1	Snake Pond GT10
2	Snake Pond LT10
3	Pimlico Pond GT10
4	Pimlico Pond LT10
5	Peters Pond GT10
6	Peters Pond LT10
7	Mashpee-Wakeby Pond GT10 W
8	Mashpee-Wakeby Pond GT10 E
9	Mashpee-Wakeby Pond LT10
10	Santuit Pond GT10
11	Santuit Pond LT10
12	Upper Mashpee River GT10 W
13	Upper Mashpee River GT10 E
14	Upper Mashpee River LT10
15	Lower Mashpee River GT10
16	Lower Mashpee River LT10
17	Quaker Run
18	Santuit River GT10
19	Santuit River LT10
20	Shoestring Bay GT10
21	Shoestring Bay LT10
22	Pinquickset Cove
23	Ockway Bay GT10
24	Ockway Bay LT10
25	Popponesset Creek
26	Popponesset Bay
27	Quaker Run Well
28	Cotuit Well #5
29	Rock Landing Wells

Legend
- Town Boundary
- Bodies of Water
- Public Water Supplies (PWS)
- MEP Sub-Watershed Boundaries
- Ten Year Time-of-Travel Line

Popponesset Bay Sub-Embayments
- Fresh Water
- Mashpee River
- Ockway Bay
- Pinquickset Cove
- Popponesset Bay
- Popponesset Creek
- Shoestring Bay
- Public Water Supplies

