SEWPCC Upgrading/Expansion
Conceptual Design Report

SECTION 4 - BNR Process Refinement

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4.0 BNR Process Refinement

4.1 INTRODUCTION

The SEWPCC Upgrading/Expansion PDR, short-listed two BNR process options to be carried forward to the Conceptual Design stage for further analysis and review. The two (2) short-listed options were:

- Option C: Modified Johannesburg BNR Process with side-stream Chemically Enhanced Lamella Clarification.
- Option G: Modified Johannesburg BNR Process with IFAS media and side-stream Chemically Enhanced Lamella Clarification.

The BioWin^{TM} models presented in the PDR were set up in a manner to compare the four short-listed alternative treatment processes. As part of the Conceptual Design work a series of refinements have been made to the base BioWin^{TM} models for the short-listed Options C and G. The modeling assumptions made in Section 15 of the PDR from the basis for the CDR. This section summarizes the process and modeling refinements completed to date with specific reference to the following tasks:

- Refinement of basic BioWin^{TM} model set-up.
- Nitrifier maximum specific growth rate sensitivity analysis.
- Sensitivity analysis related to alternative wet weather flow strategies.
- Sensitivity analysis related to chemically enhanced primary treatment efficiency.
- For Option C: Comparison of proposed Modified Johannesburg Process (MJP) with Westbank Process (WB) configuration.
- Impact of low flows on BNR performance.
- Bioreactor train - sensitivity analysis.
- Comparison of Option C with Option G.

4.2 REFINEMENTS TO THE BASIC MODEL SET-UP FOR OPTION C AND OPTION G

4.2.1 Process Refinements

The following is a summary of the process refinements that were incorporated in the base model for Options C and G:

- During the comparison of alternatives in the PDR, the internal MLSS recycle and the RAS flow rates were set at 3.5 times and 0.7 times the real-time raw influent flow, i.e. the recycle flows would change corresponding to the influent flow. In reality, this assumption is not the way the plant is intended to operate. Therefore, the RAS flow rate was changed to 0.7 times the AAF and internal recycle flow rate was changed to 3.5 times AAF in lieu of the influent flows.

- The method of wasting waste activated sludge (WAS) was changed from the underflow of the secondary clarifier to directly from the bioreactor. In practice, WAS from BNR plants is generally wasted from the last stage of the aerobic zone via "surface wasting". This captures the scum and also maintains the WAS in aerobic conditions prior to solids processing.

- For Option C: The Anoxic zone was divided into two stages (2) and the aerobic zone was divided into four (4) stages to reflect the anticipated plug flow regime in the bioreactor.

- For Option G: The Anoxic zone was divided into two stages (2) and the aerobic zone was divided into two (2) stages that are completely mixed based on discussions with the supplier.

- A dissolved air flotation (DAF) thickener was added to the base model for thickening WAS. The DAF was assumed to have 90% solids capture with sub-natant water recycled back to the Primary Settling Tanks (PST).

- As part of the review of the Draft PDR it was decided to change the new additional secondary clarifiers from one (1) 33.5 m diameter and one (1) 45.7 m diameter to two (2) 45.7 m diameter clarifiers. The total surface area (including the existing three clarifiers) increased from 5920 to 6680 m^2. This change was now made in the model to reflect the earlier decision.

4.2.2 Nitrifier Maximum Specific Growth Rate

4.2.2.1 Test Results

The nitrifier maximum specific growth rate ($\mu_{AUT \cdot MAX}$) is an important kinetic parameter associated with bioreactor sizing and directly impacts the sizing for the aerobic zone of a BNR process. To determine the $\mu_{AUT \cdot MAX}$ for the SEWPCC wastewater, a series of four (4) separate high F/M bioassay tests were undertaken in accordance to the 2003 WERF document titled “Methods for Wastewater Characterization in Activated Sludge Modeling (Melcer, Dold et al. 2003). A summary of the results is shown in Table 4.1. The conclusions from these tests were as follows:

- A number of the high F/M tests showed the maximum specific nitrifier growth rate to be lower than the value initially assumed (0.9 d^{-1}) for the design. On average, the nitrifier maximum specific growth ($\mu_{AUT \cdot MAX}$) rate obtained on SEWPCC secondary effluent was 0.506 d^{-1} (average based on test No. 2 and No. 4).

- It should be noted that the maximum specific nitrifier growth rate for the synthetic wastewater was also lower than 0.9 d^{-1} value considering that the diluent did not contain any inhibitors.

- Test No. 1 included two samples of secondary effluent from the SEWPCC plant seeded with nitrifiers from a UBC pilot plant employing conventional biological nutrient removal technology. Several QA/QC problems were encountered in this test including problems related to maintaining acceptable pH and DO ranges, which could have compromised the final results.

