VI. WATER QUALITY MODELING

VI.1 DATA SOURCES FOR THE MODEL

Several different data types and calculations are required to support the water quality modeling effort for the Three Bays system. These include the output from the hydrodynamics model, calculations of external nitrogen loads from the watersheds, measurements of internal nitrogen loads from the sediment (benthic flux), and measurements of nitrogen in the water column.

VI.1.1 Hydrodynamics and Tidal Flushing in the Embayments

Extensive field measurements and hydrodynamic modeling of the embayments were an essential preparatory step to the development of the water quality model. The result of this work, among other things, was a calibrated hydrodynamic model representing the transport of water within the Three Bays system. Files of node locations and node connectivity for the RMA-2V model grids were transferred to the RMA-4 water quality model; therefore, the computational grid for the hydrodynamic model also was the computational grid for the water quality model. The period of hydrodynamic output for the water quality model calibration was a the 7 lunar-day period (14 tide cycles, or 7.25 solar days) beginning October 11, 2002 0000 EST. This period corresponds to that used in the flushing analysis presented in Chapter V. Each modeled scenario (e.g., present conditions, build-out) required the model be run for a 28-day spin-up period, to allow the model had reached a dynamic “steady state”, and ensure that model spin-up would not affect the final model output.

VI.1.2 Nitrogen Loading to the Embayments

Three primary nitrogen loads to sub-embayments are recognized in this modeling study: external loads from the watersheds, nitrogen load from direct rainfall on the embayment surface, and internal loads from the sediments. Additionally, there is a fourth load to the Three Bays system’s sub-embayments, consisting of the background concentrations of total nitrogen in the waters entering from Nantucket Sound. This load is represented as a constant concentration along the two seaward boundaries of the model grid (at Cotuit Bay and West Bay).

VI.1.3 Measured Nitrogen Concentrations in the Embayments

In order to create a model that realistically simulates the total nitrogen concentrations in a system in response to the existing flushing conditions and loadings, it is necessary to calibrate the model to actual measurements of water column nitrogen concentrations. The refined and approved data for each monitoring station used in the water quality modeling effort are presented in Table VI-1. Station locations are indicated in the area map presented in Figure VI-1. The multi-year averages present the “best” comparison to the water quality model output, since factors of tide, temperature and rainfall may exert short-term influences on the individual sampling dates and even cause inter-annual differences. Three years of baseline field data are the minimum required to provide a baseline for MEP analysis. Typically, six years of data (collected between 1999 and 2004) were available for stations monitored by SMAST and the Three Bays Alliance in the Three Bays system.

Table VI-1. Measured data and modeled Nitrogen concentrations for the Three Bays estuarine system used in the model calibration plots of Figures VI-2 and VI-3. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means. Data represented in this table were collected in the summers of 1999 through 2004, except the Vineyard sound station, which covers a longer time period.

Sub-Embayment	monitoring station	data mean	s.d. all data	N	model min	model max	model average
Mill Pond (fresh water)	TB1	1.022	0.246	36	-	-	-
Prince's Cove - south	TB2	0.699	0.192	38	0.685	0.699	0.695
Prince's Cove - north	TB3	0.602	0.131	37	0.612	0.666	0.639
Warren's Cove	TB4	0.642	0.151	36	0.561	0.642	0.595
North Bay - north	TB5	0.498	0.135	105	0.504	0.531	0.518
North Bay - south	TB6	0.515	0.129	36	0.483	0.517	0.500
North Windmill Cove	TB7	0.511	0.120	103	0.498	0.523	0.511
West Bay - north	TB8	0.383	0.117	34	0.327	0.418	0.363
West Bay - west	TB9	0.376	0.078	38	0.299	0.362	0.327
Eel River	TB10	0.481	0.125	34	0.468	0.500	0.486
Seapuit River	TB11	0.322	0.068	67	0.287	0.305	0.295
Cotuit Bay - north	TB12	0.438	0.076	64	0.364	0.484	0.414
Cotuit Bay - south	TB13	0.389	0.077	75	0.298	0.350	0.321
South Windmill Cove	TB15	0.431	0.090	27	0.369	0.467	0.402
Mellon Cove	TB16	0.411	0.094	24	0.369	0.417	0.392
Dam Pond	TB17	0.508	0.073	5	0.513	0.531	0.523
Vineyard Sound	NS	0.280	0.065	196	-	-	0.280

VI.2 MODEL DESCRIPTION AND APPLICATION

A two-dimensional finite element water quality model, RMA-4 (King, 1990), was employed to study the effects of nitrogen loading in the Three Bays estuarine system. The RMA-4 model has the capability for the simulation of advection-diffusion processes in aquatic environments. It is the constituent transport model counterpart of the RMA-2 hydrodynamic model used to simulate the fluid dynamics of Three Bays. Like RMA-2 numerical code, RMA-4 is a two-dimensional, depth averaged finite element model capable of simulating time-dependent constituent transport. The RMA-4 model was developed with support from the US Army Corps of Engineers (USACE) Waterways Experiment Station (WES), and is widely accepted and tested. Applied Coastal staff have utilized this model in water quality studies of other Cape Cod embayments, including systems in Falmouth (Howes *et al*., 2005); Mashpee, MA (Howes *et al*., 2004) and Chatham, MA (Howes *et al*., 2003).

The overall approach involves modeling total nitrogen as a non-conservative constituent, where bottom sediments act as a source or sink of nitrogen, based on local biochemical characteristics. This modeling represents summertime conditions, when algal growth is at its maximum. Total nitrogen modeling is based upon various data collection efforts and analyses presented in previous sections of this report. Nitrogen loading information was derived from the Cape Cod Commission watershed loading analysis (based on the USGS watersheds), as well as the measured bottom sediment nitrogen fluxes. Water column nitrogen measurements were utilized as model boundaries and as calibration data. Hydrodynamic model output (discussed in Section V) provided the remaining information (tides, currents, and bathymetry) needed to parameterize the water quality model of the Three Bays system.

Figure VI-1. Estuarine water quality monitoring station locations in the Three Bays estuary system. Station labels correspond to those provided in Table VI-1. Sentinel station for threshold development depicted with red symbol.