USGS

Cape Cod Commission

the estuaries project
southeastern massachusetts embayments restoration

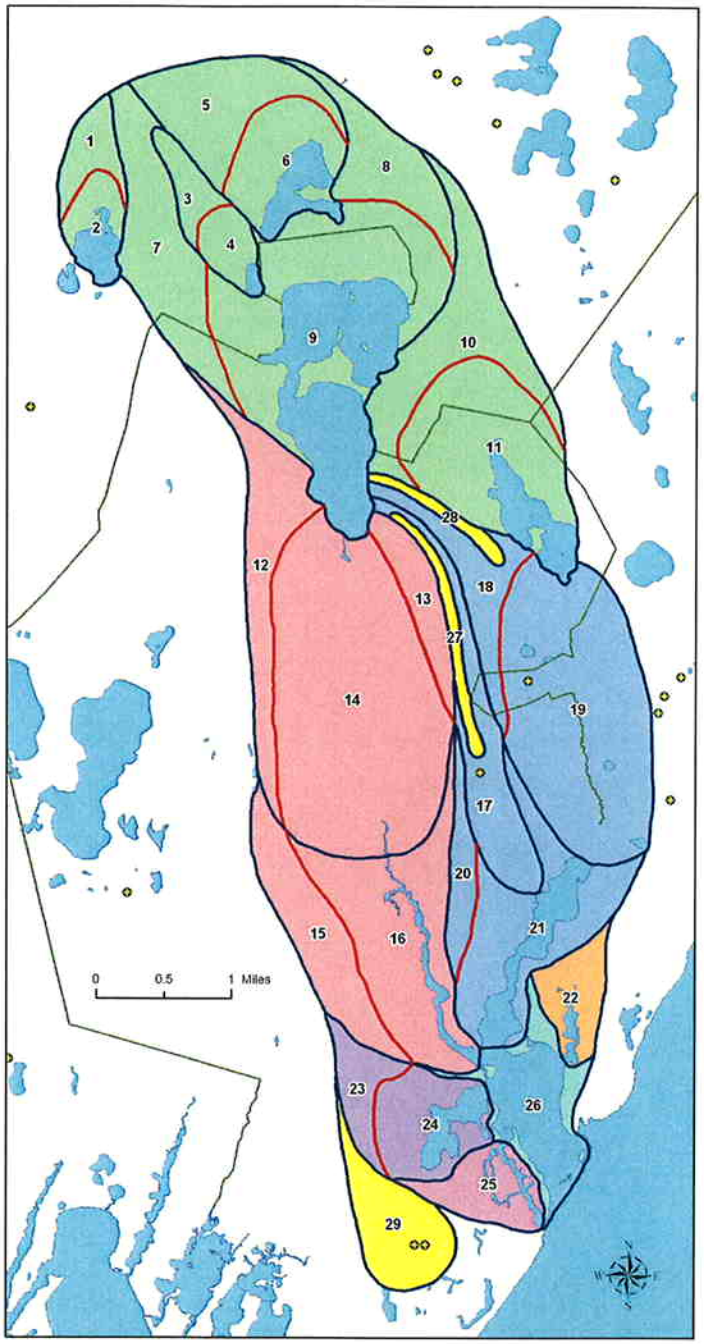

Figure III-1. Watershed and sub-watershed delineations for Popponesset Bay. Approximate ten year time-of-travel delineations were produced for quality assurance purposes and are designated with a "10" in the figure legend (above at left). Sub-watersheds to embayments were selected based upon the functional estuarine sub-units in the water quality model (see section VI).

PB-2

lower freshwater and salt water reaches of the Mashpee and Santuit Rivers provide opportunities for enhancing natural attenuation of their nitrogen loads. Restoration or enhancement of wetlands and ponds associated with the lower ends of rivers and streams discharging to estuaries is seen as providing a dual service of lowering infrastructure costs associated with wastewater management and increasing aquatic resources associated within the watershed and upper estuarine reaches.

Although the above modeling results provide one manner of achieving the selected threshold levels for the sentinel site within this estuarine system, the specific examples do not represent the only method for achieving this goal. However, the thresholds analysis provides general guidelines needed for the nitrogen management of this embayment. As the restoration process continues, the MEP will work with the Towns of Mashpee and Barnstable to develop additional specific water quality modeling scenarios, to be run to evaluate other nitrogen removal strategies. One such proposed scenario, removing the discharges from the existing wastewater facilities from the watershed (pipeline), was partially evaluated by the MEP Team. At present only a tiny fraction (<0.5%) of the watershed nitrogen loading is discharged by the existing treatment facilities. Removing this load would have a very small impact. However, with increased sewering and treatment of wastewater, discharge within the groundwatershed directly discharging to Nantucket Sound has merit. The existing MEP analysis and model provides for the determination of potential discharge sites and the concomitant improvement of the nutrient related habitat quality within the Popponesset Bay System.

Table VIII-1. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Popponesset Bay system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present septic load (kg/day)	threshold septic load (kg/day)	threshold septic load % change
Popponesset Bay	1.58	1.58	0.0%
Popponesset Creek	4.00	0.00	-100.0%
Pinquickset Cove	0.58	0.58	0.0%
Ockway Bay	2.39	0.00	-100.0%
Mashpee River	9.61	0.00	-100.0%
Shoestring Bay	6.94	0.00	-100.0%
Surface Water Sources			
Mashpee River	9.96	5.85	-41.3%
Santuit River (Shoestring Bay)	11.69	7.58	-35.2%
Quaker Run River (Shoestring Bay)	4.69	4.69	0.0%
TOTAL	51.12	19.96	-61.0%

