ENGINEERING FEASIBILITY & COST ANALYSES OF NITROGEN REDUCTION FROM SELECTED POTWS IN MASSACHUSETTS

PROJECT NUMBER 2007-01/106

Prepared for

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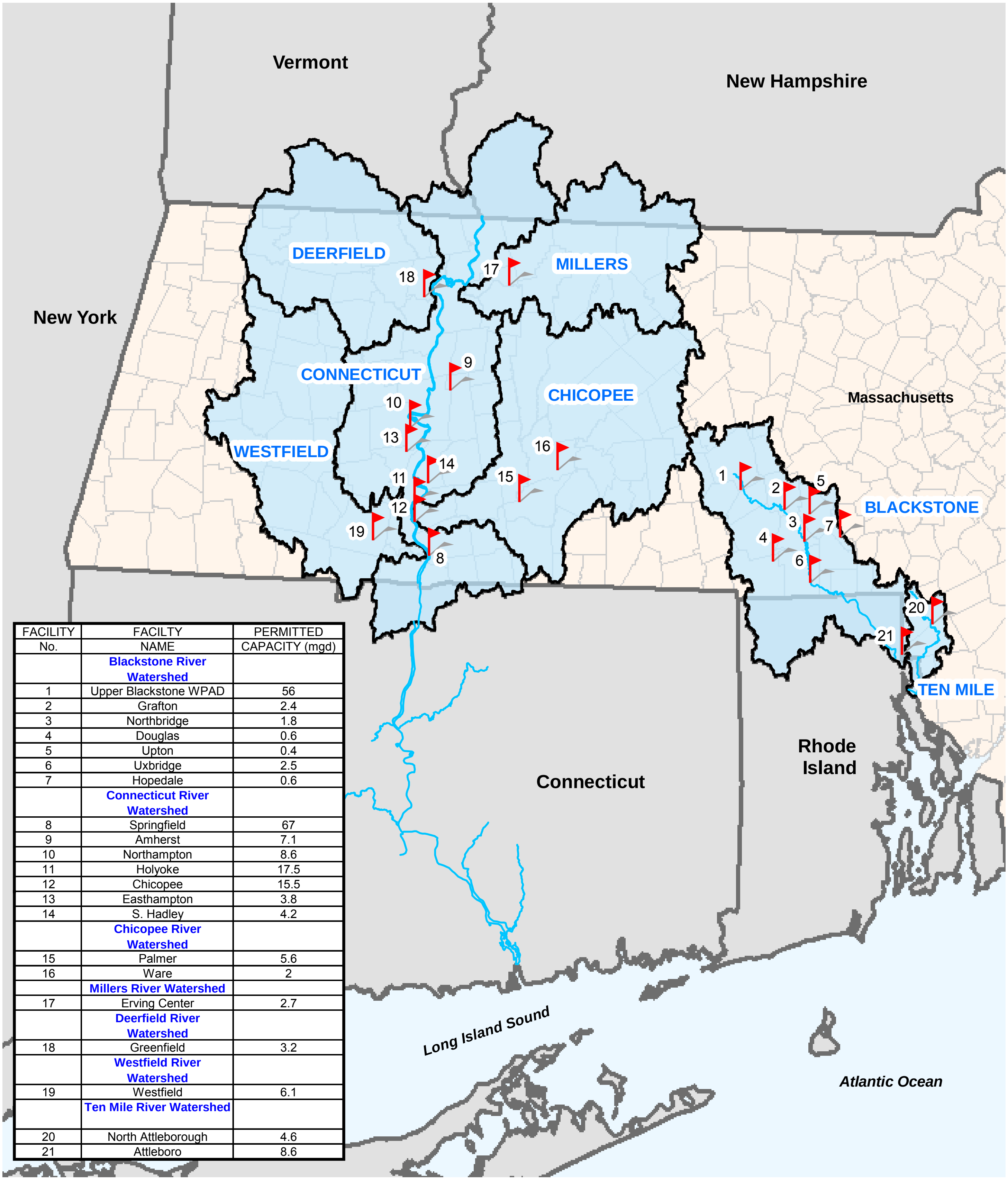
EXECUTIVE SUMMARY