VI.2.1 Model Formulation

The formulation of the model is for two-dimensional depth-averaged systems in which concentration in the vertical direction is assumed uniform. The depth-averaged assumption is justified since vertical mixing by wind and tidal processes prevent significant stratification in the modeled sub-embayments. The governing equation of the RMA-4 constituent model can be most simply expressed as a form of the transport equation, in two dimensions:

$$\left(\frac{\partial c}{\partial t} + u \frac{\partial c}{\partial x} + v \frac{\partial c}{\partial y} \right) = \left(\frac{\partial}{\partial x} D_x \frac{\partial c}{\partial x} + \frac{\partial}{\partial y} D_y \frac{\partial c}{\partial y} + \sigma \right)$$

where *c* in the water quality constituent concentration; *t* is time; *u* and *v* are the velocities in the *x* and *y* directions, respectively; D_x and D_y are the model dispersion coefficients in the *x* and *y* directions; and σ is the constituent source/sink term. Since the model utilizes input from the RMA-2 model, a similar implicit solution technique is employed for the RMA-4 model.

The model is therefore used to compute spatially and temporally varying concentrations *c* of the modeled constituent (i.e., total nitrogen), based on model inputs of 1) water depth and velocity computed using the RMA-2 hydrodynamic model; 2) mass loading input of the modeled constituent; and 3) user selected values of the model dispersion coefficients. Dispersion coefficients used for each system sub-embayment were developed during the calibration process. During the calibration procedure, the dispersion coefficients were incrementally changed until model concentration outputs matched measured data.

The RMA-4 model can be utilized to predict both spatial and temporal variations in total for a given embayment system. At each time step, the model computes constituent concentrations over the entire finite element grid and utilizes a continuity of mass equation to check these results. Similar to the hydrodynamic model, the water quality model evaluates model parameters at every element at 10-minute time intervals throughout the grid system. For this application, the RMA-4 model was used to predict tidally averaged total nitrogen concentrations throughout the sub-embayments of the Three Bays system.

VI.2.2 Water Quality Model Setup

Required inputs to the RMA-4 model include a computational mesh, computed water elevations and velocities at all nodes of the mesh, constituent mass loading, and spatially varying values of the dispersion coefficient. Because the RMA-4 model is part of a suite of integrated computer models, the finite-element meshes and the resulting hydrodynamic simulations previously developed for Three Bays also were used for the water quality constituent modeling portion of this study.

Based on measured surface water flow rates from SMAST and groundwater recharge rates from the USGS, the hydrodynamic model was set-up to include the latest estimates of flows from the Marstons Mills River (to Prince's Cove) and Little River (to Cotuit Bay). The Marstons Mills River has a mean measured flow rate of 6.6 ft^3/sec (16,100 m^3/day), which is 6.9% of the volume of the average tide prism of Prince's Cove. Little River has average flows of 1.1 ft^3/sec (3,500 m^3/day, which represents only 0.1% of the Cotuit Bay tide prism.

For each model, an initial total N concentration equal to the concentration at the open boundary was applied to the entire model domain. The model was then run for a simulated month-long (28 day) spin-up period. At the end of the spin-up period, the model was run for an additional 5 tidal-day (125 hour) period. Model results were recorded only after the initial spin-up period. The time step used for the water quality computations was 10 minutes, which corresponds to the time step of the hydrodynamics input for the Three Bays model.

VI.2.3 Boundary Condition Specification

Mass loading of nitrogen into each model included 1) sources developed from the results of the watershed analysis, 2) estimates of direct atmospheric deposition, 3) summer benthic regeneration, 4) point source inputs developed from measurements of the freshwater portions of the Marstons Mills River and Little River. Nitrogen loads from each separate sub-embayment watershed were distributed across the sub-embayment. For example, the combined watershed and direct atmospheric deposition loads for Cotuit Bay were evenly distributed at grid cells that formed the perimeter of the sub-embayment. Benthic regeneration loads were distributed among another sub-set of grid cells which are in the interior portion of each basin.

The loadings used to model present conditions in the Three Bays estuary system are given in Table VI-2. Watershed and depositional loads were taken from the results of the analysis of Section IV. Summertime benthic flux loads were computed based on the analysis of sediment cores in Section IV. The area rate (g/sec/m^2) of nitrogen flux from that analysis was applied to the surface area coverage computed for each sub-embayment (excluding marsh coverages, when present), resulting in a total flux for each embayment (as listed in Table VI-2). Due to the highly variable nature of bottom sediments and other estuarine characteristics of coastal embayments in general, the measured benthic flux for existing conditions also is variable. For present conditions, some sub-embayments (e.g., North Bay) have more than twice the loading rate from benthic regeneration as from watershed loads. For other sub-embayments the benthic flux is relatively low or negative (Cotuit Bay and Seapuit River) indicating a net uptake of nitrogen in the bottom sediments.

In addition to mass loading boundary conditions set within the model domain, concentrations along the model open boundary were specified. The model uses concentrations at the open boundary during the flooding tide periods of the model simulations. TN concentrations of the incoming water are set at the value designated for the open boundary. The boundary concentration in the Nantucket Sound region offshore Three Bays was set at 0.280 mg/L, based on SMAST data from Vineyard Sound. The open boundary total nitrogen concentration represents long-term average summer concentrations found within Vineyard Sound.

Table VI-2. Sub-embayment and surface water loads used for total nitrogen modeling of the Three Bays system, with sub-watershed N loads, atmospheric N loads, and benthic flux. These loads represent **present loading conditions** for the listed sub-embayments. *Warren's Cove and Prince's Cove Channel direct atmospheric deposition is included in the Price Cove load.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Cotuit Bay	21.778	5.786	-54.443
West Bay	19.068	4.233	3.815
Seapuit River	3.767	0.452	-5.418
North Bay	29.447	3.953	67.522
Prince's Cove	13.362	1.230	0.512
Warren Cove	12.027	*	8.830
Prince's Cove Channel	5.537	*	2.345
Surface Water Sources			
Marstons Mills River	14.518	-	-
Little River	3.962	-	-

VI.2.4 Model Calibration

Calibration of the total nitrogen model of Three Bays proceeded by changing model dispersion coefficients so that model output of nitrogen concentrations matched measured data. Generally, several model runs of each system were required to match the water column measurements. Dispersion coefficient (*E*) values were varied through the modeled system by setting different values of *E* for each grid material type, as designated in Section V. Observed values of *E* (Fischer, *et al.*, 1979) vary between order 10 and order 1000 m^2/sec for riverine estuary systems characterized by relatively wide channels (compared to channel depth) with moderate currents (from tides or atmospheric forcing). Generally, the relatively quiescent estuarine embayments of the south shore of Cape Cod require values of *E* that are lower compared to the riverine estuary systems evaluated by Fischer, *et al.*, (1979). Observed values of *E* in these calmer areas typically range between order 10 and order 0.001 m^2/sec (USACE, 2001). The final values of *E* used in each sub-embayment of the modeled system are presented in Table VI-3. These values were used to develop the “best-fit” total nitrogen model calibration. For the case of TN modeling, “best fit” can be defined as minimizing the error between the model and data at all sampling locations, utilizing reasonable ranges of dispersion coefficients within each sub-embayment.

