Assabet River
Total Maximum Daily Load
for
Total Phosphorus

Report Number: MA82B-01-2004-01

Control Number CN 201.0

COMMONWEALTH OF MASSACHUSETTS
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Please request Report Number: MA82B-01-2004-01; Control Number CN 201.0

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Front Cover
Ben Smith Impoundment showing duckweed; Free-flowing Assabet upstream of Ben Smith

Assabet River
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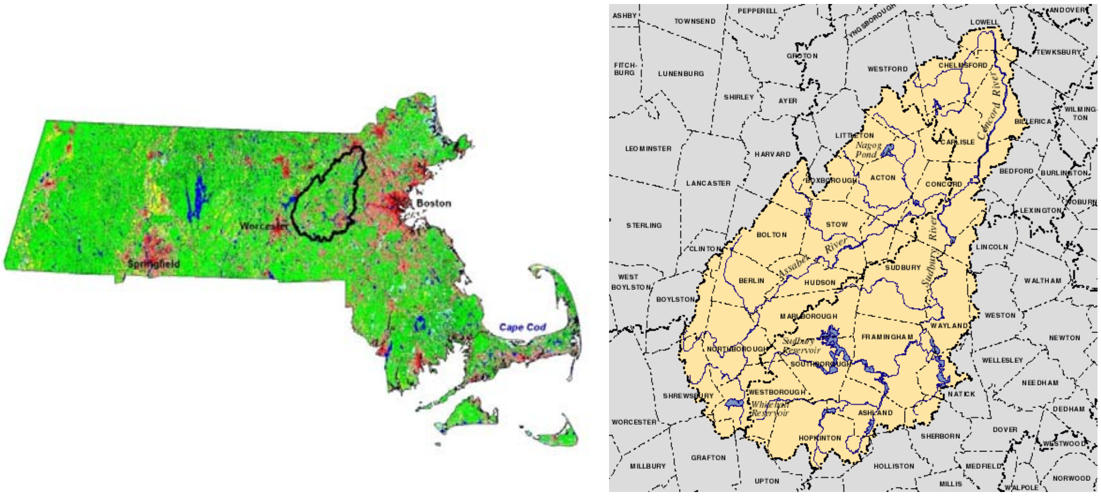
SuAsCo Watershed, Massachusetts

DEP, DWM TMDL Report MA82B-01-2004-01
Control Number CN 201.0



Location of SuAsCo Watershed, and Assabet River in Massachusetts.

Key Feature:	Total phosphorus TMDL for an effluent-dominated, impounded river.
Location:	Towns of Westborough, MA to Concord, MA - EPA Region 1; and surrounding watershed; Ecoregion XIV, subregion 59
Scope/ Size:	Watershed 174 mi^2 (111542 acres), Length Mainstem 31.8 miles
Land Uses (MassGIS 1990-91)**:**	Forested 52.7%, Urban 10.5%, Rural Residential 13.0%, Open 12.8%, Commercial 5.0%, Wetland 3.5%, Open Water 2.5%
303d listing:	Nutrients (Code 0900) 7 segments; Organic Enrichment and Low Dissolved Oxygen (Code 1200) 6 segments; Noxious Aquatic Plants (Code 2200) 1 segment
Data Sources:	ENSR International, Inc., Organization for the Assabet River (OAR), and Massachusetts Department of Environmental Protection/Division of Watershed Management.
Data Evaluation:	HSPF 10 model, Massachusetts Water Quality Standards, USEPA Nutrient Criteria Guidance, Weight of Evidence
Monitoring Plan:	Detailed monitoring plan to be developed
Control Measures:	Phosphorus limits implemented via adaptive management and NPDES permits; phosphorus remediation in sediments; possible dam removal; macrophyte management; Watershed BMPs

Executive Summary

The Massachusetts Department of Environmental Protection (DEP) is responsible for monitoring the waters of the Commonwealth, identifying those waters that are impaired, and developing a plan to bring them into compliance with the Massachusetts Water Quality Standards (314 CMR 4.0). The list of impaired waters, formerly known as the "303d list" and now as "Category 5 of the Integrated List", identifies river, lake, and coastal waters not meeting standards and the reasons for impairment.

Once a water body is identified as impaired, DEP is required by the Federal Clean Water Act to develop essentially 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, including a margin of safety, that can be discharged to a specific water body while maintaining water quality standards for designated uses, and outlining a plan to meet that goal.

This report presents a TMDL for the nutrient phosphorus as Total Phosphorus for the Assabet River in the SuAsCo (Sudbury, Assabet, and Concord) Watershed. The Assabet River is an effluent dominated stream, receiving the treated wastewater discharges from four major municipal publicly owned treatment works (POTWs) and three minor facilities. Frequently impounded by nine dams (see Appendix for list), it flows northeasterly from Westborough to Concord as a subwatershed in the Concord River Watershed. The Assabet River joins with the Sudbury River in Concord to form the Concord River which discharges into the Merrimack River in Lowell.

The Assabet River is designated as a Class B water under the Massachusetts water quality standards [314 CMR 4.05(3)b]. Class B waters are designated as capable of providing and supporting habitat for fish and other aquatic wildlife, and for primary and secondary contact recreation. The goal for the Assabet River is to achieve water quality standards as defined in Massachusetts 314 CMR 4.0. The water quality standards provide numerical and narrative criteria to meet designated uses.

The Assabet River is listed on the 1998 (and all previous versions) Massachusetts 303d list and the 2002 Massachusetts Integrated List of Waters as impaired primarily for Nutrients and for Organic Enrichment/Low Dissolved Oxygen. These pollutants and stressors are indicators of a nutrient enriched, or eutrophied, system. In freshwater systems the primary nutrient known to accelerate eutrophication is phosphorus. Therefore, in order to prevent further degradation in water quality and to ensure that the Assabet River meets state water quality standards, a Total Maximum Daily Load for total phosphorus was determined which requires decreased loadings from POTWs and from certain non-point sources, principally sediment phosphorus flux[1], and outlines corrective actions to achieve that goal. This TMDL has been developed with special emphasis on reducing the extent of nuisance macrophyte growth, meeting minimum dissolved

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[1] sediment phosphorus flux is the exchange of phosphorus either from sediments into overlying water or from the water column to the sediment. Phosphorus released from the sediment to the water column is readily available for plant growth.

oxygen criteria, reducing extreme diurnal dissolved oxygen fluctuations and excessive dissolved oxygen supersaturation, and reducing ambient total phosphorus concentrations.

The TMDL is based on data collected in 1999 and 2000. These data were analyzed to determine the extent of eutrophication, quantify the sources of phosphorus in the Assabet River, and construct a dynamic water quality model using EPA's HSPF model, under a contract to ENSR International, Inc. (ENSR), to evaluate potential control options. The HSPF model and results were developed and analyzed by ENSR and were reviewed in numerous open meetings by DEP, EPA, OAR (Organization for the Assabet River) and other stakeholder groups, the various consultants comprising the Assabet Consortium, municipal officials and employees, and others.

A field investigation of the Assabet River system was conducted by ENSR (ENSR 2001) under contract to the US Army Corps of Engineers and the Massachusetts Department of Environmental Protection. Surveys were conducted from July 1999 through October 2000 and a review of historical water quality studies was performed. The field investigation consisted of measurements of the hydrology, water quality, and aquatic vegetation of the Assabet River during 13 surveys. The goal of the field investigation was to document and quantify the presence of eutrophic conditions and associated characteristics in the Assabet River. Nutrient loadings and dynamics in the Assabet River were a primary focus of the investigation. The study also focused on characterizing the plants and algae of the Assabet River and the interrelationship between nutrients and plant production in the system. The field investigation concluded that the Assabet River receives an excess of the nutrients phosphorus and nitrogen resulting in nutrient saturation and excessive growth of aquatic vegetation. Summer-time minimum dissolved oxygen concentration measurements in the Assabet River were frequently below the water quality standard of 5.0 mg/l. Summer-time vegetation densities in the Assabet River were observed to be at levels associated with impairment of water quality and designated uses, such as primary and secondary recreation and aesthetics.

The evaluation of nutrient loadings during 6 intensive field surveys found that point sources contributed the majority of nutrient loadings to the Assabet River during most surveys. Point sources were found to be the dominant source of biologically available phosphorus (i.e., ortho-phosphorus) during all 6 surveys representing 88% to 98% of the overall available phosphorus[1] load. The study also identified that about 90% of the point source loading is in the dissolved form that is available for direct uptake by the plant community. If not taken up by plants, the dissolved phosphorus will pass through the system and not accumulate. As a result, it is assumed that non-summer time POTW discharges during other seasons and particularly high flow months will not be retained in the system for use during the growing season. Therefore, only seasonal phosphorus removal at the POTWs is warranted and effluents limits for total phosphorus will be applicable from April 1 through October 31; during the non-growing season, November 1 – March 31, effluent limits for phosphorus will not be in effect; however, due to concerns that

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[1] Total phosphorus is all of the phosphorus in a sample. Ortho-phosphorus (as used in this document) is phosphorus readily available for plant growth and is considered to be all of the phosphorus that passes through a prescribed sized filter. Hence, it is also referred to as dissolved P. Particulate P is phosphorus that is in the material that remains on the filter and generally is calculated by subtracting the filtered P from the total P.

The TMDL is based on total P because at the low concentration required by the TMDL, it is expected that all of the P will be dissolved and readily available or transformable for plants to use for growth.

particulate phosphorus, if discharged, may potentially settle in downstream impoundments during this timeframe, the POTWs will be required to optimize their treatment process to remove particulate phosphorus and conduct effluent monitoring for both total and dissolved phosphorus to support future permitting decisions.

ENSR (ENSR, 2001) summarized the details of the results of the loading analysis as follows:

> “Total nutrient loads from all significant sources to the Assabet River for four key nutrient constituents during the 6 surveys ranged as follows:
>
> - Ortho-phosphorus loadings: 52 to 319 lbs/day
> - Total Phosphorus loadings: 66 to 1,390 lbs/day
> - Nitrate loadings: 982 to 2,250 lbs/day
> - Total Nitrogen loadings: 1,190 to 3,850 lbs/day
>
> Point sources contributed a majority of all four nutrient constituents evaluated during 4 of the 6 surveys, including three summer surveys (July 1999, August 2000, and September 2000) and a winter survey (February 2000), with the following point source percentage contributions:
>
> - Ortho-phosphorus: 97% to 98%,
> - Total phosphorus: 82% to 97%
> - Nitrate: 91% to 99%
> - Total Nitrogen: 88% to 97%
>
> Non-point sources were observed to contribute the majority of total phosphorus and total nitrogen during 2 of the 6 surveys. These two surveys were both conducted during wet-weather events in March 2000 (on March 16 and on March 27) and corresponded with relatively large stream flows (375 cfs and 250 cfs). During the March 2000 wet-weather surveys, the largest stream flows and some of the largest nutrient loadings of the 6 water quality surveys were observed. During the two high-flow, wet-weather surveys, the point sources were observed to contribute the following percent contribution of the overall loading:
>
> - Ortho-phosphorus: 88% and 96%
> - Total Phosphorus: 23% and 48%
> - Nitrate: 41% and 59%
> - Total Nitrogen: 31% and 40%”

Field measurements in three impoundments indicated that sediment phosphorus flux was the principal non-point source during summertime low flow periods.

The data collected was then used by ENSR to develop a watershed and water quality model of the Assabet River using the HSPF v10 application. After calibration and validation, the model was used to evaluate multiple scenarios varying point (POTW phosphorus concentrations and flows) and non-point (principally, sediment phosphorus flux) sources. Output from the runs was compared to baseline conditions, which approximated 7Q10, which were observed in the field during July 1999. Several water quality indicators were then chosen by the modeling group to determine system response to reductions in phosphorus inputs. Since the state water quality standards provide numeric criteria for only minimum dissolved oxygen, additional indicators were also identified to evaluate impacts related to eutrophication. The indicators chosen include total biomass, duration of supersaturation of dissolved oxygen, and minimum concentration of dissolved oxygen. Ambient total phosphorus concentrations were also output and compared to USEPA guidance for suggested concentrations in flowing and impounded waters. With the exception of the minimum dissolved oxygen criteria that, had to be met throughout the system, the remaining indicators were evaluated based on a "weight of evidence" approach rather than on an individual basis.

Based on the modeling, best professional judgment, and weight of evidence it was determined that a combination of point source reductions and sediment remediation are necessary to reduce eutrophication and restore designated uses in the Assabet River.

To achieve the water quality goals embodied in this TMDL, stringent control of point source discharges of phosphorus from POTWs which discharge to the Assabet River will be needed in combination with a 90% reduction of sediment phosphorus loads. The TMDL for meeting the water quality objectives, including a margin of safety, is removal of total phosphorus from POTW effluents to 0.1 mg/L during the growing season and a 90% reduction of phosphorus sediment flux. During the non-growing season, effluent limits for phosphorus will not presently be required; however, year round monitoring and reporting of effluent data for total and dissolved phosphorus will be required because of concerns that particulate phosphorus potentially could settle in the impoundments during the non-growing season and become available for plant growth during the growing season. In addition, the POTWs will be required to optimize the removal of particulate phosphorus during the non-growing season. These requirements are summarized in Table ES-1 on the next page.

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Table ES-1
TMDL for Total Phosphorus
(minor POTWs not modeled in italics)

			POTW Effluent Limits Total Phosphorus, mg/L April 1 – October 31[1]		POTW Effluent Limits Total Phosphorus, mg/L November 1 – March 31
POTW	NPDES	Design Flow, MGD	mg/L	lbs/day @ design flow	mg/L and lbs/day
Westborough	MA0100412	7.68	0.10	6.4	Optimize for particulate phosphorus removal and monitor and report for total and dissolved phosphorus concentration
Marlborough West	MA0100480	2.89	0.10	2.4	
Hudson	MA0101788	3.00	0.10	2.5	
Maynard	MA0101001	1.45	0.10	1.2	
Powdermill Plaza[2]		---	N/A	N/A	N/A
Middlesex School[3]	*MA0102466*	0.052	0.50	0.22	0.50 mg/l / 0.22 lb/day
MCI Concord[4]	*MA0102245*	0.3	0.50	1.25	0.50 mg/l / 1.25 lb/day

[1] Includes a margin of safety of 6.1 pounds per day

2 connecting to Acton POTW – no TMDL necessary

3 Spencer Brook is receiving water – tributary to Assabet River and below all impoundments

[4] downstream of all impoundments and near confluence with Concord River

Assessment of nutrient impacts on rivers is complex and difficult. Projection of water quality for conditions substantially different from those currently existing involves some uncertainty. Based upon the uncertainties in the model projections and the present lack of information regarding the feasibility and costs associated with sediment phosphorus control and/or dam removal, the Department is proposing a two-phased adaptive management approach as follows:

Phase 1 will establish POTW effluent total phosphorus limits of 0.1 mg/l at all major POTWs discharging to the Assabet River and allow the communities sufficient time to fund and implement a detailed evaluation of impoundment sediment as a potential alternative to lower permit limits. DEP believes that some sediment and/or dam removal options will allow the Assabet River to achieve water quality standards faster and, possibly, be more cost effective, than establishing lower POTW total phosphorus limits and waiting for the system to respond over time.

Requirements will be incorporated into the NPDES permits to be developed and issued in 2004. Phase 1 will require that all POTWs be upgraded to achieve 0.1 mg/l of effluent phosphorus by April 2009 and the design should be consistent with adding new technology in the future to achieve further reductions if deemed necessary. Based upon the modeling results current permitted flows will be allowed. However, any request to increase a discharge beyond currently permitted volumes would require supporting documentation satisfying DEP's Antidegradation Policy that no other feasible alternative exists including, but not limited to, the discharge of additional treated effluent to groundwater to help restore tributary flows. Phosphorus limits will be seasonal. DEP and EPA will jointly develop an implementation strategy in the Spring of 2008 to decide if, when, and to what level additional upgrades will be needed based upon the results and recommendations of the sediment evaluation.

Phase 2 limitations will be established in permits to be reissued in 2009 if sediment remediation, based upon the results of the sediment/dam evaluation, is not pursued, and/or new phosphorus criteria that may be developed in the interim by DEP and USEPA are applicable. If the communities choose to pursue sediment remediation alternatives, a revised schedule and work plan will be negotiated in the summer and fall of 2008. If the communities choose not to pursue sediment remediation alternatives they will be required to complete phase 2 improvements during the second 5-year permit cycle and begin operating by April 2013 and achieve the new limits by April 2014.

In the interim, prior to facility upgrades in 2009, the POTWs will be required to continue optimization of seasonal removal of total phosphorus in their effluents to meet the 2000 interim NPDES permit limits for total phosphorus of 0.75 mg/l.

Long-term monitoring of the Assabet River is essential to determine the efficacy of the adaptive management controls as they are implemented, to determine whether water quality standards have been achieved, or if additional source controls will be required. EPA and DEP will develop a detailed monitoring plan prior to implementation of Phase 1 upgrades. The agencies or their agents will implement the plan with assistance from the Assabet communities to evaluate and document water quality improvements and environmental indicators after POTW upgrades are completed during Phase 1.

This TMDL can be achieved through the continued cooperation, effort, and oversight of federal, state and municipal agencies along with the watershed stakeholders.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state to identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and to establish Total Maximum Daily Loads (TMDL) for such waters for the pollutant(s) of concern. The TMDL establishes the allowable pollutant loading from all contributing sources at a level necessary to achieve the applicable water quality goals. The TMDLs 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 and attached documents (ENSR, 2001; ENSR, 2003) are 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 will serve as a guide for future implementation activities such as the development of NPDES permits, the upgrading of POTW facilities, and determining the feasibility of sediment and dam removal in order to achieve water quality standards.

The Total Maximum Daily Load for total phosphorus for the Assabet River is based primarily upon data collected or compiled by ENSR International (ENSR) funded under contracts from the Army Corps of Engineers and from the Massachusetts Department of Environmental Protection (DEP), and through the development of an HSPF (version 10) model constructed by ENSR. The Assabet River is on the Massachusetts Year 2002 Integrated List of Waters primarily for Nutrients and for Organic Enrichment/Low Dissolved Oxygen.

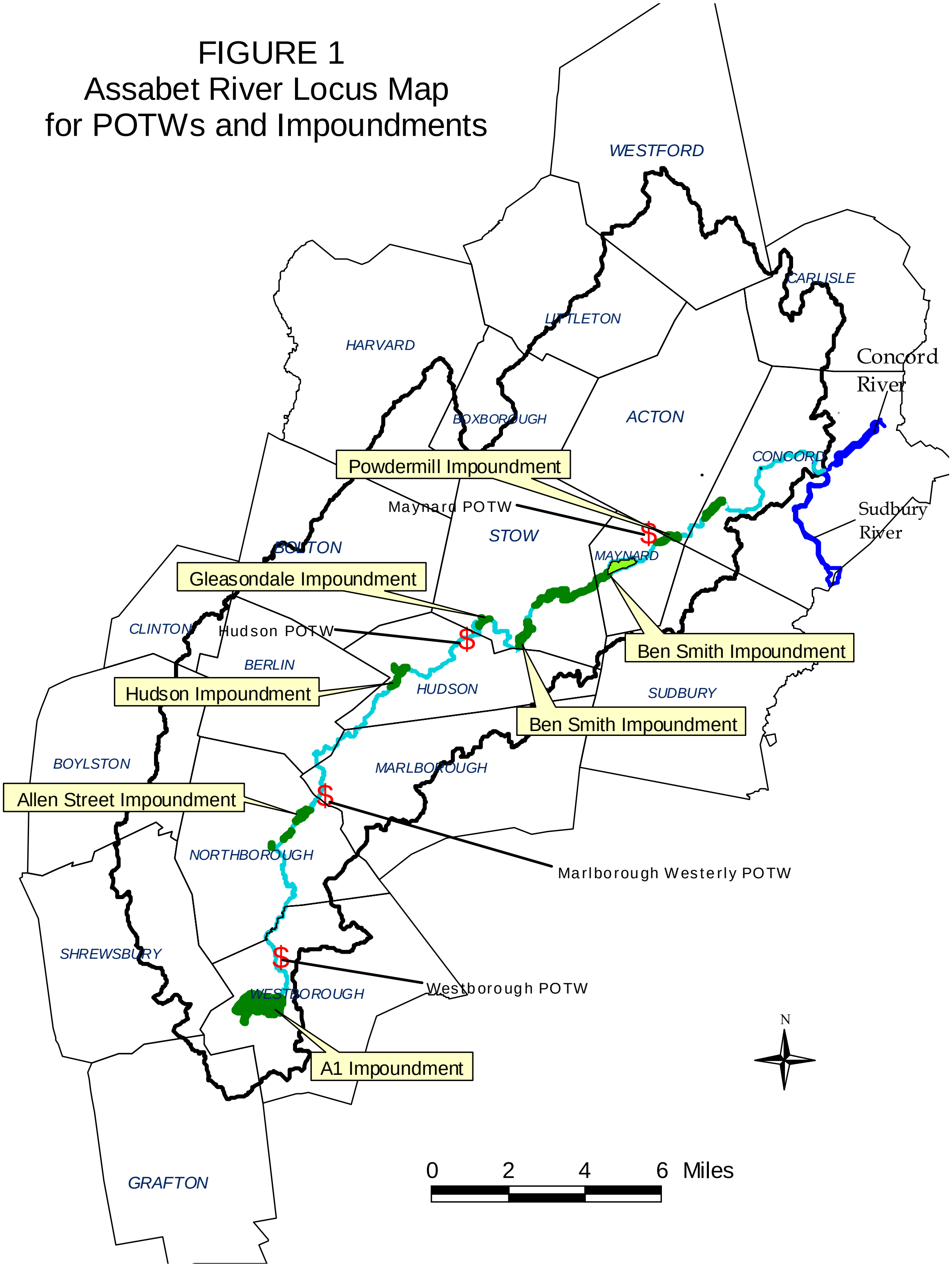
Waterbody Description

The Assabet River, 31.8 miles in length and 178 square miles in drainage area, flows northeasterly from its headwaters in the Town of Westborough to its mouth at the confluence with the Sudbury River in the Town of Concord. Along the way it passes through 10 towns and receives contributions from tributaries and subwatersheds in 8 other towns. The river alternates between medium-slope free-flowing and low-slope impounded reaches (see Figure A1 in Appendix). The headwaters emanate from the A1 Impoundment in Westborough. Shortly thereafter, the effluent from the POTW serving primarily Westborough and Shrewsbury enters the river. The first of six downstream impoundments that receive treated wastewater from one or more of the four POTWs occurs upstream of Route 20 in Northborough at the Aluminum City dam. A short riffle reach follows entering into the Allen Street impoundment in Northborough – this impoundment has seen extensive sedimentation during the last twenty years such that during the drier seasons the flow is channelized behind the dam on Allen Street. Flow either over the dam or through the spillway enters another short riffle reach before encountering a more modest slope upstream of the Northborough-Marlborough municipal boundaries at Boundary Street just before the effluent from the Marlborough West POTW enters. Flowing freely, with the exception of a slight backwater before and a pool after the Robin Hill Flood Control Dam, the Assabet weaves its way through Berlin towards Hudson. After passing under the Route I-495 Bridge, the effect of the Route 85 dam in Hudson is felt as stream velocity begins to slow prior to the Hudson impoundment. After flowing over the Hudson impoundment dam, the Assabet flows freely until Cox Street in Hudson where the effluent from the Hudson POTW enters. Below Cox Street, the effects of the Gleasondale dam and the lower slope of the river are manifested in a slowing and widening of the river. Shortly after the Gleasondale dam past the Route 62 Bridge, the Assabet's current is once again abated as the Ben Smith dam in Maynard impounds the Assabet for about 5 miles. Immediately above the Ben Smith dam, there is a diversion that shunts a portion of the flow towards the former Digital complex in Maynard. The majority of the flow, however, continues over a riffle reach through Maynard before encountering the Powdermill Dam, which has a small hydroelectric generator, northeast of Maynard. The United States Geological Survey (USGS) maintains a real-time flow gage in downtown Maynard upstream of the Powdermill impoundment. The Maynard POTW discharges to this impoundment. Below the dam, the Assabet continues towards its confluence with the Sudbury River in Concord where the two rivers become the Concord River that flows into the Merrimack River in Lowell and thence seaward to Newburyport. The final section of the Assabet is primarily free flowing until near the confluence where the river widens and slows.

The mainstream Assabet River receives the discharge from 4 major wastewater treatment facilities along its course. The four POTWs serve at least portions of seven communities: Westborough, Shrewsbury, Northborough, Hopkinton, Marlborough, Hudson and Maynard. With the exception of the Maynard POTW, these facilities discharge to the river above the USGS gage and comprise approximately 80% of the flow at the USGS gage in Maynard during low flow periods. The seven-day average flow expected once every 10 years (7Q10) is 15.1 cubic feet per second (cfs) as reported by USGS (http://ma.water.usgs.gov/) in its Streamstats file.

The four POTWs currently are operating under NPDES permits that each have seasonal total phosphorus effluent limits of 0.75 mg/l and include a schedule for preparing comprehensive wastewater management plans and environmental impact reports for upgrading their facilities. These permits are scheduled to be reissued in March 2004. During 1999 and 2000 summer-time conditions (i.e. low flow), the discharges from the treatment facilities comprised about 97% of the phosphorus loading to the river. Summary information on these POTWs is given in a succeeding section on Pollutant Sources and Background (see Table 3, page 21).

FIGURE 1
Assabet River Locus Map for POTWs and Impoundments



Problem Assessment

The mainstem Assabet River is identified in the 1998 (and all previous) 303(d) listing and the Massachusetts Year 2002 Integrated List of Waters as consisting of 7 segments plus the impounded headwater section (known variously as the A-1 or Westborough Impoundment, the Assabet River Reservoir, or the Flow Augmentation Pond). See Table 1 for the current impairment listing. The TMDL is focused on the 7 segments; the impounded headwater section has not been listed for nutrients nor organic enrichment/low dissolved oxygen. This TMDL addresses a total of 14 impairments: seven segments are listed as being impaired by nutrients , six of the segments are listed for organic enrichment and low dissolved oxygen, and one is listed for noxious aquatic plants in both the EPA-approved 1998 List of Impaired Waters (303(d) List) and the EPA-approved 2002 Integrated Waters List (Table 1). Both of the latter impairments are attributed to the over-enrichment with nutrients.

A field investigation of the Assabet River system was conducted by ENSR (ENSR, 2001) under contract to the US Army Corps of Engineers and the Massachusetts Department of Environmental Protection. Surveys were conducted from July 1999 through October 2000. The field investigation collected data on the hydrology, water quality, and aquatic vegetation of the Assabet River during 13 surveys. The goal of the field investigation was to quantify and document the presence of eutrophic conditions and associated factors in the Assabet River. Nutrient loadings and dynamics in the Assabet River were a primary focus of the investigation. The study also focused on characterizing the algae and aquatic plants of the Assabet River and the interrelationship between nutrients and aquatic vegetation in the system.

The field investigation confirmed that the Assabet River receives an excess of the nutrients, phosphorus and nitrogen, resulting in nutrient saturation and excessive growth of aquatic vegetation.

Summer-time dissolved oxygen concentrations in the Assabet River frequently were below the water quality standard of 5.0 mg/l. Dissolved oxygen data were collected during the July 1999 and August 2000 surveys by in-situ measurements at 26 river stations and in 5 river impoundments. Continuous monitors were deployed at 5 locations in the impounded areas to capture diurnal changes in dissolved oxygen concentrations to calibrate and validate the model. At mainstem sampling locations minimum dissolved oxygen concentrations were found to be below 5.0 mg/l at 9 of 21 locations at sometime during the survey. Also, diurnal dissolved oxygen concentration variations were more than 6.0 mg/l at 8 of 21 river sampling stations, and significant supersaturation of dissolved oxygen was observed (ENSR, 2000b).