RM-1

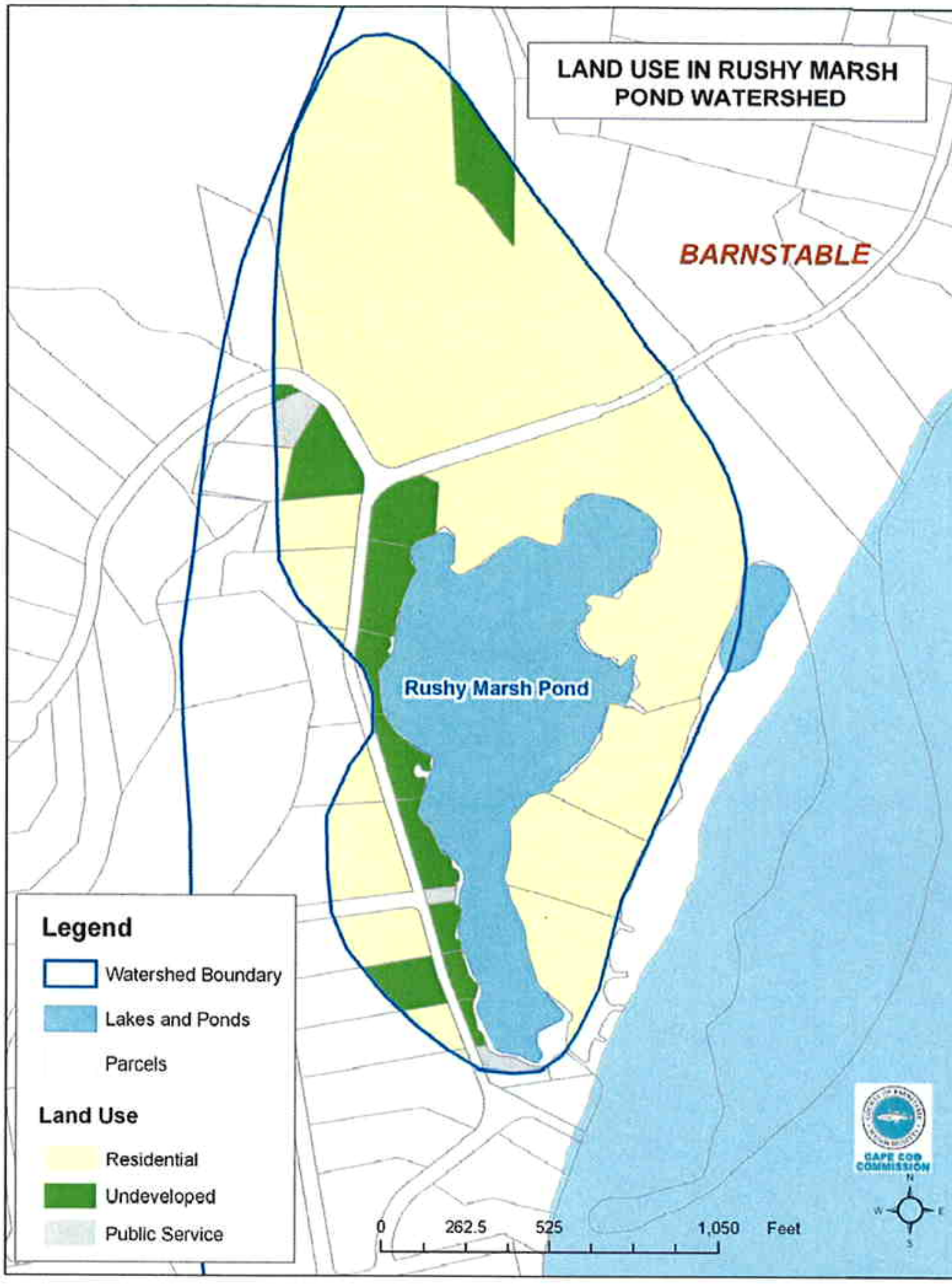

Figure IV-1. Land-use coverage in the Rushy Marsh watershed. Land use classifications are based on assessors' records provided by the Town of Barnstable. Note the shoreline overlaying the water of Nantucket Sound represents the shoreline of 19XX, while the present barrier beach shoreline is shown to the west (white/blue interface). The small pond in the barrier beach is all that remains today of the larger cove created by the spit.

RM-2

Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Rushy Marsh system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present septic load (kg/day)	threshold septic load (kg/day)	threshold septic load % change
Rushy Marsh	0.353	0.000	-100.0%

Tables VIII-3 and VIII-4 provide additional loading information associated with the thresholds analysis. Table VIII-3 shows the change to the total watershed loads, based upon the removal of septic loads depicted in Table VIII-2. Removal of 100% of the septic load from the watershed of Rushy Marsh results in an 79% reduction in total nitrogen load. Table VIII-4 shows the breakdown of threshold sub-embayment loads used for total nitrogen modeling. In Table VIII-4, loading rates are shown in kilograms per day, since benthic loading varies throughout the year and the values shown represent 'worst-case' summertime conditions. The benthic flux for this modeling effort is reduced from existing conditions based on the load reduction and the observed particulate organic nitrogen (PON) concentrations within each sub-embayment relative to background concentrations in Nantucket Sound.

