Section 9

Ten Mile River Watershed

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

SECTION 9 – TEN MILE RIVER WATERSHED

9.1 INTRODUCTION

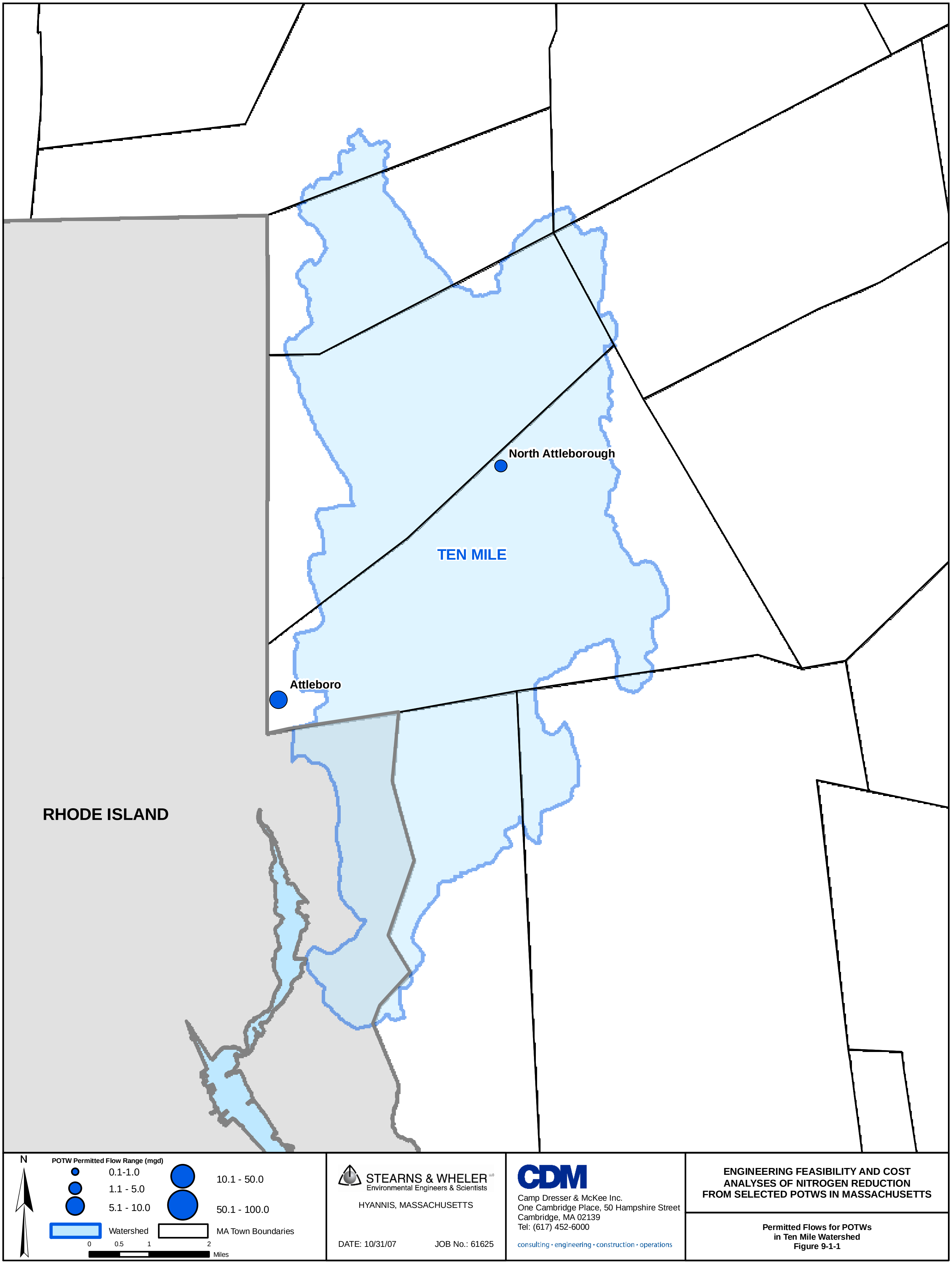
The Ten Mile River begins in the towns of Plainville and Foxboro at the confluence of the Seven Mile River and the Bungay River. It flows southward through Rhode Island to Narragansett Bay. This study includes two publicly owned treatment works (POTWs) that discharge directly to the Ten Mile River. Figure 9.1-1 shows the Ten Mile River watershed and the table below lists the two facilities and their respective sizes. The impact of nitrogen removal at each of these facilities is presented in this section.

Image from www.mass.gov

Table 9.1-1
TEN MILE RIVER POTWs

NAME OF FACILITY	RATED CAPACITY
Attleboro	8.6 mgd
North Attleborough	4.6 mgd

(continued)



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

Permitted Flows for POTWs
in Ten Mile Watershed
Figure 9-1-1

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9.2 NORTH ATTLEBOROUGH

A. **Introduction.** The North Attleborough Wastewater Treatment Facility (WWTF) is located on Cedar Road in North Attleborough, Massachusetts. It has a permitted annual average capacity of 4.61 mgd and serves the towns of North Attleborough and Plainville.

The first treatment facility was constructed in 1909 and upgraded in 1948 and 1959. The current secondary treatment facility was completed in 1980.

B. **Existing Facilities.**

1. **Description of Existing Facilities.** Flow enters the WWTF headworks facility via an inverted siphon and a single force main after which it passes through a 1-1/2”mechanical bar rack and aerated grit chamber and a screenings grinder. After the screenings grinder, the facility has a flash mixing and flocculation tank. Alum is added to the flash mixing tank in the summer. Caustic soda is added for supplementing alkalinity.

Aerial photo from google.com

After primary clarification, the flow is pumped to the first stage aeration tanks and clarifiers. It is then pumped to the second stage aeration tanks and clarifiers. The first stage may be bypassed.

The first stage system consists of four 30 ft by 30 ft aerations tanks with a 12 ft sidewater depth followed by two 80 foot diameter clarifiers with a 12 ft sidewater depth. All aeration tanks have mechanical aerators.

The second stage system consists of eight 40 ft by 40 ft aeration tanks with a 12 ft sidewater depth followed by three 80 ft diameter clarifiers with a 12 ft sidewater depth. All aeration tanks have mechanical aerators.

Secondary effluent flows through rapid sand filters, followed by chlorine disinfection and final post aeration before being discharged to the Ten Mile River. Sludge is thickened in a rotary drum thickener prior to being hauled offsite. A process flow schematic is shown in Figure 9.2-1.

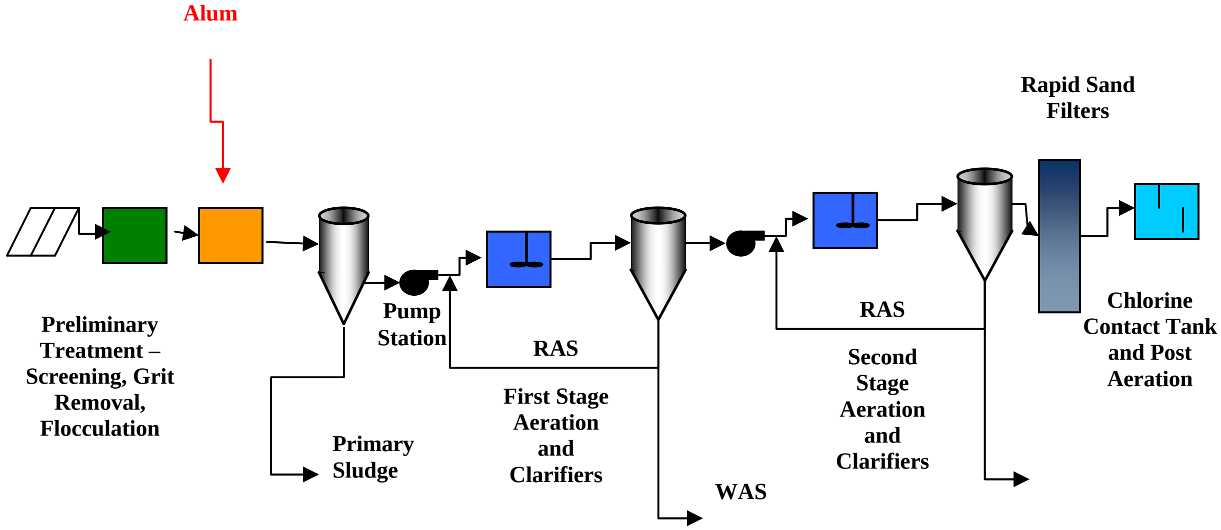


FIGURE 9.2-1:
PROCESS FLOW SCHEMATIC – EXISTING FACILITY

All plant recycle flows are returned to an onsite pumping station and then combined with plant influent. Septage is introduced to the wastewater stream prior to preliminary treatment. The influent sampler at this facility is located upstream of the grit removal facilities and thus all plant flows including internal recycle flows are part of the influent loads. The last composite sampler is located after disinfection.

The first stage is not used. In the second stage, one of the aeration tanks is used to store RAS while a second is used as an anaerobic zone for biological phosphorus removal. The plant does not try to suppress nitrification at any time of the year. Full nitrification has been maintained since early 2004. The aerators are all on VFDs and can be decreased in speed to achieve some denitrification.

There are eleven employees at the wastewater treatment facility and three for the collection system. In addition, there is one employee who handles the pretreatment programs.

Design flows and loads for the most recent upgrade are shown below in Table 9.2-1.

Table 9.2-1

DESIGN FLOWS AND LOADS

PARAMETER	VALUE
Average Monthly (design flow)	4.6 mgd
BOD	183 mg/L
TSS	228 mg/L
TN	18.5 mg/L

2. **Summary of Plant Data.** Data from January 2004 through December 2006 was provided by the Town for this study. Seasonal and annual average maximum month data are summarized in Table 9.2-.2

(continued)

Table 9.2-2

NORTH ATTLEBOROUGH WWTF
North Attleborough, Massachusetts
Monthly Averages 2004-2006

