VI. WATER QUALITY MODELING

The water quality modeling analysis approach that has been typically used for other systems that have been studied as part of the Massachusetts Estuaries Project was slightly modified for Edgartown Great Pond.

This system differs from most other systems modeled up to this point in time mainly because it does not have inlet that is open at all times to the ocean. Water quality in the Pond is managed presently by opening an inlet 2 to 3 times per year (average = 2.65 based on record of openings between 1995 and 2005), once in the spring and once in autumn. The period of time that the inlet remains open after it is breached varies between 1 and 71 days, based on observations of openings made from 1995 through 2007. On average, the pond is open 23 days total a year, which means it is closed off from the ocean nearly 94% of the time.

Because Edgartown Great Pond is actively managed in such a fashion, the water quality analysis has to include methods for determining conditions in the Pond at times when it is both open and closed to tidal exchange with the ocean. During times when the Pond inlet is breached, the RMA-4 model was used to model water quality constituent dispersion throughout the Pond's main basin and the series of coves. During the long periods when the breach is closed, a simple mass balance model was developed. As used together in this analysis, these two modeling techniques accurately simulate conditions in the Pond throughout the critical summer months, and provide a method of investigating alternatives to manage pond health.

VI.1 DATA SOURCES FOR THE MODEL

Several different data types and calculations are required to support the water quality modeling effort for the Edgartown Great Pond 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 salinity and nitrogen in the water column.

VI.1.1 Hydrodynamics and Tidal Flushing in the Embayments

Field measurements and hydrodynamic modeling of the embayment provide essential preparatory input to the water quality model development effort. The pond breach simulation discussed in Chapter V is an important tool for determining the water quality dynamics that are in effect presently, and also for investigating how possibly the pond could be managed differently in the future to further improve water quality conditions. 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. For each of the modeling scenarios presented in this chapter, the breach model was run for a typical 12-day period, based on the tide data record measured offshore of Katama Beach, beginning on November 23, 2004. These tide data were input into the analytical breach model to develop the boundary condition used to force the RMA-2 model of Edgartown Great Pond. The hydrodynamics of the breach model are not strongly dependent upon the small inter-monthly variations of the astronomical tide; therefore, the selected 12-day period is considered representative of typical tidal conditions year-round.

VI.1.2 Nitrogen Loading to the Embayments

Three primary nitrogen loads to Edgartown Great Pond 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 Edgartown Great Pond, consisting of the background concentrations of total nitrogen (TN) in the waters entering from the Atlantic Ocean during the brief periods when the inlet is open. This load is represented as a constant concentration along the seaward boundary of the RMA-4 model grid during the pond breach simulation period.

VI.1.3 Measured Nitrogen Concentrations in the Embayments

In order to create a model that realistically simulates salinity and total nitrogen concentrations in Great Pond in response to the existing flushing conditions and loadings, it was necessary to calibrate the model to actual measurements. The refined and approved data for the 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. For Edgartown Great Pond, eight years of salinity and TN measurements are available between 1995 and 2006.

Table VI-1. Measured nitrogen concentrations and salinities for Edgartown Great Pond. "Data mean" values are calculated as the average of the separate yearly means. TN data represented in this table were collected in 2003 through 2006 in Great Pond and 2002 through 2004 for salinity. The offshore Atlantic Ocean data are from the summer of 2005.

Sampling Station Location	total nitrogen			salinity		
	data mean (mg/L)	s.d. all data (mg/L)	N	data mean (ppt)	s.d. all data (ppt)	N
Jobs Neck Cove – EGP8	0.583	0.174	9	17.9	5.1	11
Jane's Cove – EGP10	0.582	0.153	7	16.5	3.4	10
Wintucket Cove – EGP9	0.597	0.123	10	18.0	3.8	11
Upper Mash Cove – EGP1	0.650	0.170	9	18.9	4.6	14
Lower Mash Cove – EGP2	0.613	0.159	9	18.2	5.6	14
Turkeyland Cove – EGP11	0.639	0.107	5	19.8	3.4	11
Upper Slough Cove – EGP4	0.711	0.193	10	16.2	4.6	32
Upper EGP Basin – EGP3	0.587	0.175	10	18.4	5.1	14
Lower EGP West – EGP5	0.595	0.187	11	20.9	4.6	14
Lower EGP East – EGP6	0.591	0.205	9	22.1	5.4	14
Atlantic Ocean	0.232	0.044	17	32.3	0.6	5

VI.2 MODEL DESCRIPTION AND APPLICATION

The overall approach used in the analysis of Edgartown Great Pond involves first developing a salinity model of the Pond. Salinity is a conservative water quality constituent, meaning that is has no active sources or sinks other than tidal exchange with the ocean. Because salinity data are conservative, they are excellent calibration data for systems such as Great Pond. In such simple systems it is an easy task to compute water recharge and rainfall rates based on the observed salinity record.

The Great Pond analysis requires that both periods when the inlet is open and closed be considered, so a two-part approach was developed. The initial period (when the Pond inlet is breached in the early summer and there is tidal exchange with the ocean) is modeled using the RMA-4 dispersion model. The following period when the inlet is closed, and the Pond behaves like a simple reservoir, is simulated using a simple mass balance model which considers fresh water inputs and constituent mass flux into the Pond (which is 0 for the salinity simulation) throughout the simulation period.

