PUBLIC COMMENT ISSUANCE DATE: JULY 9, 2016

PUBLIC COMMENT EXPIRATION DATE: AUGUST 8, 2016

**TECHNICAL CONTACT:**

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The U.S. Environmental Protection Agency (EPA) plans to **modify**
a National Pollutant Discharge Elimination System (NPDES) permit **for** the following facility
pursuant to the provisions of the Clean Water Act, 33 U.S.C. §1251 et seq:

# WEST BOISE WASTEWATER TREATMENT FACILITY
# ID-002398-1

## EPA PROPOSES TO MODIFY NPDES PERMIT

EPA proposes to modify the NPDES permit issued to the facility referenced above. The draft modification proposes to change the interim limits for total phosphorus and to remove the Dixie Slough upstream monitoring requirement. Specifically, EPA proposes the following:

- Increase the interim limit under the compliance schedule for total phosphorus from a seasonal average of 0.6 mg/L (May 1 – September 30, 2016) and 0.5 mg/L (May 1 – September 30, 2017) to an annual average (May 1 – April 30) of 2.8 mg/L;
- Remove the upstream monitoring requirement for the Dixie Phosphorus Removal Facility.

The only modifications that EPA is accepting comments on are the proposed modifications to the total phosphorus interim limits and the removal of the Dixie Slough upstream monitoring requirement.

This Fact Sheet includes:

- Information on public comment, public hearing, and appeal procedures;
- A description of the discharge location; and
- Technical information supporting the draft modified total phosphorus interim limits and removal of the upstream monitoring requirement for the Dixie Slough.

## 401 Certification for Facilities that Discharge to State Waters

The EPA is requesting that the Idaho Department of Environmental Quality (IDEQ) certify the NPDES permit for this facility, under Section 401 of the Clean Water Act. Comments regarding the certification should be directed to:

IDEQ Boise Regional Office
1445 North Orchard Street
Boise, ID 83706
Phone: (208) 373-0550
Fax: (208) 373-0287

## Public Comment

EPA will consider all substantive comments on the proposed modifications to the NPDES permit before taking final action on the modification. Persons wishing to comment on, or request a public hearing for, the proposed permit action may do so in writing by the expiration date of the public notice period. A request for a public hearing must state the nature of the issues to be raised as well as the requester's name, address, and telephone number. All comments should include name, address, phone number, a concise statement of basis of comment and relevant facts upon which it is based. All written comments should be addressed to:

Ms. Erin Seyfried
U.S. EPA, Region 10
1200 Sixth Avenue, OWW-191
Seattle, WA 98101
Fax: (206) 553-0165
E-mail: seyfried.erin@epa.gov

After the Public Notice period has ended and the public comments have been considered, EPA Region 10's Director of the Office of Water and Watersheds will make a final decision regarding permit modification. If no substantive comments are received, the conditions in the proposed permit modification will become final and the permit modification will become effective upon issuance. If substantive comments are received, EPA will respond to the comments and the permit will become effective 30 days after its issuance date, unless an appeal is submitted to the Environmental Appeals Board within 30 days.

## Documents are Available for Review

The draft NPDES permit, fact sheet and related documents can be reviewed or obtained by visiting or contacting the EPA's Regional Office in Seattle between 8:30 a.m. and 4:00 p.m., Monday through Friday (see address below). The draft permit, fact sheet, and other information can also be found by visiting the Region 10 website at "www.epa.gov/R10earth/waterpermits.htm".

U.S. EPA Region 10
1200 6th Avenue, OWW-191
Seattle, Washington 98101
(206) 553–0523

U.S. EPA Idaho Operations Office
950 West Bannock Street, Suite 900
Boise, ID 83702
(208) 378–5746

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# I. FACILITY OVERVIEW

The City of Boise (the City) owns and operates two wastewater treatment facilities (WWTFs): Lander Street Wastewater Treatment Facility (Lander Street facility) and the West Boise Wastewater Treatment Facility (West Boise facility). Both facilities treat wastewater from domestic and industrial sources. The discharge from the Lander Street facility is located at approximately river mile 49.9 on the Boise River and the West Boise facility discharge is located downstream of the Lander Street facility at approximately river mile 43.5 of the Boise River (South Channel around Eagle Island). The West Boise facility serves Boise City/Ada County, West Boise Sewer District, Garden City and Eagle Sewer District. The total population served, according to the 2010 application, is approximately 148,300. The current design flow is 24 million gallons per day (MGD). This fact sheet addresses permit modifications for the West Boise facility only.

EPA reissued the NPDES permit for the West Boise facility on March 15, 2012. On September 1, 2012, EPA modified the permit to increase the interim minimum level (IML) for mercury. On June 27, 2013, EPA modified the permit to incorporate a pilot offset project to allow the City to meet the final effluent limits using a combination of plant improvements and treatment of otherwise unregulated non-point source agricultural return flows in Dixie Slough. The offset requires the City to remove more total phosphorus within the watershed than if all phosphorus reductions occurred at the West Boise Wastewater Treatment Facility.

On June 1, 2016, the City submitted a Request for Modification of the West Boise NPDES Permit (ID-002398-1). In this letter (see Appendix B), the City requested modification of the interim limits for total phosphorus (TP) and the upstream monitoring requirement for the Dixie Phosphorus Removal Facility (DPRF) project.

# II. INTERIM LIMITS FOR TOTAL PHOSPHORUS

## A. Cause for Modification

The regulations at 40 CFR §122.62 allow for NPDES permits to be modified for cause. The cause for modification of the interim limits for total phosphorus is due to:

- Substantial alterations to the permitted facility that occurred after the permit issuance (40 CFR §122.62(a)(1));
- Installation of a treatment technology considered by the permit writer in setting interim limits for total phosphorus, which has been properly operated and maintained, but nevertheless has been unable to achieve those limits (40 CFR §122.62(a)(14); and
- The submission of new information that was not available at the time of the current permit's issuance, which would have resulted in the application of different interim total phosphorus limits at the time of the original permit issuance (40 CFR §122.62(a)(2)).

The following sections provide a detailed discussion of the alterations to the permitted facility, the installation and proper operation and maintenance of the treatment technology, and a summary of new information provided by the facility.

## B. Lower Boise River TMDL 2015 Total Phosphorus Addendum

Section 303(d) of the Clean Water Act (CWA) requires states to develop a Total Maximum Daily Load (TMDL) management plan for water bodies determined to be water quality limited segments. A TMDL is a detailed analysis of the water body to determine its assimilative capacity. The assimilative capacity is the loading of a pollutant that a water body can assimilate without causing or contributing to a violation of water quality standards. Once the assimilative capacity of the water body has been determined, the TMDL will allocate that capacity among point and non-point pollutant sources, taking into account the natural background levels and a margin of safety. Allocations for point sources are known as "waste load allocations" (WLAs).

The State of Idaho issued the *Lower Boise River TMDL 2015 Total Phosphorus Addendum* (Lower Boise River TMDL) in August 2015, which was approved by EPA on December 22, 2015. The Lower Boise River TMDL provides a total phosphorus (TP) WLA of 0.1 *mg/L* (May 1 – September 30) and 0.35 *mg/L* (October 1 – April 30) for the West Boise facility (IDEQ, 2015). The current NPDES permit (2012 Permit) for the West Boise facility includes a 10-year compliance schedule to allow for necessary treatment upgrades so the facility can achieve a final TP effluent limit of 0.07 *mg/L* (measured as a seasonal average from May 1 – September 30).

EPA is not proposing to modify the final TP effluent limits (0.07 *mg/L*) at this time. Although the recently-established WLAs are less stringent than the current final TP effluent limit in the permit, the interim effluent limits are performance-based limits that apply to the facility until July 31, 2022 when the final TP effluent limits go into effect. The 2012 Permit for the West Boise facility expires on July 31, 2017. At that time, EPA intends on reissuing this permit and will establish final TP effluent limits that are consistent with the assumptions and requirements of the WLA in the Lower Boise River TMDL.

## C. Overview of the Total Phosphorus Removal Project at the West Boise Facility

The City has completed the design and implementation of a Total Phosphorus (TP) Removal Project at the West Boise facility. The TP Removal Project is part of the City's approach to reducing effluent phosphorus to a meet a future final effluent limit of 0.07 milligrams per liter (*mg/L*). The permit has provided the West Boise facility with a 10 year compliance schedule to meet the final TP effluent limits, with interim limits to be met during that time. The TP Removal Project required the City to retrofit the treatment process at the facility to include the following key components:

- Enhanced Biological Phosphorus Removal (EBPR) – conversion of the existing aeration basins to a configuration resulting in enhanced phosphorus removal from the wastewater.

- Primary Sludge Fermentation for Production of Volatile Fatty Acids – a two-stage, complete-mix fermentation system to provide volatile fatty acids for reliable performance of the EBPR system.
- Waste Activated Sludge (WAS) and Primary Sludge Thickening – a new thickening facility utilizing rotary screen thickeners.
- Optimized phosphate release to minimize unintentional struvite precipitation.

## D. Overview of Enhanced Biological Phosphorus Removal

Enhanced biological phosphorus removal (EBPR) is a process that uses alternating anaerobic and aerobic zones to provide an environment that encourages the growth of phosphorus accumulating organisms (PAOs; US EPA 2010 and Metcalf & Eddy 2003). PAOs are heterotrophic microorganisms that take up and store phosphate in excess of their biological requirements, thereby accomplishing biological phosphorus removal. PAOs are present in activated sludge systems, however, they require specific environmental conditions in order to thrive and successfully remove phosphorus from wastewater. The following conditions are required to encourage PAO growth and EBPR within a treatment system:

- PAOs must be subjected to anaerobic conditions (e.g. no dissolved oxygen and no nitrate-nitrogen).
- PAOs require a significant amount of organic material (i.e. substrate) to be in a soluble and readily biodegradable form, such as volatile fatty acids (VFAs).
- The PAOs must be exposed to an aerobic environment following anaerobic conditions to allow for the uptake of phosphate from the wastewater.

In an anaerobic environment, PAOs take up the soluble, biodegradable substrate (i.e. VFAs) and convert it to poly-b-hydroxyalkanote (PHA), which is then stored in the cells of the PAOs. PAOs produce the energy required to convert the VFAs to PHA by the separation of polyphosphate (Poly-P) granules within the microorganism, which releases phosphate into the surrounding environment. Establishing and maintaining a strict anaerobic zone is critical for PAOs to be able to take up VFAs and store PHA. The presence of oxygen, either in a dissolved form ($O_2$), or in a combined form such as nitrites and/or nitrates ($NO_2^-$, $NO_3^-$), will disrupt the process by putting PAOs at a competitive disadvantage with other microorganisms (i.e. denitrifying bacteria). As the wastewater passes through the anaerobic phase, the concentration of VFAs will decrease and the phosphate concentration will increase.

In an aerobic environment, PAOs use oxygen to metabolize the stored PHA as a source of carbon and energy. PAOs will replenish their stored Poly-P supplies through the uptake of excess phosphate from the surrounding environment (i.e. mixed-liquor), which is the key element of enhanced biological phosphorus removal. As wastewater passes through the aerobic phase, carbon substrate will continue to decrease (measured as biological oxygen demand; BOD), as will the concentration of phosphate.

After the aerobic zone, water enters a secondary clarifier and PAOs settle to the bottom along with the activated sludge. The phosphorus stored in the PAOs is removed with the wasted activated sludge, thus producing a net removal of phosphorus.

There are a number of different EBPR treatment configurations, all of which rely on the same basic principles: anaerobic zones for PAO selection and the release of phosphorus and aerobic zones for phosphorus uptake (US EPA, 2010). For EBPR systems that require ammonia-nitrogen removal, such as the West Boise Facility, denitrification, the process by which microorganisms reduce nitrates ($NO_3^-$) to nitrogen gas ($N_2$), is required to maintain sufficient phosphorus removal. Nitrates are ultimately produced during the nitrification of ammonia-nitrogen ($NH_4$-N). The integrity of the anaerobic zone is compromised by the nitrates ($NO_3^-$), due to the availability of oxygen in a combined form, resulting in an anoxic zone. If the nitrate concentration is not reduced, then PAOs will be out-competed by other microorganisms in the uptake of biodegradable carbon sources (VFAs), therefore limiting the EBPR process. To address this, these enhanced biological nutrient removal systems incorporate anoxic zones into the treatment configuration to allow for the reduction of nitrates, thus preserving the integrity of the anaerobic zone and ensuring PAOs maintain their competitive advantage over other microorganisms in the uptake of VFAs.

West Boise's configuration follows the Westbank process (Figure 1) and distributes the primary effluent (PE) between: Anoxic Zone 1 (AX 1) to facilitate denitrification of the return activated sludge (RAS); the Anaerobic Zone (AN) to provide substrate to the microorganisms; and Anoxic Zone 2 (AX 2) to provide denitrification of the mixed-liquor since that contains additional nitrates introduced by an internal recycle stream from the end of the aeration basin. The aerobic zone (AER) enables nitrogen and phosphorus removal.

The TP Removal Project at the facility includes a waste activated sludge (WAS) Phosphate ($PO_4$-P) Release Tank and a Struvite Recovery Facility to help maximize struvite recovery in the system (Leaf, 2016*)*. Struvite is a magnesium-ammonium phosphate ($MgNH_4PO_4 \cdot 6H_2O$) compound that commonly forms in anaerobic conditions as a hard and insoluble crystal, and can interfere with instrumentation (US EPA, 2010). As discussed above, PAOs release phosphate into the surrounding environment under anaerobic conditions. The Phosphate Release Tank provides an anaerobic environment for the WAS, which promotes the release of phosphate prior to the anaerobic digestion process and minimizes uncontrolled formation of struvite in the system. Since the West Boise dewatering facility processes the Lander Street facility's digested sludge, the dewatering filtrate from the anaerobic digesters at West Boise contains a much higher concentration of phosphate. If the dewatering filtrate was immediately returned to the start of the EBPR system, it would effectively increase the influent nutrient load to the facility. To address this, the phosphate rich filtrate from the Phosphate Release Tank and the dewatering filtrate from the anaerobic digesters is processed through the Struvite

Recovery Facility before any return steams are commingled with the raw sewage influent (*not shown in Figure 1*).

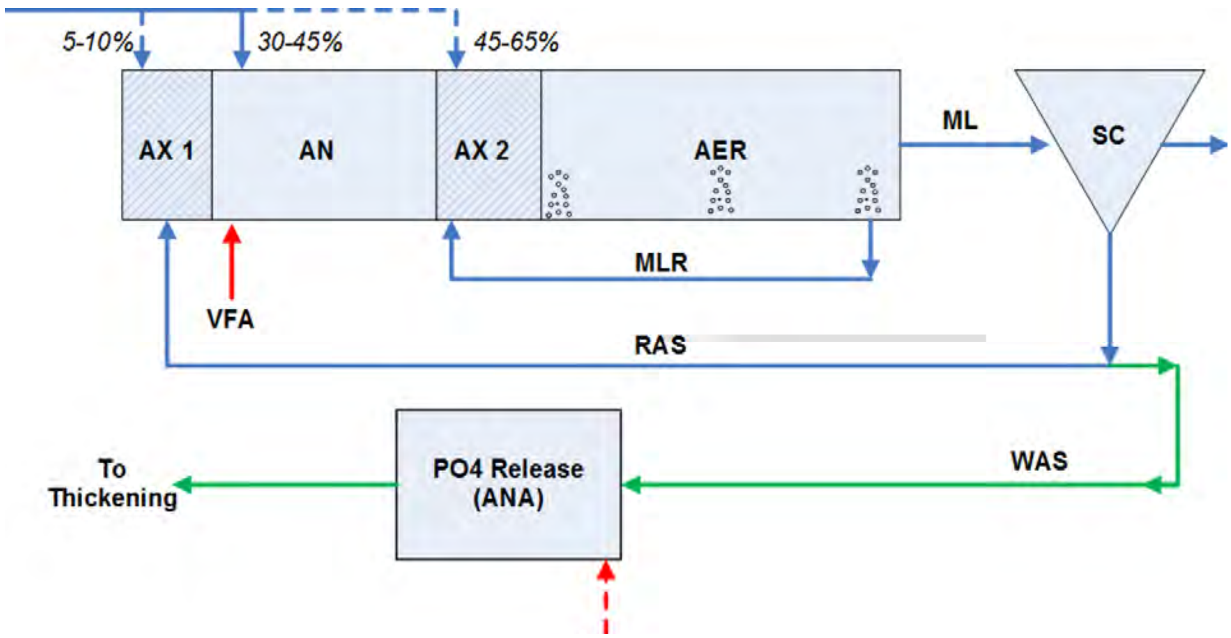


**FIGURE 1:** *EBPR treatment configuration at the West Boise Facility (Leaf, 2016).*
***AX:** Anoxic Zone; **AN:** Anaerobic Zone; **AER:** Aerobic Zone; **ML:** Mixed-Liquor; **SC:** Secondary Clarifier; **MLR:** Mixed-Liquor Recycle; **RAS:** Return Activated Sludge; **WAS:** Waste Activated Sludge; **VFA:** Volatile Fatty Acids.*



## E. WEST BOISE FACILITY EBPR PERFORMANCE RESULTS

The City's request for modification included:

- Effluent monitoring data since start-up of the EBPR system commenced at the facility (Appendix A); and
- The *West Boise Wastewater Treatment Facility Enhanced Biological Phosphorus Removal Evaluation Technical Memorandum* (*Leaf, 2016*), which was developed to summarize the ongoing optimization of the EBPR system installed at the facility, as well as to present data on the system performance (Appendix C).

The startup of the West Boise TP Removal Project began in May 2015, during which time a fermentation system was placed in operation and began producing biodegradable carbon sources (e.g. VFAs). In July 2015, phosphate release was detected in the anaerobic zone (AN; see Figure 1), which indicated that the EBPR system was developing. Beginning in September 2015, the facility began focusing on optimizing the EBPR system. Phosphate analyzers were installed at the facility and provided continuous monitoring of the primary effluent and the facility effluent.

Figure 2 presents the phosphate mass loading trends, in terms of pounds of phosphorus per day (lb- P/day), observed between September 2015 and April 2016. During this operational period, the EBPR system produced an average of 2.0 *mg/L* TP in the effluent (average from September 2015 to May 2016), with monthly averages ranging from 1.0 *mg/L* to 3.5 *mg/L* (Table 1; see also Appendix A for complete list of effluent data).