- Test No. 2, the average specific nitrifier maximum growth rate was estimated at 0.44 d^{-1}, which is a significantly lower value than initially assumed for the design purpose. At the same time, the $\mu_{AUT \cdot MAX}$ value of primary effluent was virtually the same as the $\mu_{AUT \cdot MAX}$ value of the secondary effluent. This suggests that there is no inhibition to nitrification in the primary effluent as compared to the secondary effluent.

- Test No. 3, a nitrifying seed sludge from a laboratory scale nitrifying sequencing batch reactor at the University of Manitoba was selected due to apparent problems with seed in the previous tests. The average specific nitrifier maximum growth rate was estimated at **0.858** d^{-1}. However, due to higher than expected concentration of nitrifiers in the seed the test that usually takes 5 to 7 days to complete ended within 48 hours with complete depletion of ammonia. This resulted in fewer than expected data points, which resulted in a very large confidence spread.

- Test No. 4 included two samples of secondary effluent from the SEWPCC plant and control reactor (synthetic wastewater) seeded with nitrifiers from the University of Manitoba (volume adjusted to account for quicker reaction time). The average specific nitrifier maximum growth rate was estimated at 0.57 d^{-1}, which is lower than the expected value but within the values reported in the earlier tests.

Table 4.1 - Summary of Results

Test Number	Synthetic (Control)	Secondary Effluent	Percentage (Actual/Control)
1	Not done	0.50	NA
2	0.576	0.440	76 %
3	0.938	0.858	91%
4	0.729	0.572	78%

4.2.2.2 Analysis

The SEWPCC service area is predominately residential with minimal industrial wastewater generators. Stantec's experience in other similar Western Canada cities with predominately residential customers is that nitrifier maximum specific growth rates have been in the order of $\mu_{AUT \cdot MAX} = 0.9\ d^{-1}$. The significantly lower values for the SEWPCC resulting from the high F/M bioassay tests were not expected based on the services area.

The high F/M test is a relatively new tests procedure. A review of results on other Stantec projects and through discussions with other consultants found the tests to be problematic from a control point of view. These control problems appear to be frequently resulting in lower than anticipated nitrifier maximum specific growth rate estimates. There is now a general trend in the industry not to use the high F/M test.

While the SEWPCC high F/M tests appear to provide very low results, the tests also indicate that there are no nitrifier inhibitors in the SEWPCC wastewater. This conclusion is reached by comparing the results of the synthetic control with those of the SEWPCC wastewater. As shown in Table 4.1 for Test No. 2 to 4, results for both the control and wastewater results were low, with minimal difference, indicating that the wastewater does not contain inhibitors.

4.2.2.3 Nitrifier Growth Rate Sensitivity Analysis

A sensitivity analysis using steady-state BioWin^{TM} modeling was undertaken for maximum month spring flow conditions to study the impact of various $\mu_{AUT \cdot MAX}$ and bioreactor sizing on effluent TN. These results are presented in Table 4.2 and Appendix B.

Table 4.2 - Static Modeling Results with different $\mu_{AUT \cdot MAX}$ - Option C

$\mu_{AUT \cdot MAX}$ (d^{-1})	Design Flow (ML/d)	Temp. (^{o}C)	SRT (d)	Aerobic Reactor Volume (ML)	Overall Reactor Volume (ML)	MLSS (mg/L)	Effluent				
							TSS	$cBOD_5$	TN	TP	pH
0.9	111	10	10	21.8	31.3	4543	7.5	4.00	9.00	0.33	6.44
0.8	111	10	10	21.8	31.3	4543	7.5	4.52	18.66	0.33	6.67
0.8	111	10	10	24.0	33.5	4489	7.5	3.77	10.47	0.34	6.48
0.7	111	10	10	21.8	31.3	4551	7.5	4.76	23.30	0.33	6.75
0.7	111	10	10	32.0	41.5	4295	7.4	3.15	10.85	0.38	6.40

The results of the above exercise indicate the following:

- As expected, the effluent TN concentration increased under the maximum month flow condition in spring when the maximum nitrifier growth rate decreased from 0.9 d^{-1} to 0.7 d^{-1}. The decrease did not affect any of the other parameters.

- For $\mu_{AUT \cdot MAX}$ of 0.8 d^{-1}, the aerobic volume had to be increased by approximately 10% under the same SRT to maintain the effluent TN concentration around 10 mg/L. Similarly, when $\mu_{AUT \cdot MAX}$ was decreased further to 0.7 d^{-1}, the aerobic volume had to be increased by approximately 47 % to maintain a similar effluent TN concentration.

Although the steady-state model runs showed that effluent TN concentration exceeded the licence limits when the nitrifier maximum growth rates were reduced, a dynamic simulation was run during the most critical time i.e. the design year spring period to better understand of the effect of a reduced $\mu_{AUT \cdot MAX}$ value on the effluent TN. These results are shown in Table 4.3 below.

