SEWPCC Upgrading/Expansion
Preliminary Design Report

SECTION 8 - BIOLOGICAL NUTRIENT REMOVAL PROCESS OPTIONS

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8.0 Biological Nutrient Removal Process Options

8.1 INTRODUCTION

The new Environment Act Licence (EAL) for the expansion and upgrade of the South End Water Pollution Control Centre (SEWPCC) facility requires the City to implement nutrient removal to <15 mg/L TN and < 1 mg/L TP. These effluent quality requirements mean that the City will have to upgrade their secondary treatment plant to provide ammonia removal and total nitrogen control as well as phosphorus removal. Experience in North America, and Western Canada in particular, has shown that biological nitrification and denitrification simultaneously with biological phosphorus removal (BNR techniques) would be most appropriate for application at the SEWPCC.

The objectives of this section are:

- Briefly present the available treatment technologies applicable to the SEWPCC project;
- Short-list the most applicable treatment technologies for further evaluation;
- Present additional information on the short-listed technologies; and,
- Utilize a screening matrix to select the four (4) or five (5) most applicable technologies for the SEWPCC for further detailed evaluation.

To accomplish this, this report section identifies the available secondary process options for upgrading the SEWPCC to meet the new license effluent limits for carbonaceous BOD (cBOD), TSS, TN, Ammonia-nitrogen and TP removal. Initially a long list of twenty-two (22) BNR process options are identified and a brief discussion of their advantages, disadvantages and applicability to the SEWPCC project is provided. As part of the discussion we also present physical-chemical treatment options for the treatment of peak wet weather flows. Based on this preliminary evaluation twelve (12) of the process options are screened out for technical reasons described in the memorandum. The remaining ten (10) short-listed options, which are most applicable to the SEWPCC, are then evaluated in further detail.

At the end of this section, the screening matrix utilized to further reduce the list of treatment options for more detailed evaluation and the results of the Technical Workshop No. 1 is presented. By the end of the preliminary design the Project Team will need to reduce this list even further to the two (2) or three (3) most applicable technologies for further evaluation in the conceptual design. By the end of the conceptual design the Project Team will have selected the preferred methodology to upgrade / expand the SEWPCC.

8.2 DESIGN CRITERIA FOR BNR PROCESS EVALUATION

In order to keep the project on schedule, Stantec had to proceed with the development of the long list of BNR process options and the short listing of these options prior to the availability of any design flow data. To accomplish this, assumptions were made based on the representative flows and loads for discussion purposes.

Since the majority of BNR plants in cold climates are designed based on the maximum spring month, this was adopted as the design flow for the short listing of process options. Based on review of existing reports on SEWPCC (EarthTech, 2006), the following projected (Year 2022) flows and loadings were adopted:

- Maximum spring month flow of 108 ML/d and provided the following influent loading rates:
- TSS loading of 13,325 kg/d
- BOD_5 loading of 15,224 kg/d
- TKN loading of 3,719 kg/d
- TP loading of 587 kg/d

Using this flow and associated loads, the component unit processes for each of the selected processes are sized. Some of the alternatives include biological treatment of the complete maximum month flows and loads that would be directed to the plant in 2022. However, in order to minimize the capital cost of the project while still achieving the licence requirements, most of the options are sized considering physical-chemical treatment of high storm and spring snowmelt flows and loads to produce an acceptable blended effluent quality.

It should be noted that although the process design for the BNR plant is based on the maximum month flows and loads, the plant unit processes will be designed hydraulically to accommodate maximum day flows and the gates and channels will be designed hydraulically for maximum hourly flows. The bioreactors will be able to treat 2.5 times the max month design flow for short periods of 6 or 8 hours but prolonged high flows will have to be bypassed to the last pass of the aerobic bioreactors or the excess flows treated in a side stream process.

The 2002 nitrification study report and conceptual design reports prepared by Earth Tech provided an analysis of available raw and primary effluent quality to that time. As well, based upon expected growth scenarios, per capita contributions of BOD_5, TSS, Nitrogen, Phosphorus, and estimates of storm and snowmelt impacts, future raw and primary effluent quality characteristics for key parameters were predicted on a seasonal basis. For the purposes of this preliminary screening of options these characteristics were utilized along with the flows stated above to size components of the options.

Stantec has some concern about the quality predictions, particularly for storm flow and snowmelt periods, because of some of the assumptions made in the previous reports (the storm and snowmelt period concentrations of major parameters don’t show an expected reduction of concentration during these high flow periods). A comprehensive sampling program undertaken as a part of the current study together with a statistical analysis of past data will be used in modification of the raw waste quality for the completion of the predesign, conceptual, and detailed design stages of the SEWPCC facility upgrade. A preliminary analysis of historical primary effluent and 2005 influent data is enclosed with the appended memorandum (see Figures 4 through 6 in Appendix E). This supports the expected reduction in pollutant concentration with increasing flows.

As part of the Earth Tech nitrification and conceptual design studies estimates and predictions were made of flows throughout the year and these were combined with the above quality information to predict loads of BOD, TSS, Ammonia-N, Nitrate-N, Total Kjeldahl-N, Total Nitrogen (N), Total Phosphorus, and ortho-Phosphorus. These raw wastewater loads were predicted for spring, summer, fall and winter periods for both average and maximum month periods as well as peak day. Using past experience on primary clarifier performance the loads of these parameters contained in predicted primary effluent flows were calculated.

These loads were used in our preliminary modeling (Stantec spreadsheet, and BioWin) and sizing of components of the selected biological processes considered at this screening stage.

The use of this past information is conservative and close enough for treatment process screening and development of preliminary opinions of probable cost.

8.3 OTHER FLOW CONSIDERATIONS

8.3.1 CSO Diversions to NEWPCC

The SEWPCC catchment area contains four combined sewer districts of Baltimore, Cockburn, Mager and a portion of Metcalf. These districts, in part, contribute to the significant wet weather flows experienced at the SEWPCC. This situation is particularly true during the spring snowmelt period when the sewage temperatures are also very cold (<10 deg Celcius). These high flows may deliver spike loads of BOD_5, TSS, Nitrogen and Phosphorus at high concentration during the initial flush of the system. This initial flush will only last a few hours and will be followed by more dilute flows through the majority of the wet weather event.

The effect of designing a plant for these elevated flows and loads is that the facility must be sized significantly larger than for average loading conditions. If a portion of these flows could be diverted to a larger treatment facility (e.g. at the NEWPCC), the unit capital cost for the diversion and the additional treatment capacity may be less than for providing the treatment capacity at the smaller facility (SEWPCC).

As part of this project Stantec will undertake a preliminary evaluation of the potential to divert part or all of the peak wet weather flow to the NEWPCC. The relative costs of diversion and treatment at the NEWPCC will be compared with the provision of the higher capacity and treatment at the SEWPCC. The extent of such a diversion has not yet been determined but could potentially result in 10 to 20 ML/day being diverted to the NEWPCC catchments during wet weather events. This would result in a corresponding reduction in design capacity of the SEWPCC of 10 to 20 % . For the purposes of this screening analysis we have not included the impact of diversion on the size and costs of the plant. Such an analysis will be considered at the conceptual design stage on a smaller number of options.

8.3.2 I & I Reduction

The SEWPCC experiences very high wet weather peaks that will be costly to convey to the treatment facility and treat once they arrive. The SEWPCC service area includes approximately 10,000 ha in the southern portion of the City of Winnipeg. Parts of the area have weeping tiles from buildings connected directly into the sanitary sewer and there is suspicion that a portion of the homes with sump pumps have redirected their flow into the sanitary sewer. Several businesses within the service area have also been found to be using groundwater for their air conditioning / cooling operations and then discharging this water into the sanitary sewer, and there may be others. These factors along with the traditional leaking pipes and cross-connected catch basins all contribute to the high peak flows.

The City of Winnipeg recently retained an engineering consultant to investigate, identify and develop plans for cost-effective, practical reduction of inflow and infiltration from the SEWPCC service area wastewater collection system. Once the magnitude of these potential reductions is known the City will be in a position to estimate the cost of reducing this contributing flow. Our Team will also be able to estimate the treatment cost savings related to any potential peak flow reductions. With these two sources of information the City will then be in a position to determine if they will deal with these flows by reducing them at the source, treating them at the plant or a combination of these two options. For the purpose of this screening analysis we have not considered any impacts that I & I reduction could have on the treatment plant capacity or loading.

8.4 BIOLOGICAL NUTRIENT REMOVAL

8.4.1 General

The following describes the basic concepts of biological wastewater treatment with particular emphasis on biological nutrient removal (BNR) as applicable to the SEWPCC project. A discussion of twenty-two (22) alternatives applicable for the secondary system upgrade for SEWPCC follows the basic descriptions.

Advanced wastewater treatment is directed toward the removal of biodegradable organics, suspended solids and nutrients in both colloidal and dissolved forms. Advanced biological treatment is achieved by growing a community of microorganisms in a bioreactor that utilizes dissolved and colloidal matter as a food source to produce various end products such as carbon dioxide, water, nitrogen gas, and new cell tissue. Because cell tissue has a specific gravity slightly greater than that of water, the resulting cells can be removed from the treated liquid by gravity settling in the secondary clarifiers.

The two (2) critical nutrients of interest in wastewater treatment are nitrogen and phosphorus, which are also essential growth elements for microorganisms involved in wastewater treatment. As such, some removal of both nitrogen and phosphorus always occurs (to match growth requirements) during all biological treatment. This results in a cell mass that contains approximately 12 percent nitrogen and 2 percent phosphorus by weight. When a biological wastewater treatment system is engineered to remove nutrients in excess of these amounts, it is called biological nutrient removal (BNR). In essence, BNR is comprised of two processes:

- Biological nitrogen removal
- Enhanced biological phosphorus removal (EBPR)

Nitrogen Removal

Removal of nitrogen is a two-step process. In the first step, known as nitrification, ammonia is oxidized by nitrifying bacteria to nitrite and eventually to nitrate. This step requires oxygen and is carried out in an aerobic cell (presence of molecular oxygen) of the bioreactor. Nitrate is then converted to nitrogen gas in an anoxic zone of the bioreactor (no molecular oxygen; oxygen present either as dissolved oxygen or in combined form, such as nitrate). Organic carbon contained in the raw wastewater or an external carbon provides a carbon source for the microorganisms involved. This step is known as denitrification. Usually, any organic nitrogen originally present in wastewater is converted to ammonia very quickly in the bioreactor by aerobic organisms.

Phosphorus Removal

Biological phosphorus removal is achieved by exposing the activated sludge microorganisms to a sequence of anaerobic and aerobic conditions. Two main conditions have to be satisfied for successful biological phosphorus removal: absence of oxygen or nitrate, and the presence of short chain volatile fatty acids (SCVFAs) in the anaerobic zone.

Alternatively, phosphorus can be removed by chemical precipitation applied to suspended growth, attached growth or a combination of suspended and attached growth systems.

For a successful operation of a BNR facility, it is essential to expose the microorganisms to anaerobic, anoxic and aerobic conditions. All these conditions can be achieved within one bioreactor that comprises several zones (cells). In the BNR process, phosphorus is removed with the waste sludge while nitrogen is removed as elemental nitrogen gas. A general description of possible bioreactor cells is presented below:

- **Pre-anoxic Zone**: RAS is fed to this zone together with the primary effluent. Any nitrates in the RAS are denitrified prior to the mixed liquor flow entering the anaerobic zone. The **readily** available organics in the primary effluent ensure rapid denitrification in the zone.

This zone is also referred to as RAS denitrification zone. This zone protects the anaerobic zone from nitrates, which interferes with EBPR.

- **Anaerobic Zone**: Denitrified RAS from the pre-anoxic zone is mechanically mixed with short chain volatile fatty acids (SCVFA) from the fermenter supernatant in this zone. Some VFA will also be present in the raw wastewater particularly in the summer. The truly anaerobic environment that is created favors the proliferation of bio-P bacteria that can use energy, stored in the form of polyphosphate, to absorb simple carbon sources (principally SCVFAs). This is usually provided by fermenting primary sludge. The fermentate is added directly to the anaerobic zone in the ratio of 5:1 VFA to total P (see Figure 8.1). The absorbed carbon is metabolized in the subsequent anoxic and aerobic zones. Because bio-P bacteria internally store carbon in this anaerobic zone, they subsequently enjoy a competitive advantage over other heterotrophic bacteria in the aerobic zone and proliferate in the system.

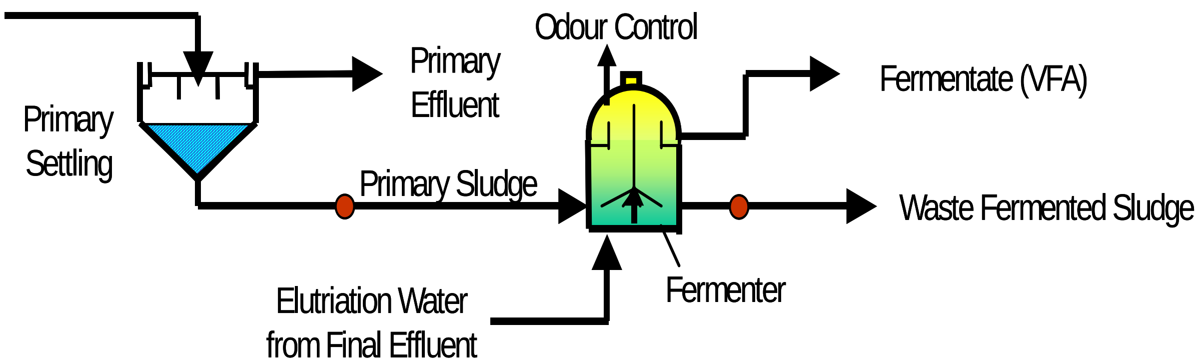

Figure 8.1 - Fermentation of Primary Sludge

- **Anoxic Zone**: Generally, two mechanically mixed cells are provided where anaerobic zone effluent mixed liquor, remaining primary effluent, and recycled nitrified mixed liquor from the end of the aerobic zone are mixed and allowed to react in the absence of oxygen. Nitrates available in the mixed liquor recycle become the oxygen source, or terminal electron acceptor. Through this biochemical reaction, nitrates are converted to water and elemental nitrogen. Most of this nitrogen evolves from solution as nitrogen gas and is released to the atmosphere in the subsequent aerobic zones. A substantial fraction of the biodegradable organics present in the incoming wastewater is consumed in this zone.

- **Aerobic Zone**: In this zone, carbon metabolism is completed, and nitrification and P uptake occur. Two to four aerated cells are generally employed, depending upon the size of the system, the nutrient limits, and the existing system constraints. Accurate dissolved oxygen concentration control is imperative to ensure that minimal oxygen is recycled to the anoxic zone where it would interfere with denitrification, to reduce energy costs, and to allow some control of sludge settleability.

There are two main types of biological treatment, each defined on the basis of how the microorganisms are grown – suspended growth and attached growth. In suspended growth systems, the microorganisms are held in suspension, usually by mixing. In attached growth systems, the microorganisms grow on a fixed media. Hybrid systems employ both suspended and attached growth components.

Both attached and suspended growth systems can achieve excellent secondary treatment - defined as removal of organic matter and suspended solids – usually in the range of 95 – 98% TSS and BOD_5 removal. However, if biological removal of nutrients (nitrogen and phosphorus) is required, a sequence of specific environmental conditions needs to be provided for the microorganisms – either in a continuous flow mode or with respect to time. In general, all the preceding types of systems can achieve a high efficiency of biological nutrient removal, but most experience in cold climates at a large scale is with suspended growth processes. A general discussion on these types of system follows.

8.4.1.1 Suspended Growth Systems

There are two types of aerobic suspended growth treatment systems – those with cellular recycle (activated sludge) and those generally without (lagoons). Lagoons are not considered further in this memo as an appropriate option for the SEWPCC expansion/upgrading.

In suspended growth activated sludge treatment systems, a portion of the settled biomass is returned from the secondary clarifiers to the bioreactor to maintain the microorganism concentration at an optimum level. That portion is called Return Activated Sludge (RAS). Excess microorganisms are removed from the treatment system as Waste Activated Sludge (WAS). Sludge can be wasted from mixed liquor or from RAS. The amount of solids within the system divided by the amount of the wasted solids is defined as the Solids Retention Time (SRT). Thus, control of the SRT is achieved by the daily wastage rate. Suspended growth systems typically operate in a continuous flow mode, but can also be operated as a batch process, such as Sequencing Batch Reactor (SBR).

The contents of the bioreactor, referred to as Mixed Liquor (ML), consist of wastewater, microorganisms and suspended and colloidal matter. The particulate fraction of the ML is referred to as Mixed Liquor Suspended Solids (MLSS).

There are many different suspended growth BNR process configurations for both nitrogen and phosphorus removal, including Bardenpho (4-stage), modified Bardenpho (5-stage), University of Cape Town (UCT), modified UCT, and Modified Johannesburg (MJ) process. Many of these configurations are designed to limit nitrate addition to the anaerobic zone. The MJ process has frequently been designed and operated in many cold weather applications, including the Edmonton Gold Bar WWTP, Alberta, Vernon WWTP, British Columbia, and Missoula WWTP, Montana. The pre-anoxic zone ensures that nitrates in the return sludge are denitrified prior to the anaerobic zone. A process schematic of the MJ process is illustrated in Figure 8.3. A source of simple carbon compounds such as volatile fatty acids (VFA) is essential for biological phosphorus removal.

8.4.1.2 Attached Growth Systems

Attached growth systems are described as those where the microorganisms involved in the biochemical conversion of organics and nutrients are attached to some form of an inert packing material (such as rock, gravel, sand and a wide range of plastic and synthetic materials). In general, the attached growth systems can be classified into three general classes of processes as follows:

- *Non-submerged attached growth*. Examples: several basic types of attached growth systems – including Trickling Filters (TF) and Rotating Biological Contactors (RBC). The attached biomass periodically sloughs off from the support media and is settled in secondary clarifiers. There is no return of the settled biomass from the clarifier to the TF or RBC.

- *Activated sludge with fixed-film packing.* These are often referred to as hybrid systems. A key example is the integrated fixed-film activated sludge process (IFAS) technology utilizing several proprietary packing materials that are either suspended in the mixed liquor or fixed in the aeration tanks. Because of its relevance to the SEWPCC, a further discussion on this option is provided below.

- *Submerged attached growth.* Processes involve no separate clarification step and excess solids from biomass growth and influent suspended solids are captured within the packing matrix. Examples include Biological Aerated Filters (BAF), which are commonly marketed under the proprietary trade names of *Biocarbone™*; *Biofor™* and *Biostyr™* and Fluidized-bed bioreactors (FBBR).

8.4.1.3 Combined Suspended Growth and Attached Growth/Hybrid Systems

A classic example of the combined suspended growth and attached growth is the integrated fixed film activated sludge process or IFAS. The IFAS system utilizes both suspended and fixed-film biomass for biological wastewater treatment, particularly improving nitrification in either new or existing aeration tanks. The incorporation of fixed-film biomass in the aeration tank allows an increase in the overall biomass inventory of the system without actually increasing the mixed liquor suspended solids and solids loading to the secondary clarifier (since the media is retained within the aeration tank). The increased biomass also increases the solids retention time (SRT) or sludge age of the system providing enhanced treatment (e.g. nitrification at low temperature or shorter system SRT) and potentially higher volumetric loading rates. In addition, IFAS systems allow better settleability of the suspended biomass and an increased resilience to shock loads. In IFAS systems, careful design of the aeration systems are critical to ensure meeting the increased oxygen demand associated with the additional biomass and in maintaining the required residual dissolved oxygen concentration in the system.

The design of the fixed film media is key to the success of the process. While several types of synthetic media have been developed, some of the key types are discussed in this memorandum. These are primarily proprietary attached growth processes, which are combined with suspended growth BNR systems to reduce the size of the aerobic zones – particularly for nitrification. The types of media can be divided into the following categories with examples as follows.

- Free-floating type (suspended within the tankage)
  - Compressible or sponge-type media (e.g. *LinPor*® and *Captor*® processes)
  - Non-compressible plastic media (*AnoxKaldnes*™ and *Hydroxyl Pac* media)
- Fixed packing type (placed in the aeration tank)
  - Rope type media or looped cord or strand media (*Ringlace* products, *AccuWeb* by Brentwood Industries, *Biomatrix* media by Biomatrix Technologies and *Cleartec* media by EIMCO)

In the Captor® and Linpor® processes foam pads with a specific density of about 0.95 g/cm^3 are placed in the bioreactor in a free-floating fashion and retained by an effluent screen. The pad volume can account for 20 to 30 percent of the reactor volume. Mixing from the diffused aeration system circulates the foam pads in the system, but without additional mixing methods, they may tend to accumulate at the effluent end of the aeration basins and float at the surface. An air knife is installed to continuously clean the screen and a pump is used to return the packing material to the influent end of the reactor. Solids are removed from a conventional secondary clarifier and wasting is from the return line as in the activated-sludge process. The principal advantage for the sponge packing systems, like all other IFAS media, is the ability to increase the loading on an existing plant without increasing the solids load on existing secondary clarifiers, as most of the biomass is retained in the aeration basin. Loading rates for BOD of 1.5 to 4.0 kg/m^3/d with equivalent MLSS concentrations of 5,000 to 9,000 mg/L have been achieved with these processes. Based on the results of full-scale and pilot-scale tests with the sponge packing installed it appears that nitrification can occur at apparent lower SRT values, based on the suspended growth mixed liquor, than those for activated sludge without internal packing.

Both *AnoxKaldnes*™ and *Hydroxyl Systems* market their plastic media under the *AnoxKaldnes* Moving Bed™ and Hyroxyl's fixed-film moving bed biological treatment processes (F^{3}R and

F³RAS). *AnoxKaldnes* Moving Bed™ bioreactor (MBBR) was developed by a Norwegian company, Kaldnes Miljøteknologi. The process consists of adding small cylindrical-shaped polyethylene carrier elements (specific density of 0.96 g/cm^3) in aerated or non-aerated basins to support biofilm growth. The small cylinders are about 10 mm in diameter and 7 mm in height with a cross inside the cylinder and longitudinal fins on the outside. The biofilm carriers are maintained in the reactor by the use of a perforated plate (5 x 25 mm slots) at the tank outlet. Air agitation or mixers are applied in a manner to continuously circulate the packing. The packing may fill 25 to 50 percent of the tank volume. The specific surface area of the packing is about 500 m^2/m^3 of bulk packing volume. The MBBR does not require any return activated-sludge flow or backwashing. A final clarifier is used to settle sloughed solids. The MBBR process provides an advantage for plant upgrading by reducing the solids loading on existing clarifiers. The presence of packing materials discourages the use of more efficient fine bubble aeration equipment, which would require periodic drainage of the aeration basin and removal of the packing for diffuser cleaning.

There are several installations of the MBBR process in Europe and the list is growing in North America. The installation in Bergamo, Italy is of significances to the SEWPCC as it utilizes a pure Oxygen MBBR for tertiary nitrification downstream of a pure oxygen (three-stage UNOX® system) suspended growth process that provides carbonaceous removal. A typical layout for cBOD and nitrogen removal utilizing the MBBR technology is shown in Figure 8.2.

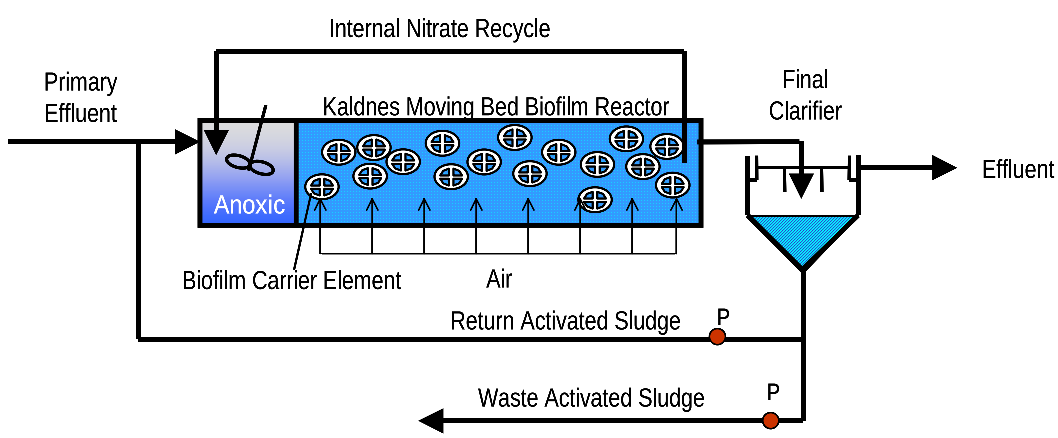

Figure 8.2 - Moving Bed Bioreactor (MBBR) Utilizing Free Floating Plastic Media

Unlike the free floating plastic media, the Ringlace® packing is a looped polyvinyl chloride material that is about 5 mm in diameter. It is placed in about 25 to 35% of the activated-sludge basin volume in modules with individual strands at 40 to 100 mm apart. The specific surface area provided ranges from 120 to 500 m^2/m^3 of tank volume. The packing placement location in the aeration tank is important. To provide efficient contact with the wastewater the packing should be placed along one side of the aeration vessel with the aeration equipment providing a spiral roll pattern for flow through the packing. Spiral roll aeration is usually less efficient than full floor coverage aeration with fine bubble diffusers. Several Ringlace® installations have experienced problems with red worms, which has eventually resulted in performance deterioration. For this reason many practitioners have tended to favor the free-floating non-compressible media over Ringlace®.

8.4.2 INITIAL SCREENING OF TREATMENT OPTIONS FOR THE SEWPCC

There are several options to expand the capacity and upgrade the treatment requirements at the SEWPCC. Probably the most straightforward method based upon proven technology would be to create a nitrifying/denitrifying HPO activated sludge system and utilize chemical precipitation of phosphorus using either alum or ferric chloride. To achieve this requires expansion of the existing HPO bioreactors for additional aeration cells and in increasing the aerobic sludge age for achieving nitrification. Also, addition of an anoxic cell ahead of the aerobic cells is required for denitrification using the organics in the primary effluent for a carbon source. Two-recycle lines can be used for denitrification of RAS and nitrified mixed liquor in the system. The divalent metallic precipitant would be added to the last aerobic cell to precipitate the phosphorus and have it settle out in the final clarifiers. This would be very similar to the Modified Ludzack-Ettinger process (MLE) widely used with air-activated sludge to nitrify and denitrify nitrogen in wastewater to elemental nitrogen gas.

