SECTION 8.0
NEWPCC – SECOND PRIORITY CONTROL ALTERNATIVES

8.1 PREAMBLE

Table 8.1 below indicates the target ammonia concentrations for the Best Practicable and the Second Priority Levels of Control for the North End Water Pollution Control Centre (NEWPCC).

Table 8.1: Target Ammonia Concentrations

Standard	Target NH_3-N Level
Best Practicable Level of Control	2 mg/L
Second Priority Level of Control	
• High Level	8 mg/L
• Moderate Level	14 mg/L

To achieve the Best Practicable Level of Control in effluent ammonia as described in Section 4.2 will require full nitrification of the entire NEWPCC effluent flow (dry weather). To achieve the Second Priority Levels of Control will require less ammonia reduction than the Best Practicable Level.

Designing and operating an activated sludge process to perform only partial nitrification for the full NEWPCC secondary treatment flow can be problematic. Due to kinetics, partial nitrification of the full flow stream becomes very erratic and unpredictable as relatively small fluctuations in sludge age or oxygen supply can result in significant variations in effluent quality. Consequently, it becomes necessary to consider options that can be designed and operated to fully nitrify only a portion of the flow and then blend it with the non-nitrified portion.

After extensive discussion among members of the study team, a long list of alternatives that could have the potential to meet the effluent targets for the second priority levels of control was formulated for the NEWPCC. Preliminary screening-level process simulations were done using the BioWin™ wastewater treatment process simulator to gain a general understanding of the performance of each alternative under projected 2041 flow and loading conditions.

The long list of second priority control alternatives included:

- **Construct a new treatment train in parallel to the existing HPO plant:** A portion of the primary effluent would be diverted away from the existing HPO plant and fed to a new parallel train comprised of a single stage activated sludge process designed to fully nitrify. The portion treated in the new train would be varied, and the new train appropriately sized, to achieve the two second-priority levels of ammonia control under consideration.

- **Reaerate the Return Activated Sludge (RAS) Flow:** The RAS flow from the final clarifiers of the existing HPO plant would be passed to a reaeration basin wherein the ammonia in the RAS would be nitrified.
- **Alter the existing HPO bioreactors to a step feed configuration:** The existing HPO reactors would be converted to a step feed configuration.
- **Construct a second stage treatment system using a fixed film process:** A fixed film biological treatment system would be added as a second stage following the HPO system. This facility would be sized to treat a portion of the secondary effluent, the portion being adjusted to provide a combined effluent that would meet the desired level of control.

The above alternatives were further evaluated by the study team members considering many parameters including integration with existing facilities, constructability during operation, and complexity of operation. The evaluation process lead to a short list of two potential alternatives as follows:

- Construct a new treatment train in parallel to the existing HPO plant; and
- Reaerate the Return Activated Sludge (RAS) Flow.

The short-listed alternatives were evaluated in detail to facilitate the selection of the approach to carry forward as the basis of the conceptual design for the second priority control alternatives. The short-listed alternatives are discussed in this section.

Separate treatment of the centrate generated in the sludge management facilities at the NEWPCC will be beneficial in terms of reducing the discharge of ammonia from the plant. In addition, centrate treatment could form an integral part of any future upgrading strategy, allowing a reduction in the magnitude of the facilities required to achieve nitrification in the secondary treatment plant. Therefore, separate centrate treatment has been considered as a refinement to the short-listed alternatives.

8.2 NEW TREATMENT TRAIN PARALLEL TO THE EXISTING HPO PLANT

As indicated in the preamble, it is problematic to reliably conduct partial ammonia reduction by limiting the extent of nitrification in an activated sludge system through either oxygen control or sludge age. A more practical approach to meet the second priority levels of control is to provide complete nitrification for only a portion of the primary effluent. The existing HPO system would continue to perform only carbonaceous treatment on the balance of the primary effluent. The effluent from the nitrifying and non-nitrifying treatment trains would be combined with the blended effluent providing the desired level of ammonia treatment.

A new parallel activated sludge system would be constructed to fully nitrify enough of the primary effluent to reliably achieve the second priority levels of ammonia control in the blended effluent from the two biological treatment systems. This system is illustrated in Figure 8.1. Full nitrification of only a portion of the flow with subsequent blending will result in both stable operation and compliance with the second priority effluent target levels. Also, because the process is amenable to upgrading to a biological nutrient removal configuration, this approach allows the flexibility to meet more stringent effluent limits, for nitrogen and phosphorus, should these be required in the future.

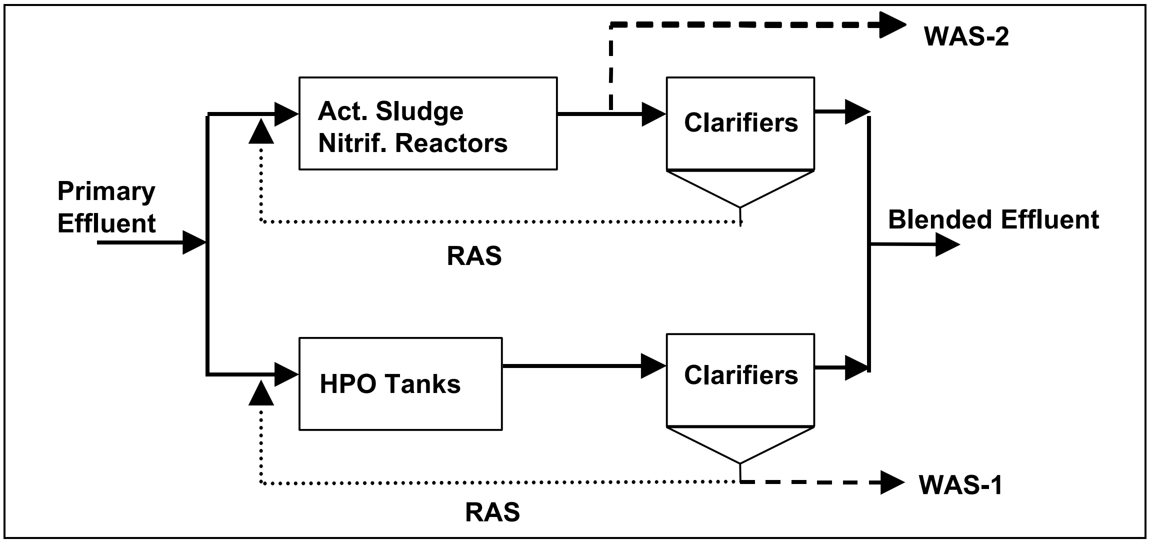


Figure 8.1: Parallel Activated Sludge Nitrification and the Existing HPO

8.2.1 High Level of Control – Parallel System

To achieve the high level of ammonia control, approximately 55 percent of the primary effluent would be treated in the new parallel nitrifying activated sludge system. This will reduce the flows to the existing HPO trains to about 15 percent per train as indicated in Table 8.2. Reduction of flow to the existing trains together with the ventilation of the last cells of each train would most likely allow for nitrification to proceed in these trains in any event. For the specific circumstances of the NEWPCC, diverting 55 percent of the primary effluent to a separate parallel treatment train will result in flow and loading conditions on the existing HPO system that approach those estimated in Section 4.0 to accomplish nitrification in the HPO system.

Table 8.2: Flow Proportions for High Level of Ammonia Control

Parallel Treatment Trains	Flow Proportion (%)
New Parallel Train	55
Existing HPOAS System	
Train 1	15
Train 2	15
Train 3	15
Total	**100**

8.2.2 Process Design and Operating Specifications – High Level of Control with Parallel Treatment

To meet a high level of ammonia control, there will be four new bioreactors with a total volume of 46,000 m^3. The selection zone in each reactor will be mixed using one 16 kW mixer. Three 450 kW blowers with capacity of 290 nm^3/min each, would supply oxygen and mixing for the aerobic zones of the bioreactors. Six final clarifiers each at 52 m diameter would be required in this option to sustain reliable performance under the flow and load conditions of year 2041. The design data for the new parallel nitrification system capable of high level of ammonia control are presented in Table 8.3.

If centrate treatment were implemented as part of this option, the amount of flow to the new parallel line could be decreased from 55 to 45 percent with a downsizing effect of approximately 24 percent on the total volume of the nitrifying tankage. The bioreactor tankage volume will be reduced from 46,000 m^3 in the case of no centrate treatment to 35,000 m^3 with centrate treatment. Reduction of flow will also reduce the required final clarification capacity. The number of new clarifiers will be reduced to from six to four at 52 m diameter. Assuming that separate centrate treatment is implemented, the split in flows and major tankage components (approximate sizing) that would have to be added to allow for a high level control of ammonia are as shown in Table 8.4 and Table 8.5.

A disadvantage of the parallel train approach is that the final plant configuration would be more complex due to the additional independent treatment trains involved. Separate centrate treatment would add somewhat to the overall complexity but not by a large degree.

Table 8.3: Design Data for Nitrification System (High Level of Ammonia Control with Parallel Treatment Train)

Description	Units	Values
Bioreactors		
Basic Design Parameters		
SRT	d	10-15
HRT	h	7
MLSS	mg/L	2000-3800
Number of Bioreactors		4
Total Volume	m^3	~ 46000
Bioreactor Dimension		
LxWxD	m	86x30x4.5
Each Bioreactor Zone Volumes		
Anoxic	m^3	1350
Aerobic 1	m^3	5130
Aerobic 2	m^3	5130
Bioreactor Mixing		
Anoxic		
Number of Mixers		1
Mixer Size	kW	16
Actual Oxygen Demand		
Aerobic 1		
Average	mg/L/h	30.3
Maximum	mg/L/h	54.5
Aerobic 2		
Average	mg/L/h	27
Maximum	mg/L/h	43.2
Aeration Parameters		
α, alpha		
Aerobic 1		0.55
Aerobic 2		0.60
β, beta		
Aerobic 1		0.95
Aerobic 2		0.95
Residual DO		
@ average demand	mg/L	2
@peak demand	mg/L	1
Standard Oxygen Transfer Rate		
Aerobic 1		
Average	kg/d	8947
Maximum	kg/d	14172
Aerobic 2		
Average	kg/d	7308
Maximum	kg/d	10794
Blowers		
Number		4
@ Average Flow		2
@ Maximum Flow		3
Standby		1
Capacity per Blower	nm^3/min	290
Size	kW	450

Table 8.3: Design Data for Nitrification System (High Level of Ammonia Control with Parallel Treatment Train) [continued]

Description	Units	Values
Clarifiers		
Basic Design Parameters		
Surface Overflow Rate (SOR)		
Average	m^3/m^2-h	0.5
Peak	m^3/m^2-h	0.7
Solids Loading Rate (SLR)		
Average	kg/m^2-h	2.5
Peak	kg/m^2-h	6.8
Number of Units		6
Dimensions		
Diameter	m	52
Side wall depth (SWD)	m	5
Floor Slope	percent	2

Table 8.4: Flow Proportions With Implementation of Separate Centrate Treatment (High Level of Ammonia Control with Parallel Treatment Train)

Parallel Treatment Trains	Flow Proportion (%)
New Parallel Train	45
Existing HPOAS System	
Train 1	9
Train 2	23
Train 3	23
Total	**100**

Table 8.5: Tankage Components (Separate Centrate Treatment + New Parallel Treatment Train for High Level of Ammonia Control)

Description	Units	Values
New Parallel Line Bioreactors		
Number		3
Total Volume	m^3	~ 35000
Dimension (LxWxD)	m	86x30x4.5
New Parallel Line Final Clarifiers		
Number		4
Diameter	m	52
SWD	m	5
Centrate Treatment Bioreactor		
Number		2
Total Volume	m^3	4800
Dimension (LxWxD)	m	20x20x6
Centrate Treatment Final Clarifiers		
Number		2
Diameter	m	12

8.2.3 High Level of Control - Site Layouts for Parallel Treatment

The site layout considered for this option including the locations of the new bioreactors, new clarifiers, effluent route and the blower building is shown in Dwg. NE-8.1. Dwg. NE-8.2 shows the layout of the new bioreactors and clarifiers site layout. A process flow diagram is presented in Dwg. NE-8.3.

8.2.4 High Level of Control – Model Output for Parallel Treatment

The model simulation of the NEWPCC performance with a parallel nitrifying train and centrate treatment for high level of ammonia control resulted in projections shown in Figures 8.2 to 8.7. The vertical bandwidth of each parameter plotted on these figures is indicative of the daily diurnal variation of the parameter.

Ammonia removal efficiency ranging from about 50 to 70 percent was predicted for the NEWPCC using the existing system HPO and a new parallel nitrifying system plus centrate treatment. The hourly influent and effluent ammonia concentrations for different seasons are illustrated in Figure 8.2. On the basis of model projections, the final effluent ammonia concentration would average about 8 mg/L during summer months except for the Maximum Week during which the concentration may reach to 14 mg/L. For other seasons, except for the Maximum Days, the average effluent ammonia concentration would remain below 10 mg/L, with variations mostly in the range of 6 to 10 mg/L.

The contribution to the blended effluent ammonia concentration from the existing HPO system and from the new parallel nitrifying system with centrate treatment are depicted in Figure 8.3. As the figure illustrates, the main source of the final effluent ammonia concentration is the effluent from the existing HPO system. The HPO system would generate an effluent with an average ammonia concentration variation in the range of about 9 to 30 mg/L during the year 2041. This is considerably higher than the ammonia concentration in the effluent from the parallel nitrifying system which would generally be in the range of 0 to 5 mg/L.

The TKN concentration in the final effluent would also be significantly lower than the concentration in the influent to the plant. TKN removal efficiency in the range of 40 to 75 percent would be achieved depending upon flow and load conditions as shown by the hourly variations of influent and blended effluent TKN concentrations in Figure 8.4.

The projected bioreactor MLSS concentrations are presented in Figure 8.5. MLSS in the new nitrifying bioreactors would vary in the range of 2,000 to 3,700 mg/L compared to the range of 900 to 2,100 mg/L predicted for the existing HPO reactors. As discussed previously, about 55 percent of the primary effluent flow should be subjected to nitrification process if high level of ammonia control is desired. The

Figure 8.2: Influent Versus Effluent Ammonia Concentration (High Level Ammonia Control)

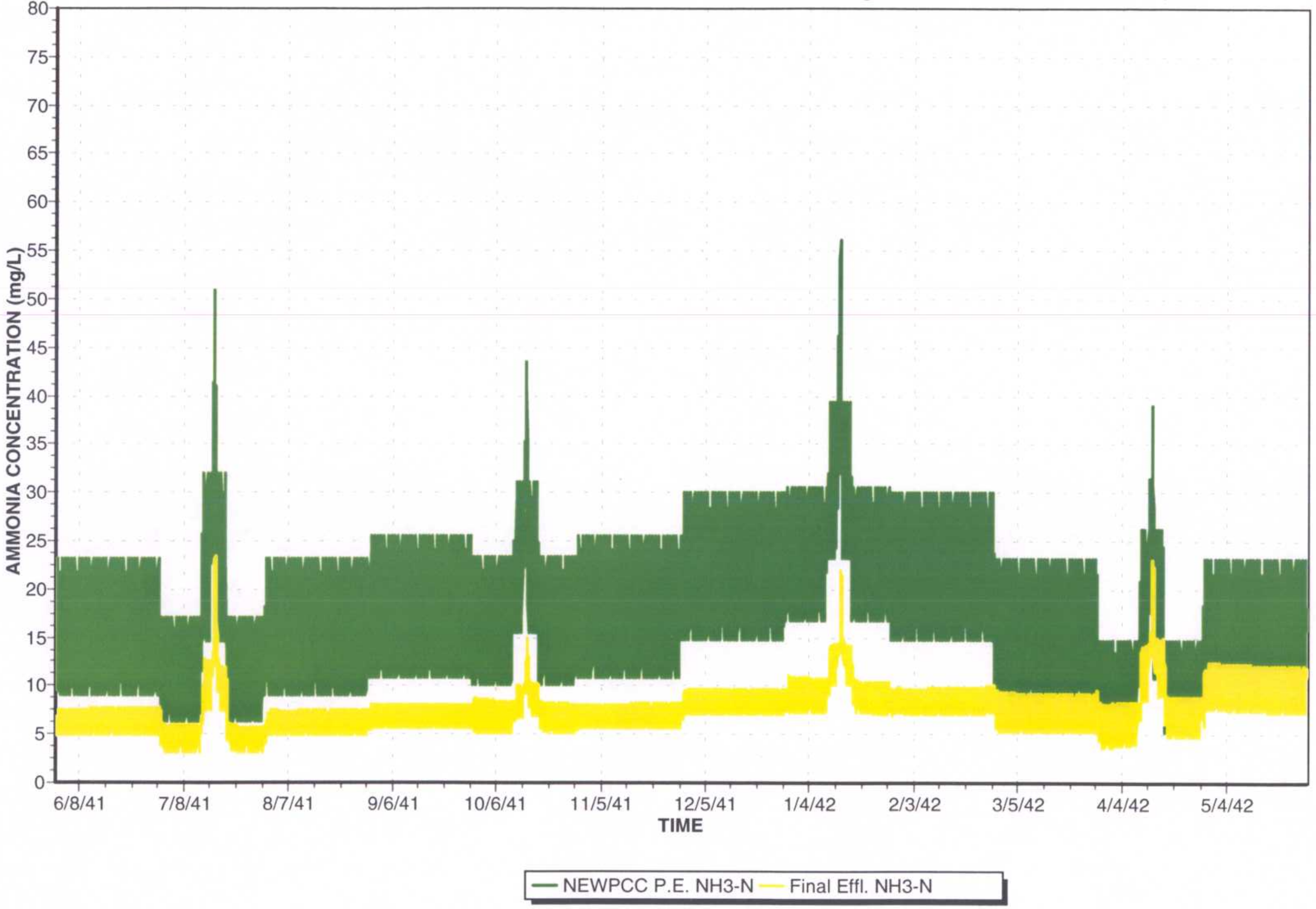


Figure 8.3: Ammonia Concentration in Different Effluent Lines (High Level of Ammonia Control)

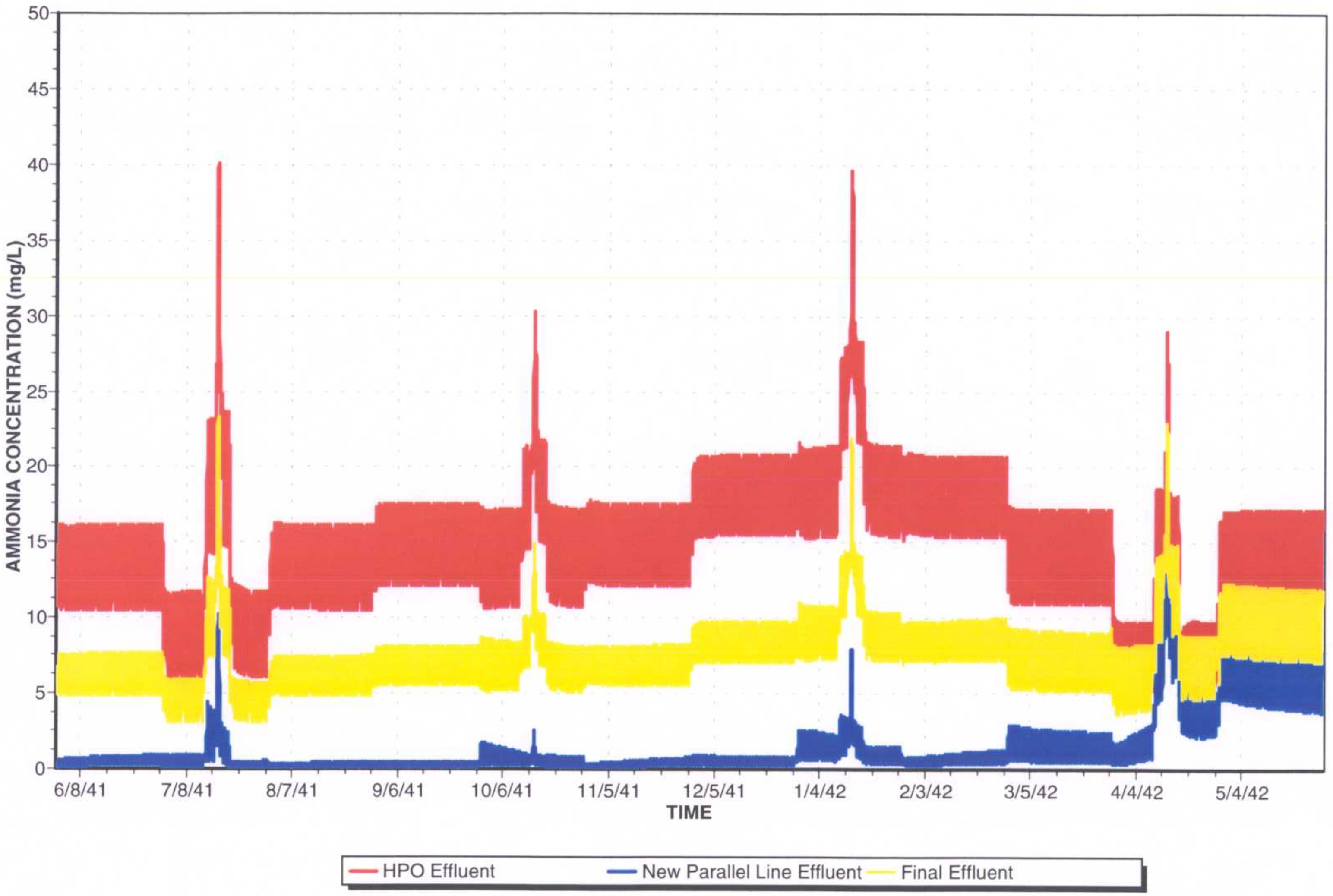


Figure 8.4: Influent Versus Effluent TKN Concentration (High Level Ammonia Control)

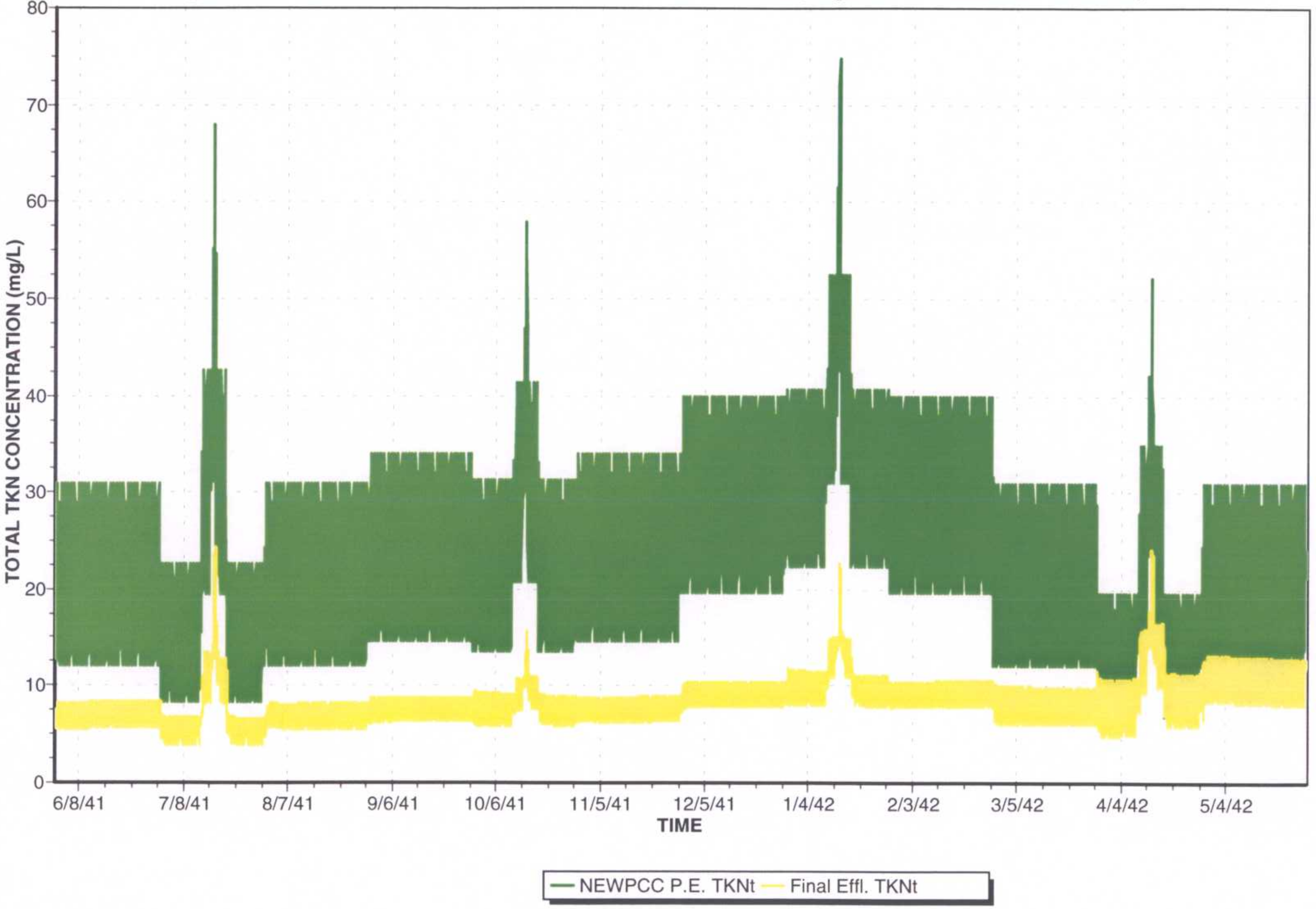


Figure 8.5: Bioreactor MLSS (High Level Ammonia Control)

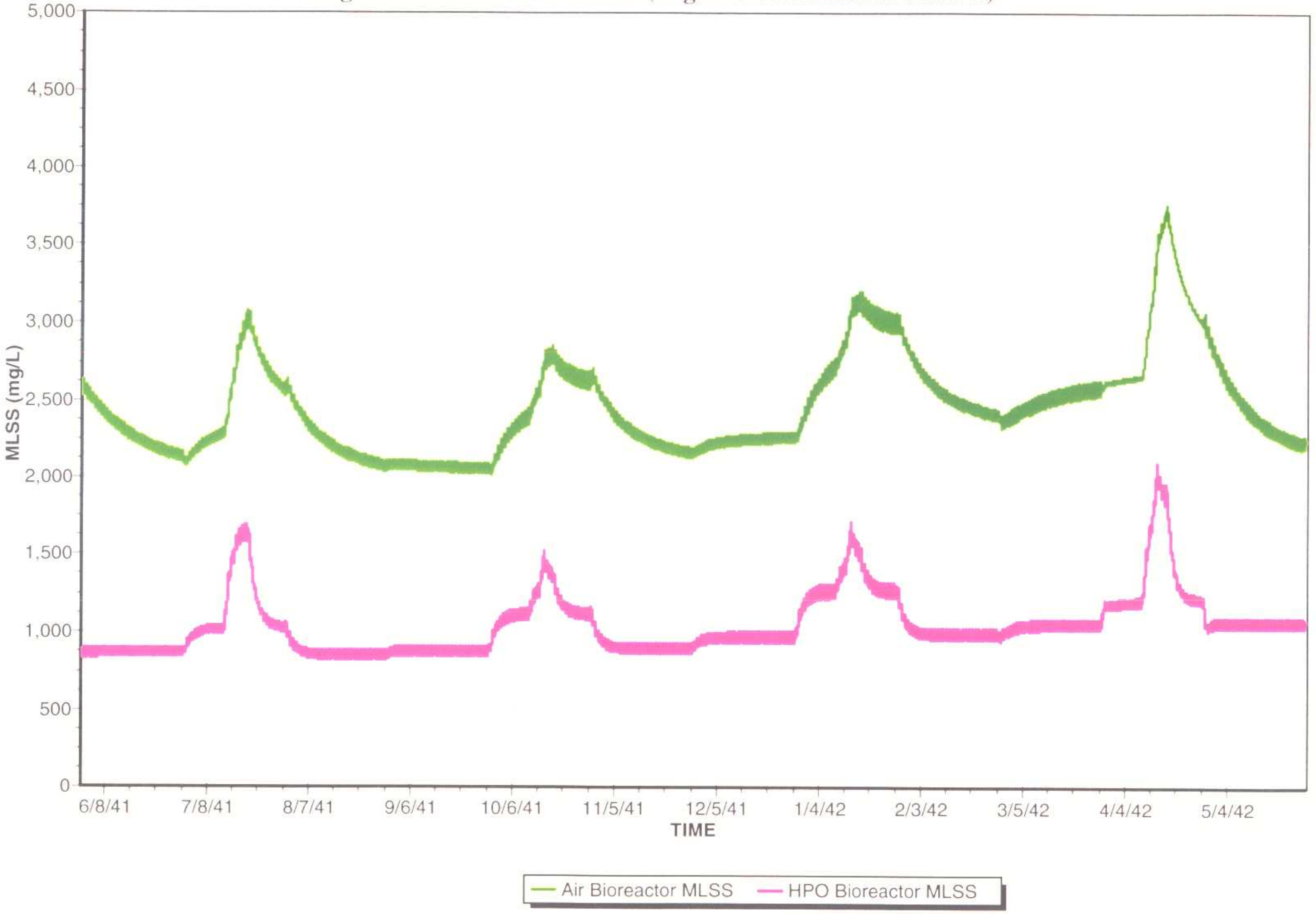


Figure 8.6: Clarifier Solids Loading Rate (High Level Ammonia Control)

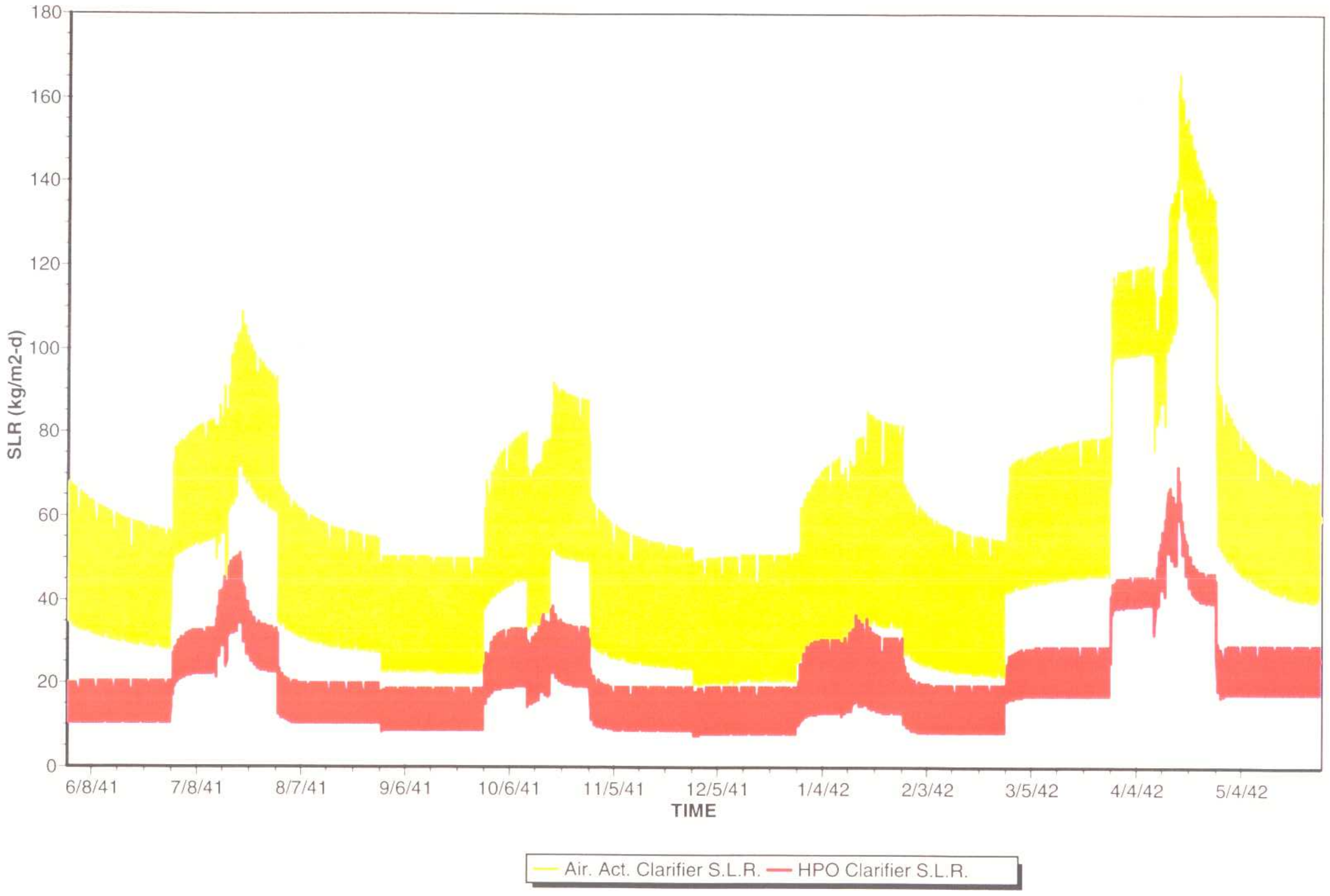
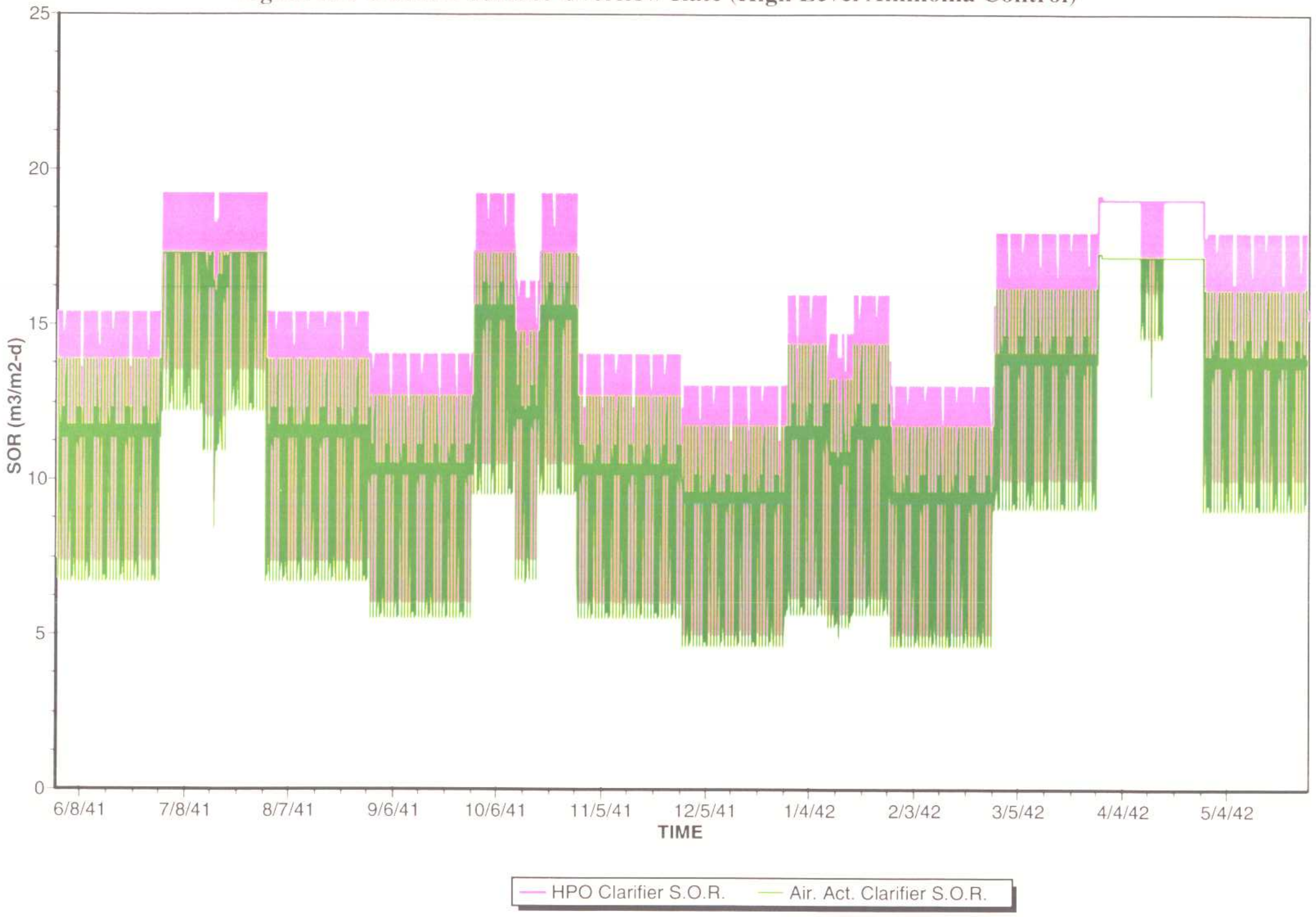


Figure 8.7: Clarifier Surface Overflow Rate (High Level Ammonia Control)



remaining 45 percent of flow will be treated in the existing HPO system. For this portion of the flow, the MLSS concentrations of the HPO bioreactors could be increased to approximately 4,200 mg/L without affecting the performance of the existing clarifiers. Under the flow conditions of 25 to 50 percent flow to the existing system, an approximate MLSS concentration of 4,500 mg/L is required to maintain nitrification process in the existing HPO reactors. As a result, for the flow proportions considered for the high level of ammonia control, it would be possible to increase MLSS concentrations in the existing HPO bioreactors to the levels suitable for the nitrification process. This would allow for nitrification of the remaining 45 percent of the primary effluent and a degree of ammonia removal approaching best practicable reduction.

The NEWPCC final clarifier operational parameters including solids loading rate (SLR) and surface overflow rate (SOR) for the year 2041 flow and load conditions are illustrated in Figures 8.6 and 8.7, respectively. Peak solids loading rates to the existing clarifiers (Figure 8.6) will remain below 75 kg/m^2-d even during the Maximum Week of spring. These loads are less than the load limit of 98 kg/m^2-d, thereby an enhancement in existing clarifier performance is anticipated. The peak SLRs to the new clarifiers would be in the range of 20 to 100 kg/m^2-d except for the Maximum Month of spring when the peak SLR could reach 160 kg/m^2-d during the Maximum Day.

The peak hourly surface overflow rates (SORs) for both systems of clarifiers, as shown in Figure 8.7, indicates variation ranges below 20 m^3/m^2-d, which is suitable for optimal performance of clarifiers.

8.2.5 High Level of Control - Statistical Analysis of the Projected Effluent Ammonia

The results of the statistical analysis on the secondary effluent ammonia concentration for high level of ammonia control are presented in Table 8.6. The assumptions, methodology, and the definitions used for statistical analysis are the same as presented in Section 4.0.

From the results shown in Table 8.6, the following can be concluded:

- Standard deviations (σ and s) indicate that the effluent ammonia has greater variations during summer (June, July and August) than other seasons.
- 95 percent of the samples taken during each month will have ammonia concentrations equal to or less than the values shown in the last column of the table for that month.

Table 8.6: NEWPCC - Results of Statistical Analysis on the Effluent Ammonia (Year 2041 - High Level of Control)

Month	Monthly AA (mg/L)	Ln (GM)	σ/GM	σ	$s_{(30\ days)}$	GM of 30 day averages	95th% 30 day GM	Exp (GM 95th%)
June	6.52	1.87	0.12	0.224	0.041	1.891	1.958	7.09
July	6.15	1.71	0.18	0.307	0.056	1.752	1.844	6.32
August	6.38	1.84	0.12	0.221	0.040	1.868	1.934	6.92
September	7.03	1.94	0.06	0.117	0.021	1.951	1.986	7.28
October	7.51	2.00	0.09	0.180	0.033	2.013	2.067	7.90
November	7.07	1.95	0.06	0.117	0.021	1.956	1.991	7.32
December	8.54	2.14	0.06	0.128	0.023	2.147	2.186	8.90
January	10.18	2.30	0.04	0.092	0.017	2.302	2.329	10.27
February	8.66	2.15	0.06	0.129	0.024	2.161	2.200	9.03
March	7.62	2.02	0.04	0.081	0.015	2.021	2.045	7.73
April	6.86	1.81	0.06	0.108	0.020	1.811	1.844	6.32
May	10.39	2.33	0.04	0.093	0.017	2.332	2.360	10.59

AA = Arithmetic Average
GM = Geometric Mean
σ = Population Standard Deviation
s = Sample Standard Deviation

8.2.6 Modest Level of Control - Parallel System

To achieve the modest level of ammonia control (14 mg/L in summer), primary effluent would be split in the proportions shown in Table 8.7. About 40 percent of the primary effluent would be diverted to the new parallel train which would be a conventional air activated sludge nitrification system. The system will be designed to fully nitrify. The remaining 60 percent of the flow would pass through the existing HPO reactors such that train 1 will receive 10 percent of the flow and the remaining two trains each will receive 25 percent. The load to train 1 would be less than the other trains. This lower load, plus the ventilation of the fourth cells would encourage nitrification within train 1 of the existing HPO system.

Table 8.7: Flow Proportions in Modest Level of Control

Parallel Treatment Trains	Flow Proportion (%)
New Parallel Train	40
Existing HPOAS System	
Train 1	10
Train 2	25
Train 3	25
Total	**100**

The other two trains of the existing HPO system would provide carbonaceous BOD removal only as they do at present. It would be preferable to dedicate the square clarifiers to the HPO nitrifying train as these clarifiers would have the lesser risk of upset due to denitrification in the sludge blankets. Based on preliminary modelling, due to the solids loading rate limitation on the existing secondary clarifiers, each existing train will reach its capacity at about 27 to 30 percent of the 2041 design load.

8.2.7 Process Design and Operating Specification – Modest Level of Control with Parallel Treatment

The new parallel air activated sludge system would be designed to nitrify 40 percent of the year 2041 primary effluent flow. The new system will consist of three bioreactors and four final clarifiers. The design data are presented in Table 8.8. The new bioreactors will have a total volume of 30,000 m^3 and operate at an SRT of 10 to 15 days. Each bioreactor will have one inlet anoxic zone with capacity of approximately 5 ML followed by two aerobic zones each with approximate capacity of 12.5 ML. The initial anoxic zone will cause denitrification of some of the nitrates present in the RAS line. It also improves settling properties of the biological floc and reduces the oxygen requirement. Mixing in the anoxic zones will be provided by a 16 kW mixer. Aeration in the aerobic zones will be supplied by a fine bubble diffused aeration system supported by blowers each with a capacity of 200 nm^3/min. Two blowers will operate for average loading conditions and three at maximum loading conditions.

The effluent from the bioreactors will flow to four circular clarifiers, each 52 m in diameter. The effluent from these clarifiers will be blended with the effluent from the existing HPO system to form the final effluent of the NEWPCC prior to the disinfection process.

A refinement of the parallel plant approach would be to implement separate treatment of centrate to take advantage of the ammonia reduction by this method. Centrate treatment, as discussed in Section 6.0, will reduce the influent ammonia load by approximately 25 percent. By nitrifying the centrate directly, the new parallel treatment train could be downsized, while still achieving the modest level of control. Another advantage is that the implementation could be staged, whereby the first step would be to construct the centrate treatment facility, and the second step to construct the parallel nitrifying treatment trains.

Table 8.8: Design Data for Nitrification System (Moderate Level of Ammonia Control with Parallel Treatment Train)

Description	Units	Values
Bioreactors		
Basic Design Parameters		
SRT	d	10-15
HRT	h	6.5
MLSS	mg/L	2000-4000
Number of Bioreactors		3
Total Volume	m^3	~30000
Bioreactor Dimension		
LxWxD	m	86x26x4.5
Bioreactor Zone Volumes		
Anoxic	m^3	1638
Aerobic 1	m^3	4212
Aerobic 2	m^3	4212
Bioreactor Mixing		
Anoxic		
Number of Mixers		1
Mixer Size	kW	16
Actual Oxygen Demand		
Aerobic 1		
Average	mg/L/h	34.9
Maximum	mg/L/h	62.8
Aerobic 2		
Average	mg/L/h	30.5
Maximum	mg/L/h	48.8
Aeration Parameters		
α, alpha		
Aerobic 1		0.55
Aerobic 2		0.60
β, beta		
Aerobic 1		0.95
Aerobic 2		0.95
Residual DO		
@ average demand	mg/L	2
@ peak demand	mg/L	1
Standard Oxygen Transfer Rate		
Aerobic 1		
Average	kg/d	8461
Maximum	kg/d	13403
Aerobic 2		
Average	kg/d	6778
Maximum	kg/d	10011

Table 8.8: Design Data for Nitrification System (Moderate Level of Ammonia Control With Parallel Treatment Train) [continued]

Description	Units	Values
Bioreactors (continued)		
Blowers		
Number		4
@ Average Flow		2
@ Maximum Flow		3
Standby		1
Capacity per Blower	nm^3/min	200
Size	kW	300
Clarifiers		
Basic Design Parameters		
Surface Overflow Rate (SOR)		
Average	m^3/m^2-h	0.4
Peak	m^3/m^2-h	0.6
Solids Loading Rate (SLR)		
Average	kg/m^2-h	2.4
Peak	kg/m^2-h	5.8
Number of Units		4
Dimensions		
Diameter	m	52
Side wall depth (SWD)	m	5
Floor Slope	percent	2

Table 8.9: Flow Proportions With Implementation of Separate Centrate Treatment (Modest Level of Ammonia Control with Parallel Treatment Train)

Treatment Trains	Flow Proportion (%)
New Parallel Train	34
Existing HPOAS System	
Train 1	22
Train 2	22
Train 3	22
Total	**100**

With implementation of centrate treatment, the split of flow between the existing HPO facilities and the new parallel nitrifying system would be approximately 66 percent and 34 percent, respectively, as shown in Table 8.9. The reduction of flow to the new parallel system will allow downsizing of the nitrification tankage volume to approximately 26,000 m^3 as compared to the 30,000 m^3 required volume without the use of centrate treatment. Centrate treatment does not affect the size of new clarifiers. The major tankage components with approximate sizing are shown in Table 8.10.

Table 8.10: Tankage Component (Separate Centrate Treatment + New Parallel Treatment Train for Modest Level of Ammonia Control)

Description	Units	Values
New Parallel Line Bioreactors		
Number		3
Total Volume	m^3	~ 26000
Dimension (LxWxD)	m	86x22x4.5
New Parallel Line Final Clarifiers		
Number		4
Diameter	m	52
SWD	m	5
Centrate Treatment Bioreactor		
Number		2
Total Volume	m^3	4800
Dimension (LxWxD)	m	20x20x6
Centrate Treatment Final Clarifiers		
Number		2
Diameter	m	12

8.2.8 Modest Level of Control – Site Layouts for Parallel Treatment Train

Dwg. NE-8.4 and Dwg. NE-8.5 illustrate the approximate layout of the new bioreactor and final clarifier tankage on the existing NEWPCC site. The three new bioreactors would be located immediately to the south of the existing HPO bioreactors. The four new final clarifiers would be located immediately to the west of both the existing and the new bioreactor tankage. All of the new tankage would be covered to facilitate operation under winter conditions. Secondary effluent from the new tankage would be routed along the north side of the existing bioreactors and final clarifiers. This effluent line will be joined to the existing outfall effluent line at the northeast section of the treatment plant. The blower building housing the new blowers for the new bioreactors would be located in one corner of the building housing the final clarifiers.

8.2.9 Modest Level of Control - Model Output for Parallel Treatment Train

Computer simulation of the parallel treatment process with centrate treatment for modest removal of ammonia under the flow and load conditions of year 2041 resulted in the projections presented in Figures 8.8 to 8.13. The vertical bandwidth of each parameter plotted on these figures is indicative of the daily diurnal variation of the parameter.

Figure 8.8 illustrates diurnal variations of the influent and the final effluent ammonia concentrations in different seasons. The new nitrifying system together with centrate treatment and the existing HPO system will provide ammonia removal efficiencies in the range of 35 to 55 percent. The average effluent ammonia concentration will be less than 12 mg/L during summer months except during the Maximum Week when the average concentration would reach to about 16 mg/L. For other seasons of the year

Figure 8.8: Influent Versus Effluent Ammonia Concentration (Modest Level of Control)

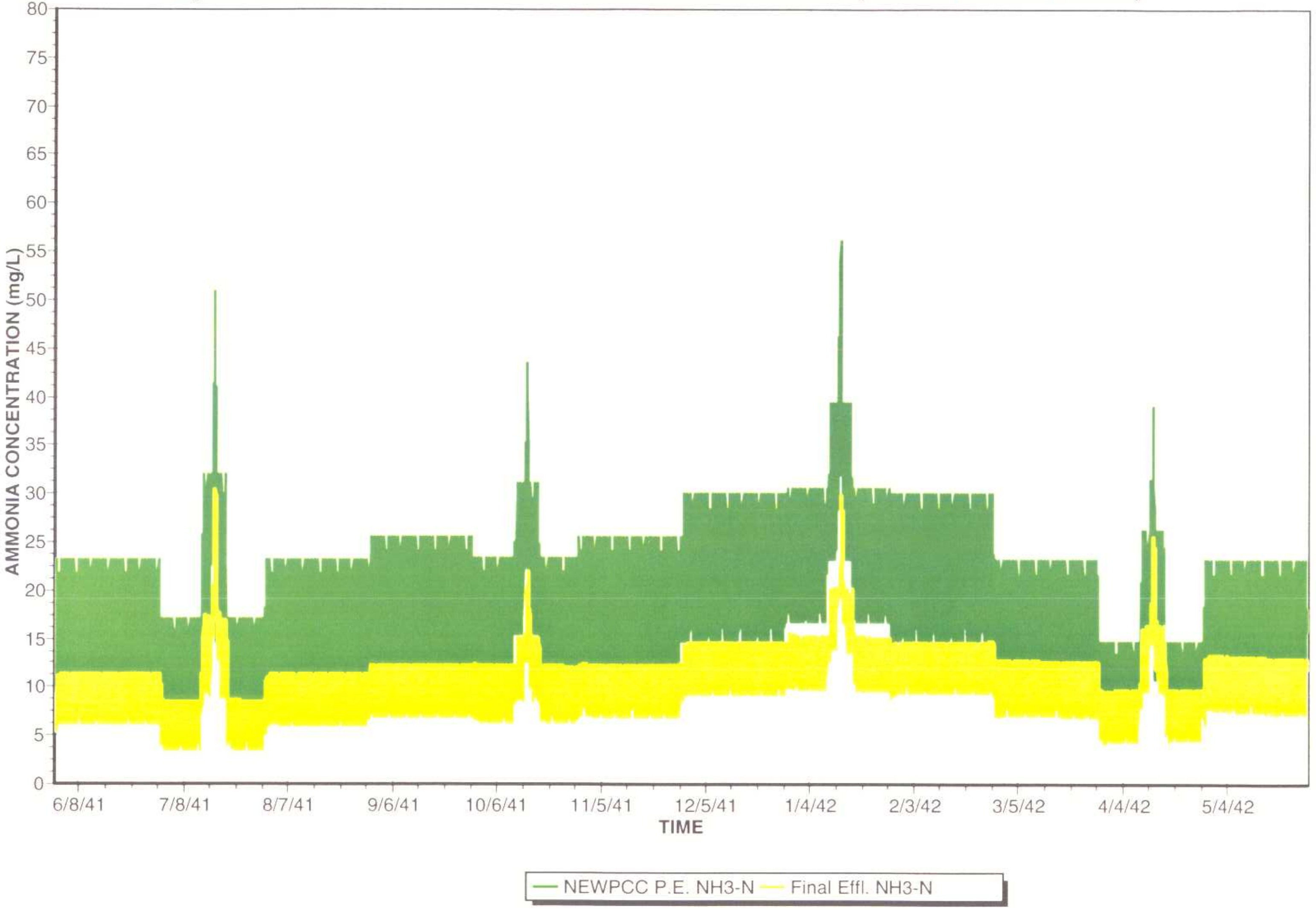


Figure 8.9: Influent Versus Effluent TKN Concentration (Modest Level of Ammonia Control)

Figure 8.10: Ammonia Concentration in Different Effluent Lines (Modest Level of Control)

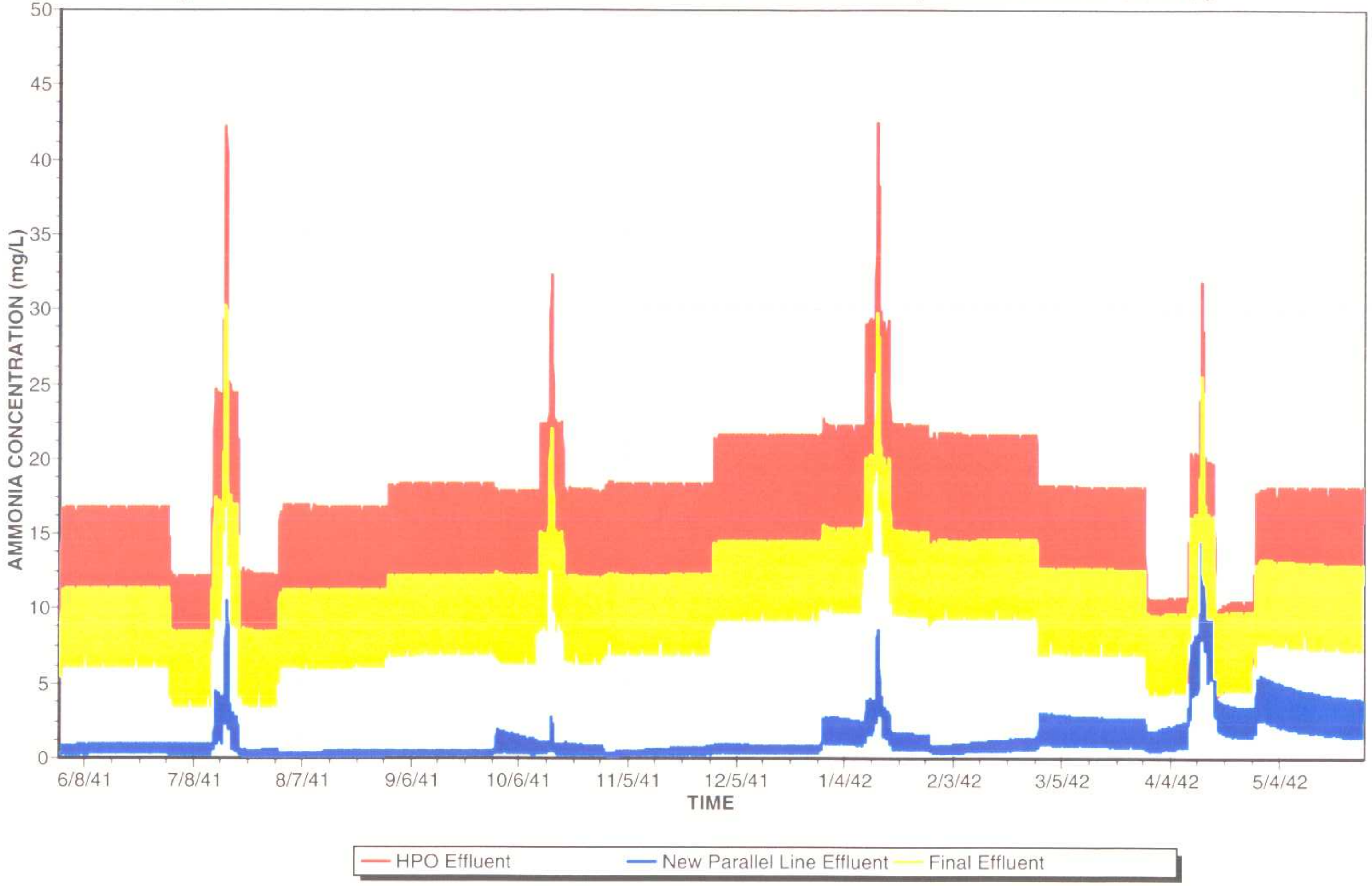


Figure 8.11: Bioreactor MLSS (Modest Level of Ammonia Control)

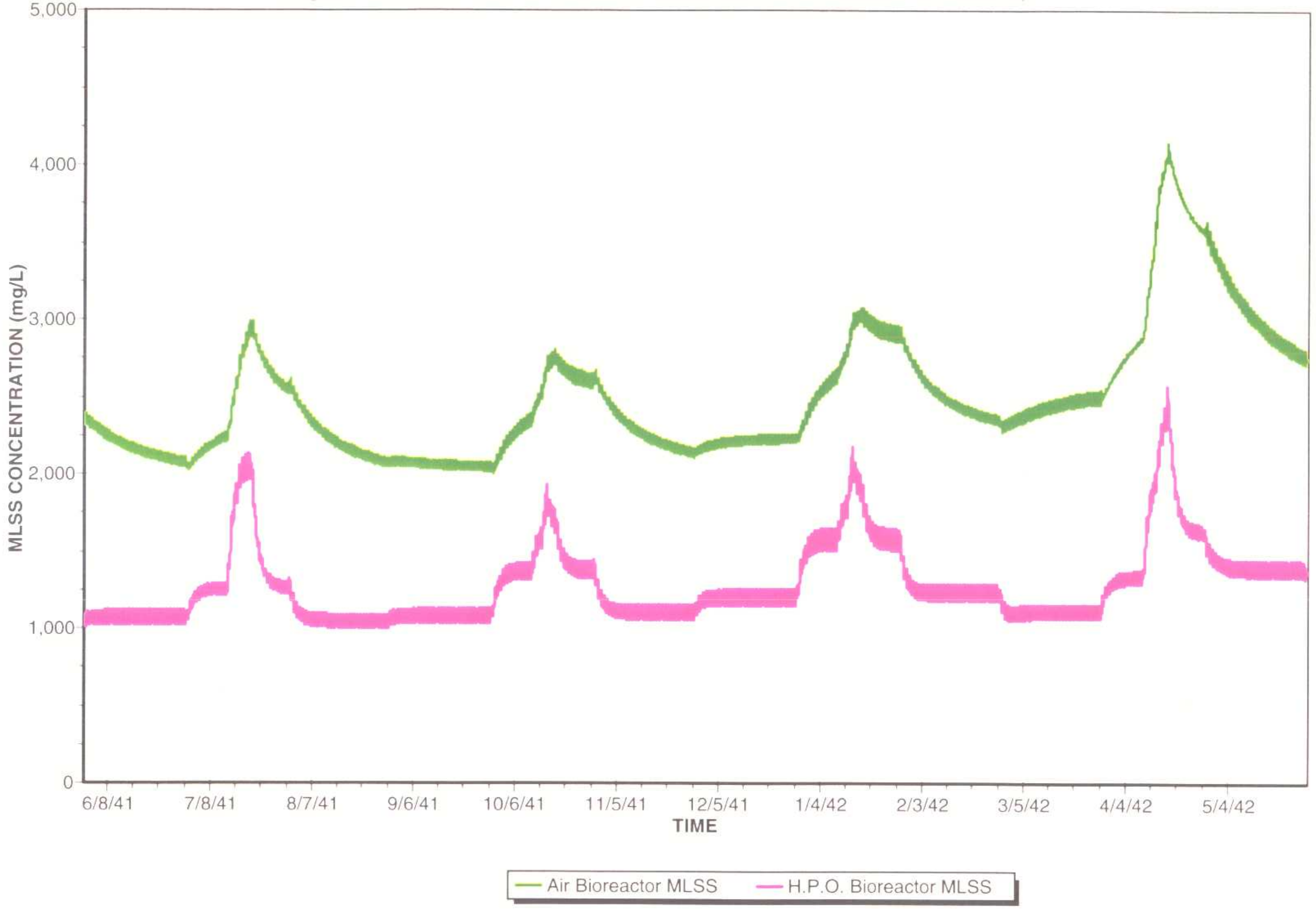


Figure 8.12: Projected Clarifier Solids Loading Rate (Modest Level of Ammonia Control)

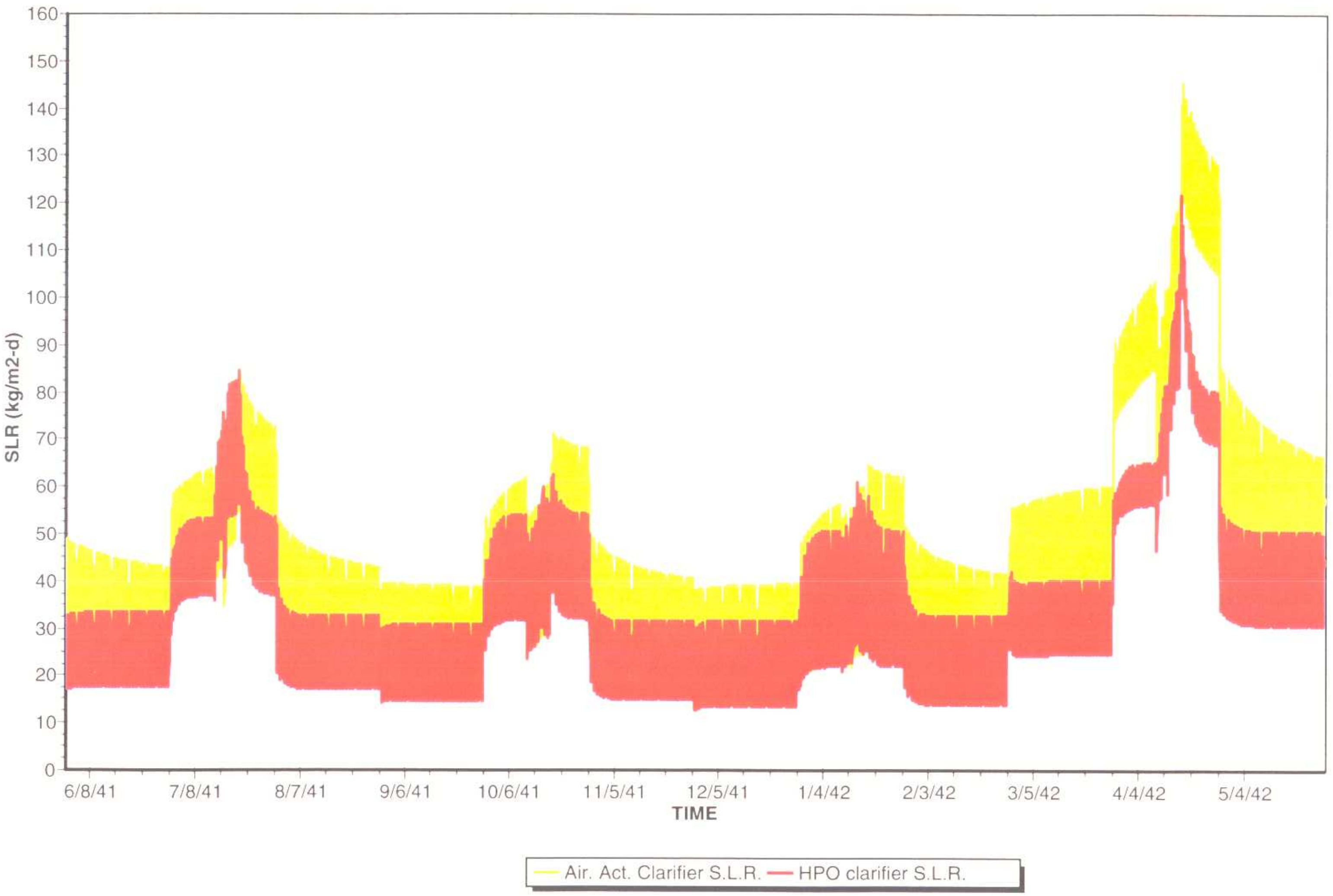


Figure 8.13: Projected Clarifier Surface Overflow Rate (Modest Level of Ammonia Control)

(except for the Maximum Weeks), the average ammonia concentration in the blended plant effluent would vary in the range of 10 to 15 mg/L.

Figure 8.10 presents the contribution of each system - the existing system, and the new parallel system - to the blended effluent ammonia concentration. The average range of the ammonia concentration in the effluent from the HPO system is several times higher than the range in the effluent from the new nitrifying system. As a result, the ammonia content of the final blended effluent will originate mainly from the HPO system. This is expected because this system would receive the larger portion of the flow and it is not operated as a nitrifying system.

The influent and the final effluent TKN concentrations (Figure 8.9) show variations similar to those observed for ammonia concentrations in Figure 8.8.

The projected bioreactor MLSS concentrations are shown in Figure 8.11, which illustrates variations in the range of 2000 to a peak of 4000 mg/L for the new nitrifying bioreactor and 1000 to a peak of 2400 mg/L for the existing HPO bioreactors.

The projections of the 360 day solids loading rates (SLR) and surface overflow rates (SOR) to the final clarifiers under the flow and load conditions of the year 2041 are shown in Figures 8.12 and 8.13, respectively. Figure 8.12 indicates that the peak solids loading to both systems of clarifiers including the existing and new ones would be well below 90 kg/m^2-d during summer, fall and winter months as well as during spring average months. Spring Maximum Month would be the critical period because peak SLRs would reach values in excess of 100 kg/m^2-d. The peak solids loading rate could reach as high as 125 kg/m^2-d for the existing clarifiers and to the range of 110 to 140 kg/m^2-d for the new clarifiers during spring Maximum Month and Maximum Week periods. At the NEWPCC, spring flows typically contain considerable quantities of fine silt due to the combined sewer system. As noted in Section 4.0 of this report, this silty material is picked up by the biological floc and “weights it down”, thus leading to improved settleability. Therefore, such high peak SLR values are not perceived to be a problem, but this will have to be evaluated in more detail before implementation.

The hourly clarifier surface overflow rates (Figure 8.13), being a function of wastewater flow, show considerable fluctuations in both systems over the 360 day period. The fluctuations, however, are within the range suitable for good performance of final clarifiers. The SORs would be in the range of 8 to 29 m^3/m^2-d for the existing HPO clarifiers, and 4 to 14 m^3/m^2-d for the new nitrification system clarifiers.

8.2.10 Modest Level of Control - Statistical Analysis of the Projected Effluent Ammonia

The results of the statistical analysis on the secondary effluent ammonia concentration (using moderate level of control) are presented in Table 8.11. The assumptions, methodology and the definitions used are the same as those described previously in Section 4.0 for statistical analysis of the data related to the Best Practicable Level of Control.

From the results shown in Table 8.11, it can be concluded that:

- 95 percent of the samples taken during each month will have ammonia concentrations equal or less than the values shown in the last column of the table for that month.
- During summer months (June, July and August), the effluent ammonia concentrations show higher variation than during other months.

Table 8.11: NEWPCC - Results of Statistical Analysis on the Effluent Ammonia (Year 2041 - Modest Level of Control)

Month	Monthly AA (mg/L)	Ln (GM)	σ/GM	σ	$s_{(30\ days)}$	GM of 30 day averages	95th% 30 day GM	Exp (GM 95th%)
June	9.35	2.22	0.12	0.267	0.049	2.255	2.335	10.33
July	8.56	2.03	0.18	0.366	0.067	2.098	2.208	9.10
August	9.22	2.21	0.12	0.265	0.048	2.240	2.320	10.17
September	10.18	2.31	0.06	0.139	0.025	2.318	2.359	10.58
October	10.69	2.34	0.09	0.211	0.039	2.366	2.429	11.35
November	10.24	2.31	0.06	0.139	0.025	2.324	2.366	10.65
December	12.36	2.51	0.06	0.150	0.027	2.517	2.563	12.97
January	14.42	2.65	0.04	0.106	0.019	2.652	2.684	14.64
February	12.51	2.52	0.06	0.151	0.028	2.530	2.575	13.14
March	10.57	2.34	0.04	0.094	0.017	2.349	2.377	10.78
April	8.07	1.99	0.06	0.119	0.022	1.993	2.028	7.60
May	10.97	2.38	0.04	0.095	0.017	2.386	2.415	11.19

AA = Arithmetic Average
GM = Geometric Mean
σ = Population Standard Deviation
s = Sample Standard Deviation

8.3 REAERATION OF RETURN ACTIVATED SLUDGE (RAS)

Another method for achieving the aerobic sludge age required for nitrification is to aerate the RAS before it is returned to the HPO bioreactors. This process is often called RAS reaeration and is illustrated schematically in Figure 8.14. This option is somewhat similar to a step feed method in that a portion of bioreactors is maintained at a higher MLSS concentration, thus allowing an increase in SRT without the need for increasing the volume of the bioreactor.

A compressed air system would be used to supply air to the RAS reaeration zone. In addition, the first cells of each HPO train would be converted to anoxic zones to recover some alkalinity and decrease oxygen consumption.

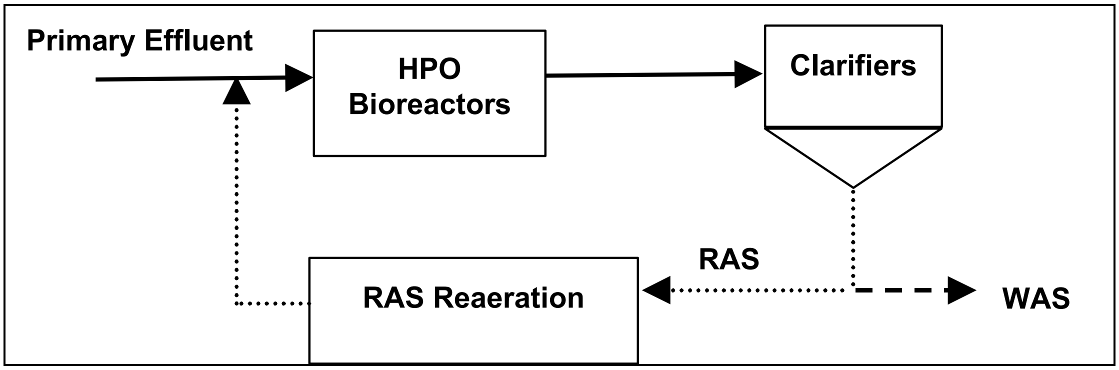


Figure 8.14: RAS Reaeration With the Existing HPO system

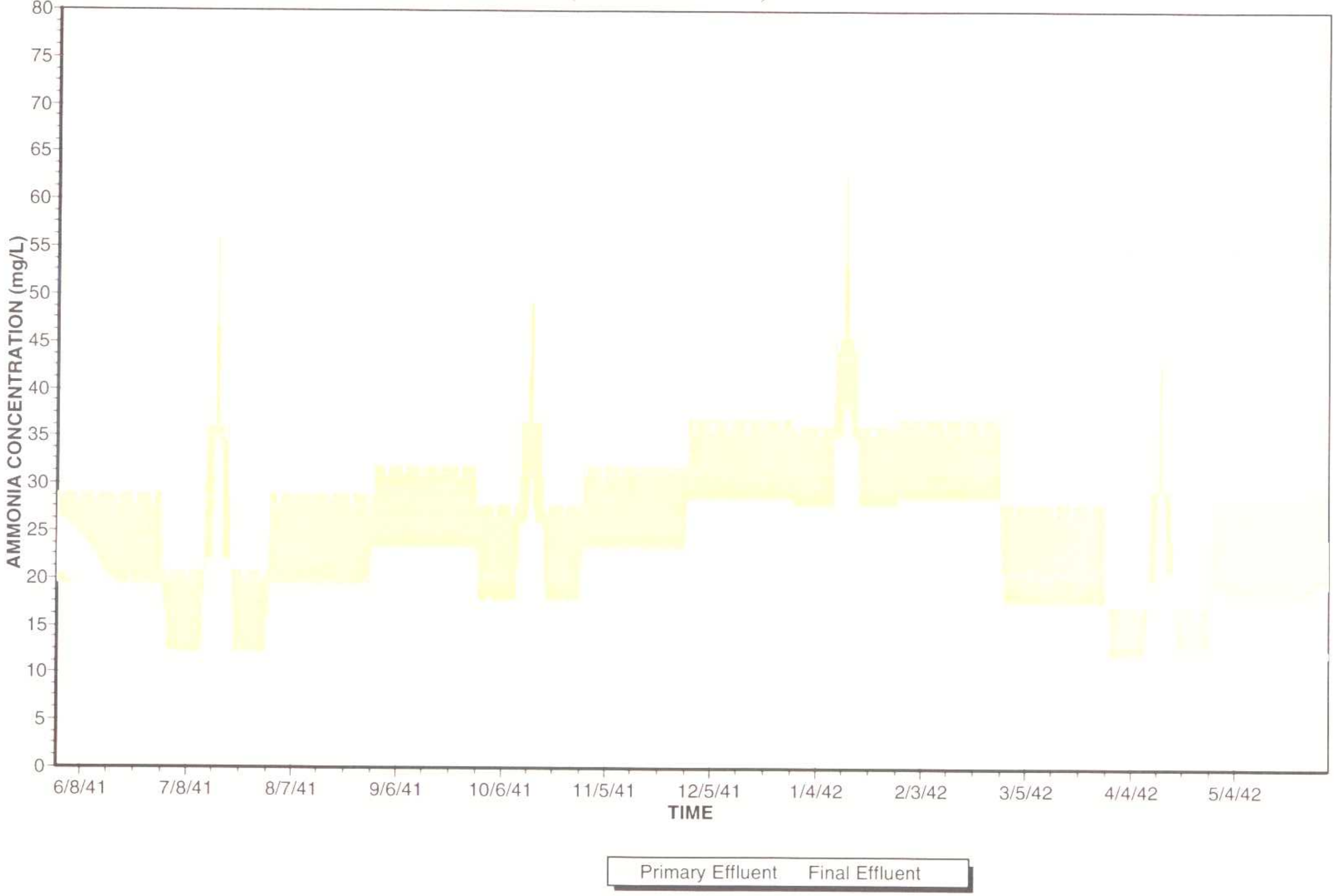
In a RAS reaeration system, a portion of the ammonia escaping the mainstream treatment system is returned to the bioreactors in the RAS flow and would, presumably, be nitrified. In addition, the nitrifying population would be continuously seeded into the main flow treatment basins (HPO) and some additional nitrification would take place. RAS reaeration is also an effective means to protect the solids inventory from washout during wet weather events because most of the solids are retained in tankage that does not directly accept fluctuating primary effluent flows.

Concern exists over whether RAS reaeration will develop and maintain a sufficient nitrifier population to provide reliable levels of ammonia control. The ammonia concentration in RAS flow (approximately the same as concentration in the final effluent) may not be sufficient to support a flourishing nitrifying biomass. To mitigate this risk somewhat, this concept could be configured so that it could eventually be upgraded and integrated into one of the previous options should it be found that adequate nitrification does not occur.

8.3.1 Modest Level of Control - RAS Reaeration

The major tankage component that would have to be added is the RAS reaeration basins having a total volume of approximately 25,000 m^3 as shown in Table 8.12. Based on cursory initial modeling, considerable reduction in ammonia could be achieved as shown in the projections of influent and final effluent ammonia concentrations in Figure 8.15. The results indicate effluent ammonia concentrations of

Figure 8.15: Influent versus Effluent Ammonia Concentration - Modest Level of Control (RAS Reaeration)



less than 15 mg/L for most parts of the summer. However, the concentration would increase to levels greater than 15 mg/L during early to mid summer.

Table 8.12: RAS Reaeration Tankage Capacity

Description	Units	Values
RAS Reaeration Basins		
Number of Bioreactors		2
Dimensions (L x W x D)	m	80 x 26 x 6.0
Total Volume	m^3	~ 25,000

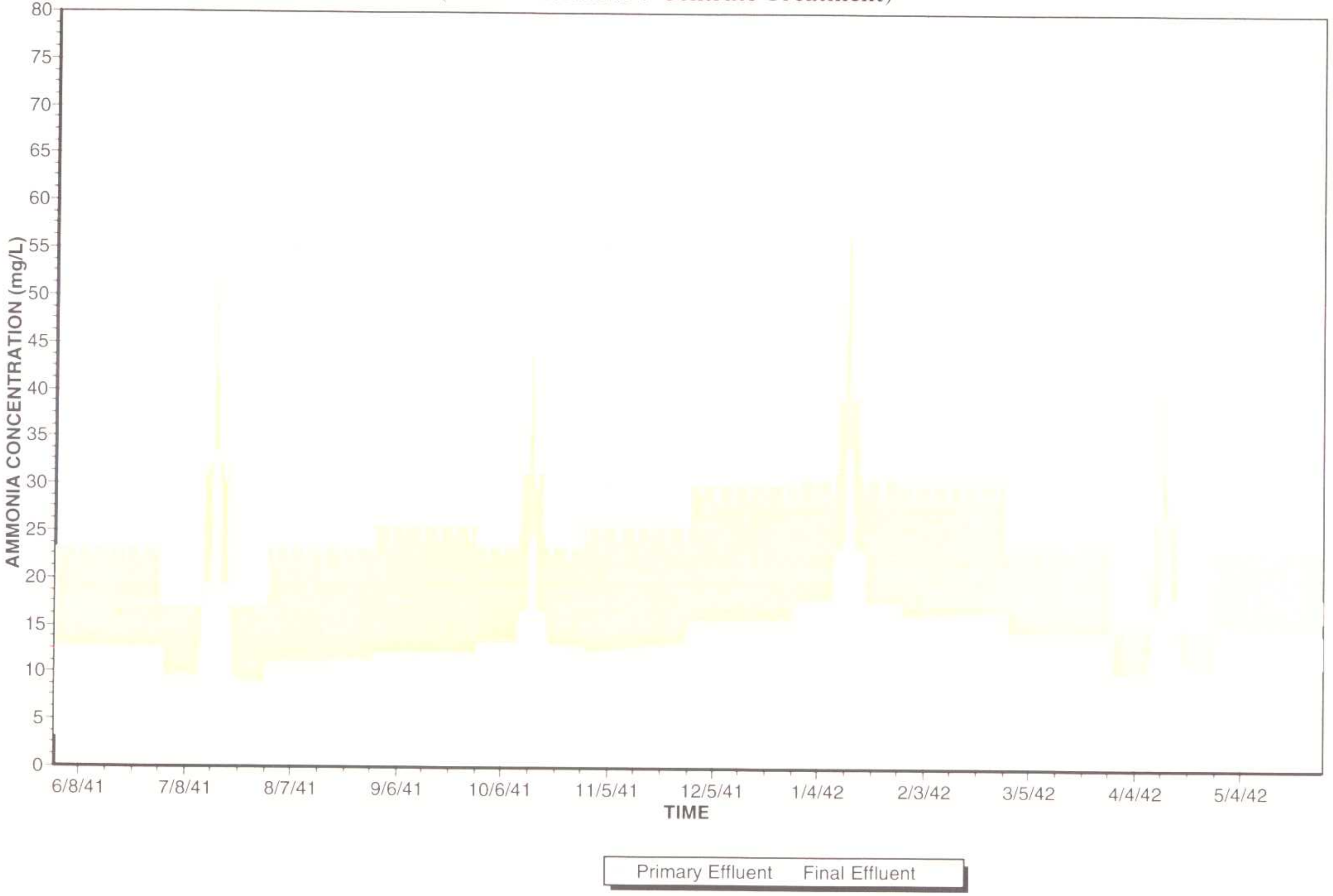
A refinement to the RAS reaeration approach that would improve the ammonia removal performance could incorporate the separate treatment of centrate to take advantage of the ammonia removal provided by this step. Based on the initial cursory modeling, the major tankage components that would have to be added are those shown in Table 8.13. The preliminary process modeling work (Figure 8.16) indicates that, with centrate treatment included, the effluent ammonia concentrations of less than 14 mg/L could be achieved during most months including summer months. However, while an improvement in effluent ammonia concentration can be realized, the performance of the system would not be adequate to meet the high level of control of 8 mg/L.

Table 8.13: Tankage Component (RAS Reaeration + Centrate Treatment)

Description	Units	Values
RAS Reaeration Basins		
Number		2
Dimensions (L x W x D)	m	80 x 26 x 6.0
Total Volume	m^3	~ 25000
Centrate Treatment Bioreactor		
Number		2
Total Volume	m^3	4800
Dimension (LxWxD)	m	20x20x6
Centrate Treatment Final Clarifiers		
Number		2
Diameter	m	12

One of the most significant concerns regarding RAS reaeration relates to the fact that the RAS pumping rates currently being used at the plant would have to be increased to obtain the degree of nitrification desired. This has implications on the adequacy of the existing secondary clarifiers. In other words, additional secondary clarifiers may be needed to make this option work and not exceed the apparent solids loading capability of the existing secondary clarifiers.

Figure 8.16: Influent Versus Effluent Ammonia Concentration - Modest Level of Control
(RAS Reaeration + Centrate Treatment)



8.3.2 High Level of Control – RAS Reaeration

As noted above, some concern exists over whether the RAS reaeration option will work as anticipated. A higher degree of confidence would exist if the reaeration basin also receives an ammonia-rich feed source (e.g. centrate) in excess of the concentrations in the general RAS flow. By supplementing the RAS reaeration basin with centrate feed, a healthy population of nitrifiers would grow in the system, primarily in the RAS reaeration zone. This would also increase nitrification activity in the existing HPO tankage. A schematic diagram of this process is illustrated in Figure 8.17. In this option, the RAS reaeration tankage would remain the same size (25,000 m^3) as in the preceding alternative. A pumping and piping system, however, would have to be constructed to convey the centrate to the RAS basin. Again, increased RAS pumping rates would be required to effectively accomplish this treatment concept which, in turn, may require additional secondary clarifier construction due to the solids loading limitations of the existing units.

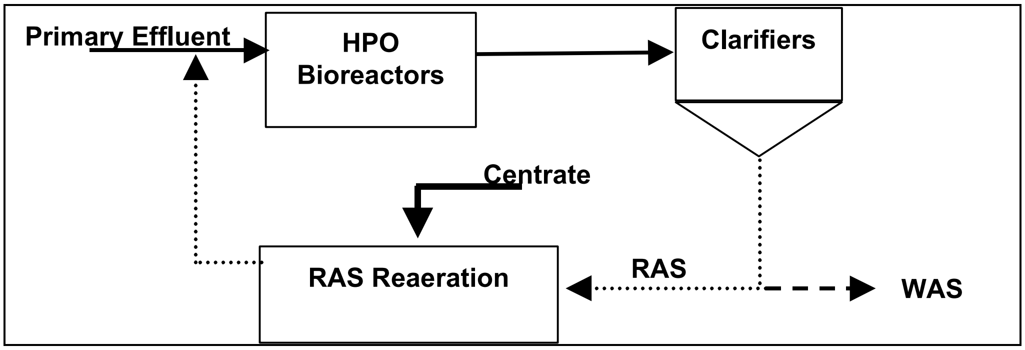


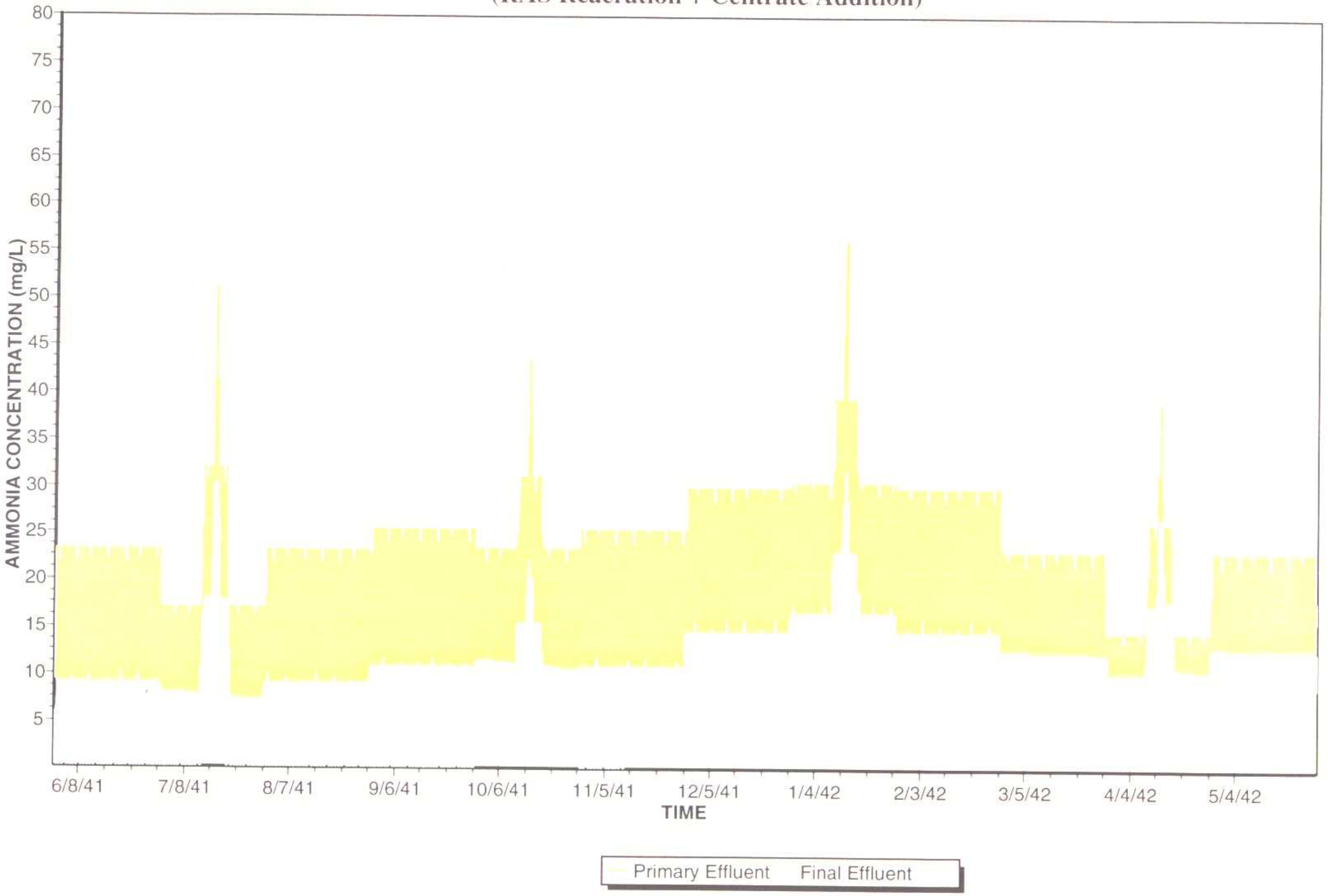
Figure 8.17: RAS Reaeration with Addition of Centrate

The preliminary modelling results, shown in Figure 8.18, indicate that centrate addition directly to the RAS reaeration zone retrofitted to the existing HPO system has the potential to meet the second priority high level ammonia control at the NEWPCC. With the exception of the maximum week, the effluent ammonia concentration would be less than 8 mg/L during summer months and most of fall season, and less than 15 mg/L during the rest of the year. Should this prove true, then this alternative would provide a relatively economical solution to achieve the high level of control. However before recommending implementation of this alternative, pilot testing should be done to verify the predicted performance of the model.

8.3.3 RAS Reraeration Site Layout

A tentative layout for two new RAS reaeration tanks is illustrated in Dwg. NE-8.6 and the process flow diagram is shown in Dwg. NE-8.7. The dimensions of the two reaeration tanks are sized such that they may easily be incorporated into other nitrification upgrade options at the NEWPCC discussed in this report.

Figure 8.18: Influent Versus Effluent Ammonia Concentration - High Level of Control (RAS Reaeration + Centrate Addition)



8.4 WASTE ACTIVATED SLUDGE THICKENING

The quantity of waste activated sludge (WAS) generated for the second priority control alternatives under 2041 flow and loading conditions at the NEWPCC would be essentially the same as for the best practicable level of control alternatives. Thus, the approach to separate thickening of WAS as developed in Section 4.0 of this report are applicable to Section 8.0 as well.

8.5 COMPARISON OF ALTERNATIVES AND SELECTION OF OPTIONS TO CARRY FORWARD

In this section, a summary of the alternatives is provided as well as the rational for selecting one alternative on which to base the conceptual design of the second priority levels of control for the NEWPCC.

On subsequent pages, presented in Table 8.14, the various alternatives are judged in accordance with non-economic criteria that include:

- Complexity and operability
- Robustness and reliability
- Expandability with respect to increased flows and loads
- Expandability with respect to a tighter ammonia permit
- Expandability with respect to implementation of phosphorus removal
- Constructability while maintaining continuing plant operation
- Space requirements for the process
- Aesthetics

On examining the results of the application of the criteria in the Table 8.14, it is noted that the existing HPO with RAS reaeration alternatives appear to be the most attractive of the activated sludge systems, particularly with respect to the complexity and operability criterion. However, the criterion for robustness and reliability indicates that the RAS reaeration alternatives should be pilot-tested prior to full-scale implementation. This is related to the uncertainty of getting the RAS reaeration process to operate in continuous nitrifying mode in a full-scale system. As a result, a conservative approach has been adopted and the process alternatives involving the construction of new activated sludge treatment trains to operate in parallel with the existing HPO system have been selected for the purposes of this study. Regardless should the City be required to implement a Second Priority Control Alternative, it is strongly recommended that one of the RAS reaeration alternatives be considered and that pilot testing be done to confirm the feasibility of the process for the NEWPCC as considerable economies would be gained should the process prove feasible.

Based on the foregoing, the approach of constructing a new parallel treatment train is selected as the basis of the conceptual design for the Second Priority Levels of Control. Because separate centrate treatment provides a significant reduction in the facilities required to meet any of the levels of control, it is assumed that this will be included as the first step.

The main advantage of centrate treatment is that the new mainstream parallel system would be somewhat smaller due to the separate treatment of the centrate than if all nitrification were to be accomplished in the main treatment trains. Another advantage is that the implementation could be staged, whereby the first step would be to construct the centrate treatment facility, and then construct the parallel nitrifying treatment trains as a second phase. Furthermore, to achieve the Best Practicable Levels of Control, the parallel train could be expanded to provide full nitrification of the full plant dry weather flow using the configuration set out for achieving the Best Practicable Level of Control (i.e., 2 mg/L summer and 6 mg/L spring).

Independent treatment of centrate also provides the opportunity to chemically tie up the phosphorus released in anaerobic digestion should biological phosphorus removal be required in the future.

Table 8.14: Comparison of the Alternatives Based Upon Non-economic Criteria

Alternative	Level of Ammonia Control	Major Components	Criteria Application	
Construct a New Activated Sludge Treatment Train in Parallel with the Existing HPO Plant:				
40% of PE to new parallel train	Modest	Bioreactors – 30,000 m^3 4 clarifiers @ 52 m dia	Complexity & Operability	2 A/S plants to operate & maintain
			Robustness & Reliability	OK
			Expandability – Flows & Loads	Add more parallel A/S trains
			Expandability – Tighter NH3-N	Add more parallel A/S trains
			Expandability – P Removal	Chem P needs more clarifiers; Bio-P more bio tanks
			Constructability during Operation	Generally OK; some tie-ins required
			Space Requirements	Consumes large area
			Aesthetics	Similar to existing & not readily visible from street
34% of PE to new parallel train with separate centrate treatment	Modest	Bioreactors – 26,000 m^3 4 clarifiers @ 52 m dia Centrate bioreactor – 4800 m^3 Centrate clarifiers – 2 @ 12 m dia	Complexity & Operability	3 A/S plants to operate & maintain
			Robustness & Reliability	OK
			Expandability – Flows & Loads	Add more parallel A/S trains
			Expandability – Tighter NH3-N	Add more parallel A/S trains
			Expandability – P Removal	Chem P needs more clarifiers; Bio-P more bio tanks
			Constructability during Operation	Generally OK; some tie-ins required
			Space Requirements	Consumes large area
			Aesthetics	Similar to existing & not readily visible from street
45% of PE to new parallel train with separate centrate treatment	High	Bioreactors – 35,000 m^3 4 clarifiers @ 52 m dia Centrate bioreactor – 4800 m^3 Centrate clarifiers – 2 @ 12 m dia	Complexity & Operability	4 A/S/ plants to operate & maintain
			Robustness & Reliability	OK
			Expandability – Flows & Loads	Add more parallel A/S trains
			Expandability – Tighter NH3-N	Add more parallel A/S trains
			Expandability – P Removal	Chem P needs more clarifiers; Bio-P more bio tanks
			Constructability during Operation	Generally OK; some tie-ins required
			Space Requirements	Consumes large area
			Aesthetics	Similar to existing & not readily visible from street

Table 8.14: Comparison of the Alternatives Based Upon Non-economic Criteria (continued)

Alternative	Level of Ammonia Control	Major Components	Criteria Application	
Existing HPO with Reaeration of the Return Activated Sludge (RAS) Flow:				
RAS reaeration only	Modest	Reaeration basin – 25,000 m^3	Complexity & Operability	1 A/S plant to operate & maintain
			Robustness & Reliability	Should be pilot tested
			Expandability – Flows & Loads	Add more HPO and/or RAS reaeration tankage
			Expandability – Tighter NH3-N	Add more HPO and/or RAS reaeration tankage
			Expandability – P Removal	Chem P needs more clarifiers; Bio-P more bio tanks
			Constructability during Operation	Generally OK; some tie-ins required
			Space Requirements	Consumes less space
			Aesthetics	Similar to existing & not readily visible from street
RAS reaeration with separate centrate treatment	Modest	Reaeration basin – 25,000 m^3 Centrate bioreactor – 4800 m^3 Centrate clarifiers – 2 @ 12 m dia	Complexity & Operability	2 A/S/ plants to operate & maintain
			Robustness & Reliability	Should be pilot tested
			Expandability – Flows & Loads	Add more HPO and/or RAS reaeration tankage
			Expandability – Tighter NH3-N	Add more HPO and/or RAS reaeration tankage
			Expandability – P Removal	Chem P needs more clarifiers; Bio-P more bio tanks
			Constructability during Operation	Generally OK; some tie-ins required
			Space Requirements	Consumes less space
			Aesthetics	Similar to existing & not readily visible from street
RAS reaeration with centrate feed directly to RAS reaeration basin	High	Reaeration basin – 25,000 m^3	Complexity & Operability	1 A/S plant to operate & maintain
			Robustness & Reliability	Should be pilot tested
			Expandability – Flows & Loads	Add more HPO and/or RAS reaeration tankage
			Expandability – Tighter NH3-N	Add more HPO and/or RAS reaeration tankage
			Expandability – P Removal	Chem P needs more clarifiers; Bio-P more bio tanks
			Constructability during Operation	Generally OK; some tie-ins required
			Space Requirements	Consumes less space
			Aesthetics	Similar to existing & not readily visible from street

8.6 ESTIMATED COSTS

The cost estimating approach set out in Section 2.4 has been used to develop representative estimates of the total cost of ownership of the facilities required to achieve the Second Priority Levels of Control for the NEWPCC. The details of the estimates are presented in Appendix A. The 95 percent confidence limit estimates are summarized in Table 8.15.

Table 8.15: Summary of Estimated Costs - Second Priority Level of Control

	Modest Level of Control	High Level of Control
Target Effluent Ammonia Concentration (Summer Dry Weather)	14 mg/L	8 mg/L
Capital Cost	$84,100,000	$92,900,000
O&M Cost	$1,610,000	$1,870,000
Total Cost (Net Present Value – 4% Discount Rate)	$117,300,000	$131,800,000