Table 4.3 - Dynamic Modeling Results Spring 2031 (March 1 to May 31) - Option C

$\mu_{AUT \cdot MAX}$ (d^{-1})	Dynamic SRT (d)	Total volume (ML)	Max. 30d rolling average effluent value				No. of Days of TN over 15 mg/L (30d rolling average)	No. of Days of TN over 15 mg/L
			TSS	$cBOD_5$	TN	TP		
0.9	10	31.3	13.9	16.3	9.5	0.6	0	0
0.8	10	31.3	13.8	16.3	11.5	0.6	0	0
0.7	10	31.3	13.8	16.5	15.7	0.6	27	27

From Table 24.3, the following conclusions can be drawn:

- Effluent TN discharge limits were met on a 30-day rolling average even when $\mu_{AUT \cdot MAX}$ was reduced to 0.8 d-1.

- When the value of $\mu_{AUT \cdot MAX}$ was reduced further to 0.7 d^{-1}, the licence limits were exceeded on 27 days during spring (calculated on a 30 days rolling average).

4.2.2.4 Recommendations

The high F/M test is developing a reputation for underestimating the nitrifier maximum specific growth rate and as a result the SEWPCC results are also likely to be underestimated. Furthermore, there are no obvious industries within the SEWPCC service area that raise concern that inhibitors could be entering the system. Therefore, it is recommended that the City proceed with Conceptual Design of the SEWPCC Upgrade/Expansion based on the standard value of $\mu_{AUT \cdot MAX} = 0.9\ d^{-1}$ used by Stantec in other Western Canada projects.

Since the nitrifier maximum specific growth rate has a significant impact on facility sizing if it is below 0.8 d^{-1}, it is recommended that a test utilizing the low F/M method be undertaken to confirm the nitrifier growth rate. This test has since been completed and it was reported that the growth rates for both Ammonia Oxidizing Bacteria (AOB) and Nitrite Oxidizing Bacteria (NOB) are lower than the typical value in presence of hauled liquid waste (HLW). The maximum specific growth rate for AOB (μ_{AOB}) was determined to be 0.70 d^{-1} in presence of HLW and 0.90 d^{-1} in absence of HLW. Further discussion is provided in Section 15 - Hauled Liquid Waste.

4.3 REVISED WET WEATHER TREATMENT STRATEGY

The wet weather treatment strategy for handling flows of up to 300 ML/d as developed in the PDR was based on utilizing a side-stream 125 ML/d capacity Chemically Enhanced Primary Treatment (CEPT) with high-rate Lamella plate primary settling tank in conjunction with the existing three (3) regular PSTs of capacity 175 ML/d. The blended primary effluent would then be directed to the BNR bioreactor, which could handle a maximum of 175 ML/d (summer only) and 125 ML/d (year round), with the remainder being by-passed around the secondary treatment process to the river. This option required pilot testing of the Lamella technology to establish the treatment efficiency under various surface overflow rates. This concept is illustrated in Figure 4.1.

Further discussions with the City and the Independent Review Team lead to the development of an alternative wet weather treatment strategy that eliminated the use of a separate side-stream Lamella primary settling tank for wet weather treatment. The new strategy as shown in Figure 4.2 incorporated the following mode of operation:

- Flows up to 175 ML/d would be handled by the existing PSTs as per normal operations.
- When flows exceed 175 ML/d, the three (3) existing PSTs would be operated on a conventional CEPT mode (using alum and polymer) for flows up to 200 ML/d.
- All flows in excess of 200 ML/d but up to 300 ML/d will bypass the PSTs and flow directly to the BNR bioreactors.

- All flows in excess of 300 ML/d but up to 415 ML/d (total raw wastewater pumping capacity) will go through screening and grit removal and will bypass the plant and be blended downstream of the UV disinfection system.
- The BNR system will handle up to 175 ML/d (summer) and 125 ML/d (year round) on a maximum day basis. Therefore, based on the influent flow, some of the influent will only receive CEPT.
- Based on the synthetic data of projected flows for the design year 2031, there are eight (8) days in the year when flows exceed 175 ML/d (7 in summer and 1 in spring); two (2) days when the flows are in excess of 200 ML/d (1 in spring and 1 in summer) and one (1) day when flows exceed 300 ML/d (1 day in summer). These events are based on a 24-hour basis.