Summer-time vegetation densities in the Assabet River were observed to be at levels associated with impairment of water quality and designated uses such as secondary recreation and aesthetics.

Due to the high phosphorus loading from the four major POTWs and the effects of the impoundments, the Assabet River is experiencing abundant rooted macrophyte growth and frequent excessive accumulations of Lemna species (duckweed) which often cover the river’s surface, particularly in the slow moving reaches, embayments, and impoundments. Decay of dying duckweed causes odors and violations of dissolved oxygen standards. Excessive growths of both floating and rooted macrophytes are detrimental to primary and secondary contact recreation. During the summer season, excessive macrophyte populations lead to large swings in dissolved oxygen resulting in supersaturation during the daytime followed by frequent depletions below the minimum dissolved oxygen standard of 5.0 mg/l at night.

Table 1

Excerpted from 2002 Massachusetts Integrated Waters Listing

Massachusetts Category 5 Waters

“Waters requiring a TMDL”

NAME	SEGMENT ID	DECSCRIPTION	SIZE	POLLUTANT NEEDING TMDL
Assabet River Reservoir (82004)	MA82004_2002	Westborough	333 acres	-Metals -Noxious aquatic plants -Turbidity -(Exotic species*)
Assabet River (8246775)	MA82B-01_2002	Outlet Flow Augmentation Pond to Westborough WWTP, Westborough. Miles 31.8-30.4	1.4 miles	-Nutrients[1] -Organic enrichment/Low DO[1] -Pathogens
Assabet River (8246775)	MA82B-02_2002	Westborough WWTP, Westborough to Route 20 Dam, Northborough. Miles 30.4-26.7	3.7 miles	-Metals -Nutrients[1] -Organic enrichment/Low DO[1] -Pathogens
Assabet River (8246775)	MA82B-03_2002	Route 20 Dam, Northborough to Marlborough West WWTP, Marlborough. Miles 26.7-24.3	2.4 miles	-Nutrients[1] -Pathogens
Assabet River (8246775)	MA82B-04_2002	Marlborough West WWTP, Marlboro to Hudson WWTP, Hudson. Miles 24.3-16.4	7.9 miles	-Cause Unknown -Metals -Nutrients[1] -Organic enrichment/Low DO[1] -Pathogens
Assabet River (8246775)	MA82B-05_2002	Hudson WWTP Hudson to Routes 27/62 at USGS Gage, Maynard. Miles 16.4-7.6	8.8 miles	-Nutrients[1] -Organic enrichment/Low DO[1] -Pathogens
Assabet River (8246775)	MA82B-06_2002	Routes 27/62 at USGS Gage, Maynard to Powdermill Dam, Acton. Miles 7.6-6.4	1.2 miles	-Priority organics -Metals -Nutrients[1] -Organic enrichment/Low DO[1] -Thermal modifications -Taste, odor and color -Suspended solids -Noxious aquatic plants[1]
Assabet River (8246775)	MA82B-07_2002	Powdermill Dam, Acton to confluence with Sudbury River, Concord. Miles 6.4-0.0	6.4 miles	-Nutrients[1] -Organic enrichment/Low DO[1] -Pathogens

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[1] being addressed in this TMDL via Total Phosphorus control

Priority Ranking

The Assabet River is a high priority based on local concerns and the extent of the eutrophication in the river. This priority is in accord with the DWM's five-year strategy to initiate work on significant but complicated long term TMDLs. One reflection of the high priority for the Assabet River is that when the towns of Westborough, Shrewsbury, Hudson and Maynard and the city of Marlborough formed a consortium to address the river's water quality issues, they were able to qualify for over 3 million dollars in planning loans from the state revolving fund.

Pollutant of Concern

Water quality surveys by ENSR in 1999 and 2000, OAR (Organization for the Assabet River) (mid-1990's on), and the Division of Watershed Management (DWM) of the Massachusetts DEP document in-stream total phosphorus concentrations that greatly exceed minimum growth guidance requirements for aquatic plants. These concentrations of total phosphorus have led to excessive growth of floating and, to some extent, rooted macrophytes in the river. Discharge data from the 4 major POTWs show that their effluents are the major source of total phosphorus both on an annual basis and especially during the low flow summer growth period (ENSR, 2001).

Additionally, the role of sediment as a recycler of nutrients, especially phosphorus, has been identified as a significant component promoting macrophyte growth in the Assabet River, particularly in impounded sections. The 5 major impoundments on the Assabet River provide an optimum habitat for macrophyte growth and especially for the floating macrophytes.

While both phosphorus and nitrogen are nutrients, phosphorus generally is the one judged to be limiting or more easily made so in freshwater. This in part rests on the fact that phosphorus is easier to remove and that some organisms can convert atmospheric nitrogen into a useable form thereby creating a nearly limitless supply (Allan, 1995; NAP, 2000). In the case of the Assabet, not only is the habitat for nitrogen fixation available, but also it is likely enhanced by the presence of duckweed (Lemna) as a host for nitrogen-fixing bacteria.

To further illustrate the relative roles of phosphorus versus nitrogen, the model scenario (run 12) with the Westborough POTW discharging to the ground simulated nearly complete removal of nitrogen from this source. The amount reduced approximates what would happen if all 4 POTWs on the Assabet achieved nearly state of the practical art removals of total nitrogen, i.e., concentrations of 5 to 8 mg/L in their effluents. The results were not demonstrably different in that total biomass reductions were 45, 47 and 48% for all POTWs at 0.2 mg/l total phosphorus (run 7), Westborough at 0.1 mg/l total phosphorus with the others at 0.2 mg/l total phosphorus (run 10), and with Westborough discharging to the ground with the other POTWs at 0.2 mg/l total phosphorus (run 12), respectively. The substantial removal of nitrogen represented by the discharge to ground at Westborough resulted in no substantial difference in predicted biomass. This helps confirm total phosphorus as the main concern at this time. Therefore, the Assabet River nutrient TMDL was developed for total phosphorus as the pollutant of concern.

The impoundments can also be seen as a stressor since they contribute to conditions that enable both floating and rooted macrophytes to reach nuisance proportions. Thus the potential of removing the dams to improve water quality should be examined although any existing use benefits that might be lost need to be considered as well.

Pollutant Sources and Background

The field investigation of the Assabet River system was conducted primarily by ENSR (ENSR, 2001) under contract to the US Army Corps of Engineers and the Massachusetts Department of Environmental Protection. Survey results from July 1999 through October 2000 and a review of historical water quality studies concluded that excessive nutrient loads were causing eutrophication.

The most consistent sources of phosphorus loading to the Assabet River are the four major POTWs in Westborough, Marlborough, Hudson, and Maynard. While non-point sources must be considered, the seasonality of the eutrophication problem, as manifested by nuisance aquatic plant growth, is most directly related to the presently high loadings of phosphorus from the POTWs combined with limited inflow from groundwater during the natural growing season for aquatic vegetation. This combination is especially important during periods of low flow and especially at 7Q10. During the growing season, non-point source contributions of phosphorus, other than from sediment phosphorus flux, are generally minor compared to the consistent contribution from the POTWs.

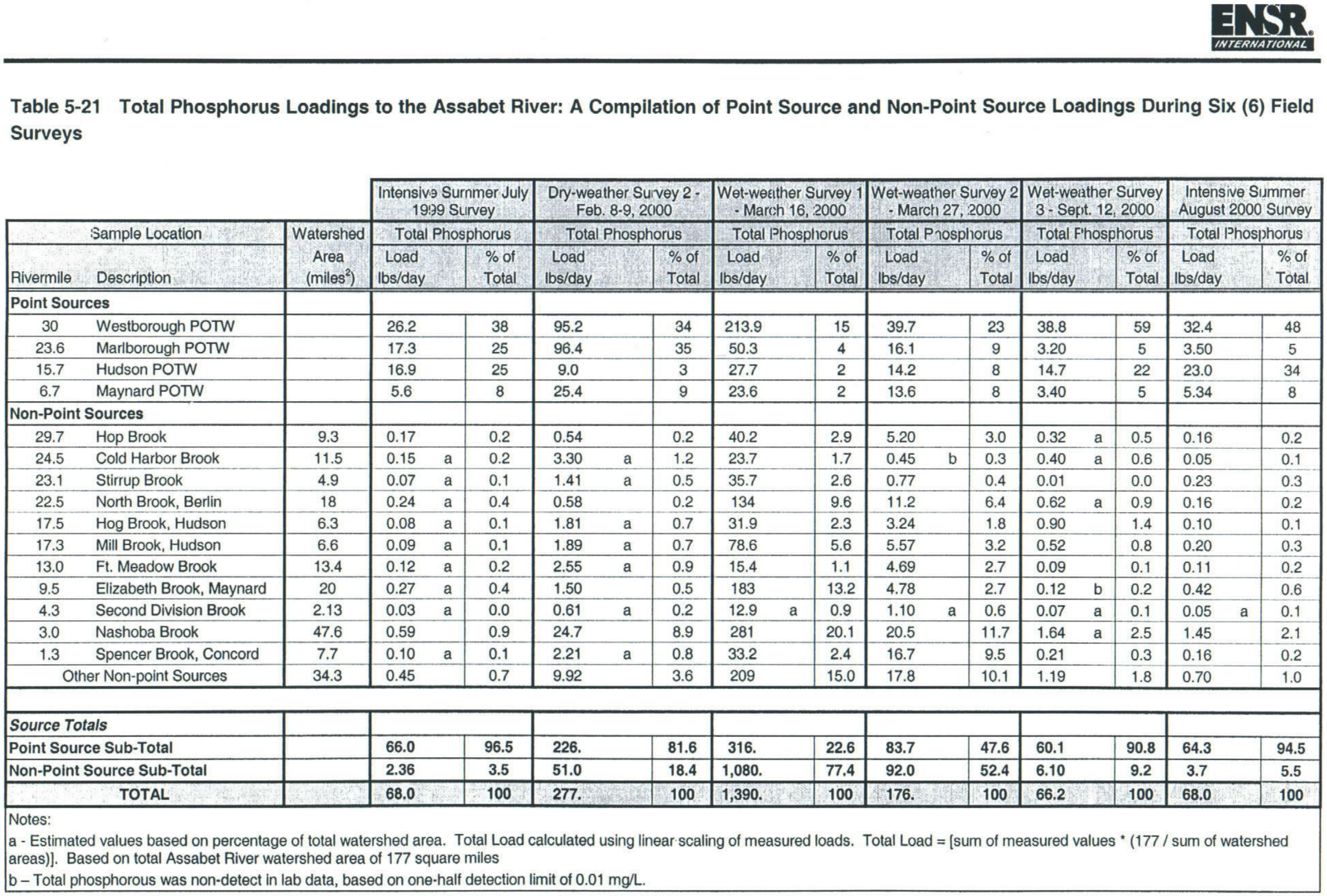
During 1999 and 2000 a number of water quality surveys were conducted to evaluate nutrient loadings to enhance understanding of the nature and extent of nutrient sources to the Assabet River. Total phosphorus loadings were estimated using concurrently measured flows and total phosphorus concentrations from point sources and from tributaries that represented non-point sources. ENSR summarized the sources and contributions of nutrients in a loading analysis as follows (ENSR, 2001):

> “The evaluation of nutrient loadings during 6 field surveys found that point sources contributed the majority of nutrient loadings to the Assabet River during most surveys. Point sources were found to be the dominant source of biologically available phosphorus (i.e., ortho-phosphorus) during all 6 surveys representing 88% to 98% of the overall available phosphorus load. Total nutrient loads from all significant sources to the Assabet River for four key nutrient constituents during the 6 surveys ranged as follows:
>
> - Ortho-phosphorus loadings: 52 to 319 lbs/day
> - Total Phosphorus loadings: 66 to 1,390 lbs/day
> - Nitrate loadings: 982 to 2,250 lbs/day
> - Total Nitrogen loadings: 1,190 to 3,850 lbs/day
>
> Point sources contributed a majority of all four nutrient constituents evaluated during 4 of the 6 surveys, including three summer surveys (July 1999, August

> 2000, and September 2000) and a winter survey (February 2000), with the following point source percentage contributions:
>
> - Ortho-phosphorus: 97% to 98%,
> - Total phosphorus: 82% to 97%
> - Nitrate: 91% to 99%
> - Total Nitrogen: 88% to 97%
>
> Non-point sources were observed to contribute the majority of total phosphorus and total nitrogen during 2 of the 6 surveys. These two surveys were both conducted during wet-weather events in March 2000 (on March 16 and on March 27) and corresponded with relatively large stream flows (375 cfs and 250 cfs). During the March 2000 wet-weather surveys, the largest stream flows and some of the largest nutrient loadings of the 6 water quality surveys were observed. During the two high-flow, wet-weather surveys, the point sources were observed to contribute the following percent contribution of the overall loading:
>
> - Ortho-phosphorus: 88% and 96%
> - Total Phosphorus: 23% and 48%
> - Nitrate: 41% and 59%
> - Total Nitrogen: 31% and 40%”

Table 2 summarizes the phosphorus sources, loadings, and percent contribution for the 6 intensive water quality survey conducted by ENSR in 1999 and 2000 as follows:

Table 2
Total Phosphorus Loadings to the Assabet River:
A Compilation of Point Source and Non-Point Source Loadings During Six Field Surveys



ENSR INTERNATIONAL

Table 5-21 Total Phosphorus Loadings to the Assabet River: A Compilation of Point Source and Non-Point Source Loadings During Six (6) Field Surveys

			Intensive Summer July 1999 Survey		Dry-weather Survey 2 - Feb. 8-9, 2000		Wet-weather Survey 1 - March 16, 2000		Wet-weather Survey 2 - March 27, 2000		Wet-weather Survey 3 - Sept. 12, 2000		Intensive Summer August 2000 Survey	
Sample Location		Watershed	Total Phosphorus		Total Phosphorus		Total Phosphorus		Total Phosphorus		Total Phosphorus		Total Phosphorus	
Rivermile	Description	Area (miles^2)	Load lbs/day	% of Total	Load lbs/day	% of Total	Load lbs/day	% of Total	Load lbs/day	% of Total	Load lbs/day	% of Total	Load lbs/day	% of Total
Point Sources														
30	Westborough POTW		26.2	38	95.2	34	213.9	15	39.7	23	38.8	59	32.4	48
23.6	Marlborough POTW		17.3	25	96.4	35	50.3	4	16.1	9	3.20	5	3.50	5
15.7	Hudson POTW		16.9	25	9.0	3	27.7	2	14.2	8	14.7	22	23.0	34
6.7	Maynard POTW		5.6	8	25.4	9	23.6	2	13.6	8	3.40	5	5.34	8
Non-Point Sources														
29.7	Hop Brook	9.3	0.17	0.2	0.54	0.2	40.2	2.9	5.20	3.0	0.32 a	0.5	0.16	0.2
24.5	Cold Harbor Brook	11.5	0.15 a	0.2	3.30 a	1.2	23.7	1.7	0.45 b	0.3	0.40 a	0.6	0.05	0.1
23.1	Stirrup Brook	4.9	0.07 a	0.1	1.41 a	0.5	35.7	2.6	0.77	0.4	0.01	0.0	0.23	0.3
22.5	North Brook, Berlin	18	0.24 a	0.4	0.58	0.2	134	9.6	11.2	6.4	0.62 a	0.9	0.16	0.2
17.5	Hog Brook, Hudson	6.3	0.08 a	0.1	1.81 a	0.7	31.9	2.3	3.24	1.8	0.90	1.4	0.10	0.1
17.3	Mill Brook, Hudson	6.6	0.09 a	0.1	1.89 a	0.7	78.6	5.6	5.57	3.2	0.52	0.8	0.20	0.3
13.0	Ft. Meadow Brook	13.4	0.12 a	0.2	2.55 a	0.9	15.4	1.1	4.69	2.7	0.09	0.1	0.11	0.2
9.5	Elizabeth Brook, Maynard	20	0.27 a	0.4	1.50	0.5	183	13.2	4.78	2.7	0.12 b	0.2	0.42	0.6
4.3	Second Division Brook	2.13	0.03 a	0.0	0.61 a	0.2	12.9 a	0.9	1.10 a	0.6	0.07 a	0.1	0.05 a	0.1
3.0	Nashoba Brook	47.6	0.59	0.9	24.7	8.9	281	20.1	20.5	11.7	1.64 a	2.5	1.45	2.1
1.3	Spencer Brook, Concord	7.7	0.10 a	0.1	2.21 a	0.8	33.2	2.4	16.7	9.5	0.21	0.3	0.16	0.2
Other Non-point Sources		34.3	0.45	0.7	9.92	3.6	209	15.0	17.8	10.1	1.19	1.8	0.70	1.0
Source Totals														
Point Source Sub-Total			**66.0**	**96.5**	**226.**	**81.6**	**316.**	**22.6**	**83.7**	**47.6**	**60.1**	**90.8**	**64.3**	**94.5**
Non-Point Source Sub-Total			**2.36**	**3.5**	**51.0**	**18.4**	**1,080.**	**77.4**	**92.0**	**52.4**	**6.10**	**9.2**	**3.7**	**5.5**
TOTAL			**68.0**	**100**	**277.**	**100**	**1,390.**	**100**	**176.**	**100**	**66.2**	**100**	**68.0**	**100**

Notes:

a - Estimated values based on percentage of total watershed area. Total Load calculated using linear scaling of measured loads. Total Load = [sum of measured values * (177 / sum of watershed areas)]. Based on total Assabet River watershed area of 177 square miles

b – Total phosphorous was non-detect in lab data, based on one-half detection limit of 0.01 mg/L.

from ENSR, Assabet River Nutrient TMDL, Phase One: Assessment, Final Report, pg 5-44

The preceding table does not show the contribution of phosphorus from sediment flux, however. As described in following sections, the reduction of sediment phosphorus flux becomes a significant factor in meeting the TMDL goals only after significant reductions in total phosphorus at POTWs are achieved.

The following table summarizes seasonal and non-seasonal total phosphorus concentrations for the POTWs from 1998-2002. In 2000 the POTWs agreed to seasonally reduce total phosphorus in their effluent to 0.75 mg/l. Non-seasonal data were not available until 2001.

Table 3

Summary of Seasonal and Non-seasonal POTW Total Phosphorus Concentrations in Effluent*

POTW	Year	Seasonal[1] Average Monthly Flow MGD	Seasonal[1] Average Monthly Total Phosphorus mg/l	Non-seasonal[2] Average Monthly Flow MGD	Non-seasonal[2] Average Monthly Total Phosphorus mg/l
Westborough	1998	5.22	1.04		
Marlborough West		2.18	3.44		
Hudson		2.6	0.67		
Maynard		1.26	0.94		
Westborough	1999	4.41	0.79		
Marlborough West		1.84	1.13		
Hudson		1.93	1.51		
Maynard		0.89	0.64		
Westborough	2000	5.09	0.89		
Marlborough West		2.27	0.49		
Hudson		2.25	1.63		
Maynard		1.11	0.45		
Westborough	2001	4.96	0.69	5.52	3.62
Marlborough West		2.07	0.51	2.30	1.85
Hudson		2.30	0.56	2.39	1.52
Maynard		1.07	0.63	1.09	2.95
Westborough	2002	4.86	0.64	5.17	3.58
Marlborough West		1.74	0.41	1.89	1.84
Hudson		1.98	0.69	2.14	2.14
Maynard		0.84	0.62	0.98	3.28

*data compiled from USEPA PCS database

[1] Seasonal = April – October inclusive
[2] Non-seasonal = January – March & November – December inclusive
note: no non-seasonal data available until 2001

The USGS has monitored flow continuously in the Assabet River with a gaging station in Maynard (http://waterdata.usgs.gov/ma/nwis/uv?01097000) since 1941. Massachusetts's water quality standards are devised to provide protection to water quality for low flow conditions that satisfy a certain statistical condition designated 7Q10. This condition is the lowest flow averaged for a consecutive 7-day period with a recurrence interval of 10 years and is determined from the continuous record at the gauging station. Based on the data since 1941, the 7Q10 for the Assabet River at Maynard is about 15.1 cfs (cubic feet/second) (http://ststdmamrl.er.usgs.gov/streamstats/). This value reflects all contributions from the watershed above the gage location including the POTW discharges from Westborough, Marlborough West, and Hudson (the Maynard POTW discharges downstream of the gage.) During the July 1999 water quality survey by ENSR, flows ranged from 14 to 22 cfs at the USGS gage at Maynard and were close to the 7Q10 flow.

Applicable Water Quality Standards

Category 5 of the 2002 Integrated List, formerly referred to as the 303(d) list, identifies multiple causes of impairment in different segments of the Assabet River (see Table 1, page 16). The two primary causes, nutrients and organic enrichment/low dissolved oxygen, are common to all of the segments and can be addressed through the control of the nutrient phosphorus. The waters of the Assabet are Class B and a warmwater fishery. Data were analyzed and judged sufficiently well documented to place all the segments of the Assabet River on the Massachusetts 303d list for 1998 (DEP, 1998) and on the 2002 listing for impairment of primary and secondary contact recreation and aesthetics.

The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen but do not contain numeric criteria for phosphorus or biomass. They do, however, contain narrative criteria for nutrients and aesthetics including nuisance vegetation. Criteria for Class B waterways are, in part:

> 314 CMR 4.05(3)(b) 1(a) states in part "Dissolved Oxygen - "a. Shall not less be less than 6.0 mg/l in cold water fisheries nor less than 5.0 mg/l in warm water fisheries."
>
> 314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations 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."
>
> 314 CMR 4.05(5)(c) states, "Nutrients – Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication".

In the absence of numeric criteria in the State Water Quality Standards, the Department uses best professional judgment (BPJ) and a "weight-of-evidence" approach that considers all available information to set site-specific permit limits, pursuant to 314 CMR 4.05(5)(c). The weight of evidence approach also considers available guidance that may have been developed related to the issue. Although little guidance is available related to specific response variables such as biomass and aesthetics, EPA has published some additional national and regional guidance for phosphorus that is outlined below.

Summary of Available Guidance

In July 2000 the U.S. Environmental Protection Agency issued a technical guidance manual for nutrient criteria in Rivers and Streams (USEPA, 2000a) The purpose of this document was to provide scientifically defensible guidance to assist States and Tribes in developing regionally based numeric nutrient and algal criteria for river and stream systems. It also describes candidate response variables that can be used to evaluate or predict the condition or degree of eutrophication in a water body. Those variables include direct measurement of nutrient concentrations as well as observable response variables such as biomass and turbidity. Among other indicators, USEPA focuses on periphyton as the chlorophyll pool as a measure for assessing nutrient enrichment. In the Assabet River however, floating biomass, particularly duckweed, is a better metric and of critical concern to local environmentalists and the general public because it impedes recreational uses and creates objectionable odors in late summer and early fall when it dies and degrades on the riverbanks.

The USEPA guidance also notes the need in some cases for an adaptive management approach where uncertainty exists. Specifically, the guidance notes the need to "(m)onitor effectiveness of nutrient control strategies and reassess the validity of nutrient criteria" as part of the criteria development process. The USEPA expands this point to say:

> "Nutrient criteria can be applied to evaluate the relative success of management activities. Measurements of nutrient enrichment variables in the receiving waters preceding, during and following specific management activities, when compared to criteria, provide an objective and direct assessment of the success of the management project."

USEPA also published two additional guidance documents relative to this issue. The first is a document produced in 2000 titled "Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion XIV (USEPA, 2000b) and the second was an earlier document developed by USEPA in 1986 titled "Quality Criteria for Water", commonly referred to as the "Gold Book" (USEPA, 1986).

The former document was intended to provide additional technical guidance and recommendations to States to develop water quality criteria and standards. The document notes that the recommendations are not a substitute for the Clean Water Act (CWA) or USEPA regulations; nor is it a regulation itself. 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 guidance goes on to recommend, based upon a statistical analysis, an in-stream phosphorus criteria for all of Ecoregion XIV (encompasses most of the eastern coast of the United States) of 31.25 µg/l and for sub-ecoregion 59 (where the Assabet is located) 23.75 µg/l. These criteria represent the 25th percentile of available data collected within the ecoregion and sub-ecoregion, respectfully (from both impaired and unimpaired waters). The major downside to the guidance, which is of concern to DEP, is that the criteria were not based upon in-stream response variables or site-specific conditions. DEP believes this is critical to the success of any nutrient management strategy.

USEPA also developed statistically based guidance values for different seasons. Given that the Assabet River is an effluent dominated stream and that approximately 90% of the phosphorus discharged from the POTWs is in dissolved form and does not settle, the primary need for phosphorus removal occurs during the summer months when river flows are low and the phosphorus is taken up by the biomass for growth. When viewed as a summer time issue the USEPA guidance criteria change slightly to the following: Ecoregion XIV – 40.0 µg/l and sub-Ecoregion 59 – 25.0 µg/l. The standard errors of the data as referenced in the document for summer time conditions are 12.0 µg/l and 26.8 µg/l respectively.

The 1986 "Gold Book" criteria also provide guidance on this issue. The guidance states for phosphate phosphorus "To prevent the development of biological nuisances and to control accelerated or cultural eutrophication, total phosphates as phosphorus (P) should not exceed 50 µg/l in any stream at the point where it enters any lake or reservoir, nor 25 µg/l within the lake or reservoir. A desired goal for the prevention of plant nuisances in streams or other flowing waters not discharging directly to lakes or impoundments is 100 µg/l total P". Thus, this guidance provides a range of acceptable criteria for phosphorus based upon specified conditions. It is with the spirit of this guidance that the TMDL for total phosphorus in the Assabet River has been developed.

USEPA, in summarizing their available guidance, clearly acknowledges the lack of definitive numerical criteria and the need for criteria that vary not only by ecoregion but also by site-specific conditions. As a result, a major effort involving detailed water quality sampling, model development and the use of the model in a predictive mode was undertaken to assess the site-specific impacts and multiple response variables to phosphorus loading in the Assabet River.

WATER QUALITY TARGETS

Nutrients – Total Phosphorus

TMDLs for nutrients, specifically total phosphorus for the Assabet River, present several challenges. Among them is the fact that straightforward relationships between nutrient concentrations and environmental responses are complex and variable. In the case of rivers, this is compounded by the fact that no generally agreed framework for evaluating nutrient impacts exists. As previously noted, in the absence of numeric criteria in the Massachusetts Water Quality Standards, the Department uses best professional judgment (BPJ) and a "weight-of-evidence" approach that considers all available information to set site-specific permit limits, pursuant to 314 CMR 4.05(5)(c). The weight-of-evidence approach also considers available guidance that may have been developed related to the issue. Limited guidance is available from USEPA relating specific response variables such as biomass and aesthetics to nutrient concentrations.

Massachusetts has narrative criteria for nutrients as described in the section above on Applicable Water Quality Standards. The goal of this TMDL is to determine site-specific numeric permit limits for nutrients, specifically total phosphorus, to control eutrophication. The symptoms of eutrophication include undesirable or nuisance concentrations of aquatic macrophytes, and, in particular for the Assabet River, excessive growths of floating macrophytes. In addition, the water quality goal is to ensure dissolved oxygen is above the minimum criterion and to maintain protective and reasonable daily variations of dissolved oxygen concentrations so that existing uses are maintained and designated uses are achieved.