However, the chemical addition would result in production of about 25 to 30 percent more sludge than biological phosphorus removal techniques. Also, the presence of the inerts in the mixed liquor would require that the bioreactors be 10 to 15 % larger. The capital and operating costs of the additional facilities and sludge management are the reason that this option is not considered for the SEWPCC and the City has indicated in the terms of reference that biological phosphorus removal will be utilized.

Based on the effluent quality stated earlier and the requirement to consider only BNR for the N and P removal, many of the treatment options can be screened out without giving them further consideration. These criteria essentially eliminate the use of fixed film biological processes such as trickling filters (TF), trickling filter solids contact (TFSC), biologically aerated filters (BAF'S), and rotating biological contactors (RBC's). Although they can be modified to provide nitrification/denitrification, they generally must depend upon chemical precipitation for P removal. Biological P removal has been achieved with TFSC type processes at several locations in BC e.g. Salmon Arm, but suspended growth anoxic zones must be added to achieve cost effective denitrification at low sewage temperature and the required size of the trickling filters is not cost effective. In addition, suspended growth processes such as Sequencing Batch Reactors (both variable and constant level types) are not considered further due to their use and cost-effectiveness in primarily small and medium scale plants.

A number of different bioreactor configurations have been developed in the past two decades specifically for biological nutrient removal in a suspended growth, single sludge configuration. The most promising bioreactor configurations to achieve the required effluent quality are described below.

8.4.2.1 Modified Johannesburg Process (MJ)

The Modified Johannesburg process has an excellent track record and has been successfully used in cold climates, such as at the **Gold Bar WWTP, Edmonton; City of Swift Current, Saskatchewan; Missoula WWTP, Montana, Hagerstown WWTP, Maryland; Little Patuxent WWTP, and Howard County WWTP, Maryland.** Experience has shown that the process is reliable and stable and allows for ease of operation. A schematic of this process is presented in Figure 8.3. SCVFA generated in the fermenters are supplied directly to the anaerobic cell of the bioreactor. This process configuration is also sometimes referred to as the Westbank process. In the Westbank Process, the secondary influent flow is split between the RAS denitrification zone and the mixed liquor anoxic zone.

A small anoxic cell in front of the anaerobic cell protects the anaerobic cell from nitrates and, thus, enhances the phosphorus removal potential. This anoxic cell is often referred to as pre-anoxic cell. The pre-anoxic cell is followed by an anaerobic cell, anoxic cell and aerobic cell. The second anoxic cell (swing cell) is typically equipped with an air supply so that it can operate in anoxic or aerobic modes, depending on the ammonia load and the season of the year. If denitrification is not required year round, the second anoxic cell typically operates as an aerobic cell in winter to maintain nitrification, and as an anoxic cell in summer to reduce the operating costs. RAS is recycled directly to the pre-anoxic cell and denitrified, together with any influent nitrate, using readily available carbon in the influent. The RAS rate is typically 0.5 to 0.9 the average influent flow rate. The advantages of this process are that it is simple and only has one internal recycle stream. The internal recycle rate is typically 2.5 to 3.5 times the average influent rate.

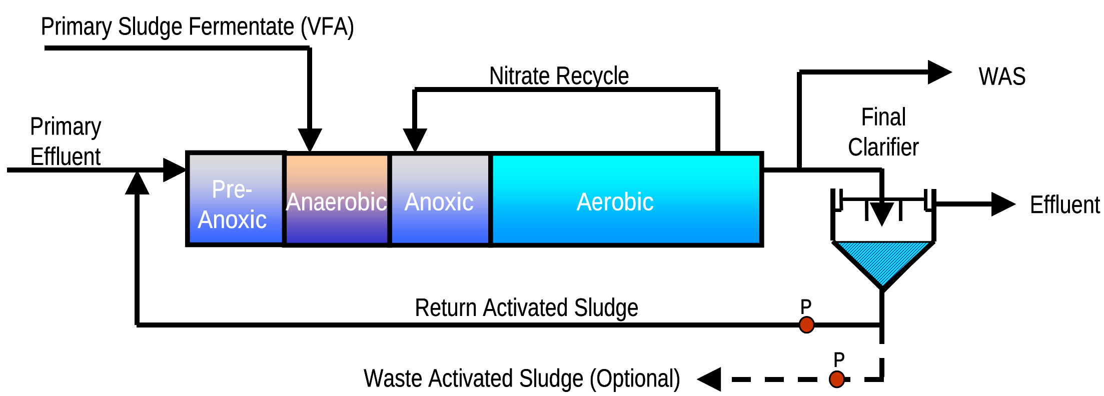

Figure 8.3 - Modified Johannesburg Process Schematic

Advantages and disadvantages of this process are presented below.

Table 8.1 - Preliminary Evaluation of Modified Johannesburg Process

Advantages	Disadvantages
▪ Best track record of BNR processes ▪ Best protection of anaerobic cells because of pre-anoxic cell ▪ Minimum recycles ▪ Minimum sludge production ▪ Reliable ▪ All of the RAS is preconditioned for bio-P growth in the anaerobic cell	▪ Operators must be familiar with BNR concepts and operation

8.4.2.2 Three Stage Bardenpho Process

The 3-stage Bardenpho process is a very simple and successful BNR configuration with a good track record. It has been successfully used in cold climates, such as at the Bonnybrook WWTP, Calgary, Alberta, and in Kelowna, British Columbia. Experience has shown that the process is reliable and stable and is easy to operate. A schematic of this process is presented in Figure 8.4. SCVFA generated in the fermenters are supplied directly to the anaerobic cell of the bioreactor.

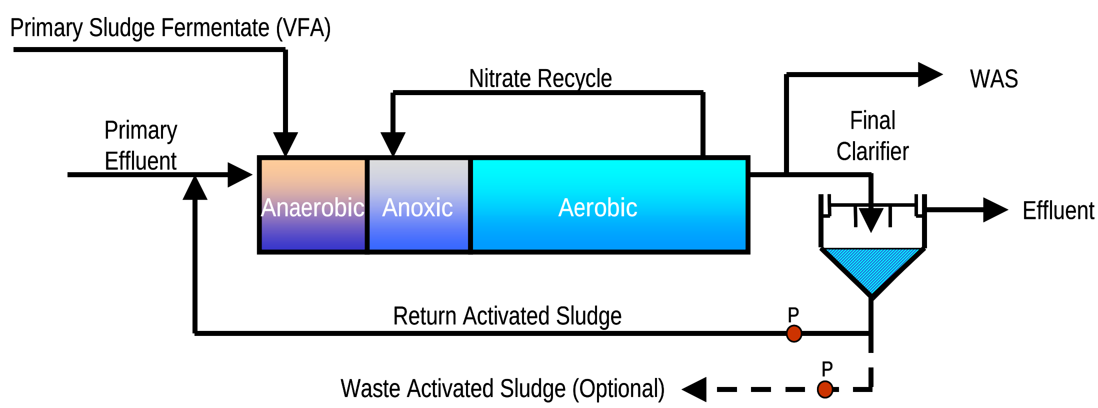

Figure 8.4 - Three (3) Stage Bardenpho Process Schematic

Influent and RAS flow directly into an anaerobic cell, followed by anoxic and aerobic cells. Only one internal recycle is required. This process is simple and easy to operate.

Advantages and disadvantages of this process are presented in Table 8.2.

Table 8.2 - Preliminary Evaluation of 3 Stage Bardenpho Process

Advantages	Disadvantages
▪ Good track record ▪ Minimum recycles ▪ Minimal sludge production ▪ Lower capital cost than other BNR options ▪ Reliable	▪ (Operators must be familiar with BNR concepts and operation ▪ No protection of anaerobic zone from nitrates in RAS or in raw sewage

8.4.2.3 University of Cape Town Process (UCT) and Virginia Initiative Process (VIP)

The University of Cape Town or UCT process is an improvement on the 3-stage Bardenpho configuration in order to protect the anaerobic zone from the negative impact of nitrates in the RAS stream. The UCT process consists of anaerobic, anoxic and aerobic zones, with the RAS stream directed to the anoxic zone of the bioreactor for denitrification as shown below.

The primary effluent flows directly into the anaerobic zone, which may also receive primary sludge fermentate for bio-P organisms. Nitrified mixed liquor is returned to the anoxic zone typically at the rate of 2 ~ 4 times the influent flow rate to maximize nitrogen removal via denitrification. Consequently, denitrified effluent from the end of the anoxic zone is recycled back to the anaerobic zone to continuously provide microorganisms required for phosphorus removal. The denitrified mixed liquor recycle rate is typically maintained at the same rate as the influent rate resulting in mixed liquor concentration in the anaerobic zone about half of the rest of the bioreactor.

The Virginia Initiative Process (VIP) is essentially a high-rate version of the UCT process with all zones having at least 2 cells in series. The basic idea behind this process is that should there be a lack of organics in the influent, preference is given to phosphorus removal. The downside of the VIP process is that it is difficult to control the nitrates in the effluent of the anoxic zone. When the zone runs out nitrates too soon, secondary phosphorus release would occur. This problem is resolved in the modified UCT process that is discussed later.

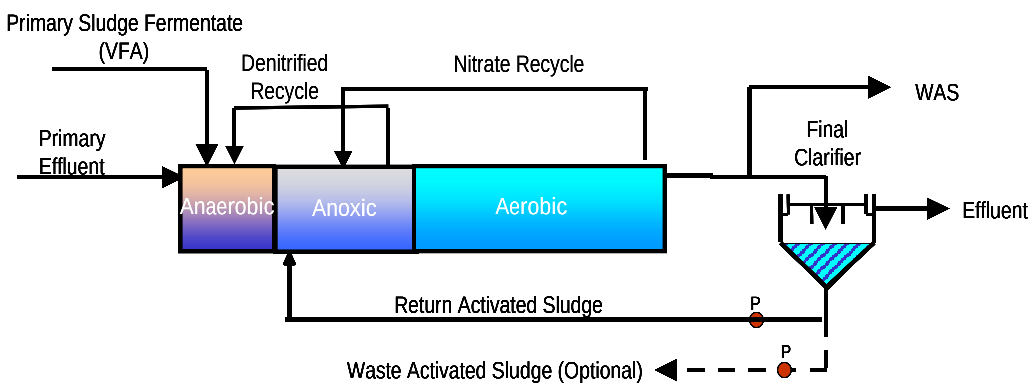

Figure 8.5 - UCT and VIP Process Schematic

Advantages and disadvantages of this process are presented below

Table 8.3 - Preliminary Evaluation of UCT/VIP Process

Advantages	Disadvantages
▪ Good protection of anaerobic cell ▪ Good phosphorus removal even with weak wastewater ▪ Produces good settling sludge	▪ Limited total nitrogen removal due to poor nitrate control ▪ More complex, more internal recycles ▪ Operators must be familiar with BNR concepts and operation

8.4.2.4 Modified University of Cape Town Process (MUCT)

The Modified University of Cape Town Process comprises four cells within the bioreactor and two internal recycles. This process is currently utilized with good success at Saskatoon, Saskatchewan (120ML/day), Penticton, British Columbia and Kalispell, Montana. A schematic of this process is presented in Figure 8.6. SCVFA generated in the fermenters are supplied directly to the anaerobic cell of the bioreactor.

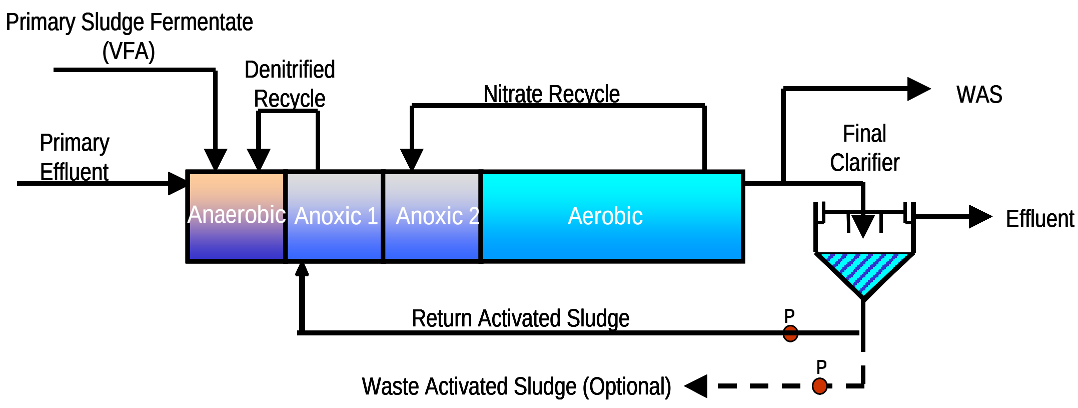

Figure 8.6 - Modified University of Cape Town (MUCT) Process Schematic

RAS is recycled to the first anoxic cell and an internal recycle returns nitrified ML from the aerobic cell to the second anoxic cell. The internal recycle to the anaerobic cell comes from the first anoxic cell. The intent of the MUCT process is to eliminate nitrate recycle to the anaerobic cell. Advantages and disadvantages of this process are presented in Table 8.4.

Table 8.4 - Preliminary Evaluation of MUCT Process

Advantages	Disadvantages
▪ Good track record ▪ Good protection of anaerobic cell ▪ Reliable	▪ More complex, more internal recycles ▪ Operator must be familiar with BNR concepts and operation ▪ Only half of the RAS solids are subjected to anaerobic conditions during recycle

8.4.2.5 Step-Feed BNR Process

A step-feed process is a modification of the conventional activated sludge process where the secondary influent feed is introduced at various locations along the length of the bioreactor. This modification allows the process train to deal with peak flows and loadings while maintaining the biomass in the bioreactor. Generally, three or more passes are utilized in this configuration for system flexibility and operation. The MLSS concentration may be as high as 5,000 to 9,000 mg/L in the first pass, while the subsequent passes have lower concentrations of MLSS as more influent feed is added. The step-feed process has the capability to carry a higher solids inventory and therefore maintain a higher sludge age for the same volume as a conventional activated sludge BNR process while at the same time protecting the secondary clarifier from being overloaded with high solid loading.

The step-feed mode is particularly beneficial during high flow events. This process allows the influent feed to be bypassed to the last pass to prevent any biomass washout from the system while minimizing the impact of solid loading to the secondary clarifier. Increased process capacity and reduced bioreactor volumes compared to other modes of operation have been well documented for the step-feed BNR process. The WWTP In Lethbridge, Alberta is an example of a step-feed BNR application. Utilization of the step-feed mode allowed the Lethbridge plant to be upgraded to both biological nitrogen and phosphorus removal within existing tankage using existing secondary clarifiers.

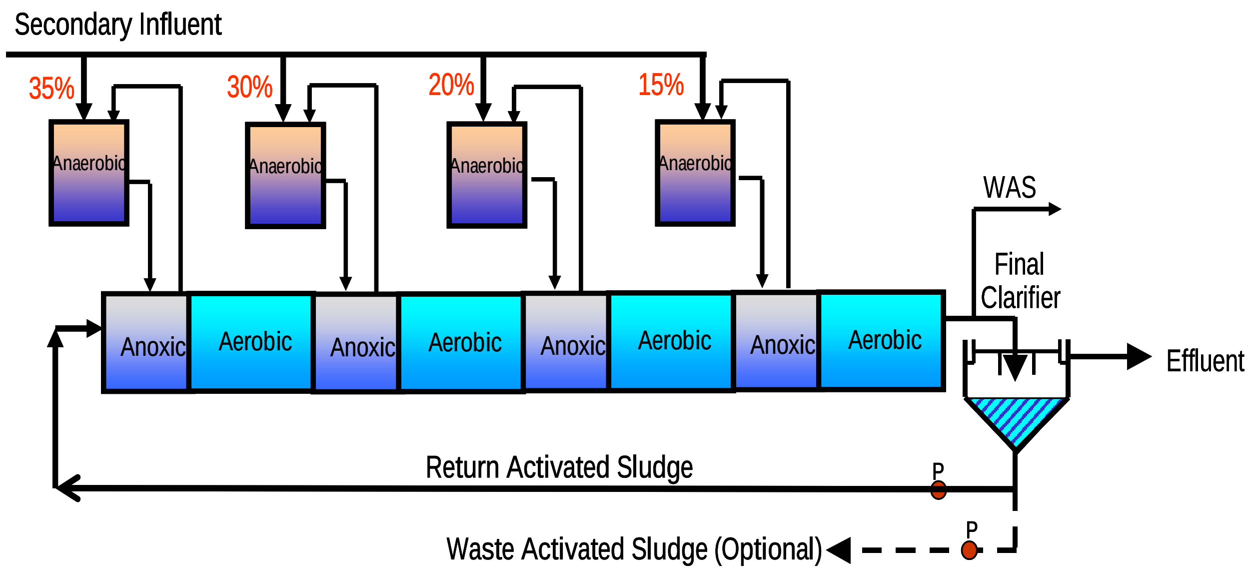

Figure 8.7 - Step-Feed BNR for N and P Removal

Advantages and disadvantages of the Step-Feed BNR process are presented in the following table.

Table 8.5 - Preliminary Evaluation of Step-Feed BNR Process

Advantages	Disadvantages
▪ Good track record ▪ Reduced bioreactor volume requirements or increased process capacity ▪ Maintains higher biomass inventory in the upper passes of the system ▪ Peak wet weather flows can be by-passed to last pass to minimize clarifier solids loading ▪ Flexible operation	▪ More complex operation and sophisticated controls required ▪ Flow splitting not often measured or known accurately ▪ Complicated process design and aeration system ▪ Operator must be familiar with BNR concepts and operation

The above BNR configurations, can all be designed and operated to achieve complete nitrification to < 1.0 mg/L NH_3 year round and can successfully denitrify to produce an effluent with 6 to 8 mg/L of total nitrogen when operating on municipal effluent.

If an adequate source of short chain carbon is supplied, such options can all achieve 0.5 to 1.0 mg/l of total phosphorus following final clarification. Typically soluble phosphorus levels of 0.02 to 0.05 mg/L can be achieved in well-designed BNR plants

8.4.3 BNR Process Enhancement/Modifications

Wastewater treatment plants are often situated in less than ideal locations, for a variety of reasons. In those situations where limited land is available, the preceding BNR process configurations can be combined with High Purity Oxygen (HPO) Activated Sludge technology, and or a Membrane Biological Reactor (MBR) to reduce the size of the facility. These modified processes require a larger capital cost outlay and usually result in higher operating costs. Although several large applications are currently being constructed or in operation, MBRs are still considered an emerging technology. The SEWPCC currently operates a HPO based secondary treatment process and therefore the use of HPO presents a viable alternative to enhance the BNR upgrade. Some of the process modifications of the main liquid stream processes discussed previously are presented below.

8.4.3.1 High Purity Oxygen (HPO)

The HPO activated sludge process was developed and commercialized by Union Carbide (Linde Division). The initial full-scale pilot program sponsored by the Federal Water Quality Administration (predecessor to the Environmental Protection Agency), EPA, was performed at a municipal plant in Batavia, NY from late 1968 and completed in 1970. In 1970, Union Carbide began commercialization of this process under the name of UNOX® system.

The UNOX® system is basically a conventional activated sludge process which is fed from a pure oxygen gas stream (instead of air) to accomplish secondary wastewater treatment and/or nitrification in an enclosed bioreactor followed by a clarifier. The ability of the system to maintain high dissolved oxygen concentrations in the mixed liquor, and the ability to match the oxygen demand of the wastewater by staging of the reactor, allows the system to be suitable for a variety of wastewater treatment applications. For nitrification the HPO process can be applied as either a single or two step system, although, most recent plants have been designed as single step (Hagerstown, MD).

High purity oxygen, 90-95% O_2, is supplied to the bioreactor enabling the process to be operated at high MLSS concentration (2,000 mg/L - 5,000 mg/L). Submerged turbine aerators are usually equipped to provide complete mixing of MLSS in reactors. Due to high oxygen content in the air supply, the oxygen utilization rate is significantly enhanced and the bioreactor will be smaller than a conventional activated sludge bioreactor by approximately 50% of volume, e.g. 4 to 6 hours hydraulic retention times are common as opposed to 9 to 10 hours for BNR and 8 hours for activated sludge with chemical precipitation.

High purity oxygen generation at wastewater treatment facilities usually involves the use of either (i) pressure swing adsorption (PSA), (ii) vacuum pressure swing adsorption (VPSA) or vacuum swing adsorption, or (iii) cryogenic air separation. The selection of PSA / VPSA / VSA versus a cryogenic process for oxygen generation is dictated by size and the level of oxygen purity. Cryogenic processes can produce > 98% purity oxygen, but are not cost effective for plants such as the SEWPCC where demands are in the range of 10 to 20 tons / day. Cryogenic plants are typical for treatment plants with oxygen demand > 100 tons / day. PSA / VPSA / VSA plants can be a source of noise pollution, produce oxygen in the range of 90 to 95% purity (which is quite adequate for the purpose of wastewater treatment), have moderate capital costs and are easy to set-up. Equipment maintenance is on the higher side for PSA type systems compared to a cryogenic process.

The water chemistry balance in an HPO activated sludge system is more complex than an open air activated sludge system. This is due to the fact that carbon dioxide produced in the reactor during the biological oxidation process does not leave the process until the last reactor stage. The concentration of CO_2 dissolved in the mixed liquor, or in the gas space, is dependent on Henry's Law. The relationship is of primary importance in HPO nitrification systems because of the reduced pH effect on nitrifier growth rate and SRT, the sludge retention time.

The conventional HPO system operates with an effluent pH that is lower than an air system, tending to reduce nitrifier growth rate. To improve nitrifier growth rate, and also eliminate the need for chemical addition, current generation designs incorporate an "open" intermediate or final stage in the HPO system. By exposing the mixed liquor to atmosphere, dissolved CO_2 will leave the system as a result of the aerator turbulence and mixing. Incorporating an open stage option in the HPO-BNR scheme has been known to elevate the mixed liquor by pH 0.4-0.6 units.

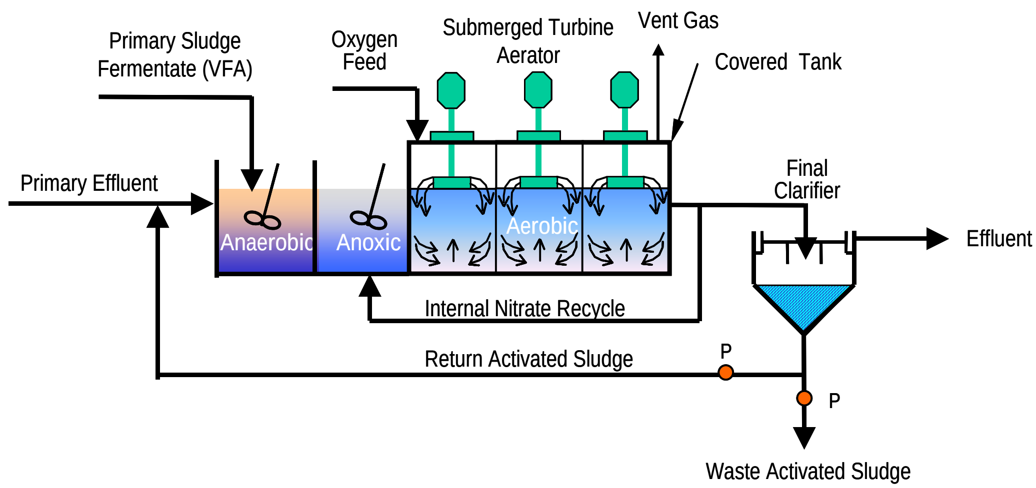

Figure 8.8 - HPO BNR Option

The relative advantages and disadvantages of HPO BNR Option are highlighted below.

Table 8.6 - Preliminary Evaluation of HPO Processes

Advantages	Disadvantages
▪ Smaller reactor tanks ▪ More effective in handling shock loads then air based processes ▪ Minimal air emissions due to covered tanks ▪ Can operate at higher MLSS levels compared to conventional processes	▪ Mechanically more complex ▪ Requires proper control of oxygen in the recycle stream for BNR configuration ▪ Becomes mixing limited under low process loading ▪ Limited use in BNR installations ▪ Requires venting of the CO_2 build-up to prevent alkalinity suppression in the mixed liquor

8.4.3.2 Membrane Bioreactors (MBR)

Membrane bioreactors (MBRs) are a variation of the activated sludge process where membranes are employed for suspended solids separation prior to effluent discharge. Thus the membrane replaces the conventional gravity-based secondary clarifier in the process train. When used in conjunction with BNR processes, these systems are often referred to as Membrane Biological Nutrient Removal (MBNR) systems. Compared to conventional BNR processes, the MBNR systems generally operate with a high MLSS concentration of 8,000 - 12,000 mg/L which allows for highly effective removal of both soluble and particulate biodegradable material in the wastewater. In addition, this higher biomass concentration equates to a higher aerobic SRT in the system. Many plants operate with SRTs exceeding 25 days, which ensures complete nitrification even under extreme cold weather operating conditions, and also resulting in lower sludge production due to endogenous decay.

There are two basic MBR configurations. In the first configuration, membrane filtration follows the activated sludge bioreactor in a separate stage and is sometimes referred to as “Separate-Stage Membrane Bioreactor”. The second configuration, and perhaps becoming more popular, is the option where the membranes are submerged in the activated sludge bioreactor tanks and is referred to as the “Immersed Membrane Bioreactor”. Some of the key manufacturers of the MBR systems include: Zenon Environmental, US Filter Memcor, Kubota Corporation, and Mitshubishi Rayon.

Two of the most common types of membranes used in wastewater application include tubular and hollow-fibre membranes. Tubular membranes are essentially membranes installed inside a porous tube and are generally arranged in a separate equipment module. Tubular membranes are typically used in Separate-Stage Membrane Bioreactors. Feed pumps are employed to develop the pressure required to drive the filtration operation. On the other hand, hollow fibre membranes are used in the “Immersed Membrane Bioreactor” configuration. Through the use of a suction duty pump, a vacuum is applied to a header connecting the membranes. The vacuum draws the treated effluent through the hollow fiber ultrafiltration membranes and into the pump. The pump then discharges the treated and filtered effluent (referred to as permeate) to downstream processes such as UV disinfection. The energy associated with permeate pumping is relatively small. An airflow is introduced to the bottom of the membrane modules, producing turbulence which scours the external surface of the hollow fibers transferring rejected solids away from the membrane surface. This airflow also provides a portion of the process air for biological oxidation of organic matter and nitrification. In addition to the tubular and hollow fibre membranes, flat sheet membranes are also available. These membranes are also immersed in the aeration tank with the advantage that the filtration operation is driven by gravity and not by a vacuum.

