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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DISCLAIMER

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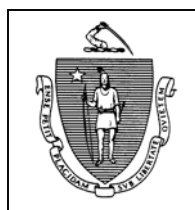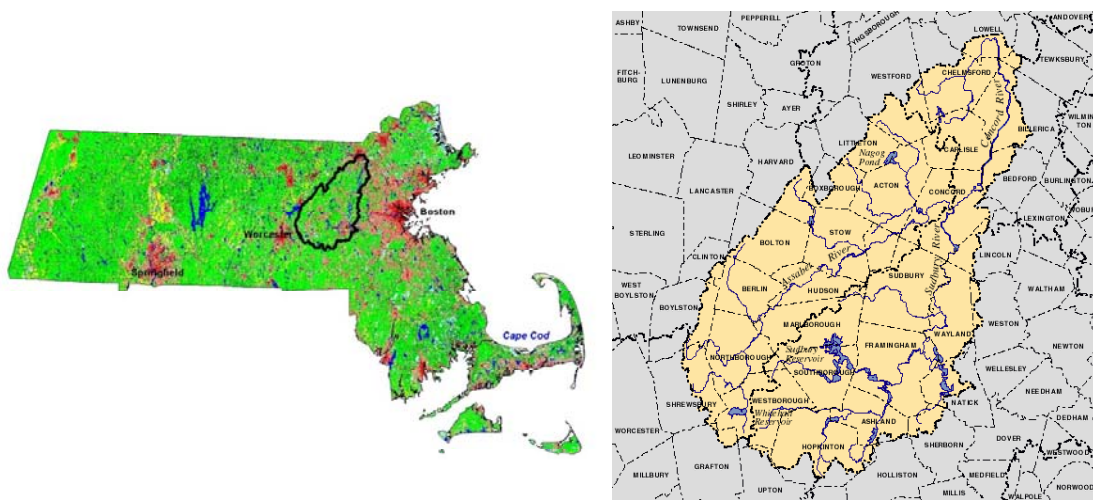
Assabet River

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SuAsCo Watershed, Massachusetts

