Section 10

Summary

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

SECTION 10 – SUMMARY

10.1 INTRODUCTION

The intent of this report is to develop planning level costs for upgrading all major POTWs in the Connecticut (and its major tributaries – Chicopee, Millers, Deerfield and Westfield Rivers), Blackstone and Ten Mile River watersheds in Massachusetts to achieve various levels of nitrogen removal at the permitted capacity of each facility. As such, it is not the intent to recommend specific upgrades but instead to determine upgrades that could achieve each of the permit conditions and to then assign a cost to those upgrades. Each facility was evaluated using the same basic evaluation techniques. These techniques 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.

Most of the facilities in this study were constructed in the late seventies and early eighties under the Clean Water Act with state and federal funding to achieve secondary treatment standards. Few have aeration volumes suitable for both nitrification and denitrification. The permitted flow of the facility was utilized for the analyses, a flow that for many communities may not be seen in the near or even long-term future. On average, the twenty-one POTWs are operating at about two-thirds of permitted 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 all of these factors results in upgrade costs that may be conservative.

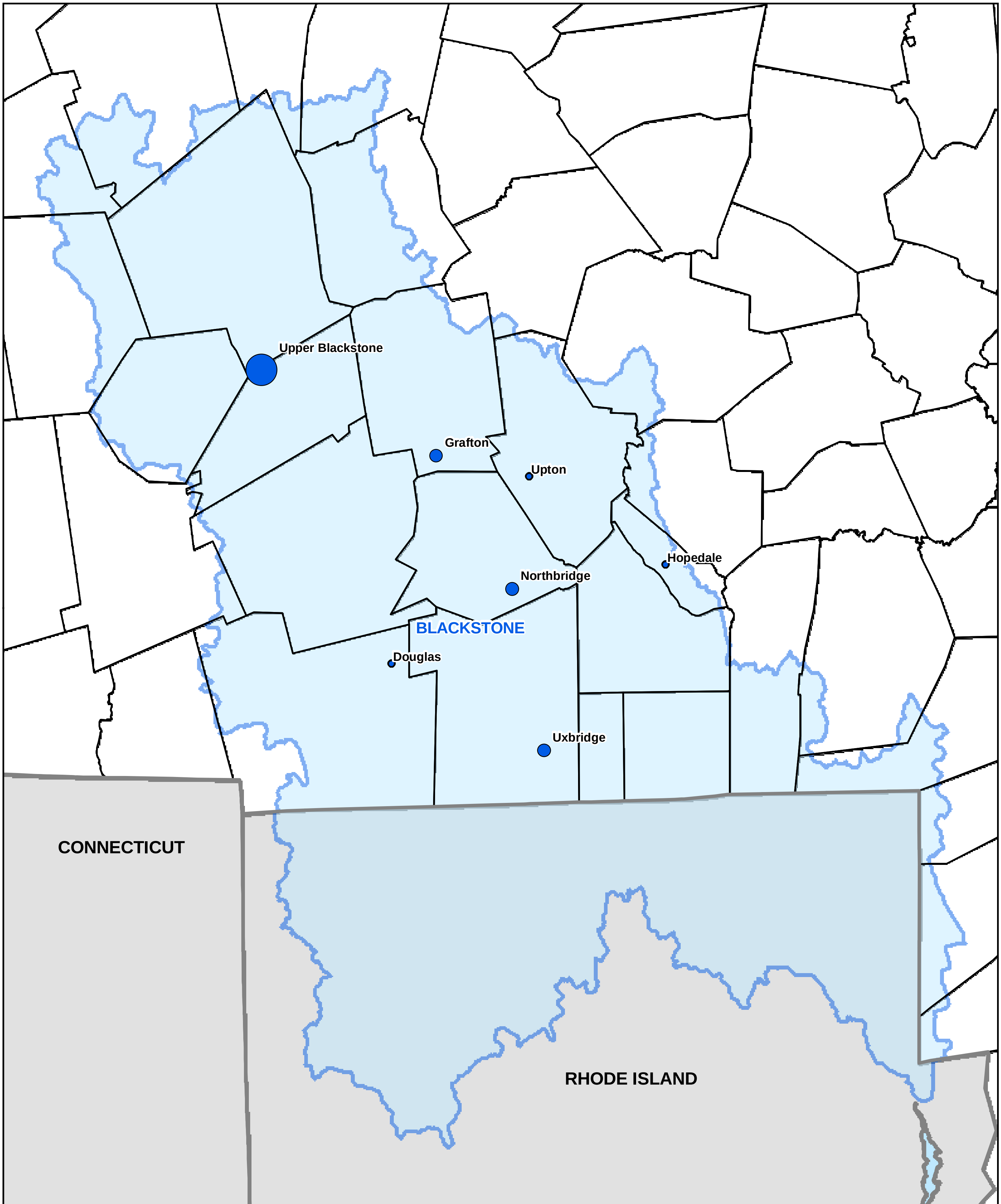
It should be noted again that the costs of the upgrades presented herein includes those associated with nitrogen removal only and does not consider any costs associated with the removal of phosphorus or any other contaminants. In addition, any baseline improvements to existing, aging processes are not included in the estimate.

In addition, some facilities in this report are currently achieving or nearly achieving annual average TN levels of 8 mg/L. Despite this these 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 outperform its limit to ensure the limit is consistently achieved.