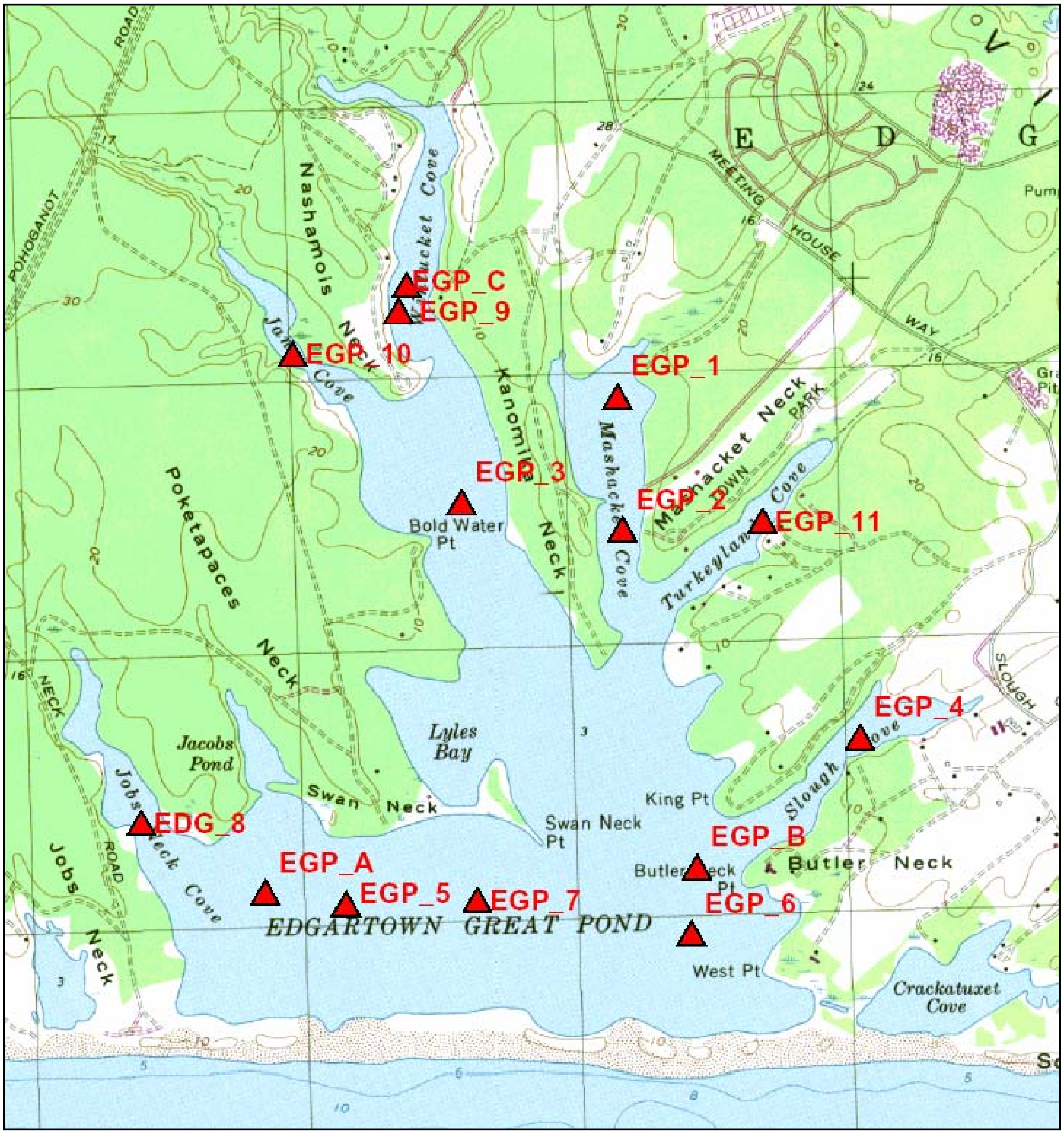

Figure VI-1. USGS topographic map showing monitoring station locations in Edgartown Great Pond that were used in the water quality analysis.

With a calibrated salinity model, a verification of the model is performed using total nitrogen, which is a non-conservative constituent. For TN, bottom sediments act as a source or sink of nitrogen, based on local biochemical characteristics. The TN model considers summertime loading 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 joint Martha's Vineyard Commission/ Cape Cod Commission watershed loading analysis, as well as the measured bottom sediment nitrogen fluxes. Water column nitrogen measurements were utilized as model boundaries and as calibration data.

VI.2.1 Model Formulation

VI.2.1.1 Dispersion Model

A two-dimensional finite element water quality model, RMA-4 (King, 1990), was employed to study the effects of water quality constituent dispersion in Great Pond during the periods when it is open to the ocean. 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 the Pond. 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 other Massachusetts estuarine systems such as Pleasant Bay (Howes *et al*., 2006); Falmouth (Howes *et al*., 2005); and Mashpee, MA (Howes *et al*., 2004), and including other periodically breached coastal ponds like Sesachacha Pond on Nantucket Island (Howes *et al*., 2006).

