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********** **Technical Memorandum** **********

To: Tom Fudala, Chair, Mashpee Sewer Commission

From: Brian Howes, Director Coastal Systems Program
Ed Eichner, Coastal Systems Program
Roland Samimy, Coastal Systems Program
Sean Kelley, Applied Coastal Research & Engineering, Inc.

RE: Scenarios Results for Popponesset Bay and Waquoit Bay based on MEP Linked Models

Date: November 15, 2012 (revised)

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This Technical Memorandum details the results of Scenario Runs completed for the Mashpee Sewer Commission using the Massachusetts Estuaries Project (MEP) Linked Watershed-Embayment Models developed for Popponesset Bay and Waquoit Bay estuary systems (Figure 1). Development of the MEP models and establishment of the nitrogen threshold for these systems are described in the respective MassDEP/SMAST MEP Nitrogen Threshold Reports.[1,2] These MEP reports indicate that both estuary systems are showing impaired habitat quality resulting from nitrogen enrichment. The Massachusetts Department of Environmental Protection (MassDEP) has formally acknowledged these assessments and has obtained nitrogen Total Maximum Daily Loads (TMDLs) from USEPA for both Popponesset Bay and Eastern Waquoit Bay.

The Scenarios Runs in this memorandum are the latest round of scenarios completed for the Town of Mashpee, the most of recent of which was six scenarios, involving 11 model runs between the two estuary systems, completed in 2009 that explored various wastewater treatment and discharge location alternatives. [3,4] The scenarios in this current Technical Memorandum are refinements of the 2009 scenarios with updated wastewater collection, treatment, and discharge options.

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[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.

[2] Howes B., S. Kelley, E. Eichner, R. Samimy, J. S. Ramsey, D. Schlezinger, P. Detjens (2011). Massachusetts Estuaries Project Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Waquoit Bay and Eel Pond Embayment System, Towns of Falmouth and Mashpee, MA, Massachusetts Department of Environmental Protection. Boston, MA. 234 pp.

[3] Eichner, E., B. Howes, S. Kelley, and J. Ramsey. December 15, 2009. MEP Technical Memo to Tom Fudala, Chair, Mashpee Sewer Commission regarding Report on Unified Database and Requested MEP Scenarios for the: (a) Popponesset Bay Estuary and (b) Eastern Basins of the Waquoit Bay System.

[4] Eichner, E., B. Howes, S. Kelley, and J. Ramsey. February 9, 2010. MEP Technical Memo to Pio Lombardo, Lombardo Associates and Tom Fudala, Chair, Mashpee Sewer Commission regarding Report on Revised Scenario 3 for Eastern Basins of the Waquoit Bay System.

The Sewer Commission scenarios discussed in this memorandum were developed with the assistance of GHD, Inc. staff. CSP/SMAST staff received the initial scenario details, including GIS coverages, from GHD along with a 2/15/12 Memorandum describing the scenarios.[5] All scenarios are based on the Unified Database that CSP/SMAST staff developed from GHD wastewater estimates and Town of Mashpee land use information.[6] This database is based on buildout assumptions, rather than existing, land use conditions and includes land use within the Popponesset Bay and Eastern Waquoit Bay MEP watersheds, including portions of the Towns of Sandwich, Barnstable, and Falmouth, as well as the remaining parcels in Mashpee that are outside of the two estuary watersheds (Figure 2). Based on the Unified Database, there are 2.7 million gallons per day (MGD) of wastewater flow within this study area. For the purposes of the scenario evaluations, GHD assigned flow to specified subwatersheds even though the discharge sites might exist within multiple subwatersheds (*e.g.*, Keeter, Back Roads, Willowbend). The scenario evaluations are based on the GHD subwatershed assignments for the discharge sites. Only wastewater discharge and treatment is altered in these scenarios; nitrogen loads from other sources (*e.g.*, fertilizers, impervious surfaces, atmospheric deposition) are remain the same in each scenario. In addition, estuary inlet configurations and bathymetry are not altered and are as detailed in the respective MEP Threshold Reports. Table 1 provides the attenuated watershed nitrogen loads for each of the scenarios based on the unified database for each Popponesset Bay subembayment and stream input, while Table 2 provides the same information for each Waquoit Bay subembayment. Details of the wastewater in each of the scenarios in this memorandum are as follows:

Option 1A for Popponesset Bay and East Waquoit Bay:
Option 1A is based on projected build-out watershed nitrogen loads and the Rock Landing Well site is the primary discharge area for wastewater from the study area. This option includes the treatment of 38% of the study area wastewater flow (1.0 MGD) to 10 mg/L TN and the discharge of the treated effluent at the Rock Landing Well site, which is outside the two estuary watersheds. This option assumes that the Rock Landing Wells would be relocated to allow treated effluent to be discharged at this site. A total of 57% of the study area wastewater flow (1.5 MGD), including the Rock Landing site and portions of Falmouth, Sandwich and Barnstable sections of the study area, is discharged outside of the watersheds. The remaining 43% of the total study area wastewater flow is discharged within the subwatersheds to the estuary: 18% remains on standard septic systems (0.48 MGD) and 14% (0.37 MGD) is treated to 3 mg/L total nitrogen (TN) and is discharged at the Back Roads site within the subwatershed to Johns Pond (Figure 3). Most of the rest of wastewater flow remaining within the watersheds is treated to 3 mg/L TN at the existing smaller wastewater treatment facilities (WWTFs).