Table VI-3. Values of longitudinal dispersion coefficient, E, used in calibrated RMA4 model runs of salinity and nitrogen concentration for the Three Bays estuary system.

Embayment Division	E m^2/sec
Cotuit Bay Inlet	5.0
Cotuit Bay	10.0
Seapuit River	5.0
West Bay Inlet	5.0
West Bay	10.0
South Windmill Cove	0.8
Mellon Cove	1.0
North Bay	10.0
Prince’s Cove - north	5.0
Prince’s Cove - south	1.0
Warren’s Cove	5.0
Dam Pond	10.0
Eel River	0.5
Little River	1.0
Marstons Mills River	5.0

Comparisons between calibrated model output and measured nitrogen concentrations are shown in plots presented in Figures VI-2 and VI-3. In these plots, means of the water column data and a range of two standard deviations of the annual means at each individual station are plotted against the modeled maximum, mean, and minimum concentrations output from the model at locations which corresponds to the SMAST monitoring stations.

For model calibration, the mid-point between maximum modeled TN and average modeled TN was compared to mean measured TN data values, at each water-quality monitoring station. The calibration target would fall between the modeled mean and maximum TN because the monitoring data are collected, as a rule, during mid ebb tide.

Also presented in this figure are unity plot comparisons of measured data verses modeled target values for each system. Computed root mean squared (rms) error is less than 0.03 mg/L, which demonstrates the exceptional fit between modeled and measured data for this system.

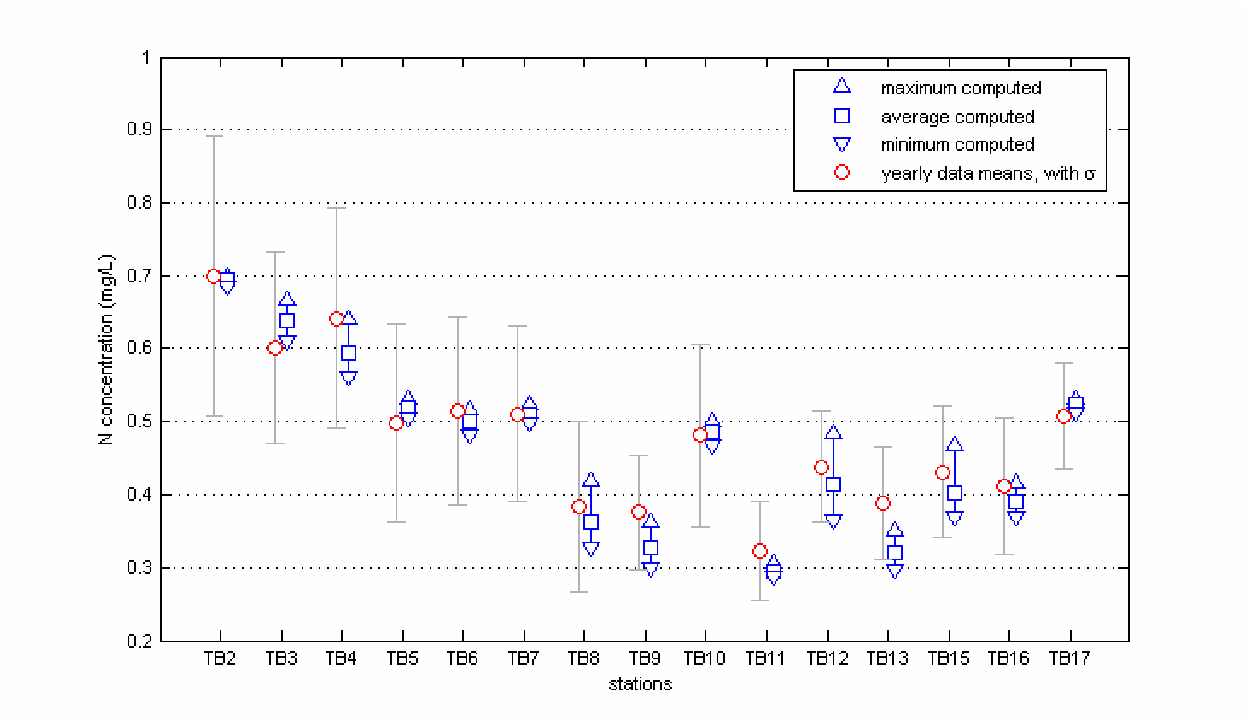

Figure VI-2. Comparison of measured total nitrogen concentrations and calibrated model output at stations in the Three Bays system. Station labels correspond with those provided in Table VI-1. Model output is presented as a range of values from minimum to maximum values computed during the simulation period (triangle markers), along with the average computed concentration for the same period (square markers). Measured data are presented as the total yearly mean at each station (circle markers), together with ranges that indicate ± one standard deviation of the entire dataset

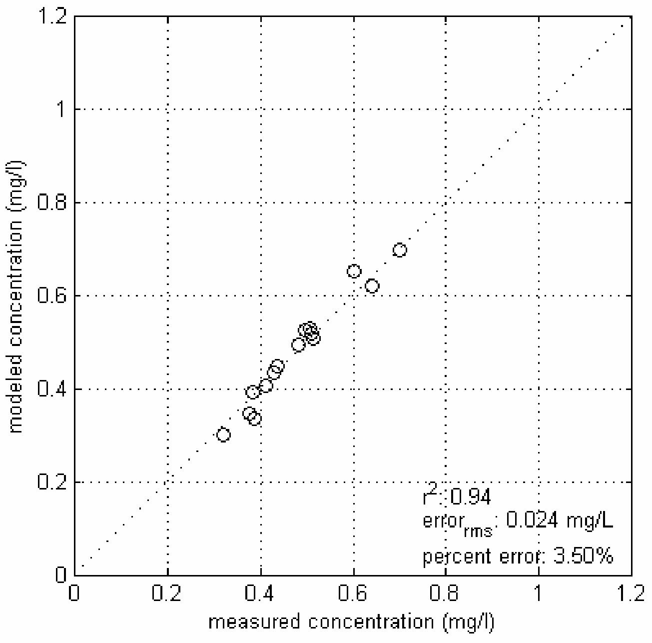

Figure VI-3. Model total nitrogen calibration target values are plotted against measured concentrations, together with the unity line. Computed correlation (R^2) and error (rms) for the model are also presented.

