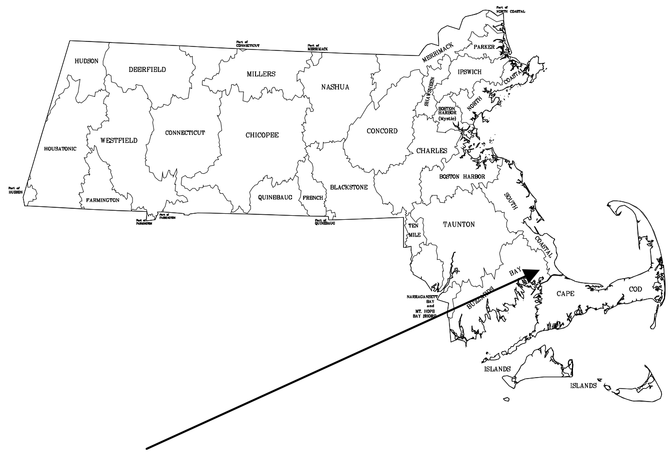
Final Total Maximum Daily Load of Total Phosphorus for White Island Pond, Plymouth/Wareham, MA

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS
IAN A BOWLES, SECRETARY
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
LAURIE BURT, COMMISSIONER
BUREAU OF RESOURCE PROTECTION
GLENN HAAS, ACTING ASSISTANT COMMISSIONER

This Page left blank.

Final Total Maximum Daily Load of Total Phosphorus for White Island Pond Plymouth/Wareham, MA

DEP, DWM TMDL Report MA95166-201009-1 CN 330.2 April 29, 2010



Location of White Island Ponds East Basin (MA95166) and West Basin (MA95173) within Buzzards Bay Watershed in Massachusetts.

NOTICE OF AVAILABILITY

Limited copies of this report are available at no cost by written request to:
Massachusetts Department of Environmental Protection
Division of Watershed Management
627 Main Street
Worcester, MA 01608

This report is also available from MassDEP's home page on the World Wide Web at:
http://www.mass.gov/dep/water/resources/tmdls.htm.

DISCLAIMER

References to trade names, commercial products, manufacturers, or distributors in this report constituted neither endorsement nor recommendations by the Division of Watershed Management for use.

Front Cover

Photograph of the White Island Pond, Plymouth showing bright bluegreen cyanobacterial bloom on the East Basin and northern shore and Cranberry Bogs located on north shore taken July 29, 2007. Ezekiel Pond is also shown as the dark clear lake to the lower right. ©2009 Tele Atlas Google Earth (http://maps.google.com/maps?ll=41.812082,-70.617218&z=15&t=h&hl=en).

Executive Summary

The Massachusetts Department of Environmental Protection (MassDEP) is responsible for monitoring the waters of the Commonwealth, identifying those waters that are impaired, and developing a plan to bring them back into compliance with the Massachusetts Surface Water Quality Standards. The list of impaired waters also referred to as category 5 of the State Integrated List of Waters or the "303d list" identifies river, lake, and coastal waters and the reason for impairment. All impaired waters listed in category 5 require the development of a TMDL report. The current and proposed integrated list and further explanation can be found at http://www.mass.gov/dep/water/resources/tmdls.htm.

Once a water body is identified as impaired, MassDEP is required by the Federal Clean Water Act (CWA) to essentially develop a "pollution budget" designed to restore the health of the impaired body of water. The process of developing this budget, generally referred to as a Total Maximum Daily Load (TMDL), includes identifying the source(s) of the pollutant from direct discharges (point sources) and indirect discharges (non-point sources), determining the maximum amount of the pollutant that can be discharged to a specific water body to meet water quality standards, and developing a plan to meet that goal.

This report develops a total phosphorus TMDL for White Island Pond, East Basin (MA95166) and West Basin (MA95173) in the Buzzards Bay Watershed in Plymouth and Wareham Massachusetts. The lakes are listed as impaired (category 5), on the "Massachusetts Year 2008 Integrated List of Waters" for nutrients, organic enrichment/low DO and noxious aquatic plants, with the East Basin also listed for turbidity. In freshwater systems the primary nutrient known to accelerate eutrophication is phosphorus. This report will satisfy the requirement of a TMDL for White Island Pond. In order to prevent further degradation in water quality and to ensure that each lake meets state water quality standards, the TMDL establishes a phosphorus limit for the lake and outlines actions to achieve that goal.

The two basins are similar in size and depth and are bordered by similar density of residential housing. The most notable difference between the two basins is the direct discharge of two major commercial cranberry bogs into the north end of East Basin. Water quality surveys have shown that the East Basin has consistently higher total phosphorus (TP) concentrations, exhibits frequent algal blooms, and does not meet the guideline for transparency (1.2 meters (m) for Secchi disk transparency). The West Basin also has somewhat elevated total phosphorus with less severe algal blooms and currently does meet the 1.2 m Secchi disk transparency guideline. The lakes are seepage lakes that are hydraulically connected and are modeled as one system with an overall average total phosphorus target set at 0.019 mg/l. The total maximum daily load is estimated as a combined load for the two-basin lake system.

Total Phosphorus Targets

Segment ID	Lake Name	Lake Area	Current Total Phosphorus (mg/l)	Target Total Phosphorus (mg/l)
MA95166	White Island Pond East basin	167 ac	0.081	0.019 (whole lake average)
MA95173	White Island Pond West basin	124 ac	0.034	

A mass balance approach using available data supplemented with nutrient export rates from the literature was used to estimate the current load of total phosphorus of 539 kg/year. The major source (50%) of phosphorus to the lake during the critical summer period is attributed to sediment recycling. This source of phosphorus is presumably due to historic inputs of phosphorus from anthropogenic sources. The major external sources are the cranberry bogs, followed by septic systems, groundwater and precipitation. The target load of 147 kg/year (or 0.40 kg/day) was determined from a suite of lake models calibrated to achieve an average in-lake total phosphorus concentration of 0.019mg/l as shown in the table below. Although the TMDL must be expressed on a daily basis, the implementation and administrative decisions should rely on achieving the annual TMDL load which is more appropriate for this slow flushing seepage lake.

White Island Pond (East and West Basins) Phosphorus TMDL Load Allocation

Source	Current Total Phosphorus Loading (kg/yr)	Target Total Phosphorus Load Allocation (kg/yr) and (percent reduction)
Load Allocation		
Groundwater	50	50 (0%)
Precipitation	35	35 (0%)
Home Septic systems	56	28 (50%)
Internal Sediment	267	13 (95%)
Makepeace Bogs	62	9 (85%)
Federal Furnace Bogs	69	10 (86%)
Additional Margin of Safety	0	2 (NA)
Total	539	147 (73%)

Although the major source of phosphorus is the sediments implementation to control the sediment source should be delayed until all external sources are controlled to the greatest extent practical. The implementation of the TMDL will require major reductions in loading from the cranberry bogs, combined with significant reductions from home septic systems. The major implementation can be achieved by a combination of best management practices (BMPs) including reducing the phosphorus fertilizer rates, reducing volumes of discharge water and reducing concentrations of total phosphorus in the discharge water.

Over time, the home septic systems will be updated to Title 5 (State Environmental Code, 310 CMR 15.000) systems and it is recommended that the Board of Health act quickly to bring all non-compliant systems into compliance. Additional controls on stormwater from construction and development in the towns of Wareham and Plymouth will be achieved as part of the Phase II stormwater permits issued by the United States Environmental Protection Agency (USEPA) and the Massachusetts Stormwater Management Regulations, 314 CMR 21.00 (DRAFT).

The successful implementation of this TMDL will require cooperative support from Federal agencies including USEPA and the Natural Resources Conservation Service (NRCS), as well as the cranberry growers, MassDEP, local volunteers, lake and watershed associations, and local officials in municipal government. A Memorandum of Agreement was signed on May 7, 2009 between the Massachusetts Department of Agricultural Resources, Massachusetts Department of Environmental Protection, the Cape Cod Cranberry Growers Association and the University of Massachusetts Cranberry Station to implement new practices on the commercial cranberry bogs that discharge to the lake. The MOA text is available at http://www.mass.gov/dep/water/resources/tmdls.htm#buzzards

In addition, a 319 grant was awarded to assist in implementation and monitoring of BMPs in the bogs, with monitoring being conducted by the Umass Cranberry Station. Funding support to aid implementation of this TMDL is available on a competitive basis under various state programs including the Section 319 Grant Program administered by MassDEP and federal funding for cranberry growers via the Environmental Quality Incentive Program (EQIP) offered by NRCS.

Table of Contents

EXECUTIVE SUMMARY 4

PROGRAMMATIC BACKGROUND AND RATIONALE 9

WATERBODY DESCRIPTION AND PROBLEM ASSESSMENT 15

WATER QUALITY STANDARDS VIOLATIONS 17

EXCEEDENCE OF OTHER WATER QUALITY THRESHOLDS 18

LAKE WATER QUALITY MONITORING 19

Results of Monitoring White Island Pond 19

Hydrologic Budget 24

Nutrient Budget Methods 25

Land use Modeling 25

Modified Nutrient Mass Balance Approach 27

Lake Model Estimates of Nutrient Loads 32

TMDL TOTAL PHOSPHORUS TARGETS 34

LOADING CAPACITY 35

WASTELOAD ALLOCATIONS, LOAD ALLOCATIONS AND MARGIN OF SAFETY 35
Loading Allocation to Nonpoint Sources 36
Margin of Safety 37

IMPLEMENTATION 37
Cranberry Bogs 38
Control of Sediment Sources 37
Control of Other Sources 40
Responsibilities for Implementation 41

REASONABLE ASSURANCES 43

WATER QUALITY STANDARDS ATTAINMENT STATEMENT 44

MONITORING **44**

PROVISIONS FOR REVISING THE TMDL **44**

PUBLIC PARTICIPATION **44**

PUBLIC COMMENT AND REPLY **45**

REFERENCES **45**

Appendix I Lake Data **51**

Appendix II Carlson Trophic State Index (TSI) **57**

Appendix III. Guidelines For Total Maximum Daily Loads Of Phosphorus From Commercial Cranberry Bog Discharges In Massachusetts. **58**

LIST OF TABLES.

TABLE 1. WHITE ISLAND POND MASS BALANCE PHOSPHORUS BUDGET 32
TABLE 2. INPUT DATA FOR LAKE MODELS OF TOTAL PHOSPHORUS 33
TABLE 3. FINAL RESULTS OF LAKE MODELS FOR WHITE ISLAND POND 34
TABLE 4. OTHER SEEPAGE LAKES IN SOUTHEASTERN MASSACHUSETTS 35
TABLE 5. WHITE ISLAND POND TMDL LOAD ALLOCATION 37
TABLE 6. TMDL TASKS AND RESPONSIBILITIES........ 42
TABLE 7. HYDROLAB DATA BASELINE LAKE MONITORING, 2000. 52
TABLE 8. WATER QUALITY DATA. BASELINE LAKE MONITORING, 2000 53
TABLE 9. WATER QUALITY DATA. BASELINE LAKE MONITORING, 2007. 54
TABLE 10. WATER QUALITY DATA. CRANBERRY BOG DATA 2007. 55

LIST OF FIGURES.

FIGURE 1. LOCUS MAP OF WHITE ISLAND POND. NEARBY EZEKIEL POND IS ALSO SHOWN. ... 16
FIGURE 2. URBANIZED AREAS SUBJECT TO PHASE II NPDES PERMITS. 17
FIGURE 3. PHOTO OF CYANOBACTERIA SURFACE BLOOM IN WHITE ISLAND POND. 20
FIGURE 4. RELATIVE TOTAL PHOSPHORUS CONCENTRATIONS (MG/L) AND SAMPLE LOCATIONS. 22
FIGURE 5. EAST WHITE ISLAND POND DO AND TEMPERATURE PROFILES. 23
FIGURE 6. WEST WHITE ISLAND POND DO AND TEMPERATURE PROFILES. 24
FIGURE 7. GROUNDWATER CONTRIBUTING AREA (MASTERSON ET AL., 2009). 26
FIGURE 8. SURFACE TOTAL PHOSPHORUS TRENDS. 31

Programmatic Background and Rationale

Section 303(d) of the Federal Clean Water Act requires each state to (1) identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. TMDLs may also be applied to waters threatened by excessive pollutant loadings. The TMDL establishes the allowable pollutant loading from all contributing sources that is necessary to achieve the applicable water quality standards. TMDLs determinations must account for seasonal variability and include a margin of safety (MOS) to account for uncertainty of how pollutant loadings may impact the receiving water's quality. This report will be submitted to the USEPA as a TMDL under Section 303d of the Federal Clean Water Act, 40 CFR 130.7. After public comment and final approval by the USEPA, the TMDL can be used as a basis for State and Federal permitting and regulatory decisions. The report will also serve as a general guide for future implementation activities such as grant funding of best management practices (BMPs). Information on watershed planning in Massachusetts is available on the web at http://www.mass.gov/dep/water/waterres.htm.

The programmatic background summary given below is intended to be general in nature and the issues described may or may not apply to the specific water body in question. The management of eutrophic freshwater lakes is typically based on a study of the nutrient sources and loads to the lakes and usually focuses on phosphorus as the important (or limiting) nutrient (Cooke et al., 2005). For TMDLs, the phosphorus loads estimated from the study can be compared to total phosphorus loadings estimated from a suite of different published lake models. A target concentration to meet Water Quality Standards is selected and a target yearly load of phosphorus is calculated for the lake. The phosphorus TMDL is established to control eutrophication in the water column, however additional plant management may be needed. A total phosphorus TMDL is established to meet Massachusetts Surface Water Quality Standards, and to maintain a minimum of 4-foot visibility in surface waters for safe recreational use (which is equivalent to the 1.2 m Secchi disc transparency). The successful implementation of this TMDL will require cooperative support from the public including lake and watershed associations, local officials and municipal governments in the form of education, funding and local enforcement. In some cases, additional funding support is available under various state programs including the MassDEP Section 319 (nonpoint source grants) and the State Revolving Fund Program (SRF); see watershed grants listed in http://mass.gov/dep/water/grants.htm

Nutrient Enrichment: Nutrients are a requirement of life, but in excess they can create water quality problems. Lakes are ephemeral features of the landscape and over geological time most tend to fill with sediments and associated nutrients as they make a transition from lake to marsh to dry land. However, this natural successional ("aging") process can be and often is accelerated through the activities of humans, especially through development in the watershed. For some highly productive lakes with developed watersheds, it is not easy to separate natural succession from "culturally induced" effects. Nonetheless, all feasible steps should be taken to reduce the impacts from cultural activities. The following discussion summarizes the current understanding of how nutrients influence the growth of algae and macrophytes (aquatic plants), the time scale used in the studies, the type of models applied and the data collection methods used to create a nutrient budget. A brief description of the rationale for choosing a target load (the TMDL) as well as a brief discussion of implementation and management options is presented. A more detailed description of fertilizer and water usage in commercial cranberry bogs is provided in Appendix III.

A detailed description of the current understanding of limnology (the study of lakes and freshwaters) and management of lakes and reservoirs can be found in Wetzel (1983), Cooke et al., (2005) and Holdren et al., 2001. To prevent cultural enrichment it is important to examine the nutrients required for growth of phytoplankton (algae) and macrophytes. The limiting nutrient is typically the one in shortest supply relative to the nutrient requirements of the plants. The ratio of nitrogen (N) to phosphorus (P) in both algae and macrophyte biomass is typically about 7 by weight or 16 by atomic ratio (Vallentyne, 1974). Observations of relatively high N/P ratios in water suggests P is most often limiting and careful reviews of numerous experimental studies have concluded that phosphorus is a limiting nutrient in most freshwater lakes (Likens, 1972; Schindler and Fee, 1974). Most diagnostic/feasibility studies of Massachusetts lakes also indicate phosphorus as the limiting nutrient. Even in cases where excess phosphorus has led to nitrogen limitation, previous experience has shown that it is easier, more cost-effective and more ecologically sound to control phosphorus than nitrogen. The reasons include the fact that phosphorus is related to terrestrial sources and does not have a significant atmospheric source as does nitrogen (e.g., nitrates in precipitation). Thus, non-point sources of phosphorus can be managed more effectively by best management practices (BMPs). In addition, phosphorus is relatively easy to control in point source discharges. Finally, phosphorus does not have a gaseous phase, while the atmosphere is a nearly limitless source of nitrogen gas that can be fixed by some blue-green algae, (i.e. cyanobacteria) potentially resulting in toxic blooms. For all of the reasons noted above, phosphorus is chosen as the critical element to control freshwater eutrophication, particularly for algal dominated lakes or in lakes threatened with excessive nutrient loading.

There is a direct link between phosphorus loading and algal biomass (expressed as chlorophyll a) in algae dominated lakes (Vollenweider, 1976). The situation is more complex in macrophyte-dominated lakes where the rooted aquatic macrophytes may obtain most of the required nutrients from the sediments. In organic, nutrient-rich sediments, the plants may be limited more by light or physical constraints such as water movement than by nutrients. In such cases, it is difficult to separate the effects of sediment deposition, which reduce depth and extend the littoral zone, from the effects of increased nutrients, especially phosphorus, associated with the sediments. In Massachusetts, high densities of aquatic macrophytes are typically limited to depths less than ten feet and to lakes where organic rich sediments are found (Mattson et al., 2004). Thus, the response of rooted macrophytes to reductions in nutrients in the overlying water will be much weaker and much slower than the response of algae or non-rooted macrophytes, which rely on the water column for their nutrients. In algal or non-rooted macrophyte dominated systems, nutrient reduction in the water column can be expected to control growth with a lag time related to the hydraulic flushing rate of the system. In lakes dominated by rooted macrophytes, additional, direct control measures such as harvesting, herbicides or drawdowns will be required to realize reductions in plant biomass within a reasonably short time scale. In both cases, however, nutrient control is essential since any reduction in one component (either rooted macrophytes or phytoplankton) may result in a proportionate increase in the other due to the relaxation of competition for light and nutrients. In addition, it is critical to establish a TMDL so that future development around the lake will not impair water quality. It is far easier to prevent nutrients from causing eutrophication than to attempt to restore a eutrophic lake. The first step in nutrient control is to calculate the current nutrient loading rate or nutrient budget for the lake.

Nutrient budgets: Nutrient budgets and loading rates in lakes are determined on a yearly basis because lakes tend to accumulate nutrients as well as algal and macrophyte biomass over long time periods compared to rivers which constantly flush components downstream. In cases of short retention time reservoirs (less than 14 days), nutrient budgets may be developed on a shorter time scale (e.g. monthly budgets from wastewater treatment plants) but the units are expressed on a per year basis in order to be comparable to nonpoint sources estimated from land use models. Nutrients in lakes can be released from the sediments into the bottom waters during the winter and summer and circulated to the surface during mixing events (typically fall and spring in deep lakes and also during the summer in shallow lakes). Nutrients stored in shallow lake sediments can also be directly used by rooted macrophytes during the growing season. In Massachusetts lakes, peak algal production, or blooms, may begin in the spring and continue during the summer and fall, while macrophyte biomass peaks in late summer. The impairment of uses is usually not severe until summer when macrophyte biomass reaches the surface of the water interfering with boating and swimming. Also, at this time of year the high daytime primary production and high nighttime respiration can cause large fluctuations in dissolved oxygen with critical repercussions for sustaining aquatic life. In addition, oxygen is less soluble in warm summer water as compared to other times of the year. The combination of these factors can drive oxygen to low levels during the summer and may cause fish kills. For these reasons the critical period for use impairment is during the summer, even though the modeling is done on a yearly basis for the reasons explained above.

There are three basic approaches to estimating current nutrient loading rates: the measured mass balance approach; the land use export modeling approach; and modeling based on the observed in-lake concentration. The measured mass balance approach requires frequent measurements of all fluvial inputs to the lake in terms of flow rates and phosphorus concentrations. The yearly loading is the product of flow (liters per year) times concentration (mg/l), summed over all sources (i.e., all streams and other inputs) and expressed as kg/year. The land use export approach assumes phosphorus is exported from various land areas at a rate dependent on the type of land use. The yearly loading is the sum of the product of land use area (Ha) times the export coefficient (in kg/Ha/yr). In some cases a combined or modified approach using both methods is used. In-lake phosphorus models provide an indirect method of estimating loading but do not provide information on the particular sources of input; however, this approach can be used in conjunction with other methods to validate results. The mass balance method is generally considered to be more accurate, but also more time consuming and more costly due to the field sampling and analysis. For this reason, the mass balance results are used whenever possible. If a previous diagnostic/ feasibility study or mass balance budget is not available, then a land use export model, such as Reckhow et al., (1980) or the NPSLAKE model (Mattson and Isaac, 1999) can be used to estimate nutrient loading.

Target Load: Once the current nutrient loading rate is identified, a new, lower rate of nutrient loading must be established which will meet surface water quality standards for the lake. This target load or TMDL can be set in a variety of ways. Usually a target concentration in the lake is established and the new load must be reduced to achieve the lower concentration. This target nutrient concentration may be established by a water quality model that relates phosphorus concentrations to water quality required to maintain designated uses including swimming (where 4 feet visibility has been a guidance value). Alternatively, the target concentration may be set based on concentrations observed in background reference lakes for similar lake types or from concentration ranges found in lakes within the same ecological region (or sub-ecoregion). In cases of impoundments or lakes with rapid flushing times (e.g., less than 14 days), somewhat higher phosphorus targets may be used because the planktonic algae and nutrients are rapidly flushed out of the system and typically do not have time to grow to nuisance conditions in the lake or accumulate in the sediments. In the case of seepage lakes (with no inlet streams) they may naturally have lower phosphorus targets, particularly if the lakes are clear water rather than dark or tea colored lakes.

Various models (equations) have been used for predicting productivity or total phosphorus concentrations in lakes from analysis of phosphorus loads. These models typically take into consideration the water body's hydraulic loading rate and some factor to account for settling and storage of phosphorus in the lake sediments. Among the more well known metrics are those of Vollenweider (1975), Kirchner and Dillon (1975), Chapra (1975), Larsen and Mercier (1975) and Jones and Bachmann (1976). These models are used to calculate the Total Maximum Daily Load or TMDL, in kilograms of the nutrient per day or per year that will result in the target concentration in the lake being achieved. The TMDL must account for the uncertainty in the estimates of the phosphorus loads from the sources identified above by including a "margin of safety". The margin of safety can be specifically included, and/or included in the selection of a conservative phosphorus target, and/or included as part of conservative assumptions used to develop the TMDL. In addition, a simple mass balance equation (model) of total load divided by total water input, may also be used to establish the minimum load (assuming no settling or loss of phosphorus) that could explain the observed concentration in the lake.

After the target TMDL has been established, the allowed loading of nutrients is apportioned to various sources that may include point sources as well non-point sources such as private septic systems and runoff from various land uses within the watershed. In Massachusetts, few lakes receive direct point source discharges of nutrients. In cases where significant point sources regulated through the National Pollutant Discharge Elimination System (NPDES) program exist upstream of a lake or impoundment, the point source will in most cases be required to use the Highest and Best Practical Treatment (HBPT) to reduce total phosphorus loading. The existing loads for NPDES point sources are calculated based on current data, not on the permitted discharge loading. New discharge mass loading limits at a treatment plant may be computed by applying the percent reduction required to meet the TMDL to the current loads. The new permitted concentrations of total phosphorus can then be calculated based on total mass loading divided by permitted flow rate for the discharge.

The nutrient non-point source analysis generally will be related to land use that reflects the extent of development in the watershed. This effort can be facilitated by the use of geographic information systems (GIS) digital maps of the area that can summarize land use categories within the watershed. This is then combined with nutrient export factors which have been established in numerous published studies. The targeted reductions must be reasonable given the reductions possible with the best available technology and Best Management Practices (BMPs). The first scenario for allocating loads will be based on what is practicable and feasible for each activity and/or land use to make the effort as equitable as possible.

Seasonality: As the term implies, TMDLs must be expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms as well. For most lakes, it is appropriate and justifiable to express a nutrient TMDL in terms of allowable annual loadings. The annual load should inherently account for seasonal variation if it is protective of the most sensitive time of year. The most sensitive time of year in most lakes occurs during summer, when the frequency and occurrence of nuisance algal blooms and macrophyte growth are typically greatest. Because the phosphorus TMDL was established to be protective of the most environmentally sensitive period (i.e., the summer season), it will also be protective of water quality during all other seasons. Additionally, the targeted reduction in the annual phosphorus load to lakes will result in the application of phosphorus controls that also address seasonal variation. For example, certain control practices such as stabilizing eroding drainage ways or maintaining septic systems will be in place throughout the year while others will be in effect during the times the sources are active (e.g., application of lawn fertilizer).

Implementation: The implementation plan or watershed management plan to achieve the TMDL reductions will vary from lake to lake depending on the type of point source and non-point source loads for a given situation. For non-point source reductions the implementation plan will depend on the type and degree of development in the watershed. While the impacts from development cannot be completely eliminated, they can be minimized by prudent "good housekeeping" practices, known more formally as best management practices (BMPs). Among these BMPs are control of runoff and erosion, well-maintained subsurface wastewater disposal systems and reductions in the use of fertilizers in residential areas, parks, cemeteries and golf courses and agriculture. Activities close to the water body and its tributaries merit special attention for following good land management practices. In addition, there are some statewide efforts that provide part of an overall framework. These include the legislation that curbed the phosphorus content of many cleaning agents, revisions to regulations that encourage better maintenance of subsurface disposal systems (Title 5 septic systems), and the Rivers Protection Act that provides for greater protection of land bordering water bodies. In some cases, structural controls, such as detention ponds, may be used to reduce pollution loads to surface waters.

Although the land use approach gives an estimate of the magnitude of typical phosphorus export from various land uses, it is important to recognize that non-point source phosphorus pollution comes from many discrete non-point sources within the watershed. Perhaps the most common phosphorus sources in rural areas are associated with soil erosion and use of phosphorus fertilizers. Soils tend to erode most rapidly following land disturbances such as construction, gravel pit operations, tilling of agricultural lands, overgrazing, and trampling by animals or vehicles. Erosion from unpaved roads is also a common problem in rural areas. Soils may erode rapidly where runoff water concentrates into channels and erodes the channel bottom. This may occur where impervious surfaces such as parking lots and roadways direct large volumes of water into ditches which begin to erode from either excessive water drainage or poorly designed ditches and culverts. Any unvegetated drainage way is a likely source of soil erosion. Home septic systems that do not meet Title 5 requirements may also be a source if located close to surface waters.

Discrete sources of nonpoint phosphorus in urban, commercial and industrial areas include a variety of sources that are lumped together as 'urban runoff' or 'stormwater' and may be considered as point sources under wasteload allocations. As many of these urban sources are difficult to identify the most common methods to control such sources include reduction of impervious surfaces, infiltration, street sweeping and other non-structural BMPS as well as treatment of stormwater runoff by structural controls such as detention ponds when this becomes necessary.

Other sources of phosphorus include phosphorus based lawn fertilizers used in residential areas, parks, cemeteries and golf courses and fertilizers used by agriculture. Manure from animals, especially dairies and other confined animal feeding areas is high in phosphorus. In some cases the manure is inappropriately spread or piled on frozen ground during winter months and the phosphorus can wash into nearby surface waters. Over a period of repeated applications of manure to local agricultural fields, the phosphorus in the manure can saturate the ability of the soil to bind phosphorus, resulting in phosphorus export to surface waters. In some cases, cows and other animals including wildlife such as flocks of ducks and geese may have access to surface waters and cause both erosion and direct deposition of feces to streams and lakes.

Perhaps the most difficult source of phosphorus to account for is the phosphorus recycled within the lake from the lake sediments. In most stratified north temperate lakes, phosphorus that accumulated in the bottom waters of the lake during stratification is mixed into surface waters during spring and fall turnover when the lake mixes. Phosphorus release from shallow lake sediments may be a significant input for several reasons. These reasons include higher microbial activity in shallow warmer waters that can lead to sediment anoxia and the resultant release of iron and associated phosphorus. Phosphorus release may also occur during temporary mixing events such as wind or powerboat caused turbulence or bottom feeding fish, which can resuspend phosphorus rich sediments. Phosphorus can also be released from nutrient 'pumping' by rooted aquatic macrophytes as they extract phosphorus from the sediments and excrete phosphorus to the water during seasonal growth and senescence (Cooke et al., 2005; Horne and Goldman, 1994). Shallow lakes also have less water to dilute the phosphorus released from sediment sources and thus the impact on lake water concentrations is higher than in deeper lakes.

The most important factor controlling macrophyte growth appears to be light (Cooke et al., 2005). Due to the typically large mass of nutrients stored in lake sediments, reductions in nutrient loadings by themselves are not expected to reduce macrophyte growth in many macrophyte-dominated lakes, at least not in the short-term. In such cases additional in-lake control methods are generally recommended to directly reduce macrophyte biomass. Lake management techniques for both nutrient control and macrophyte control have been reviewed in "Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report" and the accompanying "Practical Guide" (Mattson et al., 2004; Wagner, 2004) http://www.mass.gov/dcr/waterSupply/lakepond/geir.htm.