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_o and D_{ee} 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 nitrogen 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 20-minute time intervals throughout the grid system. For this application, the RMA-4 model was used to predict time varying salinity and total nitrogen concentrations throughout Pond during an inlet opening. For demonstration purposes, the model was used to simulate a 30 day opening to investigate how salinity and total nitrogen change with opening duration, although openings of <12 days are the norm in practice.

VI.2.1.2 Mass Balance Model

During the extended periods when Great Pond is closed off from the Ocean, the system is modeled as a simple well mixed reservoir. The concentration *c* is a function of time *t*, and can be determined using the relationship

$$c(t) = \frac{m_o + t\,\frac{dm}{dt}}{V_o + t\,\frac{dV}{dt}},$$

Where *m* is the total mass of the modeled constituent, *V* is the volume of the Pond and the subscript *o* is used to designate the initial conditions. For the salinity model, the mass flux of salt (dm/dt) into the pond is zero. Using salinity data records from the summers of 1999, 2000, 2003 and 2004, a mass balance analysis of salt was performed to determine the rate of groundwater flow and salt flux through the barrier beach to the Ocean and through the weir between Great Pond and Crackatuxet Cove. These flows are the only possible sinks for salinity in the Pond system. The four years used for this analysis were selected because in each of these years there was adequate salinity data to base the simulation. These breechings raised salinities in the Pond initially, and over the course of the summer, salinities slowly dropped as the Pond was diluted by ground water recharge and rainfall. For each simulation, the model was tuned to replicate both the fall in salinity and rise in pond surface elevation.

By this analysis, the groundwater flow out of the Pond is seen to vary based upon annual variations in rainfall and stage of the pond. In Sept-Oct 1999, the recharge rate and flow though were computed to be 13.5 ft^3/sec and 10 ft^3/sec respectively. The high flow through rate is due to the high elevation of the pond during this period (up to 3.5 ft MLLW), and indicates a large flow through the beach and to Crackatuxet Cove. In July-Aug 2000 the recharge was computed to be 13.5 ft^3/sec, with a flow through of 0.25 ft^3/sec. In June-July 2004, the computed recharge and flow through (13.7 ft^3/sec and 0.35 ft^3/sec respectively) are similar to those computed for 2000. For the final period, in July-Sept 2003, a lower recharge rate was computed of 11.0 ft^3/sec, with a flow through of 1.5 ft^3/sec.

The lower recharge rate (11.0 ft^3/sec) determined using the summer 2003 data was used in the simulations of the following water quality scenarios (e.g., build-out and no-anthropogenic loading) since it represents the likely low-end range of summertime recharge rates. This rate makes the simulations of the different load scenarios show conservative estimates of TN concentrations in the Pond (i.e., a greater increase) compared to average recharge rates.

VI.2.2 Boundary Condition Specification

Mass loading of nitrogen into the model included 1) sources developed from the results of the watershed analysis, 2) estimates of direct atmospheric deposition, and 3) summer benthic regeneration. Nitrogen loads from each separate sub-embayment watershed were distributed across the sub-embayment. For example, the combined watershed, direct atmospheric deposition and benthic flux loads for the whole Pond were evenly distributed across the cells that make up the RMA computational grid.

The loadings used to model present conditions in Edgartown Great Pond are given in

Table VI-2. Watershed and depositional loads were taken from the results of the analysis of Section IV. The watershed load in this table assumes that the WWTF plume had not washed out to its present 2007 level. 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, resulting in a total flux for the system (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. The benthic flux presented in Table VI-2 represents the net flux for the entire pond. Sediments in the northern basin of the Pond tend to have negative fluxes, which indicates that they are a nitrogen sink. The N production of the bottom sediment in other areas is greater than this sink, and as a result, the net flux from the whole pond is positive.

In addition to mass loading boundary conditions set within the model domain, concentrations along the model open boundary were specified for the dispersion model. The model uses concentrations at the open boundary during the flooding tide periods of the RMA-4 model simulations. TN concentrations of the incoming water are set at the value designated for the open boundary. The TN boundary concentration in the Atlantic Ocean region offshore the Pond was set at 0.232 mg/L, based on SMAST data collected offshore Pleasant Bay in the summer of 2005. As there is no offshore station relative to Edgartown Great Pond, the offshore station off Pleasant Bay is representative of Atlantic Ocean water that would be flowing into the Edgartown Great Pond system during a breach event. For the salinity model, the offshore concentration was set at 32.3 ppt.

Table VI-2. Embayment and surface water loads used for total nitrogen modeling of Edgartown Great Pond, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent 2003 present loading conditions for the listed sub-embayments.

embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Edgartown Great Pond	30.282	11.445	20.445

VI.2.3 Development of Present Conditions Model

To develop the water quality model of present conditions for Great Pond, the RMA-4 dispersion model and the mass balance model were separately developed to simulate salinities in the Pond.

First, three successful pond breaches were modeled using RMA-4 and the RMA-2 hydrodynamic model results. The dates and measured salinities (pre- and post-breach) are presented in Table VI-3. For each simulated time period, the dispersion model was run for the period of time that each breach was open, and the resulting pond-averaged salinity at the end of the simulation was compared to the measured value. This comparison is shown in Figure VI-2. The model output compares exceptionally well with Pond measurements made after each breach closing (R^2 correlation of 0.89 and RMS error of 0.57 ppt).