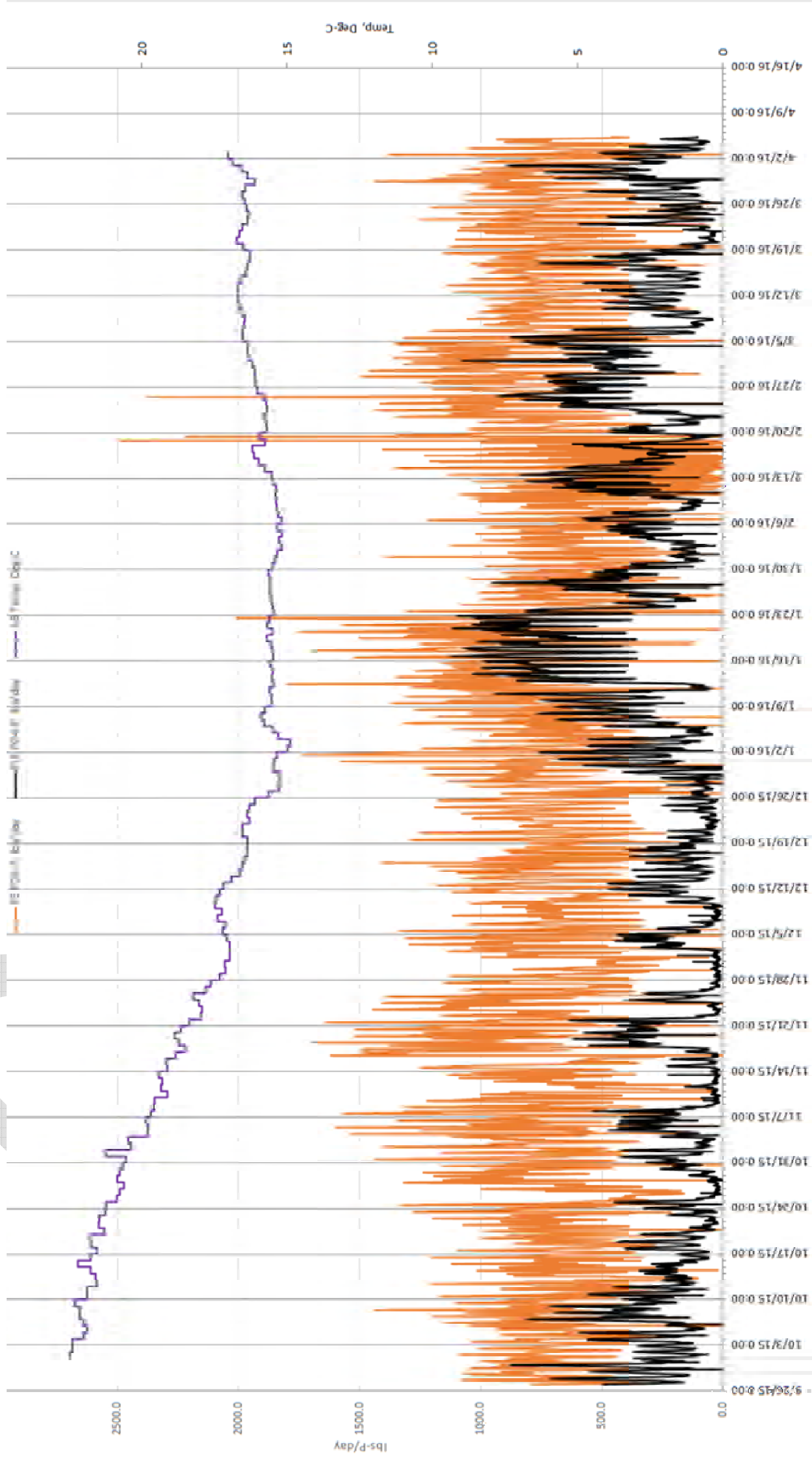


**FIGURE 2:** *Phosphate loading trends (in pounds of phosphorus per day; lb-P/d) in the primary effluent (PE; in orange) and the facility effluent (PLE; in black) between September 2015 and April 2016 (Leaf, 2016).*

| **TABLE 1:** *Total phosphorus effluent values at the West Boise facility after the EBPR system was established (Source: City of Boise).* | |
|---|---|
| **MONTH** | **AVERAGE MONTHLY TP VALUE (MG/L)** |
| September 2015 | 1.6 |
| October 2015 | 1.4 |
| November 2015 | 1.2 |
| December 2015 | 1.0 |
| January 2016 | 3.5 |
| February 2016 | 2.3 |
| March 2016 | 2.4 |
| April 2016 | 2.1 |
| May 2016 | 2.3 |
| ***Average over Operational Period (n=111)*** | ***2.0*** |

**NOTE:** *See Appendix A for complete data set.*

In October 2015, the Facility began to evaluate the preliminary results from the EBPR system in efforts to identify areas of the treatment process that needed to be optimized for better overall performance. The City identified the following unique site characteristics as contributing to the observed EBPR performance and the facility's inability, to date, to meet the current interim total phosphorus limits in the permit (*City of Boise Request for Modification Letter dated June 1, 2016*):

1. The West Boise facility accepts and manages anaerobically digested sludge from the Lander Street facility. The Lander Street facility is operating an EBPR system, resulting in solids that are high in total phosphorus and nitrogen. After the dewatering process at the West Boise facility, the dewatering filtrate, which is typically returned to the primary effluent, exhibits higher concentrations of phosphate in solution thus increasing the nutrient load entering the EBPR system and increasing the amount of substrate required by microorganisms in the EBPR system to efficiently reduce nutrient concentrations. The West Boise facility has incorporated a Struvite Recovery Facility into the treatment design to enhance the removal of phosphorus from the dewatering filtrate through precipitation prior to any return flows being commingled with primary effluent at the start of the EBPR process. However, the facility is continuing efforts to improve the performance of the Struvite Recovery Facility and dewatering system.

2. West Boise processes two (2) MGD of influent from the Eagle Sewer District. The wastewater, which is treated in an aerated lagoon at the Eagle Sewer District, has very low BOD and TSS, but has high phosphorus and nitrogen values. The low BOD and high nutrient load present in the pre-treated wastewater requires West Boise to manufacture additional carbon sources (VFAs) to maintain optimum substrate-to-nutrient ratios that can adequately support the microorganisms needed for a successful enhanced nutrient removal system. The City and Eagle Sewer District are currently evaluating other options

for handling this additional flow, including: bypassing the aerated lagoon and sending flows directly to the West Boise facility and/or holding or reducing the flows to the West Boise facility during peak loading conditions.

3. West Boise has highly dynamic influent characteristics as a result of maintaining consistent flows at the Lander Street facility. The City maintains a consistent influent flow of 10 MGD at the Lander Street facility, which requires West Boise to manage diurnal fluctuations in flow (the influent flows at West Boise range between 8 and 26 MGD).

4. Influent ammonia concentrations vary significantly during flow fluctuations and the facility has observed ammonia concentrations increasing approximately 15% from low to high flow periods. This fluctuation, coupled with low ammonia permit limitations during the winter months (October 1- April 30) at the West Boise facility, compromises EBPR efficiency. As discussed previously, the performance of EBPR is adversely impacted by the presence of nitrate in the anaerobic zone. The facility has incorporated a “swing zone” into the treatment process to allow for improved denitrification. Generally, this swing zone is operated under anoxic conditions; however, in the winter months, when the wastewater temperature decreased, the swing zone was switched to an aerobic configuration to encourage a high level of nitrification in order to meet the ammonia effluent limits in the permit. This process change resulted in less denitrification, ultimately compromising the integrity of the anaerobic zone and inhibiting the EBPR process.

The City anticipates these issues will be exacerbated by construction projects at the Lander Street facility, which would require the West Boise facility to receive and treat the additional flows.

The current interim effluent limits for total phosphorus are 0.6 *mg/L* (May 1- Sept. 20, 2016) and 0.5 *mg/L* (May 1-September 30, 2017). These limits reflect what EPA believed the facility could meet with EBPR treatment at the time EPA issued the current permit. The City provided TP effluent monitoring data from September 2015 through May 2016 (see Appendix A). The data had a coefficient of variation of 0.63, a maximum and minimum reported value of 5.7 *mg/L* and 0.2 *mg/L*, respectively, and an average of 2.0 *mg/L*.

As a result of the observed performance at the West Boise facility, the continued need to further optimize the treatment system, and the inability to meet the current interim TP limits, the City has requested a revised interim TP limit of 2.8 *mg/L* as an annual average until the final TP effluent limits go into effect in 2022.

## F. EPA’S ASSESSMENT OF THE WEST BOISE EBPR PERFORMANCE RESULTS

Based on information summarized in this Fact Sheet, EPA proposes to modify the technology-based interim TP limits for the following reasons:

- The City has completed the necessary facility upgrades on time. The required upgrades are identified in the 2012 Permit Compliance Schedule (*See* Part I.C.1.(b)(iii).
- The City appears to have appropriately operated and maintained this treatment system.
- A review of the effluent data from September 2015 through May 2016, corresponding with the completion and operation of the EBPR system, indicate that the seasonal average interim limits of 0.6 *mg/L* (May 1 – September 30, 2016) and 0.5 *mg/L* (May 1 – September 30, 2017) would be exceeded.
- Effluent quality of EBPR performance is variable. The City’s Technical Memorandum (Leaf, 2016) presents the unique challenges of retrofitting the West Boise facility that prevent the City from meeting the interim technology-based limits in the 2012 Permit. In contrast to the West Boise facility, the City has been able to achieve TP effluent limits using EBPR at the Lander Street facility of 0.5 *mg/L* on average.
- Further optimization of the facility processes are required to ensure consistent treatment efficiency and compliance with the final TP effluent limits.

In proposing this modification, EPA also recognizes the following:

- The City has undertaken robust monitoring studies to identify areas of improvement and optimization within the treatment process. EPA expects the City to continue optimization of the EBPR system. EPA will reassess achievable interim limits when the permit is reissued in 2017.
- Although the proposed modified interim TP limit (2.8 *mg/L* annual average) is higher than the 2012 Permit interim limits, requiring year-round operation of the EBPR system through a year-round limit rather than a season limit will impart a net environmental benefit of an increased removal of TP from the lower Boise River.

## G. TOTAL PHOSPHORUS INTERIM LIMIT CHANGES

EPA is proposing to modify the total phosphorus interim limits in the permit (*Permit Part I.C.1.*) based on the information presented in Sections I.C., I.D. and I.E. of this Fact Sheet. EPA proposes to revise Table 3 of the Permit has follows:

**TABLE 2:** *Effluent Limits and Compliance Dates*

| DATE | EFFLUENT LIMIT |
|---|---|
| May 1, 2013 through September 30, 2013 | Not to exceed 5.8 mg/L measured as a seasonal average[1]. |
| May 1, 2014 through September 30, 2014 | Not to exceed 5.8 mg/L measured as a seasonal average[1]. |
| May 1, 2015 through September 30, 2015 | Not to exceed 5.8 mg/L measured as a seasonal average[1]. |
| ~~May 1, 2016 through September 30, 2016~~ | ~~Not to exceed 600 µg/L measured as a seasonal average limit.~~ |
| ~~May 1, 2017 through September 30, 2017; and May 1 through September 30 ever year thereafter until the final limit is achieved~~ | ~~Not to exceed 500 µg/L measured as a seasonal average limit.~~ |
| *Beginning May 1, 2016 through April 30, 2017 and every year thereafter until the final limit is achieved.* | *Meet an annual average limit of 2.8 mg/L.*[1] |
| 10 years from the effective date of the permit | See Part I.B.3., Table 2 for final effluent limits. |

Note: [1] *Season is from May 1 through September 30.*
[2] *Reported as an annual average of all total phosphorus effluent data from May 1 – April 30 of the reporting period and submitted with the April DMR.*

The proposed modification of the interim total phosphorus limits is not subject to the anti-backsliding provisions of Section 402(o) of the Clean Water Act (CWA). Even if that section applied to interim limits, CWA Section 402(o)(2) and 40 CFR §122.44.(l)(2) allows backsliding under these circumstances because:

- There have been material and substantial alternations or additions to the permitted facility that justify the relaxation (40 CFR §122.44(l)(2)(i)(A).
- New information (other than revised regulations, guidance, or test methods) is available that was not available at the time of permit issuance and that would have justified a less stringent effluent limitation (40 CFR §122.44(l)(2)(i)(B).
- The permittee has installed and properly operated and maintained required treatment facilities but still has been unable to meet the effluent limitations (40 CFR §122.44.(l)(2)(i)(E).

# III. DIXIE PHOSPHORUS REMOVAL FACILITY UPSTREAM MONITORING

## A. Cause for Modification

The cause for modification of the permit to remove the Dixie Slough upstream monitoring requirement is due to substantial alterations to the permitted facility that occurred after the permit issuance (40 CFR §122.62(a)(1)) and submission of new information that was not available at the time of the current permit's issuance, which would have resulted in the application of different permit conditions at the time of the permit issuance (40 CFR §122.62(a)(2)).

The West Boise permit was modified to allow the City to build and operate the Dixie Phosphorus Removal Facility (DPRF) as part of their phosphorus reduction obligation. The DPRF concept design at the time of permitting included construction of an inflatable weir in Dixie Slough with gravity flow diversion into unlined ponds, chemical dosing, settling, and discharge back to Dixie Slough. Flow monitoring both upstream and downstream of the facility on the Dixie Drain was required because of concerns of groundwater interaction within the treatment process. If this occurred, it could potentially cause problems with accurately determining the amount of total phosphorus removed.

However, the final design changed significantly and now includes: an inflatable weir, pumping of Dixie Slough water into a lined sedimentation basin, and chemical dosing and settling in a lined pond prior to discharge back to Dixie Slough. Due to the design change of having lined facilities, and advice from the USGS concerning the technical feasibility of installation of an upstream monitoring station, the upstream flow monitoring location is no longer necessary.

## B. Dixie Slough Upstream Monitoring Changes

EPA is proposing to remove the requirement to establish an upstream monitoring station in Dixie Slough from the permit (Permit Part I.F.2.a.i.) based on the information provided in Section I.F. of this Fact Sheet. The proposed modification will appear as follows in the permit:

2) Monitoring stations must be established in the Dixie Slough and the Dixie Drain Facility in the following locations:

   a) Dixie Slough.
      ~~i) Upstream. Above the water diversion structure for the Dixie Drain Facility and,~~
      **i) Downstream. Between the outfall culvert and the Boise River**

   b) Dixie Drain Facility
      i) Inflow Channel to the Dixie Drain Facility
      ii) Outflow Channel from the Dixie Drain Facility.

## IV. REFERENCES

IDEQ (2015). *Lower Boise River TMDL: 2015 Total Phosphorus Addendum.* August 2015. http://www.deq.idaho.gov/media/60177413/lower-boise-river-tmdl-total-phosphorus-addendum-0815.pdf

Leaf, William (2016). *Technical Memorandum: West Boise Wastewater Treatment Facility Enhanced Biological Phosphorus Removal Evaluation.* CH2M. April 19, 2016.

Metcalf and Eddy (2003). *Wastewater Engineering: Treatment and Reuse 4th Edition.* McGraw-Hill. New York, NY.

U.S. EPA (1991). *Technical Support Document for Water Quality-Based Toxics Control.* EPA-505-2-90-001. U.S. EPA, Office of Water, Washington, D.C.

U.S. EPA (2010). *Nutrient Control Design Manual.* EPA-600-R-10-100. U.S. EPA Office of Research and Development – National Risk Assessment Research Laboratory, Cincinnati, Ohio.

## V. DEFINITIONS

***Aerobic*** *means an environment in which there is free oxygen ($O_2$) present.*

***Anaerobic*** *means an environment in which there is no oxygen present in a free or combined form.*

***Anoxic*** *means an environment in which oxygen is present in a combined form (such as nitrites, $NO_2^-$, or nitrates, $NO_3^-$) but there is no free oxygen.*

***Average annual discharge limitation*** *means the highest allowable average of "daily discharges" over a calendar year, calculated as the sum of all "daily discharges" measured during a calendar year divided by the number of "daily discharges" measured during that calendar year.*

***DMR*** *means discharge monitoring report.*

***EBPR*** *means enhanced biological phosphorus removal.*

***Enhanced biological phosphorus removal*** *means a wastewater treatment configuration applied to activated sludge systems for the increased removal of phosphate.*

***EPA*** *means Environmental Protection Agency.*

***IDEQ*** *means Idaho Department of Environmental Quality.*

***NPDES*** *means National Pollutant Discharge Elimination System, the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits under Sections 307, 402, 318 and 405 of the Clean Water Act.*

***PAOs*** *means phosphate accumulating organisms.*

***Phosphate accumulating organisms*** *are heterotrophic bacteria that are naturally present in the environment and in activated sludge.*

***RAS*** *means return activated sludge.*

***Struvite*** *means a magnesium-ammonium phosphate ($MgNH_4PO_4 \cdot 6H_2O$) compound that commonly forms in anaerobic conditions as a hard and insoluble crystal.*

***TP*** *means total phosphorus*

***VFAs*** *means volatile fatty acids.*

***Volatile fatty acids*** *means readily biodegradable compounds (i.e. acetate, butyrate, propionate) that serve as a carbon source for bacteria in activated sludge systems.*

***WAS*** *means waste activated sludge.*

***WWTF*** *means wastewater treatment facility.*

## APPENDIX A. EBPR INTERIM PERFORMANCE DATA

**TABLE A 1.** *Total Phosphorus effluent data from September 2015 through May 2016 at the West Boise Facility.*

| Sample Date | Total Phosphorus (µg/L) | Sample Date | Total Phosphorus (µg/L) | Sample Date | Total Phosphorus (µg/L) |
|---|---|---|---|---|---|
| 9/2/2015 | 2220 | 12/9/2015 | 348 | 3/8/2016 | 922 |
| 9/9/2015 | 1930 | 12/10/2015 | 823 | 3/9/2016 | 1440 |
| 9/16/2015 | 1510 | 12/15/2015 | 974 | 3/10/2016 | 2120 |
| 9/17/2015 | 997 | 12/16/2015 | 1320 | 3/15/2016 | 1620 |
| 9/22/2015 | 387 | 12/17/2015 | 1510 | 3/16/2016 | 1940 |
| 9/23/2015 | 689 | 12/22/2015 | 452 | 3/17/2016 | 3620 |
| 9/24/2015 | 1350 | 12/23/2015 | 490 | 3/22/2016 | 826 |
| 9/30/2015 | 3730 | 12/24/2015 | 648 | 3/23/2016 | 2150 |
| 10/6/2015 | 1180 | 12/29/2015 | 1440 | 3/24/2016 | 2040 |
| 10/7/2015 | 3170 | 12/30/2015 | 1790 | 3/29/2016 | 2050 |
| 10/8/2015 | 3370 | 12/31/2015 | 2420 | 3/30/2016 | 2940 |
| 10/13/2015 | 1410 | 1/5/2016 | 978 | 3/31/2016 | 3920 |
| 10/14/2015 | 1860 | 1/6/2016 | 1850 | 4/5/2016 | 1330 |
| 10/15/2015 | 1820 | 1/7/2016 | 2930 | 4/6/2016 | 1840 |
| 10/20/2015 | 1420 | 1/12/2016 | 1300 | 4/7/2016 | 2880 |
| 10/21/2015 | 767 | 1/13/2016 | 3550 | 4/12/2016 | 1280 |
| 10/22/2015 | 487 | 1/14/2016 | 5540 | 4/13/2016 | 2050 |
| 10/27/2015 | 283 | 1/19/2016 | 5120 | 4/14/2016 | 3020 |
| 10/28/2015 | 401 | 1/20/2016 | 4820 | 4/19/2016 | 1750 |
| 10/29/2015 | 696 | 1/21/2016 | 5720 | 4/20/2016 | 2100 |
| 11/3/2015 | 724 | 1/26/2016 | 1810 | 4/21/2016 | 3000 |
| 11/4/2015 | 1040 | 1/27/2016 | 3310 | 4/26/2016 | 1140 |
| 11/5/2015 | 2210 | 1/28/2016 | 4860 | 4/27/2016 | 1760 |
| 11/10/2015 | 324 | 2/2/2016 | 1400 | 4/28/2016 | 2950 |
| 11/11/2015 | 352 | 2/3/2016 | 1210 | 5/3/2016 | 1530 |
| 11/12/2015 | 701 | 2/4/2016 | 2230 | 5/4/2016 | 2100 |
| 11/17/2015 | 645 | 2/9/2016 | 1130 | 5/5/2016 | 2920 |
| 11/18/2015 | 2100 | 2/10/2016 | 1360 | 5/10/2016 | 2020 |
| 11/19/2015 | 3120 | 2/11/2016 | 3260 | 5/11/2016 | 2510 |
| 11/24/2015 | 409 | 2/16/2016 | 2400 | 5/12/2016 | 2840 |
| 11/25/2015 | 1430 | 2/17/2016 | 2140 | 5/17/2016 | 2510 |
| 11/26/2015 | 1490 | 2/18/2016 | 3040 | 5/18/2016 | 2970 |
| 12/1/2015 | 290 | 2/23/2016 | 1540 | 5/19/2016 | 3880 |
| 12/1/2015 | 1790 | 2/24/2016 | 3280 | 5/24/2016 | 1170 |
| 12/2/2015 | 361 | 2/25/2016 | 4420 | 5/25/2016 | 1300 |
| 12/3/2015 | 1390 | 3/1/2016 | 3040 | 5/26/2016 | 1780 |
| 12/8/2015 | 236 | 3/2/2016 | 4530 | 5/31/2016 | 2270 |

**SOURCE:** City of Boise. **TOTAL NUMBER OF SAMPLES (N)** = *111;* **MAX** = *5,720 µg/L*; **MIN** = *236 µg/L*, **AVERAGE** = *1,962 µg/L*; **COEFFICIENT OF VARIATION (CV)** = *0.63*

## APPENDIX B. CITY OF BOISE REQUEST FOR NPDES PERMIT MODIFICATION



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BOISE
CITY OF TREES

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# Public Works

May 31, 2016

Michael Lidgard, NPDES Unit Manager
U.S. EPA, Region 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101

Re: West Boise Wastewater Treatment Facility NPDES Permit (ID0023981) Major Permit Modification Request

Dear Mr. Lidgard,

The City of Boise (City) would like to thank you and your staff for your March 17 and 18, 2016 visit to the West Boise Wastewater Treatment (West Boise) and Dixie Phosphorus Removal Facility (DPRF). The City has made substantial progress in achieving water quality goals and resource recovery however still faces significant challenges in implementing Enhanced Biological Phosphorus Removal (EBPR) due to the unique circumstances at West Boise. This letter is written to follow up on our March 17 and 18 conversations regarding the need for major permit modifications to the West Boise NPDES permit.