Table VIII-3. Comparison of sub-embayment ***total attenuated watershed loads*** (including septic, runoff, and fertilizer) used for modeling of present and threshold loading scenarios of the Rushy Marsh system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	present load (kg/day)	threshold load (kg/day)	threshold % change
Rushy Marsh	0.447	0.093	-79.1%

Table VIII-4. Threshold sub-embayment loads and attenuated surface water loads used for total nitrogen modeling of the Rushy Marsh system, with total watershed N loads, atmospheric N loads, and benthic flux

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Rushy Marsh	0.093	0.203	-0.113

Comparison of model results between existing loading conditions and the selected loading scenario attempting to achieve the target TN concentrations at the sentinel station is shown in

TB-1

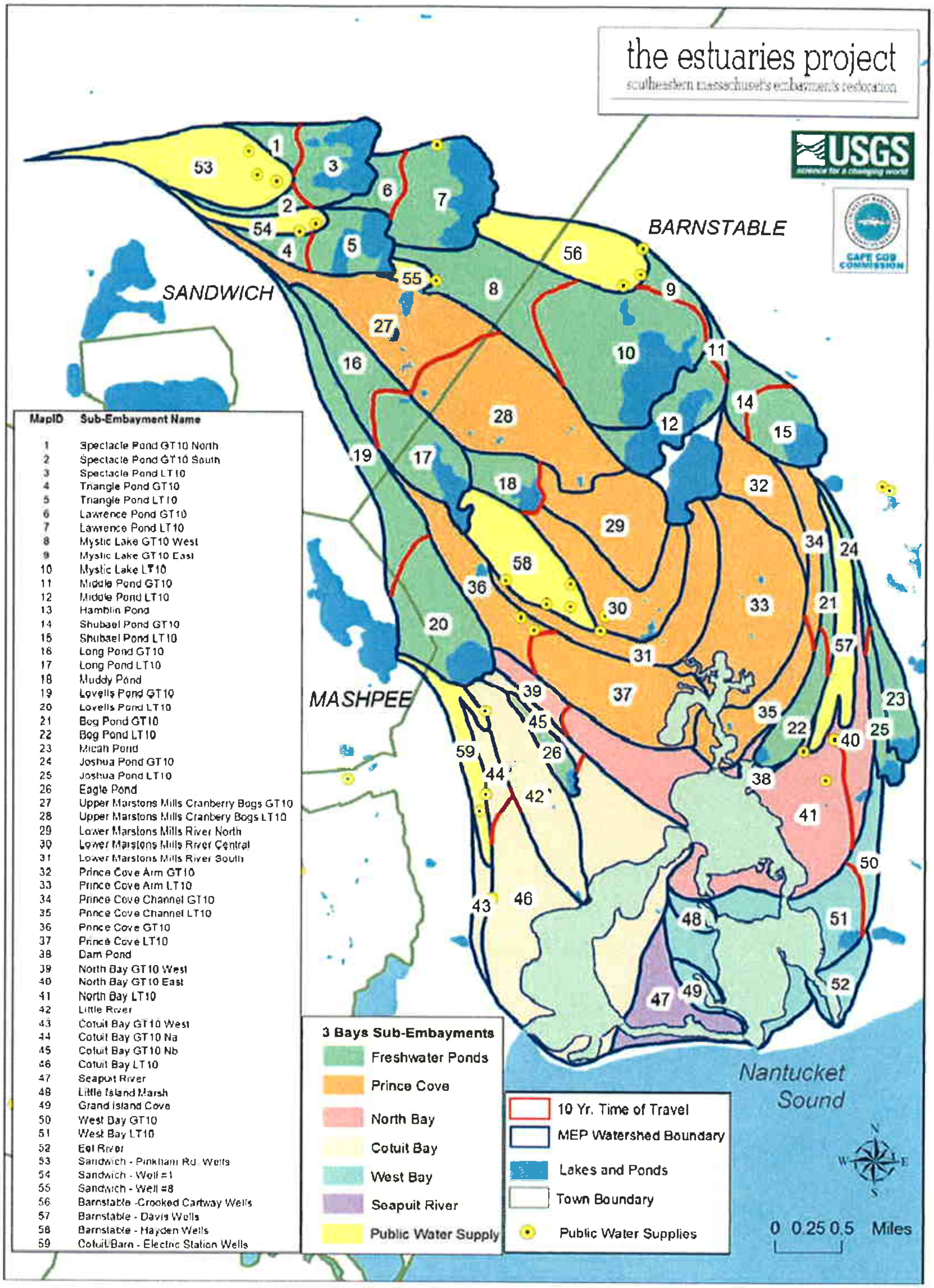

Figure III-1. Watershed and sub-watershed delineations for the Three Bays estuary system. Approximate ten year time-of-travel delineations were produced for quality assurance purposes and are designated with a "10" in the watershed names (above). Sub-watersheds to embayments were selected based upon the functional estuarine sub-units in the water quality model (see section VI).