10.2 WATERSHED SUMMARIES

The facilities that were included in this study are shown in Table 10.2-1 along with corresponding plant flows and existing permit conditions. Figures 10.2-1 through 10.2-3 show the locations of all of these facilities.

(continued)



N

POTW Permitted Flow Range (mgd)

- 0.1-1.0
- 1.1 - 5.0
- 5.1 - 10.0
- 10.1 - 50.0
- 50.1 - 100.0

Watershed

MA Town Boundaries

0 1 2 4 Miles

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

Permitted Flows for POTWs in Blackstone Watershed
Figure 10-2.1

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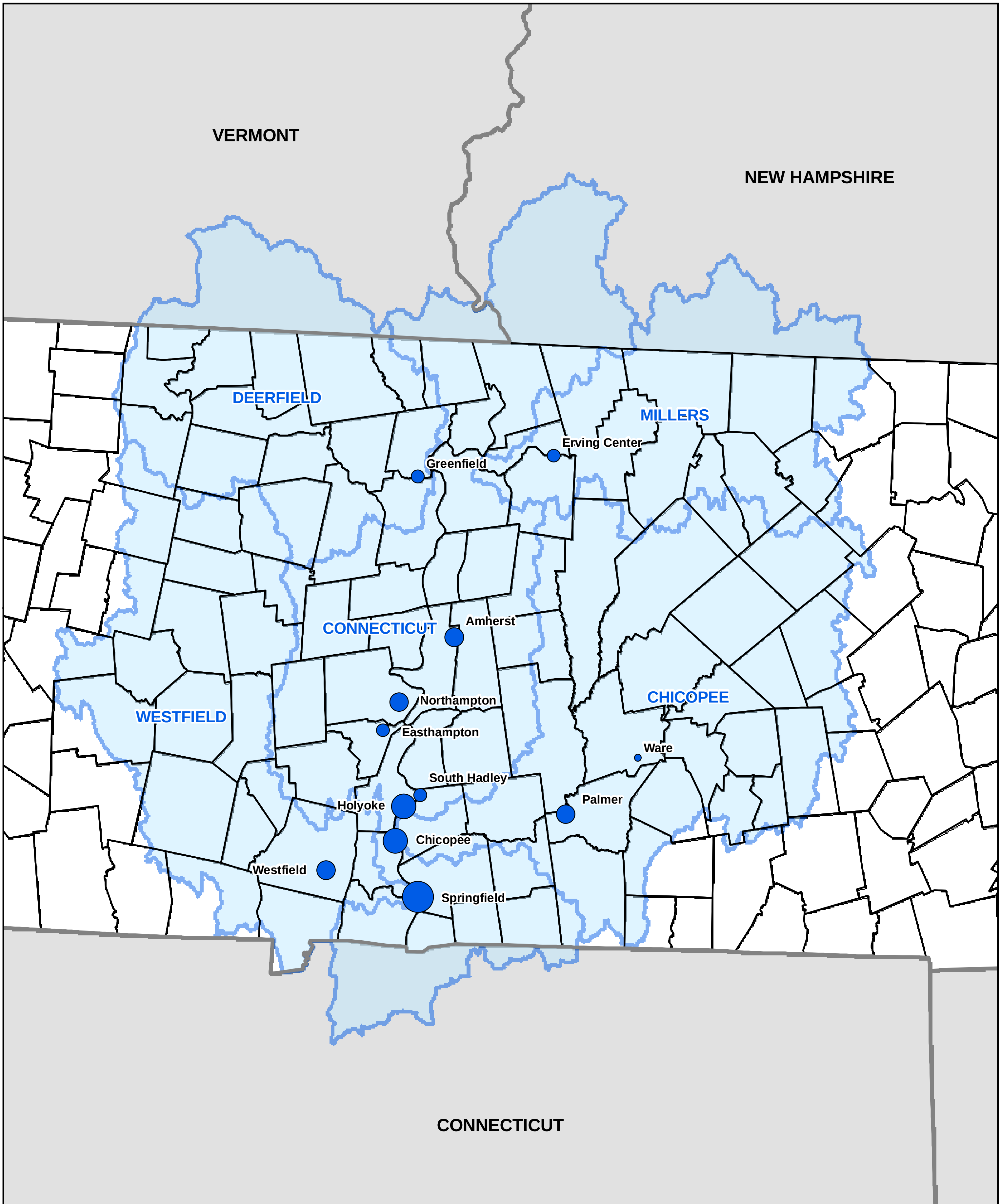

N

POTW Permitted Flow Range (mgd)

0.1-1.0
1.1 - 5.0
5.1 - 10.0
10.1 - 50.0
50.1 - 100.0

Watershed
MA Town Boundaries

0 2.5 5 10 Miles

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Permitted Flows for POTWs in Connecticut Watershed and the Chicopee, Millers, Deerfield and Westfield Subwatersheds
Figure 10-2.2

