FINAL

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Bend Water Reclamation Facility
SECONDARY EXPANSION

Task A1.06 Preliminary Process Evaluation Summary

submitted to

The City of Bend

submitted by

The CH2M HILL Team

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Bend Water Reclamation Facility Secondary Expansion Task A1.06 Preliminary Process Evaluation Summary

PREPARED FOR: City of Bend, Oregon

PREPARED BY: William Leaf/BOI
Adrienne Menniti/PDX
Josh Boltz/TPA

REVIEWED BY: Dave Green/PDX
Brady Fuller/BND

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Introduction

The Value Engineering (VE) Report for the City of Bend, Oregon Water Reclamation Facility (WRF) Secondary Expansion (CH2M HILL, June 2009) proposed a number of process configurations for consideration. A Process Refinement Study was conducted to help select the appropriate treatment alternative(s) to carry forward into the Project Definition and Schematic Design phases of the project. This memorandum summarizes the results of the process evaluation of each treatment alternative and provides an overview of decision-relevant, non-cost criteria for process selection. The cost analysis associated with the alternatives presented here can be found in the companion memorandum in Appendix A, *Bend WRF Secondary Expansion – Task A1.06 Preliminary Process Evaluation Cost Opinion* (CH2M HILL, October 15, 2009).

This memorandum goes on to describe and document the decision process for selecting a recommended process configuration moving forward into the predesign phase. This decision process was a combination of the present worth cost analysis as well as the non-cost evaluation work, supported by Bend operations and maintenance staff.

For the purposes of this work, the process alternatives developed during the VE effort were divided into two the following categories: (1) those alternatives that optimize treatment plant performance (that is, improved settling, peak wet weather flow treatment, enhanced total nitrogen removal, energy savings) and (2) those alternatives that provide increased treatment plant capacity.

This memorandum focuses on the treatment alternatives that provide increased treatment capacity. Each capacity alternative was first evaluated to determine the capacity provided for the current treatment plant expansion. The alternatives were then assembled into programs of improvements that could provide the Bend WRF with the needed capacity through 2030. The optimization alternatives were also evaluated to the greatest extent possible with existing available information. The appropriate optimization alternatives will be evaluated further in the Project Definition phase of the project as they apply to the chosen capacity alternatives.

Alternatives that Optimize Treatment Plant Performance

Table 1 summarizes the optimization alternatives suggested by the VE Report (CH2M HILL, June 2009), and the purpose of each alternative.

TABLE 1
Treatment Alternatives Providing Treatment Plant Optimization

VE Study Reference	Treatment Alternative	Purpose
PT-4	Wet-weather contact stabilization	Improved wet weather performance
PT-5	Anoxic/aerobic swing zone	Improved nitrification during cold weather
PT-7	High-intensity air for bulking control	Control of *Microthrix parvicella*
B-2 [a]	Mechanical mixing with aeration in the last aerobic zone	Reduced power costs associate with aeration
DG-O-3	High-strength brewery waste to digesters	Increased methane production for energy generation
DG-1 [a]	Post aerobic digestion	Improved total nitrogen removal performance, and volatile suspended solids (VSS) destruction

NOTE:
[a] Moderate Priority Proposal

Alternatives Providing Increased Treatment Capacity

Table 2 summarizes the major treatment alternatives evaluated for the expansion of the secondary treatment process for the Bend WRF and suggested by the VE Report (CH2M HILL, June 2009).

TABLE 2
Treatment Alternatives Providing Increased Capacity

VE Study Reference	Treatment Alternative
PT-1	Chemically enhanced primary treatment (CEPT)
AS-3 [a]	Aeration basin expansion (modified Ludzak-Ettinger [MLE] process) with new secondary clarifier
PT-3	Step-feed bioreactor configuration
PT-11	Integrated fixed-film activated sludge (IFAS)—use of media within a suspended growth environment; can be used with multiple bioreactor configurations
AS-1 [a]	Filtrate re-aeration
PT-6	Bioaugmentation—side-stream treatment processes that provide bioaugmentation (in addition to nitrogen removal) to help improve the overall capacity of the main bioreactor

NOTE:
[a] Moderate Priority Proposal

Methodology

Each capacity alternative presented in Table 2 was evaluated to determine the incremental capacity improvement it could provide if implemented individually. Based on this incremental capacity evaluation, programs (multiple phases) of improvements were assembled to provide the Bend WRF with the needed capacity through 2030 based on the planning projections provided in the *Bend WRF Facility Plan, City Project No. SW0701, Volume 1* (Carollo, April 2008). Each assembled program of improvements represents an alternative for secondary process expansion.

CH2M HILL's Pro2D process simulation is the primary tool used to predict performance and the associated capacity of the Bend WRF. Pro2D is a whole-plant simulator developed by our process engineers on the MS Excel platform. Pro2D tracks 70 wastewater constituents through the treatment facility, providing a complete mass-balance for the system. The industry-standard International Water Association (IWA) Activated Sludge Model (ASM) 2D and Anaerobic Digestion Model (ADM) mathematical models are included in the simulator to model biological treatment within the system. ASM 2D is a mathematical model prepared by independent experts and is commonly used in the industry to represent the biological performance and behavior of activated sludge systems. Before the analysis was completed to determine the incremental capacity improvement provided by the treatment alternatives, the simulated performance of each unit process at the Bend WRF was roughly matched to the information contained in the daily monitoring reports for November 2007.

The preferred approach would have been to fully calibrate the simulator prior to analysis because reliably predicting treatment plant performance over a range of scenarios relies heavily on the accuracy of the influent wastewater characteristics. However, wastewater characterization data were unavailable for the initial analysis, so generalized wastewater characteristics were assumed. The City began sampling for the wastewater characterization study beginning in early December 2009, following startup of the final digester that was modified in the digester mixing improvements project. Initial reviews of these characterization data indicate comparable values to those used in the process simulation. A thorough calibration of the process simulation and associated refinement of the selected process alternative will be completed during the predesign phase of the project. A sensitivity analysis will also be completed to quantify the impacts of varying influent wastewater characteristics on the selected treatment alternative. From this evaluation, operational flexibility will be incorporated into the design to accommodate variable influent wastewater characteristics to the extent possible.

The process capacity of the WRF is determined by evaluating each unit process and determining the limiting treatment component on the system. This takes into account treatment performance and reliability required to meet the associated effluent discharge requirements at the facility. As presented in the Facility Plan, the secondary treatment design is based on achieving the total nitrogen (TN) during the average annual condition and ensuring that the WRF will still nitrify during the coldest month during average daily maximum month (ADMM, per the Facilities Plan) flow and loads. At its rated capacity, each treatment alternative must be able to reliably meet the current TN limit (annual average TN less than 10 milligrams per liter [mg/L]) at the average annual temperature (17 degrees Celsius [°C]) and ADMM flow and loads. The treatment alternative must also maintain nitrification at the 30-day minimum average daily wastewater temperature (13.5°C) and ADMM flow and loads. Each individual

unit process is evaluated against industry-standard design criteria to determine their associated capacities. Separate from the current discharge criteria, the flexibility of each unit process to meet future, potentially more stringent, discharge criteria is addressed through the non-cost evaluation.

For the Bend WRF, the secondary treatment process proves to be limiting. From a process capacity perspective, the secondary clarifiers are limiting the treatment capacity of the WRF. The secondary process capacity is defined as the flow and loads that result in a solids loading rate that overloads the secondary clarifiers. Clarifier capacity is based on the state-point analysis of clarifier performance with a 10 percent derating factor on the theoretical capacity. The state-point analysis takes into account the mixed-liquor suspended solids (MLSS) concentration, secondary clarifier influent flow, return activated sludge (RAS) flow, and sludge volume index (SVI).

Common secondary design criteria are used for the evaluation of treatment alternatives. The solids residence time (SRT) was established for each treatment alternative to meet the required treatment performance while providing a factor of safety from the minimum SRT required for nitrification at a given temperature. The RAS rate was fixed at 50 percent of the influent flow for all evaluations. For the alternatives using the Modified Ludzak-Ettinger (MLE) configuration, the mixed liquor return (MLR) rate was fixed at 300 percent of the influent flow. All capacity evaluations assume an SVI of 150 milliliters per gram (mL/g) volatile suspended solids (VSS). It should be noted that this assumption increases the rated clarifier capacity of the existing plant. Historical SVI values at the WRF are relatively high and previous studies recommended an SVI value of 200 mL/g VSS. For this evaluation, it is assumed that sludge settleability will be improved with any treatment alternative selected. This would be through implementation of some of the optimization approaches previously recommended, or as an inherent improvement with some of the alternatives evaluated.

Influent Flows and Loads

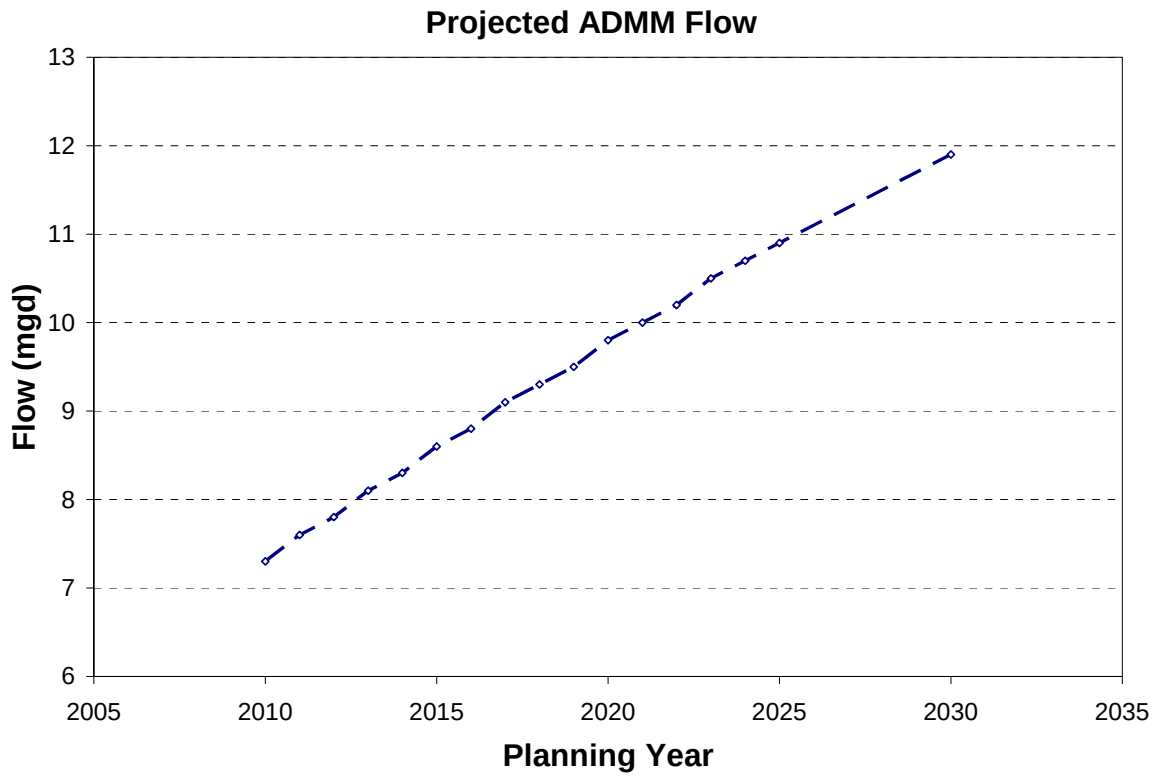
The current treatment plant capacity is summarized in Table 3. Comparing the projected treatment plant flow rate for 2010 to the treatment capacity emphasizes the fact that the Bend WRF is currently operating near its rated treatment capacity, depending on the current SVI of the system. Therefore, taking aeration basins offline for construction represents a major construction constraint. This limitation is considered in the analysis presented here.

TABLE 3
Current Treatment Plant Capacity

Condition	Plant Capacity
Existing Treatment Plant with SVI = 200 mL/g	6.0 million gallons per day (mgd)
Existing Treatment Plant with SVI = 150 mL/g	6.8 mgd
Projected 2010 AAF Flow Rate	6.7 mgd

The projected flows used for the current analysis were taken from the *Facility Plan Technical Memorandum Number 1* (Carollo, 2007) and are provided in Figure 1.

FIGURE 1
Influent Flow Projections for the Bend Water Reclamation Facility



The influent concentrations at ADMM were taken from the *Facility Plan Technical Memorandum Number 1* (Carollo, 2007) and are provided in Table 4. These influent concentrations were used to determine the loading rate of each influent parameter.

TABLE 4
Influent Concentrations at ADMM Conditions

Parameter	Concentration
Biochemical oxygen demand (BOD)	394 mg/L
Total suspended solids (TSS)	430 mg/L
Percent volatile	83 percent
Total Kjeldahl nitrogen	59 mg/L nitrogen
Ammonia Nitrogen	38 mg/L nitrogen
Total phosphorus	6 mg/L phosphorus
Influent alkalinity after pebble lime addition	200 mg/L as calcium carbonate

Overview of Optimization Alternatives

An overview of each treatment alternative is provided in this section. The first four alternatives in Table 1 may be incorporated into new aeration basins during the capacity expansion and may be beneficial enough to incorporate into existing basins, depending on the alternative selected for capacity increase. This assessment will be made during the Project Definition and Schematic Design phases of the project for optimization alternatives carried forward. The remaining alternatives have been evaluated to the greatest extent possible.

Contact Stabilization

Contact stabilization is a process configuration that conveys primary effluent to the last zone of the aeration basin during relatively short-duration peak wet weather flow events that would cause the secondary clarifiers to be overloaded with solids. During this time, RAS rates continue per normal treatment plant operation, resulting in significant storage of solids in the aeration basin zones upstream from where primary effluent is introduced. Contact stabilization improves treatment plant performance during wet weather events by reducing the clarifier solids loading rate and preventing biomass wash-out. The WRF currently has a feature to provide a level of contact stabilization, but this is undersized for future flow and loads. **An increase in capacity of wet-weather contact stabilization is recommended for incorporation into the next expansion. Additional primary effluent piping with appropriate control valves will be required between the primary effluent header in the pipe gallery and the aeration basin.**

Anoxic/Aerobic Swing Zone

During prolonged cold weather, nitrifier growth rates can slow significantly enough that complete nitrification becomes more difficult to achieve. As a result, the aerobic SRT needs to be considerably longer during colder months, when compared to warmer months, to maintain reliable nitrification. The swing zone would operate as an anoxic zone during warm weather when a lower aerobic SRT is can be used to achieve nitrification, ensuring optimized TN removal performance throughout most of the year. During cold weather, the swing zone could operate aerobically, increasing the aerobic SRT of the secondary process to maintain nitrification

performance. However, this improved nitrification performance may come at the expense of TN removal performance because of the decreased anoxic volume and associated reduction in denitrification. **To fully evaluate this alternative, the results of the treatment plant wastewater characterization study are needed because these parameters will determine the effectiveness of the swing zone and the required anoxic volume. Therefore, it is recommended that this optimization alternative be carried forward into the Project Definition Phase for complete evaluation.**

High-intensity Air for Bulking Control

Microthrix parvicella is a filamentous organism that is commonly found in treatment facilities that have incorporated biological nutrient removal. *M. parvicella* is a low-dissolved oxygen (DO) filament that grows on particulate and colloidal organic matter. It has been demonstrated that a selector, by itself, does not control this organism because selectors remove dissolved organic matter, not the particulate and colloidal load. The classic reason for *M. parvicella* is that the DO in the region just downstream of the selector is not elevated fast enough. A low-DO zone is created just downstream of the selector where particulate and colloidal "food" for *M. parvicella* (which passes through the selector) is present. This provides an environment that favors *M. parvicella* growth.

The key to controlling *M. parvicella* growth is to reconfigure the oxygen transfer system and then operate this to aerate aggressively right downstream of the anoxic zone to bring the DO up quickly. The oxygen demand right downstream of the anoxic zone is relatively high because the ammonia concentration is sufficient to "saturate" the nitrifiers (high enough so that it is non-limiting to the nitrifiers), and heterotrophic growth is driven by the availability of particulate and colloidal organic matter. This oxygen demand is predictable and can be measured. With correlations between respiration rate and required DO, the oxygen transfer need can be determined. The oxygen demand does not vary too much diurnally because the ammonia and particulate and colloidal organic matter concentrations are consistently high just downstream of the anoxic zone.

Once the oxygen demand is determined, an independent aeration zone just downstream of the anoxic zone is to be created to provide a consistent and relatively high aeration rate. This new high-intensity zone would be disconnected from the DO-based control system. Examples where this has been successful include the following:

- The Upper Occoquan Service Authority (UOSA), Centreville, Virginia, is an example of where simply providing sufficient DO corrected *M. parvicella* bulking.
- Clean Water Services' Rock Creek Facility, Beloit, Wisconsin, and the Lander Street Wastewater Treatment Facility in Boise, Idaho, step-feed systems functionally incorporate these features (by optimizing aeration distribution).

It is recommended that the high-intensity air feature be incorporated into any alternative recommended for the WRF. Providing a 'non-chemical' approach to eliminating excessive *M. parvicella* growth and reducing the SVI within the system will significantly increase the capacity and performance of the secondary treatment system. A near-term request to help with future evaluations would be for the Bend WRF to start running oxygen uptake rate (OUR) and respiration rate tests right downstream of the anoxic selector. This will help to provide a database on how we will need to reconfigure the oxygen transfer system to correct

this problem. CH2M HILL can provide specific details on the data and testing procedures recommended.

Mechanical Mixing with Aeration in the Last Aerobic Zone

When aeration basins have plug flow characteristics, organic matter and ammonia are often largely removed by the time mixed liquor enters the last aerobic zone. Air demand is typically driven by the minimum air flow required to achieve adequate mixing in this zone. When the air flow required for mixing exceeds the air flow required for treatment, high levels of DO in the last zone are present. Depending on the treatment configuration used, this high level of DO can be detrimental to biological nutrient removal (BNR) processes if additional DO is returned in a mixed-liquor recycle stream. The installation of mechanical mixing in the last zone may eliminate this higher DO, improving the overall process performance and efficiency. **To fully evaluate this alternative, the calibrated simulator will be used to predict air demands in the last aerobic zone. Therefore, it is recommended that this optimization alternative be carried forward into the Project Definition Phase for complete evaluation.**

High-strength Brewery Waste to Digester

The evaluation of incorporating high-strength wastewater from the Deschutes Brewery is presented in the technical memorandum entitled *Bend WRF Secondary Expansion Task A1.07: Preliminary WRF Process Evaluation – Deschutes Brewery Wastewater Impacts* (CH2M HILL, October 20, 2009). From a meeting with the City and Deschutes Brewery on September 23, 2009, it was concluded that direct feed to the anaerobic digesters would be the best technology for receiving the high-strength waste at the WRF. At this time it does not appear that high-strength brewery waste treatment is a feasible solution because a new anaerobic digester would be required to accommodate this high-strength wastewater. The conceptual capital cost for a new digester is approximately $7.0 million, and truck hauling of the high-strength wastewater to the Bend WRF would still be required. If in the future the City wishes to enter into a power generation operation, an economic evaluation of this addition needs to be completed.

Details on this evaluation are presented in the referenced technical memorandum.

Low-strength Brewery Waste to WRF

The evaluation of strategies to manage the low-strength wastewater from the Deschutes Brewery is presented in the technical memorandum entitled *Bend WRF Secondary Expansion Task A1.07: Preliminary WRF Process Evaluation – Deschutes Brewery Wastewater Impacts* (CH2M HILL, October 20, 2009). This evaluation work and subsequent pilot testing work concluded that there are opportunities to maximize the capacity of the existing secondary treatment process at the Bend WRF through flow and load management of the low-strength waste stream from Deschutes Brewery. Further details and information are available in a separate technical memorandum to be submitted in February 2010 to the City.

Post-aerobic Digestion

In post-aerobic digestion, anaerobically digested solids are further stabilized aerobically with an aerobic digestion step prior to dewatering. Operation of the aerobic digester using either cyclic aeration or simultaneous nitrification/denitrification (SNDN) provides TN removal without the need for an external carbon source addition, or alkalinity addition. Proper operation could decrease the soluble total inorganic nitrogen (ammonia + nitrogen oxide [NO_x]) in the

dewatering filtrate stream to below 50 mg/L, which would represent an associated decrease in plant effluent total nitrogen. This additional digestion step also enhances solids stabilization and reduces the mass of biosolids for disposal.

Although post-aerobic digestion does not add significant capacity to the WRF, the TN removal provided by the process will improve the overall nitrogen removal performance of the treatment facility. The current Pro2D analysis indicates that the dewatering filtrate recycle stream adds 6 mg/L of ammonia to the aeration basin influent, which represents 14 percent of the ammonia loading. Our predictions indicate that installation of a post-aerobic digester would decrease the effluent TN of the treatment plant by 2 mg/L nitrogen, ensuring that the effluent nitrate levels remain low in an effort to avoid more stringent regulatory requirements. **Because post-aerobic digestion does not significantly increase treatment plant capacity and the capacity improvement alternatives are expected to reliably meet the effluent TN limit of 10 mg/L nitrogen, it is recommended that post-aerobic digestion not be considered at this time for the Bend WRF.**

Summary of Recommendations for Optimization Alternatives

- Wet weather contact stabilization is recommended for incorporation in the next treatment plant expansion.
- The benefits of the anoxic/aerobic swing zone should be fully evaluated in the Project Definition phase of the project after the wastewater characterization results are available. If the cost/benefit ratio is reasonable, then this feature should be incorporated into the predesign for any new aeration basins, and possibly as a retrofit to existing basins.
- Improvements to the secondary treatment system to reduce the SVI levels are recommended for any treatment alternative selected. The use of high-intensity air as a method for reducing the growth of *M. parvicella* should be incorporated into the existing system, as well as any proposed expansion. It is recommended that OUR and respiration rate tests be conducted because these data will be used to design the high intensity air system.
- The benefits of mechanical mixing with aeration in the last aerobic zone should be more fully evaluated in the Project Definition phase of the project after the wastewater characterization results are available. Again, if the cost/benefit ratio is reasonable, then this feature should be incorporated into the predesign for any new aeration basins, and possibly as a retrofit to existing basins.
- As this time it does not appear economically realistic to discharge the high-strength wastewater from Deschutes Brewery to the Bend WRF, specifically the anaerobic digestion process. If in the future a level of co-generation is warranted by the City, a detailed evaluation of this approach will need to be completed.
- There are potential benefits for both the City of Bend and Deschutes Brewery associated with better management of the brewery's low strength wastewater. There are opportunities to equalize that flow stream and direct it to the Bend WRF during the low flow/low loading phase of the diurnal cycle at the plant. Pilot work and testing of these load management schemes is being conducted separately from this Process Evaluation Study. Details can be found in the Technical Memorandum entitled *Bend WRF Secondary Expansion, Task A1.07 – Deschutes Brewery Diurnal Flow Pilot Testing* to be submitted in February 2010 to the City.

- Post-aerobic digestion in not recommended for further consideration at this time.

Overview of Capacity Alternatives

An overview of each treatment capacity alternative is provided below. Process flow diagrams for each alternative are provided in Appendix B.