GENERAL		INFLUENT							EFFLUENT						
DATE		INF	pH	BOD	TSS	TN	NH3	Temp	DO	pH	BOD	TSS	F. COLI	NH3	TN
Month	Year	MGD		mg/L	mg/L	mg/L	mg/L	Deg C	mg/L		mg/L	mg/L	# / 100ml	mg/L	mg/L
January	2004	4.406516	7.06	101	118	17.6	14.4	11.2	7.0	6.92	10.75	5.06	8	5.75	9.6
February	2004	3.514828	7.04	125	154	29.2	15.7	10.3	7.1	6.94	9.09	2.87	10	7.69	15.7
March	2004	3.467968	7.13	111	145	25.5	14.5	10.7	7.1	7.02	8.23	2.37	0	8.40	18.50
April	2004	6.5454	6.70	57	102	14.1	7.4	11.1	7.7	6.74	15.59	19	410.0	1.03	6.30
May	2004	4.187645	6.88	83	136	14.8	10.7	13.9	7.8	6.83	9.08	10.96	2.4	0.35	5.90
June	2004	3.1083	7.06	128	187	21.0	13.0	16.2	7.6	6.75	4.90	5.77	0.9	0.20	9.40
July	2004	2.797419	7.10	120	189	21.3	14.7	18.3	7.4	6.89	3.25	3.08	0.4	0.09	9.60
August	2004	3.045129	7.04	115	167	24.5	13.7	19.0	7.1	6.94	3.80	3.03	1.3	0.02	10.10
September	2004	3.091067	7.10	103	162	24.1	14.3	19.0	7.3	6.94	3.55	3.28	6.4	0.01	9.90
October	2004	3.122548	7.19	131	169	19.6	16.1	17.9	7.7	6.90	2.49	1.74	1.2	0.03	8.40
November	2004	3.109233	7.16	144	189	22.6	14.0	15.7	7.9	6.82	2.94	2.25	2.2	0.25	7.50
December	2004	4.691871	6.88	101	138	22.0	10.5	13.6	8.5	6.70	4.25	2.85	13.8	0.41	2.10
January	2005	5.539323	6.75	87	121	16.6	9.1	11.3	9.0	6.65	3.47	2.76	18.9	0.22	3.30
February	2005	4.864107	6.81	94	121	26.2	10.6	10.7	9.1	6.64	4.65	4.11	115.8	0.23	7.50
March	2005	5.224968	6.82	78	116	15.2	10.3	10.1	8.6	6.67	10.55	11.51	19.7	0.50	6.90
April	2005	5.4946	6.71	87	94	8.2	8.8	11.4	8.0	6.65	5.69	4.43	6.8	0.25	5.70
May	2005	4.359871	6.83	100	135	18.9	8.3	13.3	7.9	6.64	4.08	2.59	10.4	0.07	6.10
June	2005	3.229467	6.96	118	156	21.6	11.7	15.8	7.3	6.75	3.47	1.84	1.1	0.21	7.80
July	2005	2.724516	7.06	137	172	20.3	14.6	17.8	6.9	6.88	3.88	2.18	0.8	0.12	9.8
August	2005	2.590419	7.13	167	199	29.5	16.3	19.1	7.1	6.95	2.19	0.85	2.5	0.01	6.1
September	2005	2.889	7.09	152	206	24.6	16.3	19.8	7.4	6.85	1.97	1.23	1.4	0.03	6.9
October	2005	5.922	6.94	103	130	36.2	10.5	17.8	8.2	6.87	4.30	5.61	169.3	0.16	6.8
November	2005	5.138	6.81	112	135	10.1	9.8	15.7	8.5	6.87	2.04	0.87	1.5	0.05	7.8
December	2005	5.100	6.86	103	136	17.8	11.2	12.7	8.3	6.84	5.57	3.66	6.5	0.22	5.3
January	2006	6.071	6.69	82	108	13.8	8.9	11.8	7.5	6.72	4.66	2.66	76.2	0.31	6.90
February	2006	5.234	6.82	109	122	16.0	9.5	11.0	7.9	6.75	6.48	3.19	10.3	0.32	4.70
March	2006	3.163	7.05	172	199	25.9	16.6	11.0	7.9	6.75	12.10	5.98	23.5	2.17	9.20
April	2006	2.935	7.11	199	234	47.9	17.1	12.4	7.9	6.85	8.90	6.63	37.6	0.99	4.30
May	2006	4.938	6.92	119	142	31.6	11.1	13.5	8.1	6.84	3.53	2.70	0.9	0.25	12.40
June	2006	6.894	6.71	68	95	13.9	7.5	15.1	7.5	6.81	10.14	17.09	33.7	0.33	4.10
July	2006	3.932	6.98	116	170	20.8	12.8	17.7	7.5	6.82	2.36	0.56	0.2	0.22	5.1
August	2006	3.018	7.12	154	189	37.1	15.5	19.5	6.9	6.87	1.27	0.04	2.1	0.01	9.2
September	2006	3.126	7.14	169	206	29.6	16.0	19.0	7.6	6.79	1.42	0.91	6.0	0.14	10.0
October	2006	3.548	7.11	143	172	20.0	16.0	18.0	8.2	6.80	0.96	0.33	8.8	0.05	1.4
November	2006	6.070	6.82	99	119	26.0	10.1	15.7	7.8	6.81	1.18	0.43	0.5	0.13	8.9
December	2006	4.019	6.96	151	142	20.7	13.6	14.1	8.0	6.83	1.59	0.13	0.5	1.39	6.6
Min. Month		2.59	6.69	57	94	8.2	7.4	10.09	6.91	6.64	0.96	0.04	0.00	0.01	1.40
Seasonal Average		**3.70**	**7.02**	**124**	**166**	**23.9**	**13.3**	**17.25**	**7.53**	**6.84**	**3.70**	**3.54**	**13.88**	**0.13**	**7.72**
Average		**4.20**	**6.96**	**118**	**152**	**22.4**	**12.5**	**14.75**	**7.76**	**6.81**	**5.12**	**4.03**	**28.09**	**0.91**	**7.66**
Max. Month		6.89	7.19	199	234	47.9	17.1	19.76	9.09	7.02	15.59	19.49	410.00	8.40	18.50

With a current average annual flow of 4.2 mgd and a permitted capacity of 4.61 mgd, this facility is operating at over 90% of its permitted capacity.

Based on the average BOD concentration of 118 mg/L and TN concentration of 22 mg/L, this wastewater would be considered weak. The TN/BOD ratio is approximately 0.19 which is fairly typical (a typical TN/BOD ratio is 0.18).

3. **Permit Requirements and Current Performance.** Monthly permit limits from the proposed permit that are relevant to this study are shown below in Table 9.2-3.

Table 9.2-3

SELECT MONTHLY PERMIT LIMITS

PARAMETER	LIMIT
BOD_5	
May – October	5 mg/L
November – April	15 mg/L
TSS	
May – October	7 mg/L
November – April	15 mg/L
Ammonia-Nitrogen	
May	3 mg/L
June – October	1 mg/L
November	7 mg/L
December – April	10 mg/L
Total Nitrogen	
May – October	8 mg/L
November – April	Report

4. **Nitrogen Removal Performance.** As can be seen in Table 9.2-2, the facility has reduced effluent ammonia to less than 1 mg/L for many of the months in the past three years. Although the average effluent TN has been less than 8 mg/L for the study period, some monthly TN levels between May and October have exceeded 10 mg/L.

C. **Nitrogen Removal Alternatives.** The existing maximum month loads over the three-year data collection period were used to determine the BioWin input data. The influent data which correspond to maximum-month loads is shown in Table 9.2-4 below for each permitting scenario. The minimum temperature for the permit condition is also shown. It should be noted that although the flow, BOD and TSS values in the table below were taken directly from the plant data in Table 9.2-2, the TN data was taken indirectly. Influent TN data is sampled only once per month and because the single sample may not be representative of the entire month, all data for the three years was used to develop a TN/BOD ratio that was applied to determine the TN concentration in the max month.

Table 9.2-4

EXISTING INFLUENT PARAMETERS

PERMIT CONDITION	PARAMETER	VALUE
Annual Average	Flow, mgd	5.92
	BOD, mg/L	103
	TSS, mg/L	133
	TN, mg/L	19.5
	Temperature, F	50
Seasonal	Flow, mgd	5.92
	BOD, mg/L	103
	TSS, mg/L	133
	TN, mg/L	19.5
	Temperature, F	56

The existing plant data was then projected to the permitted capacity of the facility to develop model input parameters for the average annual and seasonal model runs. This projected data is shown in Table 9.2-5 below.

Table 9.2-5

MODEL INPUT PARAMETERS AT PERMITTED CAPACITY

PERMIT CONDITION	PARAMETER	VALUE
Annual Average	Flow, mgd	6.50
	BOD, mg/L	103
	TSS, mg/L	133
	TN, mg/L	19.5
	Temperature, F	50
Seasonal	Flow, mgd	6.50
	BOD, mg/L	103
	TSS, mg/L	133
	TN, mg/L	19.5
	Temperature, F	56

The model input data was used to run uncalibrated simulations to determine planning level, order-of-magnitude costs for implementing different levels of nitrogen reduction at the facility.

A discussion of operational changes or minor modifications that can be made to the facility to improve current nitrogen reduction performance as well as a presentation of the simulation results are presented in the following sections.

The existing second stage consists of 8 aeration tanks. For all of the alternatives outlined below, it is assumed that the eight existing tanks would be converted into two plug flow reactors, each consisting of four of the existing tanks.

It should also be noted that there is a possibility that the first stage tanks could be used to fulfill some of the needs for future capacity, but because the first and second stages are at different elevations, use of the first stage system would require an upgrade to the pump station that conveys flow to the second stage such that it could handle the significant increase in flow from the nitrate recycle. However, this additional, constant pumping may not be desirable.

1. **Minor Modifications/Retrofits.** The plant currently is achieving some nitrogen removal.

2. **Modifications Required to Meet TN of 8 mg/L.** The modifications to the facility that are required to meet an effluent TN of 8 mg/L on a seasonal and annual average basis are as follows.

   a. **Seasonal.** At the influent TN levels for this facility, an MLE process will accomplish a seasonal effluent TN level of 8 mg/L. The BioWin model for this process is shown below in Figure 9.2-2.

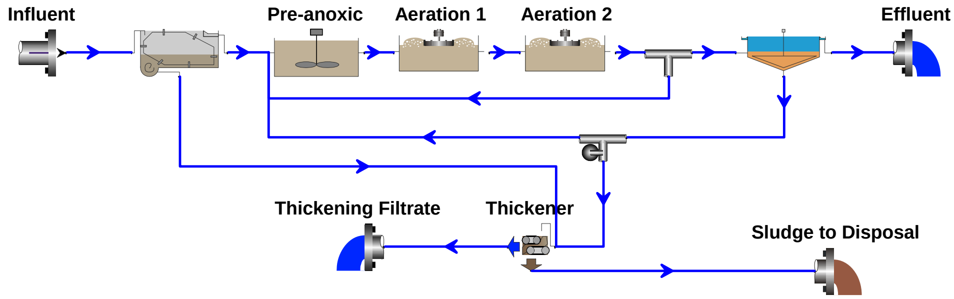


FIGURE 9.2-2 - NITROGEN REMOVAL PROCESS - SEASONAL LIMIT OF 8 mg/L

This process would require slightly more than 50% additional volume over the current second stage aeration tank capacity. Thus, in addition to the two converted plug flow reactors (consisting of the eight existing tanks), two additional reactors would be required. The new reactors would be the same size as the two existing converted plug flow reactors.

Although the existing secondary clarifiers appear to be adequately sized to handle the future flow and loading conditions, it should be noted that the clarifiers at this facility are twelve feet deep. According to TR-16, clarifiers at nitrogen removal facilities should be a minimum of 13 feet deep. Because the clarifiers meet the minimum requirements set forth in Section 2, they will have to be further evaluated to consider if they will require replacement or derating because of the shallow depth

