MEP Pleasant Bay Report
Peer Review Findings

Report to:
Orleans Board of Selectmen

Prepared by:
Orleans Wastewater Management Validation and Design Committee
August 4, 2009

MEP Pleasant Bay Report, May 2006
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ERRATA

Changes in *italics* for plain text and underlined for **bold text.**

Executive Summary

Page 10 , 1.0 Major Findings, 1st paragraph, to read:

Major findings are summarized below. *Some of the findings are based on the committee's analytical work and others are findings of the Town's consultant, Woods Hole Group (WHG). The WHG final report[1] to the town discusses their findings in detail.*

Page 10 , 1.1, to read:

1.1 *Based on data in the MEP Pleasant Bay report and water quality data collected from 2000 to 2008 and analyzed by the committee, the committee found that* nitrogen levels in most of the Orleans portion of Pleasant Bay have been dropping for 22 years. Little Pleasant Bay and Meetinghouse Pond nitrogen levels have been dropping since 2000 when water quality monitoring first began. Nitrogen levels in Pah Wah Pond have also decreased, particularly since 2006. These water bodies make up approximately 80% of the Orleans Pleasant Bay estuary.
The nitrogen levels in most of these waters now meet or are below the DEP maximum specifications. *In the case of Meetinghouse Pond the trend in the pond and its sentinel station indicate that DEP specifications may be met by 2012.* Sewering of the watershed surrounding these may not be necessary. See illustration 1 below.

80% of the Orleans Pleasant Bay waters (shown in blue) meet <u>or are soon expected</u> to meet DEP specs and may not need the sewering that is currently planned. This may reduce the cost of remediating Pleasant Bay by tens of millions of dollars.

Page 11, 1.2 to read:

In addition, the committee's analysis of water quality data shows that nitrogen levels in Arey's and Lonnie's ponds have been slowly <u>rising</u> since the year 2000.

[1] Peer Review (Independent Technical Review) of The Massachusetts Estuaries Project Report on the Pleasant Bay System, FINAL REPORT, Woods Hole Group, Inc., June 2009

Page 11, 1.3 add the following two sentences to the first paragraph:

The bias in septic nitrogen loading is based on work by the committee and the fertilizer loading bias is based on work done by a consultant for the Pleasant Bay Water Resource Alliance. The omission of nitrogen loss terms and biases in benthic flux and ocean nitrogen were identified by WHG.

Page 12, 1.8 1st sentence to read:

WHG pointed out that SMAST did not present a nitrogen mass balance in the MEP Pleasant Bay Report.

Page 12, 1.9 to read:

MEP System specifications of 0.16mg/L for eelgrass and 0.21mg/L for benthic animals drive the entire system cost but WHG found no evidence or case studies supporting the specifications or showing that achievement is critical to habitat restoration.

Page 12, additional note regarding items 1.5 and 1.7

Although he has not provided any empirical evidence, Dr. Teal has told Woods Hole Group that he continues to feel that the SMAST nitrogen threshold concentrations will bring about recovery of the benthonic habitats. Dr. Teal had an opportunity to present data or case studies supporting his feeling in the WHG draft report, in Addendum 1 to the WHG draft report and in the WHG final report; the only evidence he presented related to situations involving loss of habitat as a result of point source discharges of raw sewage and recovery of eelgrass when the raw sewage discharge ceased. One of his examples was from the Chesapeake watershed; sewage at 10 million gallons per day had been discharged into a small river over a long period of time. The sewage included high BOD and nitrogen at 30 to 40 mg/l. When the discharge of sewage ceased, eelgrass recovered. On May 7, 2009, Dr. Teal[2] had a further opportunity to present empirical evidence; the topic was discussed at length including the Chesapeake example and Dr. Teal clearly admitted that he could provide no evidence of benthonic habitat recovery in situations comparable to Pleasant Bay.

Dr. Teal also referred to recent (2008 National Park Service survey) diminishment of eelgrass abundance and density in northern portions of Little Pleasant Bay and stated that this is consistent with an increase in nitrogen loading. The National Park Service survey noted that eelgrass had diminished in some areas of Little Pleasant Bay and increased in abundance and density in other areas. Furthermore, the area of diminishment referred to by Dr. Teal is near Namequoit Point and the water quality data for Namequoit Point (2000 to 2008) shows that nitrogen levels have been decreasing for at least the 9 years sampling period.

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[2] WHG Presentation (Video Recording) Part 3 – Mr. Kirk Bosma and Dr. John Teal, Time 01:12:00 to 01:35:00 (Bibliography item 119)

FINDINGS: SECTION II: FINDINGS CONCERNING NITROGEN CONCENTRATIONS IN PLEASANT BAY FROM 2000 TO 2008

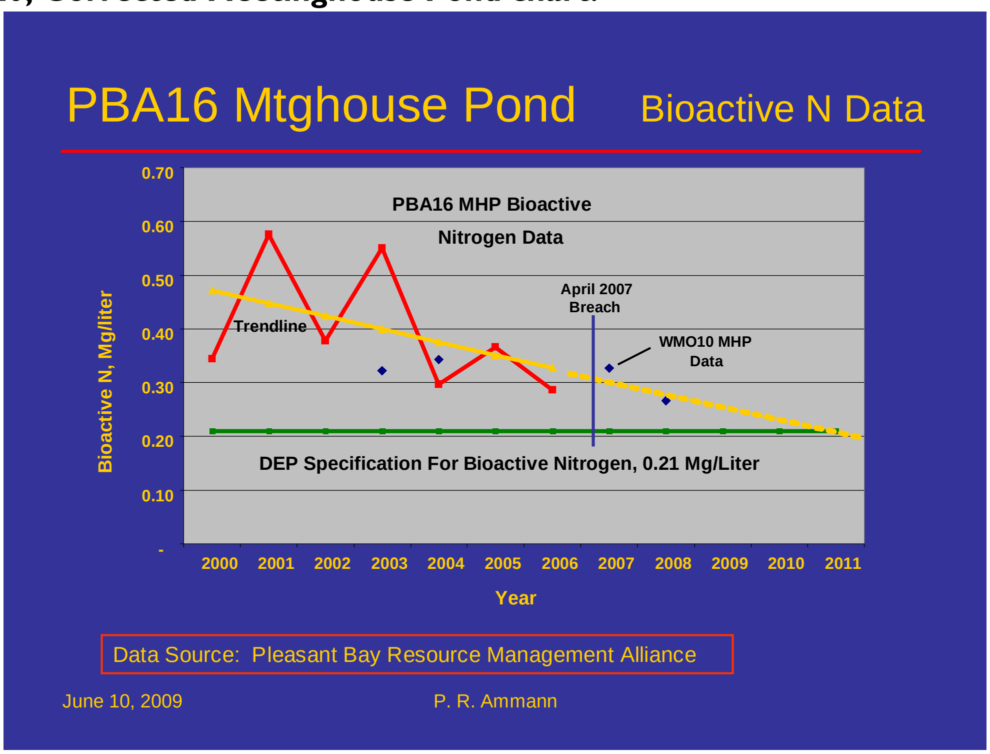
Page 18, last sentence of the 2nd paragraph to read:

In fact, some of the sampling stations have met, *or may meet*, in the near future, the DEP water quality specifications.

Page 20, 1st full paragraph to read:

Data for *a couple of* the kettle ponds also show declining concentrations of bioactive nitrogen. Data for Meetinghouse Pond are presented in Figure 2. The April 2007 Breach in the Nauset Spit opposite Minister's Point *continues to have an effect on the decreasing nitrogen concentration in the water column in Meetinghouse Pond, based on results from the sentinel station (sampling at PBA-16 was discontinued in 2006 and WMO-10 has been designated the sentinel station in the area).* The statistical trend line shows an intersection with the DEP specification in *2012*, and a statistical analysis of the data prior to the 2007 breach also points to achievement of the specification in *2012*.

Page 20, Corrected Meetinghouse Pond chart:



Pages 19 to 22, FINDINGS: SECTION II: FINDINGS CONCERNING NITROGEN CONCENTRATIONS IN PLEASANT BAY FROM 2000 TO 2008

Clarification: The notes on Figures 1 through 5 should say: "*Data Source*: Pleasant Bay Resource Management Alliance". The Pleasant Bay Resource Management Alliance is the source only for the water quality data used in the charts. The charts were prepared by the committee.

END OF ERRATA

Forward

Background

In late 2007 Paul Ammann and Ed Daly had recently finished up serving as consecutive chairmen of the design and construction phases of Orleans' new town hall. Word of a new project that was a major project for the Town costing over a hundred million dollars caught their attention. From initial inquiries with the Wastewater Management Steering Committee and their engineer of Wright-Pierce of Topsham Maine, it was learned that there had been no formal peer or technical review of the State DEP design requirements. Additionally it was noted that the Town of Orleans had in late 2005 requested that a peer review be done on the University of Massachusetts' "Linked Model". That peer review was never executed due to legal issues concerning proprietary rights claimed by the University of Massachusetts.

Messrs Ammann and Daly went to the Wastewater Management Steering Committee and the Board of Selectmen in June of 2008 and recommended that a peer review be performed. The Board of Selectmen unanimously agreed and provided funding for such a review. The Selectmen appointed a committee of seven members with relevant engineering, scientific and academic backgrounds. One member of the Wastewater Management Steering Committee was selected to provide continuity. The biographic sketches of the seven members are provided in the Appendix of this report.

A peer review is an independent process used widely in industry, medicine and academia. It is usually done by members with scientific or professional backgrounds skilled in the art of the work being reviewed. It is a process that should not be interfered with by those who may have a stake in the outcome. The members must be free to independently examine questions that arise from their study of the work being reviewed. The goal is to ensure objectivity of the peer review. Those whose work is being reviewed are always excluded from the review process.

There were objections to the formation of the peer review committee by those who thought it might erode confidence in work that had been done over many years on various boards in town. It was made quite clear by the Committee that we would have nothing to say about the CWMP prior to or during the Town Meeting in October 2008. We have kept our word and at no time took a position as a committee on the CWMP. We assured the Selectmen we would work quietly and in parallel with the ongoing CWMP campaign.

We volunteered to work on the peer review and began the process with no agenda or preconceived conclusions. We all share a commitment:

1. to serve our community;
2. to apply our scientific and technical knowledge and experience to assist the Orleans in addressing environmental and wastewater issues;
3. to ensure that we preserve and maintain the natural beauty of Orleans and its natural waters;
4. and, to ensure that, in doing so, we spend taxpayer monies in the most effective manner.

Committee Work

The Selectmen's Charge to the new Committee was to independently review the University of Massachusetts School of Marine Science and Technology Report on Pleasant Bay that was published in May 2006.

On September 15, 2008, the committee met for the first time. Paul Ammann was elected Chairmen, Ed Daly was elected Vice Chairman and Ron Collins was elected Secretary.

Review assignments to subcommittees were established based on scientific background and experience of individual members. Each subcommittee analyzed their section of the report. The final subcommittee reports, with full Committee approval, were published on the Town of Orleans Website for public inspection.

The efforts of these section reports was also instrumental in establishing key areas for an independent review by an outside qualified consulting firm, or firms. The three areas of focus were:

1. Benthic Flux Nitrogen and Its Measurement
2. Hydrodynamic and Water Quality Modeling
3. Benthonic Issues and Eelgrass Health

An RFP was prepared by the Committee and Town Administration yielded five proposals from excellent companies across the country.

The Woods Hole Group of Falmouth Mass. was awarded a contract in early 2009 for all three topics. The work of Woods Hole Group has been integrated with that of the committee.

Results of the Committee Studies were presented to the DEP and UMASS on June 10, 2009. These same findings were also provided to the Orleans Finance Committee on June 25, 2009 and to the Board of Selectmen on July 1, 2009.

Preface

The members of the Wastewater Validation and Design Committee are all dedicated to the preservation of high water quality in Orleans estuaries and harbors. Everyone in Orleans lives on or near the water. We all want our children and future generations to enjoy the waters that we hold so dear.

The key to preserving our waters is to scientifically understand changes taking place in our natural water systems, identify the root causes of any deterioration in water quality and to seek cost effective solutions to the problems. That has been our mission on this committee.

The project plan before us in Orleans Comprehensive Wastewater Plan is projected to be completed over the next 20 years at 2008 costs which may be more than a hundred and fifty million dollars. It is absolutely essential to know exactly what the problem is before risking that kind of capital investment; we must ensure that any project provides a cost effective solution to a well defined problem. To proceed without proper evaluation of the problem could lead to unnecessary expenditures.

The best potential for success is to make sure the definition of the problem is well understood before implementing a solution. The Town of Orleans has an opportunity right now to use the best aspect of adaptive management by confirming or correcting, as needed, the SMAST design requirements before committing to a solution and a project scope.

An aggressive approach to proceeding in hopes of obtaining low interest or zero-interest loans should be carefully considered. If we do not resolve uncertainties in the scope of the project before beginning any design work, any benefit that may result from obtaining low interest or zero-interest loans may well be negated by the increased costs to correct design requirements after design work has begun. It is always expensive to make changes after design is started.

The committee has published all of its work to date on the Town's website. The meetings of the committee have been open and televised. The Town Administrator and Town Counsel have approved the Committee Members to work in subgroups on separable segments of the review. To date, we have received no technical objection to any of our findings; all of which have been unanimously approved by the committee. The Committee started its investigations with no preconceived ideas. The findings in this report are based on a conscientious, objective, science-based approach. The Committee is committed to a cost effective solution for the restoration of water quality in the town's estuaries and ponds. If presented with original data, case studies or other evidence that shows our findings to be incorrect, we are committed to resolving any issues based on objective science.

Acknowledgements

The Orleans Board of Selectmen

- David Dunford Chair 2008
- Jon Fuller Chair 2009
- Mark Carron
- Margie Fulcher
- John Hinkley (Deceased)
- Sims McGrath

The Orleans Board of Selectmen had the foresight and courage to establish the Wastewater Validation and Design Committee. They felt the townspeople would want confidence in the technical foundation of the project before spending $150 million dollars on a sewer system. They believed that the people of Orleans would want to be assured that the system requirements from the State were thoroughly vetted. We thank the Board of Selectmen for their support to our committee

Woods Hole Group

The team of outstanding scientists that supported the Validation Committee with review of several major technical issues:

- Mr. Bob Hamilton –Project manager
- Dr. Jeffrey Cornwell – Benthic nitrogen specialist
- Mr. Kirk Bosma – Modeling specialist
- Dr John Teal—Benthonic habitat specialist

The Finance committee

We wish to thank out Liaison from the finance Committee, Mark Fiegel, a mathematician and computer scientist. He has assisted our committee with statistical analyses of the Pleasant Bay Report as well as the nitrogen loading survey work of the committee.

We also thank Walter Bennett, Finance Committee Chairman. We value Walter's counsel and he shared our interest in understanding the project costs and risks.

Gwen Holden Kelly

Gwen attended all our committee meetings throughout the year. She has an excellent understanding of the wastewater issues facing the town and has helped communicate those in papers she has prepared for the committee.

We want wish to thank Gwen Holden Kelly for her support in occasionally writing minutes for our committee (when our secretary was unavailable) as well as reviewing committee documents for clarity that were produced for the town website.

Our Committee

The Wastewater Management Validation and Design Committee has spend literally thousands of hours studying and analyzing the MEP Pleasant Bay Report, other MEP reports for Massachusetts estuaries, water quality data of the Pleasant Bay Resource Management Alliance, and other related documents including published scientific technical papers before publishing this report of our findings to the Board of Selectmen.:

- Paul Ammann, Chemical Engineer, Chair
- Ed Daly, Electrical Engineer, Vice Chair
- Ron Collins, Construction Manager, Secretary
- Jeff Eagles, Chemical and Environmental Engineer
- Dr. Greg Horne, Geologist
- Judy Scanlon, Marine Biologist
- Sims McGrath (until elected selectmen in March 2009)

The biographies of the committee are shown in detail in the Appendix.