The Massachusetts Department of Environmental Protection will support in-lake remediation efforts that are cost-effective, long-term and meet all environmental concerns, however, instituting such measures will be aided by continued Federal (via USEPA), and State grant support.

Financial support for various types of implementation is potentially available on a competitive basis through both the non-point source (319) grants and the state revolving fund (SRF) loan program. The 319 grants require a 40 percent non-federal match of the total project cost although the local match can be through in-kind services such as volunteer efforts. Other sources of funding include the 604b Water Quality Management Planning Grant Program and the Community Septic Management Loan Program. Information on these programs is available in a pamphlet "Grant and Loan Programs – Opportunities for Watershed Protection, Planning and Implementation" through the Massachusetts Department of Environmental Protection, Bureau of Resource Protection; see also http://www.mass.gov/dep/service/grantsfi.htm

Because the lake restoration and improvements can take a long period of time to be realized, follow-up monitoring is essential to measure interim progress toward meeting the water quality goal and guide additional BMP implementation. This can be accomplished through a variety of mechanisms including volunteer efforts. Recommended monitoring may include Secchi disk readings, lake total phosphorus, macrophyte mapping of species distribution and density, visual inspection of any structural BMPs, coordination with Conservation Commission and Board of Health activities and continued education efforts for citizens in the watershed

Water body Description and Problem Assessment

White Island Pond, a "Great Pond of Massachusetts" in Plymouth/Wareham is a large 291 acre or 118 Hectare (Ha) natural pond comprised of two major basins: West White Island Pond (124 acres) and East White Island Pond (167 acres) as shown in Figure 1. The lake level has been slightly raised by a dam at the southern end of the east basin where a stream outlet enters another set of bogs. The basins are unstratified with an overall mean depth of only 2.36 meters (7.74 feet). The lake is a clearwater seepage lake with no permanent stream inlets and the primary source of water for the lake is groundwater and direct precipitation. Such lakes are typically very clear, with very low productivity and high transparency. The White Island Pond contributing watershed is 57 % forested. Residential housing accounts for about 16 % and agricultural land use is 27% which consists primarily of cranberry growing operations. The highest density of housing is located on the western shoreline of the West Basin (see Figure 1). Plymouth and Wareham both have Notices of Intent for Phase II stormwater NPDES permits for the "urbanized area" as indicated in Figure 2 from the EPA website http://www.epa.gov/region01/npdes/stormwater/ma.html.

The East Basin is less developed and it is used as a water supply for flooding and irrigating two large commercial cranberry bogs located on the north shore. Chapter 91 Licenses are required to install and maintain structures such as flumes, pumps and dikes, on Great Ponds in Massachusetts, which includes White Island Pond. Chapter 91 Licenses #1335 and #3501 have been issued to A.D. Makepeace Company and License #1311 has been issued to Federal Furnace Cranberry Company.

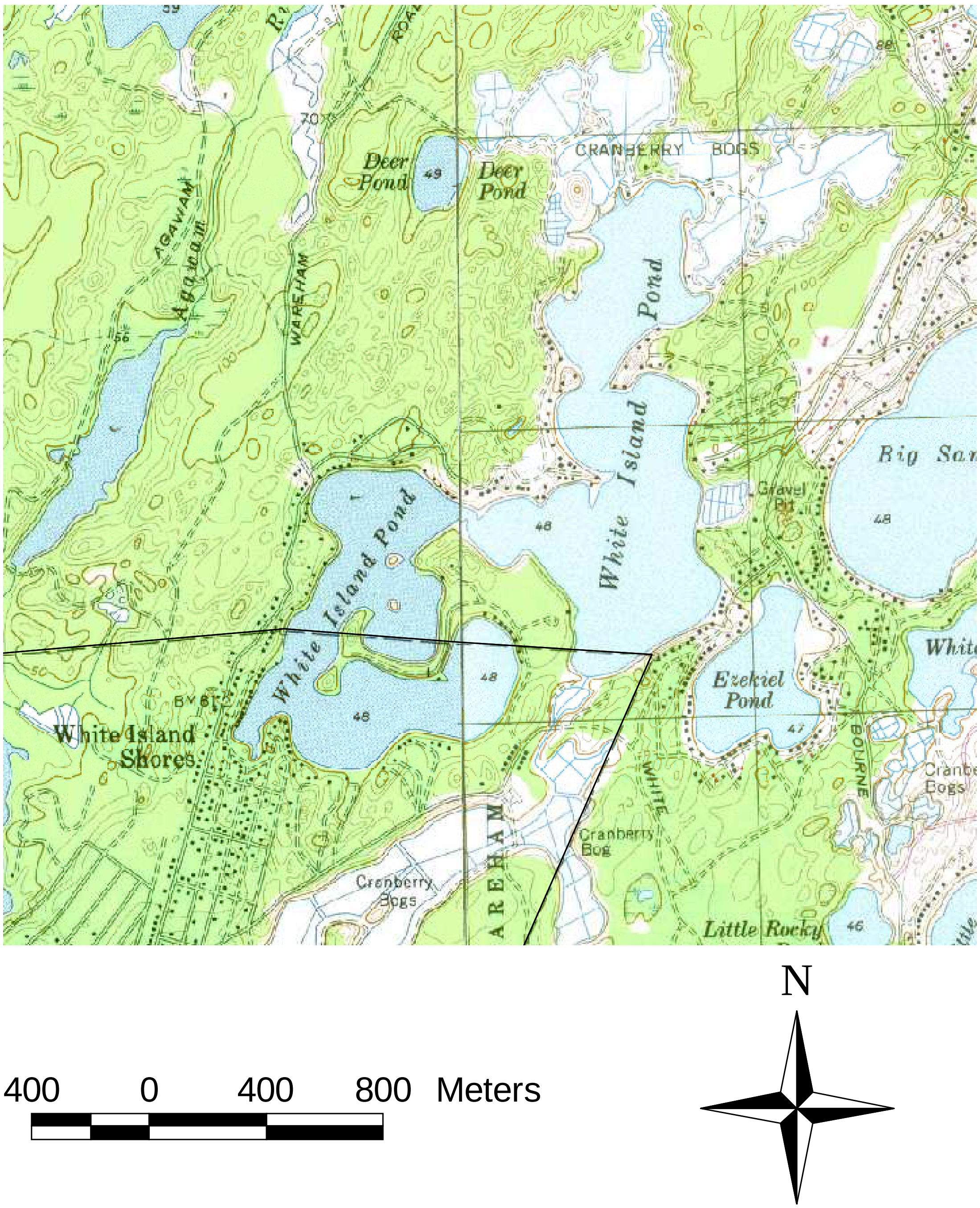


Figure 1. Locus Map of White Island Pond. Nearby Ezekiel Pond is also shown.

Figure 2. Urbanized areas subject to Phase II NPDES permits. The urbanized areas are shown as hatched areas around the pond including areas in towns of Wareham (below and left of dotted line) and Plymouth (above and right of dotted line).

The flow from the pond is manipulated during the year to both irrigate and flood the bogs. A brief description of management practices related to commercial cranberry bog operations is provided in Appendix III.

White Island Pond has a long history of nutrient related impairment of recreation. An early (1976-1978) study of the pond noted degradation of water quality in the form of algal blooms and occasional fish kills. In relative terms however, the pond was fairly clear in the early survey with the East Basin Secchi disk transparency averaging 3.76 m (over 12 feet of visibility) and always better than the 1.2 m swimming guidance. The lake ranged from low to moderately high in phosphorus at that time, with concentrations in the East Basin ranging from 0.01 to 0.05 mg/l with an average of 0.03 mg/l for surface (0-5 feet) samples (Whittaker, 1980). The cranberry bog discharge waters had total phosphorus concentrations ranging between 0.02 and 0.17 mg/l. The study recommended reducing nutrient sources from both the homes and from the cranberry bogs. For home owners the report recommended banning phosphates in detergents (which was done statewide) and septic system maintenance and upgrades for homes (see Title 5 regulations, 310 CMR 15.00). For the cranberry bogs, the report recommended that the owners reevaluate the application of fertilizers and irrigation (Whittaker, 1980).

The lake today is much more eutrophic, with blooms of toxic blue-green cyanobacteria commonly forming scums in the East Basin (see cover photo and see data below). The east basin in particular no longer meets the 1.2 m transparency guideline for safe swimming and phosphorus concentrations in the lake have greatly increased.

Water Quality Standards Violations

Both east and west basins of White Island Pond are listed on the Massachusetts 2008 Integrated List of waters in category 5, for not meeting uses and requiring a TMDL (DWM, 2007 CN 262.1). The East White Island Pond (segment # 95166) is listed for nutrients, organic enrichment/low DO, noxious aquatic plants and turbidity as well as for exotic species (not a pollutant). West White Island Pond (segment #95173) is listed for nutrients, organic enrichment/low DO, noxious aquatic plants as well as for exotic species. West White Island Pond is somewhat more transparent and currently meets the 1.2 m (4 foot) visibility guideline for swimming. The Water Quality Standards are described in the Code of Massachusetts Regulations under sections:

> 314CMR 4.05 (3) b: "These waters are designated as a habitat for aquatic life, and wildlife, and for primary and secondary contact recreation...These waters shall have consistently good aesthetic value.
>
> 1. Dissolved Oxygen:
>   a. Shall not be less than 6.0 mg/l in cold water fisheries nor less than 5.0 mg/l in warm water fisheries unless background conditions are lower;
>   b. natural seasonal and daily variations above this level shall be maintained…

and

> 314CMR 4.05 (5)(a) Aesthetics - All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.

and

> 314CMR 4.05 (5)(c) Nutrients. Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control.

Section 314 CMR 4.05(3)(b) 6 also states:

> Color and Turbidity - These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.

Exceedance of other Water Quality Thresholds

The Minimum Standards for Bathing Beaches (State Sanitary Code, Chapter VII) established by the Massachusetts Department of Public Health (MDPH) state that swimming and bathing are not permitted at public beaches when there is a lack of water clarity. The water transparency in East White Island Pond has been measured to be less than the MassDEP threshold of 4 feet (1.2 meter) of Secchi disk visibility for support of swimming in the summer of 2007 (see Table 9). West White Island Pond is more transparent and usually meets the 4 foot guidance, however the reduced transparency in the basins results in impairments of the aquatic macrophyte growth.

In addition to the above, bluegreen algae blooms were sampled in the lake and identified as potentially toxic cyanobacteria in June 2007 by MassDEP. In May 2008 MDHP collected water samples from the lake which contained levels of potentially toxic cyanobacteria blooms that exceeded the MDPH thresholds for recreational waters. The three samples were identified as *Anabaena* sp. with a median density of over 700,000 cells/ml by MassDEP staff. White Island Pond was subsequently posted to caution that people and pets should avoid areas of cyanobacteria concentration.

Lake Water Quality Monitoring

Both basins of White Island Pond were monitored during July through September, 2000 as part of a baseline survey. The lake and commercial bog discharges were also sampled in 2007 on a monthly basis from June through October. Results of the lake monitoring are presented in Appendix I.

The 2000 baseline survey consisted of monthly sampling of water at a deep hole station in each basin. The baseline survey included multi-probe profiles of dissolved oxygen, temperature, conductivity and pH. Additional sampling was done to determine Secchi disk transparency, chlorophyll a as an indicator of planktonic algal biomass, apparent color and TP. During the summer of 2000 an aquatic plant survey was conducted. Sampling details are available in the Quality Assurance Project Plan (DWM, 2000). Full results of the survey are available in the Baseline lakes 2000 Technical Memo.

The same deep hole stations were sampled again in 2007 for the multi-probe parameters, Secchi disc transparency, chlorophyll a, color and TP. Samples were also taken of water discharges from the cranberry bogs. Sampling details are available in the Quality Assurance Project Plan (DWM, 2007). The TP, chlorophyll a, and Secchi disk data from 2007 presented here have completed all quality control checks, but additional data may be added as it becomes available. Validated data are presented in Appendix I.

Results of Monitoring White Island Pond

According to the MassDEP DWM year 2000 lake baseline survey data, the East Basin had an average TP concentration of about 0.090 mg/l while the West Basin had an average TP concentration of about 0.046 mg/l. Summer Secchi disk transparency averaged 1.1 m in the East Basin and did not meet the 1.2m guidance for swimming transparency, while the West Basin was somewhat clearer with a Secchi disk of 1.8 m. Chlorophyll a concentrations in the East Basin averaged 35.4 mg/m^3 compared to 10.2 mg/m^3 in the West Basin. The East Basin chlorophyll a concentrations exceeded the 16 mg/m^3 chlorophyll a maximum cited for mesotrophic lakes (Wetzel, 2001) suggesting eutrophic conditions.

The 2000 and 2007 TP data are very similar. The data collected in the summer of 2007 further demonstrated the extent of the nutrient impairment, with numerous blooms of scum-forming blue-green cyanobacteria. Because it is more recent, the 2007 survey data has been used in the development of TMDL calculations detailed below. During the 2007 season, the East Basin never met the 1.2 m transparency guidance needed for swimming while the West Basin was again more transparent with an average of 1.7m of transparency. Chlorophyll a concentrations were somewhat higher compared to the earlier surveys. The West Basin, averaging 19.9 mg/m^3, and the East Basin averaging 41.9 mg/m^3 (indicating eutrophic conditions). The average concentration of total phosphorus in the East Basin surface waters was 0.081 mg/l compared to the 0.03 mg/l measured in the 1970's (described above). The West Basin had an average TP concentration of 0.034 mg/l giving an overall average TP for both basins of 0.057 mg/l. By way of comparison, nearby Ezekiel Pond exhibited clear water, with a TP concentration of only 0.006 mg/l in 2007. According to the commonly used Carlson trophic index (Appendix III), Ezekiel Pond would be oligotrophic (nutrient poor), while White Island Pond varies from eutrophic up to hypereutrophic.

In addition to the chemistry data presented above, the MassDEP staff noted blooms of potentially toxic cyanobacteria in the water of East White Island Pond and the pond was officially posted to caution the public against swimming as noted in the water quality violations noted above. A photo of one of the blooms being collected for identification is shown in Figure 3, below.

Figure 3. Photo of cyanobacteria surface bloom in White Island Pond.

It was also noted that the total phosphorus concentrations in the cranberry bog waters were higher in the 2007 survey as compared to the 1970's results. Two summer discharge samples collected in 2007 at A.D. Makepeace averaged 0.073 mg/l, while 2 summer discharge samples from Federal Furnace averaged 0.47 mg/l. A summary of the MassDEP total phosphorus data for the lake samples (including nearby Ezekiel Pond), the cranberry bog discharge waters, and the groundwater (from literature) are shown as vertical bars in Figure 4.

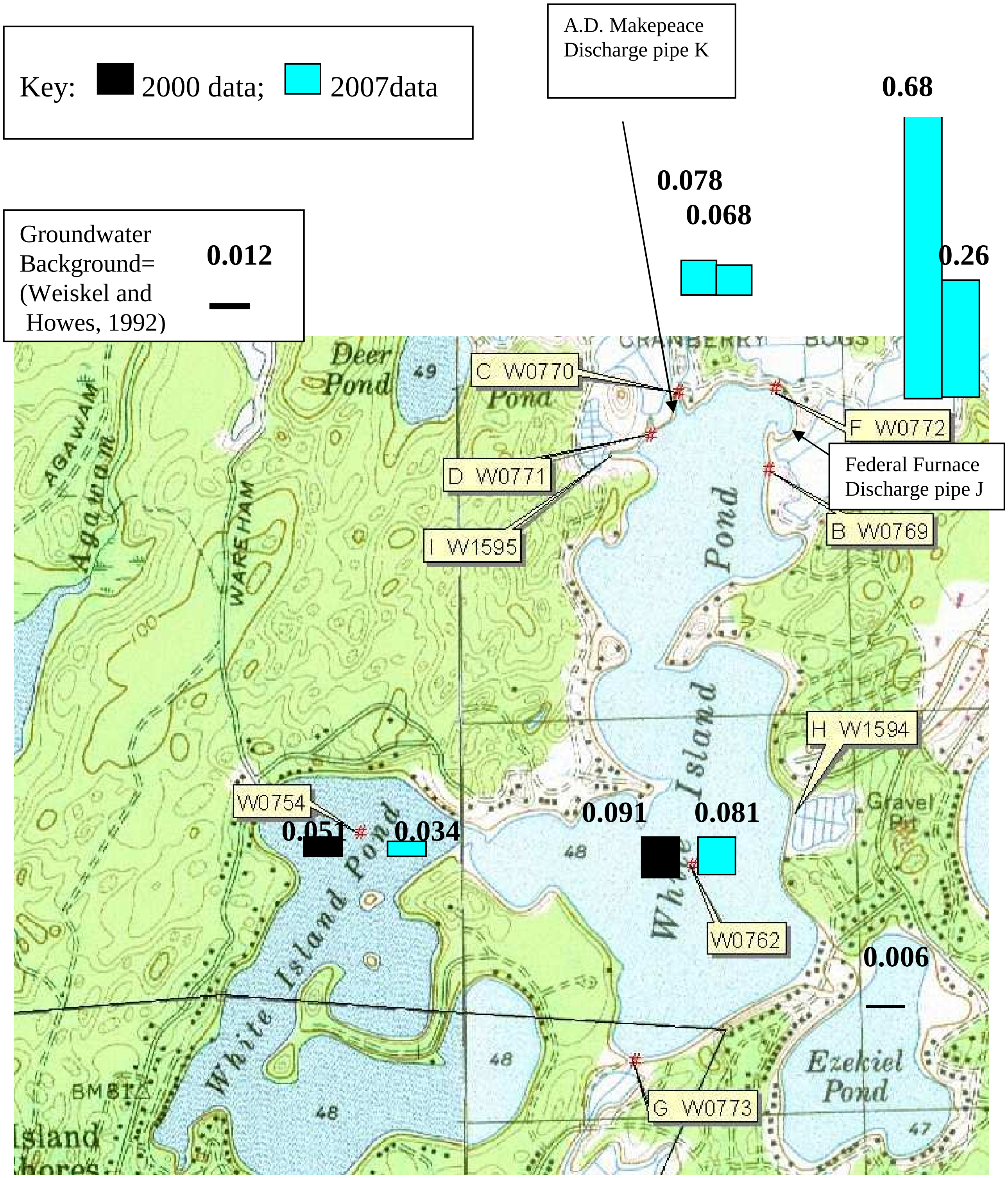
The TP data summary presented in Figure 4 indicates that both East and West White Island Pond are higher in TP than a nearby lake (Ezekiel Pond) and higher than groundwater in the region. The figure also suggests that the TP concentrations are higher in the East Basin where high concentrations of bog waters discharge to the ponds and lower in the West Basin where most of the homes are located. The results suggest that homes are not the cause of the high phosphorus, and suggest the cranberry bogs are likely to be a major source.

These results are supported by an additional 26 cranberry bog discharge samples collected by the White Island Pond Conservation Alliance (WIPCA) from 2006- early 2008 with most samples collected in 2007. Those samples were collected and analyzed promptly at a certified analytical laboratory, Groundwater Analytical. As is typical with cranberry operations those results show moderate TP concentrations during the summer discharges, 0.13 mg/l and 0.45 mg/l for Makepeace and Federal Furnace, respectively, and similar or somewhat higher concentrations during the larger fall harvest discharges with averages of 0.38 and 0.45 mg/l for Makepeace and Federal Furnace , respectively (J. Sullivan, pers.comm. 2008). Although the results from the citizen's group are not used in calculations to develop this TMDL, they do support the MassDEP results noted above.

MassDEP and WIPCA observed the bogs were discharging water to the lake on a regular basis during the summer of 2007, despite the fact that it was not a wet summer. According to the United States Geological Survey (USGS), June and July were in the normal range for runoff in southeastern Massachusetts, and July and September were significantly below average at the USGS gage sites; see:
http://ma.water.usgs.gov/drought/Surface_Water_Maps_for_Water_Year_2007.html.

Thus, the Makepeace and Federal Furnace bogs show characteristics of 'flow-through' bogs that discharge large amounts of water and nutrients to downstream receiving waters. At times the Federal Furnace bogs were observed to pump water from the lake to irrigate the bogs, while simultaneously discharging excess water back to the East Basin (J. Sullivan, WIPCA, pers. comm. 2007). As there are no streams flowing through either the Makepeace or Federal Furnace bog, this suggests that excess groundwater is being pumped off the bogs, resulting in an higher than typical volume of water being discharged to the East Basin from these bogs.

Figure 4. Relative Total Phosphorus concentrations bar graph (mg/l) and sample locations.



The dissolved oxygen (DO) and temperature profiles from 2000 showed that both the East and West basins of White Island Pond were unstratified with temperatures typically less than a degree Celsius different between the surface and the bottom (Figure 5). Although the lake dissolved oxygen was above the WQS of 5 mg/l in the profiles taken in the summer of 2000, an additional profile taken in early summer of 2007 showed low oxygen near the bottom sediments. This may indicate eutrophic conditions in the pond as algae and detritus settle to the bottom of the lake and are decomposed, resulting in low oxygen.

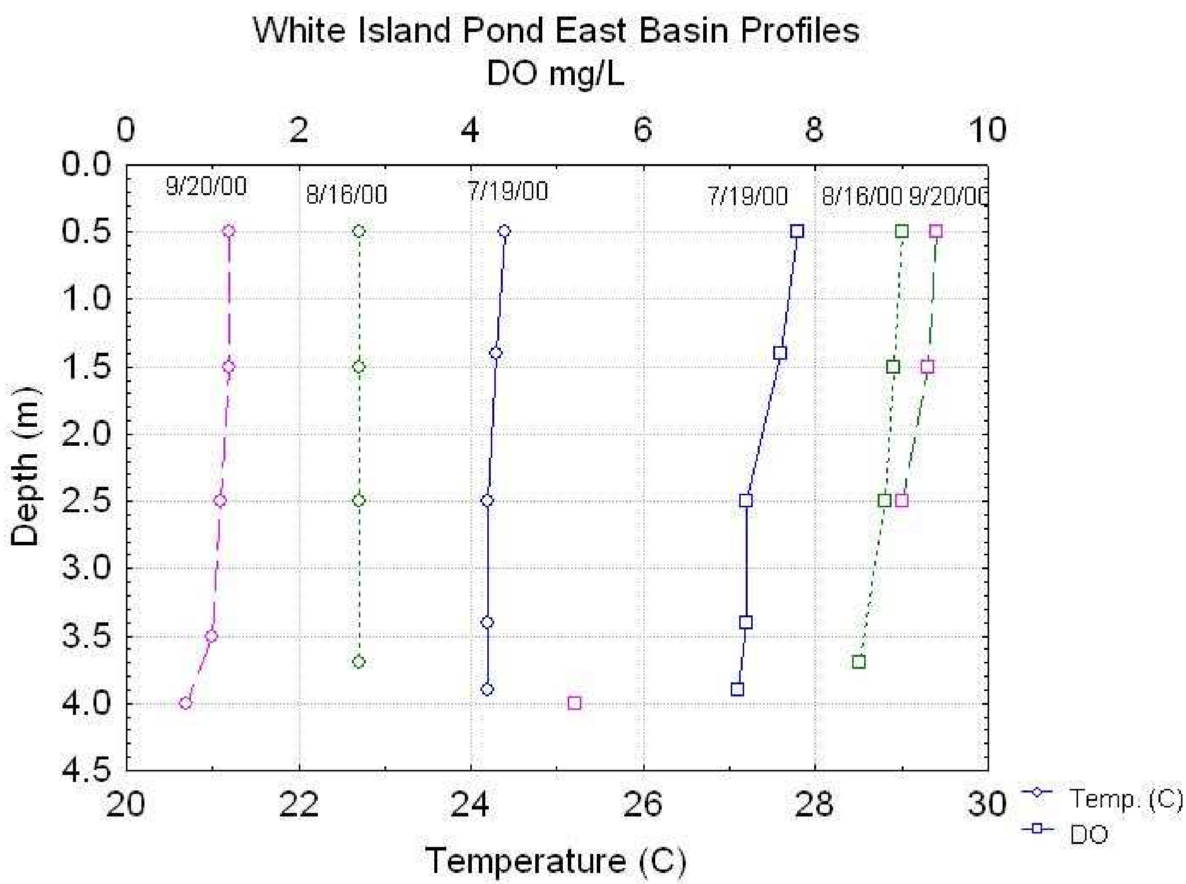


Figure 5. East White Island Pond DO and Temperature Profiles.

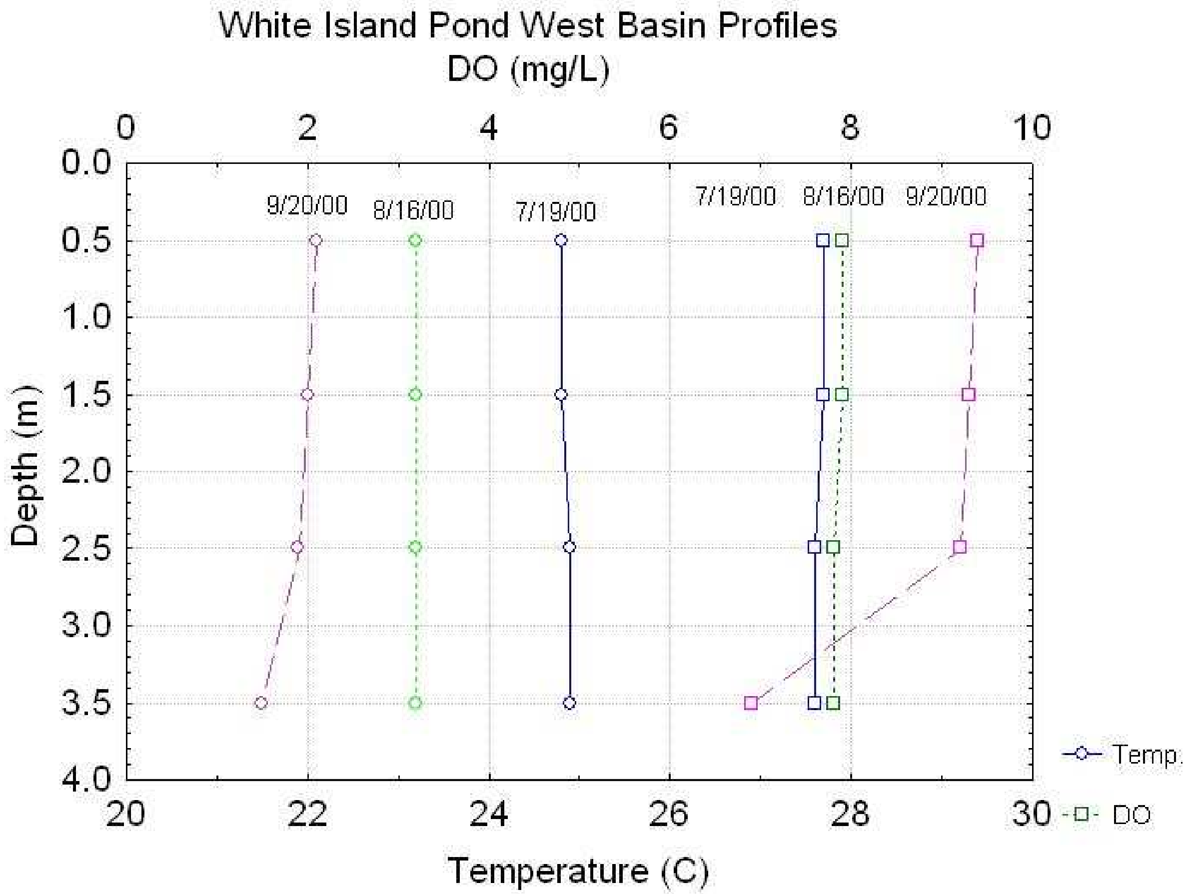


Figure 6. West White Island Pond DO and Temperature Profiles.

The overall plant density in White Island Pond is very sparse in recent surveys compared to plant surveys in the 1970's that noted nuisance conditions caused by dense plant growths in the northern bay of the east basin (Whittaker, 1980). Low plant densities are not uncommon in seepage lakes with mineral sediments but the current low density of plants outside of very shallow areas in this lake suggests light limitation caused by the low transparency of the water as seen in the recent surveys. The frequent algal blooms can shade the submerged aquatic vegetation and reduce the overall biomass.

Hydrologic Budget

There are no permanent tributary streams shown on the USGS quadrangle maps of the area (Figure 1), but the ditches of the Makepeace and Federal Furnace cranberry bogs can discharge to the lake if the boards are removed from the outlets at the end of the dikes. The East Basin has an outlet which flows south through a different set of cranberry bogs. Those bogs are presumed to discharge waters to the south away from the lake and are not discussed in this report. As a seepage lake, White Island Pond is replenished by groundwater and direct precipitation. The commercial cranberry bogs pump water from and discharge water back to the lake, although the exact volumes of water discharged are unknown. A recent study of Massachusetts commercial cranberry bogs reported an annual usage of 8-11 feet per acre (DeMoranville and Howes, (2005), which includes about 4 feet of precipitation.