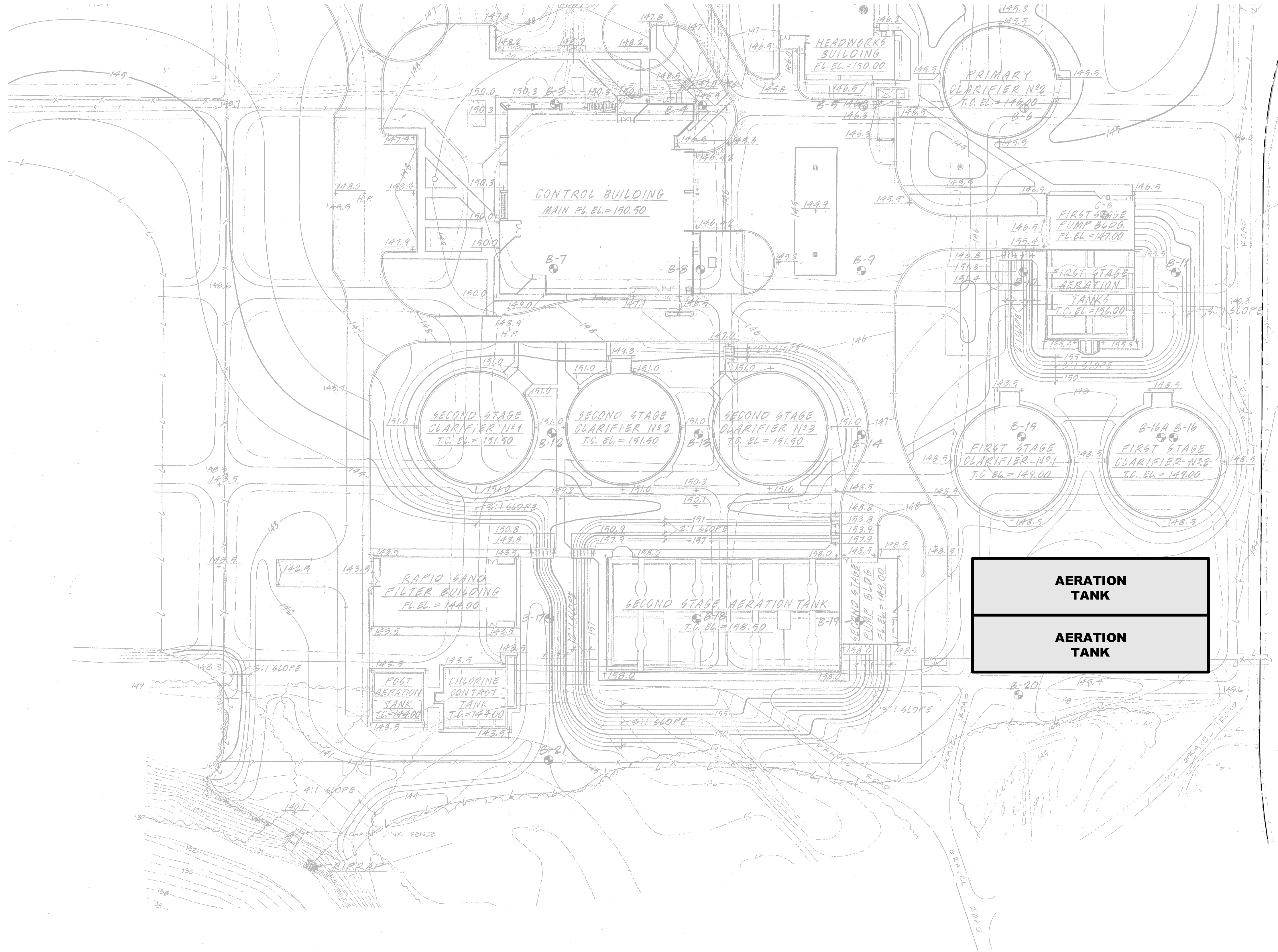
As shown in the site plan in Figure 9.2-3, the site appears to have enough space for the additional aeration tanks. Specific information regarding the results of this analysis is shown in Table 9.2-6 below.

Table 9.2-6

RESULTS FOR SEASONAL LIMIT OF 8 mg/L TN

PARAMETER	VALUE
Aerobic SRT	8 days
Total SRT	14 days
First Anoxic Fraction	42%
Total Anoxic Fraction	42%
Reaeration HRT	n/a
RAS Rate	100%
Total Volume	2.3 MG
Nitrate Recycle Rate	300%
Max MLSS at loading rate	3300 mg/L
Effluent TN	8 mg/L
Methanol Addition	No
Fixed Film Required?	No
Clarifiers?	Reuse existing second stage clarifiers
Effluent Filtration Required?	Existing, no additional

The proposed location for the new aeration tanks will either be at or across the fence line. This is not the property line and thus it is assumed that new tanks can be constructed here.



NOTES:
1. BACKGROUND IS FROM DRAWING ST–4 FROM CONTRACT DOCUMENTS ENTITLED ADVANCED WASTEWATER TREATMENT FACILITIES, NORTH ATTLEBOROUGH, MA, SITE GRADING PLAN PREPARED BY WHITMAN & HOWARD, INC. AND DATED JUNE 1977.

2. AUXILIARY FACILITIES ASSOCIATED WITH NITROGEN REMOVAL PROCESSES ARE NOT SHOWN.

40 0 40 80
1"=40'–0"

SITE PLAN
SCALE: 1"=40'–0"

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

NORTH ATTLEBORO, MASSACHUSETTS
FIGURE 9.2–3

Other plant modifications may be needed including upgrades to sludge handling to accommodate the higher sludge production. However, all facilities outside of the activated sludge process are outside of the scope of this study.

b. **Annual Average.** At the influent TN levels for this facility, an MLE process will accomplish an annual average effluent TN level of 8 mg/L. The BioWin model for this process is shown in Figure 9.2-4 below.

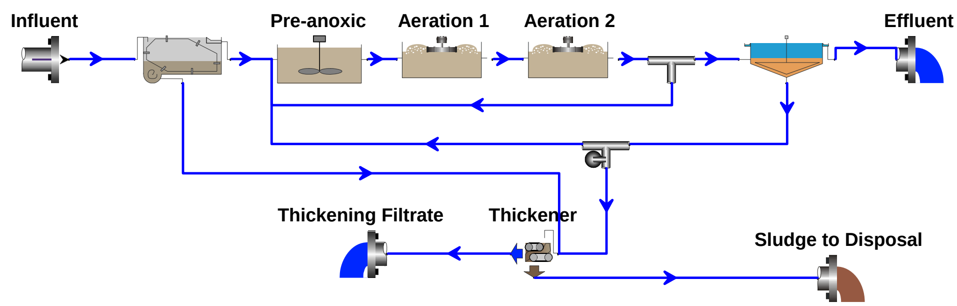


FIGURE 9.2-4: NITROGEN REMOVAL PROCESSES – ANNUAL AVERAGE LIMIT OF 8 mg/L

This process would require slightly more than 75% more volume than is currently available in the second stage aeration tanks. In addition to the two converted plug flow reactors (consisting of the eight existing aeration tanks), two additional reactors would be required. The new reactors would be the same size as the two existing converted plug flow reactors.

Although the existing clarifiers appear to be adequately sized to handle the future flow and loading conditions, it should be noted that the clarifiers at this facility are twelve feet deep. According to TR-16, clarifiers at nitrogen removal facilities should be a minimum of 13 feet deep. Because the clarifiers meet the minimum requirements set forth in Section 2, they will have to be further evaluated to consider if they will require replacement or derating because of the shallow depth.

As shown in the site plan in Figure 9.2-3, the site appears to have enough space for the additional aeration tanks. Specific information regarding the results of this analysis is shown in Table 9.2-7 below.

Table 9.2-7

RESULTS FOR ANNUAL AVERAGE LIMIT OF 8 mg/L TN

PARAMETER	VALUE
Aerobic SRT	8.8 days
Total SRT	14 days
First Anoxic Fraction	38%
Total Anoxic Fraction	38%
Reaeration HRT	n/a
RAS Rate	100%
Total Volume	2.3 MG
Nitrate Recycle Rate	300%
Max MLSS at loading rate	3300 mg/L
Effluent TN	8 mg/L
Methanol Addition	No
Fixed Film Required?	No
Clarifiers?	Reuse existing second stage clarifiers
Effluent Filtration Required?	Existing, no additional

The proposed location for the new aeration tanks will either be at or across the fence line. This is not the property line and thus it is assumed that new tanks can be constructed here.

Other plant modifications may be needed including upgrades to sludge handling to accommodate the higher sludge production. However, all facilities outside of the activated sludge process are outside of the scope of this study.

3. **Modifications Required to Meet a TN of 5 mg/L.** The modifications to the facility that are required to meet an effluent TN of 5 mg/L on a seasonal and annual average basis are as follows.

a. **Seasonal.** At the influent TN levels for this facility, a Bardenpho configuration with methanol addition will accomplish a seasonal effluent TN level of 5 mg/L. The BioWin model for this process is shown below in Figure 9.2-5 below.

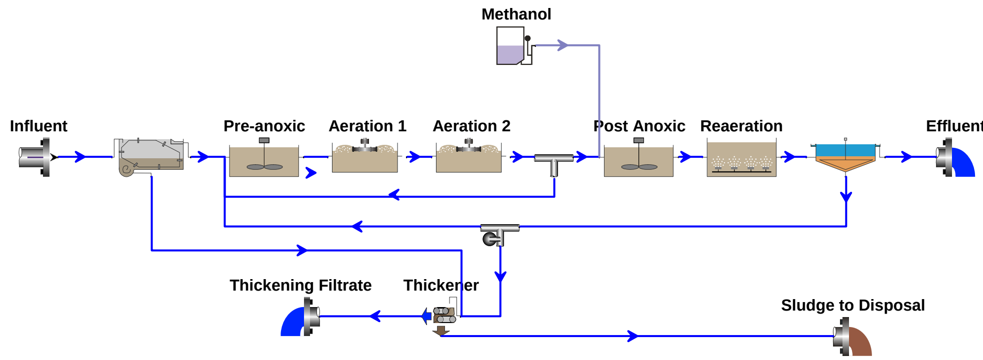


FIGURE 9.2-5:

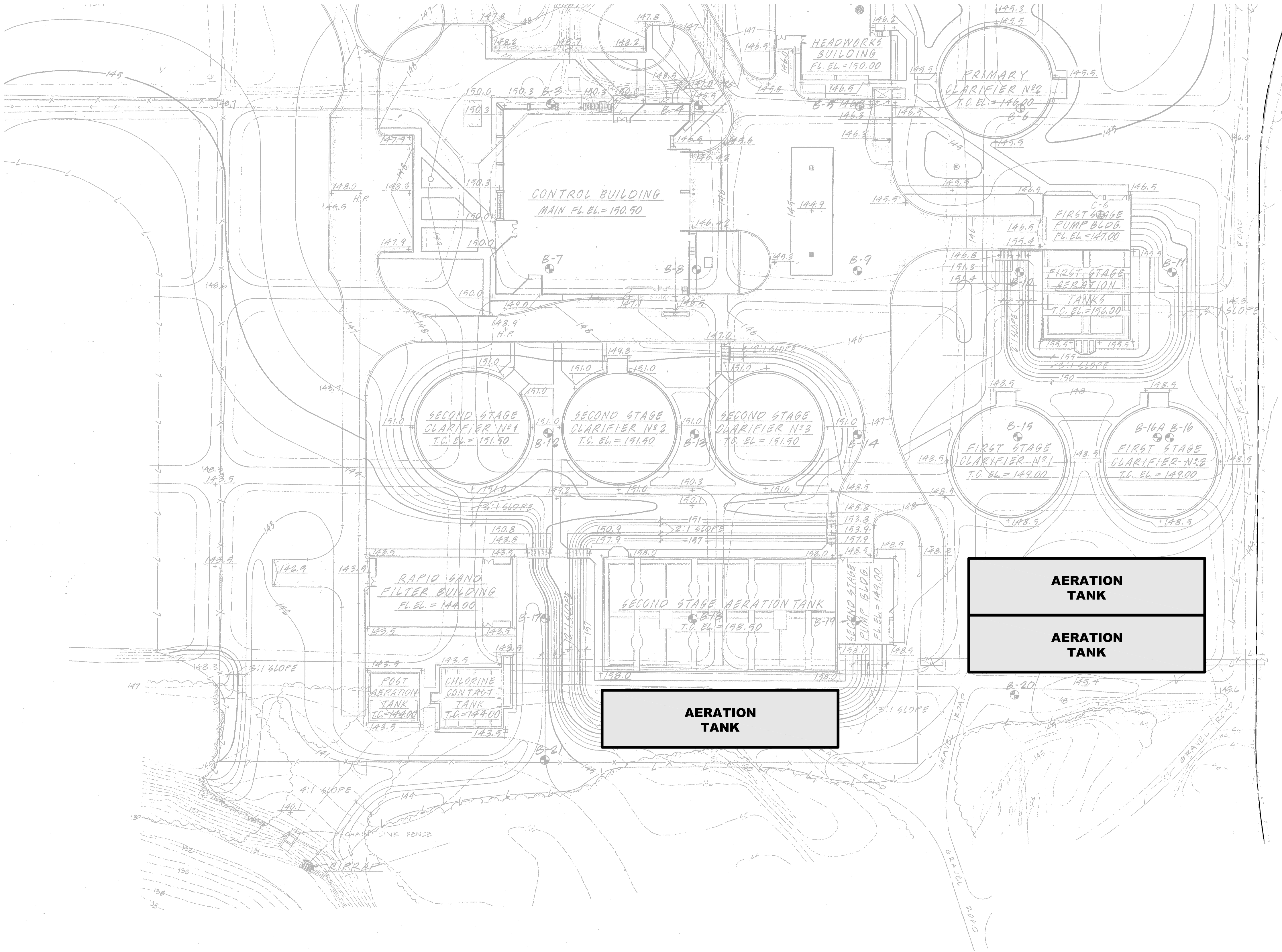
NITROGEN REMOVAL PROCESSES – SEASONAL LIMIT OF 5 mg/L

This process requires slightly more than 2-1/2 more reactors. Thus, in addition to the two converted plug flow reactors (consisting of the eight existing aeration tanks), three additional reactors would be required. The new reactors would be the same size as the two existing converted plug flow reactors.