TB-2

The basis for the watershed nitrogen removal strategy utilized to achieve the embayment thresholds may have merit, since this example nitrogen remediation effort is focused on watersheds where groundwater is flowing directly into the estuary. For nutrient loads entering the systems through surface flow, natural attenuation in freshwater bodies (i.e., streams and ponds) can help by significantly reduce the load that finally reaches the estuary. Presently, this attenuation is occurring due to natural ecosystem processes and the extent of attenuation being determined by the mass of nitrogen which discharges to these systems. The nitrogen reaching these systems is currently "unplanned", resulting primarily from the widely distributed non-point nitrogen sources (e.g. septic systems, lawns, etc.). Future nitrogen management should take advantage of natural nitrogen attenuation, where possible, to ensure the most cost-effective nitrogen reduction strategies. However, "planned" use of natural systems has to be done carefully and with the full analysis to ensure that degradation of these systems will not occur. One clear finding of the MEP has been the need for analysis of the potential associated with restored wetlands or ecologically engineered ponds/wetlands to enhance nitrogen attenuation. Attenuation by ponds in agricultural systems has also been found to work in some cranberry bog systems, as well. Cranberry bogs, other freshwater wetland resources, and freshwater ponds provide opportunities for enhancing natural attenuation of their nitrogen loads. Restoration or enhancement of wetlands and ponds associated with the lower ends of rivers and/or streams discharging to estuaries are seen as providing a dual service of lowering infrastructure costs associated with wastewater management and increasing aquatic resources associated within the watershed and upper estuarine reaches.

Although the above modeling results provide one manner of achieving the selected threshold level for the sentinel site within the estuarine system, the specific example does not represent the only method for achieving this goal. However, the thresholds analysis provides general guidelines needed for the nitrogen management of this embayment.

Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading in one possible load reduction scenario for the Three Bays system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present septic load (kg/day)	threshold septic load (kg/day)	threshold septic load % change
Cotuit Bay	17.022	13.618	-20.0%
West Bay	15.490	12.392	-20.0%
Seaptuit River	2.921	2.921	0.0%
North Bay	24.978	0.000	-100.0%
Prince's Cove	11.192	0.000	-100.0%
Warren's Cove	6.975	0.000	-100.0%
Prince's Cove Channel	4.767	0.000	-100.0%
Marstons Mills Crescent	3.573	0.000	-100.0%
Surface Water Sources			
Marstons Mills River	10.071	7.553	-25.0%
Little River	3.203	3.203	0.0%