The MBR process can be readily adapted for total nitrogen and enhanced biological phosphorus removal. The higher MLSS becomes readily anoxic in the absence of aeration, ensuring high denitrification rates. An upstream anoxic zone and anaerobic zones can be incorporated into the MBR process to function as a complete MBNR system. However, there are some key differences that exist between conventional activated sludge based BNR processes and MBNRs that require careful design considerations and these are as follows (Daigger et al. 2005):

- The return sludge flow from conventional operated gravity-based clarifiers is generally approximately equal to the process influent flow rate (between 50 and 150 % of the influent flow), while for an MBNR the return sludge flow from the membrane liquid-solids separation module is significantly greater, generally two to four times the process influent flow rate

- The dissolved oxygen (DO) concentration in the return stream from a conventional gravity based clarifier is generally very low, while the DO concentration from a membrane liquid-solids separation module (especially in immersed membrane system) is generally quite high due to the rate of aeration in the membrane module tank required for membrane scouring.

An option for a MBNR based on the modified UCT (MUCT) BNR process is shown in Figure 8.9. The process configuration addresses the above concern for high dissolved oxygen associated with the return activated sludge (from the membrane modules) by recycling it back to the aerobic zone unlike conventional BNR processes. Nitrified mixed liquor is returned to the front end of the anoxic zone while denitrified mixed liquor from the second anoxic zone is retuned to the anaerobic zone to maintain active bio-P organisms in the system. The membrane processes do not take peak flows well and the rule of thumb is that membrane plants should be designed for a peak of no greater than 2.

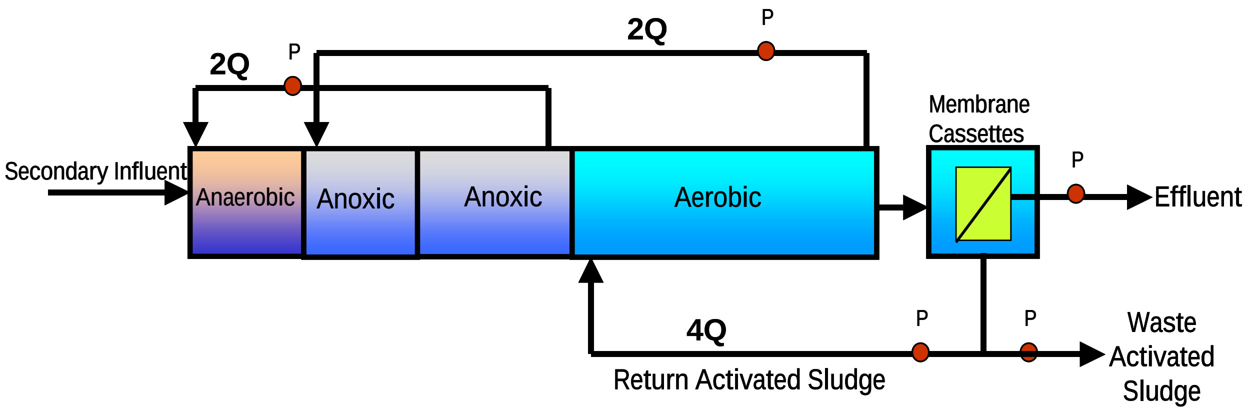

Figure 8.9 - An Example of An Immersed MBNR Configuration

The relative advantages and disadvantages of MBRs are highlighted below.

Table 8.7 - Preliminary Evaluation of MBNR Process

Advantages	Disadvantages
▪ Reduces the footprint of the WWTP (can be up to 50 ~ 80%) compared to conventional processes ▪ Produces very high quality effluent with low nitrogen and phosphorus levels ▪ No secondary clarifiers required ▪ Problems associated with poor settling and rising sludge in secondary clarifiers is eliminated ▪ Improves the performance of downstream processes such as UV disinfection ▪ Low sludge production compared to conventional BNR processes	▪ Limited track record in very large scale plants such as SEWPCC ▪ Higher energy cost with high pressure systems (particularly the separate-stage configurations) ▪ Potential for membrane fouling, clogging and scale formations ▪ Membrane replacement costs can be very high in large plants ▪ Membranes experience declining flux rates over time and in cold weather operations ▪ Generally higher capital and O&M costs than more conventional alternatives.

8.4.4 Side Stream Treatment Alternatives For Wet Weather Flows

The BNR processes discussed in this report are all capable of producing final effluents that are considerably higher quality than required by the SEWPCC licence. This fact raises the opportunity for the City to reduce the size of the BNR process and divert part of the flow through a lower cost treatment process that accomplishes a lower level of treatment (would not meet licence requirements). The two effluents would then be blended, prior to disinfection, to create an effluent that is still within the plant licence. When considering this option the designer must carefully balance the flows through each process to ensure the licence requirements are met.

There are two important reasons the City should consider the use of side-stream treatment at the SEWPCC. First, the SEWPCC experiences very high wet weather flow (PWWF) rates relative to the ADWF. These peaks often last long enough that they would threaten the health of the BNR biological processes by washing out the bacteria used to achieve treatment. If this were to occur, the bacteria takes a considerable time to regrow following the wet weather event. During this time the WWTP could be out of compliance with their operating licence. By diverting a portion of the flow during these wet weather events to a physical chemical side stream treatment method that is not susceptible to washout, the main BNR process is protected and the licence requirements are met.

The second reason that side stream treatment should be considered for the SEWPCC is that construction costs of physical chemical treatment systems is about one-third the cost of BNR systems. If the City is able to divert one third to one half of the flow through a side stream treatment process, this equates to a significant cost savings.

All of the side stream treatment options considered in this report section are physical chemical treatment methods, which involve the dosage of divalent metallic salts and polymers to a portion of the wastewater diverted away from the primary settling and biological treatment facilities after grit removal and screening. For some of the BNR options being considered, the existing final settling tanks may come available for alternate uses such as chemically enhanced sedimentation. Alternatively, new side-stream treatment processes applying increasingly high rate chemically enhanced primary processes could be constructed. These processes are capable of achieving reductions of 30-40% BOD and 50-60% TSS. The side stream treatment alternatives that may be appropriate for the SEWPCC are:

- Chemically Enhanced Primary Sedimentation
- Chemically Enhanced High Rate Clarification
  - Lamella Plate Settlers
  - Densadag 4d Process
  - Ballasted Flocculation e.g. Actiflo

Descriptions of these processes and their potential for application at the SEWPCC are discussed in details in Section 10.

8.5 DISCUSSION OF TREATMENT ALTERNATIVES FOR SEWPCC

The SEWPCC experiences high wet weather flows throughout both spring and summer. In our experience, a biological treatment process can be pushed to 150% of the rated capacity for several days with minimal loss in functionality. However, pushing the process to these flows beyond these time frames often damages the process by washing out the biological organisms the treatment process relies on. Once this occurs, it can take a considerable amount of time to regrow the bacteria, time during which the license requirements may not be met. In order to manage the process to meet effluent criteria and to protect against washouts, there are two general management alternatives for dealing with wet weather flows at the SEWPCC. These are:

- Construct a low rate biological treatment process with a larger rated capacity (approximately 2.5 times ADWF in this case), with excess flow going to bypass.
- Construct a high rate biological treatment process for a capacity approximately equal the projected AAF, operating at up to 1.5 times the ADWF, with side stream treatment via physical chemical means and bypassing of a small portion of the flows for only the highest influent flow rates.

There are a large number of biological nutrient removal configurations, which are currently utilized throughout North America. In this section we discuss the applicability of these processes for the SEWPCC. All of the BNR processes considered are based on enhanced BNR using primary sludge fermentation to sustain biological phosphorus removal and high denitrification rates. The BNR options have been considered as air activated sludge BNR processes as well as BNR processes combined with the oxygen enriched aeration technology i.e. HPO BNR.

The alternatives have been developed to maximize the reuse of existing facilities at the SEWPCC. Significant modification of some of the facilities is required for some of the options for which the main purpose of the tankage has been changed (e.g. existing secondary clarifiers converted to membrane bioreactor tanks in one of the options considered). The application of state of the art BNR technology is considered appropriate to the SEWPCC as the membrane BNR process (MBNR) would allow the use of high MLSS concentrations of around 8,000 mg/l and therefore reduce the size of additional bioreactors to upgrade and expand the system capacity. This system has a potential for higher quality effluent and eliminates the need for final clarifiers. Another emerging technology for retrofit to existing tankage and additional BNR bioreactors is the use of neutral buoyancy plastic media to enhance nitrifier populations in the aerobic cells (IFAS technology). These higher rate technologies, which are just coming into more common use in North America, are considered in both HPO BNR configurations as well as air activated sludge BNR configurations.

8.5.1 List of Alternatives

Several of the alternatives for upgrading listed and described below are combination systems in which the existing bioreactors are retrofitted using HPO/BNR technology while additional capacity is obtained by adding another technology such as MBNR.

Twenty-two (22) treatment alternatives for upgrading the SEWPCC are discussed below.

8.5.1.1 Low Rate Activated Sludge/BNR/ Modified Johannesburg Process (MJ)

Description: This is the base case option for comparison of all other options. The Modified Johannesburg process is a proven BNR option and the design provides BNR treatment for the full spring maximum month flow. Earth Tech utilized the Westbank configuration with a low MLSS concentration (2500mg/l) in the bioreactor. The MJ configuration is very similar to the Westbank and produces a similar effluent quality. The low design MLSS and max design load at cold temperature produces a large footprint bioreactor (12 hour HRT)), which is a capital intensive way of providing the required effluent quality at high flows and loads.

Comments: Shortlist for further consideration. This option presents an opportunity to handle a higher peak flows and operate under a high rate process during that period.

8.5.1.2 High Rate Activated Sludge/BNR/MJ Process

Description: Optimized high rate design. Again this is a BNR design for the ***total maximum month flows*** and loads typical of low temperature snowmelt and spring storm flow conditions. However the design MLSS is selected at 4500 mg/l which is an accepted operational level for

BNR plants in Western Canada using MJ and a variety of other BNR process configurations. It is a conservative design approach with a very good track record.

*Comment***:** Shortlist for further consideration. All of the common BNR process configurations and other processes for nutrient removal could be employed on the total max month flows and loads but there are no advantages over MJ and therefore the reminder of the process alternatives at SEWPCC are considered with diversion and side stream treatment.

8.5.1.3 Activated Sludge BNR/MJ Complete with Flow Diversion and Side Stream Treatment

Description: This high rate BNR design utilizes a design springtime flow regime of 75% of the maximum month flow to reduce the size of the bioreactor and associated unit processes. A 60 to 100 ML/day side stream physical chemical treatment process would be used for peak flows. This process could consist of chemically assisted primary sedimentation in a high rate lamella equipped sedimentation tank. By blending the BNR and side stream effluents the required effluent quality of 15 mg/l total nitrogen can be achieved. Capital and operating cost savings are expected to justify this strategy.

*Comments***.** Shortlist for further consideration. As wastewater characterization proceeds during 2006 snowmelt and storm periods, the amount of high flows that could successfully be split off and treated will be determined.

8.5.1.4 Activated Sludge/BNR/UCT Process with Partial Diversion to NEWPCC and Side Stream Treatment.

Description: The University of Capetown process configuration for BNR is certainly an option but does not provide as effective protection for the anaerobic zone for recycled nitrates as the MJ process. Therefore, phosphorus removal would not be as easily achieved. The modified UCT process could be employed as at Penticton but this involves an additional recycle pumping system and really doesn't provide any process advantages to SEWPCC.

*Comment***:** No Further Consideration

8.5.1.5 Activated Sludge /BNR/3 stage Bardenpho Process with Diversion as Above and Side Stream Treatment

Description: The 3 stage Bardenpho process is a very simple and successful BNR configuration with a good track record at places such as Kelowna and Calgary Bonnybrook but it does not provide the same degree of protection of the anaerobic zone from nitrates as the MJ process. There are really no cost or process advantages at SEWPCC to employing it rather than the MJ process**.**

Comment: No Further Consideration

8.5.1.6 Activated Sludge/Step Feed BNR with Diversion to NEWPCC and Side Stream Treatment

Description: The step feed BNR process is an excellent process to consider for low nitrogen (down to say 3 to 5 mg/l levels) and where it is important to minimize the solids loads on final clarifiers. This is the application at New York City plants where utilizing existing tankage to the maximum is important because of site constraints. However, the track record of the step feed process for BNR with biological phosphorus removal is limited to a few locations e.g. Lethbridge Alberta. Step feed capability could be a feature built into the MJ process for ease in future upgrading if effluent nitrogen requirements become more stringent.

Comment: No Further Consideration

8.5.1.7 Nitrifying/Denitrifying Activated Sludge with Diversion to NEWPCC and Side Stream Treatment

Description: This is a very effective process for converting organic and ammonia nitrogen in wastewater to nitrates and then using a recycle stream to a pre-anoxic basin where denitification to nitrogen gas occurs to achieve a high level of nitrogen removal. However, phosphorus is usually removed with this type of process by adding a chemical precipitant such as a divalent metallic salt such as ferric chloride or alum to the aeration tank. The inert solids added therefore increase the size of the bioreactor and generate about 25 to 30 % more sludge than BNR processes. Experience at most locations in western Canada show that the extra capital and operating costs of managing the sludge make the process none competitive with BNR processes where simultaneous N and P removal to low levels are required. The need to truck the sludge from the SEWPCC to the NEWPCC for processing further increases the operating costs of this option.

Comment: No Further Consideration

8.5.1.8 HPO Activated Sludge BNR Process Designed for Nitrification, Denitrification with Chemical Phosphorus Removal, Partial Flow Diversion to NEWPCC and Physical-Chemical Side Stream Treatment

Description: This option is an optimized version of the previous nitrifying denitrifying activated sludge alternative in that the use of high purity oxygen considerably reduces the aerobic bioreactor cell size. However, there is still a requirement for chemical precipitation of phosphorus with this option that translates into 25 % greater sludge volumes to handle and process. Additionally, because of the inerts in the MLSS, the reduction in bioreactor size in comparison to the MJ BNR process at 75% of maximum month flows will be small.

Comments: No Further Consideration

8.5.1.9 High Purity Oxygen (HPO) Modified Johannesburg Process with Diversion to NEWPCC and Side Stream Treatment

Description: Sized for 75% of the max month design flow and load this option will result in a very small bioreactor, which is about 25 % smaller than the AS/BNR/MJ option at a similar flow. This option is very compatible with the existing plant and makes use of the existing pressure swing oxygen generation facility. The process is proven for full BNR as demonstrated by the Hagerstown Maryland facility.

Comments. Shortlist for further consideration.

8.5.1.10 Activated Sludge/BNR/MJ/IFAS with Diversion and Side Stream Treatment

Description: This is an excellent way of further reducing the size of the BNR/MJ bioreactor to approximately the same size as the HPO/BNR/MJ bioreactor. A neutral buoyancy plastic media is loaded into the aerobic cells of the bioreactor at approximately 850 m^2 of media surface per m^3 of tank volume. The media is retained within the zone by appropriately sized stainless steel screens. Microorganisms grow on the surface of the suspended media and because of the high unit surface area available per mass of microorganisms, the aerobic degradation and nitrification rates increase by 25 to 40 %. Periodically these organisms slough off and are captured as part of the WAS in the final clarifiers. The process is currently emerging in the USA for nitrogen removal plants but has a very good track record in Europe. Currently there are demonstration facilities at the Lakeview WWTP and Highland Creek WPCP's in Toronto. The attached growth portion of the nitrifiers makes it a very important option to handle high flow variations.

Comments. Shortlist for further consideration. If this option continues to be promising after preliminary design evaluation it will be a candidate for pilot testing as part of the conceptual design assignment.

8.5.1.11 HPO/BNR/MJ/IFAS with Diversion and Side Stream Treatment.

Description: This option is a real combination of technologies. We know that the HPO has been combined with IFAS for the aerobic zones of an HPO plant at one installation in Europe but because of its very limited application to date it should be considered an emerging technology rather than proven. At this time in its evolution it would be a process to consider for future upgrades if HPO/BNR/MJ is ultimately put into service.

Comments: No Further Consideration

8.5.1.12 HPO/step Feed BNR with Diversion to NEWPCC and Side Stream Treatment.

Description: There are no applications of step feed BNR combined with HPO technology as far as we know. The reason for this is that in the step feed process there a large number of anoxic zones, which are in series with aerobic cells. For the air activated process the dissolved oxygen levels are usually between 1 and 2 mg/l, which is compatible with flow to an anoxic zone. In HPO the aerobic zone DO levels are usually around 4 mg/l in an enclosed reactor with a high oxygen concentration in the air space. Therefore the subsequent anoxic zones would have to be oversized significantly for anoxic conditions to prevail.

Comments: No Further Consideration

8.5.1.13 Membrane BNR (MBNR) with Diversion to NEWPCC and Side Stream Treatment.

Description: This is a very viable option for consideration at SEWPCC because the existing bioreactors and new bioreactors could be modified with an appropriate BNR configuration utilized at locations such as Cawley Creek for both biological nitrogen and phosphorus removal. New tanks could also be constructed to install the vacuum membrane cassettes (spiral wound bundles) as well as a housing for vacuum and recycle pumps. The new tanks would be quite small in comparison to the AS/BNR/MJ tankage because of the high MLSS concentrations carried in the bioreactors of about 8000 mg/l average. This is a very attractive option to consider in detail because final clarifiers would be freed up for retrofit as side stream physical chemical treatment.

Comments: Shortlist for further consideration. Due to the high quality of the final effluent from the MBNR modules, the spring max month side stream quantities treated could perhaps be increased and the MBNR bioreactor size significantly reduced.

8.5.1.14 MBNR with Diversion to NEWPCC and Side Stream Treatment.

Description: This is a very similar option to the previous except that the MBNR reactors could be built into the existing final clarifiers as well as the existing HPO bioreactor. Membrane cassettes could be constructed in new stand-alone tanks if spiral wound membrane bundles are used. At least one of the smaller final clarifiers would still be freed up for construction of the side stream physical chemical treatment. This option would be dependant upon the ability to retrofit the final tanks, which may require raising of the sidewalls, and certainly baffling to create efficient annular plug flow bioreactor cells.

Comments: Shortlist for further consideration

8.5.1.15 HPO/MBNR with Diversion to NEWPCC and Side Stream Treatment.

Description: Theoretically this is a very attractive option because the high purity oxygen would be excellent to maximize the bioreactor MLSS levels. However, there would probably have to be a separate compressed air supply for use in aerating around the membrane bundles. This is an emerging technology with limited hardware development because there are no known full-scale applications of combining the two technologies. It does have promise to yield the smallest possible bioreactor but would require long-term development work.

Comments: No Further Consideration

8.5.1.16 HPO/MBNR/IFAS with Diversion to NEWPCC and Side Stream Treatment

Description: This is probably the ultimate in combination of emerging high rate technologies in the BNR field. It is certainly not a proven process but has the potential for an even smaller bioreactor than the HPO/MBNR alternative. It is really only a theoretical probability, which hasn't been piloted successfully yet.

Comments: No Further Consideration

8.5.1.17 Combination of HPO/IFAS BNR and MBNR with Diversion to NEWPCC and Side Stream Treatment.

Description: This option utilizes the MBNR technology for retrofit of a major portion of the flow and load say 50 ML/day using the final clarifiers for MBNR bioreactors and separate membrane cassette bioreactors **with** retrofit of the existing HPO bioreactors as HPO/BNR/MJ/IFAS bioreactors for say 30 ML/day. In this option it would be necessary to provide membrane cassettes that could be used in conjunction with the existing HPO bioreactors operated as BOD and TSS removal units as a portion of the secondary plant solids separation until one by one some of the final clarifiers are retrofitted as MBNR bioreactors. It may be possible that one of the small final clarifiers could be used for side stream treatment. In early years the MBNR portion would be adequate to handle all the plant flows while the HPO/BNR/MJ/IFAS emerging technology combination is developed**.**

Comments: Shortlist for further consideration

8.5.1.18 Upgrading existing WWTP to HPO Nitrification/Denification System with Chemical Removal, Diversion to NEWPCC and Side Stream Treatment

Description: Same as above except the existing bioreactors retrofitted for HPO nitrification and denitrification activated sludge with chemical precipitation for phosphorus removal. This option will generate large volumes of waste activated sludge that will have to be trucked to the NEWPCC for processing.

Comments: No Further Consideration

8.5.1.19 Converting existing WWTP to HPO/MBNR with Final Clarifiers Retrofitted with Membranes with Diversion to NEWPCC and Side Stream Treatment

Description: A major portion of flow will be handled by the retrofitted final clarifiers as MBNR with the existing bioreactors retrofitted as HPO/MBNR. To date operation of MBNR plants with HPO is not known and presents a risk to the City.

Comments: No Further Consideration

8.5.1.20 Combination with Diversion to NEWPCC and Side Stream Treatment

Description: A major portion of the flow says 50 ML/day is handled by retrofit of final clarifiers as MBNR **with** the existing bioreactor as a 30 ML/day HPO/BNR/MJ. Note that no emerging technology development work is required with this option. Perhaps one of the smaller final clarifiers could be retrofit for side stream physical chemical treatment**.**

Comments: No Further Consideration. This may perhaps be a more feasible combination option than the HPO/BNR/MJ/IFAS retrofit of existing tankage.

8.5.1.21 Combination System – Activated Sludge/BNR/MJ Process with Existing HPO Plant for Side Stream

Description: This option requires a new air activated sludge BNR/MJ process handling up to 80% of the flow and load with the existing HPO facility essentially providing the side stream treatment for BOD, TSS and TP (via chemical precipitation).

Comments: Shortlist for further consideration.

8.5.1.22 Combination System – Convert Existing Facilities to HPO/BNR/MJ, Provide Additional Capacity via AS/BNR/MJ with Side Stream Treatment

Description: This option requires a new air activated sludge BNR/MJ process to operate parallel with existing facility upgraded to a HPO/BNR/MJ system complete with a chemically enhanced side stream (for wet weather treatment).

Comments: Shortlist for further consideration.

8.5.1.23 Activated Sludge/BNR/MJ with Biogradex® Technology and Side Stream Treatment

Description: The proprietary Biogradex® technology was reviewed at a later date of the preliminary design at the request of City of Winnipeg. This process option is similar to previously discussed option based on a high rate MJ BNR process, except, it includes the Biogradex® technology for vacuum degassing of mixed liquor. Side-stream physical-chemical treatment is provided for wet weather flows. Biogradex® towers placed between aerobic tanks and secondary clarifiers allows for degassing the MLSS which enhances solids settling and thickening in the clarifiers, achieving up to 2% solids in the RAS recycle stream. The high concentration of solids in the RAS facilitates the operation of bioreactors with a high MLSS of 6,000 ~ 8,000 mg/L. The higher biomass inventory in the bioreactor tanks results in a smaller bioreactor volume and a shorter hydraulic retention time compared to conventional BNR processes. The higher MLSS also facilitates a long sludge age of around 12 to 15 days to sustain nitrification at low temperatures. The degassing of the MLSS by the Biodegradex® tower prior to secondary clarification improves sludge settling characteristics and thickening, which is reported to reduce the secondary clarification area by up to 30%. Biogradex® technology has been used primarily in Europe with no operating plants in North America. The largest operating plant utilizing the Biogradex® technology has an average day capacity of 20.5 ML/d which is significantly smaller than the SEWPCC. Additionally the performance of the vacuum degassing towers at higher flow rates and low temperatures expected in Winnipeg is unknown.

Comments: No further consideration

8.6 SHORTLISTED TREATMENT ALTERNATIVES

Based on the discussion provided in the longlist of 22 alternatives for the SEWPCC expansion/upgrade ten (10) viable alternatives were shortlisted for further discussions and evaluation. These ten (10) treatment options (A-J) are presented in detail in the attached 11x17 data sheets.