Although the existing clarifiers appear to be adequately sized to handle the future flow and loading conditions, it should be noted that the clarifiers at this facility are twelve feet deep. According to TR-16, clarifiers at nitrogen removal facilities should be a minimum of 13 feet deep. Because the clarifiers meet the minimum requirements set forth in Section 2, they will have to be further evaluated to consider if they will require replacement or derating because of the shallow depth.

As shown in the site plan in Figure 9.2-6, the site appears to have enough space for the additional aeration tanks. Specific information regarding the results of this analysis is shown in the following Table 9.2-8.

(continued)



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1"=40'–0"

SITE PLAN

SCALE: 1"=40'–0"

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

NORTH ATTLEBORO, MASSACHUSETTS

FIGURE 9.2–6

Table 9.2-8

RESULTS FOR SEASONAL LIMIT OF 5 mg/L TN

PARAMETER	VALUE
Aerobic SRT	10 days
Total SRT	20 days
First Anoxic Fraction	30%
Total Anoxic Fraction	50%
Reaeration HRT	1 hr
RAS Rate	100%
Total Volume	2.9 MG
Nitrate Recycle Rate	300%
Max MLSS at loading rate	3700 mg/L
Effluent TN	5 mg/L
Methanol Addition	Yes
Fixed Film Required?	No
Clarifiers?	Reuse existing second stage clarifiers
Effluent Filtration Required?	Existing, no additional

The proposed location for the new aeration tanks will either be at or across the fence line. This is not the property line and thus it is assumed that new tanks can be constructed here.

Other plant modifications may be needed including upgrades to sludge handling to accommodate the higher sludge production. However, all facilities outside of the activated sludge process are outside of the scope of this study.

b. **Annual Average.** At the influent TN levels for this facility, a Bardenpho configuration with methanol addition will accomplish a seasonal effluent TN level of 5 mg/L. The BioWin model for this process is shown below in Figure 9.2-7.

(continued)

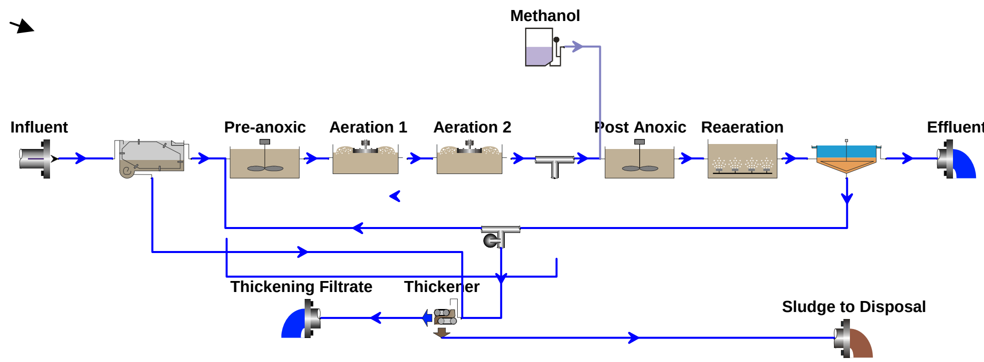


FIGURE 9.2-7:
NITROGEN REMOVAL PROCESSES – ANNUAL AVERAGE LIMIT OF 5 mg/L

This process would require approximately five reactors. In addition to the two converted plug flow reactors (consisting of eight existing aeration tanks), three additional reactors would be required. The new reactors would be the same size as the two existing converted plug flow reactors.

Although the existing clarifiers appear to be adequately sized to handle the future flow and loading conditions, it should be noted that the clarifiers at this facility are twelve feet deep. According to TR-16, clarifiers at nitrogen removal facilities should be a minimum of 13 feet deep. Because the clarifiers meet the minimum requirements set forth in Section 2, they will have to be further evaluated to consider if they will require replacement or derating because of the shallow depth.

As shown in the site plan in Figure 9.2-6, the site appears to have enough space for the additional aeration tanks. Specific information regarding the results of this analysis is shown in the following Table 9.2-9.

(continued)

Table 9.2-9

RESULTS FOR ANNUAL AVERAGE LIMIT OF 5 mg/L TN

PARAMETER	VALUE
Aerobic SRT	11 days
Total SRT	20 days
First Anoxic Fraction	27%
Total Anoxic Fraction	45%
Reaeration HRT	0.25 hr
RAS Rate	100%
Total Volume	2.9 MG
Nitrate Recycle Rate	300%
Max MLSS at loading rate	3800 mg/L
Effluent TN	5 mg/L
Methanol Addition	Yes
Fixed Film Required?	No
Clarifiers?	Reuse existing second stage clarifiers
Effluent Filtration Required?	Existing, no additional

The proposed location for the new aeration tanks will either be at or across the fence line. This is not the property line and thus it is assumed that new tanks can be constructed here.

Other plant modifications may be needed including upgrades to sludge handling to accommodate the higher sludge production. However, all facilities outside of the activated sludge process are outside of the scope of this study.

D. **Plant and Cost Summary.**

Table 9.2-10 presents flow data for the North Attleborough WWTF as well as the current nitrogen removal performance of the plant.

(continued)

Table 9.2-10

PLANT FLOW AND EFFLUENT LIMIT SUMMARY

PARAMETER	VALUE
Permitted Flow (mgd)	4.61
Existing Flow (2004-6)	4.2
% of existing capacity	91
Current average seasonal effluent TN (mg/L)	7.7
Current average annual effluent TN (mg/L)	7.7
Permit Limits Seasonal Nitrification (mg/L) Year-round nitrification (mg/L) Seasonal TN Limit Annual TN Limit	 Yes (1-3) Yes (7-10) Yes (8) Report

Table 9.2-11 presents the nitrogen removal processes identified in this section to achieve the four different permit conditions considered. Based on the loading conditions established for this facility and the subsequent BioWin modeling performed using this data, the facility improvements include adding additional aeration tanks. The requirement for additional tanks for all permit conditions even though the facility is currently averaging a TN of 8 mg/L is due to modeling under maximum month loading conditions at permitted capacity.

Table 9.2-11

NITROGEN REMOVAL PROCESS SUMMARY FOR NORTH ATTLEBOROUGH WWTF

MINOR/ MODIFICATIONS OR RETROFITS	PROCESS TO ACHIEVE SEASONAL TN OF 8 MG/L	PROCESS TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	PROCESS TO ACHIEVE SEASONAL TN OF 5 MG/L	PROCESS TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L
Currently achieving nitrogen removal	MLE	MLE	Bardenpho with methanol addition	Bardenpho with methanol addition

The modifications required at North Attleborough to convert to a new nitrogen removal process are summarized in Table 9.2-12.

(continued)

Table 9.2-12

REQUIRED MODIFICATIONS SUMMARY FOR NORTH ATTLEBOROUGH WWTF

Modifications to achieve seasonal TN of 8 mg/L	Modifications to achieve annual average TN of 8 mg/L	Modifications to achieve seasonal TN of 5 mg/L	Modifications to achieve annual average TN of 5 mg/L	Special Conditions
2 new reactors (each equal to four existing square tanks)	2 new reactors (each equal to four existing square tanks)	3 new reactors (each equal to four existing square tanks)	3 new reactors (each equal to four existing square tanks)	None

The cost estimating procedures established in Section 2 were used to estimate capital, annual O&M, and 20-year present worth costs associated with the process changes and facility modifications summarized above. The cost estimates are included in Table 9.2-13.

Table 9.2-13

COST SUMMARY FOR NITROGEN REMOVAL AT NORTH ATTLEBOROUGH[1] WWTF

Limit	Capital Costs (in millions)	Total Annual Costs[2] (in thousands)	20-Yr Present Worth (in millions)
Minor Modifications/Retrofits	None	n/a	n/a
Seasonal Effluent TN of 8 mg/L	$19	$280	$23
Annual Average Effluent TN of 8 mg/L	$19	$400	$24
Seasonal Effluent TN of 5 mg/L	$26	$280	$30
Annual Average Effluent TN of 5 mg/L	$26	$430	$32

Notes:
1. It should be noted that these costs represent one method by which this facility can achieve the stated TN goals. It is not intended to be the most cost effective method nor the recommended method, but it represents a planning tool for MassDEP to estimate the fiscal impacts of establishing total nitrogen limits.
2. Represents incremental increase over current conditions.

(continued)

9.3 ATTLEBORO

A. **Introduction.** The Attleboro Wastewater Treatment Facility (WWTF) is located at 27 Pond Street North in Attleboro, Massachusetts. It has a permitted annual average capacity of 8.6 mgd and serves the City of Attleboro only. Septage is collected from North Seekonk and Attleboro.

Prior to 1980, the Attleboro treatment facility was a trickling filter plant. The current plant was constructed in 1980. It is currently undergoing an upgrade that is expected to be completed in 2008.

B. **Existing Facilities.**

1. **Description of Existing Facilities.** Raw wastewater is conveyed to Attleboro by gravity and the South Attleboro Pump Station. The flow passes through a coarse bar rack, grit chamber and then fine screens or comminuters. Ferric chloride and lime slurry are both added to the preliminary treatment process. The flow passes through a rapid mix tank and then through a flocculation tank prior to entering primary clarification.

Aerial Photo from google.com

After primary clarification, the flow can be pumped either to the first or second stage aeration tanks and clarifiers. If pumped to the first stage, flow is then pumped to the second stage aeration tanks and clarifiers. The first stage may be bypassed.

The first stage system consists of four 40 ft by 40 ft aerations tanks with a 12 ft sidewater depth followed by three 80 foot diameter clarifiers with a 12 ft sidewater depth. The second stage system consists of ten 50 ft by 50 ft aeration tanks with a 12 ft sidewater depth followed by three 100 ft diameter clarifiers with a 12 ft sidewater depth. All aeration tanks have mechanical aerators.

Secondary effluent flows through rapid sand filters, followed by chlorine disinfection, dechlorination and post aeration before being discharged to the Ten Mile River. Sludge is thickened in gravity thickeners, blended and then dewatered prior to being hauled offsite. A process flow schematic is shown in Figure 9.3-1.

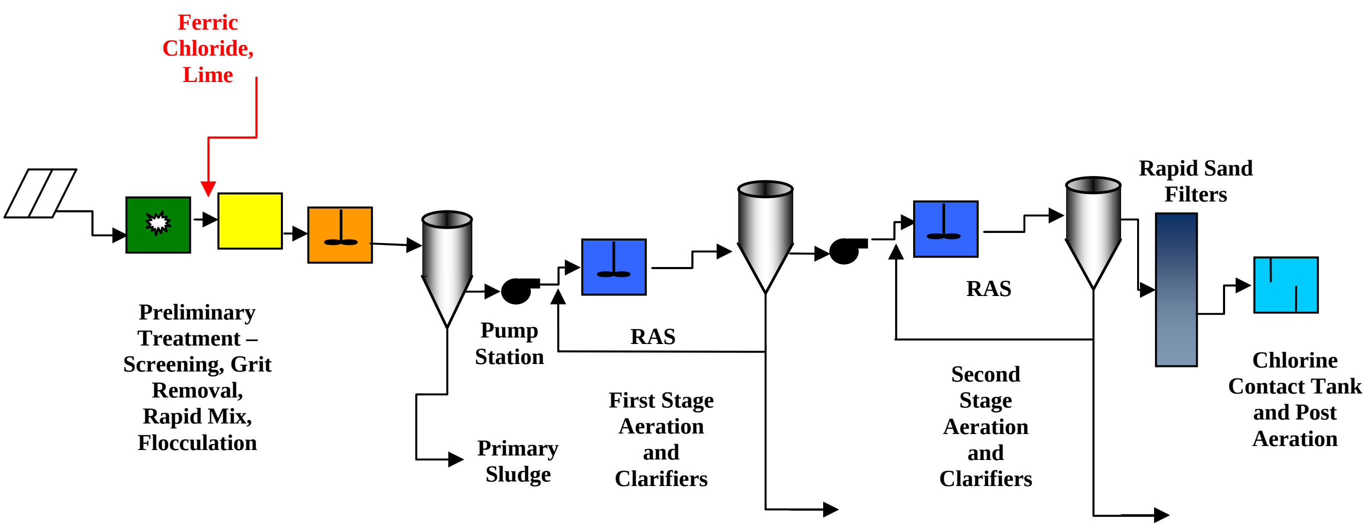


FIGURE 9.3-1: PROCESS FLOW SCHEMATIC – EXISTING FACILITY

All plant recycle flows are returned to the onsite South Attleboro Pump Station. Septage is introduced to the wastewater stream prior to preliminary treatment. The influent sampler at this facility is located downstream of the grit removal facilities and thus all plant flows including internal recycle flows are part of the influent loads. The last composite sampler is located prior to disinfection in the Filter Building.