Chemically Enhanced Primary Treatment

Process overview: The goal of CEPT is to reduce the BOD and TSS loading to the secondary treatment process by improving BOD and TSS removal in primary treatment. At a given SRT, the solids concentration is dependent on how much organic matter is removed through biological treatment. By reducing BOD and TSS in the primary treatment process, the solids concentration in the secondary process is reduced. Improved BOD and TSS removal in the primary clarifiers is accomplished by adding a chemical coagulant such as ferric chloride. A ferric chloride dose of 20 mg/L is assumed for the current analysis. Although CEPT reduces the loading to the aeration basins, the additional BOD and TSS removed in primary treatment is transferred to the digestion process. This will require an adjustment to the implementation schedule for increasing the capacity of the solids handling system.

The evaluation indicates that CEPT cannot reliably increase treatment plant capacity. This occurs for the following two reasons: (1) the primary clarifiers are already removing 71 percent of the influent TSS, leaving little room for improvement and (2) based on the assumed wastewater characteristics, denitrification becomes carbon-limited when CEPT is implemented.

Aeration Basin Expansion with Existing MLE Process

Process overview: This alternative examines the capacity increase achieved by adding a fourth aeration basin and a fourth secondary clarifier with the MLE design configuration as the existing secondary unit processes. As noted previously, additional optimization features would be included to reduce the SVI within the system.

Operational complexity: Because this alternative does not shift the operational approach at the treatment plant, there is no significant change in the operational complexity over that of the existing treatment plant.

Construction constraints: Because the new aeration basin can be constructed largely without taking existing basins offline, construction constraints are minimal with this alternative.

Technology application and experience: The MLE process has been successfully employed at many treatment facilities nationwide, including the Bend WRF.

Step-feed Bioreactor Configuration

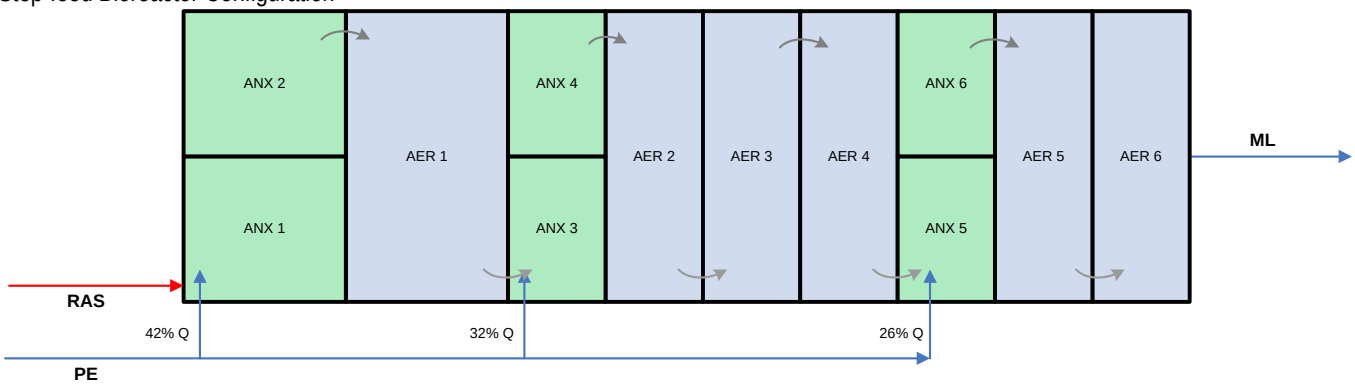
Process overview: The proposed step-feed bioreactor configuration is illustrated in Figure 2. With step-feed, the existing basins would continue to operate in parallel but would be reconfigured to split the distribution of primary effluent along the length of each basin. The RAS is introduced at the head of each basin. Because the solids concentration tapers along the basin, step-feed provides a higher solids inventory at a given SRT when compared to a system with a consistent MLSS concentration across the reactor. Similar to filtrate re-aeration, the increased solids inventory provides additional capacity in the secondary treatment system. The secondary clarifiers will essentially have the same solids loading rate as found in a traditional

MLE process. The step-feed configuration provides an increase in secondary treatment capacity without additional secondary clarifiers.

Also similar to filtrate re-aeration, the dewatering filtrate could also be fed directly to the first step-feed stage, where the biomass, and therefore nitrifier concentration, is high. Feeding this high ammonia concentration to the first aerobic zone rather than distributing it across the basin improves nitrification performance and would significantly simplify the current dewatering operations by eliminating the need to store filtrate for equalization.

Conversion to step-feed basins allows control of effluent ammonia concentration by adjusting the primary effluent flow split between the basins. The ability to bleed 1 to 3 mg/L of ammonia-nitrogen into the effluent to provide ammonia for chloramination of reuse water provides an opportunity to eliminate the current practice of introducing supplemental ammonia at the reuse system. The step-feed system would be designed with automated controls to allow optimization of the system.

FIGURE 2
Step-feed Bioreactor Configuration



Operational complexity: A step-feed system has greater operational complexity than the existing treatment facility and will likely require a higher level of automation. However, this increased automation will reduce the operational burden for treatment plant staff. The high level of automation will allow optimization of wet weather operation by allowing a gradual shift into and out of contact stabilization. Bend WRF staff members are already accustomed to a high level of automation in existing facilities (including the new headworks facility), so the operational requirements for the step-feed system should not be an issue.

Construction constraints: Reconfiguration of the existing basins prior to the construction of a new basin may not be feasible because system capacity is limited with only two basins online. The new step-feed aeration basin could be constructed largely without taking existing basins offline, limiting the construction constraints associated with this alternative. A new aeration basin can be constructed to operate either in a step-feed or standard MLE mode, allowing treatment plant staff to pilot the step-feed configuration before investing in the conversion of the existing three basins to step-feed. However, construction of a new step-feed basin will require reconfiguration of the existing RAS and primary effluent (PE) piping.

Technology application and experience: Step-feed has been implemented successfully at a number of facilities to increase system capacity and improve nutrient removal performance. Some examples of applications of this technology include Clean Water Services' Rock Creek

Treatment Facility in Oregon; the Landers Street Facility in Boise, Idaho; and the 26th Ward Water Pollution Control Plant in New York City. Furthermore, design features inherent to the step-feed configuration have been shown to reduce the growth of *M. parvicella*.

Integrated Fixed-film Activated Sludge

Process overview: As noted in "Modeling Integrated Fixed-film Activated Sludge and Moving-bed Biofilm Reactors Systems I: Mathematical Treatment and Model Development," in *Water Environment Research,* Vol. 81, June 2009 (Boltz, et al.), integrated-fixed film activated sludge (IFAS) bioreactors are hybrid suspended-growth biofilm systems that incorporate high surface area movable biofilm carriers into the activated sludge process. IFAS systems are coupled to secondary clarification processes and associated recycle streams to maintain an MLSS concentration common to activated sludge systems (a moving-bed biofilm reactor [MBBR] is a similar treatment process but these do not accumulate mixed liquor). The biofilms that develop in the media significantly increase the biomass concentration in the aeration basins so the associated aerobic SRT can be reduced. This results in an increase in treatment capacity with the same reactor volume.

Figure 3 is a schematic representation of how the existing aeration basins would be converted to the IFAS process. In essence, the first aerobic zone in each bioreactor is converted to incorporate IFAS. The remaining aerobic zones are conventional aerated zones as shown in the IFAS process flow diagram in Appendix B. The proposed IFAS zone would have the following characteristics:

- The "approach velocity" within the IFAS reactor is a key design parameter, with the criteria in the range of 30 to 35 meters per hour (m/hr). This is the velocity of the total flow going through the entire aeration basin cross-section. Given this criteria, the reactor will need to be modified accordingly. A channel would be constructed along the outer tank wall of the zones. Wastewater would flow across the tank and discharge into a launder equipped with horizontal sieves (see attached sketch for IFAS process in Appendix B). The hydraulic profile in the existing plan would require adjustment to account for increased head loss in the aeration basin, but there appears to be room to lower the profile from the second (or final) aerobic zone.
- The MLR flow rate was set to 275 percent for the preliminary concept.
- The bulk liquid DO concentration was set to 4.5 mg/L in the IFAS zone and 2.0 mg/L in the second aerobic (activated sludge) zone, allowing an ADMM of 10.5 mgd. With an increase in DO concentration to 6.0 mg/L in the IFAS zone, treatment to an ADMM of 11.9 mgd with the three existing basins appears to be achievable. Note that this will need to be confirmed once the wastewater characterization and associated calibration of the simulator is complete.
- The treatment objective was met at 67 percent fill (percentage of media included in the reactor). This is the maximum fill allowable in a moving-bed bioreactor.
- The conceptual SRT is 2.75 days and resulted in a 3,300 mg/L MLSS concentration. This SRT may be adjusted depending on sludge settling characteristics; however, it assumes that this process modification will eliminate excessive filament problems. Sludge settleability with an IFAS system is typically similar to what would be expected for a well-operating, traditional activated sludge process.

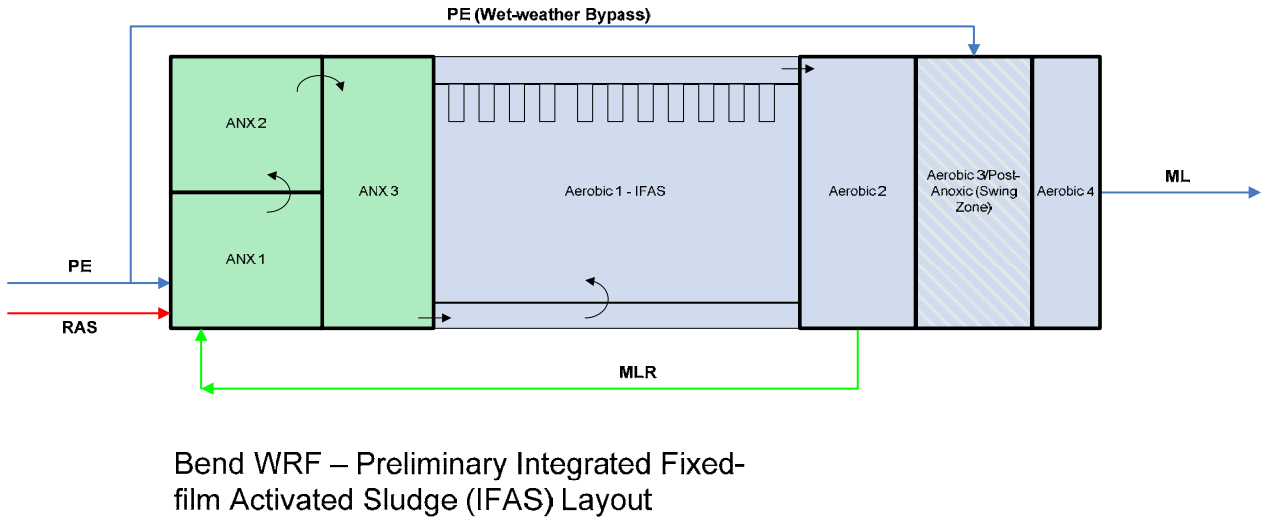
- Following the IFAS zone within the aeration basins, a post-anoxic/aerobic swing zone would need to be installed. This would allow flexibility within the system to meet the TN goal. From the initial process simulations, it appears that this will help address some of the existing alkalinity issues at the WRF. Continued evaluation is required but there may be an opportunity to reduce the supplemental alkalinity (lime addition at headworks) currently required.
- Because of the unique bioreactor layout, spray headers to control potential foaming in the IFAS zone and a special surface wasting trap to allow bleed-off of foam, while retaining the media, are recommended.
- According to the preliminary simulation, approximately 34,000 standard cubic feet per minute (scfm) of aeration air is required in the IFAS zone during 10.5-mgd ADMM conditions. This is approximately 80 percent of the total oxygen demand, with the remaining oxygen required in the following traditional aerobic zones.
- New medium-bubble diffusers would be required for the proposed IFAS zone. Assuming 40 scfm per medium-bubble diffuser, approximately 850 diffusers would be required.

There are a number of benefits in converting the bioreactors to an IFAS system, including the following:

- A significantly reduced construction timeframe will result in months of construction rather than years.
- No earthwork, minimal concrete work, and fewer construction materials are required for installation. This may be the most sustainable approach with the smallest carbon footprint for construction.
- IFAS offers the unique opportunity to provide a construction-free phasing approach for future capacity. Once this initial modification to the aeration basins is complete, the amount of IFAS media included in the reactors will determine the associated capacity of the WRF. For example, using a 46 percent fill would result in an 8.0-mgd ADMM capacity with the three existing basins (reducing the construction cost accordingly). Additional capacity from this can be achieved simply by adding more media. The plastic media is delivered in tote-sized sacks of pre-defined volume. The amount to be added can be easily cataloged. The WRF staff would simply be required to condition the media (by wetting) during a brief period prior to installation, install the additional media within the IFAS zone (requiring a boom truck or similar hoisting equipment), and manage some floating media and possible reactor foaming for approximately 3 days. After this short "startup" period, the process should become stabilized. This construction-free phasing approach allows for a "pay as you go" funding opportunity. After the initial construction phase, future capacity can be incorporated into the facility by simply purchasing additional media.
- IFAS offers the nitrification benefits inherent to biofilm reactors (increased stability, ability to handle peak influent loads). This feature allows the system to be operated with essentially a set effluent ammonia level. The system can be designed and operated to provide an effluent ammonia concentration receptive to the chlorination requirements for the reuse filtration system. This will eliminate the need for the use of supplemental ammonia as currently used by the WRF during the reuse season.

- No additional footprint is required at the WRF for new aeration basins through 2030 (a new secondary clarifier would eventually be required in 2024).

FIGURE 3
Preliminary IFAS Bioreactor Configuration



Operational complexity: No significant difference exists in operational complexity when compared to the existing MLE system. Additional foam control measures would need to be incorporated into the design because foaming can be an issue. Management of the media during initial installation to minimize floating would be required. Optimization of the MLR would be required to maintain approach velocities in the IFAS reactor within design criteria.

Construction constraints: The individual bioreactors would need to be off-line for approximately 4 to 6 weeks (previous projects have required around 4 weeks per bioreactor) to accomplish modifications to incorporate IFAS. Additional modifications to the primary effluent and mixed liquor piping around the aeration basin would be required to increase the overall hydraulic capacity of the existing system.

Technology application and experience: IFAS systems are relatively new to the United States but have been popular for a number of years in Europe, where the technology was developed. The first installation in Europe was in the early 1990s and the first U.S. installation was in 2002. Many facilities are currently using this technology. CH2M HILL has been involved in a detailed, full-scale pilot study at the James River Treatment Plant, Hampton Roads Sanitation District, Virginia. One 1.5-million gallon (MG) bioreactor was converted to an IFAS system to help determine the performance and capacity improvements with the modification. The full-scale pilot has been very successful, with a number of optimization techniques for the layout and operation of the system determined. Other projects where this technology has been used include the following:

- Broomfield: Broomfield WRF—IFAS in operation since 2003, 8-mgd facility now being expanded to 12 mgd. Includes enhanced biological phosphorus removal (EBPR) with MLE configuration option.

- South Adams County, Colorado: Williams Monaco Wastewater Treatment Plant—MBBR in operation since 2005, 7 mgd with MLE configuration.
- Cheyenne, Wyoming: Dry Creek Wastewater Treatment Plant—IFAS in operation since about 2005, 12 mgd with MLE configuration.
- Cheyenne, Wyoming: Crow Creek Wastewater Treatment Plant—MBBR in operation since about 2005, 6 mgd.

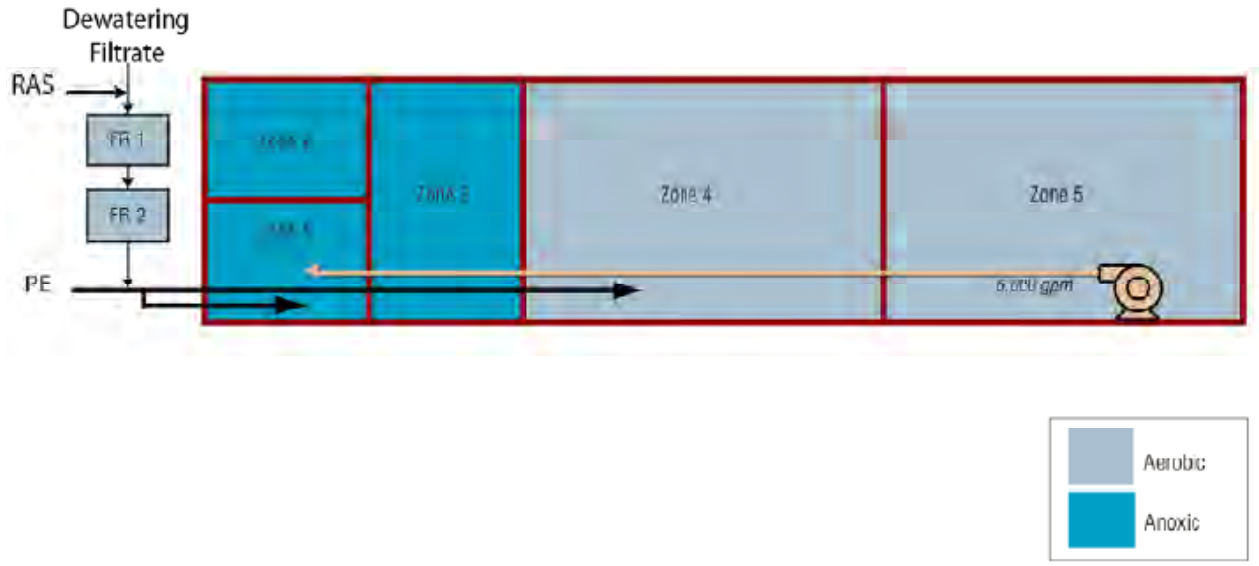
Typical drivers for the use of IFAS have been increased capacity in small (existing) facility footprint, improved nitrification and TN removal, and short timeframe for construction.

Expansion to meet future TN limits: The conceptual design for the IFAS system provides an effluent TN less than 10 mg/L. As noted in the Facility Plan, future effluent TN limits of 6 mg/L and 3 mg/L may be established. If the effluent TN limit was reduced from the current level, additional features would need to be incorporated into the system to meet the proposed effluent goals. To meet an effluent TN limit less than 6 mg/L supplemental carbon addition would be required within the bioreactors. This would be used within the anoxic environments, driving the denitrification process to provide the required performance. Tertiary treatment in the form of denitrification filters (biologically active filters, moving bed biofilm reactors, or similar) would be required to meet an effluent TN limit less than 3 mg/L.

Filtrate Re-aeration

Process Overview: Filtrate re-aeration is the proposed near-term solution for capacity expansion in the Facility Plan (Carollo, 2007) and is presented schematically in Figure 4. With filtrate re-aeration, the dewatering filtrate is mixed with the entire flow of RAS in two 0.2-MG filtrate re-aeration basins. Ammonia in the filtrate is removed in these basins where the biomass and nitrifier concentration is high, reducing the ammonia loading to the main secondary process. The capacity achieved through filtrate re-aeration basins is provided by the additional solids holding capacity for the secondary treatment system. This additional holding capacity decreases the solids concentration in the main secondary process while maintaining the same solids inventory at a given SRT. Filtrate re-aeration achieves additional capacity in a manner similar to contact stabilization or step-feed.

FIGURE 4
Filtrate Re-aeration Configuration (from Facility Plan, Carollo 2007)



Operational complexity: This alternative does not represent a significant shift in the operational approach at the treatment plant but is slightly more complex than the standard MLE process. This is typical of a contact stabilization process and the associated operational requirements.

Construction constraints: Because the filtrate re-aeration basin can be constructed largely without taking existing basins offline, there are few construction constraints associated with this alternative. However, the RAS and filtrate piping would need to be reconfigured.

Technology application and experience: Experience in the U.S. is limited. Forms of this treatment alternative have been used at the 26th Ward Water Pollution Control Plant in New York City and at the Theresa Street Wastewater Treatment Facility, Lincoln, Nebraska.

Bioaugmentation

Process overview: Bioaugmentation is a sidestream process where the ammonia in the filtrate is used to grow nitrifiers separate from the main secondary process. Bioaugmentation differs from filtrate re-aeration in that a primary process goal is to supplement the main bioreactor with nitrifiers from the side-stream treatment reactor to increase overall system capacity and treatment reliability.

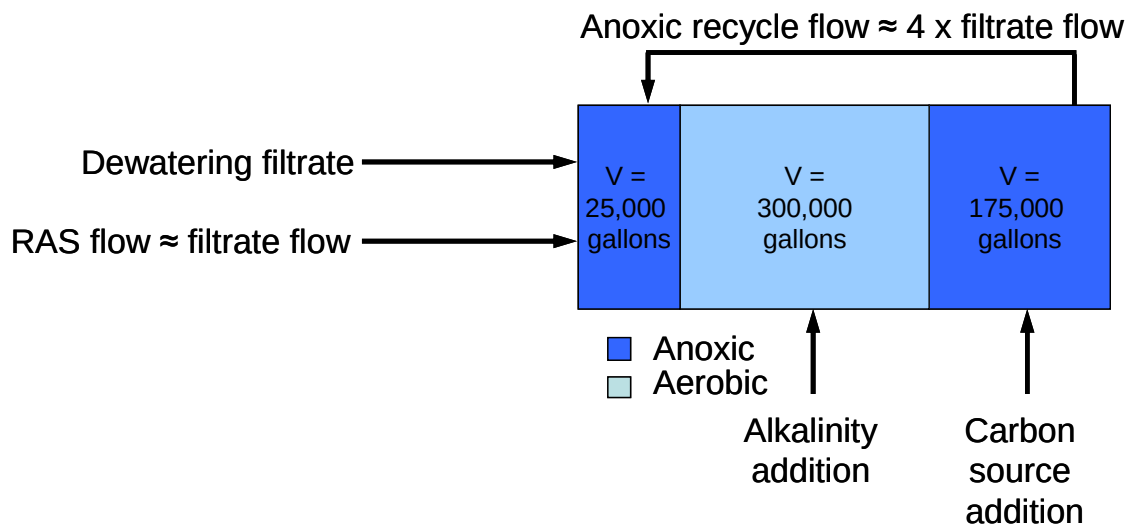
The nitrifiers grown in the bioaugmentation reactor are used to seed the main bioreactor, increasing the number of nitrifiers present in the mixed liquor. With bioaugmentation, the SRT can also be reduced to decrease the solids concentration in the system while reliably maintaining a high level of nitrogen removal. Bioaugmentation is especially advantageous at low temperatures when a longer SRT is required for nitrification. The additional nitrifier population from the bioaugmentation process allows for a reduced SRT.

The proposed bioaugmentation process for the Bend WRF is shown in Figure 5. This bioaugmentation process incorporates a pre-anoxic zone for removal of odor-causing compounds and excess dewatering polymer present in the filtrate. This pre-anoxic zone is

followed by an aerobic zone where nitrifiers are grown, followed by another anoxic zone for TN removal. The TN removal provided by this bioaugmentation configuration also reduces the TN loading to the main secondary process, increasing the TN removal reliability for the WRF. Within the side-stream treatment reactor, supplemental carbon addition is necessary for reliable denitrification, along with supplemental alkalinity addition to maintain a neutral pH. The total volume required in the side-stream treatment reactor is 0.5-MG.

Although the elimination of ammonia from the filtrate stream would reduce the alkalinity required in the main secondary process, it is expected that alkalinity addition would still be required.

FIGURE 5
Bioaugmentation Reactor Configuration



Operational complexity: This alternative represents a significant increase in the operational complexity of the system because treatment plant staff would be running two individual activated sludge processes in parallel. This treatment process would also require additional chemical addition systems.