No specific in-stream target concentration for total phosphorus will be established. Under the weight-of-evidence approach all available information will be used to set site-specific permit limits. The overall goal is to significantly reduce the amount of biomass in the system fully recognizing that not all the biomass can be removed (attached macrophytes) and that some level of biomass is necessary to provide habitat to fish and other aquatic organisms. Additional goals are to also ensure the minimum dissolved oxygen criterion are met and to reduce the duration of dissolved oxygen supersaturation. A comparison of in-stream total phosphorus concentrations, although not a target, to USEPA guidance was used to further validate the model and weight-of-evidence approach.

Biomass

Excessive biomass is considered a major impairment of designated uses in the Assabet River. Decay of dying duckweed causes odors and violations of dissolved oxygen standards. Excessive growths of both floating and rooted macrophytes are detrimental to primary and secondary contact recreation. It also causes extreme variation in dissolved oxygen leading to both supersaturation and to violations of the minimum criterion of dissolved oxygen.

The primary locations where biomass accumulates are the Assabet's impoundments where conditions most suitable for excessive macrophyte growth exist: low velocity, shallow depths, large surface area open to sunlight, and nutrient enrichment. The five major impoundments on the Assabet (Allen Street in Northborough, Hudson in Hudson, Gleasondale between Hudson and Gleasondale, Ben Smith above Maynard, and Powdermill in Maynard) provide the physical setting while the four major POTWs and sediment in the impoundments provide the nutrients that result in the observed excessive macrophyte growth.

Elsewhere on the Assabet, in the free flowing reaches (and especially in the shaded free flowing reaches), excessive floating macrophyte (especially duckweed) growth is not observed. While macrophytes do exist in the sunlit free flowing reaches, they are generally rooted species adapted to the higher velocities and do not appear to be excessive or a nuisance. It can be assumed that the point source controls implemented towards controlling floating macrophyte growth in the impoundments will have the beneficial effect of reducing rooted macrophytes, to the extent they can utilize dissolved phosphorus from the water column, in the free flowing reaches.

For the purpose of this TMDL, a substantial reduction in total biomass of at least 50% from July 1999 values is considered a minimum target for achieving designated uses.

Dissolved Oxygen

The water quality standards require that minimum dissolved oxygen of 5.0 mg/l be maintained for all flows at or greater than 7Q10. Dissolved oxygen is relatively easy to monitor and concentrations in the Assabet River are well documented in the ENSR (ENSR, 2001) report and, historically, in data reports by the Massachusetts DEP. Dissolved oxygen is also a primary component of most models including the HSPF model for the Assabet River developed by ENSR. Model output for dissolved oxygen is easily compared to the 5.0 mg/l minimum dissolved oxygen criterion to determine if this water quality target would be met under the conditions of the various modeled scenarios.

Also of concern are large daily dissolved oxygen fluctuations that can be extremely low in the early morning hours but can become extremely high (supersaturated) in the late afternoon. This condition is directly related to eutrophication and the cause of the impairment because of the amount of both floating and fixed biomass in the system. Large fluctuations and the amount of time saturated conditions is exceeded are indicators of biomass production and dissolved oxygen swings caused by plant and algae photosynthesis and respiration.

No specific targets were set for either super saturated conditions or in-stream phosphorus concentrations since these metrics were used as a surrogate to estimate the biomass response to various control measures.

LOADING CAPACITY

Evaluation Process

For the past several years, water quality data have been collected on the Assabet River, a predictive model was developed, and the effects of various control strategies were assessed through the model (ENSR 2000a, 2000b, 2001, 2003). If one were interested solely in phosphorus concentrations, then a relatively simple water quality model might suffice. Because there is no specific quantitative link between phosphorus concentrations and impacts on water quality, DEP believes phosphorus concentrations are of secondary importance as an indicator of meeting water quality goals. Thus, DEP chose to develop a model that related water quality variables and their response to different phosphorus concentrations being discharged from the POTWs as the metric by which reaching water quality goals would be measured. The system response variables modeled were selected jointly by DEP, EPA, consultants to the Assabet River Consortium and representatives of the Organization for the Assabet River (OAR). These variables include dissolved oxygen, total phosphorus concentration, and biomass.

The application used, HSPF v 10, is a complex, time variable (dynamic) one that simulates hydrology generated from precipitation and specified land uses in the watershed. It predicts in-stream water quality for several variables. HSPF was used to develop, calibrate, and verify a model for the Assabet River based on conditions monitored in 1999 and 2000. During the lowest flow week of July 1999, river flow (14 – 22 cfs) was near 7Q10 (15.1 cfs) and wastewater effluents had a flow weighted average total phosphorus concentration of slightly over 1 mg/l.

Once the model was calibrated and verified, various runs were made to evaluate improvements from reduced phosphorus loads on several response variables including biomass, minimum dissolved oxygen, per cent dissolved oxygen saturation (indicator of biomass), and in-stream phosphorus concentrations. The output from the calibrated model for the low flow week of July 1999 was used as the baseline. Output from each scenario was compared to the baseline. While it should be recognized that predicting biomass response is on the edge of the state of the art to model, DEP believes large predicted differences are qualitatively correct. Therefore these differences are important and significant in assessing whether overall water quality goals are predicted to be met and designated uses achieved.

Many model runs were made looking at the system response variables using different assumptions. POTW effluent concentrations for total phosphorus were varied from those observed in 1999 down to 0. Sediment phosphorus flux was varied in increments of 25% from those that existed in the model during calibration (100%) to an assumption that all of the sediment phosphorus flux could be eliminated (0%). Additional model runs were made to investigate the in-stream response assuming the removal of the Ben Smith Impoundment and the projected impact on response variables if the Westborough POTW were to discharge to the ground within the watershed rather than directly to the Assabet mainstem. Finally, some additional projections were made using design POTW flows and effluent phosphorus concentrations to assess the relative difference in water quality response variables that would result from increasing flows and phosphorus loads from 1999 to fully permitted conditions. Conditions and results from all scenarios are presented in Table 4.

Model Results

The model results, as summarized in Table 4, indicate that an order of magnitude reduction in POTW total phosphorus concentrations combined with a significant reduction in sediment phosphorus flux would be expected to meet water quality objectives. As previously discussed, DEP came to this conclusion based not on one single factor but rather on a combination of response variables in the model using a “weight-of-evidence” approach. The following summarizes model predictions for each of the individual response variables identified above; however, it is the combination of these results that form the basis of the Department’s position.

a. Phosphorus

As previously discussed the State of Massachusetts presently does not have numeric water quality criteria for phosphorus. In its absence DEP considered all available guidance and information and best professional judgment to make permitting decisions. In this regard DEP consulted the previously cited USEPA 2000 guidance relative to in-stream phosphorus concentrations that included a suggested in-stream phosphorus criteria during the summer months in ecoregion XIV of 40 µg/l and in sub-ecoregion 59 of 25 µg/l. In addition, 1986 “Gold Book” criteria, previously developed by USEPA, recommended total phosphates as phosphorus (P) should not exceed 0.05 mg/l in any stream at the point where it enters any lake or reservoir, 0.025 mg/l within the lake or reservoir, and 0.1 mg/l in flowing waters not discharging directly to lakes or impoundments.

Table 4
Summary of Water Quality Target Model Output

		POTW July 1999 Flows, mgd										POTW Permitted (design) Flows, mgd					
		WBORO	MWEST	HUD	MAY							WBORO	MWEST	HUD	MAY		
		5.27	1.92	1.87	0.94							7.68	2.89	3.00	1.45		
						IN-STREAM RESPONSE						IN-STREAM RESPONSE					
FLUX 100%	Run	Effluent Dissolved Phosphorus Concentrations, mg/l				% Total Biomass Reduction All Reaches	Average Tot P	Max Tot P	Min Tot P	% time <5 DO	% time DO>SAT	% Total Biomass Reduction All Reaches	Average Tot P	Max Tot P	Min Tot P	% time <5 DO	% time DO>SAT
		WBORO	MWEST	HUD	MAY												
	1	JULY 1999 concentrations				0.0%	0.308	0.671	0.141	9.5%	34.8%						
NO SMITH[1]	**11**	JULY 1999 concentrations				36.5%	0.303	0.671	0.141	10%	35%						
	13	0.500	0.500	0.500	0.500							-10.1%[2]	0.112	0.297	0.027	2.4%	39.6%
	2	0.200	0.200	0.200	0.200	8.1%	0.059	0.297	0.007	3.7%	42.8%						
	3	0.100	0.100	0.100	0.100	11.3%	0.049	0.297	0.007	2.4%	41.8%						
	4	0.050	0.050	0.050	0.050	11.3%	0.044	0.297	0.007	2.0%	41.4%						
	5	0.000	0.000	0.000	0.000	12.5%	0.039	0.297	0.007	1.4%	39.9%						
FLUX 75%																	
	15	0.100	0.100	0.100	0.100	15.6%	0.039	0.227	0.006	0.7%	41.0%						
	17	0.050	0.100	0.100	0.100	16.9%	0.036	0.227	0.006	0.5%	39.7%						
FLUX 50%																	
	18	0.050	0.050	0.050	0.050	31.9%	0.026	0.157	0.005	0.1%	36.7%						
FLUX 25%																	
	25	0.200	0.200	0.200	0.200							33.1%	0.028	0.089	0.004	0.3%	34.7%
	19	0.050	0.050	0.050	0.050	49.2%	0.017	0.086	0.004	0.0%	32.1%						
	22 & 23	0.025	0.025	0.025	0.025	52.9%	0.015	0.086	0.004	0.0%	31.5%	52.9%	0.014	0.086	0.004	0.0%	32.3%
FLUX 10%																	
	7 & 26	0.200	0.200	0.200	0.200	45.3%	0.026	0.116	0.003	2.4%	25.9%	43.0%	0.023	0.087	0.003	0.3%	25.9%
	10	0.100	0.200	0.200	0.200	46.8%	0.020	0.060	0.003	0.0%	26.0%						
	8 &14	0.100	0.100	0.100	0.100	55.6%	0.016	0.060	0.003	0.0%	23.3%	54.9%	0.015	0.045	0.003	0.0%	22.8%
	16	0.050	0.100	0.100	0.100	58.1%	0.014	0.044	0.003	0.0%	22.7%						
	9	0.050	0.050	0.050	0.050	64.2%	0.012	0.044	0.003	0.0%	21.5%						
	24	0.025	0.100	0.100	0.100	59.8%	0.012	0.044	0.003	0.0%	22.6%						
	20 & 21	0.025	0.025	0.025	0.025	67.9%	0.010	0.044	0.003	0.0%	20.6%	67.0%	0.010	0.044	0.003	0.0%	20.1%
GRND DIS[3]	**12**	0.06 & 50%	0.200	0.200	0.200	48.7%	0.017	0.047	0.003	0.0%	23.7%						
FLUX 0%																	
	6	0.000	0.000	0.000	0.000	86.2%	0.005	0.016	0.002	0.0%	8.3%						

Rows with runs separated by an "&" are July 1999 flows and Permitted (Design) flows, in that order

[1] NO SMITH indicates run with Ben Smith dam removed

[2] indicates an increase in biomass

[3] Ground disposal: return flow via groundwater @50%, quality equal to that of incremental flow (TotP=0.06 mg/l)

Model results predicting in-stream concentrations of total phosphorus by river milepoint are presented in Table 5, and, based upon these predictions, the following observations can be made:

1) Background concentrations (above the Westborough/Shrewsbury discharge) are expected to be above 0.04 mg/l and may at times be significantly higher because they originate in the A-1 impoundment in Westborough.

2) POTW reductions in phosphorus effluent concentrations to 0.2 mg/l or less without any reduction in sediment phosphorus flux all exceed the recommended guidance in multiple reaches of the Assabet. Even with POTW effluents not discharging any phosphorus, in-stream phosphorus concentrations without any sediment removal are expected to range from 0.007 mg/l to 0.12 mg/l and average 0.039 mg/l downstream from the first discharge with the highest concentrations predicted from river mile 15 to river mile 6.8 which include the Ben Smith, Gleasondale, and Powdermill impoundments.

b. Biomass

As noted previously, the model has a greater uncertainty associated with the results related to biomass than other model predictions. Despite this uncertainty and because of its importance to achieving designated uses, however, DEP believes the model can be used to predict order of magnitude differences.

The model runs using both existing and permitted (design) effluent flows near 7Q10 in-stream conditions predicted that very strict effluent limits at the POTWs only (i.e., without a significant reduction in sediment phosphorus flux), even limits of 0.0 mg/l total phosphorus, resulted in only minor biomass reductions when compared to 1999 levels (see Table 4). For example, assuming no reduction of sediment phosphorus flux, the model predicted that the total biomass in all reaches decreased only 13% from 161,300

Table 5

Predicted In-stream Total Phosphorus Concentrations by River Milepoint per Model Run

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
POTW DP[1] (mg/L)	E	0.2	0.1	0.05	0	0	0.2	0.1	0.05	WB[4] – 0.1 others - 0.2	E	WB - 0.06 others - 0.2	0.5	0.1	0.1	WB - 0.05 others - 0.1	WB - 0.05 others - 0.1	0.05	0.05	0.025	0.025	0.025	0.025	WB - 0.025 others - 0.1	0.2	0.2
POTW flow[2] mgd	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	D	E	D	E	D	D
Sed P Flux Reduction[3]	E	E	E	E	E	0%	10%	10%	10%	10%	E	10%	E	10%	75%	10%	75%	50%	25%	10%	10%	25%	25%	10%	25%	10%
Notes **River Mile**	Calib										B.S. Dam Removal[4]	GW Infil.[6]														
30.7	0.297	0.297	0.297	0.297	0.297	0.016	0.044	0.044	0.044	0.044	0.297	0.044	0.297	0.044	0.227	0.044	0.227	0.157	0.086	0.044	0.044	0.086	0.086	0.044	0.086	0.044
29.8	0.671	0.129	0.073	0.045	0.016	0.002	0.116	0.060	0.031	0.060	0.671	0.007	0.283	0.045	0.070	0.031	0.041	0.037	0.034	0.017	0.016	0.019	0.015	0.017	0.089	0.087
28.9	0.623	0.124	0.073	0.048	0.022	0.002	0.107	0.056	0.030	0.056	0.623	0.009	0.263	0.042	0.069	0.030	0.043	0.038	0.033	0.017	0.016	0.020	0.015	0.017	0.082	0.079
28	0.467	0.086	0.055	0.039	0.024	0.003	0.064	0.032	0.018	0.032	0.467	0.007	0.191	0.027	0.048	0.018	0.033	0.027	0.021	0.011	0.010	0.014	0.012	0.011	0.056	0.053
25.9	0.394	0.048	0.035	0.028	0.022	0.003	0.028	0.016	0.010	0.016	0.394	0.006	0.154	0.014	0.029	0.010	0.023	0.018	0.013	0.007	0.007	0.010	0.009	0.007	0.029	0.026
25.4	0.384	0.040	0.030	0.026	0.022	0.003	0.020	0.012	0.008	0.012	0.384	0.006	0.147	0.011	0.025	0.008	0.021	0.016	0.011	0.006	0.007	0.009	0.009	0.006	0.023	0.020
25.1	0.372	0.031	0.026	0.023	0.021	0.003	0.014	0.009	0.007	0.009	0.372	0.005	0.139	0.009	0.021	0.007	0.018	0.014	0.009	0.006	0.006	0.008	0.008	0.006	0.017	0.015
23.9	0.361	0.031	0.027	0.026	0.024	0.003	0.011	0.008	0.007	0.008	0.361	0.006	0.138	0.008	0.022	0.007	0.020	0.015	0.010	0.006	0.006	0.009	0.008	0.006	0.015	0.012
23.5	0.244	0.044	0.031	0.025	0.019	0.003	0.028	0.016	0.010	0.027	0.244	0.033	0.100	0.015	0.027	0.016	0.026	0.017	0.013	0.007	0.007	0.010	0.010	0.015	0.029	0.026
22	0.193	0.035	0.026	0.022	0.018	0.003	0.019	0.012	0.008	0.018	0.193	0.021	0.075	0.011	0.022	0.012	0.022	0.014	0.011	0.007	0.007	0.009	0.009	0.011	0.021	0.018
21.7	0.170	0.030	0.024	0.021	0.019	0.003	0.015	0.010	0.007	0.014	0.170	0.015	0.061	0.009	0.020	0.010	0.020	0.013	0.010	0.006	0.006	0.008	0.008	0.009	0.017	0.014
19.2	0.141	0.023	0.020	0.019	0.018	0.003	0.008	0.006	0.006	0.008	0.141	0.008	0.033	0.006	0.016	0.006	0.016	0.011	0.008	0.005	0.005	0.007	0.007	0.006	0.010	0.008
18	0.145	0.028	0.026	0.025	0.024	0.004	0.008	0.007	0.006	0.008	0.145	0.008	0.037	0.007	0.020	0.007	0.020	0.014	0.009	0.006	0.006	0.009	0.009	0.007	0.011	0.008
17.9	0.188	0.022	0.022	0.021	0.021	0.005	0.006	0.005	0.006	0.005	0.188	0.005	0.027	0.004	0.017	0.005	0.017	0.011	0.007	0.007	0.006	0.008	0.007	0.005	0.008	0.006
17.6	0.191	0.028	0.028	0.027	0.027	0.005	0.007	0.006	0.006	0.006	0.191	0.006	0.031	0.005	0.022	0.006	0.022	0.014	0.009	0.008	0.007	0.009	0.009	0.006	0.010	0.007
15.9	0.172	0.019	0.021	0.021	0.021	0.004	0.005	0.004	0.004	0.004	0.172	0.005	0.031	0.004	0.016	0.004	0.016	0.011	0.006	0.005	0.004	0.007	0.006	0.004	0.007	0.005
15	0.369	0.061	0.047	0.039	0.032	0.004	0.036	0.021	0.014	0.036	0.369	0.044	0.092	0.020	0.039	0.021	0.039	0.024	0.017	0.010	0.010	0.014	0.014	0.021	0.039	0.035
14.1	0.378	0.079	0.066	0.057	0.048	0.006	0.038	0.023	0.017	0.038	0.378	0.046	0.102	0.023	0.051	0.023	0.051	0.033	0.023	0.014	0.013	0.019	0.019	0.023	0.042	0.036
13.9	0.377	0.092	0.079	0.072	0.063	0.008	0.039	0.025	0.019	0.039	0.377	0.046	0.110	0.024	0.062	0.025	0.061	0.041	0.027	0.016	0.016	0.024	0.023	0.025	0.045	0.037
11.4	0.381	0.099	0.085	0.078	0.070	0.009	0.040	0.027	0.021	0.040	0.381	0.047	0.116	0.026	0.067	0.027	0.066	0.045	0.029	0.018	0.018	0.027	0.026	0.027	0.047	0.038
9.5	0.376	0.145	0.133	0.127	0.120	0.013	0.041	0.031	0.026	0.041	0.364	0.046	0.127	0.030	0.102	0.031	0.102	0.068	0.041	0.024	0.024	0.039	0.038	0.031	0.055	0.039
8.3	0.306	0.059	0.056	0.054	0.051	0.006	0.017	0.013	0.012	0.017	0.332	0.017	0.095	0.013	0.043	0.013	0.043	0.030	0.018	0.011	0.011	0.017	0.017	0.013	0.023	0.017
7.4	0.315	0.071	0.067	0.066	0.063	0.008	0.020	0.016	0.015	0.020	0.336	0.021	0.106	0.016	0.053	0.016	0.053	0.037	0.022	0.014	0.014	0.022	0.021	0.016	0.028	0.020
6.8	0.283	0.032	0.030	0.030	0.029	0.005	0.010	0.008	0.008	0.010	0.272	0.010	0.086	0.008	0.024	0.008	0.024	0.017	0.011	0.007	0.007	0.011	0.011	0.008	0.013	0.010
6.2	0.273	0.027	0.025	0.024	0.022	0.004	0.011	0.009	0.007	0.011	0.245	0.012	0.095	0.009	0.021	0.009	0.021	0.015	0.010	0.007	0.007	0.009	0.010	0.009	0.014	0.011
4.4	0.280	0.037	0.022	0.019	0.016	0.003	0.006	0.005	0.005	0.006	0.255	0.006	0.107	0.005	0.013	0.005	0.013	0.009	0.006	0.004	0.004	0.006	0.006	0.005	0.008	0.006
3.1	0.224	0.011	0.009	0.008	0.008	0.003	0.004	0.004	0.004	0.004	0.195	0.004	0.083	0.004	0.007	0.004	0.007	0.006	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004
2.4	0.224	0.012	0.009	0.009	0.009	0.003	0.004	0.004	0.004	0.004	0.195	0.004	0.084	0.004	0.007	0.004	0.007	0.006	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004
1.1	0.216	0.008	0.007	0.007	0.007	0.003	0.003	0.003	0.003	0.003	0.187	0.003	0.082	0.003	0.006	0.003	0.006	0.005	0.004	0.003	0.003	0.004	0.004	0.003	0.004	0.003
0	0.215	0.007	0.007	0.007	0.007	0.003	0.003	0.003	0.003	0.003	0.186	0.003	0.082	0.003	0.006	0.003	0.006	0.005	0.004	0.003	0.003	0.004	0.004	0.003	0.004	0.003
Average	0.308	0.059	0.049	0.044	0.039	0.005	0.026	0.016	0.012	0.020	0.303	0.017	0.112	0.015	0.039	0.014	0.036	0.026	0.017	0.010	0.010	0.015	0.014	0.012	0.028	0.023
Max	0.671	0.297	0.297	0.297	0.297	0.016	0.116	0.060	0.044	0.060	0.671	0.047	0.297	0.045	0.227	0.044	0.227	0.157	0.086	0.044	0.044	0.086	0.086	0.044	0.089	0.087
Min	0.141	0.007	0.007	0.007	0.007	0.002	0.003	0.003	0.003	0.003	0.141	0.003	0.027	0.003	0.006	0.003	0.006	0.005	0.004	0.003	0.003	0.004	0.004	0.003	0.004	0.003

[1] POTW effluent dissolved phosphorus in mg/l; E denotes concentrations for July 1999

[2] POTW flow: E = July 1999; D = design flow, mgd (Westborough, 7.68; Marlborough West, 2.89; Hudson, 3.0; Maynard, 1.45);

[3] Sediment Phosphorus Flux Reduction as a percentage of July 1999 value; E denotes July 1999 value

[4] WB = Westborough POTW

[5] Ben Smith dam removal simulated in run

[6] Groundwater infiltration of effluent simulated for Westborough POTW

kg (observed in 1999) to 141,100 kg, a reduction of only 12.5%, when all phosphorus was removed from the POTW discharges. This indicates the need to include assessment of sediment abatement measures to meet water quality goals. As POTW total phosphorus concentrations were reduced to 0.2 mg/l and sediment phosphorus flux was reduced by 90%, the total biomass was reduced to 88,300 kg, which represents about a 45% reduction of biomass from that measured in July 1999. As previously mentioned, although the biomass portion of the model has more uncertainty associated with the results, a 45% or more reduction is considered significant by DEP. When effluent total phosphorus concentrations for July 1999, flows were reduced to 0.1 mg/l, the biomass decreased by 56 %. This reduction was an additional 17,000 kg less than that predicted when the POTWs were discharging 0.2 mg/l total phosphorus. Table 6 illustrates these results.

Table 6

Effects of Sediment Flux and Effluent Concentrations on Water Quality Targets

(excerpted from Table 4)

		Effluent Dissolved P, mg/l				BIOMASS 1999 and % Reduction from 1999	Average Tot P mg/l	Max Tot P mg/l	Min Tot P mg/l	**%** time <5 DO	**%** time DO>SAT
	Run	WBORO	MWEST	HUD	MAY						
Flux 100%											
July1999 POTW flows[1]	**1**	1999 effluent values				161,300	0.308	0.671	0.141	9.5%	34.8%
July1999 POTW flows	**5**	0.0	0.0	0.0	0.0	12.5%	0.039	0.297	0.007	1.4%	39.9%
Flux 10%											
July1999 POTW flows	**7**	0.2	0.2	0.2	0.2	45.2%	0.026	0.116	0.003	2.4%	25.9%
July1999 POTW flows	**8**	0.1	0.1	0.1	0.1	55.6%	0.016	0.060	0.003	0.0%	23.3%

[1] July 1999 POTW flows (mgd): Westborough 5.27; Marlborough West 1.92; Hudson 1.87; Maynard 0.94

It should be noted that different combinations of sediment phosphorus flux reductions and POTW total phosphorus effluent reductions can also produce similar improvements. For instance, a sediment phosphorus flux reduction of 75% combined with a POTW effluent of 0.05 mg/l total phosphorus resulted in a biomass reduction of about 49% over 1999 conditions. Table 4 contains the biomass predictions for each scenario.

The model was also used to estimate biomass reductions with the same total phosphorus concentrations and sediment flux reductions using POTW design flows. The results indicate that biomass would likely remain about the same, as with existing POTW flows. For instance, at equal levels of treatment (0.1 mg/l total phosphorus) and sediment reduction (90% sediment phosphorus flux reduction) the biomass predictions for July 1999, and design flows remained essentially the same: 71,600 kg vs. 72,800 kg, respectively.

It is also of note that biomass is expected to be present even with the removal of all phosphorus from the POTW effluents and reducing the sediment phosphorus flux contribution to zero. Under this condition the model predicts that total biomass in all reaches to equal approximately

22,200 kg most of which is likely to be in the form of attached plants in the river bed rather than free floating plants (duckweed, algae, etc.).

Table 7
Effects of Permitted vs. July 1999 Flow and Maximum Phosphorus Reduction
(excerpted from Table 4)

		Effluent Dissolved P, mg/l				BIOMASS 1999 and % Reduction from 1999	Average Tot P mg/l	Max Tot P mg/l	Min Tot P mg/l	% time <5 DO	% time DO>SAT
	Run	WBORO	MWEST	HUD	MAY						
FLUX 10%											
July 1999 POTW flows[1]	**1**	1999 effluent values				161,300	0.308	0.671	0.141	9.5%	34.8%
July 1999 POTW flows	**8**	0.1	0.1	0.1	0.1	55.6%	0.016	0.060	0.003	0.0%	23.3%
Permitted flows[2]	**14**	**0.1**	**0.1**	**0.1**	**0.1**	**54.9%**	**0.015**	**0.045**	**0.003**	**0.0%**	**22.8%**
FLUX 0%											
July 1999 POTW flows	**6**	0.0	0.0	0.0	0.0	86.2% (22,200)	0.005	0.020	0.000	0.0%	8.3%

[1] July 1999 POTW flows (mgd): Westborough 5.27; Marlborough West 1.92; Hudson 1.87; Maynard 0.94

[2] Permitted flow (mgd): Westborough: 7.68 ; Marlborough West: 2.89 ; Hudson: 3.00 ; Maynard: 1.45

c. Dissolved Oxygen

There are two issues of concern when assessing the model results relative to dissolved oxygen. The first is that Massachusetts Water Quality Standards set a minimum criterion of 5.0 mg/l in-stream to protect warm water fish. This standard must be met at all times when flow is greater than or equal to 7Q10 and becomes of particular importance during low-flow conditions observed during the summer months when water temperature increases and the ability of the water to hold oxygen decreases. The second concern is large fluctuations in dissolved oxygen concentration and the amount of time supersaturated conditions exist. Large daily dissolved oxygen fluctuations result from extremely low dissolved oxygen concentration in the early morning hours followed by supersaturated and extremely high concentrations in the late afternoon. This condition is directly related to eutrophication and the amount of both floating and rooted biomass in the system and is indicative of excessive biomass.