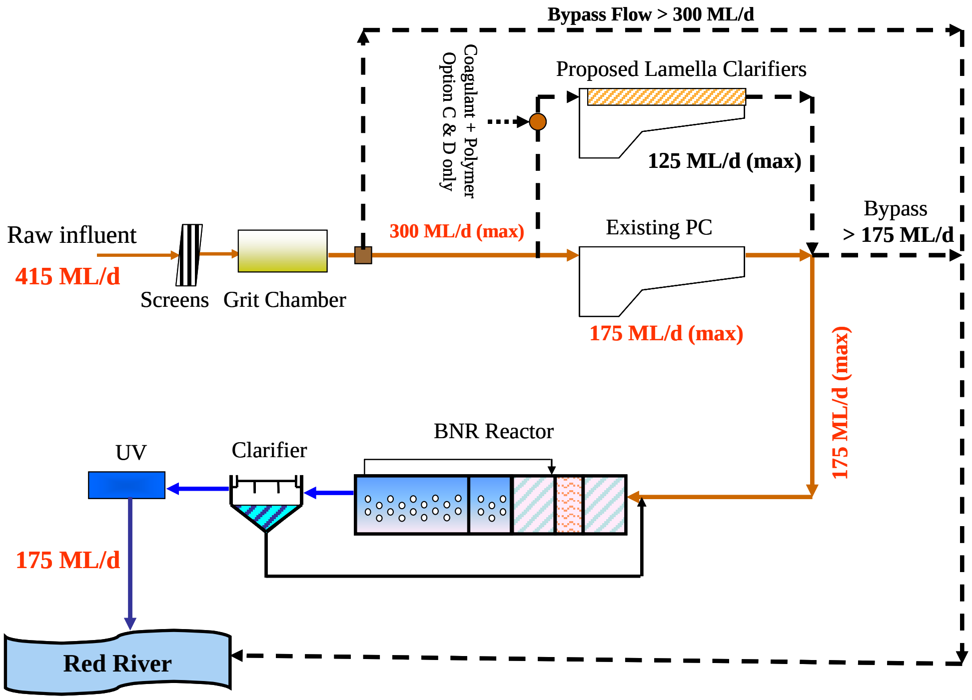

Figure 4.1: CEPT with Lamella Primary settling tank Option

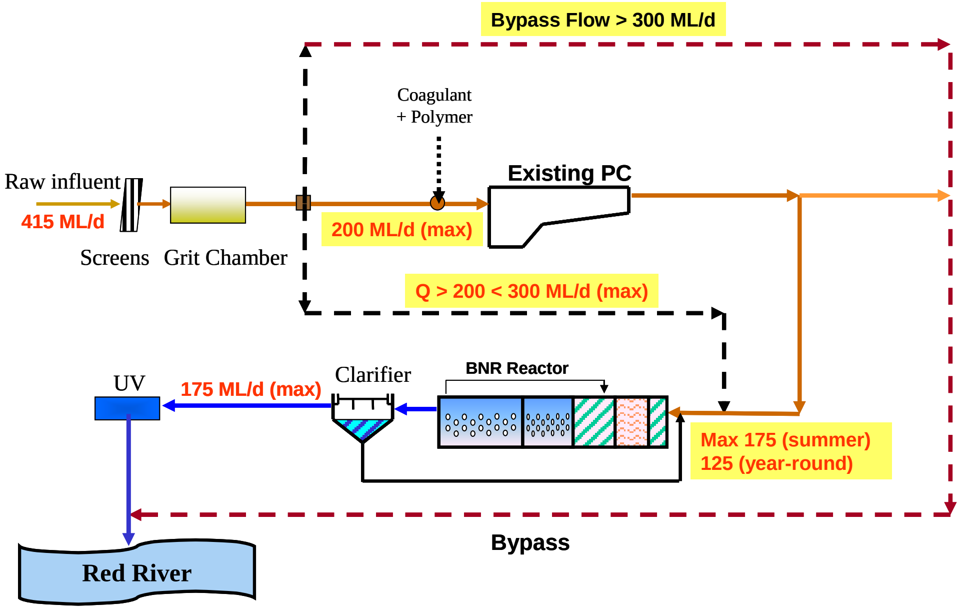

Figure 4.2: CEPT with Existing PC Only

The performance of the two wet weather treatment strategies were evaluated by steady-state BioWin™ modeling using Option C under the maximum month flow in spring and three high flows scenarios in summer. The results are summarized in Table 4.4.

Table 4.4 - Comparison of two CEPT options (static modeling)

CEPT	PC Efficiency (%)	Design Flow (ML/d)	Temp. (^{o}C)	SRT (d)	Overall Reactor Volume (ML)	MLSS (mg/L)	Effluent (mg/L)					Flow duration (d)
							TSS	cBOD$_5$	TN	TP	pH	
Lamella	65	111	10	10	31.3	4425	7.4	3.8	11.5	0.4	6.6	30
Existing PC	65	111	10	10	31.3	4429	7.4	3.8	11.5	0.4	6.6	30
Lamella	65/85[a]	300	16.7	10	31.3	2417	27.0	43.5	9.5	0.7	6.9	1
Existing PC	85	300	16.7	10	31.3	3952	23.0	39.6	7.7	0.5	6.8	1
Lamella	65/85[a]	202	16.7	10	31.3	3079	18.6	20.3	7.7	0.6	6.7	2.5
Existing PC	85	202	16.7	10	31.3	2330	14.9	21.0	13.9	0.4	6.8	2.5
Lamella	65/85[a]	178	16.7	10	31.3	3249	13.2	5.9	6.5	0.5	6.6	7
Existing PC	85	178	16.7	10	31.3	2390	12.1	8.3	14.1	0.3	6.8	7