The first stage is not used. Seven of the second stage aeration tanks are in use and others in the second stage are in standby mode. Typically two of the second stage clarifiers are in use with the third used during wet weather. The plant does not try to suppress nitrification at any time of the year. Nitrification is maintained except for occasional upset periods suspected to be caused by an unknown contaminant.

The plant has twenty six employees at the wastewater treatment facility and four for the collection system.

Design flows and loads for the current upgrade are shown below in Table 9.3-1.

Table 9.3-1
DESIGN FLOWS AND LOADS

PARAMETER	VALUE
Average Monthly (design flow)	8.6 mgd
BOD	198 mg/L
TSS	230 mg/L

2. **Summary of Plant Data.** Data from January 2004 through December 2006 was provided by the Town for this study. A summary of the monthly data is shown in Table 9.3-2. Seasonal and annual average and maximum month data is summarized in the table.

(continued)

Table 9.3-2

ATTLEBORO WWTF

Attleboro, Massachusetts

Monthly Averages 2004-2006

GENERAL		INFLUENT						EFFLUENT							
DATE		INF	pH	BOD	TSS	NH4	TEMP	DO	pH	BOD	TSS	F.COLI	TKN	NH4	TN
MONTH	YEAR	MGD		MG/L	MG/L	MG/L	DEG C	MG/L		MG/L	MG/L	# / 100ML	MG/L	MG/L	MG/L
January	2004	5.270	7.6	158	157	17.7	9.4	10.4	7.2	3.1	1.4	0	1.9	0.3	24.0
February	2004	4.803	7.6	184	170	18.2	9.4	10.4	7.3	2.4	1.3	1	1.9	0.1	18.0
March	2004	4.859	7.7	181	190	20.6	11.1	10.2	7.2	2.0	1.2	0	0.0	0.2	22.0
April	2004	7.033	7.3	143	141	14.7	10.0	9.8	7.2	3.0	2.2	1	0.6	0.3	0.6
May	2004	5.403	7.4	209	197	18.4	13.8	9.3	7.1	1.7	1.3	2	2.2	0.2	23.2
June	2004	4.905	7.5	196	222	19.5	17.2	8.6	7.1	1.5	1.1	0	0.6	0.3	24.6
July	2004	4.528	7.4	181	220	20.2	19.4	8.1	7.2	1.5	1.2	2	0.0	0.2	29.0
August	2004	4.071	7.3	191	186	23.2	21.1	7.9	7.1	1.6	1.7	1	1.5	0.6	34.5
September	2004	2.877	7.4	220	196	24.2	21.1	8.4	7.1	1.7	2.5	1	1.8	0.2	34.2
October	2004	2.685	7.5	210	218	23.2	18.9	9.3	7.2	1.4	1.0	0	1.5	0.1	33.5
November	2004	2.453	7.5	196	235	26.3	16.1	9.5	7.2	1.9	1.4	0	2.1	0.3	32.1
December	2004	3.009	7.4	176	182	21.0	12.8	10.0	7.3	1.8	1.1	1	1.1	0.2	20.1
January	2005	3.512	7.3	160	145	15.2	10.6	11.0	7.4	2.3	1.4	1	0.5	0.0	17.5
February	2005	3.498	7.4	164	158	17.0	9.4	4.5	7.2	2.4	1.1	0	1.4	0.4	25.4
March	2005	3.847	7.5	139	153	18.1	9.4	9.9	7.3	3.2	2.3	3	4.0	1.0	24.3
April	2005	4.774	7.3	141	136	12.7	11.1	9.7	7.3	2.3	1.7	1	0.0	0.2	15.0
May	2005	3.548	7.0	242	231	15.4	13.9	9.5	7.3	2.1	1.3	0	1.1	0.1	24.1
June	2005	3.251	7.5	210	232	17.5	17.8	9.1	7.3	1.4	1.5	11	1.6	0.0	17.6
July	2005	2.703	7.0	216	272	20.8	20.6	8.5	7.1	1.5	1.3	1	2.1	0.1	30.1
August	2005	2.779	7.4	276	273	34.5	23.3	8.1	7.4	1.7	1.8	1	2.4	0.1	16.4
September	2005	2.658	7.4	211	238	24.7	22.8	8.2	7.2	1.3	1.3	6	1.6	0.1	31.6
October	2005	4.604	7.4	146	170	16.2	20.0	8.7	7.4	1.6	2.3	2	0.0	0.1	29.0
November	2005	3.870	7.3	139	158	16.8	16.7	9.3	7.4	2.0	1.1	19	1.1	0.1	20.1
December	2005	3.412	7.4	150	124	17.3	13.9	10.6	7.5	2.9	1.6	945	1.0	0.0	17.0
January	2006	4.158	7.4	123	112	14.7	13.3	9.7	7.4	2.1	1.3	29	1.5	0.1	14.5
February	2006	3.615	7.4	154	131	18.8	12.8	9.6	7.3	3.0	2.6	66	2.7	3.3	12.7
March	2006	2.389	7.6	260	166	23.2	13.3	9.7	7.4	3.2	1.7	94	0.9	1.5	16.9
April	2006	2.493	7.6	250	240	27.5	15.0	9.3	7.5	4.0	6.3	2278	26.0	12.5	26.0
May	2006	3.670	7.5	208	210	18.7	16.1	9.2	7.4	2.9	3.0	97	1.0	0.0	17.3
June	2006	5.647	7.2	256	291	12.9	16.7	8.3	7.4	4.8	4.5	46	1.0	0.0	6.6
July	2006	3.581	7.3	291	307	13.2	18.9	8.3	7.5	1.4	1.0	26	1.7	0.0	14.7
August	2006	3.041	7.3	308	401	20.0	21.7	7.9	7.2	2.1	1.4	10	0.5	0.0	24.0
September	2006	2.574	7.4	224	255	39.6	20.6	8.5	7.3	1.8	1.4	15	1.4	0.0	22.4
October	2006	2.629	7.5	251	244	27.8	18.9	8.6	7.3	1.8	1.3	8	1.6	3.1	20.6
November	2006	3.872	7.4	162	167	18.4	16.7	8.8	7.6	2.4	3.5	49	2.8	3.5	20.8
December	2006	3.068	7.6	193	173	17.0	14.4	9.5	7.6	1.5	2.0	22	15.0	3.2	21.6
Min. Month		2.389	7.0	123	112	12.7	9.4	4.5	7.1	1.3	1.0	0	0.0	0.0	0.6
Seasonal Average		**3.620**	**7.3**	**225**	**242**	**22**	**19**	**8.6**	**7.3**	**1.9**	**1.7**	**13**	**1.3**	**0.3**	**24.1**
Average		**3.752**	**7.4**	**198**	**203**	**20.1**	**15.8**	**9.1**	**7.3**	**2.2**	**1.8**	**104**	**2.4**	**0.9**	**21.7**
Max. Month		7.033	7.7	308	401	39.6	23.3	11.0	7.6	4.8	6.3	2278	26.0	12.5	34.5

With a current average annual flow of 3.75 mgd (without recycle) and a permitted capacity of 8.6 mgd, this facility is operating at less than 45% of its permitted capacity. With recycle, the facility flow is between 4 and 4.5 mgd.

Based on the average BOD concentration of 198 mg/L and TN concentration of approximately 27 mg/L, this wastewater would be between weak and medium strength. The TN/BOD ratio is approximately 0.14 which is fairly low (a typical TN/BOD ratio is 0.18). However, these concentrations include plant recycle loads and are diluted by filter backwash.

3. **Permit Requirements and Current Performance.** Monthly permit limits from the current permit that are relevant to this study are shown below in Table 9.3-3.

Table 9.3-3
SELECT MONTHLY PERMIT LIMITS

PARAMETER	LIMIT
BOD_5	5 mg/L
TSS	5 mg/L
Ammonia-Nitrogen	
May	4.2 mg/L
June - October	1.5 mg/L
Nov-April	12.5 mg/L
TN	Report

The plant has performed exceptionally well meeting its average monthly permit limits for all but one month in the study period.

4. **Nitrogen Removal Performance.** This facility collects influent ammonia data. As can be seen in Table 9.3-2, the facility has an average effluent ammonia concentration of less than 1 mg/L, but has not denitrified over the study period.

C. **Nitrogen Removal Alternatives.** The existing maximum month loads over the three-year data collection period were used to determine the BioWin input data; one outlier was found in the data and not included in the analysis. The influent data which correspond to maximum-month loads are shown in Table 9.3-4 for each permitting scenario. The minimum temperature for the permit condition is also shown.

Table 9.3-4

EXISTING INFLUENT PARAMETERS

PERMIT CONDITIONS	PARAMETER	VALUE
Annual Average	Flow, mgd	5.40
	BOD, mg/L	209
	TSS, mg/L	214
	TN, mg/L	26
	Temperature, F	49
Seasonal	Flow, mgd	5.40
	BOD, mg/L	209
	TSS, mg/L	214
	TN, mg/L	26
	Temperature, F	57

The existing plant data was then projected to the permitted capacity of the facility to develop model input parameters for the average annual and seasonal model runs. This projected data is shown in Table 9.3-5.

Table 9.3-5

MODEL INPUT PARAMETERS AT PERMITTED CAPACITY

PERMIT CONDITIONS	PARAMETER	VALUE
Annual Average	Flow, mgd	12.38
	BOD, mg/L	209
	TSS, mg/L	214
	TN, mg/L	26
	Temperature, F	49
Seasonal	Flow, mgd	12.38
	BOD, mg/L	209
	TSS, mg/L	214
	TN, mg/L	26
	Temperature, F	57

The model input data was used to run uncalibrated simulations to determine planning level, order-of-magnitude costs for implementing different levels of nitrogen reduction at the facility. A discussion of operational changes or minor modifications that can be made to the facility to improve current nitrogen reduction performance as well as a presentation of the simulation results are presented in the following sections.

The existing second stage consists of 10 aeration tanks. For all of the alternatives outlined below, it is assumed that the ten existing tanks would be converted into two reactors, each consisting of five of the existing tanks.

The first stage tanks could be used to fulfill some of the needs for future capacity, but because the first and second stages are at different elevations, use of the first stage system would require an upgrade to the pump station that conveys flow to the second stage such that it could handle the significant increase in flow from the nitrate recycle. However, this additional, constant pumping may not be desirable.

The BOD concentration at the max month condition is approximately double the average condition. As a result, each of the alternatives below requires a significant number of additional tanks. Although there are more cost effective approaches to achieving the goals for this facility, the use of additional tanks is in accordance with the guidelines established for this study in Section 2.