Predictive modeling conducted for the Assabet included evaluating both these concerns. First, the model output tracked the number of hours at 30 stations throughout the river during one week of low flow conditions approximating 7Q10 that the dissolved oxygen was predicted to be less than 5.0 mg/l (see Table 4). Second, although the diurnal fluctuation at each location was estimated, the output was evaluated for the amount of time dissolved oxygen exceeded saturation concentrations during that low flow week to provide an indirect measurement of the impacts and the amount of biomass in the system.

As previously noted, data were collected during the summer of 1999 near 7Q10 conditions. Daily average flows during July 19-25, 1999, ranged from 14 cubic feet per second (cfs) to 22 cfs and were typically near 15 cfs. The 7Q10 flow at the Maynard U.S.G.S. gage is 15.1 cfs.

The calibrated model run (1), simulating the baseline July 1999 conditions, estimated that 9.5% of the time minimum dissolved oxygen violations occurred during that week and dissolved oxygen was above saturation 34.8% of the time. The calibrated model output was used as the baseline to evaluate the changes in water quality targets with changes is POTW loads, sediment phosphorus flux, and other changes as noted.

An additional model run (run 5) using July, 1999, POTW flows, 0.0 mg/l total phosphorus in the POTW effluents, and no reduction of sediment phosphorus flux, predicted a substantial reduction in the per cent of time the minimum dissolved oxygen criterion was violated but did not eliminate the violations entirely. The model predicted that minimum dissolved oxygen concentration violations decreased from 9.5% during the week to 1.4% of the time during low flow conditions. Of special note is that the reduction in biomass is only 12.5%.

Table 8
Zero Total Phosphorus Effluent with 100% Sediment Phosphorus Flux
(excerpted from Table 4)

		Effluent Dissolved P, mg/l				BIOMASS 1999 and % Reduction from 1999	Average Tot P mg/l	Max Tot P mg/l	Min Tot P mg/l	**%** time <5 DO	**%** time DO>SAT
	Run	WBORO	MWEST	HUD	MAY						
FLUX 100%											
July 1999 POTW flows[1]	**1**	1999 effluent values				161,300	0.308	0.671	0.141	9.5%	34.8%
July 1999 POTW flows	**5**	0.000	0.000	0.000	0.000	12.5%	0.039	0.297	0.007	1.4%	39.9%

[1] July 1999 POTW flows (mgd): Westborough 5.27; Marlborough West 1.92; Hudson 1.87; Maynard 0.94

These results indicate that phosphorus load reductions from sources other than POTWs are also necessary to meet water quality standards. Model runs with various reductions in the sediment phosphorus flux predicted that violations of the 5 mg/l dissolved oxygen minimum criterion could be eliminated in conjunction with POTW point source phosphorus control. Violations of the dissolved oxygen minimum criterion were eliminated when phosphorus concentrations in POTWs were reduced to 0.1 mg/l at the POTWs when combined with at least 90% sediment phosphorus flux reduction. Other combinations of sediment phosphorus flux reduction and POTW total phosphorus effluent concentrations also met the minimum dissolved oxygen criterion. For instance, POTW effluent concentrations of 0.05 mg/l combined with a sediment flux reduction of 75% also met the criterion; however, the criterion was not met when only a 50% reduction in sediment phosphorus flux was achieved. Table 9 summarizes the results with respect to violations of the minimum dissolved oxygen criterion.

Table 9
Model Runs Meeting Dissolved Oxygen Minimum Criterion
(excerpted from Table 4)

		Effluent Dissolved P, mg/l				BIOMASS 1999 and % Reduction from 1999	Average Tot P mg/l	Max Tot P mg/l	Min Tot P mg/l	% time <5 DO	% time DO>SAT
	Run	WBORO	MWEST	HUD	MAY						
FLUX 100%											
1999 POTW flows	**1**	1999 effluent values				161,300	0.308	0.671	0.141	9.5%	34.8%
FLUX 25%											
July 1999 POTW flows[1]	**19**	0.050	0.050	0.050	0.050	49.2%	0.017	0.086	0.004	0.0%	32.1%
July 1999 POTW flows	**22**	0.025	0.025	0.025	0.025	52.9%	0.015	0.086	0.004	0.0%	31.5%
Design flow[2]	**23**	0.025	0.025	0.025	0.025	52.9%	0.014	0.086	0.004	0.0%	32.3%
FLUX 10%											
July 1999 POTW flows	**10**	0.100	0.200	0.200	0.200	46.8%	0.020	0.060	0.003	0.0%	26.0%
July 1999 POTW flows	**8**	0.100	0.100	0.100	0.100	55.6%	0.016	0.060	0.003	0.0%	23.3%
Design flow	**14**	0.100	0.100	0.100	0.100	54.9%	0.015	0.045	0.003	0.0%	22.8%
July 1999 POTW flows	**16**	0.050	0.100	0.100	0.100	58.1%	0.014	0.044	0.003	0.0%	22.7%
July 1999 POTW flows	**9**	0.050	0.050	0.050	0.050	64.2%	0.012	0.044	0.003	0.0%	21.5%
July 1999 POTW flows	**24**	0.025	0.100	0.100	0.100	59.8%	0.012	0.044	0.003	0.0%	22.6%
July 1999 POTW flows	**20**	0.025	0.025	0.025	0.025	67.9%	0.010	0.044	0.003	0.0%	20.6%
Design flow	**21**	0.025	0.025	0.025	0.025	67.0%	0.010	0.044	0.003	0.0%	20.1%

[1] July 1999 POTW flows (mgd): Westborough 5.27; Marlborough West 1.92; Hudson 1.87; Maynard 0.94
[2] Design flow (mgd): Westborough 7.68; Marlborough West 2.89; Hudson 3.00; Maynard 1.45

An additional metric that was used to assess the impact of phosphorus discharges on water quality was the amount of time dissolved oxygen concentrations exceeded saturation levels. This metric was used as a surrogate to estimate the biomass response to various control measures. The results of the model indicate that a small increase may occur in the percent of time dissolved oxygen exceeded saturation values as a result of only reductions in POTW loadings; however, as sediment phosphorus flux is reduced by 90% of its 1999 value, the percent of time that dissolved oxygen would exceed saturation was reduced by approximately one third indicating a significant reduction in biomass in the system (Table 4).

In addition, diurnal fluctuations in dissolved oxygen were, on average, reduced throughout the system when both sediment flux was reduced by 90% and POTW discharge concentrations were reduced below 0.2 mg/l. The largest improvement in dissolved oxygen fluctuations occurred from river mile 25 to river mile 18 (below Marlborough West POTW to the Hudson Impoundment Dam) where diurnal fluctuations decreased from a high of about 7.5 mg/l to approximately 5.0 mg/l. From river mile 15 to river mile 9 (below the Hudson POTW in the Gleasondale and Ben Smith impoundments) fluctuations decreased from an average of about 5.5 mg/l to less than 1.0 mg/l. These results indicate significantly less photosynthetic and respiratory activity resulting from less biomass.

Design vs. July 1999 Flows

Tables 4 and 9 show that once POTW phosphorus concentrations are reduced to 0.1 mg/l at the Westborough POTW and less than 0.2 mg/l at the other three major POTWs and the sediment flux is reduced by greater than or equal to 75 % of July 1999 values there are very little differences between response variables when considering design flows versus existing flows. For example, when the sediment flux is reduced by 90% and the POTWs discharge 0.1 mg/l of total phosphorus, the model predicts that the minimum dissolved oxygen criterion would be met at both existing and design POTW flows (Runs 8 and 14, respectively). Likewise, for these two runs, there is very little difference between the amount of time dissolved oxygen levels are supersaturated (23.3% vs. 22.8% respectively), the amount of biomass present (71,600 kg vs. 72,800 kg), and in-stream phosphorus concentrations (average: 0.016 mg/l vs. 0.015 mg/l, maximum: 0.06 mg/l vs. 0.045 mg/l). These relative comparisons hold similarly for Runs 7 and 26. As a result, the TMDL will be based upon design flows rather than existing flows.

The Assabet Consortium also requested that a preliminary analysis via a model run be made using a projected flow from the Marlborough West POTW of 4.44 mgd from its current permit flow of 2.89 mgd. For consistency with the TMDL developed here, POTW effluent total phosphorus concentrations were kept at 0.1mg/l and sediment phosphorus flux was at the 90% reduction level. The results from the model run for this scenario were very similar to those from the scenario specified for the TMDL: all POTWs flow at design, 0.1 mg/l total phosphorus, and a 90% reduction in sediment phosphorus flux. Three additional runs made at POTW flows above design flow were also made. These four runs, 27-30, are reported in the ENSR Phase II report (ENSR, 2003) in an appendix.

Both DEP and USEPA have stated that any request to increase a discharge beyond currently permitted volumes would require supporting documentation satisfying DEP’s Antidegradation Policy that no other feasible alternative exists including, but not limited to, the discharge of additional treated effluent to groundwater to help restore tributary flows. Additionally, any antidegradation review will focus on whether an increase in design flow is consistent with achieving the Assabet River’s designated uses.

Summary of Model Results

The primary general conclusions from analyzing all the model results are as follows:

1) A reduction in POTW discharges of total phosphorus, by itself, is not sufficient to meet the minimum dissolved oxygen concentration standard, does not reduce biomass significantly, does not reduce the percentage of time of dissolved oxygen supersaturation, and maintains in-stream phosphorus concentrations significantly higher than USEPA guidance.

2) Reductions in sediment phosphorus flux, coupled with reductions in POTW discharges of total phosphorus, are necessary to meet the minimum dissolved oxygen concentration standard, reduce biomass significantly, reduce the percentage of time of supersaturation

significantly, and to approach the USEPA guidance for in-stream phosphorus concentrations. No significant difference was observed among the response variables when results were compared using POTW design flows and 1999 POTW flows at equivalent effluent phosphorus concentrations and sediment reductions. (specifically, from Table 4, runs 22 & 23, 8 & 14, and 20 & 21).

3) Biomass reductions of 50% or more over the baseline 1999 conditions are obtained primarily when sediment phosphorus flux is reduced by 90% and POTW total phosphorus effluent concentrations are lower than 0.1 mg/l.

4) A reduction in the Westborough POTW effluent concentration to 0.1 mg/l and all others to 0.2 mg/l with 1999 POTW flows and with a sediment flux reduction of 90% (Run 10) resulted in in-stream concentrations of less than 0.1 mg/l in the free flowing sections of the upper reaches and to less than 0.05 mg/l prior to entering the impoundments at Allen St. (RM 25.5-25.1), Hudson (RM 21.5-18.0), Gleasondale (RM 15.5-14.0), Ben Smith (RM 14.0-8.7), and Powdermill (RM 7.5-6.2).

5) Removal of the Ben Smith dam impoundment without POTW upgrades (run 11) had some benefit on the amount of biomass in the system, specifically reducing the biomass in the Ben Smith impoundment while marginally increasing it in the Powdermill impoundment, but did little to change the dissolved oxygen dynamics or result in any significant changes to in-stream phosphorus concentrations.

6) To achieve the water quality goals of reducing biomass by at least 50% based on 1999 conditions, meeting the minimum criterion for dissolved oxygen of 5.0 mg/l throughout the Assabet River, and reducing the duration of dissolved oxygen super-saturation by approximately 30% require that total phosphorus concentrations in POTW effluents be no greater than 0.1 mg/l during the growing season and that the sediment flux be reduced to 10% of its 1999 value.

TMDL

Total Maximum Daily Loads (TMDL) can be defined by the equation:

TMDL = BG + WLAs + LAs + MOS

where

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
LAs = portion allotted to (cultural) non-point sources
MOS = margin of safety

and consideration must also be give to Seasonal Variability and to Growth.

This equation can be expanded further to separate sediment loading from other non-point source loading as follows:

$$\mathbf{TMDL = BG + WLAs + Sediment + NPS + MOS}$$

where

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
Sediment = portion allotted to sediment
NPS = non-point source loadings other than sediment
MOS = margin of safety

Based upon the detailed data collection and predictive water quality modeling conducted and in consideration of all of evidence and analysis previously discussed, DEP is establishing in accordance with 314 CMR 4.05(5)(c) an effluent limit of 0.1 mg/l total phosphorus at design flows during the growing season for all POTWs discharging to the Assabet River plus a 90% reduction in sediment phosphorus flux. These limits and reductions to nutrient inputs are necessary to control accelerated and cultural eutrophication in the Assabet River so that it can meet its designated uses.

As previously noted, during the non-growing season, effluent limits for phosphorus will not be in effect; however, DEP and USEPA are concerned that the discharge of particulate phosphorus during the non-growing months may settle in downstream impoundments and slow moving reaches of the river. Therefore, the NPDES permit will require that the POTWs optimize the removal of particulate phosphorus and monitor both total and dissolved phosphorus to determine if there is a need for non-growing season limits.

As noted above, the model simulations indicate that a combination of reductions of phosphorus at the POTWs and from sediment phosphorus flux is necessary to meet water quality standards and designated uses. The model predicts that the limits identified above will result in the following:

1. the minimum dissolved oxygen criterion of 5.0 mg/l will be achieved during low flow conditions in all reaches of the Assabet River thus meeting the requirements of 314 CMR 4.05(3)(b)1(a).

2. the amount of time in-stream dissolved oxygen levels exceed saturation levels will be reduced by approximately 35% indicating a significant amount of biomass reduction.

3. biomass is expected to be reduced by 55% in the system over 1999 conditions which should meet the state criteria for “aesthetics” in 314 CMR 4.05(5)(a) and address most of the public concerns about excessive floating aquatic vegetation.

4. in-stream total phosphorus concentrations are expected to drop from an average concentration in 1999 of about 0.31 mg/l to an average concentration of 0.015 mg/l further validating the model and weight-of-evidence approach.

Waste Load Allocation

The waste load allocation for total phosphorus is summarized in the following table:

Table 10
TMDL for Total Phosphorus
(minor POTWs not modeled in italics)

			POTW Effluent Limits Total Phosphorus, mg/L April 1 – October 31[1]		POTW Effluent Limits Total Phosphorus, mg/L November 1 – March 31
POTW	NPDES	Design Flow, MGD	mg/L	lbs/day @ design flow	mg/L and lbs/day
Westborough	MA0100412	7.68	0.10	6.4	Optimize for particulate phosphorus removal and monitor and report for total and dissolved phosphorus concentration
Marlborough West	MA0100480	2.89	0.10	2.4	
Hudson	MA0101788	3.00	0.10	2.5	
Maynard	MA0101001	1.45	0.10	1.2	
Powdermill Plaza[2]		---	N/A	N/A	
Middlesex School[3]	*MA0102466*	0.052	0.50	0.22	0.50 mg/l and 0.22 lb/day
MCI Concord[4]	*MA0102245*	0.3	0.50	1.25	0.50 mg/l and 1.25 lb/day

[1] Includes a margin of safety of 6.1 pounds per day

[2] connecting to Acton POTW – no TMDL necessary

[3] Spencer Brook is receiving water – tributary to Assabet River and below all impoundments

[4] downstream of all impoundments and near confluence with Concord River

Three minor POTWs are included in the Waste Load Allocation table and the TMDL. Two of these POTWs discharge near the confluence with the Sudbury River (to form the Concord River), far downstream of any of the modeled impoundments, and the remaining one, Powdermill Plaza, will not be discharging at all since it will be connecting to the Acton POTW. The Middlesex School POTW discharges 0.22 lbs/day total phosphorus, primarily during the non-growing season, based on permitted flow and concentration. During the months of June through August flows from the Middlesex School are approximately 50% or less than flows during the normal school year. This reduced discharge significantly reduces the loading of phosphorus to the Assabet River. For MCI Concord at its design flow and recommended 0.5 mg/l total phosphorus, the waste load allocation is 1.25 lbs/day. With the TMDL based on total phosphorus of 0.1 mg/l in the effluents from the four major POTWs and the 90% reduction in phosphorus from sediment flux fully realized, predicted total phosphorus concentrations in the

Assabet River near the points of discharge of these treatment facilities are less than 0.01 mg/l. The incremental difference from the Middlesex School and MCI Concord POTWs would be less than 0.0004 and 0.011 mg/l total phosphorus, respectively. This would result in an in-stream total phosphorus concentration of less than 0.025 mg/l, a concentration that is expected to be lower than that needed to ensure meeting all designated uses affected by nutrients. Because of the above, the Department considers the proposed loads from these sources to be acceptable in terms of water quality in the mainstream Assabet River.

Load Allocation

The results from the HSPF model include two explicit sources of non-point source phosphorus: runoff combined with groundwater and flux from the sediment. Runoff combined with ground water can be separated into two components: natural background and cultural. To estimate the natural background portion, an export coefficient was used which assumes the watershed is entirely forested. An export coefficient of 0.13 kg/HA/yr was used based on the range of values summarized by Reckhow et al. assuming the entire watershed is forested yields

0.13 kg/HA/yr x 178 sq mi x 259 HA/sq mi x 2.2lbs/kg = 13,185 lbs P/yr

This load represents the natural background portion of phosphorus associated with runoff and groundwater. (There are not sufficient data to disaggregate these two components.) To apportion this over the year, daily stream flow for 1999 from the USGS gage in Maynard was used to prorate the annual load on daily time scale. The estimated daily natural background P load is assumed to be proportional to the percentage of annual flow volume represented by each day's flow. For the week of July 12-19, this amounted to 3.6 lbs/day. The HSPF model predicts approximately 4.6 lbs/day of P from non-point sources other than sediment flux during this same period. Thus the calculated cultural contribution during this low flow period is estimated to be 1 lb/day.

During the growing season, when phosphorus from runoff is at its minimum, the principal nonpoint source of phosphorus is from sediment flux. The load allocation is expressed as a reduction in phosphorus sediment flux by 90% from the 1999 values that results in a target load allocation of 2.8 lbs per day for this source.

Margin of Safety:

TMDLs must provide a margin of safety to address uncertainties in the technical analysis. In the case of the Assabet a margin of safety is provided in two ways. First, and perhaps most significant, the margin of safety is implicit with conservative assumptions used in the model. For example, the scenarios include very low point source phosphorus loads during the entire growing season and not just during the low flow period actually modeled. Second, the Department is requiring that all POTWs achieve an effluent limit of 0.1 mg/l total phosphorus to account for model uncertainties and provide a margin of safety that reductions predicted by the model will actually occur. This is relevant particularly to the model predictions of biomass reductions that are the most critical issue on the Assabet River.

The limit for total phosphorus of 0.1 mg/l at the Westborough POTW and 0.2 mg/l at the Marlboro, Hudson, and Maynard POTWs is predicted to meet the minimum dissolved oxygen criterion when combined with a reduction of 90% sediment phosphorus flux. However, the purpose of this TMDL is also to address eutrophication issues in the river and not just minimum dissolved oxygen. Therefore, other factors also must be considered. The results of simulating the 1999 flows with 0.1 mg/L P in Westborough's effluent and 0.2 mg/L in the other 3 effluents (Run 10) was close to meeting standards, but did not meet all of the goals and therefore is not considered to meet the TMDL. However, the difference between the results for two scenarios (Runs 7 and 26) with POTW effluent concentrations at 0.2mg/L P as well as for the two scenarios (Runs 8 and 14) at 0.1mg/L P, all with 90% reduction of sediment flux, for 1999 and design flows are not dramatically different. This suggests that at these relative stringent effluent limits, changes in flow have gradual impacts on water quality. Hence, using Run 10 results as a baseline to set the upper limit (and upper limit is emphasized) on the margin of safety seems within reason. While the EPA guidance phosphorus concentration was approached under these scenarios at all locations, there is uncertainty about the model's prediction of biomass, and there is a question whether or not a 90% reduction in sediment phosphorus can be completely achieved. Therefore, the Department believes effluent limits for total phosphorus of 0.1 mg/L at all POTWs are necessary as a component of the margin of safety. In addition, the margin of safety takes into consideration the fact that the communities have not yet completed their comprehensive facility planning process nor have they completed the MEPA process at this time therefore future needs have not yet been finalized.

Given the above, an upper limit for a margin of safety in pounds per day is being provided and is calculated as the difference between setting limits of 0.1 mg/l rather than 0.2 mg/l at the Marlboro West, Hudson, and Maynard facilities. Westborough was not considered since, as previously identified, a limit of 0.1 mg/l was necessary at that facility to meet minimum dissolved oxygen criterion. As a result, a margin of safety of 6.1 pounds per day is being provided in addition to the conservative model assumptions.

TMDL Comparison Summary

The following provides a summary of the existing loadings (July, 1999 conditions) and the specified TMDL total phosphorus loadings for the Assabet River:

TMDL Allocation

	TMDL lbs/day Total P	1999 lbs/day Total P
Background (BG) based on forested watershed	3.6	3.6
Load Allocation		
Watershed NPS	1.0	1.0
Sediment P Flux	2.8	28.0
Wasteload Allocation	(@ Permitted Flows)	(@ existing July 1999 Flows)
Major Dischargers		
Westborough	6.4	46.1
Marlborough West	2.4	11.3
Hudson	2.5	32.2
Maynard	1.2	3.1
Minor Dischargers		
Powdermill Plaza	0.008[1]	0.34[1]
Middlesex School	0.22[2]	0.22[2]
MCI Concord	1.25[2]	1.25[2]
Margin of Safety	6.1	-
Total	**27.5**	**127.1**

[1] connecting to Acton POTW therefore no load anticipated; used estimated average flow @ 5.0 mg/l total phosphorus

[2] estimated using design flows and 0.5 mg/l total phosphorus

Seasonal Variation

In the case of eutrophication for systems with relatively short retention times such as small impoundments, the growing season is the critical time. This suggests that nutrient loads to a flowing water system are most relevant during that period.

During 1999 and 2000 a number of water quality surveys were conducted to evaluate nutrient loadings to enhance understanding of the nature and extent of nutrient sources to the Assabet River (ENSR, 2001). Total phosphorus loadings were estimated using concurrently measured flows and total phosphorus concentrations from point sources and from tributaries, which represents non-point sources. The evaluation of nutrient loadings during 6 field surveys found that point sources contributed the majority of nutrient loadings to the Assabet River during most surveys. Point sources were found to be the dominant source of biologically available phosphorus (i.e., dissolved phosphorus) during all 6 surveys representing 88% to 98% of the overall biologically available phosphorus load.

The study also identified that about 90% of the point source loading is in the dissolved form which is not only available for direct uptake by the plant community but also will not settle. As a result there is assumed to be little likelihood that POTW discharges of dissolved phosphorus during the non-growing season and particularly during high flow months will be retained in the system for use during the growing season.

Therefore, only seasonal phosphorus removal at the POTWs is warranted and effluents limits for total phosphorus will be applicable from April 1 through October 31. During the non-growing season, November 1 – March 31, effluent limits for phosphorus will not be in effect; however, due to concerns that particulate phosphorus, if discharged, may potentially settle in downstream impoundments during this timeframe, optimization for particulate phosphorus removal will be required and effluent monitoring for both total and dissolved phosphorus will be required to support future permitting decisions. The further question of whether dissolved phosphorus might adsorb to particulate matter and settle to later become biologically active is also open and will be addressed through future monitoring programs.

Monitoring Plan for the TMDL Developed Under an Adaptive Management Approach

In order to assess the progress in and success of obtaining the TMDL's water quality goals, a systematic monitoring plan needs to be established. Data necessary to determine whether water quality goals have been met through the implementation of one or a combination of control mechanisms provided for in the TMDL need to be collected and evaluated.

The actual design of the monitoring program will be developed during the first permit cycle to incorporate the results of the sediment feasibility study that will also be developed during that time.

TMDL Implementation

The above information and modeling conducted to date indicates that both sediment remediation and POTW treatment facility improvements are necessary to achieve water quality goals.

Reduction in phosphorus in the sediments may occur naturally over a long period of time once the phosphorus levels in the effluent from the POTWs are reduced to 0.1 mg/l or lower. The reduction in sediment phosphorus flux can likely be expedited with measures such as dredging, encapsulating and/or dam removal. Given this and the importance of sediment remediation, a phased approach is recommended to allow the communities an opportunity to investigate sediment remediation and/or dam removal options which could result in achieving water quality standards and designated uses in a more cost effective manner than solely reducing point source phosphorus sources.

As previously noted, this approach requires an initial reduction in POTW effluent total phosphorus concentrations, on a seasonal basis, to 0.1 mg/l of total phosphorus in each discharge to be achieved before or during the next 5 year NPDES permit cycle ending in 2009. Also, by March 2007, the communities, in cooperation with federal and state agencies and other stakeholders, will conduct a detailed feasibility study of the dam removal and sediment control options and provide a recommended plan. The study will include, but not necessarily be limited to, identifying options for sediment remediation, investigation of potential sediment transport issues and downstream impacts, evaluation of legal issues, and recommendations for cost effective solutions to achieve water quality standards.

By the spring of 2008 a determination will be made if sediment remediation is a viable alternative. If so, a new compliance schedule will be negotiated for completion of the selected work. If DEP and USEPA determine that sediment remediation is not a viable alternative, then new permit limits would be developed based on any new information and/or standards available at that time. The new limits will be incorporated into the next permit cycle scheduled for 2009 and would have to be met by 2014.

As previously noted, USEPA guidance documents support adaptive management when dealing with the TMDL process for receiving waters with serious and complex water quality problems such as the Assabet River. Given the uncertainties associated with biomass response and the feasibility of sediment remediation, DEP believes that the adaptive management approach is appropriate.

Based on adaptive management the following implementation actions are proposed:

1. Until POTW upgrades for phosphorus removal are constructed, the POTWs will be required to continue optimization of seasonal removal of total phosphorus to meet the 2000 interim discharge limits for total phosphorus of 0.75 mg/l.

2. In the Spring of 2004 the NPDES permits will be reissued to include seasonal total phosphorus limits for all POTWs to achieve concentration based limits, loading based limits or some combination of the two to achieve 0.10 mg/l total phosphorus from April 1 to October 31. The communities would be required to achieve those limits by April 2009.

3. The communities will be allowed to investigate sediment and dam removal options that may be more cost-effective than achieving additional facility reductions. The feasibility study and recommended plan will be provided to the agencies and other stakeholders by March 2007 for additional discussion and decision-making. As previously outlined, by the spring of 2008 the agencies will make a determination if sediment remediation is a viable alternative. If so, a new compliance schedule will be negotiated for completion of the selected work. If the agencies determine that sediment remediation is not a viable alternative, then new permit limits will be developed and based on any new information

and/or standards available at that time. The new limits will be incorporated into the next permit cycle scheduled for 2009 and would have to be met by 2014.

4. During the first permit cycle a monitoring program will be developed and implemented to assess the water quality conditions, the success of remediation efforts, and if water quality goals are being achieved.

Reasonable Assurance

Implementation of the TMDL will be assured primarily through the NPDES permit process inasmuch as the point discharges are the principal source of phosphorus to the Assabet River during the period of concern (growing season). The TMDL includes adaptive management. Monitoring of the Assabet's response to incremental controls will allow a determination of whether the modeling predictions are accurate and whether the water quality goals have been achieved. If further control efforts are needed, both implementation of sediment remediation and more stringent effluent limits will be evaluated.

While not specifically addressed in the TMDL, the implementation of non-point source (NPS) controls beyond those required by Phase II Stormwater regulations may be available as a limited tradeoff for future point source loads and/or a portion of the margin of safety. This, however, will be highly dependent upon the success of any sediment remediation efforts. In the meantime, point source control based on optimization of phosphorus removal under current POTW configurations must be achieved and maintained.

Public Participation

A public meeting was held on March 25, 2004, for public review and solicitation of comments on the **Draft Assabet River Total Maximum Daily Load for Total Phosphorus** (Report Number: MA82B-01-2004-01; Control Number CN 201.0). Approximately 36 persons attended. Comments were accepted through April 12, 2004.

