Appendix 5-1. Biological Nutrient Removal Alternative Analysis

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List of Tables and Figures

The biological nutrient removal (BNR) alternative analysis focuses on facility requirements to meet current NPDES permit requirements with monthly TP discharges of 0.3 mg/L or less. Tertiary treatment system analysis to reduce monthly TP discharges below 0.3 mg/L is provided in Section 3 of the Facility Plan. The BNR alternative analysis assumes the plant continues enhanced biological phosphorus removal (EBPR). This attachment presents the BNR alternative analysis including technology screening, basis of evaluation, comparison of six treatment alternatives, economic and non-economic evaluations, and recommended approach.

Section 1: BNR Technology Screening

A review of viable BNR treatment technologies was completed with the goal of selecting up to six alternatives for detailed analysis. Technologies considered included:

- Current operating configuration (baseline)
- Baseline with wet weather step feed
- Baseline with wet weather biological contact treatment (BCT)
- Modified Johannesburg (JHB) with wet weather step feed
- Bioaugmentation reaeration (BAR) with BCT or wet weather step feed
- New treatment process such as membrane aerated bioreactors (MABR), aerobic granular sludge (AGS), or BIOCOSTM activated sludge
- Sidestream EBPR (S2EBPR)
- Above alternatives with phosphorus release and recovery upstream of the anaerobic digesters

Table D-1 summarizes the preliminary facility needs for each potential alternative along with advantages, disadvantages, and technology screening selection. Based upon the screening process four alternatives were selected for further evaluation with Alternative 5 being added after the screening process.

- Alternative 0 – Current Operations (Baseline)
- Alternative 1 – Baseline with wet weather step feed
- Alternative 2 – Modified JHB with wet weather step feed
- Alternative 3 - S2EBPR sidestream reactor (SSR) with wet weather step feed
- Alternative 4 - S2EBPR sidestream reactor with carbon (SSRC) with wet weather step feed
- Alternative 5 - Modified JHB with wet weather step feed and secondary effluent equalization

Table D-1. BNR Alternative Evaluation Technology Screening

Alternative	Preliminary Key Tankage	Advantages	Disadvantages	Screening Decision
A-Existing Operations (Baseline)	1 aeration tank 4 secondary clarifiers	Existing operations Simple operations	High capital cost 10 AT gates to open at high flow Selector prone to instability at high flows Wet weather flow gates should be automated	Selected for further evaluation
B-Baseline with wet weather step feed	0 aeration tanks 2 secondary clarifiers	Eliminates new aeration tank and 2 secondary clarifiers Protects selector at high flow Minimizes secondary clarifier SLR No stranded assets for future TN Simple operations	9 AT gates to open during wet weather flows – provide automated gates Concern with step feed flow distribution	Selected for further evaluation
C-Baseline with wet weather biological contact treatment to new aeration tank	1 aeration tank 2 secondary clarifiers	Eliminates additional primary clarifiers/grit removal One gate to operate at high flows Protects selector at high flow	Potential grit accumulation in AT Labor/availability for cleaning AT, higher grit costs for contractor cleaning/hauling Requires AT out of service for cleaning Flow control more difficult than wet weather step feed More difficult flow control if primary clarifiers are added Does not provide primary treatment for flows in excess of 80 mgd	Screened –AT cleaning concerns, desire for full treatment. and potentially less value for TN reduction
D-Modified JHB with wet weather step feed	0 aeration tanks 2 secondary clarifiers	Eliminates new aeration tank and 2 secondary clarifiers Improve TP removal performance Simple and robust operations Protects selector at high flow Minimizes secondary clarifier SLR No stranded assets for future TN	9 AT gates to open at high flow –provide automated gates on Pass 2 feed Concern with step feed flow distribution	Selected for further evaluation
E-BAR with Biological Contact or Step Feed	0 aeration tanks 2 secondary clarifiers	Biological contact eliminates new grit, primary clarifiers, and AT Minimizes secondary clarifier SLR Protects selector at high flow	Alkalinity addition to BAR may be required Direct pipe centrate to BAR tank Additional process to operate Plant has not operated existing BAR system See disadvantages under Alternative C	Screened – additional process to operate and AT cleaning concerns
F-New BNR system		Full treatment	Separate system to operate	Screened- additional process to operate and

		Eliminates additional tankage to existing BNR Potential to reduce costs (BIOCOS)	Invades aerated pond space Additional complexity and unknown systems	facility expansion into pond not desired
G-S2EBPR	0 aeration tanks 2 secondary clarifiers	Flexibility for main or sidestream EBPR Potential to better utilize carbon Protects selector at high flow No stranded assets for future TN Potential for existing selector volume to be used for denitrification	Additional process Fermenter may be required Pilot testing recommended	Selected for further evaluation
H-Phosphorus release and recovery	NA	Reduces ferric chloride usage Reduces solids production Minimizes struvite formation Improved P recycle control Resource recovery/$ Increase cake solids and improved modeling	Capital cost Separate process to operate Additional operation requirements Reduces P content in biosolids which could impact acceptance from users	Screened- additional process to operate and concern with reducing biosolids P content

1.1 Basis of Evaluation

1.1.1 Flows and Loadings

This evaluation uses the projected 2050 flows and loadings presented in Table 2-4 of the Facility Plan for facility evaluation. Facility evaluations uses a calibrated BioWin process model with a 365-day dynamic influent itinerary which captures the projected average and maximum month, week, and day loading conditions along with daily diurnal variations and seasonal temperatures.

1.1.2 Effluent Criteria

Facility evaluations are based upon the current Blue Lake National Pollutant Discharge Permit (NPDES) and total phosphorus reduction criteria presented in Section 3 of the Facility Plan. Figure D-1 shows the monthly discharge criteria used for TSS, CBOD5, and ammonia in Year 2050 assuming the current NPDES mass discharge limitations remain the same.

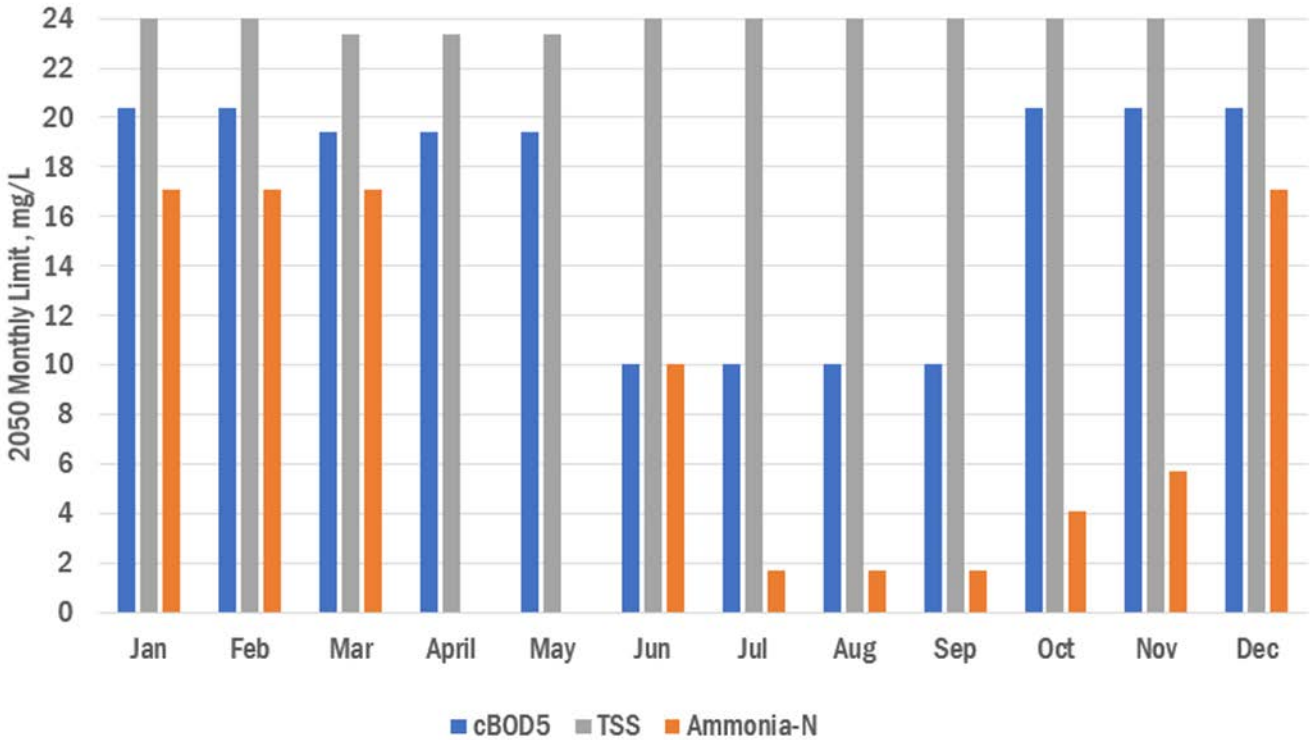

Figure D-1. Year 2050 monthly cBOD5, TSS and ammonia concentration discharge criteria