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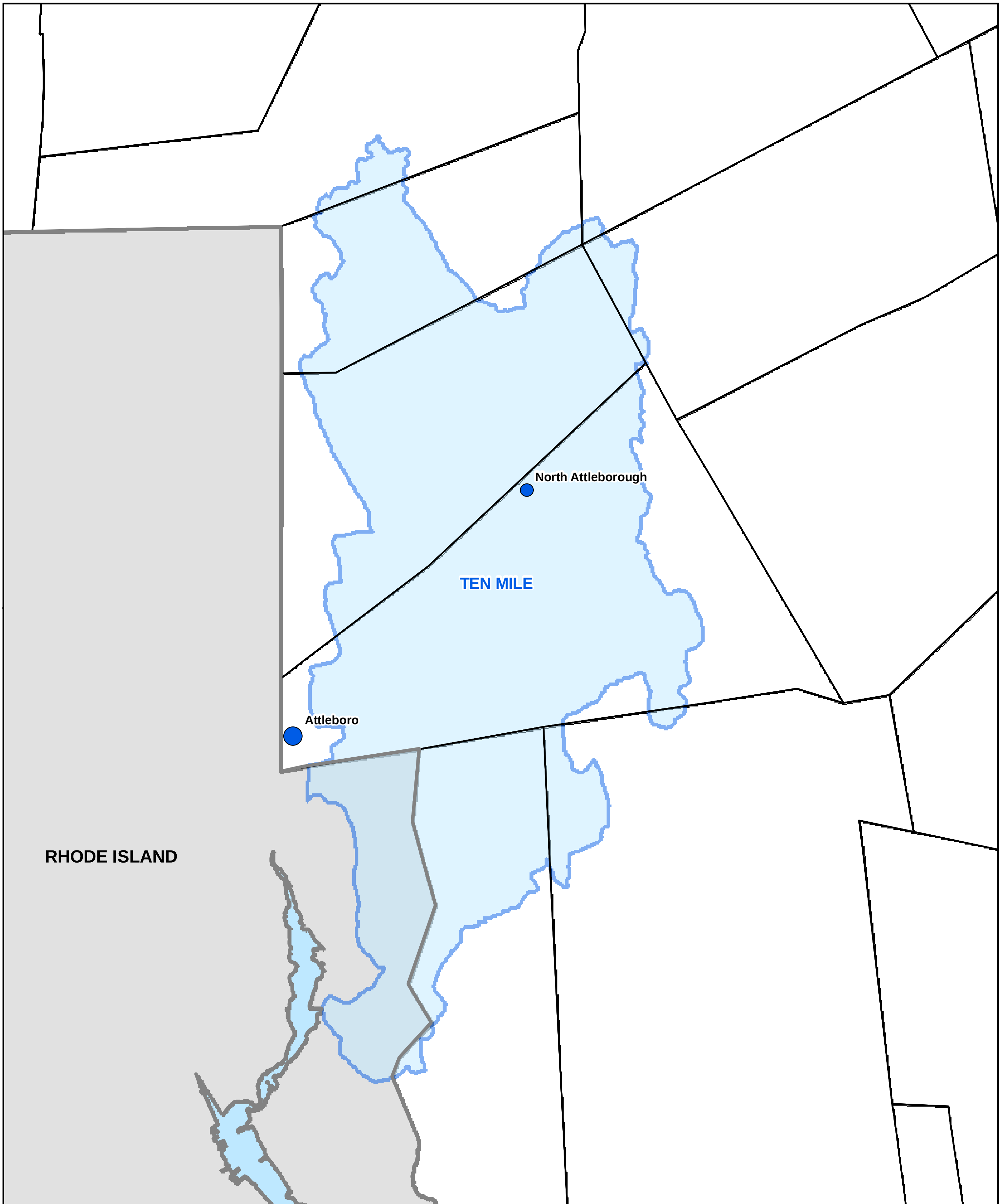

N

POTW Permitted Flow Range (mgd)

- 0.1-1.0
- 1.1 - 5.0
- 5.1 - 10.0
- 10.1 - 50.0
- 50.1 - 100.0

Watershed

MA Town Boundaries

0 0.5 1 2 Miles

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Permitted Flows for POTWs in Ten Mile Watershed
Figure 10-2.3