A contour plot of calibrated model output is shown in Figures VI-4. In this figure, color contours indicate nitrogen concentrations throughout the model domain. The output in these figures show average total nitrogen concentrations, computed using the full 5-tidal-day model simulation output period.

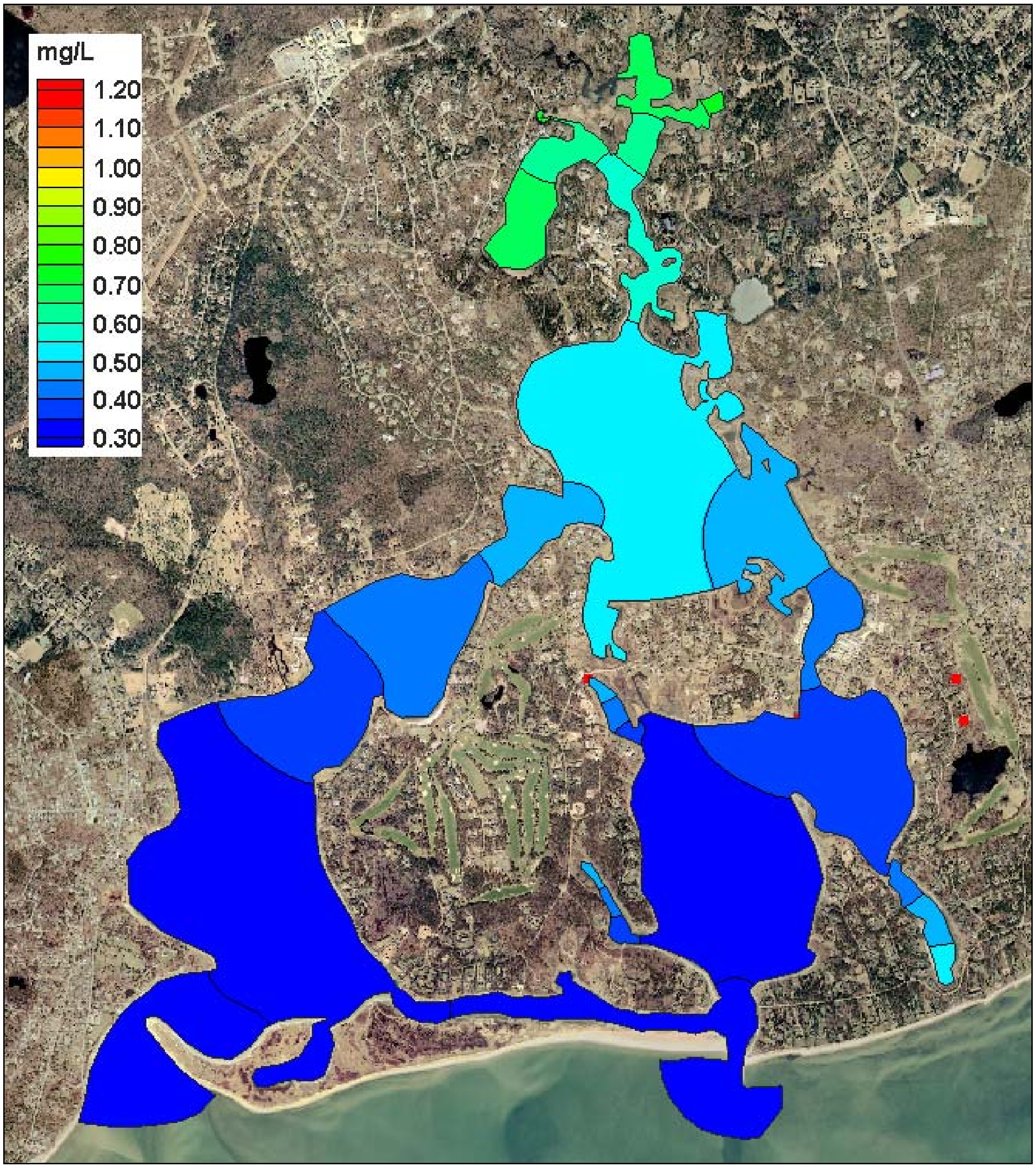

Figure VI-4. Contour plot of average total nitrogen concentrations from results of the present conditions loading scenario, for the Three Bays system.

VI.2.5 Model Salinity Verification

In addition to the model calibration based on nitrogen loading and water column measurements, numerical water quality model performance is typically verified by modeling salinity. This step was performed for the Three Bays system using salinity data collected at the same stations as the nitrogen data. The only required inputs into the RMA4 salinity model of each system, in addition to the RMA2 hydrodynamic model output, were salinities at the model open boundary, at the freshwater stream discharges, and groundwater inputs. The open boundary salinity was set at 29.6 ppt. For surface water steams and groundwater inputs salinities were set at 0 ppt. Surface water stream flow rates for the streams were the same as those used for the total nitrogen model, as presented earlier in this section. Groundwater inputs used for each model were 16.01 ft^3/sec (39,100 m^3/day) for Prince's Cove, 5.40 ft^3/sec (13,200 m^3/day) for North Bay, 3.22 ft^3/sec (7,900 m^3/day) for West Bay, 6.57 ft^3/sec (16,100 m^3/day) for Cotuit Bay, and 0.77 ft^3/sec (1,900 m^3/day) for the Seapuit River. Groundwater flows were distributed evenly in the model through the use of several 1-D element input points positioned along each model's land boundary.

Comparisons of modeled and measured salinities are presented in Figures VI-5 and VI-6, with contour plots of model output shown in Figure VI-7. Though model dispersion coefficients were not changed from those values selected through the nitrogen model calibration process, the model skillfully represents salinity gradients throughout the Three Bays estuary system. The rms error of the three models is less than 0.8 ppt, and correlation coefficient between the model and measured salinity data is 0.78. The salinity verification provides a further independent confirmation that model dispersion coefficients and represented freshwater inputs to the model correctly simulate the real physical system.