1.1.3 Process Requirements

Two key process criteria for facility sizing include the aerobic solids retention time (SRT) and secondary clarifier maximum allowable solids loading rates (SLR).

1.1.3.1 Aerobic SRT

Process analysis and BioWin model calibration showed nitrification has been inhibited during cold weather. Based upon dynamic model calibrations to match reported effluent ammonia concentrations, the BioWin default nitrifier kinetics were adjusted as follows:

- Ammonia oxidizing bacteria (AOB) maximum specific growth rate = 0.7/day
- AOB DO half saturation constant = 0.75 mg/L

Based upon historical plant operations and BioWin aerobic SRT sensitivity analysis, the minimum aerobic SRT was set at 11.5 days to maintain nitrification during the design minimum month temperature of 11 degrees Celsius. MCES staff continues to investigate the nitrification rate kinetics to determine if the design aerobic SRT can be reduced.

1.1.3.2 Secondary Clarifier Maximum Allowable SLR

Secondary clarifier maximum allowable SLR was calculated using solids inventory control (SIC) state point analysis (SPA). SPA uses sludge quality as measured by sludge volume index (SVI), peak flow rate, RAS flow rate, clarifier area and mixed liquor suspended solids to define SLR capacity. The Blue Lake 90th percentile SVI typically used for defining SPA is roughly 70 mL/g over the last 5 years of operation. Plant operating data shows the SVI values decreased significantly and stabilized with less variability after Northern Star began discharging to the Blue Lake sewerage system in roughly 2011. Northern Star is currently installing a pretreatment system which will remove the large readily biodegradable COD load which promotes excellent selector performance. As such, the design SVI for this analysis is based upon the 90th percentile SVI prior to Northern Foods discharging to the Blue lake sewerage system of 110 mL/g.

The plant return activated sludge (RAS) pumps have a rated capacity of 5 mgd/clarifier. Review of the RAS pump curves, and RAS system operating curve shows the RAS pumps have capacity to pump 6 mgd/clarifier with 10 clarifiers in service. For this analysis, the secondary clarifier maximum allowable SLR based upon SPA is 38 pounds per square foot-day (lb/sf-d) at 5 mgd/clarifier and 43 lb/sf-d at 6 mgd/clarifier.

1.1.4 Hydraulic Capacity

The existing primary and secondary treatment systems were originally design in the 1980's for a peak hour flow of 80 mgd with higher flows routed to the pond. This analysis assumes all flow is treated through primary and secondary treatment. Table D-2 identifies three existing hydraulic constraints (in red) which limits the plants' capacity to treat the peak wet weather design flows. Short-term hydraulic constraints can be alleviated by the following:

- Construct a parallel secondary effluent channel to the pond to increase capacity to 129 mgd,
- Construct a new mixed liquor splitter structure to increase capacity to 135 mgd, and
- Raise the primary clarifiers weirs by 5-inches along with automating one aeration tank inlet gate to open at influent flows of roughly 75 to 80 mgd to increase capacity to 118 to 135 mgd

These flows are based upon the influent flow rate. Analysis assumes an additional 9 mgd of recycle flow through the primary and secondary treatment systems. All alternatives assume these improvements are made immediately.

Table D-2. Blue Lake WWTP Existing Hydraulic Constraints and Recommended Improvements

Process Unit	Recommended Modification	Influent Capacity[a, b], mgd	Constraint
Secondary Clarifiers	Existing 8 secondary clarifiers	100 to 105	Weirs flooded – process performance
Secondary Clarifiers	Add parallel secondary effluent conduit/channel (8 clarifiers)	129	Weirs flooded
Secondary Clarifiers	Parallel conduit with two new 125' secondary clarifiers	135	Not applicable
Mixed Liquor Splitter Structure	Existing splitter structure	80 to 85	Weirs flooded – loss of hydraulic splitting control
Mixed Liquor Splitter Structure	Raise weirs by 0.7 feet (8 secondary clarifiers)	100 to 105	Weirs flooded – raising weir height further floods AB effluent weirs
Mixed Liquor Splitter Structure	Construct new MLSS splitter structure with 10 secondary clarifiers	135	Not applicable
Mixed Liquor Splitter Structure	Construct new MLSS splitter structure and enlarge secondary clarifier port openings with 8 secondary clarifiers	135	Not applicable
Primary Clarifiers	Existing 8 clarifiers with 2 aeration tank inlet gates open (18 total)	75 to 80	Weirs flooded – process performance
Primary Clarifiers	Existing 8 clarifiers with 2 aeration tank inlet gates open (18 total)	118 135	None (Weirs partially submerged)
Primary Clarifiers	Existing 8 clarifiers with 2 aeration tank inlet gates open (18 total)	135	Not applicable

a. Flows exclude 9 mgd of internal recycle flows through primary and secondary treatment.

b. Analysis assumes all process units in service including aerated pond. Effluent pumps operate to maintain waster surface elevation of 707.98 (HWL) at pump inlet. Analysis also assumes the pond effluent 48-inch RCP is fully functional and not filled with solids

1.2 Alternative Description

1.2.1 Alternative 0 – Current Operations (Baseline)

Alternative 0 represent current plant operating configuration. The existing plant has three inlet gates per tank to the selector zone allowing it to operate in an anaerobic/oxic (A/O) mode and modified Johannesburg (JHB) process mode which includes a RAS denitrification zone. Alternative 0's process analysis is based upon an A/O configuration as shown in Figure D-2 to maintain the anaerobic mass fraction greater than 15 percent to promote stable EBPR operations. The analysis assumes two inlet gates are open during wet weather flows to provide needed hydraulic capacity.

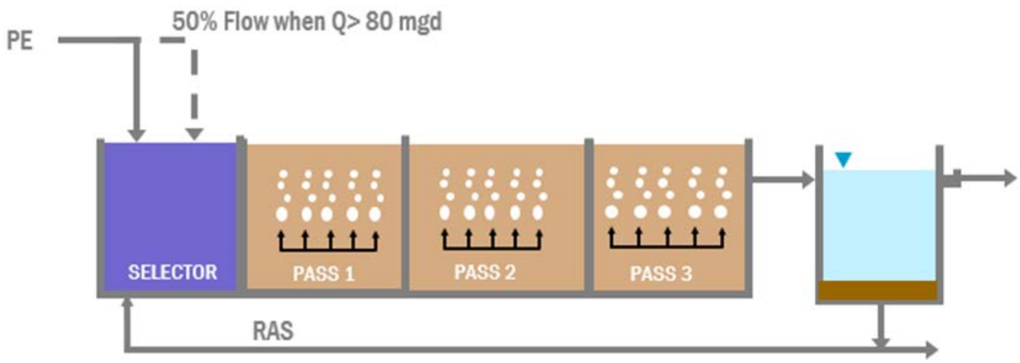

Figure D-2. Alternative 0 – Current Operations Flow Schematic

Table D-3 lists the Year 2050 design data for all alternatives selected for detailed analysis. Alternative 0 requires one new 2.3 million gallon (MG) aeration basin and four 12D-foot diameter secondary clarifiers. Figure D-3 presents a preliminary site layout which also shows a new tunnel connecting the Aeration Tank (AET) and Secondary Effluent Building (SEB) areas, which is common to all alternatives.