Option 1B for Popponesset Bay and East Waquoit Bay
Option 1B is based on projected build-out watershed nitrogen loads and keeps most of the wastewater within the estuary subwatersheds, while treating the discharged wastewater to 3 mg/L TN. This option keeps 87% of the total study area wastewater flow (2.3 MGD) within the estuary subwatersheds: 12% (0.32 MGD) remains on standard septic systems, 1% utilize cluster denitrifying septic systems @ 19 mg/L TN, and the remainder of flows are treated to 3 mg/L TN and are discharged at eleven (11) sites within the estuary watersheds (Figure 4). The Falmouth portion of the study area and a section of the Barnstable portion are discharged outside of the watersheds, while the majority of the Sandwich portion (0.37 MGD) is treated to 3 mg/L and is discharged within the Peters Pond subwatershed (*i.e.*, the "Golden Triangle" site and part of the Popponesset Bay watershed).

[5] J. Jefferson Gregg. February 15, 2012. GHD Memorandum to Mashpee Sewer Commission regarding MEP Model Run Descriptions (Options 1A, 1B, and 1C).

[6] Eichner, E., B. Howes, S. Kelley, and J. Ramsey. December 15, 2009. MEP Technical Memo to Tom Fudala, Chair, Mashpee Sewer Commission regarding Report on Unified Database and Requested MEP Scenarios for the: (a) Popponesset Bay Estuary and (b) Eastern Basins of the Waquoit Bay System.

Among the 11 sites where the bulk of the study area wastewater flow is discharged are: Willowbend, Keeter, Transfer Station, and Back Roads. The Keeter site, which receives 0.34 MGD, is located in the Rock Landing subwatershed, but borders on the Ockway Bay and Great River subwatersheds. After discussing this with GHD staff, it was decided to assign 50% of the load to Rock Landing, and 25% each to Ockway Bay and Great River. Similarly, project and GHD staff discussed and assigned the 13,908 gallons per day (gpd) @ 3 mg/L TN from the permeable reactive barriers at Pirates Cove based on the estimated watershed divide on the peninsula where Pirates Cove is located.

Option 1C for Popponesset Bay and East Waquoit Bay

Option 1C is based on projected build-out watershed nitrogen loads and treats and discharges most of Mashpee's wastewater within the two estuary watersheds and discharges the majority of the treated effluent from Falmouth, Sandwich, and Barnstable sections of the study area outside of the watersheds. This option keeps 74% of the total study area wastewater flow (2.0 MGD) within the estuary watersheds: 18% (0.48 MGD) remains on standard septic systems, 1% utilize cluster denitrifying septic systems @ 19 mg/L TN, and the remainder of flows are treated to 3 mg/L TN and are discharged at ten (10) sites within the estuary watersheds (Figure 5). Site discharges to the multiple discharge sites (*i.e.*, Keeter, Pirates Cove, Willowbend, and Back Roads) are assigned on the same basis as in Option 1B.

SCENARIO RESULTS:

Popponesset Bay Scenario Results Comparison to Threshold Nitrogen Concentrations:

Using the MEP linked model for Popponesset Bay, project staff compared the overall scenario nitrogen loads for each of the Options developed by the Sewer Commission and GHD to the threshold/TMDL loads approved by MassDEP and USEPA.[7] Based on this comparison, all three options meet the threshold values/TMDLs at the sentinel station for restoration of eelgrass in Popponesset Bay (Table 3). In addition, all three options do meet the water column TN concentrations within each of the three tributary sub-embayments that would be restorative of infaunal habitat. Among three Options, Option 1C results in the TN concentrations closest to the TMDL thresholds (*i.e.* has the highest concentrations), while Options 1A and 1B are removing more watershed nitrogen load than necessary. It should be noted that all of these scenarios included removal of wastewater from the study area for discharge outside of the watershed and that no other alternative nitrogen reduction strategies other than improved wastewater treatment were incorporated.

Eastern Waquoit Bay Scenario Results: Comparison to Threshold Nitrogen Concentrations:

Using the MEP linked model for Waquoit Bay, project staff compared the overall scenario nitrogen loads for each of the Options developed by the Sewer Commission and GHD to the threshold concentrations in the Eastern Waquoit Bay MEP Report.[8] Based on this comparison, all three options do not meet the threshold values at the sentinel station for restoration of eelgrass in Jehu Pond or Hamblin Pond (Table 4). All three options do meet the water column TN concentration that would be restorative of infaunal habitat in the Quashnet River.

The previous round of scenarios for Eastern Waquoit were based on the Eastern Waquoit MEP Linked model, which only included the eastern portions of the overall Waquoit Bay watershed (see Figure 1) and a water quality model that was based on three years (2001-2003) of water quality data. The whole

[7] 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, USEPA, Region 1 to Laurie Burt, Commissioner, Massachusetts Department of Environmental Protection.