The area of groundwater contribution (578.1 Ha) to the lake was estimated from groundwater elevations using a USGS model (Hansen and Lapham, 1992) and further refined in recent modeling by Masterson et al., (2009) as shown in Figure 7. Using this approach the annual groundwater recharge in the area of White Island Pond is estimated to be 27 inches per year. All of the water recharged from the contributing area was assumed to contribute to the lake. After consultation with USGS scientists who are updating the 2009 model, the annual groundwater contribution was modeled to be 4.2 million m^3 . Precipitation in the region is 47.6 inches per year (NOAA, 1984). When precipitation is multiplied by the surface area of the lake (118 Ha or 291 acres) this accounts for 1.2 million m^3 per year of water recharge per year. Estimated evaporative losses (Ward et al., 2004) from the lake surface reduce the net recharge from precipitation to 0.70 million m^3/year and in agreement with the Masterson et al., (2009) model. Thus, the areal water load to the lake surface is estimated to be 4.16 m/year with a flushing rate of 1.76 per year or a residence time of 207 days.

Nutrient Budget Methods

The estimation of nutrient budgets for the ponds involves a comparison of several approaches including:

1. land use modeling of nutrient loads for both ponds;
2. estimation of phosphorus mass balance using a product of water inputs (flow) and TP concentrations of each source combined with best professional judgment based on literature values for other sources including septic systems and internal sources;
3. lake modeling of nutrient loads for the lake. In order to model the predicted nutrient concentration in the lake a hydrologic (water) budget must also be constructed.

Each of these approaches is discussed below.

Land use Modeling

The NPSLAKE model of Mattson and Isaac (1999) was designed to estimate rates of phosphorus loading from various land uses in the watershed to lakes. Phosphorous inputs from septic systems and other residential uses, such as lawns, are estimated from an export coefficient multiplied by the number of homes within 100 meters of the lake. All coefficients fall within the range of values reported in other studies such as Reckhow et al., (1980). This model takes the area in hectares of land use within three major categories of land use, forest, urban and rural, and applies an export coefficient to each to predict the annual external loading of phosphorus to the lake from the watershed.

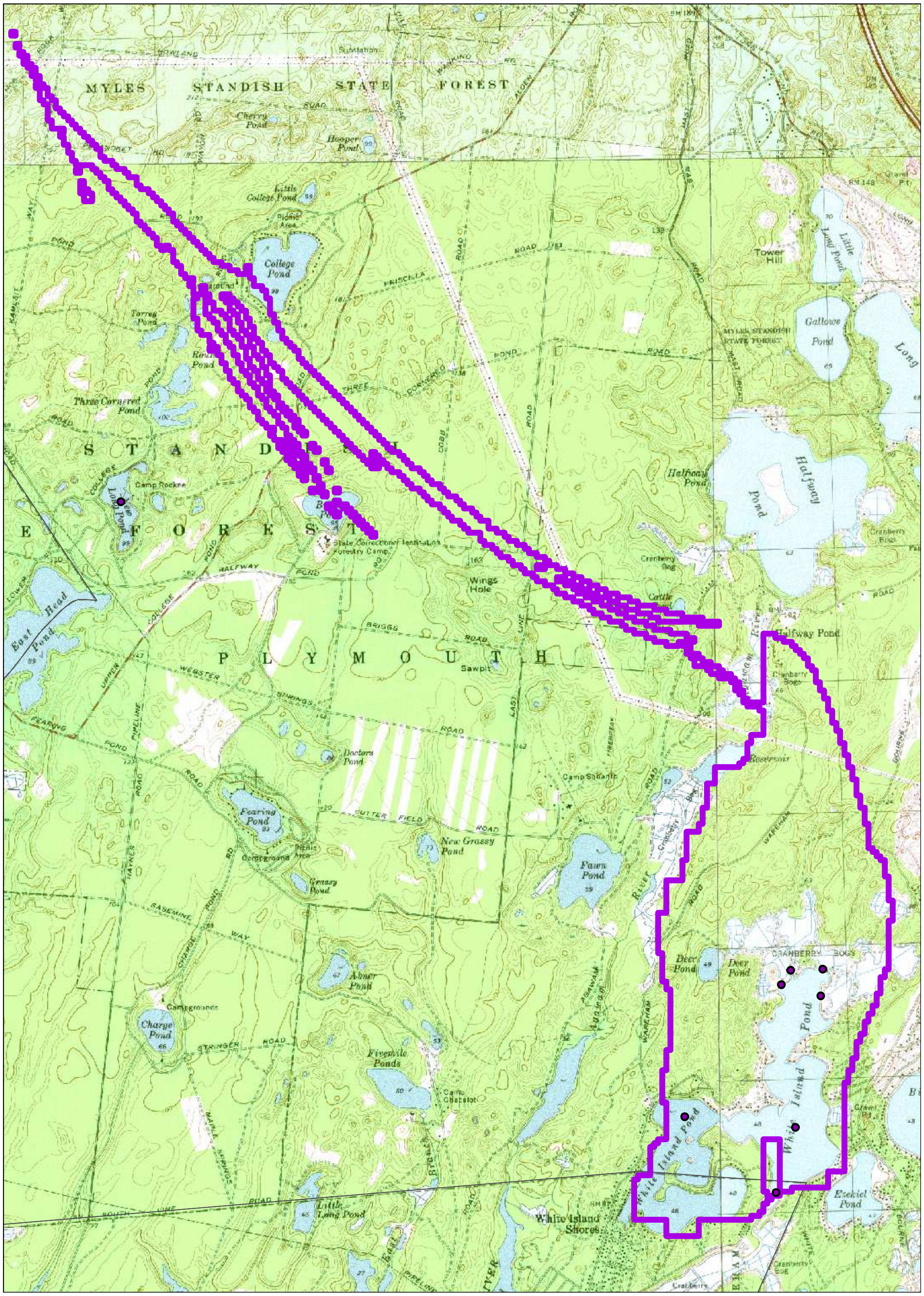


Figure 7. Groundwater contributing area (Masterson et al., 2009).

However, this land use export approach assumes that phosphorus from each land use is delivered to the lake with little attenuation. This assumption may be true for direct, fluvial discharges from bogs but may not apply to other land use source inputs where infiltration occurs. In Southeastern Massachusetts and the Cape Cod region, the water inputs to the seepage lakes common to the area are dominated by groundwater inputs that have significant attenuation by soil adsorption. Thus the land use export approach needs to be modified for use in the area surrounding White Island Pond, and the following discussion will focus on a combined, or modified mass balance approach with lake modeling used to validate the results.

Modified Nutrient Mass Balance Approach

The total load of phosphorus to White Island pond was estimated to be 539 kg per year, or approximately 1200 pounds per year, using a modified mass balance approach. The calculation of this load is based on a combination of monitoring data from 2007 and estimated literature loadings for all sources including groundwater, direct atmospheric inputs, discharges from cranberry bogs, septic systems and internal (sediment) sources. The sources and the assumptions used in the calculations are described below.

The phosphorus contributed by groundwater is calculated based on the estimated volume of groundwater entering the pond multiplied by the concentration of phosphorus in groundwater (0.012 mg/l from Weiskel and Howes, 1992). A total of 50 kg/year of phosphorus or approximately 9% of the total phosphorus load is attributed to groundwater. The phosphorus load from direct precipitation is based on the area of the lake multiplied by a loading coefficient of 0.3 kg/ha/year (Reckhow et al., 1980). A total of 35 kg/year or 7% phosphorus is attributed to direct precipitation phosphorus load.

There are two methods to determine phosphorus loadings from cranberry bogs, the cranberry export coefficient based on the work of DeMoranville and Howes, (2005) and Howes and Teal (1995) and the concentration discharge method. The cranberry export coefficient method is the primary means used to develop the TMDL and will be discussed first. Previous studies have shown a large difference in the nutrient discharge from bogs which is dependent upon the hydrology of the bogs (closed vs. flow-through bogs). Closed bogs, such as those studied by the UMass Cranberry Station (DeMoranville and Howes, 2005), typically discharge significant amounts of water in the days following the fall harvest floods, the winter frost prevention floods or the occasional pest control floods in the spring; large discharges in the summer generally do not occur in closed bogs. The flow-through bogs, such as those studied by Howes and Teal (1995), are characterized by streams that actually enter and flow through the bog complex. The phosphorus concentrations and nutrient load from these flow-through type bogs was higher than the closed bogs studied by DeMoranville and Howes (2005). The Makepeace and Federal Furnace bogs were both observed to have frequent discharges of water during the summer via pumping and thus appear to be intermediate between the closed and flow-through bogs. Although neither bog has a stream flowing through it, the bogs appear to have a significant volume of groundwater seepage which needs to be pumped off the bogs on a regular basis. Therefore, two phosphorus loadings will be estimated using the land use export method; the first is calculated with the high (flow-thru operation) coefficients and the other based on the low (closed operation) export coefficients for bogs. These two estimates will be compared to both the concentration discharge estimates of loading (below) and later compared to lake model estimates of phosphorus loading to the lake.

There are two separate commercial bog operations on the northern shore of the East Basin. The A.D. Makepeace Company cultivates 18.1 Ha of bog and Federal Furnace Cranberry Company cultivates 20.2 Ha. To calculate the "low" export estimate the recent study by the University of Massachusetts Cranberry Station and UMass Dartmouth (DeMoranville and Howes, 2005) for closed bogs is used. Based on the nature of the bogs (older bogs established on organic soils), and the relatively high concentrations of total phosphorus in the discharge waters, an export coefficient of 3.4 kg P/ha/year has been applied to the bogs. Thus, the low estimate is for phosphorus export is 131 kg/year, with Makepeace accounting for 62 kg/year and Federal Furnace accounting for 69 kg/year.

Assuming these same bogs are acting as flow-through bogs, the high land use export coefficient of 9.9 kg/ha/yr from Howes and Teal (1995) is applied to the bog areas listed above. This results in the "high" phosphorus loading estimates of 180 kg/yr and 200 kg/yr of phosphorus for the Makepeace and Federal Furnace bogs, respectively, for a total of 380 kg/yr.

An alternative estimate of phosphorus loading from the cranberry bogs (the concentration discharge method) can be used to compare to the results of primary land use export method discussed above. The method is based on the assumption that the bogs discharge about 7.5 acre-feet of water (assuming no evaporation) and the total mass load is the product of the discharge volume times the observed average total phosphorus concentration. The average concentration measured in 2007 from the A.D. Makepeace Company was relatively low at 0.073 mg/l, resulting in a somewhat smaller estimate of 30 kg/year. The average total phosphorus concentration in the Federal Furnace discharge during summer of 2007 was high at 0.47 mg/l and this results in an estimated load of 217 kg/year. It should be noted that because these bogs were discharging during the summer period they are likely to be discharging more than the nominal 7.5 acre-feet of water and thus the total load estimate of 247 kg/year is probably an underestimate. The estimate does fall between the low and high land use estimates of 131 kg/yr and 380 kg/year calculated above. , MassDEP did not monitor either fall harvest discharges and winter flood discharges. Previous work has shown that winter discharges are associated with relatively high nutrient loadings (Howes and Teal, 1995) and this is supported by volunteer data showing a high concentration (0.18 mg/l) in winter discharge at White Island Pond (J. Sullivan, WIPCA, pers. comm. 2009). As a result, it was concluded in the draft TMDL that flow-thru export coefficients more accurately reflect the operating conditions of the Makepeace and Federal Furnace operations. Therefore, under this set of assumptions, the annual phosphorus loadings from cranberry bog discharges are based on land use export coefficient of 9.9 kg/ha/yr estimate a cranberry bog annual load of 380 kg.

Based upon observed increases in total phosphorus concentrations during the summer of 2009 a large sediment load was estimated. As a result the TMDL budget was shifted to apportion greater phosphorus load to the sediments and relatively less to the commercial cranberry bog sources. Using the 3.4 kg/ha/year loading rate for organic bogs (DeMoranville and Howes, 2005) the cranberry bog discharge estimate of 62 kg/year and 69 kg/year was used for the Makepeace and Federal Furnace bogs respectively. See discussion of sediment sources below for further explanation.

Although the UMass Cranberry Station recommends phosphorus fertilizer rates of no more than 20 pounds per acre per year, it appears that many farmers exceed this recommendation. Even within the group of cranberry growers who volunteered for a nutrient reduction study, half of the bogs were applying more phosphorus fertilizer than the recommended maximum phosphorus rate at the beginning of the study (DeMoranville and Howes, 2005), sometimes by a factor of two. Similar over-application of phosphorus fertilizer to cranberries has been documented in Massachusetts (Howes and Teal, 1995). Part of the problem was due to the lack of commercial fertilizer mixes with low phosphorous to nitrogen ratios. Since the nutrient reduction study, more commercial fertilizers with lower phosphorous content have become available.

Phosphorus loading attributed to septic system contributions is calculated by taking the average of two export coefficients. First, the NPSLAKE model septic system phosphorus export coefficient of 0.5 kg/house/year was multiplied by the 224 homes located within 100 m of the White Island Pond shoreline to estimate 112 kg P/year for septic systems inputs. This initial estimate appears to be too high for the area based on monitoring results for nearby Ezekiel Pond located about 200 yards southeast of White Island. Like White Island Pond, Ezekiel Pond is a seepage pond. However, residential development is denser around Ezekiel Pond with 62 homes within 100 m of the 1750 m shoreline, resulting in an average linear density of one house every 28 m (90 feet) of shoreline. By comparison White Island Pond has 224 homes within 100 m of its 11,100 m shoreline with a house every 49.5 m (162 feet), with the majority of homes on the clearer West Basin. Although Ezekiel Pond has nearly twice as many homes per unit length of shoreline, it has remarkably clear water, with very low concentrations of total phosphorus (0.006 mg/l) in the surface water and reportedly has never experienced an algal bloom (J. Sullivan, pers. comm. 2007). This information suggests septic system phosphorus is highly attenuated in the soils of the region and that significant phosphorus plumes from the septic systems are not reaching the lakes. In fact, the lake models would predict phosphorus concentration near 0.006 mg/l for White Island Pond only if both internal loading and septic systems and cranberry bog phosphorus inputs were hypothetically set at zero. As a conservative approach it was assumed that soils in contact with leachate from septic systems will eventually saturate with phosphorus over time and eventually leach some phosphorus. Therefore, the average of the two septic system export coefficients was applied for a total load of 56 kg/year for the phosphorus load from septic systems. This would account for 10% of the total phosphorus inputs to White Island Pond. In a separate study of the larger Buttermilk Bay watershed (which includes White Island Pond), Valiela and Costa (1988) noted that gross inputs of phosphorus to the watershed (prior to adsorption and uptake) were dominated by septic systems and agricultural use of fertilizers (mainly cranberry bogs), but it was noted that the septic systems discharge to groundwater (where phosphorus is strongly adsorbed) while it is assumed the cranberry bogs discharge to surface waters with less uptake and adsorption.

In some cases the lake sediments themselves can be a source of phosphorus to the lake. Typically this occurs during periods of anoxia when iron compounds in the sediments are chemically reduced and the phosphate adsorbed to the iron is released to the bottom waters, resulting in higher phosphorus concentrations at the bottom. In shallow lakes, such as White Island Pond, this internal phosphorus can be mixed back to the surface causing additional algal growth. White Island Pond is normally well mixed with adequate oxygen, however, on one of the six dates where oxygen profiles were collected in the two years of sampling, dissolved oxygen concentrations were less than 1 mg/l at a depth approximately 1 m above the sediment surface. This typically indicates the sediments are anoxic. On the same date a higher concentration of total phosphorus was observed in the near bottom water sample compared to the surface, indicating a potential release of phosphorus from the sediments.

The internal anoxic phosphorus release from lake sediments is estimated in four ways: by difference, by mass accumulation during temporary stratification, by anoxic area multiplied by an estimated release rate and by mass accumulation in the whole lake after major cranberry discharges ceased during the summer of 2009.

To calculate the sediment source by difference the known sources above are subtracted from an independent estimate of the total load. Adding up the sources above (272 kg/year) and comparing it to the modeled total of 523 kg/year calculated from on observed concentrations (see lake models in next section), we estimate an unknown source of about 251 kg/year.

The oxygen profile of the bottom was below 1 mg/l in only one of the six dissolved oxygen (DO) profiles collected during the 2000 and 2007 summer visits, and that profile was collected on June 26, 2007. Thus, the days of anoxia were calculated as $1/6^{th}$ of the summer stratification period. The area below 3.9 m (the depth at which the low oxygen was recorded in both the East and West Basins) was calculated as 102,000 m^2 with a volume below that depth of 48,000 m^3. Using a value of anoxic phosphorus release of 6 $mg/m^2/day$ based on the rationale used for nearby Stetson Pond (BEC. 1993) a phosphorus release of 18 kg/yr was estimated and used in the draft TMDL.

Data collected during the summer of 2009 (after the draft TMDL was released) indicated an unusually marked increase in the concentrations of total phosphorus in the east basin of the lake during the summer in a period when the cranberry growers were avoiding surface discharges to the lake as shown in Figure 8. In comparison, the trend in concentrations during 2000 was a decline over the summer and the trend in 2007 was a modest increase followed by stable concentrations in late summer. Based on previous years data the lake is well mixed and surface concentrations can be multiplied by lake volume to estimate change in mass over the summer 2 month period. Using 2009 as the worst case of the three years, we estimate a rate of 44.48 kg/month (or 4.52 kg/ha/yr if the entire lake area is considered) increase in mass of phosphorus, and this is presumed to be from sediment sources. However, other sources such as increased seepage from the bogs ditches and under the bog dikes to the adjacent lake during a wet summer can not be ruled out. Evidence for increased seepage is provided by the USGS monitoring wells (http://ma.water.usgs.gov/water_statement/2009_07/index.html) that showed abnormally high (>90^{th} percentile) groundwater in southeast Massachusetts during July 2009 due to abnormally high rainfall that summer.

If this monthly increase in mass is extrapolated to 6 months of the year this source could account for a net increase of 267 kg/year. The sediments are presumably a sink for phosphorus during the colder months of the year but the budget focuses on the summer growing season when impairments are most likely to occur. Because the mass accumulation in the summer of 2009 estimate is closer to the value of 251 kg/year estimated by difference the estimate of 267 kg/year will be used in the revised phosphorus loading budget Table 1.

The phosphorus nutrient budget calculated by the combined mass balance and export coefficient values for sources is summarized in Table 1 (values may not sum to 100 percent due to rounding). For each source (row), the base unit for the source is multiplied by the appropriate time or volume and the product is multiplied by the appropriate export coefficient to yield the estimated phosphorus load in kg/year.

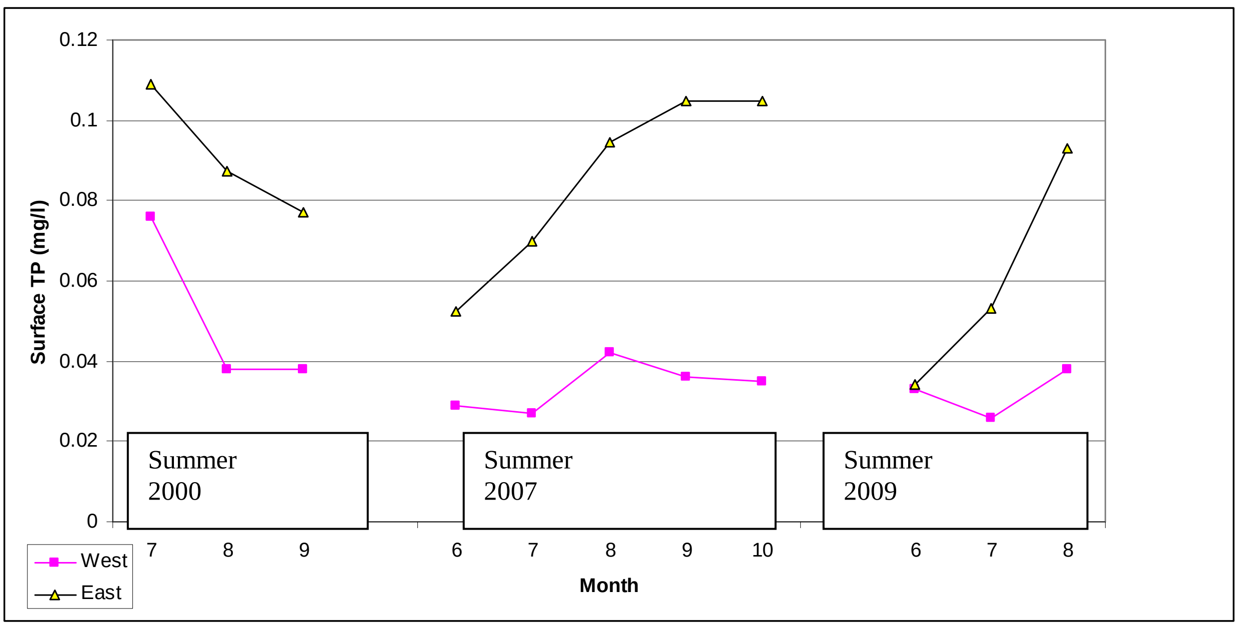


Figure 8. Surface Total Phosphorus Trends.

Table 1. White Island Pond Mass Balance Phosphorus Budget

Source	**Unit or Area (Ha)**	**Time or Volume** (m^3)	TP **(mg/l)**	Export **Coefficient** (**kg/ha/yr**)	Total Phosphorus Load (**kg/yr**)	**Percent** of Total Phosphorus Load (%)
Groundwater	**460**	**4,200,000**	**0.012**		**50**	**9**
Precipitation	**118**	**1,430,000**		**0.3**	**35**	**7**
Makepeace Bogs	**18.17**			**3.4**	**62**	**11**
Federal Furnace Bogs	**20.2**			**3.4**	**69**	**13**
Internal	**118**	**0.5 year**		**4.52**	**267**	**50**
224 Homes with Septic systems				**0.25**	**56**	**10**
Total					**539**	**100**

Lake Model Estimates of Nutrient Loads

Lake models can be used for two purposes, first to validate estimates of existing loads compared to current lake concentrations, and second to develop TMDL loads to meet new target lake concentrations. Although direct mass loading estimates are the most accurate method of constructing nutrient budgets, lake modeling can be used to validate how well the loads agree with the observed concentrations in the lake and to determine if there are missing sources or overestimated sources in the budget. Lake survey data revealed that with the exception of one day noted above (June 26, 2007), there were no differences in the total phosphorus concentrations between the surface and near bottom samples and, therefore, the surface samples were assumed to be representative of overall lake conditions. Because it is difficult to separate the inputs from the East and West Basins, and because the two basins are similar in size, the average of the two ponds is used to represent overall lake concentrations in the model. Assuming our estimates of sources are correct, and the TMDL is fully implemented, the East Basin will improve relatively more than the West Basin, and eventually both basins will have similar, acceptable water quality. Lake models can be used to predict TP from annual phosphorus loads as well as to reverse calculate predicted loads from lake TP concentrations. Rather than relying on a single lake model, a suite of five lake water quality models (Vollenweider (1975), Kirchner and Dillon (1975), Chapra (1975), Larsen and Mercier (1975) and Jones and Bachmann (1976), K. Wagner, pers. comm., 2000), were applied to determine loadings, along with a simple mass balance approach using the recently collected data for the total load and observed average concentration of total phosphorus for White Island Pond. Input data for the models is summarized in Table 2.

The five lake models used were developed and validated on north temperate lakes with relatively long retention times and similar in size and depth to White Island Pond. The reader is referred to original papers for additional details on the models assumptions, and details of calibration and validation. There are no numeric models available to predict the growth of rooted aquatic macrophytes as a function of nutrient loading estimates, therefore the control of nuisance aquatic macrophytes is based on best professional judgment.

Using the five established models and the observed 2007 average concentration of 0.057 mg/l TP, the predicted annual load ranged from 363 to 767 kg/year with an average of 523 kg/yr, which is in good agreement with the modified mass balance estimate of 539 kg/yr, estimated above. Because the lake models agree with the loading estimates we can assume the models are reasonably accurate and all sources have been accounted for. The simple mass balance model (assuming no phosphorus retention in the lake) was slightly lower at 280 kg/year and represents a lower boundary for the true load. Running the models backward with the 539 kg/yr as input, the models predict a range in concentration of 0.04 to 0.085 mg/L with an average of 0.062mg/l. Therefore, these models show good agreement with the observed average lake concentration of 0.057 mg/l TP.

Table 2. Input data for Lake Models of Total Phosphorus

Parameter	Units	Derivation	Value
Lake Total Phosphorus Conc.	mg/l	From data or model	0.057
Annual load	kg/yr		539
Areal Phosphorus Load to Lake	g $P/m^2/yr$	From data or model	0.46
Influent (Inflow) Total Phosphorus	mg/l	From data	0.059
Effluent (Outlet) Total Phosphorus	mg/l	From data	0.057
Inflow, total	m^3/yr	From data	4.90E+06
Lake Area	m^2	From data	1.18E+06
Lake Volume	m^3	From data	2.78E+06
Mean Depth	m	Volume/area	2.36
Flushing Rate	flushings/yr	Inflow/volume	1.76
Suspended Fraction	no units	Effluent TP/Influent TP	1.0
Areal Water Load	m/yr	Z(F)	4.2
Settling Velocity	m	Z(S)	2.2
Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.033
Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.65
Retention Coefficient (flushing rate)	no units	$1/(1+F^{0.5})$	0.43
Water retention time	Days	365/(Inflow/volume)	207

Table 3. Final Results of Lake Models for White Island Pond using 539 kg/year input

Method Name	Method Formula	Predicted Concentration (mg/L)	Predicted Load (G/M2/Yr)	Predicted Load (Kg/Yr)
Mass Balance	TP=L/(Z(F))*1000	0.101		
(minimum possible load)	L=TP(Z)(F)/1000		0.24	280
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	0.040		
(K-D)	L=TP(Z)(F)/(1-Rp)/1000		0.65	767
Vollenweider 1975	TP=L/(Z(S+F))*1000	0.085		
(V)	L=TP(Z)(S+F)/1000		0.31	363
Chapra	TP=L(1-R)/(Z(F)*1000	0.057		
(C)	L=TP(Z)(F)/(1-R)/1000		0.46	539
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	0.063		
(L-M)	L=TP(Z)(F)/(1-Rlm)/1000		0.42	491
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	0.067		
(J-B)	L=TP(Z)(0.65+F)/0.84/1000		0.39	457
Average of Model Values		0.062		
(without mass balance)			0.44	523
Measured in White Island Pond		0.057		
Mass Balance Input to models			0.42	539

TMDL Total Phosphorus Targets

As the term implies, TMDLs are expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may also be expressed in other terms when appropriate. For these cases, the TMDLs are expressed in terms of allowable annual loadings of phosphorus because the growth of phytoplankton and macrophytes responds to changes in annual, as well as daily, loadings of nutrients. The target phosphorus concentration must be set low enough to ensure the lake meets all designated uses. Generally, all uses for typical warm water fisheries lakes (including swimming, boating and aesthetics) can be met at the USEPA "Gold Book" recommendation of 0.025 mg/l. A further refinement of total phosphorus targets utilizes concentrations of phosphorus in lakes within uniform ecological regions (the ecoregion approach). The phosphorus concentrations predicted for White Island Pond from the Griffith et al. (1994) and Rohm et al., (1995) ecoregion maps range between 0.010 and 0.019 mg/l for typical summer to fall conditions. The United Stated Environmental Protection Agency (USEPA) has proposed a lower TP concentration for lakes in Ecoregion XIV (including White Island Pond) of 0.008 mg/l (http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/files/sumtable.pdf).

Clear water seepage lakes tend to have lower total phosphorus concentrations than typical lakes with inlet streams. The median summer surface total phosphorus concentration in other relatively unimpacted clear water seepage lakes in southeastern Massachusetts is very low (Table 4). However, White Island Pond is fairly shallow and has been impounded at the outlet to raise the water level, flooding what was once soil and this may be expected to increase the nutrient supply to the water body (Mattson et al., 2004) and supports a warm water fishery and, therefore, a somewhat higher total phosphorus target may be justified. The pond may have had some surface water and nutrient inputs from historic wetlands prior to the installation of the cranberry bogs and thus may not be a true seepage lake. Thus the target is set at the upper range of the Griffith et al., (1994) and Rohm et al., (1995) ecoregion concentrations for this area, specifically, 0.019 mg/l as an overall average for the two basins. In order to ensure that the lake meets water quality standards, the overall average should be lower than the 0.025 mg/l Gold Book number and is set to 0.019 mg/l as a margin of safety.

Table 4. Other Seepage lakes in southeastern Massachusetts

Lake name	Town	Year sampled	TP mg/l (median surface)
New Long Pond	Plymouth	2000	0.006
Ryder Pond	Truro	2004	0.010
Long Pond	Brewster	2004	0.016
Sheep Pond	Brewster	2004	0.005
Great Pond	Eastham	2004	0.014
Ezekiel Pond	Plymouth	2007	0.006

Loading Capacity

For purposes of this TMDL the annualized total phosphorus loading capacity target will be calculated as the mean of the lake models predictions that meet the 0.019mg/l target concentration. The parameters used are those listed in Table 2 with the new target (0.019 mg/l) inserted and the models (including the mass balance model) rerun to predict the phosphorus loads. The highest and lowest estimated loads were dropped as potential outliers, and the loading capacity is based on the mean of the remaining four models, which was 147 kg/year or 0.40 kg/day. Once the loading capacity, or TMDL, is obtained, the next step is to allocate the loads to the sources.