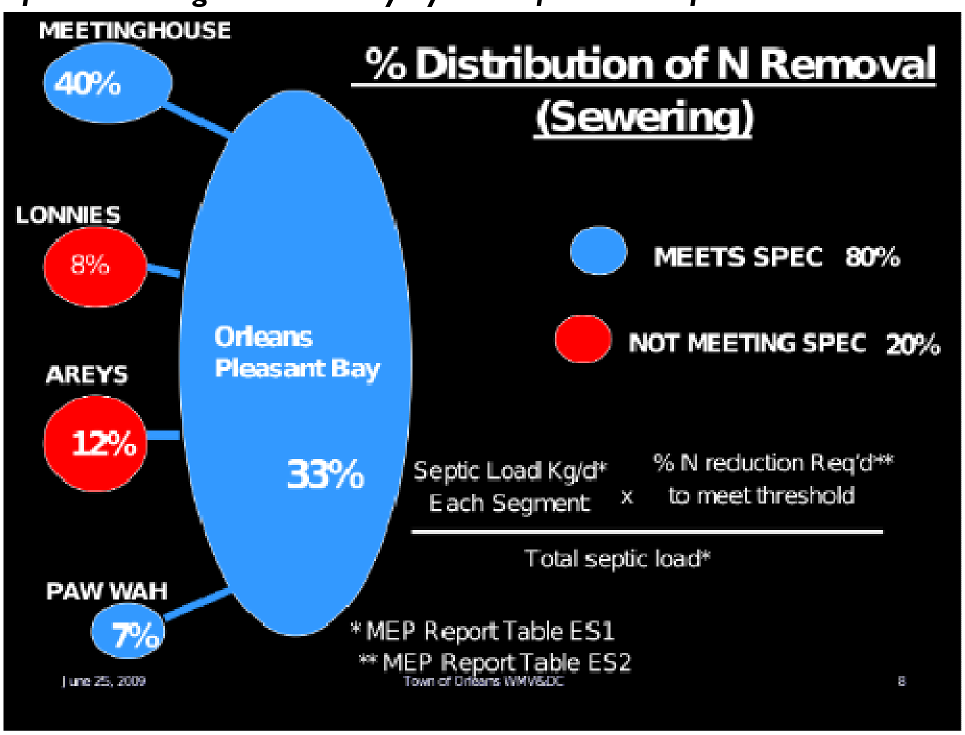
Executive Summary

1.0 Major Findings:

The major findings of the Committee and the Town's consultant, Woods Hole Group, are as follows:

1.1 Nitrogen levels in most of the Orleans portion of Pleasant Bay have been dropping for 22 years. Little Pleasant Bay and Meetinghouse Pond nitrogen levels have been dropping since 2000 when water quality monitoring first began. Nitrogen levels in Pah Wah Pond have also decreased, particularly since 2006. These water bodies make up approximately 80% of the Orleans Pleasant Bay estuary.
The nitrogen levels in these waters now meet or exceed DEP specifications. Sewering of the watershed surrounding embayments which meet DEP specifications should not be necessary. See illustration 1 below.

80% of the Orleans Pleasant Bay waters (shown in blue) meet DEP specs and may not need the sewering that is currently planned. This may reduce the cost of remediating Pleasant Bay by tens of millions of dollars.



This finding is entirely independent of the MEP Pleasant Bay Report. It is based on water quality samples taken by the Pleasant Bay Resource Management Alliance from Pleasant Bay embayments from 2000 to 2008. All of the water quality data was used; none was excluded in our analysis. The finding itself is not WMV&DC just an opinion, it is factual data compared to the DEP specification, which itself is questioned by the WMV&DC.

1.2 Nitrogen levels in Arey's and Lonnie's ponds have been slowly rising since the year 2000. The committee does not know why. In Arey's Pond the benthic flux nitrogen (that is the nitrogen that comes from the muddy sediment in the bottom of the pond) is seven times greater than the septic system nitrogen level. In Lonnie's Pond the ratio of septic nitrogen to benthic flux nitrogen is approximately 1:1. It is therefore not clear that sewering will reduce the nitrogen levels in Arey's and Lonnie's ponds to improve water quality.

The committee believes that the cause of the rising nitrogen in these two ponds needs to be better understood to determine the most effective remediation strategy.

1.3 The mathematical model for Pleasant Bay used by the University of Massachusetts, called the "Linked Model", has been used with input nitrogen loading terms that are possibly biased. These biases include septic nitrogen loading, fertilizer nitrogen, ocean nitrogen and benthic flux nitrogen; all overstate the nitrogen loading terms. In addition, some other loss terms are omitted including conversion to nitrogen gas and buried nitrogen in the sediment.

Loading biases are of a significant magnitude and all overestimate the nitrogen loading input to the Linked Model. The resulting nitrogen concentration calculations are therefore highly questionable.

1.4 In 2005, the Town of Orleans requested and DEP committed to a peer review of the "Linked Model". **<u>DEP has not undertaken the peer review</u>**. The Town does not have a peer reviewed model to conduct confirmatory runs of candidate sewering scenarios to optimize the lowest cost solution.

There is a complete lack of transparency into the Linked Model and its associated data. Completion of the model peer review using Pleasant Bay as the basis is essential to ensuring that we have a reliable tool to predict the behavior of nitrogen in Pleasant Bay.

1.5 The committee and its consultant Woods Hole Group (WHG) have found no basis for the claim that eelgrass habitat has been lost between 1951and 2001. The restoration of eelgrass is the primary DEP basis of the required remediation project for Pleasant Bay.

There is no reliable basis for asserting that there has been a significant decline in eelgrass distribution or habitat quality within Pleasant Bay over the past several decades.

1.6 The scientists at the 2009 Pleasant Bay Resource Management Alliance Symposium at Chatham concluded that, based on past history, there is a high probability that the breach will remain open and drift slowly south for the next 80 years. However, the US Geological Survey estimates that effects of global warming will cause the Atlantic Ocean level to rise between 2-5 feet over the next 90 years.

The 2007 breach is not closing and continues to improve flushing of Pleasant Bay. Tides are higher, forcing more, clean, ocean water into the Bay and the ponds around the Bay.

The Pleasant Bay inlet system will continue to provide enhanced flushing of Pleasant Bay for many decades.

1.7 The committee and its consultant Woods Hole Group (WHG) have found no basis for the MEP Pleasant Bay report claim that benthic animal habitat has been degraded as a result of increasing septic nitrogen in the drowned kettle ponds. There is no historical data to support this claim.

There is no reliable basis for asserting that there has been a decline in benthic animal habitat quality in the drowned kettle ponds of Pleasant Bay over the past several decades. Thus, the SMAST nitrogen specification for restoration of the benthic community in kettle ponds lacks empirical support and therefore appears to be arbitrary.

1.8 SMAST did not present a nitrogen mass balance in the MEP Pleasant Bay Report. A total nitrogen mass balance calculation by Committee members using data from the MEP Pleasant Bay Report shows that the outputs of total nitrogen exceed the inputs on a daily basis by more than 5,000 kilograms. This is a huge quantity of nitrogen (approximately 20%) that is unaccounted for. The Pleasant Bay TMDLs require the towns of Chatham, Harwich, Brewster and Orleans to eliminate 46 kilograms per day of septic nitrogen when a mass balance shows more than 5,000 kilograms per day missing from the system material balance.

Based on this finding, the SMAST linked embayment model is unlikely to provide a reliable basis for simulating the behavior of nitrogen in Pleasant **Bay**.

1.9 ***MEP System Spec of 0.16mg/L for eelgrass and 0.21mg/L for benthic animals drive the entire system cost but are not supported by evidence or case studies showing that achievement is critical to habitat restoration.***

2.0 Recommended Action Plan:

2.1 In order for the Town to realize the potential cost savings of elimination of unnecessary sewering of the watersheds surrounding Pleasant Bay, the Pleasant Bay TMDLs for Orleans need to be recalculated. The actions required in order to complete the TMDL recalculation are as follows:

- 2.1.1 Arrange for SMAST to meet directly with the Validation Committee members, as necessary, to agree to a resolution of the committee findings;
- 2.1.2 Conduct necessary scientific and analytical work to provide best estimate nitrogen inputs to the model;
- 2.1.3 Conduct necessary scientific and analytical work to quantify denitrification (conversion to nitrogen gas) and burial pathways;
- 2.1.4 Collect temperature and salinity data in Orleans kettle ponds to determine if they are stratified and, if they are stratified, revise the model to include modeling techniques to account for stratification;
- 2.1.5 Conduct scientific and technical work to evaluate and understand the specific reasons and biogeochemical mechanisms which are causing nitrogen concentrations to slowly increase in Arey's and Lonnie's Ponds and to explain the cause(s) of the vastly different benthic flux to septic nitrogen load ratios;
- 2.1.6 Based on the scientific work conducted in Arey's and Lonnie's Ponds, identify remediation solution(s) to address the specific problems found;
- 2.1.7 Provide a nitrogen mass balance for Pleasant Bay;
- 2.1.8 Conduct scientific and technical work showing a specific quantified explanation as to why the model can not be calibrated based on total nitrogen;
- 2.1.9 Re-calibrate the revised model based on both total and bioactive nitrogen using dispersion coefficients consistent with the model user manual and guidelines;
- 2.1.10 Conduct an independent peer review of the updated model using Pleasant Bay as the peer review basis and correct any deficiencies;
- 2.1.11 Analyze and evaluate the existing Pleasant Bay water quality data for 2000 to latest available data and determine the impact on remediation requirements;
- 2.1.12 Recalculate TMDLs with the all of the foregoing changes incorporated in the model;
- 2.1.13 Obtain WMO water quality data for the years 2001 to 2005 and 2007 and 2008 and analyze.

2.2 The draft CWMP should be revised to include the findings of the WMV&DC committee. The system design requirements for the remediation of Pleasant Bay contained in the present CWMP may not be correct. There is a potential for an immediate saving of many tens of millions of dollars by not sewering 80% of Pleasant

Bay.

2.3 Recommendations:

2.3.1 The scientists and engineers from DEP, SMAST and the WMV&DC should quickly convene and resolve questions raised by the committee's findings.

2.3.2 The WMV&DC, or another group of volunteers with appropriate scientific and engineering backgrounds should conduct a review of the Nauset / Town Cove and Rock Harbor reports when they are available. The town stands to benefit from the knowledge and understanding of the thousands of hours and money spent by the WMV&DC; this experience would permit the WMV&DC to quickly assess any problems and risks.

FINDINGS: SECTION 1

FINDINGS CONCERNING NITROGEN INPUTS TO SMAST MODEL OF PLEASANT BAY

SMAST created a computer model to simulate the hydrodynamics and nitrogen transport throughout the Pleasant Bay System. As a component of this model, SMAST, with the assistance of the USGS, created watersheds that defined the groundwater flow into various parts of the Pleasant Bay System. And with the help of the Cape Cod Commission, and departments in the Town of Orleans, SMAST estimated the nitrogen inputs into Pleasant Bay through groundwater and runoff. The WMV&DC has evaluated these estimates of the various nitrogen inputs and concluded the following:

1. Septic Discharge. In early 2009, the Committee conducted a simple analysis using a survey of property owners in the Arey's Pond watershed. It was concluded that the nitrogen contribution from septic systems is approximately 70 percent of the values calculated by the Cape Cod Commission.

The nitrogen input from septic systems is based on the equivalent number of year-round residents. Further SMAST, the Cape Cod Commission and DEP determined that the average resident generates approximately 2.7 kilograms of nitrogen per year which is discharged into the local residential septic system[3,4,5]. Thus, it is important to have an estimate of the occupancy in each property on a full year basis. Orleans has a large senior population and a large percentage of seasonal homes. The Committee assumed that generally in Orleans there is 50% year-round housing with 2.3 occupants per residence, and 50% seasonal housing with 6 persons for 10 weeks. The average occupancy is 1.73 equivalent full time annual occupants, as shown in Table 1. SMAST assumes 2.05 full time equivalent occupants[6] based on the 2000 US Census for Orleans. Assuming, these general conditions and the occupancy of 1.73 shown in Table 1, the nitrogen input from septic systems would be about 84 percent[7] of the values presented in the MEP Pleasant Bay Report.

[3] As the wastewater passes through a Title V septic system and into the groundwater, some of the nitrogen is lost, and approximately 77% or 2.1 kilograms per year ultimately enters the groundwater.
[4] Massachusetts Estuaries Project, Pleasant Bay Report, May 2006, pages 30, 32.
[5] MASSDEP Alternative Septic System Test Center at Massachusetts Military Reservation.
[6] Massachusetts Estuaries Project, Pleasant Bay Report, May 2006, pages 33.
[7] (1.73/2.05) = 84%.

Table I

Type Housing	Occupancy	Percent	Average Occupancy
Year-round [1]	2.30	50	**1.15**
Seasonal [2]	1.15	50	**0.58**
Total/Average		100	**1.73**

[1] Assume average occupancy for Orleans of 2.3 equivalent fulltime persons per year.
[2] 3 bedroom house; 2 persons/bedroom; 10 weeks/year. (2 x 3 x 10)/52 = 1.15 equivalent fulltime persons per year.

The Committee's survey of the Arey's Pond watershed, Table 2, shows that the fulltime equivalent occupancy is 1.28 full time equivalent occupants, or about 62 percent of the value used by SMAST. The calculation is shown in the next table. Note that this is a result of the fact that the survey showed that about 70 percent of the houses in the Arey's Pond watershed are used seasonally and the number of persons using the property are fewer than 2 per bedroom and actual use is less than 10 weeks per year.

Table 2

Type Housing	Occupancy	Percent	Average Occupancy
Year-round	2.46	30	**0.74**
Seasonal	0.77	70	**0.54**
Total/Average		100	**1.28**

While this survey indicates that for Arey's Pond area, occupancy is much lower than the value assumed by SMAST, it is likely that the occupancy in other watersheds may also be lower than 2.05. This finding will have a significant impact on the computations by the SMAST "linked-model" simulation of the Pleasant Bay System.

2. Fertilizer Release. SMAST assumed that 20 percent of the nitrogen contained in fertilizers applied to lawns leached into the groundwater and then into the Pleasant Bay System. A 2008 report by Petrovic[8] suggests that only 10 percent of fertilizer nitrogen leaches into the groundwater on Cape Cod. This conclusion indicates that this source of groundwater nitrogen is only 50 percent of the values calculated and used by SMAST.

[8] Petrovic, A. M., Ph. D., "Report to the Pleasant Bay Alliance on the Turfgrass Fertilizer Nitrogen Leaching Rate", 62 East Seneca Road,
Trumansburg, NY 14886, August 20, 2008

3. Benthic Flux. During warm summer months, nitrogen is introduced into the watercolumn from the sediments, particularly in the drowned kettle ponds, such as Meetinghouse and Arey's Ponds. Generally this form of nitrogen is collected in the sediments from nitrogen in the watercolumn during the cold winter months and released in the summer. SMAST collected samples of sediments from various sections of the Pleasant Bay System and conducted laboratory experiments to measure the rates in which nitrogen is released into the water in warmer months; the laboratory measurements were used as estimates. Dr. Cornwell, an expert working with the Woods Hole Group, wrote in his final report[9] that procedures used by SMAST overestimated the benthic flux values and that the actual values should be perhaps only about 70 percent of those used by SMAST in their analysis.

4. Road and Roof Runoff. Rain and snowmelt from roof tops and from paved roads and surfaces contain small amounts of nitrogen. Although the source data on concentrations vary, the total quantities are relatively small; therefore we have not analyzed these sources in detail.