[a] *Note: For Lamella option, the existing PC was modeled with 65% efficiency and the proposed Lamella with 85% efficiency for solids removal*

The following conclusions can be drawn from the above results:

- There is no significant difference in the final effluent between the Lamella primary settling tank concept and the use of the existing PSTs operated on a CEPT mode (flows in excess of 175 ML/d) with flows in excess of 200 ML/d being routed directly into the bioreactors.
- Under maximum day summer flows i.e. 300 ML/d (a one-day event), the effluents limits were exceeded for TSS and $cBOD_5$, however, this is not a problem based on a 30-day rolling average.
- Since the desired effluent can be achieved by operating the existing PSTs on a CEPT mode for flows in excess of 175 ML/d, no additional PSTs are required to meet the design year flows and loads.

A further sensitivity analysis was performed using various TSS removal efficiency and flow scenarios for the existing PSTs operated on a CEPT mode. The results are shown in Table 4.5. Based on the static BioWin^{TM} modeling results, there were no significant differences in the final effluent quality between the three scenarios. The MLSS increased corresponding to the reduced solids removal percentage in PSTs, however, the secondary clarifier was not overloaded by the increased MLSS. Jar testing conducted during the preliminary design with alum showed an average TSS removal of 82% with the optimum alum dosage of 60 mg/L. The static modeling showed that this may result in too much P removal in the PSTs causing P-limiting condition for the BNR process. Therefore, all further modeling was conducted based on a reduced alum dose and a by adopting a removal efficiency of 75% for the CEPT mode.

Table 4.5 - Static Modeling Results With Different Solids Removal Percentage in PC

CEPT Efficiency (%)	Design Flow (ML/d)	Temp. (^oC)	SRT (d)	Overall Reactor Volume (ML)	MLSS (mg/L)	Effluent (mg/L)					SC SLR (kg/m^2/h)	Flow Duration (d)
						TSS	$cBOD_5$	TN	TP	pH		
85%	300	16.7	10	31.3	3952	23.0	39.6	7.7	0.5	6.8	5.9	1
75%	300	16.7	10	31.3	3957	34.0	47.3	10.3	0.6	6.8	5.9	1
65%	300	16.7	10	31.3	3963	45.7	52.1	10.7	0.8	6.8	5.9	1
85%	202	16.7	10	31.3	2330	14.9	21.0	13.9	0.4	6.8	3.4	2.5
75%	202	16.7	10	31.3	3079	18.6	22.0	13.7	0.5	6.8	4.6	2.5
65%	202	16.7	10	31.3	3828	22.3	23.2	13.5	0.5	6.8	5.7	2.5
85%	178	16.7	10	31.3	2390	12.1	8.3	14.1	0.3	6.8	3.5	7
75%	178	16.7	10	31.3	3182	13.1	8.0	13.7	0.3	6.8	4.7	7
65%	178	16.7	10	31.3	3961	14.1	8.1	13.3	0.4	6.8	5.9	7

4.4 OPTION C: COMPARISON BETWEEN MJP AND WESTBANK PROCESS

As a part of the IRT review, it was suggested that the WB configuration be evaluated side-by-side with the Modified Johannesburg Process (MJP). The WB is similar to the MJP configuration proposed for the SEWPCC. The only difference is that in the Westbank process, the primary effluent is split between the pre-anoxic zone, the anaerobic zone and the first anoxic zone. Similar to the concept of MJP, 100% of the fermentate flow is directed to the anaerobic zone where phosphorus is release in conjunction with the assimilation of VFAs. For this comparison, the flow split to the pre-anoxic, anaerobic and the first anoxic zones was set at 5%, 15% and 80% respectively. The flow split was calculated based on the Annual Average Flow (AAF). The volumes of the respective zones for the MJP and the WB configuration were exactly the same as shown in Table 4.6.

Table 4.6 - Design Criteria for Comparison of MJP and WB

Bioreactor	Unit	Value
Bioreactor Zone Volumes:		
Pre-Anoxic	ML	1.3
Anaerobic		1.8
Anoxic-1		3.2
Anoxic-2		3.2
Aerobic-1		5.45
Aerobic-2		5.45
Aerobic-3		5.45
Aerobic-4		5.45
Total bioreactor volume	ML	31.3

Initially, a series of steady-state modeling runs were completed using BioWin^{TM} under various/critical flow conditions. The results are shown in Table 4.7. The following conclusions can be drawn from the initial model run:

- The performance of the two process under the various flow conditions were essentially the same.