Wasteload Allocations, Load Allocations and Margin of Safety

The TMDL is the sum of the wasteload allocations (WLA) from point sources (e.g., sewage treatment plants and urban stormwater and agricultural discharges from point sources such as pipes or ditches) plus load allocations (LA) from nonpoint sources (e.g., land use sources) plus a margin of safety (MOS). Thus, the TMDL can be written as:

TMDL = WLA + LA + MOS

The TMDL process requires that loads be allocated to point and non-point sources. Pipe discharges from agricultural irrigation return water are not regulated as point sources, thus all sources to White Island Pond will be considered as non-point sources. The total loading capacity of 147 kg/year represents the Total Maximum Daily Load expressed on a yearly basis. The TMDL expressed as a daily load is 147 kg/year divided by 365 days, or an average of 0.40 kg/day. However, because of the long retention time of the lake (207 days from Table 2), a yearly representation of the load is more appropriate to use. The allocation of the 147 kg/year TMDL must be reasonable and equitable and the proposed allocation is shown in Table 5. The approach used is to target anthropogenic loads that can be reduced in a cost effective manner by appropriate best management practices. Generally, the largest anthropogenic loads will be targeted for the largest reductions with all other things being equal. The individual source allocations are given below.

Loading Allocation to Nonpoint Sources

Table 5 lists the current TP loading and target TP load allocations. The groundwater is already low in concentration compared to the target concentration cannot be expected to be further reduced and the loading should remain at 50 kg/year. Although precipitation (including dry deposition) of phosphorus is influenced by anthropogenic activities to some extent, the allocated 35 kg/yr is not markedly higher than background and it is not reasonable to believe significant reductions can be made to this allocation. Private septic systems are an anthropogenic source that can be targeted for reductions as discussed in the implementation section below. Assuming some of the homes have older style septic systems, a reasonable level of reduction is 50 percent provided this reduction is implemented incrementally over a period of years as areas are sewered or properties are gradually upgraded to Title 5 systems and any non-conforming septic systems are required by the Board of Health to be upgraded. Therefore, the target allocation for septic systems is set to 28 kg/year. Internal sources may be considered partially a legacy of past anthropogenic inputs. Because internal sources of phosphorus increase as a result of anoxia associated with anthropogenic eutrophication, it can reasonably be assumed that internal sources will decline proportionately as external loading of phosphorus decreases. Because the source is a major portion of the summer budget an alum treatment or other sediment phosphorus control is likely to be needed. Assuming a 95% reduction in this source can be achieved with an approved sediment treatment the target for sediment sources is 13 kg.

The major sources of phosphorus are the load allocations attributed to the commercial cranberry bogs which discharge phosphorus directly into the lake. These findings are similar to an earlier study comparing housing and cranberry nutrient inputs in Wisconsin (Garrison and Fitzgerald, 2005). A previous study by MassDEP also found that commercial cranberry bogs exported large percentages (15-57%) of the phosphorus applied to the bogs and the discharge was greater than a nearby freshwater wetland (Gil, 1989).

The commercial bogs are large, anthropogenic sources of phosphorus and offer the greatest opportunity to achieve the TMDL goal. The new allocations are based on the bogs achieving an overall loading rate of 0.5 kg/ha/year achieved by the best performing bogs in the DeMoranville and Howes (2005) study. Multiplying the 0.5 kg/ha/year by the respective areas of the bogs gives a target allocation of 9 kg/year for A.D. Makepeace bogs and 10 kg/year for the Federal Furnace bogs as shown in Table 5. The excess additional bog loadings are targeted for elimination as discussed in the implementation section below.

Margin of Safety

The margin of safety is set by establishing a target that is below that expected to remove algal blooms and meet the visibility target of 4 feet for swimming and below the concentration levels needed to maintain designated uses. An additional margin of safety can be added as an explicit loading term. Based on allocations to point and the nonpoint sources, a load of 2 kg/year remains unallocated and this amount is added as an additional margin of safety.

Table 5. White Island Pond TMDL Load Allocation

Source	Current TP Loading (kg/yr)	Target TP Load Allocation (kg/yr)
Load Allocation		
Groundwater	50	50
Precipitation	35	35
Home Septic systems	56	28
Internal Sediment	267	13
Makepeace Bogs	62	9
Federal Furnace Bogs	69	10
Additional Margin of Safety	0	2
Total	539	147

Implementation

Implementation of the TMDL will focus on the largest sources including the sediment recycling of phosphorus during the summer and the cranberry bog discharges as shown in Table 5. Additional implementation will include upgrading failed Title 5 septic systems as required by law or by sewering areas as development increases. The groundwater is already at background concentrations and is not likely to be improved. There are no reasonable BMPs available to significantly reduce atmospheric precipitation and dryfall inputs.

Control of Sediment Sources

Because the increase in mass of total phosphorus in the lake during the summer of 2009 indicated a large phosphorus source from the sediments implementation must address the sediments in order to meet the target TMDL. The origin of this large amount of sediment phosphorus was due to historically high anthropogenic phosphorus inputs that have transferred and settled to the sediments over many years. The control of summer sediment phosphorus release in this lake can be treated with a buffered alum and sodium aluminate treatment, or with iron treatment combined with aeration or by dredging the sediments after the major surface discharges are controlled as described in Mattson et al. (2004).

Cranberry Bogs

Current practices used by commercial cranberry growers intended to achieve maximum crop yield can have unintended negative impacts on the surface waters that receive discharge water from the bogs. MassDEP is currently working with the UMass Cranberry Station and the Cape Cod Cranberry Growers Association to update recommended BMPs to ensure Water Quality Standards are met. For this TMDL the following BMPs may be required to meet the target allocations. The implementation will apply adaptive management in a series of steps (from simple cost saving BMPs to progressively more intensive BMPs) implemented over a period of years to evaluate the water quality response in the lake. The implementation plan for reducing total phosphorus discharges from the commercial cranberry bogs will begin with source reduction and amounts of phosphorus fertilizers applied and changing the ratio or N to P in fertilizer as needed and improvements to irrigation and flood water usage. In order to meet the TMDL, the bogs are targeted for loading reductions to the equivalent of 0.5 kg/ha/yr (0.45 lb/ac/yr) export. Based on the acres of bogs the allocation is 9 and 10 kg/year for the A.D. Makepeace and Federal Furnace bogs, respectively

This level of phosphorus export can be achieved by combining water conservation to limit final discharge rates to 3.5 acre-feet per acre of bog (see below) with average total phosphorus concentrations of 0.05 mg/l (the acceptable concentration to inputs to lakes from USEPA, 1986 "Gold Book"). A recent review of phosphorus export versus phosphorus fertilizer suggests that exports can be dramatically reduced with reductions in phosphorus fertilizer application while maintaining crop yields (DeMoranville et al., 2009). In fact, some bogs can show zero export or even negative phosphorus export (uptake of phosphorus) while maintaining good yields by reducing phosphorus fertilizers (DeMoranville and Howes, 2005; DeMoranville et al., 2008). The key to maintaining yields is to supply the correct amount of nitrogen (generally the limiting nutrient for cranberries) while reducing the phosphorus in the fertilizer. This is accomplished by switching from low ratios of N:P:K to higher N fertilizers with proportionately less P. Commercial cranberry growers have used high ratios in the past (bags labeled 10-12-24, 10-20-20 or even 5-15-30) where the ratio of N to P_2O_5 on the bag is 1:1.2 or 1:2 or 1:3 (Howes and Teal, 1995) and this supplies too much phosphorus for plant growth needs. The recent UMass study recommends products with bag ratios of 18-8-12 or 15-15-15 (DeMoranville and Howes, 2005). For example, in order to deliver sufficient nitrogen to the crop while reducing phosphorus applications to a target of 10 lb/ac/year phosphorus fertilizer with a N:P ratio of 2:1 such as 18-8-12, or even lower P fertilizer would be required. Caution however needs to be exercised so that the amount of nitrogen applied does not exceed the crop needs. Doing so will ensure that excess nitrogen does not migrate from the site and contribute to nitrogen enrichment in down gradient embayment systems.

Manipulation of water usage is also critical for reducing the phosphorus loading to receiving waters. In order to meet the TMDL loading targets the yearly discharge of water of 3.5 feet of water per acre bog at a concentration of 0.05 mg/l TP or less would meet the TMDL requirements. Other combinations of discharge and concentrations are also acceptable if they are demonstrated to meet the TMDL load. Excess water use results in excess water discharge with resulting excess leaching of phosphorus from the bogs. Irrigation water should be recycled from water stored in the bog ditches or in storage ponds to the greatest extent possible. During harvest the harvest water should also be recycled from section to section rather than flooding the entire bog complex at one time. After harvest the water should be retained in the bog complex for at least 1 to 3 days to allow particulate matter to settle out, but always less than 10 days to avoid excess release from sediments. Water should be discharged slow enough to minimize turbulence and erosion within the bogs. When possible, the discharge should be directed away from sensitive surface waters, particularly in the growing season. Winter floods should be withdrawn beneath newly formed ice within 10 days to avoid anoxic injury to plants and anoxic release of phosphorus from the flooded soils. Additional treatment and alternatives to winter flood discharges should be considered to meet the TMDL loading requirements. Monitoring of discharges is essential to ensure the TMDL load is being met.

If reductions in phosphorus fertilizer application and water use fail to achieve discharge concentrations of 0.05 mg/l and loadings at or below 0.5 kg/ha/year, then additional BMPs may be required by MassDEP. These may include the use of tailwater recovery for reuse within the bogs, pumping discharge water to other areas away from the lake, or the use of holding (detention) ponds that can be treated before discharge to public surface waters (DeMoranville and Howes, 2005). If the detention pond discharge still exceeds 0.05 mg/l, then discharges may require treatment with alum and sodium aluminate or other aluminum or iron compounds to bind and remove phosphorus prior to discharge to public waters (Leytem and Bjorneberg, 2005). If sufficient area is not available to build detention ponds, a system of infiltration ditches lined with iron rich sand could be designed to treat the water before discharge to the pond. A similar 'iron curtain' has been used successfully to filter out phosphorus entering Ashumet Pond on Cape Cod; see: (http://toxics.usgs.gov/topics/rem_act/phosphorus_plume.html). Because some of these techniques have not been used with cranberry bogs, additional testing may be required.

It should be noted that both A.D. Makepeace and Federal Furnace cranberry companies have implemented some of these BMPs as of 2008. They have stated that they are using low phosphorus fertilizers at low application rates. In addition, Federal Furnace has been pumping water to areas away from the lake and thus reduce summer and fall discharges to the lake.

Because of the large build up of excess phosphorus in cranberry bog soils, soil tests often show very high TP concentration that do not relate to crop yields and plant tissue tests may be more appropriate for determining fertilizer needs (DeMoranville and Davenport, 1997). Because of the high phosphorus in the soils, there may be a delayed response to the reductions in phosphorus fertilizer inputs and water discharges from the bogs. It is recommended that after fertilizers have been reduced to 10 lbs/acre/year and the water reuse BMPs have been initiated and the TMDL requirements met, that a period of at least 5 years elapse before any further and potentially more expensive in-lake BMPs be initiated. Recent studies on commercial cranberry bogs have shown that reduced phosphorus fertilizer application led to increased yield of cranberries while reducing TP concentrations in discharge water (DeMoranville et al., 2009). Additional studies on plots have shown there was no justification for using high phosphorus fertilizers. Even the zero phosphorus plots showed no signs of deficiency after 6 years of study (Roper, 2009), but tissue tests are recommended to monitor plant health.

A Memorandum of Agreement (MOA) was signed on May 7, 2009 between the Massachusetts Department of Agricultural Resources, Massachusetts Department of Environmental Protection, the Cape Cod Cranberry Growers Association (CCCGA) and the University of Massachusetts Cranberry Station to implement new practices on the commercial cranberry bogs that discharge to the lake. The MOA text is available at http://www.mass.gov/dep/water/resources/tmdls.htm#buzzards

In 2008 the growers started using lower phosphorus fertilizers (lower than the 20 lb/ac rate previously recommended by UMass Cranberry Station). As part of the MOA the growers will be pumping all discharge water away from the pond with the exception of winter discharges. The winter discharges will be studied further to evaluate if additional controls are needed. Monitoring of the practices and monitoring of discharges to the pond are the responsibility of the UMass Cranberry Station. Funding was provided by MassDEP under a 319 grant of $49,576 to the Cape Cod Cranberry Growers Association working with the UMass Cranberry Station to implement this effort. Progress will be monitored for three years at which time MassDEP will evaluate what additional controls, if any, will be required to meet the TMDL.

Control of Other Sources

The control of septic system input to reduce loadings by 50 percent may be difficult. Generally, the soils in the White Island Pond system are already efficiently binding phosphorus as noted above. Older homes with old style cesspools may be contributing disproportionate amounts of phosphorus to the groundwater near the lake. All home septic systems are required to be inspected upon sale for Title 5 compliance and to upgrade the system as required.

Another possibility for reducing the loading from septic systems is to sewer the area and thus divert phosphorus loadings to a wastewater treatment plant where it can be removed prior to discharge at a remote location. Opportunities for sewering the area may occur as developers are required to reduce nutrient loadings in the area to compensate for additional loadings of new home construction in an effort to meet other TMDLs, such as nitrogen TMDLs related to salt water estuaries. The densely populated area along the western shore of the West Basin is a potential area for sewering and this would completely eliminate the septic system phosphorus loads to the lake from those homes. A combination of these efforts is predicted to meet the 28 kg/year allocation target.

The shoreline areas of White Island Pond in both the towns of Wareham and Plymouth are included as urbanized areas and should be included in the NPDES Phase II stormwater permit for to the towns. The NPDES permits require six minimum control measures including public education, public participation, illicit discharge detection and elimination, construction site runoff control, post construction runoff control, and good housekeeping at municipal operations. The latter 'good housekeeping' control should include BMPs and a schedule of activities to control pollution. The permits also require the development of a stormwater management plan that must include mapping outfalls to receiving waters. Details on the Phase II permits are available at: http://www.mass.gov/dep/brp/stormwtr/stormhom.htm .

Responsibilities for Implementation

MassDEP has broad authority to enforce existing water laws and regulations that relate to water use and water quality. The Commonwealth has provided a strong framework to encourage watershed management through the recent modifications to on-site septic system regulations under Title 5 and by legislation requiring low phosphorus detergents.

The MassDEP will be responsible for obtaining public comment and support for this TMDL. The proposed tasks and responsibilities for implementing the TMDL are shown in Table 6. The local citizens within the watershed will be encouraged to locate and describe additional sources of erosion and phosphorus within the watershed following methods described in the MassDEP guidebook "Surveying a Lake Watershed and Preparing and Action Plan" (DEP, 2001) available at: http://www.mass.gov/dep/public/lwsguide.pdf.

Responsibility for remediation of each identified source will vary depending on land ownership, local jurisdiction and expertise. For example, the lake association or the Town may organize a septic tank pumping and inspection program for all lakeside homeowners. Usually a discount for the pumping fee can be arranged if a large number of homeowners apply together. Cranberry growers can apply for money to implement BMPs as part of the NRCS programs in soil conservation. Town public works departments will generally be responsible for reduction of erosion from town roadways and urban runoff. The Conservation Commission and Building Inspector will generally be responsible for ensuring the BMPs are being followed to minimize erosion from construction within the town. BMPs for general nonpoint source pollution control are described in a manual by Boutiette and Duerring (1994), BMPs for erosion and sediment control are presented in MassDEP (1997). See the web site http://www.mass.gov/dep/water/resources/watershe.htm for many of these publications. There is an Unpaved Roads BMP Manual and general information on nonpoint source BMPs at http://www.mass.gov/dep/water/resources/nonpoint.htm. A description of potential funding sources for these efforts is provided in the Program Background section, above.

A proactive approach to protecting the lake may include limiting development, particularly in areas near the lake, changes in zoning laws and lot sizes, requirements that new developments and new roadways include BMPs for runoff management and more stringent regulation of septic systems. As new housing development expands within the watershed, additional measures are needed to minimize the associated additional inputs of phosphorus. Although over fertilization of lawns was not apparent based on visual examination, homeowners should be encouraged to support a phosphorus lawn fertilizer ban as a town bylaw similar to that passed in Webster Massachusetts to reduce future phosphorus loadings from that source (http://www.articlearchives.com/government-public-administration/elections-politics/513475-1.html). Additional town bylaws to address fertilizer use and discharges to waters within the town may be required. Examples of town bylaws for zoning and construction, as well as descriptions of BMPs are presented in the Nonpoint Source Management Manual by Boutiette and Duerring (1994) that was distributed to all municipalities in Massachusetts. Other voluntary measures may include encouraging the establishment of a vegetative buffer around the lake. Such BMPs provide enhancements that residents should find attractive and, therefore, should facilitate voluntary implementation.

MassDEP is recommending that the lake be monitored on a regular basis, and if the lake does not meet the water quality standards additional implementation measures may be required. For example, if phosphorus concentrations remain high after watershed controls are in place, then in-lake control of sediment phosphorus recycling or control of other sources may be considered.

As phosphorus concentrations in the lake are reduced and transparency of the lake increases an increase in the growth of rooted aquatic plants is expected as increased light reaches the sediments. Reducing the supply of nutrients will not in itself result in achievement of all the goals of the TMDL and continued macrophyte monitoring and appropriate management is an essential part of the implementation plan.

Table 6. TMDL Tasks and Responsibilities

Tasks	**Responsible Group**
TMDL development	MassDEP
Develop Cranberry Farm Plan, fertilizer type and rates and water management BMPs that meet TMDL requirements	Cranberry Growers in concert with NRCS, Soil Conservation Service, the Cape Cod Cranberry Growers Association and the UMass Cranberry Station.
Develop implementation approach to support the TMDL. Monitor the progress of the operation of the bogs under the MOA agreement. Consider lowering the lake level slightly to reduce seepage into bogs.	MassDEP
Provide documentation of discharge monitoring and reasonable assurance that TMDL is being met under the MOA	UMass Cranberry Station in cooperation with CCCGA and Cranberry Growers
Approve of yearly monitoring data.	MassDEP
Ensure that noncompliant septic systems are upgraded to meet Title 5 requirements and consider inspections for compliance	Board of Health and homeowners
Use lesser amounts of lawn fertilizers, particularly low or no phosphorus fertilizers available at local farm stores	Homeowners and lake association
Monitor chlorophyll, Secchi disk	MassDEP and lake association

Tasks	Responsible Group
transparency and total phosphorus in lake	
Organize and implement TMDL education, outreach programs, write grant and loan funding proposals	Local Lake Association and Town working with consultants
After discharges are controlled implement sediment phosphorus controls such as recommended in the GEIR (Mattson, et al., 2004)	Cranberry growers, lake associations and towns with consultation with MassDEP
Implement Phase II BMPs, twice yearly road sweeping, catchbasin inspection and maintenance, install infiltration or other BMPs	Town of Plymouth and Wareham in urbanized areas
Pass town bylaws to control development, erosion from all lands, driveways and limit fertilizers on non-agricultural land.	Town Selectmen, town meeting

Reasonable Assurances

Reasonable assurances that the TMDL will be implemented include both enforcement of current laws and regulations, availability of financial incentives, and the various local, state and federal program for pollution control. Active cooperation of the cranberry growers and the Cape Cod Cranberry Growers Association, homeowners, the towns of Plymouth and Wareham, USEPA, NRCS and the UMass Cranberry Station is required for this TMDL to be effective in returning the lake to an unimpaired status.

MassDEP is responsible for the implementation and enforcement of the laws related to discharges of pollution, including any nonpoint sources, under authority of Massachusetts General Laws M.G.L. c.21§§ 26-53 and the Massachusetts Surface Water Quality Standards at 314 CMR 4.00 and the Groundwater Discharge Permit Program at 314 CMR 5.00. MassDEP is also responsible for the implementation and enforcement of M.G.L. c.91 and the Waterways Regulations at 310 CMR 9.00. Enforcement of regulations may include USEPA enforcement of the permit conditions Stormwater Phase II permits under NPDES. The Commonwealth of Massachusetts also oversees the implementation of the Title 5 regulations of onsite septic systems by the local Board of Health.

Financial incentives include Federal monies available under the 319(h) NPS program and the 604(b) and 104(b) programs, which are provided as part of the Performance Partnership Agreement between MassDEP and the USEPA. Additional financial incentives include state income tax credits for Title 5 upgrades, low interest loans for Title 5 septic system upgrades, Clean Water Act State Revolving Fund loans, and cost sharing for agricultural BMPs under the Federal NRCS program.

The recently signed MOA also provides reasonable assurance of meeting the TMDL in a timely manner. If the MOA fails to meet the TMDL then additional steps will be taken.

Water Quality Standards Attainment Statement

The proposed TMDL, if fully implemented, will result in the attainment of all applicable water quality standards, including designated uses and numeric criteria for each pollutant named in the Water Quality Standards Violations noted above.

Monitoring

Continued monitoring of the lake by the local lake association should document changes in transparency and frequency of blue-green algal blooms. In addition, a 319 grant was awarded to assist in implementation of the MOA and monitoring of BMPs in the bogs, with monitoring being conducted by the Umass Cranberry Station. MassDEP will provide review of discharges to document phosphorus concentrations and the lake response. The toxic Bluegreen algae (cyanobacteria) numbers have been monitored in the past by MassDEP and the Massachusetts Department of Public Health will continue as needed. Additional lake surveys by MassDEP in future years, as resources allow, should include Secchi disk transparency, nutrient analyses, temperature and oxygen profiles and aquatic vegetation maps of distribution and density. At that time the strategy for reducing plant cover and reducing total phosphorus concentrations can be re-evaluated and the TMDL modified if necessary. Additional monitoring of total phosphorus concentrations and transparency by local volunteer groups is encouraged when possible.

PROVISIONS FOR REVISING THE TMDL

The MassDEP reserves the right to modify this TMDL as needed to account for new information or data made available during the implementation of the TMDL. Modification of the TMDL will only be made following an opportunity for public participation and be subject to the review and approval of the EPA. New information, which will be generated during TMDL implementation includes monitoring data, new or revised State or Federal regulations adopted pursuant to Section 303(d) of the Clean Water Act, and the publication by EPA of national or regional guidance relevant to the implementation of the TMDL program. The MassDEP will propose modifications to the TMDL analysis only in the event that a review of the new information or data indicates that such a modification is warranted and is consistent with the anti-degradation provisions in the Massachusetts Water Quality Standards. The subject waterbodies of this TMDL analysis will continue to be included on the State of Massachusetts Integrated List of Waters, in the appropriate category.

Public Participation

MassDEP has met with the Cape Cod Cranberry Growers Association and the UMass Cranberry Station to develop an agreed upon scope for research that resulted in the DeMoranville and Howes (2005) report on phosphorus use and discharge in commercial cranberry bogs. MassDEP has met and cooperated with the representatives of the commercial cranberry bogs. MassDEP has also met and cooperated with Mr. Jim Sullivan of the White Island Pond Conservation Alliance on sampling the pond in 2007 and monitoring of toxic cyanobacterial blooms in the lake. Additional meetings with the above named groups is ongoing.

Public Comment and Reply

The draft TMDL was presented and public comments were received at the public meeting held on May 7, 2009 in the Plymouth town hall. Additional public comments were received in writing within a 15 day comment period following the public meeting. The public comments and the Departmental responses are included as Appendix IV to this report. The final report will be sent to U.S. EPA Region 1 in Boston for final USEPA approval.

References

Boutiette, L.N.Jr., and C.L. Duerring. 1994. Massachusetts Nonpoint Source Management Manual. "The MegaManual" A Guidance Document for Municipal Officials. Mass. Dept. Environmental Protection., Boston, MA.

Carlson, R.E. 1977. A Trophic State Index for Lakes. Limnol. Oceanogr. 22(2):361-369.

Chapra, S. 1975. Comment on "An Empirical method of estimating the retention of phosphorus in lakes." By W.B. Kirchner and P.J. Dillon. Water Resour. Res. 11:1033-1034.

Cooke, G.D., E.B. Welsh, S.A. Peterson, S.A. Nichols. 2005. Restoration and Management of Lakes and Reservoirs. 3rd Ed. Lewis Publishers. Boca Raton.

DeMoranville, C.J. and J.R. Davenport. 1997. Phosphorus forms, rates and timing in Massachusetts Cranberry Production. Acta, Hort. 446:381-388.

DeMoranville C. and B. Howes. 2005. Phosphorus dynamics in cranberry production systems: Developing information required for the TMDL process for 303d water bodies receiving cranberry bog discharge. UMass Cranberry Station, E. Wareham, MA and UMass Dartmouth, New Bedford, MA, prepared for MassDEP and USEPA. 137pp.

DeMoranville, C.J. 2006. Cranberry Best Management Practice Adoption and Conservation Farm Planning. HortTechnology 16(3):393-397.

DeMoranville, C., B. Howes, D. Schlezinger and D.White. 2009. Cranberry Phosphorus Management: How changes in practice can reduce output in drainage water. Acta Hort 810: 633-640.

Dillon, P.J. and F.H. Rigler. 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Bd. Can. 31:1771-1778.

DWM, 2000. Quality Assurance Project Plan for Baseline Lakes Survey 2000. CN 42.0 Division of Watershed Management, Department of Environmental Protection, Worcester, MA

DWM, 2007. CN 262.1. Massachusetts Year 2006 Integrated List of Waters. Department of Environmental Protection, Division of Watershed Management, Worcester, MA. http://www.mass.gov/dep/water/resources/2006il4.pdf

DWM, 2007. Sampling Plan for Baseline Lakes Survey White Island Pond. CN 294.0 Division of Watershed Management, Department of Environmental Protection, Worcester, MA

DWM, 2008. CN 281.1. Massachusetts Year 2008 Integrated List of Waters. Department of Environmental Protection, Division of Watershed Management, Worcester, MA. http://www.mass.gov/dep/water/resources/08list2.pdf

Garrison, P.J. and S.A. Fitzgerald. 2005. The role of shoreland development and commercial cranberry farming in a lake in Wisconsin, USA. J. Paleolimnology 33(2): 169-188.

Gil, L.W. 1989. Buzzards Bay Cranberry Bog Input Study. MassDEP, Div. Water Pollution Control, Westborough, MA

Griffith, G.E., J.M. Omernik, S.M. Pierson, and C.W. Kiilsgaard. 1994. Massachusetts Ecological Regions Project. USEPA Corvallis. Massachusetts DEP, DWM Publication No. 17587-74-70-6/94-D.E.P.

Hansen. B.P. and W.W. Lapham. 1992 Geohydrology and simulated ground-water flow, Plymouth-Carver aquifer, southeastern Massachusetts. USGS WRI Report 90-4204. USGS, Marlborough, MA.

Heufelder, G., and K. Mroczka. 2006. Evaluation of Methods to Control phosphorus in areas served by onsite septic systems. Environment Cape Cod, Special issue, Barnstable County Health & Env. Massachusetts. 37pp+app.

Holdren, C.W., W. Jones and J. Taggart. 2001. Managing Lakes and Reservoirs. N. Am. Lake Manage. Soc. And Terrene Inst. In coop. With Off. Water Assess. Watershed Prot. Div. U.S. Environ. Prot. Agency, Madison, WI.

Horne, A.J. and C.R. Goldman. 1994. Limnology. 2nd Ed. McGraw-Hill Inc. New York.

Howes, B.L. and J.M. Teal. 1995. Nutrient Balance of a Massachusetts Cranberry Bog and Relationships to Coastal Eutrophication. Environmental Sci. & Tech. 29(4):960-974.

Jones, J.R. and R.W. Bachmann. 1976. Prediction of phosphorus and chlorophyll levels in lakes. JWPCF 48:2176-2184.

Kirchner, W.B. and P.J. Dillon. 1975. An empirical method of estimating the retention of phosphorus in lakes. Water Resour. Res. 11:182-183.

Kittredge, D.B., Jr. and Parker, M. 1995. Massachusetts Forestry Best Management Practices Manual. Mass. Dept. Environmental Protection. Office of Watershed Management and U.S.E.P.A. 56pp.

Larsen, D.P. and H.T. Mercier. 1976. Phosphorus retention capacity of lakes. J.Fish. Res. Bd. Canada. 33:1742-1750.

Leytem, A.B. and D.L. Bjorneberg. 2005. Removing soluble phosphorus in irrigation return flows with alum additions. J. Soil Water Cons. 60(4):200-208.

Likens, G.E. 1972. Nutrients and Eutrophication.: The Limiting-Nutrient Controversy. Limnology and
Oceanography, Special Symposia Volume I. 328pp.

Lycott, 1994. Final Report, Phase II Implementation Project Quaboag & Quacumquasit Ponds Town of Brookfield, MA. Lycott Environmental Research. Southbridge, MA.

Mattson, M.D., P.J. Godfrey, R.A. Barletta and A. Aiello. 2004. Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report. Edited by Kenneth J Wagner. Department of Environmental Protection and Department of Conservation and Recreation, Executive Office of Environmental Affairs, Commonwealth of Massachusetts.