Table VI-3. Breach dates and starting and ending salinities used in the calibration of the RMA-4 dispersion model of Edgartown Great Pond.			
Date of Opening	Days Open	Starting Salinity (ppt)	Ending Salinity (ppt)
July 16, 2005	10	15	27
April 11, 2006	14	12	28
October 16, 2006	7	12	24

For time periods when the pond was closed off from the ocean, the mass balance model was used. This model requires an initial salinity and pond volume, as well as a net fresh water flux and flow-though. The mass balance model was calibrated using data from summer 2003, which is a period where good-quality contemporaneous TN, salinity, and pond elevation data exist. The initial salinity (26.0 ppt) was measured on July 22. The initial Pond volume was determined to be 168,760,000 ft^3, based on results from the hydrodynamic model. The net freshwater input to the Pond was determined to be 11.0 ft^3/sec, with a flow through discharge from the pond of 1.5 ft^3/sec.

The comparison of modeled versus measured salinities between July and September 2003 are presented in Figures VI-3 and VI-4. The comparison of modeled versus measured pond elevations between July and September 2003 are presented in Figures VI-5 and VI-6. The comparison shows that the combined mass balance model is able to simulate both salinities and elevation changes with a high degree of skill, with an R^2 correlation of 0.99 and an rms error of 0.02 ppt for the salinity model, with also an R^2 correlation of 0.99 and rms error of 0.01 ft. Also in Figures VI-4 and VI-6, the results of a model sensitivity analysis are shown. Model output for two additional cases, where the recharge rates were changed to be 15.72 (the annual average from the Cape Cod Commission) and 7.6 ft^3/sec (determined by only considering the volume required to cause the observed increase in pond elevation), shows how the model behaves as the rate is varied. This shows that the model is very sensitive to the applied recharge rate, and further indication that the recharge and flow through rates used to simulate this summer period in 2003 are close to the actual conditions of the pond during at this time. A tabulation of the salinity calibration and elevation verification data is presented in Table VI-4.

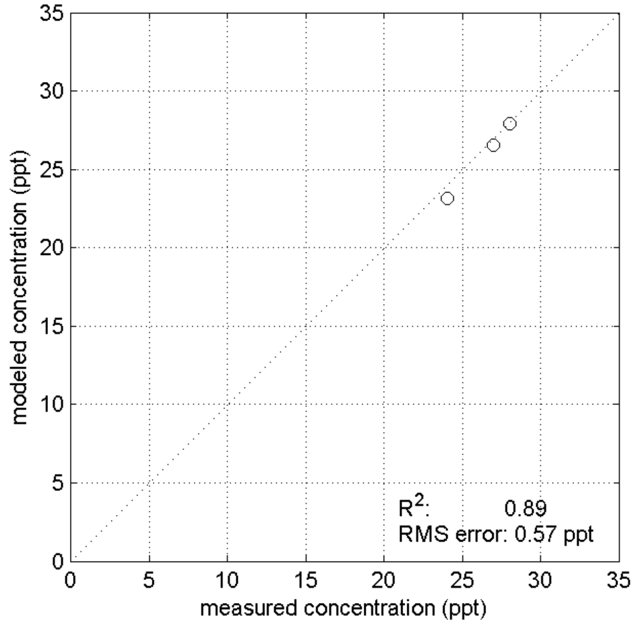

Figure VI-2. Comparison of measured and modeled salinities for successful Edgartown Great Pond breachings that occurred in July 2005, April 2006 and October 2006. RMA-4 salinity dispersion model output is compared to measured salinities at the close of each breach. For these opening events, the inlet allowed tidal exchange with the Atlantic Ocean.

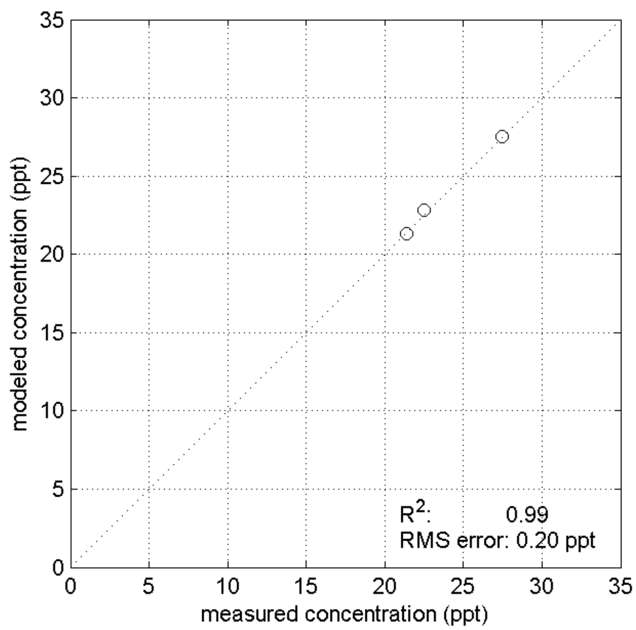

Figure VI-3. Model salinity target values are plotted against measured concentrations, together with the unity line, for the simulation period from July through September 2003. RMS error for this model verification run is 0.20 ppt and the R^2 correlation coefficient is 0.99.