- The effluent total nitrogen (TN) was higher than the permit limit of 15 mg/L for the WB configuration during maximum month condition in spring i.e. a flow of 111 ML/d.

It should be stated that additional optimization on the flow splitting of the WB configuration was not done to evaluate any process improvements in terms of effluent quality. For the most part, BioWin^{TM} simulation predicted that the two processes performed essentially the same. To investigate the performance of the WB process for TN removal during the critical month i.e. spring, a dynamic simulation run was completed. The results are presented in Tables 4.8 and 4.9. These results show that both systems are able to meet the effluent criteria on 30-day rolling average. In general, the total nitrogen removal was slightly better with the MJP configuration. The WB system also discharged more NH_3-N mass load than the MJP throughout the year, although the effluent ammonia-mass loads were still within the permit limits. Based on presentations of this data and discussions with the City, the Steering Committee decided not to consider the WB configuration further as it did not provide any significant benefits or improved plant performance over the MJP configuration. In addition, the WB process required flow splitting of the primary effluent feed to the pre-anoxic, anaerobic and first anoxic zone that added complexity to the plant operations.

Table 4.7 - Comparison of Performance of MJP and WB (Static Modeling)

Configuration	Design Flow (ML/d)	Temp. (^{o}C)	SRT (d)	Overall Reactor Volume (ML)	MLSS (mg/L)	Effluent (mg/L)					Flow duration (d)
						TSS	cBOD$_5$	TN	TP	pH	
MJP	90.4	14.7	10	31.3	3235	5.6	2.79	10.79	0.3	6.32	-
WB	90.4	14.7	10	31.3	2942	5.5	2.77	8.03	0.3	6.4	-
MJP	111	10	10	31.3	4600	7.5	4.4	13.89	0.35	6.6	30
WB	111	10	10	31.3	4146	7.4	5.27	22.27	0.33	6.75	30
MJP	178	16.7	10	31.3	3420	13.9	8.97	14.33	0.34	6.76	7
WB	178	16.7	10	31.3	2705	13.3	8.85	14.35	0.35	6.78	7
MJP	202	16.7	10	31.3	3286	18.9	20.49	13.39	0.45	6.8	2.5
WB	202	16.7	10	31.3	2736	18.3	20.53	14.17	0.44	6.81	2.5
MJP	300	16.7	10	31.3	3995	37.2	47.43	10.42	0.66	6.76	1
WB	300	16.7	10	31.3	3978	30.9	44.03	9.93	0.51	6.79	1

Table 4.8 - Comparison of Performance of MJP and WB (Dynamic Modeling – Spring 2031)

Configuration	Dynamic SRT (d)	Total volume (ML)	Max. 30d rolling average effluent value			
			TSS	cBOD$_5$	TN	TP
MJP	10	31.3	13.9	16.3	9.5	0.6
WB	10	31.3	13.9	16.7	11.1	0.6

Table 4.9 - Comparison of NH_3-N Mass Load Discharged from MJP and WB (Dynamic Modeling)

Month	Monthly max. NH_3-N mass load (kg/d)		NH_3-N Discharge limits (kg/d)
	MJP	WB	
December	114.5	152.4	1410
January	271.1	369.1	2080
February	114.2	143.5	2978
March	141.9	222.5	5153
April	1547.4	1760.6	20496
May	143.1	253.8	5890
June	69.3	130.8	3745
July	1207.7	1282.3	1996
August	50.6	94.6	1048
September	68.8	98.1	768
October	365.6	404.2	814
November	50.9	72.1	1551

4.5 IMPACT OF LOW FLOWS ON PLANT PERFORMANCE (OPTION C)

Performance of BNR plants are often impacted under low influent flow conditions, especially during the initial years during dry weather periods. The proposed MJP bioreactor configuration designed for 2031 was checked for plant performance under the measured characteristics of primary effluent using February 2007 data as the influent input in the BioWin^{TM} model. This month had the lowest flow during the whole year and the model was dynamically simulated for one week.

The influent flow data is shown in Figure 4.3. The lowest hourly flow was 20 ML/d as recorded for the week by the City.