5. Precipitation. Precipitation, containing small quantities of nitrogen oxides, falls directly on land surfaces, depositing components of acid rain. The estimated amounts are small compared to the total nitrogen inputs into the Pleasant Bay system.

6. Direct Precipitation. Precipitation, containing small quantities of nitrogen oxides, falls directly on the salt water body surfaces. The estimated amounts are small compared to the total nitrogen inputs into the Pleasant Bay System.

SMAST estimates of nitrogen inputs into the Arey's Pond watershed are shown in the center column of next Table. Estimates prepared by the Wastewater Management Validation & Design Committee are shown in the right column. For this particular watershed, the estimated nitrogen input is only 64 to 66 percent of the SMAST amount. As shown in Table 3, the septic and benthic flux sources are the largest nitrogen sources.

[9] Cornwell, J. C., Ph. D., "FINAL REPORT, Peer Review (Independent Technical Review)of The Massachusetts Estuaries Project Report on the Pleasant Bay System", Wood Hole Group, Inc., East Falmouth MA 02536, pages 1 – 12.

Table 3

Source	Arey's Pond[1] (Kg/Day)	Alternate-Estimate[2] (Kg/Day)
Natural Background	**0.47**	**Not Avail.**
Land Use	**0.53**	**0.34**
Lawn Fertilizer		0.090
Road and Roof Runoff		0.085
Natural Precipitation		0.160
Septic Systems	**0.78**	**0.42 to 0.58**
Atmospheric Deposition	**0.18**	**0.13**
Total Input	**1.96**	**0.89 to 1.05**
Benthic Flux	**6.00**	**4.20**
Total Load	**7.96**	**5.09 to 5.27**
Ratio Benthic to Septic	**7.69**	**7.24 to 10.00**

[1] Estimates from Pleasant Bay Report, May 2006, page ES-11 (Table ES-1a).
[2] Estimated by WMV&DC.

FINDINGS: SECTION II

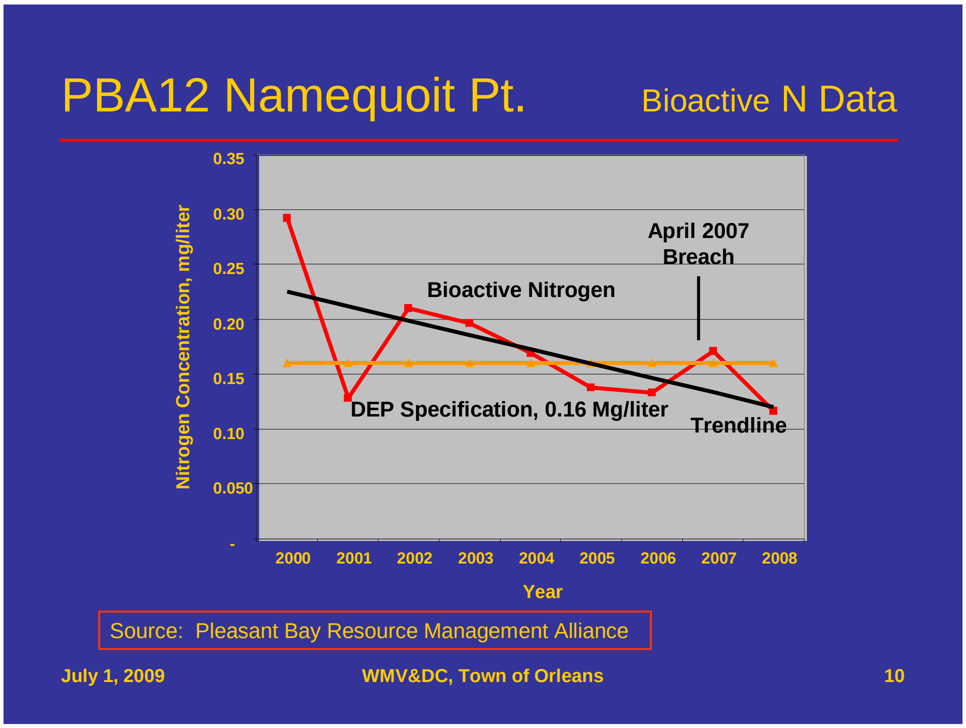
FINDINGS CONCERNING NITROGEN CONCENTRATIONS IN PLEASANT BAY FROM 2000 TO 2008

The MA DEP has established threshold water quality specifications for restoring the health of eelgrass and the benthic communities in Pleasant Bay and in the kettle ponds (e.g., Meetinghouse, Lonnie's, etc). These specifications are discussed in a prior section of this report. In the 2004 or 2005 timeframe, SMAST calculated the nitrogen reduction requirements (TMDLs) for the Pleasant Bay System and its contributing watersheds.

The Pleasant Bay Resource Management Alliance has collected number of water quality samples for SMAST in each year beginning in 2000 and continuing through 2008. The WMV&DC has analyzed the resulting data and the results suggest that nitrogen concentrations in a large part of Pleasant Bay and contiguous kettle ponds are decreasing, not increasing as previously suggested to the public. In fact, some of the sampling stations have met, or will meet in the near future, the DEP water quality specifications.

The sentinel station to observe water quality with respect to the health of eelgrass is PBA12, located just off Namequoit Point in Little Pleasant Bay. The DEP specification of 0.16 mg of bioactive nitrogen per liter has been achieved since 2004 (5 years), as shown in Figure 1.

Figure 1



The bioactive nitrogen concentrations are shown in the red line, and the statistical trend line is shown in black. The trend line is decreasing even using just the data prior to the April 2007 breach. The DEP specification is shown in gold. Again, note that the source of the data is the Pleasant Bay Resource Management Alliance.

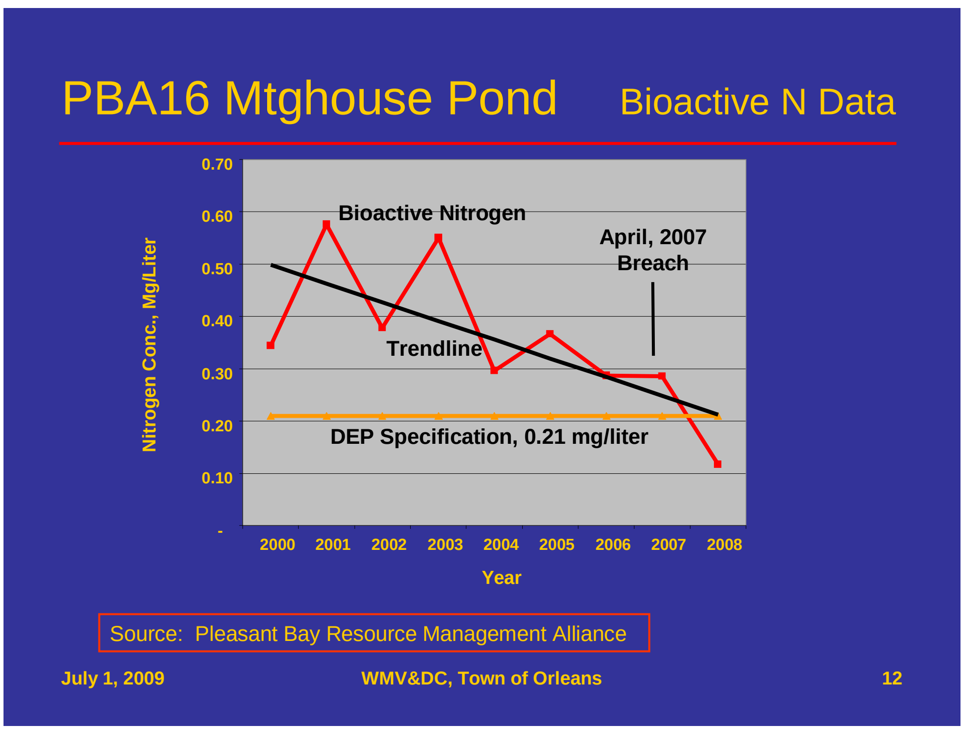
SMAST modeling of Pleasant Bay using tidal conditions as they were in 1986 and into 1987 prior to the breach occurring at Chatham Light is described in Chapter IX of the MEP Pleasant Bay report[10]. The model output data estimates the bioactive nitrogen concentration at Namequoit Point in 1987 prior to the Chatham Light breach to be 0.279 mg/l (based on 2005 estimated nitrogen loads). Assuming that the 1987 septic and fertilizer nitrogen loads were 50% of the corresponding 2005 loads (quite likely a low estimate of the 1987 loads), the Namequoit Point bioactive nitrogen level in 1987 was approximately 0.26 mg/l (59% above the DEP specification) compared with the current, 2008 level of 0.12 mg/l (26% below the DEP specification). It is clear from the modeling information that bioactive nitrogen and indeed total

[10] Massachusetts Estuaries Project, Pleasant Bay Report, May 2006, Chapter IX, page 219.

nitrogen have been decreasing in most areas of Pleasant Bay since 1987. It is also clear from the same modeling information that, if and when the inlet configuration were to return to the pre-1987 configuration, even with the elimination of all septic nitrogen from Pleasant Bay watersheds, the Namequoit Point bioactive nitrogen concentration would be approximately 0.23 mg/l (45% above the DEP specification). Zero septic nitrogen with the pre-1987 inlet conditions would likely make the DEP specification unachievable without applying some alternative technology to improve water quality. *Note: all of the foregoing paragraph assumes that the SMAST models reliably predicts the behavior of nitrogen in Pleasant Bay.*

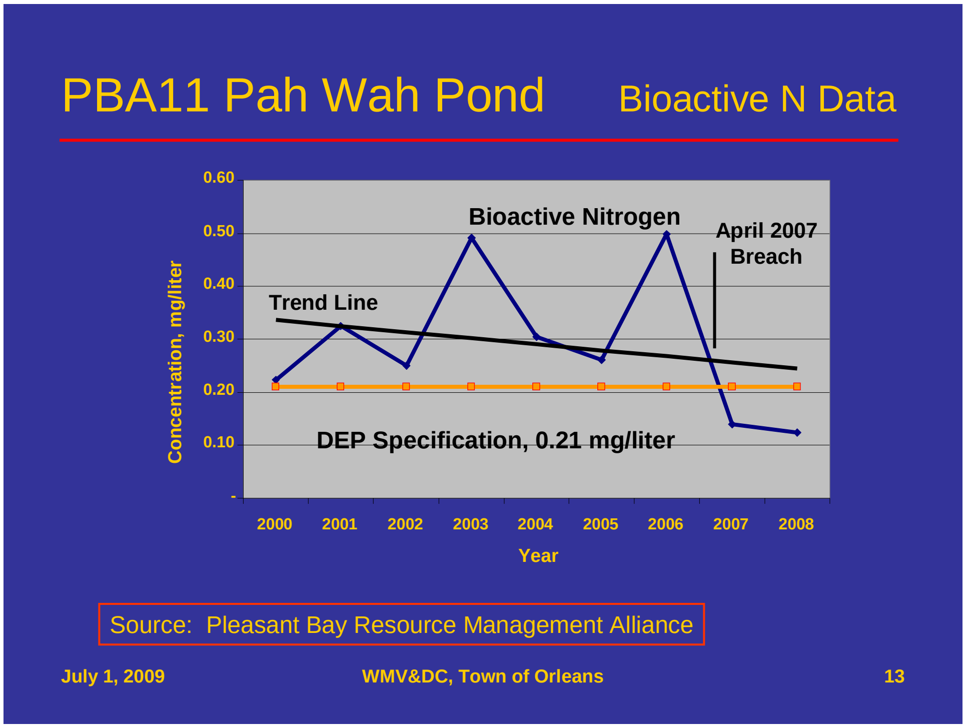
Data for Meetinghouse and Paw Wah kettle ponds also show declining concentrations of bioactive nitrogen. Data for Meetinghouse Pond are presented in Figure 2. The April 2007 Breach in the Nauset Spit opposite Minister's Point has had a dramatic effect on the water quality of Meetinghouse Pond; in 2008, the concentrations of bioactive nitrogen have decreased significantly below the DEP threshold specification of 0.21 mg bioactive nitrogen per liter. The statistical trend line shows an intersection with the DEP specification in 2008, but a statistical analysis of the data prior to the 2007 breach still points to achievement of the specification in 2011.

Figure 2



Water quality data are shown for Pah Wah Pond in Figure 3[11]. The impact of the 2007 breach was evidently significant, as the bioactive nitrogen concentrations dropped to less than 0.15 mg bioactive nitrogen per liter, compared to the DEP threshold of 0.21 mg/liter. This reflects improved flushing by the waters in Little Pleasant Bay (see PBA12 data).

Figure 3



[11] Note: "Note: Five samples were taken in 2007 in the channel that connects Pah Wah Pond with Little Pleasant Bay, as compared with prior years when the samples were taken in the deepest part of the pond. In 2008, samples were taken at the same location in the channel on two dates. Subsequently, the next three samples were taken at the deepest part of Pah Wah Pond, as were all the samples prior to 2007. The bioactive nitrogen concentrations measured in the five samples in 2008 were approximately the same independent of the sample location, and very similar to the five 2007 measurements."

In contrast to the previous figures, data collected for Lonnie's and Arey's Ponds, Figures 4 and 5, show increasing bioactive nitrogen concentrations from 2000 to 2008 (Lonnie's Pond) or 2006 (Arey's Pond). The reasons are not clearly understood, but flushing of these two kettle ponds would appear to be less efficient than for other water bodies describe earlier.

Figure 4

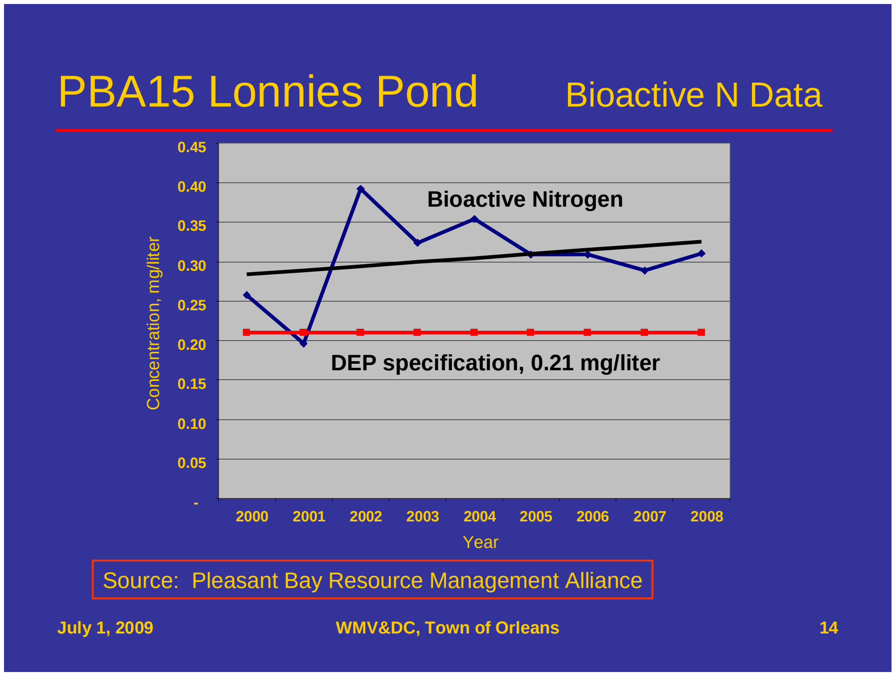
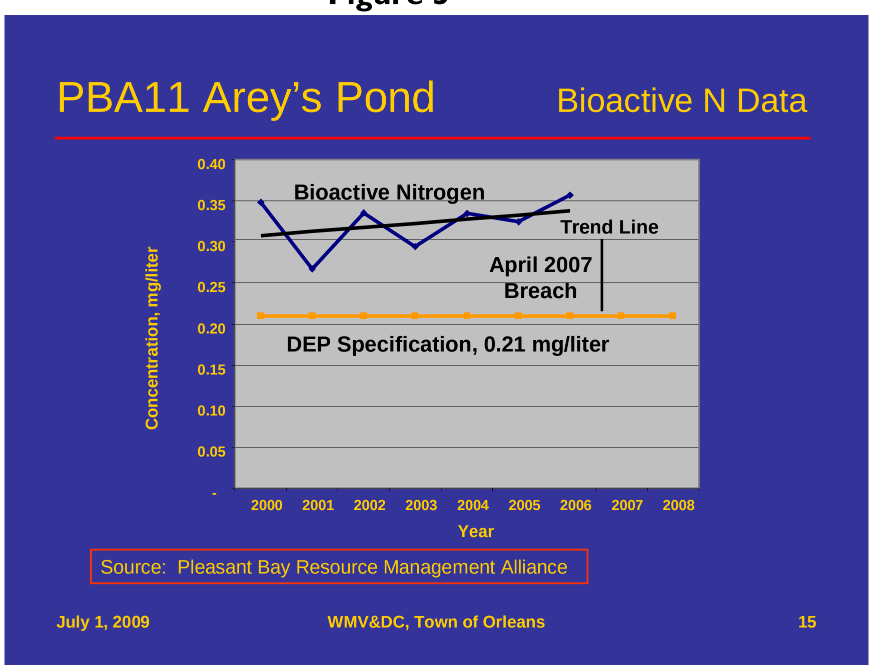


Figure 5



RECOMMENDATIONS FOR FURTHER INVESTIGATION

The review of the estimated nitrogen inputs described by SMAST in the Pleasant Bay Report (2006) and the review of the water quality data suggest the need for more information before beginning the design of the Orleans water remediation program.