The states of Connecticut and Rhode Island have established nitrogen removal programs to improve water quality in Long Island Sound and Narragansett Bay, respectively. Central and western Massachusetts have a number of Publicly Owned Treatment Works (POTWs) that discharge within the Connecticut River (and four of its tributaries – the Chicopee River, Millers River, Deerfield River, and Westfield River), the Blackstone River, and the Ten Mile River watersheds, all of which eventually flow to either Long Island Sound or Narragansett Bay, but historically have not been subjected to effluent nitrogen limits. This report evaluates the point sources of nitrogen from twenty-one of these POTWs in central and western Massachusetts and estimates the costs associated with reducing the nitrogen discharge from each. Figure ES-1 presents the POTWs evaluated.

Evaluations of the twenty-one POTWs include the use of the BioWin simulation package to aid in determining:

- the maximum nitrogen reduction, either seasonal or year round, resulting from operational and minor modifications/retrofits to the existing facility under ***existing*** flows;
- upgrades and associated costs required to meet an effluent concentration of 8 mg/L total nitrogen seasonally (May –October) and annually at ***permitted*** flows; and,
- upgrades and associated costs required to meet an effluent concentration of 5 mg/L total nitrogen seasonally (May – October) and annually at ***permitted*** flows.

The description of each facility in this report includes a discussion regarding minor modifications/retrofits and recommended upgrades to achieve the various nitrogen limits. A standard evaluation approach was developed for determining recommended upgrades. This did not result in, nor was it a project goal to determine, the most cost-effective approach for each facility to achieve the different levels of nitrogen removal.



FACILITY No.	FACILTY NAME	PERMITTED CAPACITY (mgd)
	Blackstone River Watershed	
1	Upper Blackstone WPAD	56
2	Grafton	2.4
3	Northbridge	1.8
4	Douglas	0.6
5	Upton	0.4
6	Uxbridge	2.5
7	Hopedale	0.6
	Connecticut River Watershed	
8	Springfield	67
9	Amherst	7.1
10	Northampton	8.6
11	Holyoke	17.5
12	Chicopee	15.5
13	Easthampton	3.8
14	S. Hadley	4.2
	Chicopee River Watershed	
15	Palmer	5.6
16	Ware	2
	Millers River Watershed	
17	Erving Center	2.7
	Deerfield River Watershed	
18	Greenfield	3.2
	Westfield River Watershed	
19	Westfield	6.1
	Ten Mile River Watershed	
20	North Attleborough	4.6
21	Attleboro	8.6

N

0 5 10 20 Miles

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DATE: 3/27/08 JOB No.: 61625

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MASSACHUSETTS DEP
WASTEWATER TREATMENT FACILITY
TOTAL NITROGEN REMOVAL

WATERSHEDS AND POTWs
Figure ES-1

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The total costs to achieve annual TN limits of 8 and 5 mg/L at the twenty-one facilities evaluated in this report is over $750 million and $900 million, respectively, based on the assumptions made in this evaluation. These assumptions include the use of permitted flows and assumed influent nitrogen concentrations when data was not available. The permitted flow used for each facility is a flow that, for many communities, may not be realized in the near-term or even long-term future. On average, the twenty-one POTWs are operating at about two-thirds of permitted capacity with five facilities operating at or less than 50% capacity. Also, the majority of the facilities did not have influent nitrogen data and as a result, critical data had to be assumed. The combination of these two factors results in upgrade costs that may be conservative. The summary of the upgrade costs and associated modifications for all facilities is shown in Table ES-1.