[8] TMDLs were approved for Quashnet River, Hamblin Pond, Little River, Jehu Pond, and Great River in the Waquoit Bay System on November 7, 2007, but the approval letter only references nitrogen loading rates (in kg/day) rather than concentrations. Concentrations are used here.

Waquoit Bay MEP assessment includes the whole watershed and estuary, including the eastern portions, and the water quality model was completed based on nine years (2002-2010) of water quality data.[9] The refinements in the whole system linked model likely play a significant role in the scenarios not meeting the thresholds for the Eastern Waquoit subembayments.

The results of the whole system assessment also indicate that the proposed changes in the eastern portion of the watershed are insufficient on their own to meet the Threshold concentrations throughout the system. This result reinforces that water quality management in Waquoit Bay will have to be coordinated among all three towns in the watershed.

[9] Howes B., S. Kelley, E. Eichner, R. Samimy, J. S. Ramsey, D. Schlezinger, P. Detjens (2011). Massachusetts Estuaries Project Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Waquoit Bay and Eel Pond Embayment System, Towns of Falmouth and Mashpee, MA, Massachusetts Department of Environmental Protection. Boston, MA.

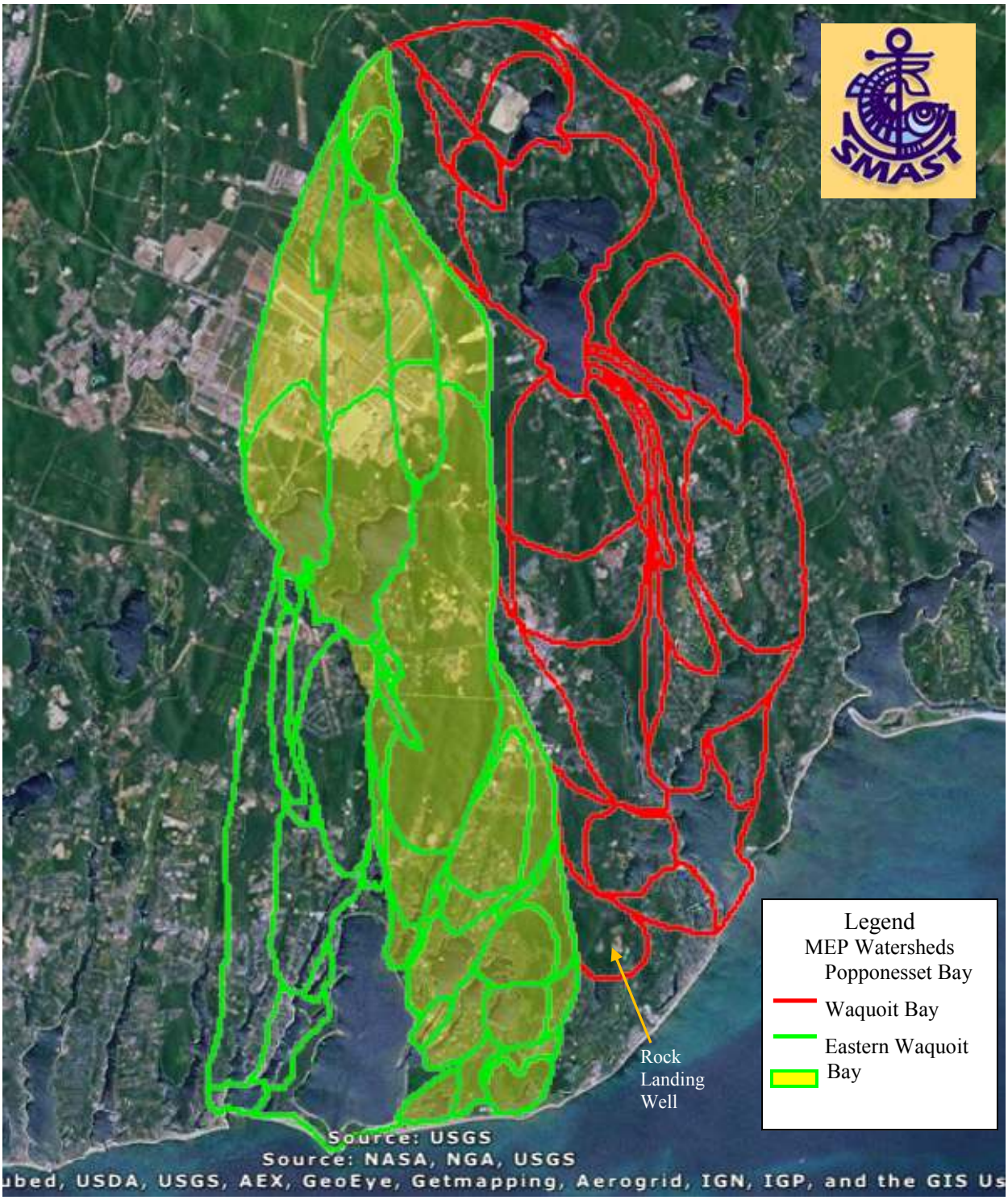

Figure 1. Popponesset Bay and Waquoit Bay Massachusetts Estuaries Project Watersheds. Also shown is the MEP watershed to Eastern Waquoit Bay, which was incorporated into the whole Waquoit Bay MEP assessment. The Popponesset Bay watershed delineations include the contributing area to the Rock Landing well.