Construction constraints: Because the bioaugmentation basin can be constructed largely without taking existing basins offline, the construction constraints associated with this alternative are reduced. Process piping, such as the RAS and filtrate systems, would need to be reconfigured.

Technology application and experience: There are few applications of full-scale bioaugmentation systems nationwide, limiting the industry-wide experience with this technology. However, this has been a proven approach for improving facility capacity in places such as the 26th Ward Water Pollution Control Plant in New York City.

Implementation Approach for Providing 2030 Treatment Capacity

Based on the results of this incremental evaluation, the five alternatives listed in Table 5 will provide the Bend WRF with secondary capacity through the year 2030 or beyond. The

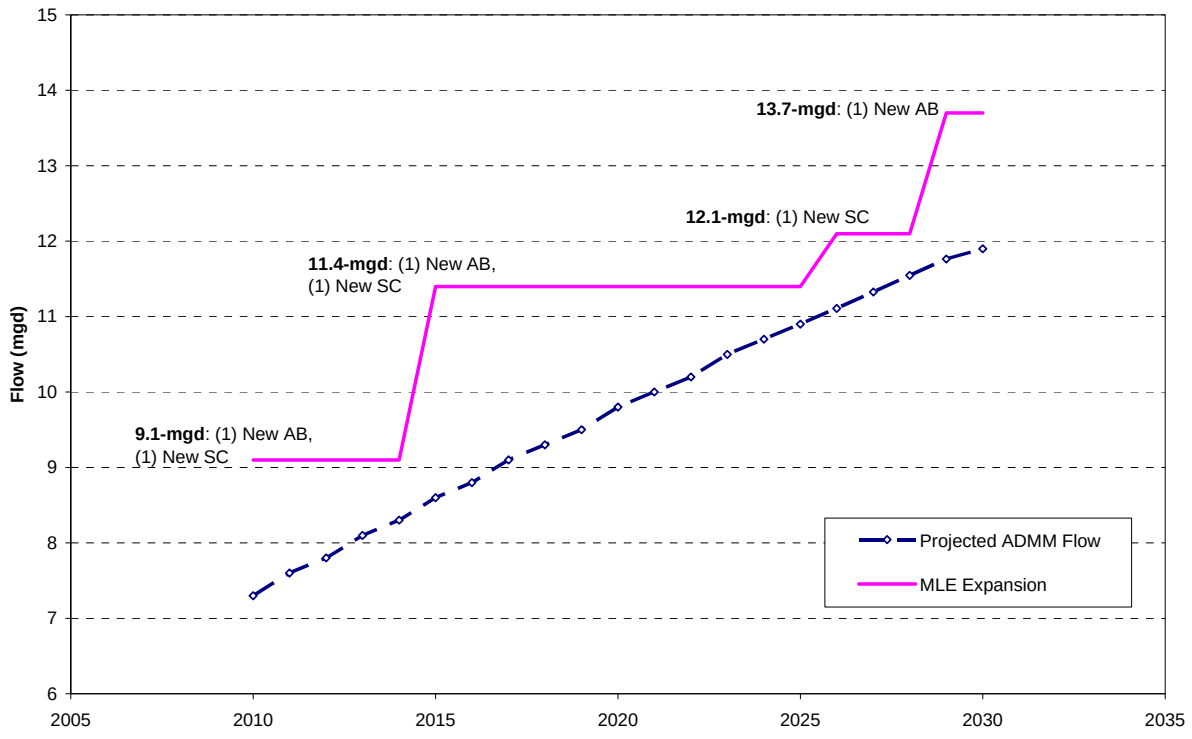
implementation schedule for each alternative is shown in Figure 6 (a through f). All alternatives will require a new primary clarifier and a new blower facility.

Table 5
Improvements Required to Provide the Bend WRF with 2030 Treatment Capacity

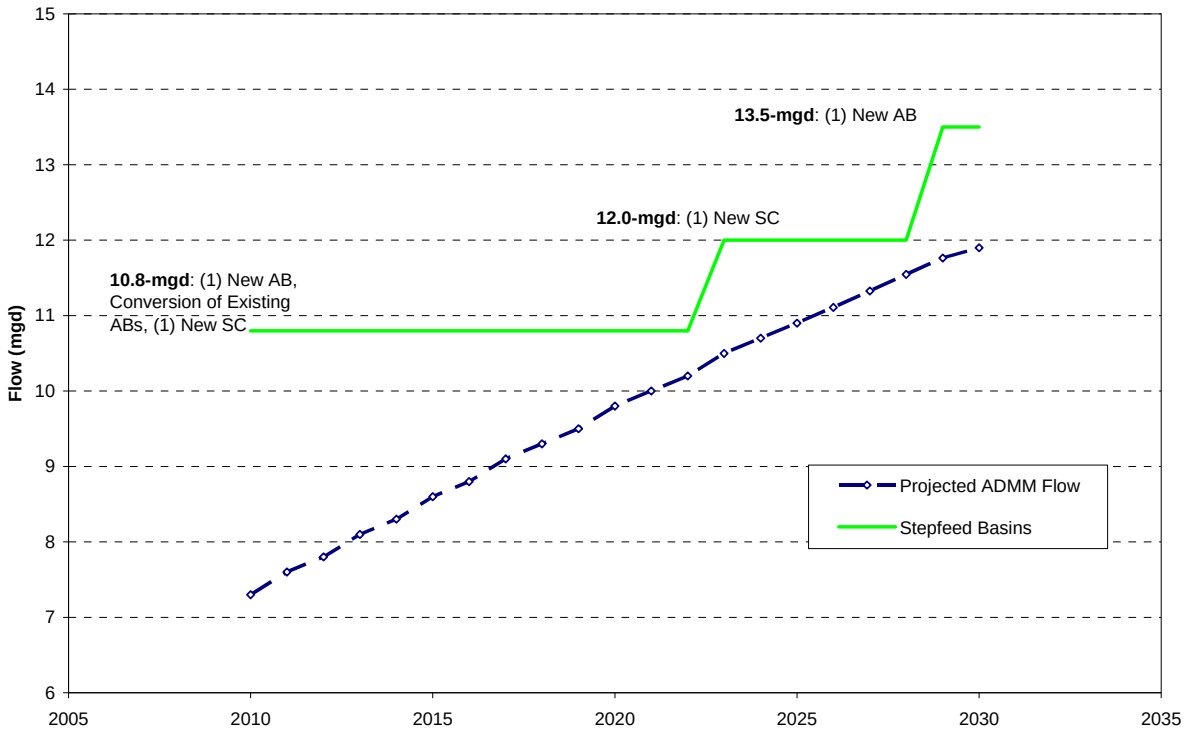
	Program of Improvements			
Alternative	**Capacity (mgd)**	**Number of 1.05 MG Bioreactors**	**Number of 80-foot Secondary Clarifiers**	**Number of Additional Bioreactors (Volume of Each)**
Existing Treatment Plant	6.8	3	3	
Projected 2030 ADMM Capacity	11.9			
AS-3. MLE	13.7	6	6	
PT-3. Step-feed	13.5	5	5	
PT-11. IFAS	12.0	3	4	
AS-1. Filtrate Re-aeration	12.1	5	5	2 (0.2 MG)
PT-6. Bioaugmentation	13.5	5	5	1 (0.5 MG)

FIGURE 6
Implementation Schedules through 2030 for Capacity Alternatives

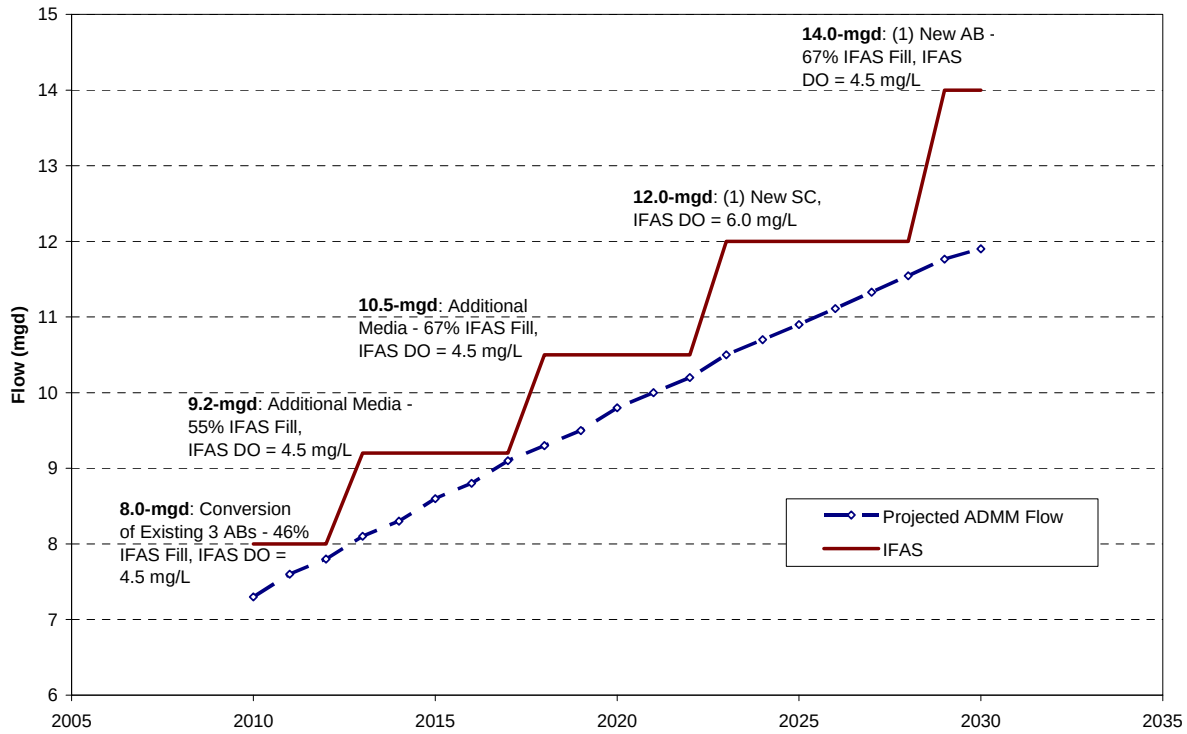
(a) MLE Alternative (AS-3)



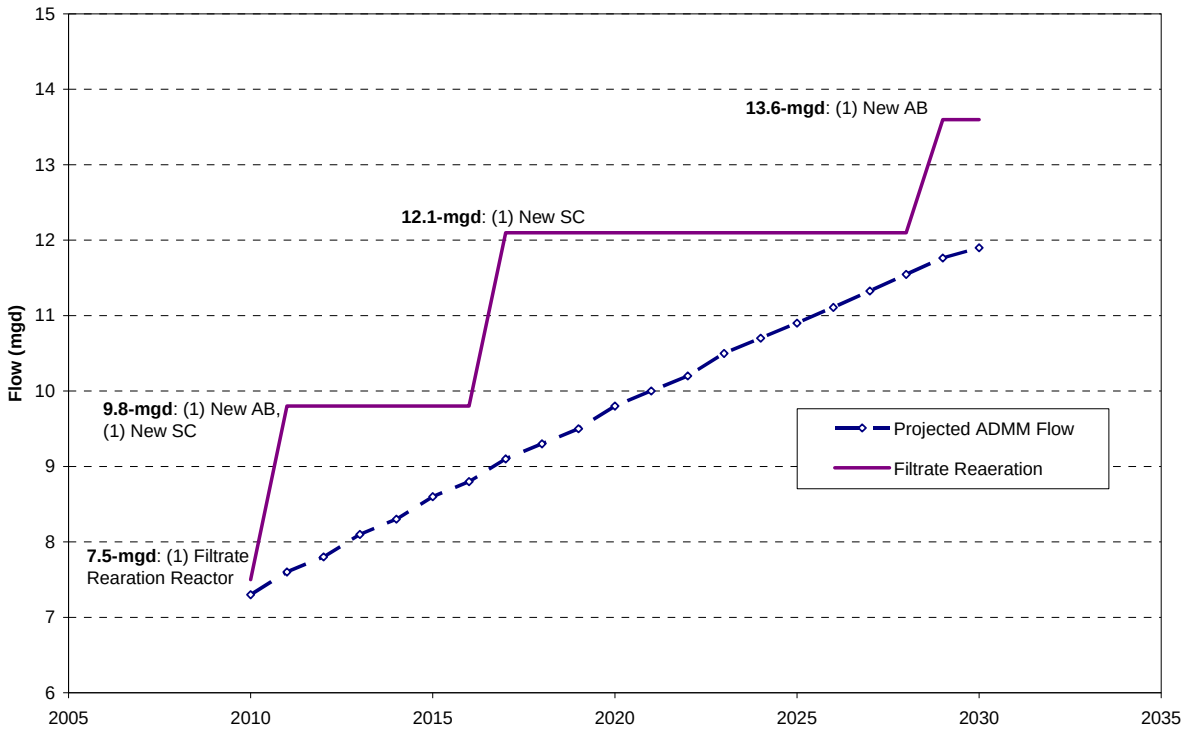
(b) Stepfeed (PT-3)



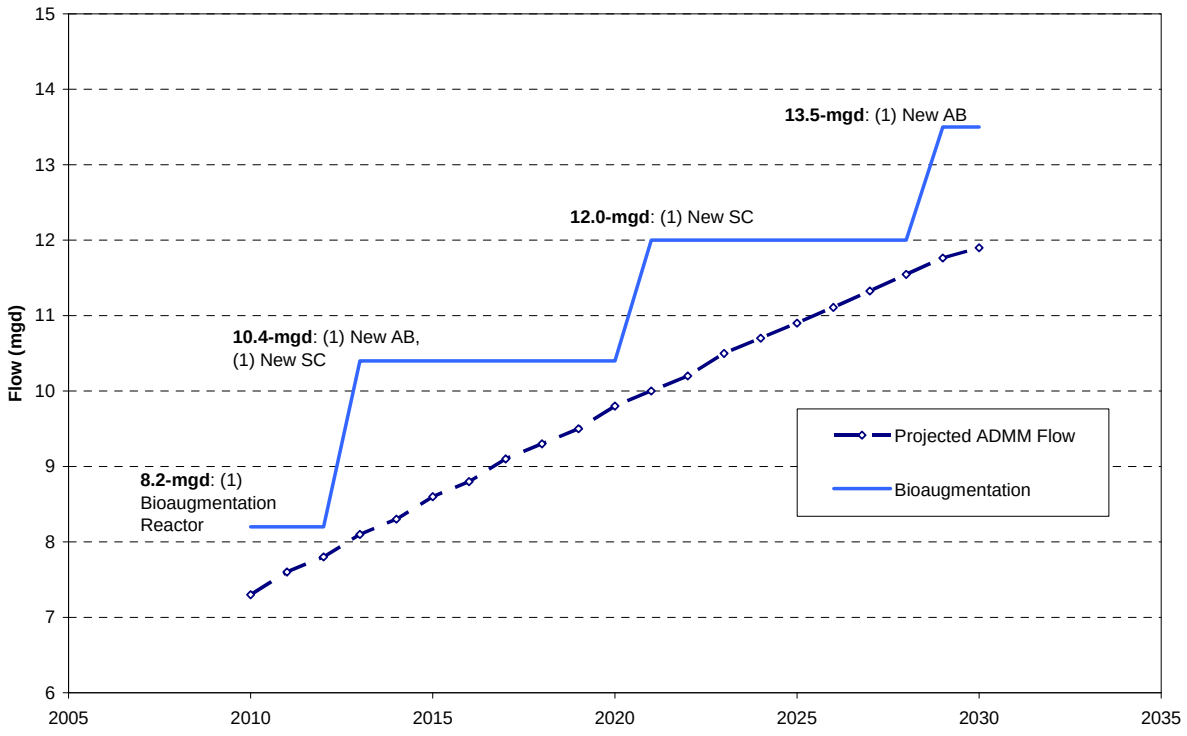
(c) IFAS (PT-11)



(d) Filtrate Reaeration (AS-1)



(e) Bioaugmentation (PT-6)



The implementation schedules are presented for each alternative through the planning period to 2030. These implementation schedules only include the major secondary treatment unit processes and do not include unit processes common to all alternatives (primary clarifier, gravity thickener, etc.). For the majority of the alternatives the phased approach to expansion will require the construction of additional unit processes. The IFAS alternative, presented in Figure 6c, would only require additional media within the reactor for some of the interim capacity increases. In addition, as discussed previously, the operation of the DO level within the IFAS zone would need to be adjusted to meet future build-out capacities (it is assumed that the system would be designed for this increase in DO during the initial aeration basin conversion project).

A summary of the initial implementation phases for the associated treatment alternative are presented in Table 6.

TABLE 6
Incremental Capacity Results

Alternative	Plant Capacity
AS-3. New MLE Basin	9.1 mgd
PT-3. Capacity with four step-feed basins.	10.8 mgd
PT-11 IFAS. Conversion of aeration basins with 46 percent media fill	8.0 mgd
PT-6. Bioaugmentation	8.2 mgd
AS-1. Filtrate re-aeration (contact stabilization)	7.5 mgd

Cost Opinion

The details for the cost opinion are presented in the companion technical memorandum found in Appendix A. A summary of the cost opinion results is presented in Table 7.

TABLE 7
Bend WRF Process Evaluation – Conceptual Cost Opinion Summary

Alternative	Implementation Year	Total Capital Cost (2009 Dollars)	Present Worth (2030) [a, b]
AS-3. MLE			$23,218,000
	2010: (1) AB, (1) SC, Blowers	$16,929,000	
	2014: (1) AB, (1) SC	$8,385,000	
	2015: (1) Primary Clarifier	$1,390,000	
	2025: (1) Secondary Clarifier	$1,936,000	
PT-3. Step-feed			$20,412,000
	2010: (1) AB, (1) SC, Conversion of Existing ABs to Step-feed, Blowers	$17,988,000	
	2015: (1) Primary Clarifier	$1,390,000	
	2022: (1) Secondary Clarifier	$1,936,000	

TABLE 7
Bend WRF Process Evaluation – Conceptual Cost Opinion Summary

Alternative	Implementation Year	Total Capital Cost (2009 Dollars)	Present Worth (2030) [a, b]
PT-11. IFAS			$20,567,000
	2010: Conversion of (3) ABs to IFAS (46-percent Fill), Blowers	$15,744,000	
	2013: Additional Fill to ABs (55-percent Fill)	$391,000	
	2015: (1) Primary Clarifier	$1,390,000	
	2018: Additional Fill to ABs (67-percent Fill)	$521,000	
	2024: (1) Secondary Clarifier	$1,936,000	
AS-1. Filtrate Re-aeration			$22,757,000
	2010: (1) Filtrate Re-aeration Reactor	$3,726,000	
	2011: (1) AB, (1) SC, Blowers	$18,071,250	
	2015: (1) Primary Clarifier	$1,390,000	
	2017: (1) Secondary Clarifier	$1,936,000	
PT-6. Bioaugmentation			$22,589,000
	2010: (1) Bioaugmentation Reactor	$3,726,000	
	2012: (1) AB, (1) SC, Blowers	$18,071,000	
	2015: (1) Primary Clarifier	$1,390,000	
	2020: (1) Secondary Clarifier	$1,936,000	

NOTES:
[a] The present worth calculations take into account the implementation schedule presented in Figure 6.

[b] Present worth calculations are based on Total Construction Cost, not Total Capital Costs. (Total Capital Costs include non-construction costs such as permitting, engineering, services during construction, etc).

Summary

Table 8 provides a summary of the decision-relevant, non-cost criteria presented in this memorandum.

TABLE 8
Comparison of Secondary Expansion Alternatives

Process	Advantages	Disadvantages
AS-3 MLE Basin	• Existing process, no shift in process operational knowledge • Can implement contact stabilization for wet weather operation • Few construction constraints because does not require existing basins to be taken offline	• Existing *Microthrix parcivella* issues will require additional modifications to existing basins to improve sludge settleability • Requires largest expansion of basin volume to reach 2030 capacity (up to six total aeration basins are required)
PT-3 Step-feed	• Increased capacity over MLE configuration for same basin volume • Eliminates pumping costs associated with mixed liquor recycle • Can bleed 2 to 3 mg N/L of ammonia into effluent for reuse water chloramination • Design features provide improved settleability with reduction in *Microthrix parcivella* growth • Improved wet weather operating mode, similar to contact stabilization • Direct feed of filtrate to bioreactor (similar to filtrate re-aeration) provides simplified dewatering operations and improved nitrogen removal performance • Significant historical design and operating experience available • Minimal construction constraints if new step-feed basin is constructed first.	• Higher operational complexity than MLE configuration, requires additional automation • Reconfiguration of existing basins without construction of a new basin may not be feasible as system capacity is limited with two aeration basins in service • Modifications to primary effluent and RAS piping required • Internal baffle modifications may be required
PT-11 IFAS	• Relatively short timeframe required for conversion of existing aeration basins to IFAS system • Smallest overall basin volume required to reach 2030 capacity (3 existing basins converted to IFAS system with three existing secondary clarifiers). • Improved nitrification reliability due to biofilm growth of nitrifiers on plastic media • Recent, successful full-scale pilot design and operating experience available (James River WWTP)	• Some construction constraints because requires operating with only two basins during conversion • Improvements to existing piping required to provide associated hydraulic capacity • Costs of integrated fixed-film plastic media subject to variable pricing (tied directly to price of oil) • Modification of aeration system required • Relatively new technology to United States (significant experience in Europe) • Significant initial capital investment with conversion of all three aeration basins

TABLE 8
Comparison of Secondary Expansion Alternatives

Process	Advantages	Disadvantages
AS-1 Filtrate Re-aeration	• Few construction constraints because does not require existing basins to be taken offline • Increase in capacity similar to contact stabilization approach • Reduction in ammonia load from filtrate stream	• Existing *Microthrix parcivella* issues will require additional modifications to existing basins • For the same additional reactor volume, does not provide as much capacity as bioaugmentation • Future expansion of aeration basins required • Modifications to RAS and filtrate piping required
PT-6 Bio-Augmentation	• Provides opportunity to phase capital cost expenditure over time • For the same additional reactor volume, provides more capacity than filtrate reaeration • Few construction constraints because does not require existing basins to be taken offline • Can implement contact stabilization for wet weather operation • Provides total nitrogen removal increasing nitrogen removal reliability for the WRF	• Requires alkalinity addition and external carbon source addition • Highest operational complexity compared to other alternatives • Would require a significant shift in dewatering operation to provide a relatively continuous stream of warm filtrate. This may not be feasible for the Bend WRF. • Limited amount of design and operating experience relative to the other alternatives
DG-1 Post-aerobic digestion	• Provides improved TN removal performance • Improved reduction in VSS and associated biosolids • Improved dewaterability of digested solids	• Minimal capacity improvements

Recommendations for the Path Forward to Predesign

This Process Refinement Study was conducted to help select the appropriate treatment alternative(s) to carry forward into the Project Definition and Schematic Design phases of the project. This memorandum presents the technical basis for evaluating and selecting a preferred process solution for the next major phase of capacity expansion at the Bend WRF. That technical basis is a result of the treatment process analysis, the cost evaluation work, and the process benefits described in Table 8.