VI.2.6 Build-Out and No Anthropogenic Load Scenarios

To assess the influence of nitrogen loading on total nitrogen concentrations within the Three Bays system, two standard water quality modeling scenarios were run: a "build-out" scenario based on potential development (described in more detail in Section IV) and a "no anthropogenic load" or "no load" scenario assuming only atmospheric deposition on the watershed and sub-embayment, as well as a natural forest within each watershed. Comparisons of the alternate watershed loading analyses are shown in Table VI-4. Loads are presented in kilograms per day (kg/day) in this Section, since it is inappropriate to show benthic flux loads in kilograms per year due to seasonal variability.

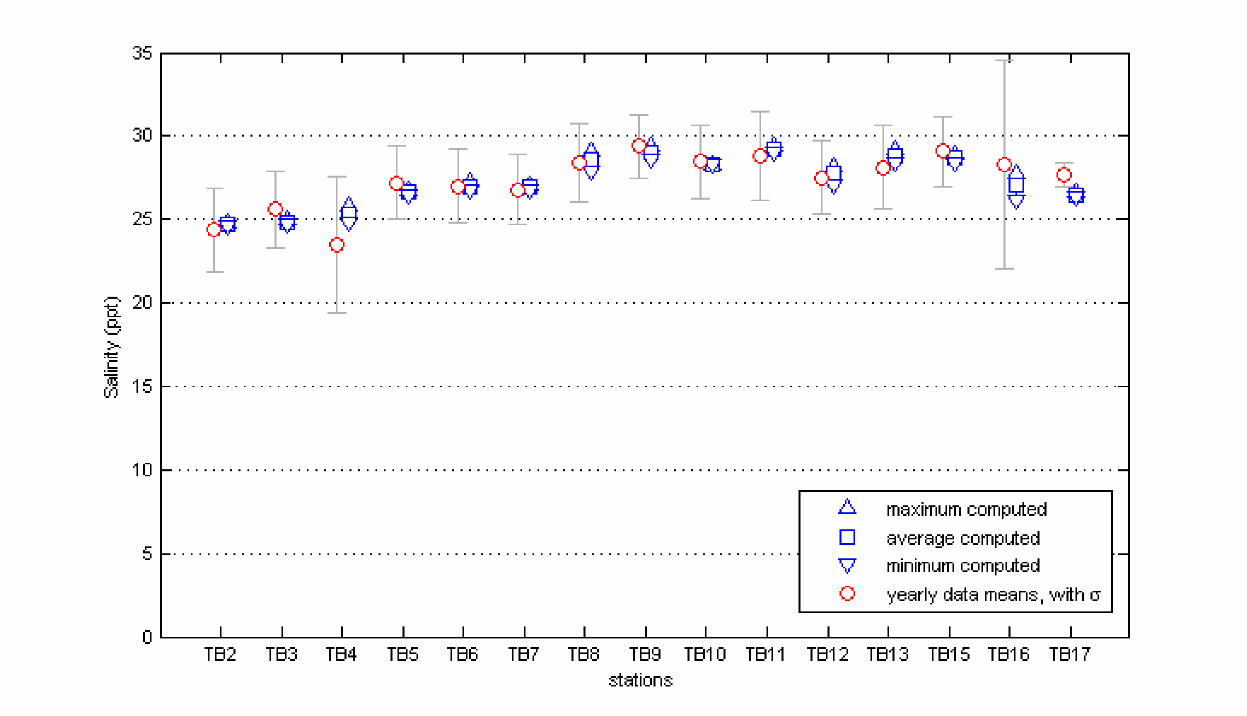

Figure VI-5. Comparison of measured and calibrated model output at stations in Three Bays. Stations labels correspond with those provided in Table VI-1. Model output is presented as a range of values from minimum to maximum values computed during the simulation period (triangle markers), along with the average computed salinity for the same period (square markers). Measured data are presented as the total yearly mean at each station (circle markers), together with ranges that indicate ± one standard deviation of the entire dataset.

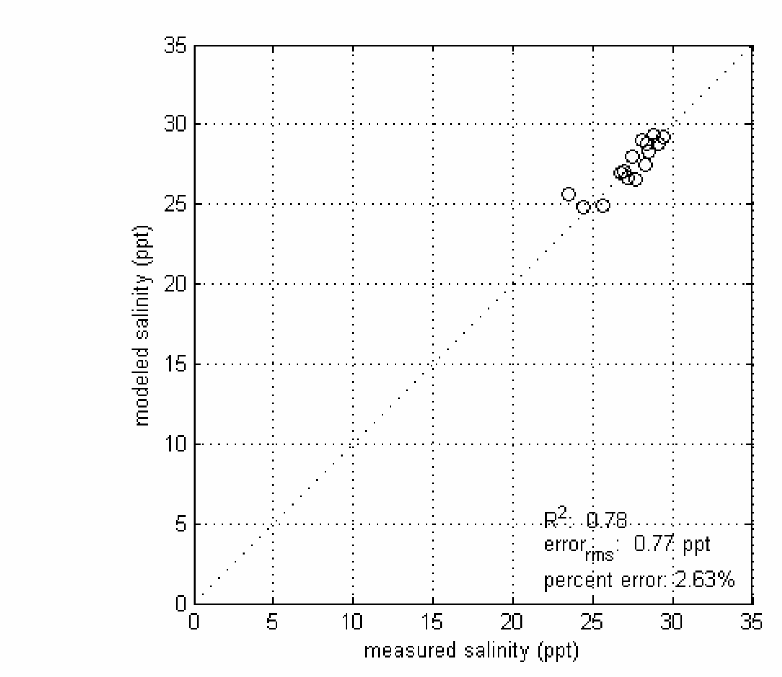

Figure VI-6. Model salinity target values are plotted against measured concentrations, together with the unity line. Computed correlation (R^2) and error (rms) for each model are also presented.