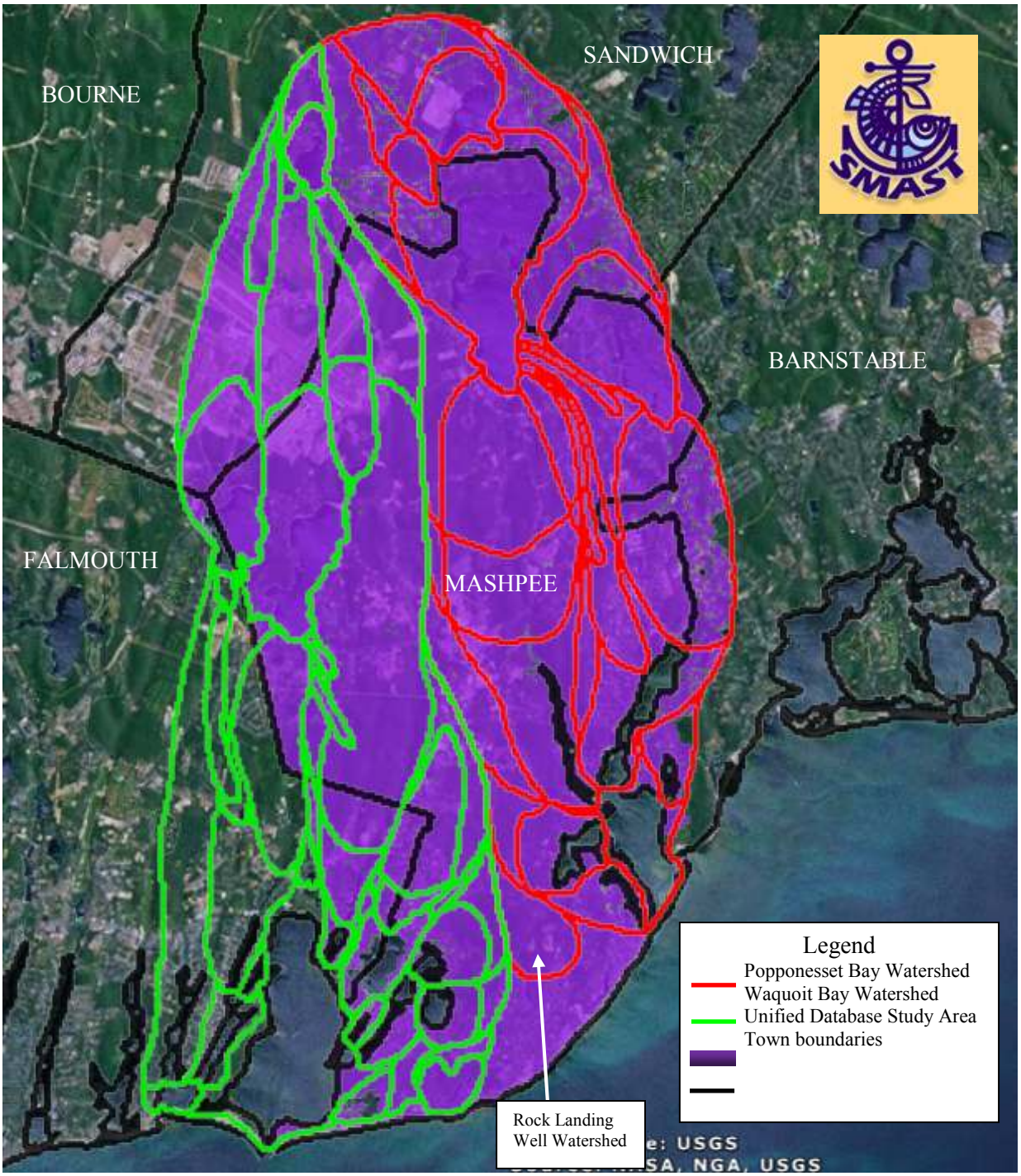

Figure 2. Mashpee Unified Database Study Area.
The Mashpee Unified Database Study area includes all of the Town of Mashpee and portions of three other towns (Barnstable, Falmouth, and Sandwich). Portions of the Unified Database also extend outside of the estuary watersheds to Popponesset Bay and Waquoit Bay, mostly notably the Rock Landing Well contributing area. It should also be noted that extensive portions of the Waquoit Bay watershed are not included in the Unified Database Study area.