Table D-3. Existing Permit BNR alternative Evaluation Key Process Design Data. (Year 2050)

Items	Units	Alternative 0: Baseline	Alternative 1: Baseline with Wet Weather Step Feed	Alternative 2: Modified JHB with Wet Weather Step Feed	Alternative 3: S2EBPR SSR with Wet Weather Step Feed	Alternative 4: S2EBPR SSRC with Wet Weather Step Feed	Alternative 5: Modified JHB with Wet Weather Step Feed and SE Equalization
Mainstream Bioreactors							
Additional 2.3 MG basins	No.	1	0	0	1	1	0
Total volume	MG	21.96	19.66	19.66	19.96[a]	19.96[a]	19.66
Total SRT	days	13.8	13.8	17.1	18.3	18.3	17.1
Aerobic/Anaerobic SRT	days	11.5/2.4	11.5/2.4	11.5/2.4	11.5/2.4[a]	11.5/2.4[a]	11.5/2.4
Maximum month MLSS	mg/L	3,800	4,300	4,400	4,200	4,800	4,400
MLSS at PHWWF	mg/L	3,800	3,200	3,350	3,250	3,750	2,900
Dissolved Oxygen	mg/L	1.8	1.8	1.8	1.8	1.8	1.8
Aeration Demand (average)	scfm	38,850	38,850	37,640	37,940	39,770	37,740
Final Clarifiers							
Additional 125-ft clarifiers	No.	4	2	2	2	4	0
Clarifiers in service	No.	12	10	10	10	12	8
Diameter	feet	125	125	125	125	125	125
Return sludge flow	mgd/clarifier	5.0	5.0	5.0	5.0	6.0	6.0
Design sludge volume index	mL/g	110	110	110	110	110	110
PHWWF SOR[b]	gal/ft^2-d	795	955	955	955	795	1190
PHWWF SLR[b]	lb/ft^2-d	38	36	38	37	40	41
Filtration capacity required	mgd	65	65	60	70	70	65
Average ferric chloride	gal/d	640	630	355	635	590	380
Annual dewatered cake	lb TSS/d	61,120	60,700	60,300	61,620	62,010	60,330

a. Excludes 2.0 MG sidestream reactor

b. Peak hour wet weather flow (PHWWF) surface overflow rate (SOR) and solids loading rate (SLR) include 9 mgd of plant internal recycle flows

Figure D-3. Alternative 0 – Baseline Layout (Year 2050)

1.2.2 Alternative 1 – Baseline with Wet Weather Step Feed

Alternative 1 is similar to the baseline operating alternative with the following additions:

- During wet weather flow events greater than 75 to 80 mgd, the inlet gate at the end of Pass 2 is opened thereby splitting flow 50:50 between the selector zone and end of Pass 2 as shown in Figure D-4. This wet weather step-feed approach offers several advantages over Alternative 0 including reducing the secondary clarifier SLR and stabilizing EBPR operations during high flows. The Pass 2 step feed gate is automated to simplify plant operations during and after the high flow event.
- Two baffle walls are added to each existing selector to segment the selector into three zones. The baffle walls will promote higher food:microorganism (F:M) in the initial selector zone where secondary influent is fed which can promote improved sludge quality (lower SVIs) and minimize back mixing in the selector zone itself promoting plug flow characteristics.
- Secondary clarifier flocculation well depth is increased from 5 to 8 feet (1/2 side water depth) or replaced with a new flocculation well. The changes to the flocculation well will minimize the sludge density current promoting a larger clarification zone, reducing clarifier sludge blankets at high flow, and reducing effluent suspended solids during critical loaded conditions. This analysis assumes the flocculation well is replaced with a new fiberglass baffle.

Similar to Alternative 0, Alternative 1 process analysis assumes an A/O configuration to maintain the anaerobic mass fraction greater than 15 percent to promote stable EBPR operations. This alternative could also be operated in a Modified JHB configuration with a RAS denitrification zone (Alternative 2) with a lower than targeted anaerobic mass fraction.

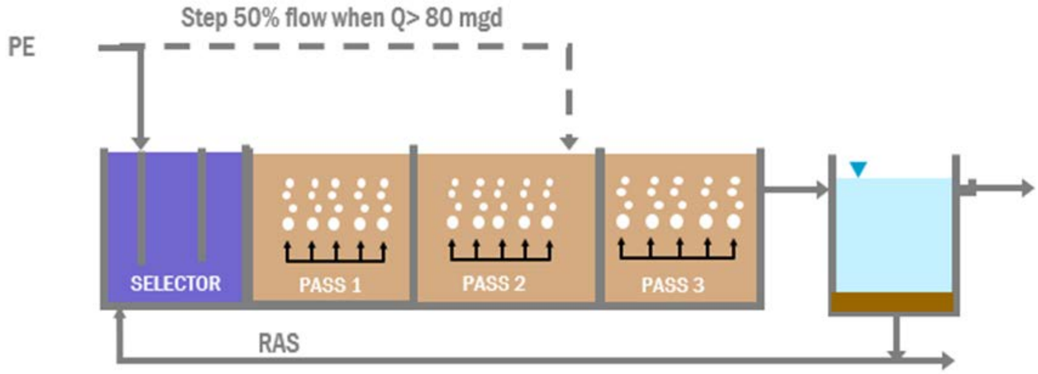

Figure D-4. Alternative 1 – Baseline with Wet Weather Step Feed Flow Schematic

Table D-3 lists Alternatives 1's key design data. Use of the Pass 2 wet weather step-feed reduces facility requirements significantly compared to baseline operations. Under this alternative, additional aeration tanks are not required, and the number of additional secondary clarifiers is reduced from 4 to 2. Figure D-5 shows a site layout of Alternative 1's key facility needs.