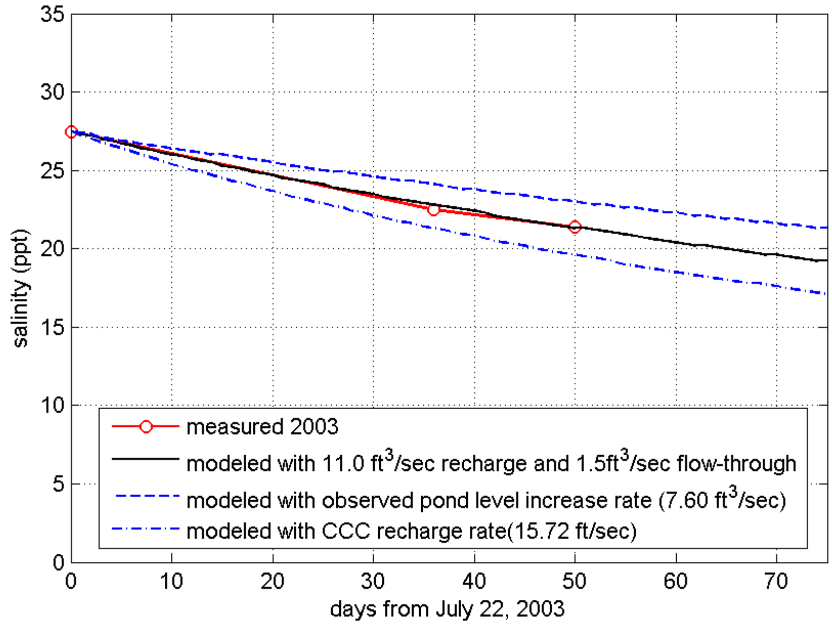

Figure VI-4. Comparison of measured (red line with circles) and modeled (black line) salinities through the summer of 2003, from after the June breaching of an inlet to the Atlantic Ocean. This period through the summer was simulated using the mass balance model. Results of the sensitivity analysis are also presented, showing model output using recharge rate reported by the Cape Cod Commission (CCC) and the rate determined using only the measured surface elevation increase of the pond during this same period.

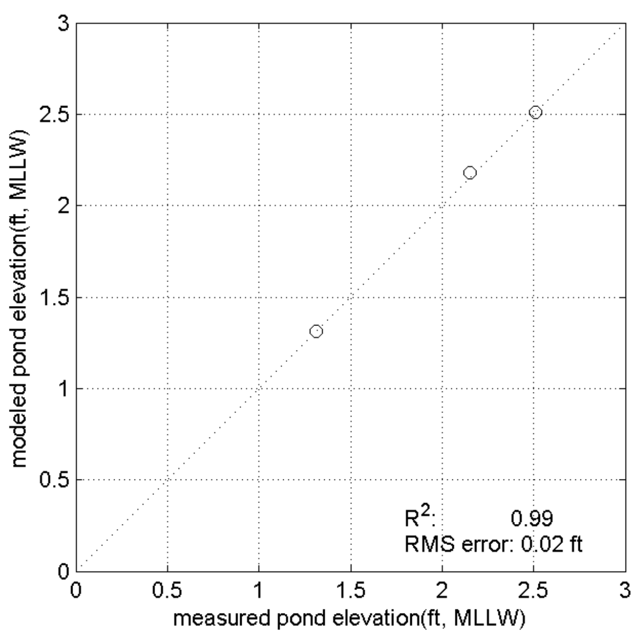

Figure VI-5. Model pond elevation target values are plotted against measured elevations, together with the unity line, for the simulation period from July through September 2003. RMS error for this model verification run is 0.02 ppt and the R^2 correlation coefficient is 0.99.

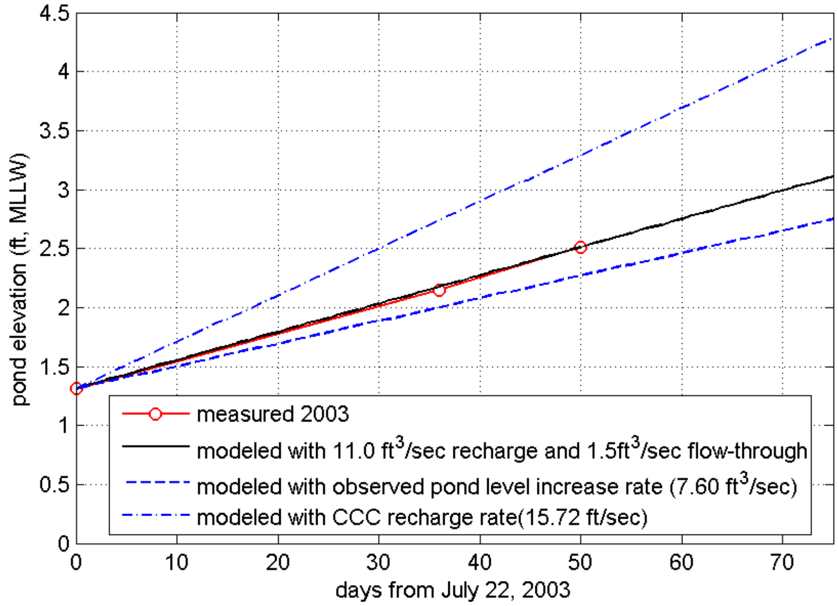

Figure VI-6. Comparison of measured (red line with circle markers) and modeled (black line) pond elevations through the summer of 2003, from after the June breaching of an inlet to the Atlantic Ocean. This period through the summer was simulated using the mass balance model. Results of the sensitivity analysis are also presented, showing model output using recharge rate reported by the Cape Cod Commission (CCC) and the rate determined using only the measured surface elevation increase of the pond during this same period.