The Upper Blackstone Water Pollution Abatement District is the only one of the facilities that is currently being upgraded to achieve nitrogen removal (an annual average TN of 8 to 10 mg/L although not required by the current permit). This facility has also undergone a recent facilities planning process that determined a 20 year design flow projection of 45 mgd (80% of the permitted flow of the facility). Thus, in addition to the evaluation at permitted capacity, this facility was also evaluated at the reduced design flow. As shown in Table ES-1, the upgrade costs for the 45 mgd facility were significantly less than those associated with upgrades at permitted capacity. With all other analyses completed at the permitted flow of the facilities, a similar reduction in upgrade costs may be seen when more realistic design year flows are used.

(continued)

Table ES-1

FACILITY MODIFICATION AND COST SUMMARY

POTW NAME	OPERATIONAL OR LOW COST RETROFITS	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 8 MG/L	CAPITAL COSTS TO ACHIEVE SEASONAL TN OF 8 MG/L (MILLIONS)	MODIFICATIONS TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	CAPITAL COSTS TO ACHIEVE ANNUAL TN OF 8 MG/L (MILLIONS)	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 5 MG/L	CAPITAL COSTS TO ACHIEVE SEASONAL TN OF 5 MG/L (MILLIONS)	PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L	CAPITAL COSTS TO ACHIEVE ANNUAL TN OF 5 MG/L (MILLIONS)
Blackstone River Watershed									
Upper Blackstone Water Pollution Abatement District at 56 mgd	Ongoing upgrade to operate in MLE, A/O and A^2/O modes	Add two aeration tanks, IFAS in aerobic zones, and two new clarifiers	$130	Add two aeration tanks, IFAS in aerobic zones, and two new clarifiers	$130	Add two aeration tanks, IFAS in aerobic zones, two new clarifiers, denitrification filter, intermediate pump station, and methanol facility	$180	Add two aeration tanks, IFAS in aerobic zones, two new clarifiers, denitrification filter, intermediate pump station, and methanol facility	$180
Upper Blackstone Water Pollution Abatement District at 45 mgd (1)	Ongoing upgrade to operate in MLE, A/O and A^2/O modes	Currently designed to achieve annual average TN of 8 mg/L and monthly limit of 8-10 mg/L				Add one aeration tank, IFAS in all tanks, one clarifier	$90	Add one aeration tank, IFAS in all tanks, one clarifier	$90
Grafton Wastewater Treatment Plant	None	Add two aeration tanks, one clarifier, denitrification filter, intermediate pump station, and a methanol facility	$28	Add two aeration tanks, IFAS to all tanks, one clarifier, denitrification filter, intermediate pump station, and a methanol facility	$41	Add two aeration tanks, one clarifier, denitrification filter, intermediate pump station, and a methanol facility	$28	Add two aeration tanks, IFAS to all tanks, one clarifier, denitrification filter, intermediate pump station, and a methanol facility	$41
Northbridge Wastewater Treatment Plant	Cycle aeration in SBR up to 1.3 mgd	Add one SBR and a building to accommodate equipment	$6	Add one SBR and a building to accommodate equipment	$6	Add one SBR and a building to accommodate it, a denitrification filter, intermediate pump station and a methanol facility	$16	Add one SBR and a building to accommodate it, a denitrification filter, intermediate pump station and a methanol facility	$16
Douglas Wastewater Treatment Facility	Currently achieving some nitrogen removal	Add two SBRs	$4.4	Add two SBRs	$4.4	Add two SBRs	$4.4	Add two SBRs	$4.4
Upton Wastewater Treatment Facility	None	Add one new aeration tank	$5.1	Add one new aeration tank with IFAS in each tank	$7.3	Add one new aeration tank and a methanol facility	$5.3	Add one new aeration tank with IFAS in each tank and a methanol facility	$7.4
Uxbridge Wastewater Treatment Facility	Currently achieving some nitrogen removal	Add five aeration tanks	$25	Add eight aeration tanks with denitrification filters, intermediate pump station and methanol facility	$44	Add seven aeration tanks	$32	Add eight aeration tanks with denitrification filters, intermediate pump station and methanol facility	$44