Mattson, M.D. and R.A. Isaac. 1999. Calibration of Phosphorus Export coefficients for Total Maximum Daily Loads of Massachusetts Lakes. Lake and Reservoir Man. 15(3):209-219.

Mattson, M.D. 2008. Draft Guidelines for Total Maximum Daily Loads of Phosphorus from Commercial Cranberry Bog Discharges in Massachusetts. Division of Watershed Management, MassDEP TM-T-1, CN 307.0

MassDEP, 1997. Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas. A Guide for Planners, Designers and Municipal Officials. Massachusetts Dept. Environmental Protection., EOEA, State Commission for Conservation of Soil, Water and Related Resources, Natural Resources Conservation Service USDA.

MassDEP, DWM. 1998. Commonwealth of Massachusetts, Summary of Water Quality, 1998. Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP, 2001. Massachusetts Volunteers Guide for Surveying a Lake Watershed and Preparing an Action Plan. Department of Environmental Protection, Boston MA.

MassDEP. 2007. Massachusetts Surface Water Quality Standards. Mass. Dept. Environmental Protection, Division of Water Pollution Control, Technical Services Branch. Westborough, MA http://www.mass.gov/dep/service/regulations/314cmr04.pdf

Masterson, J.P., Carlson, C.S., and Walter, D.A., 2009, Hydrogeology and simulation of groundwater flow in the Plymouth-Carver-Kingston-Duxbury aquifer system, southeastern Massachusetts: U.S. Geological Survey Scientific Investigations Report 2009–5063, 110 p.

Parent, L.E. and S. Marchand. 2006. Response to Phosphorus of Cranberry on High Phosphorus Testing Acid Sandy Soils. Soil Sci. Soc. Am. J. 70:1914-1921.

Reckhow, K.H. 1979. Uncertainty Analysis Applied to Vollenweider's Phosphorus Loading Criteria. J. Water Poll. Control Fed. 51(8):2123-2128.

Reckhow, K.H., M.N. Beaulac, J.T. Simpson. 1980. Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. U.S.E.P.A. Washington DC. EPA 440/5-80-011.

Rohm, C.M., J.M. Omernik, and C.W. Kiilsgaard. 1995. Regional Patterns of Total Phosphorus in Lakes of the Northeastern United States. Lake and Reservoir Man. 11(1): 1-14.

Roper, T.R. 2009. Mineral Nutrition of Cranberry: What we know and what we thought we knew. Acta Hort. 810:613-625.

Schindler, D.W. and E.J. Fee. 1974. Experimental Lakes Area: Whole-Lake Experiments in Eutrophication. J. Fish. Res. Bd. Can. 31:937-953.

SCS, 1978. Flood Hazard Analyses Upper Quaboag River (including East Brookfield River, Seven Mile River, Turkey Hill Brook, Cranberry River, Great Brook) Worcester County, Massachusetts. USDA Soil Conservation Service, Amherst, MA.

Smith, C.S. and M.S. Adams. 1986. Phosphorus transfer from sediments by Myriophyllum spicatum. Limnol. Oceanogr. 31(6):1312-1321.

Snow, P.D., and F.A. DiGiano. 1976. Mathematical Modeling of Phosphorus Exchange Between Sediments and Overlying Water in Shallow Eutrophic Lakes. Sept. 1976 Report No. Env. E. 54-76-3, Envir. Eng. Dept. Civil Eng. UMass, Amherst, MA.

Sullivan, Jim. 2008. President, White Island Pond Conservation Alliance Inc. Personal Communication Emails.

USEPA. 1986. Quality Criteria for Water 1986. United States Environmental Protection Agency, Washington, DC. EPA 440/5-86-001.

USEPA. 2000 Ambient Water Quality Recommendations. Rivers and Streams in Nutrient Region XIV. United States Environmental Protection Agency, Washington, DC. EPA 822-B-00-022. http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_14.pdf

USEPA. 2001 Ambient Water Quality Recommendations. Lakes and Reservoirs in Nutrient Region XIV. United States Environmental Protection Agency, Washington, DC. EPA 822-B-00-022. http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes/lakes_14.pdf

Valiela, I. And J.E. Costa. 1988. Eutrophication of Buttermilk Bay, a Cape Cod Coastal Embayment: Concentrations of Nutrients and Watershed Nutrient Budgets. Environ. Man. 12(4):539-553.

Vallentyne, J.R. 1974. The Algal Bowl – Lakes and Man. Ottawa, Misc. Spec. Publ. 22. Dept. of the Environ. 185pp.

Vollenweider, R.A. 1975. Input-Output Models with Special Reference to the Phosphorus Loading Concept in Limnology. Sch. Zeit. Hydrologic 37:53-84.

Vollenweider, R.A. 1976. Advances in Defining Critical Loading Leveles for Phosphorus in Lake Eutrophication. Mem. Ist. Ital. Idrobiol., 33:53-83.

Wagner, K. 2000. ENSR. Email personal communication.

Wagner, K. 2004. The Practical Guide to Lake Management in Massachusetts. Prepared for MassDEP and DCR by ENSR International, Westford, MA.

Ward, A.D., S.W.Trimble, and M.G. Wolman. Environmental hydrology. 2nd Ed. CRC Press. 475pp.

Whittaker, G.E. 1980. White Island Pond Water Quality Study August 1976-May 1978. Mass. Div. Of Water Pollution Control, Westborough, MA. Pub. No. 1200-4-92-100-7-80-C.R.

Weiskel, P.K. and B.L. Howes. 1992. Differential transport of sewage-derived nitrogen and phosphorus through a coastal watershed. Environ. Sci. Tech. 26(2):352-360.

Wetzel, R.G. 2001. Limnology. Lake and River Ecosystems. 3nd Ed. Saunders College Publishing. New York.

Appendix I Lake Data

The East and West Basins of White Island Pond were monitored during July through September, 2000 as part of a baseline survey. Both basins were also sampled in 2007 on a monthly basis from June through October. The lake surveys were conducted to provide information on the current chemical, physical and biological conditions of the lake system (i.e. in-lake and in the surrounding watershed). In addition, the surveys were conducted during the summer and early fall to coincide with maximum growth of aquatic vegetation, highest recreational use, and highest lake productivity.

The 2000 baseline survey consisted of monthly sampling of water at a deep hole station in each basin. *In situ* measurements using the Hydrolab® (measures dissolved oxygen, water temperature, pH, conductivity, and depth and calculates total dissolved solids and % oxygen saturation) were recorded. At the deep hole stations measurements were recorded at various depths creating profiles. In-lake samples were also collected for alkalinity, total phosphorus, apparent color, and chlorophyll *a* (an integrated sample). Samples of the cranberry bog water were also collected and analyzed for TP and Soluble Reactive Phosphorus (SRP). Procedures used for water sampling and sample handling are described in the *Grab Collection Techniques for DWM Water Quality Sampling Standard Operating Procedure* and the *Hydrolab® Series 3 Multiprobe Standard Operating Procedure* (MassDEP 1999b and MassDEP 1999c). The Wall Experiment Station (WES), the Department's analytical laboratory, supplied all sample bottles and field preservatives, which were prepared according to the WES *Laboratory Quality Assurance Plan and Standard Operating Procedures* (MassDEP 1995). Samples were preserved in the field as necessary, transported on ice to the MassDEP Wall Experiment Station (WES), and analyzed according to the WES Standard Operating Procedure (SOP). Both quality control samples (field blanks, trip blanks, and split samples) and raw water quality samples were transported on ice to WES on each sampling date; they were subsequently analyzed according to the WES SOP. Apparent color and chlorophyll *a* were measured according to standard procedures at the MassDEP DWM office in Worcester (MassDEP 1999d and MassDEP 1999e). An aquatic macrophyte survey was conducted in August. The aquatic plant cover (native and non-native) and species distribution was mapped and recorded. Details on procedures used can be found in the *Baseline Lake Survey Quality Assurance Project Plan* (DEP DWM 1999a).

The same deep hole stations were sampled again in 2007 for the multi-probe parameters, Secchi disc transparency, chlorophyll a, color and TP. Samples were taken of the discharge flows from the cranberry bogs. Sampling details are available in the Quality Assurance Project Plan (DWM, 2007). Sampling was conducted in accordance with the procedures noted above.

Data from the surveys is presented in the tables below.

Macrophyte surveys are typically conducted during the late summer at the peak of macrophyte growth (generally in July/August/September). The macrophyte data are used in several ways:

1. to determine if the macrophyte growth causes nuisance conditions such that the lake would be listed or delisted on the state's 303d list for violations of water quality standards;
2. to determine if the lake meets designated uses in the 305b assessments;
3. to monitor changes in density of plant growth following implementation of a TMDL;
4. to document invasive species distributions in the state, and
5. to suggest macrophyte management options for the lake.

The data are used to validate Total Maximum Daily Load (TMDL) phosphorus loading models and to document the present trophic conditions as well as assessing the status of lake's designated uses. The total phosphorus data are used to evaluate accuracy of land use loading estimates (Mattson and Isaac 1999) of total phosphorus to lakes by comparing predictions of lake concentrations based on modeling to actual measured lake concentrations. These may be used as a basis for estimation of internal loading or other unmeasured phosphorus sources. Concurrently a lake database will be developed for both 303d development and for 305b evaluation based on lakes that are on the current 303d list. The data contained in this database along with the other data collected are used in TMDL development or to monitor lakes for changes in water quality and nuisance plant growth after TMDL implementation.

Table 7. Hydrolab data Baseline Lake Monitoring, 2000.

White Island Pond (Palis: 95166)
Unique_ID: 762 Station: A
Description: deep hole in southern lobe of East Basin, Plymouth

Date	OWMID	Time	Depth	Temp	pH	Cond@ 25C	TDS	DO	SAT
		(24hr)	(m)	(C)	(SU)	(uS/cm)	(mg/l)	(mg/l)	(%)
7/19/2000									
	LB-0656	10:02	0.5	24.4	6.4	49.4	31.6	7.8	92
		10:11	1.4	24.3	6.3	49.3	31.6	7.6	89
		10:17	2.5	24.2	6.3	49.1	31.4	7.2	85
		10:23	3.4	24.2	6.2	49.1	31.4	7.2	84
		10:30	3.9	24.2	6.2	49.2	31.5	7.1	83
8/16/2000									
	LB-0747	14:13	0.5	22.7	6.8u	46.9	30.0	9.0	103
		14:17	1.5	22.7	6.7	46.9	30.0	8.9	101
		14:22	2.5	22.7	6.7	46.9	30.0	8.8	101
		14:26	3.7	22.7	6.6	47.1	30.1	8.5u	96u
9/20/2000									
	LB-0836	12:57	0.5	21.2	7.3ci	46.4	29.7	9.4	105
		13:04	1.5	21.2	7.1ci	46.4	29.7	9.3	103
		13:10	2.5	21.1	6.6i	46.4	29.7	9.0	100
		13:16	3.5	21.0	6.0i	47.0	30.1	**u	**u
		13:23	4.0	20.7	5.8i	48.1	30.8	5.2u	57u

White Island Pond (Palis: 95173)
Unique_ID: 754   Station: A
Description: deep hole in northern lobe of West Basin, Plymouth

Date	OWMID	Time	Depth	Temp	pH	Cond@ 25C	TDS	DO	SAT
		(24hr)	(m)	(C)	(SU)	(uS/cm)	(mg/l)	(mg/l)	(%)
7/19/2000									
	LB-0657	11:40	0.5	24.8	6.0	48.5	31.0	7.7	91
		11:46	1.5	24.8	6.1	48.6	31.1	7.7	91
		11:52	2.5	24.9	6.0	48.6	31.1	7.6	90
		11:59	3.5	24.9	6.1	48.7	31.1	7.6	90
8/16/2000									
	LB-0751	12:50	0.5	23.2	6.0	46.8	29.9	7.9	91
		13:00	1.5	23.2	6.0	46.8	29.9	7.9	90
		13:03	2.5	23.2	5.9	46.8	29.9	7.8	90
		13:08	3.5	23.2	5.9	46.8	29.9	7.8	90
	LB-0975	13:16 m	3.5m	23.2 m	6.0 m	46.8m	29.9 m	7.8m	90m
		13:20 m	2.5m	23.2 m	6.0 m	46.8m	29.9 m	7.9m	91m
		13:24 m	1.5m	23.2 m	6.0 m	46.7m	29.9 m	7.9m	91m
		13:29 m	0.5m	23.2 m	6.0 m	46.8m	29.9 m	7.8m	90m
9/20/2000									
	LB-1167	15:00	0.5	22.1	7.0u	46.2	29.6	9.4	106
		15:06	1.5	22.0	7.0	46.4	29.7	9.3	105
		15:12	2.5	21.9	6.6	46.3	29.6	9.2	104
		15:19	3.5	21.5	5.7	46.9	30.0	6.9u	77u

Table 8. Water Quality Data. Baseline Lake Monitoring, 2000 .

East White Island Pond (Palis: 95166)
Unique_ID: W0762   Station: A
Description: deep hole in southern lobe of East Basin, Plymouth

Date	Secchi	Secchi Time	Station Depth	OWMID	Sample Depth	Relative Depth	Alkalinity	TP	Apparent Color	Chl a
	(m)	24hr	(m)		(m)		(mg/l)	(mg/l)	PCU	(mg/m3)
7/19/2000	1.2	10:30	4.5							
				LB-0645	0.5	Surface	3	0.12	--	--
				LB-0646	0.5	Surface	4	0.098	--	--
				LB-0648	0 - 3.6	Integrated	--	--	--	** m
				LB-0649	**m	Near Bottom	4m	0.099m	--	--
8/16/2000	1.1	14:07	4.3							
				LB-0738	0.5	Surface	4	0.085	--	--
				LB-0739	0.5	Surface	4	0.084	--	--
				LB-0740	0.5	Surface	4	0.093	--	--
				LB-0741	3.7	Near Bottom	4	0.089	--	--
				LB-0743	0 - 3.7	Integrated	--	--	--	35.4
9/20/2000	1.1	12:35	4.5							
				LB-0832	**m	Surface	2	0.077	23	--
				LB-0833	**m	Surface	2	0.077	23	--
				LB-0834	**m	Near Bottom	2m	0.080m	17m	--
				LB-0835	0 - 4.0	Integrated	--	--	--	35.5 h

West White Island Pond (Palis: 95173)

Unique_ID: W0754   Station: A
Description: deep hole in northern lobe of West Basin, Plymouth

Date	Secchi	Secchi Time	Station Depth	OWMID	Sample Depth	Relative Depth	Alkalinity	TP	Apparent Color	Chl a
	(m)	24hr	(m)		(m)		(mg/l)	(mg/l)	PCU	(mg/m3)
7/19/2000	2.0	11:45	4.0							
				LB-0652	0.5	Surface	2	0.076	--	--
				LB-0653	3.5	Near Bottom	<2	0.048	--	--
				LB-0654	0 - 3.5	Integrated	--	--	--	5.7
8/16/2000	2.2	12:30	4.0							
				LB-0748	0.5	Surface	4	0.038	--	--
				LB-0749	3.5	Near Bottom	3	0.037	--	--
				LB-0750	0 - 3.5	Integrated	--	--	--	11.8
9/20/2000	1.3	14:30	4.0							
				LB-0849	0.5	Surface	<2	0.038	<15	--
				LB-1165	3.5	Near Bottom	2	0.037	<15	--
				LB-1166	0 - 3.5	Integrated	--	--	--	13.1 h

Table 9. Water Quality Data. Baseline Lake Monitoring, 2007.

East White Island Pond (Palis: 95166)
Unique_ID: W0762   Station: A
Description: deep hole in East Basin, Plymouth   **DATA from 2007 fieldsheet/WES Lab report**

Date	Secchi	Secchi Time	Station Depth	OWMID	Sample Depth	Relative Depth	TP	Chl a
	(m)	24hr	(m)		(m)		(mg/l)	(mg/m3)
6/26/2007	1.3	14:15	4.9	LB-3901	0.2	Surface	0.052	
				LB-3902	0.2	Surface	0.053	
				LB-3903	3.9	Near Bottom	0.076	
				LB-3904	0-3.9	Integrated	-	20.4
				LB-3905	0-3.9	Integrated	-	20.2
7/25/2007	1.0	11:00	4.6					
				LB-3942	0.2	Surface	0.072	
				LB-3943	0.2	Surface	0.068	
				LB-3944	3.6	Near Bottom	0.067	
				LB-3946	0-3.6	Integrated	-	47.8
				LB-3947	0-3.6	Integrated	-	45.0
8/21/2007	0.8	11:40	4.7					
				LB-3982	0.2	Surface	0.094	
				LB-3983	0.2	Surface	0.095	
				LB-3984	3.7	Near Bottom	0.090	
				LB-3986	0-3.7	Integrated	-	**
				LB-3987	0-3.7	Integrated	-	**
9/24/2007	0.7	11:55	4.7					
				LB-4012	0.5	Surface	0.10	
				LB-4013	0.5	Surface	0.11	
				LB-4014	3.7	Near Bottom	0.13	
				LB-4016	0-3.7	Integrated	-	62.
				LB-4017	0-3.7	Integrated	-	56.
10/18/2007				LB-4032	0.2		0.11	
				LB-4033	0.2		0.10	

West White Island Pond (Palis: 95173)
Unique_ID: W0754   Station: A
Description: deep hole in West Basin, Plymouth **DATA from 2007 fieldsheet/WES Lab report**

Date	Secchi	Secchi Time	Station Depth	OWMID	Sample Depth	Relative Depth	TP	Chl a
	(m)	24hr	(m)		(m)		(mg/l)	(mg/m3)
6/26/2007	2.0	13:15	4.6					
				LB-3913	0.2	Surface	0.029	
				LB-3914	0-3.6	Integrated	-	7.6
				LB-3915	3.6	Near Bottom	0.068	
7/25/2007	2.1	12:50	4.7					
				LB-3951	0.2	Surface	0.027	
				LB-3952	3.7	Near Bottom	0.067	
				LB-3953	0 - 3.6	Integrated	-	22.8
				LB-3954	0.2	Grab		
8/21/2007	1.6	13:22	4.4					
				LB-3991	0.2	Surface	0.042	
				LB-3992	3.4	Near Bottom	0.056	
				LB-3993	0-3.5	Integrated	-	23.4 d
9/24/2007	1.4	12:40	4.2					
				LB-4021	0.5	Surface	0.036	
				LB-4022	3.2	Near Bottom	0.044	
				LB-4023	0 - 3.2	Integrated	-	25.7
10/18/2007	1.7	12:30	4.0	LB-4041	0.2	Surface	0.035	

Table 10. Water Quality Data. Cranberry Bog Data 2007.

Federal Furnace Pipe J inlet to East White Island Pond
Unique_ID: W1600 Station: J
Description: Cranberry bog discharge pipe (approx 10 inch diameter) at eastern edge of northern lobe

Date	Secchi	Secchi Time	Station Depth	OWMID	QAQC	Sample Depth	Relative Depth	TP	SRP
	(m)	24hr	(m)			(m)		(mg/l)	(mg/l)
6/26/2007	--	132:40	--	LB-3920		--		0.68	--
10/18/2007	--	12:01	--	LB-4034		--		0.26	--

Makepeace Pipe K inlet East White Island Pond
Unique_ID: W1601 Station: K
Description: Cranberry bog discharge pipe (approx 16   inch diameter) at northwestern edge of northern lobe

Date	Secchi	Secchi Time	Station Depth	OWMID	QAQC	Sample Depth	Relative Depth	TP	SRP
	(m)	24hr	(m)			(m)		(mg/l)	(mg/l)
7/25/2007	--	10:50	--	LB-3970		--		0.078	0.034
8/21/2007	--	10:40	--	LB-3960		--		0.068	0.026

“ ** ” = Censored or missing data

“ -- ” = No data

“ b ” = **b**lank Contamination in lab reagent blanks and/or field blank samples (indicating possible bias high and false positives).

“ **d** ” = precision of field **d**uplicates (as RPD) did not meet project data quality objectives identified for program or in QAPP; batch samples may also be affected

“ **h** ” = **h**olding time violation (usually indicating possible bias low)

“ **m ”** = **m**ethod SOP not followed, only partially implemented or not implemented at all, due to complications with sample matrix (e.g. sediment in sample, floc formation), lab error (e.g., cross-contamination between samples), additional steps taken by the lab to deal with matrix complications, and lost/unanalyzed samples

Appendix II Carlson Trophic State Index (TSI)

Carlson's Trophic State Index and Attributes of Lakes.
(Modified from http://dipin.kent.edu/tsi.htm#A%20Trophic%20State%20Index Carlson and Simpson (1996).

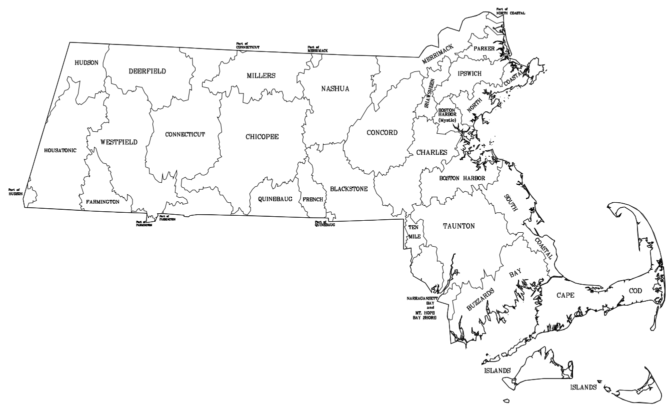
A list of possible changes that might be expected in a north temperate lake as the amount of algae changes along the trophic state gradient.

TSI	Chl (ug/L)	SD (m)	TP (ug/L)	Attributes	Water Supply	Fisheries & Recreation
<30	<0.95	>8	<6	**Oligotrophy:** Clear water, oxygen throughout the year in the hypolimnion	Water may be suitable for an unfiltered water supply.	Salmonid fisheries dominate
30-40	0.95-2.6	8-4	6-12	Hypolimnia of shallower lakes may become anoxic		Salmonid fisheries in deep lakes only
40-50	2.6-7.3	4-2	12-24	**Mesotrophy:** Water moderately clear; increasing probability of hypolimnetic anoxia during summer	Iron, manganese, taste, and odor problems worsen.	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate
50-60	7.3-20	2-1	24-48	**Eutrophy:** Anoxic hypolimnia, macrophyte problems possible		Warm-water fisheries only. Bass may dominate.
60-70	20-56	0.5-1	48-96	Blue-green algae dominate, algal scums and macrophyte problems	Episodes of severe taste and odor possible.	Nuisance macrophytes, algal scums, and low transparency discourage swimming and boating.
70-80	56-155	0.25-0.5	96-192	**Hypereutrophy:** (light limited). Dense algae & macrophytes		
>80	>155	<0.25	192-384	Algal scums, few macrophytes		Rough fish dominate; summer fish kills possible

Appendix III. Guidelines for Total Maximum Daily Loads of Phosphorus from Commercial Cranberry Bog Discharges in Massachusetts.

Mark D. Mattson

MassDEP TM-T-1, CN307.0, DWM February 9, 2009



<u>NOTICE OF AVAILABILITY</u>

Limited copies of this Guideline are available at no cost by written request to:
Massachusetts Department of Environmental Protection
Division of Watershed Management
627 Main Street
Worcester, MA 01608

DISCLAIMER

References to trade names, commercial products, manufacturers, or distributors in this report constitute neither endorsement nor recommendations by the Division of Watershed Management.

Introduction

The purpose of this document is to evaluate available information on the operation of commercial cranberry bogs in relation to discharges of nutrients, particularly phosphorus, into sensitive receiving waters such as freshwater lakes. The current operation of water use and fertilizer use is summarized to estimate the annual discharge of phosphorus from commercial bogs. In addition, the available information from the literature is summarized to establish new Best Management Practices for both water use, reuse and discharge as well as phosphorus fertilizer rates that are expected to result in receiving waters attaining all relevant Water Quality Standards.

Commercial cranberry production is a major crop in southeastern Massachusetts. The cranberry is a native wetland plant (*Vaccinium macrocarpon*) that is planted into bogs and fertilized like other crops. But unlike other crops, cranberries require frequent irrigation and seasonal flooding. The discharge of waters from the bogs, from excessive rain or groundwater inputs, return flows from irrigation during the growing season or due to discharge of the flood waters allows nutrients such as phosphorus and nitrogen, to be discharged from the bogs to nearby or downstream surface waters. It is this large discharge of nutrient rich water that is a concern to local water quality because the nutrient can stimulate the growth of nuisance aquatic plants and algae.

Currently, many of the large recreational lakes in southeastern Massachusetts are impaired by various combinations of nutrients, noxious aquatic plants (includes algae), turbidity (due to algae blooms) and impairments of low dissolved oxygen and organic enrichment. Many of these lakes receive large discharges of water from nearby commercial bogs and these lakes are listed in the Massachusetts 2006 Integrated list (MassDEP, CN 262.1, 2007; http://www.mass.gov/dep/water/resources/2006il4.pdf) as impaired (Category 5) under Section 303d of the Federal Clean Water Act: New Bedford Reservoir in Acushnet, Noquochoke Lake in Dartmouth, Parker Mills Pond and Tihonet Pond in Wareham, White Island Pond and Billington Sea in Plymouth and Wareham, Furnace Pond and Stetson Pond in Pembroke, Wampatuck Pond in Hanson, Lower Mill Pond, Upper Mill Pond and Walkers Pond in Brewster, Santuit Pond in Mashpee, West Monponsett Pond in Halifax/Hanson.

According to the Federal Clean Water Act, the state must develop allowable nutrient budgets or Total Maximum Daily Loads (TMDLs) for these waters such that they fully support all designated uses. In addition to these there are numerous streams and coastal embayments downstream of the bogs that are also listed as impaired by nutrients. Many of the smaller lakes and streams in the region have not been assessed but may be threatened by excess nutrients because they are also located near the discharge areas of the commercial bog operations. Similar problems with lake eutrophication have been seen in Wisconsin (the leading producer of cranberries) where cranberry production was implicated as the major source of nutrients (Garrison and Fitzgerald, 2005). This report reviews the operation of the bogs and reviews the literature on fertilizer use and nutrient export from commercial bogs and natural wetlands and provides guidance for the development of total phosphorus Total Maximum Daily Loads for freshwater lakes.

Background on Commercial Bog Operations

Historically, commercial cranberry bogs were created over natural wetlands but natural wetlands have been protected since the development and revisions of the Wetlands Protection Act in Massachusetts between 1963-1972. Any new commercial bogs created in Massachusetts since that time are required to be constructed in upland areas by grading the land level and adding sand as the plant bed. A series of dikes, ditches, pumps and flumes allows for periodic flooding and sand is added to the beds as a rooting medium. Water enters as rainfall and is pumped in for frequent irrigation. In some cases surface water runoff, a natural stream or groundwater seepage may add additional water to the bogs and is also discharged as needed (i.e., a flow-through bog; see Figure 1). The fall harvest occurs by flooding the bogs to allow the berries to be knocked loose and float into collection areas. After harvest the water is discharged to nearby surface waters. Flooding also occurs temporarily during winter to allow ice formation to protect vines from freezing. Flooding may also occur at other times for insect control. Typically, commercial cranberry bogs require about 10 acre-feet of water, including rainfall, each year for combined irrigation and flooding purposes (DeMoranville and Howes, 2005).