1. Septic System Discharge Rates.

The Committee's survey of the Arey's Pond watershed suggests that SMAST overestimated the nitrogen contribution from the local population. Arey's Pond represents only about 8 percent of the septic nitrogen source into the Orleans section of the Pleasant Bay System. The three largest watershed areas are: Meetinghouse Pond (23%), Namequoit River (19%), and the Lower section of The River (18%), as shown in Table 4. The properties of these watersheds should be surveyed to obtain an improved estimate of the nitrogen inputs from these areas. The cost is estimated at $1,000 in expenses plus analytical time.

2. Nitrogen Levels in Kettle Ponds.

The nitrogen concentrations have been rising in Arey's and Lonnie's Ponds from 2000 to 2008. Two contributors to this observation may be (1) poor flushing from The River, and (2) possible stratification of the watercolumn in the pond. If the former condition controls the local pond conditions, then reducing the nitrogen inputs (i.e., septic, fertilizer) should result in a slow decrease in nitrogen levels in the watercolumn. If stratification is a cause, then reducing the nitrogen inputs may not be sufficient.

The important issue is that we do not know what is causing the increase in bioactive nitrogen concentrations. Further study of at least one pond is required to address important requirements issues, before beginning a remedial design:

a. A statistically designed experiment to measure benthic flux rates over a representative area of the sediments,
b. A statistically designed experiment to sample and analyze the "fetid mud" sediments to determine the concentrations of nitrogen species and sulfur (and any other metals/compounds) that could affect the health of the benthic community.
c. A carefully planned study of the stratification of the pond (salinity) and nitrogen and oxygen concentrations as a function of depth and location and the tidal cycle during periods of varying temperatures.
d. Development of a 3-dimensional model to simulate the behavior of the water column and correlation with field data.

Table 4

Source	Total Input (Kg N/Day)[1]	Percent
Meetinghouse Pond	21.15	23
Namequoit River	17.83	19
The River - Lower	16.60	18
Pochet Neck	9.40	10
The River - Upper	9.32	10
Arey's Pond	7.48	8
Pah Wah Pond	5.57	6
Lonnies Pond	4.26	5
Total	91.61	100

FINDINGS: SECTION III

FINDINGS CONCERNING BENTHONIC HEALTH OF PLEASANT BAY

The fundamental driving force for the remediation of groundwater in Orleans that is discharged into Pleasant Bay is the health of benthic or bottom-dwelling organisms within the Bay. It has been asserted, and it is widely assumed that habitat health within the Bay has declined significantly over the past several decades as a consequence of increasing contamination by septic effluent within the groundwater. However, the WMV&DC has not been able to validate the conclusion that Pleasant Bay has suffered major or even significant environmental degradation resulting in the decline of benthic health or habitat quality over any period during the past 58 years.

When considering the environmental health of Pleasant Bay it is important to understand the distinction between the major lagoonal embayments (such as "Big Bay" and "Little Bay") and the smaller semi-isolated drowned kettles (such as Meetinghouse, Lonnie's, Arey's and Paw Wah Ponds) with their associated drainage tributaries leading in to the major embayments. These two distinctly different parts of the Pleasant Bay system originated differently and evolved with different histories over the past several thousand years. The environmental contrasts between the two are quite obvious, as summarized below.

Pleasant Bay **Lagoons & Kettles**

Environmental Attribute	Open Bays & Lagoons	Drowned Kettles
Substrate	well washed sand	fetid black mud
Organic Matter	low concentration	high concentration
Turbidity	low throughout	increases with depth
Dissolved Oxygen	>6 mg/l, Class SA	altern. hypoxic-oxic
Groundwater N	comparable	comparable
Residence Time	approx. 1 day	approx. 1 day
Eelgrass	widespread ~50%	not significant
Benthic Fauna & Other Factors	healthy & diverse shellfish harvests	stressed & depleted >330 boat moorings

The major benthic communities in Pleasant Bay that are believed to have been impacted most significantly by septic effluent are the eelgrass meadows that are widespread and abundant in the major lagoons, and the interstitial infauna that live within the mud on the bottom of the drowned kettles. The shellfish communities, which are the richest resource within the Bay, seem not to have been affected adversely.

EELGRASS HEALTH

Although it is widely assumed that eelgrass meadows within the major embayments and lagoons have been adversely impacted by increasing levels of nitrogen in Bay waters, resulting in significant decreases in both distribution and density throughout the Bay, the WMV&DC has found no reliable evidence supporting this belief. For the past 14 years eelgrass has inhabited approximately 50% of the subaqueous area of Pleasant Bay, a very widespread and healthy distribution within comparable embayments in New England. We and our consultants from the Woods Hole Group agree that prior to 1995 no reliable data exist regarding the accurate areal distribution of eelgrass within the Bay.

The assumption that presumed declines in eelgrass distribution are the result of increasing levels of nitrogen within the Bay is unfounded in fact. We and the Woods Hole Group have found that numerous other environmental variables may be detrimental to eelgrass viability. Most notable among these detriments within Pleasant Bay are burial by storm and overwash deposits, commercial shellfish harvesting, and infection by wasting disease.

The two major findings by the WMV&DC concerning eelgrass health are:

- There is no reliable basis for asserting that there has been a significant decline in eelgrass distribution or habitat quality within the major embayments of Pleasant Bay over the past several decades.
- There is no rational ecologic basis for ranking the relative impacts of the various potential causes of environmental stress on eelgrass, and claiming that the likely cause of presumed declines in areal distribution is septic effluent.

BENTHIC INFAUNA

As previously noted, shellfish communities within Pleasant Bay are both diverse and abundant. This is true not only within the major lagoons, but also around the perimeters of the drowned kettles and especially along their draining tributaries. However, the central deeper portions of the drowned kettles have depaupered and depleted benthic communities, and seem not to ever have been eelgrass habitats. As indicated in the previous table, the bottoms of the kettles are highly stressed habitats, characterized by organic-rich fetid mud, high levels of suspended sediment, and low levels of dissolved oxygen. Consequently, they are inhabited principally by stress-tolerant communities of interstitial infauna with low population levels and low diversity.

The drowned kettles are relatively impaired with their central bottoms approximating quasi "dead zones". The WMV&DC does not know if this impairment is the consequence of septic effluent, other influences, or intrinsically natural. There is no basis for believing that the kettles are recipients of higher levels of nutrients than other parts of the Bay system, and their flushing rates are comparable with the major lagoons. The drowned kettles may not be amenable to remediation, nor responsive to nitrogen reduction.

The major findings of the WMV&DC concerning the health of benthic fauna are:

- The major lagoonal embayments within Pleasant Bay are essentially healthy benthonic habitats with good water quality, and rich and diverse faunal communities.
- The central deeper bottoms of the drowned kettles are stressed habitats with poor water quality, characterized by low oxygen and high suspended sediment.
- Whether the stressed benthonic habitats in the kettles are reflective of anthropogenic degradation or natural causes is an unresolved question.

NUTRIENT-RELATED HEALTH

The fundamental assertion of the SMAST-MEP report on Pleasant Bay is clearly stated on page 193:

> "It is almost certain that a primary cause of the observed eelgrass decline results from increasing water column nitrogen levels within these environments … eelgrass restoration is the primary nitrogen management goal within Pleasant Bay"

There is no evidence of a significant documented decline in eelgrass since 1995. Nevertheless, the Massachusetts DEP has used the statement asserted above as the basis for establishing permissible threshold levels for nitrogen concentrations in various parts of Pleasant Bay, and these constitute the basis for establishing acceptable TMDLs of nitrogen discharges into Orleans' groundwater.

Neither the WMV&DC nor the Woods Hole Group has been able to document an empirical foundation for establishing an optimal or critical threshold for nitrogen concentrations in marine embayments comparable with Pleasant Bay. Marine ecology has not identified at what point ecologic health-dependant nitrogen levels change from being a beneficial nutrient to a detrimental pollutant. Neither the Woods Hole Group nor the Committee have found case studies that have shown restoration of eelgrass beds or benthic faunal communities in settings comparable with Pleasant Bay as a result of nitrogen concentrations having been reduced to the levels specified by the DEP.

The major finding of the WMV&DC concerning nutrient-related health is:

- The nitrogen threshold levels determined for Pleasant Bay have no empirical foundation.

FINDINGS: SECTION IV

FINDINGS CONCERNING MODELING

Variances versus Biases

The Massachusetts Estuaries Project (MEP) Pleasant Bay Report[12] presents data in the form of estimates and measurements. For instance, nitrogen loads (e.g. septic system sources) are estimated based on data such as water meter readings and assumptions about the occupancy of each property. Nitrogen concentrations of Pleasant Bay waters are measurements resulting from the application of standard laboratory analytical procedures. Although data in the MEP Pleasant Bay Report is presented as specific numbers, which the reader may assume are known exactly, the reality is that all estimates and measurements include some variance, accuracy or margin of error which is associated directly to the way the estimate or measurement was made and the techniques used.

All scientific work includes variances. The variance indicates a range, plus or minus, over which the measurement or data may vary. The Woods Hole Group (WHG) stated in our May 7, 2009 meeting that according to University of Massachusetts, Dartmouth, School of Marine Science and Technology (SMAST), the SMAST linked embayment model (hereafter referred to as "the model" or simply "model") has an expected variance of plus or minus 20%. This means that, if random, minor errors in the data used to calibrate the model do not exceed 20%, the model would still be valid and within its margin of error.

Biases are quite different. Biases are deviations (non-random) that are the result of a known or suspected error.

Linked Embayment Model Reliability to Simulate Nitrogen Behavior in Pleasant Bay

As a result of work done by Woods Hole Group and committee members, four principle concerns regarding the model's reliability to simulate nitrogen behavior in Pleasant Bay have been identified; the first three may be symptoms of the model's inability, as structured, to handle the complexity of the Pleasant Bay estuarine system and the fourth raises concerns regarding the biases and omissions in terms of the nitrogen inputs and outputs to the Pleasant Bay watercolumn system:

1. Failure of the SMAST model to calibrate based on total nitrogen;
2. Magnitude of the calibration factors required to achieve model calibration based on bioactive nitrogen;
3. Indications of stratification of the Orleans drowned kettle ponds;

[12] Massachusetts Estuaries Project, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Orleans, Chatham, Brewster and Harwich, Massachusetts, Final Report, May 2006 by SMAST and Massachusetts Department of Environmental Protection (DEP)

4. And, lack of a bona fide nitrogen mass balance (i.e. an accounting for all the nitrogen inputs and outputs showing that Nitrogen Inputs – Nitrogen Outputs = 0 over some time period) in the MEP Pleasant Bay Report.

Pleasant Bay – A Complex Estuarine System

Pleasant Bay is the largest and most complex of all the estuarine systems evaluated in the MEP program which includes 89 estuaries in southeastern Massachusetts. It consists of large, shallow lagoons connected to drowned kettle ponds, which may be relatively deep, by a system of rivers and other small waterways.
WHG acknowledged that the SMAST methodology may be adequate for many of the estuarine systems in Massachusetts. However, WHG identified three major uncertainties that suggest that, due to the size and complexity of the Pleasant Bay estuarine system, the SMAST model may not reliably predict the behavior of nitrogen in Pleasant Bay.

1. Model Calibration Failure. Woods Hole Group stated that SMAST calibrated their model and established nitrogen threshold concentrations based on total nitrogen for all of the approximately 33 estuarine systems for which final reports have been issued to date. The MEP Report for Chatham estuaries[13] states that, for the Bassing Harbor system, the model encountered "difficulties" in the calibration process when using total nitrogen as a basis for the calibration process. SMAST switched to calibration using bioactive nitrogen; the explanation[14] provided by SMAST lacks transparency and shows that SMAST lacks a full understanding of nitrogen species[15] in Pleasant Bay.

   The failure of the SMAST model to calibrate based on total nitrogen is alarming and the lack of an adequate explanation of the failure causes additional concern.

   Only for Pleasant Bay, SMAST used bioactive nitrogen as the basis for model calibration and for establishing threshold nitrogen concentrations. Neither the Wastewater Management Validation & Design Committee nor Woods Hole Group understands why the change was made.

2. Magnitude of Calibration Factors. In order to calibrate the SMAST model, a set of 6753 calibration factors, technically referred to as 'dispersion coefficients', must be determined such that the model outputs, in nitrogen concentration terms, closely match the observed nitrogen concentrations measured in Pleasant Bay water quality samples. Model reliability is extremely sensitive to changes in the

[13] Massachusetts Estuaries Project, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Stage
Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor, and Muddy Creek, Chatham, Massachusetts, Final Report, December 2003 by
SMAST and DEP, p. 173
[14] MEP Pleasant Bay Report (Ref 2), p. 228.
[15] Appendix: Water Quality Nitrogen Components

calibration factors as cited by WHG[16]. "A sensitivity analysis was conducted by Howes et al.[17] (2001) for certain parameters in the MEP linked model. The sensitivity analysis revealed that by far the most sensitive parameter in the overall linked model approach was the dispersion coefficients assigned in the water quality modeling. The Howes et al. (2001) sensitivity assessment found that by changing the dispersion values used in the calibrated model by 2 times or -0.5 times the selected value could change the predicted nitrogen concentration anywhere from -19 to +93% depending on the location in the estuary. Therefore, even a small change in the dispersion coefficients would have a significant impact on the predicted nitrogen levels."

Although Dr. Howes showed that doubling the factor produced a huge change in the nitrogen concentrations, SMAST used calibration factors that are nearly 10 times[18] the recommended values. This may be a symptom of the model encountering difficulty with the complexity of Pleasant Bay. WHG has stated that the unusual calibration factors introduce an uncertainty which exceeds the model's plus or minus 20% variance.

3. <u>Stratification of Drowned Kettle Ponds.</u> WHG reported that the linked model is probably adequate as applied to the main basins of Pleasant Bay; they are relatively shallow and appear to be vertically well mixed. SMAST measured temperature and salinity profiles in some of the Chatham sub-embayments to show that they were not stratified. No such measurements were done in the Orleans saltwater ponds. WHG evaluated temperature and salinity profiles made in 2001 by Horne and Horne[19] for Arey's pond and concluded that it is stratified. WHG told us that failure of the SMAST model to account for pond stratification introduces a bias in the model exceeding the model's plus or minus 20% variance.

   According to the MEP Pleasant Bay Report[20], the MEP linked embayment model approach "includes a 2D or 3D embayment circulation model depending on the embayment structure." So, had SMAST gathered data on salinity and temperature in the Orleans kettle ponds and identified the stratification as WHG did, they had 3D model modules, that according to WHG, SMAST could have easily employed to model the stratified ponds.

4. <u>Lack of a Nitrogen Balance.</u> WHG pointed out the lack of a bona fide nitrogen mass balance in the MEP Pleasant Bay Report as a cause for concern. A basic scientific principle is the law of conservation of mass. This principle requires that,

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[16] Hole Group, Final Report, Peer Review (Independent Technical Review) of The Massachusetts Estuaries Project Report on the Pleasant Bay System, June 2009
[17] Howes, Brian L, John S. Ramsey, and Sean W. Kelley. 2001. Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis. October 2000-October 2001.
[18] Woods Hole Group, Final Report to Orleans (Ref 5), p. ES-12
[19] Horne, G.S. and C.F. Horne. 2001. Reconnaissance Hydrography of the Upper Reaches of Little Pleasant Bay, Orleans, MA: Report to the Pleasant Bay Resource Management Alliance.
[20] MEP Pleasant Bay Report, p. 7

over some period of time (i.e. a day or a year), if the nitrogen concentration does not change, the quantity of nitrogen going into the water column must equal the quantity of nitrogen leaving the water column.

Of further concern regarding the lack of a mass balance by SMAST is the omission of significant nitrogen loss pathways in the SMAST analysis. In other words, SMAST failed to include all the pathways by which nitrogen leaves the Pleasant Bay system. This will be addressed in detail later.

All of the quantities discussed here are in terms of total nitrogen. According to the water quality data provided in the MEP Pleasant Bay Report, the Pleasant Bay waters contain roughly 39,000 kg of nitrogen at mid-tide. At high tide the nitrogen is approximately 50,000 kg and at low tide there would be about 28,000 kg in the bay waters.

Each day approximately 23,300 kg of nitrogen enters Pleasant Bay. This includes 89 kg of septic nitrogen (less than 0.4%) plus nitrogen from fertilizer and all other sources. Of the 23,300 kg, more than 99% is from natural sources (i.e. rainfall and Atlantic Ocean tidal waters). Using the SMAST model, the only loss pathway identified is tidal flow leaving the bay and passing into the Atlantic Ocean. This output of nitrogen is roughly 28,400 kg per day. So, according to the data in the MEP Pleasant Bay Report, roughly 5,100 kg/day more nitrogen leaves Pleasant Bay waters than goes into Pleasant Bay waters. The system can not lose 5,100 kg/day. This is a huge number; more than 20% of all the nitrogen loads going into the bay daily.

This violates the law of conservation of matter and raises the question of how reliable can a model be that is based on data which does not satisfy the most basic of scientific principles. WHG seems to have had good reason to be concerned about the lack of a nitrogen mass balance in the MEP Pleasant Bay Report.

<u>Summary: Linked Embayment Model Reliability.</u> Based on the findings, the SMAST linked embayment model is unlikely to provide a reliable basis for simulating the behavior of nitrogen in Pleasant Bay.

Nitrogen Inputs to the SMAST Linked Embayment Model

In our meeting on June 10, 2009, Mr. Eichner (SMAST) stated that MEP makes conservative estimates of nitrogen loadings. This contradicts the MEP Pleasant Bay Report[21] which says that MEP uses "realistic 'best-estimate' nitrogen loadings."

[21] MEP Pleasant Bay Report, p. 7

Biases in the SMAST Total Present Load. The SMAST linked embayment model has the following nitrogen inputs to the Pleasant Bay watercolumn:

1. Septic systems
2. Fertilizers
3. Rainfall (impinging on land area of the Pleasant Bay watershed)
4. Road and roof runoff
5. Rainfall (impinging on the surface of Pleasant Bay itself)
6. Benthic flux (nitrogen exchange between the watercolumn and the sediment (sand, mud or other materials at the bottom of the water column))
7. Natural background
8. Atlantic Ocean tidal water

Inputs 1 to 6 are included in the SMAST Total Present Load[22] and for all of Pleasant Bay estuary system totals 397.4 kg/day.

Through work done by WHG and the committee, we have identified biases in the SMAST Present Total Load components as follows:

1. Septic system nitrogen load. The Wastewater Management Validation & Design Committee conducted a demographic survey of the Arey's Pond watershed areas and found that SMAST septic nitrogen loading may be overstated by 20 to 40%. The demographic survey showed that residents knew well the dwelling occupancy levels during periods matching the water use data employed by SMAST. The survey also shows that the assumptions and commonly used "thumb' rules of the SMAST analysis may not fit the population structure and residential property use of Orleans.

2. Fertilizer nitrogen load. Petrovic[23], in a study conducted for the Pleasant Bay Alliance, has shown that the SMAST fertilizer loads may be overstated by 50%.

3. Benthic flux nitrogen load. Laboratory benthic flux measurements were conducted in the absence of illumination and therefore, do not include the denitrification by benthic microalgae which takes place in light. In addition, the SMAST "benthic flux" data is not true benthic (or solute) flux but includes an unquantified component related to settling of particulate organic nitrogen (PON). The unquantified PON component adds to the lack of transparency. However, based on the WHG results, it is estimated that the SMAST benthic flux nitrogen loadings may be overstated by 30 to 40%.

Note that each one of the biases (1) exceed the +/- 20% variance of the SMAST modeling system; (2) are not random; and (3) are overstatements of nitrogen loads. The impact of the biases on the SMAST Total Present Load of 397.4 kg/day is that it the total present load may

[22] MEP Pleasant Bay Report, Executive Summary, Table ES-1.
[23] Report to the Pleasant Bay Alliance on the Turfgrass Fertilizer Nitrogen Leaching Rate, A.M. Petrovic, August 2008.

be 262 to 300 kg/day or 66 to 75% of the SMAST estimate and this does not account for nitrogen pathway losses that were not considered by SMAST.

Nitrogen Losses Omitted by SMAST.

Nitrogen loss pathways omitted by SMAST include the following:

1. Microbial denitrification, adsorption and other natural processes that attenuate nitrogen in the vadose zone and the groundwater;
2. Denitrification (conversion to inert nitrogen gas) at the sediment watercolumn interface;
3. And, burial of nitrogen containing materials in sediment that removes them from the system.

Nitrogen Attenuation in the Vadose Zone and the Groundwater. Valiela et al[24] and Thoms et al[25] have challenged long held assumptions in the scientific and management community, that nitrogen, particularly as nitrate, travels great distances in groundwater without attenuation or loss. By measurement at West Falmouth Harbor, Thoms et al[24] have shown nitrate removal by processes such as microbial denitrification and adsorption reduce wastewater nitrogen loads by 56% or more between the point of introduction to the soil and entry into the marine embayment. Valiela's nitrogen loading model, which has been employed in Cape Cod estuarine systems including Waquoit Bay, similarly accounts for processes such as denitrification and includes approximately 74% attenuation of septic nitrogen in its transport from the receiving tank to the embayment.

Nitrogen attenuation in the vadose zone and groundwater by denitrification, adsorption and other natural processes was not considered in the SMAST model or analysis.

Denitrification at the Sediment-watercolumn Interface. Ammoniacal nitrogen and nitrates are converted to nitrogen gas by microbial activity at the ediment watercolumn interface. This nitrogen loss pathway was not considered by SMAST.

Burial of Nitrogen Containing Materials. Some nitrogen containing materials become buried in the sediment and unavailable to the watercolumn. This nitrogen loss pathway was not considered by SMAST.

Dr. Jeffrey Cornwell, Woods Hole Group, stated that denitrification and burial may be very important pathways for nitrogen to leave the Pleasant Bay system.

These three nitrogen loss pathways are all net overstatements of the nitrogen inputs to the

[24] John W. Brawley,, Glynnis Collins, James N. Kremer, Chi-Ho Sham and Ivan Valiela, J Environ Qual 29:1448-1461 (2000)
[25] T. Thoms, A. E. Giblin, and K. H. Foreman, Biol. Bull. 205: 242–243. (October 2003)

Pleasant Bay watercolumn. By their omission, the quantity of nitrogen going into the water has been overstated.

A rough estimate of impact of the omissions of the three loss pathways on the SMAST Total Present Load of 397.4 kg/day, when combined with the previously discussed biases, is that it the total present load may be in the range of 222 to 300 kg/day or 56 to 75% of the SMAST estimate.

Bias in the Nitrogen Input from Atlantic Ocean Tidal Water. WHG has stated[26]: "The background nitrogen concentration in the Atlantic Ocean region offshore of Pleasant Bay was set at 0.094 mg/L based on data collected at station PBA-17A in the summer of 2005. This value was calculated on a single summer of data,… Considering MEP requires a minimum of three years of baseline field data within the estuary in order to be simulated in the linked-model approach, and multi-year averages are used for model-data comparisons, it would be reasonable that the background levels should also be sampled over multiple years. Although the data may not have been available at the time of the report, bioactive nitrogen concentrations observed at the same station (PBA-17A) and analyzed by SMAST during the summers of 2006 and 2007 were 0.079 mg/L and 0.071 mg/L, respectively."

Thus the nitrogen load in Atlantic Ocean tidal water may be overstated by about 20%.

Summary of Nitrogen Loading Biases and Omissions. The Wastewater Management Validation & Design Committee has identified biases in four of the SMAST nitrogen inputs and omission by SMAST of three important nitrogen loss pathways (outputs). Each is significant in its own right and each is an overstatement of the nitrogen loadings to Pleasant Bay.

These findings mean that the nitrogen loadings and nitrogen outputs from the Pleasant Bay system used by SMAST are highly unlikely to be representative of the actual nitrogen sources and losses in Pleasant Bay. Since the SMAST loadings were those used to calibrate the SMAST linked embayment model, this means that the calibration is highly unlikely to be valid and the use of the model for simulation of nitrogen is unlikely to be valid.

[26] Woods Hole Group, Final Report to Orleans (Ref 5), p.46

Appendix A

GLOSSARY OF DEFINITIONS, ACRONYMS AND UNITS

ACDP - Acoustic Doppler Current Profiler

ACEC – Area of Critical Environmental Concern (Massachusetts State government designation for environmentally sensitive areas)

Activated Sludge - An aerobic, biological wastewater treatment process which uses the metabolic reactions of microorganisms to treat effluent.

Aerobic – Condition where free oxygen is present (also referred to as oxic)

Anaerobic – Condition where free oxygen is not present or is unavailable (also referred to as anoxic)

Advection - transport with a moving fluid (e.g. nitrogen from septage systems is filtered through the vadose zone to the water table; ground water transports the nitrogen seaward by advection.)

Algae Blooms - A growth of algae resulting from excessive nutrient (nitrogen or phosphorus) levels or other physical and chemical conditions that enable algae to reproduce rapidly. The overgrowth of algae can form scums and mats, and reduce the amount of oxygen as they decay.

Anoxic - chemical or biological process proceeding without oxygen; also referred to as anaerobic

Anthropogenic – Of, relating to, or resulting from the influence of human beings on nature.

Aquifers – Geologic formations (rock, sand, or gravel) that are saturated and sufficiently permeable to yield significant quantities of water.

Attenuate – Reduce the force or amount or magnitude.

Benthic – Occurring at the bottom of the sea or lake (e.g., benthic organisms).

Benthic Flux - the process of soluble chemicals (e.g. chemical compounds containing nitrogen) being transferred out of or into the bottom of aquatic systems. More specifically, benthic flux (sometimes referred to as internal recycling) represents the transport of dissolved chemical species across the solid-liquid interface at the bottom of aquatic systems. The flux of solutes can be either positive (into the water column from the sediment) or negative (out of the water column into the sediment) and can vary over multiple temporal and spatial scales.

Benthic Infauna – organisms (animal) living in the sediment on the bottom of salt or fresh water systems (e.g. rivers, lakes, ponds, bays, seas)

Benthic Regeneration – The regrowth of organisms on lake or sea floors.

Benthonic – of or related to the sediment material at the bottom of the water column.

Best Management Practices (BMPs) – or Best Practices are practices or methods accepted to be the best currently available in terms of the costs and benefits involved.

Biodiversity – Biological diversity in an environment as indicated by the numbers of different species of plants and animals. A sustained high level of biodiversity indicates a stable ecological system.

Biological Assimilation – The process in which nourishment (nutrients) is absorbed into living tissue. Nitrogen is bioassimilated by photoplankton using photosynthesis.

Biological Mediated Denitrification or Biologically Mediated Denitrification - The removal of nitrogen (nitrates, nitrites) via natural (microbial) processes resulting in the release of nitrogen gas into the air.

Biomass – A measure of the amount of living matter per unit area or volume of habitat.

Biota - A community of plant and animal organisms.(also referred to as flora and fauna)

Bioactive N - DIN + PON

BOD - Biochemical Oxygen Demand: a measure of water quality reflecting the rate of oxygen uptake by micro-organisms in the water column; expressed in mg/L

BoH - Board of Health.

CCC - Cape Cod Commission

Cluster System – A wastewater collection and treatment system where two or more facilities, but less that an entire community, is served.

CMR – Code of Massachusetts Regulations.

Combined Sewer Overflow (CSO) – A sewer pipe or system through which both sanitary wastewater and stormwater flows. During significant precipitation events, stormwater is mixed with sanitary flow.

Critical Resource Area – Localities that have been judged to be essential to the ecological well-being of the environment. They are subject to protection under MGL c. 1

Cultural eutrophication – The accelerated aging process of waterbodies resulting from human sources of nutrients that stimulate the growth of aquatic plants and lead to the depletion of dissolved oxygen.

CWA - Federal Clean Water Act.

CWMP – Comprehensive Wastewater Management Plan

CZM – Massachusetts Office of Coastal Zone Management.

DEP - Department of Environmental Protection, Massachusetts State Government

Deposition – The process by which pollutants absorbed by the atmosphere are released to land or water through precipitation or wind.

Depuration - Process of flushing toxins from shellfish before they are sold by holding them in tanks of clean water for a fixed amount of time.

DIN - dissolved inorganic nitrogen (e.g. nitrate and nitrite)

DO or D.O. - dissolved oxygen

DON - dissolved organic nitrogen

DOS - dissolved oxygen saturation: Usually expressed in ppm or mg/l, it is the maximum quantity of oxygen that will dissolve in water at a specific temperature. Dissolved oxygen saturation in seawater is strongly dependent on salinity and temperature. %DOS is the percentage of the oxygen saturation level in a specific sample.

Down Gradient - The direction that ground water flows; similar to "downstream" for surface water. Under gravitational force, ground water flows "down" from a higher level to a lower level.

Ecosystem – The system of living organisms that interact with one another and their physical environment, functioning as an ecological unit.

Effluent – Treated or untreated wastewater from a treatment facility or unit (e.g. septic system) that is discharged into the environment.

Effluent Trading – Strategies/tools to reduce problem pollutants in rivers and streams, lakes, estuaries, and coastlines. Trading allows a wastewater treatment plant, factory, or other facilities that discharge waste into a waterbody to purchase controls of a particular pollutant elsewhere in the watershed, instead of installing tighter controls for that pollutant at the plant or factory.

Embayment – A bay or a conformation resembling a bay.

EOEA – The Executive Office of Environmental Affairs.

EPA – The United States Environmental Protection Agency.

Estuary – Partially enclosed body of water that consists of fresh and saltwater where the tide meets the river's current. (see embayment)

Eutrophication – A waterbody's natural aging process due to enrichment in dissolved nutrients that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen.

Euxinic - region of restricted circulation and stagnant or anaerobic conditions.

Flushing Rates – The time it takes for an entire volume of water in system to be exchanged, usually expressed in days or years.

GIS - Geographic Information System (PB/MEP report refers to **MassGIS** (used for land use analysis and other) also Cape Cod Commission GIS "system")

GPD – Gallons Per Day.

Ground Water – Water below the land surface in a saturated zone.

Ground Water Discharge Permit Program – 314 CMR 5.00 establishes that discharges of pollutants to the ground waters of the Commonwealth will be regulated by DEP pursuant to MGL c.21, § 43, and that the outlets for these types of discharges and the treatment works associated with these discharges also be regulated by DEP.

Habitat – An environment in which plants and animals live, feed, find shelter, and reproduce.

Holding Time - Amount of time needed in a septic tank to allow for some decomposition of solids.

Holocene - (Originating from the Greek *holos* for "whole" or "entire") Geologic epoch which began about 10,000 years ago; some suggest that we have recently begun the **Antropocene** epoch (originating from the Greek *anthropos* for "mankind").

Hydrodynamic Model - in our case, a model of a natural water system (e.g. Pleasant Bay estuary) describing the flow of water during a tidal cycle (tidal prism) in terms of quantity (cubic meters), direction and velocity (meters per second) for the purposes of quantifying the behavior of nutrients (e.g. nitrogen) in terms of residence times and flushing efficiency in the system. A hydrodynamic model which accurately describes water flows is an essential tool to understanding the impact of nutrient management actions on water quality and ecosystem health.

hypoxic - chemical or biological proceeding with limited oxygen; oxygen deficient conditions

Infaunal - sediment dwelling animals

Infiltration - Downward movement of water through soil.

Innovative/Alternative (I/A) Systems - Advanced on-site wastewater treatment and disposal systems that provide additions or alternatives to one or more of the components of a conventional system while providing at least an equivalent degree of environmental and public health protection. I/A systems are becoming more widely used, particularly for cost-effective upgrades of failing systems on difficult sites that cannot accommodate a conventional system. I/A technologies also are used for enhanced treatment to reduce nitrogen in nitrogen sensitive areas.

Integrated Water Resources Management Planning – Process to evaluate all technical and management aspects of water and wastewater resources needed for ecological and human health and develop a strategy to meet these needs.

Interim Wellhead Protection Areas (IWPA) – Applicable to public water systems using wells or wellfields that lack DEP-approved Zone IIs. The IWPA is a half-mile radius measured from the well or wellfield for sources whose approved pumping rate is 100,000 gallons per day or greater.

Invasive Species – Aggressive and spreading plants or animals that do not naturally occur in a specific area and whose introduction may cause economic or environmental harm.

Kg/day – kilograms per day (one kilogram is equals to 2.2 pounds)

Linked-Model - SMAST linked watershed-embayment model

Local Residence Time - Average time for water to migrate from a point in a sub-embayment to a point outside the sub-embayment.

Mass Balance – Standard engineering and scientific calculations based on the law of conservation of mass; a quantitative accounting for all of the material (e.g. nitrogen) going into or out of a system (e.g. the waters of Pleasant Bay). The material entering or leaving the system may be in the form of a gas, liquid or solid.

Massachusetts Clean Waters Act – MGL c.21, § 26-53, which prohibits the discharge of pollutants to waters of the Commonwealth without a permit, unless exempted by regulation.

MDC - Massachusetts Metropolitan District Commission.

Mean High Water – A tidal datum. The mean of all the high water heights observed over the National Tidal Datum Epoch (see National Tidal Datum Epoch).

Mean Low Water - A tidal datum. The mean of all the low water heights observed over the National Tidal Datum Epoch. (see National Tidal Datum Epoch).

MEP – Massachusetts Estuaries Project.

MEPA – Massachusetts Environmental Policy Act.

Mesotrophic (p 9 ¶3) characterized by a medium level of productivity of carbon compounds (e.g. algal) and moderate nutrient impact. Systems characterized by high carbon productivity are referred to as eutrophic.

Mg/L – Milligrams Per Liter. (also mg/l)

MGD – Million Gallons Per Day.

MGL – Massachusetts General Laws.

Mitigate – To take corrective action to eliminate pollution or reduce its impact.

MPN - Most probable number.

NAVD - North American Vertical Datum, 1988

NGVD - National Geodetic Vertical Datum; NGVD 29 refers to the NGVD of 1929

National Pollutant Discharge Elimination System (NPDES) - A federal permit program established in 1972 by the Federal Water Pollution Control Act, known as the Clean Water Act. NPDES regulates the discharge of pollutants into waterbodies. Massachusetts is not authorized to administer the NPDES program.

National Tidal Datum Epoch - The 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain maen values for mean low water and mean high water.

Natural Attenuation – Using a naturally occurring system (wetland or pond) to reduce the amount of nitrogen impact on an estuary.

NEIWPCC – The New England Interstate Water Pollution Control Commission.

Nitrate – Component of fertilizer. Considered a broad indicator of the contamination of groundwater. The nitrogen species in marine systems that is most responsible for eutrophication. Nitrate = NO_3

Nitrite – A salt or ester of nitrous acid. An intermediate oxidation state of nitrogen, between nitrate and ammonia. Nitrite = NO_2

Nitrogen Cycle – Continuous cyclic progression of chemical reactions in which atmospheric nitrogen is compounded, dissolved in rain, deposited in the soil, assimilated and metabolized by bacteria and plants, and returned to the atmosphere by organic decomposition.

Nitrogen Loading - The input of nitrogen to estuaries and embayments from natural and anthropogenic sources.

Nitrogen Threshold - Maximum amount of nitrogen that an estuary or embayment can assimilate without adversely changing its character and use. Also known as the critical nitrogen limit.

Nonpoint Source – Pollution from many diffuse sources that is carried to surface waters by runoff or ground water. Nonpoint source pollution is typically caused by sediment, nutrients, and organic and toxic substances originating from land-use activities and/or the atmosphere.

NSFC – National Small Flows Clearing House.

Nutrient Sink – Waterbodies/wetlands that hold nutrients in the water column or in the sediments, making them either temporarily or permanently unavailable for biological processes.

Nutrient Trading - Strategies/tools to reduce problem pollutants in rivers and streams, lakes, estuaries, and coastlines. Trading allows a wastewater treatment plant, factory, or other facilities that discharge waste into a waterbody to purchase controls of a particular pollutant elsewhere in the watershed, instead of installing tighter controls for that pollutant at the plant or factory.

Nutrients – Any substance required by plants and animals for normal growth and maintenance e.g., nitrogen and phosphorus.

Nitrogen analyses:

- **DIN**: dissolved inorganic nitrogen (e.g. nitrate and nitrite)
- **DON**: dissolved organic nitrogen
- **PON**: particulate organic nitrogen
- **TON**: total organic nitrogen
- **Total N**: Total nitrogen consisting of DIN + PON + DON
- **Bioactive N**: DIN + PON

Off-Line - Stormwater treatment systems designed to retain a standing volume of stormwater to allow for a physical settling of suspended particles and for other biological and chemical treatment processes to occur.

On-Line - Stormwater treatment systems designed to treat stormwater at a designated flow rate. The retention time in these systems is very short.

On-Site Treatment and Disposal System – A natural system or mechanical device used to collect, treat, and discharge or reclaim wastewater from an individual dwelling without the use of community-wide sewers or a centralized treatment facility. It includes a septic tank and a leach field.

Organic pollutants – Carbon-based pollutants such as proteins, carbohydrates, and fats and oils, present in wastewater.

Orthophosphate: PO_4

Oxic - chemical or biological process using oxygen (indicates abundant available oxygen); also referred to as aerobic

Pathogen – An agent such as a virus, bacterium, or fungus capable of causing disease.

Pleasant Bay Water Resource Management Alliance also referred to as The Pleasant Bay Alliance

Plug flow - the velocity of the fluid is assumed to be constant across any cross-section of the system; plug flow in a river or estuary means that the water is unidirectional and of constant speed anywhere across the water body

POC - particulate organic carbon

Point Source – Pollution from discernable, confined, and concrete conveyances, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling rock, concentrated animal feeding operation, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigation agriculture.

Pollutants – Any element or property of sewage, agricultural, industrial, or commercial waste, runoff, leachate, heated effluent, or other matter in whatever form, and whether originating at a point or nonpoint source, that is or may be discharged, drained, or otherwise introduced into any sewage system, treatment works, or waters of the Commonwealth.

Pollution Trading – A regulatory tool that allows pollution sources to reallocate responsibilities for pollution reduction among themselves and find the most cost-effective reduction measures in order to meet regulatory requirements.

PON - particulate organic nitrogen

POTW – Publicly Owned Treatment Works.

ppm – Parts Per Million.

ppt - parts per thousand (certainly not parts per trillion)

Recharge – The return of water to an underground aquifer by natural or artificial means.

Remediation – Corrective action taken to eliminate pollution or reduce its impact.

Residence Times – The average time required for a particle of water or pollutant to migrate through an estuary.

RFP - request for proposal

Rotating Biological Contactor (RBC) - Wastewater treatment technology that uses bacteria grown on partially submerged plates to treat effluent.

SMAST - School of Marine Science and Technology, University of Massachusetts at Dartmouth

Salinity – The measure of the salt content of water (often expressed in ppt (parts per thousand)

SD - Secchi disc depth, an indirect measure of water clarity, reflecting suspended matter (turbidity) (predominantly sediment or plankton, strongly affected by sampling variables)

Sediment – Mineral and organic material that settles from suspension in the water column.

Senescence - advanced aging process

Septic tank – A buried tank designed to receive and pretreat wastewater from individual homes by separating settleable and floatable solids from wastewater. A component of an on-site wastewater treatment and disposal system.

Sequencing Batch Reactor (SBR) - Wastewater treatment technology in which aeration and clarification are carried out sequentially in the same tank.

Sessile - Describing a marine or freshwater organism that is permenantly attached to another surface.

Sewage – The water-carried human or animal wastes from residences, buildings, industrial establishments, or other places, together with such ground water infiltration and surface water as may be present.

SMAST – The University of Massachusetts School of Marine Science and Technology.

Soil Absorption System (SAS) – System of trenches, chambers, pits, fields, or beds, and distribution lines that receives effluent from a septic tank and transmits it to the soil for treatment in a biological mat and subsequent disposal to the underlying soils.

State Revolving Fund (SRF) – This program assists towns, cities, and wastewater districts in the financing of water pollution abatement projects. There are two types of funding through this program: the Clean Water and Drinking Water State Revolving Fund grants (CWSRF and DWSRF). The clean water fund supports low interest loans to help communities build/upgrade wastewater facilities. The drinking water fund supports low interest loans to help communities build/upgrade water treatment systems.

Sub-embayment - Cove within an embayment.

Surface Water - All waters other than ground waters within the jurisdiction of the Commonwealth, including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, coastal waters and vernal pools.

System Residence Time - Average time for water to migrate through an entire estuarine system.

Tidal Flushing – The exchange of water from an estuarine system to the waterbody into which it empties.

Total Maximum Daily Load (TMDLs) – The greatest amount of a pollutant that a waterbody can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation, and fishing.

Turbidity – A measure of soil or organic particles that cloud the water and do not allow light rays to pass through.

Tidal prism - volume of water (cubic meters) moving in and out of an estuary during the tidal cycle

Tidal harmonics - For information on tidal harmonic constituents like M_2, NOAA site has definitions http://tidesandcurrents.noaa.gov/harmonic_cons_defs.html

TON - total organic nitrogen

Total N - Total nitrogen consisting of DIN + PON + DON

TN - Total nitrogen

TP - total pigment, contributed by and reflective of phytoplankton standing populations; (this should correlate negatively with SD and positively with DIN)

USGS or U.S. Geological Survey - United States Geological Survey (U.S. government agency in Department of Interior)

Vadose zone - unsaturated soil between the surface of the earth and the water table (ground water)

Water Column – The open-water environment, as distinct from the bed or shore, that may be inhabited by marine or fesh water organisms.

Water Quality – Pertaining to the presence and amount of pollutants in water.

Wetlands Protection Act (WPA) – MGL c. 131, § 40. Under the provisions of the Act, no person may remove, fill, dredge, or alter certain resource areas without first filing a Notice of Intent and obtaining an Order of Conditions. The Act requires that the Order contain conditions to contribute to the following interests: protection of public and private surface and ground water supply, flood control, storm damage prevention, prevention of pollution, protection of fisheries, land containing shellfish, and protection of wildlife habitat.

WMV&DC - Orleans Wastewater Management Validation & Design Committee

Woods Hole Group, Inc. or WHG – environmental science consultant group contracted by Orleans to investigate specific aspects of the MEP Pleasant Bay Report.

WWTF - Waste Water Treatment Facility

WWTP – Wastewater Treatment Plant.

Zone II – That area of an aquifer that contributes water to a well under the most severe pumping and recharge conditions that can be anticipated. See 310 CMR 22.00 for a more detailed regulatory definition: http://www.state.ma.us/dep/brp/dws/files/310cmr22.pdf

Appendix B

THE WASTEWATER MANAGEMENT VALIDATION & DESIGN COMMITTEE

Biographical Sketches

Paul Ammann, Chairman: Mr. Ammann holds B.S. and M.S. degrees in Chemical Engineering from the Massachusetts Institute of Technology. He worked in industry approximately 25 years, and subsequently as a consultant, and was a licensed professional engineer in the Commonwealth of Massachusetts until his retirement.
In positions with major companies and as a consultant he has been responsible for conceptualizing, designing, testing, and implementing technologies involving pollution control; hazardous waste handling and remediation; and metallurgical and chemical processes. As a consultant, he has concentrated his work in the environmental area to include the analysis of policies, technologies, and costs associated with the cleanup of hazardous waste sites. He has assisted companies in structuring research and development efforts, and aided policymakers in assessing the cost implications of various regulatory scenarios. Mr. Ammann also has worked with companies and their legal counsel and legal committees in connection with settlement and litigation matters at Superfund sites.

Ed Daly, Vice Chairman: Mr. Daly, a missile guidance engineer, holds a B.S. in Electrical Engineering and a M.S. in Electrical and Electronic Engineering from Northeastern University and is a graduate of the Raytheon Executive Management Program. Prior to retiring to Cape Cod, Mr. Daly served as the major program manager for Raytheon's Saudi Arabian program in which position he was responsible for deployment of Hawk and Patriot missile air defense systems, including all supporting logistics facilities for training, maintenance depots, housing bases for employees, a major medical facility, and a desalination plant on the Red Sea. Earlier in his career, Mr. Daly served as Raytheon Laboratory manager for the design of the Patriot missile, including oversight of the flight test program at White Sands Missile Range in New Mexico, and as a missile guidance engineer for AVCO where he was responsible for the design of telemetry equipment for the Minuteman and Titan ICBM missiles. He holds two registered U.S. patents and has been published in several professional journals.

Ron Collins: Mr. Collins serves as construction project manager for the Town of Orleans in which position he is responsible for budget and cost forecasting; task scheduling; scope of work changes; requisition and change order approval; and project closeout. In that role, he has overseen the renovation of the Orleans Town Hall and Police Department, and the Lots Hollow Road reconstruction, among other initiatives. Prior to assuming his current position with Orleans, Mr. Collins held senior project design and management positions for several multi-million-dollar construction programs both in the United States and Europe, including expansion of a semiconductor manufacturing facility in San Antonio, Tex.; upgrading and retrofitting a semiconductor manufacturing facility in Kokomo, Ind.; construction of a semiconductor manufacturing facility in Rousset, Fr.; and the construction of a new diagnostic production facility in Falmouth, Mass. Mr. Collins holds a B.S. in Civil Engineering from the

Wentworth Institute of Technology and has completed course work towards an M.S. degree at the Worcester Polytechnic Institute.

Jeffrey Eagles: Mr. Eagles retired to Cape Cod in 2002 following 20 years of service in the semiconductor industry with the BOC Group, a multinational industrial gas company, where he marketed, and managed the sale and servicing of gases, vacuum pumps, and a range of chemical processing equipment used to convert highly toxic gases to safe byproducts. In addition to BOC assignments in the U.S., Mr. Eagles also lived and worked in Taiwan, Japan, and the United Kingdom during that period. Prior to joining BOC, Mr. Eagles served as project control manager for a Raytheon Company petrochemical plant construction project in Alberta, Can. As a commissioned Naval Officer during the 1970s, Mr. Eagles served in Admiral H.G. Rickover's headquarters engineering organization, where he was responsible for environmental and waste treatment aspects related to radioactive materials generated on U.S. Navy submarines, surface ships; and shipyards and land-based facilities, including two commercial electrical power generating plants. Mr. Eagles earned a B.S in Chemical Engineering from Tufts University and an S.M. in Hydrogeochemical Engineering from Harvard University, School of Engineering and Applied Science. He also holds an M.B.A. from Harvard University. He completed all course work toward an M.S. in Nuclear Engineering while on duty with the U.S. Navy.

Greg Horne: Dr. Horne received his Ph.D. in geology from Columbia University in 1968. He joined the faculty of Wesleyan University in 1970, and two years later initiated one of the first undergraduate programs in environmental sciences in the United States at Wesleyan as an outgrowth of the university's traditional geology department. Over the next 30 years, Dr. Horne spearheaded the development of that program with a primary focus on coastal marine science. As an adjunct of that work, he developed and implemented a vigorous research program on the Connecticut River estuary, the largest estuary in New England, and served as director of the Essex Marine Laboratory in Essex, Conn. Dr. Horne also collaborated with colleagues at the West Indies Laboratory at St. Croix, USVI, on the ecology of Caribbean coral reefs. He served for 20 years as an officer on the Board of Control of the Connecticut Experiment Station in New Haven, Conn., that state's major environmental facility. He has published the results of his research with the Connecticut River estuary and Long Island Sound in peer-reviewed scientific journals on the topics of tidal circulation; estuarine hydraulics; sediment transport; coastal erosion; salt marsh evolution; sea level change; and Quaternary coastal development. Dr. Horne retired to the Cape in 2000, and has since focused his interests on the health of Pleasant Bay.

Sims McGrath: Mr. McGrath is a managing partner with the design/build firm HMD Architects LLC, where he is responsible for business development and project management. He also owns a decorating and home furnishings firm and is the sole proprietor of a Lower Cape residential services business. Mr. McGrath has been active in Orleans Town government for many years, having served on several key boards and committees, the Board of Health, Wastewater Management Plan Steering Committee, and Planning Board, among these. An Orleans resident since 1984, he is a graduate of Syracuse University. Mr. McGrath resigned from the Wastewater Management Validation & Design Committee in March 2009 following his election to the Orleans Board of Selectmen.

Judith Scanlon: Ms. Scanlon, a marine biologist, has been a member of numerous Orleans boards and committees charged with overseeing environmental issues for the Town, including the Wastewater Management Steering Committee; Conservation Commission; and the Shellfish and Waterways Advisory Committee. As a member of the Orleans Marine and Freshwater Water Quality Task Force, she has participated in the Town's Pleasant Bay water quality sampling program. In her professional career, Ms. Scanlon worked for nine years as a researcher with Battelle Ocean Sciences; a fisheries technician with National Oceanic and Atmospheric Administration (NOAA); a guest investigator for the Woods Hole Oceanographic Institution; and director for Environment, Occupational Safety & Health for Suffolk University. She currently owns and manages Lakefarm Gardens, a small farm in Orleans. Ms. Scanlon holds a B.A. in marine biology from Roger Williams University.

Appendix C

Analysis Of Requirements For Remediation Of The Pleasant Bay System

	Present controllable watershed load (kg/day)	Percent controllable watershed reductions (%)	Present required reductions (kg/day)	Unnecessary reductions (kg/day)	Remaining implementation (kg/day)
Meetinghouse Pond	6.20	83	5.15	5.15	
The River - Upper	2.77	37	1.02	1.02	
The River - Lower	3.88	37	1.44	1.44	
Lonnies Pond	2.44	33	0.81		0.81
Areys Pond	1.30	29	0.38		0.38
Namequoit River	2.74	37	1.01		1.01
Pah Wah Pond	1.86	61	1.13		1.13
Pochet Neck	8.42	51	4.29	4.29	
Little Pleasant Bay	8.13	28	2.28	2.28	
Totals	37.74	46	17.51	14.18	3.33
	Possible decrease in remediation in Pleasant Bay System:			81%	19%

Appendix D

Water Quality Nitrogen Components

DON = amino acids, amines, urea (relatively non-supportive of phytoplankton in shallow Estuaries)

PON = nearly all living or dead phytoplankton – this is nitrogen contained in the organism structure

DIN = NO_3, NO_2 , NH_4^+ (nitrate, nitrite and ammoniacal forms)

Bioactive Nitrogen

Total Nitrogen

Total Nitrogen = [Bioactive Nitrogen] + DON = DIN + PON + DON

Bioactive Nitrogen = DIN + PON

DON = dissolved organic nitrogen (primarily products of fermentation or decay of organic matter

PON = particulate organic nitrogen

DIN = dissolved inorganic nitrogen

Appendix E

Bibliography of Readings and Reference Documents

Most of the referenced documents are available in an electronic bibliography accompanying this report. The reference number in this list matches numbers in parentheses (.e.g. (1)) at the start of the file in the electronic bibliography.

1. Massachusetts Estuaries Project, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Little Namskaket Marsh Estuarine System, Orleans, MA, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, Draft Report, June 2007.

2. Massachusetts Estuaries Project, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Namskaket Marsh Estuarine System, Orleans, MA, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, Draft Report, June 2007.

3. Executive Summary: Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis, Project Period: October 2000 – October 2001 Prepared By: Brian L. Howes, School of Marine Science and Technology University of Massachusetts Dartmouth; John S. Ramsey & Sean W. Kelley, Applied Coastal Research and Engineering, Inc. Prepared For: Massachusetts Department of Environmental Protection Bureau of Resource Protection And U.S. Environmental Protection Agency Region I

4. Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis, Project Period: October 2000 – October 2001 Prepared By: Brian L. Howes, School of Marine Science and Technology University of Massachusetts Dartmouth; John S. Ramsey & Sean W. Kelley, Applied Coastal Research and Engineering, Inc. Prepared For: Massachusetts Department of Environmental Protection Bureau of Resource Protection And U.S. Environmental Protection Agency Region I

5. Executive Summary: Massachusetts Estuaries Project, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Towns of Orleans, Chatham, Brewster and Harwich, Massachusetts, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, May 2006

6. Massachusetts Estuaries Project, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Towns of Orleans, Chatham, Brewster and Harwich, Massachusetts, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, May 2006

7. Massachusetts Estuaries Project, Pleasant Bay Report: Wastewater Validation & Design Committee Summary of Chapter IV (Watershed Nitrogen Loading), November 2008.

8. Massachusetts Estuaries Project, Pleasant Bay Report: Wastewater Validation & Design Committee Summary of Chapter V (Hydrodynamic Modeling), November 2008.

9. Massachusetts Estuaries Project, Pleasant Bay Report: Wastewater Validation & Design Committee Summary of Chapter VI (Water Quality Modeling), November 2008.

10. Massachusetts Estuaries Project, Pleasant Bay Report: Wastewater Validation & Design Committee Summary of Chapter VII (Assessment of Embayment Nutrient Related Ecological Health), November 2008.

11. Massachusetts Estuaries Project, Pleasant Bay Report: Wastewater Validation & Design Committee Summary of Chapter VIII (Critical Nutrient Threshold Determination and Development of Water Quality Targets), November 2008.

12. Massachusetts Estuaries Project, Pleasant Bay Report: Wastewater Validation & Design Committee Summary of Chapter IX (Impacts to Water Quality Due to Inlet Migration), November 2008.

13. Cottam, C. 1934. Eelgrass disappearance has serious effects on waterfowl and industry. U.S. Dept. Agric., Yearbook, Separate 1430.

14. Cottam, C. 1933. Eelgrass, valuable sea plant, dying of mysterious disease. Sci. New Letter 24:73.

15. Cottam, C and D.A. Munro. 1954. Eelgrass status and environmental relations. J. Wildl. Manag. 18: 449-460

16. Dexter, R. W. 1953. Recession of eelgrass at Cape Ann, Massachusetts. Ecology 34:229-231.

17. De Jonge, V.N. and D.J. De Jong. 1992. Role of tide, light and fisheries in the decline of *Zostera marina L.* in the Dutch Wadden Sea. Netherlands Institute for Sea Research, Publication Series No. 20, pp 161-176.

18. Duarte, C.M., J.W. Fourqurean, D. Krause-Jensen, and B. Olesen. 2006. Dynamics of seagrass stability and change. Pp. 271-294. *In* W.D. Larkum, R.J. Orth and C.M. Duarte (eds.) Seagrasses, Biology, Ecology and Conservation. Springer, The Netherlands.

19. Fourqurean, J.W. and M.B. Roblee. 199. Florida Bay: A recent history of ecological changes. Estuaries 22:345-357.

20. Frederiksen, MF, D. Krause-Jensen, M. Holmer and J.S. Laursen. 2004. Long-term changes in area distribution of eelgrass (*Zostera marina) in Danish coastal waters.* Aquat. Bot. 78:167-181.

21. Gallegos, C.L. 2001. Calculating optical water quality targets to restore and protect submersed aquatic vegetation: overcoming problems in partitioning the diffuse attenuation coefficient for photosynthetically active radiation. Estuaries 24:381-397.

22. Hauxwell, J., J. Cebrian, C. Furlong, and I. Valiela. 2001. Macroalgal canopies contribute to eelgrass (*Zostera marina*) decline in temperate estuarine ecosystems. Ecology 82:1007-1022.

23. Hauxwell, J., J. Cebrian, and I. Valiela. 2003. Eelgrass *Zostera marina* loss in temperate estuaries: relationship to land-derived nitrogen loads and effect of light limitation imposed by algae. Mar. Ecol. Prog. Ser. 247:59-73.

24. McGlathery, K.J. 2001. Macroalgal blooms contribute to the decline of seagrass in nutrient-enriched coastal waters. J. Phycol. 37:453-456.

25. Olsen, J.L., S.T. Wytze, J.A. Coyer, T.H. Reusch, M. Billingham, C. Bostrom, E. Calvert, H. Christie, S. Granger, R. La Lumiere, N. Milchakova, M.P. Oudot-Le Secq, G. Procaccini, B. Sanjabi, E. Serrao, J Veldsink, S. Widdicombe and S. Wyllie-Echeverria. 2004. North Atlantic phylogeography and large-scale population differentiation of the seagrass *Zostera marina* L. Molecular Ecology 13:1923-1941.

26. Orth, R.J. and K. Moore 1983. Chesapeake Bay: An unprecendented decline in submerged aquatic vegetation. Science 222: 51-52.

27. Orth, R.J., M.C. Harwell and G.J. Inglis. 2006. Ecology of seagrass seeds and dispersal strategies. Pp. 111-133. *In* W.D. Larkum, R.J. Orth and C.M. Duarte (eds.) Seagrasses, Biology, Ecology and Conservation. Springer, The Netherlands.

28. Orth, Robert J., Tim J.B. Carruthers, William C. Dennison, Carlos M. Duarte, James W. Fourqurean, Kenneth L. Heck, Jr., A Randall Hughes, Gary A. Hendrick, W. Judson Kenworthy, Suzanne Olyarnik, Fred T. Short, Michelle Waycott, and Susan L. Williams. 2006. A global crisis for seagrass ecosystems. Bioscience 56:987-996.

29. Rasmussen, E. 1977. The wasting disease of eelgrass (*Zostera marina)* and its effects on environmental factors and fauna. Pp. 1051 in C.P. McRoy and C. Helfferich (eds.). Seagrass Ecosystems. New York, Marcel Dekker.

30. Short, F.R. and S. Wyllie Echeverria 1996. Natural and human induced disturbance of seagrasses. Environ. Conserv 23: 17-27.

31. Short, F.T. and D.M. Burkick. 1996. Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, MA. Estuaries 19:730-739.

32. Short, F.T., D.M. Burdick, S. Granger, and S. Nixon. 1996. Long-term declines in Eelgrass, *Zostera marina* L., linked to increased housing development. Pp. 291-298. *In* J. Kuo, R.C. Phillips, D.I. Walker and H. Kirkman (eds.), Seagrass Biology: Proceedings of an International Workshop, Rottnest Island, Western Australia.

33. Valiela, I. and J.E. Costa. 1988. Eutrophication of Buttermilk Bay: a Cape Cod coastal embayment: concentrations of nutrients and watershed nutrient budgets. Environ. Manag. 12:539-553.

34. Valiela, I., K. Foreman, M. LaMontague, D. Hersh, J. Costa, P. Peckol, BDeMeo-Anderson, C.D' Avanzo, M. Babione, C.H. Sham, J. Brawley, and K. Lajth. 1992. Coupling of watersheds and coastal waters: sources and consequences of nutrient enrichment in Waquoit By, Massachusetts. Estuaries 15:443-457.

35. Walker, D.I., G.A. Kendrick, and A.J. McComb. 2006. Decline and recovey of seagrass ecosystems-The dynamics of change. Pp. 551-565. *In* W.D. Larkum, R.J. Orth and C.M. Duarte (eds.) Seagrasses, Biology, Ecology and Conservation. Springer, The Netherlands.

36. Hydrodynamic Model of Chatham Harbor/Pleasant Bay including 2007 North Breach, Sean Kelley and John Ramsey, Applied Coastal Research and Engineering, Inc. 15 July 2008.

37. Assessment of Water Quality, Road Runoff, and Bulk Atmospheric Deposition, Guanella Pass Area, Clear Creek and Park Counties, Colorado, Water Years 1995–97 By Michael R. Stevens U.S. GEOLOGICAL SURVEY Water-Resources Investigations Report 00–4186

38. **Urban Drainage Modelling and Water Sensitive Urban Design 2006,** Modelling of road runoff pollution load and sources in the city of Göteborg, Sweden

39. Embayment Restoration and Guidance for Implementation Strategies, Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection, 2003

40. Embayment Restoration and Guidance for Implementation Strategies (Appendices), Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection, 2003

41. Nitrogen input from residential lawncare practices, N.L. Law, Center for Watershed Protection, Ellicott City, MD

42. Pleasant Bay Alliance, 2008 Symposium (slides)

43. Executive Summary, Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays System Barnstable, Massachusetts, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection

44. Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays System Barnstable, Massachusetts, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection (Chapter V)

45. Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays System Barnstable, Massachusetts, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection (Chapter VI)

46. Executive Summary, Massachusetts Estuaries Project Linked Watershed-Embayment Modeling to Determine Critical Nitrogen Loading Thresholds for Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor and Muddy Creek, Chatham, MA, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, December 2003

47. Massachusetts Estuaries Project Linked Watershed-Embayment Modeling to Determine Critical Nitrogen Loading Thresholds for Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor and Muddy Creek, Chatham, MA, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, December 2003 (Chapter VI)

48. Executive Summary, Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Nantucket Harbor, Town of Nantucket, Massachusetts, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, November 2006 (Chapter V)

49. Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Nantucket Harbor, Town of Nantucket, Massachusetts, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, November 2006 (Chapter VI)

50. Executive Summary, Massachusetts Estuaries Project, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for West Falmouth Harbor, Falmouth, Massachusetts University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, May 2006

51. Massachusetts Estuaries Project, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for West Falmouth Harbor, Falmouth, Massachusetts University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, May 2006

52. Multiple Approaches to Tracing Nitrogen Loss in the West Falmouth Wastewater Plume T. Thoms, A. E. Giblin (Colorado College, Colorado Springs, CO), and K. H. Foreman (Marine Biological Laboratory, Woods Hole, MA) Biol. Bull. 205: 242–243. (October 2003)

53. Massachusetts Estuaries Project Linked Watershed-Embayment Model to Re-evaluate Critical Nitrogen Loading Thresholds for Stage Harbor/Oyster Pond, Sulphur Springs/Bucks Creek and Taylors Pond/Mill Creek Chatham, Massachusetts, Massachusetts University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, February 2007

54. Massachusetts Estuaries Project Linked Watershed-Embayment Modeling to Determine Critical Nitrogen Loading Thresholds for Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor and Muddy Creek, Chatham, MA, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, December 2003 (Chapter VIII)

55. ELM, An Estuarine Nitrogen Loading Model: Formulation and Verification of Predicted Concentrations of Dissolved Inorganic Nitrogen. Valiela Ivan; Mazzilli Stefano; Bowen Jennifer L.; Kroeger Kevin D.; Cole Marci L.; Tomasky Gabrielle; Isaji Tatsu, "Water, Air, and Soil Pollution," 157:365-391, 2004.

56. Application of a Nitrogen Loading Model to the Gargathy Bay Watershed, Accomack County, VA: Implications for Future Development, Juliette Poleto and Mark J. Brush, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA 23062, February 2007

57. Valiela, I., Nitrogen Loading Model Diagram, 1997

58. Valiela, I., Nitrogen in Groundwater, 2004

59. Effects of watershed land use on nitrogen concentrations and d15 nitrogen in groundwater, MARCI L. COLE, KEVIN D. KROEGER, J. W.MCCLELLAND and I. VALIELA, Biogeochemistry (2006) 77: 199–215

60. Submarine groundwater discharge: Nitrogen biogeochemistry of the discharge zone, K. D. Kroeger and M. A. Charette, Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543 (2007)

61. Assessment of models for estimation of land-derived nitrogen loads to shallow estuaries, Ivan Valiela, Jennifer L. Bowen and Kevin D. Kroeger, Boston University Marine Program, Marine Biological Laboratory, Woods Hole, MA 02543

62. Estimating Historical Nitrogen Loads from the Great Bay Watershed, Jim Latimer, US EPA Office of Research and Development, Atlantic Ecology Division, Narragansett, RI

63. Nitrogen loading to Pleasant Bay, Cape Cod: application of models and stable isotopes to detect incipient nutrient enrichment of estuaries, Ruth H. Carmichael *, Brendan Annett, Ivan Valiela, Boston University Marine Program, Marine Biological Laboratory, Woods Hole, MA 02543, USA

64. Linking nitrogen in estuarine producers to land-derived sources, James W. McClelland and Ivan Valiela, Boston University Marine Program, Marine Biological Laboratory, Woods Hole, Massachusetts 02543, Limnol. Oceanogr.. 43(4), 1998. 577-585

65. Dissolved Nitrogen Dynamics in Groundwater Under a Coastal Massachusetts Forest, Eve-Lyn S. Hinckley, Christopher Neill, Richard McHorney, and Ann Lezberg (The Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts 02543), Biol. Bull. 201: 288–290. (October 2001)

66. Massachusetts Estuaries Project Linked Watershed-Embayment Modeling to Determine Critical Nitrogen Loading Thresholds for Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor and Muddy Creek, Chatham, MA, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection, December 2003

67. Inter-municipal Watershed Planning and TMDL Implementation to Restore Embayment Water Quality on Cape Cod: Three Case Studies of Towns Sharing Coastal Watersheds, September 2008 (DRAFT REPORT) Prepared for and submitted to: The United States Environmental Protection Agency, University of Massachusetts Dartmouth School of Marine Science and Technology, Massachusetts Department of Environmental Protection

68. ACEC Regulatory Summary: file:///D:/Bibliography/(68)ACEC%20Regulatory%20Summary.htm

69. ACEC Guide, Massachusetts Executive Office of Energy and Environmental Affairs.

70. ACEC Regulations: Massachusetts 301 CMR: EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS

71. MASSACHUSETTS AREAS OF CRITICAL ENVIRONMENTAL CONCERN (ACEC) , September 2008

72. ACEC Resource Management Plan

73. New Approach to Urban Water Management, Swiss Federal Technical Institute – Novaquatis Integrated Research Project on Urine Diversion Toilets (2007)

74. J. Eagles, Sediment Nitrogen Flux Notes, 17 January 2009.

75. Adaptive Management Guide, US Department of Interior (available on DOI/EPA website)

76. QUALITY ASSURANCE PROJECT PLAN (QAPP) BENTHIC NUTRIENT FLUX STUDIES: 2004 -2005, Task 16 MWRA Harbor and Outfall Monitoring Project, Contract No. S366, *Submitted to:* MASSACHUSETTS WATER RESOURCES AUTHORITY, Environmental Quality Department, 100 First Avenue, Charlestown Navy Yard, Boston, MA 02129, (617) 242-6000, *Prepared by:* Jane Tucker and Anne Giblin, Marine Biological Laboratory, *Submitted by:* Battelle Duxbury Operations, 397 Washington Street, Duxbury, MA 02332, (781) 934-0571, September 2005

77. Benthic algae control sediment–water column fluxes of organic and inorganic nitrogen compounds in a temperate lagoon, *Anna Christina Tyler and Karen J. McGlathery,* Department of Environmental Sciences, P.O. Box 400123, University of Virginia, Charlottesville, Virginia 22904; *Iris C. Anderson,* School of Marine Science, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia 23602, *Limnol. Oceanogr.,* 48(6), 2003, 2125–2137

78. Nitrogen fluxes, denitrification and the role of microphytobenthos in microtidal shallow-water sediments: an annual study, Kristina Sundback, Alison Miles, Eva Goransson Department of Marine Botany, Goteborg University, PO Box 461,405 30 Goteborg, Sweden, MARINE ECOLOGY PROGRESS SERIES Vol. 200: 59-76.2000 Published July 14

79. Role of Benthic Microalgae in the Restoration of the Shallow-water Lynnhaven River System, Mac Sisson, Bill Johnston, Brian Rheinhart, Steve McLaughlin, Mark Hudgins, Yuepeng Li, and Jian Shen, Virginia Institute of Marine Science, City of Virginia Beach and US Army Corps of Engineers, March 2009

80. Wastewater Management Validation & Design Committee, Report to Board of Selectmen, Ed Daly, 1 July 2009.

81. The Massachusetts Estuaries Project, Embayment Restoration and Guidance for Implementation Strategies, 2003, Massachusetts Department of Environmental Protection

82. Wastewater Management Validation & Design Committee, Report to Board of Selectmen, Paul Ammann, 1 July 2009.

83. Orleans Board of Selectmen, CHARGE TO THE WASTEWATER MANAGEMENT VALIDATION & DESIGN COMMITTEE, September 2008.

84. Wastewater Management Validation & Design Committee, Report to Board of Selectmen, Paul Ammann and Jeffrey Eagles, 18 March 2009.

85. ENHANCING WASTEWATER MANAGEMENT ON CAPE COD: PLANNING, ADMINISTRATIVE AND LEGAL TOOLS, REPORT TO BARNSTABLE COUNTY, JULY 2004, Prepared By: Wright-Pierce, 99 Main Street, Topsham, Maine 04086; Teal Ltd, 567 New Bedford Road, Rochester, Massachusetts 02770; CLF Ventures, 62 Summer Street, Boston, Massachusetts 02110

86. Coastal Systems Program, School of Marine Science & Technology, Massachusetts Estuaries Project: Status of Application of Approach Workshop on Restoring and Protecting Coastal Waters U.S. EPA & Cape Cod Commission, Howes, B.L., November 16, 2006

87. Demographer says Cape's future depends on young, Cape Cod Times, 26 June 2009.

88. Demographer says people abandoning the Cape, Cape Cod Times, 27 April, 2007

89. Fate of Anthropogenic Nitrogen in a Nearshore Cape Cod Aquifer Elizabeth J. Westgate1, Kevin D. Kroeger, Wendy J. Pabich, and Ivan Valiela, (Boston University Marine Program, Marine Biological Laboratory, Woods Hole, Massachusetts 02543) Biol. Bull. 199: 221–223. (October 2000)

90. USGS Website Toxic Nutrients (2009)

91. Simultaneous Measurement of Denitrification and Nitrogen Fixation Using Isotope Pairing with Membrane Inlet Mass Spectrometry Analysis, SOONMO AN, WAYNE S. GARDNER, AND TODD KANA, Marine Science Institute, University of Texas at Austin, Port Aransas, Texas 78373, and Horn Point Laboratory, The University of Maryland Center for Environmental Science, Cambridge, Maryland 216132, APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Mar. 2001, p. 1171–1178

92. Internal Nutrient Cycling in Florida Bay: Denitrification, Nitrogen Fixation and the Role of Microalgae, Jeffrey C. Cornwell, W. Michael Kemp, Michael S. Owens, Jessica Davis and Eric Nagel, University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge MD.

93. USGS Website, Biogeochemistry of Carbon and Nitrogen in Aquatic Environments, Carbon and Nitrogen Cycling in Groundwater, Cape Cod Study Site

94. Benthic respiration and nitrogen release in Buzzards Bay, Massachusetts, Banta, GT, Giblin, AE, Hobbie, JE, Tucker, J, Journal of Marine Research [J. MAR. RES.]. Vol. 53, no. 2, pp. 107-135. 1995.

95. A SIMPLE TOOL FOR PREDICTING THE DENITRIFICATION RATE POTENTIAL IN THE VADOSE ZONE BASED ON SAND, SILT OR CLAY COMPOSITION, TUCHOLKE, Maria B. and MCCRAY, John E., Environmental Science & Engineering, Colorado School of Mines, 1500 Illinois Street, Golden, CO 80401, mtucholk@mines.edu

96. Wastewater Management Validation & Design Committee, Presentation to DEP & SMAST, Paul Ammann, 10 June 2009.

97. Wastewater Management Validation & Design Committee, Presentation to DEP & SMAST, Dr. Greg Horne, 10 June 2009.

98. Wastewater Management Validation & Design Committee, Presentation to DEP & SMAST, Jeffrey Eagles, 10 June 2009.

99. Report to the Pleasant Bay Alliance on the Turfgrass Fertilizer Nitrogen Leaching Rate, By A. Martin Petrovic, Ph.D., 62 East Seneca Road, Trumansburg, NY 14886, August 20, 2008

100. GROUND WATER DISCHARGE TO PLEASANT BAY, Dr. Gregory S. Horne, December 8, 2008

101. National Estuarine Nutrient Criteria, US EPA Office of Science and Technology, Thoughts about input from National Estuaries Experts Workgroup, Jonathan Sharp, MAC Meeting 20 February 2006

102. Town of Mashpee, Popponesset Bay, & Waquoit Bay East Watersheds, Nitrex Technology Scenario Plan, Submitted to: Town of Mashpee, Sewer Commission, 16 Great Neck Road, North Mashpee, MA 02469, August 1, 2008, Submitted by: Lombardo Associates

103. Coastal Resources Planning and Management: Edgartown Great Pond, Edgartown, MA, Final Report, Woods Hole Oceanographic Institute, September 1993.

104. COMPREHENSIVE WASTEWATER MANAGEMENT, CITIZENS ADVISORY COMMITTEE (CAC), January 18, 2006, Town Hall Meeting Room, Main Street, Chatham, Massachusetts - 4:00 pm

105. Importance of Dissolved Organic Nitrogen and Phosphorus to Biological Nutrient Cycling, George A. Jackson and Peter M. Williams, Deep Sea Research, Vol. 32, No. 2, pp 223 to 235, 1985

106. Phosphorus Mass Balance for the Washington-Sammamish Watershed, Washington, By Stephanie Brock, Shanti Colwell, Mariah McPherson, Greg Moen, Seshu Vaddey

107. Evaluating phosphorus migration from septic systems near Otsego Lake, Joyce E. Green, Rufus J. Thayer Otsego Lake Research Assistant, summer 2001. SUNY College of Environmental Science and Forestry, Syracuse, NY.

108. Water Quality and the Effects of Changes in Phosphorus Loading to Muskellunge Lake, Vilas County, Wisconsin Water-Resources Investigations Report 03– 4011 U.S. Department of the Interior, U.S. Geological Survey

109. Nitrogen and Phosphorus Limitation in Mill and Green Ponds and the Effects of Nutrient Enrichment, Joel Creswell[1,5], Rebecca Karasack[2,5], Rebecca Johnson[3,5], and Hannah Shayler[4,5], [1]Environmental Studies Program, Macalester College, Saint Paul, MN 55105; [2]Department of Environmental Studies, Dickinson College, Carlisle, PA 17013; [3]Department of Environmental Studies, Oberlin College, Oberlin, OH 44074; [4]Environmental Studies Program, Connecticut College, New London, CT 06320; [5]Semester In Environmental Science, Marine Biological Laboratory, Woods Hole, MA 02543 (April 2001)

110. Climate-Driven Ocean Changes Affect Estuaries, Pacific Ocean Cooling Triggers Phytoplankton Blooms in San **F**rancisco Bay, USGS

111. EPA Quality System – QA Project Plans, EPA

112. Massachusetts Estuaries Project, Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators, Interim Report, Brian L. Howes, Roland Samimy, Brian Dudley (MEP Technical Team), For: Massachusetts Department of Environmental Protection (DEP), July21, 2003, Revised: September 16, 2003, Revised: December 22, 2003, MassachusettsDepartment of Environmental Protection

113. The Technology Acceptance Reciprocity Partnership Protocol for Stormwater Best Management Practice Demonstrations, Endorsed by California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia, Final Protocol 8/01, Updated: 7/03

114. Peer Review (Independent Technical Review) of the Massachusetts Estuaries Project Report on the Pleasant Bay System, DRAFT REPORT, Woods Hole Group, Inc., April 2009

115. Peer Review (Independent Technical Review) of the Massachusetts Estuaries Project Report on the Pleasant Bay System, DRAFT REPORT – ADDENDUM 1, Woods Hole Group, Inc., April 2009

116. Peer Review (Independent Technical Review) of The Massachusetts Estuaries Project Report on the Pleasant Bay System, FINAL REPORT, Woods Hole Group, Inc., June 2009

117. FINAL Pleasant Bay System Total Maximum Daily Loads For Total Nitrogen, (Report # 96-TMDL-12,Control #244.0), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS IAN A. BOWLES, SECRETARY, MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION ARLEEN O'DONNELL, COMMISSIONER, BUREAU OF RESOURCE PROTECTION, GLENN HAAS, ACTING ASSISTANT COMMISSIONER, May, 2007

118. Nitrogen cycling: A review of the processes, transformations and fluxes in coastal ecosystems, R. Purvaja, R. Ramesh, A. K. Ray and Tim Rixen, CURRENT SCIENCE, VOL. 94, NO. 11, 10 JUNE 2008

119. WHG Presentation (Video Recording) Part 3 – Mr. Kirk Bosma and Dr. John Teal, Time 01:12:00 to 01:35:00 http://207.228.236.138/town_orleans_videos/wmvdc/WHG-Peer-3.wmv