Table ES-1 (continued)

FACILITY MODIFICATION AND COST SUMMARY

POTW NAME	OPERATIONAL OR LOW COST RETROFITS	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 8 MG/L	CAPITAL COSTS TO ACHIEVE SEASONAL TN OF 8 MG/L (MILLIONS)	MODIFICATIONS TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	CAPITAL COSTS TO ACHIEVE ANNUAL TN OF 8 MG/L (MILLIONS)	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 5 MG/L	CAPITAL COSTS TO ACHIEVE SEASONAL TN OF 5 MG/L (MILLIONS)	PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L	CAPITAL COSTS TO ACHIEVE ANNUAL TN OF 5 MG/L (MILLIONS)
Hopedale Wastewater Treatment Facility	None	Add seven aeration tanks, two clarifiers and methanol facility	$23	Add eight aeration tanks, two clarifiers and methanol facility	$25	Add seven aeration tanks, two clarifiers and methanol facility	$23	Add eight aeration tanks, two clarifiers and methanol facility	$25
Connecticut River Watershed									
Springfield Wastewater Treatment Facility	None	Nitrate recycle pumps and other minor modifications to existing aeration tanks	$4.5	Structural modifications to four existing aeration tanks; new diffusers; nitrate recycle pumps; two new clarifiers	$23	Nitrate recycle pumps and other minor modifications to existing aeration tanks; two new clarifiers	$56	Structural modifications to four existing aeration tanks; new diffusers; nitrate recycle pumps; three new clarifiers	$65
Amherst Wastewater Treatment Plant	None	Add two aeration tanks, one clarifier, denitrification filters, intermediate pump station and methanol facility	$48	Add four aeration tanks, one clarifier, denitrification filters, intermediate pump station and methanol facility	$61	Add two aeration tanks, one clarifier, denitrification filters, intermediate pump station and methanol facility	$48	Add four aeration tanks, one clarifier, denitrification filters, intermediate pump station and methanol facility	$61
Northampton Wastewater Treatment Facility	None	50% more volume added to end of existing tanks; conversion to plug flow; aeration equipment; nitrate recycle pumps; 2 new clarifiers; demolition existing digesters	$20	50% more volume added to end of existing tanks; conversion to plug flow; aeration equipment; nitrate recycle pumps; IFAS system; one new clarifier; methanol feed facility; demolition existing digesters	$35	50% more volume added to end of existing tanks; conversion to plug flow; aeration equipment; nitrate recycle pumps; IFAS system; one new clarifier; methanol feed facility; demolition existing digesters	$36	50% more volume added to end of existing tanks; conversion to plug flow; aeration equipment; nitrate recycle pumps; IFAS system; two new clarifiers; methanol feed facility; demolition existing digesters	$39
Holyoke Wastewater Treatment Facility	None	BAFs and denitrification filters; methanol feed facility; intermediate pump station	$99	BAFs and denitrification filters; methanol feed facility; intermediate pump station	$99	BAFs and denitrification filters; methanol feed facility; intermediate pump station	$99	BAFs and denitrification filters; methanol feed facility; intermediate pump station	$99
Chicopee Wastewater Treatment Facility	None	IFAS system in aeration tanks; replace aeration equipment; denitrification filters; methanol feed facility; 4 new stacked clarifiers; intermediate pump station; demolition of old digesters	$65	Demolition of oxygenation tanks and clarifiers; nitrification and denitrification filters; intermediate PS; methanol feed facility	$87	IFAS system in aeration tanks; replace aeration equipment; denitrification filters; methanol feed facility; 4 new stacked clarifiers; intermediate pump station; demolition of old digesters	$65	Demolition of oxygenation tanks and clarifiers; nitrification and denitrification filters; intermediate PS; methanol feed facility	$87