TABLE 8.8
Winnipeg SEWPCC
Preliminary Capital Cost Estimates for Comparative Analysis - Options A to J
Revised May 5, 2006

Item #	Description	Unit	Unit Price	Option A - AS/BNR/MJ Low Rate @ 165 ML/d No Side Stream		Option B - AS/BNR/MJ High Rate @ 165 ML/d No Side Stream		Option C - AS/BNR/MJ High Rate @ 100 ML/d With CEP Side Stream		Option D - HPO/BNR/MJ @ 100 ML/d With CEP Side Stream	
				Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	SITE WORKS										
1.1	Allowance for roads & landscaping	1	$435,000	1	$435,000	1	$435,000	1	$435,000	1	$435,000
1.2	Allowance for yard piping	1	$875,000	1	$875,000	1	$875,000	1	$875,000	1	$875,000
1.3	Excavation	m3	$12	92000	$1,104,000	86000	$1,032,000	48000	$576,000	56000	$672,000
1.4	Backfill	m3	$25	13800	$345,000	12900	$322,500	7200	$180,000	8400	$210,000
	Sub-Total Site Works				**$2,759,000**		**$2,664,500**		**$2,066,000**		**$2,192,000**
	HEADWORKS										
2.1	Allowance for additional pump, grit removal and 10 mm screens	1	$4,300,000	1	$4,300,000	1	$4,300,000	1	$4,300,000	1	$4,300,000
2.2	Additional cost for 2 mm screens	1	$2,500,000		$0		$0		$0		$0
					$0		$0		$0		$0
	Sub-Total Headworks				**$4,300,000**		**$4,300,000**		**$4,300,000**		**$4,300,000**
	PRIMARIES & VFA										
3.1	Additional primary clarifier	m2	$5,085	2462	$12,519,270	2462	$12,519,270	1467	$7,459,695	1467	$7,459,695
3.2	Fermenters	m3	$1,065	6414	$6,830,910	6414	$6,830,910	5100	$5,431,500	5100	$5,431,500
3.3	Building over primary clarifier	m2	$715	2708	$1,936,363	2708	$1,936,363	1614	$1,153,796	1614	$1,153,796
	Sub-Total Primaries & VFA				**$21,286,543**		**$21,286,543**		**$14,044,991**		**$14,044,991**
	BIOREACTOR										
4.1	New Bioreactor	m3	$630	79625	$50,163,750	55200	$34,776,000	30900	$19,467,000	22200	$13,986,000
4.2	Upgrade blower building	m2	$1,200	500	$600,000	500	$600,000	500	$600,000	500	$600,000
4.3	Modify existing bioreactor	m3	$300	6600	$1,980,000	6600	$1,980,000	6600	$1,980,000		$1,500,000
4.4	IFAS media	m3	$500	na		na		na		na	
4.5	Convert clarifiers into bioreactor	m3	$500	na		na		na		na	
4.6	Concrete cover on HPO tanks	m2	$540	na		na		na		2800	$1,512,000
4.7	Allowance for oxygen generation	1	$1,900,000							1	$1,900,000
4.8	Building over additional bioreactor	m2	$715	17500	$12,512,500	12100	$8,651,500	6800	$4,862,000	4500	$3,217,500
	Sub-Total Bioreactor				**$65,256,250**		**$46,007,500**		**$26,909,000**		**$22,715,500**
	SOLIDS SEPARATION										
5.1	Secondary Clarifiers	m2	$2,700	4165	$11,245,500	6560	$17,712,000	3280	$8,856,000	4165	$11,245,500
5.2	Supply Membrane & Equipment	each	$145,000	na		na		na		na	
5.3	Install membranes & equipment	%	50%	na		na		na		na	
5.4	Concrete Membrane Tanks	m3	$1,200	na		na		na		na	
5.5	Building for MBR ancillary equipment	m2	$1,200	na		na		na		na	
5.6	Building over tanks	m2	$715	4998	$3,573,570	7872	$5,628,480	3936	$2,814,240	4998	$3,573,570
	Sub-Total				**$14,819,070**		**$23,340,480**		**$11,670,240**		**$14,819,070**
	SOLIDS HANDLING										
6.1	Allow WAS thickening using DAF	LS	$8,750,000	1	$10,500,000	1	$10,500,000	1	$8,750,000	1	$8,750,000
6.2	Allowance for sludge blending tank	LS	$940,000	1	$940,000	1	$940,000	1	$940,000	1	$940,000
6.3	Building	m2	$1,200	1250	$1,500,000	1250	$1,500,000	1250	$1,500,000	1250	$1,500,000
	Sub-Total Solids Handling				**$12,940,000**		**$12,940,000**		**$11,190,000**		**$11,190,000**
	SIDE STREAM TREATMENT										
7.1	Allowance for clarifiers with lamella	LS	$20,000,000	0	$0		$0	1	$20,000,000	1	$20,000,000
7.2	Allow. to add lamella to exist. clarifiers	LS	$15,000,000		$0		$0		$0		$0
7.3	Building over clarifiers	m2	$715		$0		$0	1000	$715,000	1000	$715,000
	Sub-Total Slip Stream Treatment				**$0**		**$0**		**$20,715,000**		**$20,715,000**
	DISINFECTION										
8.1	Allowance for UV expansion	1	$10,000,000	1	$10,000,000	1	$10,000,000	1	$10,000,000	1	$10,000,000
8.2	Building	m2	$1,200	1000	$1,200,000	1000	$1,200,000	1000	$1,200,000	1000	$1,200,000
	Sub-Total Disinfection				**$11,200,000**		**$11,200,000**		**$11,200,000**		**$11,200,000**
	OTHER ITEMS										
9.1	Allowance for Control and SCADA	1	$2,500,000	1	$2,500,000	1	$2,500,000	1	$2,500,000	1	$2,500,000
9.2	Allowance for electrical distribution	1	$1,000,000	1	$1,000,000	1	$1,000,000	1	$1,000,000	1	$1,000,000
9.3	Allowance for service tunnel				$3,000,000		$3,000,000		$2,800,000		$3,000,000
9.4	Allowance for odour control		$5,000,000	1	$5,000,000	1	$5,000,000	1	$5,000,000	1	$5,000,000
	Sub-Total Other Items				**$11,500,000**		**$11,500,000**		**$11,300,000**		**$11,500,000**
	Sub-Total Items 1 to 9				**$144,060,863**		**$133,239,023**		**$113,395,231**		**$112,676,561**
	Division 1 Cost	%	5%		$7,203,043		$6,661,951		$5,669,762		$5,633,828
	TOTAL - CONSTRUCTION				**$151,263,906**		**$139,900,974**		**$119,064,992**		**$118,310,389**
	Contingency, Engineering and Adminstration Fees	%	35%		$52,942,367		$48,965,341		$41,672,747		$41,408,636
	TOTAL PROJECT COST				**$204,206,273**		**$188,866,315**		**$160,737,739**		**$159,719,025**

Item #	Description	Option E - MBNR New Tanks @ 100 ML/d Plus Side Stream		Option F - MBNR Retrofit in Clarifiers @ 100 ML/d With CEP Side stream		Option G - AS/BNR/MJ/IFAS @ 100 ML/d With CEP Side Stream		Option H - Comb. HPO/BNR/MJ/IFAS @ 20 ML/d & MBNR @ 80 ML/d With CEP Side		Option I - Comb. BNR / MJ @100 ML/D and HPO for Side Stream		Option J - Comb. HPO / BNR @ 20 ML/D & AS / BNR @ 80 ML/D with CEP for Side Stream	
		Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	SITE WORKS												
1.1	Allowance for roads & landscaping	1	$435,000	1	$435,000	1	$435,000	1	$435,000	1	$435,000	1	$435,000
1.2	Allowance for yard piping	1	$875,000	1	$875,000	1	$900,000	1	$875,000	1	$875,000	1	$875,000
1.3	Excavation	50000	$600,000	32000	$384,000	44000	$528,000	44000	$528,000	56000	$672,000	56000	$672,000
1.4	Backfill	7500	$187,500	4800	$120,000	6600	$165,000	6600	$165,000	8400	$210,000	8400	$210,000
	Sub-Total Site Works		**$2,097,500**		**$1,814,000**		**$2,028,000**		**$2,003,000**		**$2,192,000**		**$2,192,000**
	HEADWORKS												
2.1	Allowance for additional pump, grit removal and 10 mm screens	1	$4,300,000	1	$4,300,000	1	$4,300,000	1	$4,300,000	1	$4,300,000	1	$4,300,000
2.2	Additional cost for 2 mm screens	1	$2,500,000	1	$2,500,000		$0	1	$2,500,000		$0		$0
			$0		$0		$0		$0		$0		$0
	Sub-Total Headworks		**$6,800,000**		**$6,800,000**		**$4,300,000**		**$6,800,000**		**$4,300,000**		**$4,300,000**
	PRIMARIES & VFA												
3.1	Additional primary clarifier	1467	$7,459,695	1467	$7,459,695	1467	$7,459,695	1467	$7,459,695	2462	$12,519,270	1467	$7,459,695
3.2	Fermenters	5100	$5,431,500	5100	$5,431,500	5100	$5,431,500	5100	$5,431,500	5100	$5,431,500	5100	$5,431,500
3.3	Building over primary clarifier	1614	$1,153,796	1614	$1,153,796	1614	$1,153,796	1614	$1,153,796	2708	$1,936,363	1614	$1,153,796
	Sub-Total Primaries & VFA		**$14,044,991**		**$14,044,991**		**$14,044,991**		**$14,044,991**		**$19,887,133**		**$14,044,991**
	BIOREACTOR												
4.1	New Bioreactor	15900	$10,017,000	4300	$0	17200	$10,836,000	na	$0	38625	$24,333,750	30000	$18,900,000
4.2	Upgrade blower building	500	$600,000	500	$600,000	500	$600,000	500	$600,000	500	$600,000	500	$600,000
4.3	Modify existing bioreactor	6600	$1,980,000	6600	$1,980,000	6600	$1,980,000	6600	$1,980,000		$1,500,000		$1,500,000
4.4	IFAS media	na		na		14600	$7,300,000	3625	$1,812,500		$0		$0
4.5	Convert clarifiers into bioreactor	na		17000	$8,500,000	na		12600	$6,300,000		$0		$0
4.6	Concrete cover on HPO tanks	na		na		na		na			$0		$0
4.7	Allowance for oxygen generation										$0		$0
4.8	Building over additional bioreactor	3400	$2,431,000	1150	$822,250	3400	$2,431,000	0	$0	8500	$6,077,500	6500	$4,647,500
	Sub-Total Bioreactor		**$15,028,000**		**$11,902,250**		**$23,147,000**		**$10,692,500**		**$32,511,250**		**$25,647,500**
	SOLIDS SEPARATION												
5.1	Secondary Clarifiers	na		na		3280	$8,856,000	na		6560	$17,712,000	3280	$8,856,000
5.2	Supply Membrane & Equipment	150	$21,750,000	150	$21,750,000	na		120	$17,400,000		$0		$0
5.3	Install membranes & equipment		$10,875,000		$10,875,000	na			$8,700,000		$0		$0
5.4	Concrete Membrane Tanks	2280	$2,736,000	800	$960,000	na		1370	$5,655,000		$0		$0
5.5	Building for MBR ancillary equipment	1800	$2,160,000	700	$840,000	na		1010	$3,675,750		$0		$0
5.6	Building over tanks	1800	$1,287,000	700	$500,500	3936	$2,814,240	900	$643,500	7872	$5,628,480	3936	$2,814,240
	Sub-Total		**$38,808,000**		**$34,925,500**		**$11,670,240**		**$36,074,250**		**$23,340,480**		**$11,670,240**
	SOLIDS HANDLING												
6.1	Allow WAS thickening using DAF	1	$8,750,000	1	$8,750,000	1	$8,750,000	1	$8,750,000	1	$7,000,000	1	$8,750,000
6.2	Allowance for sludge blending tank	1	$940,000	1	$940,000	1	$940,000	1	$940,000	1	$940,000	1	$940,000
6.3	Building	1250	$1,500,000	1250	$1,500,000	1250	$1,500,000	1250	$1,500,000	1250	$1,500,000	1250	$1,500,000
	Sub-Total Solids Handling		**$11,190,000**		**$11,190,000**		**$11,190,000**		**$11,190,000**		**$9,440,000**		**$11,190,000**
	SIDE STREAM TREATMENT												
7.1	Allowance for clarifiers with lamella	1	$20,000,000	1	$20,000,000	1	$20,000,000	1	$20,000,000		$0	1	$20,000,000
7.2	Allow. to add lamella to exist. clarifiers	1	$15,000,000	1	$15,000,000		$0	1	$15,000,000		$0		$0
7.3	Building over clarifiers	1000	$715,000	1000	$715,000	1000	$715,000	1000	$715,000		$0	1000	$715,000
	Sub-Total Slip Stream Treatment		**$35,715,000**		**$35,715,000**		**$20,715,000**		**$35,715,000**		**$0**		**$20,715,000**
	DISINFECTION												
8.1	Allowance for UV expansion	1	$2,500,000	1	$10,000,000	1	$10,000,000	1	$10,000,000	1	$10,000,000	1	$10,000,000
8.2	Building	1000	$1,200,000	1000	$1,200,000	1000	$1,200,000	1000	$1,200,000	1000	$1,200,000	1000	$1,200,000
	Sub-Total Disinfection		**$3,700,000**		**$11,200,000**		**$11,200,000**		**$11,200,000**		**$11,200,000**		**$11,200,000**
	OTHER ITEMS												
9.1	Allowance for Control and SCADA	1	$2,500,000	1	$2,500,000	1	$2,500,000	1	$2,500,000	1	$2,500,000	1	$2,500,000
9.2	Allowance for electrical distribution	1	$1,000,000	1	$1,000,000	1	$1,000,000	1	$1,000,000	1	$1,000,000	1	$1,000,000
9.3	Allowance for service tunnel		$2,000,000		$2,000,000		$2,500,000		$2,500,000		$3,000,000		$3,000,000
9.4	Allowance for odour control	1	$5,000,000	1	$5,000,000	1	$5,000,000	1	$5,000,000	1	$5,000,000	1	$5,000,000
	Sub-Total Other Items		**$10,500,000**		**$10,500,000**		**$11,000,000**		**$11,000,000**		**$11,500,000**		**$11,500,000**
	Sub-Total Items 1 to 9		**$137,883,491**		**$138,091,741**		**$109,295,231**		**$138,719,741**		**$114,370,863**		**$112,459,731**
	Division 1 Cost		$6,894,175		$6,904,587		$5,464,762		$6,935,987		$5,718,543		$5,622,987
	TOTAL - CONSTRUCTION		**$144,777,665**		**$144,996,328**		**$114,759,992**		**$145,655,728**		**$120,089,406**		**$118,082,717**
	Contingency, Engineering and Adminstration Fees		$50,672,183		$50,748,715		$40,165,997		$50,979,505		$42,031,292		$41,328,951
	TOTAL PROJECT COST		**$195,449,848**		**$195,745,042**		**$154,925,989**		**$196,635,232**		**$162,120,698**		**$159,411,668**

8.7 OPINION OF PROBABLE CONSTRUCTION AND O & M COSTS

8.7.1 Capital Costs

Opinion of probable capital costs for the ten (10) short listed options (A-J) is presented in Table 8.8. Due to the preliminary nature of the estimate for a large number of options, unit processes are costs based on $/m^3 or $/m^2 from similar projects. These estimates should be considered to be $\pm$ 40%. For the opinion of probable cost at the completion of the preliminary design we will size major equipment, obtain budgetary costs from suppliers and do a quantity take-off for concrete and other plant components.

8.7.2 Operation and Maintenance Costs

The opinion of probable annual operation and maintenance (O & M) costs are presented in Table 8.8. The following assumptions were made to arrive at the O & M costs:

- Staffing costs are based on $50,000 per person (e.g. $600,000 for 12 staff).
- Chemical costs (item 2a) is based on using alum for side stream treatment and chemicals required for membrane cleaning.
- Sludge hauling costs are based on current rates and increased proportional to the increase in sludge production.
- Energy costs are prorated based on current values to allow increase in energy usage due to additional unit processes.
- Repairs and maintenance based on current annual expenditure of $453,000 + 2% of the capital cost.
- Administration cost prorated to reflect increase in plant staff and overall plant operations.

8.8 EVALUATION PROCESS AND CRITERIA

In order to reduce the number of alternatives to a manageable list for the development of further details and development of conceptual cost estimates, a simple evaluation system for further screening of the options with the City was adopted. The discussions for the evaluation process were facilitated by Dr. Bill Oldham. Dr. Bob Dawson, P.Eng. provided the technical information to assist the steering committee in completing the scoring process as a group during the technical workshop. A matrix of alternatives (Option A-J) versus evaluation factors was utilized so that a tabular side-by-side comparison can be made.

Factors utilized for the evaluation of options are discussed in the following paragraphs.

TABLE 8.9
Winnipeg SEWPCC
Preliminary Operating and Maintenance Cost Estimates for Comparative Analysis- Option A to J
Revised May 5, 2006

	Description	Existing Plant	Option A - AS/BNR/MJ Low Rate / 165 ML/d no Side Stream	Option B - AS/BNR/MJ High Rate / 165 ML/d no Side Stream	Option C - AS/BNR/MJ High Rate / 100 ML/d with CEP Side Stream	Option D - HPO/BNR/MJ / 100 ML/d with CEP Side Stream	Option E - MBNR in new tanks / 100 ML/d with CEP Side Stream	Option F - MBNR Retrofit in Clarifier / 100 ML/d with CEP Side Stream	Option G - IAS/BNR/MJ/ IFAS / 100 ML/d with CEP Side Stream	Option H - Comb. HPO/AS/BNR/MJ for 20 ML/d & MBNR for 80 ML/d with CEP Side Stream	Option I - Comb. 100 ML/d AS/BNR/MJ and Exist. HPO for Side	Option J - Comb. HPO/AS/BNR for 20 ML/d & AS/BNR/MJ for 80 ML/d with CEP Side Stream
1	Labour Cost	$601,000	$900,000	$900,000	$800,000	$850,000	$900,000	$900,000	$800,000	$950,000	$850,000	$900,000
2a	Chemical for CEP side stream treatment	$0	$0	$0	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$475,000	$200,000
2b	Polymer for WAS thickening using DAF	$0	$180,000	$180,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$120,000	$150,000
3	Sludge hauling & tipping fees	$457,000	$525,000	$525,000	$550,000	$550,000	$550,000	$550,000	$550,000	$550,000	$627,000	$550,000
4	Energy/power	$807,000	$1,875,000	$1,875,000	$1,560,000	$1,680,000	$2,040,000	$2,040,000	$1,560,000	$1,900,000	$1,800,000	$1,600,000
5	Repairs/maintenance	$453,000	$2,160,913	$1,998,585	$1,700,928	$1,690,148	$1,993,252	$1,996,376	$2,068,252	$2,020,796	$1,715,563	$1,686,896
6	Membrane replacement reserve	$0	$0	$0	$0	$0	$425,000	$425,000	$0	$340,000	$0	$0
6	Administration and others	$44,000	$66,000	$66,000	$58,667	$62,333	$66,000	$66,000	$58,667	$69,667	$62,333	$66,000
	TOTALS	**$2,362,000**	**$5,706,913**	**$5,544,585**	**$5,019,595**	**$5,182,482**	**$6,324,252**	**$6,327,376**	**$5,386,919**	**$6,180,463**	**$5,649,896**	**$5,152,896**

Staffing level	12	18	18	16	17	18	18	16	19	17	18
Average Annual Flow	80 ML/d	80 ML/d	80 ML/d	80 ML/d	80 ML/d	80 ML/d	80 ML/d	80 ML/d	80 ML/d	80 ML/d	80 ML/d
Percent solids in sludge	3.0%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
Repairs/maintenance	Existing + 1.5% capital cost excl C&E	Existing + 1.5% capital cost excl C&E	Existing + 1.5% capital cost excl C&E	Existing + 1.5% capital cost excl C&E	Existing + 1.5% capital cost excl C&E	Existing + 1.5% capital cost excl C&E	Existing + 1.5% capital cost excl C&E	Existing + 1.5% capital cost excl C&E	Existing + 1.5% capital cost excl C&E		

Instead of numerical score or weights, a relative point system was developed. Option A – the low rate ASP/BNR/MJ process was accepted as a base case for the SEWPCC upgrade/expansion project. For each of the evaluation factors considered the remaining nine (9) options were compared with option A on a relative scale of positive (+), negative (-) or no effect (0). As an example, for capital costs, if an option is cheaper to construct compared to option A, it scored a "+" point. If it was considered to be more expensive than option A, it scores a "-" point. If the capital costs are the same, then that option is assigned a "0" point. The same process is repeated for all the evaluation factors that are listed below.

A description of what is meant by each factor is provided below.

- **Capital Cost**: The estimates prepared for this report section (Table 8.8) will be used in the evaluation.
- **Operating Cost**: The estimates of operating cost prepared for this report section (Table 8.9) will be used in the evaluation.
- **Track Record in a Similar Climate**: Most of the processes considered have a track record in Canada the USA or Europe. Only a very limited number of the BNR options are used commonly in Western Canada. Factors such as fewer installations and emerging technologies were considered in the scoring process.
- **Ease of Operation**: The complexity of a process from a process, hydraulic, or mechanical point of view was considered in scoring. Experience with air activated BNR processes is excellent in Western Canada so these considerations were made in the scores. Processes with one or more different processes were scored lower.
- **Ease of Maintenance**: Considerations were made for the mechanical complexity of the processes, processes requiring multiple mechanical pieces of equipment with significant routine adjustment and preventative maintenance would receive less points.
- **Flexibility to Upgrade**: There has been a trend in Western Canada for effluent quality standards to become increasingly stringent particularly with respect to nutrients and microbiological and toxicity parameters. Winnipeg is probably no exception. Those processes that can be easily modified without addition of more unit processes would receive the positive score. Some of the processes might already achieve lower levels of a particular parameter and this should lead to a higher score.
- **Reliability and Risk of Failure**: Consistent production of effluent quality is a major requirement in Winnipeg. The options are robust to withstand operational variations and those with some degree of redundancy for equipment malfunction should receive positive points.
- **Ability to Accommodate High Flows and Loads**: Biological processes for nutrient removal are susceptible to variations in flow and load. Those options which minimize the load and flow variation or those for which operational protocols can easily be adjusted to

accommodate both high and low variations should receive a better score than options with lesser capability in this regard.

- **Compatibility with Existing Facilities**: Some of the options make use of the existing facilities for very similar purposes and these would be scored higher. However, the main objective here is not to abandon existing infrastructure and if it can technically be used to create a different unit process this should also be considered in the scoring.

- **Effluent Quality:** The options, which are able to consistently meet or do better than the effluent goals, should receive positive scores.

- **Ease of Construction:** Construction of the proposed SEWPCC upgrade/expansion will require maintaining the existing facility in operation. Scoring for this criteria will be allocated based on how the key components of the proposed alternatives can be constructed around the existing facility with minimum disruption compared to the base option.

- **Impact on Existing Processes:** Factors to be considered include sludge quality and quantity and impact on the performance of the downstream processes such as UV disinfection.

The scoring for the ten (10) treatment options were carried out as a group involving the City's steering committee and Stantec personnel. The final score based on the approach discussed in this section and evaluation factors are presented in Table 8.10.

Table 8.10
Winnipeg SEWPCC Upgrading
Screening Matrix (Evaluation Sheet)

Evaluation Factor	A	B	C	D	E	F	G	H	I	J
	AS/BNR/MJ Low Rate	AS/BNR/MJ High Rate	AS/BNR/MJ High Rate Side Stream	HPO/BNR/MJ Side Stream	MBNR New Bioreactor Side Stream	MBNR Retrofit Final Clarifiers Side Stream	AS/BNR/MJ/IFAS Side Stream	Combination HPO/BNR/MJ/IFAS & MBNR & Side Stream	Combination BNR/MJ and HPO for Side Stream	Combination HPO/BNR & AS/BNR and Side Stream
Capital Cost	0	0	+	+	0	0	+	0	+	+
Operating Cost	0	0	+	+	-	-	0	-	0	+
Track Record	0	0	0	-	-	-	-	-	0	-
Ease of Operation	0	+	+	+	0	0	0	-	0	-
Ease of Maintenance	0	0	-	-	-	-	-	-	-	-
Flexibility to Upgrade	0	0	0	0	+	+	0	+	0	0
Reliability and Risk of Failure	0	0	+	+	+	+	+	-	+	+
Ability to Accommodate	0	0	+	+	+	+	+	+	+	+
Compatibility with Facilities	0	0	0	+	0	+	0	+	+	+
Effluent Quality	0	0	-	-	+	+	-	+	-	-
Ease of Construction	0	0	0	0	0	-	0	0	+	0
Impact on Downstream Processes	0	0	-	-	-	-	-	-	0	-
Total Potential Points	0	1	2	2	0	0	-1	-2	3	0

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OPTION A - ACTIVATED SLUDGE / BIOLOGICAL NUTRIENT REMOVAL / MJ / LOW RATE/ 165 ML/D – NO SIDE STREAM TREATMENT

Process Description

This process is a very conservative biological nutrient removal plant design for Winnipeg SEWPCC. The bioreactor will be designed for the spring snowmelt period, maximum month flows and loads to treat biologically all flows directed to the plant. Flows in excess of 250 will be bypassed before or after primary treatment up to 250 ML/d and blended prior to UV disinfection.

The Modified Johannesburg process consists of a sequence of anoxic, anaerobic and aerobic bioreactor cells in series. Raw wastewater is introduced to the pre-anoxic cell (no oxygen) along with return activated sludge (RAS) recycled from the final clarifiers. In this zone, the RAS is denitrified to protect the anaerobic zone from nitrates. In the next cell (anaerobic zone), volatile fatty acids (VFA) generated from the primary sludge are contacted with the AS/wastewater mixture and specific bio-P organisms that initiate a metabolic pathway to store carbon as poly hydroxyl butyrate (PHB) internally under anaerobic conditions (no oxygen, no nutrients). In the next cell in the series, nitrates recycled at a high rate from the last aerated cell in the bioreactor are denitrified by denitrifying bacteria using carbon in the incoming waste as a source of carbon. Nitrogen is removed from the wastewater as nitrogen gas.

This series of pre-anoxic, anaerobic, anoxic cell which are mixed vertically using propeller mixers, occupy about 30% of the bioreactor volume. In a series of aerobic cells, fine bubble aeration, usually done with diffusers located on the floor of the bioreactor, provides oxygen for a number of biological reactions. Organic carbon is degraded by the micro-organisms in the activated sludge to carbon dioxide, water, and more bacteria cells. Organic nitrogen is converted to ammonia by the heterotrophic bacteria and subsequently nitrifying bacteria convert the ammonia to nitrates. There nitrates are recycled at 3 to 3.5 times the plant inflow rate to the anoxic zone. Dissolved phosphorus contained in the organisms is settled out in the final settling tanks and then removed the wastewater in the waste activated sludge (WAS) which are then thickened up to 3 to 5% solids of the sludge dry weight.

The residual organics, solids not oxidized in the bioreactor and the phosphorus contained in the organisms is settled out in the final settling tanks and removed from the wastewater in the waste activated sludge (WAS) which are then thickened to 3 to 5% solids and directed to sludge stabilization. Return activated sludge is recycled to the pre-anoxic zone to seed the biological process at a rate of about 70% of average daily flow.

In this process the MLSS is purposely kept low at about 2500 mg/L resulting in a long bioreactor retention time of approximately 12 hours during the 10^{0}C low temperature period. This allows for a large volume of sludge in the bioreactor to accommodate high flow variations without overloading the final clarifiers.