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Table 10.2-1

FLOWS AND PERMIT SUMMARY

	PERMITTED FLOW (MGD)	EXISTING FLOW (2004-2006) (MGD)	% OF PERMITTED CAPACITY	CURRENT AVERAGE SEASONAL EFFLUENT TN (MG/L)	CURRENT AVERAGE ANNUAL EFFLUENT TN (MG/L)	PERMIT LIMITS [6]			
						SEASONAL NITRIFICATION	WINTER NITRIFICATION	SEASONAL TN LIMIT	WINTER TN LIMIT
Blackstone River Watershed									
Upper Blackstone Water Pollution Abatement District	56.0	38.2	68.2	9.8 [1]	10.7 [1]	yes (2-5)	yes (10-12)	no	no
Grafton	2.4	2.0	84.2	13.5 [1]	14.3 [1]	yes (5)	yes (10-15)	no	no
Northbridge	2.0	1.1	55.0	6.5 [1,4]	7.9 [1,4]	yes (2)	yes (9)	no	no
Douglas	0.6	0.2	35.0	3.4 [4]	5.2 [4]	yes (5)	no	no	no
Upton	0.4	0.2	40.0	19.0	17.5	yes (2.3)	yes (7)	no	no
Uxbridge	2.5	0.9	37.2	15.1	13.7	yes (5)	yes (10-15)	no	no
Hopedale	0.588	0.4	68.0	13.5 [2]	13.5 [2]	yes (2-5)	yes (11)	no	no
Total	**64.5**	**43.0**	**66.7**						
Connecticut River Watershed (and sub watersheds)									
Springfield	67.0	46.4	69.3	5.4 [4]	5.3 [4]	no	no	report	report
Amherst	7.1	4.2	59.4	13.0	14.0	report	report	report	report
Northampton	8.6	4.6	53.5	20.8	20.8	no	no	report	report
Holyoke	17.5	9.1	52.0	11.5	9.4	report	report	report	report
Chicopee	15.5	10.2	65.8	20.0 [3]	20.0 [3]	report	report	report	report
Easthampton	3.8	2.4	63.2	13.5 [3]	13.5 [3]	report	report	report	report
S. Hadley	4.2	2.9	69.0	27.7	26.4	no	no	no	no
Palmer	5.6	2.4	42.9	21.6	25.6	report	report	report	report
Ware	1.0	0.7	67.8	14.1	15.8	yes (1)	report	report	report
Erving Center	2.7	1.8	66.7	N/A	N/A	yes (5-10)	yes (10-15)	report	report
Greenfield[5]	4.7	3.8	81.7	14.6	14.4	no	no	report	report
Westfield	6.1	4.0	65.6	7.4 [4]	9.2	yes (3)	report	no	no
Total	**143.8**	**92.5**	**64.3**						
Ten Mile River Watershed									
Attleboro	8.6	3.8	43.6	24.1	21.7	yes (1.5-4.2)	yes (12.5)	report	report
North Attleborough	4.6	4.2	91.1	7.7 [4]	7.7 [4]	yes (1-3)	yes (7-10)	yes (8)	report
Total	**13.2**	**8.0**	**60.2**						

Notes:

1. Includes estimated TKN of 1.5 mg/L
2. Estimate - Only ammonia is measured
3. Estimate - No nitrogen data collected
4. Meeting 8 mg/L limits at current flow
5. 4.65 mgd was the current design flow used for analysis despite lower permitted flow of 3.2 mgd
6. Seasonal is defined as May-October. Winter is November-April

The results of the evaluations of these facilities are shown in two attached tables. Table 10.2-2 shows the nitrogen removal processes resulting from the plant evaluations. Table 10.2-3 provides a summary of the modifications that would be required to convert to the nitrogen removal processes listed in Table 10.2-2 and the resulting costs for these modifications. The following are discussions regarding each of the three major watersheds.

Two additional tables present nitrogen removal and cost results. Table 10.2-4 shows the current and projected effluent nitrogen loads for the facilities in the study. Table 10.2-5 provides a cost summary of the upgrade required to achieve annual effluent TN levels of 5 and 8 along with the respective cost per pound of TN removed for each facility.

A. **Blackstone River Watershed.** Of the seven wastewater treatment facilities evaluated in the Blackstone River watershed, all but one, Grafton, is operating at less than 70% of the permitted hydraulic capacity of the facility. Three of these facilities, Douglas, Upton and Uxbridge, are operating at or below 40% capacity. So, although this study analyzed costs to achieve the varying effluent TN limits at ***permitted*** capacity, expected design year (20-year) flow estimates should be established as a next step in refining the estimates presented herein. It should be noted that the Upper Blackstone Water Pollution Abatement District represents 87 percent of the total permitted flow discharged to the Blackstone River.

Currently all of the facilities are required to achieve an ammonia limit of 5 mg/L or less from May to October and all but one plant, Douglas, are required to achieve some level of nitrification in the winter months (ranging from 7 to 15 mg/L). Based on the limited plant data, it appears as though only two facilities, Douglas and Northbridge are currently achieving a TN of less than 8 mg/L seasonally and year round. The Upper Blackstone facility, although currently discharging a TN on average of 10.7 annually, will have the capability to achieve a TN of 8 to 10 mg/L annually up to the annual average design year (2020) flow of 45 mgd at the completion of the ongoing treatment facility improvements expected in August 2009.

As shown in Table 10.2-3, the total capital cost for all seven facilities is estimated at $220 million for 8 mg/L and $290 million for 5 mg/L if only seasonal limits must be achieved at the permitted flow capacity. The estimated capital cost to achieve an annual effluent TN concentration of 8 mg/L at all seven facilities is $250 million in today’s dollar. This costs increases to over $300 million in order to achieve an annual effluent TN concentration of 5 mg/L.

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 significant reduction in upgrade costs will likely be seen when more realistic design year flows are used.