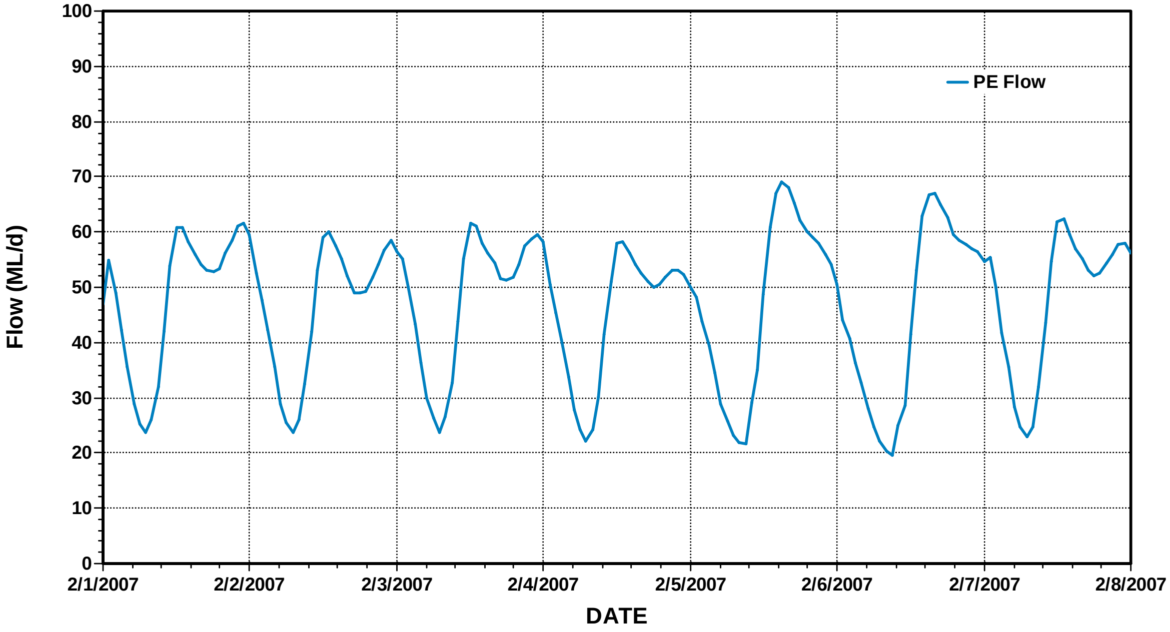

Figure 4.3: Influent Flow Input for BioWin^{TM} Model – Feb. 2007 Flow

The results of the dynamic simulation for the week are presented in Table 4.10. The following key conclusions can be drawn:

- Effluent criteria was met at all times.
- TN limits of 15 mg/L exceeded for approximately 13 hours. However, on a daily average basis, the effluent TN met the licence. The maximum daily average TN concentration in effluent under this low flow condition was 14.6 mg/L.
- Based on the current low flow and primary effluent characteristics and maintaining a bioreactor MLSS of around 2600 mg/L on an average basis, the proposed MJP could be successfully operated to handle low flows during dry weather periods.

Table 4.10 - Dynamic Simulation Results - Actual Flow in a Week of Feb. 2007

Configuration	Flow (ML/d)	Temp. (^{o}C)	SRT (d)	Overall Reactor Volume (ML)	MLSS (mg/L)	Effluent (mg/L) - maximum daily			
						TSS	cBOD$_5$	TN	TP
MJP	47	13.3	10	31.3	2602	2.7	2	14.6	0.3

4.6 OPTION C: BIOREACTOR TRAINS – SENSITIVITY ANALYSIS

The PDR for the SEWPCC upgrade/expansion was completed on the basis of 5 bioreactor trains for both Option C (MJP) and Option G (MJP with IFAS). During the conceptual design, alternate bioreactor designs consisting of either 3 trains or 4 trains were investigated for cost effectiveness and better utilization of the existing HPO reactors while still maintaining the operational flexibility. A series of steady-state models were completed with the following objectives:

- Compare 3 trains vs. 4 trains at an AAF of 90.4 ML/d.
- Conduct sensitivity analysis for both 3 or 4 train bioreactor trains with one (1) train out of service.

Table 4.11 shows the BioWin^{TM} results when one train of bioreactors is out of service under AAF condition. From the results, the effluent quality was not affected by the working volumes of the bioreactors. When two out of three trains were operated, the MLSS was higher than 4500 mg/L, which is normal for the MJP under such circumstances. However, the MLSS could be reduced to 4364 mg/L when the system SRT was lowered to 9 days while maintaining an acceptable TN concentration in the effluent. Based on operational considerations, a bioreactor design incorporating a 4-train system is recommended given the size of the proposed SEWPCC facility and the desired process flexibility of the system.