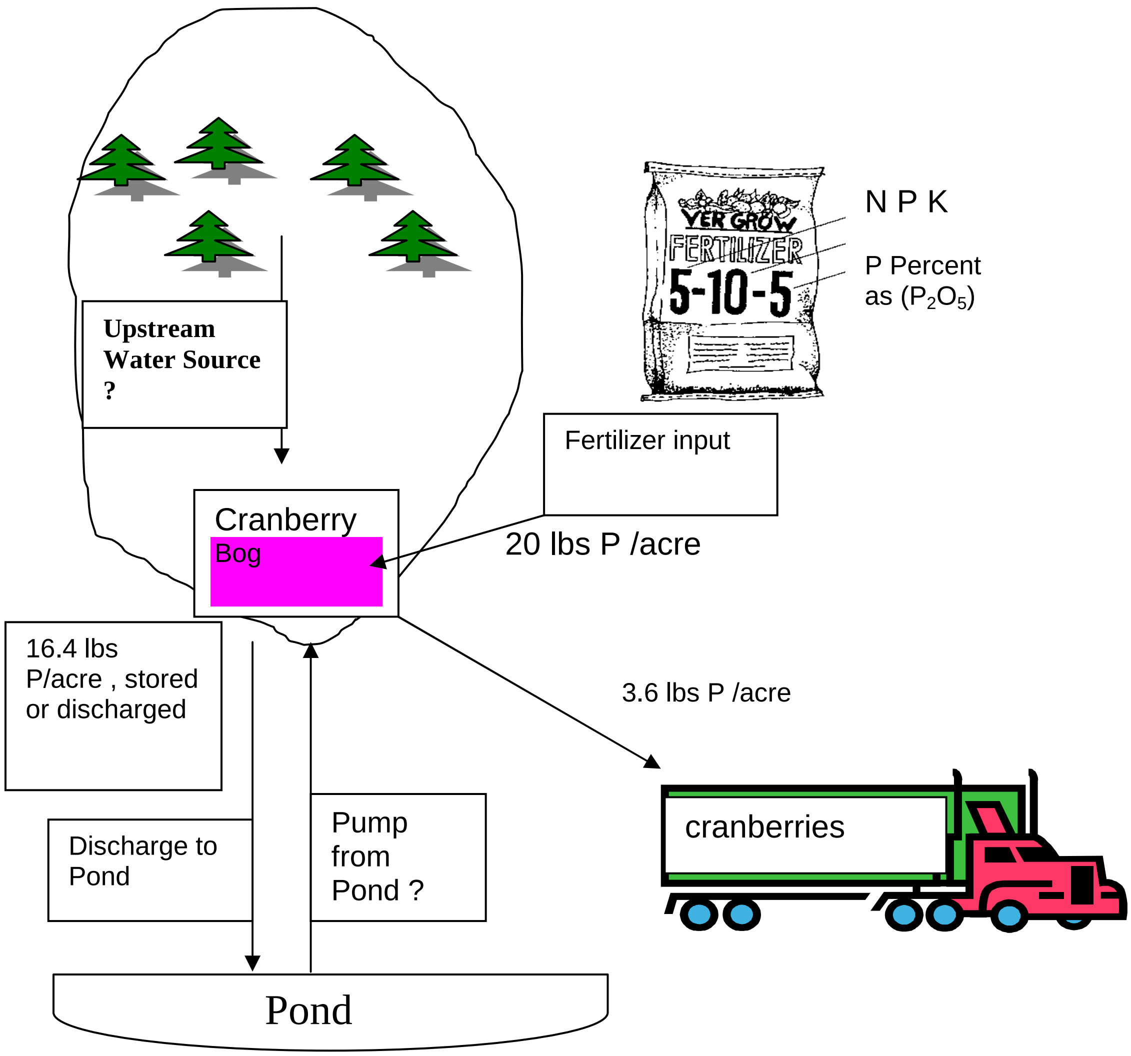


Figure 1. Schematic Diagram of a Phosphorus Budget for a Cranberry Bog.

Up until recently, the recommended phosphorus fertilizer inputs for traditional cranberry bogs has been 20 pounds per acre per year, according to the University of Massachusetts Cranberry Station publications http://www.umass.edu/cranberry/services/bmp/phosphorus.shtml although higher rates are recommended in some cases. The Best Management Practices are under review by the University and by MassDEP. Typical commercial bogs often use higher rates than the recommended 20 lbs/ac/yr (22.4 kg/ha/yr) as shown in Table 16 in DeMoranville and Howes, (2005). In that study, half of the bogs were applying phosphorus fertilizer at rates of 31 to 45 lbs P/ac/yr (27.9-39.8 kg/ha/yr) in the first year of the study. These rates are similar to a study of a nearby bog where the rates of phosphorus fertilizer application were 29.2 lb P/ac/yr (Howe and Teal, 1995). The harvest of berries and associated leaves and twigs removes about 3.6 pounds of phosphorus per acre each year (DeMoranville and Howes, 2005). If a bog were fertilized at the recommended rate (20 lbs/ac/yr) it implies that 16.4 pounds per acre (18.3 kg/ha/yr) are potentially available for buildup in the soil or for downstream export (see Figure 1). Over many years of excess phosphorus application soils are expected to become saturated with excess phosphorus and may start to export more phosphorus over time.

Review of Fertilizer Application and Crop Yield

Several lines of evidence are available on the phosphorus fertilizer requirements of cranberries. As noted in Roper et al., 2004, a number of early studies had identified that 22 kg/ha/yr (20 lbs/acre/yr) was sufficient for commercial cranberry operations, but the studies did not examine if lower fertilizer rates would also be sufficient. More recent studies in Massachusetts have found that yields of cranberry are not very responsive to phosphorus in fertilizer at any rate, presumably because of over fertilization in past years has built up a supply of phosphorus in the cranberry soils. These studies include the recent whole bog studies as well as smaller, but more detailed plot studies in Massachusetts (DeMoranville and Howes, 2005; DeMoranville, 2006) which found no reduction in cranberry yield as phosphorus was lowered to less than 20 lbs/acre/year and in some cases yields increased with lower or even no phosphorus applied at all. In the Eagle Holt bog fertilizer rates were reduced to 16.1 kg/ha and 6.3 kg/ha (14.3 lb/ac and 5.6 lb/ac) in 2003 and 2004, respectively, and yields actually increased by 31 percent over the previous two years (DeMoranville and Howes, 2005). The average yield for all six bogs in the first two years was 135 bbl/acre/yr, but the yield actually increased to 155 bbl./acre/yr during the next 2 years as fertilizer was reduced on the six bogs studied by DeMoranville and Howes (2005). The final recommendations of the DeMoranville and Howes (2005) study was that 20 lbs/acre/year of phosphorus fertilizer are sufficient and that typical native cranberries on organic soils may have lower targets of 10-15 lbs/acre/year unless tissue tests show deficiency (<0.1% in August).

An extended multiyear study of four of the experimental bogs also showed that the three lowest phosphorus fertilizer rates below 10 kg/ha/yr (averaging about 6 lb/ac/yr) produced cranberry yields greater than the median of all the treatments (Figure 2). These results are supported by recent work of Parent and Marchand (2006) who found there were year-to-year differences and site-to-site differences in cranberry production, but found there was no benefit to adding phosphorus on the yield of cranberries in a Quebec study. Additional studies on plots have shown there was no justification for using high phosphorus fertilizers to increase yields . Even the zero phosphorus plots showed no signs of deficiency after 6 years of study (Roper, 2009).

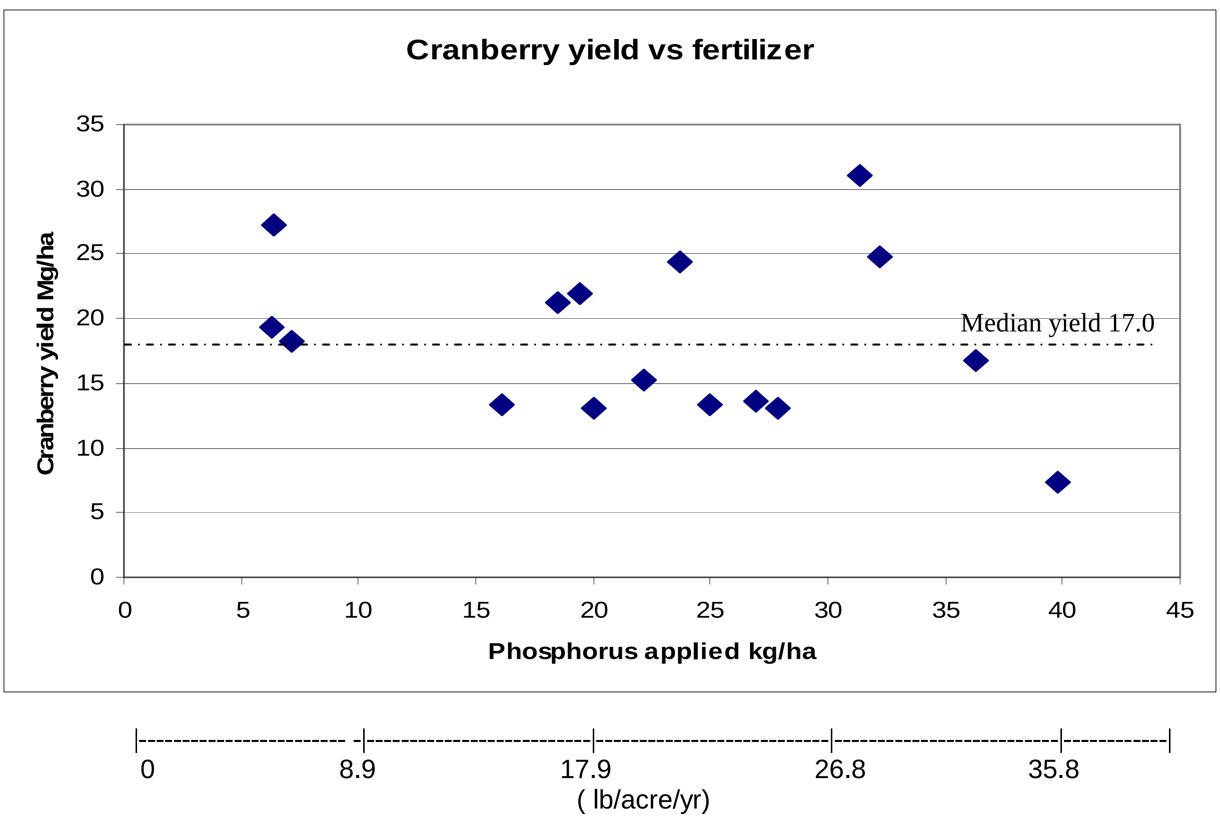


Figure 2. Cranberry yield vs. Fertilizer Rates (Data from DeMoranville et al., 2009).

Export of Phosphorus from Commercial Cranberry Bogs

There have been two recent studies on nutrient export from commercial cranberry bogs in Massachusetts. The first study (Howes and Teal, 1995), focused on a flow-thru bog while the second study (DeMoranville and Howes, 2005), was more extensive and included varying fertilizer rates, and measuring cranberry yields along with both net and gross export of nutrients from six commercial bogs over several years. Much of the following discussion will focus on the more recent study (DeMoranville and Howes, 2005).

The bogs studied by DeMoranville and Howes (2005) showed variation in export related to soil type and fertilizer rates. The two upland bogs on mineral soils (Mineral 5 and 6 in Figure 3) with essentially no discharges other than harvest discharges had total phosphorus concentrations equal to or less than 0.1 mg/l in discharge water, with resulting low export rates of about 0.5 kg/ha/yr. The four organic bogs studied by DeMoranville and Howes (2005), were established bogs on organic (wetland) soils with periodic discharges during the growing season as well as during harvest or winter floods. These bogs tend to have concentrations of phosphorus between 0.15 and 0.5 mg/l in the discharge water and tend to discharge about 3 kg/ha/yr (see Figure 3, Organic 1-4). The median of the organic bog net discharge in the first year (prior to major reductions in fertilizer application was 3.4 kg/ha/yr and is the best estimate of typical organic cranberry bog export in Massachusetts. Because the total discharge of water (per unit area) was similar from the series of six bogs there is a linear relationship between the net discharge of phosphorus from the bogs and the concentration of phosphorus in the discharge water (Figure 3). Lacking other information the net export from bogs can be estimated from the average total phosphorus concentration as shown in Figure 3 as: net export (kg/ha/yr) = -0.59+8.83*Conc. (mg/l), N=18, r^2=0.47, α=0.001. The flow-thru bog was reported to export large amounts of phosphorus (9.9 kg/ha/yr) with the major discharge events having phosphorus concentrations averaging 0.53 mg/l during winter floods (Howes and Teal, 1995). Recent studies on commercial cranberry bogs have shown that reduced phosphorus fertilizer application did not suppress the yield of cranberries, rather yields increased while reducing TP concentrations in discharge water (DeMoranville et al., 2009).

Much of the phosphorus exported from the bogs is associated with flood discharges. In particular, flood waters held for more than about 10 days leads to anoxia and the release of phosphorus (DeMoranville and Howes, 2005).

Export of total phosphorus from natural wetlands and forested watersheds was also reviewed by DeMoranville and Howes (2005). The literature suggests that freshwater wetlands such as beaver ponds, peat soil wetlands, and wetlands bordering streams export between 0.41 kg/ha/year and 0.68 kg/ha/year (median of 0.47 kg/ha/yr), while cypress swamps and tidal saltwater marshes export higher amounts. The forested wetland system in Westport Massachusetts had a gross export of 0.14 to 0.15 kg/ha/yr of phosphorus. This is in general agreement with a review of phosphorus export from various land uses that indicates forests export an average of 0.236 kg/ha/yr, while row crops export an average of 4.46 kg/ha/yr (Reckhow et al., 1980). Thus, the overall mean fluvial export of 1.65 and 3.02 kg/ha/yr (net and gross, respectively) reported for commercial cranberry bogs by DeMoranville and Howes (2005) indicates cranberries export much larger amounts of phosphorus than forests or typical freshwater wetlands, but generally export less than agricultural row crops. Note that net fluvial phosphorus exports are lower than gross fluvial exports if the bogs are using source water with high concentrations of phosphorus. Flow-through bogs may export higher amounts of phosphorus than most row crops (Howes and Teal, 1995).

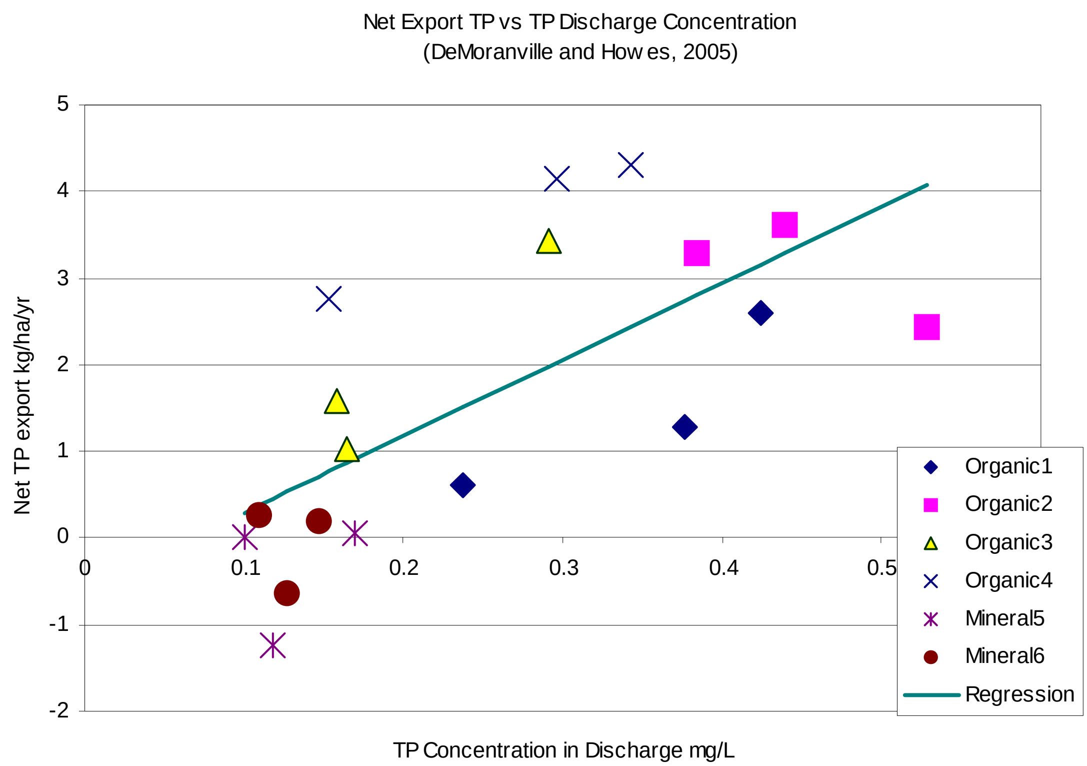


Figure 3. Net TP Export vs. TP Concentration.

Lake Nutrient Budgets

Nutrient budgets for impaired lakes require knowledge of nutrient export from local sources including point sources (discharges from pipes or other discrete sources as well as various land uses that discharge nonpoint source pollution. This report examines nutrient budgets from commercial cranberry operations within Massachusetts as diagramed in Figure 1. Nutrient budgets are typically presented both as net budgets and as gross discharge budgets and as 'fluvial budgets'. The nutrient budgets measure (or estimate) all nutrients entering the bog and all nutrients leaving the bog as shown in the schematic diagram below. Generally, the two major nutrient inputs to a bog are nutrients in the irrigation water and nutrient in the fertilizers. The two major nutrient losses from a bog are nutrients discharged in released water, and nutrients in plant materials harvested from the bog (berries as well as leaves and twigs). From a water quality standpoint we are most interested in the 'fluvial budget', that is, the amount of nutrients delivered to a lake via natural water inputs compared to the additional nutrients in discharge water that enter the bog due to commercial bog operations. Other imports to the bogs (such as fertilizers) and exports from the bog, such as phosphorus in the crop of cranberries, are accounted for outside of the fluvial budget in the total budget.

From a lake water quality point of view there are two general types of bogs and associated nutrient budgets to consider: autochthonous nutrient sources and allochthonous nutrient sources. First, where the source of bog irrigation and floodwater is a tributary to the receiving pond or is the receiving pond itself (autochthonous), the most appropriate nutrient flux is the net fluvial nutrient budget. In such bogs the original nutrients in the irrigation and flood waters was either in the lake or would have entered the lake in the absence of bog operations. In that case, the nutrients in the input source water are subtracted from the fluvial outputs to calculate the net difference. In other words the extra amount of nutrients entering the pond due to the cranberry bog operation is the net fluvial export from the bog. Corrections may be required if the source water is polluted from previous discharges from the same bog. The second case would be a bog that gets irrigation and flood water from an outside water source (allochthonous), that is, from a source that normally would not enter the receiving pond. Typically this is a groundwater well or stream or source pond that is not tributary to the receiving pond. In this case the gross fluvial export is calculated as the input to the receiving pond, because the input to the pond includes both the nutrients from the bog as well as nutrients in the original source water. The nutrients from both the water as well as nutrients derived from fertilizers are new inputs to the bog as a result of management operations.

Target loads and nutrients to maintain water quality standards.

The Massachusetts Water Quality Standards 314CMR4.05 http://www.mass.gov/dep/service/regulations/314cmr04.pdf) state conditions for best available technology (BAT) for point and nonpoint sources including publicly owned treatment works (POTWs) and other sources:

> Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control.

In addition, water withdrawals are regulated under the Water Management Act regulations http://www.mass.gov/dep/service/regulations/310cmr36.doc. These regulations allow for registration and/or permitting of water withdrawals for cranberry operations including regulations regarding water conservation, water quality, farming practices and reporting requirements to protect other water uses. Water withdrawals may be established under nonconsumptive use which means any use of water which results in its being discharged back into the same water source at or near the withdrawal point in substantially unimpaired quality and quantity.

As a general guideline, concentrations should not exceed 0.050 mg/l in any stream entering a lake or pond (USEPA, 1986). The USEPA has issued guidance for water quality nutrient concentrations of total phosphorus of 0.031 mg/l for rivers in southeastern Massachusetts (USEPA, 2000; http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_14.pdf.)

The lakes in southeastern Massachusetts may be considered as belonging to two general types: lakes with tributaries and seepage lakes with no tributaries. The seepage lakes are fed mainly by groundwater and direct precipitation and tend to be more oligotrophic, clear water lakes. Some seepage lakes are set in organic soils that may contribute dissolved organic compounds that color the water and this may result in higher phosphorus levels The clear water seepage lakes are thus more sensitive to nutrient inputs and generally should have lower total phosphorus concentrations. Clearwater seepage lakes in southeastern Massachusetts may reasonably be expected to have concentrations of total phosphorus of less than 0.020mg/l and possibly as low as 0.008 mg/l (MassDEP, in prep.; USEPA, 2001; http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes/lakes_14.pdf).

Thus, inputs from external sources must be limited to meet the state's Water Quality Standards and to protect designated uses. The nutrient management requirements to meet Water Quality Standards may vary depending on the receiving water but at a minimum, discharges should not exceed the EPA guideline of 0.1 mg/l for streams and the 0.05 mg/l for tributaries to lakes. By way of comparison, current National Pollutant Discharge Elimination System (NPDES) permits for typical wastewater treatment plant discharges in Massachusetts are set at 0.1 mg/l in the discharges to sensitive receiving waters. Extensive Best Management Practices may be required in order to ensure receiving waters meet the state's Water Quality Standards.

Best Management Practices Protective of Water Quality

The data from the six commercial cranberry bogs studies in the DeMoranville and Howes (2005) study was further analyzed to examine the relationship of fertilizer rates on cranberry yields, concentrations of phosphorus in discharge waters and downstream export of nutrients. The data indicate that if most protective BMPS recommended by DeMoranville and Howes (2005) are followed, export of phosphorus from commercial bogs can be reduced with little or no impact on crop yields.

For bogs that discharge to sensitive surface waters some combination of the following BMPs may be required. Specifically, no more phosphorus than the lower range of fertilizer rates of 10-15 lbs/acre/year recommended by DeMoranville and Howes (2005) may be required. In addition, the recommended best management of water use (using tailwater or retention ponds to remove phosphorus prior to discharge, holding floodwater 1-3 days, but less than 10 days, with slow discharge and winter flood control to minimize flood holding times to avoid anoxia) may be required. Fertilizers with ratios of $N:P_2O_5$ of greater than 1:1 and preferably 2:1 such as commercial 18-8-12 or 12-6-8 may be required. If discharges are to a sensitive clear water seepage bog the additional BMPS recommended by DeMoranville and Howes (2005) of installing tailwater recovery or other physical barriers or filtration may be required to meet water quality standards.

If the recommended phosphorus fertilizer rates of 10-15 lb/acre/year are followed the data suggest commercial cranberry bogs will achieve net fluvial discharges of less than 1 kg/ha/year. This can typically be achieved if total phosphorus concentrations in discharge waters are at or below 0.1 mg/l (Figure 3) and/or, if increase in phosphorus concentration between source water to discharge water is held to an increase of no more than 0.032mg/l (assuming 10 acre feet of water use and no reuse of source water). If the discharge is to sensitive waters then lower export rates may be required. A discharge of 0.5 kg/ha/yr (higher than forests but lower than row crops) may be required and this could be achieved if discharge concentrations follow than the EPA 'Gold Book' (EPA, 1986) guidelines of 0.050mg/l for discharges to lakes and discharge volumes are limited to 3.3 acre-feet per acre bog per year or less. Bogs discharging to less sensitive waters may be able to discharge 5 acre-feet or more as long as net nutrient loading rates are kept low by reuse of water or other BMPs.

References

DeMoranville, C.J. and B. Howes. 2005. Phosphorus dynamics in cranberry production systems: Developing the information required for the TMDL Process for 303D waterbodies receiving cranberry bog discharge. MassDEP 01-12/319. Umass Amherst Cranberry Station, E. Wareham, MA and Umass Dartmouth SMAST, New Bedford, MA. 137pp.

DeMoranville, C.J. 2006. Cranberry Best Management Practice Adoption and Conservation Farm Planning. HortTechnology 16(3):393-397.

DeMoranville, C., B. Howes, D. Schlezinger and D.White. 2009. Cranberry Phosphorus Management: How changes in practice can reduce output in drainage water. Acta Hort 810: 633-640.

Garrison, P.J. and S.A. Fitzgerald. 2005. The role of shoreland development and commercial cranberry farming in a lake in Wisconsin, USA. J. Paleolimnology 33(2): 169-188.

Howes, B.L. and J.M. Teal. 1995. Nutrient Balance of a Massachusetts Cranberry Bog and Relationships to Coastal Eutrophication. Environmental Sci. & Tech. 29(4):960-974.

Parent, L.E. and S. Marchand. 2006. Response to Phosphorus of Cranberry on High Phosphorus Testing Acid Sandy Soils. Soil Sci. Soc. Am. J. 70:1914-1921.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients. EPA 44/5-80-011. USEPA, Washington DC. 214pp.

Roper, T.R. 2009. Mineral Nutrition of Cranberry: What we know and what we thought we knew. Acta Hort. 810:613-625.

USEPA. 1986. Quality Criteria for Water 1986. United States Environmental Protection Agency, Washington, DC. EPA 440/5-86-001.

USEPA. 2000 Ambient Water Quality Recommendations. Rivers and Streams in Nutrient Region XIV. United States Environmental Protection Agency, Washington, DC. EPA 822-B-00-022. http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_14.pdf

USEPA. 2001 Ambient Water Quality Recommendations. Lakes and Reservoirs in Nutrient Region XIV. United States Environmental Protection Agency, Washington, DC. EPA 822-B-00-022. http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes/lakes_14.pdf

Appendix IV. White Island Pond Total Phosphorus TMDL Public Meeting and Response to Comments

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENERGY & ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Division of Watershed Management, 627 Main Street 2nd Floor, Worcester, MA 01608

DEVAL L. PATRICK
Governor

TIMOTHY P. MURRAY
Lieutenant Governor

IAN A. BOWLES
Secretary

LAURIE BURT
Commissioner

Public Meeting: White Island Pond Draft TMDL,
Plymouth Town Hall, Plymouth MA May 7, 2009
Presenters: Dr. Mark D. Mattson and Dr. Kim Groff
Attendees

Name	Address or Affiliation
Kim Michaelis	Town of Plymouth
Leslie O'Shea	Mass DEP/SERO
David Clark	Herring Ponds Watershed Assoc.
PAULA KULETZ	" " " "
Jim Sullivan	WIPCA
TED BURKE	White Island Pond
John A Dawes Sr	White Island Pond CA
JOHN P. KELLY	White Island Pond Conservation Alliance
Frank Condon	White Island Pond Cons. All.
ED PACEWICZ	CHAIRMAN - WAREHAM CLEAN WATER COMMITTEE
Mike Melaragni	WATD
Lauren Liss	Rubin and Rudman
George Rogers	A.D. Makepeace
Jeff LaFleur	CCCGA
Jenifer Pinkham	Schlossberg + Assoc. LLC
Walter Morrison III	Federal Furnace Booster
Joseph & Kathleen Chisholm	White Island
Helen Hapgood	White Island / Ezekiel
Paul Hapgood	White Island / Ezekiel

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENERGY & ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Division of Watershed Management, 627 Main Street 2nd Floor, Worcester, MA 01608

DEVAL L. PATRICK
Governor

TIMOTHY P. MURRAY
Lieutenant Governor

IAN A. BOWLES
Secretary

LAURIE BURT
Commissioner

Public Meeting: White Island Pond Draft TMDL,
Plymouth Town Hall, Plymouth MA May 7, 2009
Presenters: Dr. Mark D. Mattson and Dr. Kim Groff
Attendees

Name	Address or Affiliation
STEVE MATALIANO	5 MOHAWK CIR. PLYMOUTH
Lucile + Kevin Leary	19 Centennial St / owner 38 Billington Sea Rd.
Michael Lenny	42 Billington Sea Rd (Billington Sea Ass)
Jim Sampson	196 Black Cat Rd (Billington Sea Assoc.)
Brian Wick	CCCGA
Mel/Wayne Fisher	White Island Pond
Thomas Perkins	White Island Pond.
Tom Bilcha	( ) ( ) ( )

Response to Comments
Phosphorus TMDL for White Island Pond

Comments received verbally at the public meeting:

Comment 1: Not much has changed with regard to addressing water quality problems at White Island Pond since 1982. Why did DEP choose to engage in a Memorandum of Agreement (MOA) with the Cape Cod Cranberry Growers Association and the UMass Cranberry Experiment Station regarding the development of best management practices for nutrient application, water use and return flows rather than taking enforcement action? If the conditions of the MOA are not met by the cranberry growers, under the law, what authority does the MassDEP have to ensure the agreement is met?

Response: MassDEP believes that the MOA specifies the appropriate measures that need to be taken in order to achieve the water quality improvements and that this cooperative approach is the most expeditious method for getting the remedial measures in place to address water quality problems at White Island Pond. The federal and state Clean Water Act (CWA) statutes and related regulations grant certain exemptions from wastewater discharge permitting requirements for agricultural related discharges; this relief extends to the cranberry industry. If the MOA is not complied with, MassDEP can opt out of the MOA and will not have given up any rights to enforce MassDEP water quality regulations.

It should be noted that the growers have already begun to implement the practices outlined in the MOA.

Comment 2: EPA guidance documents (e.g., Ambient Water Quality Criteria recommendations for Rivers and Streams in Nutrient Ecoregion XIV (US EPA, 2000b)) suggest a phosphorus concentration of 8 ppb is appropriate and the EPA "Gold Book", which is 22 years old, suggests a phosphorus level of 25 ppb. The average phosphorus in seepage lakes in the region is about 9 ppb, and neighboring Ezekiel Pond is 6 ppb. How did MassDEP arrive at the phosphorus target of 19 ppb, instead of a lower value of 8 ppb as suggested by EPA guidance?

Response: The EPA values were intended to provide technical guidance and recommendations to States to develop water quality criteria and standards. It also notes that State authorities retain the discretion to adopt approaches on a case-by-case basis that differ from the guidance when appropriate and scientifically defensible. The Nutrient Ecoregion XIV targets identified in EPA guidance were based largely on information collected on lakes in Maine and New Hampshire. The lakes in these areas are deep in contrast to White Island pond, which is relatively shallow, and generally not representative of lakes in South Eastern Massachusetts. A blanket recommendation of 0.008mg/l for all lakes in Massachusetts is not appropriate. The law allows MassDEP to establish water quality standards, including site specific standards and targets for TMDLs based on the conditions at the site. We have provided detailed information to support the TMDL target, while the EPA blanket recommendation is not specific to the pond.

The target value of 19 ppb was established after comparison of the above recommendations to a range of typical lake concentrations found in earlier eco-regional lake studies. The literature suggests a target of 0.019 mg/l will attain all designated uses including swimming. This target of 19 ppb requires addressing the sediment phosphorus load and aggressive 85% reductions of phosphorus loads from the cranberry industry and 50% reductions in loads from of home septic systems.