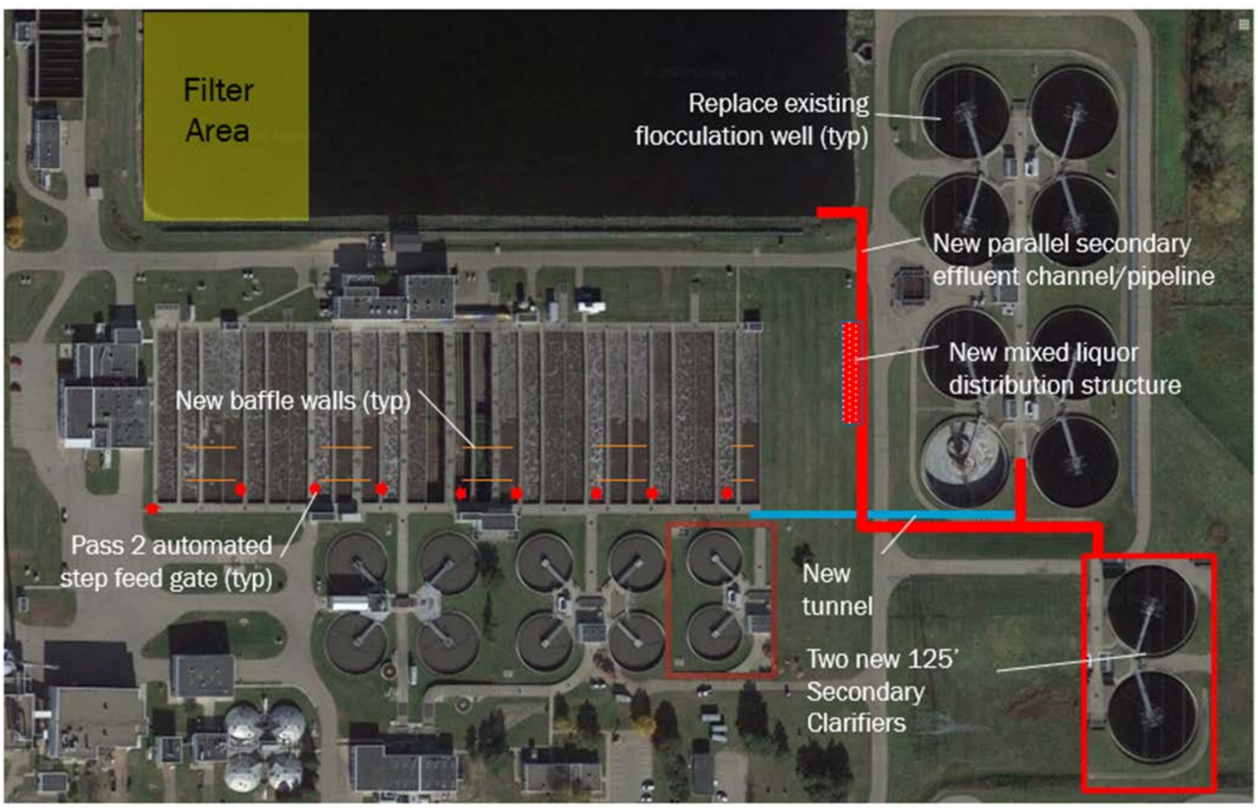

Figure D-5. Alternative 1 – Baseline with Wet Weather Step Feed Layout (Year 2050)

1.2.3 Alternative 2 – Modified Johannesburg (JHB) with Wet Weather Step Feed

Alternative 2 changes the flow schematic from an A/O configuration to a Modified JHB configuration. Under this alternative a dedicated RAS denitrification zone is added upstream of the selector as shown in Figure D-6 to reduce return sludge nitrates to improve EBPR performance. The aeration tank step feed and additional baffle walls and secondary clarifier flocculation baffle modifications described under Alternative 1 are completed plus an additional selector zone equal into size to 1/3 of the existing selector zone is added to meet the minimum anaerobic mass fraction. The additional selector zone requires adding a baffle wall and cutting, removing, capping and re-anchoring the existing Pass 1 ceramic diffuser aeration grid in the new selector zone area. This analysis assumes the new selector zone is mixed using a submersible mechanical mixer.

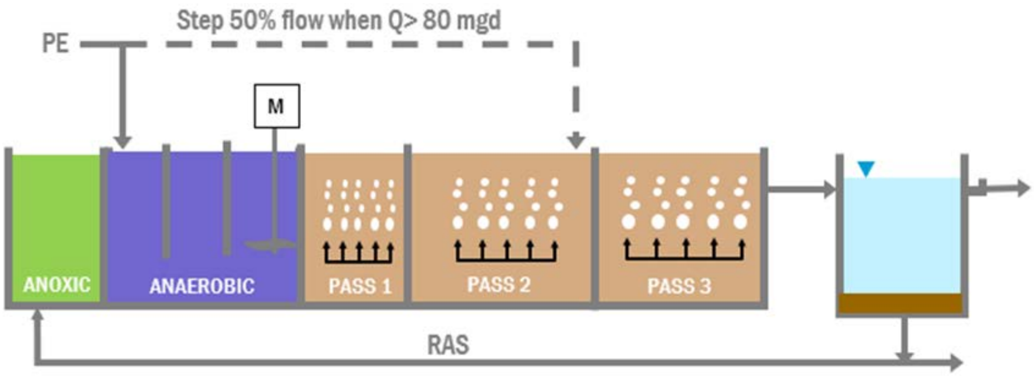

Figure D-6. Alternative 2 – Modified JHB with Wet Weather Step Feed Flow Schematic

Table D-3 lists Alternatives 2's key design data. Similar to Alternative 1, Alternative 2 does not require additional aeration tanks and requires two additional secondary clarifiers. A key advantage of this alternative is the reduced ferric chloride demands which are 45 percent lower than Alternative 1. Figure D-7 shows Alternative 2's site layout.

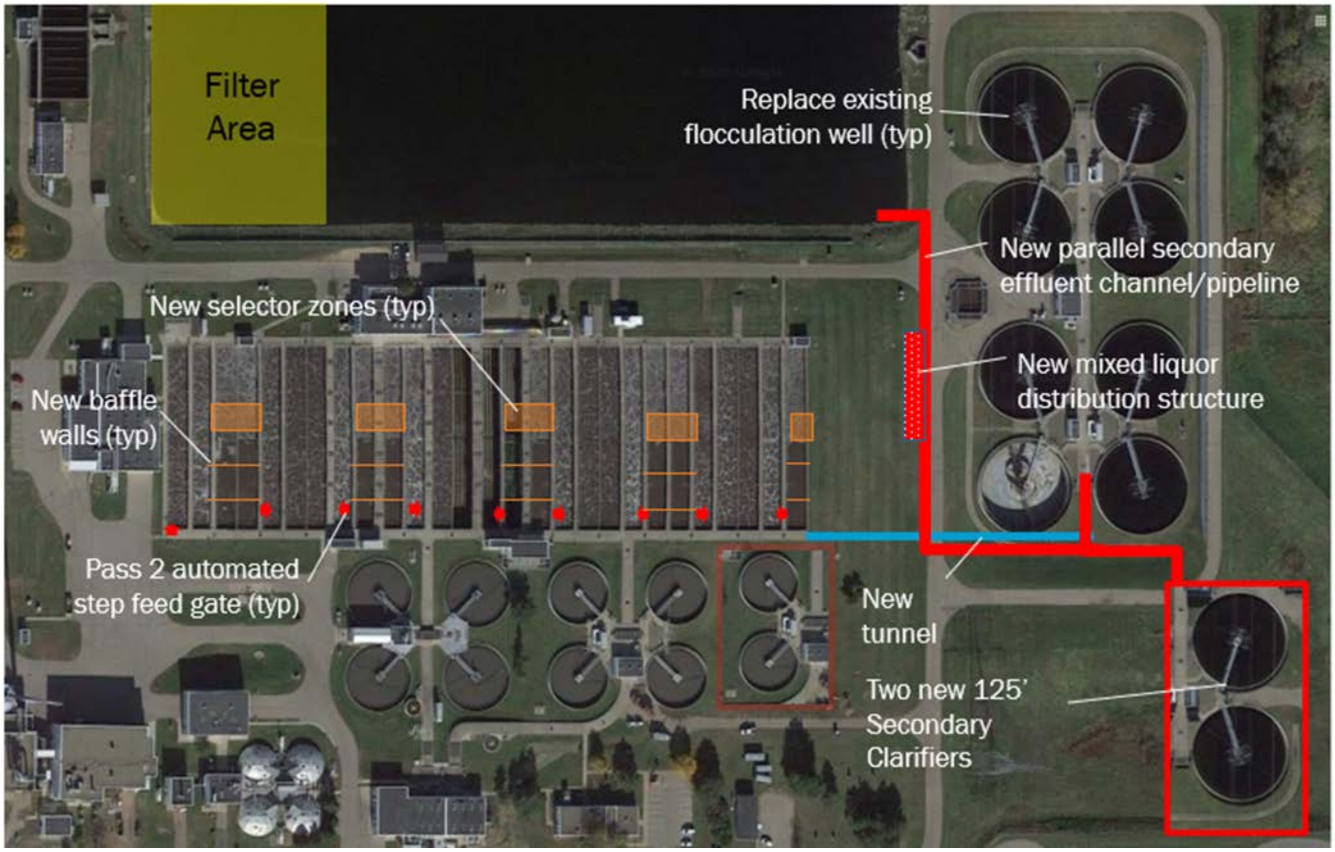

Figure D-7. Alternative 2 – Modified JHB with Wet Weather Step Feed Site Layout (Year 2050)

1.2.4 Alternative 3 – Sidestream EBPR (S2EBPR) Sidestream Reactor (SSR) with Wet Weather Step Feed

Alternative 3 evaluates S2EBPR using a sidestream reactor (SSR) configuration. Alternative process modeling is based upon best available information since S2EBPR process modeling it is not well established with existing process models and should be confirmed with pilot- and full-scale demonstration testing.