Response To Comments

Please see Appendix 4 (page 63) for the response to comments.

References

ENSR, 2000a : Proposal to Develop a Nutrient TMDL for the Assabet River, ENSR International, April 2000

ENSR, 2000b : SuAsCo Watershed Assabet River TMDL Study, Phase One Interim Report, ENSR International, U.S. Army Corps of Engineers, MA Department of Environmental Protection, June 2000.

ENSR, 2001 : SuAsCo Watershed Assabet River TMDL Study, Phase One: Assessment Final Report, ENSR International, U.S. Army Corps of Engineers, MA Department of Environmental Protection, November 2001.

ENSR, 2003 : "SuAsCo Watershed Assabet River TMDL Study, Phase Two: Analysis, Draft Report, ENSR International June 2003 (under review).

NAP, 2000: Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution, National Academies Press, 2000.

USEPA, 1986 : "Quality Criteria for Water 1986", EPA 440/5-86-001, May 1986.

USEPA, 2000a : "Nutrient Criteria Technical Guidance Manual, Rivers and Streams, EPA/ 822-B-00-002, July 2000.

USEPA, 2000b : "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Ecoregion XIV", EPA 822-B-00-022, December 2000.

Appendices

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Appendix 1

Figure A-1 - Schematic of Summer 1999 Minimum Dissolved Oxygen Concentrations and Physical Representation of the Assabet River

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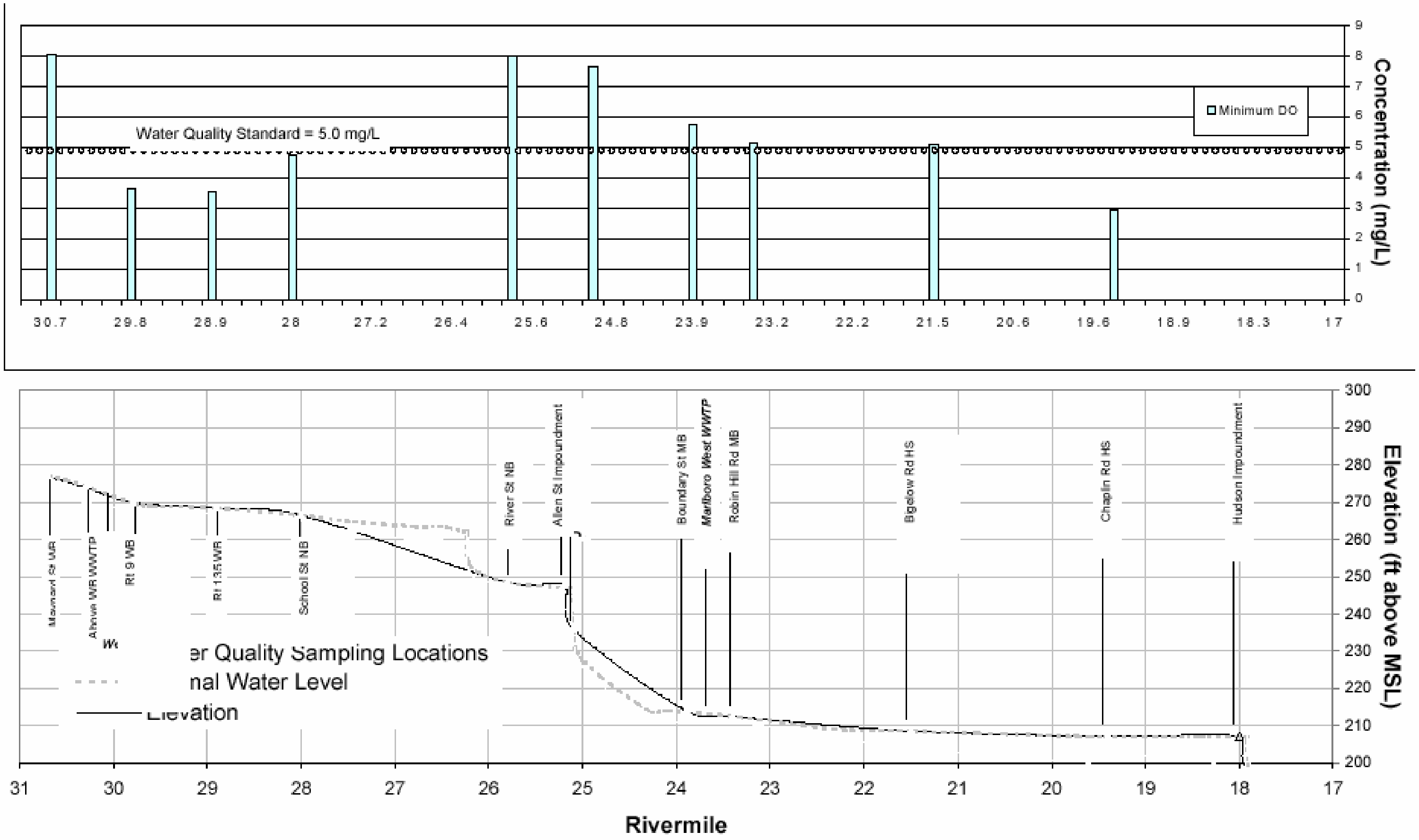
Figure A-1

Figure 5-1(a) Summer 1999: Minimum Dissolved Oxygen Concentrations Measurements with Schematic Physical Representation of the Assabet River (RM 18-31)



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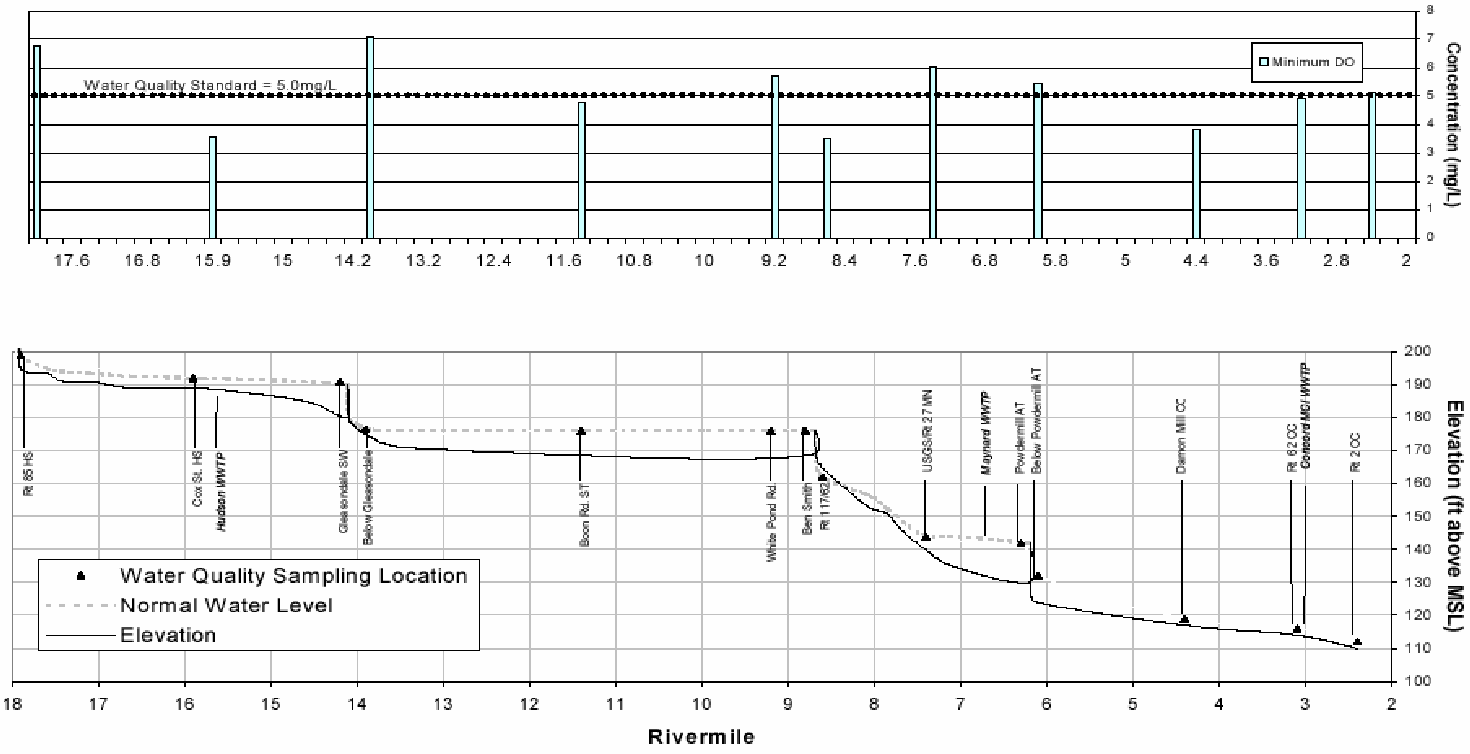
5-47

November, 2001

Figure A-1 continued

Figure 5-1(b) **Summer 1999: Minimum Dissolved Oxygen Concentrations Measurements with Schematic Physical Representation of the Assabet River (RM 2-18)**



Appendix 2

Table A-1 - Summary of Model Runs

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Table A-1

Scenario Summary Assabet HSPF Model

(existing = effluent concentrations and/or flows, and sediment P flux for 1999)

(see footnote for permitted and projected flows)

Run	POTW Dissolved Phosphorus mg/l	POTW Flow	Sediment P Flux Reduction	Notes
1	Existing	Existing	existing	
2	0.2	Existing	existing	
3	0.1	Existing	existing	
4	0.05	Existing	existing	
5	0	Existing	existing	
6	0	Existing	0% existing	
7	0.2	Existing	10% existing	
8	0.1	Existing	10% existing	
9	0.05	Existing	10% existing	
10	Westborough – 0.1 others – 0.2	Existing	10% existing	
11	Existing	Existing	existing	Ben Smith dam removed
12	Westborough – 0.57 others – 0.2	Westborough – 50% of existing; others @ existing	10% existing	effluent to groundwater @ Westborough
13	0.5	permitted[1]	existing	
14	0.1	permitted[1]	10% existing	
15	0.1	Existing	75% existing	
16	Westborough – 0.05 others – 0.1	Existing	10% existing	
17	Westborough – 0.05 others – 0.1	Existing	75% existing	
18	0.05	Existing	50% existing	
19	0.05	Existing	25% existing	
20	0.025	Existing	10% existing	
21	0.025	Existing	25% existing	
22	Westborough – 0.025 others – 0.1	Existing	10% existing	
23	0.025	permitted[1]	10% existing	
24	0.025	permitted[1]	25% existing	
25	0.2	permitted[1]	25% existing	
26	0.2	permitted[1]	10% existing	
27	0.2	projected	25% existing	
28	0.2	projected	10% existing	
29	0.1	permitted w Marl W projected[2]	10% existing	
30	0.1	permitted w Marl W projected[2]	25% existing	

[1] permitted flows, mgd: Westborough 7.68; Marlborough Westerly 2.89; Hudson 3.00; Maynard 1.45

[2] permitted with Marl W projected, mgd: Westborough 7.68; Marlborough Westerly 4.44; Hudson 3.00; Maynard 1.45

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Appendix 3

Table A-2 – List of Dams on the Assabet River

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Table A-2
List of Dams on the Assabet River

(courtesy of OAR)

(Listed upstream to downstream)

Nichols Dam (A-1) - Westborough
Old Sawmill Dam (Route 20) - Northborough
Woodside Dam (Allen Street) - Northborough
Tyler Flood Control Dam (Robin Hill Road) - Marlborough
Hudson Dam (Route 85) - Hudson
Gleasondale Dam - Stow
Ben Smith Dam – Maynard
Powdermill Dam - Maynard
Damonmill Dam (*breached, but does back up water in higher flows.) – West Concord

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Appendix 4

Response to Comments

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Assabet River Phosphorus TMDL

Response to Comments

June 1, 2004

Notice to Reviewers: The following pages provide DEP's responses to questions and issues raised on the Department's draft Assabet River Nutrient Total Maximum Daily Load for Total Phosphorus (Report # MA 82B-01-2004-01; Control Number CN201.0). A public meeting was held on March 25, 2004 at Marlborough High School in Marlboro MA and the public comment period ended on April 12, 2004. The comments listed below were extracted from letters received during the comment period. Original letters can be viewed at the following address.

DEP, Division of Watershed Management

627 Main St., 2nd Floor

Worcester, MA 01608

Comments and responses are provided below from each agency, group, municipality, or individual that commented. To aid you in your review comments are provided in **bold** and DEP responses are provided in *italics*.

U.S. EPA

Comment #1: EPA New England has reviewed the draft TMDL for total phosphorous for the Assabet River. On January 27, 2004, EPA offered comments on a draft of the document; some of EPA's comments were addressed and others were not. The comments set out below reflect some of EPA's previous comments and new comments that reflect changes that occurred in the draft. An optimization requirement alone may not be sufficient to ensure that the particulate phosphorus being discharged in the winter period is minimal. A winter phosphorus limit may be necessary.

Response #1: Although DEP understands EPA's concern DEP also believes it is premature to set a winter limit at this time. There are several reasons for this. First, DEP does not have sufficient data during the winter to properly evaluate how much particulate phosphorus is actually discharged from the Assabet facilities. It is for this reason DEP has requested additional data collection and reporting so we can properly assess the potential for any impacts. Second, DEP is concerned that meeting a winter phosphorus limit may not be possible while the facilities are under construction for upgrades. A future limit however may be appropriate once new facilities are available. DEP believes that a requirement to monitor total phosphorus and filtered phosphorus and to optimize the removal of particulate phosphorus during the winter months is a reasonable expectation during the upgrade period. This information will help in refining any further requirements. By flagging the concern about particulate P in the winter, DEP has alerted the design engineers that this needs to be considered in any treatment train proposed. Right now, DEP is of the opinion that this is sufficient at this time, pending further investigation as noted in the response to the following question.

Comment #2: The assumptions in the TMDL that the particulate component of the total phosphorus discharged during the winter period is insignificant and that the dissolved fraction will pass through the system should be checked and verified as part of the adaptive management strategy. Of particular concern is the potential for dissolved phosphorus to adsorb to particulate matter in the water column and the potential for certain macrophytes to continue taking up dissolved phosphorus in the winter period.

Response #2: It should be noted that DEP believes that by optimizing the removal of particulate phosphorus in the non-growing season when treatment facilities are upgraded, will adequately control this constituent.

DEP agrees that EPA, the Consortium and DEP have an interest in better understanding the physical dynamics of P discharged in the non-growing season and suggests this issue be incorporated into the monitoring program needed to evaluate the adaptive management approach recommended for the TMDL.

Comment #3: A decision on appropriate interim limits for total phosphorus will be made as part of the compliance schedule contained in the re-issued permits or in separate administrative orders. This decision needs to also consider the appropriateness/necessity of interim limits and/or optimization requirements in the winter period in order to minimize the accumulation of phosphorus in the sediments. The TMDL makes a recommendation for seasonal interim limits of 0.75 mg/l but does not include or reference an evaluation of whether lower limits are feasible for the 4 -5 year period necessary to upgrade the facilities.

Response #3: It is not clear how reliable removals can be at the various treatment plants given current design and operating constraints. DEP considers the 0.75 mg/L limit for TP during the growing season to be a reasonable upper limit while encouraging the POTWs to do as well as practical with the given constraints, including those associated with construction of additional treatment needed to achieve the effluent quality required by the TMDL. We note that this limit is already being achieved based on review of current discharge monitoring reports (DMRs).

Comment #4: The TMDL should include a discussion of the implications of the Maynard discharge location, i.e., directly into the Powder Mill impoundment, and the potential benefits of relocating the discharge if removal of the Powder Mill dam is not feasible.

Response #4:Modeling conducted to date indicates that the goals of the TMDL would be met if Maynard were to achieve an effluent concentration of 0.1 mg/l in concert with a 90% sediment reduction of phosphorus. DEP agrees that relocating Maynard's discharge to below the Powder Mill impoundment may provide additional environmental benefit however a significant amount of additional information would be needed to properly assess the legal and technical issues associated with this action. DEP believes this issue should be fully evaluated outside the context of the TMDL and in concert with the sediment evaluation study proposed by the TMDL or, as an alternative option, be addressed in the CWMP process.

Comment #5: The discussion relative to the Middlesex School discharge should note that the permit limit for the facility will be driven by water quality concerns in Spencer Brook as opposed to the main stem of the Assabet River. A limit of 0.5 mg/l total phosphorus would not be expected to be protective of Spencer Brook.

Response #5: DEP considers the seasonal effluent limit of 0.5 mg/L P for this facility appropriate for the present for several reasons. First, as indicated in the TMDL, The Middlesex School POTW discharges 0.22 lbs/day total phosphorus, primarily during the non-growing season, based on permitted flow and concentration. During the months of June through August flows from the school are approximately 50% or less than the rest of the year which results in a significantly reduced loading to the river. Based on a mass balance calculation DEP estimates that the incremental increase in concentration from this facility on the Assabet River phosphorus concentration to be about 0.0004 mg/l. Second, the model developed by DEP was not designed to evaluate the potential impact of the Middlesex School on Spencer Brook. Until such as model is developed DEP believes the proposed limit is appropriate.

Comment #6: An MCI Concord discharge at 0.5 mg/l total phosphorus has the potential to raise the in-stream concentration of phosphorus at 7Q10 flows by approximately 10 ug/l. This is a significant effect relative to national guidance for in-stream phosphorus concentrations. Given the uncertainties of achieving a 90% reduction in sediment phosphorus loadings and the significant eutrophication of the downstream Concord River, EPA does not believe that 0.5 mg/l is an appropriate limit. It is EPA's position that, at a minimum, a limit based on "Highest and Best Practical Treatment" is appropriate.

Response #6: As stated in the TMDL DEP considers the effluent limit of 0.5 mg/L P for this facility appropriate at this time. DEP is of the opinion that the potential impacts of this increase is negligible because the discharge is downstream of the impounded sections in the Assabet River and the resulting in-stream concentration during 7Q10 conditions would be less than the in-stream national guidance values used by EPA under the conditions of the TMDL. Finally, any potential impacts to the Concord River system downstream cannot be evaluated until a TMDL for that system is developed.

City of Marlborough – CDM

Comment #1: Selected Indicator and Target Values. The selected indicators and their respective target values need to be better defined.

Primary Indicators

Minimum Dissolved Oxygen: The state water quality standard states the dissolved oxygen shall not be less than 5.0 mg/L in warm water fisheries. This is the most important standard and we have no objection to complying with this standard.

Secondary Indicators

Total Biomass: A target of 50% reduction of total biomass from the July 1999 levels is selected. No basis is given for the selected reduction level. It appears the selected target level is arbitrary.
Page 28 of 50 of the TMDL report states, "While it should be recognized that predicting biomass response is on the edge of the state of the art to model, DEP believes that large predicted differences are qualitatively correct."

Page 30 of 50 goes on to state, "… DEP believes the model can be used to predict order of magnitude differences."

Based on the analysis of the model runs, specifically a comparison between runs 7, 10 and 14, there appears to be no measurable or defendable difference between all four major POTWs discharging 0.1 mg/L total phosphorus – a 55% reduction in total biomass – and all four major POTWs discharging 0.2 mg/L total phosphorus – a 45% reduction in total biomass. Given the significant capital and operation and maintenance cost increases associated with the difference in meeting a 0.1 mg/L versus a 0.2 mg/L total phosphorus limit, and the suspect environmental benefit produced by the lower limit, the 0.1 mg/L limit is not justified.

Response #1: DEP concurs that the target of a 50% reduction in biomass is based on judgment. Floating biomass in particular clearly is an issue and DEP considers the 50% reduction goal a minimum objective given its own long experience in monitoring and assessing the Assabet River. DEP also considers the reduction in phosphorus to affect principally the floating macrophytes since rooted macrophytes derive much of their nutrition from the sediment.

One needs to keep in mind that the model projections are based on a 90% reduction in P flux from the sediment. This is the most uncertain goal in the TMDL and therefore DEP considers the 0.1 mg/L limit for TP during the growing season, combined with a conservative margin of safety, a prudent and achievable goal with substantial water quality benefits. The inability to achieve fully the 90% reduction could result in more stringent effluent limits and will be determined through the adaptive management approach recommended for implementation of controls.

<u>Comment #2: Duration of Dissolved Oxygen Super saturation</u>: A target of 30% reduction in the duration of dissolved oxygen super saturation from July 1999 levels is selected. Again, no basis for the selected reduction level is given and the target value appears to be selected arbitrarily. A better indicator for a eutrophic river system is to evaluate the percent of time the dissolved oxygen is greater than 125 percent of saturation. This is a better indicator of the potential harmful levels of dissolved oxygen and is used by many states to indicate eutrophic conditions in streams.

Response #2: The 125% of saturation target that is referred to is not a MA state standard and as such using it is arbitrary as well. Nevertheless, DEP has revisited the model the results, which, indicate that during the low flow week in July 1999 the model predicts that dissolved oxygen exceeded 125% from 0% to 46% of the time in various reaches. When POTW phosphorus concentrations were decreased to 0.1 mg/l at Westborough and 0.2 mg/l at the other POTWs combined with a 90% reduction in sediment phosphorus contribution that value, although reduced, was still exceeded from 0 to 42% of the hours for specific reaches. Likewise with all the POTW effluent phosphorus concentrations reduced to 0.1 mg/l at permitted flows and a 90% reduction in sediment phosphorus a similar variation was observed. The results indicate that exceedances of the suggested 125% saturation criteria will be reduced overall in the system by 50%. This is based on the 125% DO saturation being exceeded 12% of the time in 1999 and 6% of the time under the TMDL scenario (0.1 mg/L P at the POTWs at design flows and 90% reduction in sediment P flux.)

It is important to reiterate that because there is no numeric standard in MA for these indicators (with the exception of minimum dissolved oxygen) the Department chose to use a weight of evidence approach to make its determinations rather than to rely on any specific indicator.

Comment # 3: Diurnal Range of Dissolved Oxygen: Though stated on page 6 of the Executive Summary, this indicator is not used in the evaluation.

DEP Response: The large diurnal variation in dissolved oxygen is cited as a general indicator of excessive biomass. As such, it is part of the weight of evidence, but was used only qualitatively. While reference to this variable remains in the body of the TMDL document, we are clarifying the Executive Summary since it was not one of the primary indicators used in the weight of evidence approach.

Other Indicators:

Comment #4: Why was information on Chlorophyll a not used? Chlorophyll a is traditionally used as an indicator for eutrophic river systems (Blackstone and Charles River). This would be especially true for the Assabet River system. Chlorophyll a can be used as a surrogate for phytoplankton and even duckweed, which apparently plagues the river system. The response of Chlorophyll a to reduction of phosphorus would be an important indicator to consider.

In addition to being a nutrient/growth indicator, Chlorophyll a can be related to Secchi disk depth, which is an excellent indicator of aesthetics for recreation. This relationship has been studied on a number of lakes in the US (Onondaga Lake) and proven to provide a good indicator of the reduction of phytoplankton and free floating aquatic plants, and the improvement of water clarity for recreation use.

Response #4: Most of the chlorophyll and vegetation in the Assabet River is in rooted and floating macrophytes. As such, the water column chlorophyll, which is the normal measure when chlorophyll is reported, is less relevant. Indeed, for river systems, attached periphyton is considered the preferred indicator for chlorophyll. The limited relevance of water column chlorophyll in a river system in general and the Assabet in particular is the main reason why the ENSR study was directed to make its best estimates of biomass in rooted and floating macrophytes, which DEP considers the more appropriate indicator for nutrient impairment in this system. For lakes and large, deep impoundments, DEP concurs that water column chlorophyll is an appropriate variable to assess.

Comment #5: Margin of Safety. Page 40 of the report indicates, "*TMDLs must provide a margin of safety to address uncertainties in the technical analysis.*" The report acknowledges that the margin of safety is implicit with the conservative assumptions used in the model, but includes a second margin of safety to account for model uncertainties. The margin of safety used in this analysis, 6.1 lb/day, is equivalent to the difference in setting a phosphorus limit of 0.1 mg/L rather than 0.2 mg/L at the permitted design flows for the Marlborough, Hudson and Maynard POTWs. The margin of safety accounts for 22 percent of the TMDL allocation. This appears to be excessive for a number of reasons:

Response #5: One needs to note that the run from which the margin of safety was calculated was for (1999) POTW flows rather than design flows. Therefore, the 6.1 pounds MOS represents an upper limit for this estimate. DEP is of the opinion that the uncertainties associated with achieving a 90% reduction in P flux from the sediment of the Assabet River makes having a larger than usual MOS appropriate. If only a 50% reduction in sediment flux were achieved, more than the entire explicit MOS would be needed to reach the TMDL, and permit limits would have to be lowered.

Comment #6: The TMDL allocation assumes under 7Q10 conditions the POTWs are discharging the permitted capacity flow. The treatment plants would typically discharge much less than permitted capacity when the River is at 7Q10.

Response #6: While true, effluent will be composing a high percentage of the ambient water and therefore remains a concern. Also 7Q10 is the river flow upon which water quality standards are based. Nutrients, unlike some other pollutants, have effects over a broader range of flow and for a longer period of time. Also, it is not so much the concentration of a nutrient, phosphorus in this case, but the in-stream response that is the concern. Therefore, nutrient controls throughout the growing season make the most sense and are, for the most part, desirable without regard to river flow during that season. In addition, the permit would authorize the communities to discharge up to their design flow and therefore we must assume that this could occur at 7Q10 conditions. What flow the facilities are discharging at the present time is not relevant to potential future conditions that are being addressed in the permit.

Comment #7: In order to achieve compliance of a given permit limit, effluent discharges must be consistently less than the permit limit. As an example, the Marlborough Westerly Plant currently has a seasonal total phosphorus limit of 0.75 mg/L, but in 2002 the effluent discharge averaged 0.41 mg/L.

Response #7: Exactly how the NPDES permit will be written with regard to meeting the 0.1 mg/L P designated in the TMDL will be presented in the draft permit for public review and comment. The Department appreciates and encourages the fact that some POTWs have been able to do better than required by the current permits in this transition phase.

Comment #8: There seems to be inconsistency in the units modeled and the units in the permit limit. Back-up data from the ENSR Modeling Report reflects POTW discharges in terms of ortho-phosphorus concentrations, which is a fraction of the total phosphorus. The TMDL Report and the permit limits are based on total phosphorus. Please clarify.

Response #8: DEP believes that with concentrations as low as 0.1 mg/L in an effluent, all of the phosphorus will be in a dissolved form readily available for use by plants. Principally for that reason and the fact that various dissolved forms of phosphorus can be transformed into another form relatively quickly, DEP believes that setting limits based on total phosphorus is appropriate.

Comment #9: Model Simulations. It appears that the HSPF model was run only for the low flow week of July, rather than for the month or the summer season. Though the POTWs dominate the loadings under low flow conditions, river systems with long travel times, such

as the Assabet River, are responding to the pulse load of phosphorus from the last rain event.

It would be beneficial to see what reduction occur to the biomass under more typical summer conditions with a reduction of total phosphorus from the POTWs. The biomass reduction in the river may be very small during an average summer flow conditions, if the non-point sources can still support large aquatic plant growth. A full TMDL should be done, not just a low flow waste load allocation.

It would also be beneficial to see the relative phosphorus loadings for a typical summer season from point sources, non-point sources and sediment under existing conditions and proposed conditions. This information would be useful to determine the cost-effectiveness of reducing the point sources to 0.1 mg/L.