(continued)

Table 10.2-2

NITROGEN REMOVAL PROCESS SUMMARY

POTW NAME	PERMITTED CAPACITY	CURRENT PROCESS	PROCESS USED TO ACHIEVE SEASONAL TN OF 8 MG/L	PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	PROCESS USED TO ACHIEVE SEASONAL TN OF 5 MG/L	PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L	DATE OF LAST MAJOR UPGRADE	SPECIAL CONDITIONS
Blackstone River Watershed								
Upper Blackstone Water Pollution Abatement District	56 mgd	Ongoing upgrade to operate in MLE, A/O and A^2/O modes	MLE (or A^2/O with IFAS)	MLE (or A^2/O with IFAS)	MLE (or A^2/O with IFAS) plus a denitrification filter	MLE (or A^2/O with IFAS) plus a denitrification filter	Ongoing	Hazardous waste on site
Grafton Wastewater Treatment Plant	2.4 mgd	None	Nitrification in aeration tanks plus a denitrification filter	Nitrification in aeration tanks plus a denitrification filter	Nitrification in aeration tanks plus a denitrification filter	Nitrification in aeration tanks plus a denitrification filter	1979	
Northbridge Wastewater Treatment Plant	2.0 mgd	Standard SBR process	Cycle air and add one SBR	Cycle air and add one SBR	Cycle air and add one SBR and a denitrification filter	Cycle air and add one SBR and a denitrification filter	2002	
Douglas Wastewater Treatment Facility	0.60 mgd	Standard SBR process	Cycle air and add two SBRs	Cycle air and add two SBRs	Cycle air and add two SBRs	Cycle air and add two SBRs	Ongoing	
Upton Wastewater Treatment Facility	0.40 mgd	None	Bardenpho(1)	Bardenpho with IFAS(1)	Bardenpho with methanol addition	Bardenpho with IFAS and methanol addition	1999	
Uxbridge Wastewater Treatment Facility	2.5 mgd	Currently operates in Ludzack-Ettinger configuration	MLE	Nitrification in aeration tanks plus a denitrification filter	Bardenpho	Nitrification in aeration tanks plus a denitrification filter	1979	
Hopedale Wastewater Treatment Facility	0.588 mgd	None	Bardenpho with methanol addition(1)	Bardenpho with methanol addition(1)	Bardenpho with methanol addition	Bardenpho with methanol addition	1983	
Connecticut River Watershed								
Springfield Wastewater Treatment Facility	67 mgd	Ludzack-Ettinger	MLE	MLE	Bardenpho	Bardenpho	1998	
Amherst Wastewater Treatment Plant	7.1 mgd	None	Nitrification in aeration tanks plus a denitrification filter	Nitrification in aeration tanks plus a denitrification filter	Nitrification in aeration tanks plus a denitrification filter	Nitrification in aeration tanks plus a denitrification filter	1979	
Northampton Wastewater Treatment Facility	8.6 mgd	Ludzack-Ettinger	Bardenpho(1)	Bardenpho with IFAS and methanol addition(1)	Bardenpho with IFAS and methanol addition	Bardenpho with IFAS and methanol addition	1994	Extremely space-limited site
Holyoke Wastewater Treatment Facility	17.5 mgd	None	Biological aerated filter and denitrification filter	Biological aerated filter and denitrification filter	Biological aerated filter and denitrification filter	Biological aerated filter and denitrification filter	1977	Space-limited site
Chicopee Wastewater Treatment Facility	15.5 mgd	High purity oxygen activated sludge	Single-stage nitrification with IFAS plus a denitrification filter	Biological aerated filter and denitrification filter	Single-stage nitrification with IFAS plus a denitrification filter	Biological aerated filter and denitrification filter	1977	Space-limited site
POTW NAME	**PERMITTED CAPACITY**	**OPERATIONAL OR LOW COST RETROFITS**	**PROCESS USED TO ACHIEVE SEASONAL TN OF 8 MG/L**	**PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L**	**PROCESS USED TO ACHIEVE SEASONAL TN OF 5 MG/L**	**PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L**	**DATE OF LAST MAJOR UPGRADE**	**SPECIAL CONDITIONS**
Easthampton Wastewater Treatment Facility	3.8 mgd	Activated sludge w/ mechanical aerators	MLE	MLE	Bardenpho	Bardenpho	1971	
South Hadley Wastewater Treatment Facility	4.2 mgd	Activated sludge w/ mechanical aerators w/ VFDs	Bardenpho with methanol addition(1)	Bardenpho with methanol addition(1)	Bardenpho with methanol addition	Bardenpho with methanol addition	Ongoing	

Table 10.2-2 (continued)

NITROGEN REMOVAL PROCESS SUMMARY

POTW NAME	PERMITTED CAPACITY	OPERATIONAL OR LOW COST RETROFITS	PROCESS USED TO ACHIEVE SEASONAL TN OF 8 MG/L	PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	PROCESS USED TO ACHIEVE SEASONAL TN OF 5 MG/L	PROCESS USED TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L		SPECIAL CONDITIONS
Chicopee River Watershed								
Palmer Water Pollution Control Facility	5.6 mgd	Activated sludge w/ coarse and fine bubble diffusers	Bardenpho[1]	Bardenpho[1]	Bardenpho with methanol addition	Bardenpho with methanol addition	1994	Space-limited site
Ware Wastewater Treatment Facility	1 mgd	Activated sludge w/ mechanical aerators	MLE	MLE	Bardenpho	Bardenpho	1983	TMDHL being established for headworks
Millers River Watershed								
Erving Center Wastewater Treatment Facility	2.7 mgd	None needed - Facility is nutrient deficient					1977	95% of the incoming wastewater is from a papermill
Deerfield River Watershed								
Greenfield Wastewater Treatment Facility	3.2 mgd[2]	Trickling filters	Biological aerated filter and denitrification filter	Biological aerated filter and denitrification filter	Biological aerated filter and denitrification filter	Biological aerated filter and denitrification filter	2000	Located in flood plain; potential Native American burial grounds on site
Westfield River Watershed								
Westfield Wastewater Treatment Facility	6.1 mgd	Ludzack-Ettinger	Bardenpho with IFAS and methanol addition[1]	Bardenpho with IFAS[1]	Bardenpho with IFAS and methanol addition[1]	Bardenpho with IFAS and methanol addition[1]	2005	Extremely space-limited site; located in floodway
Ten Mile River Watershed								
North Attleborough Wastewater Treatment Facility	4.61 mgd	Currently achieves nitrogen removal	MLE	MLE	Bardenpho with methanol addition	Bardenpho with methanol addition	1980	
Attleboro Wastewater Treatment Facility	8.6 mgd	Install timers for cyclical aeration	MLE	MLE	Bardenpho	Bardenpho with methanol addition	2008	