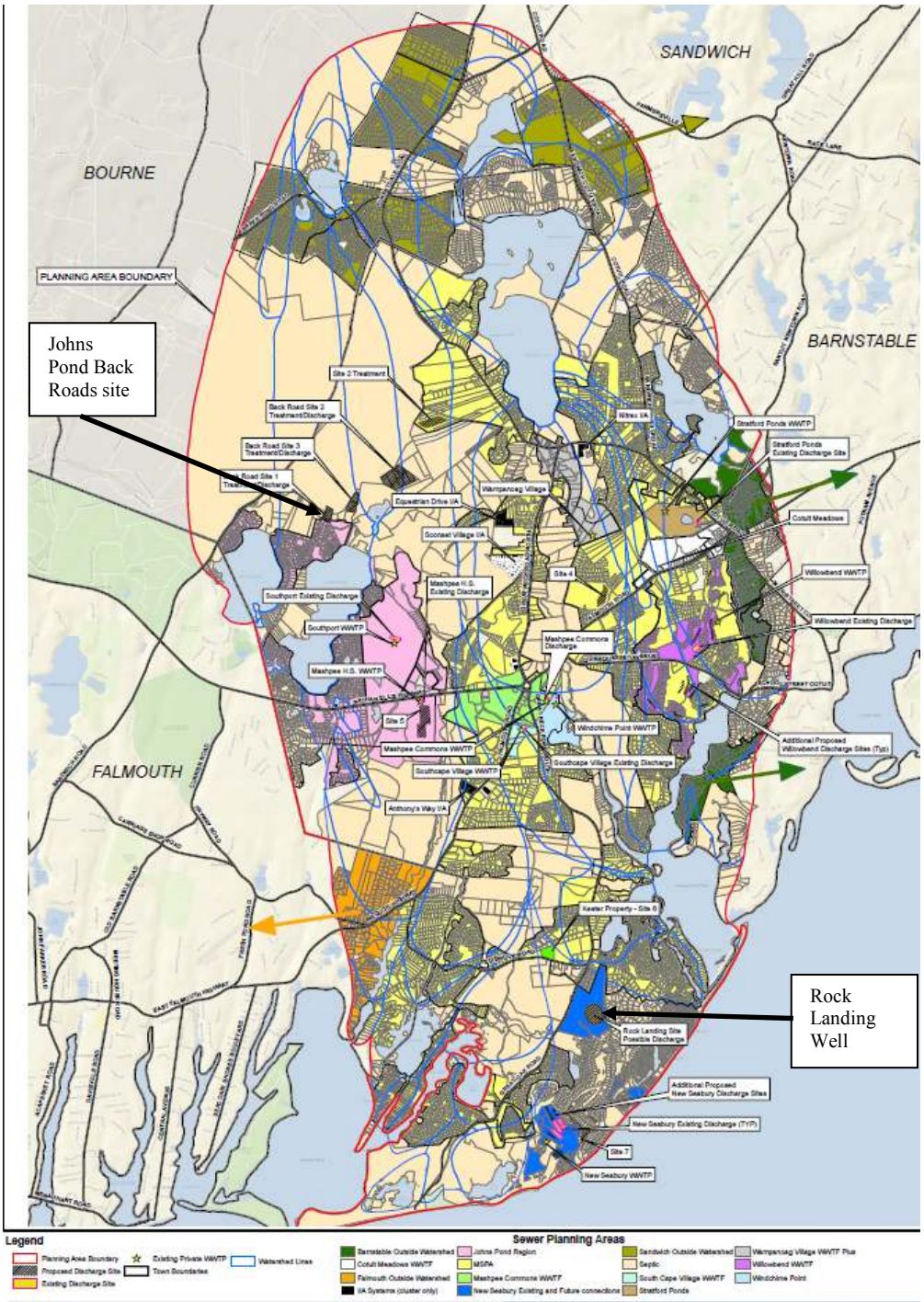

Figure 3. Option 1A Scenarios.

38% of the Unified Database study area treated wastewater flow (1.0 MGD) discharged at the Rock Landing Well site; the Rock Landing Wells would be relocated. 57% of the total study area wastewater flow (1.5 MGD) is discharged outside of the watersheds, including the Rock Landing site and portions of the Falmouth, Sandwich and Barnstable sections (note orange, yellow, and green arrows above, respectively). Of the wastewater remaining within the estuary watersheds, 18% remains on standard septic systems (0.48 MGD) and 14% (0.37 MGD) is treated to 3 mg/L TN and discharged at the Johns Pond portion of the Back Roads site. Modified from Figure 2 in GHD 2/15/12 memo.