Based on this technical work and cost evaluation, CH2M HILL would propose the following actions regarding the major capacity-oriented alternatives:

- **CEPT.** Not effective in providing increased capacity. No further analysis needed. Drop this alternative from further consideration.
- **Aeration Basin Expansion (MLE process) with new Secondary Clarifier.** Proven process, but more costly than step-feed. Continue to evaluate this alternative as a baseline for comparison to other solutions.
- **Step-feed Bioreactor Configuration.** Proven process, less costly than MLE. Further consideration is warranted.
- **IFAS.** Relatively new process when compared to MLE or step feed, but this has been proven in a number of applications, similar cost to step-feed. Further consideration is warranted.
- **Filtrate Re-aeration.** More operationally complex than MLE, step-feed, or IFAS. More costly than step-feed and IFAS, relative to the benefits provided. Continue to evaluate this alternative as a solution representative of the April 2008 Bend WRF Facility Plan recommendations.
- **Bioaugmentation.** More operationally complex than MLE, step-feed, or IFAS. More costly than step-feed and IFAS. Drop this alternative from further consideration.

This technical work and the cost analysis presented in this memorandum form the basis of the decision process moving forward. In order to minimize the predesign effort, it is still important to take the recommended alternatives (IFAS, filtrate re-aeration, expanded MLE basins, and step-feed) and select a single, preferred approach.

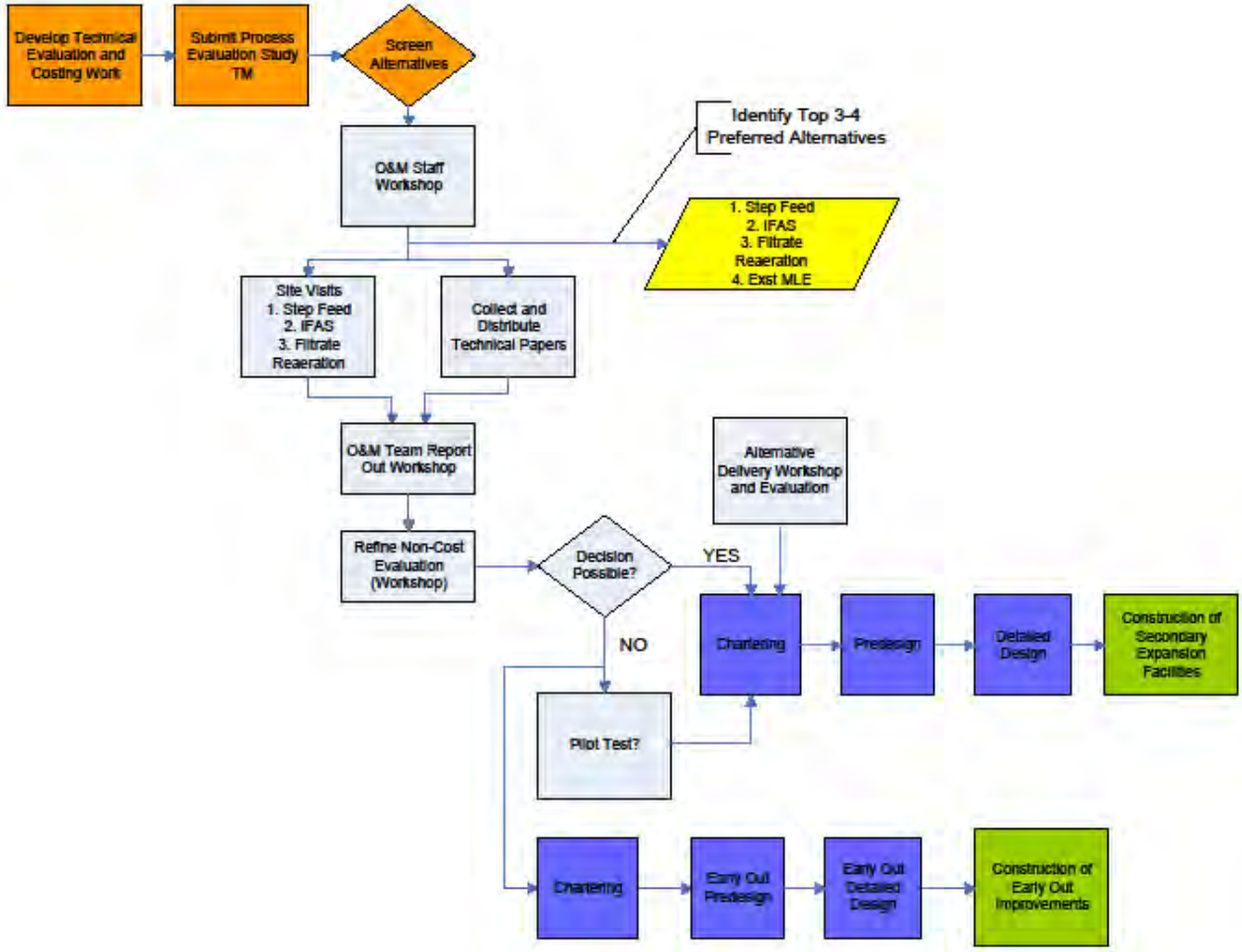
The decision process for selecting that single, preferred process solution is currently being refined, and will be captured in this technical memorandum before the memorandum is finalized.

Process Alternative Selection

The technical and cost evaluation effort has provided the basis for screening the list of major capacity-oriented alternatives generated through the VE Study and Process Evaluation tasks. The City and the Consultant team agreed that selection of a single, preferred approach for the secondary expansion of the Bend WRF should be carried forward to predesign. A process was developed and implemented to help make this decision.

The decision-making process is depicted in Figure 7. Following the technical evaluation and costing work, a detailed screening of proposed alternatives was completed. The screening process involved the distribution of technical papers and visits to operating treatment facilities employing the technologies under consideration. This provided a better understanding for staff of each viable alternative and helped determine the advantages and disadvantages relative to application at the City of Bend. The City purposefully engaged affected City staff with Operations and Maintenance (O&M) responsibilities to provide a balanced review of the process alternatives and to prepare and present reports back to the entire City O&M stakeholder group.

FIGURE 7
Decision Process—Process Evaluation Study



Site visits to multiple operating facilities featuring these technologies were completed by review teams from the City and CH2M HILL. Table 9 lists the operating facilities visited (see site visit photos on enclosed CD).

TABLE 9
Bend WRF Process Evaluation—Treatment Technologies Site Visits

Process Alternative	Facility Visited
IFAS	Williams Monaco Wastewater Treatment Plant, Henderson, Colorado: 7-mgd MBBR (2004) Broomfield WRF, Broomfield Colorado: 8-mgd IFAS (2003) Dry Creek Wastewater Treatment Plant, Cheyenne BOPU, Cheyenne, Wyoming: 12-mgd IFAS (2005)
Step-feed bioreactor configuration	Rock Creek AWWTF, Clean Water Services, Hillsboro, Oregon
Filtrate Re-aeration	New York City, 26th Ward WPCP: New York, New York

After the completion of the operating facility tours, on January 13, 2010, the City review teams presented their findings to City O&M stakeholders and the CH2M HILL design team. Copies of the staff PowerPoint presentations are included in Appendices C through F. Based on this review of the proposed technologies, the non-cost criteria used for the evaluation of alternatives was refined. The screening criteria are presented in Figure 8. The non-cost evaluation and ranking of each alternative was completed by City staff and compiled by the consultant team. A blank form used by staff for this ranking is shown in Figure 9. Each criterion was weighted equally, although following scoring it was observed that the relative ranking of the highest ranked alternatives would not change should different weighting factors be applied.

The final rankings from City staff are presented in Figure 10. The IFAS alternative is the highest ranked alternative, followed by the step-feed configuration. Based on this non-cost evaluation and previous costing work, the IFAS alternative will be carried forward into design.

On February 1, 2010 a workshop was conducted with City O&M stakeholders to reveal the scoring and discuss additional comments or concerns. The following list is a summary of major topics of discussion as documented in meeting notes. Several of these discussion topics will warrant further evaluation and design detailing in predesign phase. Meeting notes from the February 1 workshop are included as Appendix G.

February 1, 2010, O&M Stakeholder workshop findings and observations (summarized from meeting notes):

1. Develop graphics for phasing, costs, and capacity during predesign. This will be good for Council and other instructional use for those unfamiliar with the work to-date.
2. IFAS can be added over time to a reactor to incrementally increase treatment capacity. Need to develop an approach to ease the effort involved with adding media to IFAS basins so that O&M staff can perform that function in the future as growth increases capacity demands.
3. A fourth secondary clarifier is not needed until about 2023 with all IFAS options. During predesign, the design team needs to evaluate the timing and approach to flow split for this future clarifier.

4. During predesign, the design team needs to evaluate the time involved with new basin versus retrofit. A new aeration basin would take 12 to 18 months. Modifying existing basins may take 6 to 8 weeks per basin.
5. Pre-purchase or pre-selection of equipment (IFAS, blowers, maybe other equipment) would likely be incorporated into the design approach. During predesign, determine the approach to design, as well as evaluate alternative delivery of the constructed project (construction manager/general contractor, design-build, conventional design-bid-build, etc.)
6. Four primary vendors of IFAS media currently exist (Veolia, IDI, World Water Works, and Entec). Vendors/suppliers should be encouraged to give presentations to O&M staff during predesign.
7. Bend staff will set up meeting with Department of Environmental Quality to review Process Evaluation technical memorandum and decision process.
8. Bend staff will coordinate with the Public Works director to review the Process Evaluation recommendations and path forward to predesign.
9. Bend staff will set up workshop with Council to report the results of the Process Evaluation study.

FIGURE 8
Screening Criteria

	BRAINSTORMING CRITERIA (from Workshop) INCLUDED IN SCREENING CRITERIA					
	Proven state of technology	Constructability	Ease of operation	Ease of maintenance	Adaptability to future regulatory requirements	Ability to meet cash flow requirements and rate schedule
SCORE	SCORING CRITERIA					
1	Few full scale installations.	Construction sequencing will result in failure to meet permit limits. MOU with DEQ unlikely.	Significant operational complexity associated with proposed process expansion	Significant maintenance complexity associated with proposed process expansion	Process is not adaptable to future regulatory requirements (reduced TN, TSS, BOD, nutrients). Significant GHG emission risk.	Does not meet current cash flow and rate schedule
2		Construction possible only with DEQ Memorandum of Understanding				
3	Some full scale installations, limited operating experience. Mixed reviews	Extended periods of reduced process capacity, but possible to implement without permit excursions	New unit process, but relatiely simlilar operational complexity to existing processes	New unit process, but relatiely simlilar maintenance complexity to existing processes	Process is neutral related to future regulatory requirements. GHG emissions can be managed with well-understood operation techniques.	Meets current cash flow and rate schedule
4		Typical sequencing constraints required.				
5	Well demonstrated, Bend staff familiar with it	No sequencing constraints. Start process off-line with little or no impact to other operations	Similar to, or improves operating conditions, over existing conditions.	Similar to, or improves maintenance efforts, over existing conditions.	Process provides advantages/adaptability to meet future regulatory limits. No negative Greenhouse Gas (GHG) effects.	Improves on current cash flow and rate schedule

FIGURE 9
Secondary Process Options—Blank Form

Bend WRF Secondary Expansion Process Evaluation

	SECONDARY PROCESS OPTIONS	Proven state of technology	Constructability	Ease of operation	Ease of Maintenance	Adaptability to future regulatory requirements	Ability to meet current cash flow and rate schedule	TOTAL SCORE	
	Weighting	1.0	1.0	1.0	1.0	1.0	1.0		Add written comments in this column for each alternative.....
1	**Process Alternatives**								
a.	**Alternative 1 - Step Feed**								
b.	**Alternative 2 - IFAS**								
c.	**Alternative 3 - Filtrate Reaeration**								
d.	**Alternative 4 - Existing MLE**								

FIGURE 10
Secondary Process Options—Final Rankings from City Staff

Bend WRF Secondary Expansion Process Evaluation

	SECONDARY PROCESS OPTIONS	Proven state of technology	Constructability	Ease of operation	Ease of Maintenance	Adaptability to future regulatory requirements	Ability to meet current cash flow and rate schedule	TOTAL SCORE
1	**Weighting**	1.0	1.0	1.0	1.0	1.0	1.0	
	Process Alternatives							
a.	**Alternative 1 - Step Feed**	4.3	3.5	3.7	3.7	4.4	3.3	**23**
b.	**Alternative 2 - IFAS**	4.4	4.3	4.9	4.1	4.7	3.4	**26**
c.	**Alternative 3 - Filtrate Reaeration**	2.7	2.7	2.6	2.5	2.7	2.4	**16**
d.	**Alternative 4 - Existing MLE**	4.7	3.3	4.4	3.3	3.0	2.6	**21**
e.								
g.								
h.								

Recommendations for Path Forward into Project Definition and Predesign

Completion of this process evaluation memo concludes the Task A1.06 Process Evaluation work. This completes the alternative analysis phase of the project which was initiated during the VE Study performed in June 2009. The consultant team has prepared a scope amendment for predesign of the selected secondary process alternative along with the other facilities recommended by the Facilities Plan (primary clarifier, disinfection improvements, hydraulic bottleneck elimination, blower efficiency upgrades, solids improvements).

The goal of the Project Definition phase of the work will be to evaluate alternatives identified in the Facilities Plan and define constraints, design criteria, and other factors that will influence the layout, treatment capacity, and operation of the recommended facilities. The result of that phase of the predesign will be a recommended and definitive project (or group of projects). Example activities to be performed during Project Definition include definition of City objectives, standards, and preferences; definition of external constraints and standards; definition of process functional requirements; detailed process calculations to size facilities; development of process schematics; equipment alternatives and recommended equipment, and limited drawings of new facilities. The project definition report is expected to include the following technical memoranda:

1. Executive Summary
2. External Constraints, Standards, and Regulatory Requirements
3. Subsurface Conditions and Preliminary Geotechnical Recommendations
4. Seismic/Structural Evaluation of Existing Facilities to be expanded/upgraded
5. Site Civil—Topographic Survey, Grading, Landscape and Access, Site Circulation Evaluation (Vehicular), Utility Coordination (technical memorandum prepared by WHPacific).
6. Process Design Criteria
7. Overall Treatment Process Evaluation
8. Unit Process Evaluation, Selection, and Sizing
9. Preliminary Process Flow Diagrams and Process Control Strategy
10. Attachment: Major Equipment Selection
11. Evaluation of Existing Facilities for Upgrade or Modification (including conversion of some or all of the existing aeration basins to IFAS)
12. Hydraulic Profile
13. Energy Efficiency and Sustainability Opportunities
14. Preliminary Project Sequencing Plan and Construction Cost Estimates

15. Project Delivery Analysis and Recommendations

Following approval of the Project Definition report the predesign effort will be initiated. This predesign work is intended to be a plant-wide predesign effort, developing predesign-level drawings and technical memorandum focused on the first overall phase of improvements defined in the Facilities Plan. This predesign effort will account for future improvements (future secondary clarifier, for instance) in regard to hydraulic grade, site layout, and flow split, and this predesign will develop drawings and limited details associated with those future facilities.

The design approach will be based on interactive workshops and informal deliverables (such as, sketches, preliminary drawings, catalog cuts, and workshop meeting minutes) and formal deliverables (Project Definition, Schematic Design, and technical memorandums as defined herein). City review workshops will be conducted after submission of each formal draft deliverable.

Conclusion

The process evaluation work performed under this task has demonstrated the effectiveness of a formal VE process. Potential secondary process alternatives were compared to the alternatives developed in the April 2008 Bend WRF Facilities Plan and the City has benefitted from this additional scrutiny and objective review by Consultant and City staff of all the alternatives. The selected IFAS alternative will provide the benefits summarized below while meeting critical commitments to ratepayers and regulators.

IFAS was the selected alternative for the expansion of the Bend WRF for the following reasons:

- **Affordability**. IFAS is cost competitive with other treatment plant expansion alternatives.
- **Ease of Future Expansion.** Once the IFAS infrastructure is in place, future expansion can be accomplished by adding more IFAS media. Thus, the process can more easily accommodate rapid growth or increased industrial discharges.
- **Reliability of Operation**. The use of attached growth for nitrification eliminates the concern of nitrifier washout due to low SRT or low temperature.
- **Improved Operational Control**. The effluent ammonia concentration can be controlled by adjusting the dissolved oxygen level in the IFAS zone, providing the opportunity to eliminate ammonia addition for chloramination of the reuse water.
- **Improved Settleability.** The low SRT operation associated with the IFAS technology will washout *M. parvicella* and provide chemical free control of filamentous bulking.
- **Reduced Construction Impacts**. The addition of a new IFAS aeration basin can occur largely without disruption of the existing process and provide the needed capacity to retrofit the existing basins without concern over available capacity. Conversely, while the retrofit of existing basins is a major construction effort, the duration is relatively short for each basin. Thus, the IFAS process provides some flexibility in construction scheduling depending on the needs of the City of Bend and WRF.

- **Acceptability of Process with Plant Staff**. During the process selection, staff from the City of Bend toured operating IFAS facilities and found the IFAS process well liked by other operators due to its ease of maintenance and operation.

Appendices

Appendix A: Task A1.06 Preliminary Process Evaluation Cost Opinion (CH2M HILL, October 15, 2009)

Appendix B: Process Flow Diagrams for Capacity Increase Alternatives

Appendix C: IFAS Site Visit Reports

Appendix D: Side Stream Site Visit Reports

Appendix E: Site Visit Reports—Step-feed

Appendix F: Process Evaluation Site Visit Summary

Appendix G: Meeting Notes—February 1, 2010

Appendix H: Process Evaluation QA-QC Review Comments

APPENDIX A

Task A1.06 Preliminary Process Evaluation Cost Opinion (CH2M HILL, October 15, 2009)

Bend Water Reclamation Facility (WRF) Secondary Expansion
Task A1.06 Preliminary Process Evaluation Cost Opinion

TO: Jim Wodrich/City of Bend
Paul Roy/City of Bend
Scott Thompson/City of Bend

COPIES: Dave Green/CH2M HILL
Brady Fuller/CH2M HILL
Adrienne Menniti/CH2M HILL

FROM: William Leaf/CH2M HILL

DATE: October 15, 2009

This memorandum presents the preliminary capital costs developed as part of the process evaluation task. These conceptual costs will be used as part of the decision-making analysis to help determine the process configuration to be carried forward to design.

Background

The Value Engineering (VE) study resulted in several process recommendations. Additional analyses of these alternatives were performed and are documented in a technical memorandum, "Bend Water Reclamation Facility (WRF) Secondary Expansion Task A1.06 Preliminary Process Evaluation Summary," dated November 2, 2009, by CH2M HILL. Opinions of capital cost were prepared using CH2M HILL's CPES cost estimating database. Life-cycle cost evaluations were also performed using the methodology documented in a technical memorandum, "Bend WRF – Deschutes Brewery Evaluation Financial Analysis Basis," dated September 1, 2009, by CH2M HILL. This methodology detail is repeated herein so this memorandum can stand alone and be complete for review.

Costs Opinions

The objective of the life-cycle cost evaluation is to provide a comparison between the alternatives. Given the conceptual level of the alternatives evaluation, the cost opinion includes contingencies and markups for each alternative. During future design phases, contingencies and allowances to capture additional project costs are refined and reduced as design details become available, allowing for a more detailed cost estimate. These estimates are intended to be used only for comparing initial conceptual alternatives for the purpose of screening them to a reasonable few for further evaluation. **These cost estimates should not be used for financial planning or rate impact analysis.**

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This estimating effort adopts the classification of estimates as defined by the Association for the Advancement of Cost Engineering (AACE). The industry classification system is Recommended Practice-17R-97: "Cost Estimate Classification System" and 18R-97: "Cost Estimating Classification System as Applied in Engineering, Procurement, and Construction for the Process Industries."

Figure 1 shows the relationship of level of detail to the expected accuracy of the estimate.

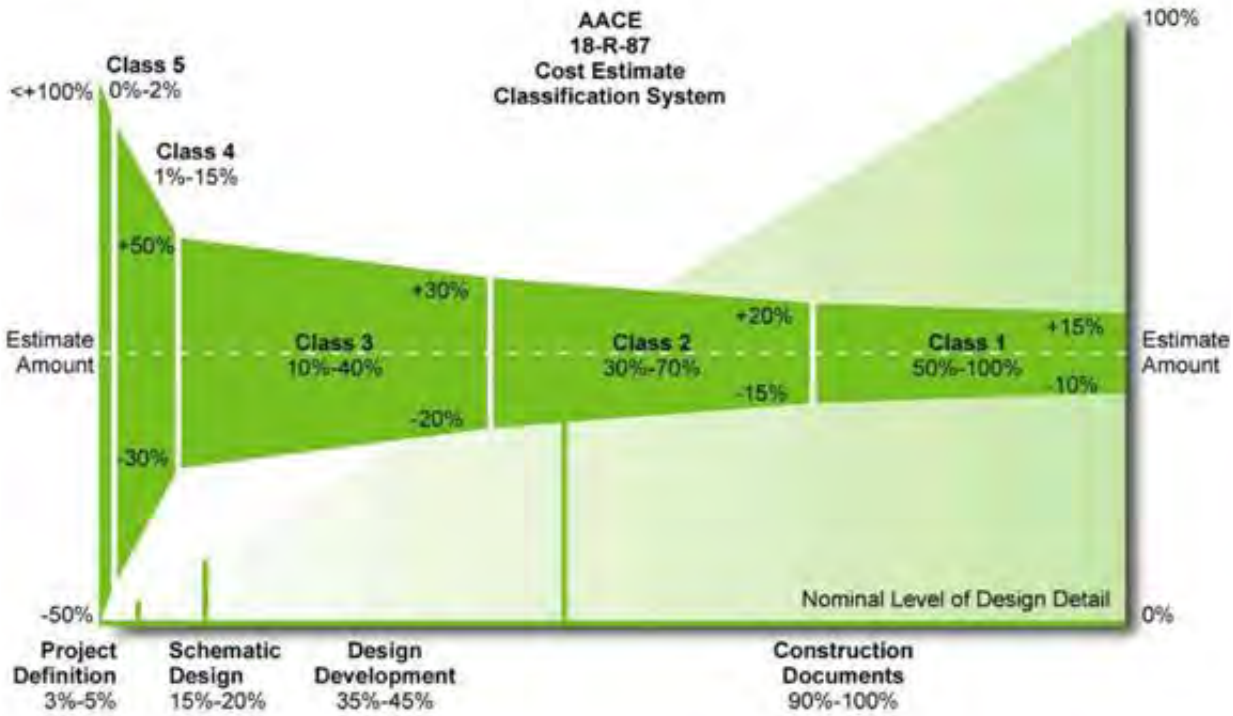

FIGURE 1. Construction Cost Estimate Accuracy Ranges

The capital costs within this project definition report are defined as order-of-magnitude-level (Class 4) estimate as defined in the AACE International Recommended Practice No. 18R-97, *Cost Estimate Classification System As Applied in Engineering, Procurement, and Construction for the Process Industries.* An estimate of this type is normally expected to be within +50 percent or –30 percent of the actual construction cost. The final cost of the projects will depend on actual labor and materials costs, actual site conditions, productivity, competitive market conditions, bid dates, seasonal fluctuations, final project scope, final project schedule, and other variables. As a result, the final project costs will vary from the estimates presented in this report.

Capital and operations and maintenance (O&M) cost opinions will be developed to allow comparison of alternatives for a 20-year planning period.