<u>DEP, DWM TMDL Report MA82B-01-2004-01</u>
<u>Control Number CN 201.0</u>

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	NPDES	Design Flow, MGD	POTW Effluent Limits Total Phosphorus, mg/L April 1 – October 31[1]		POTW Effluent Limits Total Phosphorus, mg/L November 1 – March 31
			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
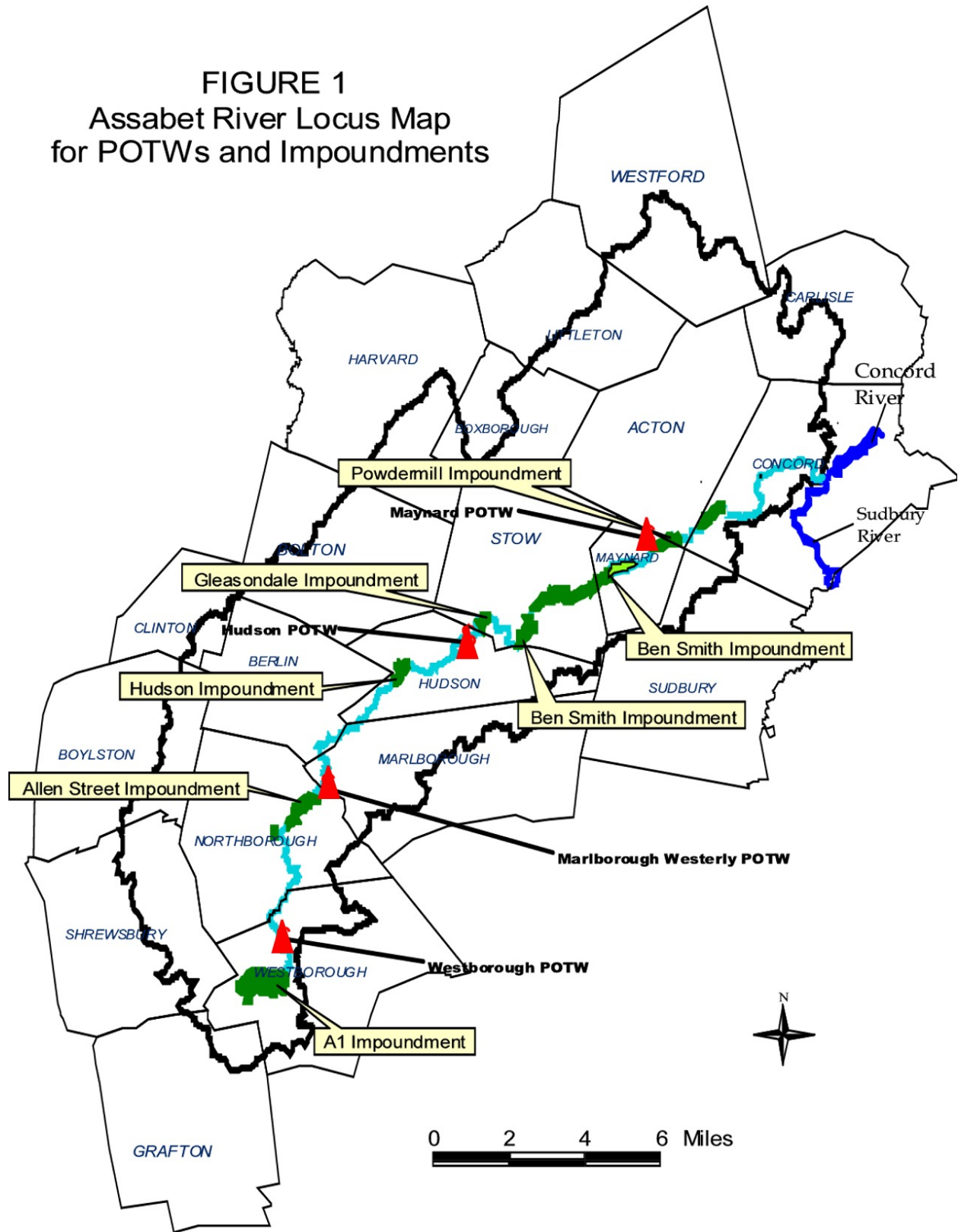
Problem Assessment

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

[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

| Sample Location | | Watershed Area (miles²) | Intensive Summer July 1999 Survey Total Phosphorus | | Dry-weather Survey 2 - Feb. 8-9, 2000 Total Phosphorus | | Wet-weather Survey 1 - March 16, 2000 Total Phosphorus | | Wet-weather Survey 2 - March 27, 2000 Total Phosphorus | | Wet-weather Survey 3 - Sept. 12, 2000 Total Phosphorus | | Intensive Summer August 2000 Survey Total Phosphorus | |
Rivermile	Description		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	1998	2.18	3.44		
Hudson	1998	2.6	0.67		
Maynard	1998	1.26	0.94		
Westborough	1999	4.41	0.79		
Marlborough West	1999	1.84	1.13		
Hudson	1999	1.93	1.51		
Maynard	1999	0.89	0.64		
Westborough	2000	5.09	0.89		
Marlborough West	2000	2.27	0.49		
Hudson	2000	2.25	1.63		
Maynard	2000	1.11	0.45		
Westborough	2001	4.96	0.69	5.52	3.62
Marlborough West	2001	2.07	0.51	2.30	1.85
Hudson	2001	2.30	0.56	2.39	1.52
Maynard	2001	1.07	0.63	1.09	2.95
Westborough	2002	4.86	0.64	5.17	3.58
Marlborough West	2002	1.74	0.41	1.89	1.84
Hudson	2002	1.98	0.69	2.14	2.14
Maynard	2002	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	Calib										B.S. Dam Removal[4]	GW Infil.[6]														
River Mile																										
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)

	Run	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
		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)

	Run	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
		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:

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:

<div align="center">

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

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POTW	NPDES	Design Flow, MGD	POTW Effluent Limits Total Phosphorus, mg/L April 1 – October 31[1]		POTW Effluent Limits Total Phosphorus, mg/L November 1 – March 31
			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)
<u>Major Dischargers</u>		
Westborough	6.4	46.1
Marlborough West	2.4	11.3
Hudson	2.5	32.2
Maynard	1.2	3.1
<u>Minor Dischargers</u>		
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.

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