The City respectfully requests a Major NPDES Permit Modification of the West Boise permit consistent with 40CFR122.62 for:

1. Modification of the Interim limits for Total Phosphorus, and
2. Modification of the upstream monitoring requirement for the DPRF project

<u>Interim Limit for Total Phosphorus</u>

The West Boise permit requires the City to comply with seasonal average interim limit for total phosphorus (TP) of 600 ug/l May 1, 2016 through September 1, 2016 and 500 ug/l May 1, 2017 through September 30, 2017.

The City has timely installed and properly operated EBPR, the technology anticipated to achieve the interim limits for the May-September periods of 2016 and 2017. Additionally, the City has installed and properly operated a nutrient recovery facility at West Boise that removes approximately 400 pounds of phosphorus per day in the form of struvite. Struvite is a magnesium-ammonium-phosphate that serves as feed stock for commercial and residential fertilizer.

For the period September 2015 to April 2016 performance of the EBPR has resulted in effluent total phosphorus of approximately 2.0 mg/L with monthly averages ranging from 1.0 mg/l to 3.5 mg/L. We anticipate summer performance will be better, however EBPR will not be able to meet the technology based interim limits of 600 ug/l and 500 ug/l TP seasonal average contained in the permit.

During the March 17, 2016 site visit, the City shared with EPA a number of unique site characteristics at West Boise that contribute to the observed EBPR performance, including:

- West Boise processes recycle and dewatering side streams from two WWTFs
  - Lander Street Wastewater Treatment Facility (Lander Street) is now operating in EBPR which helps avoid chemical use in the primary treatment system and results in total phosphorus and nitrogen discharges below permitted requirements. However, this increases the bio-availability of total phosphorus and nitrogen in the solids that are sent to West Boise.
  - Lander Street process configuration offers no opportunity for further removal of total phosphorus from recycle streams.
  - Lander Street solids that have been processed in the anaerobic digesters are sent to West Boise for dewatering and consolidation prior to being beneficially reused at the 20-Mile South Biosolids Application Site
  - This is the equivalent of the total phosphorus and nitrogen from an additional WWTF being processed at West Boise

- West Boise processes two million gallons per day (MGD) of influent from the Eagle Sewer District that has very low BOD and TSS but rich in phosphorus and nitrogen
  - West Boise receives approximately 2 MGD of pre-treated wastewater from the Eagle Sewer District with minimal BOD (i.e., low in carbon) thereby contributing to the carbon vs nutrient imbalance.
  - The minimal BOD requires West Boise to manufacture volatile fatty acids (VFAs) to provide additional "food" for the microorganisms used to remove phosphorus
  - The fermenter that generates VFAs is yet another variable in the EBPR process whose performance is still being optimized

- West Boise manages significant diurnal fluctuations in flow, BOD, and nutrient loading
  - Lander Street is baseloaded with a consistent influent flow of approximately 10 MGD to promote stable EBPR
  - Because Lander Street is baseloaded, West Boise manages the significant diurnal fluctuations that occur over any given 24-hour period
  - West Boise flow can fluctuate between 8 and 26 MGD which makes optimizing the EPBR challenging
    1. Flow increases can be as high as 2.5 times low flow
    2. Ammonia concentrations increase approximately 15% from low to high flow
    3. Increased pounds of ammonia results in significant nitrate in the plant process streams which negatively impacts EBPR (nitrate consumes VFAs)
    4. Eagle Sewer District diurnal flows are lesser, but also result in increased loading with no accompanying carbon for denitrification

- West Boise addresses stringent ammonia limitations during the winter months while maintaining EBPR
  - Phosphorus removal and nitrogen removal often work at cross purposes, i.e., maximizing ammonia removal can put the EBPR process at risk
  - As noted previously, West Boise experiences significant diurnal flows and the ammonia loadings are higher during maximum flows

    - During winter months when the EBPR process is more challenging to operate, West Boise also has a stringent maximum day winter ammonia limit of 1.493 mg/L (299 pounds/day) which results in a potential conflict between TP and ammonia removal

- In the future, these challenges will be exacerbated by construction projects at our Lander Street facility to meet future permit requirements that may require more load shifting to West Boise
    - In the coming years, the Lander Street facility will be under construction for upgrades to meet upcoming NPDES requirements and retrofit aging infrastructure
    - During certain times, Lander Street construction will require load shifting to West Boise which will exacerbate the significant challenges noted previously

Information to support these assertions are enclosed including the effluent data from September 2015 through April 2016 as well as a Technical Memorandum on EBPR performance and steps for optimization of the EBPR process prepared by our wastewater process consultant CH2M.

Based on this information, the City respectfully requests modification of the West Boise TP technology based interim limits to technologically achievable levels based on 40CFR122.62.a.(1),(2), and (16). Specifically, we are requesting a modified West Boise TP interim limit of 2.8 mg/L as an annual average. This proposed interim limit is derived from our experience and observed performance of the West Boise EBNR process under different seasonal conditions. During the warmer months of May to September, we will strive to produce effluent at levels of 1.8 mg/L TP. During the colder months of October to April, we will strive to produce effluent at levels of 3.5 mg/L TP. We request the proposed interim limit of 2.8 mg/L annual average be effective 10/1 – 9/30 each year leading to the final permit limits of 0.07 mg/L by 2022 (likely to be updated to final seasonal limits of 0.10 mg/L and 0.35 mg/L based on final LBR TMDL).

Taken as a whole, we believe the proposed interim limit of 2.8 mg/L TP annual average is appropriate for several reasons:

- Provides a net annual environmental benefit of ~45,000 pounds of TP/year removed from the lower Boise River when compared to the existing interim limits (assumes flows of 18 MGD)
- Provides an appropriate safety factor for a new technology being operated during the highly variable shoulder seasons and winter months
- Aligns with the approved TMDL suggesting that winter limits are necessary to address water quality concerns in the lower Boise River and Snake River
- As previously presented, the City maintains our commitment to meeting the final effluent limit of 0.07 mg/L by 2022 as currently written in the West Boise NPDES permit

Dixie Phosphorus Removal Facility Upstream Monitoring

The West Boise permit was modified to allow the City to build and operate the DPRF as part of our phosphorus reduction obligation. We appreciate EPA modifying the West Boise permit to include this innovative approach that will result in additional non-point phosphorus being removed from the watershed and providing water quality benefits to the Snake River and Brownlee Reservoir that otherwise would not occur.

The DPRF concept design at the time of permitting was construction of an inflatable weir in Dixie Slough with gravity flow diversion into unlined ponds, chemical dosing, settling, and discharge back to Dixie Slough. Flow monitoring both upstream and downstream of the facility on the Dixie Drain was required because of concerns of groundwater interaction within the treatment process. If this occurred, it could potentially cause problems with accurately determining the amount of total phosphorous removed.

Final design changed significantly, with construction of an inflatable weir, pumping of Dixie Slough water into a lined sedimentation basin, and chemical dosing and settling in a lined pond prior to discharge back to Dixie Slough. Due to the design change of having lined facilities and advice from USGS[1] concerning the technical feasibility of installation of an upstream monitoring station, the upstream flow monitoring location is no longer necessary.

The City respectfully requests modification of the West Boise permit to remove the Dixie Slough upstream monitoring requirement based on 40CFR122.62.a.(1) and (2).

Should you or your staff have additional questions or require additional information on the City of Boise West Boise Major Permit Modification request, please feel free to contact me at 208.384.3942 or sburgos@cityofboise.org.

Thanks again for your recent visit to Boise and for your consideration of the City's major permit modification request.

Sincerely,

Stephan L. Burgos
City of Boise Environmental Division Manager

cc: Neal Oldemeyer
IDEQ Southwest Regional Office
SAR 276

[1] Molly Wood Dixie Slough site visit with John Drabek on June 24, 2015

# APPENDIX C. TECHNICAL MEMORANDUM: WEST BOISE WASTEWATER TREATMENT FACILITY EBPR EVALUATION (LEAF, 2016)



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# West Boise Wastewater Treatment Facility Enhanced Biological Phosphorus Removal Evaluation



| | |
|---|---|
| PREPARED FOR: | City of Boise |
| PREPARED BY: | William Leaf/CH2M, P.E. |
| REVIEWED BY: | Barry Rabinowitz/CH2M, Ph.D., P.Eng., BCEE |
| | Sam Jeyanayagam/CH2M, Ph.D., P.E., BCEE |
| | Bruce Johnson/CH2M, P.E., BCEE |
| | Kim Fries/CH2M, P.Eng. |
| FREIEDATE: | April 19, 2016 |



This technical memorandum (TM) is developed to summarize the ongoing optimization of the enhanced biological phosphorus removal (EBPR) system installed at the West Boise Wastewater Treatment Facility (WWTF). The TM presents the startup and commissioning activities, the ongoing sampling efforts, and system performance to date. There are a number of features particular to the West Boise WWTF that have an impact on the operation of the EBPR system, each of which are described in detail. CH2M has completed a level of steady-state and dynamic process modeling, helping the ongoing optimization effort. A recommendation for future optimization activities is included, along with the long-term monitoring requirements proposed for operations staff.

## Background

The City of Boise has two publicly owned treatment works, the West Boise WWTF and Lander Street WWTF. The recently completed Total Phosphorus (TP) Removal Project at the West Boise WWTF included the construction of key components allowing for the removal of the phosphorus through EBPR from the facility. The features include:

- Enhanced Biological Phosphorus Removal (EBPR) – conversion of the existing aeration basins (bioreactors) to a process similar to the “Westbank” configuration.
- Primary Sludge Fermentation for the generation of Volatile Fatty Acids – a two-stage, complete-mix fermentation system to provide volatile fatty acids for reliable performance of the EBPR system.
- Waste activated sludge (WAS) and primary sludge (PSD) thickening – a new thickening facility utilizing rotary screen thickeners. This system works in combination with the fermentation system to provide the required thickening of the PSD for the two-stage, complete mix system.
- Optimized phosphate release to minimize unintentional struvite precipitation – an anaerobic zone within the bioreactor for the WAS stream will be used to provide an additional level of orthophosphate release from the system. The filtrate stream from the follow-on thickening process will provide a phosphate-rich stream for use at the Struvite Production Facility.

These key facilities interact with the remaining unit processes at the WWTF to provide a level of EBPR and overall TP removal from the facility. The Struvite Production Facility by Multiform Harvest, Inc. was installed at the WWTF previously, and now with EBPR in operation this nutrient recovery facility is in full operation.

A site plan of the West Boise WWTF is presented in Figure 1.

Figure 1. West Boise WWTF – April 2014

The TP Removal Project is part of the City's strategy of reducing effluent phosphorus to meet a future 0.07 milligram per liter (mg/L; 70 micrograms per liter [µg/L]) TP limitation, through a sustainable and innovative treatment approach. This project provides the initial step in removing TP from the system, anticipating that future tertiary treatment and nutrient trading will be required to achieve the final treatment goal. The West Boise WWTF currently operates under the framework established in the National Pollutant Discharge Elimination System (NPDES) Permit Number ID-002398-1, effective May 1, 2012 and later modified to August 1, 2012. The NPDES Permit limits and compliance schedule for TP are presented in Table 1 and Table 2. The permit includes the interim treatment requirement of 600 µg/L of TP, on a seasonal average from May 1, 2016 through September 30, 2016. This value drops to 500 µg/L of TP for the 2017 season, and is held here until the final TP value of 70 µg/L is required.

The *Lower Boise River TMDL – 2025 Total Phosphorus Addendum* (IDEQ, 2015) was recently approved by the United States Environmental Protection Agency (EPA). This addendum presents information on the allocations of TP required for the Lower Boise River. This addendum includes a load allocation and associated target TP concentration for publicly owned treatment works of 350 µg /L on a monthly average basis from October 1 to April 30. This seasonal limit places additional requirements for TP removal at the WWTF, and it is anticipated that future NPDES permits will have this concentration as an effluent limit. In addition, the document includes a discussion about the target TP concentrations for the May to September season being based on monthly averages (where the existing NPDES permit requirements are based on a seasonal average).

Table 1. West Boise NPDES Permit – Effluent Limitations

| | Average Monthly Limit | Average Weekly Limit | Maximum Daily Limit | Monthly Geometric Mean Limit | Instantaneous Maximum Limit |
|---|---|---|---|---|---|
| $BOD_5$ | 20 mg/L<br>2000 lbs/day | 30 mg/L<br>3000 lbs/day | --- | --- | --- |
| TSS | 30 mg/L<br>3000 lbs/day | 45 mg/L<br>4500 lbs/day | --- | --- | --- |
| Removal Rates for $BOD_5$ and TSS (see Note 1) | 85% minimum | --- | --- | --- | --- |
| Total Ammonia as N **May 1 – Sept 30** | 788 µg/L<br>157.7 lbs/day | --- | 2435 µg/L<br>487 lbs/day | --- | --- |
| Total Ammonia as N **Oct 1 - Apr 30** | 398 µg/L<br>80 lbs/day | --- | 1493 µg/L<br>299 lbs/day | --- | --- |
| Mercury, Total Recoverable | 0.009 µg/L<br>0.002 lbs/day | --- | 0.019 µg/L<br>0.004 lbs/day | --- | --- |
| Total Phosphorus[2] **May 1 – Sept 30** | 70 µg/L<br>14 lbs/day | 84 µg/L<br>16.8 lbs/day | — | — | — |
| *E. coli* bacteria | --- | --- | --- | 126 colonies per 100 ml | 406 colonies per 100 ml |
| Note 1. The monthly average removal rates must be calculated from the arithmetic mean of the influent concentration values and the arithmetic mean of the effluent concentration values for that month.<br>Note 2. The permittee may meet the effluent limits for total phosphorus using the Dixie Drain offset. See Part I.B.6 | | | | | |

Table 2. West Boise WWTF NPDES Permit – Total Phosphorus Compliance Schedule

| Date | Effluent Limit |
|---|---|
| **May 1, 2012 through September 30, 2013** | Not to exceed 5.8 mg/L measured as a seasonal average. |
| **May 1, 2012 through September 30, 2014** | Not to exceed 5.8 mg/L measured as a seasonal average. |
| **May 1, 2012 through September 30, 2015** | Not to exceed 5.8 mg/L measured as a seasonal average. |
| **May 1, 2016 through September 30, 2016** | Not to exceed 600 µg/L measured as a seasonal average. |
| **May 1, 2017 through September 30, 2017 and May 1 through September 30 every year thereafter until the final limit is achieved** | Not to exceed 500 µg/L measured as a seasonal ~~monthly~~ average limit. |
| **10 years from the effective date of the permit** | See Part I.B.3, Table 2 for final effluent limits |

Note: Season is from May 1 through September 30

The ammonia-nitrogen ($NH_3$-N) effluent limits required in the NPDES permit are an important value when discussing the overall treatment potential of the West Boise WWTF. There are seasonal limits for $NH_3$-N, with the more stringent criteria established in October 1 to April 30. As will be discussed later in the TM, the average monthly limit and maximum daily limits have an impact on the EBPR performance of the West Boise WWTF during the winter months.

# Phosphorus Removal Methodology

The City of Boise's West Boise WWTF and Lander Street WWTF provide treatment for the City's wastewater, with discharge from each plant into the Boise River. The West Boise WWTF is a 24 million gallons per day (mgd; average day maximum month [ADMM]) facility, with the Lander Street WWTF being rated at 15 mgd ADMM. A unique aspect of the City's system is that the anaerobically digested sludge from the Lander Street WWTF is sent to the West Boise WWTF for dewatering (prior to the biosolids being hauled to the City's Twenty Mile South Farm, where they are beneficially used for agricultural purposes). Given this connection, the interaction of the two treatment facilities affects the overall TP removal from both facilities. The Lander Street WWTF is shown in Figure 2.


Figure 2. Lander Street WWTF

The Lander Street WWTF implemented a chemically enhanced primary treatment (CEPT) system to help meet the NPDES permit limits established (effluent limit of 1,000 µg/L, May 1 to September 30). This system was successful in achieving the NPDES permit limits, but the WWTF staff worked to established EBPR recently in their existing system. The staff have been able to operate the step-feed, conventional activated sludge basins with EBPR successfully. With only secondary treatment at the facility, the average effluent TP values from Lander Street WWTF for this past season have been exceptional at 300 µg/L.

As described previously, the TP Removal Project incorporated a number of key unit processes at the West Boise WWTF, allowing a level of EBPR. The West Boise WWTF process flow diagram is presented in Figure 3, highlighting how the new unit processes integrate into the facility.

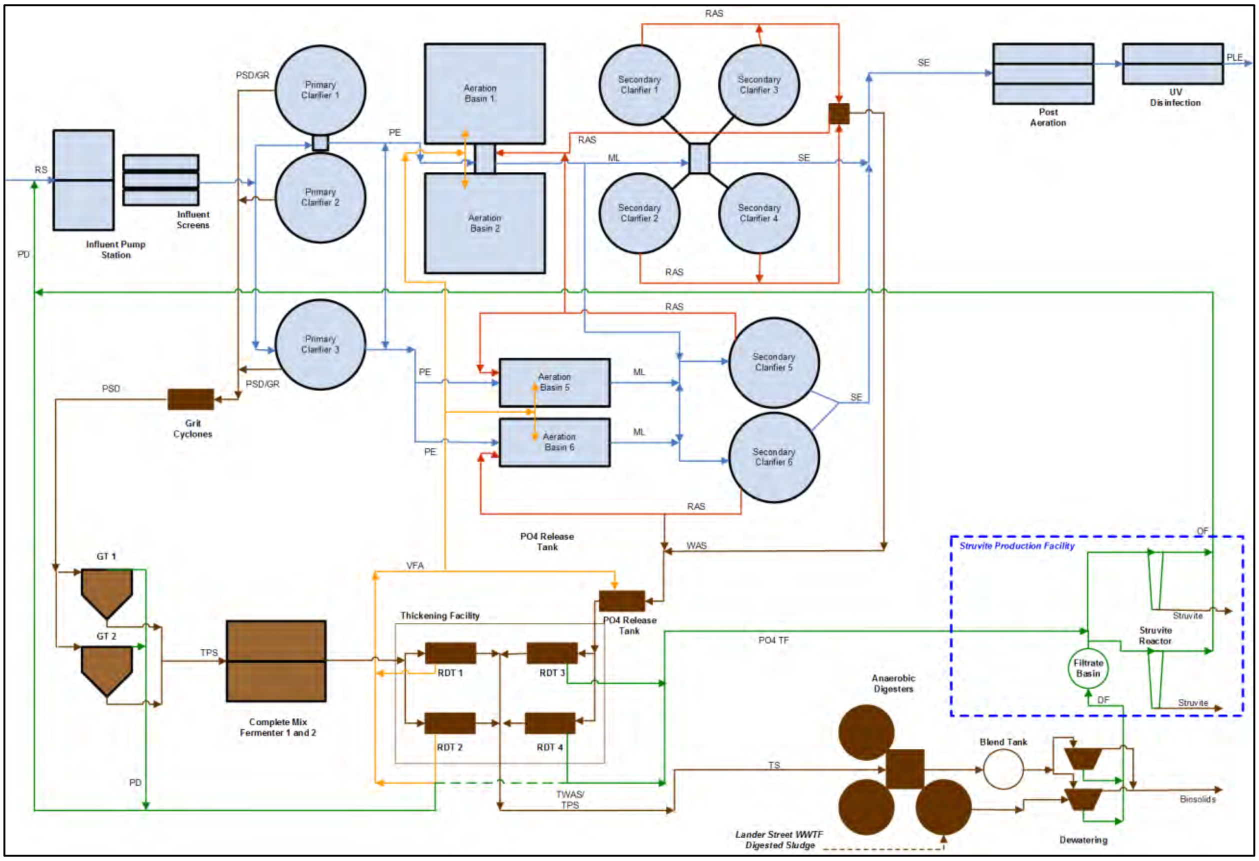



Figure 3. West Boise WWTF – Process Flow Diagram

## Enhanced Biological Phosphorus Removal

The concept of EBPR in wastewater treatment is well documented, with numerous publications and references available. A few of these references are cited within the TM, each providing a good understanding of the technology (WEF, 2010; Jeyanayagam, 2015; Jeyanayagam and Downing, 2015; Coats et al., 2011a; Coats et al., 2011b; Neethling et al., 2005; Khunjar et al., 2015; Bott and Parker, 2011; Grady et al., 2011; Bott et al., 2009; Drury et al., 2005; Horgan et al., 2010; Johnson et al., 2005; Parker et al., 2009). However, research is ongoing on EBPR because there is still much to learn in the industry on this methodology for phosphorus removal.