Response # 9: HSPF is a continuous simulation model and simulates flows and loads over multiple years. While the year 2000 was near average in flow, 1999 was a low flow year and flow approximated 7Q10 for the week used as the to evaluate water quality impacts. Because HSPF is a continuous model, the results for any given week include the influence of prior flows and loads. It should be noted that while storm loads do deliver substantial amounts of total phosphorus, much of it is in particulate form and the more readily available dissolved phosphorus was derived from POTW effluents as noted in ENSR's report on water quality in the Assabet River. Also, Nashoba Brook, the largest tributary to the Assabet River, delivers its load below the impoundments on the Assabet and therefore has no effect on these.

Water quality standards are based on 7Q10 flows, so this flow remains the hydrologic condition on which permit limits are based. In addition, nutrient impacts are a continuum and therefore affect more than just low flows.

Estimates for the contributions from each of the major sources have been made for the critical low flow week and are presented in the TMDL. Currently, these are the only readily available figures.

Comment #10: Sediment Oxygen Demand Reduction. The major source of sediment oxygen demand in the Assabet River system is from the aquatic plants. The POTW's discharge very low levels of BOD suggesting that BOD is not the leading cause of oxygen depletion. The reduction of biomass and the reduction of the phosphorus sediment flux will reduce the sediment oxygen demand and the overall oxygen depletion. Was the sediment oxygen demand dynamics accounted for in the model?

Response #10: SOD was considered constant over time and was based on field measurements at several locations. Less emphasis was placed on sediment oxygen demand since the dynamics of dissolved oxygen appear to be more a result of nutrient impacts as reflected in both the occurrence of super-saturation and high values of DO ranges.

Comment #11: Data Collection. The model was calibrated on data collected in 1999 and 2000. During this time the POTWs along the river were discharging much higher levels of phosphorus than currently being discharged. As presented in Table 3, in 1998 the total phosphorus load from the four POTWs averaged 132 lb/day, in 1999 and 2000 the

load was reduced to 75 and 82 lbs/day respectively, and in 2001 and 2002 the load was further reduced 54 and 48 lbs/day, respectively. Given the 64% reduction in the point source loads in five years, it would seem to be prudent to undertake additional sampling to validate the model and provide a benchmark of water quality data since the POTWs were charged with meeting the 0.75 mg/L seasonal phosphorus limit.

Response #11: DEP agrees that given the substantial changes that have and will occur over time, monitoring the river's response is highly desirable, especially since natural variation and the system's memory complicate interpretation of results. This means that multiple data sets likely are needed to separate the effects of various major factors. A monitoring plan will be developed with input from all the parties upon completion of the permitting process. The data collected as effluent phosphorus concentrations are reduced also can be used to refine the model to reduce uncertainties in its projections in the future.

Comment #12: Data Presentations. Table 5 – Predicted In-stream Total Phosphorus Concentrations by River mile point per Model Run, is a beneficial representation of the data. Could a similar table be prepared for dissolved oxygen? It would be important to understand where in the river and to what degree dissolved oxygen falls below 5.0 mg/l for the various model runs.

Response #12: The data requested are not available for all runs. However, the distribution of the 480 hours within the low flow week of July 1999 (run#1) during which DO was less than 5 mg/L is presented below. Note that for the TMDL scenario, all DO concentrations are predicted to be equal to or greater than 5 mg/L.

	July, 1999	
Mile Point	*Hours DO*	*% Time*
	< 5mg/L	*DO<5mg/L*
30.7	*0*	*0*
29.8	*130*	*77*
28.9	*0*	*0*
28	*83*	*49*
25.9	*0*	*0*
25.4	*0*	*7*
25.1	*0*	*21*
23.9	*0*	*8*
23.5	*0*	*70*
22	*0*	*7*

21.7	*0*	*7*
19.2	*0*	*14*
18	*0*	*23*
17.9	*165*	*98*
17.6	*0*	*0*
15.9	*0*	*77*
15	*0*	*0*
14.1	*47*	*28*
13.9	*0*	*0*
11.4	*43*	*26*
9.5	*0*	*0*
8.3	*0*	*70*
7.4	*0*	*0*
6.8	*0*	*72*
6.2	*12*	*7*
4.4	*0*	*0*
3.1	*0*	*70*
2.4	*0*	*58*
1.1	*0*	*29*
0	*0*	*1*
Total	*480*	*10*

Information on the other runs is presented in graphical format in ENSR's report on the modeling effort.

Comment #13: Seasonal Limit Range. The TMDL proposes seasonal phosphorus limits applicable from April 1 through October 31. This time frame seems excessive since it is under 7Q10 conditions that the River is most vulnerable. The river flow in April and May is much higher than average due to snow melt and rainfall. A more reasonable timeframe for seasonal permits would be from June 1 through September 30. Even within this range a stepped phosphorus limit would be more appropriate based on historic plant flows and river flows.

Response #13: This issue will require further discussion with EPA that will take place during the permit process.

Comment #14: Increased Treatment Plant Flow. It is disheartening that runs 25, 26, 27, 28 and 30, which do not support the case of a 0.1 mg/L phosphorus limit at the POTW's, were not included in Table 4 of the draft TMDL report. These runs compare permitted and projected treatment plant flows with sediment flux of 10 and 25% of existing sediment flux. It is clear from this data that increased flow from the POTWs can, in fact, be beneficial to the river system. Presumably runs 27, 28 and 30 could be included in Table 9 – Model Runs Meeting Dissolved Oxygen Minimum Criteria. Please include these runs in the final TMDL report.

Response #14: Potential water quality impacts, while important, are only one aspect of increasing flow from the POTWs. Other significant questions need to be addressed before any decision can be made on this issue. DEP notes that while the results presented in ENSR's report can be used as part of an overall assessment, a full evaluation of all relevant questions is needed and requires a separate and detailed effort as noted previously. It should be also noted that the beneficial impact you refer to from using projected flows is still based on the ability to significantly reduce sediment phosphorus flux. Since the ability to reach these levels remains uncertain so do the potential beneficial results that you have cited. The results of the simulation runs for flows greater than current design capacities (runs 27-30) will appear in an appendix of the modeling report by ENSR. Runs 25 & 26 that were based on permitted flows have been added to appropriate tables in the TMDL.

Comment #15: Evaluation of Dam Removal. Sediment accumulation, caused by the impoundments on the river, has been identified as having a significant impact on the river quality. It is proposed that the Assabet consortium communities, in conjunction with the DEP and the Army Corps of Engineers, perform a study evaluating the sediment and the potential impact of dam removal on river quality. Prior to spending hundreds of thousands of dollars, it would be prudent to use the model to evaluate the river under the various scenarios with one or more of the dams removed. It is suspected that the removal of the dams in conjunction with an upgrade of the treatment plants to treat to a 0.2 mg/L phosphorus level would achieve the water quality goals in the River. This consideration could save the communities hundreds of thousands of dollars in operating costs each year.

Response #15: While removal of dams is an option to consider carefully, there remain concerns about the feasibility of doing so and the potential impacts on water quality downstream given the fairly slow moving system. Initial model runs included an evaluation of removing the Ben Smith Dam and although it appeared to be beneficial in that area there was also an increase in biomass in downstream impoundments. It is DEP's position that the feasibility of removing these dams and an evaluation of downstream impacts needs to occur prior to additional model runs. A major first step in this process is already underway through a $200,000 cooperative effort with USGS to inventory the amount and quality of the sediment behind the major dams on the Assabet River.

Towns of Northborough & Shrewsbury – Fay, Spofford and Thorndike (both communities used FST and submitted the same comments)

Comment #1: We request that Tables 4 and 5 be modified to include all model runs (presently, the results of model run nos. 25 – 28, and 30 are not presented). In addition, we request that text/discussion of the results from those additional model runs be included in the report section titled "Model Results", from pages 28 through 37. Additional documentation needs to be provided in this section of the report to demonstrate why the POTW effluent limit of 0.10 mg/l for Total Phosphorus will be required, vs. 0.20 mg/l. We note the results from model runs 26 and 28 in particular. Under these scenarios, the estimated total phosphorus concentration will exceed the limit of 0.05 mg/l adopted by the Department for about a 2 to 3 mile stretch of a 31 mile river, for 7 days over a 10 year period. The cost for the communities to achieve the required discharge permit level of 0.10 mg/l is quite substantial, compared with the relatively minor environmental benefit that results.

Response #1: The TMDL deals with present design flows only. While the results for higher than design flows will be included at least as an appendix in the modeling application report by ENSR, other issues related to increasing flow that need to be addressed are beyond the scope of this TMDL. In addition, the Department believes that a limit of 0.1 mg/l is needed to account for uncertainties associated with the removal/inactivation of sediment phosphorus. DEP does not have nor have we set a specific limit for phosphorus, so the reference to 0.05 mg/L P was not intended to be such (it is EPA guidance only). As previously stated DEP used a weight-of evidence approach to set permit limits rather than to rely on any one indicator.

Comment #2: DEP presents the implementation actions for achieving the goal of the TMDL, which include total phosphorus limit at 0.10 mg/l, and 90% reduction in sediment phosphorus flux. It is the Town's understanding that new NPDES permits will set limits and requirements only for control of the point source discharge of total phosphorus. Where the removal of the sediment phosphorus is based upon a study to be completed by the Army Corp of Engineers, and is out of the control of the communities, we request that the requirement for 90% reduction in sediment phosphorus flux not be included as a condition of the new NPDES permits.

Response #2: This request is more appropriately addressed in the draft NPDES permit rather than in the TMDL. However, the communities are being given the opportunity to evaluate sediment reduction and/or controls to potentially avoid additional phosphorus reductions in future permits. It is true that DEP and the communities have requested the technical and financial assistance of the Army Corps of Engineers to assist with this evaluation however it is ultimately the communities' decision to pursue these other options in lieu of additional treatment requirements. Again, a major first step has been taken through the USGS study financed through federal and state grants.

Comment #3: At meetings with the regulators and Consortium representatives, it was agreed that the communities would participate in sharing up to 35% of the cost for a study of the removal of sediments in the Assabet River to achieve the 90% reduction goal in sediment phosphorus flux. The study is to be performed by the Army Corps of Engineers.

It was also agreed that the communities would be actively involved in the decision making process as to whether the recommended plan from the report would be cost effective to pursue. The TMDL does not reference the 35% share of the cost, nor does it reference the communities' involvement in decision making, moving past the report. This language needs to be incorporated into the TMDL, specifically under paragraph 3 of the implementation actions outlined on page 44 of 50. There are also instances where the text of the TMDL is written in a way that suggests that the communities, not the Army Corps, will be undertaking the sediment removal study (paragraph 1, at the top of page 44 of 50).

Response: 3: DEP is aware that the communities have agreed to contribute 35% of the cost for the Army Corps study once the report and its recommendations for implementation are accepted. Although DEP applauds these efforts the cost share is not relevant to the technical details of the TMDL report and therefore language indicating the cost share have not been included in the final TMDL. DEP also agrees that the Towns need to be involved with the development of that report and the proposed recommendations that come from it however future permitting decisions will continue to the responsibility of EPA and DEP.

See previous comment for response to the issue of responsibility to conduct the sediment study.

Comment #4: As noted at the Public Hearing held March 25, 2004, the comment was made that the Army Corps had no funding for new projects this fiscal year. This obviously has impacts on the ability to perform the required study on sediment removal, and ultimately, the ability to move forward with the actual removal of the sediment. We re-iterate that, as agreed at meetings with the regulators and Consortium representatives, the communities will participate in up to 35% of the cost of the study, as they are not in a position to fund this study in full.

Response #4: DEP understands your position and supports the Corps of Engineers' request for funds sufficient to do the evaluation as proposed.

Comment #5: We note that the model run results (with P concentrations and Sediment P Flux Reductions held constant) show that for POTW flows from the Marlborough Westerly plant, there is no measurable adverse impact whether the permitted flow is used, or the projected flow is used. In most instances, there is a benefit to the predicted total phosphorous concentrations with the higher (projected) POTW flow. As the Town of Northborough proceeds with Phase III of the CWMP, we request that the Department recognize that the increase in flows does not adversely impact water quality in the river with respect to phosphorus, and if discharge to groundwater of treated effluent is not feasible (following the Phase III process), that lower limits of phosphorous (i.e., treating to < 0.10 mg/l to hold the daily loading constant) not be required.

Response #5: DEP recognizes that an increase in flow, according to the model, may have a positive impact in-stream from a nutrient standpoint however that impact is not realized unless a significant reduction of sediment phosphorus is also achieved. In addition, potential impacts associated with increased flows go beyond nutrient related impacts. There are also secondary impacts that need to be considered and evaluated such as where the additional water is coming from and what the potential impacts may be on the smaller tributaries where withdrawals may occur. These issues are considered outside the scope of this TMDL. DEP notes that while the results presented in ENSR's report can be used as part of an overall assessment, a full *evaluation of all relevant questions is needed and requires a separate and detailed effort as noted previously.*

Town of Maynard – Dufresne-Henry

Comment #1: The only critique of the draft study was that a "margin of safety" of almost 100% was provided in the model and this led to the proposed P limit of 0.10 mg/l. The DEP is requiring the P = 0.1 mg/l vs. 0.2 mg/l in order to… "account for model uncertainties and provide a margin of safety…". To me this seems extremely conservative given the conservatism already built into the model. For Maynard this has real impact as the added treatment is more complex and the added costs are $700,000 capital and $67,000/year O&M.

Response #1: As noted earlier, the model projections are based on a 90% reduction in P flux from the sediment. This is the most uncertain goal in the TMDL and therefore DEP considers the 0.1 mg/L limit for TP during the growing season a prudent and achievable goal with substantial water quality benefits. The inability to achieve this target could result in more stringent effluent limits and will be determined through the adaptive management approach recommended for implementation of controls.

Comment #2: In my opinion it may be more prudent and certainly less costly for P removal of 0.2 mg/l be implemented by 2009 and then go to greater P removal by 2014 based on the results of the monitoring program. Right now the proposed limit of P = 0.10 mg/l is conjectured on natural processes in the sediments to reduce 90% of P from these sources over a long time period. How long is the question? The treatment processes for Maynard presented in the Phase 2-Wastewater Disposal Alternatives of the CWMP is modular in concept and can be modified to go from 0.2 mg/l to 0.1 mg/l P by replacing the non pressure filter discs with fine membrane pressure filter discs.

Response #2: See response to preceding comment. In addition, it is difficult to predict the time required for sediment P flux to fully respond to lower external loads, but estimates in the literature suggest a decade or more is needed.

Organization for the Assabet River (OAR) with additional documentation provided by Dr. William Walker (Dr. Walkers full comments are provided as Attachment 2 for reference)

Comment #1: The draft TMDL will allow winter and total annual point source loads to increase. These increases will undermine the benefits of substantial point source reductions during the growing season. Winter Total Phosphorus (TP limits should be required to cap or reduce loads.

Under the draft Assabet TMDL, the annual TP loads to both the Assabet and the Concord Rivers will increase because the TMDL allows the municipal wastewater treatment plants (POTWs) to expand discharges to design flows, an increase of 4 million gallons per day (mgd), without mandating phosphorus removal during the winter or "non-seasonal" period (Nov.-March), except at two minor facilities, MCI Concord and Middlesex School. Using seasonal and non-seasonal 2002 flow and TP concentrations data[1], current annual TP loads to the Assabet, and from the Assabet to the Concord River, are 47,724 pounds per year. Under the draft TMDL, assuming the same wintertime 2002 TP concentrations at the treatment plants, the annual TP load would increase 10,387 pounds or 22% to 58,111 pounds per year. This is due to increases in the winter TP load, which would increase 17,903 pounds or 48% under the TMDL from 37,526 to 55,429 pounds. Even if wintertime effluent TP concentrations decreased slightly in the future, the annual TP load to the Assabet and Concord Rivers would likely remain what it is now. See Table 1, *POTW TP Loads:" Current" (2002) versus TMDL* and Attachment 1 (OAR's table's can be found in Attachment #1 to this document), *Analysis of Seasonal, Winter and Annual Point Source TP Loads under 2002 and TMDL conditions*.

Table 1: POTW Total Phosphorus Loads: "Current" (2002) vs. TMDL

	Total Phosphorus Loads (lbs.)		
Scenario	Seasonal (April-Oct)	Winter (Nov – March)	Annual
"Current" (2002)	10,199	37,526	47,724
TMDL	2,682	55,429	58,111
Percent Change	74% decrease	48% increase	22% increase

The problem with increasing or even maintaining the current winter load is that the impact of current winter TP loads on the Assabet and Concord Rivers is unknown. Like the Assabet, the Concord River is a low-gradient, impounded river that suffers from cultural eutrophication caused primarily by excessive nutrient loads from wastewater treatment plants. For additional discussion of this topic see response to Question #4 in the enclosed *Memorandum* from William W. Walker, Jr., Ph.D. to Susan Beede, Organization for the Assabet River, dated June 19, 2003.

Recommendations:

Because it is likely that *current* winter phosphorus loads are adding to the mass of stored phosphorus available to plants and algae during the growing season, winter TP loads at municipal plants should be capped or reduced. The draft TMDL's requirement to "optimize particulate phosphorus removal" will not guarantee a cap or reduction and is too vague to be enforced without quantitative limits. By contrast, the 2003 draft NPDES permit for the Marlborough East WWTP requires year-round TP removal and contains a winter TP limit of 0.75 mg/L. We suggest that this requirement be mandated for the Assabet wastewater treatment plants as well.

Monitoring and research should be initiated as soon as possible to establish more specific winter limits so that any necessary plant modifications can be implemented along with upgrades required to meet the seasonal 0.1 mg/L TP limits at the municipal plants by 2009. During the Assabet TMDL assessment phase, ENSR attempted to quantify how much phosphorus settled out or was adsorbed by organic material in the impoundments during the winter period. This work, which was never completed, should be reviewed as part of the new effort. Finishing the Concord River nutrient TMDL in the near future would also help to establish winter TP loads from the Assabet that will not aggravate the river's water quality problems.

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[1] Reported on page 22 of the draft TMDL.

Response #1: DEP considers it likely that the total load will not increase very much in the winter compared to 2002 given the requirement that removal of particulate P be optimized as part of the TMDL.. While we cannot predict the exact impact this will have, it will mitigate any increases in load caused by design flows being reached. Also, and perhaps more important, for a river system, it is DEP's position that seasonal rather than annual nutrient loads are the primary concern in terms of impacts. DEP is concerned about the particulate load that could settle in impoundments during the winter and therefore is requiring its removal be optimized during the winter. Also, we expect that the treatment processes needed to meet the TMDL will be in place well ahead of the 4 MGD increase. This will allow time to revisit the issue as part of the adaptive management approach. Finally, during the interim, DEP believes that the requirement to monitor, optimize treatment and report results is reasonable given the POTWs will be constructing major upgrades to their facilities in order to achieve the limits set in the TMDL.

Comment # 2) The margin of safety proposed in the draft TMDL is invalid because the baseline TMDL scenario used to calculate it is unlikely to meet water quality standards and support designated uses.

Under the baseline TMDL scenario, i.e. the TMDL *without* the margin of safety, all the POTWs are at design flows, the Westborough plant has seasonal TP limits of 0.1 mg/L TP, the other POTWs have 0.2 mg/L, and sediment phosphorus flux is reduced 90%. Although MA DEP assumed that this TMDL would meet water quality standards, and used it to calculate the margin of safety, it was not run by the HSPF model. A scenario with the same limits and 90% sediment P flux reduction, (Scenario #10) was run, but at 1999 POTW flows. Consequently, one must rely on the model output from Scenario #10, to infer whether the baseline TMDL would meet water quality standards and support designated uses. See Table 2, page 4.[2]

Based on ENSR's assessment in the draft model report[3] and MA DEP's weight-of-evidence analysis for the TMDL, the baseline TMDL would be unlikely to meet water quality standards and support designated uses. The draft ENSR model report identified Scenario #10 as a *potentially acceptable management scenario*, but noted on page ES-4, that the scenario "Met minimum DO requirements but other eutrophication indicators were still predicted to be present." Regarding biomass, the draft TMDL stated on page 26, "For the purpose of this TMDL, a substantial reduction in total biomass of at least 50% from July 1999 values is considered a minimum target for achieving designated uses." But the model predicted that Scenario #10 would reduce biomass by 46.8%, not 50% relative to July 1999 values. In addition, the draft TMDL explained on page 37 that to achieve water quality goals, the duration of dissolved oxygen super-saturation should be reduced approximately 30% relative to 1999 values. But the model predicted that under Scenario #10, the duration of DO super-saturation would be reduced by 25%, not 30% relative to 1999 values. It is also questionable whether the baseline TMDL scenario would meet minimum DO criterion in all river reaches, because the other scenario most similar to the TMDL baseline scenario, Scenario #7, did not.[4]

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[2] It should be noted that when scenarios that assume 90% sediment P flux reduction are run at the same POTW TP concentrations at both 1999 and design flows (i.e. Scenarios #14 & #8, and #21& #20), total biomass reduction is greater (1,200 – 1,500 Kgs) under 1999 flows than design flows, and the duration of DP super-saturation is slightly lower (0.5%) under design flows than 1999 flows.

[3] *SuAsCo Watershed, Assabet River TMDL Study, Phase Two: Analysis, Draft Final Report,* January 2004.

[4] Scenario #7 is all POTWs @ 1999 flows, TP limits of 0.2 mg/L and 90% reduction in sediment P flux.

Finally, one must consider the difference in daily TP loads to the river from POTWs under the baseline TMDL (18.6 lbs/day) versus Scenario #10 (12.3 lbs per day). Again, see Table 2, page 4. The daily POTW TP load under the baseline TMDL scenario is 6.3 lbs greater than under Scenario #10. And if one looks at the ranking of scenarios by biomass reduction in Table 2, daily TP loads from the POTWs correlate well with daily TP loads from the POTWs. The lower the daily load, the greater the predicted reduction in biomass. If Scenario #10 will not meet standards with a daily POTW TP load of 12.3 pounds, there is little chance that the baseline TMDL, with a load of 18.6 lbs/day, would meet standards either.

Recommendations: The draft TMDL should caveat or remove references to this TMDL baseline scenario and define the margin of safety in narrative as the conservative assumptions used in the model. A quantitative margin of safety could be determined at a later date as part of the adaptive management process.

Table 2: Management scenarios ranked by % biomass reduction (relative to July 1999)

	Scenario Description						
Rank	Model Run #	Total Phosphorus Limits (mg/L)	POTW Flows	% Biomass Reduction	Total Biomass (Kg)	% time DO > 100% sat	Seasonal Load (lbs/day)
1	20	0.025 mg/L	1999	67.9%	51,700	20.6%	2.1
2	21	0.025 mg/L	Design flow	67.0%	53,200	20.1%	3.1
3	9	0.050 mg/L	1999	64.2%	57,800	21.5%	4.2
4	24	Wbro 0.025 mg/L others 0.10 mg/L	1999	59.8%	64,900	22.6%	5.0
5	16	Wbro 0.050 mg/L others 0.10 mg/L	1999	58.1%	67,600	22.7%	6.1
6	8	0.10 mg/L	1999	55.6%	71,600	23.3%	8.3
7	14 (TMDL)	0.10 mg/L	Design flow	54.9%	72,800	22.8%	12.5
8	29	0.10 mg/L	Design flow, except Marlb. @ 4.4 mgd	54.1%	74,800	23.4%	13.8
9	#10	Wbro 0.10 mg/L, others 0.20 mg/L	1999	46.8%	85,800	26.0%	12.3
10?	TMDL without margin of safety (not modeled)	Wbr 0.10 mg/L, others 0.20 mg/L	Design flow	Unknown	Unknown	Unknown	18.6

Response #2: The results of simulating the 1999 flows with 0.1 mg/L P in Westborough's effluent and 0.2 mg/L in the other 3 effluents was close to meeting standards, but as noted did not meet all of the goals and therefore is not considered to meet the TMDL. Also, the difference between the results for the two scenarios (runs 7 & 26) with POTW effluent P concentrations of 0.2 mg/l, and 90% reduction of sediment with existing and permitted flows) as well as for the runs 8 & 14 (0.1 mg/l, and 90% reduction of sediment with existing and permitted flows) are not dramatically *different when comparing indicator responses between existing and design loadings. This suggests that at the relative stringent effluent limits, changes in flow have minor impacts on water quality. Hence using run 10 to set the upper limit on the margin of safety was reasonable from DEP's perspective. In addition, some of the conservative assumptions, such as the POTWs discharging at design flows during the low flow period, and uncertainties, it is anticipated that using the results of this run in estimating the margin of safety is useful as an upper limit. As such, the explicit margin of safety used here is larger than often is the case in other TMDLs. This is prudent given the uncertainties regarding the degree to which P flux from the sediment can be removed. It should be noted that one would expect a reduction over time in P flux from the sediment in response to the reduction in POTW loads. One might expect that the P flux would eventually be reduced by the same percentage down to some constant value as is the external load. The question is the response time that this would require if not aided by active control or removal of sediment.*

Comment #3: Sediment is not an independent source of phosphorus. By treating sediment as an independent source of phosphorus, the draft TMDL diminishes the role of the point sources in the creation and correction of the river's eutrophication problem.

The draft TMDL should be revised to include more accurate information about phosphorus dynamics in river systems and explain the limitations of Assabet HSPF model in simulating them.

In the long run, sediment P flux is dependent on the external P load to the river. Throughout most, though not all of the draft report, the TMDL presents the sediment phosphorus flux as a discrete and independent phosphorus source unaffected by reductions in phosphorus loads from the wastewater treatment plants. This is scientifically inaccurate. It also diminishes the real importance of wastewater treatment plants in the creation and correction of the Assabet's eutrophication problem. The report should describe the nature of sediment phosphorus flux and the limitations of the model with regard to sediment phosphorus flux. Specifically, the draft TMDL should explain that the HSPF model has no feedback mechanism to simulate reductions in sediment P flux as wastewater treatment plant loads are reduced and this is why sediment flux reductions had to be "manually" set to test different phosphorus management scenarios. This is why under Scenario #5, where POTW phosphorus loadings were set to zero without any sediment phosphorus flux reduction, the model predicted only a 12.5 % decrease in biomass production. The absence of this background information is of particular concern in the sections titled *Model Results* (pages 28-36) and *Summary of Model Results* (pages 36-37). For a more technical discussion of this issue, see responses to Questions #1- #3 in the enclosed *Memorandum* from William W. Walker, Jr., Ph.D. to Susan Beede, Organization for the Assabet River, dated June 19, 2003.

Recommendations:
The draft TMDL should be revised, particularly in the discussions of modeling results, to include more accurate information about phosphorus loading and cycling in rivers and limitations of the Assabet HSFP model. It should also document how the sediment P Flux allocation was calculated based on the assessment work conducted by UMass Dartmouth under contract to ENSR. In addition, the draft TMDL report should make it clearer that if sediment remediation and dam removal are determined to be infeasible or too costly, then the best way to reduce sediment phosphorus flux is to further reduce the load of phosphorus discharged by the wastewater treatment plants. Restoration of water quality in the river would probably take

longer, possibly many years, but well-established ecological principles suggest that as external TP loads are reduced to the river, sediment P releases would also decrease and eventually reach a state of equilibrium.

Response #3: DEP believes that the sediment flux and POTW loads of P ultimately are not independent.. There is a question of response time and therefore the DEP considers an assessment of possible activity to shorten the response time desirable. Modeling internal sediment processes is a complicated effort in itself. The data requirements and uncertainties in process kinetics argue against pursuing this effort when the most readily controllable sources are addressed with the reduced loads eventually being reflected in lessening contributions of phosphorus from the sediment. Both field data and model calibration were used to incorporate phosphorus flux from the sediment into the Assabet River model. Also sine the HSPF model did not simulate sediment processes the sediment contribution was specified independently in the TMDL. As noted previously, the inability to reduce phosphorus flux from the sediment will result in lower limits in the POTW effluents if water quality standards are not met.