The costs included in this evaluation are:

- **Capital Costs**. Capital costs are associated with building new facilities or expanding and renovating existing facilities. Capital costs shall include construction costs, non-construction costs, and land acquisition costs, and other factors identified as follows:

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The facility construction cost includes the cost for building a new unit process or treatment facility in order to satisfy a specific treatment objective. In addition, other project elements are typically needed to integrate the new unit process or treatment facility into the WRF. The additional project elements are calculated as a percentage of the facility construction cost. The additional project elements include demolition if required, overall site work (5%), plant computer system (5%), yard electrical (10%), and yard piping (4%). The sum of the facility construction cost and the additional project elements is a construction cost subtotal.

Contractor markups shall be added to the construction cost subtotal. Contractor markups include overhead (10%), profit (5%), mobilization, bonds, and insurance (5%). Construction contingency (30%) is also added to the construction cost subtotal with markups.

In addition to construction costs, an allowance for non-construction costs shall be provided. The non-construction cost allowance is calculated as a percentage of the construction cost subtotal with the contractor markups. For this evaluation an allowance for permitting/administration (5%), engineering (10%), services during construction (5%) and commissioning and start-up (5%) are included as non-construction costs (25% total).

Land acquisition costs are assumed to be zero for the WRF because the City owns all the existing property required. Deschutes Brewery should substantiate any claims for land acquisition costs for market rate cost information.

The construction cost with contractor markups subtotal, the non-construction cost subtotal, and the land acquisition cost subtotal are summed to obtain the project capital cost total. The capital costs are all rounded up to the nearest $10,000. Table 1 provides an example of the capital cost workup for a representative facility construction of $10,000,000.

For this evaluation all capital costs are based on January 2009 dollars. An escalation factor to adjust the construction cost subtotal to the mid-point of construction (May 2010) in order to properly budget and account for inflation that may occur during planning, design, and construction of the project is included (5%). In addition, it will be necessary to assess the local market conditions for treatment plant construction and assess whether a market adjustment factor is warranted to reflect the bidding climate in the local market. For this initial analysis a 5 percent factor is included to account for market adjustment.

- **Operations and Maintenance Costs**. O&M costs are associated with the daily requirements for maintaining and operating the wastewater treatment facilities. O&M costs include labor, power, chemicals, equipment maintenance and equipment replacement. An additional increment of O&M costs is estimated for each alternative and presented in 2009 dollars. A 20 percent contingency is added to obtain the total estimated incremental O&M costs. The incremental O&M costs are increased each year by 3 percent. For this evaluation the O&M costs are based on the following factors:
  - Labor: estimated using WRF empirical model for publicly owned treatment works (POTWs) based on annual average day flows, influent biological oxygen demand

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5-day (BOD_5) concentrations, average labor rate of $35/hour, and observed sludge yield specific for individual treatment plants.

- Power: $0.06/kilowatt-hour (includes usage, demand, and transmission charges)
- Ferric Chloride (40 percent solution): $372/dry ton
- Aluminum Sulfate (48.5 percent solution): $330/dry ton
- Equipment Maintenance Materials: Figured as a percentage of the initial capital cost (2% finishes, 1% equipment, 0.1% mechanical, and 1% electrical)

- **Life-cycle Cost**. The life-cycle cost analysis converts all expenditures that occur during the project into a single equivalent present value sum at the time of the analysis. Thus, the streams of expenditures associated with each alternative can be compared on the same basis.

  It is assumed that the construction can be financed at an interest rate of approximately 6 percent per year, and inflation is about 3 percent per year. The real value of money is the interest rate less the inflation rate, or about 3 percent per year. The life-cycle analysis is based on a real discount rate of 3 percent per year. The present worth of O&M costs is estimated with a gradient series present worth factor and a discount rate of 3 percent.

  The life-cycle cost is defined as the following, where Pw is the present worth: Life Cycle Cost = P_w (Construction Cost) + P_w (Operation and Maintenance Cost).

TABLE 1
Capital Cost Estimating Approach Example

Item			Cost
Facility Construction Cost			$10,000,000
Additional Project Elements			
Demolition	0%		$-
Overall Sitework	10%		$1,000,000
Plant Computer System	5%		$500,000
Yard Electrical	10%		$1,000,000
Yard Piping	4%		$400,000
Construction Cost with Additional Project Elements – Subtotal			$12,900,000
Contractor Markups			
Overhead	10%	$12,900,000	$1,290,000
Subtotal			$14,190,000
Profit	5%	$14, 190,000	$709,500
Subtotal			$14,889,500
Mobilization/Bonds/Insurance	5%	$14,889,500	$744,975
Subtotal			$15,644,475

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TABLE 1
Capital Cost Estimating Approach Example

Item			Cost
Contingency	30%	$15,644,475	$4,693,350
Construction Cost with Contractor Markups – Subtotal			$20,337,825
Escalation @ 5% per year	1 Years @5%	$20, 337,825	$1,016,900
Subtotal			$21,354,725
Market Adjustment Factor (Central Oregon construction market)	5%	$21,354,725	$1,067,740
Subtotal			$22,422,465
Non-Construction Costs			
Permitting/Admin	5%	$22,422,465	$ 1,121,086
Engineering	10%	$22,422,465	$ 2,242,173
Services During Construction	5%	$22,422,465	$ 1,121,086
Commissioning, Startup, Documentation	5%	$22,422,465	$ 1,121,086
Non-Construction Cost – Subtotal	25%		$28,027,159
Land Acquisition Costs	Acres	cost/acre	
Land Cost (not included for Bend WRF)			$--
Administration & Legal for Land Transaction			$--
Land Acquisition Cost – Subtotal			$--
Project Capital Cost – Total			**$28,028,000**

Capital Cost Development

A number of treatment alternatives have been evaluated as part of this preliminary process evaluation. An initial cost opinion is developed for the following:

- PT-3 Step-feed Bioreactor Configuration: Addition of one (1), 1.05-MG bioreactor in a step-feed layout
- PT-6 Bioaugmentation: Addition of one, 0.5-MG side-stream bioreactor treating the dewatering filtrate prior to return to the main aeration basin(s)
- PT-11 Integrated Fixed-film Activated Sludge (IFAS): Conversion of existing aeration basins to incorporate an IFAS system.
- AS-6 MLE Aeration Basin Expansion: New 1.05-MG aeration basin, using the Modified Ludzak-Ettinger (MLE) configuration
- Primary Clarifier: Addition of one, 65-foot-diameter primary clarifier

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- Secondary Clarifier: Addition of one, 80-foot-diameter secondary clarifier

The individual capital costs by implementation year along with the present worth value for each of the unit processes are presented in Table 2.

TABLE 2
Bend WRF Process Evaluation - Conceptual Cost Opinion Summary

Alternative	Implementation Year	Total Capital Cost (2009 Dollars)	Present Worth (2030)[1., 2.]
AS-3. MLE			$ 23,218,000
	2010: (1) AB, (1) SC, Blowers	$16,929,000	
	2014: (1) AB, (1) SC	$8,385,000	
	2015: (1) Primary Clarifier	$1,390,000	
	2025: (1) Secondary Clarifier	$1,936,000	
PT-3. Step-feed			$ 20,412,000
	2010: (1) AB, (1) SC, Conversion of Existing ABs to Step-feed, Blowers	$17,988,000	
	2015: (1) Primary Clarifier	$1,390,000	
	2022: (1) Secondary Clarifier	$1,936,000	
PT-11. IFAS			$ 20,567,000
	2010: Conversion of (3) ABs to IFAS (46 percent Fill), Blowers	$15,744,000	
	2013: Additional Fill to ABs (55 percent Fill)	$391,000	
	2015: (1) Primary Clarifier	$1,390,000	
	2018: Additional Fill to ABs (67-percent Fill)	$521,000	
	2024: (1) Secondary Clarifier	$1,936,000	
AS-1. Filtrate Re-aeration			$ 22,757,000
	2010: (1) Filtrate Re-aeration Reactor	$3,726,000	
	2011: (1) AB, (1) SC, Blowers	$18,071,250	
	2015: (1) Primary Clarifier	$1,390,000	
	2017: (1) Secondary Clarifier	$1,936,000	
PT-6. Bioaugmentation			$ 22,589,000
	2010: (1) Bioaugmentation Reactor	$3,726,000	
	2012: (1) AB, (1) SC, Blowers	$18,071,000	
	2015: (1) Primary Clarifier	$1,390,000	
	2020: (1) Secondary Clarifier	$1,936,000	

[1] The present worth calculations take into account the implementation schedule presented in Figure 6 in the main text.

[2] Present worth calculations are based on Total Construction Cost, not Total Capital Costs. (Total Capital Costs include non-construction costs such as permitting, engineering, services during construction, etc).

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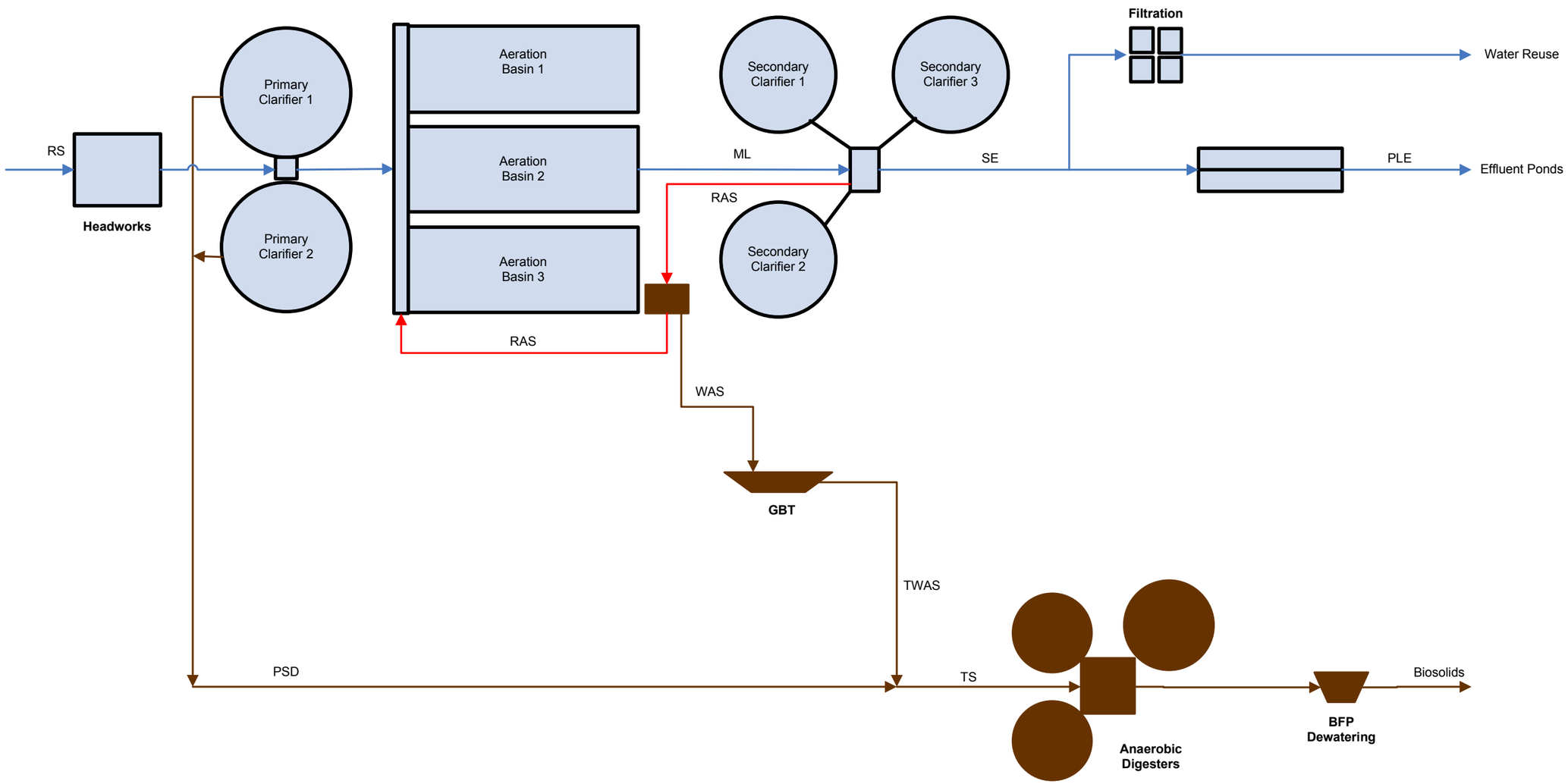
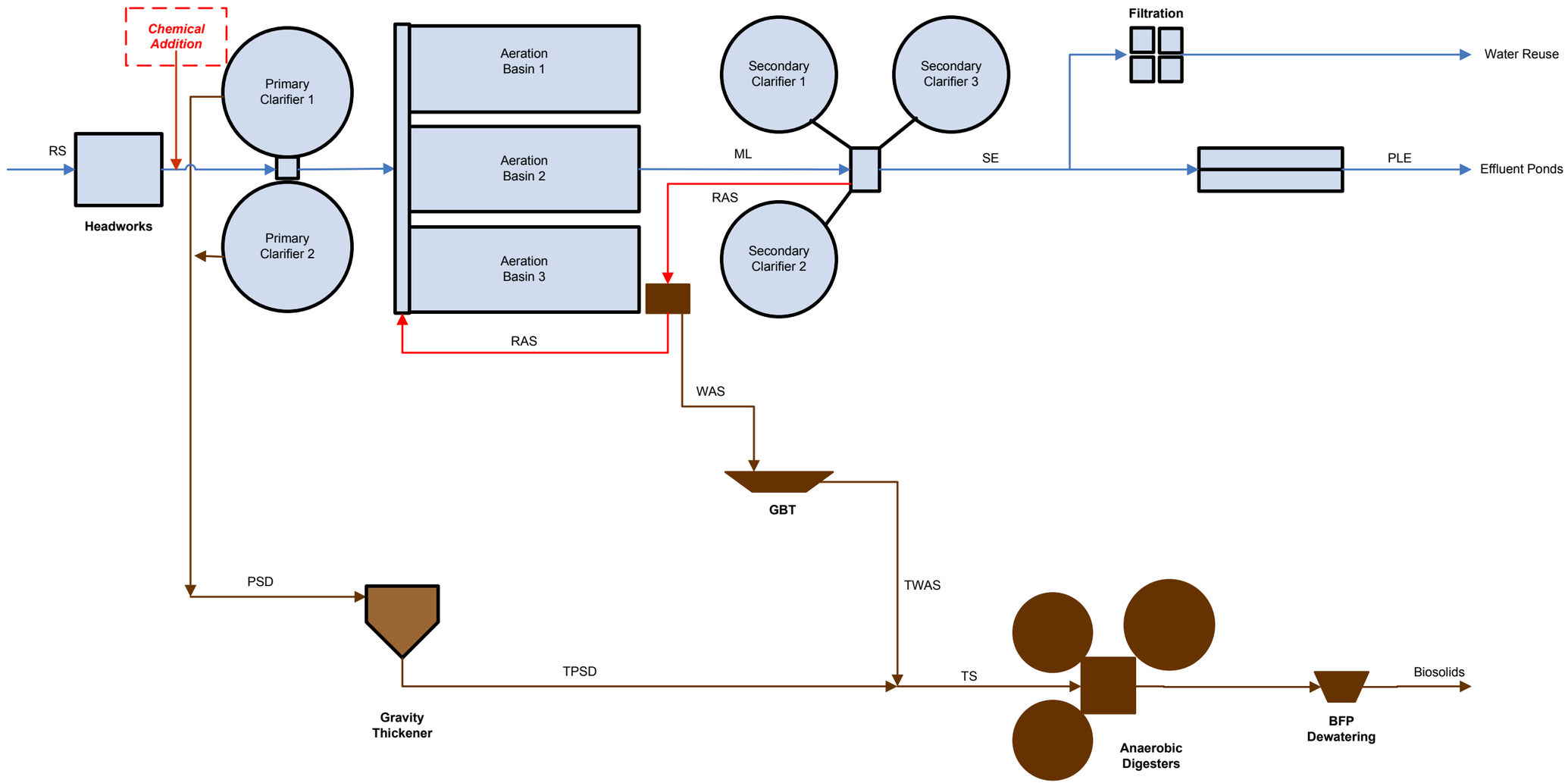
APPENDIX B

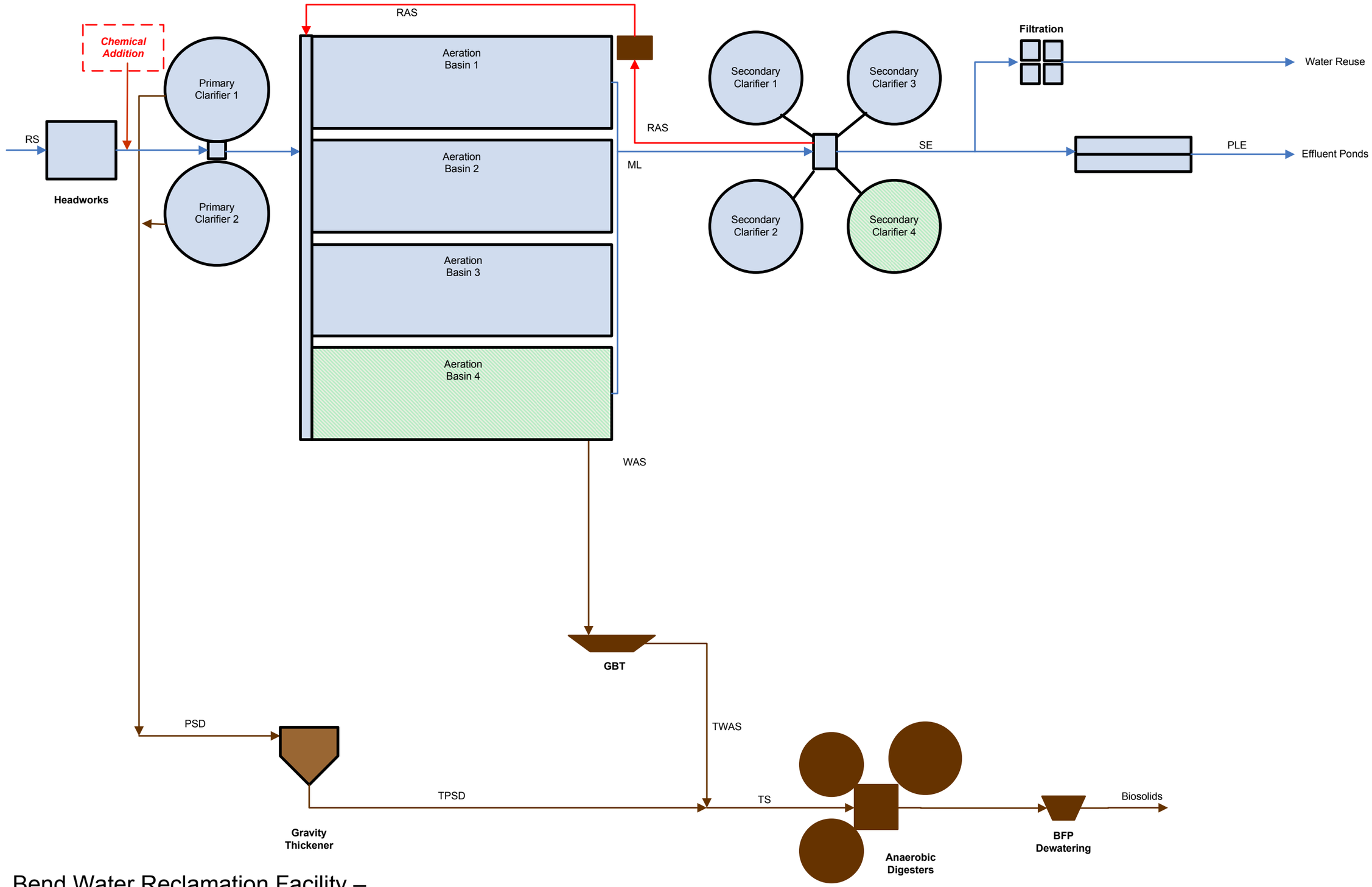
Process Flow Diagrams for Capacity Increase Alternatives



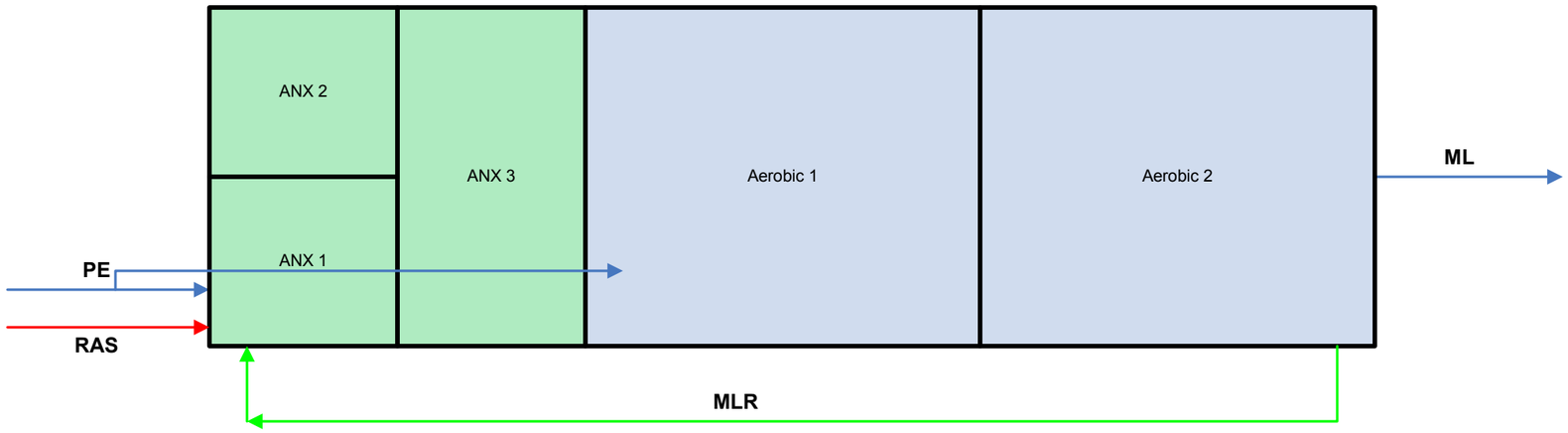
Bend Water Reclamation Facility –
Existing Layout