Enhanced biological phosphorus removal is established through the development of heterotrophic organisms, which under certain environmental conditions have the ability to remove phosphorus in excess of their metabolic requirements. These heterotrophic organisms, collectively described as phosphate accumulating organisms (PAOs), are always present in some level in activated sludge systems but are not found in large quantities unless environments are present allowing for their selective advantage. To promote EBPR within the system, the following is required:

- The PAOs must be subjected to anaerobic conditions (no dissolved oxygen [DO] or nitrate-nitrogen [$NO_3$-N] present).
- A substantial portion of the carbonaceous food supply must be made available as soluble readily biodegradable substrate (predominantly volatile fatty acids [VFAs]) within the anaerobic environment to enable the growth of PAOs.

- The PAOs must be exposed to an aerobic environment following the anaerobic environment to enable the cyclical storage and consumption of certain storage products within PAOs.

Figure 4 provides two graphical examples of the EBPR mechanism and associated bioreactor profile (Jeyanayagam, 2015; Jeyanayagam and Downing, 2015). These figures describe the interactions between the anaerobic and aerobic sections of the bioreactor. Within the anaerobic environment, the PAOs utilize the VFAs and store them as poly-b-hydroxyalkanote (PHA), which is a high-energy carbon product. The energy for this absorption is provided by the separation of polyphosphate (Poly-P or PP)) granules within the organism. This separation of PP granules within the organisms causes the release of $PO_4$-P into solution. Magnesium (Mg) and potassium (K) are also released into solution at a molar ratio of P:Mg:K at 1.0:0.33:0.33 to maintain the charge balance. This phenomenon is reflected by the relatively high $PO_4$-P concentration found within the anaerobic zones (as shown in the profiles in Figure 4). At the end of the anaerobic zone, the $PO_4$-P concentration in the bulk liquid is at its highest and the VFA concentration is low. The PAO have a high amount of PHA and relatively low amount of PP when they enter the subsequent anoxic or aerobic zones.

Once the PAOs pass into the aerobic environment, the DO is used by the organisms to oxidize carbonaceous substrate, including the stored fraction of PHA within the PAOs, providing the energy needed for cell growth and that needed to replenish the $PO_4$-P, which is stored in the re-established PP granules. The cations of Mg and K are also absorbed by the PAO to retain the charge balance. With the readily available DO within the aerobic environment, the PAOs do not have to compete for the external carbon sources. The aerobic metabolism of the PAOs increase energy production and associated cell growth, resulting in phosphorus being taken up in the aerobic environment by the increased PAO population in the mixed-liquor. The profiles in Figure 4 highlight how the concentration of $PO_4$-P is reduced in the aerobic environment, while the amount of PAO storage of Poly-P is increased. Orthophosphate is removed from the secondary treatment system through the wasting of the phosphorus-rich sludge concentrated in the secondary clarification process. The TP leaving in the secondary effluent is made up of any remaining $PO_4$-P in solution and the particulate fraction of phosphorus associated with the secondary effluent total suspended solids (TSS).

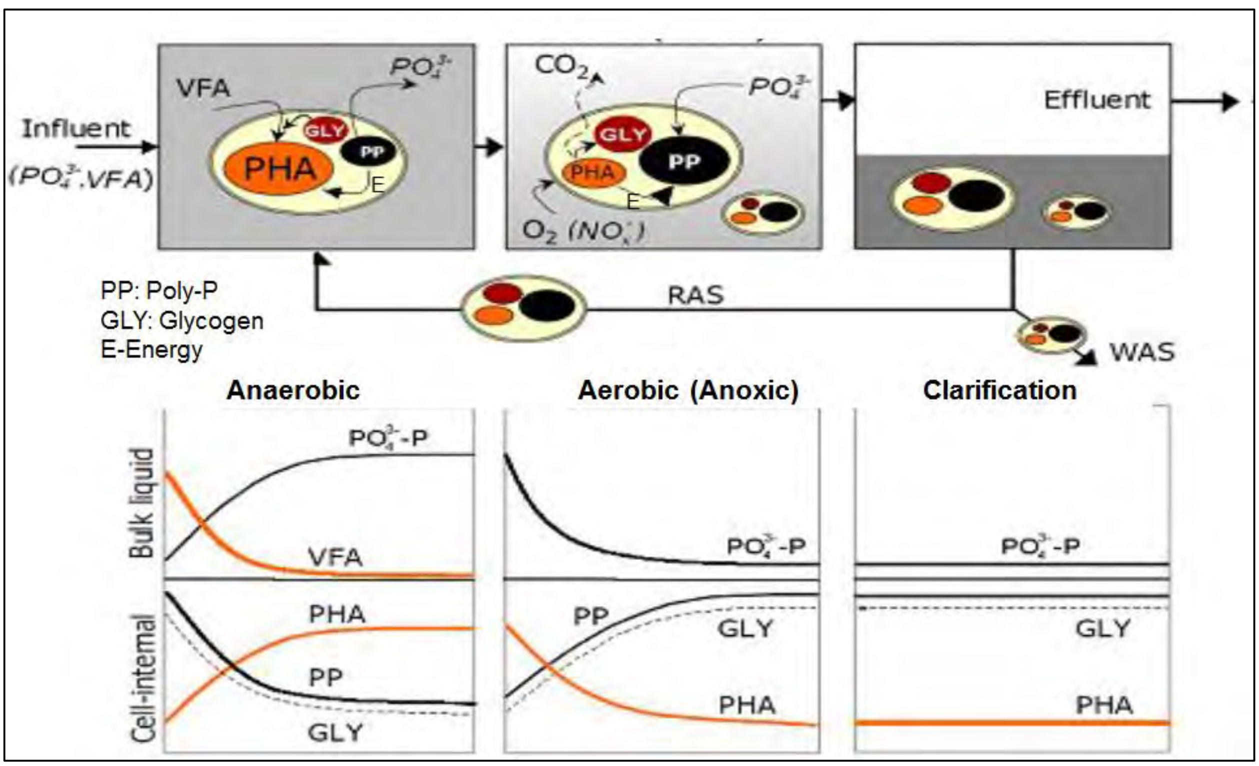
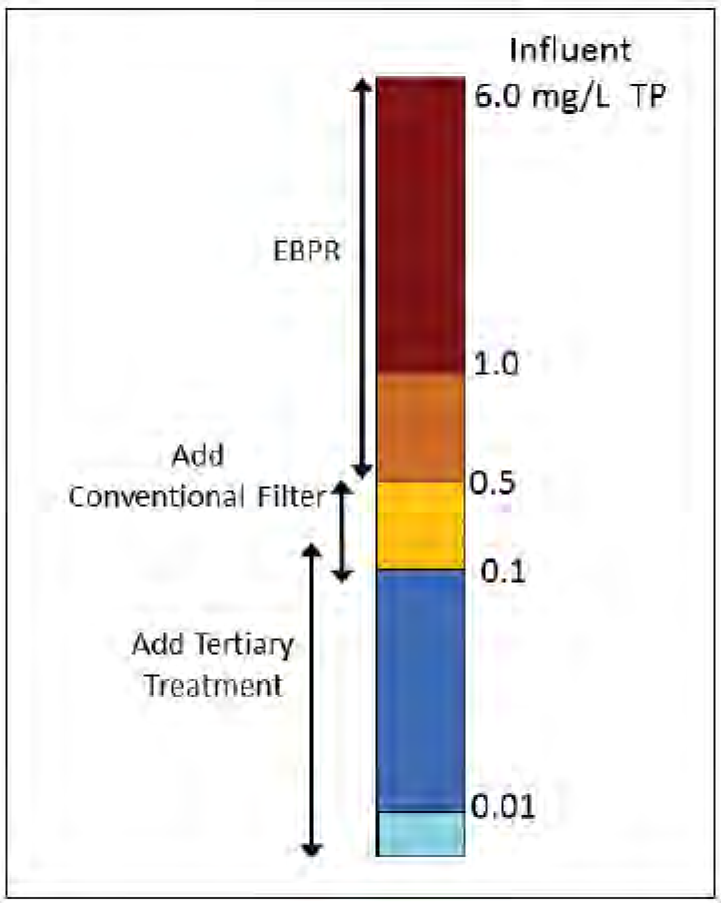



Figure 4. Simplified EBPR Mechanism and Bioreactor Profile

For EBPR systems that require ammonia-nitrogen ($NH_3$-N) removal, a level of denitrification is required within the bioreactors to optimize the phosphorus removal process. An anoxic environment is incorporated into these systems, allowing for the reduction of $NO_3$-N, which is the nitrogen formed through the nitrification process. With a high level of $NO_3$-N present in an aeration basin, a true anaerobic environment cannot be achieved. Without reduction of the $NO_3$-N concentration, the PAOs will not have the selective advantage over other heterotrophic organisms, because these denitrifying organisms have the energy source necessary (through reduction of nitrates) to successfully compete with PAOs for the available readily biodegradable carbon. As the PAOs pass into the anoxic environment from the anaerobic environment, they do continue to contribute to the overall treatment process. The PAOs provide a level of denitrification within this anoxic environment, and take up some $PO_4$-P, but most of this uptake does occur in the aerobic environment.

The anticipated performance from an EBPR system is detailed in Figure 5. As seen in the figure, some EBPR plants without tertiary treatment can achieve concentrations down to 1.0 mg-as phosphorus (P)/L on average. Some facilities without tertiary treatment have been able to achieve effluent levels averaging 0.5 mg-P/L (500 µg/L). However, these facilities typically do not have an extensive solids handling treatment component and the associated recycle streams. The City's Lander Street WWTF is an example of a facility, without a significant TP load in the recycle stream, that is able to provide exceptional performance from an EBPR process in a secondary treatment facility. To achieve effluent TP levels lower than 0.5 mg-P/L reliably, tertiary treatment is required.




Source: Jeyanayagam, 2015

Figure 5. Effluent Phosphorus Levels Achievable

The West Boise WWTF aeration basins have been converted into the Westbank configuration, providing features described previously to provide a level of EBPR. The basin configuration is illustrated in Figure 6, which also shows the connection to the WAS Phosphate Release Tank. This layout provides the sequential environments necessary to promote EBPR. A defined anaerobic zone is included, together with two anoxic environments, and the aerobic environment. The primary effluent (PE) is distributed between Anoxic Zone 1 (AX 1), Anaerobic Zone (AN), and Anoxic Zone 2 (AX 2), with the design goal to provide flexible PE distribution to optimize the EBPR process. Anoxic Zone 1 is used to provide for a level of denitrification of the return activated sludge (RAS). This zone is followed by the anaerobic zone, where the VFA-rich fermentate addition (generated from the PSD fermentation process) is introduced. Anoxic Zone 2 follows and is included to provide a level of denitrification of mixed-liquor, as an internal recycle stream conveys $NO_3$-N- rich mixed-liquor from the end of the aeration basin to this zone. A "swing" zone follows AX 2, where the aeration grid can be turned off to allow for an extension of this anoxic environment. The aerobic zone in the aeration basins provides the nitrification required in the system together with the update of $PO_4$-P as described above.

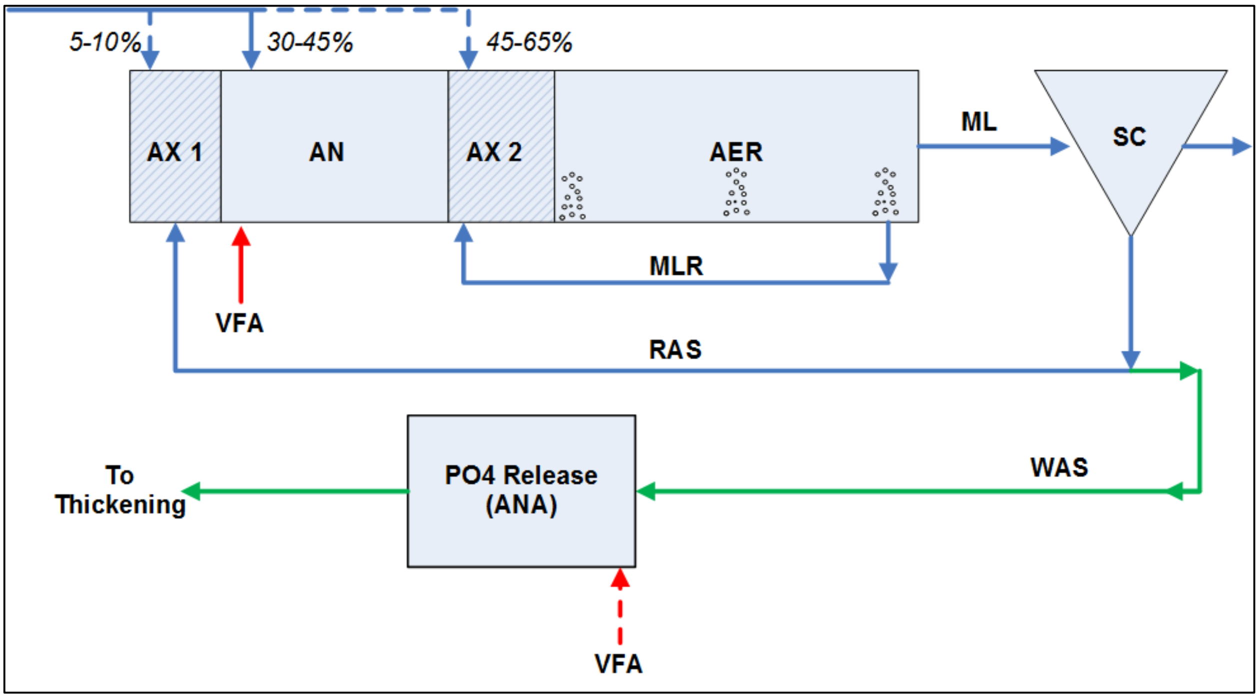



Figure 6. West Boise WWTF – Aeration Basins Configuration (Westbank Process)

Another key feature to the overall removal of phosphorus at the West Boise WWTF is the associated management of $PO_4$-P throughout the solids handling unit processes and return streams. A challenge for EBPR removal systems coupled with anaerobic digestion is the relatively high level of $PO_4$-P returned to the PE through the solids handling process recycle streams. As the Poly-P rich WAS stream goes through the anaerobic digestion process, the PP granules are separated as described in the discussion above with an associated release of soluble $PO_4$-P into the liquid environment (along with Mg and K). This material remains in solution through the dewatering process, resulting in a high concentration of $PO_4$-P within the dewatering filtrate that is typically returned to the PE. In the case of the West Boise WWTF, with the addition of the Lander Street WWTF digested sludge (that is also Poly-P rich from the EBPR process in operation at that plant) there is an elevated level of $PO_4$-P in the dewatering filtrate. The City identified this significant issue and implemented a nutrient recovery technology to help reduce this high level of $PO_4$-P in the return stream, while creating a beneficial by-product. The Struvite Recovery Facility by Multiform Harvest, Inc. intentionally promotes the formation of struvite (Magnesium Ammonium Phosphate [$MgNH_4PO_4 \cdot 6H_2O$]). Unintentional struvite formation has historically been a significant burden in EBPR facilities if allowed to propagate in an uncontrolled manner. The TP Removal Project included a WAS $PO_4$-P Release Tank to help maximize struvite recovery in the system and minimize the unintentional formation of struvite to the extent possible. This unit process provides an anaerobic environment for the WAS, promoting the release of $PO_4$-P prior to the anaerobic digestion process. After the $PO_4$-P Release process, WAS is thickened and the $PO_4$-P rich filtrate is sent direct to the struvite recovery process. Because the Mg and K ions are co-released during this process, the ion imbalance commonly found in EBPR sludge is improved, which will potentially mitigate some of the adverse dewatering impacts that have been found in EBPR plants (Shimp et al., 2013; Benisch et al., 2015).

Given the relatively complicated mechanisms for EBPR to occur in a secondary treatment process, a number of items are required to provide a well-operating system. The top six prerequisites identified by Jeyanayagam (2015) are:

- Feed the PAOs
- Protect the anaerobic zone
- Maximize P uptake in the aerobic zone
- Maximize solids capture
- Minimize recycle loads
- Minimize competition

The results of the ongoing EBPR optimization and evaluation effort are detailed in the following sections of this TM. These results will be measured against these prerequisites, helping identify some of the areas where the ongoing optimization effort can be focused.

# EBPR Performance Results

The startup and commissioning activities for the West Boise WWTF TP Removal Project commenced, for the majority of the unit processes, in the summer of 2015. In May 2015, the fermentation system was placed in operation, allowing for a level of readily biodegradable carbon to be conveyed to the aeration basins and WAS $PO_4$-P Release Tank. The aeration basins were not seeded with EBPR sludge, so the required environment within the bioreactors had to develop. It was anticipated that two to three solids retention time (SRT) cycles would be required to develop a viable population of PAOs within the mixed-liquor. The total SRT at the West Boise WWTF averaged approximately 15 days, requiring approximately 45 days to develop the EBPR environment. In July 2015, $PO_4$-P release was noticed in the anaerobic zone of Aeration Basin 5 – indicating that EBPR was becoming established. Aeration Basin 5 had EBPR occurring prior to EBPR in Aeration Basins 1 and 2, primarily because of ongoing construction activities that required periodic disruption of EBPR operation. Toward the end of July, $PO_4$-P release was starting to occur in the anaerobic zone of Aeration Basins 1 and 2. The results of the sampling effort during the summer months in the anaerobic zones for $PO_4$-P are presented in Figure 7. Beginning in July 2015, a significant increase in $PO_4$-P was evident in the bioreactor anaerobic zone.

Another indicator of the EBPR development at West Boise WWTF was the performance of the WAS $PO_4$-P Release Tank. As discussed previously in the TM, when the PAOs are subjected to an anaerobic environment, they release $PO_4$-P into the bulk liquid. The WAS PO4-P Release Tank provides an anaerobic environment for the WAS, but for $PO_4$-P release, the associated Poly-P needs to be stored within the PAOs prior (as per Figure 4, the amount of Poly-P increases across the aerobic environment as $PO_4$-P is taken into the organism). Figure 8 highlights progression of this release in the WAS P-release tank through the summer, with the bulk-liquid $PO_4$-P concentration increasing during July 2015.