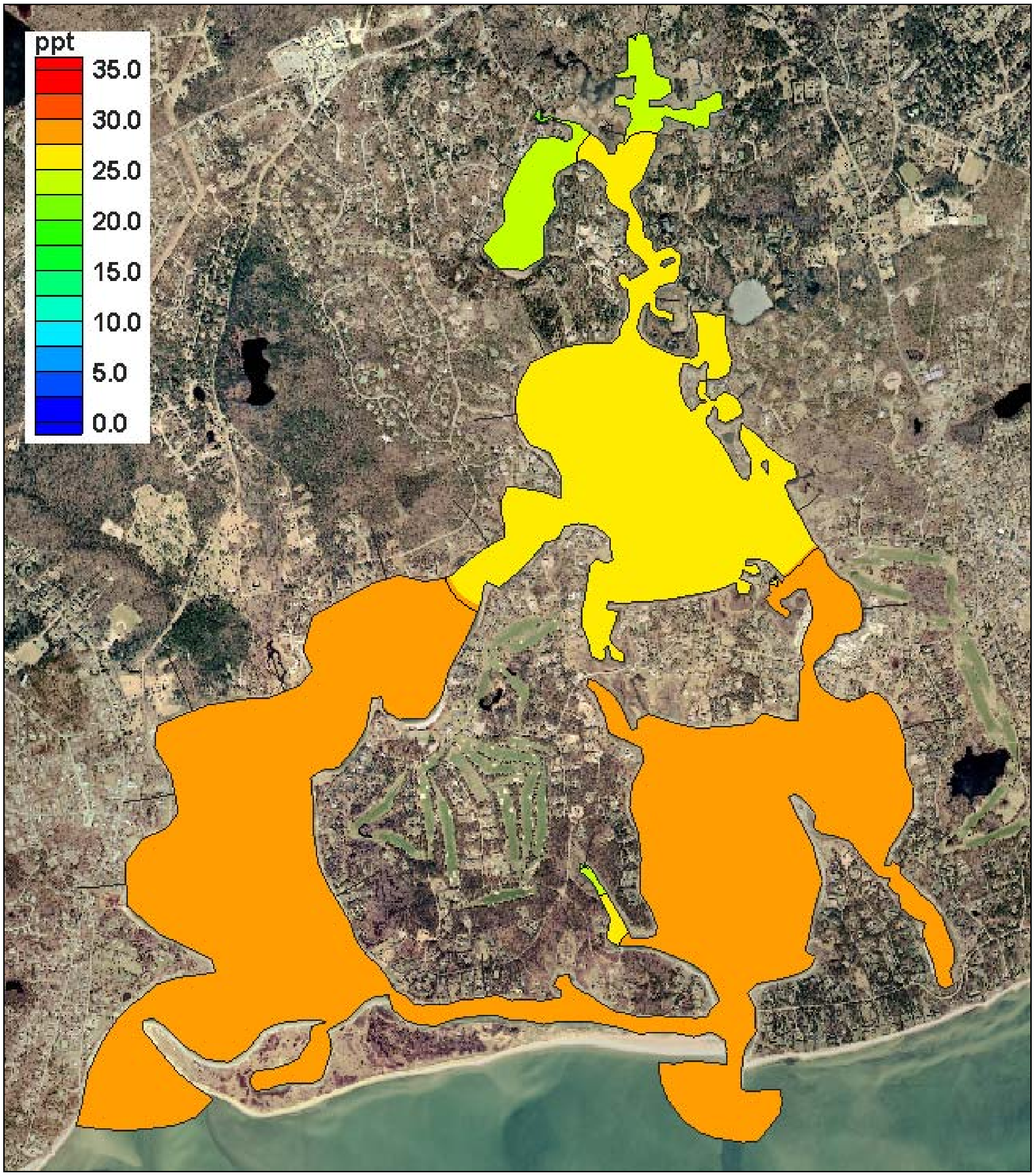

Figure VI-7. Contour Plot of modeled salinity (ppt) in the Three Bays system.

Table VI-4. Comparison of sub-embayment watershed loads used for modeling of present, build-out, and no-anthropogenic (“no-load”) loading scenarios of the Three Bays 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)	build out (kg/day)	build-out % change	no load (kg/day)	no load % change
Cotuit Bay	21.778	24.463	12.3%	1.975	-90.9%
West Bay	19.068	20.077	5.3%	1.170	-93.9%
Seapuit River	3.767	4.507	19.6%	0.452	-88.0%
North Bay	29.447	32.370	9.9%	1.970	-93.3%
Prince’s Cove	13.362	15.197	13.7%	1.137	-91.5%
Warren’s Cove	12.027	15.290	27.1%	1.945	-83.8%
Prince’s Cove Channel	5.537	6.564	18.6%	0.515	-90.7%
Surface Water Sources					
Marstons Mills River	14.518	17.008	17.2%	1.641	-88.7%
Little River	3.962	4.830	21.9%	0.471	-88.1%

VI.2.6.1 Build-Out

In general, certain sub-embayments would be impacted more than others. The build-out scenario indicates that there would be less than a 6% increase in watershed nitrogen load West Bay as a result of potential future development. Other watershed areas would experience much greater load increases, for example the loads to the Little River would increase 22% from the present day loading levels. A maximum increase in watershed loading resulting from future development would occur in the Warren’s Cove watershed, where the increase would be 3.263 kg/day, or 27% more than present conditions. For the no load scenarios, almost all of the load entering the watershed is removed; therefore, the load is generally lower than existing conditions by over 85%.

For the build-out scenario, a breakdown of the total nitrogen load entering each sub-embayment is shown in Table VI-5. The benthic flux for the build-out scenarios is assumed to vary proportional to the watershed load, where an increase in watershed load will result in an increase in benthic flux (i.e., a positive change in the absolute value of the flux), and *vise versa*.

Projected benthic fluxes (for both the build-out and no load scenarios) are based upon projected PON concentrations and watershed loads, determined as:

$$(\textit{Projected N flux}) = (\textit{Present N flux}) * [PON_{projected}]/[PON_{present}]$$

where the projected PON concentration is calculated by,

$$[PON_{projected}] = R_{load} * \Delta PON + [PON_{(present\ offshore)}],$$

using the watershed load ratio,

$$R_{load} = (\textit{Projected N load}) / (\textit{Present N load}),$$

and the present PON concentration above background,

$$\Delta PON = [PON_{(present\ flux\ core)}] - [PON_{(present\ offshore)}].$$

Table VI-5. Build-out sub-embayment and surface water loads used for total nitrogen modeling of the Three Bays 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)
Cotuit Bay	24.463	5.786	-57.241
West Bay	20.077	4.233	3.821
Seapuit River	4.507	0.452	-5.562
North Bay	32.370	3.953	72.223
Prince's Cove	15.197	1.230	0.559
Warren's Cove	15.290	-	9.491
Prince's Cove Channel	6.564	-	2.526
Surface Water Sources			
Marstons Mills River	17.008	-	-
Little River	4.830	-	-

Following development of the nitrogen loading estimates for the build-out scenario, the water quality models of each system were run to determine nitrogen concentrations within each sub-embayment (Table VI-6). Total nitrogen concentrations in the receiving waters (i.e., Nantucket Sound) remained identical to the existing conditions modeling scenarios. Total N concentrations increased the most in the upper portions of the system, with the largest change at a station in Prince's Cove (+7.6% at TB2), with the least change occurring in West Bay (+1.3% at TB9) closer to the inlet to Nantucket Sound. Color contours of model output for the build-out scenario are present in Figure VI-8. The range of nitrogen concentrations shown are the same as for the plot of present conditions in Figure VI-4, which allows direct comparison of nitrogen concentrations between loading scenarios.