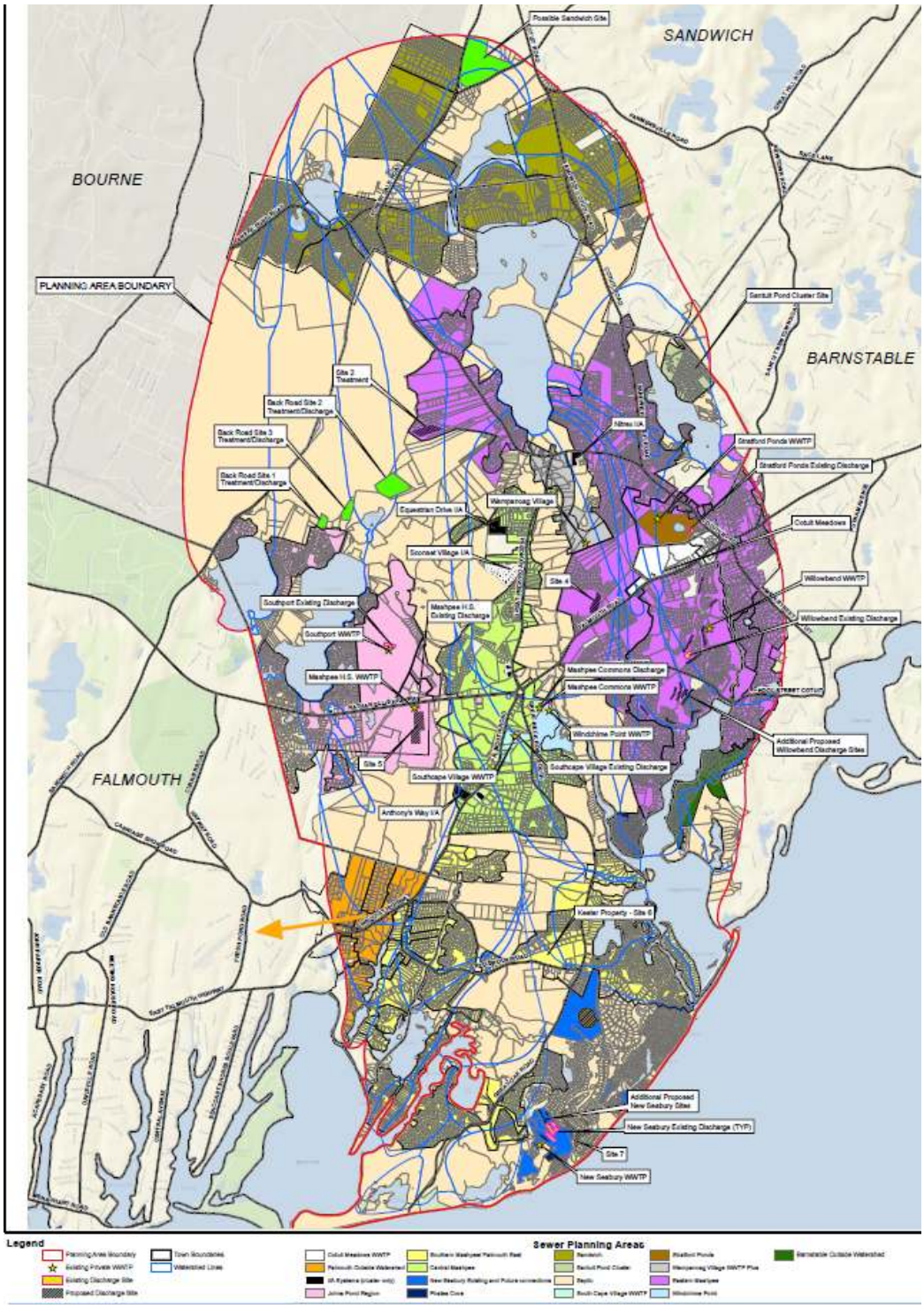

Figure 4. Option 1B Scenarios.

87% of the total study area wastewater flow (2.3 MGD) is treated to 3 mg/L TN and discharged at 11 sites within the estuary watersheds; 12% (0.32 MGD) of study area flow remains on standard septic systems. Portions of the Falmouth and Barnstable sections of the study area are discharged outside of the watersheds, while the Sandwich portion (0.37 MGD) is treated to 3 mg/L and is discharged within the Peters Pond subwatershed. Modified from Figure 3 in GHD 2/15/12 memo.