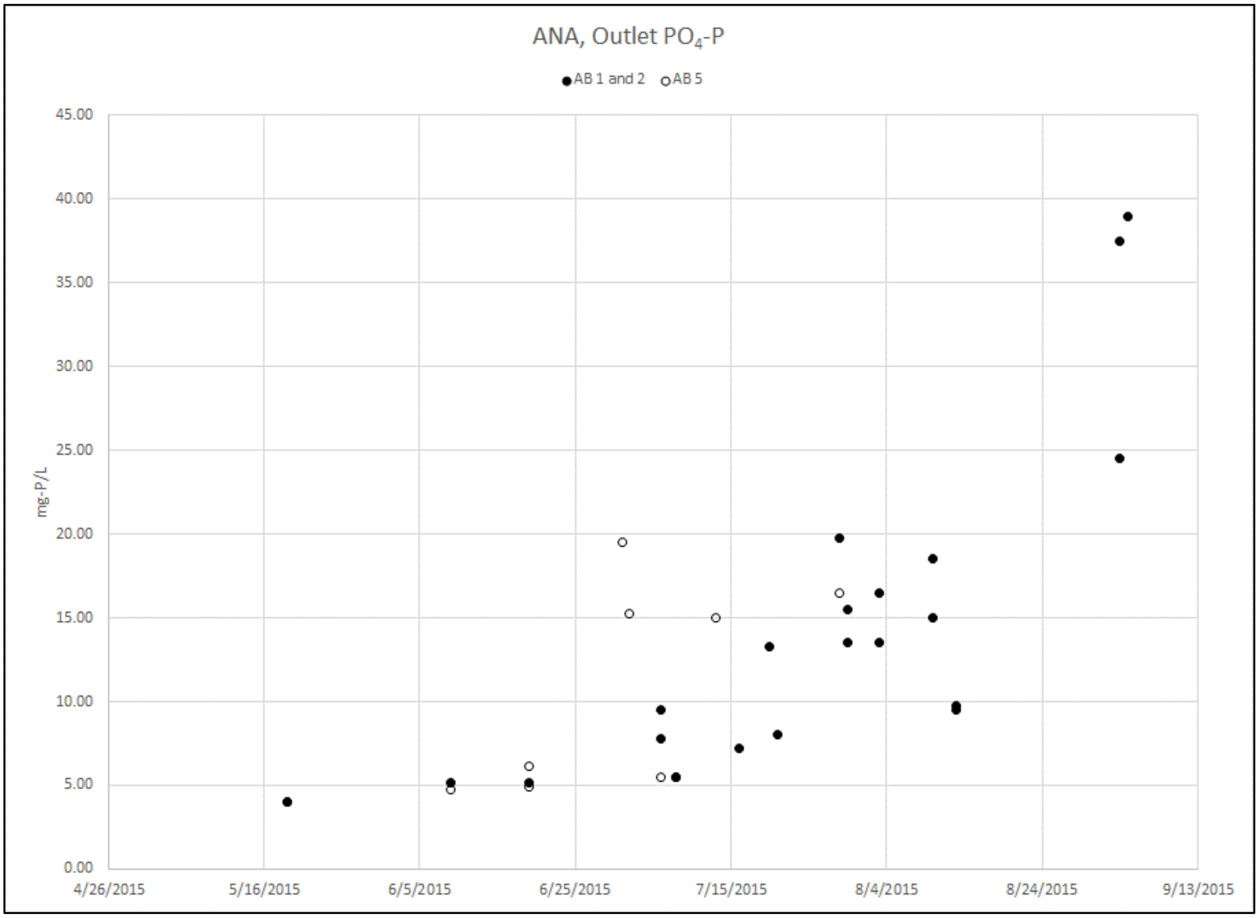



Figure 7. West Boise WWTF – Aeration Basin Anaerobic Zone Bulk-liquid $PO_4$-P Concentration

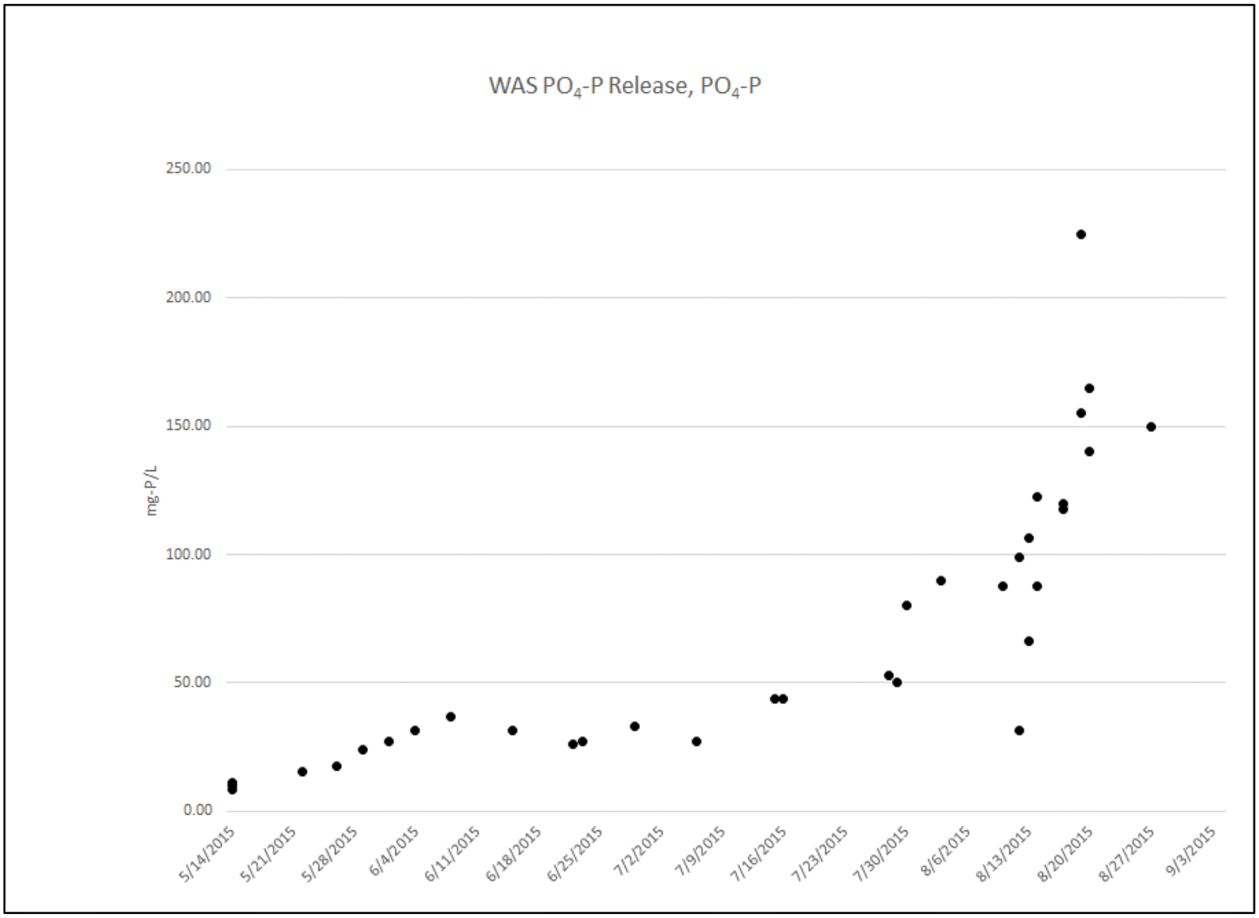



Figure 8. West Boise WWTF – WAS $PO_4$-P Release Tank Bulk-liquid $PO_4$-P Concentration

The bioreactor effluent $PO_4$-P improved throughout the summer months, trending down as EBPR became established. The effluent $PO_4$-P concentrations during the summer profiling period are presented in Figure 9. While these data present a relatively short view of the EBPR performance at West Boise, the information does highlight how the process was stabilizing through the summer months.

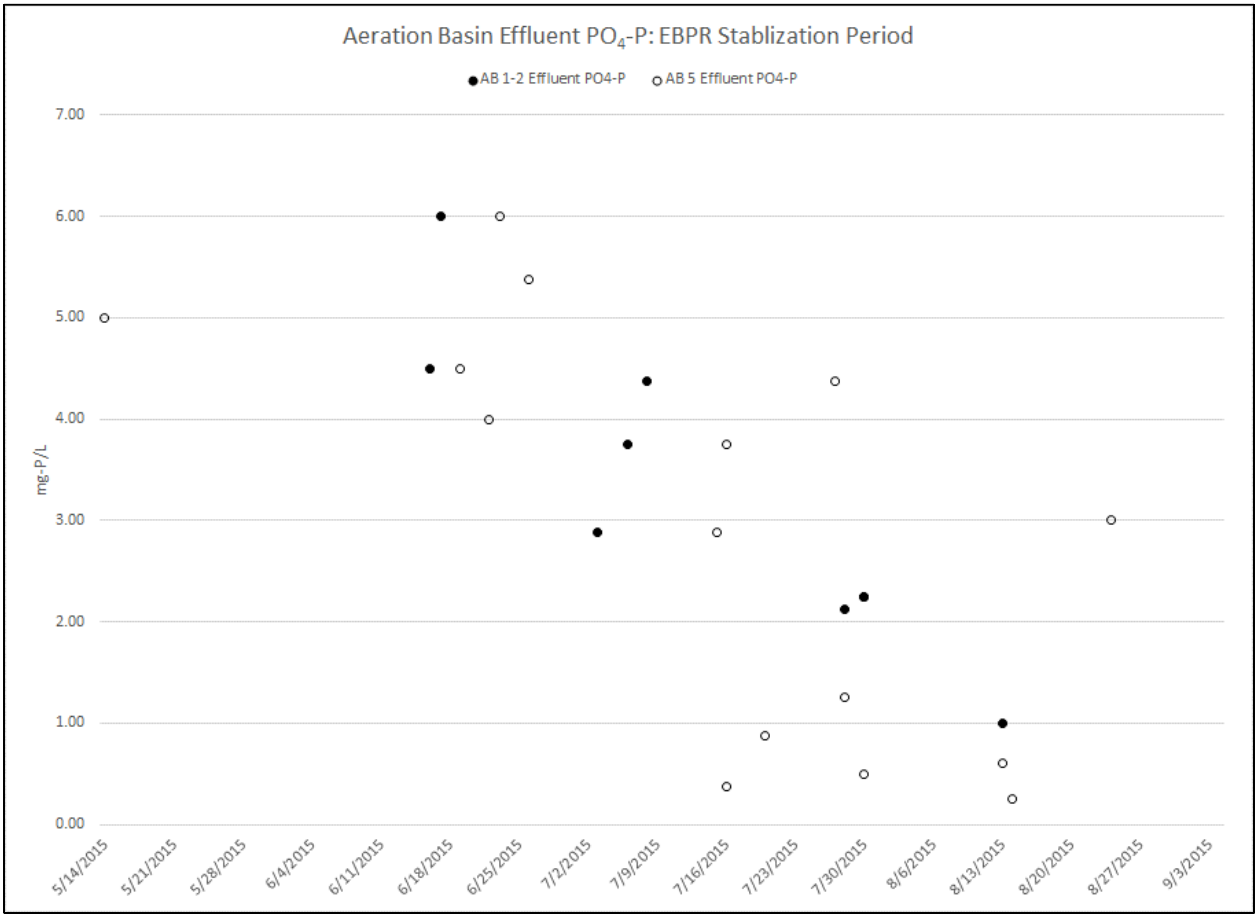



Figure 9. West Boise WWTF – Aeration Effluent bulk-liquid $PO_4$-P Concentration

At the end of the summer, moving into the winter months, the EBPR process continued in operation with the focus changing to optimize the overall performance of the system. On-line $PO_4$-P analyzers (HACH Phosphax™) were installed the West Boise WWTF, providing continuous monitoring of the PE and plant effluent (PLE) $PO_4$-P concentrations. While these meters do not measure the TP values, they do provide a good representation of the real-time performance of the EBPR system because $PO_4$-P is implicated in EBPR reactions. The $PO_4$-P trends from September through to the date of development of this TM are presented in Figures 10 and 11. Figure 10 identifies the PE and PLE $PO_4$-P, together with the influent wastewater flow to the West Boise WWTF and aeration basin temperature. During this period, the flow distribution to the aeration basins was adjusted between the internal zones. Initially 10 percent of the PE was directed to AX 1; 60 percent PE to AN 1; and 30 percent PE to AX 2 (10:60:30). This distribution was adjusted to 10:45:45 and then 10:30:60. The mass loading for the $PO_4$-P values in terms of pounds of P per day (lbs-P/day) is presented in Figure 10, along with the aeration basin temperature. The RAS flow for Aeration Basin (AB) 1 and 2 was set at 50 percent of the PE through March 4, 2016, and flow-paced accordingly (with a low-flow cap). The internal mixed-liquor recycle (MLR) for AB 1 and AB 2 is a constant flow set at approximately 90 percent of the average daily PE. The RAS flow for AB 6 was also set at 50 percent of the PE to March 4, 2016 with a similar flow-pacing approach as for AB 1 and 2. The MLR for AB 6 is set at approximately 200 percent of the average daily PE flow, operating at a constant flow rate. On March 4, 2106, the RAS rate for all of the aeration basins was adjusted to 40 percent of the PE flow.

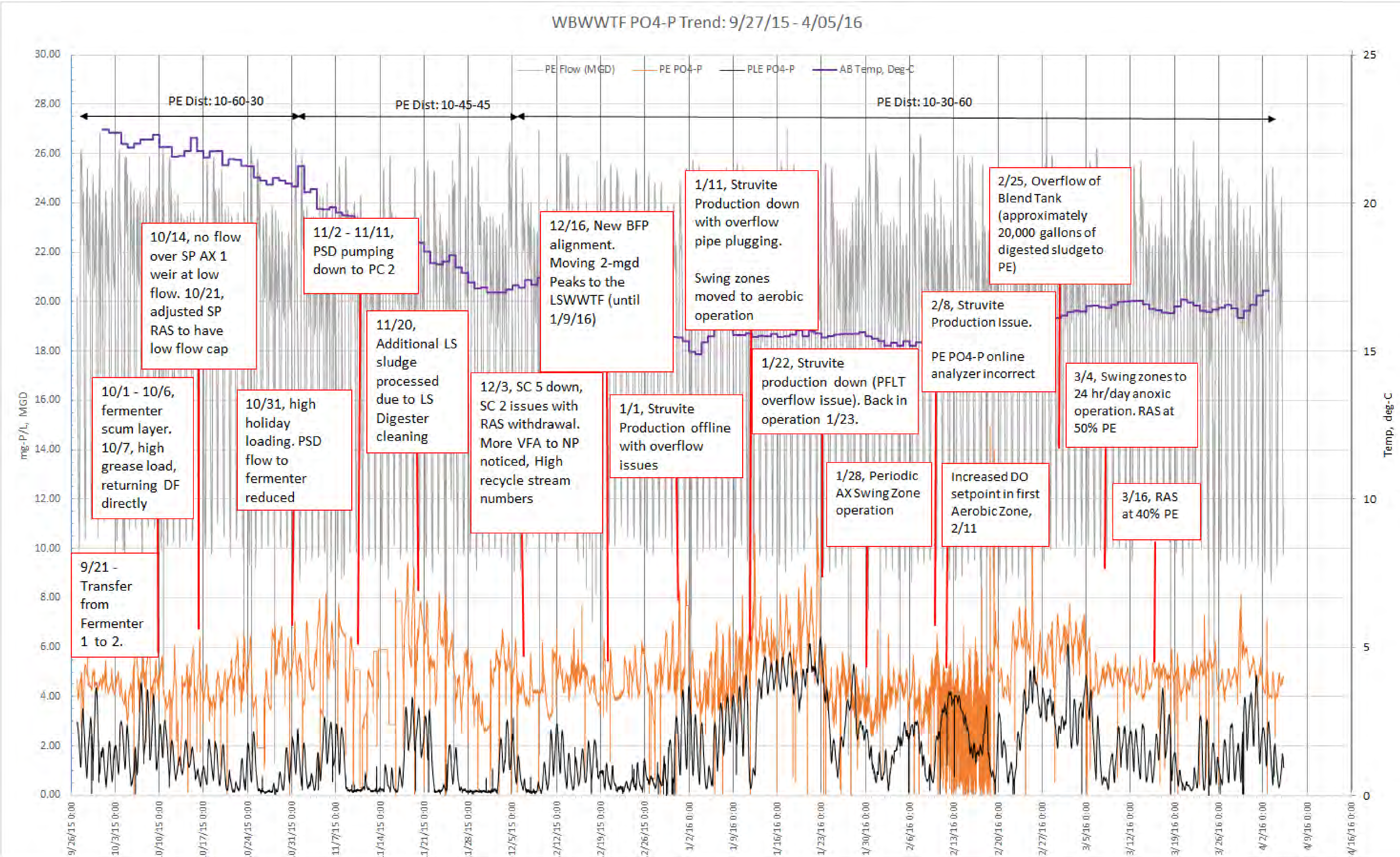



Figure 10. West Boise WWTF – Online PO4-P Measurement (EBPR Performance)

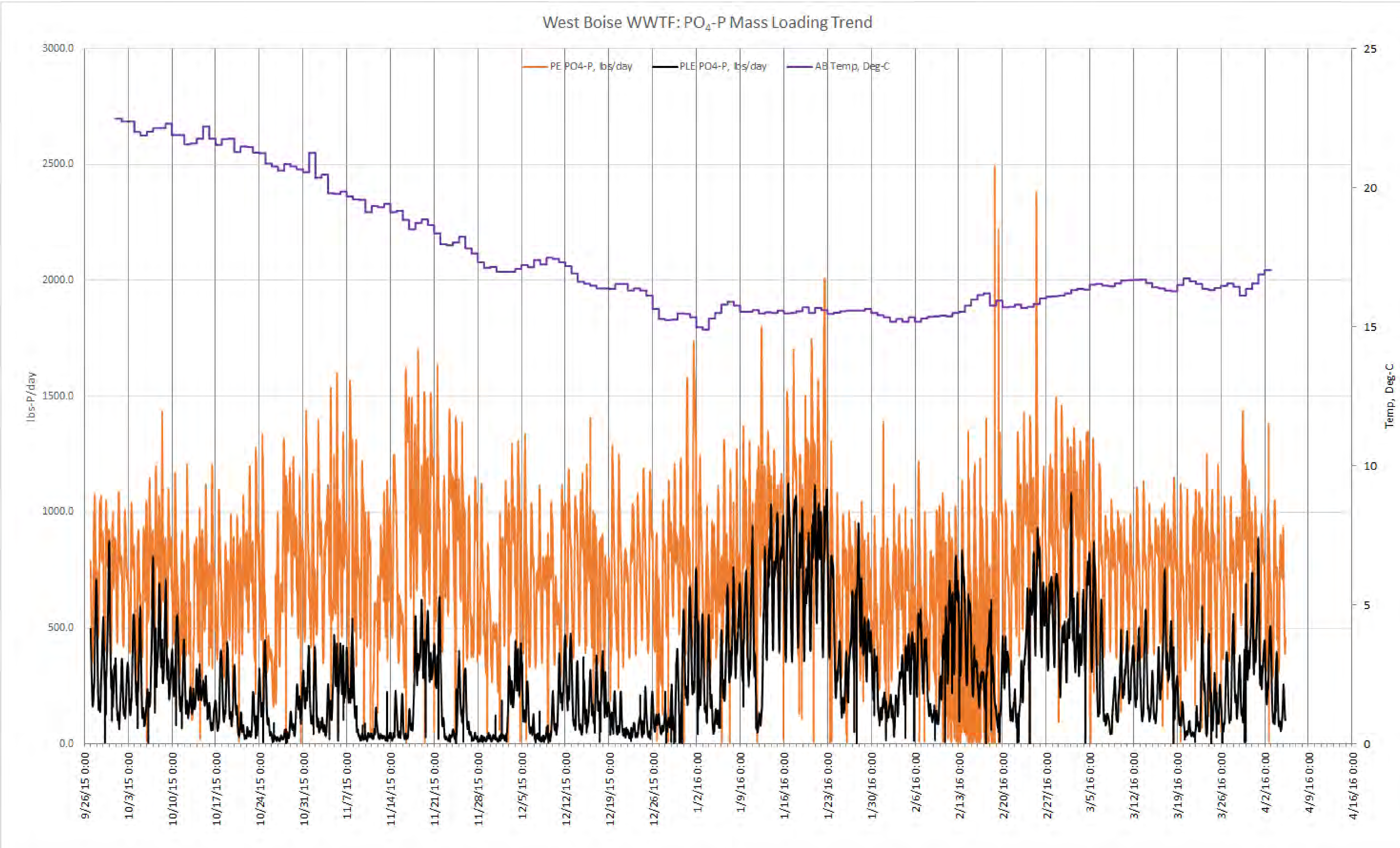



Figure 11. West Boise WWTF – PO4-P Measurement, Mass Loading (EBPR Performance)

The online measured $PO_4$-P values in Figures 10 and 11 align closely with the $PO_4$-P values measured in the laboratory. The TP values at this time are higher given the particulate fraction included in the effluent TSS from the WWTF. However, during this period the West Boise WWTF has seen some historically low effluent TSS values (averaging less than 5 mg/L in December 2015). Figure 12 details the effluent TP values from the end of the summer EBPR startup and optimization through March 2016.