1. **Minor Modifications/Retrofits.** The plant currently has approximately 37% of the recommended volume required to meet an annual average effluent TN of 8 mg/L and it has approximately 53% of the recommended volume required to meet a seasonal average effluent TN of 8 mg/L. With the plant currently running at approximately 43% of its design capacity, it would seem that cyclical aeration (cycle aerators on and off) would allow the plant to denitrify at least seasonally to a level of approximately 8 mg/L, but this performance will likely tail off in the winter.

2. **Modifications Required to Meet TN of 8 mg/L.** Modifications to the facility that are required to meet an effluent TN of 8 mg/L on a seasonal and annual average basis are as follows.

   a. **Seasonal.** At the influent TN levels for this facility, an MLE process will accomplish a seasonal effluent TN level of 8 mg/L. The BioWin model for this process is shown below in Figure 9.3-2.

(continued)

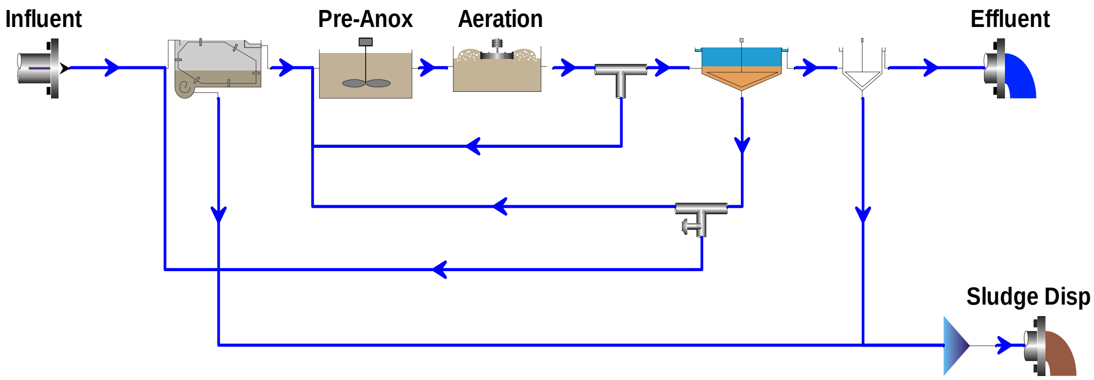


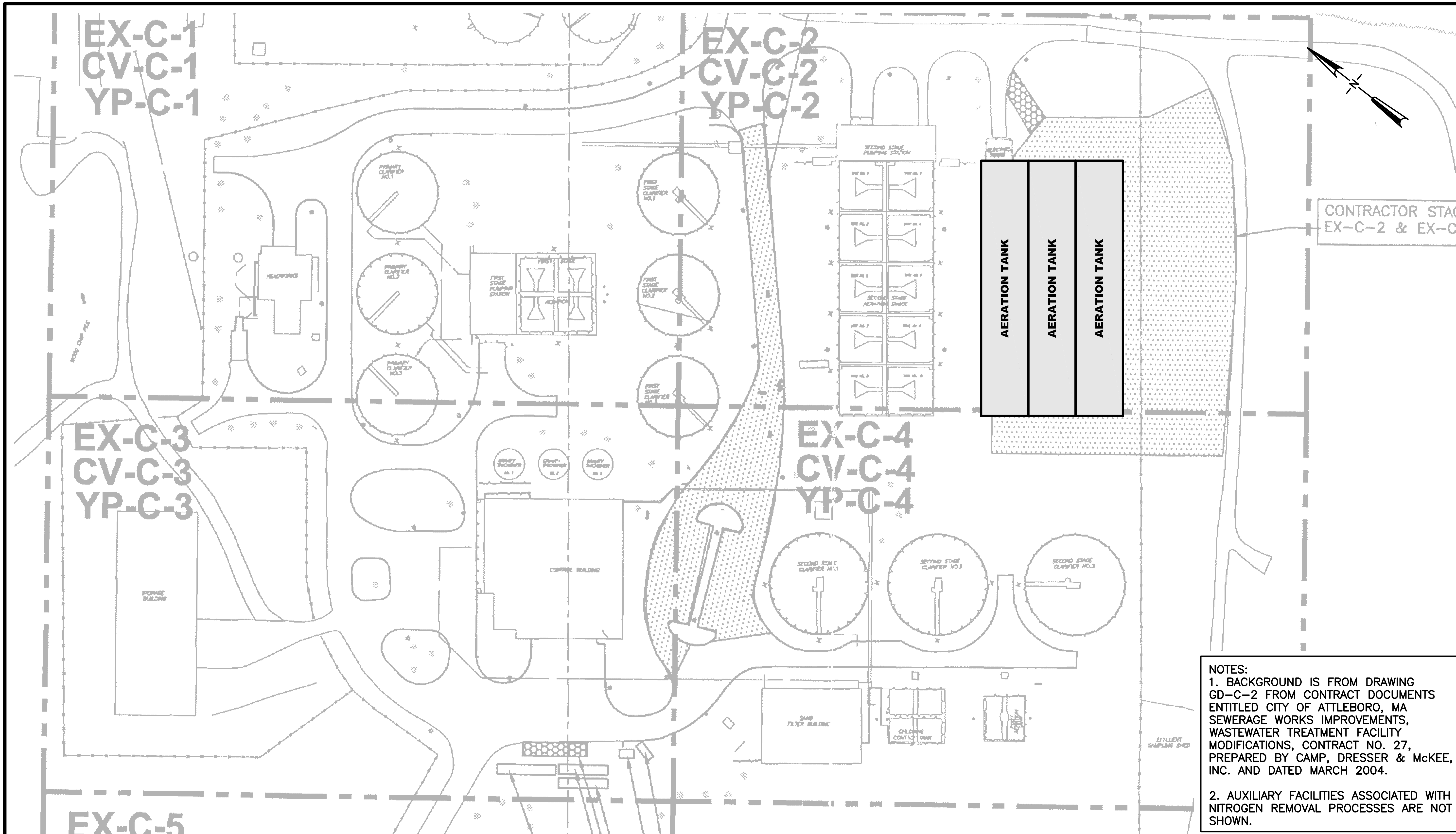
FIGURE 9.3-2: NITROGEN REMOVAL PROCESSES - SEASONAL LIMIT OF 8 mg/L

This process would require approximately double the current second stage aeration tank capacity. In addition to the two converted plug flow reactors (consisting of the ten existing aeration tanks), three additional plug flow reactors would be required. The new reactors would be the same size as the two existing converted plug flow reactors.

Although the existing clarifiers appear to be adequately sized to handle the future flow and loading conditions, it should be noted that the clarifiers at this facility are twelve feet deep. According to TR-16, clarifiers at nitrogen removal facilities should be a minimum of 13 feet deep. Because the clarifiers meet the minimum requirements set forth in Section 2, they will have to be further evaluated to consider if they will require replacement or derating because of the shallow depth.

As shown in the site plan in Figure 9.3-3, the site appears to have enough space for the additional reactors. Specific information regarding the results of this analysis is shown in Table 9.3-6 below.

(continued)



NOTES:
1. BACKGROUND IS FROM DRAWING GD-C-2 FROM CONTRACT DOCUMENTS ENTITLED CITY OF ATTLEBORO, MA SEWERAGE WORKS IMPROVEMENTS, WASTEWATER TREATMENT FACILITY MODIFICATIONS, CONTRACT NO. 27, PREPARED BY CAMP, DRESSER & McKEE, INC. AND DATED MARCH 2004.

2. AUXILIARY FACILITIES ASSOCIATED WITH NITROGEN REMOVAL PROCESSES ARE NOT SHOWN.

SITE PLAN

SCALE: 1"=100'-0"

Login name: JDF
Filename path: J:\60000\61265 MADEP\10\Drawings\Fig
Filename: ATTLEBORO-CH9.dwg
Latest Revision: Friday, April 04, 2008

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

ATTLEBORO, MASSACHUSETTS

FIGURE 9.3–3

Table 9.3-6

RESULTS FOR SEASONAL LIMIT OF 8 mg/L TN

PARAMETER	VALUE
Aerobic SRT	6.6 days
Total SRT	8.5 days
First Anoxic Fraction	22%
Total Anoxic Fraction	22%
Reaeration HRT	n/a
RAS Rate	100%
Total Volume	5.6 MG
Nitrate Recycle Rate	300%
Max MLSS at loading rate	3600 mg/L
Effluent TN	8 mg/L
Methanol Addition	No
Fixed Film Required?	No
Clarifiers?	Reuse existing second stage clarifiers
Effluent Filtration Required?	Existing, no additional

The modifications related to the proposed upgrades described above do not appear to require any structure demolition. The aeration tanks can be constructed in portions of the site that are currently unused.

Other plant modifications may be needed including upgrades to sludge handling. However, all facilities outside of the activated sludge process are outside of the scope of this study.

b. **Annual Average.** At the influent TN levels for this facility, an MLE process will accomplish an annual average effluent TN level of 8 mg/L. The BioWin model for this process is shown below in Figure 9.3-4 below.

(continued)