Table VI-4. Comparison of measured data and model output for summer 2003 mass balance model calibration-verification period.

Date, 2003	measured salinity (ppt)	measured TN (mg/L)	measured pond elevation (ft, MLLW)	modeled salinity (ppt)	modeled TN (mg/L)	modeled pond elevation (ft, MLLW)
July 22	27.5	0.493	1.3	27.5	0.493	1.3
August 26	22.5	0.802	2.2	22.6	0.815	2.2
September 9	21.4	0.895	2.5	21.3	0.895	2.5

The Great Pond RMA-4 model can be used to show how pond salinities respond through a 30-day period. In Figure VI-7, output from the model in presented for three selected starting salinities. These model results are based on the minimum recharged rate of 11.0 ft^3/sec and a flow through rate of 1.5 ft^3/sec.

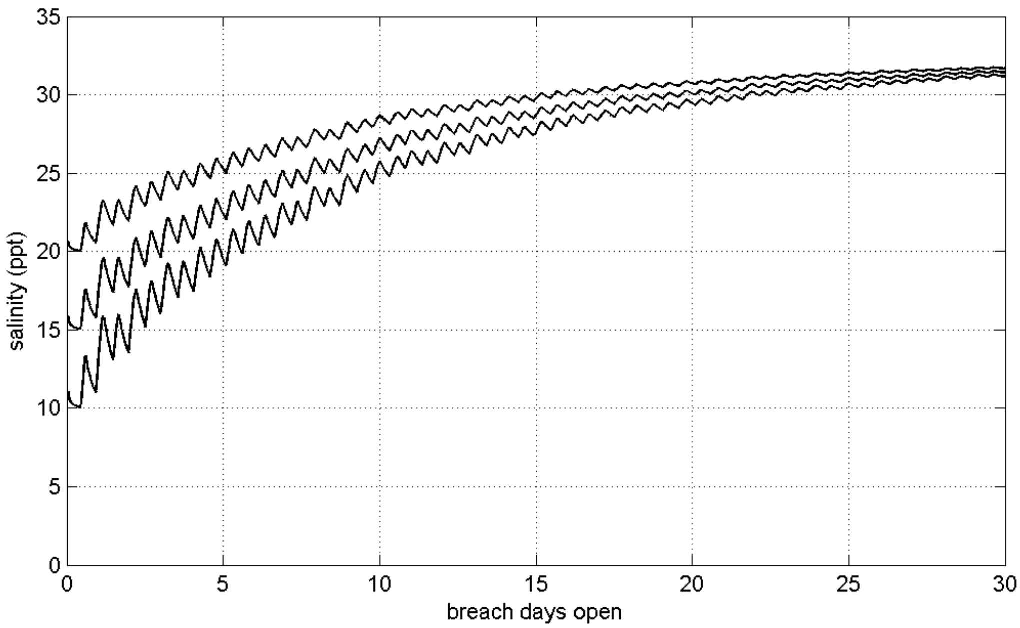

Figure VI-7. RMA-4 model output for Edgartown Great Pond showing how pond averaged salinities vary as a function of initial salinity concentration (here for 10, 15 and 20 ppt) and number of days open for the breach. Model results based on minimum recharge rate of 11.0 ft^3/sec with 1.5 ft^3/sec flow through. Model results also assume a fully open breach for the complete simulation period.

VI.2.4 Total Nitrogen Model Development

With the completion of the salinity model, it was possible to use the components to simulate total nitrogen.

The mass balance model was used to simulate the period following the breach closure in June 2003. This model used the same N mass loading rates as the dispersion model and included the same 11.0 ft^3/sec freshwater input used in the calibration of the salinity model.

Model output is compared to measurements for the summer 2003 period in Figure VI-8 and VI-9. Similar to the results of the salinity model, the comparison demonstrates a high degree of modeling skill, with an R^2 correlation of 0.99 and an RMS error of 0.01 mg/L. Model sensitivity to the applied recharge rate is indicated also in Figure VI-9. Rates were varied between the CCC estimate of the rate (15.72 ft^3/sec) and 7.6 ft^3/sec (again, determined by only considering the volume required to cause the observed increase in pond elevation). Like the salinity analysis, the results show that the model is very sensitive to the applied recharge rate, and indicate that the recharge and flow-through rates used to simulate this period in 2003 is close to actual conditions.

Similar to the salinity model, the Edgartown Great Pond RMA-4 model can be used to show how pond TN concentrations respond through a 30-day period. In Figure VI-7, output from the model is presented for three selected starting TN concentrations and uses TN concentrations (2003-2006) and present loading conditions. These model results are based on the minimum recharged rate of 11.0 ft^3/sec and a flow through rate of 1.5 ft^3/sec.