Notes:

1. These facilities had assumed influent TN concentrations and were unable to use the MLE process based on these assumed TN levels
2. Analyses were based on a treatment capacity of 4.65 mgd since the facility is currently operating at 118% of its permitted hydraulic capacity.

(continued)

Table 10.2-3

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 10.2-3 (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 10.2-3 (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 10.2-3 (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.

As shown in Table 10.2-4, many of the facilities are currently discharging less total nitrogen than they would be with an annual average limit of 8 mg/L and at their permitted capacity. Overall the facilities are discharging 80% of the total nitrogen that would be allowed at this permit limit at their respective permitted annual average day capacities.

Table 10.2-5 shows the costs in terms of dollars spent per pound of TN removed. According to this table, the Upper Blackstone WPAD and the Northbridge Wastewater Treatment Plant are the most cost effective facilities to upgrade (on a dollars per pound of nitrogen removed basis), but this is at the permitted capacity of the respective facilities. However, the cost of improvements to achieve an annual limit at the permitted flow capacity at Hopedale is quite high, with unit costs at over $100,000 per pound of TN removed. But again, a check on the appropriateness of the use of permitted capacity, versus a more realistic design year flow should be evaluated and actual influent nitrogen concentrations as opposed to assumed ones should be considered.

Although beyond the scope of this analysis, it is important to note that nineteen impoundments exist on the Blackstone River from the headwaters to the Rhode Island border and the travel time from the headwaters to Narragansett Bay can be up to twenty days in the summer months. Because of this, it is expected that some natural attenuation of total nitrogen occurs in the river system, primarily behind the impoundments. So one pound of total nitrogen discharged from a treatment facility in Massachusetts does not equate to one pound of total nitrogen at the Rhode Island border or in Narragansett Bay.

B. **Connecticut River Watershed.** Of the twelve wastewater treatment facilities evaluated in the Connecticut River watershed and subwatersheds (Chicopee, Millers, Deerfield and Westfield Rivers), all but one, Greenfield, are operating at less than 70 percent of the permitted hydraulic capacity of the facility. Greenfield is operating above its permitted capacity so it was analyzed based on its design average day capacity of 4.65 mgd. One facility, Palmer, is operating at less than 50 percent capacity. So, again, although this study analyzed costs to achieve the varying effluent TN limits at ***permitted*** capacity, expected design year (20-year) flow estimates should be established as a next step in refining the estimates presented herein since nine of the facilities are operating at less than two thirds of the permitted capacity. The largest facility in the Connecticut River watershed, Springfield, represents about 50 percent of the total permitted (and current) flow discharged to the river.

Only three of the facilities (Ware, Erving Center, and Westfield) are required to nitrify seasonally and only Erving Center is required to achieve some level of nitrification in the winter months (15 mg/L). Based on the limited plant data, it appears as though Springfield, Amherst, Northhampton, Holyoke, and Palmer/Monson, achieves some level of seasonal nitrification at current plant flows. Three facilities, Springfield, Erving Center and Westfield are currently achieving a TN of < 8 mg/L seasonally and Springfield and Erving Center achieve this limit year round at current plant flows (note Erving Center facility is nutrient limited as 95 percent of the incoming wastewater is from a paper mill).

(continued)

Table 10.2-4
ANNUAL MASS LOADING SUMMARY

POTW	PERMITTED FLOW (MGD)	EXISTING FLOW (2004-2006) (MGD)	% OF PERMITTED CAPACITY	CURRENT AVERAGE ANNUAL EFFLUENT TN (MG/L)(5)	CURRENT AVERAGE ANNUAL EFFLUENT TN (LB/DAY)	AT PERMITTED CAPACITY	
						ANNUAL EFFLUENT TN LOAD AT 8 MG/L (LB/DAY)	ANNUAL EFFLUENT TN LOAD AT 5 MG/L (LB/DAY)
Blackstone River Watershed							
UBWPAD	56.0	38.2	68.2	10.7	3409	3736	2335
Grafton	2.4	2.0	84.2	14.3	241	160	100
Northbridge (1)	2.0	1.1	55.0	7.9	72	133	83
Douglas (2)	0.6	0.2	35.0	5.2	9	40	25
Upton (2)	0.4	0.2	40.0	17.5	23	27	17
Uxbridge (2)	2.5	0.9	37.2	13.7	106	167	104
Hopedale (3)	0.588	0.4	68.0	13.5	45	39	25
Total	**64.5**	**43.0**	**66.7**	**11.8**	**3906**	**4303**	**2689**
Connecticut River Watershed (and sub watersheds)							
Springfield	67.0	46.4	69.3	5.3	2051	4470	2794
Amherst	7.1	4.2	59.4	14	493	474	296
Northampton	8.6	4.6	53.5	20.8	798	574	359
Holyoke	17.5	9.1	52.0	9.4	713	1168	730
Chicopee (3)	15.5	10.2	65.8	20	1701	1034	646
Easthampton (3)	3.8	2.4	63.2	13.5	270	254	158
S. Hadley	4.2	2.9	69.0	26.4	639	280	175
Palmer (2)	5.6	2.4	42.9	25.6	512	374	234
Ware	1.0	0.7	67.8	15.8	89	67	42
Erving Center	2.7	1.8	66.7	7.1	107	180	113
Greenfield	3.2(6)	3.8	81.7	14.4	456	310	194
Westfield	6.1	4.0	65.6	9.2	307	407	254
Total	**143.8**	**92.5**	**64.3**	**15.1**	**8137**	**9591**	**5994**