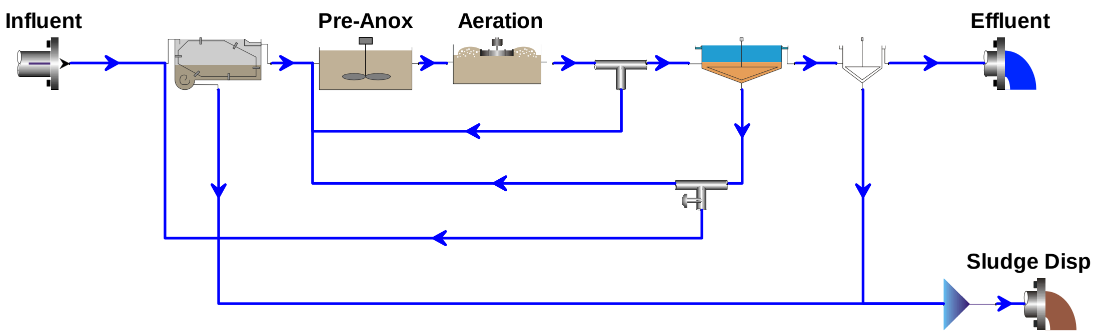


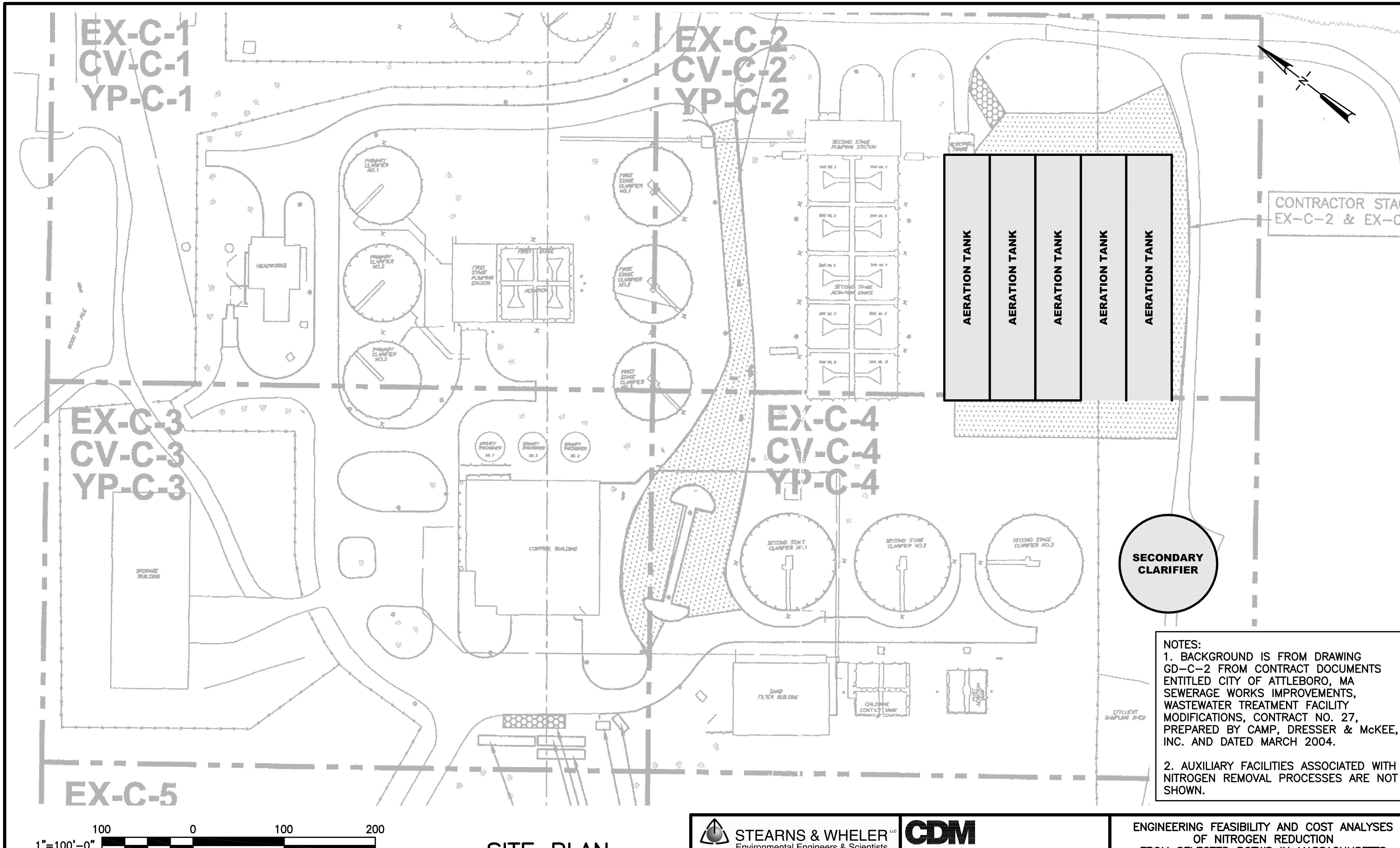
FIGURE 9.3-4: NITROGEN REMOVAL PROCESSES – ANNUAL AVERAGE LIMIT OF 8 mg/L

This process would require more than three times the current second stage aeration tank capacity. In addition to the two converted plug flow reactors (consisting of the ten existing aeration tanks), five additional plug flow reactors would be required. The new reactors would be the same size as the two existing converted plug flow reactors.

In addition to the new aeration tanks, it is anticipated that the facility will require one additional secondary clarifier (in addition to the existing three) to operate at the future flow and loading conditions. It should be noted that the existing clarifiers at this facility are twelve feet deep. According to TR-16, clarifiers at nitrogen removal facilities should be a minimum of 13 feet deep. Because the clarifiers meet the minimum requirements set forth in Section 2, they will have to be further evaluated to consider if they will require replacement or derating because of the shallow depth.

As shown in the site plan in Figure 9.3-5, the site appears to have enough space for the additional aeration tanks. Specific information regarding the results of this analysis is shown in Table 9.3-7 as follows.

(continued)



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2. AUXILIARY FACILITIES ASSOCIATED WITH NITROGEN REMOVAL PROCESSES ARE NOT SHOWN.

SITE PLAN

SCALE: 1"=100'-0"

Login name: JDF
Filename path: J:\60000\61265 MADEP\10\Drawings\Fig
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Latest Revision: Friday, April 04, 2008

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

ATTLEBORO, MASSACHUSETTS

FIGURE 9.3-5

Table 9.3-7

RESULTS FOR ANNUAL AVERAGE LIMIT OF 8 mg/L TN

PARAMETER	VALUE
Aerobic SRT	9.5 days
Total SRT	12 days
First Anoxic Fraction	21%
Total Anoxic Fraction	21%
Reaeration HRT	n/a
RAS Rate	100%
Total Volume	7.9 MG
Nitrate Recycle Rate	300%
Max MLSS at loading rate	3600 mg/L
Effluent TN	8 mg/L
Methanol Addition	No
Fixed Film Required?	No
Clarifiers?	Reuse existing second stage clarifiers and add one new one
Effluent Filtration Required?	Existing, no additional

The modifications related to the proposed upgrades described above do not appear to require any structure demolition. The aeration tanks can be constructed in portions of the site that are currently unused.

Other plant modifications may be needed including upgrades to sludge handling. However, all facilities outside of the activated sludge process are outside of the scope of this study.

3. **Modifications Required to Meet a TN of 5 mg/L.** The modifications to the facility that are required to meet an effluent TN of 5 mg/L on a seasonal and annual average basis are as follows.

a. **Seasonal.** At the influent TN levels for this facility, a Bardenpho configuration will accomplish a seasonal effluent TN level of 5 mg/L. The BioWin model for this process is shown below in Figure 9.3-6.

(continued)

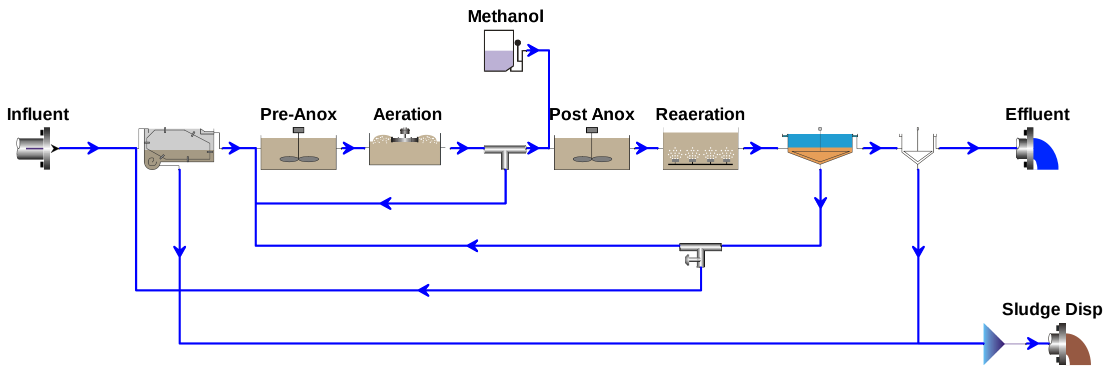


FIGURE 9.3-6: NITROGEN REMOVAL PROCESSES – SEASONAL LIMIT OF 5 mg/L

This process would require four times the current second stage aeration tank capacity. In addition to the two converted plug flow reactors (consisting of the ten existing aeration tanks), six additional reactors would be required. The new reactors would be the same size as the two existing converted plug flow reactors.

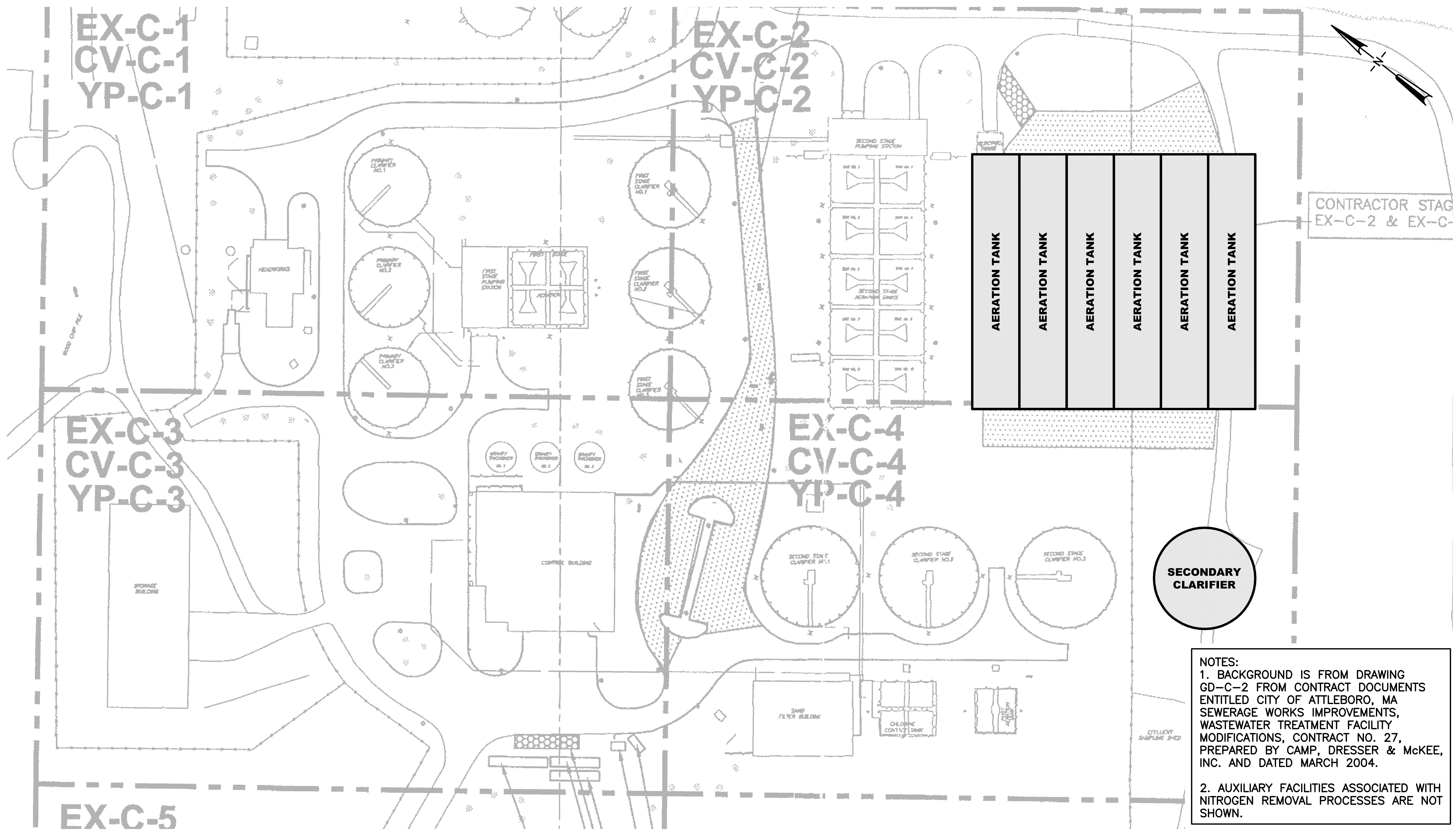
In addition to the new aeration tanks, it is anticipated that one additional secondary clarifier be added to the existing three to operate at the future flow and loading conditions. It should be noted that the existing clarifiers at this facility are twelve feet deep. According to TR-16, clarifiers at nitrogen removal facilities should be a minimum of 13 feet deep. Because the clarifiers meet the minimum requirements set forth in Section 2, they will have to be further evaluated to consider if they will require replacement or derating because of the shallow depth.

As shown in the site plan in Figure 9.3-7, the site appears to have enough space for the additional aeration tanks. Specific information regarding the results of this analysis is shown in Table 9.3-8 below.

Table 9.3-8

RESULTS FOR SEASONAL LIMIT OF 5 mg/L TN

PARAMETER	VALUE
Aerobic SRT	6.8 days
Total SRT	14 days
First Anoxic Fraction	21%
Total Anoxic Fraction	42%
Reaeration HRT	1.2 hrs
RAS Rate	100%
Total Volume	9.0 MG
Nitrate Recycle Rate	300%



NOTES:
1. BACKGROUND IS FROM DRAWING GD-C-2 FROM CONTRACT DOCUMENTS ENTITLED CITY OF ATTLEBORO, MA SEWERAGE WORKS IMPROVEMENTS, WASTEWATER TREATMENT FACILITY MODIFICATIONS, CONTRACT NO. 27, PREPARED BY CAMP, DRESSER & McKEE, INC. AND DATED MARCH 2004.