Comment 3: The TMDL study is greatly appreciated and I am hopeful that the approach will be successful. Why is it necessary for Cranberry Grower to release water to the lake in winter months rather than pumping the water to upland areas?

Response: Water requirements for the cranberry industry vary throughout the year. Fall harvest timing is flexible and water can be reused from one small section of the bog to another small section as the berries are harvested sequentially. The final discharge volume is relatively small using this technique. Winter frost protection floods on the other hand are time sensitive and all bog sections are typically flooded at the same time to protect the plants, and the water subsequently discharged with short notice if the water becomes low in oxygen. Thus, winter floods often involve greater amounts of water that may need to be removed more quickly. During winter months the volume of water is large and management strategies for addressing these inputs are not immediately implementable. MassDEP intends to monitor these winter flood releases and evaluate whether other operational measures can be implemented.

Comment 4: Who will be responsible for enforcement of this agreement? What assurances can you give us that water quality on White Island Pond will improve in the future?

Response: During the term of the MOA MassDEP will monitor the work of Dr. Carolyn DeMoranville , et. al of theUMass Amherst Cranberry Station, E. Wareham, MA, to ensure the validity of results. MassDEP can withdraw from the MOA at any time. If parties do not abide by the agreement, MassDEP will consider its options to either obtain compliance with the MOA or to withdraw from the MOA and take an alternative approach to address water quality problems in White Island Pond. MassDEP believes the management practices being undertaken in accordance with the MOA will improve water quality within White Island Pond. MassDEP will continue to evaluate conditions within White Island Pond during and after the MOA to assess water quality and to determine whether additional remedial measures are necessary.

Comment 5: Are Cranberry Growers mandated under the agreement to notify of winter flood releases?

Response: Monitoring will be conducted by the UMass Cranberry Station and reported to MassDEP in regular reports. The growers have agreed to cooperate with the study.

Comment 6: Many houses on the lake have shallow water supply wells that draw water from the Lake. Are algal toxins regulated through the Clean Water Act? What assurances do we have that algal toxins are not a threat to private residential drinking water supply wells?

Response: Algal toxins are not specifically regulated. The chance of a groundwater supply impact from an algal bloom is very low for the following reasons. First, very high levels of algal cell concentrations would need to be present before health effects are seen. In the case of toxic algae the most common health effect is skin irritation. Second, algae are filtered out of the water when water is transported through the ground. The local Board of Health is responsible for monitoring for toxic algal blooms and posting signage in the event that a potential public health threat exists. MassDEP has also sampled White Island Pond for toxic algae and has notified the State Department of Public Health, local Board of Health and the White Island Pond Conservation Alliance when such toxic algae are detected.

Comment 7: What is the amount of phosphorus in the sediments of the pond?

Response: A detailed study of sediments would be required to determine this.

Comment 8: Have there been changes to the DRAFT TMDL for White Island Pond and the Final report?

Response: The White Island Pond TMDL is in draft form. MassDEP is currently in the process of collecting public comments on the draft report. As the public comment period is closed, the TMDL will be amended as needed, based on the comments received, and the Final TMDL will be submitted to EPA for approval.

Comment 9: How did the Lake model used in the development of the DRAFT TMDL address the dynamics of mixing between the East and West White Island ponds? The ambient concentration in the East Pond appears to be about 4 times higher than the TMDL target phosphorus level of 19 ppb. The higher concentration of phosphorus in the East Pond is likely due to its proximity to the inputs form the two Cranberry growing operations.

Response: The mixing dynamics between the two ponds is complicated by withdrawals and discharges in the East basin and this mixing was not modeled directly. Instead the model treats the ponds as one unit with an average target concentration of 19 ppb phosphorus. It is anticipated that there will be variability in the concentration of phosphorus between the lakes, with the East Pond being somewhat higher in phosphorus concentration than the West Pond. If the concentration of total phosphorus in both basins is averaged over a year and meets the target of 19 ppb of phosphorus then we expect that the water quality objectives with be achieved in both basins.

Comment 10: White Island Pond Association has been working to educate the public regarding alternative dish detergents and other measures to reduce the phosphorus loads associated with lawns and septic systems. MassDEP has appropriately identified the sources of phosphorus and selected a suitable remedy.

Response: No response needed.

Comment 11: Isn't it time for the agricultural industry to be held to the same standard as other industries?

Response: Legislative action would be necessary to change the federal and state Clean Water Act to remove the discharge permitting exemptions provided for agricultural related discharges.

Comment 12: Will Title 5 septic systems remove 50% of the phosphorus as required by the TMDL? What is the status of other alternative septic designs, such as the iron oxide system?

Response: There is a large difference between the performance of old fashioned cesspools and current title 5 systems involving a tank for settling and initial bacterial action and then a leaching area. In the leaching area or "soil absorption system", naturally occurring good bacteria, along with chemical changes brought about by the positive and negative charges on surfaces of soil particles and the presence of oxygen, all work together to make the effluent safe enough to join the ground water. The goal of the TMDL is to identify and eliminate non-conforming and failed systems. Conforming systems if properly designed and maintained should not present a problem.

MassDEP also allows the use of approved alternative septic systems. These alternative systems may include substitutes or alternatives for one or more parts of a conventional on-site system, or may be fundamentally different approaches intended to eliminate the need for a standard Title 5 system. Before being used, each new type of alternative technology must be reviewed and receive approval from MassDEP. The Barnstable County Department of Health and Environment currently conducts testing of alternative systems; information regarding their program and alternative systems is available on their website at: http://www.barnstablecountyhealth.org/AlternativeWebpage/index.htm. MassDEP has approved one system, the RID Phosphorus Removal System, for pilot testing; information regarding alternative systems that are approved by MassDEP, or are under review, can be found at: http://www.mass.gov/dep/water/wastewater/techsum.htm.

Comment 13: Does MassDEP have a prediction of when the East and West White Island ponds may meet the standard of 4ft transparency? Who is responsible for posting the lake when there is a violation of this standard?

Response: MassDEP conducted a visual inspection of White Island Pond on May 7in early summer 2009 (the day of the public meeting). At the time water was observed to be very clear as compared to the same time last year. However, it is too early to know if water quality improvements are already occurring. It is also difficult to predict how fast improvements will occur associated with the management strategies being implemented. The MOA will be effective for three years. During this period MassDEP will monitor the water quality to ensure that the measures adopted are effective in improving water quality.

The 4 ft transparency target is not a water quality standard at this time. This guideline was developed through the Massachusetts Department of Public Health (MDPH) which states that swimming and bathing are not permitted at public beaches when there is a lack of water clarity.

However, this guidance value of 4 ft is being considered as a water quality target for nutrient control to ensure that swimming is not impeded.

A public health notice was posted for White Island Pond because of cyanobacteria in 2007 & 2008. Posting is the responsibility of the local Board of Health. Note that not all algal blooms have toxic cyanobacteria. Although this activity is not directly under the purview of MassDEP we can assist local government and the Department of Public Health in confirming the presence of cyanobacteria if requested and if resources are available

Comment 14: Can Cranberry Growers pipe discharges directly to a river and by-pass a pond?

Response: Cranberry growers have the option to discharge to a point downstream of the pond. In this case the pipe would be quite long and may not be the most cost effective solution. This practice also has the potential to create problems downstream and therefore the Department would have to evaluate any such proposal for unintended consequences.

<u>Comments received via mail after the meeting:</u>

Attorney Jenifer M. Pinkham, on behalf of client
Federal Furnace Cranberry Company:

Comment 15:

Farming Practices – As is apparent in the TMDL, that the major onus is on the growers to significantly reduce their phosphorous input to WIP and FFCC is expected to reduce its phosphorous input into WIP by 95 percent. FFCC's goal is to take steps and measures and implement practices to achieve a maximum total annual discharge load of 10 kg of total phosphorous as required by the TMDL. While FFCC is willing to attempt and make every effort to meet this high burden, it requests that it is allowed to determine which practices to implement, how to implement such practices and when to implement such practices to meet the intended result. FFCC want to maintain flexibility to achieve the result using practices that it determines will both allow it to have a successful crop and meet the maximum total annual discharge load of 10 kg of total phosphorous. FFCC respectfully requests that the DEP does not micromanage the farming practices of the cranberry growers.

Response: The purpose of the MOA is to implement and evaluate different irrigation return and management approaches that the growers on White Island Pond and MassDEP have agreed can be reasonably put in place and have the potential to significantly improve water quality in White Island Pond and meet the TMDL. MassDEP is willing to be flexible provided the goals of the TMDL are achieved.

Comment 16:

More specifically, on page 6 of the TMDL, it states, "The major implementation can be achieved by a combination of best management practices (BMPs) including reducing phosphorous fertilizer rates, reducing volumes of discharge water and reducing concentrations of total phosphorous in the discharge water." This is of concern to FFCC. First, these are practices not necessarily BMPs, so they should not be referred to as such. Second, instead of prescribing the practices, which dictates how the growers grow their crop, FFCC requests that the DEP strike everything after "achieved" and insert, "by reducing the total annual discharge load of total phosphorous into White Island Pond."

Response: MassDEP's intent was simply to identify ways in which the TMDL could be achieved. What the measures are called is secondary to achieving the goals of the TMDL, which is to reduce the loading rate to achieve to achieve water quality standards. We believe that reducing fertilizer application rates to the lowest level that maintains acceptable crop yield is a commonly accepted practice irrespective of how irrigation return flows are managed. The loading rate to White Island Pond is a product of volumes discharged and concentration. To the extent that discharges associated with cranberry cultivation are returned to White Island Pond, reduced discharge volume and phosphorous concentrations will be needed to meet the TMDL. If the growers can divert discharge water or otherwise meet the TMDL then the TMDL requirements are met.

Comment 17:

On page 36, it states, "For this TMDL the following BMPs may be required to meet the target allocations." Again, BMPs should be changed to "practices." In addition, it is unclear what BMPs are "required," if any. Further, FFCC does not want to be bound to perform any particular practice, as if such practice has an unintended consequence, it would be bound to continue it anyway. The 319 Grant will study the practices and may recommend additional practices (that are not contained in the TMDL). FFCC respectfully requests that the DEP focus on the reduction in total annual discharge load of total phosphorous instead of what practices FFCC will use to reach that goal.

Response: The TMDL is not an enforcement document, rather it is a technical document to be used by the Department to restore water quality. Accordingly, the practices referred to as BMPs and other recommendations are not enforceable orders, per se. In addition to establishing the TMDL, MassDEP seeks to provide ideas and recommendations on how the TMDL can be met. In the case of irrigation return flows associated with cranberry cultivation, MassDEP is of the opinion that additional BMPs may be necessary to meet the TMDL. It is anticipated that the MOA will be a positive step toward meeting the TMDL requirements. Likewise, the intent is that the practices used in the 319 grant will also assist to achieve the TMDL. The TMDL however does not exclude the growers from using alternative approaches to achieve the TMDL goal. It will however be incumbent upon the growers to properly document, monitor and report the practices and BMPs used and their overall effectiveness in meeting the TMDL load reductions.

Comment 18:

On page 37 and 38, the TMDL reads, "The implementation plan for reducing total phosphorous discharges from the commercial cranberry bogs will begin with source reduction in the form and amounts of fertilizers applied and improvements to irrigation and flood usage." FFCC requests that everything after bogs be removed as the DEP should not micromanage FFCC's farming practices. Further, "the form and amounts of fertilizers" is incorrect as it is not a reduction in the form and amount of fertilizer but a reduction in phosphorous that is necessary.

FFCC requests that DEP inserts after "bogs", the following language, "will be achieved by the growers using a host of practices, including reducing the amount of phosphorous applied per acre per year and water management practices aimed at reducing the total amount of phosphorous into WIP."

Response: Your comment letter noted in the introduction that FFCC has already reduced phosphorus per acre, pumped water and irrigation water to an upland site and pumped flood waters to an upland site. Thus the implementation has already begun, and the description of the implementation is in fact accurate. The reference to the form of the fertilizer should be read to mean the ratio of N to P (which FFCC has addressed in 2008) and the amounts are also less, in terms of phosphorus fertilizer applied. The text has been changed to clarify this point.

Comment 19:

The next sentence at issue is, "As an added benefit, the reduction in fertilizer used should also result in a cost savings for the grower who no longer has to purchase unneeded fertilizer." This should be removed. It is incorrect for two reasons: (1) growers should not be required to reduce fertilizer, as it is only necessary to reduce phosphorous; and (2) the costs associated with changing their farming practices and purchasing new forms of fertilizer may be more expensive to the grower.

Response: The statement was removed from the text however the growers have stated that they have already reduced phosphorus fertilizers and this will be continued under the MOA. As long as they can demonstrate that the TMDL limits are met then further requirements are not needed. As the demand for lower phosphorus fertilizers grows we expect the availability of these formulations to be sufficient to meet the needs.

Comment 20:

On page 38, the TMDL states, "If reductions in fertilizer application and water use fail to achieve discharge concentrations…then additional BMPs are required." First, the amount of phosphorous applied per acre per year will be reduced not fertilizer overall. FFCC requests that the language be removed and the following language inserted, "If the suggested phosphorous fertilizer reduction and water management techniques fail to achieve the total annual discharge load of 10 kg of total phosphorous, then other practices will be suggested."

Response: The text was changed to clarify that it is phosphorus application rate that is important.

Comment 21:

In the second and third paragraphs, there are references to "BMPs" and we request that those be changed to "practices."

a. *Water Management* – Currently, A.D. Makepeace Company is required pursuant to its Chapter 91 license to keep WIP at a certain level. It would be extremely beneficial to the cranberry growers if this level were lowered, as less water would flow from WIP into the bog structure. With the current water level, water is constantly flowing into the bog structure from WIP, and FFCC is forced to constantly pump this water to the upland area. The current level is quite high, and A.D. Makepeace Company and the WIP Association have informed us that both are in favor of lowering the level of WIP. The homeowners have complained about beach erosion due to the high levels. Further, the lower water level will result in less phosphorous input from non-compliant septic systems that may not have enough soil between the cesspool and the pond to properly clean the waste before it enters WIP. If the water table is lowered, it will result in more soil to naturally clean the waste before it enters WIP. FFCC respectfully requests that this matter be addressed in the Final TMDL.

b. *Fertilizer Application* – As stated above, FFCC requests that it have the ability and flexibility to apply fertilizer to its crop when it sees fit and in the amounts and concentrations that it determined necessary (not to exceed UMASS Cranberry Stations' recommendations).

Response: Regarding BMPs, the reduction of unnecessary phosphorus fertilizer application is a recognized BMP. The diversion of high concentration nutrient water away from lakes was also favorably reviewed in the Generic Environmental Impact Report on lake management for Massachusetts (Mattson et al., 2004; see http://www.mass.gov/dcr/waterSupply/lakepond/geir.htm) and is considered a Best Management Practice in this case. Under the MOA the growers are allowed flexibility when determining fertilizer application rates. If the BMPs and other agreed upon practices in the MOA fail to meet the TMDL target or if Water Quality Standards are not met then additional BMPs or other practices may be required. Lowering the level of the lake will also be considered. MassDEP has reached a verbal agreement with A.D. Makepeace to maintain somewhat lower the water levels between elevation of 48.2 and 47.2 feet, which is within the range of the current permit limits.

Comment 22:

Water Body Description and Comparison – The TMDL continually compares White Island Pond to Ezekiel Pond, and there are important differences in the two bodies of water which are not noted in the TMDL. The two ponds are in close proximity and in the same watershed contributing to the formation of Red Brook. However, the bathymetric maps (see attached) indicate two very different types of water bodies. Ezekiel Pond is a classic kettle hole with fairly steep slopes that is spring fed, and there is no inlet or outlet that is visible on the maps. Conversely, White Island Pond's bathymetric maps evidence much more gradual slopes with slight incline, and in particular, in the east body there are large shallow areas in the northern half of WIP. It is of importance and should be noted that there are no visible streams entering White Island Pond, and that the cranberry bogs at the north end of the pond were formally fresh water swamps or marshes, and in fact, if all cranberry growing was ceased, water would naturally flow from the bog area into WIP. In addition, the TMDL never mentions that there is a dam located at the far end of WIP, and that if the dam were not there WIP would look completely different. FFCC does not know how much water flows through the dam but suggests that the DEP should investigate this. FFCC's understanding is that water used to seep out and come up in springs where the old headwaters of Red Brook were by Century Bog.

In addition, there was no description of the soil types surrounding WIP in the TMDL which may be important to the levels of phosphorous in WIP. The soil is comprised of peat, sanded muck, and Scarboro Series soils (see attached).

Response: The mean and maximum depths of the two ponds are similar with Ezekiel Pond being slightly deeper as noted. The text has been changed to include a discussion of the dam and this is reflected in the discussion of the target concentration as well. As indicated in the report, this information was used to set a slightly higher phosphorus target than other nearby seepage lakes without dams. The attached soil map and discussion referenced do not indicate any specific reference to phosphorus content.

Comment 23:

Homeowners' Responsibility – While FFCC acknowledges it contributes phosphorous to WIP and is willing to be part of the solution to restore WIP to health, it urges the DEP to increase the recommendations for homeowners with respect to septic systems and fertilizer use on their lawns. The Lake Association could work with the DEP to educate the homeowners regarding their responsibilities and what actions they can take to reduce phosphorous input to WIP. The homeowners should be informed which lawn fertilizers may be used on their lawn. Further, the homeowners should know if their septic system is Title 5 compliant. We recommend that a survey be conducted to determine how many homes have compliant systems.

Response: Low phosphorus lawn fertilizers are now included in the implementation table. The recommendation to survey the homes for compliance with Title 5 was also added .

Written Comments of A.D. Makepeace

Comment 24:

In fact, Makepeace has already undertaken significant and important steps to improve the quality of White Island Pond. To date, Makepeace has:

- reduced phosphorous applications to a rate lower than the UMass recommendation of 20 pounds per acre (provided tissue test results indicated that phosphorus in the plants are being maintained within the adequate range);

- ceased fall fertilization;

- used slow-release, encapsulated phosphorus fertilizer on cranberry bogs;

- timed discharges of flood waters; and

- conducted periodic tissue testing of cranberry plants to determine if any adjustment of phosphorus application is warranted.
- begun taking Bog 3 out of production, and converting this area into a new tail water retention pond;

- begun redirecting irrigation return flows, except for winter flood water, Bog 1, Bog 2, Bog 4 and Bog 5 into the new retention pond; and

- planned for measuring flowed winter water (via estimation of acre feet) and metering pumped winter water, if feasible, to calculate the phosphorus load entering White Island Pond.

Makepeace has agreed that if in any year, the amount of irrigation return flow from Bog 1, Bog 2, Bog 4 and Bog 5 to the new retention pond exceeds the capacity of the new retention pond, then:

(i) water in excess of new retention pond capacity will be pumped to uplands, and

(ii) the following year, Makepeace will install a sprinkler pump in the new retention pond and excess new retention pond water can be used to irrigate the Makepeace White Island Pond bogs.

Makepeace is undertaking all of these steps to improve the pond as part of an innovative pilot project jointly sponsored by DEP, the Department of Food and Agriculture, the Cape Cod Cranberry Grower's Association, the UMass Cranberry Station, and Federal Furnace Cranberry Company.

Response: Your comments are noted.

Comment 25:

However, it is critically important that Makepeace be afforded the maximum flexibility to meet that standard – 9 kg/yr phosphorus for Makepeace – in a way that also best serves the needs of cranberry growers. Because of this need for flexibility, Makepeace asks the DEP clarify that the methods for implementation spelled out in the draft TMDL are recommended measures, rather than requirements. Specifically, Makepeace feels that the practices listed above will achieve the 9 kg/yr phosphorus standard without the need, for example, to limit annual water discharge to 3.5 feet/acre bog; to limit annual fertilizer applications to 10 lbs/acre phosphorus; or to impose a requirement that winter flood waters beneath newly formed ice be withdrawn within 10 days.

Response: As stated above, the TMDL is a technical evaluation that identifies needed reductions to meet water quality standards. In the context of the TMDL document, any BMPs, practices or other measure referred to as "required" are the types of actions MassDEP believes may be needed to meet the TMDL. The Best Management Practices included in the MOA – as partially referenced above in Makepeace's comment #25 - are expected to meet the TMDL requirements. If however, the TMDL target is not met or Water Quality Standards are not met, then the TMDL states that additional BMPs may be required at a future date.

Comment 26:

Finally, in supporting this draft TMDL, Makepeace stresses that while the TMDL may be appropriate for the particular facts and circumstances involved in White Island Pond, the TMDL cannot be used as a blanket precedent for dealing with phosphorus – or other nutrient – loads from other bogs into different water bodies.

The continued vitality of the cranberry industry is important not only to Makepeace, but also to the economy and culture of this region. We appreciate DEP's willingness to acknowledge cranberry farmers' unique challenges in the context of water resource protection, and we look forward to continuing to work with you to make the pilot program a success.

Response: Your comments are noted.

Comments of Wareham Board of Selectmen:

Comment 27:

White Island Pond TP (total phosphorous) levels have increased from 0.12mg/l to 0.52mg/l between 2000 and 2007 (east basin). According to this report, DEP recommends a target average TMDL for phosphorous at 0.019mg/l, yet the EPA has recommended TP levels for this Ecoregion (region XIV) to be 0.008mg/l. The DEP's recommendation is more than twice the recommendation that the federal government (EPA) set over twenty years ago. We ask the DEP to reconsider the TP levels that are set in this TMDL draft report of phosphorous for White Island Pond.

Response: For clarification, the White Island Pond surface concentrations average about 0.081mg/l and 0.034mg/l in the East and West basins respectively.

Please see the response to comment #2 regarding the EPA recommendations regarding TP concentrations. The target of 0.019mg/l represents a reduction of about 67% in surface concentrations and a 73% reduction in loading. To reach a level of 0.008mg/l would require an estimated 86% reduction in concentration and higher reductions in loadings. The economic impacts of implementing of such a plan would probably be too costly for the cranberry growers and the homeowners to bear and .may not be cost effective. If the TMDL target of 0.019 mg/l does not restore all uses to the pond within a reasonable time, then a reexamination of the TMDL can be considered.

Comment 28:
The report states that DEP will work with UMass Cranberry Station and the Cape Cod Cranberry Growers' Association to update recommended BMPs (best management practices) to ensure Water Quality Standards are met by using source reduction in the form and amounts of fertilizers, and improvements to irrigation and flood water usage over a period of years to evaluate the water quality response in the pond. These are the same recommendations that were given in the evaluation of the study of the 1970s. We respectfully request that the DEP use its authority to mandate BMPs and require substantive actions such as non-permeable tail water recovery ponds.

Response:
Please see the response to comment #11. Also additional types of tailwater recovery ponds and additional BMPs may be examined if the current MOA fails to meet the objectives. However, the use of non-permeable tailwater recovery ponds may not be practical in this case because of the volume of water that needs to be managed. Not only do the growers need to manage the water used for the cranberry bog operations, but also groundwater seepage and water from White Island Pond that flows back into the bog complex. In addition, by percolating through the ground, the water is naturally treated and phosphorus is attenuated by the under lying soils.

Comment 29:
Of the proposed recommendations, the one that is of utmost concern to the Wareham Board of Selectmen, especially in our capacity as sewer commissioners, is the recommendation of switching from a low ratio of N:P:K (nitrogen: phosphorous: potassium) to higher nitrogen fertilizers with proportionately less phosphorous. The DEP recommendation amounts to a 50 to 80% increase in nitrogen! The Town of Wareham completed a CWMP/SEIR for nitrogen less than ten years ago. Since that time, we have spent approximately $24 million to upgrade our Water Pollution Control Facility (to discharge nitrogen at a rate of 4ppm). Our residents have incurred nearly $11 million in betterments, with approximately another $20 million in projects to be built and billed over the next three years, all in an attempt to limit the town's nitrogen loading into the estuaries.

Response: The comment confuses the ratio of nitrogen to phosphorus in the fertilizer bag with the number of bags or total mass of fertilizers applied. MassDEP recommends a lower ratio of phosphorus, with a higher ratio of nitrogen, but the total amount of nitrogen applied is based not on the ratio, but on the soil tests that determine plant requirements for nitrogen. Thus fewer bags of fertilizer may be applied (and the same or less nitrogen mass of fertilizer applied) when using the higher N to P bags. No increase in nitrogen fertilizer rate per acre is suggested and no additional nitrogen loading to the estuaries is expected due to a change in the ratio recommended in this report. The goal is to decrease the amount of fertilizer to the point where it matches the needs of the crop and thus would minimize the off-site migration of either phosphorus or nitrogen.

Comment 30:
The Buzzards Bay Estuary Project's draft report on nitrogen recommends another WPCF upgrade (to a discharge rate of less than 3ppm) and a reduction of the current nitrogen load in our estuaries by 55%. The Buzzards Bay Estuary Project report holds the cranberry industry harmless, despite that, the discharge from the bogs are the second largest contributor to the excess nitrogen load.

Response: The White Island Pond phosphorus TMDL does not specify rates of nitrogen loading. Comments on nitrogen reduction are beyond the scope of this study and should be addressed during TMDL development associated with the Massachusetts Estuary Project.

Comment 31:
By the DEP recommending increasing nitrogen use on the cranberry bogs on one hand, and requiring the town to limit our nitrogen load on the other hand hardly seems fair to our residents. The cranberry industry, while very valuable to the region, has contributed to the destruction of the scallop / shell fishing industry that was a part of Wareham for over three hundred years. Again, non-permeable tail water recovery ponds, that allow the water to be used and reused, will not only protect the waters, but will allow the cranberry industry to contribute to solving both the phosphorous and nitrogen problems that have a detrimental effect on Wareham waterways and our economy.

Response: See comment and response number 28 and 29 above. No increase in nitrogen fertilizer rate is recommended. Non-permeable tailwater recovery ponds and additional BMPs may be examined if the current MOA fails to meet the objectives.

Comment 32:
The report suggests passing town by-laws to control development, address fertilizer use and discharges to waters within the town. Wareham has an open town meeting form of government and has been unable to address any issues with by-laws that the cranberry industry opposes, most recently, nitrogen limits. It is also our understanding that the town is unable to create by-laws that will affect current cranberry bogs; therefore, regardless of what by-laws we could possibly pass, they will not affect what is currently discharged into White Island Pond.

Response: The recommendations for bylaws were intended to limit lawn fertilizers, which the Town has the authority to do. This has been clarified in the final version.

Comment 33:
We feel it is environmentally irresponsible to ask the cranberry growers to monitor themselves and for the DEP to wait five years to see if any voluntary changes have worked. The phosphorous loads have more than quadrupled in seven years; in another five (even with the recommendations), they could double from the current levels, while the nitrogen load contribution from the bogs could increase 50 to 80%! We respectfully request the DEP reconsider its recommendations and take an aggressive, proactive approach by mandating tail water recover ponds immediately and an effective, independent monitoring program with milestones and measurements to ensure compliance.

Response: MassDEP is unaware of any study showing a quadrupling of loading to White Island Pond in the past 7 years. With implementation of the MOA we expect a reduction of 85% of phosphorus loading from the cranberry bogs to White Island Pond, not an increase. The MOA has an effective term of three years. MassDEP believes the management practices identified within the MOA will bring about an overall water quality improvements within White Island Pond. As stated above, MassDEP will monitor compliance with the MOA on an ongoing basis and can withdraw from the MOA at any time. As noted in response 29 above, no increase in nitrogen load is expected.

Comments of Dr. Carolyn DeMoranville, UMass Cranberry Experiment Station.

Comment 34:

pg. 25 lines 2-3. The reference to annual water usage of 8-11 acre feet of water in cranberry production is somewhat misleading. In the three years studied in the cited work, more than 4 feet of the total input of water into the bogs was rainfall. That rainfall was included in the estimated input water budget of 8-11 feet. Water export calculations assumed infiltration and evapotranspiration were the routes for a portion of the export. As presented in this document, one gets the impression that all of the 8-11 acre feet of usage originates from the surface waters taken from the pond and is then discharged back into those surface waters.

Response: This has been clarified in the final report.

Comment 35:
pg. 34 top paragraph and Table 4. I concur with setting the P standard for White Island Pond higher than that for deep kettle seepage ponds such as Ezekiel. In addition to White Island Pond being more shallow, it is a glacial outwash lake and as such historically, most likely had surface streamflow entering it in addition to groundwater seepage -- most likely though the wetland that were converted to cranberry bogs. As such it would be expected to have higher 'natural' P.

Response: The text was modified to address this comment.

Comment 36:

pg. 37 line 7-10. The reference to 'water conservation' to limit discharge to 3.5 acre feet is somewhat misleading. This volume approximates the minimum required for harvest and winter flooding of well-leveled bogs -- such volume is then discharged after harvest/winter. In the case of the WIP bogs, up-welling groundwater creates a semi-flow-through situation. It is those additional volumes of water that increase the total water discharged and it is those volumes that must be addressed to meet the TMDL requirements.

Response: The reference to 3.5 acre-feet and 0.05mg/l is simply a statement of the calculations regarding the amount of loading that could meet the TMDL target. As specified in the MOA the irrigation return flows, except for winter flood water, is not discharged to the pond, but is discharged to retention ponds and upland areas. It is expected that the winter flood, which is expected to be discharge to the pond according to the MOA, can be met with 3.5 acre-feet of water.

Comment 37:

Pg 37 lines 10-13. There is reference to a plot of P export vs. applied P fertilizer suggesting that exports are reduced with reduced fertilizer. The reader is referred to Appendix III. However, the appendix contains no such plot, but rather figures showing export vs. concentration in discharge water and fertilizer vs. yield.

Response: The reference has been changed in the final version.

Comment 38:

pg. 37 lines 22-25. This sentence seems to indicate that the target rate for phosphorus (P) should be 10 pounds per acre. This is not a standard recommendation, especially for hybrid cranberry cultivars. Further, if one were to target 10 pounds, it could easily be met using an 18-8-12 or 18-8-18 (the more current formulation) applied at rates sufficient to meet nitrogen needs of native cranberry cultivars. However, as more formulations with low P in the ratio become available it may be best to avoid referencing specific ratios and formulations but rather to recommend total application amounts so as to avoid implying that one specific product must be used.

Response: The sentence was modified to make it clear that this was used as an example.

Comment 39:

pg. 38 first paragraph. Much of this is fairly speculative and untested in cranberry settings. Some of these alternatives are proposed in upcoming research projects but I am not sure of the appropriateness of inclusion in this document, at least in this level of detail.

Response: The additional BMPs mentioned in the text, such as the use of aluminum to treat discharge waters, and the use of iron to bind phosphorus are all well documented in other settings, but have not been applied to cranberry bogs. We have modified the text to say additional testing may be required for application in cranberry bogs.

Comment 40:

pg. 38 Line 27-28. While the statement regarding zero phosphorus plots showing no deficiency after 6 years is accurate, this was one location in Wisconsin. Historically, P ratios in fertilizers used in cranberry production there were higher than those in fertilizers applied to Massachusetts bogs. There is also experimental evidence of yield decline in cranberries with zero P fertilizers. The important point is that P should be reduced in conjunction with monitoring of P levels in the cranberry tissue.

Response: The text was modified to say monitoring tissue P levels is recommended.

Comment 41:

pg. 41 last item in table. Based on the previous text, this refers to bylaws to control use of fertilizers on *non-agricultural* lands. This should clearly stated.

Response: The text was changed to make this clear.

Additional Comments of Dr. Carolyn DeMoranville, UMass Cranberry Experiment Station related to Appendix III Guidelines for Total Maximum Daily Loads of Phosphorus from Commercial Cranberry Bog Discharges in Massachusetts.

Comment 42:

pg. 57. Lines 4-5. Summarizing the literature to *establish* new Best Management Practices (BMPs) is not a common approach. BMPs should become established only after they have been demonstrated to be achievable and effective in field settings. Prior to that, they are only potentially useful practices.

Response: All Best Management Practices should be based both on a literature review and those should include field tests. Field tests have been conducted on low phosphorus fertilizer rates and they have been shown to be achievable and effective. The important point is that the BMPs must result in receiving waters meeting all applicable Water Quality Standards, and no BMP can be recommended that results in a violation of Water Quality Standards.

Comment 43:

pg. 57 line 9-10. Cranberries are unique in the seasonal flooding requirement. However, they are far from unique in requiring irrigation. As in the main document, the text seems to imply that water flowing out of cranberry bogs other than for flood discharges is due to excessive irrigation. In the case of WIP, it is primarily due to upwelling groundwater in the lowest-elevation sections of the bog systems. In some other instances (Howes and Teal, 1995), perennial surface streams flow through the bogs. In other, less common instances, outflow may be attributed to intense rain events such as summer storms. Often, the only significant flow is that associated with the movement of flood waters (DeMoranville and Howes, 2005).

Response: The text was changed to include rain and groundwater as sources.

Comment 44:

pg. 58 First line of text. The wording implies that the recommendation has changed. That is true in that we now recommend NO MORE than 20 lb/acre and encourage growers to use less than that with proper monitoring of tissue test response. It may be appropriate to include this explanation of how recommendations have changed.

Response: The text was changed to note that the BMPs are now under review by the University and by MassDEP.

Comment 45:

pg. 59 line 15-18. The Parent and Marchand study showed no response in yield on the selected beds; beds that were selected due to high soil P levels. This should not be taken to indicate that cranberries in Quebec, or elsewhere do not require P fertilizer. There is however, no question that the limit of 20 lb/acre is well supported (providing tissue P levels are in the normal range – 0.1 to 0.2%) and that there is evidence that lower rates may suffice, at least over the short term.

Response: The text clearly states that no increase in yields were noted with phosphorus additions. It is not clear why the these cranberry bogs studied in Quebec would require P fertilizer at this time.

Comment 46:

pg. 60 Second paragraph. Upland bogs on mineral soils are not the majority of Massachusetts bogs but do represent a significant number of acres. Further, recently renovated organic bogs, with added surface sand, may be more similar to these upland bogs than to the organic bogs in the study, depending on system hydrogeology. Averaging the 4 organic bogs in the study as the basis of predicting 'typical bogs' may be misleading particularly as many growers have been implementing reduced P fertilizer based on the information generated in the DeMoranville and Howes (2005) study. As growers in that study reduced P inputs, P export declined, in one instance to similar levels as that in the upland soils bogs.

Response: The text referring to these as ‘typical’ was removed.

Comment 47:

pg. 60 Second paragraph. The regression relationship is interesting but limited to certain bog types and water management.

Response: The types of bogs used were clarified and are explained in the text.

Comment 48:

pg. 60 Second paragraph. In the last sentence, the research showed increased yields on those bogs but was not designed to ascertain a cause-effect relationship, that is, there is no evidence that the fertilizer reduction *led* to the increased crop.

Response: The text was changed to say yields increased with low phosphorus fertilizers.

Comment 49:

pg. 60 Last paragraph. While it is true that based on the average of the bogs in the DeMoranville and Howes (2005) study, P export was greater than that from native wetlands, a closer examination of the data shows that after accounting for the P load in the incoming waters, net export could be quite low and even negative. This information should be included as it is relevant to the following section 'Lake Nutrient Budgets'.

Response: Both the net and gross exports are reported in the paragraph. Text was added to explain the difference between net and gross.

Comment 50:

pg. 62 last 2 lines. Extensive BMPs may be required in some instances but the DeMoranville and Howes (2005) study showed P concentrations approaching 0.1 mg/l achieved by decreasing P fertilizer applications, with no additional BMP implementation. Perhaps, this should read *may be needed.*

Response: The text was changed to indicate they may be required.

Comment 51:

Page 63. BMPs should include target P rates (per acre per season) but should not prescribe actual ratios or formulations since these could be interpreted to exclude other materials that achieve the target rate. On upland bogs, based on the study, it may be possible to achieve goals without reduction of P to less than 20 lb/acre. Again this will be site specific.

Response: The text was changed to say some combination of BMPs may be required and the specific fertilizer ratios are clearly stated as an example.

Comment 52:

Pg 63, line 9. Indicating that a BMP must be followed is implying that BMPs are regulatory. While there may be merit in such an approach in specific non-compliant instances, I do not feel that this approach is appropriate in a guidance document such as this Appendix. Again, prescriptive ratios or formulations may not be the best approach.

Response: The text was changed to say that the BMPs may be required in some circumstances and when deemed necessary to meet the goals of the TMDL..

Comment 53:

Pg 63, last paragraph. Several scenarios for achieving various water quality objectives are given. It would be valuable to have examples (reusing pond water or using upstream source water and discharging to a pond) for discharge of 5 acre-feet, in my estimation a good approximation for a bog system where only harvest and winter floods are discharged (and other flow either doesn't exist or is recycled away from the receiving sensitive body). Such examples could be very valuable as guidance in designing management practice choices to meet site-specific water quality goals.

Response: Your example was added.

Comments of James M. Sullivan, President White Island Pond Conservation Alliance

Comment 54:
We are very pleased with the TMDL and the agreement with the Cranberry Association. Continued testing and monitoring is the only way that the pond can be rehabilitated. We feel that testing of the bogs effluent should be done by an independent laboratory. This lab should be tasked with the COLLECTION and TESTING of the water samples. These results can then be sent to the DEP for evaluation. The White Island Pond Conservation Alliance Inc will also continue its water sampling and testing and will forward all results to the DEP. As I know you are aware the pond is currently experiencing a horrendous algae bloom (equal to last springs). But if we all remain vigilante I am confident that this problem will be corrected.

Response: According to the MOA and the recently awarded 319 grant, the University of Massachusetts Cranberry Experiment Station will be in charge of sampling and the samples will be sent to be tested at the University SMAST lab. MassDEP is also collecting samples from the lake to be compared to both the University results and with the results provided by the White Island Pond Conservation Alliance.

Comments of Barry Cosgrove for the Blackmore Pond Homeowners Association

Comment 55:
The TMDL has no enforcement mechanism. Therefore, what assurances can be provided that the Tasks and Responsibilities described are to be performed (by the growers in particular)?

Response: TMDLs by themselves are not enforcement documents, they are technical reports that evaluate the problem and recommend solutions where known. The implementation of the TMDL in this case is being conducted through the MOA with the Cape Cod Cranberry Growers Association and with the University of Massachusetts Cranberry Station. If MassDEP determines there are violations of the conditions of the MOA we have the option to withdraw from the agreement and take action as needed.

As noted above, the growers have already started to implement practices consistent with the terms of the MOA.

Comment 56:
The referenced Memorandum of Understanding (MOA) also notes that compliance with the TDML is expected, yet it can be cancelled upon 30 days notice. How then is there to be an assurance of any performance?

Response: If the MOA is canceled by any party then, after 30 days, MassDEP can take action within its regulatory authority to maintain compliance with the Water Quality Standards.

Comment 57:
It appears that grant funds will be used for part of the scope of this project. Is it appropriate to use taxpayer funding for such a project and if so, at what point and under what circumstances would it no longer be appropriate to use taxpayer funding in connection with improving the health of the waterways or for remediation purposes?

Response: Massachusetts has a long history of using grants and low interest loans to support efforts to improve water quality in the Commonwealth. In many cases the availability of financial assistance is a major factor behind successful efforts to protect and improve water quality in Massachusetts. Decisions on funding are generally made on a case-by-case basis.

Comment 58:
Why it is the remediation of pollution caused by the cranberry operations is being financed by taxpayers at all?

Response: The 319 grant program is designated to be used to remedy nonpoint sources of pollution. Irrigation return flows are considered nonpoint sources.

Comment 59:
And, what if the grant is not approved or is insufficient to finance the activities called for under the TMDL? Should not the identified responsible parties be obligated to finance the work called for under the TMDL and the MA from internally generated funds?

Response: MassDEP believes the measures being implemented in association with the MOA, some of which are supported by 319 grant funding ,have the potential to significantly improve water quality in White Island Pond and meet the TMDL. If water quality does not satisfactorily improve or the TMDL is not met as a result of efforts in association with the MOA, MassDEP will explore its other regulatory options to require actions whether there is availability of additional funding or not.

Comment 60:
The MOA and the TMDL place heavy responsibility and reliance on the Cranberry Extension Station for certain testing and test reporting. It is noteworthy that this same agency failed in the performance of similar tasks in connection with its work at Blackmore Pond. Indeed, SMAST has reported that in some past cases the sample collection, storage and delivery work performed by the Extension Station was very poor. What safeguards are in place to double check the Extension Stations' performance?

Response: Although there were some issues with late delivery of data and reports these issues were resolved. In the current grant the scope of work will include provisions to ensure the timely delivery of data. In addition, a Quality Assurance Project Plan (QAPP) which includes quality assurance testing is required for this grant.

Comment 61:
The identified goal for White Island Pond is 19 ppb. Yet the EPA calls for 8 ppb for ponds such as White Island. Why? The explanation in the draft to date is not scientifically compelling.

Response: Please see response to comment #2 and #27. The EPA recommendation for 0.008 mg/l (8ppb) for total phosphorus is largely based on lakes sampled in other states. A blanket recommendation of 0.008mg/l for all lakes in the state is not appropriate. The law allows MassDEP to establish water quality standards, including site specific standards and targets for TMDLs based on the conditions at the site. We have provided detailed information to support the TMDL target, while the EPA blanket recommendation is not specific to the pond.

Comment 62:
The Cape Cod Pond and Lake Stewards (PALS) water quality snapshot in 2001, which was supported by SMAST and the Cape Cod Commission, collected nutrient samples from 195 ponds. Using this data, the Cape Cod Commission applied the EPA nutrient criteria procedures and determined criteria for total phosphorus (see Eichner and others, 2003). The EPA nutrient criteria guidance defines two approaches to determining nutrient criteria: one based on so-called "reference" or relatively pristine ponds and another based on all available pond data regardless of water quality conditions. The respective standards based on the surface water samples from the Cape Cod dataset are total phosphorus, 7.5 ppb and 10 ppb (Eichner and others, 2003). Hence, why 19 ppb for White Island Pond?

Response: The EPA guidance does allow the use of statistical 'frequency approach' of reference lakes and all lakes, but it also allows, and in fact encourages states to use other, more scientifically defensible approaches including site specific data to establish nutrient criteria for the states surface water. MassDEP is in the process of developing these nutrient criteria. Also, not all lakes are equal, the lakes and soils on the Cape can be significantly different in other parts of the state. It is for this reason that we used ecoregion data as the basis of our target setting process.

Comment 63:
The MOA makes reference to the importance and appropriateness of water measuring devices in connection with the quantity of water being measured with the testing protocols. Mischief proof, low cost and accurate meters are imperative. Why then is metering not compulsory as part of this project?

Response: The MOA specifies that when appropriate, pump meters will be used. In some cases, flow meters are difficult and unreliable to use in ditches where flows can be in either direction and may be unrelated to water depth, thus a compulsory use of meters may not be the best approach.

Comment 64:
The level of phosphorous attributable to septic systems around White Island Pond was calculated without regard to the fact that a material number of these homes are occupied for seasonal use

only. Why was this unambiguously important metric not considered? Does not the failure to consider this fact overstate materially the quantity of phosphorous estimated to be attributable to the septic tanks?

Response: Septic system inputs were a small portion of the total load even assuming all homes are occupied year round. Moreover, given the uncertainty of the septic system loading rate per household, it was not deemed necessary nor cost effective to conduct a door-to-door survey to determine seasonal occupancy.

Comment 65:
The TMDL and MOA make reference to Chapter 91 and other laws. Future enforcement action relative to Chapter 91 violations and other laws are only deferred for now, correct?

Response: Enforcement actions will be deferred as specified in the MOA as follows:
For the term of this MOA, MassDEP agrees to extend enforcement forbearance to the Pilot Program Participants with respect to their compliance with Massachusetts General Laws Chapter 21 and Chapter 91 and 314 CMR 4.00 and 310 CMR 9.00 provided that (1) the Pilot Program Participants fully comply with the terms and conditions of the Pilot Program and (2) the implementation of this MOA does not result in a significant and/or immediate threat to public health, safety, welfare or the environment. This paragraph shall not preclude MassDEP from investigating complaints it receives regarding a Pilot Program Participant, nor from responding with appropriate enforcement to evidence that the Pilot Program Participant may have violated MassDEP's regulations or otherwise created a significant and/or immediate threat to public health, safety, welfare or the environment. MassDEP agrees to work cooperatively with DAR to provide compliance assistance to Pilot Program Participants prior to undertaking any enforcement action.

Comment 66:
All of the data generated (including the identified quarterly reports) in connection with the MOA and the TMDL will be made publically available, correct?

Response:
The data generated and submitted to MassDEP as described in the MOA and/or data otherwise submitted to MassDEP as part of 319 grant projects and/or TMDL evaluations is public information and can be reviewed by the public upon request.

Comment 67:
Who, specifically, will be conducting the water discharge tests?

Response: The growers will be reporting discharge volumes and these will be checked by the UMass Cranberry Station. The UMass Cranberry Station staff will be collecting water samples . The actual nutrient testing is planned to be conducted by the SMAST lab.

Comment 68:

What safeguards are in place to assure that the required monitoring of the water discharges into White Island Pond (in particular) are being conducted properly?

Response: Quarterly reports will be prepared by the UMass Cranberry Station and the Cape Cod Cranberry Growers Association. Results will be compared to results from samples collected by MassDEP staff and by the White Island Pond Conservation Alliance.

Comment 69:
Is it reasonable to assign this discharge testing to the growers? (Imagine if Major League baseball assigned its drug testing protocol to the players themselves!)

Response: In nearly all cases where discharge permits are issued to towns and industries for wastewater discharges MassDEP assigns the responsibility of testing to the permittee. MassDEP may conduct testing to ensure reliability of the data and performs site inspections and analytical data review. In this case, the sampling is not assigned to the growers; it is assigned to UMass, thus providing this project with a higher level of assurance. Additional testing of the water will be done by MassDEP and others as noted above.

Comment 70:
Will backup tests will be performed to verify this testing?

Response: Yes, see comments 68 and 69 and responses above.

Comment 71:
What is the meaning of the term "emergency discharges" to White Island Pond? Who determines if an emergency exists? Who verifies this circumstance (if any)?

Response: The term is not defined in the MOA, however any discharge declared by the growers as an emergency will be reviewed by MassDEP.

Comment 72:
Following the comment period, will all questions and comments and responses thereto be made publically available?

Response: Yes, with the exception of minor editorial or spelling corrections, all comments and responses will be included in the final TMDL.

Comment 73:
Will a second draft TMDL be issued before the Final TMDL document is issued?

Response: No. After the comment period is closed the draft is modified as needed to address the response to comments and the Final TMDL is sent to EPA for approval. Once the Final is approved the Final TMDL will be posted on the MassDEP website and the draft will be removed.

Comment 74:
Will any/all EPA comments/changes to the TMDL also be subject to an additional comment period?

Response: No.

Comments of Edward J. Pacewicz, Chairman,Wareham Clean Water Committee

Comment 75:

Comment: Test data from 1976-1978 identified a problem with phosphorous loading. The same recommendations issued in 1980 for cranberry bogs, "that owners reevaluate the application of fertilizer and irrigation", are being recommended in 2009. Total phosphorous concentrations in the cranberry bog waters were higher in the 2007 survey as compared to the 1970's results. As the above data shows, the phosphorous loading from cranberry bogs has increased over the past 29 years. Obviously, other methods such as tail water recovery ponds must be implemented at this time to manage the phosphorous loading coming from cranberry bogs if we expect to have any positive effect on White Island Pond.

Response: While the earlier report recommended that the growers reevaluate their practices, the current report provides a numeric loading target that the growers must meet. The growers are being specifically targeted for a large reduction in loading and the BMPs listed in the MOA are expected to meet the target. If measures currently being implemented in association with the MOA are not effective, MassDEP will evaluate other actions – possibly including expanded tailwater recovery ponds – that might be needed to meet the TMDL and water quality goals.

Comment 76:

Comment: The tmdl (0.019 mg/l) for phosphorous is set, in this report, at more than twice the level suggested by the united states environmental protection agency (0.008 mg/l). The EPA Ecoregion XIV report was done in December, 2001 and the USEPA Gold Book report was done in 1987. Why are we using a 22 year old standard when we have a standard set less than 8 years ago? There is very little justification in the report to increase the targeted level of phosphorous. Table 4 - other seepage lakes in southeastern Massachusetts, shows six (6) lakes with an average TP mg/l (median surface) of 0.009 mg/l. This figure is much closer to the suggested EPA figure of 0.008 mg/l than the TMDL figure of 0.019mg/l. Don't we want white island pond to be as clean as other similar ponds in southeast Massachusetts? The standard should be changed to the EPA suggested standard of 0.008mg/l. This standard can be achieved if all discharge from cranberry bogs into white island pond is stopped.

Response: Please see response to comment #2, #27 and #61. The EPA number of 0.008mg/l is not a standard . It should be noted that White Island Pond is shallower than most lakes listed in Table 4. Also, since the lake is dammed, it has flooded terrestrial soils and historically may have had some surface water inputs from wetlands prior to the construction of the bogs. All of these factors suggest a higher TP target of 0.019mg/l is appropriate.

Comment 77:

Comments: on page 17 of this TMDL draft report, a reference is made to an early study (1976-1978) of white island pond. This report recommended that cranberry bog owners reevaluate the application of fertilizers and irrigation (Whittaker, 1980). Thirty years later, on page 37, this report recommends the same thing, reduction in the form and amounts of fertilizers applied and improvements to irrigation and flood water usage which will be implemented over a period of years to evaluate the water quality response in the lake. Thirty years is long enough to evaluate the water quality response in the lake. It is time for intensive BMPs, such as non-permeable tail water recovery ponds, to be implemented immediately. All discharge from cranberry bogs into white island pond must be stopped now.

Response: See response to comment #28 and #75 above.

Comment 78: Comments: this report recommends increasing the amount of nitrogen in fertilizer while reducing the amount of phosphorus in the fertilizer. White island pond and the cranberry bogs referenced in this report are in the watershed of the Wareham River estuary system. The Massachusetts estuaries project report, titled, "Linked watershed-embayment model to determine critical nitrogen loading thresholds for the Wareham River, Broad Marsh and Mark's Cove embayment system, Wareham Massachusetts", draft report – June 2007, has determined that the Wareham river estuary system is severely overloaded with nitrogen. This report recommends increasing the amount of nitrogen being used in the identified cranberry bogs which will exacerbate the nitrogen overloading in the Wareham river estuary system. The remedy of this problem should not cause another problem. How would this recommendation assist in reducing the amount of nitrogen currently being input by cranberry bogs into the Wareham river estuary system? This issue can be resolved by requiring the cranberry bogs to use manmade non-permeable tail water recovery ponds. This would keep the discharge out of white island pond and out of the ground water which could affect other bodies of water.

Response: Please see response to comment #29. The recommendation was not to increase the amount of nitrogen applied rather it was to seek fertilizer formulations with a higher ratio of nitrogen to phosphorus. The goal is to decrease the "load" of phosphorus to the lake. Also of note is that another goal is to try to match the fertilizer use to that needed for the crop and decrease the amount of over-fertilization that may be occurring of both nitrogen and phosphorus. Thus it is not the intent of this TMDL to encourage application of nitrogen fertilizers at a higher rate.

Comment 79:
Comments: immediate action must be taken to stop the discharge from the cranberry bogs from entering white island pond. Waiting 5 years for any action at this point is not productive.

Response: See comments and responses #s 4, 13, 33, 59, and 75 above.

Comment 80:

PAGE 40 – "Additional town bylaws to address fertilizer use and discharges to waters within the town may be required." Comments: please provide examples of bylaws that would control the discharge of cranberry bogs into waters within the town.

Response: Town bylaws regarding fertilizer use have been restricted to non-agricultural usage. Webster Massachusetts provides one example where a by-law was recently passed placing a ban on phosphorus lawn fertilizers (http://www.articlearchives.com/government-public-administration/elections-politics/513475-1.html).

Comment 80: Comments: An independent consulting firm funded by the cranberry growers will provide MassDEP, the White Island Homeowers Association and the cranberry growers with scientific information showing that the TMDL is being met. I do not consider the UMass Cranberry Station as being independent nor unbiased.

Response: Your comments are noted.

Comment 81: Comments: please provide examples of bylaws that control development, erosion from all lands, driveways and control fertilizer use by cranberry bog owners.

Response: Examples of common environmental bylaws are available on the website http://www.umass.edu/masscptc/examplebylaws.html . Also see comment and response #80 above.

Comment 82:

Page 42 – "MONITORING – Continued monitoring of the lake by the local lake association should document changes in transparency and frequency of blue-green algal blooms. Additional monitoring of total phosphorous concentrations by local volunteer groups is encouraged." Comments: an independent consulting firm funded by the cranberry growers will provide MassDEP, the White Island Homeowers Association and the cranberry growers with scientific information and data regarding the results of monitoring white island pond.

Response: Your comments are noted.

Comment 83: PAGE 63 – "If discharges are to a sensitive clear water seepage bog (pond) the additional BMPS recommended by DeMoranville and Howes (2005) of installing tail water recover or other physical barriers or filtration may be required to meet water quality standards." Comments: non-permeable tailwater recovery ponds should be implemented immediately to stop all discharge from the cranberry bogs into white island pond.

Response: See comments and responses #s 28 and 75 above.

Comments of Thomas Belcher, Plymouth MA:

Comment 84: On page 24 the report indicates "The East Basin has an outlet which flows south through a different set of cranberry bogs. Those bogs are presumed to discharge waters to the south away from the lake and are not discussed in this report." This is a rather large set of bogs and can siphon huge amounts of recharge water from the pond and although it is never discharged back into the pond, do you think the withdrawal of all this potential recharge water, lowering the pond's water levels, leaving less water for the sun to warm faster, and less water to absorb the nutrient levels, could actually be having a negative impact on the water quality?

Response: No siphoning action was observed at the dam. The dam acts to keep water levels relatively higher in the pond than downstream. If the practices outlined in the MOA do not result in achieving the TMDL, this option could be considered in the future however further evaluation would need to be conducted to determine the potential impact on private wells adjacent to the pond. .

The impact of increased temperature and less dilution water is expected to be minor compared to the benefit of lower water levels resulting in lower groundwater levels near the lake and less infiltration of groundwater into the Federal Furnace and Makepeace bogs upstream. With less infiltration, less pumping of excess water out of the bog ditches would be expected, resulting in fewer discharges to White Island Pond. Such a step would only be taken following the appropriate review of impacts.

Comment 85:

On page 26 the report provides a diagram of the groundwater contributing area, while on page 29 its stated "First, the NPSLAKE model septic system phosphorus export coefficient of 0.5 kg/house/year was multiplied by the 224 homes located within 100 m of the White Island Pond shoreline to estimate 112 kg P/year for septic systems inputs. This initial estimate appears to be too high for the area based on monitoring results for nearby Ezekiel Pond located about 200 yards southeast of White Island." My question is, do you think the only homes septic systems actually contributing nutrients into the pond are the homes within 100 m of the pond which are located within the groundwater contributing area diagram on 26? If you overlay that diagram on the Arial photo provided on page 1 of the draft report, the home totals seem to be drastically reduced. This is because virtually all of that recharge area is forest and agricultural land. Of those homes within 100 m of the pond located in this contributing area, many are vacant family cottages that haven't been occupied in years and the ones that are have very limited usage as the owners are elderly and/or summer homes which are used only a few weekends per year.

Response: Phosphorus from septic systems is not expected to move great distances through groundwater. Also see comments and responses to #12 and #64 above.

Comment 86:

On page 27 the report discusses “that Closed bogs, such as those studied by the UMass Cranberry Station (DeMoranville and Howes, 2005), typically discharge significant amounts of water in the days following the fall harvest floods, the winter frost prevention floods or the occasional pest control floods in the spring. Given the close proximity of these bogs, do you think it would also help if they coordinated and shared the same water when flooding for pest control and harvesting? In the absent of a tail water recovery/reuse system, it just seems another possible option would be that if only one bog owner flooded their bogs for one or two weeks for pest control or harvesting, that rather than discharge that water back into the pond, it could be diverted to the other bog owner for the same purpose, ultimately limiting the volume of water taken from the pond while somewhat controlling the discharge, as then only one owner would be withdrawing, while the other owner would be discharging that same (first owners) water back into the pond, rather than both, ultimately limiting the amount of nutrients reaching the pond as a result of this, verses their current process. It might also be helpful to the pond if this process was implemented within the series of bogs of each owner; it appears from the photo on page one that each owner manages about four separate bogs within their series of canals and bogs, located on the northern shore of the eastern basin of the pond. So if they flood two bogs at a time for pest control and harvesting, rather than all four (or even eight for both owners) at once and then divert that water from the fist two to their next two, and from there, to the other owners first two and so on… I have to believe this process would greatly reduce the nutrient levels of the pond and help keep the water levels higher, cooler, and better able to absorb the nutrients which will ultimately be discharged once all bogs received the proper pest control and harvesting and I don’t see how that would be a big impact for the owners. Obviously winter frost prevention would still need to done, but I would think this type of reuse and coordination during pest control and harvesting would have to help the pond. Obviously a tail water recovery and reuse system would be better, but this may help in the event that never happens.

Response: The growers and MassDEP are aware of the benefits of sequential flooding of sections of bogs to reuse the flood waters and reduce the total amount of water required. The growers already use sequential flooding in many cases. In some cases pests and diseases may be transmitted with floodwaters to other bogs and this must also be considered.

Comment 87: I was also wondering if you think the final report would include a recommendation section which might be helpful in addressing the problems identified in this report?

Response: The recommendations are available in the implementation section of the report and in the appendix to the report.

Comment 88: Recent data suggests a larger sediment source and proportionately smaller external sources.

Response: Although 2009 indicated a potential for a larger sediment source this was apparently an unusual year hydrologically. Nevertheless, the 2009 data were used as a worst case scenario to reallocate more phosphorus to a sediment source and proportionately less to current cranberry bog discharges. In any case, the phosphorus in the sediments is attributable to historically high external phosphorus inputs to the lake and the final target allocations are not significantly changed because the target TMDL load and target phosphorus concentration did not change.