100.2 39.7 → 60.4%

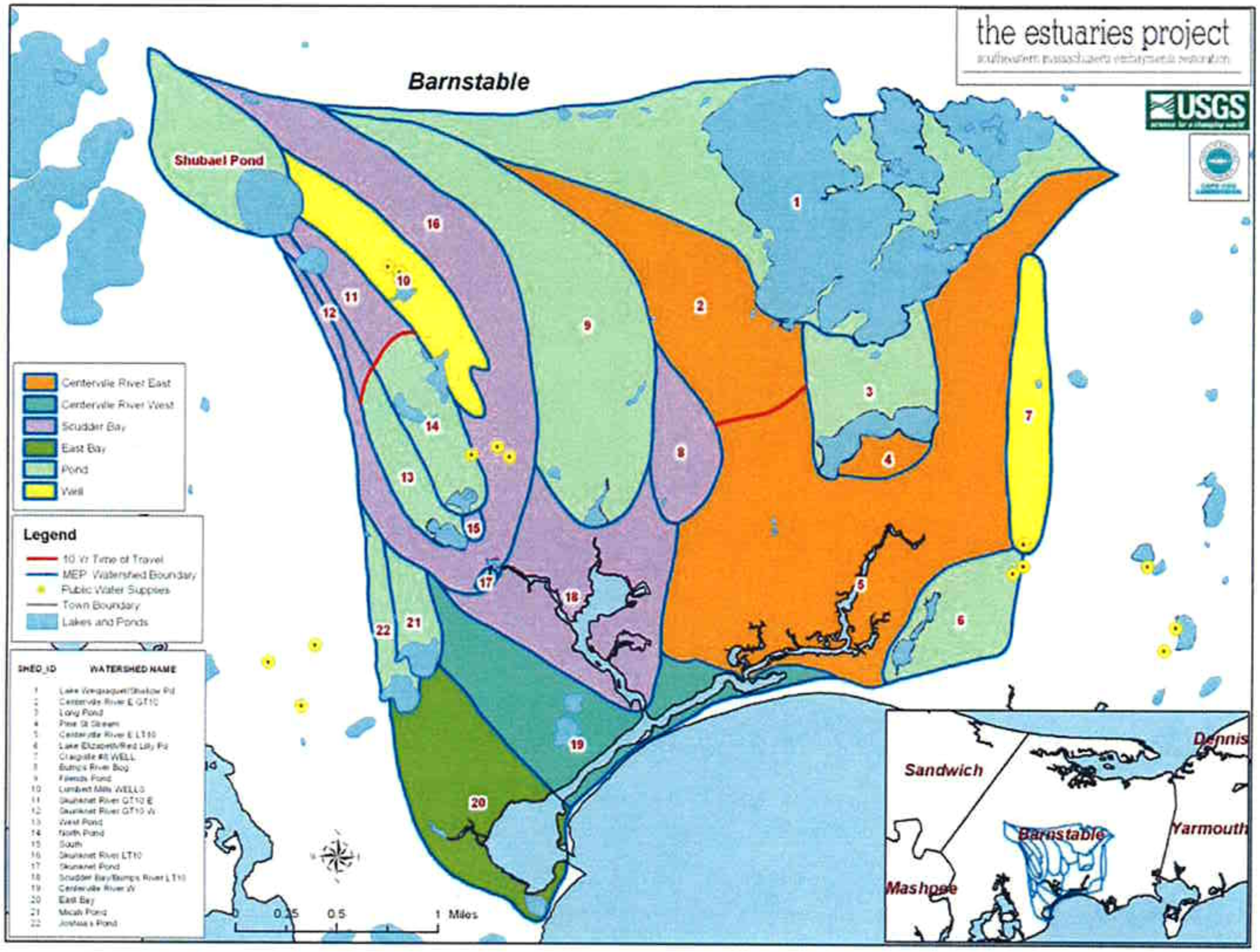

Figure III-1. Watershed and sub-watershed delineations for the Centerville River/East Bay estuary system. Approximate ten year time-of-travel delineations were produced for quality assurance purposes and are designated with a "10" in the watershed names (above). Sub-watersheds to embayments were selected based upon the functional estuarine sub-units in the water quality model (see section VI).

CVR-1

CVR-2

Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Centerville River estuary system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present septic load (kg/day)	threshold septic load (kg/day)	threshold septic load % change
Centerville River East	45.929	9.184	-80.0%
Scudder Bay	11.619	11.619	+0.0%
Centerville River West	7.704	7.704	+0.0%
East Bay	6.301	6.301	+0.0%
Surface Water Sources			
Pine Street Stream	2.512	2.512	+0.0%
Lake Elizabeth Stream	1.836	1.836	+0.0%
Bumps River	14.321	14.321	+0.0%
Skunknett River	17.337	17.337	+0.0%

107.6 70.8 34.2%

Tables VIII-3 and VIII-4 provide additional loading information associated with the thresholds analysis. Table VIII-3 shows the change to the total watershed loads, based upon the removal of septic loads depicted in Table VIII-2. Removal of 80% of the septic load from the Centerville River East watershed results in a 66% reduction in total nitrogen load. Table VIII-4 shows the breakdown of threshold sub-embayment and surface water loads used for total nitrogen modeling. In Table VIII-4, loading rates are shown in kilograms per day, since benthic loading varies throughout the year and the values shown represent 'worst-case' summertime conditions. The benthic flux for this modeling effort is reduced from existing conditions based on the load reduction and the observed particulate organic nitrogen (PON) concentrations within each sub-embayment relative to background concentrations in Nantucket Sound.