2. AUXILIARY FACILITIES ASSOCIATED WITH NITROGEN REMOVAL PROCESSES ARE NOT SHOWN.

SITE PLAN
SCALE: 1"=100'-0"

Login name: JDF
Filename path: J:\60000\61265 MADEP\10\Drawings\Fig
Filename: ATTLEBORO-CH9.dwg
Latest Revision: Friday, April 04, 2008

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ATTLEBORO, MASSACHUSETTS

FIGURE 9.3–7

Table 9.3-8 (continued)

RESULTS FOR SEASONAL LIMIT OF 5 mg/L TN

PARAMETER	VALUE
Max MLSS at loading rate	3700 mg/L
Effluent TN	5 mg/L
Methanol Addition	No
Fixed Film Required?	No
Clarifiers?	Reuse existing second stage clarifiers and add one new one
Effluent Filtration Required?	Existing, no additional

The modifications related to the proposed upgrades described above do not appear to require any structure demolition. The aeration tanks can be constructed in portions of the site that are currently unused.

Other plant modifications may be needed including upgrades to sludge handling. However, all facilities outside of the activated sludge process are outside of the scope of this study.

b. **Annual Average.** At the influent TN levels for this facility, a Bardenpho configuration with methanol addition will accomplish a seasonal effluent TN level of 5 mg/L. The BioWin model for this process is shown below in Figure 9.3-8.

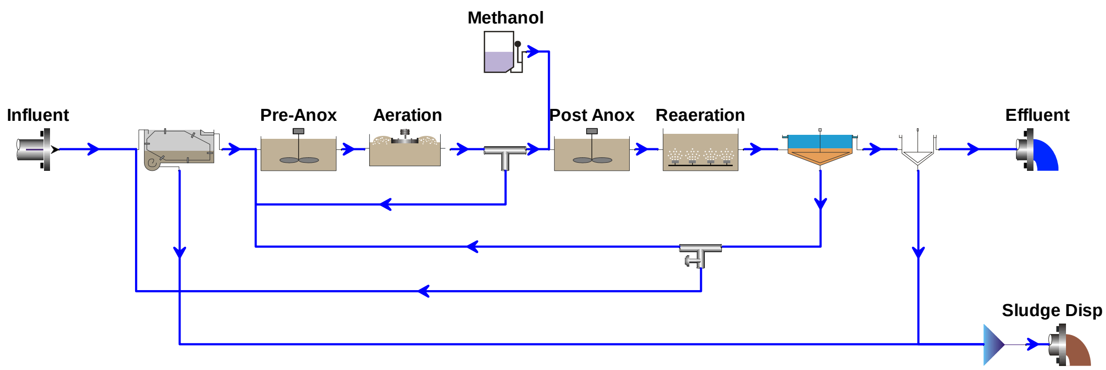


FIGURE 9.3-8:

NITROGEN REMOVAL PROCESSES – ANNUAL AVERAGE LIMIT OF 5 mg/L

This process would require approximately five times the current second stage aeration tank capacity. In addition to the two converted plug flow reactors (consisting of the ten existing tanks), eight additional reactors would be required. The new reactors would be the same size as the two existing converted plug flow reactors.

In addition to the new aeration tanks, it is anticipated that the facility will require one additional secondary clarifier (in addition to the existing three) to operate at the future flow and loading conditions. It should be noted that the existing clarifiers at this facility are twelve feet deep. According to TR-16, clarifiers at nitrogen removal facilities should be a minimum of 13 feet deep. Because the clarifiers meet the minimum requirements set forth in Section 2, they will have to be further evaluated to consider if they will require replacement or derating because of the shallow depth.

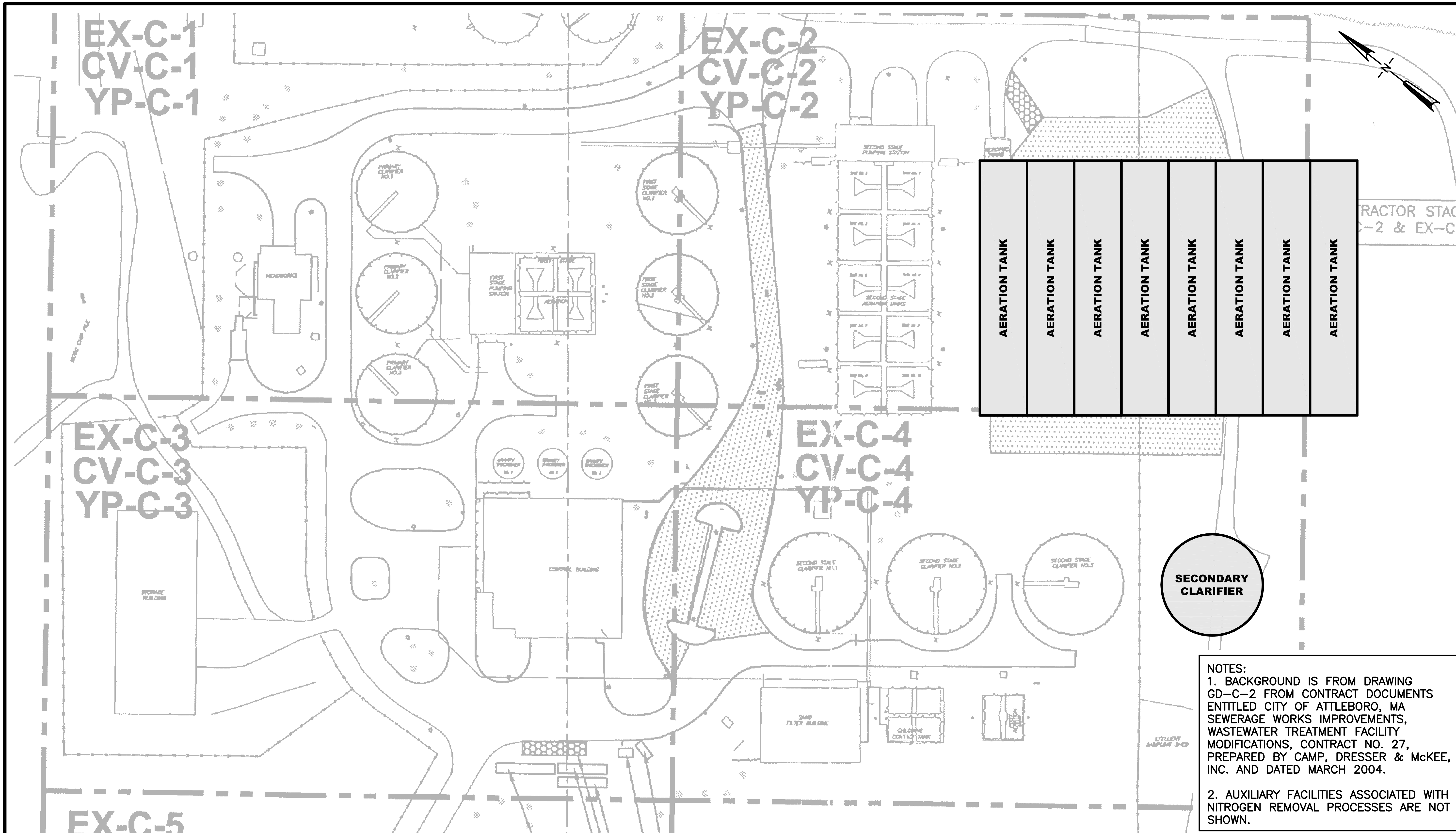
As shown in the site plan in Figure 9.3-9, the site appears to have enough space for the additional aeration tanks. Specific information regarding the results of this analysis is shown in Table 9.3-9 below.

Table 9.3-9

RESULTS FOR ANNUAL AVERAGE LIMIT OF 5 mg/L TN

PARAMETER	VALUE
Aerobic SRT	10.8 days
Total SRT	18 days
First Anoxic Fraction	23%
Total Anoxic Fraction	40%
Reaeration HRT	1.5 hrs
RAS Rate	100%
Total Volume	11.2 MG
Nitrate Recycle Rate	300%
Max MLSS at loading rate	3800 mg/L
Effluent TN	5 mg/L
Methanol Addition	Yes
Fixed Film Required?	No
Clarifiers?	Reuse existing second stage clarifiers and add one new one
Effluent Filtration Required?	Existing, no additional

The modifications related to the proposed upgrades described above do not appear to require any structure demolition. The aeration tanks can be constructed in portions of the site that are currently unused.



NOTES:
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2. AUXILIARY FACILITIES ASSOCIATED WITH NITROGEN REMOVAL PROCESSES ARE NOT SHOWN.

100 0 100 200
1"=100'–0"

SITE PLAN
SCALE: 1"=100'–0"

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ATTLEBORO, MASSACHUSETTS

FIGURE 9.3–9

Other plant modifications may be needed including upgrades to sludge handling. However, all facilities outside of the activated sludge process are outside of the scope of this study.

D. **Plant and Cost Summary.** Table 9.3-10 presents flow data for the Attleboro WWTF as well as the current nitrogen removal performance of the plant.

Table 9.3-10

PLANT FLOW AND EFFLUENT LIMIT SUMMARY

PARAMETER	VALUE
Permitted Flow (mgd)	8.6
Existing Flow (2004-6)	3.75
% of existing capacity	43.6
Current average seasonal effluent TN (mg/L)	24.1
Current average annual effluent TN (mg/L)	21.7
Permit Limits Seasonal Nitrification (mg/L) Year-round nitrification (mg/L) Seasonal TN Limit Annual TN Limit	 Yes (1.5-4.2) Yes (12.5) Report Report

Table 9.3-11 presents the nitrogen removal processes identified in this section to achieve the four different permit conditions considered. Based on the loading conditions established for this facility and the subsequent BioWin modeling performed using this data, the facility improvements include adding a number of additional aeration tanks and, for most permit conditions, an additional clarifier.

Table 9.3-11

NITROGEN REMOVAL PROCESS SUMMARY FOR ATTLEBORO WWTF

MINOR/ MODIFICATIONS OR RETROFITS	PROCESS TO ACHIEVE SEASONAL TN OF 8 MG/L	PROCESS TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	PROCESS TO ACHIEVE SEASONAL TN OF 5 MG/L	PROCESS TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L
Cyclical Aeration	MLE	MLE	Bardenpho	Bardenpho with methanol addition

The modifications required at Attleboro to convert to a new nitrogen removal process are summarized in Table 9.3-12.

Table 9.3-12

REQUIRED MODIFICATIONS SUMMARY FOR ATTLEBORO WWTF

MODIFICATIONS TO ACHIEVE SEASONAL TN OF 8 MG/L	MODIFICATIONS TO ACHIEVE ANNUAL AVERAGE TN OF 8 MG/L	MODIFICATIONS TO ACHIEVE SEASONAL TN OF 5 MG/L	MODIFICATIONS TO ACHIEVE ANNUAL AVERAGE TN OF 5 MG/L	SPECIAL CONDITIONS
3 new reactors (each equal to five existing square tanks)	5 new reactors (each equal to five existing square tanks), one new clarifier	6 new reactors (each equal to five existing square tanks), one new clarifier	8 new reactors (each equal to five existing square tanks), one new clarifier	None

The cost estimating procedures established in Section 2 were used to estimate capital, annual O&M, and 20-year present worth costs associated with the process changes and facility modifications summarized above. The cost estimates are included in Table 9.3-13.

Table 9.3-13

COST SUMMARY FOR NITROGEN REMOVAL AT ATTLEBORO WWTF[1]

LIMIT	CAPITAL COSTS (IN MILLIONS)	TOTAL ANNUAL COSTS[2] (IN THOUSANDS)	20-YR PRESENT WORTH (IN MILLIONS)
Minor Modifications/Retrofits	Minor	N/A	N/A
Seasonal Effluent TN of 8 mg/L	$38	$430	$43
Annual Average Effluent TN of 8 mg/L	$60	$610	$68
Seasonal Effluent TN of 5 mg/L	$70	$430	$75
Annual Average Effluent TN of 5 mg/L	$88	$690	$97

Notes:
1. It should be noted that these costs represent one method by which this facility can achieve the stated TN goals. It is not intended to be the most cost effective method nor the recommended method, but it represents a planning tool for MassDEP to estimate the fiscal impacts of establishing total nitrogen limits.
2. Represents incremental increase over current conditions.