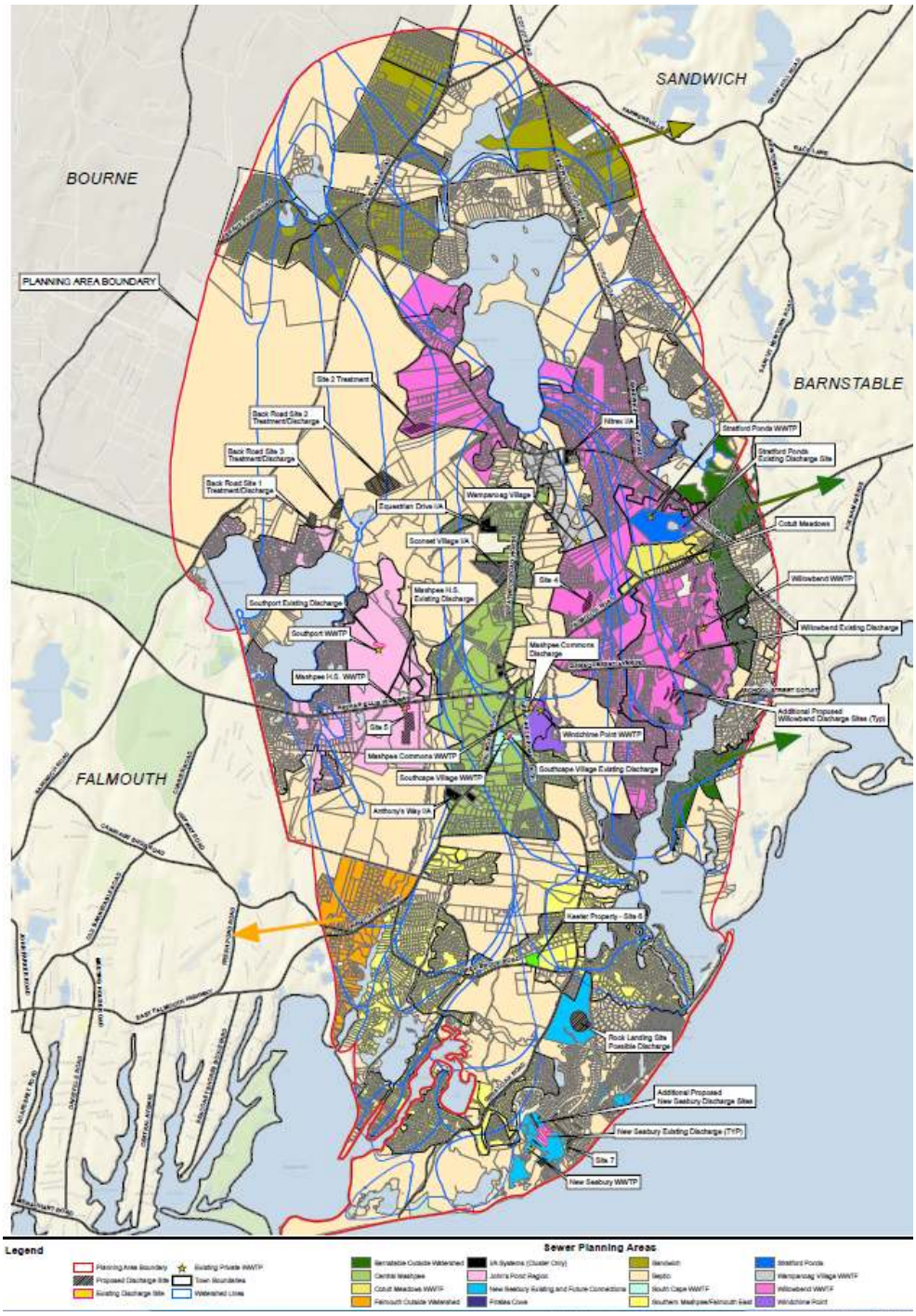

Figure 5. Option 1C Scenarios.

74% of the total study area wastewater flow (2.0 MGD) is treated and discharged at 10 sites within the estuary watersheds: 18% (0.48 MGD) remains on standard septic systems, 1% utilize cluster denitrifying septic systems @ 19 mg/L TN, and the remainder of flows are treated to 3 mg/L TN and are discharged at ten (10) sites within the estuary watersheds. The majority of the treated effluent from Falmouth, Sandwich, and Barnstable sections of the study area is discharged outside of the watersheds (see orange, yellow, and green arrows, respectively). Site discharges to multiple discharge sites (*i.e.*, Keeter, Pirates Cove, Willowbend, and Back Roads) are assigned on the same basis as in Option 1B. Modified from Figure 4 in GHD 2/15/12 memo.

Table 1. 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. All scenarios loads are based on build-out nitrogen loading conditions using the updated SMAST unified land use 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 Buildout load (kg/day)	threshold (kg/day)	threshold % change	Scenarios (all are buildout conditions)					
				Option 1A		Option 1B		Option 1C	
				(kg/day)	% change	(kg/day)	% change	(kg/day)	% change
Popponesset Bay	1.98	1.82	-8.1%	0.66	-66.7%	0.66	-66.7%	0.66	-66.7%
Popponesset Creek	5.35	0.95	-82.2%	1.01	-81.1%	1.01	-81.1%	1.01	-81.1%
Pinquickset Cove	0.98	0.76	-22.0%	0.72	-26.5%	0.72	-26.5%	0.72	-26.5%
Ockway Bay	3.16	0.76	-76.0%	0.95	-69.9%	1.92	-39.4%	1.90	-40.0%
Mashpee River	17.13	2.50	-85.4%	3.82	-77.7%	4.13	-75.9%	4.13	-75.9%
Shoestring Bay	9.76	2.26	-76.8%	4.12	-57.8%	2.62	-73.1%	4.20	-56.9%
Surface Water Sources									
Mashpee River	30.31	13.67	-54.9%	11.81	-61.0%	13.56	-55.3%	13.93	-54.1%
Santuit River	20.55	11.47	-44.2%	11.18	-45.6%	11.09	-46.0%	14.70	-28.5%
Quaker Run River	6.62	5.98	-9.6%	2.10	-68.3%	2.10	-68.3%	2.10	-68.3%
TOTAL	**95.84**	**40.18**	**-58.1%**	**36.36**	**-62.1%**	**37.81**	**-60.5%**	**43.34**	**-54.8%**