Sidestream RAS fermentation relies on the hydrolysis and fermentation of RAS solids in a dedicated SSR to provide the needed volatile fatty acids (VFA) to drive the EBPR process. This analysis leverages the existing Aeration Tank 0 (AT0) BAR design in which AT0 can be operated as the SSR for RAS fermentation. For this alternative 10 to 15 percent of the RAS flow is pumped to AT0. AT0 provides roughly 5 to 7 days of SSR SRT depending upon RAS flow and whether the tank is intermittently mixed to promote longer SRTs/more hydrolysis. AT0 contents are then pump back to the main liquid stream aeration tanks. AT0/SSR contents are mixed using submersible mixers.

Process analysis shows the existing aeration tank selector zones shown in Figure D-8 are required to maintain secondary effluent monthly TP discharges below 1.0 mg/L. Analysis also shows pumping AT0 fermented RAS back to the RAS distribution box or beginning of Pass 2 does not impact predicted TP removal. This analysis assumes AT0 contents are pumped to Pass 2 to utilize the existing RAS piping and minimize piping changes at the RAS distribution box.

Aeration Tank Pass 2 step feed and selector baffles and secondary clarifier flocculation baffle modifications are also required with this alternative.

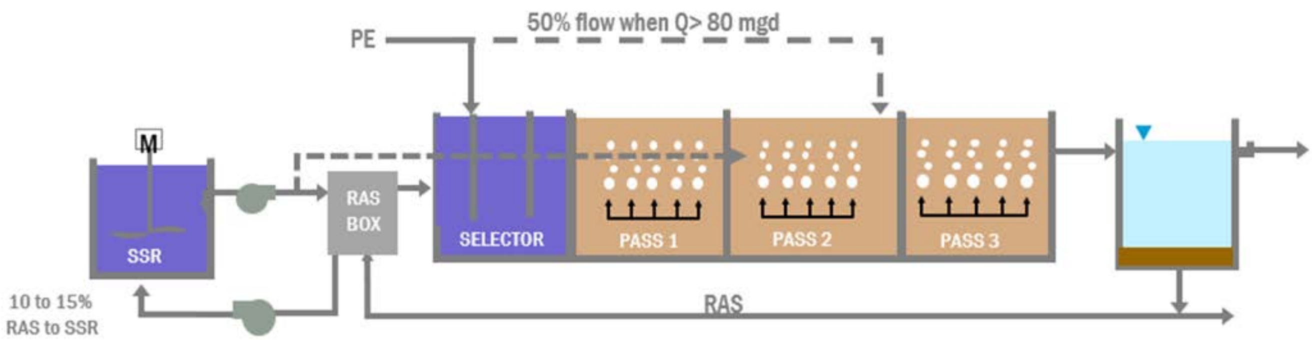

Figure D-8. S2EBPR SSR with Wet Weather Step Feed Flow Schematic

Table D-3 lists Alternative 3's design data which shows one additional aeration tank, and two secondary clarifiers are required in addition to converting AT0 into an SSR. Figure D-9 illustrates the major improvements needed for Alternative 3.

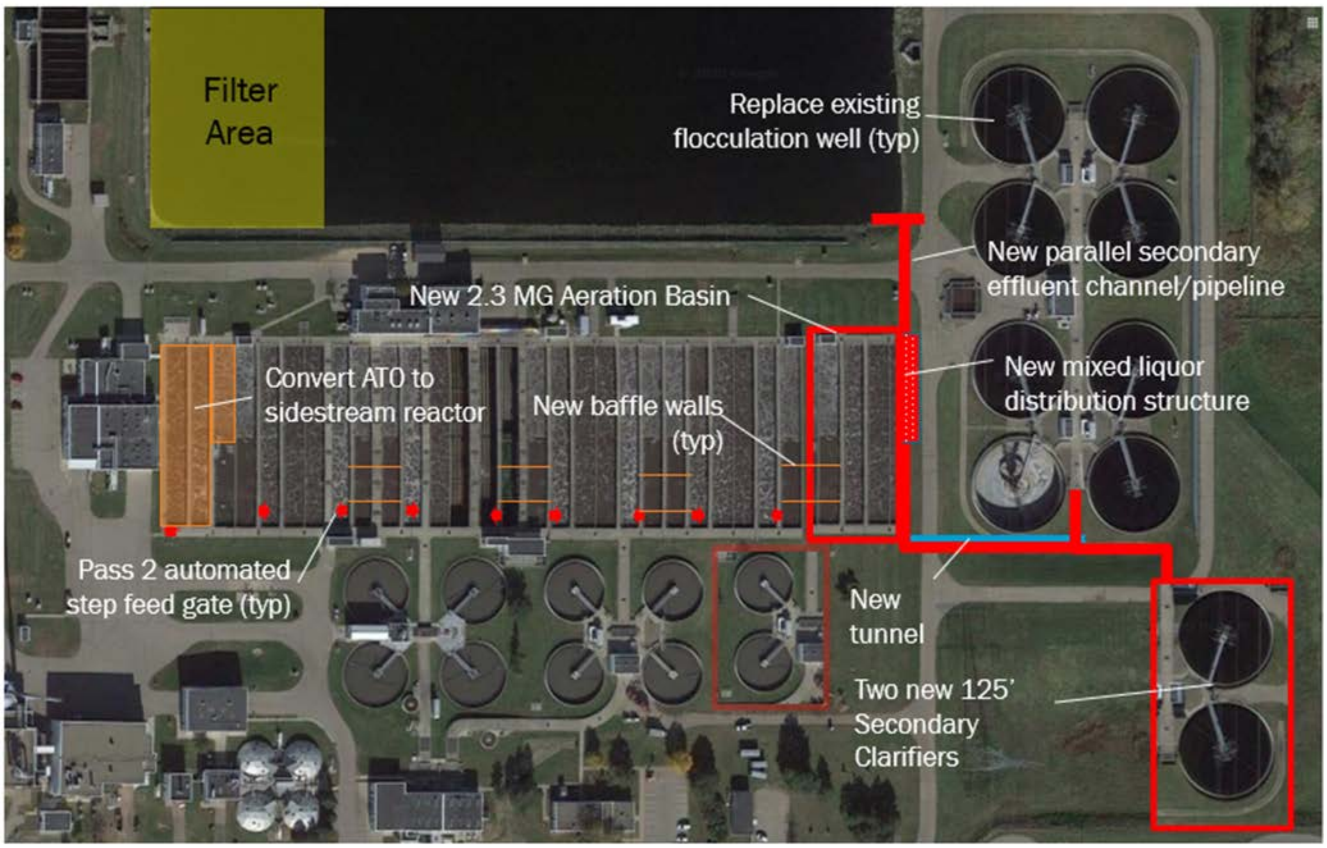

Figure D-9. Alternative 3 – S2EBPR SSR with Wet Weather Step Feed Layout

1.2.5 Alternative 4 – S2EBPR Sidestream Reactor with Carbon (SSRC) and Wet Weather Step Feed

Alternative 4 converts the plant into a S2EBPR configuration having a dedicated SSR with carbon addition (SSRC). Alternative process modeling is based upon best available information since it is not well established with existing process models and should be confirmed with pilot- and full-scale demonstration testing.

Sidestream RAS Fermentation with Supplemental Carbon mixes the RAS flow with a VFA source, such as primary sludge fermentate in a SSR reactor as shown in Figure D-10. This alternative is nearly identical to Alternative 3 except carbon is added to the SSR. For this alternative, it is assumed the existing gravity thickeners are operated as single-stage fermenters/thickeners and the thickener overflow is routed by gravity to ATO (SSR) as a carbon source.

System sizing is based upon pumping 10 to 15 percent of the RAS flow to ATO. ATO provides roughly 3 to 4 days of SRT depending upon RAS flow and whether the tank is intermittently mixed to promote longer SRTs. ATO contents are then pump back to the main liquid stream aeration tanks. ATO/SSR contents are mixed using submersible mixers.