Table 4.11 - Option C: Comparison with Different Working Bioreactor Trains

Design Flow (ML/d)	Temp. (^oC)	SRT (d)	Working trains/ total trains	Overall Reactor Volume (ML)	MLSS (mg/L)	Effluent				
						TSS	cBOD$_5$	TN	TP	pH
90.4	10	10	3/3 or 4/4	31.3	3178	5.5	3.01	9.67	0.31	6.38
90.4	10	10	3/4	23.48	4231	5.8	3.12	9.88	0.32	6.38
90.4	10	10	2/3	20.87	4757	5.9	3.18	9.96	0.33	6.38
90.4	10	9	2/3	20.87	4364	5.8	3.29	10.35	0.31	6.44

4.7 OPTION G

Two options were shortlisted at the end of the Preliminary Design and carried forward to the Conceptual Design stage for further evaluation. These options were Option C and Option G. Option G is similar to Option C, except that biofilm carrier elements are added in the aerobic zones. Option G is also referred in general as the Integrated Fixed Film Activated Sludge or IFAS. Some of the key advantages of the IFAS process are as follows:

- increases biomass inventory without a need for increasing MLSS in the bioreactor.
- promotes growth of nitrifiers on carrier material.

- increases aerobic SRT that in turn promotes nitrification.
- increases biomass inventory facilitating a reduced aerobic volume requirement.
- attached growth provides better protection of the nitrifiers against washout, shock load or a toxic-spill.

Some of the disadvantages of the IFAS process are as follows:

- Proprietary process.
- Media loss/replacement over time adds to O&M costs.
- Limited experience in Canada. There are no plants in Western Canada.

Several types of proprietary biofilm carrier elements are available in the market. These are generally categorized under either fixed type or suspended/floating media. A detailed discussion on the media types was provided in Section 8 of the PDR. For the SEWPCC, fixed type media was not considered as it is prone to several problems, such as:

- marginal increase in SRT and consequently nitrification.
- proliferation of red worms which prey on the nitrifiers and also impacts effluent TSS.

The Conceptual Design for Option G was completed based on a plastic neutral density floating media from Anox Kaldness (K1 media). The Anox Kaldness media provides the following advantages:

- long track record with numerous plants in North America and Europe.
- low media degradation potential.

Should Option G be selected for final design, other floating media options such as sponge (Linpor™) or other plastic media (ActiveCell™) will be revisited as part of the Conceptual Design work. The bioreactor design for Option G is summarized in Table 4.12. The sizing of the aerobic zones was provided by Anox Kaldness utilizing their in-house proprietary software.

Table 4.12 - Bioreactor Design for Option G

Bioreactor	**Unit**	% of Fill of biofilm carrier	**Value**
Bioreactor Zone Volumes:			
Pre-Anoxic	ML	Nil	1.3
Anaerobic		Nil	1.8
Anoxic-1		Nil	3.2
Anoxic-2		Nil	3.2
Aerobic-1		32.8%	8.54
Aerobic-2		49%	8.54
Total bioreactor volume	ML		26.6
K1 media bulk density	m^2/m^3		500

To compare the performance of Option C with Option G, steady-state modeling runs were completed under various flow conditions. These results are summarized in Table 4.13. The model set-up is shown in Figure A3 (Appendix A) and model outputs are shown in Appendix C.

Table 4.13 - Comparison of Option C and Option G

Option	Design Flow (ML/d)	Temp. (°C)	SRT (d)	Aerobic tank volume (ML)	Overall Reactor Volume (ML)	MLSS (mg/L)	Effluent					SC SLR (kg/m2/h)
							TSS	**cBOD$_5$**	**TN**	**TP**	**pH**	
Option C	111	10	10	21.8	31.3	4543	7.5	4	9	0.33	6.44	4.92
Option G	111	10	6.71	17.08	26.68	2833	6.9	4.37	13.58	0.34	6.58	3.06
Option C	300	16.7	10	21.8	31.3	3970	48.7	49.76	9.82	0.82	6.9	5.83
Option G	300	16.7	6.07	17.08	26.68	3542	30.1	46.08	7.56	0.57	6.92	5.16
Option C	202	16.7	10	21.8	31.3	3535	19.2	21.06	9.28	0.43	6.7	5.26
Option G	202	16.7	7.3	17.08	26.68	2372	18	22.76	11.2	0.42	6.79	3.53
Option C	178	16.7	10	21.8	31.3	3517	14	8.97	8.33	0.33	6.64	5.17
Option G	178	16.7	7.38	17.08	26.68	2308	13.3	11.5	10.46	0.32	6.74	3.36

Following conclusions can be drawn from the above results:

- Performance of both the Options are relatively similar.
- Option G (based on Anox Kaldness media) requires approximately 22% lower aerobic volume and an overall 15% less bioreactor volume compared to Option C.
- Operating MLSS for Option G is significantly less than Option C. This leads to a lower solids loading rate to the secondary clarifiers.

4.8 COMPARISON OF OPTION C AND OPTION G

The purpose of this section was to refine the process design of Options C and G. The findings of this section are that both options could be successfully implemented at the SEWPCC. How they would be sized and the corresponding effluent quality has been defined. In Section 5.0 the operating considerations and the capital and operation/maintenance costs associated with each option are evaluated and a preferred option for the SEWPCC Upgrade/Expansion project is recommended.