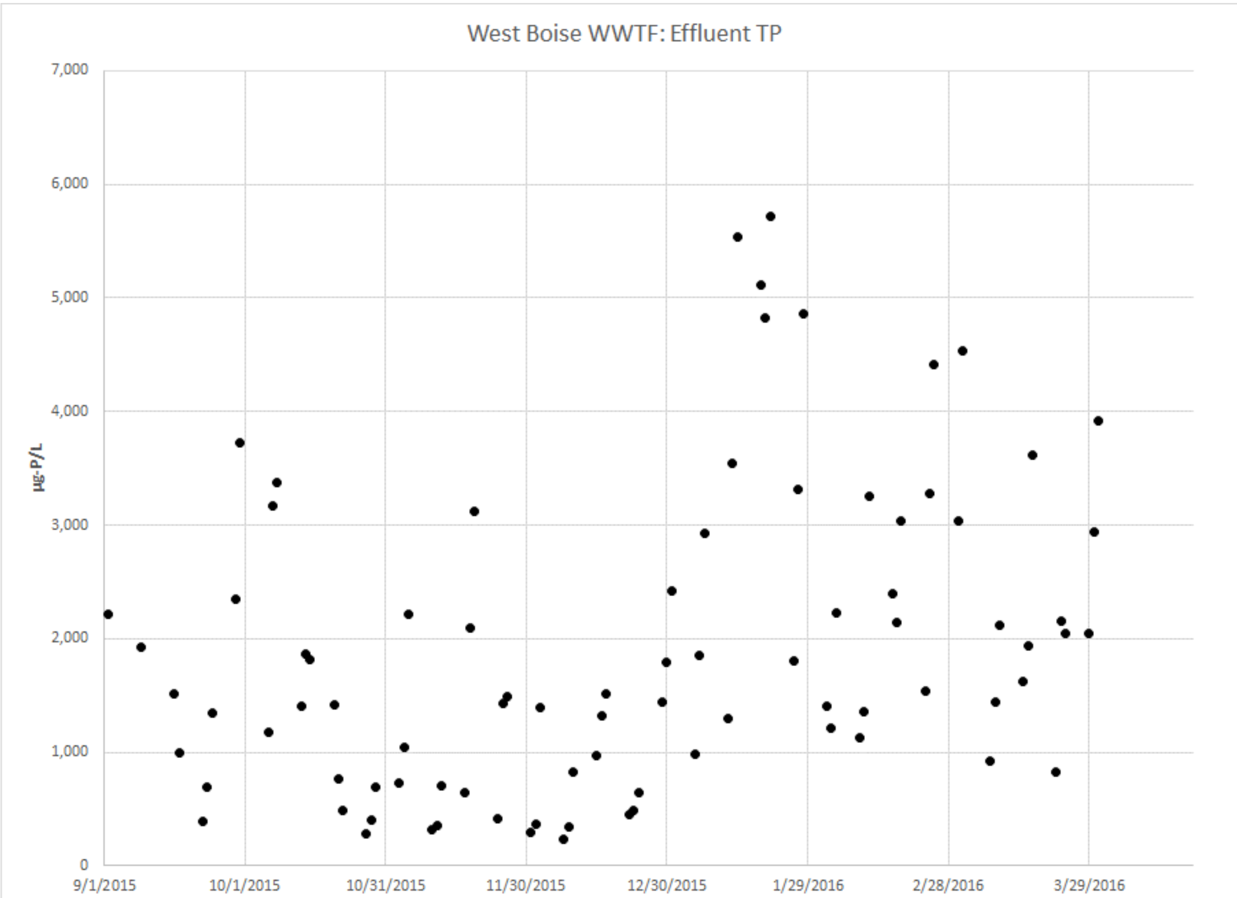



Figure 12. West Boise WWTF – Effluent Total Phosphorus

The results of the effluent TP, based on the measured values required for compliance with the NPDES permit are:

| | |
|---|---|
| • Monthly Average – September 2015 | 1,685 µg/L |
| • Monthly Average – October 2015 | 1,405 µg/L |
| • Monthly Average – November 2015 | 1,187 µg/L |
| • Monthly Average – December 2015 | 966 µg/L |
| • Monthly Average – January 2016 | 3,482 µg/L |
| • Monthly Average – February 2016 | 2,284 µg/L |
| • Monthly Average – March 2016 | 2,368 µg/L |
| • Average (period of record September 2015 to March 2016) | 1,900 µg/L |

The primary sludge fermentation facility was started in May 2015, with well-developed VFA generation by July 2015. The fermentation system did have periods of significant foaming requiring additional levels of operation and maintenance throughout the EBPR startup and commissioning period. However, even with the foam and scum issues there was a good level of VFA formation available for use in the EBPR process. Figure 13 presents the performance of the fermentation system to date. The figure includes both the VFA concentration (mg/L) and resulting mass load available (lbs/day). The City of Boise's

Central Lab, using an ion chromatography system (Dionex™ system – Application Note 123), measured the VFA concentration.

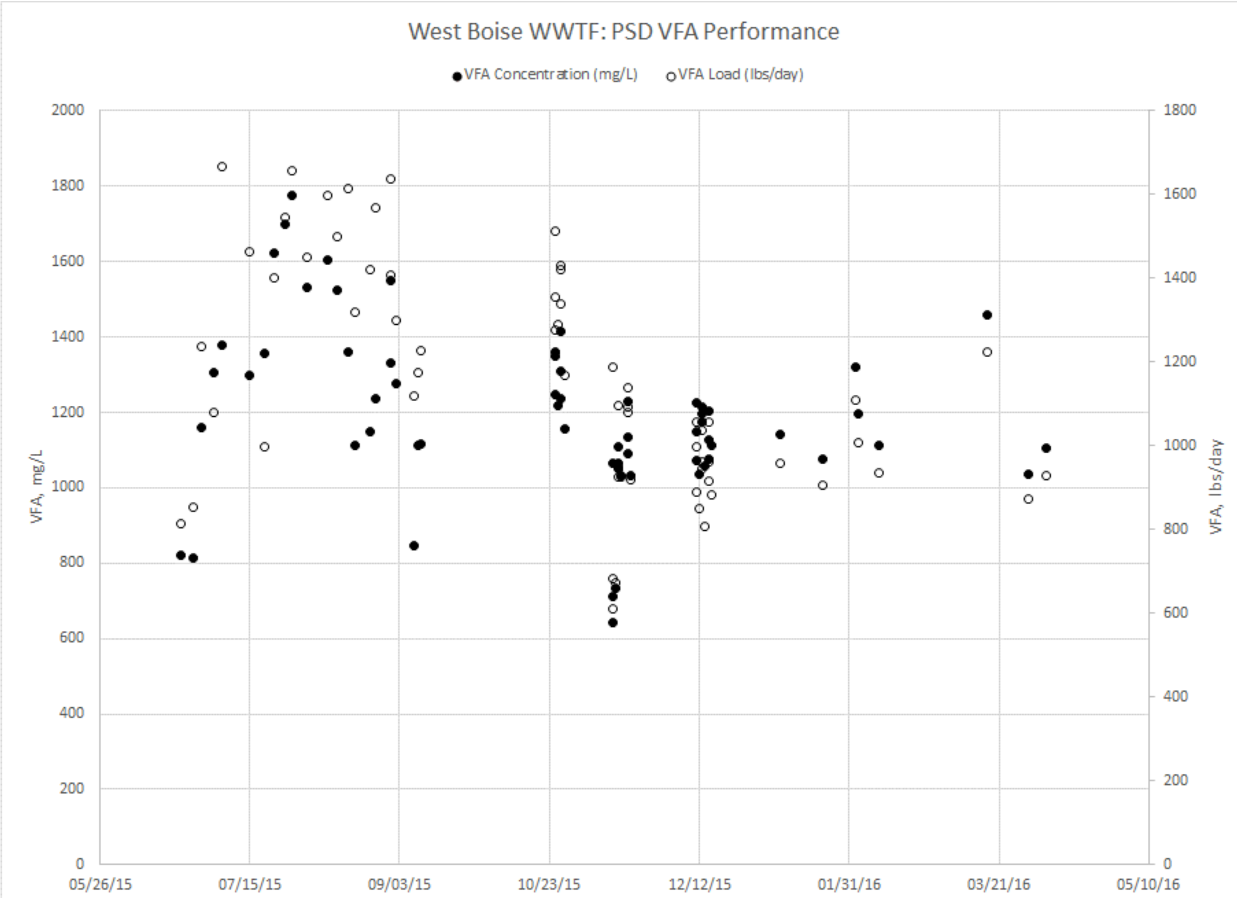


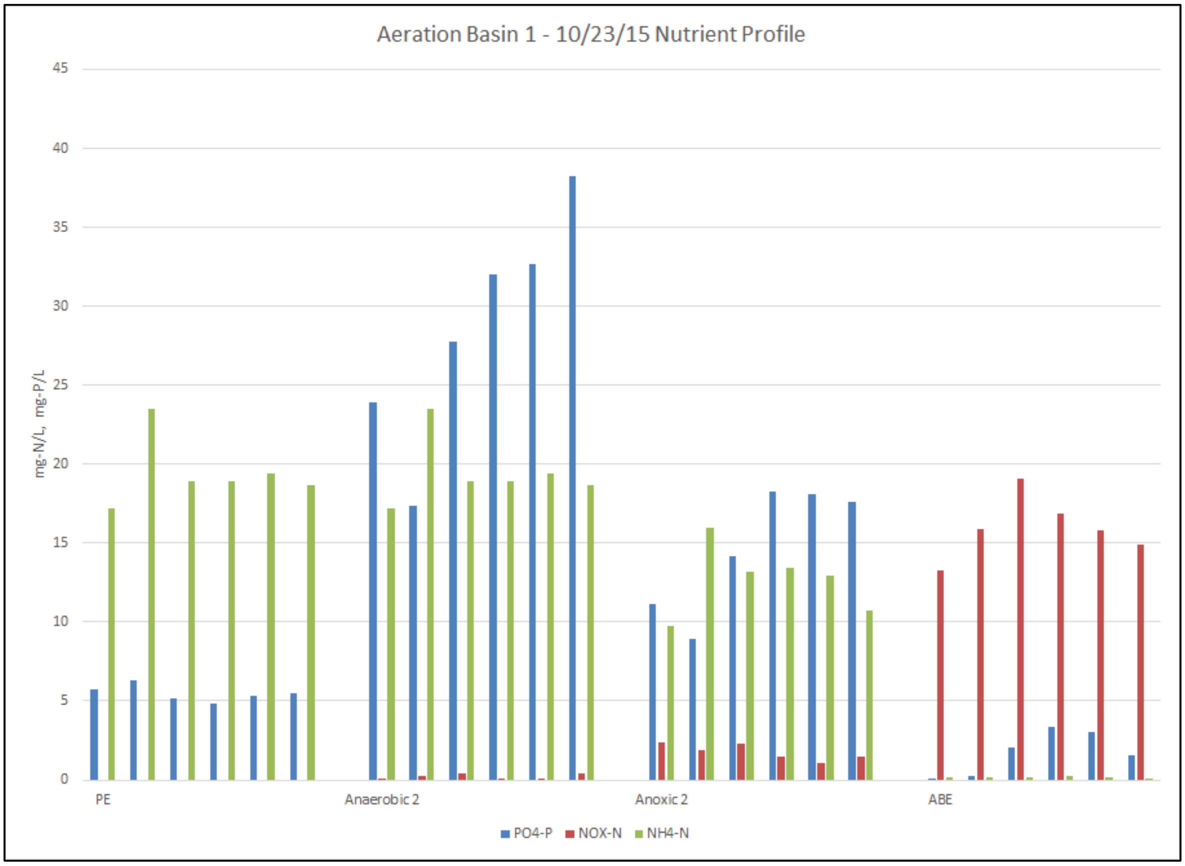

Figure 13. West Boise WWTF – Primary Sludge Fermentation Performance

## Baseline Sampling Campaign

In October 2015, the City started a significant sampling campaign to help establish baseline results of the EBPR performance at the facility. The concept was to run the EBPR system with minimal adjustments, outside of those required for typical operation, and measure the associated performance of the system. The only major adjustment during this period was the PE flow distribution discussed previously. The initial PE flow distribution was 10:60:30 (AX 1:AN 1:AX 2), followed by 10:45:45, and then 10:30:60. The PE flow distribution was established in design, but the intent of this was to find an optimal PE distribution. The campaign includes samples from a number of key areas in the EBPR process:

- Aeration basin diurnal profiling
- Plant drain diurnal trends
- Primary effluent diurnal VFA fractionation trends
- Fermented primary sludge VFA fractionation
- Struvite recovery influent and effluent
- Dewatering washwater characterization

Results from this effort are presented in the following figures. Figures 14, 15, and 16 provide a comparison of aeration basin profiling and three different periods during the sampling campaign.



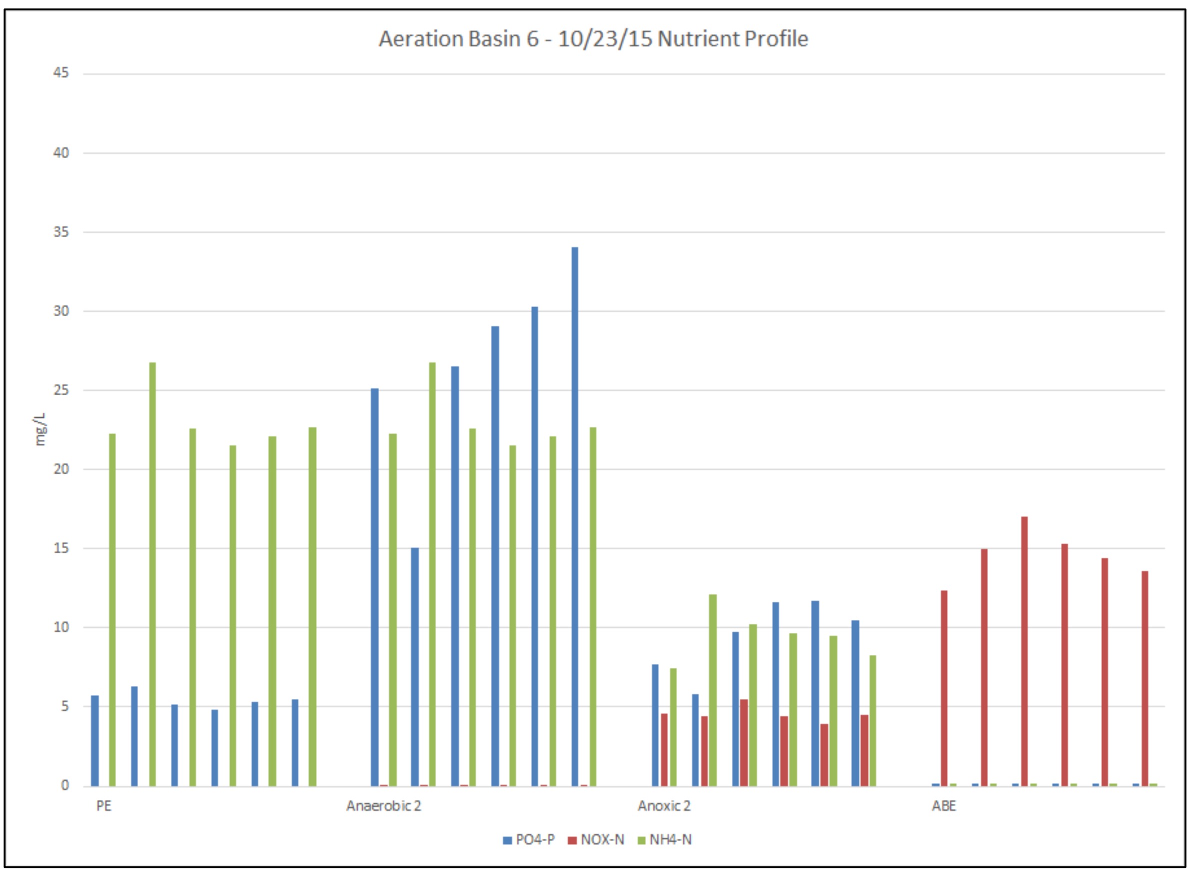
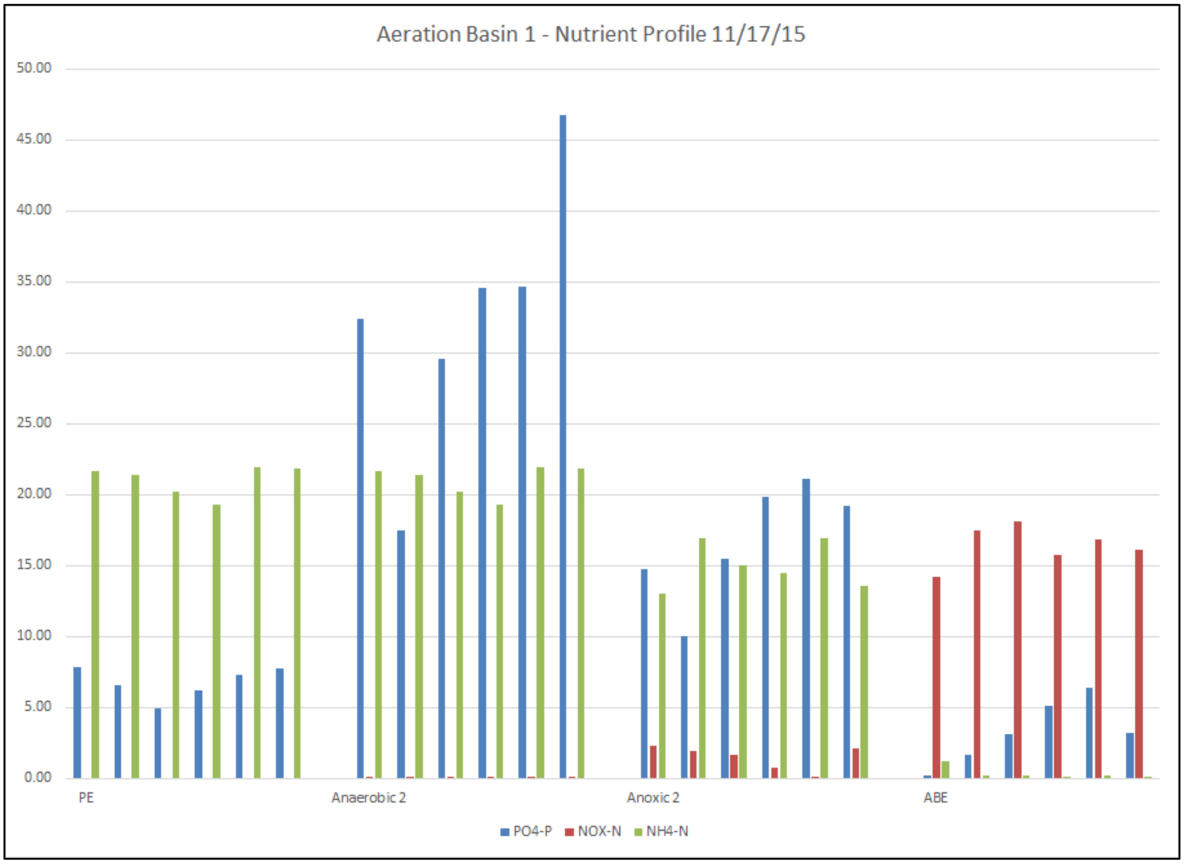




Figure 14. West Boise WWTF – AB 1 and AB 6 Nutrient Profile Comparison (10-23-15), 10:60:30 PE Flow Distribution