Table ES-1 (continued)

FACILITY MODIFICATION AND COST SUMMARY

POTW NAME	OPERATIONAL OR LOW COST RETROFITS	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 8 MG/L	CAPITAL COSTS TO ACHIEVE SEASONAL TN OF 8 MG/L (MILLIONS)	MODIFICATIONS TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	CAPITAL COSTS TO ACHIEVE ANNUAL TN OF 8 MG/L (MILLIONS)	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 5 MG/L	CAPITAL COSTS TO ACHIEVE SEASONAL TN OF 5 MG/L (MILLIONS)	PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L	CAPITAL COSTS TO ACHIEVE ANNUAL TN OF 5 MG/L (MILLIONS)
Easthampton Wastewater Treatment Facility	Operate at higher SRT; install timers on aerators	one new aeration tank; conversion of existing to plug flow; aeration equipment; nitrate recycle pumps	$11	one new aeration tank; conversion of existing to plug flow; aeration equipment; nitrate recycle pumps	$11	one new aeration tank; conversion of existing to plug flow; aeration equipment; nitrate recycle pumps; one new clarifier	$13	one new aeration tank; conversion of existing to plug flow; aeration equipment; nitrate recycle pumps; one new clarifier	$13
South Hadley Wastewater Treatment Facility	Operate at higher SRT; utilize new VFDs to simulate cyclical aeration	50% more bioreactor volume; convert two existing aeration tanks to plug flow; nitrate recycle pumps; aeration equipment; methanol feed facility	$16	50% more bioreactor volume; convert two existing aeration tanks; nitrate recycle pumps; aeration equipment; one clarifier; methanol feed facility; demolition of digesters	$19	50% more bioreactor volume; convert two existing aeration tanks; nitrate recycle pumps; aeration equipment; one clarifier; methanol feed facility; demolition of digesters	$19	50% more bioreactor volume; convert two existing aeration tanks; nitrate recycle pumps; aeration equipment; two clarifiers; methanol feed facility; demolition of digesters	$22
Chicopee River Watershed									
Palmer Water Pollution Control Facility	Operate at higher SRT; turn off first grid of diffusers to create anoxic zones; install FRP baffles	one new aeration tank; conversion of existing to plug flow; aeration equipment; nitrate recycle pumps; one new clarifier	$18	two new aeration tanks; conversion of existing to plug flow; aeration equipment; nitrate recycle pumps; one new clarifier	$22	one new aeration tank; conversion of existing to plug flow; aeration equipment; nitrate recycle pumps; one new clarifier; methanol feed facility	$18	two new aeration tanks; conversion of existing to plug flow; aeration equipment; nitrate recycle pumps; one new clarifier; methanol feed facility	$23
Ware Wastewater Treatment Facility	Install timers on aerators for cyclical aeration	Modify two existing aeration tanks to plug flow; aeration equipment; nitrate recycle pumps	$6.6	Modify two existing aeration tanks to plug flow; aeration equipment; nitrate recycle pumps	$6.6	Modify two existing aeration tanks to plug flow; aeration equipment; nitrate recycle pumps	$6.6	Modify two existing aeration tanks to plug flow; aeration equipment; nitrate recycle pumps	$6.6
Millers River Watershed									
Erving Center Wastewater Treatment Facility	Minimal Costs - Facility is nutrient deficient								
Deerfield River Watershed									
Greenfield Wastewater Treatment Facility	None	BAFs and denitrification filters; methanol feed facility; intermediate pump station; compensatory storage	$49	BAFs and denitrification filters; methanol feed facility; intermediate pump station; compensatory storage	$49	BAFs and denitrification filters; methanol feed facility; intermediate pump station; compensatory storage	$49	BAFs and denitrification filters; methanol feed facility; intermediate pump station; compensatory storage	$49

Table ES-1 (continued)