Table VIII-3. Comparison of sub-embayment ***total attenuated watershed loads*** (including septic, runoff, and fertilizer) used for modeling of present and threshold loading scenarios of the Centerville River estuary system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	present load (kg/day)	threshold load (kg/day)	threshold % change
Centerville River East	55.737	18.992	-65.9%
Scudder Bay	14.452	14.452	+0.0%
Centerville River West	9.463	9.463	+0.0%
East Bay	8.627	8.627	+0.0%
Surface Water Sources			
Pine Street Stream	3.452	3.452	+0.0%
Lake Elizabeth Stream	2.274	2.274	+0.0%
Bumps River	16.912	16.912	+0.0%
Skunknett River	21.260	21.260	+0.0%

LB & HC -1

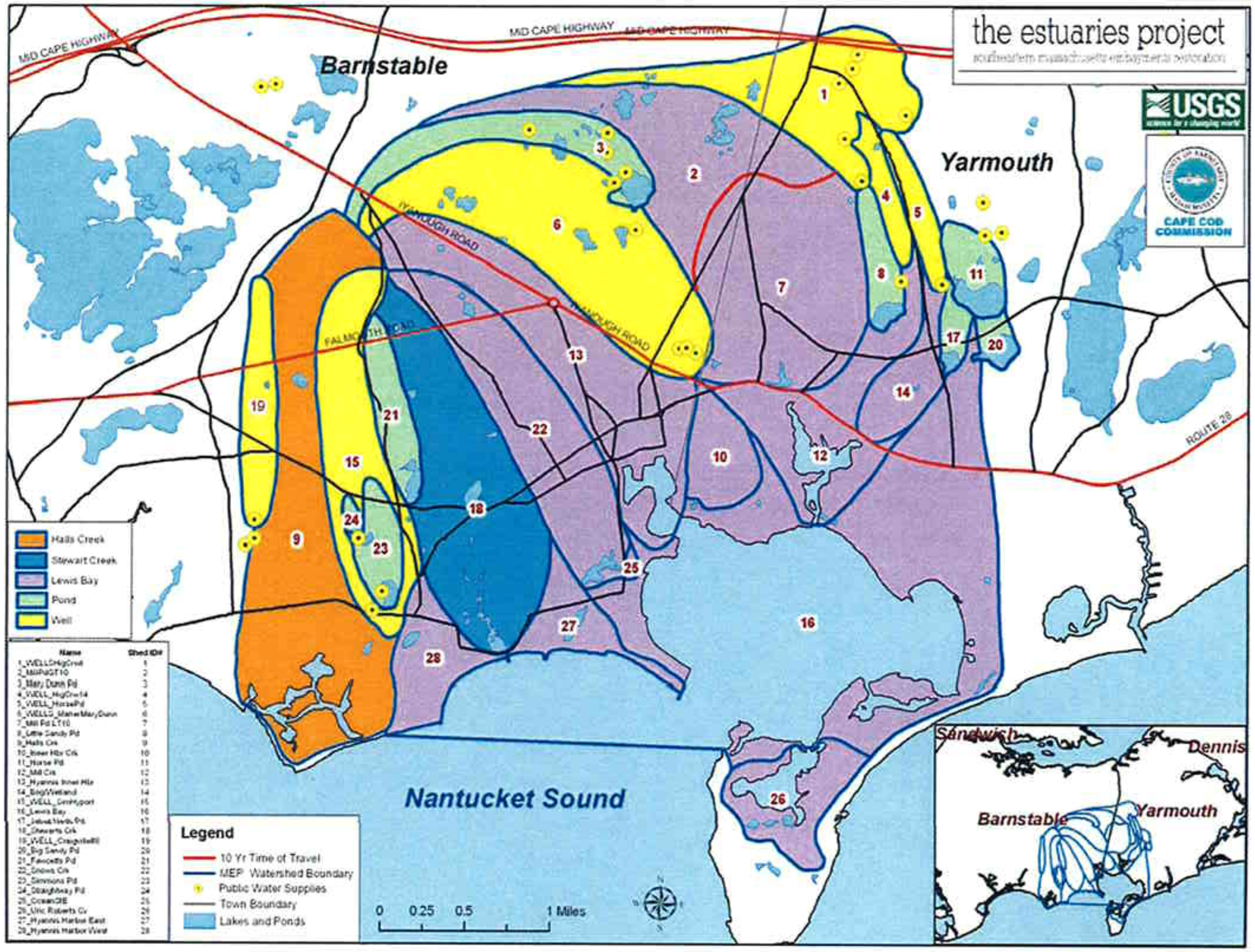

Figure III-1. Watershed and sub-watershed delineations for the Lewis Bay estuary system. Approximate ten year time-of-travel delineations were produced for quality assurance purposes and are designated with a "10" in the watershed names (above). Sub-watersheds to embayments were selected based upon the functional estuarine sub-units in the water quality model (see section VI).