Like Alternative 3, process analysis shows the existing aeration tank selector zones shown in Figure D-10 are required to maintain secondary effluent monthly TP discharges below 1.0 mg/L. Analysis also shows pumping ATO contents back to the RAS distribution box or beginning of Pass 2 does not impact predicted TP removal. This analysis assumes ATO contents are pumped to Pass 2 to utilize the existing RAS piping and minimize piping changes at the RAS box.

Aeration tank Pass 2 step feed and selector baffles and secondary clarifier flocculation baffle modifications are also required with this alternative.

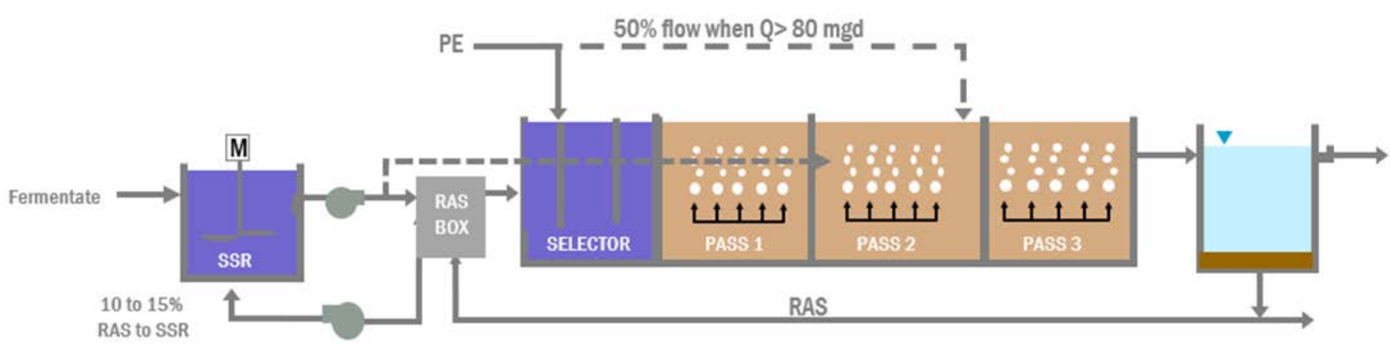

Figure D-10. S2EBPR SSRC with Wet Weather Step Feed Flow Schematic

Table D-3 shows Alternative 4 requires 1 additional aeration tank and 4 additional 125-foot secondary clarifiers. Facility requirements for this alternative are greater than Alternative 3 since GTO routed directly to ATO/SSR increases the secondary influent TSS load thereby increasing MLSS concentrations compared to non-fermented GTO combined with routing GTO to the primary clarifiers for TSS removal. Figure D-11 shows Alternative 4's site layout.

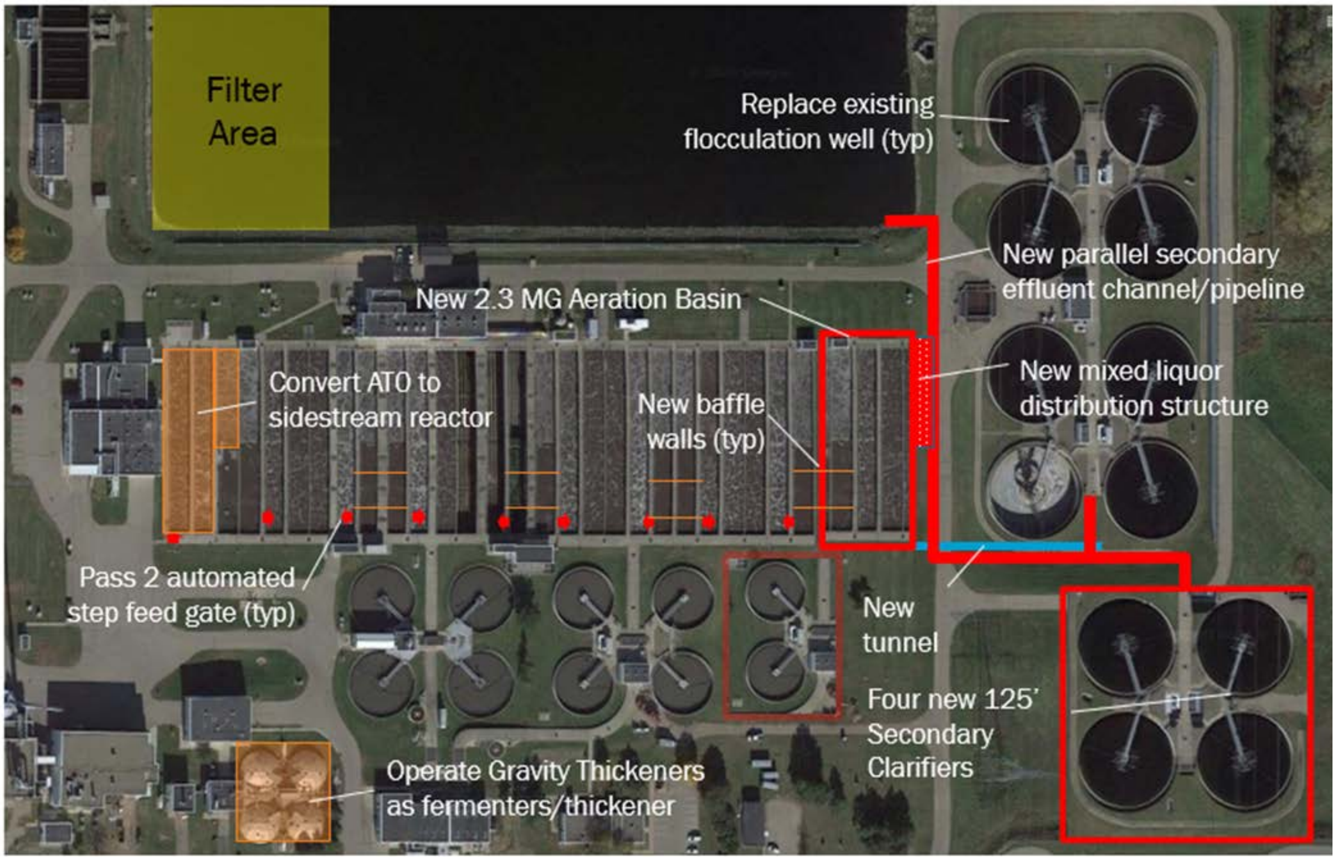

Figure D-11. S2EBPR SSRC with Wet Weather Step Feed Site Layout

1.2.6 Alternative 5 – Modified JHB with Wet Weather Step Feed and Secondary Effluent Flow Equalization

Alternative 5 combines Alternative 2 process modifications to promote stable EBPR with secondary effluent flow equalization to de-couple plant hydraulics and secondary clarifier process limitations. Under this alternative, when influent flows exceed 129 mgd (or secondary effluent flows including recycles exceed 138 mgd), secondary effluent is diverted to an equalization basin as shown in Figure D-12. By diverting excess high flows, the hydraulic and secondary clarifier SLR capacities of the eight existing secondary clarifiers are de-coupled provided the new parallel secondary effluent channel discussed in Section 1.1.4 above is constructed.

This alternative provides a new 3 MG asphalt-lined equalization basin and pump station downstream of the secondary clarifiers as shown in Figure D-13. This alternative does not require additional aeration basins nor secondary clarifiers provided these additional modifications to Alternative 2 are completed:

- One additional Pass 2 automated step feed gate is provided (total of two per aeration tank) to divert 66 percent of the flow to Pass 2 during wet weather events. Flow diversion to Pass 2 will be subject to MLSS concentration and SVI. Under normal operating conditions the step-feed initiation flow of 75 to 80 mgd does not change; however, under 2050 maximum month MLSS and design SVI of 110 mL/g the step-feed may need to be initiated at 65 mgd.
- A swing zone is added to each aeration tank rather than extending the selector zone. This will allow the system to operate with an extended selector under normal operations and convert to A/O mode by aer-

ating the swing zone during high MLSS periods (4300 mg/L) to reduce MLSS concentrations and maintain acceptable secondary clarifier SLRs.

Process analysis shows the secondary effluent equalization basin is not required until Year 2040. Table D-3 lists other Alternative 5 design data.