FACILITY MODIFICATION AND COST SUMMARY

POTW NAME	OPERATIONAL OR LOW COST RETROFITS	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 8 MG/L	CAPITAL COSTS TO ACHIEVE SEASONAL TN OF 8 MG/L (MILLIONS)	MODIFICATIONS TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	CAPITAL COSTS TO ACHIEVE ANNUAL TN OF 8 MG/L (MILLIONS)	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 5 MG/L	CAPITAL COSTS TO ACHIEVE SEASONAL TN OF 5 MG/L (MILLIONS)	PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L	CAPITAL COSTS TO ACHIEVE ANNUAL TN OF 5 MG/L (MILLIONS)
Westfield River Watershed									
Westfield Wastewater Treatment Facility	None	Modify existing three aeration tanks; add IFAS system; increase blower capacity; nitrate recycle pumps; methanol feed facility	$17	Modify existing three aeration tanks; add IFAS system; increase blower capacity; nitrate recycle pumps; methanol feed facility	$16	Modify existing three aeration tanks; add IFAS system; increase blower capacity; nitrate recycle pumps; methanol feed facility	$17	Modify existing three aeration tanks; add IFAS system; increase blower capacity; nitrate recycle pumps; methanol feed facility;	$17
Ten Mile River Watershed									
North Attleborough Wastewater Treatment Facility	Currently achieving some nitrogen removal	Combine each set of four existing tanks into a single reactor (total of two modified tanks), add two new tanks - same size as modified tanks	$19	Combine each set of four existing tanks into a single reactor (total of two modified tanks), add two new tanks - same size as modified tanks	$19	Combine each set of four existing tanks into a single reactor (total of two modified tanks), add three new tanks - same size as modified tanks, add a methanol facility	$26	Combine each set of four existing tanks into a single reactor (total of two modified tanks), add three new tanks - same size as modified tanks, add a methanol facility	$26
Attleboro Wastewater Treatment Facility	Cyclical aeration	Combine each set of five existing tanks into a single reactor (total of two modified tanks), add three new tanks - same size as modified tanks	$38	Combine each set of five existing tanks into a single reactor (total of two modified tanks), add five new tanks - same size as modified tanks, add one new clarifier	$60	Combine each set of five existing tanks into a single reactor (total of two modified tanks), add six new tanks - same size as modified tanks, add one new clarifier	$70	Combine each set of five existing tanks into a single reactor (total of two modified tanks), add eight new tanks - same size as modified tanks, add one new and a methanol facility	$88

Notes:

1. The Upper Blackstone Water Pollution Abatement Facility is the only one included in this study that has undergone a recent wastewater facility plan and a current nitrogen removal upgrade at a flow that is less than the permitted capacity.

This study is not intended to be a substitute for a thorough evaluation that would be required if a facility were to embark on any major improvements. Further, the cost estimates are "order of magnitude" projections for nitrogen removal only based on the best available data and the noted limitations of this study. As such, they should be used for broad planning purposes in determining where more specific evaluations are warranted in the context of meeting the interstate nutrient loading goals. The usefulness of this study lies not in the individual facility evaluations, but more in the estimated total dollars established for upgrades in the individual watersheds or for the entire project.

Some of the facilities in this report are currently achieving or nearly achieving annual average TN levels of 8 mg/L. Despite this, these same facilities have some costs associated with achieving a limit of 8 mg/L. There are several reasons for this. In some cases, the facility would not be able to continue to achieve low levels of TN at their permitted capacity. In other cases where the facility is near its permitted capacity and still achieving TN levels close to 8 mg/L, the evaluations in this report were conducted at maximum loading conditions and minimum temperatures, a condition that these facilities may not yet have experienced. It should be noted that any facility that is designed to achieve an effluent limit of 8 mg/L will have safety factors built into the design which will allow the facility to typically outperform its limit to ensure the limit is consistently achieved.