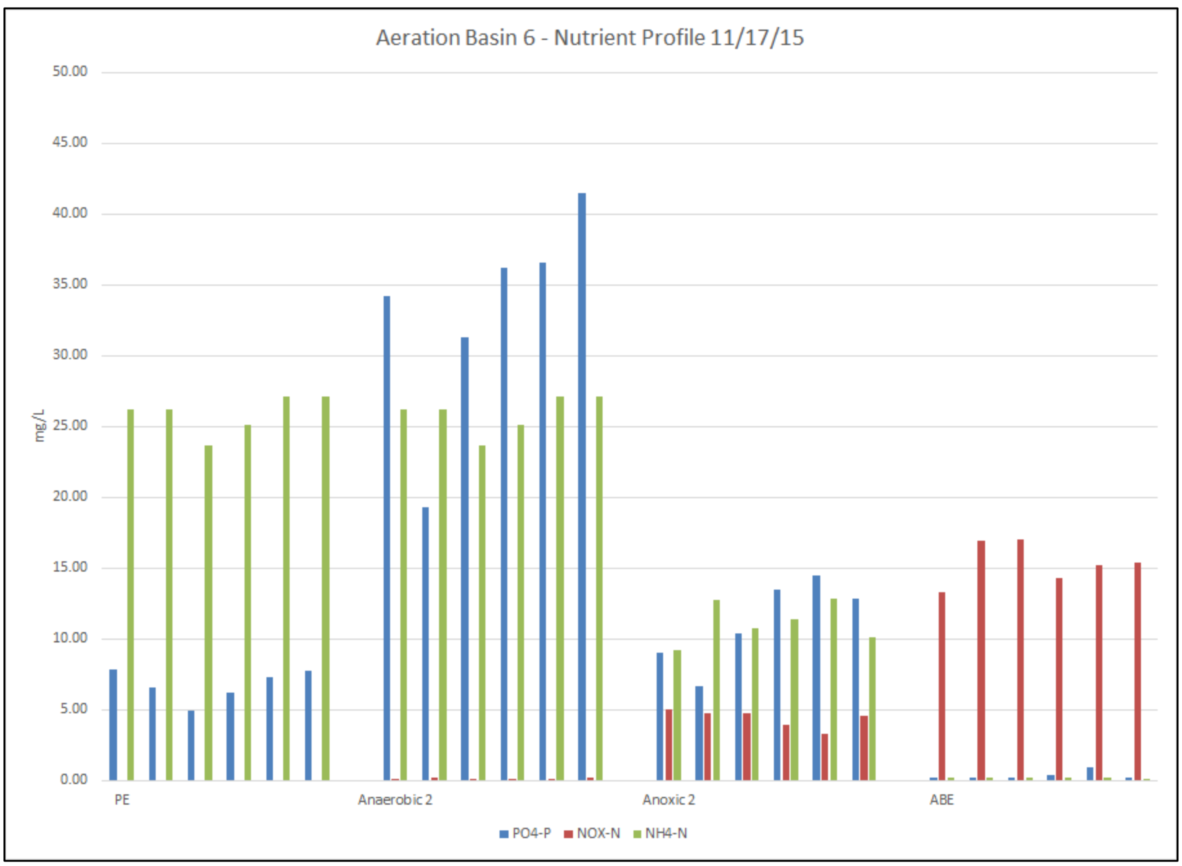
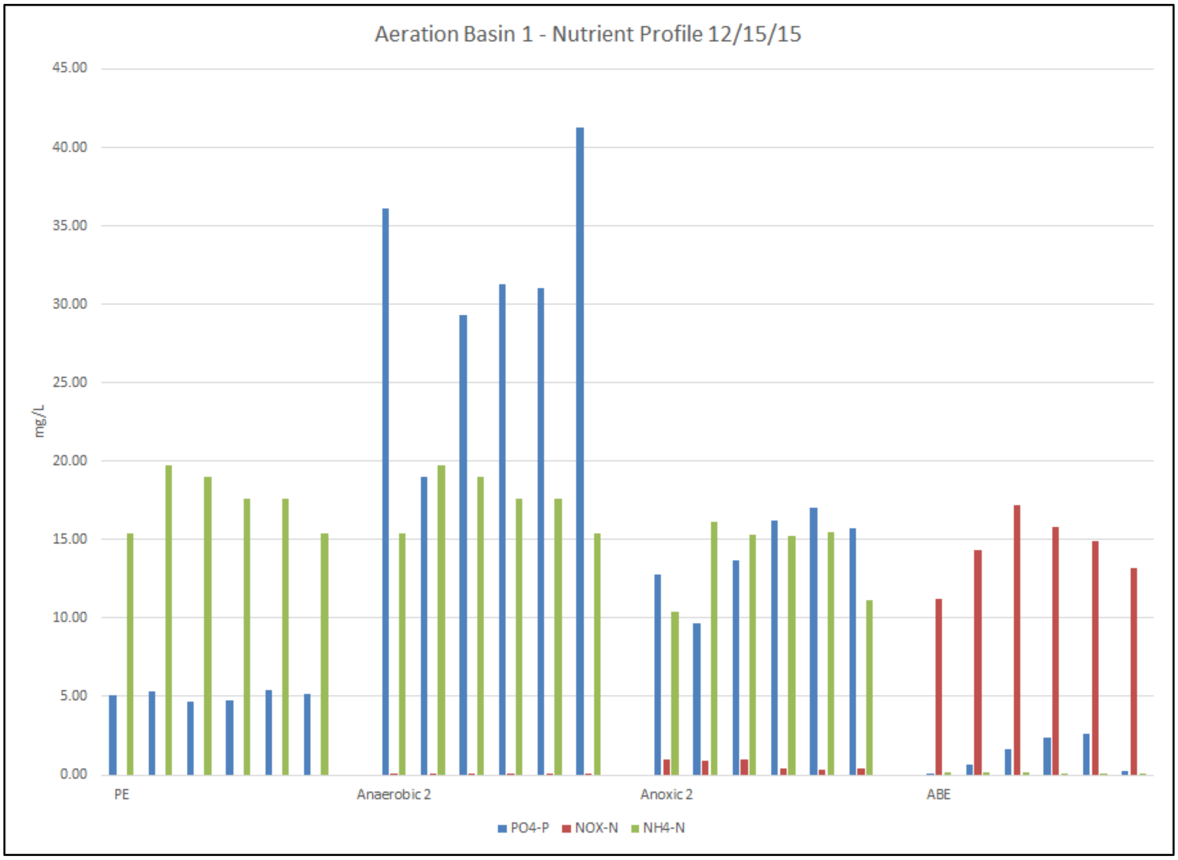




Figure 15. West Boise WWTF – AB 1 and AB 6 Nutrient Profile Comparison (11-17-15), 10:45:45 PE Flow Distribution



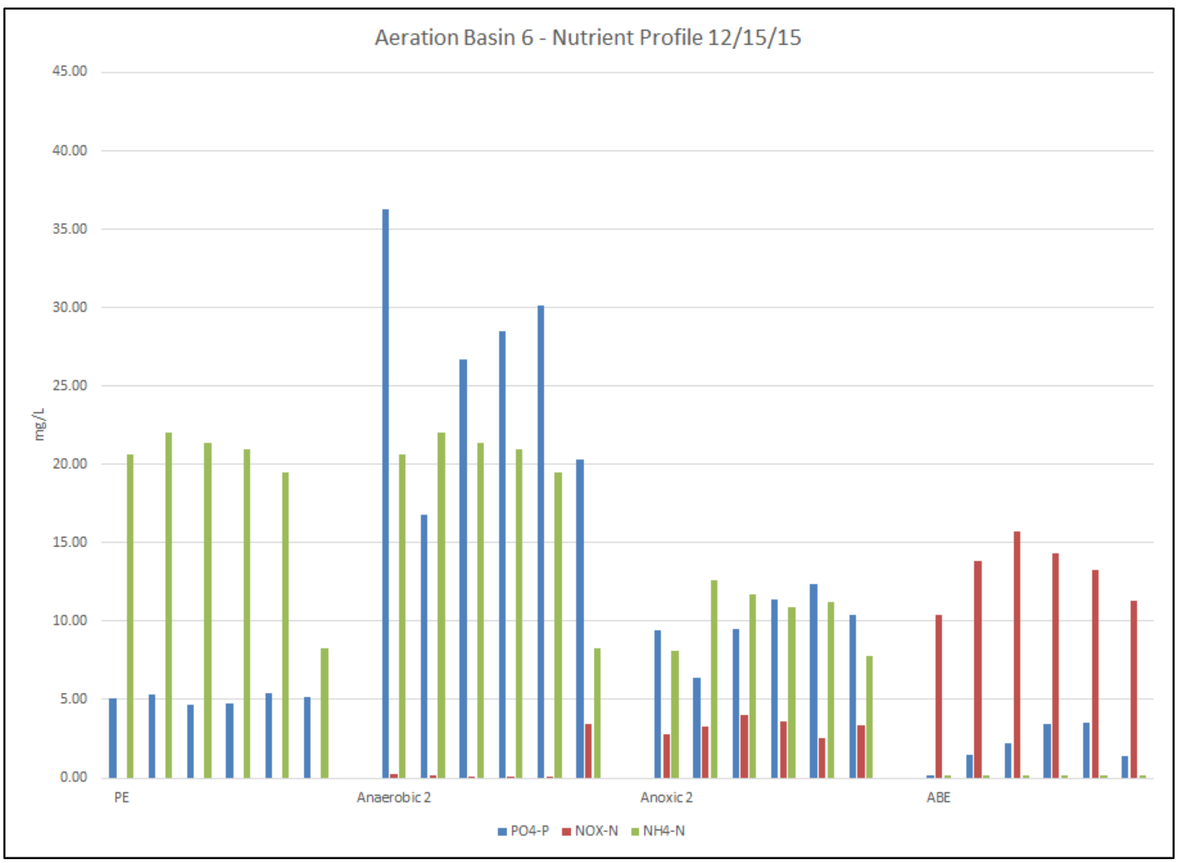




Figure 16. West Boise WWTF – AB 1 and AB 6 Nutrient Profile Comparison (12-15-15), 10:30:60 PE Flow Distribution

The bars included in Figures 14, 15, and 16 represent the diurnal sampling on the date shown, with these samples collected at 4 hour intervals from 8 AM until approximately 4 AM (on the following day). The intent of the charts is to highlight the variation in the constituents throughout the day. As an example, Figure 15 details how the bioreactor effluent $PO_4$-P in Aeration Basin 1 increases throughout the day. In this same figure, the bioreactor effluent $PO_4$-P in Aeration Basin 6 does not show a similar increase.

The PO4-P, Total P, and $NH_3$-N characteristics from the diurnal impacts of the process drain are detailed in Figure 17.

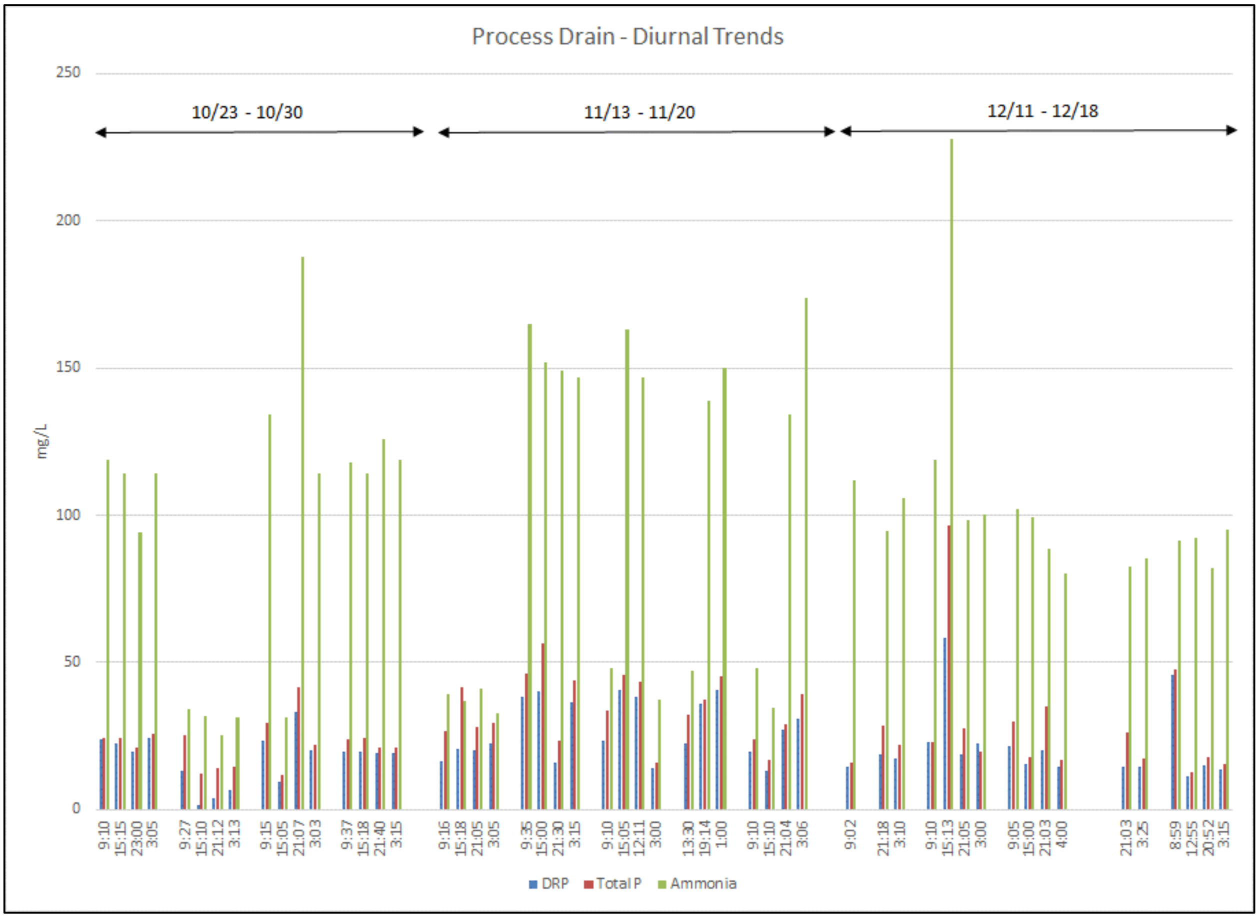



Figure 17. West Boise WWTF – Process Drain Diurnal Trends (DRP = PO4-P, Total P, and Ammonia-Nitrogen)

The process drain values are measured at the Plant Drain Wet Well, the location where all of the process drain recycle streams return to the main WWTF influent stream. The process drain sample is collected at this location, which is after treatment from the struvite recovery facility. An example of the data presented in Figure 17 is discussed for the December 11 to 18 period. The average $PO_4$-P value from the December 11 to 18 period is 21.1 mg-P/L with a few spikes approaching 50 mg-P/L. The associated average TP value from this time period is 27.6 mg-P/L, but with a spike up to 96 mg-P/L. During this same period, the struvite recovery reactors receiving the filtrate from the WAS $PO_4$-P Release Tank averaged an influent of 124 mg-P/L of $PO_4$-P and 128 mg-P/L of TP. The dewatering filtrate averaged 327 mg-P/L of $PO_4$-P prior to the struvite recovery reactors. There are two process drain flow streams from the dewatering system (belt filter presses [BFPs]). The washwater from the dewatering system bypasses the struvite recover reactor, going directly to the process drain. During the startup and shutdown sequences for the BFPs, digested sludge is directed to this same process drain allowing for a bypass of the struvite recovery reactor. During normal operation of the dewatering system, the filtrate (separated from the washwater) is sent to the struvite recovery facility.

There is a concern of potentially high levels of $PO_4$-P being returned through the washwater from the dewatering system. A diurnal profile of this washwater drainage was completed, documenting the potential recycle of TP to the plant drain system. Table 2 presents the results of this diurnal sampling effort. This sampling would also capture any BFP upsets or sludge bypass scenarios that may have occurred.

Table 2. West Boise WWTF – Dewatering Washwater Diurnal Trend

| Date | Time | Total P | TSS |
|---|---|---|---|
| 12/14/2015 | 18:06 | 28 | 677 |
| 12/14/2015 | 21:14 | 35.2 | 885 |
| 12/15/2015 | 1:20 | 9.99 | 206 |
| | | | |
| 12/15/2015 | 17:12 | 54.2 | 1320 |
| 12/15/2015 | 21:15 | 33.5 | 852 |
| 12/16/2015 | 3:10 | 3.94 | 28.4 |
| | | | |
| 12/16/2015 | 17:43 | 52.3 | 1450 |
| 12/16/2015 | 21:17 | 28.8 | 797 |
| 12/17/2015 | 2:47 | 473 | 936 |

The results of diurnal sampling of the VFA concentration in the PE are shown in Figure 18. The distribution of VFAs (butyrate, acetate, and propionate) are also shown, with the stacked bar indicating the amount of each. A line is shown highlighting the mass of VFAs introduced to the aeration basins given the PE flow at the time. The data are measured during the three PE flow distribution scenarios discussed previously (for 10:60:30, 10:45:45, and 10:30:60 [AX 1:AN 1:AX 2]). For each of these scenarios three days of diurnal sampling were completed, with four samples collected each day. The stacked bar in the chart represents the value for the particular sample during the day, with the time for that sample included on the chart.

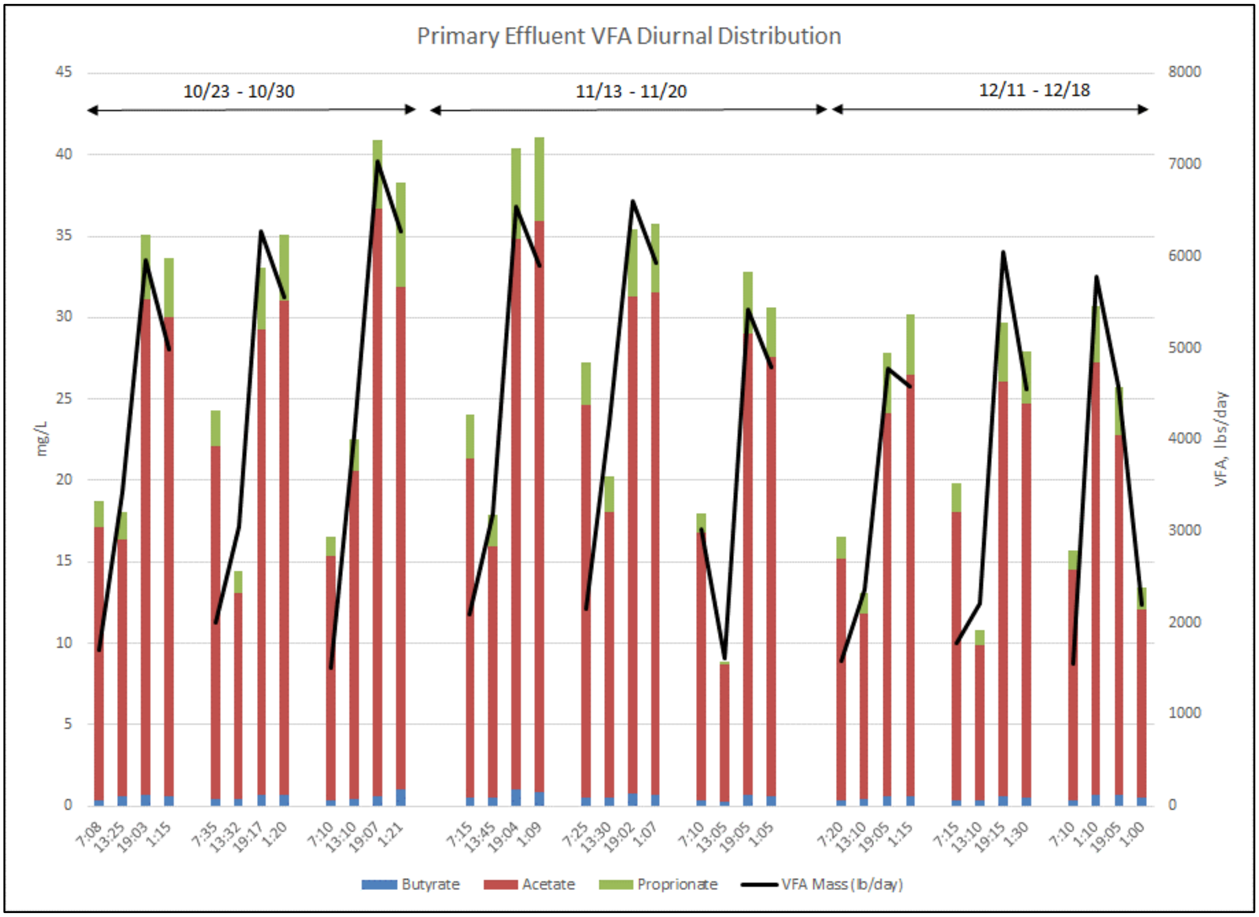



Figure 18. West Boise WWTF – Primary Effluent VFA Diurnal Trends

Figure 19 presents the VFA distribution from the PSD fermentation process for this sampling campaign. As with the previous graph, the distribution of butyrate, acetate, and propionate are shown as stacked bars for each sample time. The associated mass of VFAs is represented with a line for each period, with the values plotted against the secondary y-axis of the chart. The data are measured during the three PE flow distribution scenarios discussed previously (for 10:60:30, 10:45:45, and 10:30:60 [AX 1:AN 1:AX 2]). For each of these scenarios, three days of diurnal sampling were completed, with four samples collected each day from the fermenter. The stacked bar in the chart represents the value for the particular sample during the day, with the time for that sample included on the chart.