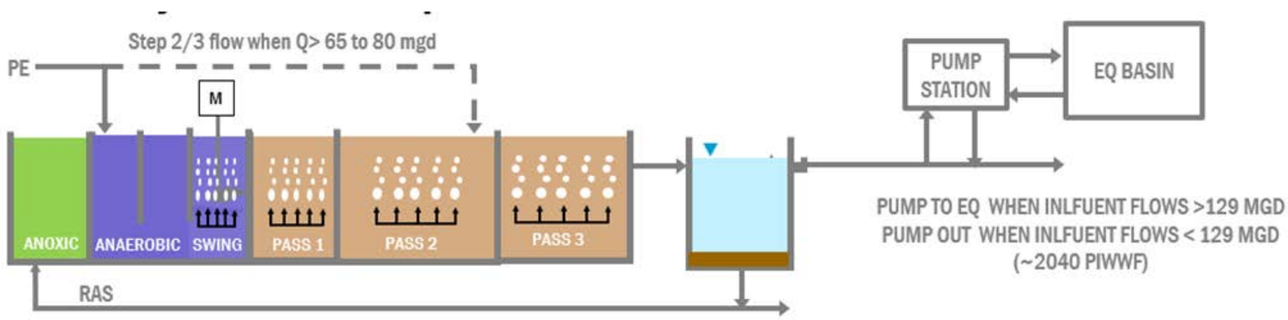

Figure D-12. Alternative 5 – Modified JHB with Wet Weather Step Feed and Secondary Effluent Equalization Flow Schematic

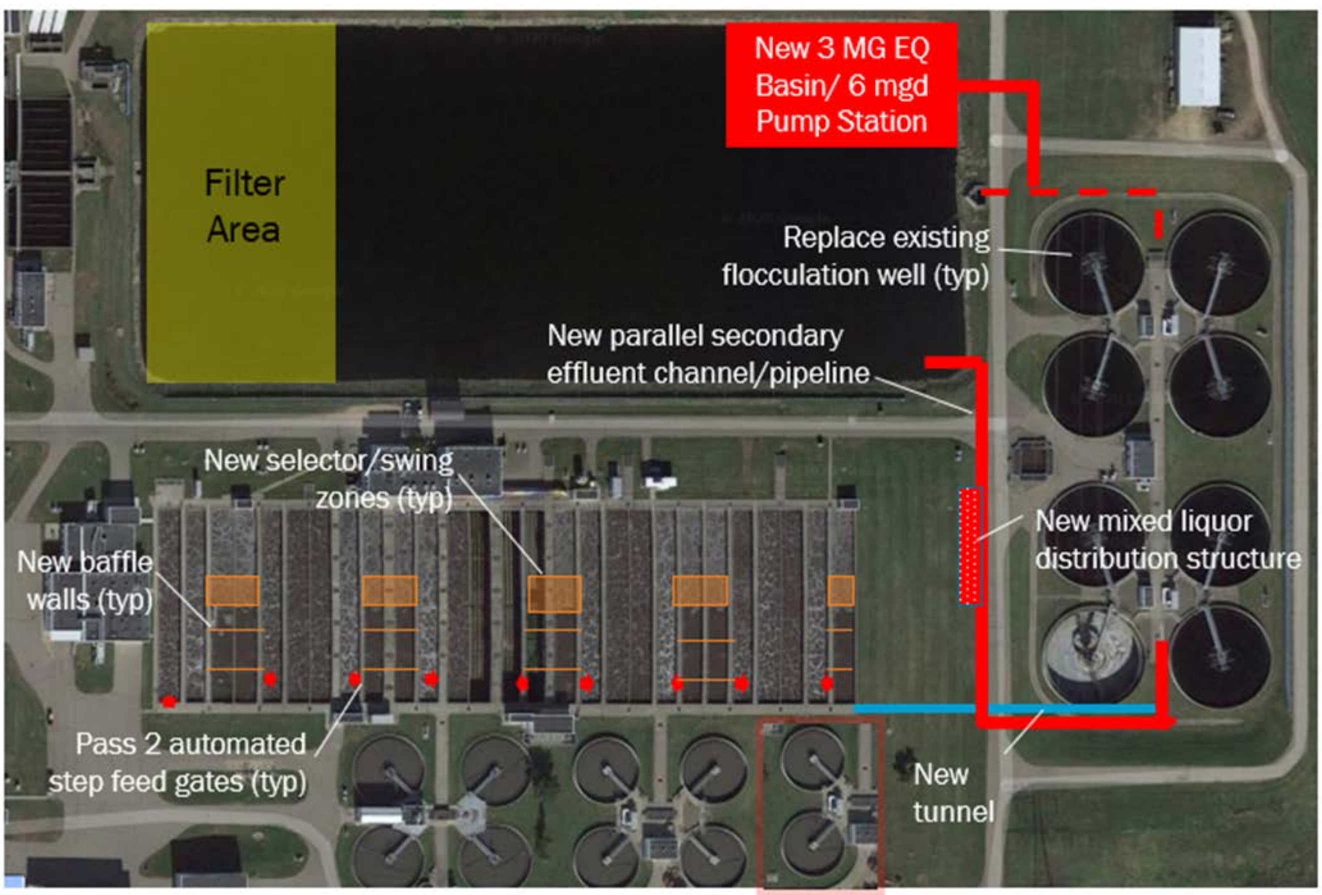

Figure D-13. Alternative 5 – Modified JHB with Wet Weather Step Feed and Secondary Effluent Equalization Site Layout (Year 2050)

1.3 Economic Evaluation

Comparative capital costs, annual operating costs, and life cycle present worth for each alternative were developed. Developed costs represent Class 5 estimates for Conceptual Level Planning and alternative comparison in accordance with the Association for the Advancement of Cost Engineering International (AACE). Expected accuracy for Class 5 estimates typically range from -50 to +100 percent, depending on the technological complexity of the project, appropriate reference information and the inclusion of an appropriate contingency determination. Construction costs are based upon process unit costs from similar projects and vendor proposals adjusted to Year 2020 dollars. All cost estimates assume construction begins in 2020 (cost not escalated for construction mid-point) and operations start in 2025. The economic analysis uses the assumptions provided in Tables D-4 and D-5.

Table D-4. BNR Alternative Analysis Capital Cost Assumptions

Item	Assumption
Net Cost Mark-up	
HVAC/Plumbing	5%
Electrical and Instrumentation	21%
Gross Cost Mark-ups	
Undefined detail contingency	50%
Final Markup	
General Requirements	15%
Escalation to midpoint	0%
Engineering and administration	20%

Table D-5. BNR Alternative Analysis Annual Operating and Net Present Value Assumptions

Item	Assumption
Electricity	$0.075/kWh
Labor rate (O&M staff)	$112,445/FTE
Ferric Chloride	$1.35/gallon
Solids processing	$700/dry ton
Interest rate	3%
Discount rate	3%
Life-cycle cost period	years

1.3.1 Capital Costs

Capital costs are based facility requirements defined in each of the above alternative descriptions. Capital costs assumes the existing selector zone air mixing systems remain. If the air mixing systems are replaced with submersible mechanical mixers, the capital cost estimates for each alternative increase by roughly $5 million. Capital costs assume the aerated pond remains operational. This should be reviewed further since there will periods up to 6 months in which no flow is routed to the pond when tertiary filters are installed. If the pond is decommissioned, the plant will lose a key low head hydraulic conveyance structure which if replaced with equivalent piping/channels has a capital cost of roughly $15 million. No provisions for groundwater dewatering have been included in the cost estimates.

Table D-6 shows Alternative 5 has the lowest capital cost of roughly $48 million with Alternative 1 and 2 capital cost being slightly higher at $52 to $55 million, respectively. The three remaining alternatives capital costs are 45 percent or more greater than Alternative 5. The existing investment in mainstream EBPR results in high capital costs for S2EBPR making these alternatives less attractive unless pilot- and demonstration testing shows an additional aeration basin is not required (Alternative 3).