Table 10.2-4 (continued)

ANNUAL MASS LOADING SUMMARY

POTW	PERMITTED FLOW (MGD)	EXISTING FLOW (2004-2006) (MGD)	% OF PERMITTED CAPACITY	CURRENT AVERAGE ANNUAL EFFLUENT TN (MG/L)(5)	CURRENT AVERAGE ANNUAL EFFLUENT TN (LB/DAY)	AT PERMITTED CAPACITY: ANNUAL EFFLUENT TN LOAD AT 8 MG/L (LB/DAY)	AT PERMITTED CAPACITY: ANNUAL EFFLUENT TN LOAD AT 5 MG/L (LB/DAY)
Ten Mile River Watershed							
Attleboro (2)	8.6	3.8	43.6	21.7	679	574	359
North Attleborough (4)	4.6	4.2	91.1	7.66	268	308	192
Total	**13.2**	**8.0**	**60.2**	**14.7**	**947**	**881**	**551**

Notes:

1. Annual average effluent TN for Northbridge estimated at 8 mg/L
2. Currently operating at less than 50% permitted capacity
3. Annual average effluent TN for Easthampton, Hopedale and Chicopee estimated at 13.5 mg/L
4. Currently operating at greater than 90% permitted capacity
5. Data is taken from Table 10.2-1. See that table for information regarding data origin.
6. Analyses were based on a treatment capacity of 4.65 mgd since the facility is currently operating at 188% of its permitted hydraulic capacity

(continued)

As shown in Table 10.2-3, if only seasonal limits must be achieved at the permitted flow capacity, total capital cost for all twelve facilities is estimated at $365 million for 8 mg/L and $420 million for 5 mg/L. The estimated capital costs to achieve an annual effluent TN concentration of 8 mg/L annually at all twelve facilities is almost $435 million in today's dollar. This costs increases to over $500 million in order to achieve an annual effluent TN concentration of 5 mg/L

As shown in Table 10.2-4, the sum of nitrogen discharged from all facilities is currently below what it would be at a permit limit of 8 mg/L at the permitted flow of all facilities. This is mostly due to the exceptional performance of the Springfield facility.

Table 10.2-5 shows the costs in terms of dollars spent per pound of TN removed. According to this analysis, it appears that the Westfield facility could achieve an annual TN limit of 8 mg/L at the design capacity for the lowest unit price of about $14,000/lb of nitrogen removed. On the other hand, the two most expensive facilities to upgrade on dollars per pound of nitrogen removed basis are the Holyoke and Chicopee plants. It should also be noted that of the twelve facilities, Northhampton, Holyoke and Westfield are extremely space-limited sites and another, Greenfield, has significant site limitations with the presence of a Native American burial ground and a floodplain. But again, a check on the appropriateness of the use of permitted capacity, versus a more realistic design year flow should be evaluated and actual influent nitrogen concentrations as opposed to assumed ones should be considered.

C. **Ten Mile River Watershed.** The two facilities discharging to the Ten Mile River have different characteristics. The Attleboro facility is operating at about 44 percent of the total permitted capacity, while the North Attleborough facility is operating at over 90 percent of its permitted capacity. Both are required to nitrify seasonally and the Attleboro facility is required to nitrify year round. In recently issued draft permits, both plants received an 8 mg/L TN limit seasonally, yet it is the North Attleboro facility which, based on limited plant data, has been able to achieve an 8 mg/L TN limit year round.

As shown in Table 10.2-3, if only seasonal limits must be achieved at the permitted flow capacity, total capital cost for both facilities is estimated at $60 million for 8 mg/L and $100 million for 5 mg/L. The estimated capital cost to achieve an annual effluent TN concentration of 8 mg/L annually at both facilities is almost $80 million in today's dollar. The cost increases to $114 million in order to achieve an annual effluent TN concentration of 5 mg/L. Note that both towns are currently exploring the most cost-effective way to achieve the draft permit limit of 8 mg/L at current flows.

As shown in Table 10.2-5, the cost to remove one pound of nitrogen at the annual average limit of 8 mg/L for these facilities is between $47,000 and 57,000/ lb of nitrogen removed.