> OAR also asked Dr. Walker if it reasonable to assume that 90% of the sediment phosphorus contribution can actually be removed from the Assabet? Dr. Walker's response is "Probably not" And he discusses the issue in great detail. (Once again a full copy of Dr. Walker's response is provided in the appendix to this document).

DEP's Comment: DEP considers the reduction in sediment flux by 90% as the biggest challenge with the largest uncertainty. This uncertainly has led the Department to incorporate a combination of conservative assumptions and larger than usual explicit margin of safety as part of this TMDL. At the same time, DEP considers the sediment flux to be in large part a reflection of the external loads to the system and as the external load is reduced, so will be the sediment flux of P, at least to some relatively low minimum value. The question is the degree to which this will happen (e.g., will it be a linear response so that any percentage reduction in external load will result in a comparable reduction in the P flux from the sediment, at least to an irreducible minimum) and the time this response will require to manifest itself if not aided by physical removal or control of sediment

Comment #4: The TMDL lacks and should include an in-stream target phosphorus concentration.

The draft TMDL states on page 26 that there is "No specific in-stream target concentration for total phosphorus." The DEP's reason appears on page 27, "Because there is no specific quantitative link between phosphorus concentrations and impacts on water quality, DEP believes phosphorus concentrations are of secondary importance as an indicator of meeting water quality."
This is not consistent with most phosphorus TMDLs, including others conducted by MA DEP (i.e. The French River Lakes TMDL), which do set ambient TP targets or goals. Please explain the basis of DEP's decision not to select ambient phosphorus targets, i.e. cite studies and/or literature that support DEP's position.

Recommendations: In addition to the attainment of the minimum DO criterion and the minimum 50% reduction in total biomass from 1999 values, the TMDL should adopt an in-stream target or goal, perhaps an *interim* target or goal to help guide implementation of the TMDL. The advantages of doing this are that 1) phosphorus is the primary causal factor driving water quality problems, 2) success can be gauged more readily through monitoring, and 3) TP concentrations can be forecast with greater certainty using HSPF or simpler mass-balance models for impoundments. For a more detailed discussion of this topic see responses to Questions #5 and #6 in enclosed *Memorandum* from William W. Walker, Jr., Ph.D. to Susan Beede, Organization for the Assabet River, dated June 19, 2003.

Response #4:DEP continues to consider the in-stream concentration of nutrients important, but secondary to the problem's manifestation---excessive biomass in this case. Unlike pollutants such as toxicants, there may not be a one to one correspondence of concentration and adverse impact as one considers different locations. Thus, until a more direct link is established between nutrient concentration and impact, DEP considers the nuisance variable to be the biomass—especially of floating macrophytes—to be the issue of concern in river systems.

The framework for assessing nutrient impacts on lakes is much more advanced than it is for rivers. In addition, the framework is based on large lakes and involves planktonic algae rather than periphyton and floating macrophytes. While DEP is in the process of assessing what criteria should apply to rivers and streams, the focus is on impacts as being more relevant than concentration although we remain open to the possibility that meaningful concentration guidelines may be derived from our evaluations.

OAR also asked Dr. Walker if **it was appropriate to use EPA's recommended numeric phosphorus criterion of 0.024 mg/L (for sub-ecoregion 59) as a basis for setting NPDES permit limits?**

Dr. Walker reviewed much of the history of the effort to set nutrient criteria and notes that in his opinion EPA's 0-.024 mg/l P guidance would probably be defensible and a protective goal for the Assabet River.

DEP's Comment on OAR's question and Dr. Walker's Response: As noted in the TMDL, the projected conditions are a substantial change from those upon which the model was calibrated and verified. Model uncertainties tend to increase as the deviations from the original "present" conditions (in this case for the year 1999) increase. At the same time, DEP considers EPA's guidance on P concentrations helpful but not definitive. As previously noted, in river systems plant abundance is considered a better indicator of impairment caused by excessive nutrient concentrations even though it presents a greater challenge in modeling. The uncertainties in both the relevance of nutrient concentrations for a given site and the challenges of predicting biomass quantities underlie DEP's weight–of-evidence approach and our determination that an adaptive management approach is needed to implement nutrient controls in the Assabet River system. It is also extremely important to note that EPA's guidance was developed based on a statistical analysis of phosphorus concentrations in both impaired and unimpaired in waters. That analysis did not consider the impacts on designated uses nor did it correlate in-stream phosphorus concentrations to other eutrophication indicators as was done in the Assabet TMDL. For this reason DEP believes the approach used here is more relevant to attaining designated uses than the guidance developed by EPA.

Comment #5: The TMDL lacks and should provide more specific information about the monitoring program.

Under an adaptive management approach, monitoring is critically important. The MA DEP needs to describe in the TMDL what parameters will be the focus of the monitoring program and why. For example, given that biomass reduction is one of the two key management targets, how will biomass production be assessed and when? Without a sound monitoring program, adaptive management is just delay. See responses to Questions #5 and #6 in enclosed *Memorandum* from William W. Walker, Jr., Ph.D. to Susan Beede, Organization for the Assabet River, dated June 19, 2003.

Response #5: DEP agrees with OAR's comment and considers the monitoring program an essential aspect of the adaptive management approach. We will be working with all interested parties in the near future to design a targeted monitoring program aimed at identifying the Assabet's response to decreased phosphorus loads.

Comment #6: Seasonal interim limits at municipal treatment plants should be 0.5 mg/l TP

Phosphorus loads from wastewater treatment plants should be reduced as much as possible during the next four years (i.e. before the 0.1 mg/L limits go into effect). Currently, all four POTWs can meet a TP limit of 0.5 mg/L and the Marlborough Westerly plant has already achieved an average monthly TP limit of 0.41 mg/L (in 2002). In addition, the Marlborough Easterly plant, which discharges to Hop Brook in the Sudbury River watershed, was recently given a 0.5 mg/L interim TP limit in its draft NPDES permit. For these reasons, the Assabet plants should get an interim seasonal TP limit of 0.5 mg/L, not its existing limit of 0.75 mg/L, in the next NPDES permits.

Response #6: DEP is encouraging the POTWs to do the best they can in the interim until new facilities are on line. While the POTWs often are doing better than the 0.75 mg/L limit, they may not be able to meet their best performance on a continuous basis and DEP recognizes that current design and operating constraints particularly during facility upgrades are challenges that must be acknowledged. As such, DEP believes that the limit of 0.75 mg/L P as a monthly average concentration improves the situation while recognizing the potential constraints. It should be noted that the design of the Marlborough East plant is for two-stage biological treatment. This gives it more flexibility with a greater ability to achieve the lower P limit set in the interim permit.

Comment #7: Minors: MCI Concord & Middlesex School TP limits should be 0. 1 mg/L, not 0.5 mg/L.

MCI Concord – The proposed year-round TP limit of 0.5 mg/L for MCI Concord discharge is based on low in-stream phosphorus concentrations predicted by the model assuming full implementation the TMDL scenario, including the 90% reduction in sediment phosphorus flux. The location of the discharge downstream of the Assabet impoundments apparently was also a consideration. While we support year-round phosphorus removal at all the wastewater treatment plants, the 0.5 mg/L TP is inadequate and should be lower to account for the uncertainty of the model predictions and likelihood of reducing sediment phosphorus flux by 90%. In addition, the discharge is located upstream of the Concord River, which has a serious eutrophication problem and three dams.

Another concern regarding the proposed 0.5 mg/L TP limit is equity. At this limit, MCI Concord, *a state-owned facility*, would be allowed to discharge a bigger phosphorus load to the Assabet during the April – October growing season than the Town of Maynard, even though at design flows, the volume of Maynard's discharge will be five times greater than MCI-Concord's.

Middlesex School – The draft TMDL assumes that the Middlesex School plant discharges to the Assabet River and uses the same permit limit justification given for MCI Concord. However, the Middlesex plant discharges to Spencer Brook, an Assabet tributary with little dilution that enters an impoundment named Angier's Pond less than a mile downstream from the plant. The pond is owned by the Concord Rod & Gun Club and is used for recreation. Currently, Middlesex School plans to construct a new, state-of-the-art treatment facility that uses membrane reactor technology. Because the water quality and nutrient dynamics of Spencer Brook were not modeled as part of the TMDL analysis, the agencies should rely on the 1986 EPA "Gold Book" and more recent phosphorus guidance to set limits for this new plant. In particular, the EPA Gold Book recommends that total phosphates as phosphorus should not exceed 0.050 mg/L in any stream at the point where it enters any lake or reservoir, nor 0.025 mg/L within the lake or reservoir. Using these criteria, the Middlesex limit should probably be no more than 0.1 mg/L TP. Given that particulate phosphorus can settle in Angiers Pond during the winter, we also support MA DEP's proposed requirement for year-round phosphorus removal.

DEP Response: As previously stated in prior responses DEP considers the seasonal effluent limit of 0.5 mg/L P for these facilities appropriate for the present for several reasons. First ,as indicated in the TMDL, The Middlesex School POTW discharges 0.22 lbs/day total phosphorus, primarily during the non-growing season, based on permitted flow and concentration. During the months of June through August flows from the school are approximately 50% or less than the rest of the year which results in a significantly reduced loading to the river. Based on a mass balance calculation DEP estimates that the incremental increase in concentration from this facility on the Assabet River phosphorus concentration to be about 0.0004 mg/l. Second, as you have noted, the model developed by DEP was not designed to evaluate the potential impact of the Middlesex School on Spencer Brook. Until such as model is developed DEP believes the proposed limit is appropriate.

As for the MCI- Concord facility: As stated in the TMDL DEP considers the effluent limit of 0.5 mg/L P for this facility appropriate at this time. DEP is of the opinion that the potential impacts of this increase is negligible because the discharge is downstream of the impounded sections in the Assabet River and the resulting in-stream concentration during 7Q10 conditions would be less than the in-stream national guidance values used by EPA under the conditions of the TMDL. Finally, any potential impacts to the Concord River system downstream cannot be evaluated until a TMDL for that system is developed.

Comment # 8: The draft TMDL will increase the volume of wastewater in the river by 4 mgd, making the river 100% effluent throughout its length at 7Q10, and raising the existing 7Q10 from 15.1 cfs to approximately 20 cfs[5] when the POTWs reach design flows. This will increase the frequency and duration of critical conditions when the river is mostly wastewater effluent.

Increasing wastewater flows to the Assabet River by 4 mgd or more will, as stated previously, increase the frequency and duration of conditions where the river is comprised almost entirely of wastewater effluent. These increases will have a number of potential impacts that should be addressed as part of any antidegradation review before any flows increases beyond design flows, are granted by the agencies. First, increased wastewater flows to the Assabet River will dewater already hydrologically stressed sub-basins in the Assabet watershed. For example, only an about 1 mgd of the additional 4 mgd will come from the MWRA. The remaining 3 mgd will be taken from ground and surface water sources in the Assabet and Sudbury Basins. USGS has recently completed a ground-water modeling project that establishes a water budget for these sub-basins (*Simulation of Ground-Water Flow and Evaluation of Water Management Alternatives in the Assabet River Basin, Easter, Massachusetts, January 7, 2004* , in review) and will help prioritize groundwater recharge sites. Increased wastewater flows may also harm the reproductive health of fish and other aquatic life that live in the cocktail of pharmaceuticals, personal care products, and industrial chemicals discharged by the Assabet's six wastewater plants. Recent studies have documented many instances of endocrine disruption in fish that inhabit effluent-dominated rivers like the Assabet. Most of these studies are summarized and reviewed in a 2003 NOAA Technical Memorandum titled, *Endocrine Disruption in Fish, An Assessment of Recent Research and Results.* A fish study should be done for the Assabet and Concord Rivers as soon as possible.

Finally, the Assabet is a major tributary of the Concord River, which is the town of Billerica's only public drinking water supply. Since 1970, the volume of wastewater effluent contributed by Assabet municipal plants to Billerica's drinking water source has more than doubled, increasing from 5 to 11 mgd. When the Assabet municipal plants reach design flows, Billerica will receive another 4 mgd, for a total of 15 mgd of wastewater. In the future, drawing public drinking water from such an effluent-dominated source may be a public health concern.

DEP Response: DEP concurs with the concern about water supply issues and these will be addressed through procedures established under the Water Management Act. Also, it is not clear that there is a one to one correspondence between effluent flow and flow measured at the Maynard gage. The dynamics of infiltration of ground water into the Assabet and exfiltration from the Assabet are yet to be fully defined. Also, during low flow periods, treatment plant flows also are low relative to their design flow . As noted elsewhere, any proposed increased in wastewater flows beyond present design capacities must address a number of questions and needs to be done in a comprehensive fashion. This TMDL is not intended nor is it assessing the substantive questions associated with such a proposal

This TMDL deals with in-stream water quality impacts associated with the discharge of nutrients. Based on the Department's analysis, including results from the HSPF mode, we conclude that the recommended effluent limits and reductions in sediment flux of phosphorus will correct use impairments related to nutrient loads in the Assabet River.

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[5] Summer and early fall POTW flows at design flows would be lower than actual design flows, so the "new" 7Q10 would be less than 15 mgd (total POTW design flow) or 23 cfs.

Questions such as endocrine disruptors and pharmaceuticals remain an ill- defined concern at this point and are universal issues. Until a better definition of risks is established at a national level, it is difficult to address them with any confidence in the current science.

The flow in the Concord River at Billerica includes the flow of the Sudbury and that from the entire drainage of the Assabet River. While the fraction contributed by highly treated wastewater will increase to some degree, it is not an unusual situation especially in less water rich parts of the country. Also, the increased treatment of the discharges as well as continued high level treatment of the water Billerica draws from the Concord River is expected to continue to produce potable water that meets all of the regulatory requirements.

OAR also asked Dr. Walker to assess the following question.

> "The Assabet River Consortium has argued that increasing the volume of wastewater discharged to the river to design flows would have a small impact on water quality. Do you agree? "

Dr. Walker points out the complicated nature of analyzing the situation and the many factors that need to be considered including downstream impacts.

DEP's Comments on OAR's question and Dr. Walker's Response: As noted in the above response, this TMDL deals with in-stream water quality impacts associated with the discharge of nutrients. Based on the Department's analysis, including results from the HSPF mode, we conclude that the recommended effluent limits and reductions in sediment flux of phosphorus at design flows will correct use impairments related to nutrient loads in the Assabet River.

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Additional Issues Raised by OAR to Dr. Walker and DEP Comments on them.

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1) **Is dissolved oxygen a good surrogate for biomass (in ENSR's model)?**

   Dr. Walker points out that many factors affect dissolved oxygen.

DEP's Comment on OAR's Question and Dr. Walker's Response: DEP basically concurs that many variables affect DO and notes that in the modeling done for the Assabet, change in nutrient loads was the main perturbation and therefore accounts for most of the DO variation exhibited in the modeling results. The variation in dissolved oxygen results were driven by changes (i.e., reductions) in biomass that were driven by lower nutrient loads and concentrations. Therefore, DEP feels that changes in DO in this model do reflect nearly exclusively changes in biomass.

2) **How much confidence can we have in the model's prediction that the minimum DO criterion will be met in all reaches under 7Q10 with the WWTPs at 0.1 mg/TP and current sediment phosphorus release reduced by 90%?**

   Dr. Walker notes that with "These measures would likely result in substantial reductions in river TP concentrations, reductions in aquatic productivity, and improvements in dissolved oxygen regime." But that "…it is not possible to specify with

much certainty the precise degrees of point-source and sediment control required to achieve the numeric dissolved oxygen standard throughout the river."

DEP's Comment on OAR's Question and Dr. Walker's Response: DEP considers the model predictions reasonable and secure enough to guide major decisions. The Department notes that all models have a degree of uncertainty and in this case has led to the Department's conclusion that an adaptive management approach supported by a targeted monitoring program makes the most sense.

3) How should the TMDL be finished, i.e. P loads calculated?

Dr. Walker notes that "…existing data and modeling support the application of best available technology to reduce point source loadings, at least to the 0.1 mg/L level as an interim limit." He also notes that "…the TMDL should be approached in an iterative or adaptive fashion, as recommended in a recent evaluation of the TMDL process by the National Research Council."

DEP's Response: DEP concurs that targeted monitoring and refinement of the HSPF water quality model as load reductions are achieved not only is prudent but also is the foundation for guiding the adaptive management approach. Such an effort should include all interested parties.

Additional comments from OAR presented in the order they appear in the Draft TMDL document.

(Page 3) Under "Land Uses", please indicate what year the land use information represents.

DEP Response: DEP has inserted the citation to the MA GIS 1990-1991 layer in the TMDL.

Executive Summary (ES)

(ES, page 4) it would be helpful to include Figure 1 on page 14 in the Executive Summary.

DEP Response: DEP believes that the inclusion of Figure 1 in the document is sufficient .

(ES, page 4, 3rd paragraph) The text should mention that there are three minor NPDES dischargers and nine dams (although one is for flood control and another other is now breached.)

DEP Response: The Executive Summary of the TMDL has been revised to note the additional 3 minor discharges and nine dams. The list of dams has been provided in the appendix of the TMDL.

Dams: (Listed upstream to downstream)
Nichols Dam (A-1) - Westborough
Old Sawmill Dam (Route 20) - Northborough
Woodside Dam (Allen Street) - Northborough
Tyler Flood Control Dam (Robin Hill Road) - Marlborough

Hudson Dam (Route 85) - Hudson
Gleasondale Dam - Stow
Ben Smith Dam – Maynard
Powdermill Dam - Maynard
Damonmill Dam (*breached, but does back up water in higher flows.) – West Concord

(ES, page 4, 5th paragraph) The summary should explain what is meant by "sediment phosphorus flux."

DEP Response: The following wording has been added as a footnote:

Sediment phosphorus flux is phosphorus in the sediment that dissolves and transfers into the water column under certain conditions and is readily available to plants for growth.

(ES, page 5, 1st paragraph) OAR was an active member of the TMDL modeling TAC, attending all meetings and reviewing all model output.

DEP Response: This is duly noted in the text and will be clarified.

Phosphorus chemistry/cycle

(ES, page 5 & 6) The Executive Summary should explain why the TMDL is for *total phosphorus* The ES should provide a brief explanation of the phosphorus cycle in rivers and the differences between total phosphorus, ortho-phosphorus and particulate (organic) phosphorus. For example, the executive summary, as well as the rest of the draft TMDL report, give the impression that total phosphorus and ortho-phosphorus are discrete and additive substances. In other words, the report should clearly explain that ortho-phosphorus and particulate phosphorus are part of total phosphorus.

DEP Response: The following wording has been added as a footnote:

Total phosphorus is all of the phosphorus in a sample. Ortho-phosphorus (as used in this document) is phosphorus readily available for plant growth and is considered to be all of the phosphorus that passes through a prescribed sized filter. Hence, it is also referred to as dissolved P. Particulate P is phosphorus that is in the material that remains on the filter and generally is calculated by subtracting the filtered P from the total P.

The TMDL is based on total P because at the low concentration required by the TMDL, it is expected that all of the P will be dissolved and readily available or transformable for plants to use for growth

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(Page 36) The scenario where all POTWs are at 0.2 mg/l ortho P and sediment flux is reduced 90% *was only run at July 1999 flows*, so it is unknown how it would have compared to the same scenario run at design flows. The statement on the top of page 36 should be changed to POTW phosphorus concentrations from 0.2 mg/l or less to *0.1 mg/L or less*.)

DEP Response: DEP agrees that it should and will be noted that the flow for Run 10 was at 1999 and not design flows. Thus this run should be viewed as not being definitive for design flows. At the same time, Runs 8 and 14 with all POTWs at 0.1 mg/L P and 90% reduction in sediment P flux are not much different in the response variables between 1999 flows and design flows. DEP considers this general agreement an indication that the same is also likely to be true. for Run 10 *were it simulated at design instead of 1999 POTW flows. As noted previously, DEP considers Run 10 not to be meeting all the objectives of the TMDL but does consider it useful in setting an upper limit for calculating the margin of safety.*

At the same time and to avoid any ambiguity, wording in the TMDL is being clarified to note that with Westborough at 0.1 mg/L P or less and the other 3 facilities at less than 0.2 mg/L P, the value of response variables vary within a relatively narrow range.

(Page 37) Item #5. The text should explain that this run (Scenario#10) was done at *1999 POTW flows*. It was not run at design flows.

DEP Response: This now is explicit in the text.

River Stewardship Council

Thank you for the opportunity to comment on the above mentioned report. This Assabet River TMDL is a critically important part of water quality management in the Assabet River, and the basis for determining wastewater discharge limits, based on water quality, into the future. The Sudbury, Assabet and Concord Wild and Scenic River Stewardship Council (RSC) identifies water quality impairment as one of the most significant issues facing the Wild and Scenic Rivers, because of its deleterious impacts on the 'outstandingly remarkable resources ' for which the Rivers were given the national designation.

In 1999, 29 miles of the Sudbury, Assabet and Concord Rivers were nationally designated as wild and scenic rivers because of their resource values including outstanding scenery, ecology, recreation opportunities, historical significance and unique place in literary history. The River Stewardship Council was created and authorized to work with the National Park Service to promote the long term protection of the rivers. The RSC is comprised of representatives from each of the 8 shoreline communities, the Commonwealth, federal government and Organization for the Assabet River and Sudbury Valley Trustees.

This draft TMDL is a major step forward in providing the information needed to protect the Assabet River, as well as the Concord River into which it flows. DEP and EPA deserve credit for their dogged focus on the serious water quality impairments found on the Assabet. This TMDL has helped to quantify the problems and through the modeling efforts has provided useful data needed to develop state/federal permits that address necessary water quality improvements in the River. With this in mind, the RSC has the following comments and concerns:

Comment #1: The modeling efforts in the TMDL have looked at a range of alternative scenarios for water quality improvements, including both phosphorus removal at POTWs and reduction of phosphorus contribution from sediment accumulated in the impoundments. The model runs show that stringent phosphorus limits on wastewater discharges and significant reductions of phosphorus from sediment will both be required to meet water quality standards. However, the feasibility of reducing this sediment contribution by 90% is still in question, for scientific and economic reasons. Considering this uncertainty, the TMDL places too much emphasis on the phosphorus reductions from the sediment flux. This is not adequately addressed in the discussion of the margin of

safety required by the TMDL process. By not requiring the dischargers to reduce phosphorus as much as possible now, the TMDL is postponing difficult decisions to the next permit round in 2009 and allowing the River to remain in greater violation of standards.

DEP Response: As noted previously, it is not clear how reliable removals can be at the various treatment plants given current design and operating constraints. DEP considers the 0.75 mg/L limit for TP during the growing season to be a reasonable upper limit while encouraging the POTWs to do as well as practical with the given constraints, including those associated with construction of additional treatment needed to achieve the effluent quality required by the TMDL We note that this is already being done based on review of current discharge monitoring reports (DMRs). Also, the time estimated for design and construction of the required facilities to upgrade treatment is already extremely short.

Reduced external loads of phosphorus to the river eventually will reduce the amounts coming from the sediment. This is likely to take a long time without some direct action, which is why assessing possible actions to speed and perhaps enhance the process are proposed. The TMDL as written recognizes the significant role sediment plays in water quality when low levels are phosphorus from the point sources are achieved. It also recognizes that once low levels are achieved it may be more practical and cost effective to remove phosphorus from the sediment than to add additional sophisticated technologies to the point sources. As such DEP incorporated into the TMDL a mechanism for the communities to investigate more cost effective alternatives during the next permit cycle.

Comment #2: The report does not recommend reduced discharge limits for the minor POTWs because the modeling effort indicates that they do not have a significant impact on water quality in the main stem of the Assabet when coupled with phosphorus reductions upstream. This should be reconsidered for a number of reasons.

- **As proposed, this TMDL contains significant inequities among those parties discharging into the river. While four municipalities will be making significant and costly improvements to their plants, private entities and the State should also be required to participate in water quality improvements.**
- **Because Middlesex School is renovating and upgrading their facility and Concord MCI is being issued a new permit, this is an appropriate time to include more stringent phosphorus limits (Powdermill Plaza is not relevant because it is hooking into the Acton POTW).**
- **Although these discharges are smaller, reductions similar to those imposed on the major POTWs may provide an incremental improvement to the River. Although these POTWs discharge below the impoundments on the Assabet River, they discharge into the Wild and Scenic segment and also contribute to the phosphorus load in the Concord River.**
-

DEP Response: As previously stated in prior responses DEP considers the seasonal effluent limit of 0.5 mg/L P for these facilities appropriate for the present for several reasons. First ,as indicated in the TMDL, The Middlesex School POTW discharges 0.22 lbs/day total phosphorus, primarily during the non-growing season, based on permitted flow and concentration. During the months of June through August flows from the school are approximately 50% or less than the rest of the year which results in a significantly reduced loading to the river. Based on a mass *balance calculation DEP estimates that the incremental increase in concentration from this facility on the Assabet River phosphorus concentration to be about 0.0004 mg/l. Second, as you have noted, the model developed by DEP was not designed to evaluate the potential impact of the Middlesex School on Spencer Brook. Until such as model is developed DEP believes the proposed limit is appropriate.*

As for the MCI- Concord facility: As stated in the TMDL DEP considers the effluent limit of 0.5 mg/L P for this facility appropriate at this time. DEP is of the opinion that the potential impacts of this increase is negligible because the discharge is downstream of the impounded sections in the Assabet River and the resulting in-stream concentration during 7Q10 conditions would be less than the in-stream national guidance values used by EPA under the conditions of the TMDL. Finally, any potential impacts to the Concord River system downstream cannot be evaluated until a TMDL for that system is developed.

Comment #3: The decisions made on the Assabet River will have an impact on the Concord River- a river that is also on the State 303(d) list of impaired waters. There are several water quality issues on the Concord River and it serves as the source of drinking water for the Town of Billerica. The Concord River is wide and slow moving, and is impounded at the Billerica Dam. The Concord River TMDL will have to consider the contribution of phosphorus from the Assabet River as well as the influence of the Dam on water quality upstream. As it is presently proposed, the Assabet River TMDL could allow for an increase in pounds of phosphorus flowing into the Concord River. This is due in part to allowable increased flows as the POTWs reach design flows, as well as an unknown concentration of phosphorus discharged during the winter months when the phosphorus limit is relaxed. There should be no increase in the annual load of phosphorus from the Assabet into the Concord River.

The State should consider whether the recommended phosphorus limits on the Assabet will be adequate to meet the TMDL limits for the Concord River. Furthermore, the State should begin the TMDL for the Concord River as soon as possible so that the results will be available by 2009 when the second phase of the Assabet River management strategy is being implemented.

DEP Response: It is expected that meeting water quality goals set forth in the TMDL for the Assabet River will be compatible with any controls needed to protect the Concord River. However, this issue will revisited when assessing water quality issues on the Concord River.

Comment #4: Additional monitoring must be done on the phosphorus discharges in the winter. Monitoring must show that 90% of the phosphorus is dissolved throughout the winter months and that that phosphorus is truly moving through the system and not becoming available during the growing season. Additional analysis should also determine if the remaining 10% particulate phosphorus is staying in the system and contributing to eutrophication in the Assabet River. Monitoring should also establish how much phosphorus load is being carried from the Assabet into the Concord River. Until this research is complete, winter phosphorus limits should be imposed. Without a credible monitoring program that provides data necessary to address the many remaining questions, it will be impossible to make informed and responsible decisions as part of this phased management strategy.