Further, many of the facilities included in this study may also be facing future limits on other parameters including phosphorus and certain metals resulting in the need for advanced treatment. The focus of this report is strictly on nitrogen removal and thus evaluations and costs estimates only consider the impacts of nitrogen removal on these facilities. In addition, any baseline improvements to existing, aging processes are not included in the estimate.

In moving forward with the results of this report the following should be considered:

1. Truth check on permitted capacity. Due to the exodus of many large water use industries in the watersheds analyzed, the permitted capacity of many of the facilities is well above a twenty year projected flow in the service area. Needs analyses should be performed and modeling re-run based on both current and more realistic design year flows.

2. Facilities should be encouraged to increase sampling of nitrogen components in influent, primary effluent and final effluent to get a better understanding of the constituent profile across the plant. These parameters include TKN, ammonia, nitrate, and nitrite. Characterization of the influent should also be done so that this data can then be used in conjunction with the nitrogen series in the BioWin simulations to reduce the need to use default values in the modeling.

3. Further investigation of conversion of a conventional activated sludge process to an MLE process to achieve seasonal or year-round nitrogen removal at both current and more realistic design year treatment plant flows within existing and/or new tankage.

4. Nitrogen trading with the watersheds.

5. Obtaining a better understanding of the fate and transport of total nitrogen discharged from POTWs in Massachusetts on Long Island Sound and Narragansett Bay.

This study will provide the Commonwealth of Massachusetts with preliminary information necessary to assess technical and financial impacts associated with potential nitrogen reduction alternatives to the POTWs in Massachusetts that contribute nitrogen to Narragansett Bay and Long Island Sound. This report will help communities to begin identifying possible nitrogen reduction alternatives and associated costs. It will also assist the commonwealth in effectively assessing the financial impacts of future total nitrogen limits within each watershed required to meet the water quality goals of Narragansett Bay and Long Island Sound.

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Appendices

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GLOSSARY OF COMMON ACRONYMS

BAF	Biological Aerated Filters
BFP	Belt Filter Press
BOD	Biochemical Oxygen Demand
$CaCO_3$	Calcium Carbonate
CBOD	Carbonaceous BOD
COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflows
DAF	Dissolved Air Flotation
DO	Dissolved Oxygen
ENR	Engineering News Record
EPA	Environmental Protection Agency
EQ	Equalization
F. Coli.	Fecal Coliform
Fna	Fraction of Influent TKN which is Ammonia
FRP	Fiberglass Reinforced Plastic
Ft	Feet
GBT	Gravity Belt Thickener
gpd	Gallons per Day
gpd/ft^2	Gallons per Day per Square Foot
HRT	Hydraulic Retention Time
IFAS	Integrated Fixed Film Activated Sludge
I/I	Infiltration/Inflow
kwh	Kilowatt-Hour
lb	Pound
lbs/d	Pounds per Day
MassDEP	Massachusetts Department of Environmental Protection
MG	Million Gallons
mgd	Million Gallons per Day
mg/L	Milligrams per Liter
mL	Milliliters
MLE	Modified Ludzack-Ettinger
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
mmol/L	Millimoles per Liter
NH3	Ammonia
NH4	Ammonium
NO2	Nitrite
NO3	Nitrate
NPDES	National Pollutant Discharge Elimination System
O&M	Operations and Maintenance
PACl	Polyaluminum Chloride

GLOSSARY OF COMMON ACRONYMS
(continued)

POTW	Publicly Owned Treatment Works
PS	Pump Station
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
RAS	Return Activated Sludge
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition
SRT	Solids Retention Time
SVI	Sludge Volume Index
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
TVSS	Total Volatile Suspended Solids
UBWPAD	Upper Blackstone Water Pollution Abatement District
UV	Ultraviolet
VFD	Variable Frequency Drive
WAS	Waste Activated Sludge
WERF	Water Environment Research Foundation
WPCF	Water Pollution Control Facility
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant