SECTION 4.0
BEST PRACTICABLE LEVEL OF CONTROL

4.1 PREAMBLE

The target ammonia effluent concentrations for Best Practicable Level of Control for the City of Winnipeg Water Pollution Control Centres (WPCCs) are based on a proposed summer concentration of 2 mg/L, with the average not exceeding 6.0 mg/L during spring. The WPCCs will have to treat greater flows and loads by the end of the design life of the facilities (year 2041). To achieve these effluent objectives at the higher flows and loads, the treatment plants will need to operate at solids retention times (SRTs) that are much longer than the SRTs at which the plants are currently operated. For the North End Water Pollution Control Centre (NEWPCC) and the South End Water Pollution Control Centre (SEWPCC), new tankage will be required to maintain the required higher solids inventory at reasonable mixed liquor suspended solids (MLSS) concentrations in the bioreactors and solids loading rates on the final clarifiers. pH control will also be required to ensure that low values do not inhibit autotrophic activity.

4.2 NORTH END WATER POLLUTION CONTROL CENTRE (NEWPCC)

4.2.1 Model Input

BioWin™ has been used to model the bioreactors. Estimated 2041 hourly flows and loads, illustrated in Figures 2.4 to 2.8, Section 2.2.2, were used as data input to all the simulation runs performed to model the proposed nitrification upgrading options and their performance. Hourly inputs were derived for each day of the 360 days of a synthetic "year" so that a realistic annual pattern could be input to the computer model. The development of hourly flows and loads, and the approach to modeling have been discussed in detail in Sections 2.2.2 and 2.3, respectively.

The partitioning constants used to describe the wastewater characteristics necessary for the model were listed in Table 2.11.

The secondary treatment process will treat flows up to 400 ML/d. Consistent with current practice at the NEWPCC, primary effluent flows in excess of 400 ML/d are assumed to bypass around the secondary section of the plant in all the process options evaluated.

4.2.2 Preliminary Considerations and the Selected Option

There are two approaches that can be taken to provide the additional secondary treatment tankage required for nitrification at the NEWPCC:

Option A: Increase the bioreactor tankage to provide sufficient solids inventory to maintain nitrifying organisms in the system but still be able to operate within the solids loading limitations of the existing square (with rounded corners) and rectangular final clarifiers.

Option B: De-rate the existing high purity oxygen (HPO) aeration tankage and associated square and rectangular final clarifiers and construct new activated sludge bioreactor and final clarifier tankage. The amount of de-rating of the existing tankage would be such that it would operate with a sufficiently long SRT to enable nitrification yet not overload the solids removal capability of the existing final clarifiers. The new tankage would specifically be designed to nitrify the flows not processed by the exiting tankage.

A preliminary analysis of both approaches indicated that the Option B is preferred for the following reasons:

- To satisfy the proposed treated effluent NH_3-N limits using Option A, an additional 12 to 18 HPO bioreactors would be necessary. This would place the relative ratio of bioreactor size to final clarifier size out of proportion with respect to common practice in HPO plant experience elsewhere.
- Complete reliance would be placed on the existing final clarifiers to perform well enough to meet the relatively stringent proposed treated effluent limits. Given the limitations of these clarifiers with respect to current design practice, this is considered to be a significant risk.
- De-rating of the existing tankage by directing less flow and load to it will take some stress from the existing facility and enable it to perform in a more reliable fashion to meet the proposed treated effluent limits.
- The new bioreactor and final clarifier tankage would be designed and operated in accordance with current state-of-the-art practice specifically to achieve nitrification and thus would present less risk than would the existing bioreactor tankage of not meeting the stringent treated effluent quality limits.

4.2.3 Splitting of Flows Between Existing and New Tankage

Table 4.1 presents a preliminary analysis of the limitations of the existing HPO tankage. This analysis was used to estimate the amount of flow that could be diverted from the existing HPO tankage to new tankage and to maintain nitrification in both the existing and the new tankage.

Table 4.1: Preliminary Analysis of Existing NEWPCC Limitations

Parameter	Units	Value
Critical Spring Flow rate	ML/d	400
Current Critical Spring MLSS	mg/L	2,300*
Existing HPO Bioreactor Volume	m^3	30,133
Existing Final Clarifier Surface Area	m^2	13,132
Current Q_{RAS}/Q_{SI} Ratio	dimensionless	0.40
Possible Future Q_{RAS}/Q_{SI} Ratio	dimensionless	0.75
Biomass Inventory for Nitrification	kg	344,000**
Estimated Critical Final Clarifier SLR	kg/ m^2/d	98.08

* From plant operating experience.
** From preliminary modeling work.

The table is based on information obtained from the operating staff of the plant indicating that the existing final clarifiers cannot tolerate MLSS concentrations higher than about 2300 mg/L under critical high flow springtime conditions. Given the current returned activated sludge (RAS) rate of 40 percent of secondary influent flow, this MLSS concentration results in an average solids loading rate (SLR) of about 98 kg/m^2/d. Assuming a RAS rate no less than 75 percent of secondary influent flow for a nitrifying plant, the MLSS that can be tolerated while still meeting the SLR limitation on the final clarifiers, for various percentages of flow directed to the existing tankage can be estimated. These estimates are summarized in column 4 of Table 4.2 and plotted in Figure 4.1 as the curvilinear line decreasing with increasing percentages of flow directed to the existing HPO tankage.

The MLSS concentration in the existing tankage required to maintain nitrification under springtime conditions is shown in column 3 of Table 4.2. A biomass inventory of 344,000 kg was estimated from initial modeling work as necessary to maintain nitrification under springtime conditions if all flow was to be directed to the existing HPO plant. The equivalent MLSS concentrations for lesser amounts of flow are presented in the Table and plotted in Figure 4.1 as the straight line increasing with increasing percentage of flow directed to the existing HPO tankage.

The two lines in Figure 4.1 intersect at about 40 percent of spring flows directed to the existing tankage. At the point of intersection, the estimated MLSS concentration is about 4,500 mg/L. To provide for operational flexibility in case of tankage being out of service, it is recommended that the secondary influent flow diversion facility be designed to direct from 25 to 50 percent of secondary influent to the existing HPO tankage.

Table 4.2: Percent Flow Versus MLSS Required to Nitrify and to Maintain SLR

1	*2*	*3*	*4*
Percent Flow to Existing HPO Tankage	**Value (ML/d)**	**MLSS (mg/L) Required:**	
		To Nitrify	**To Maintain SLR**
10	40	1,142	18,400
20	80	2,283	9,200
30	120	3,425	6,133
40	160	4,566	4,600
50	200	5,708	3,680
60	240	6,850	3,067
70	280	7,991	2,629
80	320	9,133	2,300
90	360	10,274	2,044
100	400	11,416	1,840

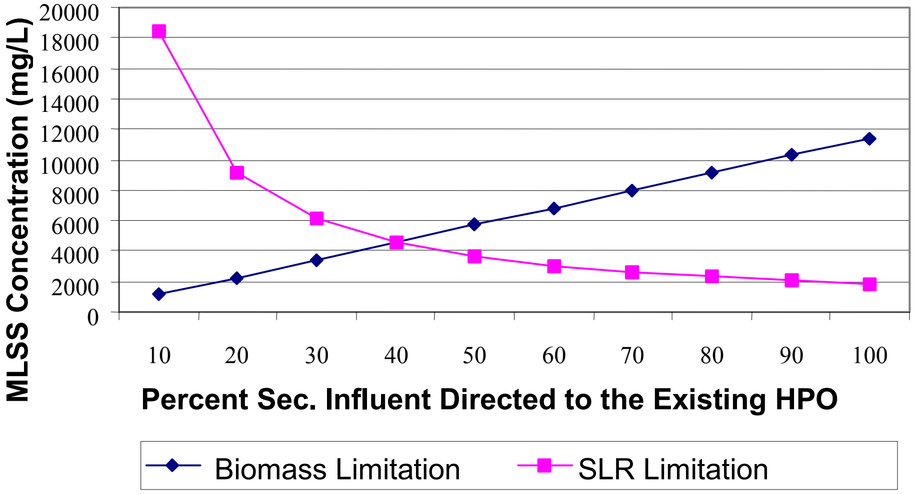


Figure 4.1: Estimating Operating Conditions for Various Spring Flows Directed to Existing HPO Tankage

4.2.4 Process Design and Operational Parameters

Table 4.3 summarizes the basic design and operating parameters for the existing and new tankage. For the example used in this table, it is assumed that one-third of the projected 2041 secondary influent flow (33.3 percent) would be directed to the existing six HPO bioreactors and ten square and sixteen rectangular final clarifiers. The balance of the secondary influent flow (66.7 percent) would be directed to the new tankage, which will consist of four rectangular bioreactors and six circular clarifiers.

Table 4.3: NEWPCC - Process Design for 2041 Flow and Loads (Option B for Best Practicable Level of Control)

Description	Units	Values
Bioreactor Tankage		
Existing Bioreactors		
Number		6
Dimension (L x W x SWD)	m	68.3 x 17.1 x 4.3
Total Volume	m^3	30,133
New Bioreactors		
Number		4
Dimension (L x W x SWD)	m	80 x 26 x 6
Total Volume	m^3	49,920
Clarifier Tankage		
Existing Final Clarifiers		
Square:		
Number		10
Dimension (L x W x SWD)	m	20 x 20 x 4.65
Area	m^2	4,000
Rectangular:		
Number		16
Dimension (L x W x SWD)	m	69.35 x 8.23 x 3.65
Area	m^2	9,132
New Final Clarifiers:		
Number		6
Diameter	m	52
Side Wall Depth	m	5
Area	m^2	12,742

The nominal operating conditions for the various seasons of the year are summarized in Table 4.4. The 75 percent return activated sludge pumping rate for both the existing and the new tankage is much higher than is presently practiced at the plant. The higher RAS rate is intended to minimize the sludge blanket in the final clarifiers to minimize the risk of floating sludge due to denitrification in the sludge blankets. The seasonal MLSS concentrations reported in Table 4.4 were taken from the dynamic simulation results for maximum week flow and loading conditions and are consistent with SRTs of 10, 12, 8 and 8 days for the winter, spring, summer and fall seasons, respectively. The MLSS concentrations used in the existing bioreactor tankage in Table 4.4 are substantially higher than can be carried in the plant under current flows and loads without upsetting the existing final clarifiers. The hydraulic de-rating of the existing tankage, by diverting two-thirds of the flow to the new tankage, results in a solids loading rate on the existing final clarifiers that is similar to current conditions at the NEWPCC.

Table 4.4: Seasonal Operating Conditions
(Option B for Best Practicable Level of Control)

Parameter	Unit	Winter		Spring		Summer		Fall	
		Existing	New	Existing	New	Existing	New	Existing	New
Flow	ML/d	70.3	140.7	129.9	260.1	96.9	194.1	83.3	166.8
SRT	d	10	10	12	12	8	8	8	8
HRT	h	10.29	8.51	5.57	4.61	7.46	6.17	8.69	7.18
MLSS*	mg/L	2600	3400	3100	3800	2300	2800	2100	2600
Q-RAS		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
SLR	$kg/m^2/d$	24.34	65.72	53.65	135.78	29.7	74.64	23.3	59.54
SOR	m/h	0.22	0.46	0.41	0.85	0.31	0.63	0.26	0.55

* Maximum Week MLSS

4.2.5 Bioreactor Configuration

The bioreactor model configuration is presented in Figure 4.2. The results of preliminary modeling work indicate that the critical time of the year for meeting the proposed NH_3-N limits is the spring when flows are highest and wastewater temperatures are lowest. Fortunately, conditions in the river during the spring will not require full nitrification due to the high flows in the river. Thus, as indicated in Figure 4.2, it is proposed that a step feed capability be included in the bioreactor configurations to allow up to 25 percent of the bioreactor volume to operate as a RAS reaeration zone during colder periods when the treated effluent NH_3-N limit is not as stringent. Operating in a RAS reaeration mode will have the benefit of increasing the SRT of the system without increasing the volume of the bioreactor. The preliminary modeling work for the NEWPCC showed a bioreactor volume saving of about 17 percent in this regard. The potential downside is that treated effluent NH_3-N concentration will be somewhat higher; however, this is not perceived to be a problem because the proposed effluent limit is expected to be less stringent at these times.

To accomplish RAS reaeration/step feed in the existing HPO bioreactor tankage, a second point of introduction of secondary influent would be constructed by adding a tee and two valves to the existing line as it enters the bioreactors. Downstream of the tee, one line would introduce secondary influent to Zone 1 of the bioreactor, while the other line would introduce secondary influent to Zone 2 of the bioreactor.

With respect to the new bioreactor tankage, it is proposed to install two step feed points, one at the 12.5 percent by volume point and the other at the 25 percent by volume point in the bioreactor. This will offer more operational flexibility, particularly for other periods of colder wastewater temperature.

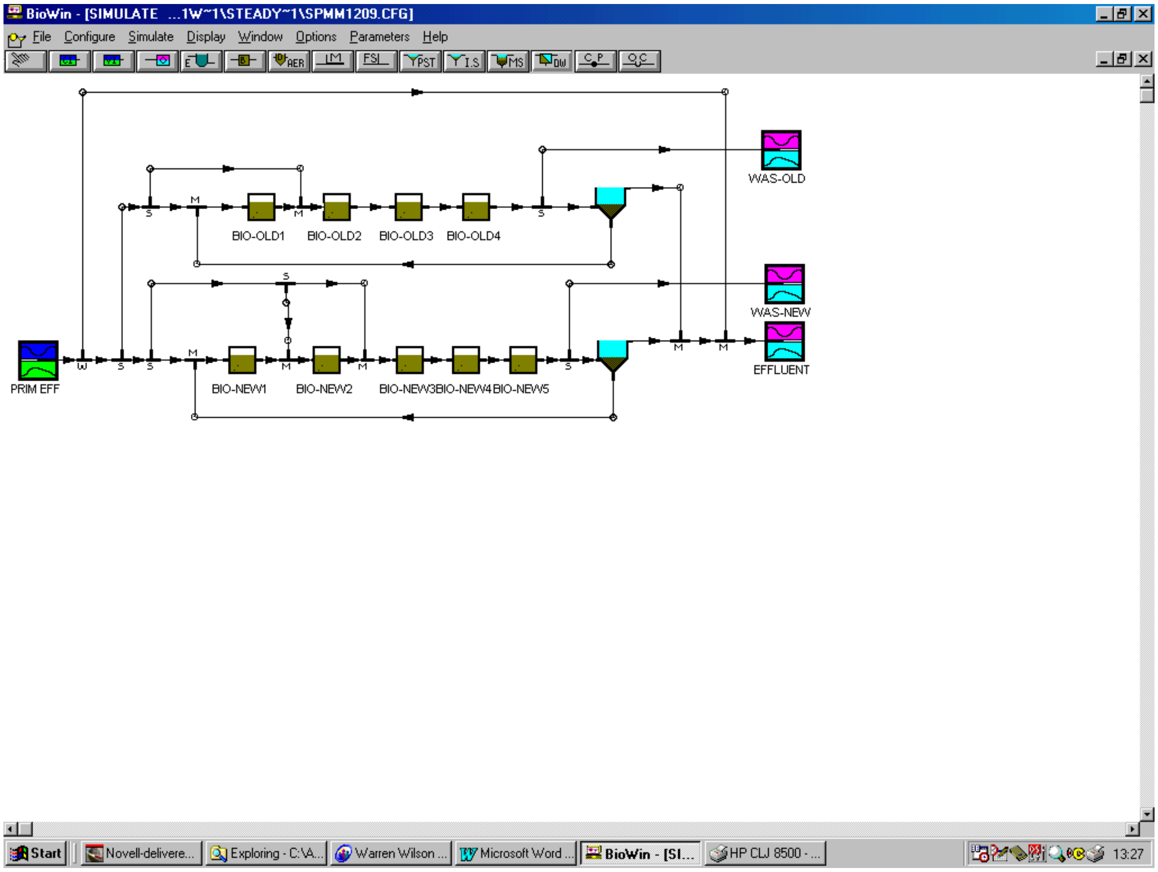


Figure 4.2: Bioreactor Model Configuration for NEWPCC—Best Practicable Level of Control Using Option B—De-rate Existing HPO System and Build New Parallel Conventional Activated Sludge System

4.2.6 Projected Performance

Dynamic simulations covering the NEWPCC operation over four seasons were performed for the projected 2041 flow and loading conditions. The modeling results are presented in Figure 4.3 for the summer period, Figure 4.4 for the fall period, Figure 4.5 for the winter period, and in Figure 4.6 for the spring. These figures present the projected seasonal variations of flow, final effluent ammonia concentration, bioreactor MLSS, and final clarifier surface overflow rates and solids loading rates for the projected 2041 flow and load conditions. The vertical bandwidth of each parameter plotted on these figures is indicative of the daily diurnal variation of the parameter.

4.2.7 Oxygen and Aeration Requirements

The oxygen requirements for the existing HPO plant currently average about 35 tonnes per day. A preliminary analysis of the projected oxygen requirements at 2041 flows and loads for nitrifying one-third of the primary effluent flow indicates that the oxygen requirements for the existing bioreactors would be approximately the same as at present.

Analysis of simulator output data for the four seasons indicates that operation under projected 2041 winter temperatures and flows and loads at a 10 day SRT will result in the highest air demands of the year. Airflow to the new bioreactors for a sustained peak period during maximum week loading conditions for winter operation is projected to be about 17 nm^3/s. For average day winter conditions, the airflow will be 12.5 nm^3/s. Thus for preliminary sizing, it is suggested that four blowers be installed for the new bioreactors, each with nominal rated capacity of 6.0 nm^3/s. This configuration will satisfy the air demand associated with the sustained peak period during maximum week loading conditions with 33 percent standby capacity, and also provide sufficient turndown for minimum flows. Two blowers in operation would more or less be sufficient to meet the average winter conditions.

4.2.8 Site Layout – NEWPCC

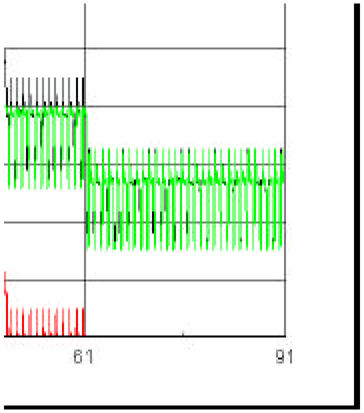
Drawing NE-4.1 and Drawing NE-4.2 show a site plan and a layout of the modified treatment plant, respectively. The process flow diagram is illustrated in Drawing NE-4.3.

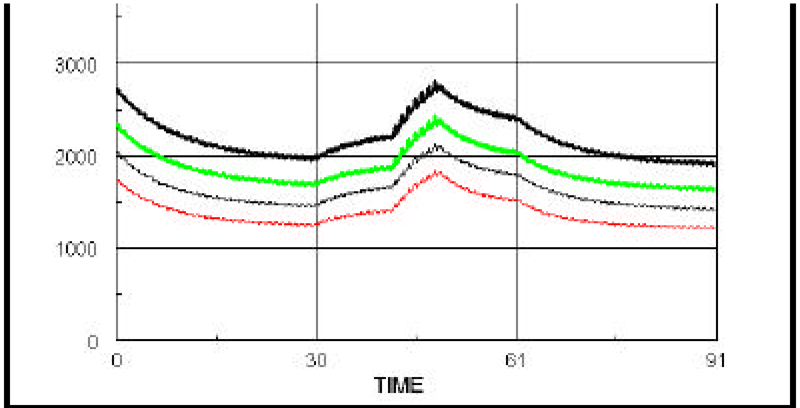
The four new bioreactors would be located immediately south of the existing HPO bioreactors. The six new final clarifiers would be located immediately west of both the existing and the new bioreactor tankage. All of the new tankage would be covered to facilitate operation under winter conditions. Secondary effluent from the new tankage would be routed along the north side of the existing bioreactors and final clarifiers. The blower building housing the new blowers for the new bioreactors would be located in one corner of the building housing the final clarifiers.

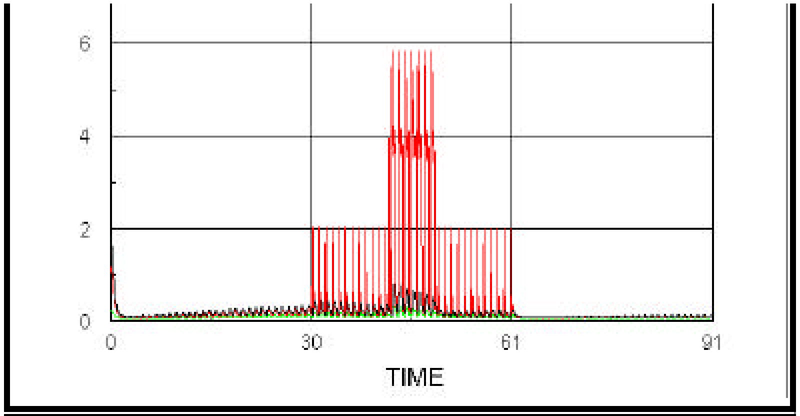
4.2.9 Best Practicable Level of Control - Statistical Analysis of the Projected Effluent Ammonia

Statistical analysis was performed on the simulation model output database as well as its related transformed (natural logarithm) database, using the following assumptions and equations. The model output data were transformed to the natural logarithmic database to provide a normal frequency distribution.

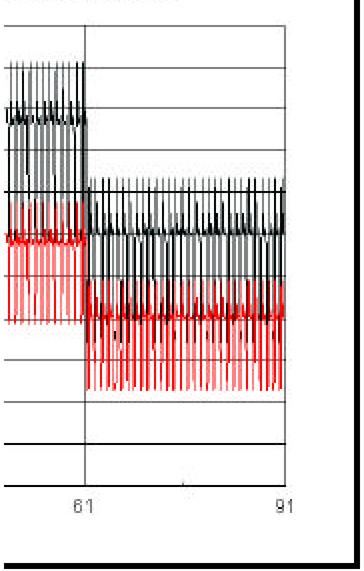
The model output database was used in calculations of Arithmetic Averages (AA) and Geometric Means (GM), and the transformed database was used to determine the population and sample Standard Deviations represented by σ and s, respectively. The results of the statistical analysis are summarized in Table 4.5.



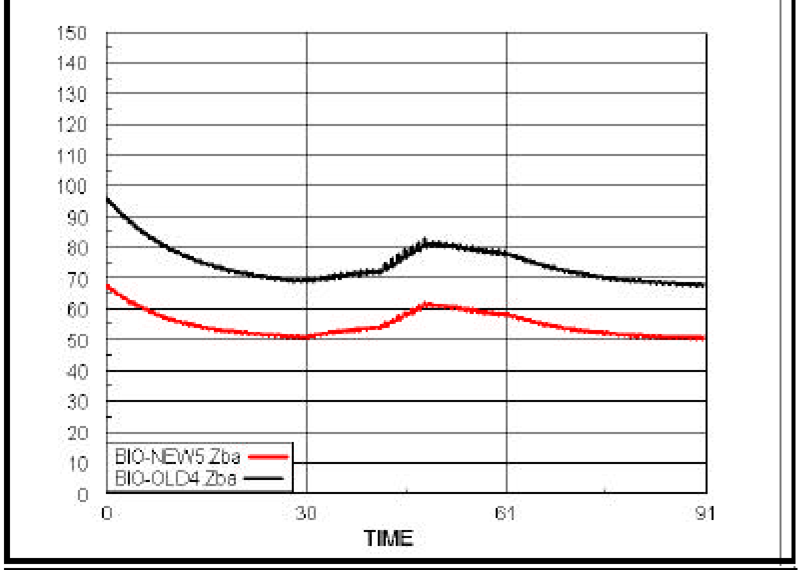




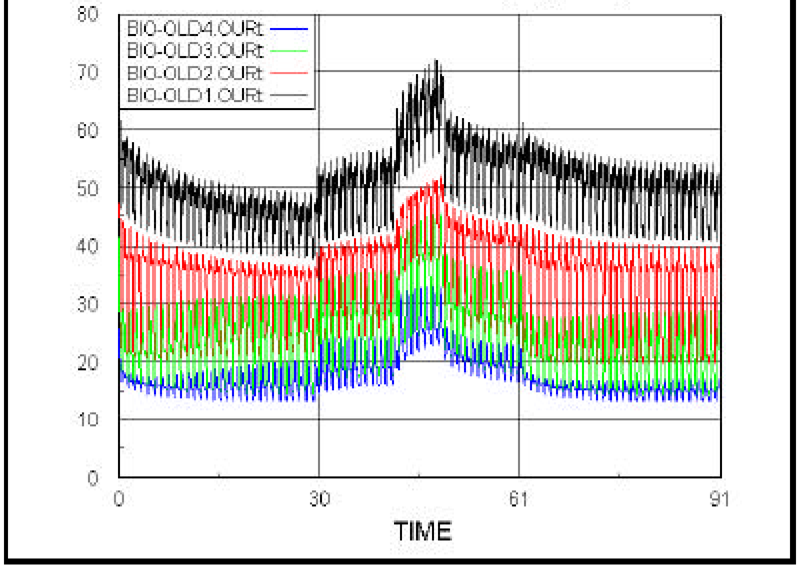
low (m3/day)



Autotrophs (mg/L)

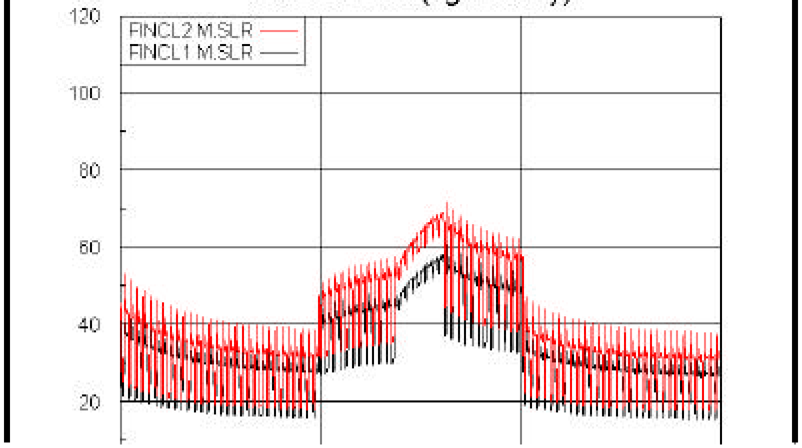


Old Bioreactor OURt (mg/L/hr)

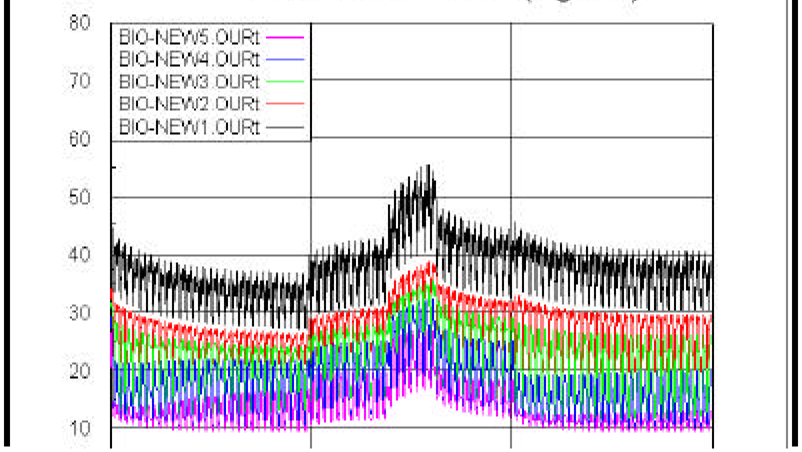


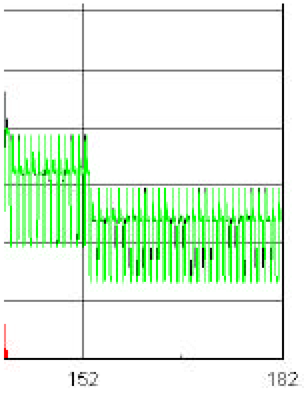
low (m3/day)

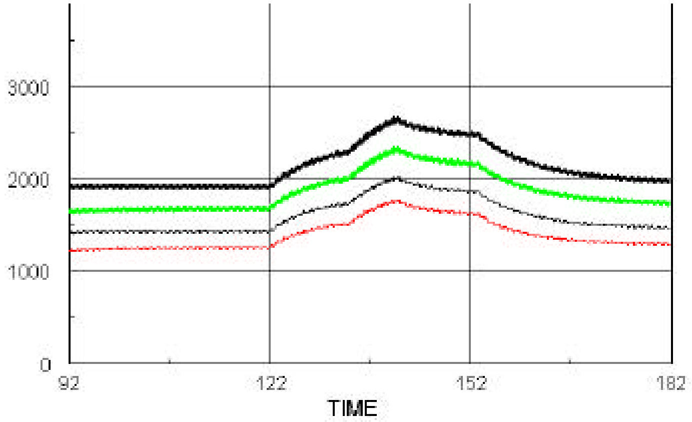
Clarifier SLR (kg/m2/day)

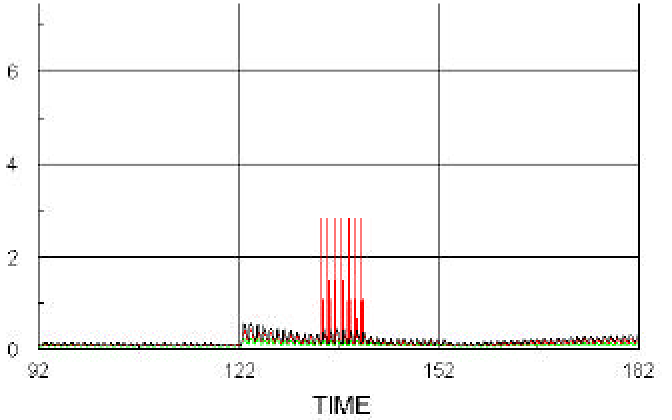


New Bioreactor OURt (mg/L/hr)









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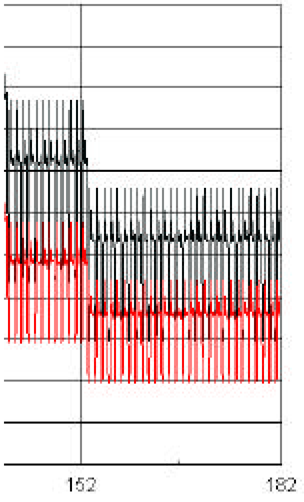
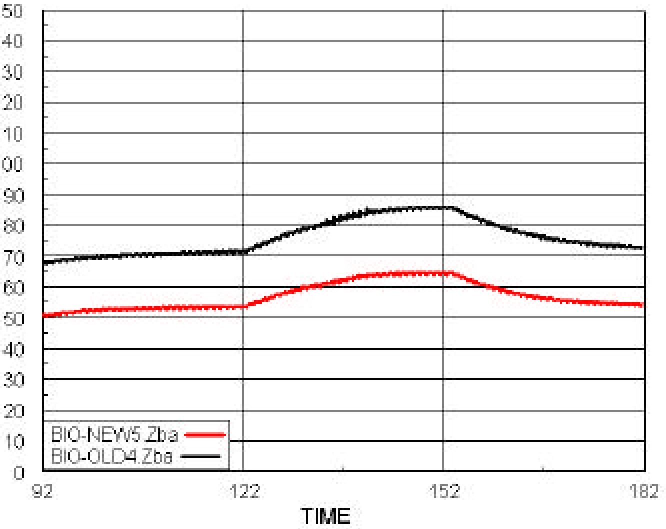
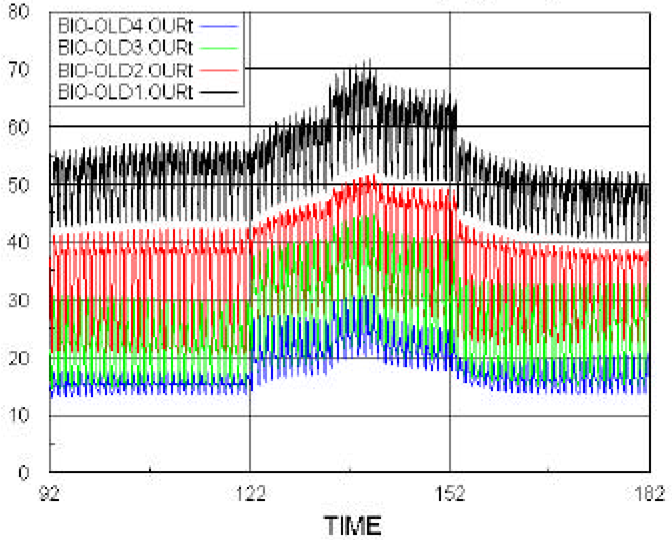


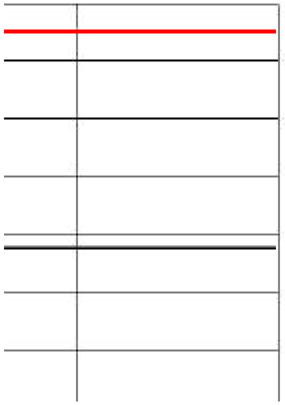
Autotrophs (mg/L)



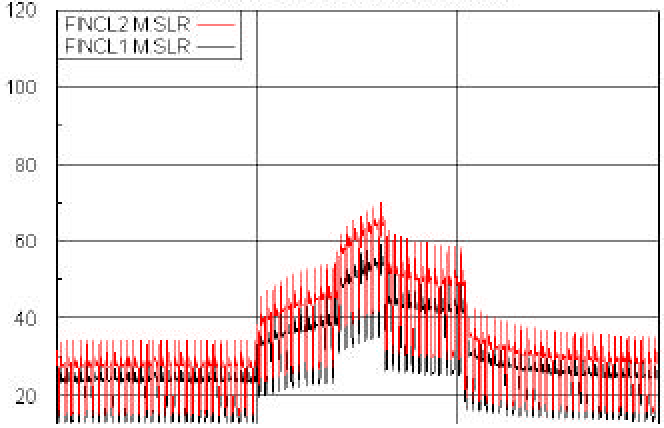
Old Bioreactor OURt (mg/L/hr)



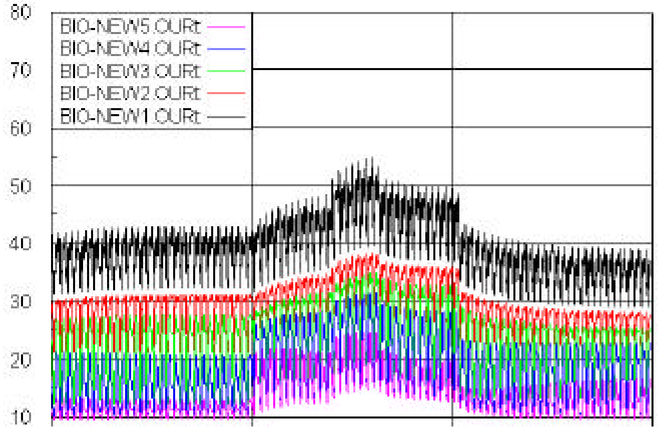
low (m3/day)

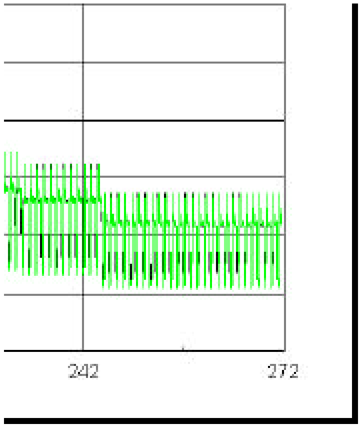


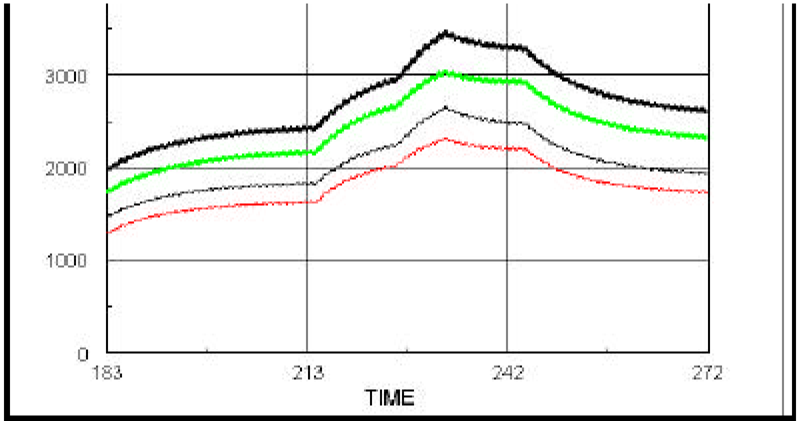
Clarifier SLR (kg/m2/day)

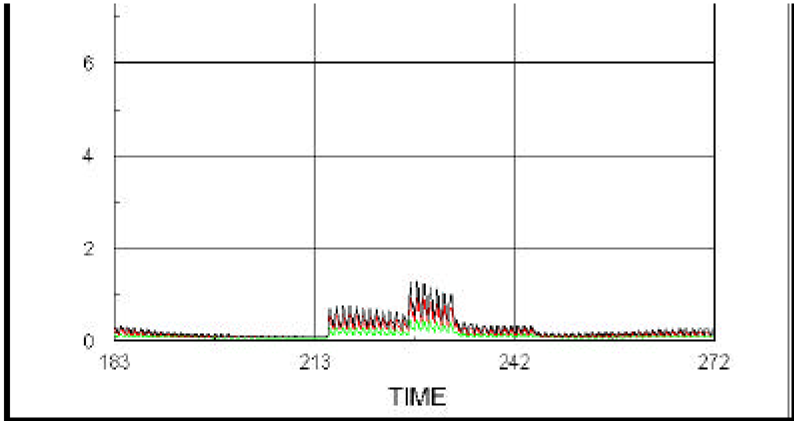


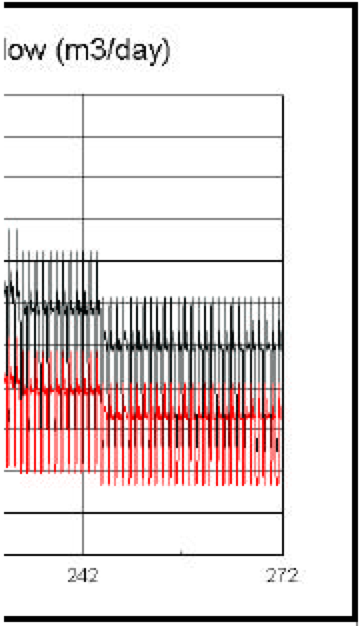
New Bioreactor OURt (mg/L/hr)







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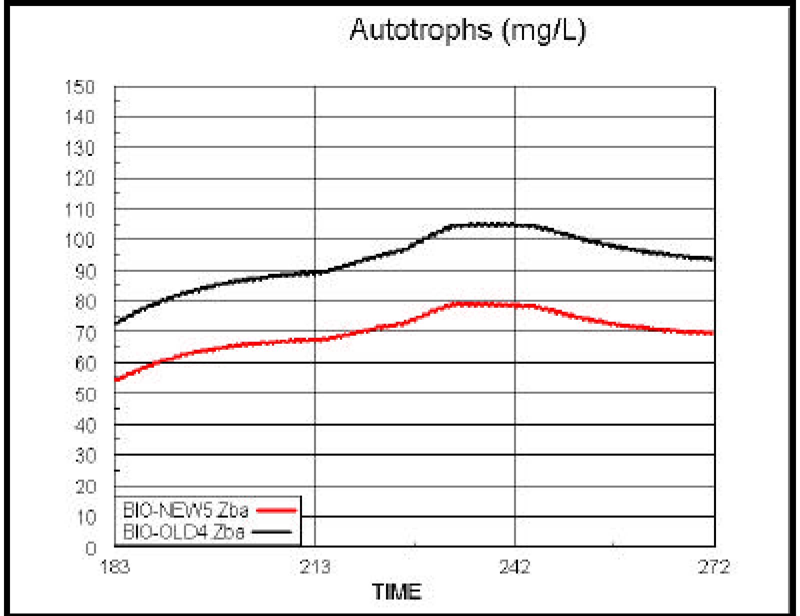
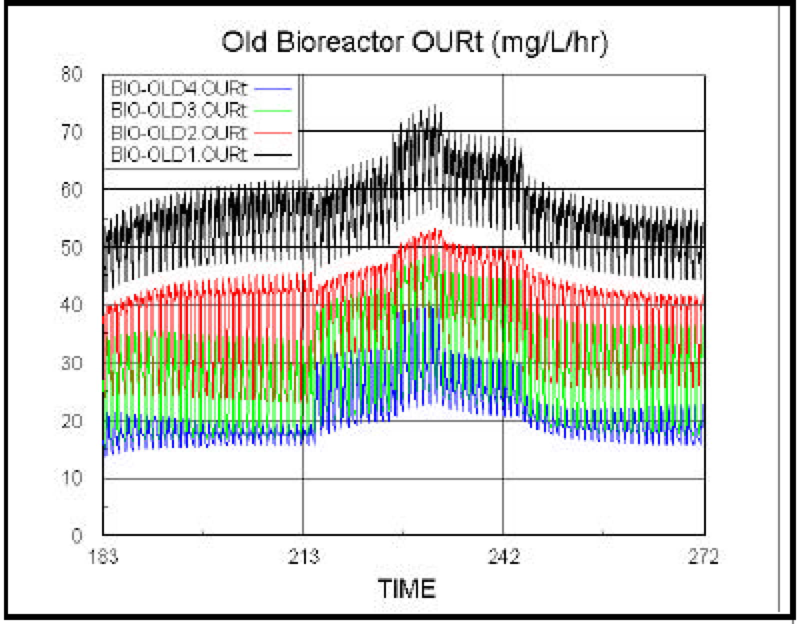
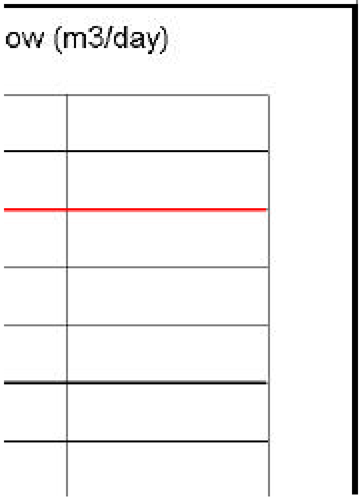

Autotrophs (mg/L)


Old Bioreactor OURt (mg/L/hr)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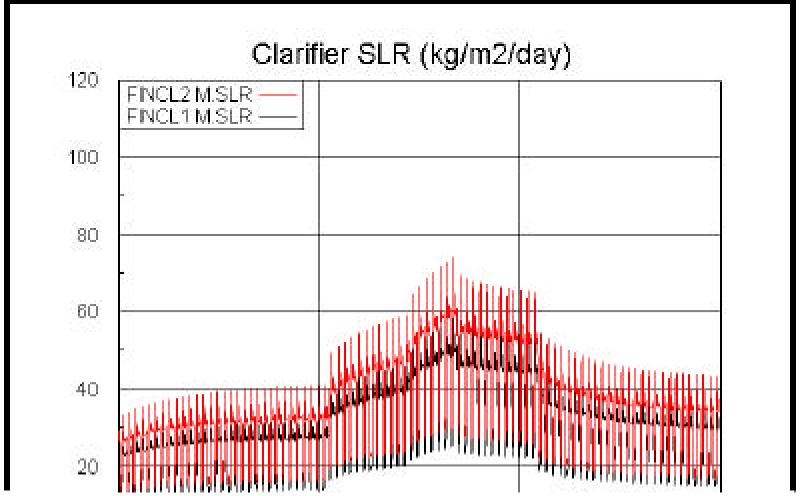
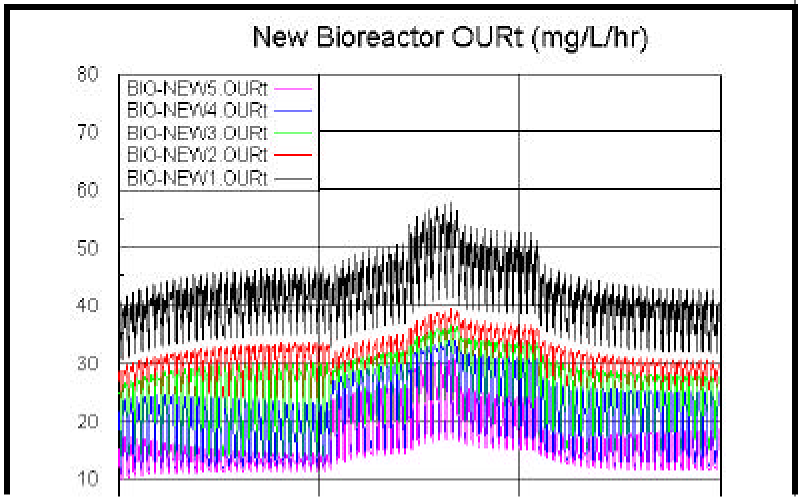

Clarifier SLR (kg/m2/day)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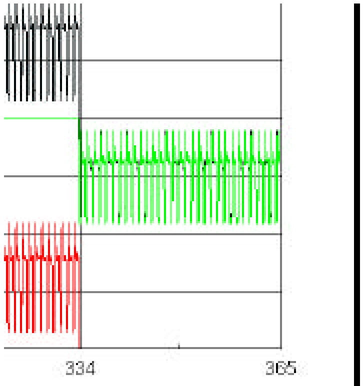

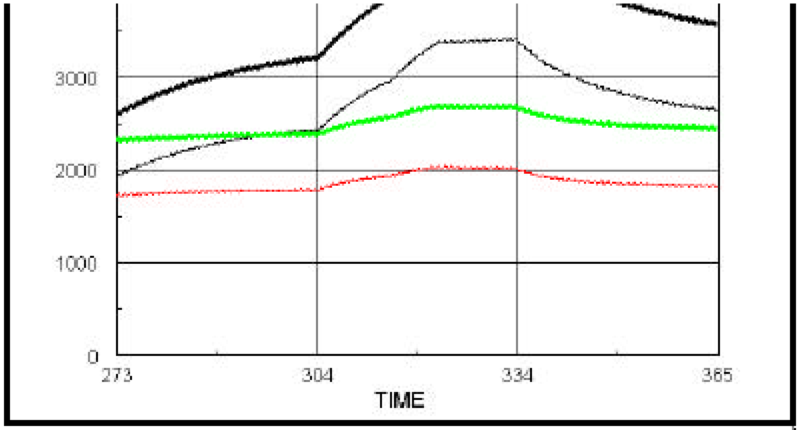

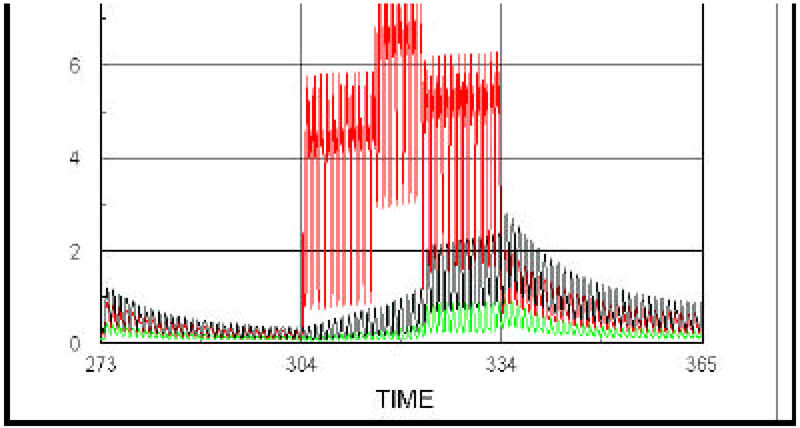

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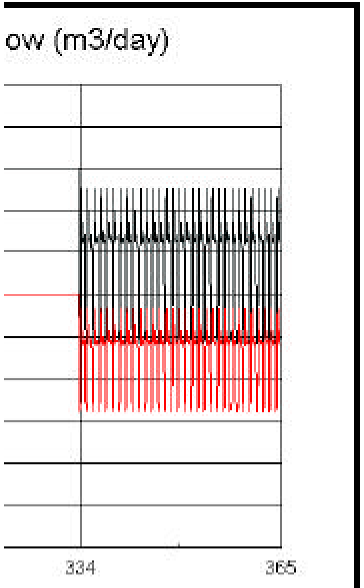
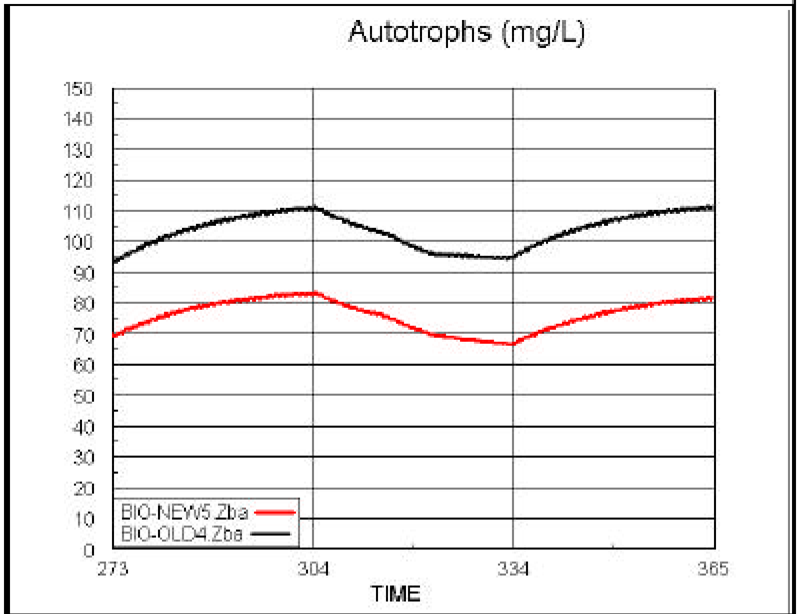
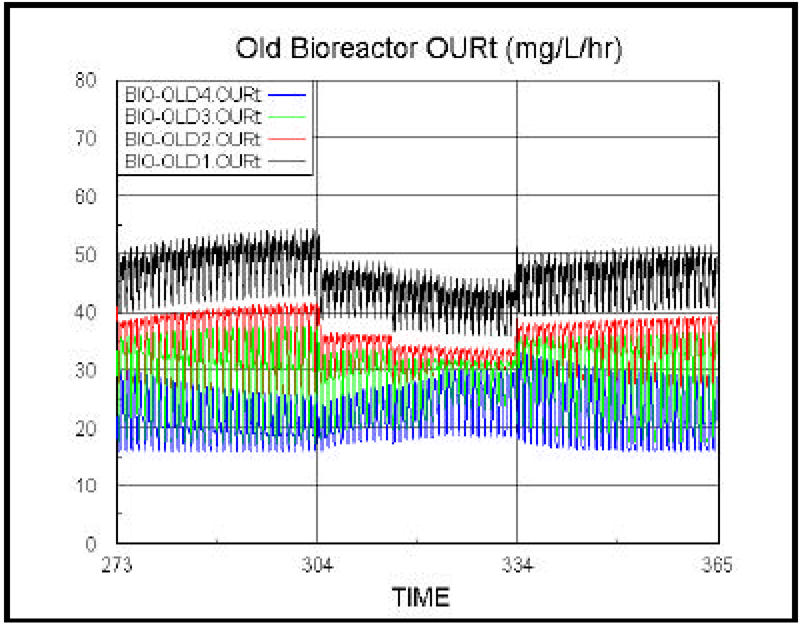


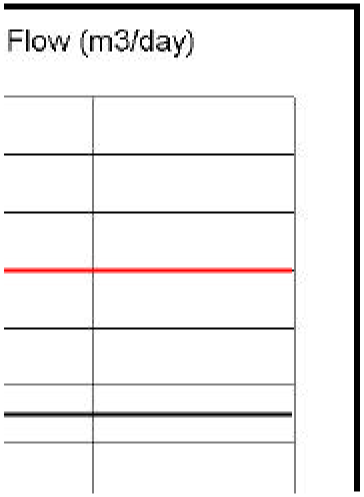
Autotrophs (mg/L)



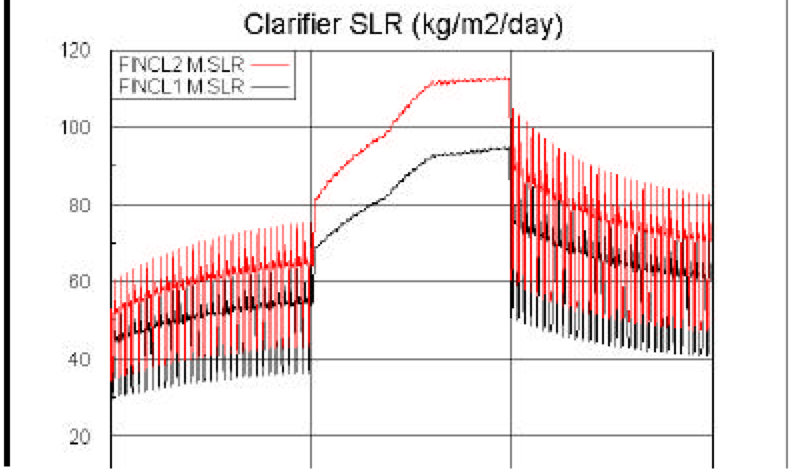
Old Bioreactor OURt (mg/L/hr)



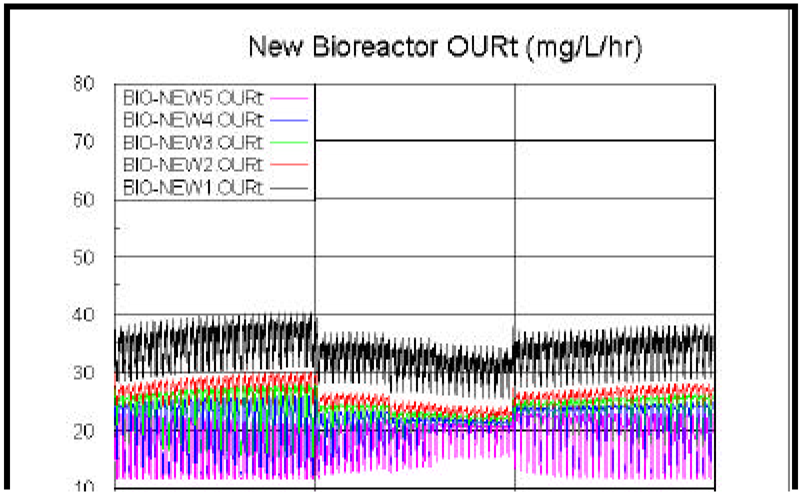
Flow (m3/day)



Clarifier SLR (kg/m2/day)



New Bioreactor OURt (mg/L/hr)



Assumptions:

- Variation of the monthly GM of transformed data represents variation of the GM of the model data.
- The ratios of monthly σ/GM for the population, shown in the 4th column of Table 4.5, are fixed values developed on the basis of experience with other databases similar to the database used in this analysis.
- Mean of the population is equal to the mean of the 30 day averages of transformed data.

Equations:

$$s_{(30\ \text{days})} = \sqrt{[(\sigma)^2/30]}$$

where: $\sigma = (\sigma/GM) \times GM$

Assuming mean of the population is equal to the mean of the 30 days averages of the transformed data. Then:

$$GM_{(30\ \text{days})} = [GM + (\sigma)^2/2\ ] - [s^2_{(30\ \text{days})}/2]$$

Monthly GM (95th %) was calculated as:

$$95^{th}\%_{(\text{Monthly GM})} = (GM_{30\text{days}} + 1.645s)$$

Based upon the statistical analysis of the secondary effluent ammonia concentration, it can be concluded that:

- Variation in effluent ammonia concentration is higher during summer months than other months.
- 95 percent of the samples in each month would have ammonia concentrations equal or less than the related value shown in the last column of Table 4.5.

Table 4.5: NEWPCC - Results of Statistical Analysis on the Effluent Ammonia (Year 2041 – Best Practicable 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	0.31	-1.36	0.12	-0.163	0.030	-1.344	-1.295	0.27
July	0.25	-1.51	0.18	-0.271	0.049	-1.470	-1.389	0.25
August	0.11	-2.26	0.12	-0.271	0.049	-2.220	-2.139	0.12
September	0.12	-2.14	0.06	-0.128	0.023	-2.129	-2.091	0.12
October	0.24	-1.51	0.09	-0.136	0.025	-1.504	-1.463	0.23
November	0.19	-1.72	0.06	-0.103	0.019	-1.716	-1.685	0.19
December	0.57	-0.70	0.06	-0.042	0.008	-0.695	-0.683	0.51
January	1.36	0.22	0.04	0.009	0.002	0.221	0.224	1.25
February	0.57	-0.59	0.06	-0.036	0.007	-0.593	-0.583	0.56
March	2.42	0.85	0.04	0.034	0.006	0.848	0.858	2.36
April	2.62	0.91	0.06	0.054	0.010	0.909	0.925	2.52
May	4.17	1.41	0.04	0.056	0.010	1.408	1.425	4.16

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

4.3 WASTE ACTIVATED SLUDGE THICKENING - NEWPCC

4.3.1 General

Operation of the NEWPCC to achieve stringent ammonia limits depends upon reliable and consistent operation of other processes. Most importantly, performance of primary sedimentation dictates the ability of the secondary treatment process to maintain the solids retention time (SRT) or solids inventory necessary to culture autotrophic bacteria.

One major deterrent to reliable and consistent operation of the primary sedimentation tanks is the practice of co-thickening waste activated sludge with the primary sludge in these tanks. As part of a nitrification upgrade, separate thickening is recommended. This change to the plant achieves the following:

- Reduces carry-over of solids to the secondary treatment process.
- Reduces solubolized load that is transferred to the secondary treatment process with the primary effluent.
- Improves thickened sludge solids concentrations to reduce hydraulic loading on digesters and reduce dewatering centrate volumes.

4.3.2 Secondary Sludge Quantities

Treatment modeling conducted to size the secondary treatment facilities for nitrification also allowed an estimate of sludge production. For the design year (2041), sludge production estimates are as shown in Table 4.6.

Table 4.6: NEWPCC Secondary Sludge Production Estimates[1]
(Best Practicable Level of Control)

Description	Units	Value
Secondary Sludge Loads		
Summer	kg/d	23,347
Fall	kg/d	22,533
Winter	kg/d	21,615
Spring	kg/d	25,218
Maximum Week[2]	kg/d	37,827
Secondary Sludge Flows[3]		
Summer	m^3/d	3,891
Fall	m^3/d	3,756
Winter	m^3/d	3,603
Spring	m^3/d	4,203
Maximum Week[2]	m^3/d	5,044

Notes:
1. Sludge production estimates are based on achieving nitrification at the plant at predicted 2041 flows and loads.
2. Maximum week quantity is 1.5 times the average spring value.
3. Secondary sludge flows are based on withdrawal of RAS at a concentration of 6,000 mg/L under average conditions and 7,500 mg/L during peak loading conditions.

4.3.3 Thickening Options – Process Selection

The selection of secondary sludge thickening processes generally focuses on three options: dissolved air flotation (DAF), gravity belt thickeners (GBTs), and centrifuges. Larger plants generally implement centrifuge thickening while medium size facilities will use DAF or GBTs. GBTs are more common in smaller facilities. Odour control requirements, nutrient removal, or other factors can alter the selection.

At the NEWPCC, centrifuges are used for dewatering digested sludges. Six large units (Penwalt Sharples PM76000) were installed to provide sufficient capacity so that the City could dewater sludge eight hours per day, six days per week. However, experience has shown that continuous operation results in less equipment maintenance. The operational strategy employed at the plant entails 24 hour operation, seven days per week. One centrifuge is used for part of the week, while on the remaining days of the week two centrifuges are used to dewater digested sludge. As a result of this change in operating strategy, at least three centrifuges are considered available for alternative service.

The possibility that these three centrifuges could be modified for use as thickening machines has been discussed with the equipment vendor. Two options are available, described as follows:

1. **Minimum Modification:** The centrifuges could be modified by adding a "BD" disk to the scroll, at the inflection point in the bowl between the beach and the cylinder. The centrate dams would be replaced with new weirs that would increase pool depth within the machine. The cost of this change-over would be minimal. The centrifuge would have varying capacity, depending upon whether polymer was added, as shown in Table 4.7. The motors and drive are sufficient to handle the loading that would be imposed with or without polymer.

Table 4.7: Variation in Centrifuge Capacity – Minimum Modification

Parameters	Units	Without Polymer	With Polymer
Flow Capacity	L/s	12.6	25.2
TWAS Concentration	%	5 to 6	5 to 6
Recovery	%	85	95
Polymer Dosage	kg/T	0.0	1.5

2. **Major Modification:** The entire rotating assembly could be replaced with a bowl and scroll designed specifically for thickening. Capabilities are summarized in Table 4.8. Throughput would improve without polymer addition; however, with polymer addition, throughput would increase only slightly. The machine motor and drive is incapable of handling much over 27 L/s.

Table 4.8: Variation in Centrifuge Capacity – Major Modification

Parameters	Units	Without Polymer	With Polymer
Flow Capacity	L/s	19	27
TWAS Concentration	%	5 to 6	5 to 6
Recovery	%	85	95
Polymer Dosage	kg/T	0.0	1.5

With polymer addition, two centrifuges with minor modifications would be capable of thickening the projected WAS quantities until 2041, under average conditions. Similarly, with major modifications, two centrifuges with polymer addition would be capable of handling the 2041 average conditions. Under predicted maximum conditions, the capacity of two centrifuges would be exceeded, regardless of whether minor or major modifications were implemented. Major modifications provide little benefit; accordingly, the centrifuges would be provided with only the minor modification and provisions would be made for polymer addition.

Because the existing three centrifuges can be retrofitted to achieve secondary sludge thickening, it is unlikely that other options are cost effective in comparison. The retrofit option is adopted for further analysis.

Under peak loading conditions, there would be no standby capacity—three centrifuges are necessary to thicken the predicted secondary sludge quantities. Standby will have to be provided either by return to the present co-thickening operation, installation of another centrifuge, or the installation of another thickening device. It is possible that a DAF unit could be installed for centrate treatment from dewatering and thickening, as well as standby secondary sludge thickening. Secondary scum and foam flows could also be directed to this treatment unit. For the purposes of this study, standby service is assumed to be provided by returning to the existing operational technique – co-thickening. However, prior to the implementation, further work should investigate the option of a centrate/foam/standby DAF unit.

4.3.4 Process Description

Design data for waste activated sludge (WAS) thickening are summarized in Table 4.9. Dwg. NE-4.4 schematically illustrates the thickening process flow diagram. The following paragraphs summarize the major components of the sludge thickening system.

WAS would be withdrawn from the return activated sludge (RAS) lines in each of the secondary treatment modules, as necessary to control the solids retention time in each of these areas. It would be conveyed to a relatively small holding tank – the WAS Feed Tank. This tank provides a ‘wide spot in the line’ to allow buffering of small fluctuations in feed flow rates and to allow intermixing of the sludge from the operating secondary treatment modules.

Centrifugal WAS feed pumps would withdraw WAS from the Feed Tank and convey it to the operating centrifuges. One pump would be dedicated to each centrifuge. Variable speed drives on each pump would allow the flow rate to be controlled within tight tolerances.

Polymer would be added upstream of the centrifuge at one of three points. The polymer would be provided from a new system sized to mix and feed a maximum of 3 kg/T of polymer (115 kg/d), diluted to a reasonable concentration. The system would incorporate the feed of dry polymer to a wetting system, age tank and feed tank. The arrangement is similar to the existing polymer system used for dewatering. One polymer feed pump will be dedicated to each centrifuge.

The three modified centrifuges will accept the sludge and generally will operate at relatively constant speed and differential speed. The torque controller would be disabled as it is not sufficiently sensitive for thickening service.

The dewatering pumps and feed hoppers placed under the dewatering centrifuges would be removed when the change to thickening service is implemented. In the envisioned arrangement, each thickening centrifuge discharges thickened sludge to a small hopper that is mounted over a progressive cavity pump. This pump conveys the thickened WAS (TWAS) to a sludge blend tank. In the sludge blend tank, the TWAS is mixed with thickened primary sludge (TPS) from the primary clarifiers. The blend tank is sized to hold approximately 8 hours of sludge from the two sources.

Recirculating pumps, which discharge above the liquid surface, mix the blend tank. The above-surface discharge controls foam accumulations in the tank. Foul air from the headspace will be directed to odour control or through small carbon canisters for odour removal.

Thickened sludge (TS) pumps feed the blended sludge to the digesters. Three pumps are provided, two duty and one standby. Each pump is sized to handle 50 percent of the peak sludge load. They are controlled to pump at a relatively consistent rate and the level in the blend tank is allowed to vary to account for normal diurnal variations in the sludge generation rates.

Centrate from the thickening centrifuges would be collected and discharged to the gravity drain that presently handles centrate from dewatering. The drain line is presently a 350 mm pipe. This pipe will be enlarged to a minimum of 600 mm to handle the additional flow from thickening.

Table 4.9: NEWPCC Secondary Sludge Thickening – Design Data

Description	Units	Value
Basic Design Parameters[1]		
Secondary Sludge Loads		
Average	kg/d	23,180
Maximum Week[2]	kg/d	37,827
Secondary Sludge Flows[3]		
Average	m^3/d	3,865
Maximum Week[2]	m^3/d	5,045
WAS Feed Tank		
Number		1
HRT	min	30
Volume	m^3	120
Dimensions		
Length	m	10
Width	m	3
SWD	m	4.0

Table 4.9: NEWPCC Secondary Sludge Thickening – Design Data (continued)

Description	Units	Value
Centrifuge Thickening		
Number of Units		3
Capacity per unit, L/s	L/s	25
Performance		
Thickened WAS concentration	%	5 to 6
Solids Capture	%	95
Polymer System		
Type		Dry
Dosage		
Average	kg/T	1.5
Maximum	kg/T	3.0
Capacity	kg Polymer/d	115
Feed Concentration	%	0.5
Aging Time	min	60
Thickened Sludge Pumps		
Number		3
Capacity	L/s	5
TDH4	m	30
Sludge Blend Tank		
Number		1
HRT	h	8
Volume	m^3	300
Dimensions		
Diameter	m	6.5
SWD	m	9.0
Sludge Blend Mixing Pumps		
Number		2
Capacity	L/s	80
TDH	m	15
Thickened Sludge Pumps		
Number		3
Capacity	L/s	8
TDH	m	30

Notes:
1. Sludge production estimates are based on achieving nitrification at the plant at predicted 2041 flows and loads.
2. Maximum week quantity is 1.5 times the average spring value.
3. Secondary sludge flows are based on withdrawal of RAS at a concentration of 6,000 mg/L under average conditions and 7,500 mg/L during peak loading conditions.
4. TDH values listed for pumps are estimates only and will have to be derived on the basis of final arrangement.

4.4 SOUTH END WATER POLLUTION CONTROL CENTRE (SEWPCC)

4.4.1 Model Input

Similar to the NEWPCC, hourly flows and loads in the year 2041 were used to simulate nitrification options for the SEWPCC. Projections of the hourly flows and loads to the SEWPCC are described in Section 2.0 of this report.

The secondary process will have to treat flows up to the peak dry weather flow. This requirement is the current stipulation, which is assumed to continue. For analysis of the plant, it was assumed that future (2041) flows are allowed to bypass secondary treatment when they exceed 150 ML/d. This flow is approximately 2.0 times the predicted average dry weather flow. This ratio is consistent with the current bypass ratio employed in the plant (ADWF = 58 ML/d). However, it is higher than the peak dry weather flow projected in this report (125 ML/d). The use of 150 ML/d as the bypass flow setpoint is conservative and should ensure that the plant design is capable of handling all potential scenarios.

The key parameter in the modeling exercise is the SRT. Sufficiently high SRTs are required to ensure that nitrification remains stable. Various initial runs were conducted to determine appropriate SRT settings. The selected values for the modelled period are shown below. Wasting rates were modulated through the modelled year to achieve these target values.

Month 1 to 3	10.5 to 11.5 days
Month 4 to 6	12 to 13 days
Month 7 to 9	8 to 9.5 days
Month 8 to 12	9 to 10 days

4.4.2 Preliminary Considerations and the Selected Option

There are two basic options available that would provide the additional tankage required for nitrification at the SEWPCC, as follows:

- Parallel High Purity Oxygen (HPO) trains could be constructed and a lesser portion of the flow directed to the existing tankage. The last cell of each HPO train would be modified to allow de-gassing. Primary effluent and RAS would be split to the existing and new trains in proportion to the reactor volume in each train. Mixed liquor discharged from all of the reactors would combine and then be re-split prior to the secondary clarifiers. The pure oxygen system would be substantially increased in size to handle the additional loads on the new tankage. One other alternative would entail providing the new tankage with conventional aeration systems.
- The existing 16 oxygenation cells could be re-configured to become the initial zone of new bioreactors. The new bioreactor tankage would be

provided with conventional aeration systems to allow the oxygenated effluent to de-gas. Fewer process trains would be constructed, thereby simplifying the split of primary effluent and RAS flows.

For this conceptual design, the second configuration option has been chosen. This option requires that fewer tanks be constructed; it minimizes the need for an addition to the oxygen system; and it provides for de-gasification in the new tankage. Other options might be considered in future work prior to implementation.

4.4.3 Process Design and Operational Parameters

Secondary Clarifier Modeling and Sizing

As an initial step in process assessment, the secondary clarifiers were assessed to determine the limiting mixed liquor suspended solids (MLSS) concentrations that could be handled at the design flows, without clarifier upset. Two scenarios were considered:

- Scenario 1 - existing three secondary clarifiers
- Scenario 2 - existing secondary clarifiers plus a new 45.7 meter diameter unit.

The new unit included in the second scenario is the same diameter as the clarifier constructed in the last expansion. In the two scenarios, the MLSS concentration that could be handled was derived on the basis of the projected flows and the available clarifier area. SEDRIC™, a computer based modeling tool for secondary clarifiers, was used for the analysis. The results are summarized in Table 4.10.

To account for fluctuations in operation, bioreactor design MLSS concentrations should not exceed 90 percent of the limiting MLSS, which is derived in the preceding exercise. Bioreactor sizing, covered in the following subsection, will require a total solids inventory that averages 68,000 kg, with a maximum inventory of 110,800 kg. The bioreactor volume, assuming that there is no reaeration or step feed, would be 38,500 m^3 if the MLSS concentration was limited to 2,880 mg/L (90 percent of 3,200 mg/L) and 27,350 m^3 if the MLSS was limited to 4,050 mg/L (90 percent of 4,500 mg/L). The volume of the existing bioreactors totals approximately 6,450 m^3. A new clarifier would have a volume of approximately 9,840 m^3 (assuming SWD = 6.0 metres). Thus, the total additional tankage volume would be slightly less if another clarifier was constructed. The second scenario has other advantages related to the aeration system sizing; thus, the option with one additional clarifier is adopted for this conceptual design. In addition, RAS pump capacities will be increased to facilitate the higher return rates associated with the high solids loading rates envisioned for this option. The design data for the new secondary clarifiers are summarized in Table 4.11.

Table 4.10: SEWPCC Secondary Clarifier Modeling

Description	Units	Scenario 1	Scenario 2
Flows			
Peak dry weather flow*	ML/d	150	150
Clarifiers			
Clarifiers 1 and 2			
Number		2	2
Diameter	m	33.5	33.5
Area	m^2	880	880
Clarifiers 3 and 4 (future)			
Number		1	2
Diameter	m	45.7	45.7
Area	m^2	1,640	1,640
Total Area	m^2	3,400	5,040
Mixed Liquor Characteristics			
SVI	mL/g	150	150
Limiting MLSS	mg/L	3,200	4,500
Overflow Rates			
Average	$m^3/m^2/d$	26.5	17.8
Peak	$m^3/m^2/d$	44.0	29.8
Solids Loading Rates (at Limiting MLSS)			
Average	$kg/m^2/d$	136	169
Peak	$kg/m^2/d$	240	310
RAS Requirements			
RAS:ADWF Ratio		1.2	2.2
Flow	ML/d	108	198

* Average values calculated on basis of peak dry weather flow divided by 1.7.

Table 4.11: SEWPCC Secondary Clarifier Design

Description	Units	Value
Basic Design Parameters		
Peak flow	ML/d	150
Maximum MLSS	mg/L	4,050
Limiting SVI	mL/g	150
Secondary Clarifiers		
No. 1 and No. 2		
Dimensions		
Diameter	m	33.5
SWD	m	4.55
RAS Pumps		
Number		3
Capacity	L/s	350
No. 3 and No. 4		
Dimensions		
Diameter	m	45.7
SWD – No. 3	m	4.55
SWD – No. 4	m	5.5
RAS Pumps		
Number		3
Capacity	L/s	700

Bioreactor Configuration

The bioreactor was configured as shown in Figure 4.7. The initial two bioreactor cells (Bioreactor 1 and Bioreactor 2) each represent a combination of two of the existing oxygen reactor cells. The second two bioreactors represent new bioreactor tankage. The main flow to this bioreactor module was split to represent the number of modules into which the plant would be divided. Ultimately, it was decided to direct 25 percent of the flow to the modelled module; hence, there would be a total of four modules. Flow into the bioreactors was configured to allow step feed or reaeration (just RAS) in the front one or two bioreactors.

The clarifier, was modelled using aggressive performance parameters so that it did not limit plant operation through the model runs. WAS is wasted from the mixed liquor rather than the RAS to facilitate simpler SRT management.

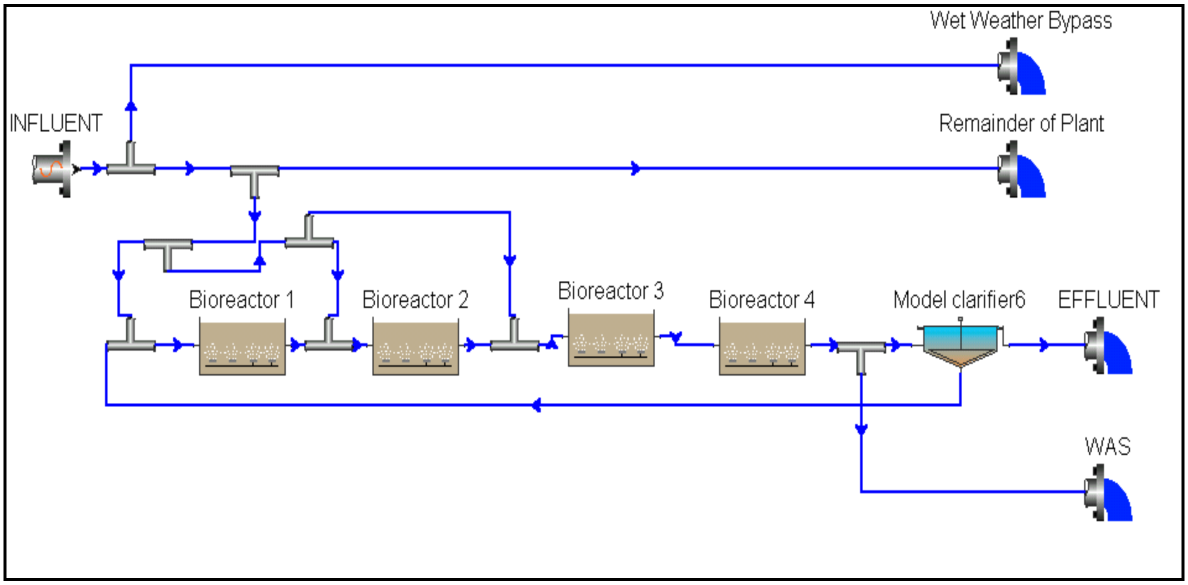


Figure 4.7: Bioreactor Model Configuration

4.4.4 Projected Performance

Modeling results highlighted that the critical period for nitrification was the spring. Loads are higher and the SRT needed to maintain nitrification is highest (due to low temperatures). However, conditions in the river do not mandate full nitrification during this period. According to river modeling data, when the August ammonia concentration requirement is 2.0 mg/L, the May requirement is at least three times higher and the April requirement at least 11 times higher. This information indicates that some nitrification will be necessary at the end of the spring runoff period, but not to the extent required during the critical warmer periods later in the summer and early fall.

For this reason, it was decided to introduce reaeration during the spring months. Reaeration entails bypassing primary effluent around the initial zone(s) of the bioreactor so that only RAS enters that zone. Reaeration allows a greater sludge inventory to be held in smaller tankage, as the initial zones have higher solids concentrations. Fully nitrified effluent can not be obtained as the autotroph contact time with the influent ammonia loads is reduced. However, it is possible to achieve 5 to 10 mg/L.

The modeling results are depicted in Figure 4.8 for the winter period, Figure 4.9 for the spring, Figure 4.10 for the summer period, and in Figure 4.11 for the fall. The vertical bandwidth of each parameter plotted on these figures is indicative of the daily diurnal variation of the parameter. For the modeling run depicted, reaeration using approximately 25 percent of the tankage was incorporated in the maximum month spring period. About half of that volume was used for reaeration during the remainder of the spring and for the maximum month period during the summer. In the summer, the use of any more tankage for reaeration would result in ammonia concentrations above 2 mg/L. Even with 12.5 percent reaeration, the average was only just slightly below 2 mg/L.

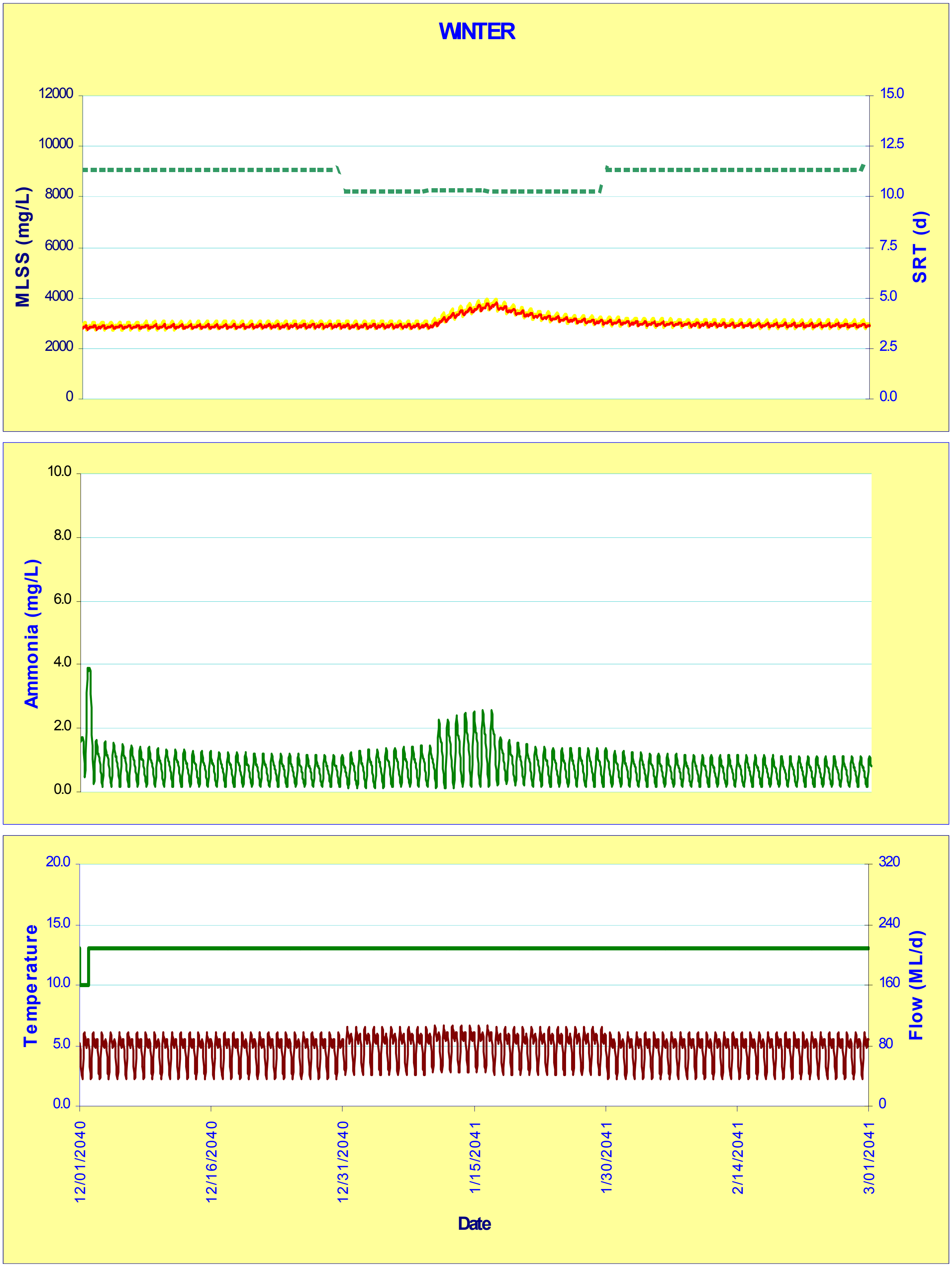


Figure 4.8: Winter Period Modeling Results

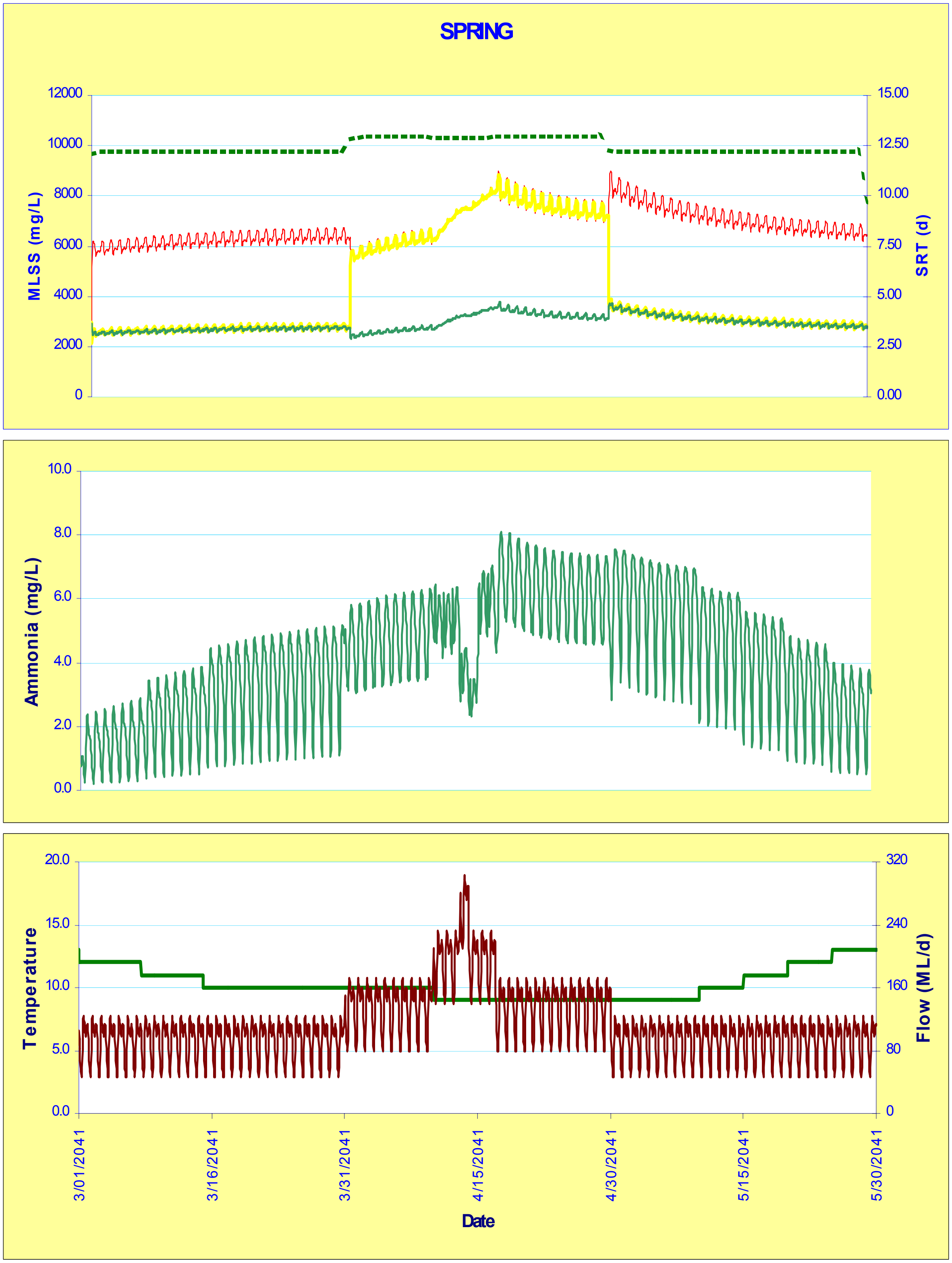


Figure 4.9: Spring Period Modeling Results

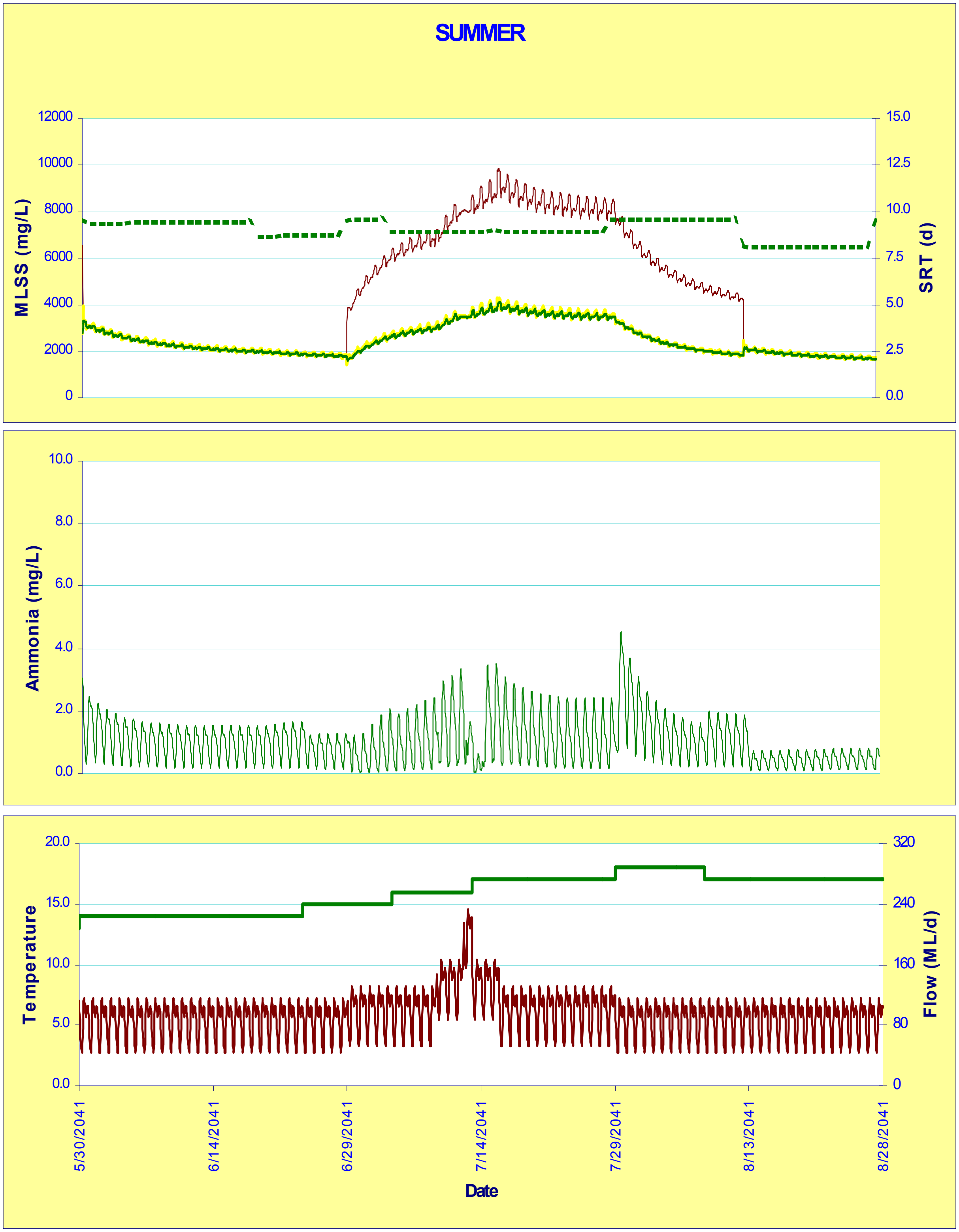


Figure 4.10: Summer Period Modeling Results

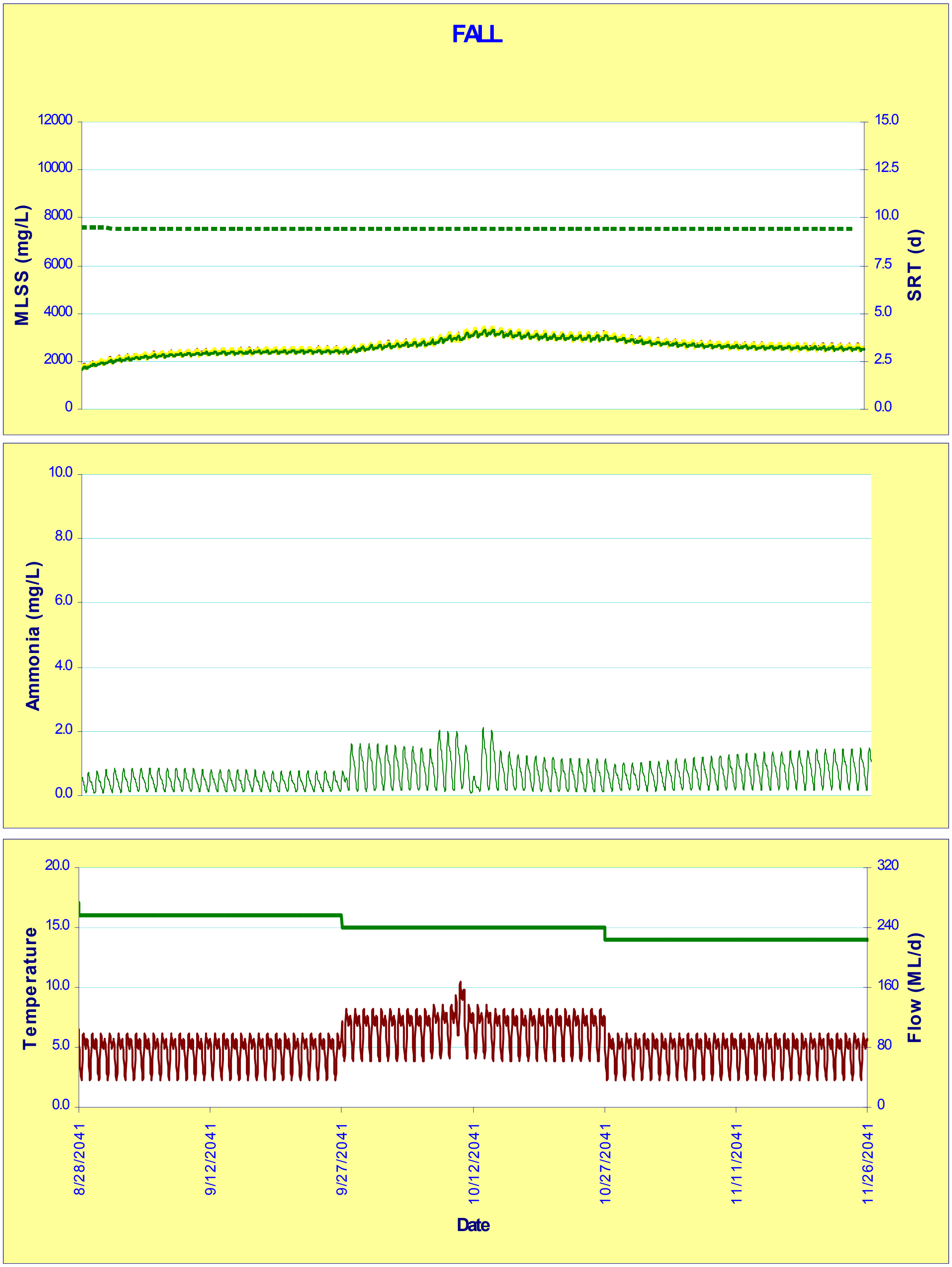


Figure 4.11: Fall Period Modeling Results

4.4.5 Bioreactor Sizing and Operational Specifications

Based on the above findings, the aeration basin sizing has been established, as shown in Table 4.12. Four modules with this configuration are envisioned for the ultimate 2041 flows and loads.

Table 4.12: SEWPCC Bioreactor Sizing (Best Practicable Level of Control)

Description	Units	Volume
Volume		
Bioreactor Cell 1 (2 existing oxygen cells)	m^3	810
Bioreactor Cell 2 (2 existing oxygen cells)	m^3	810
Bioreactor Cell 3 (new aeration cell)	m^3	2000
Bioreactor Cell 4 (new aeration cell)	m^3	2,005
Total Volume	m^3	5,625
HRT @ ADWF (87 ML/d)	h	6.2

4.4.6 Aeration Requirements

BioWin predicts oxygen demand in each modelled, aerated cell. The average, maximum, and minimum process oxygen demands for the four bioreactors in the model are indicated in Table 4.13.

Table 4.13: SEWPCC Bioreactor Oxygen Demands

Description	Units	Average	Maximum	Minimum
Bioreactor Cell 1	kg O_2/d	1,055	2,015	450
Bioreactor Cell 2	kg O_2/d	900	1,645	600
Bioreactor Cell 3	kg O_2/d	1,735	2,895	895
Bioreactor Cell 4	kg O_2/d	1,355	2,565	630

These “actual” oxygen demands have been converted to “standard” oxygen transfer requirements on the basis of retaining the pure oxygen system in the initial two bioreactor cells while providing a fine bubble aeration system in the latter two cells.

The peak oxygen demand in the first two cells of all bioreactors is 21 tonnes per day. This demand matches the capacity of the existing oxygen generation system, not including any allowance for standby or reserve capacity.

Derivation of the standard oxygen transfer requirements in the second two cells of the four bioreactor modules are based on the aeration parameters listed in Table 4.14.

Table 4.14: SEWPCC Aeration Design Parameters

Description	Units	Bioreactor Cell 3	Bioreactor Cell 4
Alpha	dimensionless	0.60	0.65
Beta	dimensionless	0.95	0.95
Residual DO	mg O_2/L	2.0	2.0
Atmospheric pressure	kPa	98	98
SOTE (Standard Oxygen Transfer Efficiency)	%	30	30

Fine bubble aeration would achieve a Standard Oxygen Transfer Efficiency (SOTE) of approximately 30 percent at a reactor depth of 5.0 metres. Based on this SOTE, the total air demand is 405 nm^3/min. To provide this air supply, four 300 hp blowers (3 duty and 1 standby) are required. Design parameters for the blowers are listed in Table 4.15.

Table 4.15: SEWPCC Blower Design Parameters

Description	Units	Bioreactor Cell 4
Air Requirement,	nm^3/min	405
Temperature Maximum,	°C	35
Minimum	°C	-30
Relative Humidity		
At max Temp.	%	75
At min Temp.	%	100
Atmospheric pressure	kPa	98
Backpressure	kPa	55
Blowers Number		4
Capacity,	nm^3/min	135
Size	hp	300

The minimum temperature would be maintained by tempering the inlet air to the blowers. Tempering reduces the required motor size and prevents hoar frost accumulations on the inlet filters.

4.4.7 Process Description

The design data for the nitrification upgrade to the plant is summarized in the various tables in the preceding subsections. The basic operation of the various elements is summarized in the following subsections.

Primary Clarifiers

The primary clarifiers would be operated essentially as they are at present with the exception that co-thickening of WAS with primary sludge would not be practiced for the same reasons as cited for the NEWPCC. Without co-thickening, sludge blankets would be reduced, pumping frequency would be lower and pump operation period would be shorter.

Bioreactors

Flow would be split to the reconfigured bioreactors to ensure relatively equal flows to the four modules. The oxygen system would be reconfigured to provide oxygen to the first four cells of each train in a manner similar to present. Oxygen supply would be modulated to maintain vent gas purity at the relocated vents between 35 and 40 percent.

Reaeration would be instituted during high flow and load periods. During the spring, the primary effluent will be diverted to the head of the new aeration cells. During the summer, primary effluent might be diverted to the third oxygen cell. Diverting to the head of the aeration basins is not recommended due to the predicted reduction in ammonia removal.

In the aeration basins, air is supplied to two aeration zones in each basin. The air supply to each zone is controlled to maintain a residual dissolved oxygen concentration of at least 2.0 mg/L.

RAS always will be returned to the head of the bioreactor. As with primary effluent, RAS is split evenly between the four modules. WAS is withdrawn from a selective wasting chamber in the mixed liquor channel. An alternative wasting point is provided in the RAS header(s) feeding the bioreactors.

Secondary Clarifiers

Mixed liquor flow will be split to the four clarifiers in proportions shown in Table 4.16.

Table 4.16: Mixed Liquor Split to the Final Clarifiers

Clarifier	% Mixed Liquor Flow
Clarifier 1	16.7
Clarifier 2	16.7
Clarifier 3	33.3
Clarifier 4	33.3

RAS is withdrawn from the existing RAS system at rates that are appropriate to the sludge settleability. The maximum RAS rate is two times the ADWF – 175 ML/d.

Sludge blankets are maintained at less than 0.3 metres to ensure that rising sludge problems do not occur. In the existing three clarifiers, some enhancements to improve flocculation will be considered in the plant modification. No allowance has been allowed for this work at this time.

4.4.8 Site Layout

Dwg. SE-4.1 shows a site plan of the modified plant while Dwg. SE-4.2 provides a layout of the plant. The process flow diagram is illustrated in Dwg. SE-4.3.

4.4.9 Best Practicable Level of Control - Statistical Analysis of the Projected Effluent Ammonia

The results of the statistical analysis of effluent ammonia concentration (using best practicable level of control) are presented in Table 4.17. The assumptions, methodology, and the definitions are the same as those described for the NEWPCC.

The results of statistical analysis indicate 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.
- Effluent ammonia concentrations show higher variations during summer months (June, July and August) than other months.

Table 4.17: SEWPCC - Results of Statistical Analysis on the Effluent Ammonia (Year 2041 – Best Practicable 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	1.01	-0.18	0.12	-0.021	0.004	-0.175	-0.169	0.84
July	1.16	-0.23	0.18	-0.042	0.008	-0.231	-0.218	0.80
August	0.93	-0.41	0.12	-0.049	0.009	-0.410	-0.395	0.67
September	0.43	-1.00	0.06	-0.060	0.011	-0.993	-0.975	0.38
October	0.76	-0.54	0.09	-0.049	0.009	-0.539	-0.524	0.59
November	0.71	-0.51	0.06	-0.031	0.006	-0.509	-0.500	0.61
December	0.81	-0.41	0.06	-0.025	0.004	-0.410	-0.402	0.67
January	0.91	-0.31	0.04	-0.013	0.002	-0.314	-0.310	0.73
February	0.66	-0.58	0.06	-0.035	0.006	-0.574	-0.564	0.57
March	2.69	0.80	0.04	0.032	0.006	0.804	0.814	2.26
April	5.46	1.67	0.06	0.100	0.018	1.672	1.702	5.49
May	4.39	1.36	0.04	0.054	0.010	1.364	1.380	3.98

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

4.5 WASTE ACTIVATED SLUDGE THICKENING - SEWPCC

4.5.1 WAS Production

The predicted secondary sludge generation rates are summarized in Table 4.18. WAS flow rates have been estimated on the basis of mixed liquor wasting rather than RAS wasting. Where mixed liquor wasting is implemented, SRT control is simpler and it is possible to incorporate selective wasting. Selective wasting suppresses the proliferation of biological foam causing organisms (*Nocardia sp* and *M. Parvicella*).

Table 4.18: SEWPCC WAS Generation Rates (Best Practicable Level of Control)

Description	Units	Value
WAS Generation Rates		
Average	kg/d	6,500
Maximum	kg/d	11,760
WAS Flow		
Average	m^3/d	185
Maximum	m^3/d	300

4.5.2 Thickening Options

There are three options that are generally used for thickening sludge at medium to large wastewater treatment plants such as the SEWPCC—dissolved air flotation (DAF), gravity belt thickeners (GBTs), and centrifuges. DAF and GBT are favoured at medium sized plants due to the high capital costs associated with centrifuges. Of these two options, DAF has been chosen for this conceptual design. The final selection should be revisited prior to implementation. The WAS thickening process flow diagram is shown in Dwg. SE-4.4.

In DAF thickening, air and water are mixed under pressure so that the water becomes saturated with dissolved air. This pressurized, saturated water is introduced with the sludge into a flotation tank. When the pressure is relieved, air evolves from solution into small bubbles. The rising bubbles become enmeshed in sludge particles, ensuring that the resulting particles are buoyant. Floating sludge forms a blanket on the surface of the DAF which is skimmed from the surface. Clarified subnatant is collected and a portion recycled to be re-saturated under pressure. The remaining subnatant discharges to the plant drain for re-treatment. Generally, subnatant has TSS concentrations less than 200 mg/L.

DAF design is based on providing sufficient dissolved air to effectively float the influent solids. A minimum air:solids ratio of 0.03 (mass basis) is required for secondary sludge thickening. DAF tank sizing is a function of the solids loading rate that can be applied. Generally, without polymer addition, solids loading rates are limited to about 3 kg/m^2/h on an average basis and for maximum loading conditions, 6 kg/m^2/h. If polymer is added, the average and maximum solids loading rates can be raised to 5 kg/m^2/h and 12 kg/m^2/h, respectively. To limit the size of the system, polymer addition has been incorporated in the SEWPCC conceptual design. These and other important design parameters are listed in Table 4.19.

Table 4.19: SEWPCC DAF Design

Description	Values	Value
Basis Design Parameters		
WAS Generation Rates		
Average	kg/d	6,500
Maximum	kg/d	11,760
Solids Loading Rates		
Average	kg/m^2/h	5.0
Maximum	kg/m^2/h	12.0
A/S Ratio	dimensionless	0.03
Capture efficiency	%	93
Target solids concentration	%	4.0
Polymer dosage		
Average	kg/T	0.75
Maximum	kg/T	1.5
DAF Units		
Number		3
Dimensions		
Length	m	8.0
Width	m	3.0
SWD	m	3.0

4.6 WEST END WATER POLLUTION CONTROL CENTRE (WEWPCC)

4.6.1 Model Input

Similar to the NEWPCC and the SEWPCC, hourly flows and loads in the year 2041 were used to simulate nitrification options for the WEWPCC. Projections of the hourly flows and loads to the WEWPCC are described in Section 2.0 of this report.

The secondary process will have to treat flows up to the peak dry weather flow. This requirement is the current stipulation, which is assumed to continue. For analysis of the plant, it was assumed that future (2041) flows are allowed to bypass secondary treatment when they exceed 60 ML/d. This flow is approximately 2.0 times the predicted average dry weather flow. This ratio is higher than the current bypass ratio employed in the plant (Ratio = 1.7). It also is higher than the peak dry weather flow projected in this report (52.9 ML/d). The use of 60 ML/d as the bypass flow setpoint is conservative and should ensure that the plant design is capable of handling all potential scenarios. It is presumed that the changes implemented to achieve nitrification, in concert with recent plant modifications, will result in improved sludge settleability that will enable the higher flows to be handled through the secondary clarifiers.

The key parameter in the modeling exercise is the SRT. Sufficiently high SRTs are required to ensure that nitrification remains stable. Various initial model runs were conducted to determine appropriate SRT settings. The selected values for the modelled period are shown below. Wasting rates were modulated through the modelled year to achieve these target values.