DEP Response: DEP does agree that a well designed and executed efficient monitoring program is a key element in the adaptive management approach. A proposed design will be drafted shortly for review by interested parties.

Barbara Offenhartz – BHO Associates

Comment #1: Crafting a sound monitoring approach to following the effects of incremental control options should be of primary importance. The draft TMDL report describes two important initial steps - additional sediment studies and off-season monitoring at the waste water treatment plants.

I would hope that the practice of including all interested stakeholders in the crafting of such a monitoring plan will be continued.

DEP Response: As noted above, DEP recognizes the importance of continuing stakeholder involvement as we move into another phase of improving and protecting the quality of the Assabet River.

Larry Gomes

Comment #1: While I am sure that no one (including me) is against improving water quality, the real question always comes down to cost. Our town officials have estimated that meeting some of the proposed water quality standards set by your department would quadruple our water and sewer rates.

On top of this year's 10% property tax hike that means our family would be paying almost $700 per month, just in local taxes and water and sewer fees, never mind our mortgage, insurance, utilities and maintenance.

I am NOT in favor of installing any new equipment in our sewer treatment plant for the removal of phosphorus unless there is funding from Federal and State government to defray at least 75% of the cost.

I am in favor of doing the following to help reduce the flow of phosphorous into the Assabet River:

1. Ban the use of high phosphate fertilizers in MA.

2. Ban the use of all dishwashing detergents, laundry detergents and soaps that contain high levels of phosphorous in MA.

3. Work with local farmers and homeowners in the Assabet watershed to reduce or discontinue use of pesticides. If pesticides must be used, work with landowners to insure run off is not reaching the Assabet River.

4. 4. Work with farmers in the Assabet watershed to insure that animal waste is not contributing to water quality issues.

5. 5. Remove any unused dams using federal, state of private funding to promote better water flow in the Assabet river.

As Massachusetts residents, we are reeling from the massive increases that have occurred over the past 3 years in local taxes, state fees, health insurance, homeowners insurance, car insurance, fuel costs and utility bills.

The only bright spot has been lower interest rates, which has not saved us enough to offset the other increases. We simply cannot afford to have unfunded mandates handed down from Federal and State Government.

I hope that you will be sensible in your approach to solving this problem by implementing the low cost measures I have proposed first and then monitoring the results, before considering more costly measures.

It makes absolutely no sense to permit the use high phosphate detergents and soaps, which subsequently forces us to install high priced equipment to remove it. Legislation is a lot less expensive, so lets do all we can to reduce the amount of phosphates going in, before jumping to the conclusion that high priced removal equipment is required.

If you eventually find out this equipment is really necessary, be sure to bring some funding with you.

Everyone can and must play a role in improving and protecting the quality of the environment. This does mean that all need to be cognizant of practices that may make only a small contribution from one person’s care, but a big difference if all observe good practices. Hence, actions such as using low phosphorus detergents, judicious use of fertilizers and good practices for disposing of household wastes are just some of the personal responsibilities that are playing a bigger role in improving the environment. It is a measure of the success we have achieved in controlling wastes from municipalities and industries that personal practices are playing a larger role in the remaining problems. At the same time, effective waste treatment by municipalities and industries remains a fundamental aspect of protecting the environment and such obligations continue to require considerable commitment.

DEP Response: DEP certainly understands your concerns and recognizes that other sources of nutrients can and should be reduced where possible to address the issue. In some cases actions have already taken place such as the ban on phosphate detergents in 1994. In addition, legislation has been filed and is pending to control the phosphate dish washing detergents. Federal grants are also available to address other non-point sources of nutrients such as those that you have mentioned. Although all of these measures, if implemented, will help reduce the primary source of nutrients in the Assabet River that presently originate from the four major treatment facilities that discharge there. Since these facilities account for up to 90% of the nutrients entering the river when flows are low they must be addressed to solve this problem.

During the period of the grants program, state and federal funds paid for up to 90% of the eligible capital costs for wastewater treatment facilities. Many communities, including those discharging to the Assabet River availed themselves of this subsidy to improve existing treatment. The state revolving fund, a loan program with subsidized interest rates, has replaced the grants program and while not as generous as the grants program, still offers important financial support. A major consideration that municipalities and their consultants assess is the most cost effective ways to meet environmental quality standards. The 30 years since the passage of the Clean Water Act and other environmental legislation has resulted in substantial improvements to the quality of the environment and public health. Continued progress is necessary and this indeed does incur costs. The challenge is to meet those objectives in the most cost effective manner with the least possible financial burden as possible.

Attachment #1 – Organization For the Assabet River (OAR) Attachments

Attachment 1 - Analysis of Seasonal, Winter and Annual Point Source TP Loads to Assabet River under 2002 and TMDL conditions, (page 1 of 2)

"Current" Conditions

TP POTW Loads at Seasonal (April-Oct) 2002 Flows & Mon. Ave TP (mg/L)

WWTPs	Seasonal Flow (April-Oct) mgd from draft TMDL	Seasonal TP Concentration (mg/L)	4/1-10/31 Daily TP (lbs/day)	Seasonal TP (lbs/214 days)	Total Annual POTW TP Load
Westboro	4.86	0.64	26.0	5,555	28,877
Marlboro W.	1.74	0.41	6.0	1,274	5,656
Hudson	1.98	0.69	11.4	2,440	8,211
Maynard	0.84	0.62	4.3	930	4,981
Seasonal Total of All POTWS			**48**	**10,199**	
Annual Total fo All POTWs					**47,724**

TP POTW Loads at "non-seasonal" (Jan, Feb, March, Nov, Dec) 2002 Flows & Mon. Ave TP (mg/L)

WWTPs	Non-seasonal average monthly flow from draft TMDL, mgd	Non-seasonal 2002 average monthly TP concentration (mg/L)	Non-seasonal daily TP (lbs/day)	Non-seasonal TP (lbs/151 days)	Total Annual POTW TP Load
Westboro	5.17	3.58	154	23,323	28,877
Marlboro W.	1.89	1.84	29	4,382	5,656
Hudson	2.14	2.14	38	5,771	8,211
Maynard	0.98	3.28	27	4,050	4,981
Non-Seasonal Total of all POTWs			**249**	**37,526**	
Annual Total of All Point Sources					**47,724**

Attachment 1 - Analysis of Seasonal, Winter and Annual Point Source TP Loads to Assabet River under 2002 and TMDL conditions, (page 2 of 2)

TMDL

Seasonal Point Source TP Loads under TMDL with POTWs and Minors at Design Flows						
WWTPs	Design Flows (mgd)	Seasonal TP Concentration (mg/L)	Daily Seasonal Point Source TP Load (lbs/day)	Seasonal Point Source TP Load (lbs/214 days)	Total Annual Point Source TP Load	Additional seasonal TP load (lbs/214 days) if Marlborough @4.4 mgd
Westboro	7.68	0.10	6.41	1,372	36,017	
Marlboro W.	2.89	0.10	2.41	516	7,217	**270**
Hudson	3.00	0.10	2.50	536	8,626	
Maynard	1.45	0.10	1.21	259	6,252	
Total POTW Loads			**12.53**	**2,682**	**58,111**	
MCI Concord	0.30	0.50	1.25	268	457	
Middlesex School	0.052	0.50	0.22	46	79	
Seasonal Total of Minors			**1.47**	**314**	**536**	
Total Point Source Loads			**14.00**	**2,997**	**58,647**	

"Non-seasonal" (Jan, Feb, March, Nov, Dec) Point Source TP Loads at design flows & 2002 mg/L TP						
WWTPs	Design Flows (mgd)	2002 non-seasonal average monthly TP concentration (mg/L)	Daily non-seasonal Point Source TP Load (lbs/day)	Non-seasonal TP Load (lbs/151 days)	Total Annual POTW TP Load	Additional non-seasonal TP load (lbs/151 days) if Marlborough @4.4 mgd
Westboro	7.68	3.58	229.44	34,646	36,017	
Marlboro W.	2.89	1.84	44.38	6,701	7,217	**3,501**
Hudson	3.00	2.14	53.57	8,090	8,626	
Maynard	1.45	3.28	39.69	5,993	6,252	
Total POTW TP Load			**367.08**	**55,429**	**58,111**	
MCI Concord	0.30	0.50	1.25	189	457	
Middlesex School	0.052	0.50	0.22	33	79	
Non-Seasonal Total of Minors		1.00	1.47	222	**536**	
Total Point Source Loads			**369**	**55,651**	**58,647**	

Attachment #2 – Dr. William Walker Comments

Dr. William Walker Comments and Responses to OAR Questions

1) Is dissolved oxygen a good surrogate for biomass (in ENSR's model)?

In the model, dissolved oxygen is influenced by biomass and several other factors (reaeration, sediment oxygen demand, BOD loadings, temperature, flow, solar radiation, etc.). While there is a linkage (both in the model and in reality) between biomass and dissolved oxygen, it is not one-to-one and not all of the mechanisms are represented in the model. The linkage is complex because there are many forms of biomass (phytoplankton, periphyton, floating mats, rooted plants) and many mechanisms (photosynthesis, respiration, die-off & decay, sediment coupling, and physical effects related to stagnation and reductions in reaeration rates). Because of this complexity, there is a great deal of uncertainty in modeling these interactions and in the quantitative forecasts.

In a qualitative sense, there would be a tendency for dissolved oxygen conditions to improve with sufficient reductions in nutrients and biomass. It is possible that the system could meet the DO standard in the main channels (modeled portion), but not the DO or narrative nuisance aquatic growth standards in the peripheral areas and backwaters of the impoundments or following episodic vegetation dieoff events. Based upon experience modeling phosphorus dynamics in treatment wetlands (Kadlec & Walker, 1999; 2003), biomass is likely to be more responsive to reductions in P load than indicated by the HSPF simulations. Similarly, the following statement is somewhat pessimistic (ENSR, 2001, Page ES-6) *"For each nutrient constituent, concentrations were observed to be at least one order of magnitude (i.e. 10 times) higher than nutrient limiting concentrations indicating that concentrations of these nutrients would have to be reduced dramatically before biologic productivity in the system diminished"*. This statement may apply somewhat to suspended phytoplankton, but not necessarily to other vegetation types (mats, periphyton, rooted plants), which account for a much higher percentage of the plant biomass & associated organic loads. Given the abundant vegetation and the dominance of point sources, it would not be unrealistic to classify the river impoundments as "treatment wetlands" during summer low flows. For a given set of hydrologic conditions, average phosphorus storage in treatment wetland vegetation (on a mass per unit area basis) has been observed to vary roughly in proportion to average ambient water column total P concentration at levels up to and exceeding 1 mg/liter, well above those experienced in the Assabet (Kadlec & Walker, 1999; 2003). Similar relationships have been observed on a seasonal basis for treatment wetlands in Michigan, as well as Florida. Variations in P storage reflect variations in biomass and tissue P content (luxury uptake) that occur in response to variations in water column P concentration. HSPF does not represent all of these mechanisms.

Similarly, there may be qualitative shifts in vegetation types (loss of duckweed, floating mats) at P concentrations that are above "growth-limiting" levels. Floating vegetation can pose a particular problem with respect to dissolved oxygen because they restrict reaeration, contribute dissolved oxygen to the air instead of the water (unlike phytoplankton & submerged plants), and can impose a substantial oxygen demand upon death, sedimentation, and decay. Sas (1989) showed that dominance of nuisance bluegreen algae was generally eliminated when total phosphorus concentrations were reduced from >.10 mg/L to the 0.05-0.08 mg/L range in European shallow lakes and impoundments subject to restoration activities. Achievement of "growth-limiting levels" (say .005 mg/L of soluble reactive P) is not necessary to accomplish such improvements.

2) How much confidence can we have in the model's prediction that the minimum DO criterion will be met in all reaches under 7Q10 with the WWTPs at 0.1 mg/TP and current sediment phosphorus release reduced by 90%?

These measures would likely result in substantial reductions in river TP concentrations, reductions in aquatic productivity, and improvements in dissolved oxygen regime. Given limitations in the data and modeling, it is not possible to specify with much certainty the precise degrees of point-source and sediment control required to achieve the numeric dissolved oxygen standard throughout the river. Based upon the historical data showing decreasing P concentrations from upstream to downstream and upon basic water and mass-balances, it seems more likely that P concentrations consistent with meeting the oxygen standard would be achieved in the lower reaches than in the upper reaches. The lower reaches appear to be more susceptible to algal growth because impoundment water residence times are longer.

It is not clear that snapshots of the river provided by 2 synoptic summer low-flow surveys (primary basis for model calibration) reflect the true critical conditions with respect to dissolved oxygen. Significantly lower DO levels may occur in the more stagnant backwater areas of the impoundments (vs. the main channel stations that were monitored and modeled) and/or following episodic die-off of algal blooms or mats. For example, I have noticed distinct odors of hydrogen sulfide in the vicinity of the Power Mill dam occasionally in late summer. These may have been associated with hot, calm weather and/or episodic dieoff of vegetation. Dissolved oxygen levels must have been significantly below those observed in the surveys in order for hydrogen sulfide to be present.

So, there is no assurance that the standard would be met in all reaches and at all times, even if the model were "perfect" and simulations showed compliance in the main channel under summer low flows. But, there is little doubt that significant water quality improvements would result from implementation of a 0.1 mg/l limit.

3) Is it reasonable to assume that 90% of the sediment phosphorus contribution can actually be removed from the Assabet?

Probably not.

Based upon fundamental mass-balance concepts, the sediment should not be considered an independent source of phosphorus. Sediment P releases represent recycling of P historically discharged into the river from the watershed and point sources. So, in the long run (possibly a few years to decades), some reduction in sediment P release rate would be expected following a significant reduction in external P loads. The model does not reflect this feedback mechanism. Therefore, the effects of sediment P release on water column P concentrations are likely to be over-estimated in model runs with reduced external loadings but constant sediment flux (i.e. the model forecasts are pessimistic in this regard).

Management scenarios modeled by ENSR involve various combinations of effluent P limits (e.g., 0.05, 0.1, 0.2, existing) and assumed reduction in sediment flux (e.g., 0%, 25%, 50%, 75%, 90%). It is not appropriate to consider these as independent factors because the sediment P flux is, in the long run, dependent on the external P load to the river. Without extraordinary measures to reduce sediment P flux (e.g., dredging, chemical treatment), it is unlikely that the percent reduction in sediment P flux would exceed the percent reduction in external P load (point + nonpoint). Mass balance calculations for 1999 summer low-flow conditions indicate that effluent P concentrations of 0.2, 0.1, and 0.05 mg/l correspond to total load reductions of 76%, 86%, and 91%, respectively. These would be upper bound estimates of percent reduction in sediment P load without special intervention.

Laboratory sediment flux measurements are subject to experimental artifacts and may not reflect actual conditions in the field. For one thing, the measurement process involves removal of biological components that may offset or enhance P releases. The predicted benefits of sediment P reductions based upon direct application of measured flux rates in the model are questionable.

Reductions in sediment P release could be accelerated by instream measures, such as dredging or alum application. Additional sediment P data (horizontal & vertical profiles with P speciation) would be needed to evaluate the potential effects of dredging. Depending on vertical distributions, there is some risk that sediment P releases would increase following dredging. For example, the sediment P content may be higher in deeper layers of the sediment (potentially exposed by dredging) because substantially higher P concentrations were typical of domestic wastewaters (up to ~5 mg/liter vs. ~1 mg/L) prior to the late 1970's when use of phosphate detergents were curtailed and when treatment plants were not being designed or operated to remove phosphorus. Dredging may, however, have beneficial effects on dissolved oxygen that are not directly related to P release (removal of organic matter and improved circulation). Alum treatment may have more direct immediate effects than dredging, but would probably have to be repeated at regular intervals because the alum would be buried by new sediment loads.

Based upon the laboratory studies and field measurements conducted by ENSR, the P releases occur primarily under aerobic conditions and are probably related to decomposition of plant material and other organic substances, as opposed to chemical mechanisms which would trigger much higher release rates under anaerobic conditions. The latter may occur in deep holes or episodically following plant dieoff events. Since the measured aerobic release rates are already relatively low, I doubt that a 90% reduction could be achieved or that a reduction of this magnitude is necessary to achieve water quality standards if external loads are sufficiently reduced.

Because a portion of the historical P loads will bleed back into the water column via the sediment for a period of time, there may be a time lag between reduction in current point-source loads and full response of water column P concentrations in the River and its impoundments. Sediment P feedback is more likely to be important in the lower impoundments with longer residence times than in the upper reaches. Additional river monitoring, sediment studies, and model refinements will help to develop realistic expectations for the river response time and to apply instream treatments (dredging, chemical treatment), should the projected response times be unacceptably long. Despite the uncertainties, it is not defensible to use the existence of a sediment P load as a basis for balking at implementation of point-source controls. Most of the P being recycled from the sediments came from the wastewater plants to begin with. If historical loads were used to justify future loads, impaired water bodies would never be restored.

4) The Assabet River Consortium has argued that increasing the volume of wastewater discharged to the river to design flows would have a small impact on water quality. Do you agree?

It would depend upon your definition of "small impact". While it is not possible to answer your question quantitatively without conducting an independent modeling exercise, a few relevant concepts are outlined below.

While secondary to concentration, variations in point-source flows should also be considered in the TMDL. Specification of concentration limits alone would be insufficient to guarantee that water quality standards would still be met if point-source flows were increased.

When the river is ~100% effluent, the inflow P concentrations to the upper reaches are independent of flow. However, concentration within and downstream of the impoundments would increase with flow because hydraulic residence times and phosphorus sedimentation would decrease. This would be a second-order effect (not proportionate). Rough calculations using a simple phosphorus retention model suggest that a 70% increase in total wastewater flow (say, from 10 to 17 mgd) at a discharge concentration of 0.1 mg/l would result in ~30% increase in P concentration in the lower reaches of the River.

Treating the sediment reflux as an independent source (inappropriate, as discussed above), would tend to artificially reduce the sensitivity of the simulated river P concentrations to point-source flow.

To the extent that the river functions as a treatment wetland in the summer, higher flows and loads would potentially increase biomass and nutrient storage in the rooted or otherwise anchored vegetation. This process would occur over a seasonal time scale. P releases resulting from respiration and decay of that vegetation may, in turn, supplement organic loads, nutrient loads and algal productivity during the critical summer low-flow conditions. It is not clear whether this type of mechanism is reflected in the HSPF simulations. While the model stores phosphorus in biomass, it does not appear to account for fluctuations in tissue P content in response to water column P concentration (luxury uptake), which can be very important.

Higher flows and loads would be a potential concern for the downstream Concord River. Potential impacts on that system would be controlled more by the phosphorus load from the Assabet than by its concentration. For that reason, total P load to the Concord River should be considered as a criterion in evaluating alternative wastewater management scenarios for the Assabet.

Given existing modeling uncertainties, it would be difficult, at this point, to establish an absolute requirement to limit discharge volumes. If an adaptive approach to the TMDL were taken (i.e. involving incremental decreases in discharge concentrations and/or implementation of instream control measures until water quality standards are met, see Question 6), then the end point (expressed in terms of final effluent P concentration limits) might be lower if discharge volumes are allowed to increase. This would depend upon how the river actually responds to implementation of interim P limits.

5) Is it appropriate to use EPA's recommended numeric phosphorus criterion of 0.024 mg/L (for subecoregion 59) as a basis for setting NPDES permit limits?

For reasons stated above, dissolved oxygen in the main channel under summer low flows is only a surrogate for system-wide compliance with water quality standards with respect to DO, pH, and nuisance plant growths. Because of the difficulties associated with modeling (and monitoring) all of the mechanisms controlling dissolved oxygen, consideration should be given to adopting an instream goal for total phosphorus that would serve as an alternative surrogate. Major advantages of doing this are (1) phosphorus is the primary causal factor driving the water quality problems (2) success can be gauged more readily through monitoring (3) TP concentrations can be forecast with greater certainty using HSPF or simpler mass-balance models for impoundments (e.g., BATHTUB, Walker, 1999). This approach has apparently been taken in evaluating eutrophication problems in other local basins (Mass DEP, 2002, Draft). Adoption of a P criterion would simplify the process and enable determination of an “end point” with greater certainty using HSPF and/or a simpler mass-balance model. In my opinion, EPA’s 0.024 mg/L P criterion (USEPA, 2000) would probably be a defensible and protective goal for the Assabet. This criterion is based upon a statistical summary of regional data and does not account for site-specific factors that would influence the linkage of phosphorus concentration to algal/plant growth and to violations of water quality standards. To some extent, these relationships can be characterized using simple empirical methods (Walker, 1999; 2003) applied to data from the Assabet impoundments and possibly others in the region. Further data analysis and modeling could be done to determine whether site-specific adjustment of the criterion is appropriate to account for any unique features of the Assabet impoundments.

EPA's "classical" criteria for phosphorus are 0.05 mg/L for streams entering impoundments and 0.025 mg/L for impoundments (USEPA,1976). These are based not upon ecoregion concepts, but upon generalized correlations between phosphorus levels and eutrophication-related water quality problems. Target P concentrations ranging from 0.01 to 0.035 ug/L were selected by Mass DEP in developing TMDL's for lakes and impoundments in the French River Basin (Mass DEP, 2002, Draft). Site-specific P criteria ranging from 0.008 to 0.060 mg/L have been developed for other lakes & impoundments based upon correlations with direct indicators of use impairment, such as frequencies of nuisance algal blooms, depressed transparency, and/or violations of pH or dissolved oxygen standards, and used as a basis for setting TMDL's (Walker, 2003). Given that summer water residence times in the Assabet River impoundments (particularly Ben Smith & Powdermill) appear to be sufficient to allow development of severe nuisance algal blooms (based upon measured chlorophyll-a concentrations > 30 ug/L), as well as extensive algal mats, periphyton, floating vegetation, and rooted vegetation, it is unlikely that an appropriate P criterion for these systems would be outside of the above range.

While subject to refinement through further data analysis and modeling, the 0.024 mg/L ecoregion criterion would appear to be a protective goal for the Assabet, based its similarity to the classical criterion for impoundments (0.025 mg/l, USEPA, 1976) and upon impoundment features that are known to support high algal and plant productivity. Because of phosphorus sedimentation in the impoundments, it is possible that a 0.024 mg/l criterion could be met in some of them with effluent P concentrations higher than 0.024 mg/L. Mass balances indicate that the impoundments trap about two thirds of the external phosphorus load under summer low flow (i.e. the load discharged downstream to the Concord River is about one third of the total external load). Since point sources account for >95% of the load under such conditions, an average discharge concentration of 0.072 mg/L for all point sources in the basin would be consistent with achieving 0.024 mg/L in the outflow from the last impoundment (Powder Mill) if the percentage of the external load removed by all impoundments were assumed to be constant. With the same assumption, lower average effluent concentrations (approaching the 0.024 mg/L criterion) would be needed to meet the criterion in the upstream impoundments because less phosphorus is removed in those impoundments. The above preliminary calculations are intended only to illustrate a simpler, alternative method (vs. HSPF) to deriving effluent limits to achieve the impoundment P criterion. Results would vary depending upon how the mass balance is formulated (e.g., HSPF vs. the constant retention assumption vs. a variety of other empirical models).

If EPA's (1976) criterion for streams entering impoundments (0.05 mg/L) were adopted, it would be directly applicable to the discharges because net phosphorus removal in stream segments is typically negligible and there is very little dilution of the effluents under summer low flows. For example, the Westboro discharge essentially constitutes the entire inflow to the first impoundment under summer low-flow conditions, so that the 0.05 mg/L instream criterion, if adopted, would be directly applicable to that discharge.

Although I have not undertaken an extensive review of the HSPF application, results presented by ENSR provide a basis for evaluating impacts of alternative permit limits. Figure 1 shows phosphorus concentrations as a function of river mile predicted by HSPF for various effluent P limits (0.2, 0.1, 0.05 mg/L) and assumed reductions in sediment P flux (0%, 90%). They are derived from ENSR's simulations of 1999 summer low-flow conditions. Predicted concentrations are compared with the 0.024 mg/L criterion. As discussed above, one limitation of HSPF is that it does not simulate the coupling of the sediment and water column mass balances. The 0% and 90% flux reduction simulations probably bound the actual river responses. It is apparent that River miles 30-25 and 15-8 are the most susceptible to high P concentrations. The latter segment includes two impoundments (Gleasondale & Ben Smith). Predicted average phosphorus concentrations in this segment are 0. 035, 0.023, and 0.018 mg/L for effluent P levels of 0.2, 0.1, and 0.05 mg/L, respectively, and a 90% reduction in sediment P flux. HSPF simulations also indicate that the dissolved oxygen standard would be violated at frequencies of 2.4%, 0%, and 0%, respectively, also with a 90% reduction in sediment P flux.

The HSPF results indicate that point-source effluent P reductions at least to the 0.1 mg/L level would be required to meet the 0.024 mg/L phosphorus criterion in the impoundments, as well as to meet the dissolved oxygen standard. Simpler massbalance calculations described above indicate that even lower effluent P levels (0.024 – 0.072 mg/L) may be required to achieve the phosphorus criterion in each impoundment. Given the likelihood that actual reductions in sediment P flux will be less than 90%, the modeling uncertainty, and the requirement under TMDL regulations to provide a margin of safety, permit limits well below 0.1 mg/L may eventually be required.

6) How should the TMDL be finished, i.e. P loads calculated?

Despite their limitations, existing data and modeling support the application of best available technology to reduce point-source loadings, at least to the 0.1 mg/l level as an interim permit limit. It is not clear that a 90% reduction in sediment P load can be achieved or is necessary in order to achieve water quality standards, provided that external P loads are sufficiently reduced. As discussed above, existing data or modeling do not support initial application of sediment control measures, pending further evaluation of the sediments and monitoring of river responses to interim load reductions.

Given data limitations and modeling uncertainties, the TMDL should be approached in an iterative or adaptive fashion, as recommended in a recent evaluation of the TMDL process by the National Research Council (NRC, 2001). Walker (2003b) describes how an iterative approach can be taken in developing phosphorus TMDL's to achieve water quality goals with the desired margin of safety in a cost-effective manner, given the uncertainties that are typically involved in setting goals, predicting the performance of control measures, and predicting impoundment responses. Beyond the above first step (<=0.1 mg/L interim permit limit), further reductions in point, nonpoint, and/or sediment loads may be necessary to achieve water quality goals. Potential needs for such measures can be assessed after implementation of interim effluent limits under an adaptive process that is supported by additional monitoring, data analysis, model refinements, evaluation and possible implementation of instream measures, and possible refinement of water quality goals.

Continued water quality monitoring is essential to determine whether TMDL objectives are met and to evaluate the potential need for additional control measures. Future monitoring should include additional synoptic surveys under summer low-flow conditions (with multiple samples collected at each site over the course of week or so), as well as periodic (weekly or biweekly) sampling in and immediately downstream of the major impoundments over the course of the growing season. More frequent monitoring of effluent water quality would also be appropriate (daily during synoptic surveys, otherwise at least weekly). To account for diel variations in effluent quality, effluents should be monitored with 24-hour composite samples, as opposed to grab samples.

To reduce forecast uncertainty, refinements to the HSPF application should be made periodically based upon additional data and/or advances in the state-of-the art. Given uncertainties in HSPF (or any) model, the feasibility of also applying a simpler phosphorus-balance model should be investigated. Existing data are more than adequate to support this type of effort. Once calibrated, mass balance models are much easier and less expensive to use in evaluating alternative management strategies. A parallel modeling effort would provide an independent check on HSPF forecasts of phosphorus and chlorophyll-a under various allocation scenarios and a partial basis for evaluating the robustness of the model forecasts and any resulting management decisions.