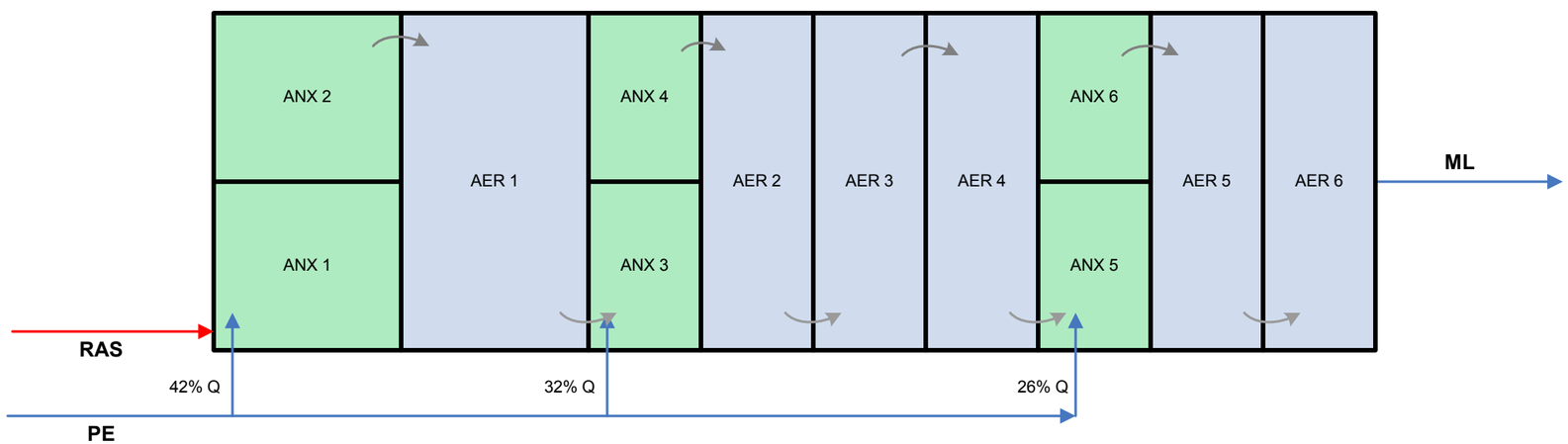
Bend Water Reclamation Facility –
Chemically Enhanced Primary Treatment



Bend Water Reclamation Facility –
Secondary Expansion (MLE Process)

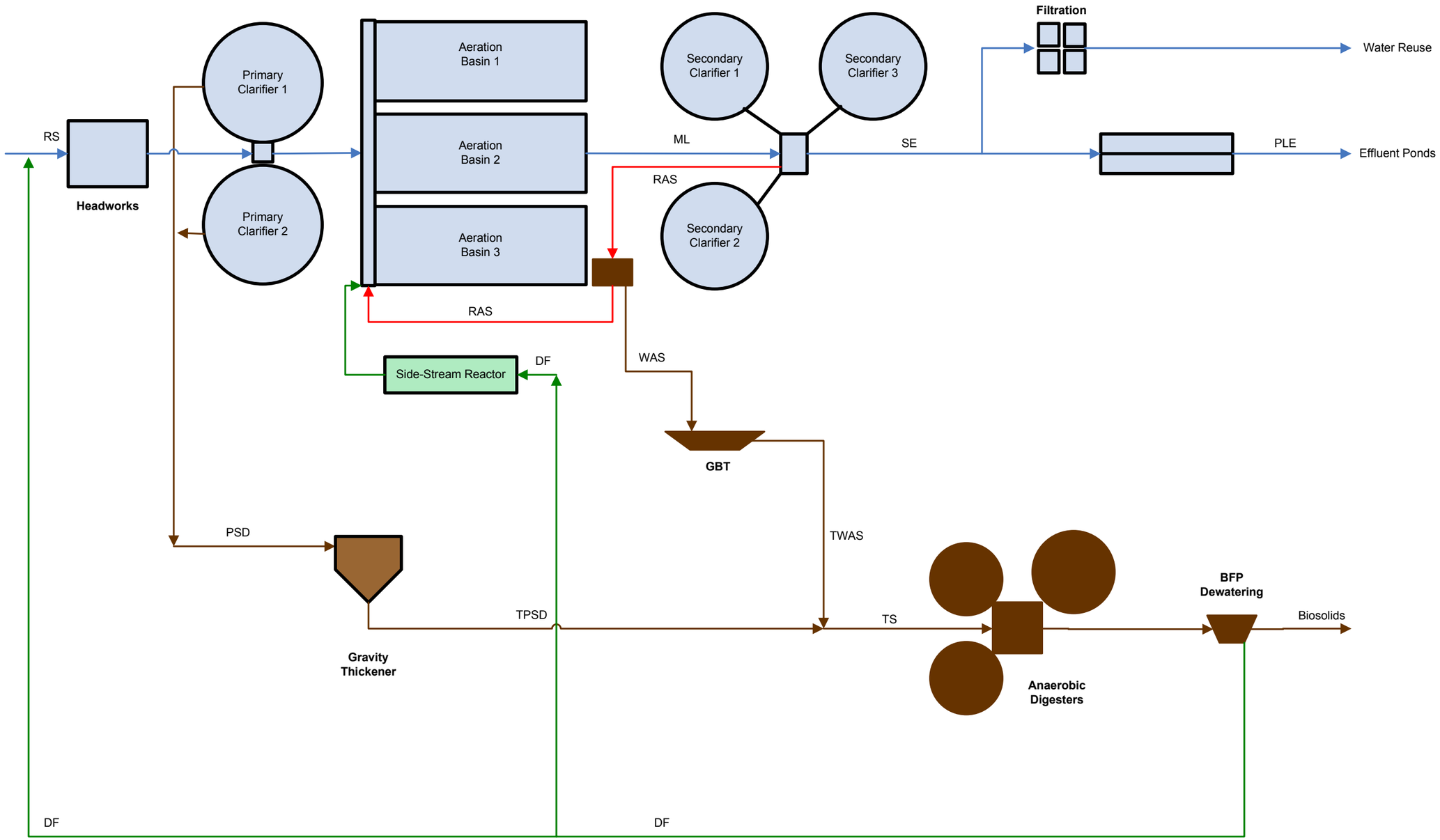


Existing Aeration Basin Configuration

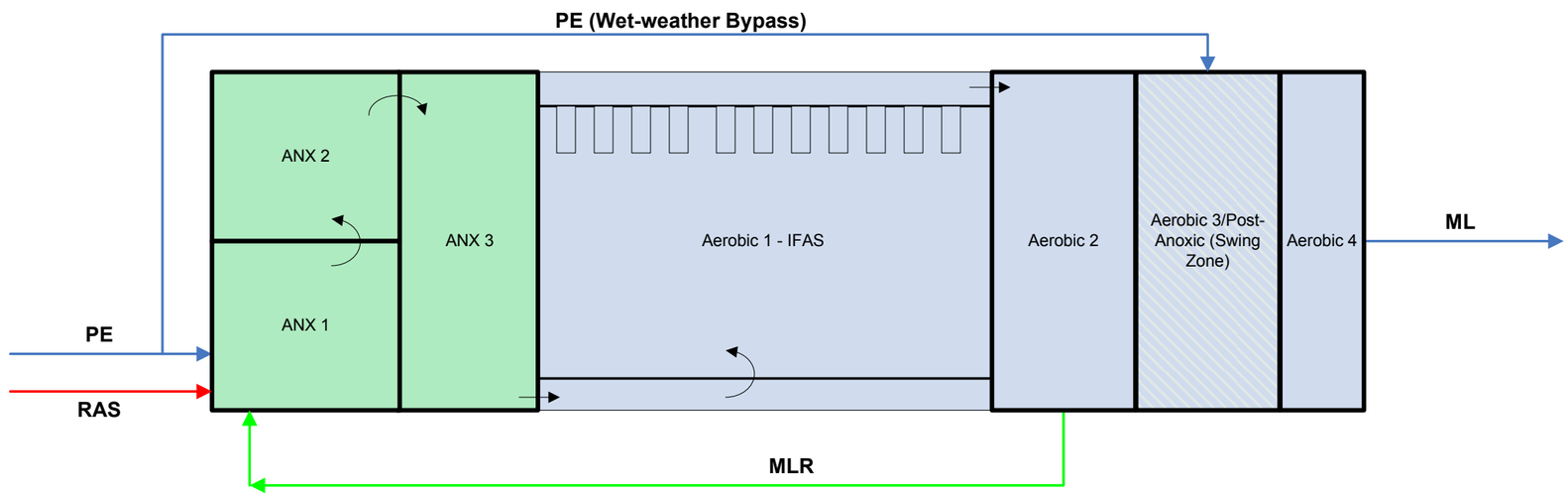


Proposed Step-Feed Configuration – Alternative 2

Bend Water Reclamation Facility



Bend Water Reclamation Facility – Side-stream Treatment (Bioaugmentation)



Bend WRF – Preliminary Integrated Fixed-film Activated Sludge (IFAS) Layout

APPENDIX C

IFAS Site Visit Reports

Site Visit Reports

Secondary Improvements Project

Bend WRF Staff

January XX, 2010

Agenda

- Overview of Site Visits – Wodrich
- Site Visit Reports:
  - Filtrate Reaeration
  - IFAS and MBBR Facilities
  - Step Feed Facilities
- Non-Cost Evaluation Process
  - Introduction
- Next Steps

Overview

- Overview of project – work to date
  - Facility Plan
  - Value Engr
  - Process Evaluations
    - Screening of best ideas
    - Cost comparisons
- Site Visits
  - Approach to site visit teams
- Technical papers
- Next Steps

IFAS and MBBR

But mostly just IFAS……

IFAS and MBBR Facilities

- Overview
- History of Unit Process/Technology
- Operational Evaluation
- Reliability and Robustness
- Maintenance Feedback
- Startup Issues
- Constructability Issues

IFAS and MBBR Facilities

- Overview
  - Sites visited
    - South Adams County, CO - Williams Monaco WPCF, 7 mgd
    - Cheyenne, WY Dry Creek WPCF 6 mgd
    - Broomfield, CO 8mgd
  - What were the drivers with this process
    - Total Nitrogen Permit
    - Reducing Filaments
    - Robust System
    - Small Footprint
    - Reduced Construction Schedule

IFAS and MBBR Facilities

- **History of Unit Process/Technology**
  - Existing Facilities/Proven Installations in USA or Elsewhere
    - **Broomfield, CO**
    - **Dry Creek, Cheyenne, WY**
    - **Williams Monaco, South Adams County, CO (MBBR)**
    - James River, Virginia Demonstration/Full Scale
    - Yucaipa, CA
    - Wildcat Hill, AZ WWTP
    - Fairplay, CO WWTP
    - Lubbock, TX
    - Groton, CT WWTP
  - Early Project Mishaps
    - Christies Beach, AUS
    - Lakeview WWTP,Canada Demonstration
    - Rasio WWTP, Finland
      - These plants were early pioneers and all had similar problems including hydraulics, media distribution, velocity and adequate aeration.
  - Currently there are 15 WWTPs in design or under construction using IFAS

- **Similarities to Bend WRF**
  - Facilities visited were similar in size, typical climate swings (CO and WY) and all had total nitrogen limitations in the permit driving the process change

Operational Evaluation

- **What process control parameters are being used by the operations staff?**
    - D.O. (decreased from 2.0 to 1.6-7 at Cheyenne reducing aeration costs)
    - Cheyenne hasn't made any seasonal adjustments
    - SRT dropped significantly due to biofilm mass
    - Inline NH3 Control at South Adams County WWTP as primary control loop (MBBR)
  - **How does this process differ from the previous process…Better or worse?**
    - Many differences between previous processes-all for the better
    - Biofilm allows for more mass in same volume (SRT reduction)
    - Less process control, simpler, more ROBUST
    - Better Total Nitrogen Removal
    - Using less aeration than previous processes, less blower maintenance as fewer blowers required then before
    - Aeration is coarse bubble so no membranes to clean annually

Operational Evaluation (cont.)

- **Have you had any filamentous or other biological problems?**
    - Filaments haven't been a major issue even though Broomfield has lots of restaurants
    - Broomfield and Cheyenne have implemented spray nozzles utilizing chlorinated water for foam and use this occasionally fall and spring (seasonal)

- **If PLC/SCADA control is an important aspect, has it been programmed to your satisfaction?**
    - These plants all had SCADA and had no significant issues.

Reliability and Robustness

- **Are there any seasonal changes in process control?**
    - The WWTP's visited did not make many changes seasonally, only adjusting D.O due to cold water temps
    - Cheyenne makes very few process changes…if any
    - Broomfield rarely made process changes. Occasionally adjusting WAS to balance the mass in the basins.

- **How does this process perform at high flow or other adverse conditions?**
    - All of the WWTPs visited rarely witnessed high flows
    - Cheyenne WWTP had a contractor waste all of their solids by accident and they were able to get back to their operating solids concentration within 2 days and thus had only 2 days of effluent quality issues.

Maintenance Feedback

- **What additional maintenance requirements have developed?**
  - Less maintenance (no membranes to clean)
  - Media can get into the sieves occasionally (Broomfield)
  - Overall, none of the plants required very much maintenance
- **Are any special skills needed for maintenance?**
  - Not an issue, pretty low maintenance. This allowed their operators to work on other areas
- **IFAS system cleaning of the basins.**
  - Keep the media in suspension and pump using hydrostal pumps to other tanks or basins while you take one basin out of service, then pump back. **Cleaning really isn't an issue if the headworks have good screens and /or grit removal**.
- **Have there been or will there be significant O&M costs associated with the process? Chemicals?**
  - Nope!

Startup Issues

- **How was the start-up process? Were there issues that needed resolved?**
  - Initial start-up process took 10 days to see better removal in TN, TSS, BOD and 30 days to be in full operation. (Broomfield)
  - Cheyenne no problems
- **Has your design team been active with your challenges/needs?**
  - Yes, the operators seemed to be happy and glad to see the consultant

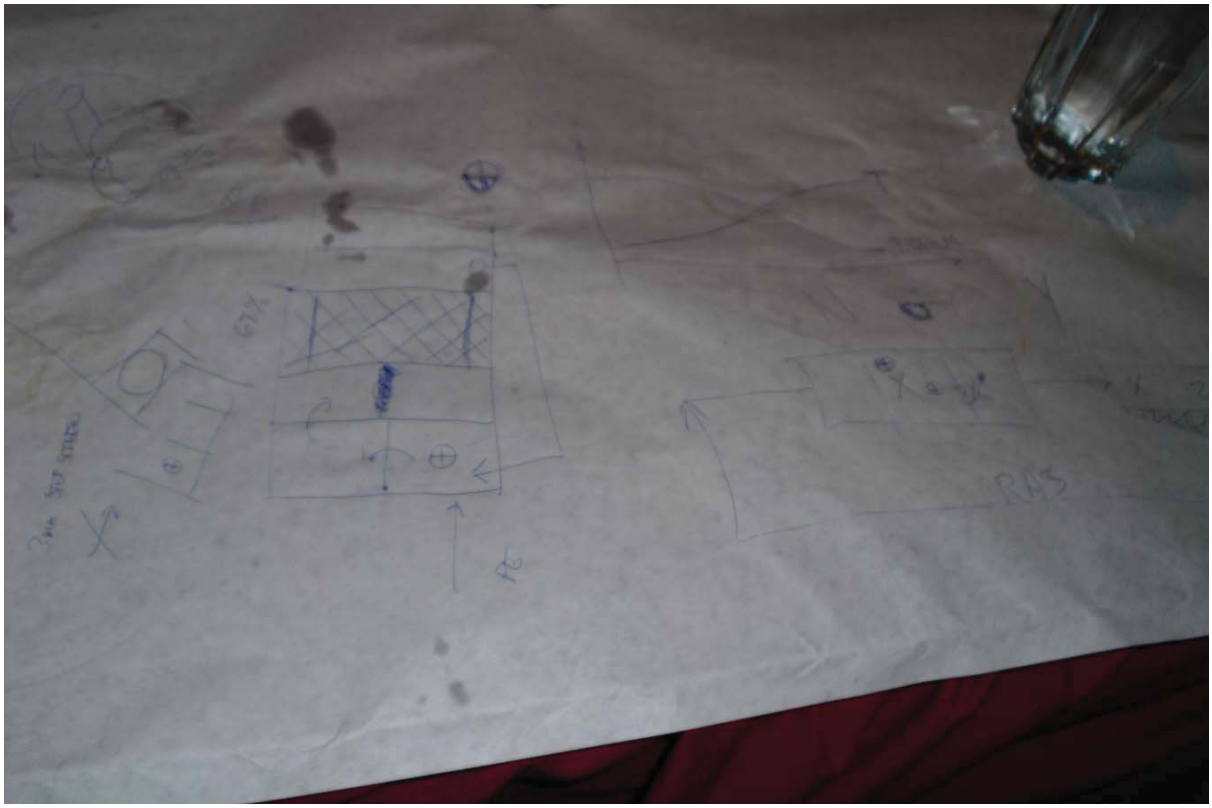
Constructability Issues

- **Does this system require proprietary equipment or systems?**
  - Yes, media is proprietary with two primary mfrs. Recommendation from Broomfield is to stick with one vendor for the package. Less finger pointing.

- **What were some of the design challenges, if you could change any, what would they be?**
  - Adequate basin velocity is a big consideration
  - Sprays (foam suppression) should be added as a backup.
- **Was your budget met for the project, if not how badly missed and why?**
  - Budget was met and all plants had extra media stored
  - Broomfield saved money from other process options as they were able to do the retrofit to the existing plant

Miscellaneous Questions

- **Have goals been met?**
  - TN, BOD, TSS removals are very consistent and much improved over the previous process
  - Overall, a resounding Yep!
- **Did you analyze other treatment plants with similar flow/load/ temp. who incorporated this technology to help you arrive to the decision to select it?**
  - Broomfield looked at other plants, step feed and other process considerations prior to deciding to use IFAS, primarily due to footprint
  - Cheyenne did not do much in terms of looking at other considerations
- **Are you and your staff satisfied with the results of this process change?**
  - Yes, a Robust yes. ☺ Yup, Yeppers
- **What would be your best advise for us as we proceed?**
  - The operators were advising to go with this system. Go with one vendor to simplify the process and utilize their experience. Suggests having spray nozzles available for foam excursions. **Broomfield is adding another basin based on the experience.**


RAB

What’s it look like in action?

IFAS Media In Action

CITY OF CHEYENNE
WASTEWATER TREATMENT FACILITIES
DRY CREEK PLANT
UPGRADE AND EXPANSION
CHEYENNE BOARD
OF
PUBLIC UTILITIES
PRESIDENT: JAMES T. APPLEGATE
SECRETARY: WORTH STORY
MEMBERS: BERNARD B. NEWLAND
MARSHALL E. BROYLES
JAMES D. VANVELZER
DIRECTOR: B. HERMAN NOE
CONSULTANT: RAY L. SHERARD
CONTRACTOR:
KLOEFKORN-BALLARD
CONSTRUCTION/DEVELOPMENT INC.
ENGINEER:
BLACK & VEATCH
ENGINEERS-ARCHITECTS
COMPLETED 1989
DRY CREEK WATER RECLAMATION FACILITY IMPROVEMENT PROJECT
CITY OF CHEYENNE, WYOMING
(2002 - 2008)
MAYOR AND CITY COUNCIL
BOARD OF PUBLIC UTILITIES
BOARD MEMBERS
BOARD STAFF
ENGINEERS
GENERAL CONTRACTORS

CITY OF BROOMFIELD
WASTEWATER TREATMENT FACILITY

APPENDIX D

Side Stream Site Visit Reports

Site Visit Reports

Secondary Improvements Project

Bend WRF Staff

January XX, 2010

Filtrate Reaeration

- Overview
- History of Unit Process/Technology
- Operational Evaluation
- Reliability and Robustness
- Maintenance Feedback
- Startup Issues
- Constructability Issues

Filtrate Reaeration

- Overview

  Mesa Arizona
  - New regional plant, Carollo design

  26 th. Ward New York
  - Centralized Solids Centrifuge Facility taking solids from 5 WPCFs

  Lincoln Nebraska (phone survey)
  - Upgrade to existing Facilities, HDR Design
  - One month in service
  - 20 MGD, one anoxic zone, mixed liquor recycle 0.75 MGD filtrate re-aeration tank, run belt press 10-12 hrs. day for four days, so filtrate return is intermittent.

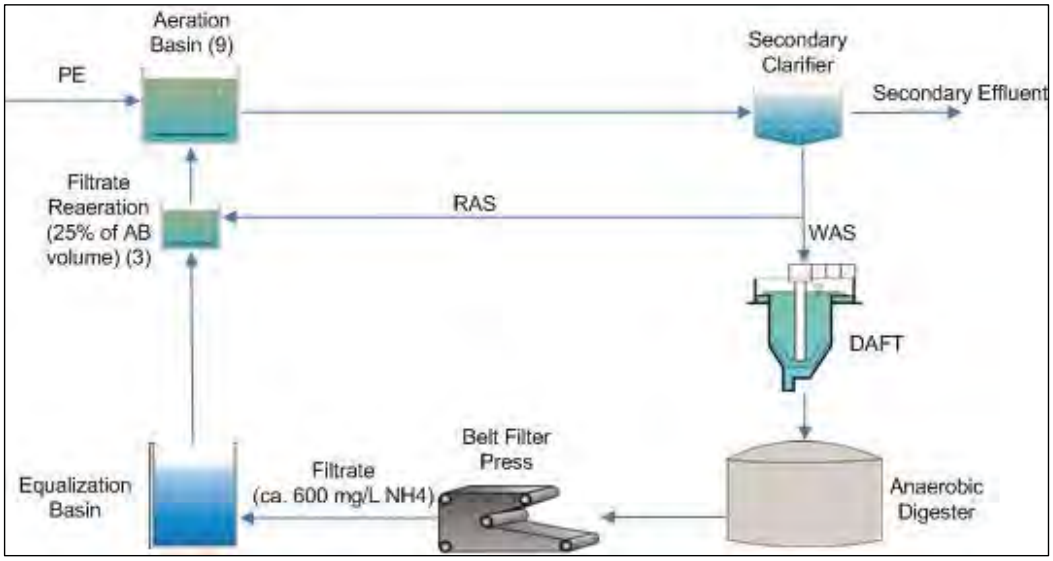
  Appleton, WI (phone survey)

  B & C Design-15 years in service
  - 12 MGD, 600 mg/l ammonia filtrate, 6 hour dentition time, 60% - 80% RAS rate. Had four serpentine aeration basins, turned one of the serpentine to a filtrate re-aeration basin then flow to the other three serpentine aeration basins.
  - **WEF 2008**
  - Numerous Papers and presentations-Very little consensus