Design Criteria – AS / BNR / MJ / LOW RATE no Side Stream Treatment

Maximum Month – Spring
Design Flow – 165 ML/d
F/M ratio – 0.1
SRT – 12 days @ 10^{0}C
SRT – 8 days @ 20^{0}C
MLSS – 2,500 to 3,000 mg/L
RAS rate – 50% to 70% Q
HRT – 12 hours
Design Temperature – 10^o C
BNR Configuration – Mod. Johannesburg

Bioreactor:
- **Total Size – 82.5 ML (V)**
- Pre anoxic – 3.3 ML 4% (V)
- Anaerobic – 4.5 ML 5.5% (V)
- Anoxic – 16.9 ML 20.5% (V)
- Aerobic – 57.8 ML 70% (V)

- Bioreactor – open air
- Tank depth – 5.0 metres deep

Secondary settling tank:
- SOR 18 m^3/m^2/day average
  40 m^3/m^2/day maximum
- SLR 5 kg/m^2/hr average
  9 kg/m^2/hr maximum

Air requirements:
- carbonaceous 1.2 kg O_2/kg BOD removed
- 4.5 kg O_2/kg NH_3-N nitrified

Expected Performance (mg/L)

	BNR Effluent 250 ML/d	Bypass Effluent 100 ML/d	Blended Effluent 350 ML/d
BOD	4	76	24
TSS	6	98	32
TKN	< 2.0	8.5	4
NH3	<1.0	8.3	3.1
NO3	< 5.0	0.2	3.6
Total nitrogen	<8	9	8.2
Ortho P	<0.05	0.05	0.05
Total P	<0.7	3	1.4
Fecal Coliform			< 200 FC/100 ML

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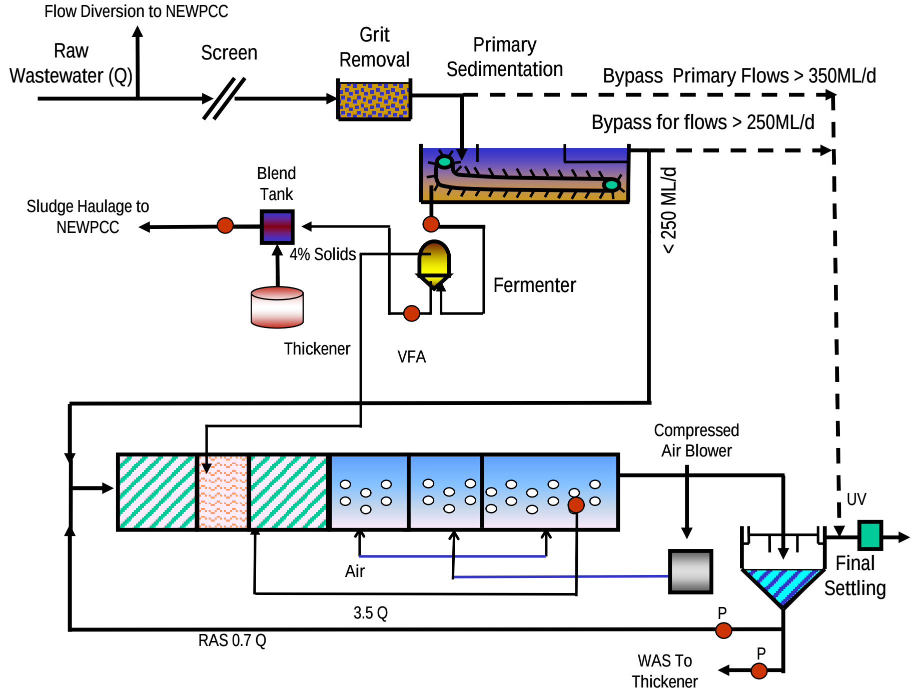
OPTION A - ACTIVATED SLUDGE / BIOLOGICAL NUTRIENT REMOVAL / MJ / LOW RATE / 165 ML/D - NO SIDE STREAM TREATMENT



Advantages

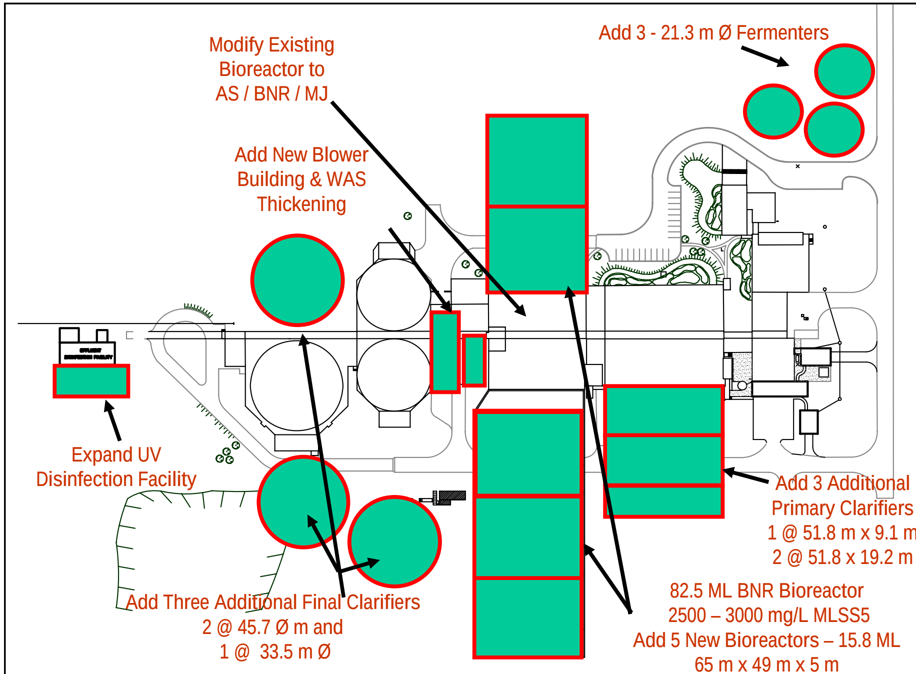
- Proven technology; widely used in Western Canada and Northern USA such as Edmonton, Vernon, BC and Missoula, Montana
- Ease of operation with similar flow and load regimes in summer and winter
- High flows and loads considered in the design
- Capability to increase MLSS for more capacity
- Solids loads on final clarifier is low
- All flows receive BNR treatment
- High quality effluent

Disadvantages

- Can get re-release of phosphorus and ammonia in the summer
- Large bioreactor – 82.5 ML
- Higher capital cost than high rate MJ/BNR
- Higher operating cost than high rate MJ
- Larger footprint than high rate MJ
- Primary sludge fermentation capacity large because of total load for nutrient removal

Comments

- Very conservative design – similar to Earth Tech conceptual design
- Base case for comparison with optimized designs
- Large bioreactor and final clarifiers
- Operational difficulties low winter and summer loads.



Components to be Upgraded

- Expand headworks: screening and grit removal
- Add 3 additional primary clarifiers (2 @ 995 m^2 and 1 @ 472 m^2)
- Add 3 – 21.3 m dia primary sludge fermenters
- Modify existing 6.6 ML bioreactor to 4 pass MJ/BNR configuration
- Modify bioreactor aeration system – fine bubble compressed air
- Construct new blower building – 4 blowers @ 275m^3/min
- Add 5 – 4 pass MJ/BNR bioreactors; 65 m x 49 m x 5 m deep; 15.8 ML each
- Provide WAS thickening (dissolved air flotation)
- Expand UV disinfection to 350 ML/d

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OPTION B - ACTIVATED SLUDGE / BIOLOGICAL NUTRIENT REMOVAL / MJ / HIGH RATE / 165 ML/D - NO SIDE STREAM TREATMENT

Process Description

This process is a high rate biological nutrient removal plant design which is less conservative than the same treatment process operated at a lower rate by using a lower MLSS. The bioreactor will be designed for the spring snowmelt period, maximum month flows and loads to treat biologically all flows directed to the plant.

The Modified Johannesburg process consists of a sequence of anoxic, anaerobic and aerobic bioreactor cells in series. Raw wastewater is introduced to the pre-anoxic cell (no oxygen) along with return activated sludge (RAS) recycled from the final clarifiers. In this zone, the RAS is denitrified to protect the anaerobic zone from nitrates. In the next cell (anaerobic zone), volatile fatty acids (VFA) generated from the primary sludge are contacted with the AS/wastewater mixture and specific bio-P organisms that initiate a metabolic pathway to store carbon as poly hydroxyl butyrate (PHB) internally under anaerobic conditions (no oxygen, no nutrients). In the next cell in the series, nitrates recycled at a high rate from the last aerated cell in the bioreactor are denitrified by denitrifying bacteria using carbon in the incoming waste and PHB as a source of carbon. Nitrogen is removed from the wastewater as nitrogen gas.

This series of pre-anoxic, anaerobic, anoxic cell which are mixed vertically using propeller mixers, occupy about 30% of the bioreactor volume. In a series of aerobic cells, fine bubble aeration, usually done with diffusers located on the floor of the bioreactor, provides oxygen for a number of biological reactions. Organic carbon is degraded by the micro-organisms in the activated sludge to carbon dioxide, water, and more bacteria cells. Organic nitrogen is converted to ammonia by the heterotrophic bacteria and subsequently nitrifying bacteria convert the ammonia to nitrates. There nitrates are recycled at 2.5 to 3.5 times the plant inflow rate to the anoxic zone. Granular phosphorus contained in the organisms is settled out in the final settling tanks and then removed the wastewater in the waste activated sludge (WAS) which is then thickened by up to 3 to 5% solids of the sludge dry weight.

The residual organics, solids not oxidized in the bioreactor and the phosphorus contained in the organisms is settled out in the final settling tanks and removed from the wastewater in the waste activated sludge (WAS) which are then thickened to 3 to 5% solids and directed to sludge stabilization. Return activated sludge is recycled to the pre-anoxic zone to seed the biological process at a rate of about 70% of average daily flow.

In this process the MLSS is kept high at about 4,500 mg/L resulting in a shorter bioreactor retention time of approximately 9 hours during the 10^{0}C low temperature period. This compares with an HRT of 12 hours when using the same process but with a lower MLSS of 2,500 mg/L. The higher MLSS allows for a smaller volume of sludge in the bioreactor.

Design Criteria – AS / BNR / MJ / HIGH RATE No Side Stream Treatment

Maximum Month – Spring
Design Flow – 165 ML/d
F/M ratio – 0.08
SRT – 12 days @ 10^{0}C
SRT – 8 days @ 20^{0}C
MLSS – 4,500 mg/L
RAS rate – 70% Q
HRT – 8.5 to 9.0 hours
Design Temperature – 10^{o} C
BNR Configuration – Mod. Johannesburg

Bioreactor:
- **Total Size – 61.8 ML (V)**
- Pre anoxic – 2.5 ML 4% (V)
- Anaerobic – 3.4 ML 5.5 % (V)
- Anoxic – 12.7 ML 20.5 % (V)
- Aerobic – 43.2 ML 70 % (V)

- New bioreactor modules – open air
- 4 – 4 pass bioreactors
- 40 m x 42 m x 5 m deep

Secondary settling tank:
- SOR 18 m^3/m^2/day average
  40 m^3/m^2/day maximum
- SLR 5 kg/m^2/hr average
  9 kg/m^2/hr maximum

Air requirements:
- Carbonaceous 1.2 kg O_2/kg BOD removed
- 4.5 kg O_2//kg NH_3-N nitrified

Expected Performance (mg/L)

	BNR Effluent 250 ML/d	Bypass Effluent 100 ML/d	Blended Effluent 350 ML/d
BOD	4	76	24
TSS	6	98	32
TKN	< 2.0	8.5	4
NH3	<1.0	8.3	3.1
NO3	< 5.0	0.2	3.6
Total nitrogen	<8	9	8.2
Ortho P	<0.05	0.05	0.05
Total P	<0.7	3	1.4
Fecal Coliform	< 200 FC/100 ML		

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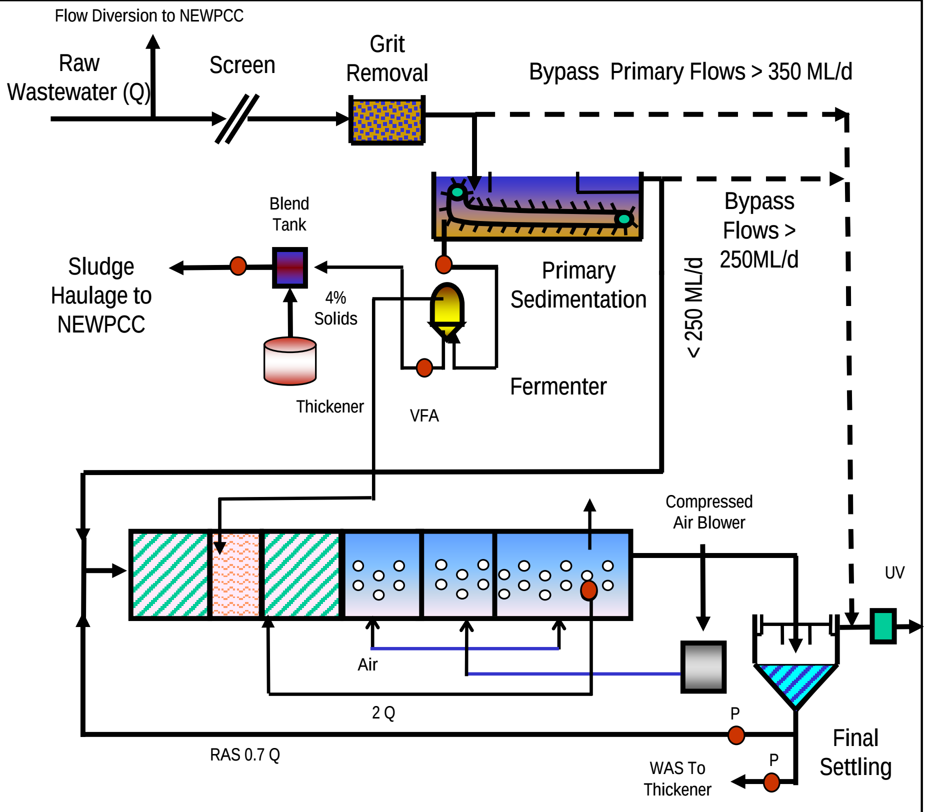
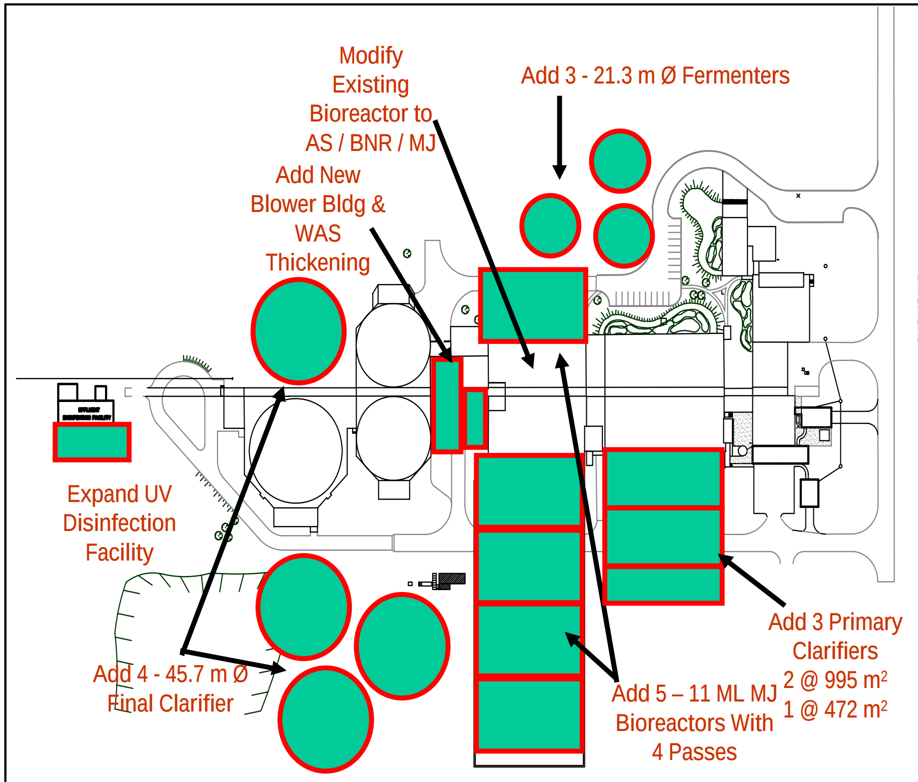
OPTION B - ACTIVATED SLUDGE / BIOLOGICAL NUTRIENT REMOVAL / MJ / HIGH RATE / 165 ML/D - NO SIDE STREAM TREATMENT





Advantages

- All flows receive BNR treatment
- Smaller footprint than low rate MJ/BNR
- High flows and loads considered in the design of the bioreactor
- Proven technology.
- Ease of operation with similar flow and load regimes in summer and winter
- Easy to retrofit existing plant
- High quality effluent

Disadvantages

- Significantly larger final clarifiers construction is required; 4 – 45.7 m dia clarifiers are required.

Comments

- Optimized design for BNR for maximum month flows and loads – spring snowmelt period
- Definitely a proven technology in use throughout Western Canada

Components to be Upgraded

- Expand headworks: screening and grit removal
- Add 3 additional primary clarifiers (2 @ 995 m² and 1 @ 472 m²)
- Add 3 – 21.3 m dia. 6 m deep static primary sludge fermenters
- Modify existing 6.6 ML bioreactor to 4 pass MJ/BNR configuration
- Modify bioreactor aeration system – fine bubbled compressed air
- Construct new blower building – 4 blowers @ 275 m³/min
- Add 5 – 4 pass MJ/BNR bioreactors; 50 m x 44 m x 5 m deep; 11 ML each
- Add 4 additional 45.7 m. dia final clarifiers
- Provide WAS thickening (dissolved air flotation)
- Expand UV disinfection to 350 ML/day

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OPTION C - ACTIVATED SLUDGE / BIOLOGICAL NUTRIENT REMOVAL / MJ / HIGH RATE / 100 ML/D PLANT WITH PHYSICAL & CHEMICAL SIDE STREAM TREATMENT

Process Description

This process includes a high rate MJ BNR process and physical chemical treatment of wet weather flows > 150 ML/d. The Modified Johannesburg process consists of a sequence of anoxic, anaerobic and aerobic bioreactor cells in series. Raw wastewater is introduced to the pre-anoxic cell (no oxygen) along with return activated sludge (RAS) recycled from the final clarifiers. In this zone, the RAS is denitrified to protect the anaerobic zone from nitrates. In the next cell (anaerobic zone), volatile fatty acids (VFA) generated from the primary sludge are contacted with the AS/wastewater mixture and specific bio-P organisms that initiate a metabolic pathway to store carbon as poly hydroxyl butyrate (PHB) internally under anaerobic conditions (no oxygen, no nutrients). In the next cell in the series, nitrates recycled at a high rate from the last aerated cell in the bioreactor are denitrified by denitrifying bacteria using carbon in the incoming waste as a source of carbon. Nitrogen is removed from the wastewater as nitrogen gas. This series of pre-anoxic, anaerobic, anoxic cell which are mixed vertically using propeller mixers, occupy about 30% of the bioreactor volume.

In a series of aerobic cells, fine bubble aeration, usually done with diffusers located on the floor of the bioreactor, provides oxygen for a number of biological reactions. Organic carbon is degraded by the micro-organisms in the activated sludge to carbon dioxide, water, and more bacteria cells. Organic nitrogen is converted to ammonia by the heterotrophic bacteria and subsequently nitrifying chemotrophic bacteria convert the ammonia to nitrates. These nitrates are recycled at 3 to 3.5 times the plant inflow rate to the anoxic zone. In the aerobic zone, the bio P organisms take up the phosphorus in excess of tehir metabolic rate and store the phosphorus internally. Phosphorus contained in the organisms is settled out in the final settling tanks and then removed from the wastewater in the waste activated sludge (WAS) which is thickened up to 3 to 5% solids of the sludge dry weight using dissolved air flottation.

The residual organics, solids not oxidized in the bioreactor and the phosphorus contained in the organisms is settled out in the final settling tanks and removed from the wastewater in the waste activated sludge (WAS) which is then thickened to 3 to 5% solids and directed to sludge stabilization. Return activated sludge is recycled to the pre-anoxic zone to seed the biological process at a rate of about 70% of average daily flow.

In this process the MLSS is kept high at about 4,500 mg/L resulting in a relatively short bioreactor retention time of approximately 9 hours during the 10ºC low temperature period. This compares with an HRT of 12 hours when using the same process but with a lower MLSS of 3000 mg/L. The higher MLSS allows for a smaller bioreactor to be utilized to maintain a long sludge age of around 12 to 15 days to sustain nitrification at low temperatures.

The treated effluent is then blended with the effluent from the chemically enhanced primary side stream treatment of 200 ML/d prior to disinfection using ultraviolet light.

Design Criteria – AS / BNR / MJ / HIGH RATE with Side Stream Treatment

Maximum Month: Spring
Design flow – 100 ML/d – treats 150 ML/d
F/M ratio – 0.08
SRT – 12 days @ 10ºC
SRT – 8 days @ 20ºC
MLSS – 4,500 mg/L
RAS rate – 70% Q
HRT – 9 hours
Design Temperature – 10º C
BNR Configuration – Mod. Johannesburg

Bioreactor:
- **Total Size – 37.5 ML (V)**
- Pre anoxic – 1.5 ML 4% (V)
- Anaerobic – 2.1 ML 5.5 % (V)
- Anoxic – 7.6 ML 20.5 % (V)
- Aerobic – 26.3 ML 70 % (V)

Side Stream Treatment: - 200 ML/d
Lamella plate clarifier SOR – 10 m/hr
Alum addition – 20 – 80 mg/L
Polymer addition – 1.0 to 1.5 mg/L

New bioreactor modules – open air
- 4 – 4 pass bioreactors
- 40 m x 38.6 m x 5 m deep

Secondary settling tank:
- SOR 18 m^3/m^2/day average; 40 m^3/m^2 day maximum
- SLR 5 $kg/m^2/hr$ average; 9 $kg/m^2/hr$ maximum

Air requirements:
- Carbonaceous 1.2 kg O_2/kg BOD removed
- 4.5 kg O_2//kg NH_3-N nitrified

Expected Performance (mg/L)

	BNR Plant @150 ML/d	Side Stream Treatment @200 ML/d	Blended Effluent @ 350 ML/d
BOD (mg/L)	4	38	22
TSS (mg/L)	6	40	25
TKN (mg/L)	< 2.0	7.5	5.1
NH3 (mg/L)	<1.0	6.5	4.1
NO3 (mg/L)	< 5.0	0.2	2.3
Total Nitrogen (mg/L)	<8	7.9	7.9
Ortho P	<0.05	0.05	0.05
Total P	<0.7	0.7	0.7
Fecal Coliform (FC/100 ml)			< 200

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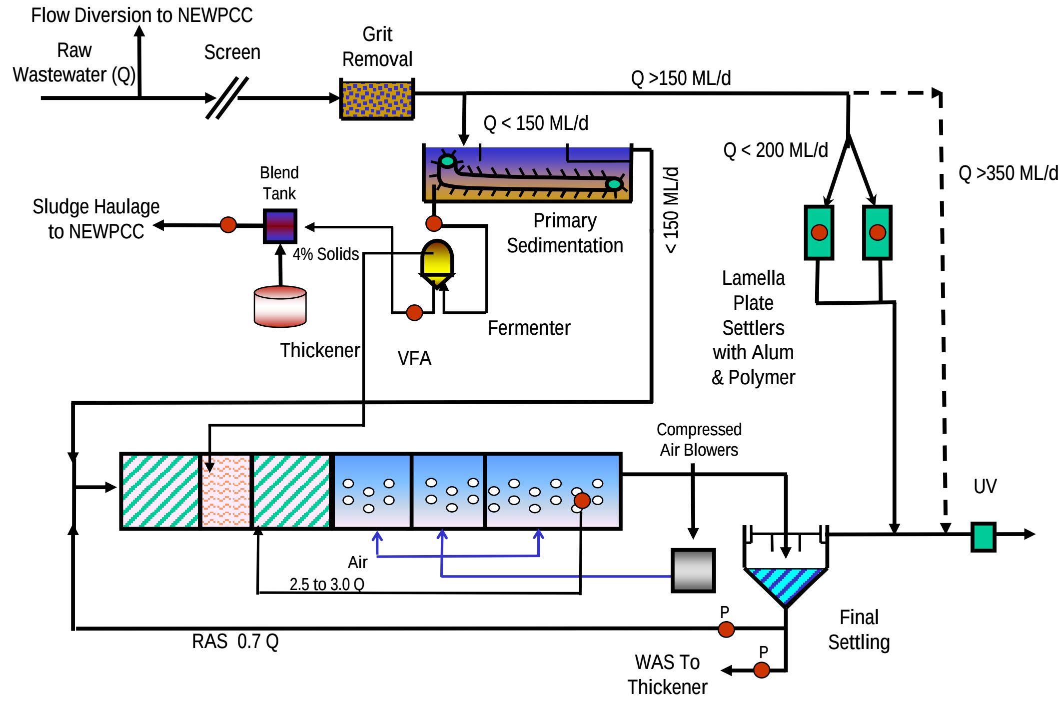
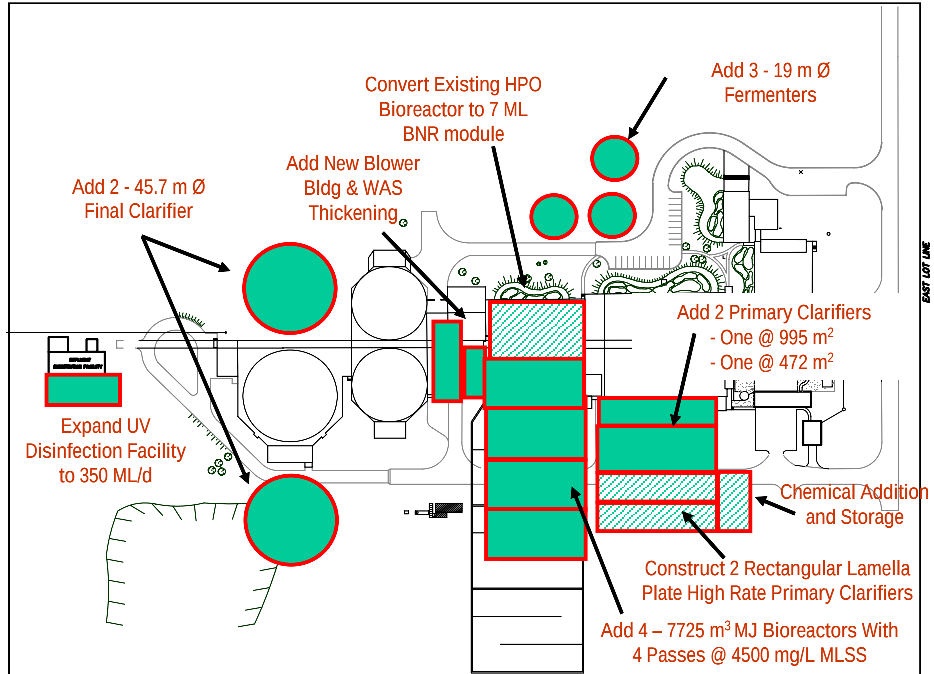
OPTION C - ACTIVATED SLUDGE / BIOLOGICAL NUTRIENT REMOVAL / MJ / HIGH RATE / 100 ML/D PLANT WITH PHYSICAL & CHEMICAL SIDE STREAM TREATMENT





Advantages

Smallest bioreactor requirement for AS/BNR/MJ design – 37.5 ML

- Significant capital cost savings
- Lower operating cost
- Proven technology.
- Smaller footprint for plant than MJ without diversion & side stream (25%)
- Ease of operation because side stream treatment available for high flows
- Minimum additional final clarifier
- Reduced chance of storm flow washout

Disadvantages

- Effluent blending is required
- Side stream treatment needed
- Operation of two different processes
- Large volume of sludge produced periodically (high in inerts)

Comments

- Smallest footprint for capital cost for a proven BNR technology
- Ease to operate plant
- Process easily automated

Components to be Upgraded

- Expand headworks: screening and grit removal
- Add 2 additional primary clarifiers (1 @ 472 m^2 and 1 @ 995 m^2)
- Add 3 – 19 m dia. 6 m deep static primary sludge fermenters
- Modify existing 6.6 ML bioreactor to AS/MJ/BNR configuration
- Modify bioreactor aeration system to fine bubbled compressed air
- Construct new blower building – 4 blowers @ 165 m^3/min
- Add 4 – 4 pass AS/MJ/BNR bioreactors; 7.7 ML each
- Add 2 additional 45.7 m. dia final clarifier
- Provide WAS thickening (dissolved air flotation?)
- Expand UV disinfection to 350 ML/day
- Construct side stream treatment (e.g. rectangular lamella plate clarifier) 2 @ 416 m^2 each
- Construct chemical feed and storage building

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OPTION D - HIGH PURITY OXYGEN / BIOLOGICAL NUTRIENT REMOVAL / MJ / 100 ML/D WITH SIDE STREAM TREATMENT

Process Description

In the conventional oxygen enriched activated sludge process used for BOD_5 and TSS removal, three or four activated sludge (AS) cells in series are generally included in an enclosed tank. The aeration transfer efficiency can be maximized and the cold temperature effects can minimized by the enclosed structure. Similar to the conventional activated sludge system, the mixed population of preconditioned organisms (activated sludge) utilizes organics in the wastewater as a food source and converts them to activated sludge (AS) biosolids, carbon dioxide and water under high oxygen transfer rate. Suspended solids in the influent are either degraded biologically or entrapped in the AS and settled out in the final clarifiers along with the biosolids. A portion of the sludge is returned to the inlet of the bioreactor to seed the process. Low pH may result due to carbon dioxide accumulation in the gas headspace and this can limit the rate of nitrification. Alum can be added to the bioreactor influent to enhance phosphorus removal by chemical precipitation

Organic nitrogen is rapidly broken down to ammonia even at the low sludge ages of 3 to 4 days used for secondary treatment as currently experienced at SEWPCC. In order to convert ammonia to nitrates (nitrification) through the activity of the chemotrophic bacteria, *Nitrospira, Nitrobacter and Nitrosomonas,* high MLSS levels and sludge age of 8 to 12 days in the aerobic portion of the bioreactor are required.