1.3.2 Annual Operating Costs

The annual operating costs developed for each alternative include the following items:

- Assumes first year of operation is 2025 and continue through year 2050
- Annual average energy costs reflect the difference in blower energy compared to Alternative 0 plus additional energy demands for new mixers and S2EBPR RAS pumping.
- Combined ferric chloride usage for secondary/tertiary systems.
- Annual average solids processing costs for additional solids generated compared to Alternative 0. Assumes additional solids generated do not impact solids processing facility sizing.
- Annual operations and maintenance labor hours based on 1800 hours worked each year and paid for 2080 hours per year.
- Annual maintenance materials at 2 percent of equipment costs

Annual operating costs, except labor and mixer energy, are escalated yearly based upon the average flow rate. Labor hours are assumed constant during the 25-year planning cycle. Table D-6 shows Alternative 2 has the lowest annual comparative O&M costs based upon significant reduction in ferric chloride usage and associated processing of inert ferric solids generated.

1.3.3 Net Present Value

Net present values (NPV) for each alternative were calculated based upon the capital costs and NPV of annual operating costs. Table D-6 shows Alternative 5 has the lowest NPV of $50 million followed by Alternative 2 NPV of $56 million (12 percent higher) and Alternative 1 NPV of $58 million (16 percent higher). Comparing Alternative 2 and 5’s NPV, Alternative 2’s NPV is slightly higher than the 10 percent difference in which planning alternative costs are considered equal.

Table D-6. Existing Permit BNR Alternative Evaluation Capital and Annual Operating Costs and Net Present Value

Items	Alternative 0: Baseline	Alternative 1: Baseline with Wet Weather Step Feed	Alternative 2: Modified JHB with Wet Weather Step Feed	Alternative 3: S2EBPR SSR with Wet Weather Step Feed	Alternative 4: S2EBPR SSRC with Wet Weather Step Feed	Alternative 5: Modified JHB with Wet Weather Step Feed and SE Equalization
Demolition	$ 430,000	$430,000	$430,000	$430,000	$430,000	$ 430,000
Yard piping	$2,240,000	$760,000	$760,000	$760,000	$2,240,000	$ 760,000
Aeration Tank 9	12,980,000	-	-	$12,980,000	$12,980,000	-
Aeration Tank Tunnel Sections	$3,460,000	$3,460,000	$3,460,000	$3,460,000	$3,460,000	$3,460,000
Aeration Tank Baffle Walls	-	$990,000	$1,480,000	$990,000	$990,000	$1,480,000
Pass 2 Automated Step feed gates	-	$480,000	$480,000	$400,000	$400,000	$960,000
Aeration Tank Mixers	-	-	$1,350,000	$ 1,160,000	$1,160,000	$1,350,000
Selector/swing zone modifications	-	-	$240,000	-	-	$2,640,000
AT0 RAS/Mixed Liquor Pumps	-	-	-	$580,000	$580,000	-
Mixed liquor distribution box	$8,610,000	$8,610,000	$8,610,000	$8,610,000	$ 8,610,000	$8,610,000
Secondary clarifier floc baffles	$1,330,000	$1,330,000	$1,330,000	$1,330,000	$1,330,000	$1,420,000
Secondary Clarifier Tunnels	$9,050,000	$9,050,000	$9,050,000	$9,050,000	$9,050,000	$9,050,000
Secondary Clarifier stairwell	$260,000	$260,000	$260,000	$260,000	$260,000	$260,000
Secondary Clarifiers - yard piping	$1,940,000	$1,940,000	$1,940,000	$1,940,000	$1,940,000	$1,940,000
Secondary Clarifiers	$18,740,000	$9,370,000	$9,370,000	$9,370,000	$18,740,000	-
Secondary Clarifier Gallery	$7,180,000	$5,040,000	$5,040,000	$5,040,000	$7,180,000	-
Secondary Clarifier Electrical Bldg	$720,000	$720,000	$720,000	$720,000	$720,000	-
East Drainage Pump station	$1,240,000	$1,240,000	$1,240,000	$1,240,000	$1,240,000	-
Gravity thickener/overflow mods	-	-	-	-	not included	-
EQ basin/pump station/ piping	-	-	-	-	-	$7,400,000
Total Construction	**$68,180,000**	**$43,680,000**	**$45,760,000**	**$58,320,000**	**$71,310,000**	**$39,760,000**
Engineering and Administration	$13,636,000	$8,736,000	$9,152,000	$11,664,000	$14,262,000	$7,952,000
Total Capital Cost	**$81,816,000**	**$52,416,000**	**$54,912,000**	**$69,984,000**	**$85,572,000**	**$47,712,000**
Comparative Annual O&M costs (2025)						
Energy	-	-	$(10,000)	$ 23,000	$41,000	$(9,000)
Ferric Chloride	$230,000	$226,000	$127,000	$230,000	$214,000	$136,000
Solids Handling	-	$(39,000)	$(76,000)	$47,000	$84,000	$(70,000)
Maintenance/Labor	-	-	$7,500	$7,200	$7,200	$20,000
Comparative annual O&M	$230,000	$187,000	$49,000	$307,000	$346,000	$77,000
Net Present Value	**$89,000,000**	**$58,000,000**	**$56,000,000**	**$79,000,000**	**$96,000,000**	**$50,000,000**

All costs presented in 2020 dollars

1.4 Non-Economic Evaluation

Table D-7 summarizes the non-economic advantages and disadvantages for Alternatives 1,2 and 5. Alternatives 0, 3, and 4 are not included based upon the high capital costs and NPV.

Alternative 2 provides the most reliable, robust and simple operations. Alternative 2 also provides the benefit of the least consumables (ferric chloride) for TP removal, lowest O&M requirements, and plant familiarity when feeding secondary influent at the second influent gate, rather than the first tank inlet gate. Alternative 5 increases operational complexity with adding secondary effluent flow equalization, Pass 1 swing zone operation, and when to begin Pass 2 wet weather step feed since step feed can be process initiated rather than hydraulic capacity initiated. Alternative 1 also represents very simple operations, however annual operating costs are higher than Alternative 2 and 5 making it less attractive.

1.4.1 Recommendation

Alternative 2 – Modified JHB with Wet Weather Step Feed is recommended for continued BNR to meet the current NPDES permit. This recommendation reflects the most reliable, robust and simple operations with the least annual operating requirements. This alternative also provides the opportunity to implement Alternative 5 in the future which could decrease future expansion costs projected for Year 2040.

Table D-7. Existing Permit BNR Alternative Evaluation Non-Economic Comparison

Alternative	Advantages	Disadvantages
Alternative 1 – Baseline with Wet Weather Step Feed	Significant capital cost reduction from baseline; Additional baffles walls promote improved sludge quality and RAS denitrification if desired; Step-feed “protects” selector at high flows; Simple wet weather operations with one automated gate/tank	Anaerobic selector “undersized” if RAS denitrification zone used; Increased ferric usage compared to Alternatives 2 and 5.
Alternative 2 – Modified JHB with Wet Weather Step Feed	Significant capital cost reduction from baseline; Improved TP performance with lowest ferric demands; Additional baffles walls promote improved sludge quality; Step-feed “protects” selector at high flows; Simple wet weather operations with one automated gate/tank; Flexibility to implement Alternative 5 in future if needed; Reduces flow required for filtering to achieve effluent TP goals	Additional mixers in new selector zone (if mixers used)
Alternative 5 – Modified JHB with Wet Weather Step Feed and Secondary Effluent Equalization	Lowest capital cost and net present value Improved TP performance and reduced ferric demands with dedicated RAS denitrification Additional baffles walls promote improved sludge quality, Step-feed “protects” selector at high flows Less clarifier equipment to maintain	SE equalization process increases complexity in terms of operations and when to step feed to Pass 2 Increases number of Pass 2 wet weather step feed gates from 1 to 2. Additional mixers in new selector zone Pass 1 swing zone may increase complexity For potential future TN reduction, clarifier process capacity becomes limiting versus hydraulic capacity minimizing effectiveness of SE equalization in future