Table VI-6. Comparison of model average total N concentrations from present loading and the build-out scenario, with percent change, for the Three Bays system.

Sub-Embayment	monitoring station	present (mg/L)	build-out (mg/L)	% change
Prince's Cove - south	TB2	0.695	0.748	+7.6%
Prince's Cove - north	TB3	0.639	0.684	+7.1%
Warren's Cove	TB4	0.595	0.634	+6.6%
North Bay - north	TB5	0.518	0.545	+5.2%
North Bay - south	TB6	0.500	0.525	+4.8%
North Windmill Cove	TB7	0.511	0.536	+4.9%
West Bay - north	TB8	0.363	0.371	+2.2%
West Bay - west	TB9	0.327	0.331	+1.3%
Eel River	TB10	0.486	0.500	+2.9%
Seapuit River	TB11	0.295	0.297	+0.9%
Cotuit Bay - north	TB12	0.414	0.430	+3.8%
Cotuit Bay - south	TB13	0.321	0.327	+1.7%
South Windmill Cove	TB15	0.402	0.412	+2.3%
Mellon Cove	TB16	0.392	0.398	+1.7%
Dam Pond	TB17	0.523	0.551	+5.3%

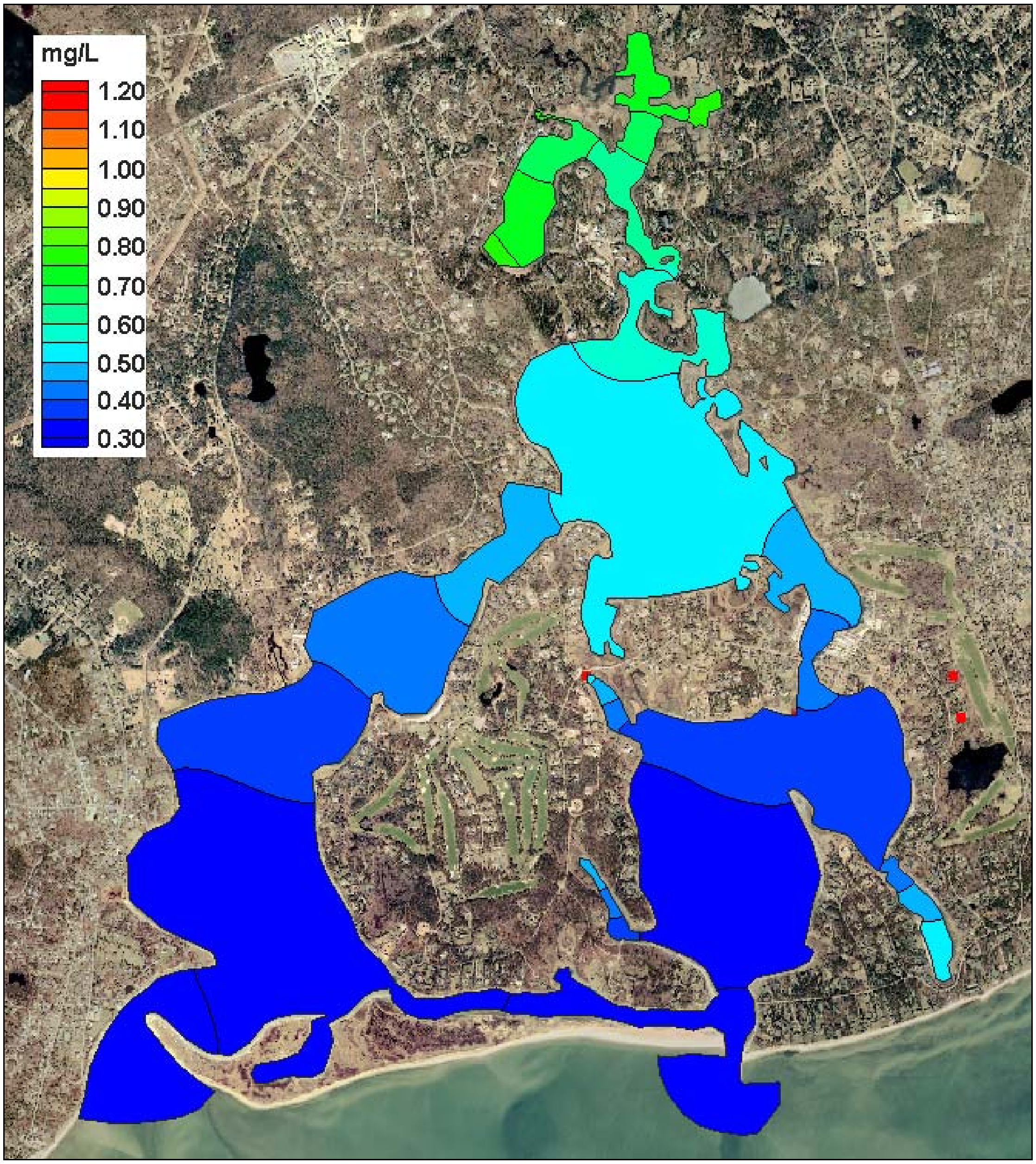

Figure VI-8. Contour plot of modeled total nitrogen concentrations (mg/L) in the Three Bays system, for projected build-out loading conditions.

VI.2.6.2 No Anthropogenic Load

A breakdown of the total nitrogen load entering each sub-embayment for the no anthropogenic load ("no load") scenarios is shown in Table VI-7. The benthic flux input to each embayment was reduced (toward zero) based on the reduction in the watershed load (as discussed in §VI.2.6.1). Compared to the modeled present conditions and build-out scenario, atmospheric deposition directly to each sub-embayment becomes a greater percentage of the total nitrogen load as the watershed load and related benthic flux decrease.