(continued)

Table 10.2-5

COST SUMMARY

POTW	PERMITTED FLOW (MGD)	EXISTING FLOW (2004-2006) (MGD)	INFLUENT TN BASED ON TN/BOD RATIO (MG/L)[1]	ESTIMATED AVERAGE EFFLUENT TN AT PERMITTED CAPACITY W/O UPGRADING FACILITY [2] (MG/L)	COST TO ACHIEVE ANNUAL EFFLUENT TN LOAD AT 8 MG/L (1,000 $)	COST TO ACHIEVE ANNUAL EFFLUENT TN LOAD AT 8 MG/L $/LB TN REMOVED [3]	COST TO ACHIEVE ANNUAL EFFLUENT TN LOAD AT 5 MG/L (1,000 $)	COST TO ACHIEVE ANNUAL EFFLUENT TN LOAD AT 5 MG/L $/LB TN REMOVED [4]
Blackstone River Watershed								
UBWPAD at 56 mgd	56.0	38.2	23.64	24	$130,000	$18,000	$180,000	$21,000
UBWPAD at 45 mgd	*45.0*	*38.2*	23.64	8	***to be completed in 2009***		*$90,000*	$80,000
Grafton	2.4	2.0	41.59	35	$41,000	$77,000	$41,000	$69,000
Northbridge	2.0	1.1	37.56	31	$6,000	$16,000	$16,000	$37,000
Douglas	0.6	0.2	44.33	37	$4,400	$31,000	$4,400	$28,000
Upton	0.4	0.2	50.90	51	$7,300	$51,000	$7,400	$48,000
Uxbridge	2.5	0.9	44.53	37	$44,000	$73,000	$44,000	$66,000
Hopedale	0.588	0.4	57.75	48	$25,000	$128,000	$25,000	$119,000
Subtotal or Average[5] [6]	**64.5**	**43.0**			**$257,700**	**$56,000**	**$317,800**	**$55,000**
Connecticut River Watershed (and sub watersheds)								
Springfield	67.0	46.4	35.28	9	$23,000	$46,000	$65,000	$30,000
Amherst	7.1	4.2	41.64	35	$61,000	$39,000	$61,000	$35,000
Northampton	8.6	4.6	47.40	34	$35,000	$19,000	$35,000	$17,000
Holyoke	17.5	9.1	19.08	16	$99,000	$87,000	$99,000	$63,000
Chicopee	15.5	10.2	19.62	16	$87,000	$81,000	$87,000	$60,000
Easthampton	3.8	2.4	31.17	26	$11,000	$19,000	$13,000	$20,000
S. Hadley	4.2	2.9	41.58	35	$19,000	$20,000	$22,000	$21,000
Palmer	5.6	2.4	29.26	24	$23,000	$30,000	$23,000	$26,000
Ware	1.0	0.7	43.05	36	$6,600	$29,000	$6,600	$26,000
Erving Center	2.7	1.8	N/A	N/A	$0	N/A	$0	N/A
Greenfield	3.2[7]	3.8	24.84	21	$49,000	$100,000	$49,000	$81,000
Westfield	6.1	4.0	38.22	30	$16,000	$14,000	$28,000	$22,000
Subtotal or Average[5]	**139.1**	**92.5**			**$429,600**	**$44,000**	**$488,600**	**$36,000**
Ten Mile River Watershed								
Attleboro	8.6	3.8	27.47	23	$60,000	$57,000	$88,000	$69,000
North Attleborough	4.6	4.2	22.34	19	$19,000	$47,000	$26,000	$50,000
Subtotal or Average[5]	**13.2**	**8.0**			**$79,000**	**$52,000**	**$114,000**	**$60,000**
Overall Total or Average[5]	**216.8**	**143.5**			**$766,300**	**$49,000**	**$920,400**	**$45,000**

Notes:
1. The influent TN concentration is calculated by multiplying the 3-year average influent BOD concentration by the influent TKN/BOD ratios established for each facility in the report.
2. This is the estimated effluent TN at permitted flow with the existing facilities. For most facilities, this value differs from the average 3-year influent TN concentration by the particulate TKN portion of the influent TN. It is assumed that particulate TKN is 17% of the influent TN concentration and that all of it is removed with the existing processes. For other facilities, BioWin models were run to estimate the effluent TN concentration.
3. Based on permitted flow and the net TN yielded when 8 mg/L is subtracted from the estimated average effluent TN established for each facility.
4. Based on permitted flow and the net TN yielded when 5 mg/L is subtracted from the estimated average effluent TN established for each facility.
5. $/lb TN Removed is an average.
6. Does not include Upper Blackstone at 45 mgd
7. Analyses were based on a treatment capacity of 4.65 mgd since the facility is currently operating at 118% of its permitted hydraulic capacity.

10.3 NEXT STEPS

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. It should be reiterated that this analysis is conservative in that:

1. Costs were based on permitted flow capacity when overall; the facilities on average are currently operating at only about two thirds of the hydraulic capacity.

2. Annual average permit conditions were modeled as monthly limits.

3. Standardized (non-site specific) approach was utilized to analyze each facility.

It also should be reiterated that the simulation results are based on non-calibrated models since no characterization (such as COD fractions, BOD to COD ratio, and ammonia fraction of TKN) of plant influent was completed. In addition, limited nitrogen data was available, so most simulations are based on assumed data.

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.