Table 2. Scenario Watershed Nitrogen Loads: Waquoit Bay

Attenuated total nitrogen loads by subembayment and surface water input to Waquoit Bay are presented for each Mashpee Sewer Commission scenario. All scenarios loads are based on build-out nitrogen loading conditions using the updated SMAST unified land use database for Mashpee; MEP build-out loads are presented for comparison. 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 Buildout load (kg/day)	threshold (kg/day)	threshold % change	Scenarios (all are buildout conditions)					
				Option 1A		Option 1B		Option 1C	
				(kg/day)	% change	(kg/day)	% change	(kg/day)	% change
Waquoit Bay	3.17	2.09	-34.1%	2.28	-28.1%	2.28	-28.1%	2.28	-28.1%
Childs River - upper	14.08	4.08	-71.1%	12.58	-10.6%	12.58	-10.6%	12.58	-10.6%
Eel Pond - east branch	2.32	0.82	-64.7%	2.25	-3.1%	2.25	-3.1%	2.25	-3.1%
Eel Pond - south basin	0.55	0.52	-4.9%	0.54	-1.8%	0.54	-1.8%	0.54	-1.8%
Eel Pond - west branch	22.98	8.81	-61.7%	16.28	-29.2%	16.28	-29.2%	16.28	-29.2%
Quashnet River	3.36	1.50	-55.4%	1.00	-70.2%	1.00	-70.2%	1.00	-70.2%
Hamblin Pond	7.12	0.95	-86.6%	1.26	-82.3%	1.26	-82.3%	1.26	-82.3%
Little River	1.44	0.21	-85.3%	0.27	-81.2%	0.27	-81.2%	0.27	-81.2%
Jehu Pond	4.22	1.02	-75.7%	1.07	-74.7%	1.07	-74.7%	1.07	-74.7%
Great River	4.70	1.00	-78.8%	1.12	-76.2%	2.08	-55.6%	2.08	-55.8%
Sage Lot Pond	3.66	1.62	-55.7%	1.74	-52.4%	1.74	-52.4%	1.74	-52.4%
Surface Water Sources									
Childs River - freshwater	26.39	4.12	-84.4%	11.43	-56.7%	11.43	-56.7%	11.43	-56.7%
Moonakiss River (upper Quashnet)	35.26	13.47	-61.8%	13.20	-62.6%	13.22	-62.5%	13.22	-62.5%
Red Brook -freshwater	10.98	2.10	-80.9%	2.00	-81.8%	2.28	-79.2%	2.28	-79.2%
TOTAL	**140.23**	**42.30**	**-69.8%**	**67.01**	**-52.2%**	**68.28**	**-51.3%**	**68.27**	**-51.3%**

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

Comparison of TN concentrations for present conditions, threshold loading, and three modeled buildout loading scenarios for the Popponesset Bay system. TMDL/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. All scenarios meet the TMDL/MEP Thresholds.

TMDL section	Habitat threshold	Present	TMDL/MEP Threshold	Scenario Option 1A	Scenario Option 1B	Scenario Option 1C
		mg/L	mg/L	mg/L	mg/L	mg/L
Popponesset Bay - head	eelgrass	0.464	0.38	0.359	0.366	0.381
Mashpee River - mid to lower	infauna	0.712	0.4 - 0.5	0.447	0.474	0.492
Shoestring Bay - upper to lower	infauna	0.631	0.4 – 0.5	0.433	0.440	0.481
Ockway Bay - upper	infauna	0.567	0.4 – 0.5	0.413	0.436	0.451

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

Table 4. Threshold Comparison Results for Mashpee Sewer Commission Scenarios: Waquoit Bay

Comparison of TN concentrations for present conditions, threshold loading, and three modeled buildout loading scenarios for the Waquoit Bay system. MEP threshold concentrations for Waquoit Bay are 0.380 mg/L TN for eelgrass (primary), and between 0.400 and 0.500 mg/L TN for infauna (secondary). TMDLs were established for Quashnet River, Hamblin Pond, Little River, Jehu Pond, and Great River in 2007, but the official EPA approval letter does not contain TN concentrations. The thresholds listed below are from the MEP reports for Eastern Waquoit Bay and the overall system. The MEP thresholds for Quashnet River, Hamblin Pond, Little River, Jehu Pond, and Great River did not change in the evaluation of the entire system.

TMDL section	Habitat threshold	Present	TMDL/MEP Threshold	Scenario Option 1A	Scenario Option 1B	Scenario Option 1C
		mg/L	mg/L	mg/L	mg/L	mg/L
East Waquoit – TMDL established						
Jehu Pond - WB1	eelgrass	0.630	0.446	0.471	0.481	0.481
Great/Little River - WB3	eelgrass	0.427	0.38	0.355	0.359	0.359
Hamblin Pond - WB4	eelgrass	0.521	0.38	0.390	0.398	0.398
Quashnet River - WB7, WB8	infauna	0.704	0.52	0.502	0.503	0.503
Rest of Waquoit - MEP Report ready for review						
Upper Waquoit Bay - WB12	eelgrass	0.400	0.38	0.358	0.359	0.359
Mid Childs River - CR2	eelgrass	0.651	0.38	0.688	0.687	0.687
Upper Eel River - ER1	infauna	0.669	0.5	0.679	0.679	0.679

Notes:

1) shaded cells indicate Scenarios that meet TMDL/MEP thresholds for eelgrass or infauna.
2) MEP Thresholds for rest of Waquoit are from: Howes B., S. Kelley, E. Eichner, R. Samimy, J. S. Ramsey, D. Schlezinger, P. Detjens (2011). Massachusetts Estuaries Project Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Waquoit Bay and Eel Pond Embayment System, Towns of Falmouth and Mashpee, MA, Massachusetts Department of Environmental Protection. Boston, MA.