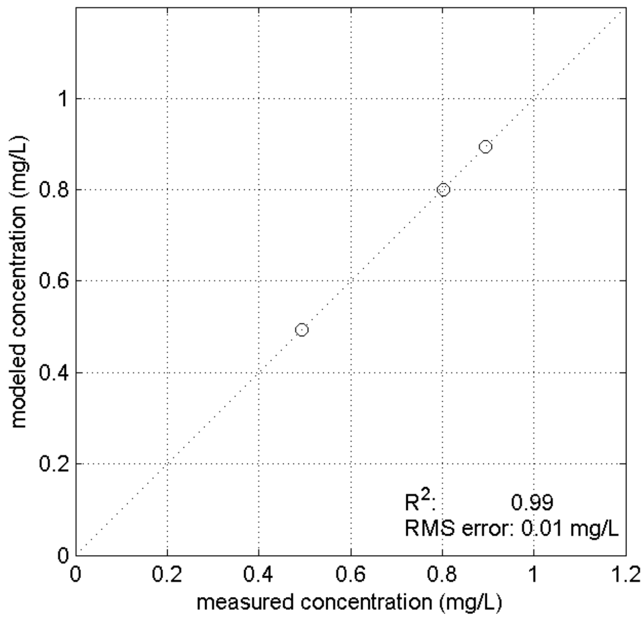

Figure VI-8. Model pond TN target values are plotted against measured concentrations, together with the unity line, for the simulation period from July through September 2003. RMS error for this model verification run is 0.01 mg/L and the R^2 correlation coefficient is 0.99.

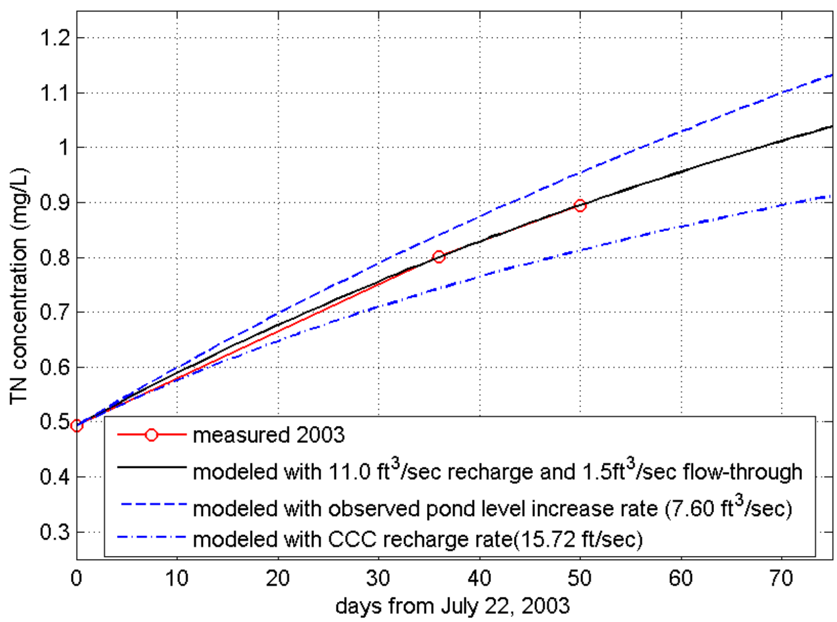

Figure VI-9. Comparison of measured (black line) and modeled (red line with circle markers) TN concentrations through the summer of 2003, from after the June breaching of an inlet to the Atlantic Ocean. This period through the summer was simulated using the mass balance model. Results of the sensitivity analysis are also presented, showing model output using recharge rate reported by the Cape Cod Commission (CCC) and the rate determined using only the measured surface elevation increase of the pond during this same period.