Table 1

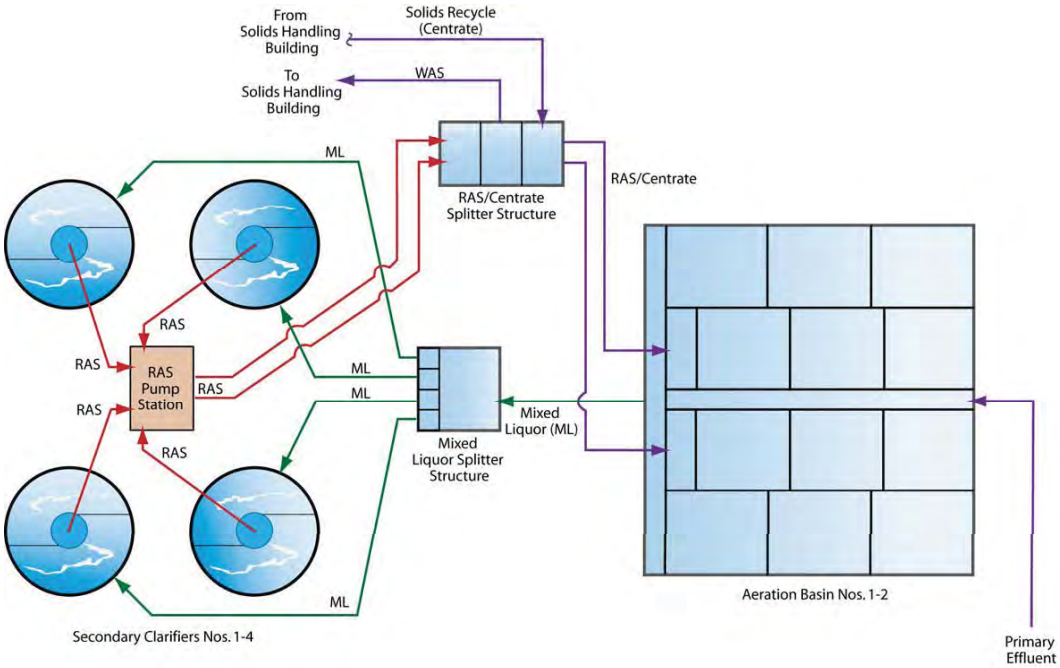
Criteria	Appleton WWTP, WI	26th Ward WPCP, NY	Theresa St. Plant, Lincoln, NE	Greenfield WRF, Mesa, AZ
Facility Features				
Rated Capacity, mgd	15.5 (Wet weather flows: 100 mgd)	Appr. 67	27 after latest expansion (before that 14 mgd)	16 mgd (Max. month flow: 24 mgd)
Current Capacity, mgd	10 mgd		About 15 mgd	6 mgd (approx.)
in operation since	1994	1996 (Step feed BNR implemented in 1997, Centrate treatment discontinued during BNR retrofit, restarted in March 1998/2000)	October 2007 (The plant is still under construction and will be in full operation starting February 2008)	June 2007 (Wet stream started in October 2006. Solids stream started in April 2007).
Facility Contact				
Name	Chris Shaw, Deputy Director & Operation Supervisor	Louis Carrio Chief of the Div. of Laboratories in the Bureau of Wastewater Treatment, NYCDEP	Brad Barbur Assistant Supervisor of Operations	Ronald Lopez Wastewater Treatment Plant Supervisor
Phone	920-832-5945	718-595-5014	402-441-7965	480-644-6014

NY, NY Biosolids Facility 26th Ward



Appleton, WI

Mesa Greenfield Plant



Mesa Greenfield WPCF

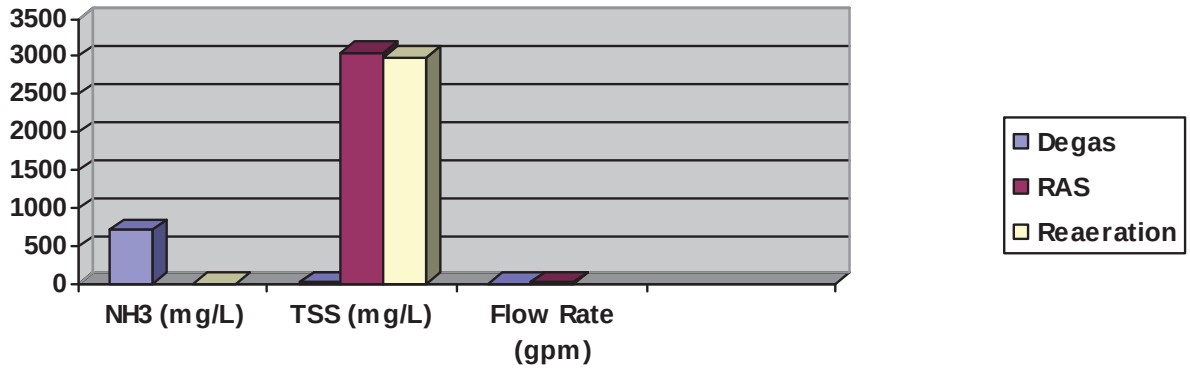
Filtrate Reaeration

- History of Unit Process/Technology
  - Existing Facilities (Proven Installations?) in USA or elsewhere
    - New York
    - Dallas, TX
    - Lincoln, NE
    - Appleton, WI
    - Winnepeg, MA
    - Czech Republic
  - Similarities to Bend WRF
    - Dallas, TX retrofit degas basins (questionable results –WEF)
    - Mesa Greenfield WRF has a Total Nitrogen (TN) limit of 10 mg/L, based on a five-month rolling geometric mean. This limit is governed by the plant's Aquifer Protection Permit (APP) and does not differentiate between the different forms of nitrogen (ammonia, nitrate, nitrite, organic N).

Filtrate Reaeration

- Operational Evaluation
  - Complexity or Simplicity
    - Operates similar to a standard contact stabilization
    - Does not appear to be too complex operationally but biology may be more complex
    - Very dependent on the ability to maintain RAS concentration in relation to the NH3 concentration.
  - Level of automation required
    - Standard monitoring
  - Additional sampling or testing required for process control (see next slide Pilot)
    - Monitoring of Ammonia, TSS, DO, flow

Re-aeration Study, 8/5/08



	NH3 (mg/L)	TSS (mg/L)	Flow Rate (gpm)
Degas	720	26	2
RAS		3048	27
Re-aeration	0.16	2984	

Filtrate Reaeration

- Reliability and Robustness
  - Ability to handle shock and peak loads
    - One of the benefits is that we store nitrifiers in a separate tank (0.75 MG tank at Mesa) reduces the chance of shocking or washing out solids.
  - Ability to operate with failed automation or instrumentation
    - Dependent on design (ie. Flow control issue- Pumping in manual)

Filtrate Reaeration

- Maintenance Feedback
  - Ease of maintenance
    - Similar to an Aeration Basin (ie. Diffusers, DO control, flow control)
  - Access issues (same)
  - Frequency of maintenance (same)
  - Type of maintenance staff needed (same, nothing too technical)

Filtrate Reaeration

- Startup Issues
  - Flexibility
  - Complexity –complex biology-depends on the firms experience
  - Time needed for startup (Lincoln 1 yr)
  - Mesa example was very underloaded
  - Lincoln, Nebraska had some problems initially tuning the flow split, etc. Recent call (December 09) operator is now satisfied with NH3 removal.

Filtrate Reaeration

- Constructability Issues
  - Impacts to operation, during construction
    - The basin is a separate process so this minimizes impact to existing operations, fairly easy switchover.
  - Phasing opportunities
    - See above, easy but would need to add tankage
  - Ability to accommodate resurgence of residential growth-This is comparable to adding another aeration basin in that it reduces the aeration required on the existing basins and provides additional solids inventory to treat the ww.
  - Ability to accommodate Deschutes Brewery expansion or others
    - Similar to above, just more load, design to allow for this.
  - Construction schedule
    - Construction could proceed in parallel to early out projects in the existing basins (High Intensity Aeration, etc)

Other considerations

- **Maintain current wash water separation from solids dewatering processes and not be combined with filtrate, since it**
  - **a) reduces the ammonia concentration of the re-aeration basin influent.**
  - **b) Decreases volumes to be treated in the side-stream basins, thus reduces size of reactors needed.**
- **Have the flexibility to adjust RAS flows to the re-aeration basins in order to balance the solid inventory, alkalinity, and aeration requirements in the re-aeration basin and main stream secondary treatment system for optimized nitrification.**
- **Filtrate flow equalization provides a steady ammonia feed load to the aeration basins. Flow paced feed control of the side stream to the main stream aeration basins improves operability and generates a more steady secondary treated effluent quality.**

APPENDIX E

Site Visit Reports—Step-feed

Site Visit Reports

Secondary Improvements Project

Bend WRF Staff

January XX, 2010

Agenda

- Overview of Site Visits – Wodrich
- Site Visit Reports:
  - Filtrate Reaeration
  - IFAS and MBBR Facilities
  - Step Feed Facilities
- Non-Cost Evaluation Process
  - Introduction
- Next Steps

Overview

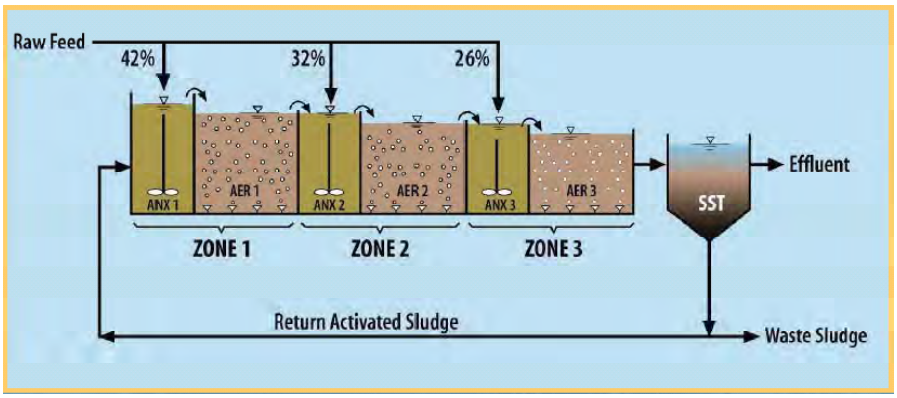
- Overview of project – work to date
  - Facility Plan
  - Value Engr
  - Process Evaluations
    - Screening of best ideas
    - Cost comparisons
- Site Visits
  - Approach to site visit teams
- Technical papers
- Next Steps

Step Feed Facilities

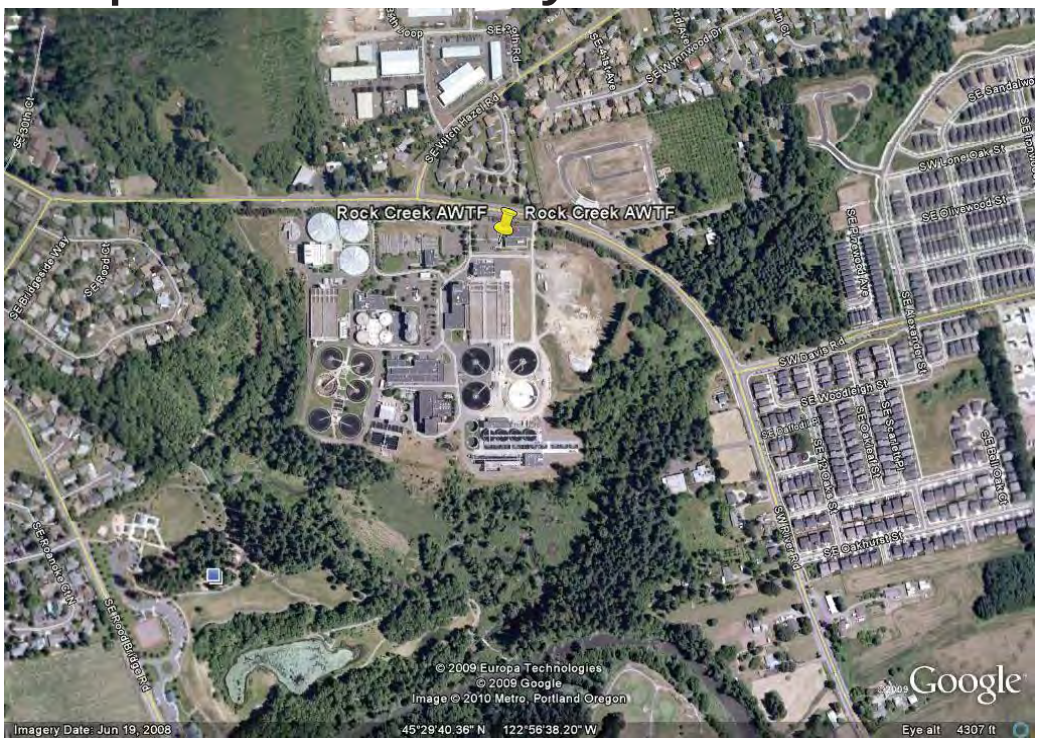
- Overview
- History of Unit Process/Technology
- Operational Evaluation
- Reliability and Robustness
- Maintenance Feedback
- Startup Issues
- Constructability Issues

Step Feed Facilities

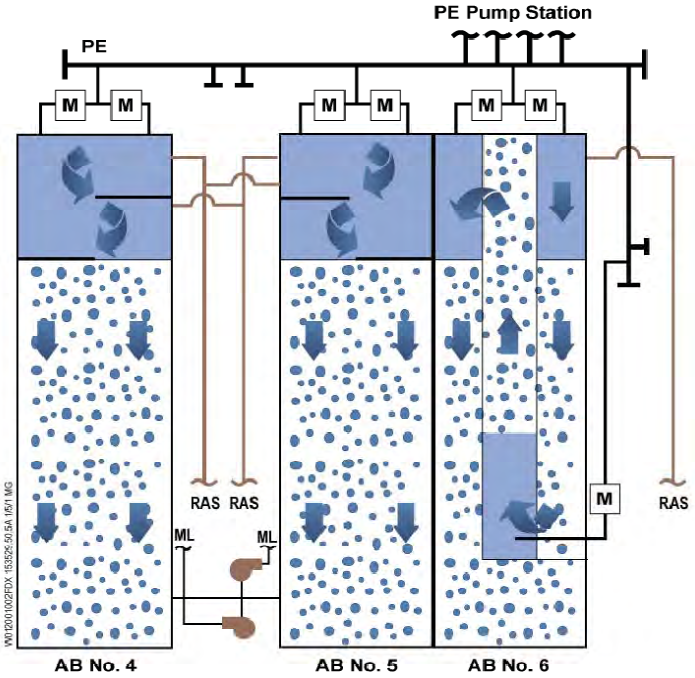
- Overview
  - Rock Creek AWTF Hillsboro, OR
    - Hybrid system
      - Basins 1 thru 5 MLE
      - Basin 6 Step Feed BNR
      - Basin 7 (new) Step Feed EBPR



Step Feed Facility – Rock Creek



Step Feed Facility – Rock Creek



Step Feed Facility – Rock Creek

Step Feed Facilities

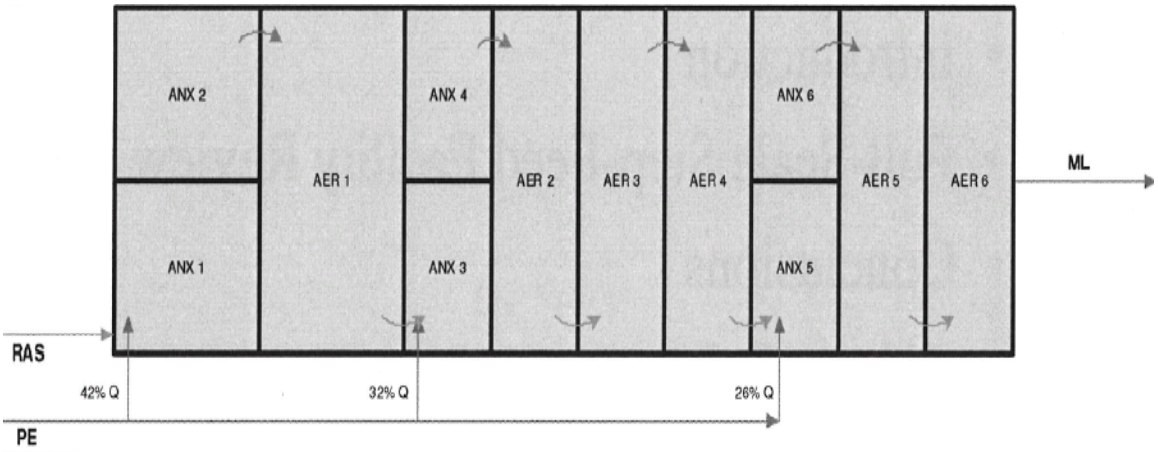
- History of Unit Process/Technology
  - Existing Facilities/Proven Installations in USA or elsewhere
    - Rock Creek AWTF, Hillsboro, Oregon
    - Fairfax County Virginia Department of Public Works
    - South Austin, Texas Regional WWTP
    - Piscataway, Maryland WWTP
    - Lander Street WWTP, Boise, Idaho
    - Vancouver, Washington Westside WWTP
    - Lethbridge, Alberta, Canada WWTP
    - Mangere WWTP Auckland, New Zealand
    - Changi WRP Singapore
  - Similarities to Bend WRF

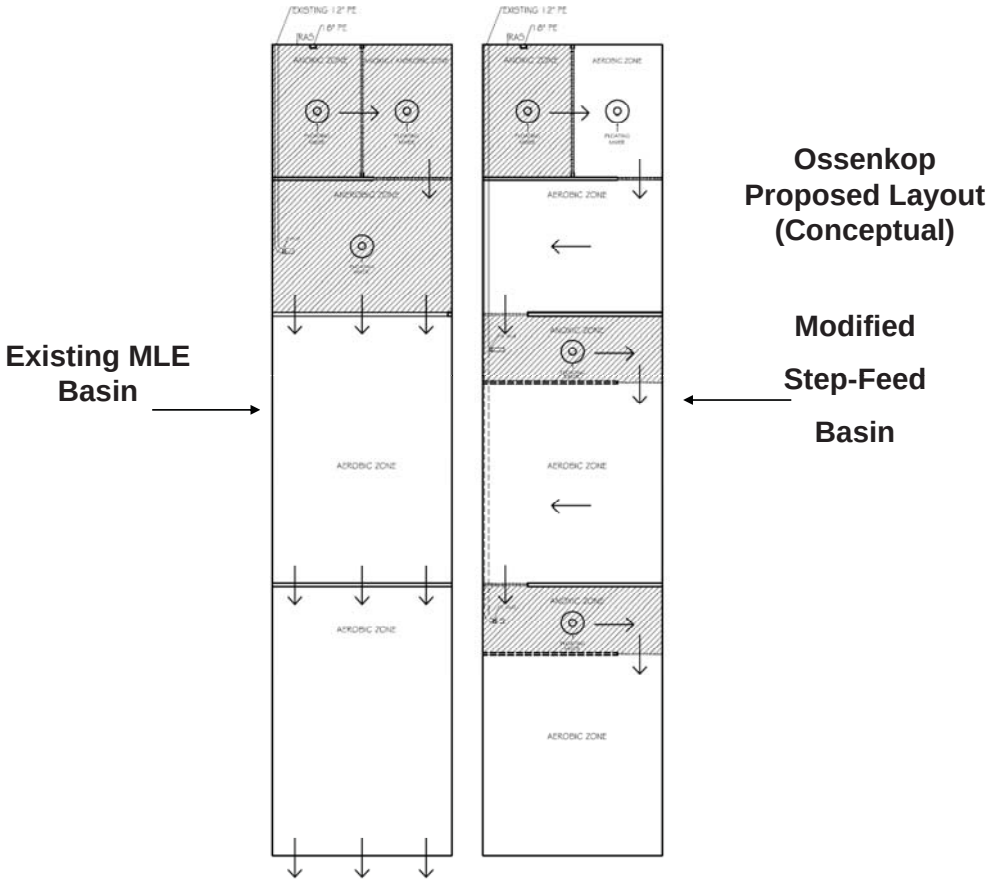
Step Feed Facilities

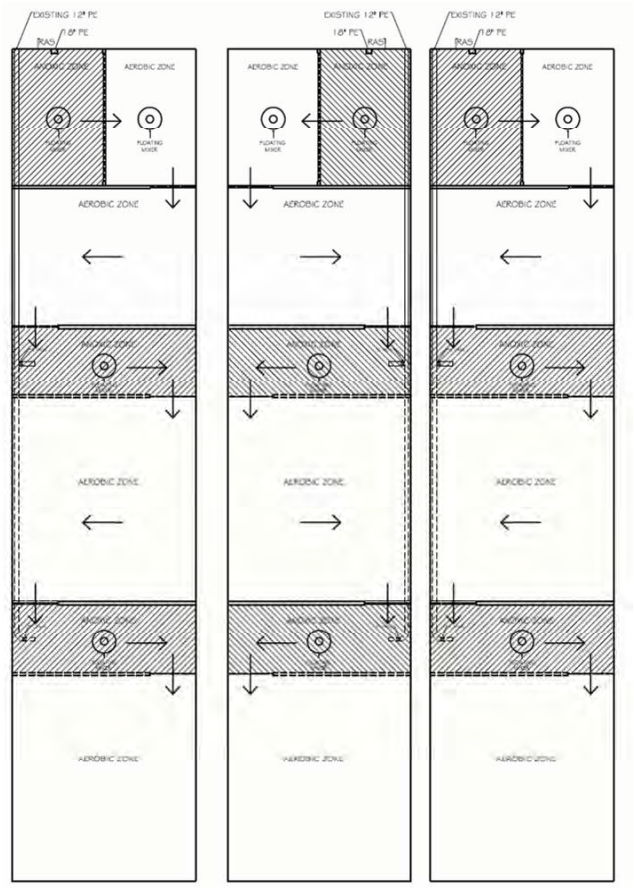
Similarities to Bend WRF

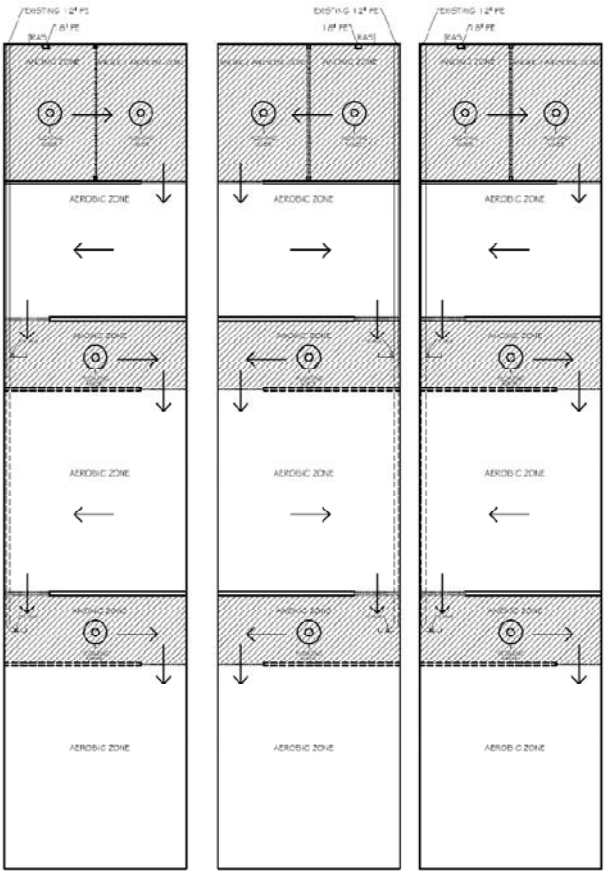
Bend WRF – Proposed Layout

Single Basin (Conceptual)




Existing MLE Basin
Ossenkop Proposed Layout (Conceptual)
Modified Step-Feed Basin
AEROBIC ZONE


Ossenkop Proposed Layout (Conceptual)
AEROBIC ZONE



Ossenkop Proposed Layout (Conceptual)

Step Feed Facilities

- Operational Evaluation
  - Process control parameters
  - Level of automation required
  - Additional sampling or testing required for process control
  - Etc

Step Feed Facilities

- Reliability and Robustness
  - Ability to handle peak flows
  - Ability to operate with failed automation or instrumentation
  - Etc.

Rock Creek AWTF

- Maintenance Feedback
  - Ease of maintenance
  - Access issues
  - Frequency of maintenance
  - Type of maintenance staff needed (instrument techs or mechanical or ?)
  - Etc.

Rock Creek AWTF
Maintenance Feedback

Rock Creek AWTF
Maintenance Feedback

Rock Creek AWTF
Maintenance Feedback

Rock Creek AWTF
Maintenance Feedback

Sanitare Fine Bubble Diffusers

Rock Creek AWTF
Maintenance Feedback

Rock Creek AWTF
Maintenance Feedback

Step Feed Facilities

- Startup Issues
  - Flexibility
  - Complexity
  - Time needed for startup
  - Etc.