Month 1 to 3	10.5 to 11.5 days
Month 4 to 6	11 to 12 days
Month 7 to 9	8 to 9.5 days
Month 8 to 12	9 to 10 days

4.6.2 Preliminary Considerations and the Selected Option

Unlike the NEWPCC and the SEWPCC, the WEWPCC is an air activated sludge plant. The two complete mix basins provided in this plant have a total volume of 10,500 m^3; sufficient to provide a hydraulic retention time of 8.5 hours at the design ADWF. Based on the experience at the other two plant, this retention time should make it possible to achieve nitrification without any need for additional tankage. The nitrification options considered in this conceptual design have focused on an arrangement that does not entail the construction of any additional bioreactor volume.

The bioreactors likely will require some reaeration to enable nitrification to be maintained during cooler periods of the year. In addition, conversion of the plant to provide anoxic selectors at the head of a series of tanks (configured to achieve near plug flow conditions), would provide some benefit. To achieve these objectives, the conceptual design has incorporated some re-configuration of the existing tankage so that two small zones are provided at the head of the tank. During the spring period, these would receive return activated sludge (RAS) and would be aerated to provide a degree of RAS reaeration. During the remainder of the year, they would be used as aerobic or anoxic selectors. For this conceptual design, it is presumed that these basins would remain aerated; however, more detailed examination in later stages of project implementation would likely prove that design as mixed anoxic basins would provide a cost benefit in oxygen supply and settleability control.

4.6.3 Process Design and Operational Parameters

Secondary Clarifier Sizing Limitations

As an initial step in process assessment, the secondary clarifiers were assessed to determine the limiting mixed liquor suspended solids (MLSS) concentrations that could be handled at the design flows, without clarifier upset. The MLSS concentration that could be handled was derived on the basis of the projected flows and the available clarifier area. SEDRIC™ , a computer based modelling tool for secondary clarifiers, was used for the analysis. Figure 4.12 illustrates the relationship between SVI and MLSS for the projected primary flows and the existing WEWPCC secondary clarifiers.

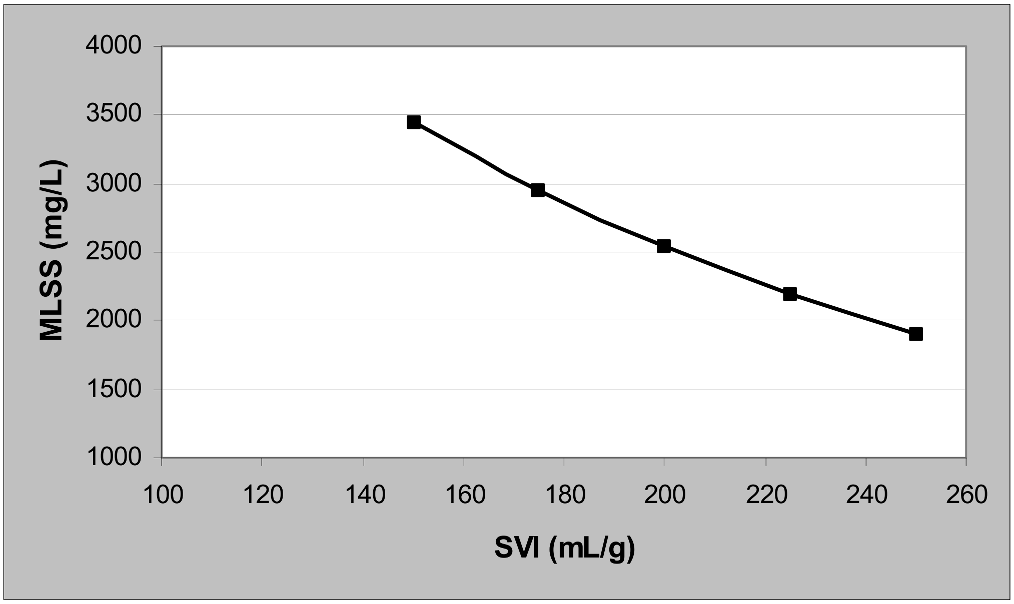


Figure 4.12: WEWPCC Secondary Clarifiers Allowable MLSS versus SVI

The graph shows that as the SVIs increase, the MLSS that can be handled decreases. Historically, the SVIs have been high at the WEWPCC. Implementation of nitrification will incorporate several features that suppress the tendency for bulking conditions. For this reason, a design SVI of 175 mL/g has been selected for the plant analysis. At this SVI, the MLSS concentration that can be handled by WEWPCC clarifiers is about 2900 mg/L. To provide some safety factor, the bioreactor should be designed to achieve an MLSS concentration of about 2,500 mg/L.

Bioreactor sizing, covered in the following subsection, will require a total solids inventory that averages 20,100 kg, with a maximum inventory of 26,900 kg. With an existing volume of 10,250 m^3, the average MLSS concentration would be about 2,000 mg/L and the maximum concentration, about 2,650 mg/L. The higher MLSS inventory is only required during the spring. During this time, it is not necessary to maintain low effluent ammonia concentrations; however, relatively low effluent concentrations are necessary shortly after the spring period. Incorporation of reaeration is ideally suited to this type of effluent requirement. Nitrifier populations can be conserved through the spring so that they are available when full nitrification becomes necessary. The loss of nitrification efficiency that is associated with reaeration will not cause effluent concentrations that endanger discharge requirements. Hence, reaeration has been incorporated in the design specifically to handle spring flows and loads without increasing the existing secondary clarifier capacity. The design parameters for these clarifiers are summarized in Table 4.20.

Table 4.20: WEWPCC Secondary Clarifier Design

Description	Value
Basic Design Parameters	
Peak flow, ML/d	60
Maximum MLSS	2,500
Limiting SVI, mL/g	175
Maximum solids loading rate, kg/m^2/d	150
Secondary Clarifiers	
No.	2
Dimensions	
Diameter, m	33.5
SWD, m	4.0
RAS Pumps	
Number	3
Capacity, L/s	260

RAS Pumping

The maximum RAS rate is 1.5 times the ADWF – 45 ML/d or 520 L/s. The existing RAS pumps are sized to pump 330 L/s – two duty pumps each at 165 L/s (plus one standby pump). For this conceptual design, it is assumed that the motors could be replaced and the pumps increased in speed from 900 rpm to 1500 rpm. This increase in operating speed allows the pumps to convey close to the required flow. Alternatively, a fourth RAS pump could be installed so that each clarifier would have two duty pumps.

Bioreactor Configuration

The bioreactor was configured as shown in Figure 4.13. The initial two bioreactor cells (Bioreactor 1 and Bioreactor 2) each represent 12.5 percent of the existing bioreactor. The latter two cells (Bioreactor 3 and Bioreactor 4) each represent 37.5 percent of the volume. The main flow to this bioreactor module was split, 50 percent to the module and 50 percent bypass, to represent the two modules into which the plant is divided. Flow into the bioreactors was configured to allow step feed or reaeration (just RAS) in the front one or two bioreactors.

The first bioreactor cell is not aerated during conventional operation. This cell acts as an anoxic zone where nitrates recycled with the RAS are used in bacterial metabolism, in the absence of dissolved oxygen. During periods when primary effluent bypasses the initial zone (reaeration), the first cell (reaearation zone) would be aerated and the second cell would not be aerated but would be mixed (anoxic zone). An anoxic zone has been incorporated in the WEWPCC bioreactor design for the following reasons:

1. An anoxic zone at the head of a bioreactor, when fed with primary effluent (readily biodegradable substrate) reduces the likelihood of bulking.
2. Oxygen demands are lower due to the recovery of 'oxygen' from nitrates in the RAS.
3. Alkalinity recovery in the anoxic zone ensures that pH depression does not occur.

The clarifier was modeled using aggressive performance parameters so that it did not limit plant operation through the model runs. WAS is wasted from the mixed liquor rather than the RAS to facilitate simpler SRT management.

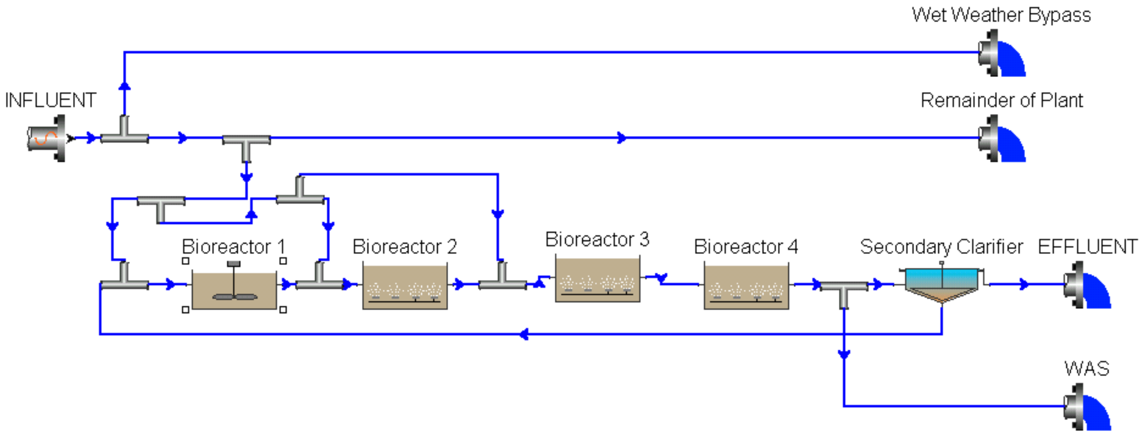


Figure 4.13: Bioreactor Model Configuration

The initial two bioreactor cells (Bioreactor 1 and Bioreactor 2) each represent 12.5 percent of the existing bioreactor. The latter two cells (Bioreactor 3 and Bioreactor 4) each represent 37.5 percent of the volume. The main flow to this bioreactor module was split, 50 percent to the module and 50 percent bypass, to represent the two modules into which the plant is divided. Flow into the bioreactors was configured to allow step feed or reaeration (just RAS) in the front one or two bioreactors.

4.6.4 Projected Performance

Modeling results highlighted that the critical period for nitrification was the spring. Loads are higher and the SRT needed to maintain nitrification is highest (due to low temperatures). However, conditions in the river do not mandate full nitrification during this period. According to Red River modeling data, when the August ammonia concentration requirement is 2.0 mg/L, the May requirement is at least 3 times higher and the April requirement at least 11 times higher. Assuming that the same pattern exists in the Assiniboine River, this information indicates that some nitrification will be necessary at the end of the spring runoff period, but not to the extent required during the critical warmer periods later in the summer and early fall.

For this reason, it was decided to introduce reaeration during the spring months. Reaeration entails bypassing primary effluent around the initial zone(s) of the bioreactor so that only RAS enters that zone. Reaeration allows a greater sludge inventory to be held in smaller tankage, as the initial zones have higher solids concentrations. Fully nitrified effluent can not be obtained as the autotroph contact time with the influent ammonia loads is reduced. However, it is possible to achieve 5 to 10 mg/L.

The modeling results are depicted in Figure 4.14 for the winter period, Figure 4.15 for the spring, Figure 4.16 for the summer period, and in Figure 4.17 for the fall. The vertical bandwidth of each parameter plotted on these figures is indicative of the daily diurnal variation of the parameter. For the modeling run depicted, reaeration using approximately 25 percent of the tankage was incorporated in the maximum month spring period. During the remainder of the year, primary effluent was directed to the initial cell of the bioreactor, which was operated in an anoxic mode.

The modelling runs indicated that the maximum MLSS was always maintained below 2,500 mg/L, as required for effective clarification and during the critical summer and fall periods, effluent ammonia concentrations were always below 2 mg/L. These concentrations climbed to above 6 mg/L in the spring. Based on these findings, the bioreactor cell size has been established as follows:

Bioreactor Cell 1	880 m^3
Bioreactor Cell 2	880 m^3
Bioreactor Cell 3	1,760 m^3
Bioreactor Cell 6	1,760 m^3
Total Volume, one module	5,280 m^3
HRT at ADWF (30 ML/d)	8.5 h