Table VI-7. "No anthropogenic loading" ("no load") sub-embayment and surface water loads used for total nitrogen modeling of the Three Bays 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)
Cotuit Bay	1.975	5.786	-35.901
West Bay	1.170	4.233	3.360
Seapuit River	0.452	0.452	-4.412
North Bay	1.970	3.953	36.481
Prince's Cove	1.137	1.230	0.224
Warren's Cove	1.945	-	4.409
Prince's Cove Channel	0.515	-	1.125
Surface Water Sources			
Marstons Mills River	1.641	-	-
Little River	0.471	-	-

Following development of the nitrogen loading estimates for the no load scenario, the water quality model was run to determine nitrogen concentrations within each sub-embayment. Again, total nitrogen concentrations in the receiving waters (i.e., Nantucket Sound) remained identical to the existing conditions modeling scenarios. The relative change in total nitrogen concentrations resulting from "no load" was significant as shown in Table VI-8, with reductions greater than 45% (at TB2) occurring the upper portions of the system. Results for each system are shown pictorially in Figure VI-9.

Table VI-8. Comparison of model average total N concentrations from present loading and the no anthropogenic ("no load") scenario, with percent change, for the Three Bays system. Loads are based on atmospheric deposition and a scaled N benthic flux (scaled from present conditions). Sentinel threshold stations are in bold print.

Sub-Embayment	monitoring station	present (mg/L)	no load (mg/L)	% change
Prince's Cove - south	TB2	0.695	0.379	-45.4%
Prince's Cove - north	TB3	0.639	0.370	-42.1%
Warren's Cove	TB4	0.595	0.365	-38.7%
North Bay - north	TB5	0.518	0.350	-32.4%
North Bay - south	TB6	0.500	0.346	-30.8%
North Windmill Cove	TB7	0.511	0.349	-31.6%
West Bay - north	TB8	0.363	0.305	-15.9%
West Bay - west	TB9	0.327	0.294	-10.0%
Eel River	TB10	0.486	0.336	-30.9%
Seapuit River	TB11	0.295	0.279	-5.4%
Cotuit Bay - north	TB12	0.414	0.315	-24.0%
Cotuit Bay - south	TB13	0.321	0.286	-10.9%
South Windmill Cove	TB15	0.402	0.315	-21.6%
Mellon Cove	TB16	0.392	0.310	-20.9%
Dam Pond	TB17	0.523	0.351	-32.9%

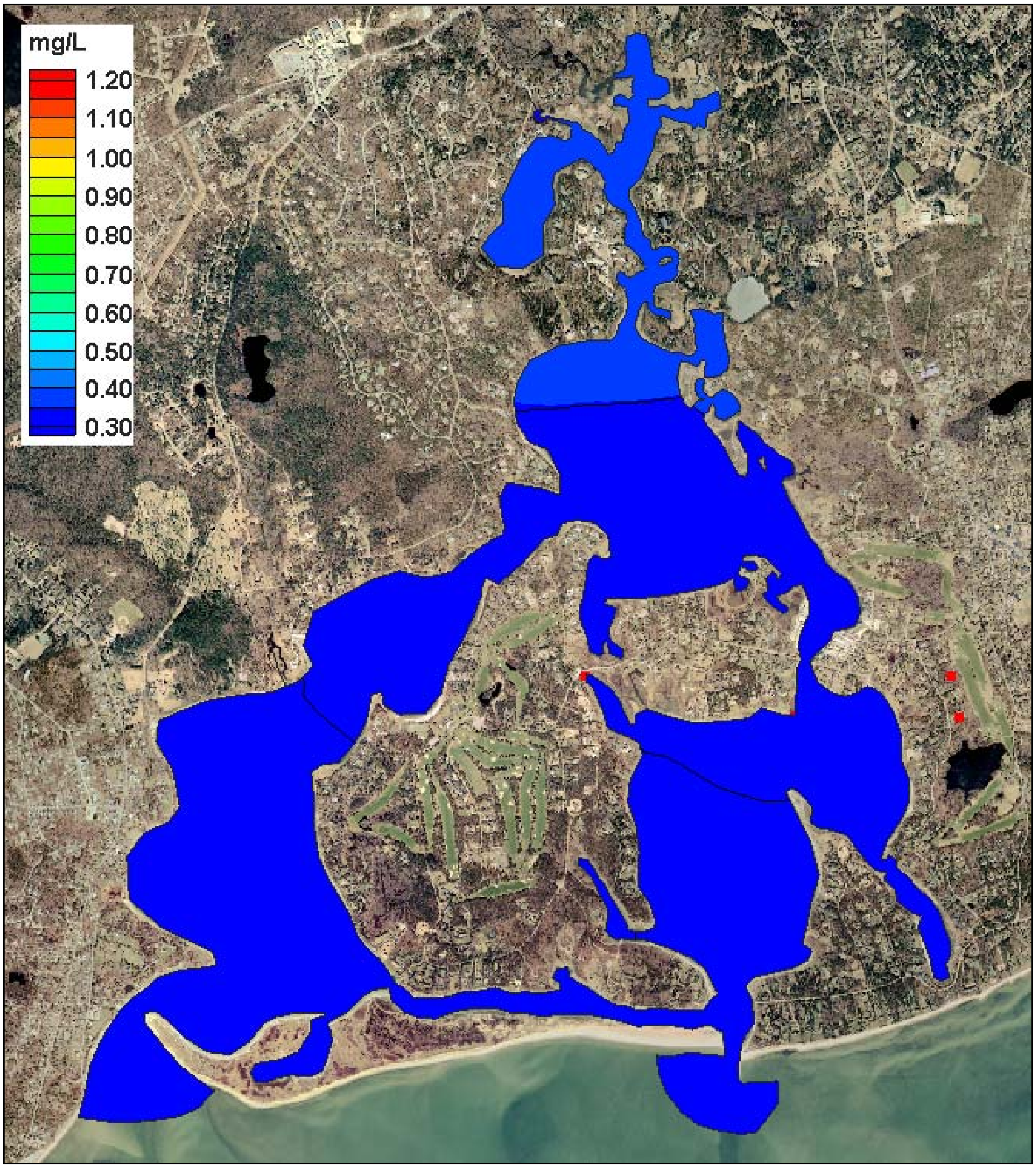

Figure VI-9. Contour plot of modeled total nitrogen concentrations (mg/L) in Three Bays, for no anthropogenic loading conditions.