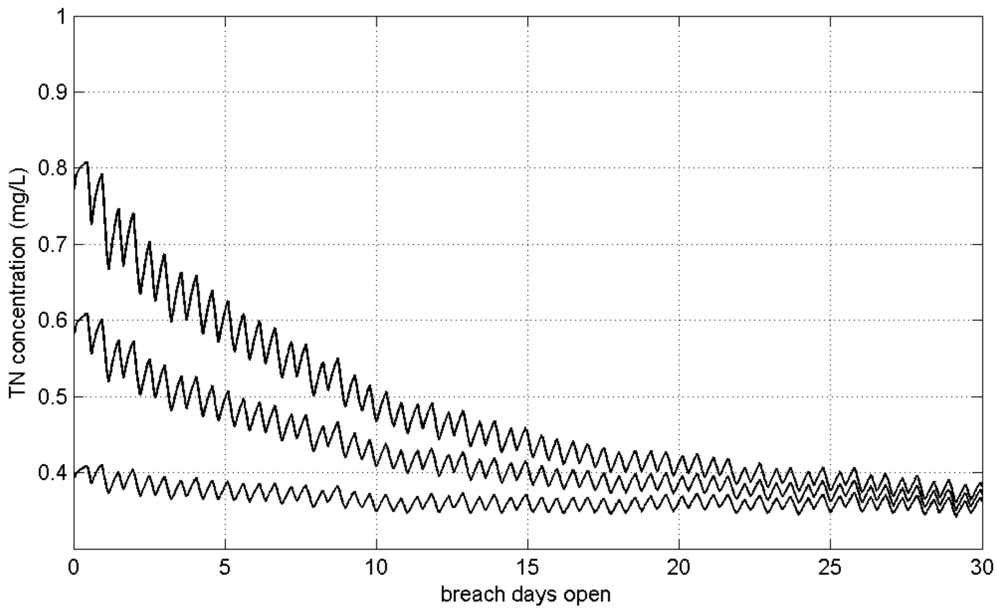

Figure VI-10. RMA-4 model output for Edgartown Great Pond present (2003) loading conditions (Table VI-1), showing how pond averaged TN concentrations vary as a function of initial TN concentration (here for 0.80, 0.60 and 0.40 mg/L) and number of days open for the breach. Model results based on minimum recharge rate of 11.0 ft^3/sec with 1.5 ft^3/sec flow through. Model results also assume a fully open breach for the complete simulation period.

VI.2.5 Present 2007 Load Scenarios

The watershed load to Great Pond has decreased since 2003, as the reduced load from the upgraded WWTF has reached the pond (Table VI-5).

Table VI-5. Sub-embayment and surface water loads used for total nitrogen modeling of Edgartown Great Pond, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent 2007 present loading conditions for the listed sub-embayments (lower load results from newer WWTF Plume).

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Edgartown Great Pond	25.608	11.445	20.445

VI.2.6 2007, Build-Out and No Anthropogenic Load Scenarios

To assess the influence of nitrogen loading on total nitrogen concentrations in Great Pond, the standard “build-out” and “no-load” water quality modeling scenarios were run. These runs included two “build-out” scenarios, 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. An alternate 2007 scenario was also run to determine how conditions have changed in the Pond since the reduced WWTF load has reached the Pond. Comparisons of the alternate watershed loading analyses are shown in Table VI-6. 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.

Table VI-6. Comparison of sub-embayment watershed loads used for modeling of present (2003), present 2007, build-out, and no-anthropogenic ("no-load") loading scenarios of Edgartown Great Pond. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	Present 2003 load (kg/day)	Present 2007 (kg/day)	Present 2007 change	build-out (kg/day)	build-out change	no load (kg/day)	no load % change
Edgartown Great Pond	30.292	25.608	-15.5%	48.666	+60.7%	2.759	-90.9

VI.2.6.1 2007 Loading

The watershed load to Great Pond has decreased since 2003, as the reduced load from the upgraded WWTF has reached the pond. The load breakdown is presented in Table VI-7. The benthic flux for all 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-7. Sub-embayment and surface water loads used for total nitrogen modeling of Edgartown Great Pond, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent 2007 present loading conditions for the listed sub-embayments (Loading in 2007 less than 2003 due to "new" WWTF Plume.).

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Edgartown Great Pond	25.608	11.445	18.133

Using these 2007 loads, the RMA-4 model was run to determine the TN concentration after a 12-day breach, which is a typical opening time span from the available record of openings. Using a starting concentration of 0.60 mg/L, at the end of 12-days, the model shows that the pond averaged TN concentration is 0.41 mg/L. Using this as an input to the mass balance model to simulate the closed summer period after the breach, the TN concentration rises to 0.761 mg/L at 45 days, and 0.994 at 90 days post breach. For each scenario, total nitrogen concentrations in the receiving waters (i.e., the Atlantic Ocean) remained identical to the existing conditions modeling scenario.

VI.2.6.2 Build-Out

A breakdown of the total nitrogen load entering the Pond for the modeled Build-out scenario is shown in Table VI-8.

Table VI-8. **Build-out scenario** sub-embayment and surface water loads used for total nitrogen modeling of the Edgartown Great Pond 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)
Edgartown Great Pond	48.666	11.145	29.511

For the modeled build-out scenario (given an initial concentration of 0.60 mg/L), modeled TN concentrations drop to 0.45 mg/L at the end of the RMA-4 12-day breach simulation. Using the mass balance model to extend the build-out simulation through the summer, the concentration is computed to be 1.069 mg/L 45 days after the closure of the breach, and 1.478 mg/L 90 days after closure of the breach.

VI.2.6.3 No Anthropogenic Load

A breakdown of the total nitrogen load entering the Pond sub for the no anthropogenic load (“no load”) scenarios is shown in Table VI-9. 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-9. “**No anthropogenic loading**” (“no load”) sub-embayment and surface water loads used for total nitrogen modeling of the Great Pond 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)
Edgartown Great Pond	2.759	11.145	6.861

Following development of the nitrogen loading estimates for the no load scenario, the water quality model was run to determine nitrogen concentrations in the Pond. Again, total nitrogen concentrations in the receiving waters (i.e., Atlantic Ocean) remained identical to the existing conditions modeling scenarios.

For the modeled no-anthropogenic scenario (given an initial starting concentration of 0.60 mg/L), modeled TN concentrations decreased to 0.35 mg/L at the end of the RMA-4 12-day breach simulation. Using the mass balance model to extend the no anthropogenic load simulation through the summer, the concentration is computed to be 0.441 mg/L 45 days after the closure of the breach, and 0.501 mg/L 90 days after closure of the breach.