Step Feed Facilities

- Constructability Issues
  - Impacts to operation, during construction
  - Phasing opportunities
  - Ability to accommodate resurgence of residential growth
  - Ability to accommodate Deschutes Brewery expansion or others
  - Construction schedule
  - Etc.

Step Feed Facility – Rock Creek

Filtrate Reaeration

- Overview
- History of Unit Process/Technology
- Operational Evaluation
- Reliability and Robustness
- Maintenance Feedback
- Startup Issues
- Constructability Issues

Filtrate Reaeration

- Overview
  - Sites visited or Info Collected from
  - Etc.

Filtrate Reaeration

- History of Unit Process/Technology
  - Existing Facilities/Proven Installations in USA or elsewhere
  - Similarities to Bend WRF

Filtrate Reaeration

- Operational Evaluation
  - Complexity or Simplicity
  - Level of automation required
  - Additional sampling or testing required for process control
  - Etc

Filtrate Reaeration

- Reliability and Robustness
  - Ability to handle shock loads
  - Ability to handle peak flows
  - Ability to operate with failed automation or instrumentation
  - Etc.

Filtrate Reaeration

- Maintenance Feedback
  - Ease of maintenance
  - Access issues
  - Frequency of maintenance
  - Type of maintenance staff needed (instrument techs or mechanical or ?)
  - Etc.

Filtrate Reaeration

- Startup Issues
  - Flexibility
  - Complexity
  - Time needed for startup
  - Etc.

Filtrate Reaeration

- Constructability Issues
  - Impacts to operation, during construction
  - Phasing opportunities
  - Ability to accommodate resurgence of residential growth
  - Ability to accommodate Deschutes Brewery expansion or others
  - Construction schedule
  - Etc.

IFAS and MBBR Facilities

- Overview
- History of Unit Process/Technology
- Operational Evaluation
- Reliability and Robustness
- Maintenance Feedback
- Startup Issues
- Constructability Issues

IFAS and MBBR Facilities

- Overview
  - Sites visited or Info Collected from
  - Etc.

IFAS and MBBR Facilities

- History of Unit Process/Technology
  - Existing Facilities/Proven Installations in USA or elsewhere
  - Similarities to Bend WRF

IFAS and MBBR Facilities

- Operational Evaluation
  - Complexity or Simplicity
  - Level of automation required
  - Additional sampling or testing required for process control
  - Etc

IFAS and MBBR Facilities

- Reliability and Robustness
  - Ability to handle shock loads
  - Ability to handle peak flows
  - Ability to operate with failed automation or instrumentation
  - Etc.

IFAS and MBBR Facilities

- Maintenance Feedback
  - Ease of maintenance
  - Access issues
  - Frequency of maintenance
  - Type of maintenance staff needed (instrument techs or mechanical or ?)
  - Etc.

IFAS and MBBR Facilities

- Startup Issues
  - Flexibility
  - Complexity
  - Time needed for startup
  - Etc.

IFAS and MBBR Facilities

- Constructability Issues
  - Impacts to operation, during construction
  - Phasing opportunities
  - Ability to accommodate resurgence of residential growth
  - Ability to accommodate Deschutes Brewery expansion or others
  - Construction schedule
  - Etc.

Wrap-up and Next Steps

APPENDIX F

Process Evaluation Site Visit Summary

Process Evaluation Summary

Secondary Improvements Project

Bend WRF Staff

February 1, 2010

Agenda

- Overview– Wodrich
- Where are we-Decision Analysis-Wodrich
- Non-Cost Evaluation Process Results-Roy
  - Discussion
- Next Steps

Overview

- Overview of project – work to date
  - Facility Plan
  - Value Engineering
  - Process Evaluations
    - Screening of best ideas
    - Cost comparisons
    - Site Visits
    - Technical papers
- Next Steps
    - Choose a process

Decision Path

- See Handout

Results of Operations and Maintenance Evaluation

Bend WRF Secondary Expansion Process Evaluation

	SECONDARY PROCESS OPTIONS	Proven state of technology	Constructability	Ease of operation	Ease of Maintenance	Adaptability to future regulatory requirements	Ability to meet current cash flow and rate schedule	TOTAL SCORE
1	Weighting	1.0	1.0	1.0	1.0	1.0	1.0	
	Process Alternatives							
a.	**Alternative 1 - Step Feed**	4.3	3.5	3.7	3.7	4.4	3.3	**23**
b.	**Alternative 2 - IFAS**	4.4	4.3	4.9	4.1	4.7	3.4	**26**
c.	**Alternative 3 - Filtrate Reaeration**	2.7	2.7	2.6	2.5	2.7	2.4	**16**
d.	**Alternative 4 - Existing MLE**	4.7	3.3	4.4	3.3	3.0	2.6	**21**
e.								
g.								
h.								

Next Steps

- Finalize Process
- Predesign (Start in February)
- Final Design
- Construction (Bid Fall 2010)

APPENDIX G

Meeting Notes—February 1, 2010

Bend WRF Secondary Expansion
Task A1.06 Process Evaluation
February 1, 2010 Process Evaluation Meeting
Scoring, Ranking, and Selection of Alternatives

ATTENDEES:

Brady Fuller – CH2M HILL
Steve Simpson – City of Bend
Jim Ossenkop– City of Bend
Chris Struck– City of Bend
Marc Mickey– City of Bend
Joe Burghardt – City of Bend
Elmer Roshone – City of Bend
Mike Gillette– City of Bend
William leaf – CH2M HILL
Greg Mooney– City of Bend
Justin Walsworth– City of Bend
Scott Thompson – City of Bend
Dave Green – CH2M HILL
Jim Wodrich – City of Bend
Paul Roy – City of Bend

FROM: Brady Fuller

DATE: February 1, 2010

VENUE: WRF Training Room

Jim/Peggy to add all O&M staff to EADOC.

Jim provided summary of project to date including process evaluation and modeling, site visits, technical paper review, staff presentations, scoring.

Does weighting all criteria equally at 1.0 seam ok? Staff had no comments on weighting. Weighting does not appear to have much, if any effect, on the final ranking of alternatives.

What reservations does O&M staff have on IFAS?

1) cost (up front costs were perceived to be high by a few staff).

City and CH2M HILL are discussing different modes of implementing IFAS (using only existing AB's, building a new AB, etc.) Alternatives for phasing (Bill Leaf described)

Build-out capacity can be achieved now in existing tankage. IFAS media currently costs about $850/cy.

a) Doing retrofits can be "quick" - a few months for each basin, but this does require removing existing basin from service.

b) Build a new aeration basin with IFAS, and this has a few options

   a. Operate it as IFAS as separate train (with separate clarifier)

   b. Operate in parallel as MLE. Different SRT's is a challenge.

c. Do b) and convert 1, 2 or 3 existing MLE to IFAS (two aeration basins with IFAS together with existing secondary clarifiers provide siginificant capacity increase, up to 9-mgd depending on IFAS fill)

Develop phasing, costs, mark capacity during pre-design – have a graph that depicts this…would be good for Council and other 'instructional' use.

IFAS can be added over time to a reactor, starting with as little as 25% fill (depending on the number of aeration basins converted) and moving toward 67% fill.

Capacity scenarios developed during Process Evaluation Study: 8 MGD, 9.2 MGD, and 10.5 MGD and then add even more air to further increase nitrification.

46% addition of IFAS media to all existing reactors gets plant to 8 mgd, 55% fill results in 9.2 mgd, and 67%fill results in 10.5 mgd.

Question from staff. Is a 4th secondary clarifier required? Yes, by 2023 with all IFAS options.

Time involved with new basin vs. retrofit. A new AB would take 12 – 18 months. Modifying existing basins may take 6-8 weeks per basin.

Deschutes Brewery impact is presently equivalent to about 3000 EDU. Shifting Deschutes Brewery waste to discharge only at night would free up some capacity for additional housing growth.

Recognize that there are cost trade offs between blower capacity, dissolved oxygen levels, and media costs.

Long term issue with media. Are you tied to sieve design and air grid layout dictated by the manufacturer? What if a certain style/size of media is not available in the future?

Need to develop an approach to ease the effort involved with adding media to IFAS basins so that O&M staff can perform that function in the future as growth increases capacity demands.

IFAS is driven by TN Limits in most places it's selected. Given the rising pressure on Northwest utilities to meet more stringent nutrient requirements, it's likely that more IFAS systems will be implemented, possibly reducing unit costs. Media costs are tied to petroleum market and pricing.

Pre-purchase or pre-selection of equipment seems likely (IFAS, blowers, maybe other equipment).

How many vendors for IFAS media? MOP 8 has a measles chart.

1. Veolia
2. IDI
3. Siemens
4. Entec

Vendors should be encouraged to give presentations to O&M staff during pre-design.

Action Item Summary

1. **Jim/Peggy to add all O&M staff to EADOC.**
2. **CH2M HILL to finalize Tech Memo on Process Evaluation work and decision process.**
3. **CH2M HILL will support Bend staff in ongoing Deschutes Brewery work and finalize tech memo and recommendations.**
4. **Bend staff to set up meeting with DEQ to review Process Evaluation TM and decision process.**
5. **Bend staff to set up workshop with Council to review Process Evaluation recommendations and path forward.**

APPENDIX H

Process Evaluation QA-QC Review Comments

City of Bend Review Comments

Date:	3/4/10	Project Name:	Secondary Expansion
Department:	UTILTIES	Submittal:	DRAFT Process Evaluation Study
Reviewer:			Page 1 of 10

Item #	Dwg Sht/ Spec Paragraph	Comments	Type	Consultant Response
1	**Paul Roy Comments**			
2	**Page 9 – first bullet of summary**	Is wet weather contact stabilization still necessary with the selection of IFAS?		**Contact stabilization may be required during peak wet weather flows to reduce secondary clarifier solids loading to avoid overloading conditions, and also protect the solids inventory within the anoxic zones. While a reduced SRT (and associated mixed liquor concentration) is inherent to the IFAS system, reducing the number of secondary clarifiers required at the buildout conditions, the existing anoxic selectors preceding the aerobic zones will remain. The necessity of contact stabilization for treating peak wet weather flows will be verified further during predesign.**
3	**Page 26 – first paragraph**	The City purposely….experienced city staff. Replace experienced with "affected"		**"Experienced" has been replaced with "affected" in the first paragraph of page 26**
4	**Page 28 – bullet #8**	Before council we need a workshop with the PW Director		**Bullet #8 on Page 28 has been revised to incorporate this action time. At the time of the memo revision, these action items have already been completed. However, it was chosen to maintain the future tense because the bulleted list is an excerpt from meeting minutes.**
5	**Page 28 – bullet #9 (new)**	Council workshop will be to "report" the findings and path forward		**A new bullet #9 has been added to page 28 to incorporate this comment. Please also see the Consultant Response to Item #4.**

COMMENT TYPE:
'F' - FATAL FLAW MUST BE REVISED
'S' - SERIOUS PROBLEM, NEEDS TO BE ADDRESSED. COULD ESCALATE TO 'F' IF LEFT UNATTENDED.
'C' - COORDINATION PROBLEM. DISCIPLINE NEEDS TO TALK.
'N' - NOTE TO DESIGNER, ITEM, NOT SERIOUS, NO NEED TO INCORPORATE, BUT COULD RESULT IN A BETTER PRODUCT IN FUTURE.

City of Bend Review Comments

Date:	3/4/10	Project Name:	Secondary Expansion
Department:	UTILTIES	Submittal:	DRAFT Process Evaluation Study
Reviewer:			Page 2 of 10

Item #	Dwg Sht/ Spec Paragraph	Comments	Type	Consultant Response
6	**Page 33**	Conclusion is weak. Need to provide the reasons for the selection and include the benefits to the COB. What about ease of expansion, industrial flows, operational ease, low maintenance? What about cost savings? Impact on schedule.		**The conclusion on page 33 has been expanded to include a summary of the factors driving the decision of IFAS as the selected alternatives for the Bend WRF expansion.**
7	**Steve Prazak-Lab comments**			
8	**Task A1.07 page 5 section 3.3** Second paragraph	Second paragraph is a duplicated statement found in the first paragraph of this section.		**Items #8, #9, #10 and #11 do not refer to the Process Evaluation summary. They refer to the Deschutes Brewery Diurnal Flow Pilot Testing Technical Memorandum which is not currently under revision.**
9	**Task A1.07 pg14 section 3.5.2** Figure 7	Difficult to interpret.		**Items #8, #9, #10 and #11 do not refer to the Process Evaluation summary. They refer to the Deschutes Brewery Diurnal Flow Pilot Testing Technical Memorandum which is not currently under revision.**
10	**Task A1.07 pg15 section 3.5.2** WRF Operational Parameters	The statement that addresses the increased SVI as being coincidental is most likely correct.		**Items #8, #9, #10 and #11 do not refer to the Process Evaluation summary. They refer to the Deschutes Brewery Diurnal Flow Pilot Testing Technical Memorandum which is not currently under revision.**

COMMENT TYPE:
- **'F' - FATAL FLAW MUST BE REVISED**
- **'S' - SERIOUS PROBLEM, NEEDS TO BE ADDRESSED. COULD ESCALATE TO 'F' IF LEFT UNATTENDED.**
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City of Bend Review Comments

Date:	3/4/10	Project Name:	Secondary Expansion
Department:	UTILTIES	Submittal:	DRAFT Process Evaluation Study
Reviewer:			Page 3 of 10

Item #	Dwg Sht/ Spec Paragraph	Comments	Type	Consultant Response
11	**Task A1.07 pg 16 section 4.1** First paragraph	Increase in system SVI levels: ?'s – Will the selected IFAS alternative alleviate this situation? Will OUR and respiration rate tests be sufficient (this was brought up in the 2ndary Expansion Summary)?		**Items #8, #9, #10 and #11 do not refer to the Process Evaluation summary. They refer to the Deschutes Brewery Diurnal Flow Pilot Testing Technical Memorandum which is not currently under revision.** **Please also see the Consultant Response for items #17. Incorporation of settleability control into the design of the treatment plant expansion will continue to be considered throughout the design process.**
12	**Greg Mooney Comments**			
13	**p.14 Fig 3**	Anoxic basin 3-incorporate Fine bubble diffusers.		**Since the majority of nitrifier activity is expected to occur on the IFAS media, the benefit of incorporating additional aerobic volume for cold-weather nitrification is limited with IFAS. However, other benefits of incorporating an initial swing zone prior to the IFAS zone and of incorporating an anoxic/aerobic swing zone downstream of the IFAS zone will be evaluated further during predesign. Therefore use of additional aeration (fine bubble or coarse bubble) will be evaluated in predesign.**
14	**Scott Thompson Comments**			

COMMENT TYPE: 'F' - FATAL FLAW MUST BE REVISED
'S' - SERIOUS PROBLEM, NEEDS TO BE ADDRESSED. COULD ESCALATE TO 'F' IF LEFT UNATTENDED.
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City of Bend Review Comments

Date:	3/4/10	Project Name:	Secondary Expansion
Department:	UTILTIES	Submittal:	DRAFT Process Evaluation Study
Reviewer:			Page 4 of 10

Item #	Dwg Sht/ Spec Paragraph	Comments	Type	Consultant Response
15	p.3 4th para	Assumes we maintain the 10 mg/L TN in Permit		**The incorporation of the secondary anoxic/aerobic swing zone provides the Bend WRF with flexibility to enhance total nitrogen removal should treatment for future, more stringent effluent limits be required. The incorporation of a secondary anoxic zone after the IFAS zone could be used with external carbon addition allow the Bend WRF to meet total nitrogen permit limits less than 10 mg/L. External carbon addition in the first anoxic zone can also improve total nitrogen removal. A more detailed process analysis is required to determine to what level of total nitrogen removal can be reliably achieved at the Bend WRF when a secondary anoxic zone and external carbon addition is incorporated. It is also important to recognize the conversion of the swing zone from aerobic to anoxic will also likely decrease the overall treatment capacity of the system.**
16	p. 4 Influent Flow and Loads	M.O.U. with DEQ is a viable option for construction		**The phasing of construction of the IFAS system to provide the required capacity will be addressed in greater detail during the predesign phase of the project and will be a critical design decision. CH2M HILL will work with the City of Bend and other stakeholders as necessary to determine the best approach to accomplish the treatment plant expansion. It is understood that a MOU with DEQ for construction phase is one alternative approach.**

COMMENT TYPE:
- 'F' - FATAL FLAW MUST BE REVISED
- 'S' - SERIOUS PROBLEM, NEEDS TO BE ADDRESSED. COULD ESCALATE TO 'F' IF LEFT UNATTENDED.
- 'C' - COORDINATION PROBLEM. DISCIPLINE NEEDS TO TALK.
- 'N' - NOTE TO DESIGNER, ITEM, NOT SERIOUS, NO NEED TO INCORPORATE, BUT COULD RESULT IN A BETTER PRODUCT IN FUTURE.

City of Bend Review Comments

Date:	3/4/10	Project Name:	Secondary Expansion
Department:	UTILTIES	Submittal:	DRAFT Process Evaluation Study
Reviewer:			Page 5 of 10

Item #	Dwg Sht/ Spec Paragraph	Comments	Type	Consultant Response
17	**p.7 High Intensity Air**	Would this be required with IFAS?		**The decreased operational SRT of the IFAS system is expected to be below the washout SRT of *Microthrix parvicella.* Therefore, IFAS provides inherent *M. parvicella* control. The higher operating DO concentrations in the IFAS zone (4.5 mg/L compared to 2.0 mg/L for activated sludge) will also serve to reduce the conditions favoring *M. parvicella* growth.** **Depending on the chosen approach for phasing/construction of the IFAS system, modification of the existing aeration system to provide high-intensity air would help control *M. parvicella* if the treatment plant will operate both IFAS and traditional activated processes for a length of time.**
18	**p.7 Optimization**	Agree. More characterization		**The results of the detailed wastewater treatment plant characterization will be used during the design of the Bend WRF expansion. Additional characterization and sampling may be required to determine the appropriate high-intensity air system design, if still warranted as outlined in the Consultant Response to Item #17.**
19	**p. 9 Optimization of Alternatives**	Wet Weather plant upgrades should be evaluated as a wastewater issue. Anoxic/Aerobic swing zone, is this viable for IFAS.		**Please see the Consultant Response to Item #2 regarding the wet weather plant upgrades.** **Please see the Consultant Response to Items #13 and #15 regarding anoxic/aerobic swing zones.**

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City of Bend Review Comments

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20	p.12 first bullet	"Channel/launder"?-can this be done with piping, flow meters and FCVs in lieu of open channel? Foam Area?		**Options for configuring the IFAS zone and other infrastructure will be evaluated further in predesign in collaboration with the City of Bend and with consideration to hydraulic constraints and ease of operability.**
21	p.13 First Bullet	Interesting-Reduce lime addition		**The system will be optimized for TN removal, through the management of effluent NH3 values possible with an IFAS system (see Item #23) and the possible use of a post anoxic/aerobic swing zone. With the additional post anoxic zone, an increase in denitrification may be possible allowing for improved alkalinity recovery. It is not anticipated that the need for supplemental alkalinity will be eliminated. However, there may be a capacity reduction associated with implementing this post-anoxic zone. The relative benefits of incorporating a post-anoxic zone will be evaluated further during predesign. Please also see Consultant Response to Items #13 and #15.**
22	p. 13 sixth bullet	It would be ideal if we could fully capitalize the benefit of "sustainability" in this project		**During the collaborative design process, CH2M HILL will work with the City of Bend to identify design features that enhance sustainability and determine if these features are desired in the final treatment plant design.**

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Item #	Dwg Sht/ Spec Paragraph	Comments	Type	Consultant Response
23	**p.13 eighth bullet**	Very Interesting, complex in regards to coliform or TN requirements		**The level of nitrification achieved by the biofilm is directly related to the DO concentration in the IFAS zone. This relationship provides the opportunity to optimize the system based on the effluent requirements of the plant. The IFAS system will be designed in collaboration with the City of Bend to provide sufficient operational flexibility to allow optimization of effluent ammonia if this is desired.**
24	**p.14 Ops complexity**	Need to thoroughly analyze proper foam control and management		**CH2M HILL agrees that the IFAS system should be designed with the tools required to mitigate and control potential foaming issues.**
25	**p. 14 construction constraints**	4-6 weeks construction – Seems and MOU would be a viable option for cost savings		**See Consultant response to item #16.**
26	**Jim Wodrich Comments**	Very Good Report/Work.		
27	**p.3**	Wastewater characterization/Sensitivity analysis comment in text needs to be clarified in Project Definition/Schematic Design phase to close the loop.	**C**	**The proper level of wastewater characterization and model calibration will be determined early in predesign and used to design the treatment plant expansion.**
28	**p.4**	SVI<200 assumption in all options. Verify how selected IFAS option makes this assumption viable as we move forward.	**C**	**CH2M HILL agrees that the design should address potential settleability issues at the Bend WRF and will continue to consider this concern. Please see Consultant Response to Item #17 for further elaboration on sludge settleability in an IFAS system.**
29	**p.7 last para**	Seems like the recommendations here should be bolded alos just like the other options	**C**	**The recommendations have been bolded for consistency.**

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30	p.13	Define in more explanation how the swing zone will help with alkalinity. How does this impact the future requirements for lime addition at the headworks, can we move the feed location?	C	**During the predesign phase, the benefits and necessity of incorporating the post-anoxic/aerobic swing zone will be evaluated more fully. Please also see the Consultant Response to Item #13, #15 and #21.**
31	p.13	Are there a large number of vendors that provide "medium bubble" diffusers? Do they come specified with the IFAS vendor package?	C	**Historically, the diffuser package has been specified and supplied as part of the IFAS media vendor package. CH2M HILL will be reviewing the procurement approach with the City during the Project Definition Phase.**
32	p.19 fig C	It would be nice to have a new figure to compare to this showing the option for building a new aeration basing first then retrofitting the existing basins and how that effects the graph, maybe in the project definition/schematic design phase.	C	**The phasing of construction of the IFAS system to provide the required capacity will be addressed in greater detail during the predesign phase of the project and will be a critical design decision.**
33	p. 22	Need (1) New AB, Retrofit basins 1,2,3	C	**The IFAS process can meet the capacity requirements for the City of Bend through the year 2030 without the construction of a new aeration basin. For the comparative cost evaluation, the construction of a new aeration basin was not considered for IFAS because this aeration basin is not required until the year 2030. This approach is consistent for the IFAS, MLE and stepfeed alternatives.**
34	p.32 Tasks	Project Definition/Schematic Design should alos include P&ID's and Process Loop Descriptions.	C	**Preliminary Process Loop Descriptions and P&IDs will be developed as part of the Project Definition/Schematic Design Phase. The report has been updated accordingly (p. 32)**

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35	General	See attached Authorization to Proceed with the IFAS Process Selection dated March 23, 2010	C	
36		End of Comments		

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Item #	Dwg Sht/ Spec Paragraph	Comments	Type	Consultant Response

FORM NO.	4.02.5
TITLE:	QA/QC Review Comments Form
PURPOSE:	This form is to be used by the project team to note comments and concerns for each design deliverable submittal. This form can be used by anyone to note comments on any consultant deliverable or product. The project manager should provide the completed form including all designer responses to the project team members prior to the subsequent design submittal.
PREPARED BY:	Project Team Reviewers and Project Manager
DIRECTED TO:	Consultants
COPIES TO:	Files

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