In order to achieve denitrification, a pre-anoxic cell to which nitrified effluent is recycled would have to be added prior to the aerobic AS cells. High purity oxygen, 90-95% O_2, is supplied to the bioreactor enabling the process to be operated at high MLSS concentrations (4,500 – 5,000 mg/L). Submerged turbine aerators are usually equipped to provide complete mixing of MLSS in reactors. Due to high oxygen content in the air supply, the oxygen utilization rate is significantly enhanced and the bioreactor will be smaller than a conventional activated sludge bioreactor by approximately 50% of volume, e.g. 5 to 6 hours of hydraulic retention times are common as opposed to 9 to 10 hours for BNR and 8 hours for AC with chemical precipitation (CP). High purity oxygen can be generated on site using a pressure swing molecular sieve as currently available at SEWPCC or liquid oxygen can be purchased from commercial suppliers. There are many examples of large O_2 enriched AS plants in Canada, e.g. Winnipeg North End 300 ML/d, Calgary Fish Creek 70 ML/d as well as the Winnipeg SEWPCC.

The oxygen enriched activated sludge process described can be modified as a BNR process. For example, an anoxic zone can be added before or after the aeration basin for denitrification. Similarly, an anaerobic zone can be included to achieve biological phosphorus removal. The pre-anoxic zone can be sized larger than for the air activated Modified Johannesburg process to insure denitrification of the recycled nitrate as well as de-oxygenation of the high D.O levels in the recycle streams. As well the last section of the HPO bioreactor is vented to the atmosphere to allow CO_2 and excess O_2 in the air space to escape. The effluent is then blended with the effluent from the chemically enhanced primary side stream treatment of 20 to 30 ML/d prior to disinfection.

This process is essentially a BNR system that allows a higher volumetric loading and higher oxygen transfer rate in the aerobic zone. The whole process takes a larger footprint than the oxygen enriched AS with chemical precipitation process because of the additional tankage required. An example of a BNR process with oxygen enriched activated sludge is shown in the following figure. This is similar to a plant in Hagerstown, Maryland, which has a capacity of 30 Ml/d, which is about one third the capacity of Winnipeg SEWPCC. At Hagerstown, a variation of the modified Johannesburg configuration is used, which includes a large pre-anoxic zone to protect the anaerobic zone from recycled nitrates and to account for the higher oxygen carryover than conventional MJ process.

Design Criteria – HPO / BNR / MJ with Side Stream Treatment

Maximum Month: Spring
Design flow – 100 ML/d
F/M ratio – 0.06
SRT – 12 days
MLSS – 4000 – 6000 mg/L; typical 5,500
RAS rate – 50 to 70 % Q
HRT – 7.0 hours
Design Temperature – 10º C
BNR Configuration – Mod. Johannesburg

Bioreactor:
- **Total size – 28.8 ML (V)**
- Pre anoxic – 1.6 ML 5.5% (V)
- Anaerobic – 1.7 ML 6.0% (V)
- Anoxic – 5.3 ML 18.5% (V)
- Aerobic – 20.1 ML 70% (V)
- Last portion of aerobic tank is vented

Side Stream Treatment:
Lamella plate clarifier SOR – 10 m/hr
Alum addition – 20 – 80 mg/L
Polymer addition – 1.0 to 1.5 mg/L

- Bioreactor – covered
- Tank depth – 5.0 metres deep

Secondary settling tank:
- SOR 18 m^3/m^2 day average; 40 m^3/m^2 day maximum
- SLR 5 $kg/m^2/hr$ average; 9 $kg/m^2/hry$ maximum

Air requirements:
- 90 – 98% O_2 purity
- Carbonaceous 1.2 kg O_2/kg BOD removed
- 4.5 kg O/kg NH_3-N nitrified

Expected Performance

	BNR Blended Plant @ 150 ML/d @ 350 ML/d	Side Stream Treatment @ 200 ML/d	Effluent
BOD (mg/L)	4	38	22
TSS (mg/L)	6	40	25
TKN (mg/L)	< 2.0	7.5	5.1
NH3 (mg/L)	<1.0	6.5	4.1
NO3 (mg/L)	< 5.0	0.2	2.3
Total Nitrogen (mg/L)	<8	7.9	7.9
Ortho P	<0.05	0.05	0.05
Total P	<0.7	0.7	
Fecal Coliform (FC/100 ml)	< 200		

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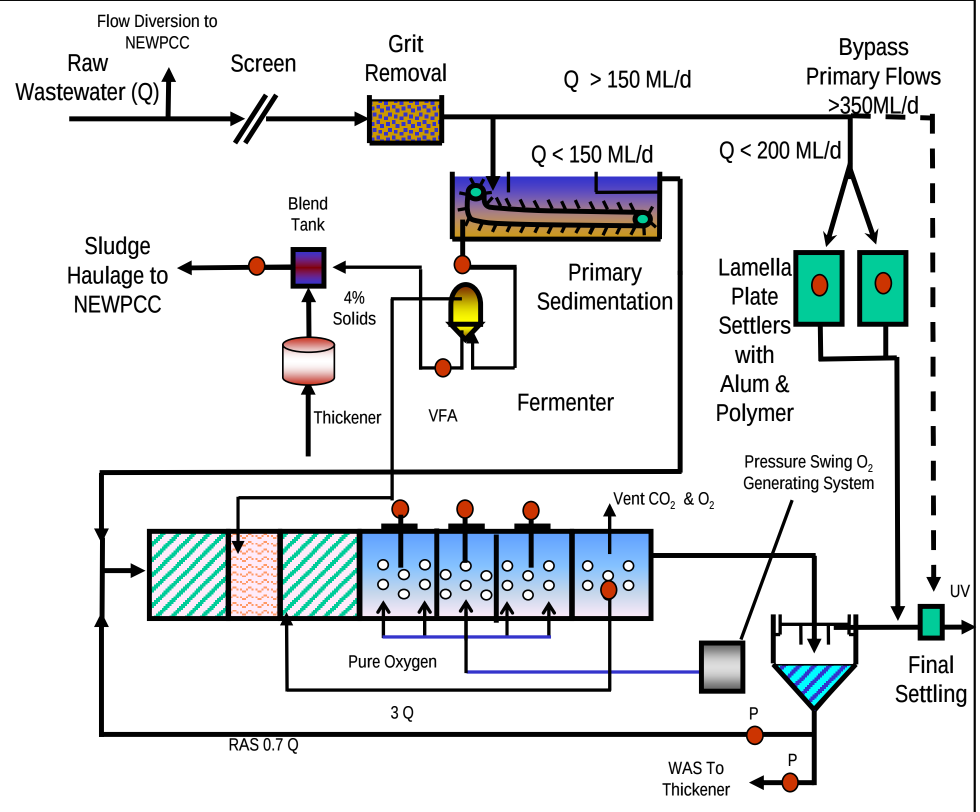
OPTION D - HIGH PURITY OXYGEN / BIOLOGICAL NUTRIENT REMOVAL / MJ / 100 ML/D / WITH SIDE STREAM TREATMENT



Advantages

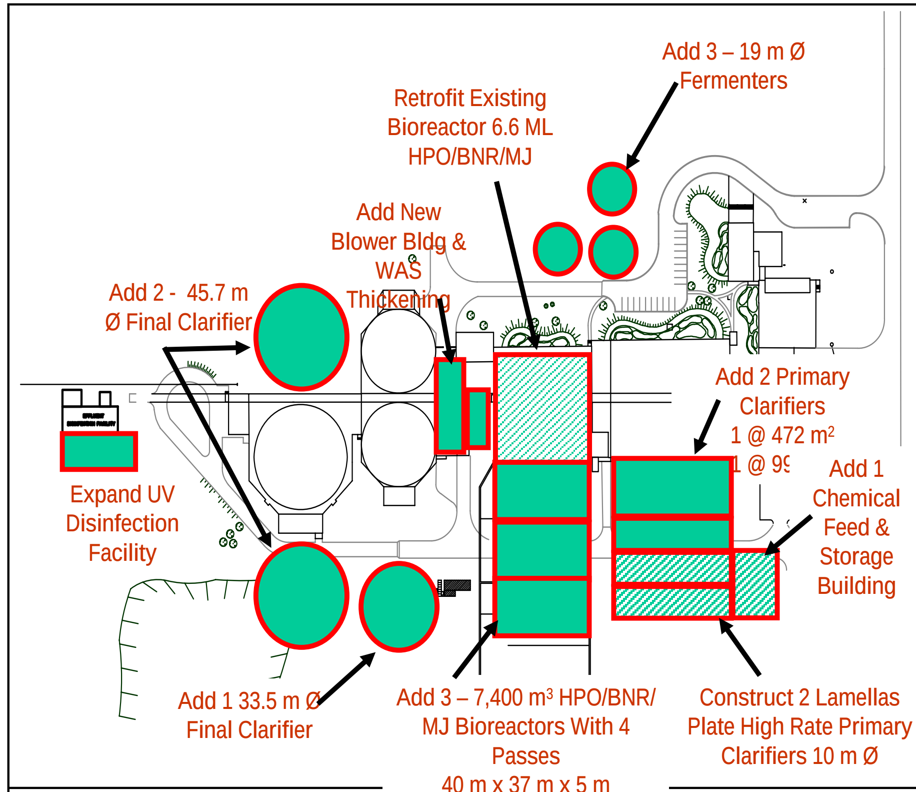
- Proven technology
- Smaller footprint than CAS BNR
- Utilizes the existing O_2 generation equipment
- Winnipeg staff are familiar with aeration system.
- Bioreactor – 20% - 25% smaller then AS/BNR/MJ

Disadvantages

- Limited applications – e.g Hagerstown Md. USA
- Higher operation cost than AS BNR – 5%
- Need to Control O_2 concentration in recycle stream to denifrification – anoxic zones.
- More maintenance requirements than AS/BNR.
- Provide larger anoxic zone

Comments

- Good option for SEWPCC
- Excellent choice if combined with storm flow control by diversion and side stream treatment.



Components to be Upgraded

- Expand headworks: screening and grit removal
- Add 2 additional primary clarifiers (1 @ 995 m² and 1 @ 472 m²)
- Add 3 – 19 m dia. 6 m deep static primary sludge fermenters
- Modify existing 6.6 ML bioreactor to 4 pass MJ/BNR/HPO configuration
- Modify aeration system in existing bioreactor
- Expand pressure swing HPO generator system
- Construct 3 new covered HPO/MJ/BNR bioreactors to add 22.2 ML
- Add 3 additional final clarifiers (2 @ 45.7 m Ø and 1 @ 33.5 m Ø)
- Provide WAS thickening (dissolved air flotation)
- Expand UV disinfection to 350 ML/d
- Construct side stream treatment e.g. Lamella plate clarifiers (2 rectangular @ 416 m² each for flows > 150 ML/d)
- Add chemical feed and storage building

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<u>OPTION E</u> - MEMBRANE BIOLOGICAL NUTRIENT REMOVAL / 100 ML/D PLANT WITH PHYSICAL CHEMICAL SIDE STREAM TREATMENT

<u>Process Description</u>

This is essentially a high rate biological nutrient removal process in which semi - impermeable membranes are utilized for solids separation rather final settling tanks. The pore size of the membranes is in the ultra filtration range of 0.04 to 0.08 m for hollow fibre membranes. Plate membranes with 0.4 um pore sizes can also be used instead of hollow fibres. Because of the highly effective solids separation, the mixed liquor biological solids (MLSS) can be maintained at an average of 8,000 mg/L in the smaller-sized bioreactor.

The BNR process configuration utilized for nitrogen removal and biological phosphorus removal is the UCT with high internal recycle rates to maintain high solids. The first zone is an anaerobic zone to which the volatile fatty acids (VFA's) are added as a simple carbon source along with recycled mixed liquor and the primary effluent. Bacteria capable of biological phosphorus removal store the VFA as PHB's and initiate a growth cycle of the bio P organisms. The mixed liquor is recycled at about 2 times average flow from the end of the anoxic zone to insure that no oxygen and no nitrate are introduced in the anaerobic zone. In the anoxic zone, denitrification of recycled nitrates occurs with nitrogen removed from the wastewater as nitrogen gas which is scrubbed out of the mixture by aeration in the subsequent aerobic reactor cells.

In the final aerobic zone which occupies about 70% of the bioreactor volume, organic material is degraded to carbon dioxide and water; organic nitrogen is converted to ammonia, ammonia is nitrified to nitrates though the action of chemotrophic bacteria and phosphorus is accumulated in the cells of the bio P organisms. Compressed air is introduced into the aerobic zone via fine bubble diffusers for mixing of the MLSS and to satisfy the oxygen requirements of organic carbon degradation and nitrification. A recycle pump transfers mixed liquor containing a high concentration of nitrates from the end of the aerobic zones to head end of the anoxic zone. The aerobic zone also received a high (4 x Q) recycle flow of concentrated mixed liquor – e.g. 10,000 to 12,000 mg/L from the membrane solids separation tanks. **This is essentially the same process as outlined in the other MBNR option except that new bioreactor tankage is added.**

The flux rate for the Zenon hollow fibre membranes is 0.44 m^3/m^2/day of membrane surface. Hollow fibre membranes are typically contained in cassettes which are mounted in a 3.5 m deep concrete channels. Vacuum pumps draw water through the hollow fibres or hollow plates which provide for solids separation. For the design flow of 100 ML/d and based on Zenon cassettes, 15 channels with 10 cassettes in each channel would be required. The permeate is then blended with the effluent from the chemically enhanced primary side stream treatment of 200 ML/d prior to disinfection.

Cyclical coarse bubble aeration is provided in the cassette tanks for scouring of the membrane surface. A backpulse reverses the flow through the membrane using permeate at intervals ranging between 10 and 30 minutes. Also to relax the membranes, they are taken out of service for one or two minutes at 8 to 10 minutes intervals. Recovery cleaning is done by taking one tank containing one row of 10 membranes out of service and soaking in caustic or citric acid at intervals of 2 to 6 months. The tank with the membrane cassettes is covered with a heated enclosure. A separate adjacent building houses the permeate pumps, blowers and other equipment associated with the operation of the membranes.

<u>Design Criteria – MBNR with Side Stream Treatment</u>

Maximum Month: Spring
Design flow – 100 ML/d
F/M ratio - 0.07
SRT – 15 days @ 10^{o}C
SRT – 8 days @ 20^{o}C
MLSS – 8,000 mg/L
RAS rate – 4 x Q
HRT – 5.4 hours
Design Temperature – 10^{o} C
BNR Configuration – Custom design approximately UCT process

<u>Bioreactor:</u>

- **Total Size – 22.5 ML (V)**
- Anaerobic – 1.8 ML 8 % (V)
- Anoxic – 5.0 ML 22 % (V)
- Aerobic –15.7 ML 70 % (V)
- Aerobic cassettes tanks – 4.3 ML

<u>Side Stream Treatment:</u>
Lamella plate clarifier SOR – 10 m/hr
Alum addition – 20 – 80 mg/L
Polymer addition – 1.0 to 1.5 mg/L

Bioreactor – open air
Tank depth – 5. metres

<u>Membrane Separation (based on Zenon product)</u>

- Air scouring using coarse bubble aeration
- Membrane flux rate: 0.44 $m^3/m^2/d$ @ ADF
- Module: 31.6 m^2 each
- Cassette: 48 modules
- Cassette capacity at ADF: 670 m^3/d each

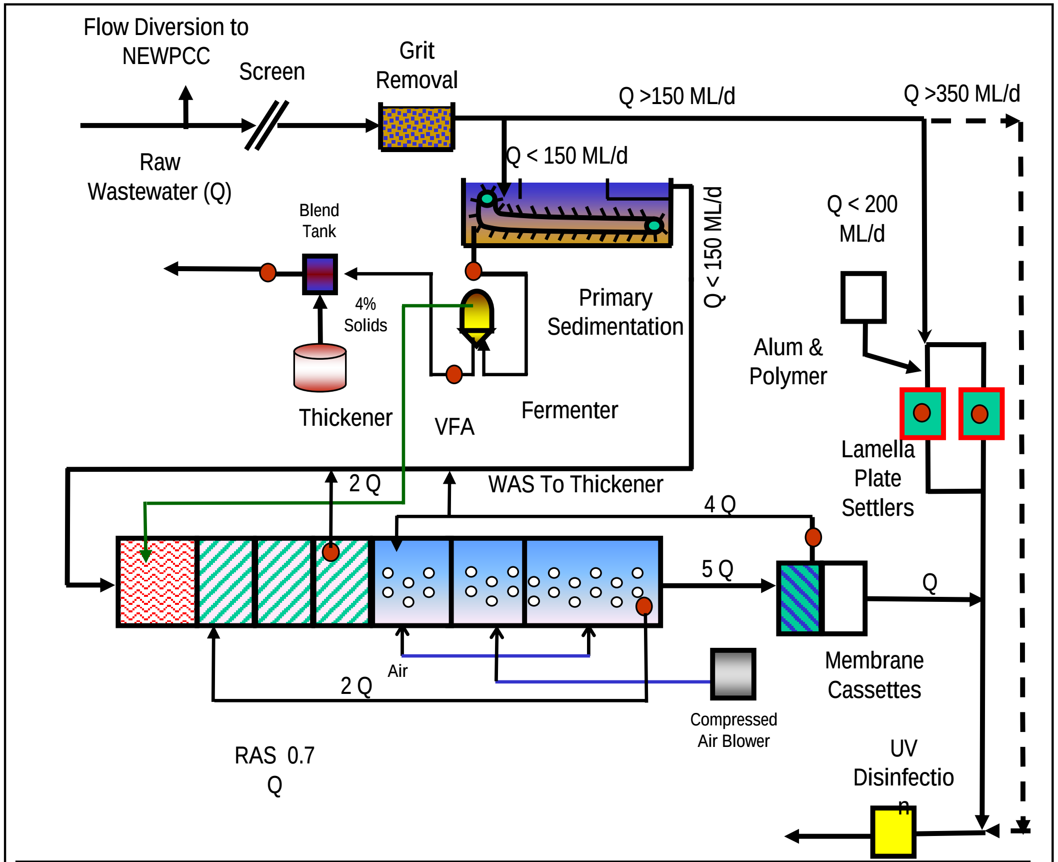
Air requirements:

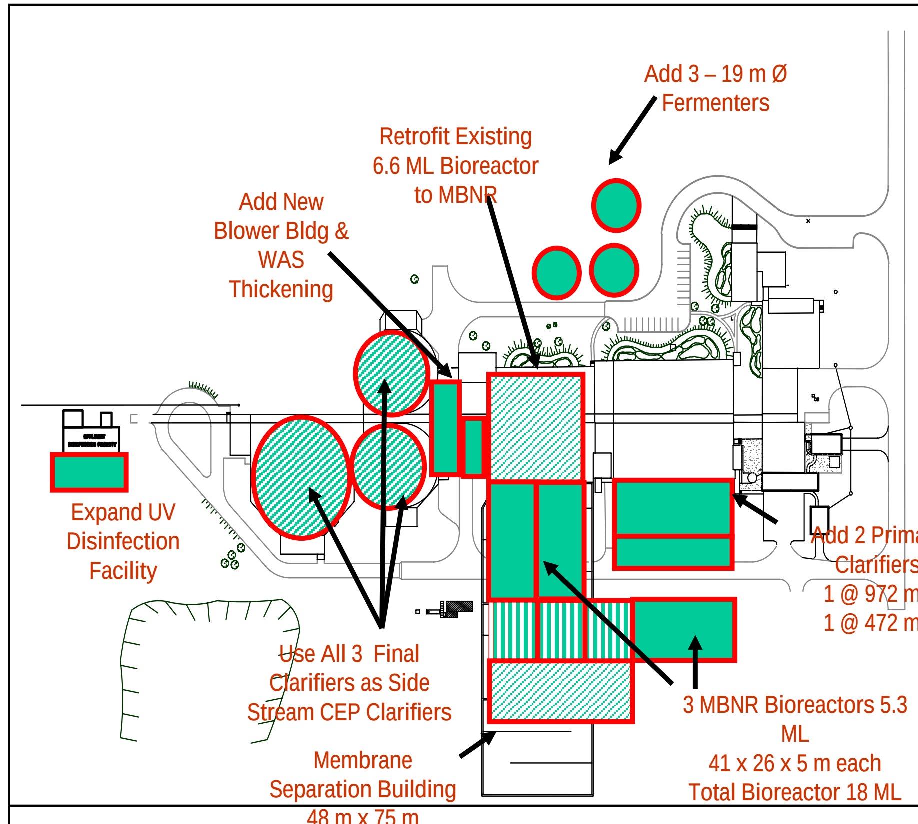
- Carbonaceous 1.2 kg O_2/kg BOD removed
- 4.5 kg O_2/kg NH_3-N nitrified
- Additional air required for scouring membrane bundles

<u>Expected Performance</u>

	BNR Blended Plant @ 150 ML/d @ 350 ML/d	Side Stream Treatment @ 200 ML/d	Effluent
BOD (mg/L)	3	38	23
TSS (mg/L)	3	40	24
TKN (mg/L)	< 0.5	7.5	4.5
NH3 (mg/L)	<1.0	6.5	4.1
NO3 (mg/L)	5.0	0.2	2.2
Total Nitrogen (mg/L)	6.0	7.9	7.1
Ortho P	<0.02	0.05	0.03
Total P	<0.15	0.7	0.5
Fecal Coliform (FC/100 ml)	< 200		

OPTION E - **MEMBRANE BIOLOGICAL NUTRIENT REMOVAL / 100 ML/D PLANT WITH PHYSICAL CHEMICAL SIDE STREAM TREATMENT**





Advantages

- High quality effluent
- Very small bioreactor
- Excellent bacterial and protozoan control
- No additional clarifiers constructed
- Existing final clarifiers available for side stream treatment
- Easier to achieve more stringent effluent quality including TP < 0.15 mg/l, low N, solids and BOD_5
- Ultimate site capacity much greater using this technology
- Smaller UV units required

Comments

This is the state of the art BNR technology

Disadvantages

- Fine screening required (1 – 2 mm)
- No use of existing HPO system
- Track record limited for full BNR
- Higher operating cost than MJ/AS/BNR
- High level of mechanical maintenance required
- Abandon some final clarifier capacity
- Membrane lifespan not fully known; 5 to 10 years
- Blending of effluent required with side stream
- Clarifier retrofit to bioreactor only
- Higher level of plant automation required

Components to be Upgraded/Constructed

- Expand headworks: grit removal
- Fine screening (1 or 2 mm opening)
- Add 2 additional primary clarifiers (1 @ 995 m² and 1 @ 472 m²)
- Add 3 – 19 m dia. 6 m deep static primary sludge fermenters
- Modify existing 6.6 ML bioreactor to MJ configuration
- Modify aeration system in existing bioreactor
- Build 3 new MBNR air activated modules (5,300 m³ each)
- Provide new blower building and 4 blowers @ 165 m³/min
- Construct membrane cassette tanks and building for vacuum pumps, equipment and blowers dedicated to membrane solids separation tanks
- Provide chemical addition in the existing final clarifiers used for side stream chemically enhanced primary treatment
- Provide WAS thickening (dissolved air flotation)
- Expand UV disinfection to 350 ML/d

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OPTION F - MEMBRANE BIOLOGICAL NUTRIENT REMOVAL / REUSE CLARIFIERS / 100 ML/D WITH PHYSICAL AND CHEMICAL SIDE STREAM TREATMENT

Process Description

This is essentially a high rate biological nutrient removal process in which semi - impermeable membranes are utilized for solids separation rather final settling tanks. The pore size of the membranes is in the ultra filtration range of 0.04 to 0.08 um for hollow fibre membranes. Plate membranes with 0.4 um pore sizes can also be used instead of hollow fibres. Because of the highly effective solids separation, the mixed liquor biological solids (MLSS) can be maintained at an average of 8,000 mg/L in the smaller-sized bioreactor.