LB & HC-2

reduction in loading from this source to the main basin of Lewis Bay (Watershed 16) and an 80% reduction from this source to Hyannis Inner Harbor (Watershed 13). The distribution of tidally-averaged nitrogen concentrations associated with the above thresholds analysis is shown in Figure VIII-1.

Lewis Bay Estuary: Watershed nitrogen loads to Lewis Bay were sequentially lowered, using reductions in septic effluent discharges only, until the nitrogen levels reached the threshold level at the sentinel station chosen for the Lewis Bay Embayment System (BHY-3 located in the eastern basin of Lewis Bay), and at the secondary stations in Uncle Roberts Cove, Hyannis Inner Harbor and Mill Creek. It is important to note that load reductions can be produced by reduction of any or all sources or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment. The load reductions presented below represent only one of a suite of potential reduction approaches that need to be evaluated by the community. The presentation is to establish the general degree and spatial pattern of reduction that will be required for restoration of this nitrogen impaired embayment.

As shown in Table VIII-2, the nitrogen load reductions within the system necessary to achieve the threshold nitrogen concentrations required using: 1) Existing Removal Scenario B (as requested by the Towns of Yarmouth and Barnstable) with 2) additional removal of septic N loading to produce an 80% total reduction in loading from this source to the main basin of Lewis Bay (Watershed 16) and 3) an 80% reduction from septic N Loading to Hyannis Inner Harbor (Watershed 13). The distribution of tidally-averaged nitrogen concentrations associated with the above thresholds analysis is shown in Figure VIII-1.

Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Lewis Bay system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present septic load (kg/day)	threshold septic load (kg/day)	threshold septic load % change
Lewis Bay	26.490	5.299	-80.0%
Uncle Roberts Cove	0.214	0.214	0.0%
Mill Creek	13.570	1.926	-85.8%
Hyannis Inner Harbor	6.847	1.808	-73.6%[1]
Snows Creek	7.970	9.088	+14.0%
Stewarts Creek	21.564	24.178	+12.1%
Surface Water Sources			
Chase Brook	2.488	2.479	-0.3%
Mill Pond	10.425	10.068	-3.4%
Hospital Creek/Hyannis Inner	1.907	0.326	-82.9%

[1] Hyannis Inner Harbor is a combination of Hyannis Inner Harbor watershed (13), and Wells Mary Dunn watershed (6) thus the 80% reduction in septic loading for the threshold does not result in a direct 80% reduction in septic loading.

91.5 55.4 40%

Tables VIII-3 and VIII-4 provide additional loading information associated with the thresholds analysis. Table VIII-3 shows the change to the total watershed loads, based upon the removal of septic loads depicted in Table VIII-2. Removal of septic loads from Existing

LB & HC-3

Table VIII-6. Comparison of sub-embayment ***total watershed loads*** (including septic, runoff, and fertilizer) used for modeling of present and threshold loading scenarios of the Halls Creek system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	present load (kg/day)	threshold load (kg/day)	threshold % change
Halls Creek	21.534	32.918	+52.9%
Halls Creek Stream (freshwater)	1.597	3.345	+109.4%
System Total	23.132	36.263	+56.8%

Table VIII-7. Threshold sub-embayment loads used for total nitrogen modeling of the Halls Creek system, with total watershed N loads, atmospheric N loads, and benthic flux

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Halls marsh	32.918	0.630	6.649
Halls Creek (freshwater)	3.345	-	-
System Total	36.263	0.630	6.649

Table VIII-8. Comparison of model average total N concentrations from present loading and the threshold scenario, with percent change, for the Halls Creek system. Loads are based on atmospheric deposition and a scaled N benthic flux (scaled from present conditions). The threshold station is shown in bold print.

Sub-Embayment	monitoring station	present (mg/L)	threshold (mg/L)	% change
Halls Creek - stream	BC-13	1.189	2.037	+71.4%
Halls Creek - mid	**BC-14**	**0.469**	**0.557**	**+18.9%**
Halls Creek - inlet	BC-15	0.385	0.432	+12.1%