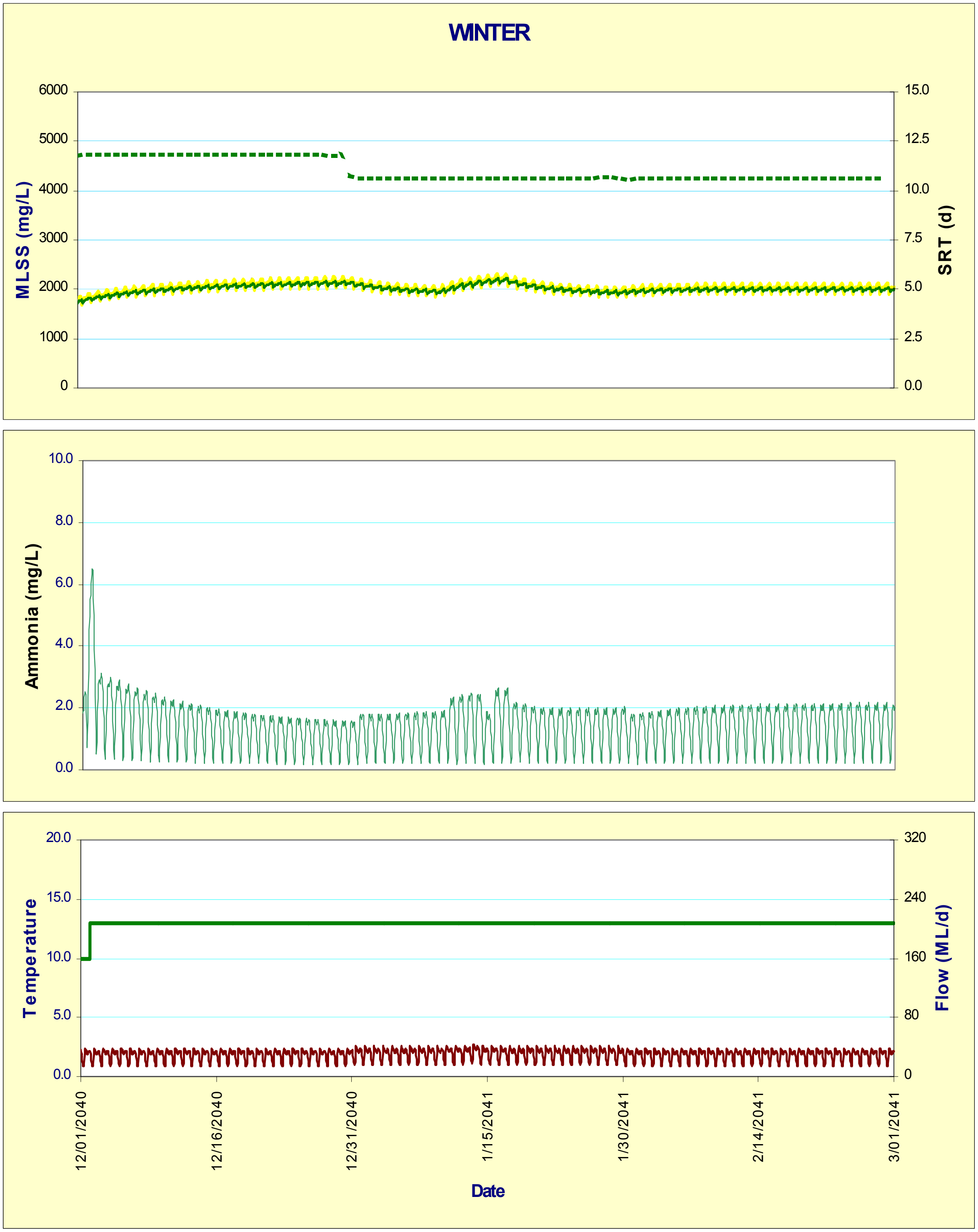


Figure 4.14: Winter Period Modeling Results

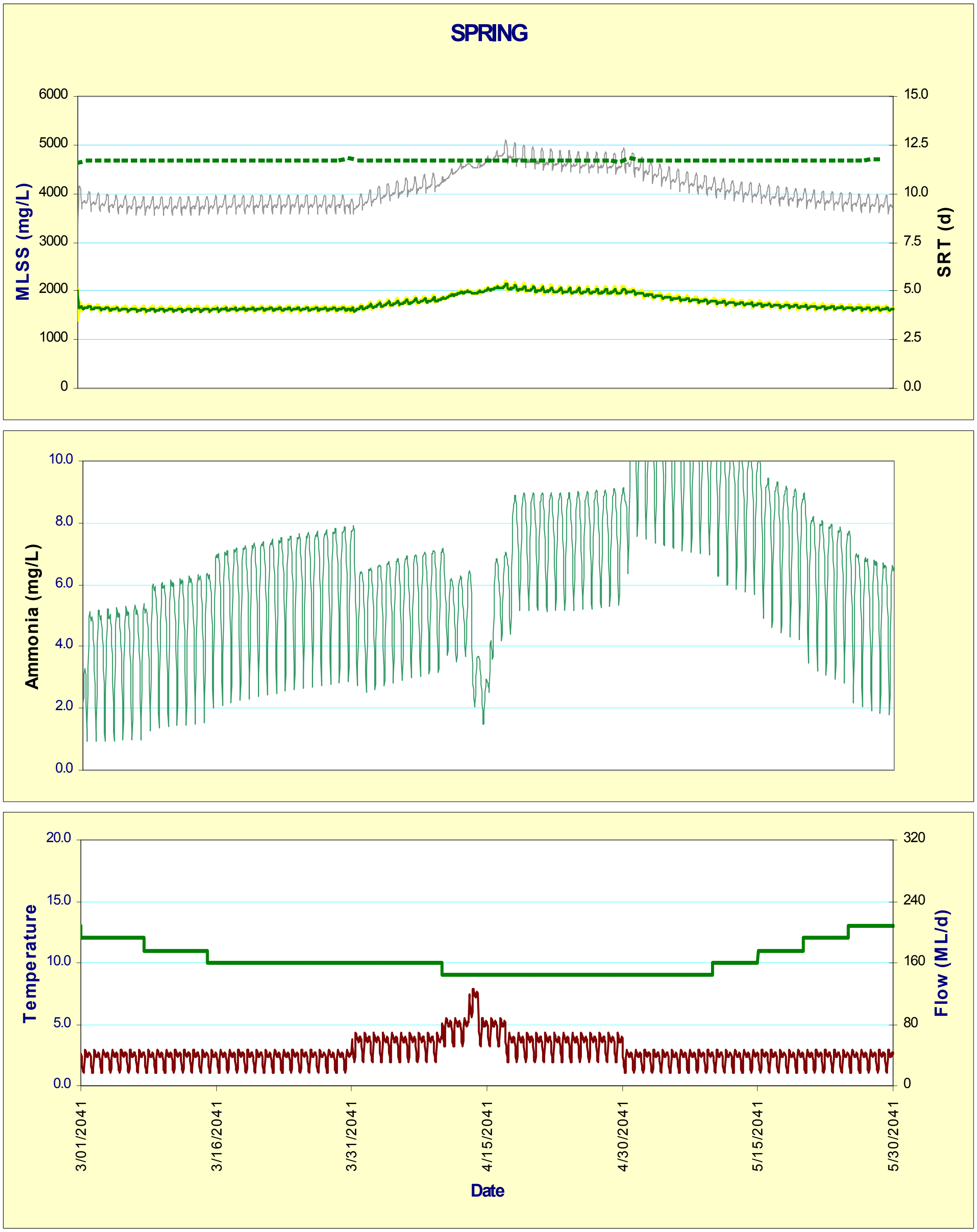


Figure 4.15: Spring Period Modeling Results

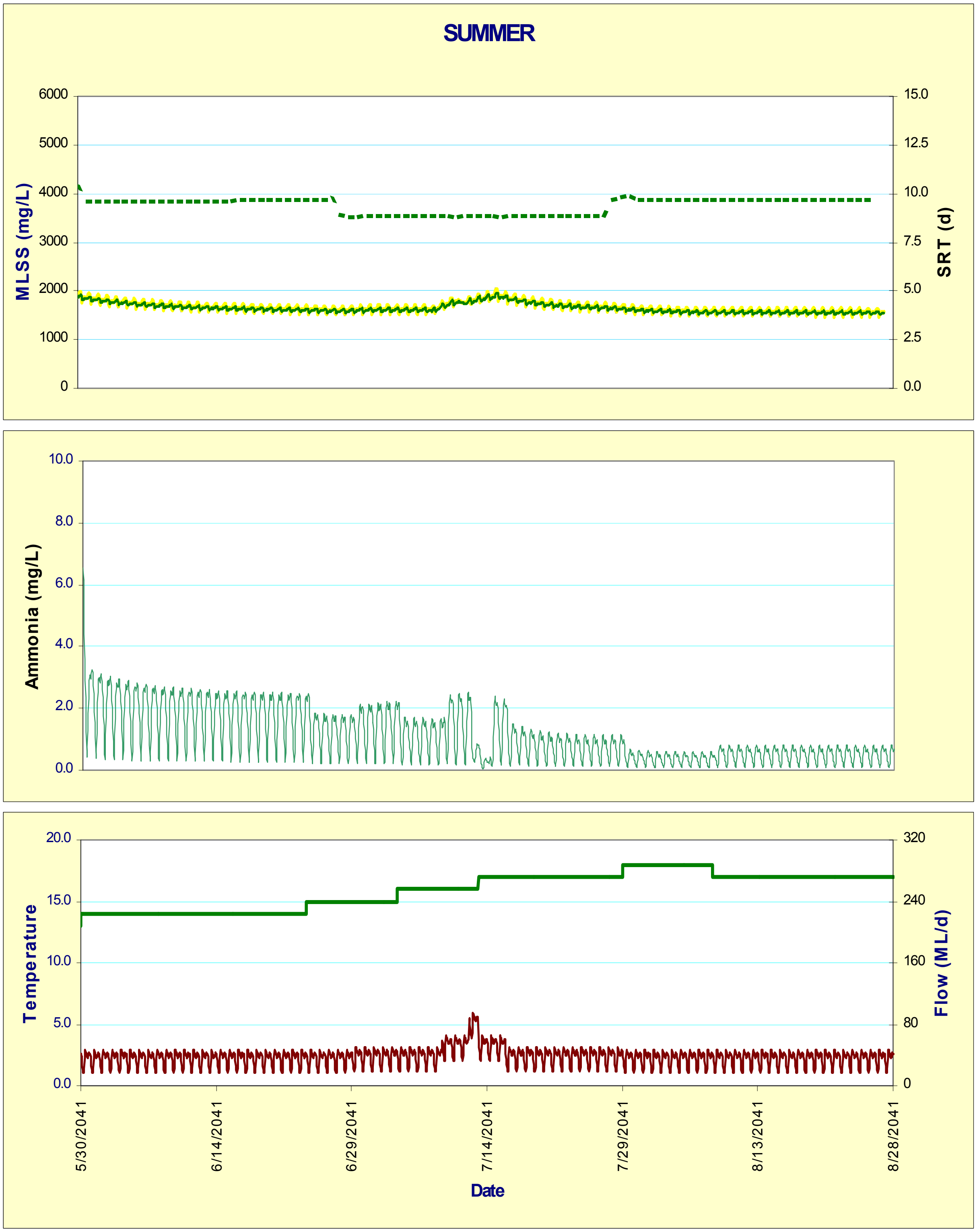


Figure 4.16: Summer Period Modeling Results

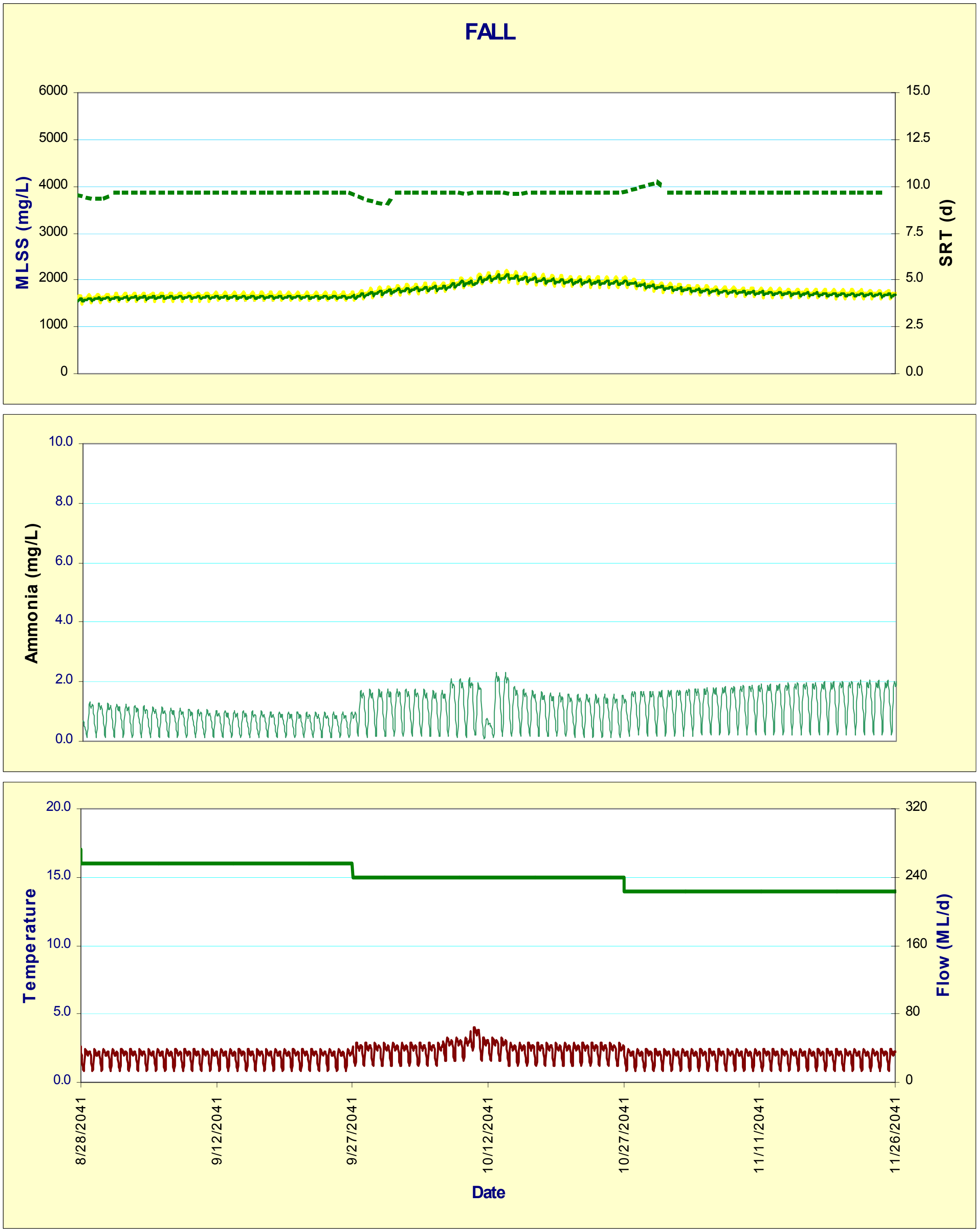


Figure 4.17: Fall Period Modeling Results

Aeration Requirements

BioWin predicts oxygen demand in each modelled, aerated cell. The average, maximum, and minimum process oxygen demands for the four bioreactors in the model are indicated in Table 4.21.

Table 4.21: WEWPCC Bioreactor Oxygen Demands

Description	Average[1]	Maximum[2]	Minimum
Bioreactor Cell 1, kg O_2/d	0	865	0
Bioreactor Cell 2, kg O_2/d	660	-	235
Bioreactor Cell 3, kg O_2/d	1,005	1,395	550
Bioreactor Cell 4, kg O_2/d	765	1,200	380

Notes:
1. Average oxygen demands occur while first cell is unaerated.
2. Maximum oxygen demands occur while first cell is in reaeration and second cell is unaerated.

These “actual” oxygen demands have been converted to “standard” oxygen transfer requirements on the basis of retaining the coarse bubble aeration system. Derivation of the standard oxygen transfer requirements in the four bioreactor cells are based on the aeration parameters listed in Table 4.22.

Table 4.22: WEWPCC Aeration Design Parameters

Description	Bioreactor Cell 3	Bioreactor Cell 4
Alpha, dimensionless	0.90	0.90
Beta, dimensionless	0.95	0.95
Residual DO, mgO_2/L	2.0	2.0
Atmospheric pressure, kPa	98	98
SOTE, percent	12	12

Fine bubble aeration will achieve a Standard Oxygen Transfer Efficiency (SOTE) of approximately 12 percent at a reactor depth of 5.0 metres. Based on this SOTE, the total air demand is 220 nm^3/min. The existing three blowers are all rated at 150 nm^3/min. Accordingly even with the slightly higher backpressure due to fine bubble aeration, the existing blower capacity is more than sufficient for the system.

4.6.5 Process Description

The design data for the nitrification upgrade to the plant is summarized in the various tables in the preceding subsections.

The basic operation of the various elements is summarized in the following subsections.

Primary Clarifiers

The primary clarifiers would be operated as they are at present. Without co-thickening, sludge blankets would be reduced, pumping frequency would be lower and the pump operation period would be shorter.

Bioreactors

Flow would be split to the reconfigured bioreactors to ensure relatively equal flows to the two modules. The aeration system would be reconfigured to suit the new compartments in the two bioreactors.

Reaeration would be instituted during the spring due to high flow and load during this period. During that operating mode, primary effluent will be diverted to the head of the second bioreactor cell.

The air supply to each aerated cell is controlled to maintain a residual dissolved oxygen concentration of at least 2.0 mg/L.

RAS always will be returned to the head of the bioreactor. As with primary effluent, RAS is split evenly between the two modules. WAS is withdrawn from a selective wasting chamber in the mixed liquor channel. An alternative wasting point is provided in the RAS header(s) feeding the bioreactors.

Secondary Clarifiers

Mixed liquor flow is split to the two clarifiers equally. RAS is withdrawn from the existing RAS system at rates that are appropriate to the sludge settleability. Sludge blankets are maintained at less than 0.3 metres to ensure that rising sludge problems do not occur.

4.6.6 Plant Layout

No expansions of existing liquid stream facilities at the WEWPCC is required to achieve the best practicable level of ammonia control. All modifications required are incorporated within the existing structures.

Dwg. WE-4.1 presents the site plan, while Dwg. WE-4.2 shows the bioreactor layout. The process flow diagram and the sludge thickening flow diagram are shown in drawings Dwg. WE-4.3 and Dwg. WE-4.4, respectively.

A new sludge thickening facility, as described in Section 4.7, will be located near the head of the plant to minimize piping runs between the thickening system and the existing thickened sludge storage tank.

4.6.7 Best Practicable Level of Control - Statistical Analysis of the Projected Effluent Ammonia

The model projected effluent ammonia concentrations for the WEWPCC were analyzed using the statistical procedure described in previous sections for the NEWPCC. The results of the statistical analysis are summarized in Table 4.23.

As shown by the standard deviation in Table 4.23, the effluent ammonia concentration shows more variation during the spring period and the month of August.

The last column of Table 4.23 presents the upper limit ammonia concentration that is predicted to occur in 95 percent of the samples taken during each month. Consequently, 95 percent of the samples taken during each month will have ammonia concentrations equal to or less than the value shown in the last column for that month.

Table 4.23: WEWPCC - Results of Statistical Analysis on the Effluent Ammonia (Year 2041 – Best Practicable 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	1.81	0.43	0.12	0.051	0.009	0.429	0.444	1.56
July	1.04	-0.22	0.18	-0.040	0.007	-0.223	-0.211	0.81
August	0.46	-0.93	0.12	-0.112	0.020	-0.925	-0.892	0.41
September	0.71	-0.50	0.06	-0.030	0.005	-0.498	-0.489	0.61
October	1.10	-0.12	0.09	-0.010	0.002	-0.116	-0.113	0.89
November	1.30	0.11	0.06	0.007	0.001	0.110	0.112	1.12
December	1.55	0.24	0.06	0.014	0.003	0.241	0.245	1.28
January	1.40	0.17	0.04	0.007	0.001	0.166	0.168	1.18
February	1.44	0.21	0.06	0.013	0.002	0.209	0.213	1.24
March	5.28	1.59	0.04	0.063	0.012	1.588	1.608	4.99
April	6.26	1.78	0.06	0.107	0.019	1.786	1.818	6.16
May	8.22	2.06	0.04	0.082	0.015	2.063	2.088	8.07

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

4.7 WASTE ACTIVATED SLUDGE THICKENING – WEWPCC

Consistent nitrification will be dependent upon stable plant operation. As with the SEWPCC and NEWPCC, separate secondary sludge thickening is recommended to simplify liquid stream process operation and to ensure consistently higher thickened sludge densities. This subsection outlines the considerations related to implementation of this process at the WEWPCC.

4.7.1 Sludge Quantities

The predicted secondary sludge generation rates have been extracted from the model runs for the plant and are summarized in Table 4.24.

Table 4.24: WEWPCC WAS Generation Rates

Description	Value
WAS Generation Rates	
Average, kg/d	3,845
Maximum, kg/d	5,720
WAS Flow	
Average, m^3/d	1,925
Maximum, m^3/d	2,860

WAS flow rates have been estimated on the basis of mixed liquor wasting rather than RAS wasting. Where mixed liquor wasting is implemented, SRT control is simpler and it is possible to incorporate selective wasting. Selective wasting suppresses the proliferation of biological foam causing organisms (*Nocardia sp* and *M. Parvicella*).

4.7.2 Process Selection

There are three options that are generally used for thickening secondary sludge at medium to large wastewater treatment plants such as the WEWPCC – dissolved air flotation (DAF), gravity belt thickeners (GBTs), and centrifuges. DAF and GBT are favoured at medium sized plants due to the high capital costs associated with centrifuges. Of these two options, DAF has been chosen for this conceptual design. The final selection should be revisited prior to implementation.

Refer to Subsection 4.5.2 for a description of the DAF alternatives. To limit the size of the WAS thickening system at the WEWPCC, polymer addition has been incorporated in the conceptual design. These and other key design parameters are listed in Table 4.25.

Table 4.25 WEWPCC DAF Design

Description	Value
Basis Design Parameters	
WAS Generation Rates	
Average, kg/d	3,990
Maximum, kg/d	5,720
Solids Loading Rates	
Average, kg/m^2/h	5.0
Maximum, kg/^{m2}/h	12.0
A/S Ratio, minimum	0.03
Capture efficiency, percent	93
Target solids concentration, percent	4.0
Polymer dosage	
Average, kg/T	0.75
Maximum, kg/T	1.5
DAF Units	
Number	2
Dimensions	
Length, m	7.5
Width, m	2.5
SWD, m	3.0

4.8 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 Best Practicable Level of Control for the three WPCCs. The details of the estimates are presented in Appendix A. The 95 percent confidence limit estimates are summarized in Table 4.26.

Table 4.26: Summary of Estimated Costs - Best Practicable Level of Control

	NEWPCC	SEWPCC	WEWPCC
Capital Cost	\$112,000,000	\$33,100,000	\$3,900,000
O&M Cost	\$2,150,000	\$615,000	\$100,000
Total Cost (Net Present Value – 4% Discount Rate)	\$157,000,000	\$46,000,000	\$6,140,000