The BNR process configuration utilized for nitrogen removal and biological phosphorus removal is the UCT with high internal recycle rates to maintain high solids. The first zone is an anaerobic zone to which the volatile fatty acids (VFA's) are added as a simple carbon source along with recycled mixed liquor and the primary effluent. Bacteria capable of biological phosphorus removal store the VFA as PHB's and initiate a growth cycle of the bio P organisms. The mixed liquor is recycled at about 2 times average flow from the end of the anoxic zone to insure that no oxygen and no nitrate are introduced in the anaerobic zone. In the anoxic zone, denitrification of recycled nitrates occurs with nitrogen removed from the wastewater as nitrogen gas which is scrubbed out of the mixture by aeration in the subsequent aerobic reactor cells.

In the final aerobic zone which occupies about 70% of the bioreactor volume, organic material is degraded to carbon dioxide and water; organic nitrogen is converted to ammonia, ammonia is nitrified to nitrates though the action of chemotrophic bacteria and phosphorus is accumulated in the cells of the bio P organisms. Compressed air is introduced into the aerobic zone via fine bubble diffusers for mixing of the MLSS and to satisfy the oxygen requirements of organic carbon degradation and nitrification.

A recycle pump transfers mixed liquor containing a high concentration of nitrates from the end of the aerobic zones to head end of the anoxic zone. The aerobic zone also received a high (4 x Q) recycle flow of concentrated mixed liquor – e.g. 10,000 to 12,000 mg/L from the membrane solids separation tanks.

The flux rate for the Zenon hollow fibre membranes is 0.44 m^3/m^2/day of membrane surface. Hollow fibre membranes are typically contained in cassettes which are mounted in a 3.5 m deep concrete channels. Vacuum pumps draw water through the hollow fibres or hollow plates which provide the solid/liquid separation. For the design flow of 100 ML/d and based on Zenon cassettes, 15 channels with 10 cassettes in each channel would be required. The permeate is then blended with the effluent from the chemically enhanced primary side stream treatment of 200 ML/d prior to disinfection.

Cyclical coarse bubble aeration is provided in the cassette tanks for scouring of the membrane surface. A backpulse reverses the flow through the membrane using permeate at intervals ranging between 10 and 30 minutes. Also to relax the membranes, they are taken out of service for one or two minutes at 8 to 10 minutes intervals. Recovery cleaning is done by taking one tank containing one row of 10 membranes out of service and soaking in caustic or citric acid at intervals of 2 to 6 months. The tank with the membrane cassettes is covered with a heated enclosure. A separate adjacent building houses the permeate pumps, blowers and other equipment associated with the operation of the

Design Criteria – MBNR / Reuse Clarifiers for Side Stream Treatment

Maximum Month: Spring
Design flow – 100 ML/d
F/M ratio - 0.07
SRT – 15 days @ 10°C
SRT – 8 days @ 20°C
MLSS – 8,000 mg/L
RAS rate – 4 X Q
HRT – 5.4 hours
Design Temperature – 10° C
BNR Configuration – Custom design approximately UCT process

Bioreactor:

- **Total Size – 22.5 ML (V)**
- Anaerobic – 1.8 ML 8 % (V)
- Anoxic – 5.0 ML 22 % (V)
- Aerobic –15.7 ML 70 % (V)
- Aerobic cassettes tanks – 4.3 ML (V)

Side Stream Treatment:
Lamella plate clarifier SOR – 10 m/hr
Alum addition – 20 – 80 mg/L
Polymer addition – 1.0 to 1.5 mg/L

Bioreactor – open air
Tank depth – 5 metres

Membrane Separation (based on Zenon product)

- Air scouring using coarse bubble aeration
- Membrane flux rate: 0.44 m^3/m^2/d @ ADF
- Module: 31.6 m^2 each
- Cassette: 48 modules
- Cassette capacity at ADF: 670 m^3/d each

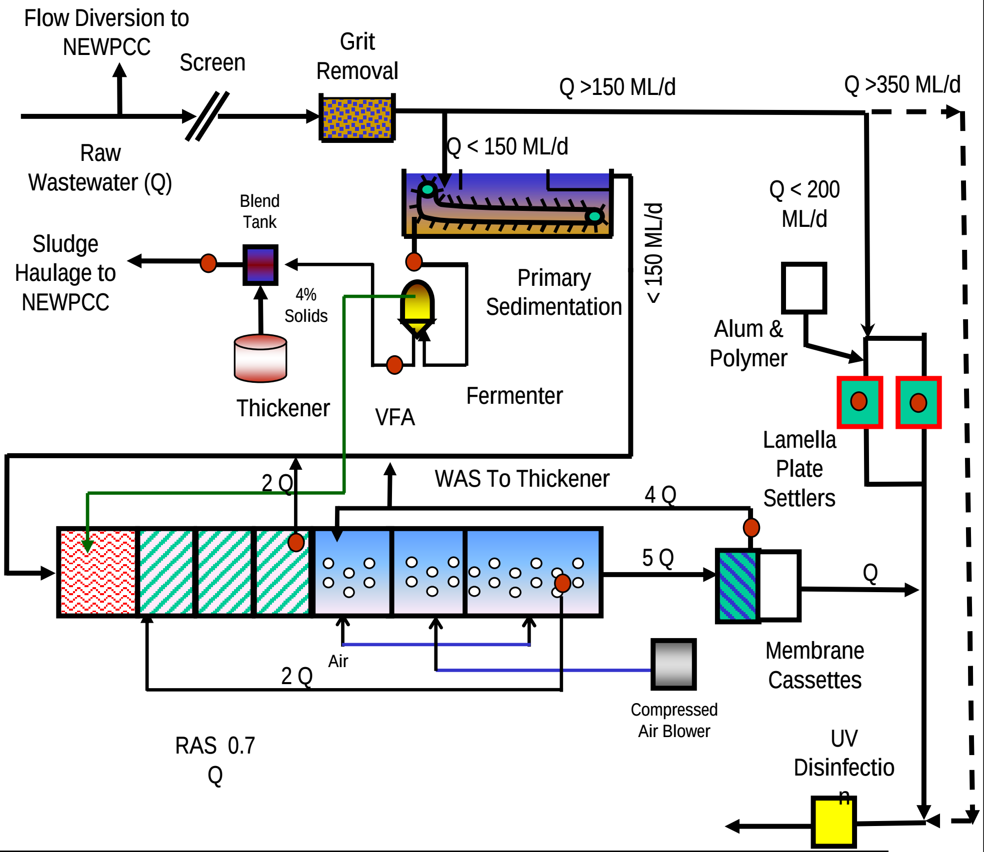
Air Requirements:

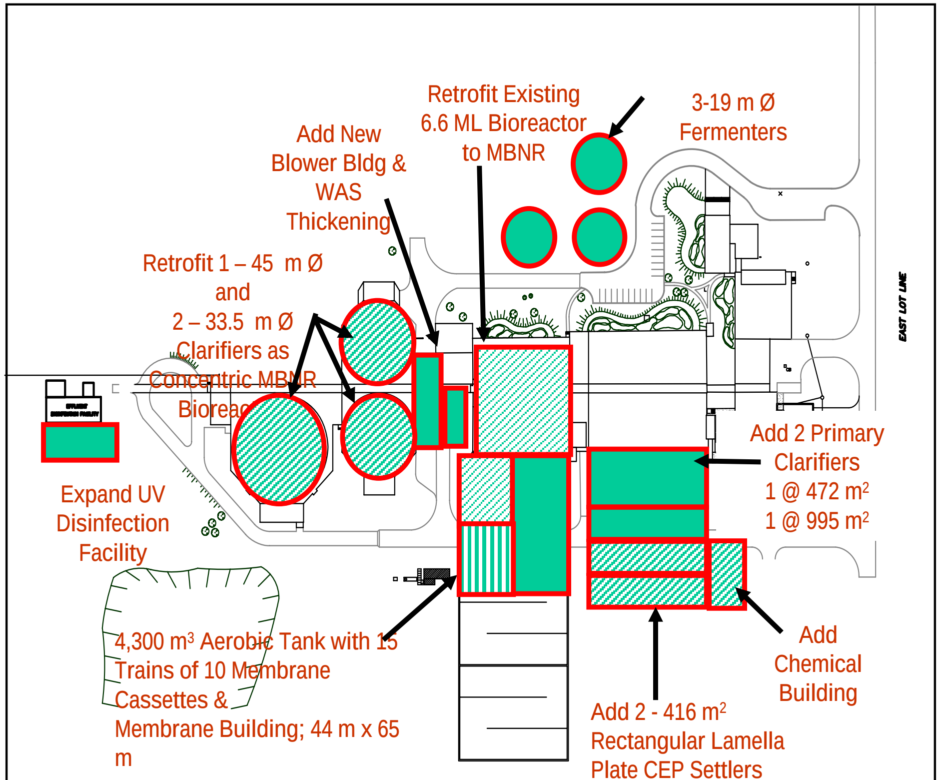
- Carbonaceous 1.2 kg O_2/kg BOD removed
- 4.5 kg O_2/kg NH_3-N nitrified
- Additional air required for scouring membrane bundles

Expected Performance

	BNR Blended Plant @ 150 ML/d @ 350 ML/d	Side Stream Treatment @ 200 ML/d	Effluent
BOD (mg/L)	3	38	23
TSS (mg/L)	3	40	24
TKN (mg/L)	< 0.5	7.5	4.5
NH3 (mg/L)	<1.0	6.5	4.1
NO3 (mg/L)	5.0	0.2	2.2
Total Nitrogen (mg/L)	6.0	7.9	7.1
Ortho P	<0.02	0.05	0.03
Total P	<0.15	0.7	0.5
Fecal Coliform (FC/100 ml)	< 200		

OPTION F - **MEMBRANE BIOLOGICAL NUTRIENT REMOVAL / REUSE CLARIFIERS / 100 ML/D WITH PHYSICAL AND CHEMICAL SIDE STREAM TREATMENT**





Advantages

- High quality effluent
- Smallest additional tankage for bioreactor and membrane equipment
- Maximum re-use of existing final clarifiers
- No additional clarifiers construction
- Possible conversion of final clarifier for high flow stream stream treatment

Disadvantages

- Fine screening required (1 – 2 mm)
- No use of existing HPO system
- Track record limited to full BNR
- Continued operation during conversion may be problematic
- Higher operating cost
- High level of mechanical maintenance
- Membrane lifespan not fully known; 5 to 10 years
- Blending of effluent required with side stream

Comments

Components to be Upgraded/Constructed

- Expand headworks: grit removal
- Fine screening (1 or 2 mm opening)
- Add 2 additional primary clarifier (1 @ 995 m² and 1 @ 472 m²)
- Add 3 – 19 m dia. 6 m deep static primary sludge fermenters
- Modify existing 6.6 ML bioreactor to MJ configuration
- Modify all existing final clarifiers as concentric MBNR bioreactors
- Modify aeration system in existing bioreactor
- Provide new blower building and 4 blowers @ 165 m³/min.
- Construct membrane cassette tanks 4.3 ML and building for vacuum pump equipment and dedicated blowers for the solids separation tank
- Provide WAS thickening (dissolved air flotation)
- Expand UV disinfection to handle 350 ML/d
- Add 2 416 m² lamella plate clarifiers

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OPTION G - ACTIVATED SLUDGE / BIOLOGICAL NUTRIENT REMOVAL / MJ / IFAS / 100 ML/D PLANT WITH PHYSICAL AND CHEMICAL SIDE STREAM TREATMENT

Process Description

A modified Johannesburg series of pre-anoxic, anaerobic, anoxic and aerobic cells in series will be utilized to remove organics, solids, nitrify, denitrify and remove phosphorus using a similar sequence of biological reactors as previously described for the Modified Johannesburg process. The suspended growth MLSS will be retained at about 4000 mg/L during the winter period. However, in the aerobic section of the bioreactor, neutral buoyancy plastic media will be contained by appropriately sized stainless steel screens.

Attached aerobic growth will occur on the surface of the media effectively increasing the biomass in the aerobic zone by 25% to 40%. In particular, an increase in the nitrifying organisms will also occur which would effectively increase the sludge age by a similar percentage. The use of the submerged plastic media will significantly increase the overall rate of nitrification and therefore reduce the size of the bioreactor by about 25% to 30%. The larger mass of organisms in the bioreactor will provide a very stable biological process particularly at high flows and loads since there will be less washout of nitrifying organisms.

Periodically a portion of the attached growth will slough off and become part of the MLSS which will settle out in the final settling tank and either be returned as RAS or wasted to remove solids, BOD and phosphrorus. Primary sludge will be required to generate VFA/s for biological phosphorus removal.

As portion of the spring flow e.g. 200 ML/d will be diverted prior to primary treatment and treated in lamella plates settlers by addition of alum and polymers. The two streams from the side stream treatment and the IFAS/BNR plant will be blended prior to UV disinfection. Usually coarse bubble aeration diffusers are used with IFAS media since the media subsequently breaks up the air flow into the equivalent of fine bubble aeration.

Design Criteria – AS / BNR / IFAS With Side Stream Treatment

Maximum Month – Spring
Design Flow – 100 ML/d
F/M ratio – __
SRT – 7 days @ 10⁰C (for MLSS)
SRT – 5 days @ 20⁰C (for MLSS)
MLSS – 4,500 mg/L + 1,000 mg/L IFAS
RAS rate – 70% Q
HRT – 5.7 hours
Design Temperature – 10º C
BNR Configuration – Mod. Johannesburg
+ IFAS

Bioreactor:

- **Total Size – 23.8 ML (V)**
- Pre anoxic – 1.4 ML 6% (V)
- Anaerobic – 2.1 ML 9 % (V)
- Anoxic – 5.7 ML 24 % (V)
- Aerobic –14.6 ML 61 % (V)

Typical Media Requirements:

- 50% of aerobic zone volume occupied by media
- Media surface area 590 m^2/m^3 media
- 20 mm 0 polyethylene carrier media

New bioreactor modules – open air

- 2– 4 pass bioreactors
- 40 m x 30 m x 5 m deep

Secondary settling tank:

- SOR 18 m^3/m^2/day average
  40 m^3/m^2/day maximum
- SLR 5 $kg/m^2/hr$ average
  9 $kg/m^2/hr$ maximum

Air requirements:

- Carbonaceous 1.2 kg O_2/kg BOD removed
- 4.5 kg O_2//kg NH_3-N nitrified

•Note: Nitrifiers grow on media surfaces and therefore increase the effective sludge mass and sludge age.

Side Stream Treatment:
Lamella plate clarifier SOR – 10 m/hr
Alum addition – 20 – 80 mg/L
Polymer addition – 1.0 to 1.5 mg/L

Expected Performance (mg/L)

	BNR Plant @150 ML/d	Side Stream Treatment @200 ML/d	Blended Effluent @ 350 ML/d
BOD (mg/L)	4	38	22
TSS (mg/L)	6	40	25
TKN (mg/L)	< 2.0	7.5	5.1
NH3 (mg/L)	<1.0	6.5	4.1
NO3 (mg/L)	< 5.0	0.2	2.3
Total Nitrogen (mg/L)	<8	7.9	7.9
Ortho P	<0.05	0.05	0.05
Total P	<0.7	0.7	0.7
Fecal Coliform (FC/100 ml)			< 200

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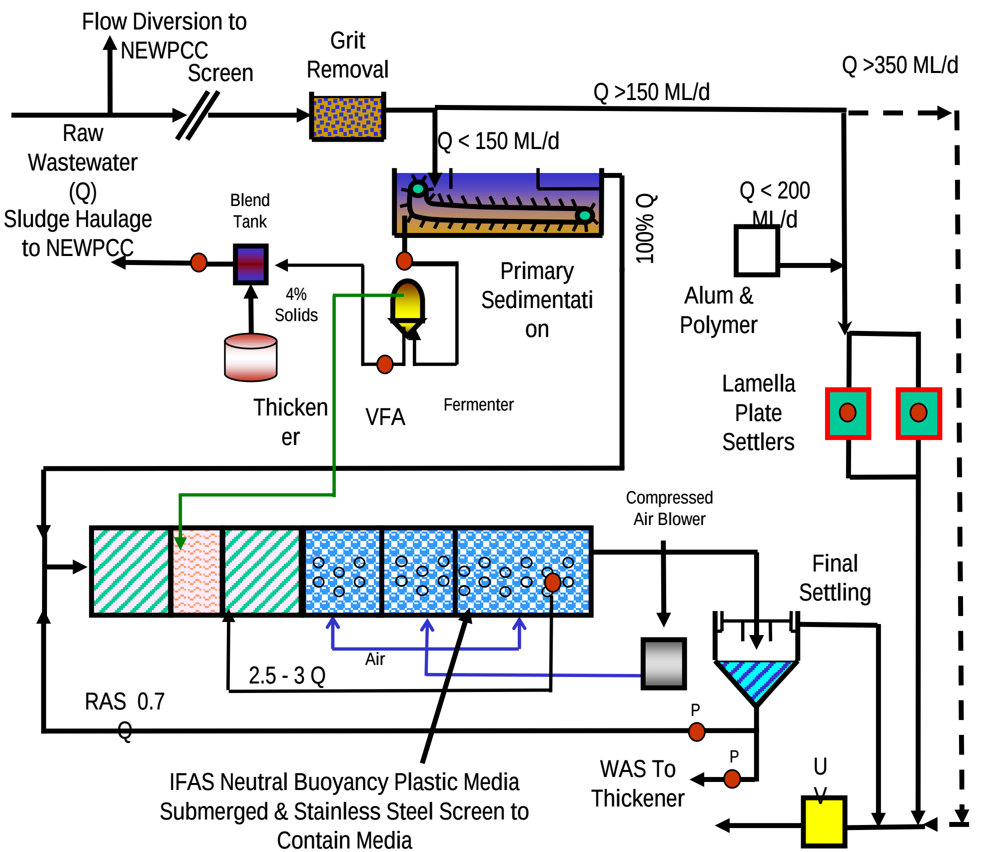
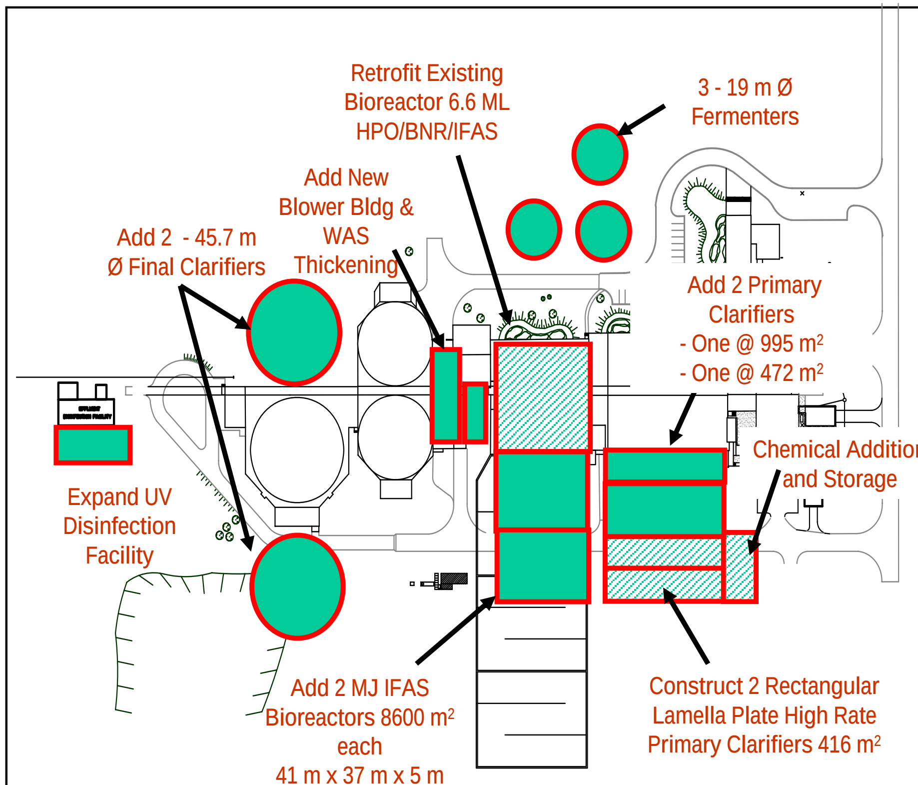
OPTION G - ACTIVATED SLUDGE / BIOLOGICAL NUTRIENT REMOVAL / MJ / IFAS / 100 ML/D WITH PHYSICAL AND CHEMICAL SIDE STREAM TREATMENT





<u>Advantages</u>

- IFAS neutral buoyancy media reduces bioreactor size of MJ process
- IFAS media provides protection of nitrifiers for high flows
- IFAS improves sludge settleability characteristics
- Solids load on clarifier low enough for only one additional clarifiers
- Capital cost savings for bioreactor construction

<u>Disadvantages</u>

- IFAS is not a common technology in Canada (but is commonly used in Europe)
- Probably best to pilot plant IFAS
- No continued use of existing HPO system
- Solids productions on the side stream treatment
- IFAS for bio P & N removal rare
- Media expensive
- Dewatering of the tanks difficult

<u>Comments</u>

<u>Components to be Upgraded/Constructed</u>

- Expand headworks: screening and grit removal
- Add 2 additional primary clarifiers (1 @ 995 m² 1 @ 472 m²)
- Add 3 – 19 m dia. 6 m deep static primary sludge fermenters
- Modify existing 6.6 ML bioreactor to MJ configuration with IFAS
- Modify aeration system to fine bubble diffusers
- Provide new blower building and 4 blowers @ 165 m³/min each
- Add 2 – 4 pass bioreactors MJ with IFAS, 8,600 m³ each
- Add 2 additional 45.7 m dia. final clarifiers
- Provide WAS thickening (dissolved air flotation)
- Add 2 – 416 m² rectangular lamella plate settlers for side stream treatment
- Expand UV disinfection to handle 350 ML/d
- Add 2 416 m² lamella plate clarifiers

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OPTION H – 100 ML/D PLANT - COMBINATION / HPO/ BNR / MJ / IFAS & MBNR WITH PHYSICAL AND CHEMICAL SIDE STREAM TREATMENT

Process Description

In this option, the existing bioreactors are converted using the HPO/BNR/MJ/IFAS process for around 30 ML/d of the flow. An MBNR system is developed for 120 ML/d of the flow by constructing concrete tanks and by converting one 45.7 and one 33.5 mØ final clarifier into membrane bioreactors.

Process descriptions for these facilities have been discussed previously in this section.

The remaining 33.5 mØ final clarifier is then available for chemically enhanced primary treatment of screened and degritted storm or snowmelt flows in areas of 150 ML/d.

There will have to be accurate flow split facilities following the headwater.

The combination of processes will be more difficult to operate but this combination will allow full scale demonstration of the HPO/BNR/IFAS system which could be applied at other facilities in Winnipeg.

HPO / BNR / MJ / IFAS

Design Flow – 20 ML/d
F/M ratio – .08
SRT – 12 days @ 10^{0}C for susp. growth
SRT – 12 days @ 20^{0}C for susp. growth
MLSS – 4,500 mg/L + 1,000 mg/L IFAS
RAS rate – 70% Q
HRT – 8.0 hours
Design Temperature – 10º C
BNR Configuration – Mod. Johannesburg + IFAS

Bioreactor:

- **Total Size – 6.6 ML (V)**
- Pre anoxic – 0.4 ML 6% (V)
- Anaerobic – 0.5 ML 9 % (V)
- Anoxic – 1.6 ML 24 % (V)
- Aerobic – 4.1 ML 61 % (V)

Media Requirements:

50% of aerobic zone occupied by media

Secondary settling tank:

- SOR 18 m^3/m^2/day average
  , 40 m^2/m^2/day maximum
- SLR 5 kg/m^2/hr average
  9 kg/m^2/hr maximum

MBNR Retrofit

Design flow – 80 ML/d
F/M ratio - 0.07
SRT – 15 days @ 10^{0}C
SRT – 8 days @ 20^{0}C
MLSS – 8,000 mg/L
RAS rate – 4 x Q
HRT – 5.4 hours
Design Temperature – 10º C
BNR Configuration – Custom design approximately UCT process

Bioreactor:

Total Size – 15 ML (V)

- Anaerobic – 1.2 ML 8 % (V)
- Anoxic – 3.3 ML 22 % (V)
- Aerobic – 10.5 ML 70 % (V)
- Aerobic cassettes tanks – 4.5 ML (V)
- 3 – 4 pass bioreactors
- 25 m x 40 m x 5 m deep

Air requirements:

- Carbonaceous 1.2 kg O_2/kg BOD removed
- 4.5 kg O_2//kg NH_3-N nitrified
- Additional air needed for scouring of membrane bundles.

Expected Performance (mg/L)

	MBNR @ 120ML/d	Side Stream Treatment @ 200ML/d	BNR/IFAS HPO @ 30ML/d	Blended Effluent @350ML/d
BOD (mg/L)	3	38	4.0	23
TSS (mg/L)	3	40	6.0	24.5
TKN (mg/L)	< 0.5	7.5	2.0	4..6
NH3 (mg/L)	< 1.0	6.5	< 1.0	4.1
NO3 (mg/L)	< 5.0	0.2	< 5.0	0.8
Total Nitrogen (mg/L)	< 6	7.9	< 8.0	2.2
Ortho P (mg/L)	< 0.02	0.05	0.05	0.04
Total P (mg/L)	< 0.15	0.7	0.7	0.5
Fecal Coliform (FC/100 ml)				< 200

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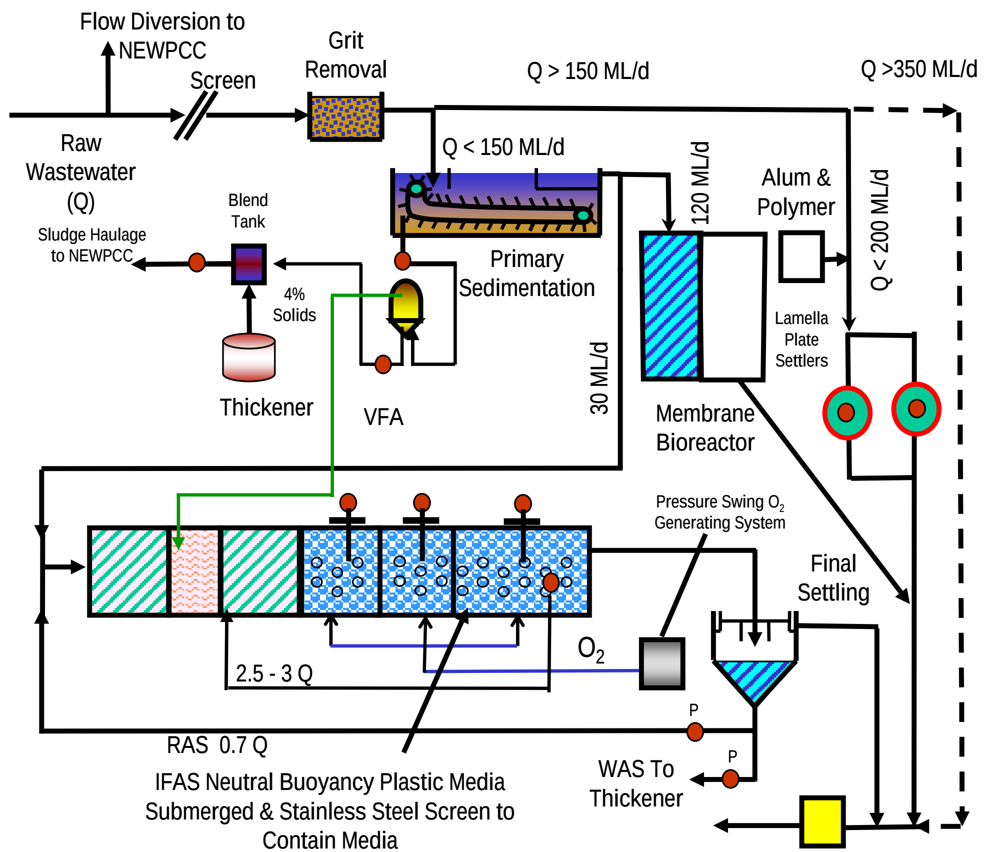
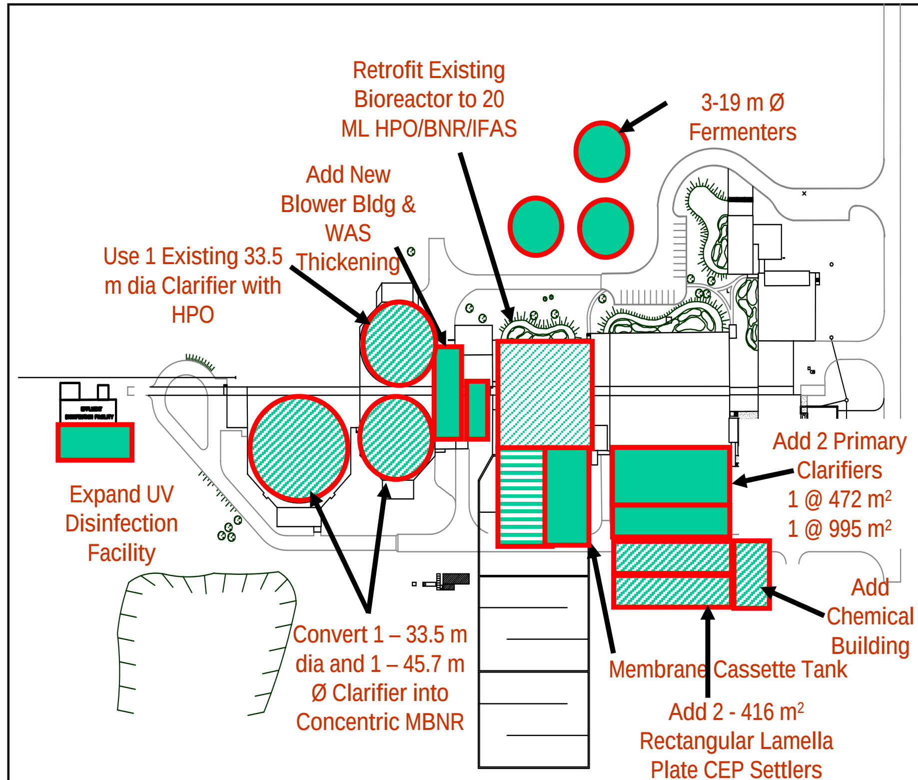
OPTION H – 100 ML/D PLANT - COMBINATION HPO/ BNR / MJ / IFAS & MBNR WITH PHYSICAL AND CHEMICAL SIDE STREAM TREATMENT





Advantages
- HPO system utilized for existing bioreactor
- Maximum capacity achieved from existing bioreactor as BNR
- IFAS technology utilized and proven on a small capacity component
- Minimum modification for BNR to existing bioreactor
- Maximum re-use of existing final clarifiers – MBNR and Final Clarifiers
- Minimum new bioreactor required
- High quality effluent for major portion of flow

Disadvantages
- Fine screen required for MBNR portion of flow
- Mix of several technologies at the plant
- Combination of HPO/BNR/IFAS is not proven
- Capital and operating cost difficult to estimate – probably high
- Need to construct high capacity side stream clarifiers
- Additional solids generated by side stream treatment
- No known HPO/BNR/IFAS systems for bio P & N removal

Comments
- Minimizes needs tank construction
- Allows development of important IFAS technology for Winnipeg

Components to be Upgraded/Constructed

- Expand headworks: screening and grit removal
- Provide fine screening 2mm opening
- Add 2 additional primary clarifier (1 @ 995 m^2 and 1 @ 472 m^2)
- Add 3 – 19 m dia. 6 m deep static primary sludge fermenters
- Convert existing bioreactor to 30 ML HPO/BNR/MJ/IFAS bioreactor
- Install IFAS media in aerobic cell of existing bioreactor
- Provide new blower building and 3 blowers
- Convert 1 – 33.5 m dia and 1 – 45.7 m Ø clarifier into concentric MBNR
- Provide WAS thickening (dissolved air flotation)
- Expand UV disinfection to 350 ML/day
- Convert 1 – 33.5 m dia final clarifier to side stream CEP facility.

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OPTION I – COMBINATION SYSTEM – NEW 100 MG/D BNR PLANT WITH AS / BNR / MJ PROCESS AND EXISTING PLANT - HPO PLANT FOR SIDE STREAM

Process Description

This option provides a new activated sludge biological nutrient removal modified Johannesburg plant designed for a flow and load of 100 ML/d, which will operate side by side with the existing HPO secondary treatment plant. The HPO facility will essentially provide the side stream treatment.

During flow and load times up to maximum **month** design flows, the BNR plant will handle 80% of the flow and load for biological nutrient removal. At the flows increase with snowmelt or during storms, the flow and load diverted to the HPO plant will increase until the BNR plant is handling 150 ML/d and the HPO side stream plant is handling up to 100 ML/d during high flow periods. The effluent will be blended and provided with UV effluent disinfection.

The BNR plant has been adequately described in Option C and will essentially provide nitrification/denitrifcation and biological phosphorus removal to the wastewater following screening, grit removal and primary sedimentation. Although the plant is designed for 100 ML/d, it will be capable of handling flows and loads up to 150 ML/d for 5 or 6 days in a row while maintaining excellent N, P, BOD, and TSS removal. As previously indicated, those plants have very stable performance and can routinely achieve < 1.0 mg/L ammonia, 8 mg/L total N, 0.7 mg/L total P, < 6 mg/L BOD, < 8.0 mg//L TSS. Primary sludge fermentation will be required to generate **VFA's** to sustain biological P removal. The waste activated sludge from the BNR plant will be thickened using a DAF to 3.5 to 4.5% solids and blended with the 6% solids waste fermented primary sludge.

The HPO plant will convert the incoming organic carbon (BOD & COD) to carbon dioxide, water and additional activated sludge cells in the existing 6.6 ML 4 cell bioreactor. The waste activated sludge will be settled out in the existing final settling tanks. Co-thickening of the WAS from the HPO plant could be continued in primary tanks dedicated to the HPO plant. At normal flows and loads, the HPO plant would be idled to keep the organisms alive and then ramped up to handle higher flows and loads as snowmelt and high summer storms occur.

Design Criteria

HPO/Secondary Plant

Design flow – 70 ML/d – will handle 100 ML/d for long periods
F/M ratio – 0.2 to 0.3
SRT – 6 days @ 10^{0}C
SRT – 3 days @ 20^{0}C
MLSS – 5,500 mg/L
RAS rate – 1.25% Q
HRT – 2.2 hours
Design Temperature – 10^o C

Bioreactor:

- **Total Size – 6.6 ML (V)**
- Aerobic – 6.6 ML 100 % (V)

Air Requirements

- Carbonaceous 1.2 kg O_2/kg BOD removed
- Nitrification 4.5 kg/ O_2/kg NH_3 – N removed

AS/BNR/MJ Secondary Plant

Design flow – 100 ML/d – will handle 150 ML/d for 5 – 6 days
F/M ratio – 0.08
SRT – 12 days @ 10^{0}C
SRT – 8 days @ 20^{0}C
MLSS – 4,500 mg/L
RAS rate – 0.2 x Q
HRT – 9 hours
Design Temperature – 10^o C
BNR configuration – Modified Johannesburg

Bioreactor:

- **Total Size – 37.5 ML (V)**
- Pre anoxic – 1.5 ML 4% (V)
- Anaerobic – 2.1 ML 5.5% (V)
- Anoxic – 7.7 ML 20.5% (V)
- Aerobic –26.2 ML 70 % (V)

Primary Setting

- SOR – 40 m3/m2 day

Final Settling

- SOR 18 m^3/m^2 day average
- SLR 5 kg/m^2 hour average

Expected Performance

	BNR Plant @ 150 ML/d	Side Stream Treatment @ 100 ML/d	Blended Effluent @ 350 ML/d
CBOD (mg/L)	6	15	8
TSS (mg/L)	8	15	8
TKN (mg/L)	< 2.0	7.5	3
NH3 (mg/L)	<1.0	6.5	2.3
NO3 (mg/L)	< 5.0	0.5	2.3
Total Nitrogen (mg/L)	<8	8.0	8
Ortho P	<0.05	0.05	0.05
Total P	<0.7	0.7	0.7
Fecal Coliform (FC/100 ml)			< 200

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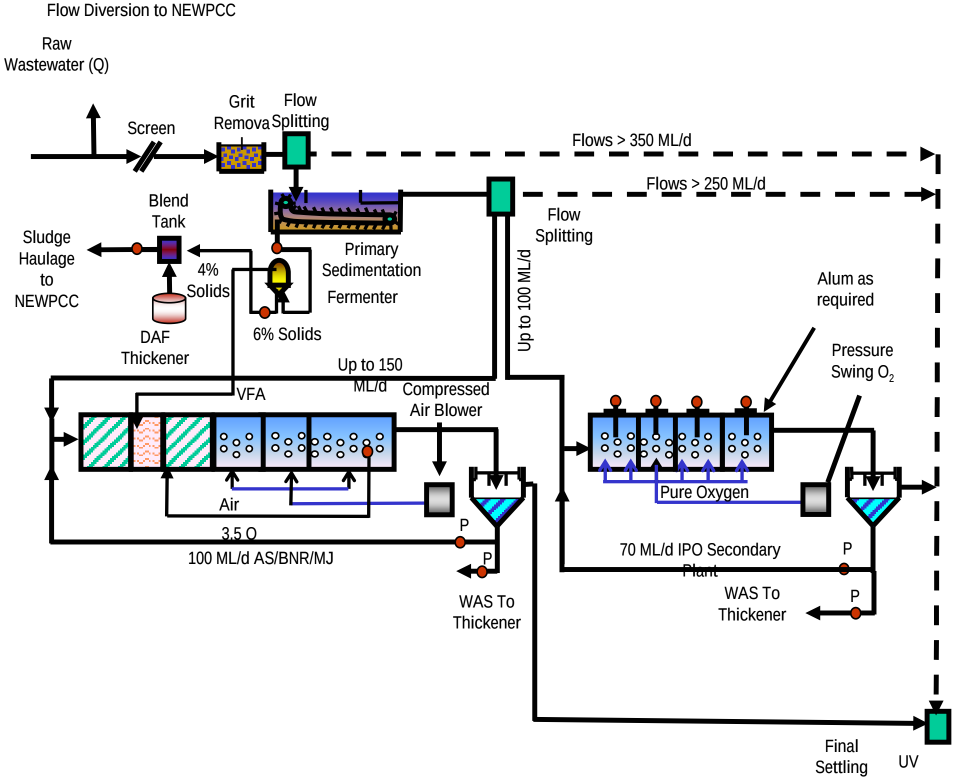
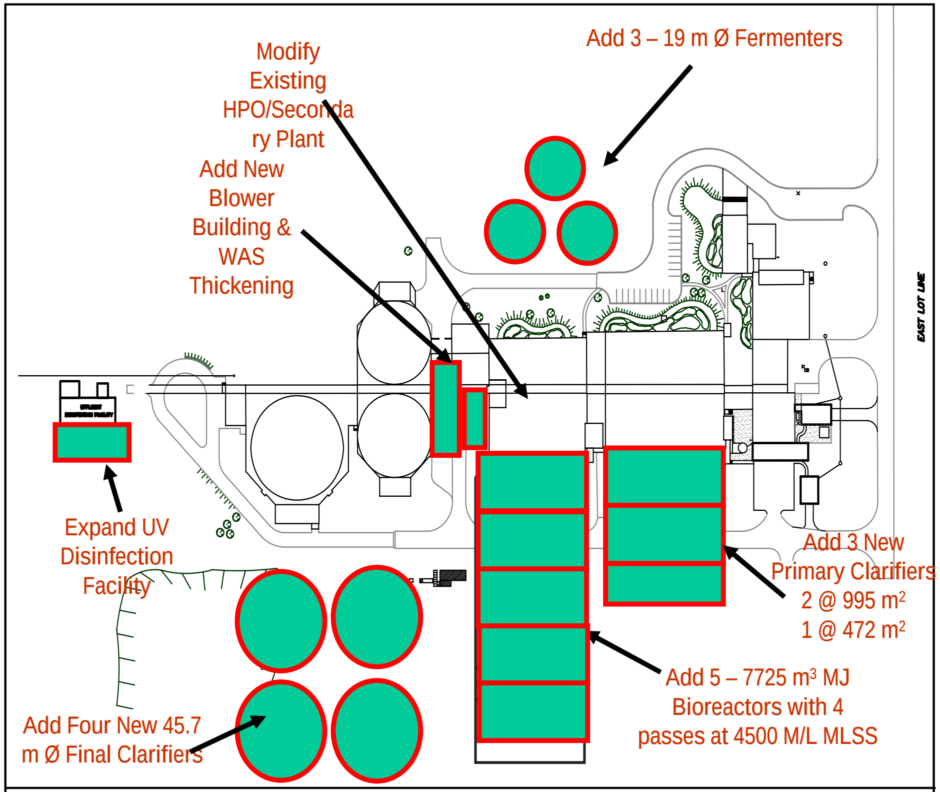
OPTION I – COMBINATION SYSTEM – NEW 100 ML/D BNR PLANT WITH AS / BNR / MJ PROCESS AND EXISTING PLANT HPO PLANT FOR SIDE STREAM





Advantages

- No changes in existing HPO plant
- Better side stream quality than physical chemical treatment
- Good load control on BNR plant
- Proven technology
- Easiest of all options to retrofit
- High quality effluent
- Reasonable capital and operating cost
- Excellent reuse of existing infrastructure
- Easily automated
- Operating staff experienced with HPO secondary treatment
- Continue co-thickening for HPO WAS

Disadvantages

- Large number of final clarifiers required
- High yield of biological sludge
- High impact on downstream sludge management and costs
- Higher operating cost than using physical chemical side stream treatment
- Operational protocols will need to be developed for low loads and transition phase

Comments

- Good utilization of existing infrastructure
- Can phase out the HPO as infrastructure ages and phase in physical chemical treatment

Components to be Upgraded

- Expand headworks screening and grit removal
- Add three additional primary clarifiers. 1 @ 472 m² and 2 @ 995 m²
- Add 3 – 19 m Ø 6m deep static primary fermenters
- Build new blower building, 4 – blowers at 165 m³/min
- Add 5 – 4 pass AS/BNR/MJ bioreactor 7.7 ML/each
- Add 4 new 45.7 m dia final clarifiers
- Provide WAS thickening for BNR plant
- Expand UV disinfection to 350 ML/d
- Provide standby chemical addition – alum feed

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OPTION J – COMBINED SYSTEM – EXISTING FACILTIES MODIFIED TO HPO/BNR/MJ 20 ML/D - ADDITIONAL CAPACITY AS/BNR/MJ – NEW FACILTIES 100 ML/D WITH SIDE STREAM TREATMENT 200 ML/D

Process Description

In this option, the existing HPO bioreactor will be retrofit to Modified Johannesburg configuration by installation of appropriate baffling, mixing equipment, and recycle pumps to created anoxic, aerobic and anaerobic cells.

Some adjustment of aeration equipment will be required. As discussed in Option D, nitrification, denitrification and bio P removal will be achieved.

Primary sludge fermenters will be provided to generate sufficient VFA for biological nutrient removal for 100 ML/d. With the VFA in fermentate distributed to the Modified HPO/BNR and new 80 ML/d AS/BNR facilities.

Four additional AS/MJ/BNR bioreactors will be constructed along with final clarifiers, WAS thickening, blowers, for 80 ML/d BNR plant as described in Alterative C.

The BNR facilities will successfully remove nutrient to a low level up to a capacity of 150 ML/d for short periods of 5 to 6 days.

Flows in excess of 150 ML/d will be treated in 2 side stream lamella plate clarifiers by chemically enhanced (CEP) primary treatment up to 200 ML/d.

Design Criteria:

HPO/BNR/MJ:

Maximum Month: Spring
Design flow – 20 ML/d
F/M ratio – 0.06
SRT – 12 days
MLSS – 4000 – 6000 mg/L; typical 5,500
RAS rate – 50 to 70 % Q
HRT – 7.0 hours
Design Temperature – 10° C
BNR Configuration – Mod. Johannesburg

Bioreactor:

- **Total size – 5.8 ML (V)**
- Pre anoxic – 0.3 ML 5.5% (V)
- Anaerobic – 0.35 ML 6.0% (V)
- Anoxic – 1.1 ML 18.5% (V)
- Aerobic – 4.05 ML 70% (V)
- Last portion of aerobic tank is vented

Side Stream Treatment:

Lamella plate clarifier SOR – 10 m/hr
Alum addition – 20 – 80 mg/L
Polymer addition – 1.0 to 1.5 mg/L

AS/BNR/MJ:

Maximum Month: Spring
Design flow – 80 ML/d
F/M ratio – 0.08
SRT – 12 days @ 10°C
SRT – 8 days @ 20°C
MLSS – 4,500 mg/L
RAS rate – 70% Q
HRT – 9 hours
Design Temperature – 10° C
BNR Configuration – Mod. Johannesburg

Bioreactor:

- **Total Size – 29.6 ML (V)**
- Pre anoxic – 1.2 ML 4% (V)
- Anaerobic – 1.6 ML 5.5 % (V)
- Anoxic – 6.1 ML 20.5 % (V)
- Aerobic – 20.7 ML 70 % (V)

Secondary settling tank:

- SOR 18 m^3/m^2 day average
  40 m^3/m^2 day maximum
- SLR 5 $kg/m^2/hr$ average
  9 $kg/m^2/hr$ maximum

Expected Performance

	BNR Plant HPO & AS/MJ @ 150 ML/d	Side Stream Treatment @ 200 ML/d	Blended Effluent @ 350 ML/d
BOD (mg/L)	4	38	22
TSI (mg/L)	6	40	25
TKN (mg/L)	< 2.0	7.5	5.1
NH3 (mg/L)	<1.0	6.5	4.1
NO3 (mg/L)	< 5.0	0.2	2.3
Total Nitrogen (mg/L)	<8	7.9	7.9
Ortho P	<0.05	0.05	0.05
Total P	<0.7	0.7	0.7
Fecal Coliform (FC/100 ml)			< 200

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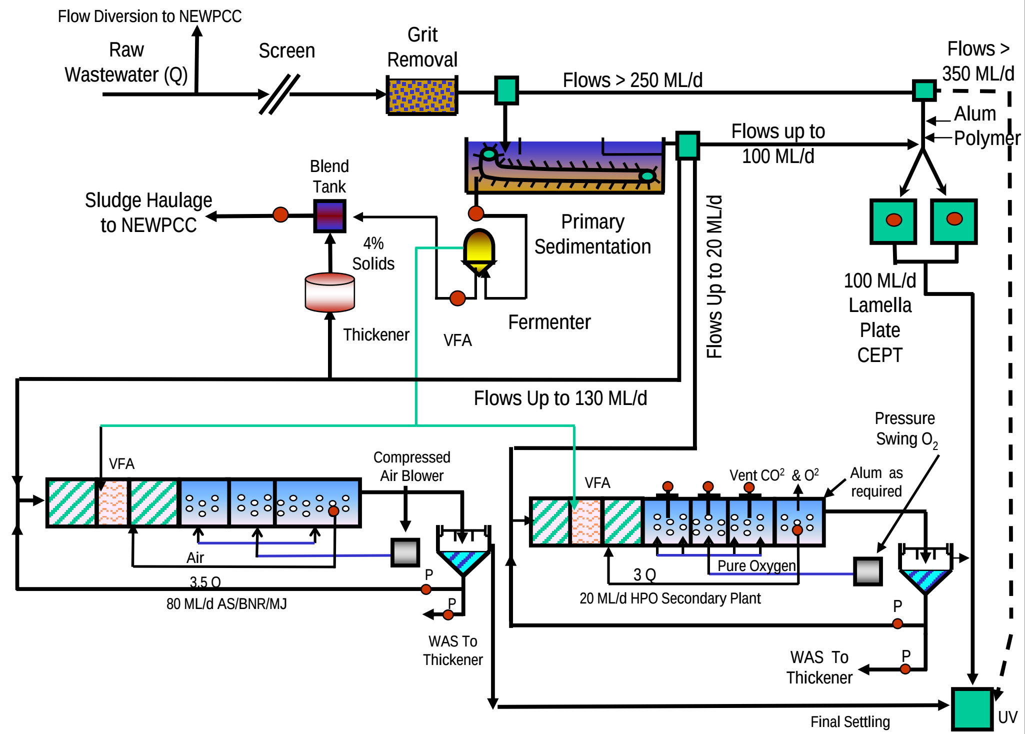
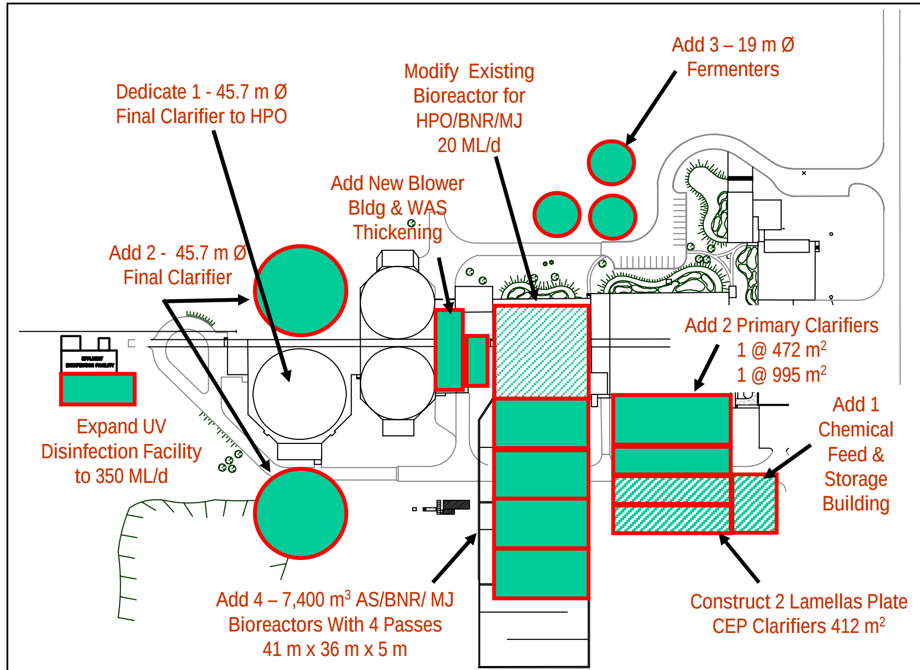
OPTION J – COMBINED SYSTEM – EXISTING FACILTIES MODIFIED TO HPO/BNR/MJ 20 ML/D - ADDITIONAL CAPACITY AS/BNR/MJ – NEW FACILTIES 100 ML/D WITH SIDE STREAM TREATMENT 200 ML/D





Advantages

- Reuse of existing facilities
- Proven process
- Handles high flows and loads easily
- Reasonable capital and operating cost

Disadvantages

- Two BNR process to be operated
- Effluent blend required
- Large volume of sludge periodically produced (high in inerts)

Components to be Upgraded

- Expand headworks: screening and grit removal
- Add 2 additional primary clarifiers (1 @ 995 m^2 and 1 @ 472 m^2)
- Add 3 – 19 m dia. 6 m deep primary sludge fermenters
- Modify existing 6.6 ML bioreactor to MJ/BNR/HPO configuration
- Construct new blower building, 4 blowers @ 130 m^3/min
- Add 4 – 4 pass AS/MJ/BNR bioreactors 7.5 ML each
- Add two additional final clarifiers 45.7 m Ø
- Provide WAS thickening for both plants
- Expand UV disinfection faculties to 350 ML/d
- Construct side stream treatment lamella plate rectangular settlers 2 @ 412 m^2
- Construct chemical additional and storage building

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