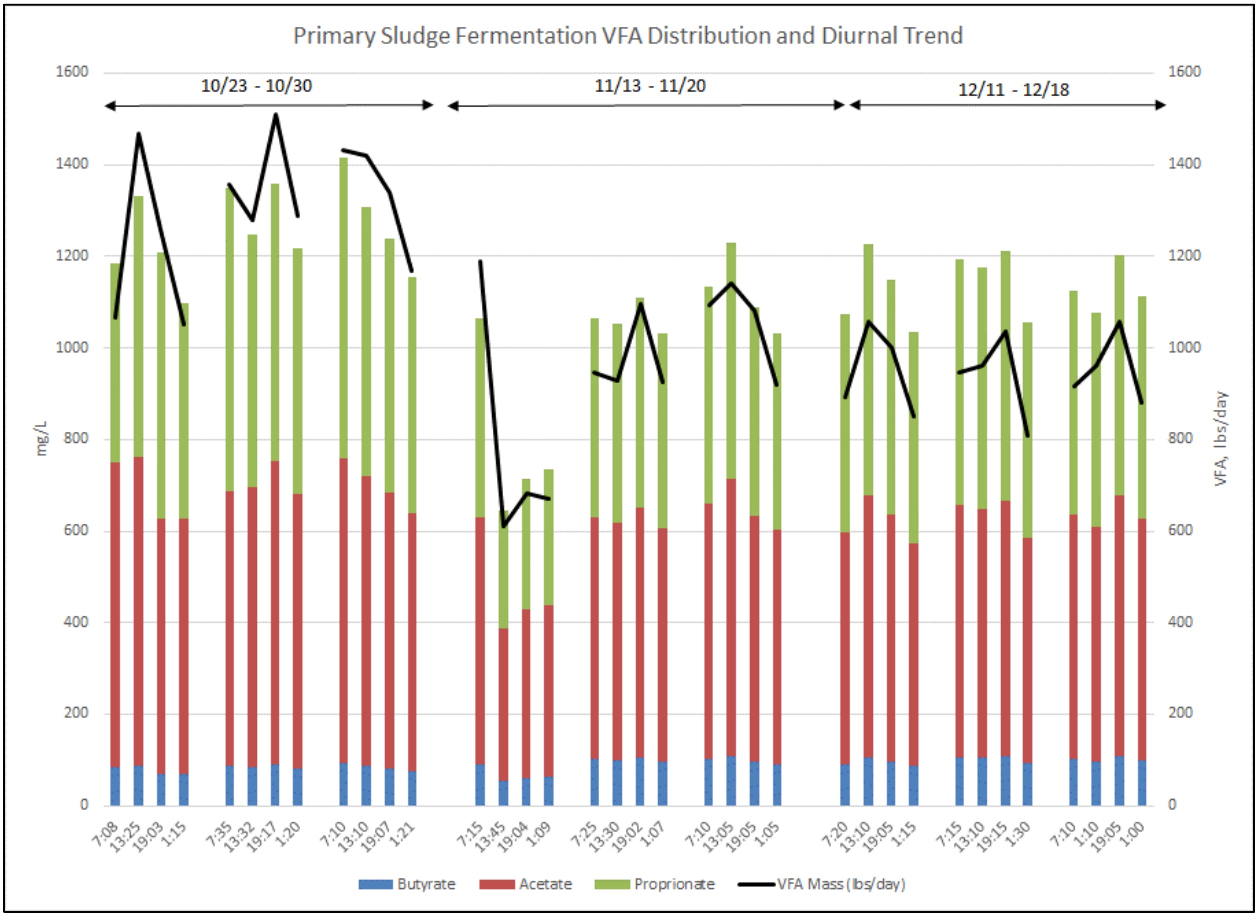



Figure 19. West Boise WWTF – PSD Fermentation VFA Diurnal Trends

Recently, the City completed an additional sampling campaign to document the diurnal impacts of the raw influent together with the process drain. The wastewater characteristics of $PO_4$-P, TP, $NH_3$-N, TSS, and chemical oxygen demand (COD) are measured from January 11 through January 18, 2016 on a diurnal basis for both the raw sewage and process drain. The $PO_4$-P loading for the raw sewage and process drain (and combined values for the PE loading) are compared in Figure 20. Figure 21 presents a similar comparison for the ammonia-N loading from the raw sewage, process drain, and PE.

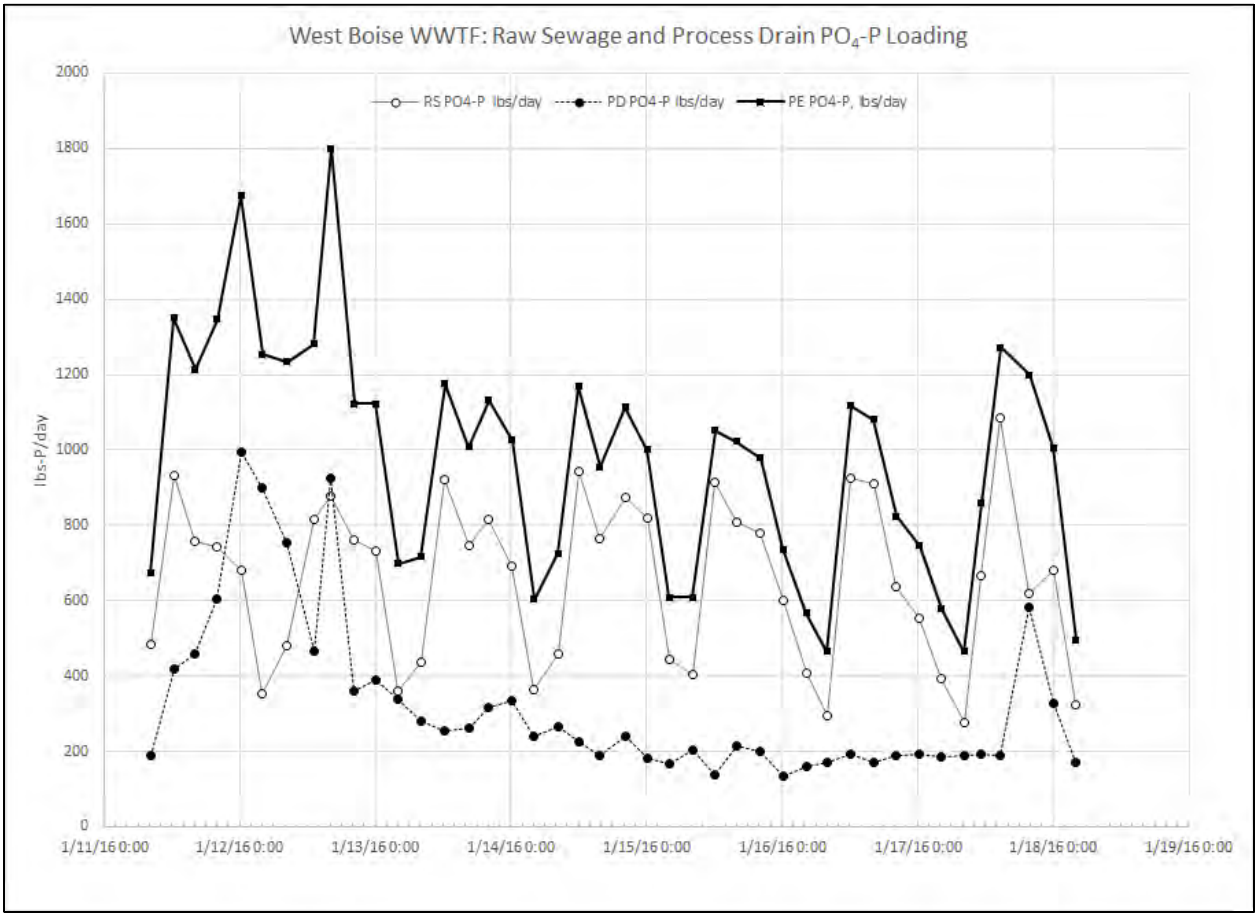



Figure 20. West Boise WWTF – Raw Sewage and Process Drain Diurnal $PO_4$-P Loading

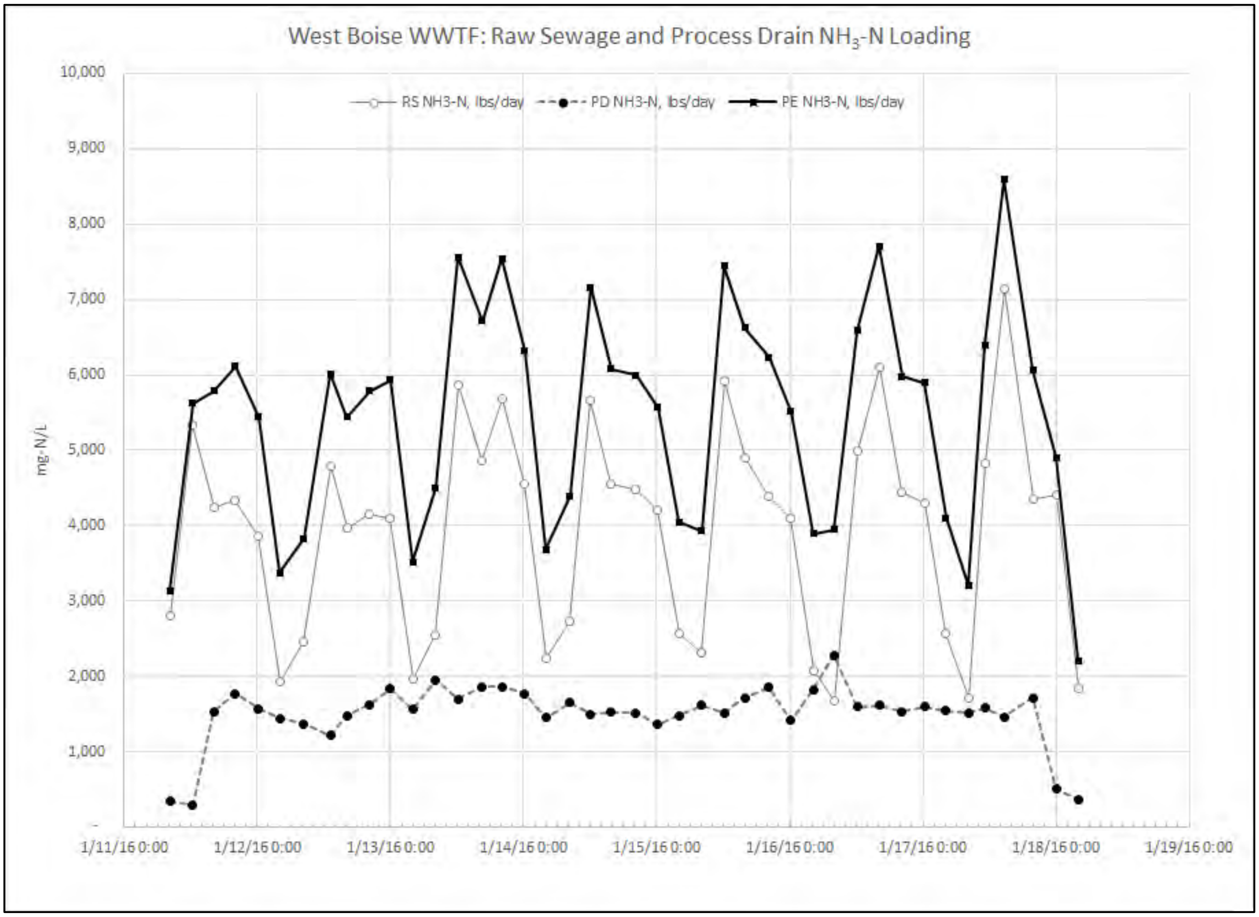



Figure 21. West Boise WWTF – Raw Sewage and Process Drain Diurnal $NH_3$-N Loading

## Aeration Basin Profiling

Additional aeration basin profiling was implemented at the West Boise WWTF in February 2016. During this timeframe, 80-percent of the primary effluent flow is sent to Aeration Basin 1 and 2, with 20-percent of the primary effluent flow being conveyed to Aeration Basin 6. Aeration Basin 5 is not in service. The intent of this profiling effort is to continue monitoring the nutrient concentrations across the bioreactors, working to identify optimization opportunities in the system. There are similar trends in the nutrient profiles as in the previous baseline sampling campaign. Concentrations of $PO_4$-P, $NO_3$-N, and $NH_3$-N are measured from the end Anoxic Zone 1, Anaerobic Zone, and Anoxic Swing Zone. Additional samples are collected from all of the aerobic zones as well, helping identify the aerobic P-uptake capacity of the system. The profiles are initially collected for Aeration Basin 1 at 8:00, 14:00, and 20:00. Lower influent flow and loading conditions occur around 8:00, where the 14:00 and 20:00 timeframe reflects higher loading conditions at the WWTF. The actual concentrations measured from the grab samples are presented in the following figures. These concentrations do reflect the dilution from the varying PE feed into each bioreactor, the RAS flow, and the internal MLR stream.

Figure 22 highlights the nutrient profile in Aeration Basin 1 for the following: RAS stream (RAS), Anoxic Zone 1 (AX1), Anaerobic Zone 2 (N2), Anoxic Zone 2 – Swing Zone (X2), Aerobic Zone 2 (2), Aerobic Zone 3 (3), Aerobic Zone 4 (4) and Aerobic Zone 5 (5). The profiles for multiple days with samples collected at 14:00 are shown in Figure 23. The nutrient profiles at 20:00 are shown in Figure 24.

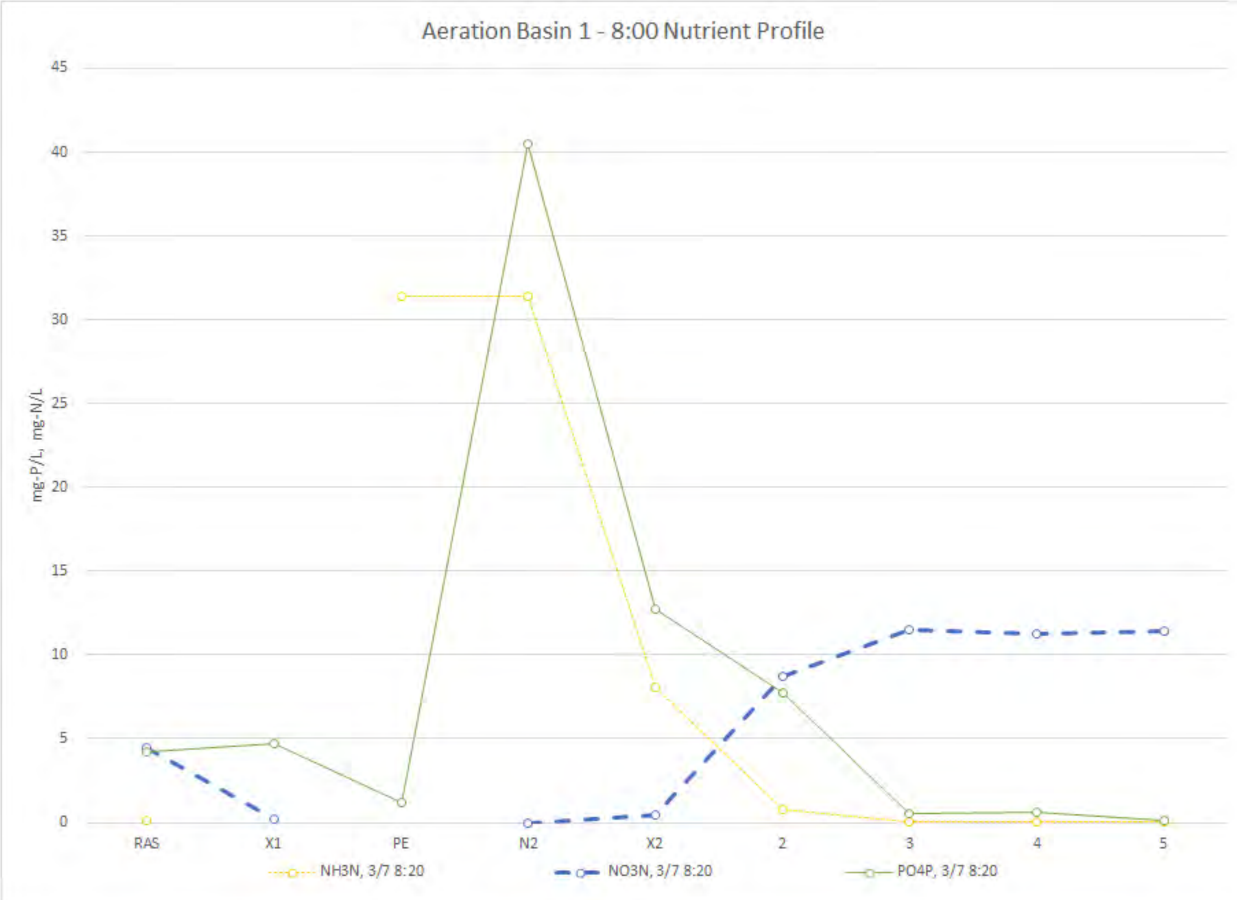



Figure 22. West Boise WWTF – Aeration Basin 1 Nutrient Profile, 8:20 (PE = 5.31 MGD, RAS = 2.22 MGD)

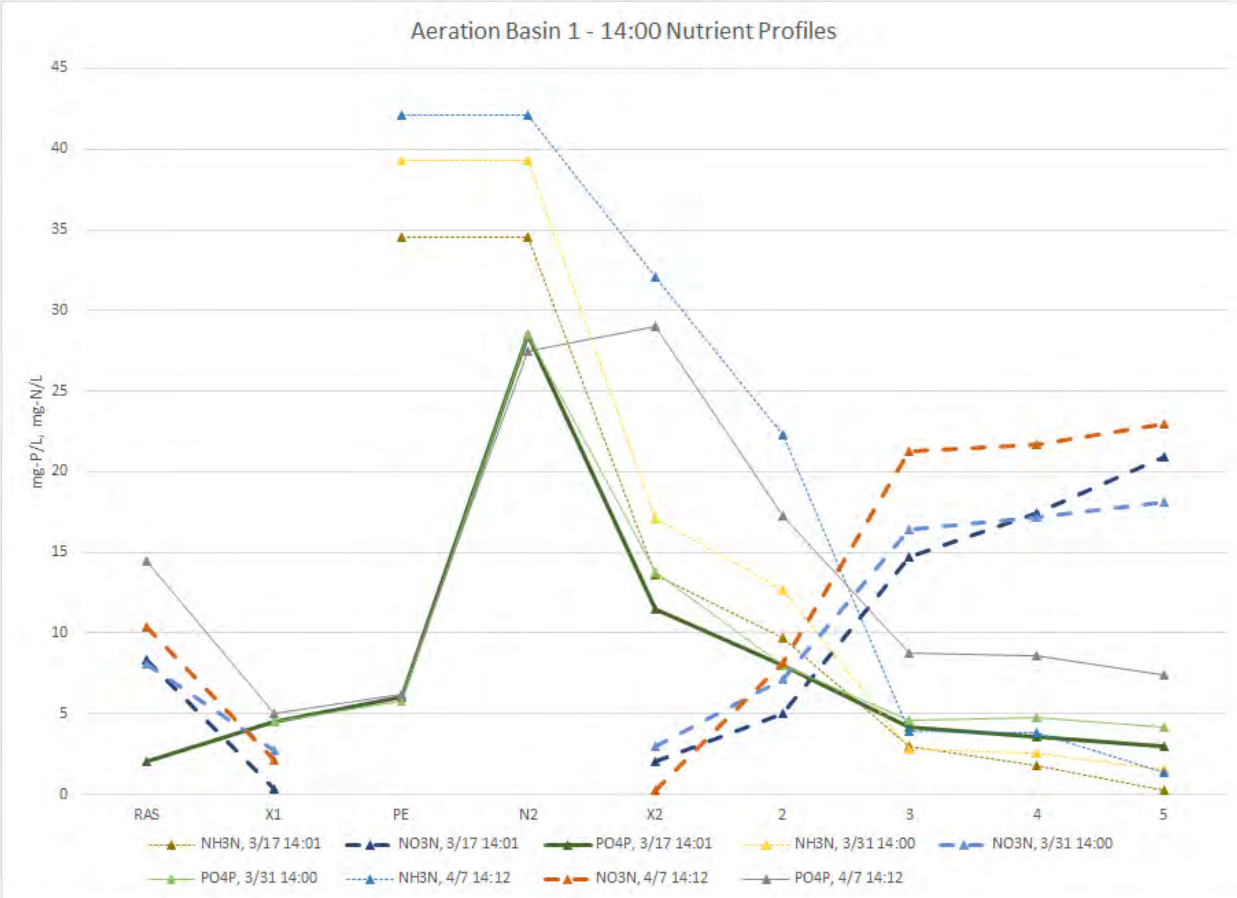



Figure 23. West Boise WWTF – Aeration Basin 1 Nutrient Profile, 14:00 (Average PE = 8.5 MGD, Average RAS = 3.1 MGD)

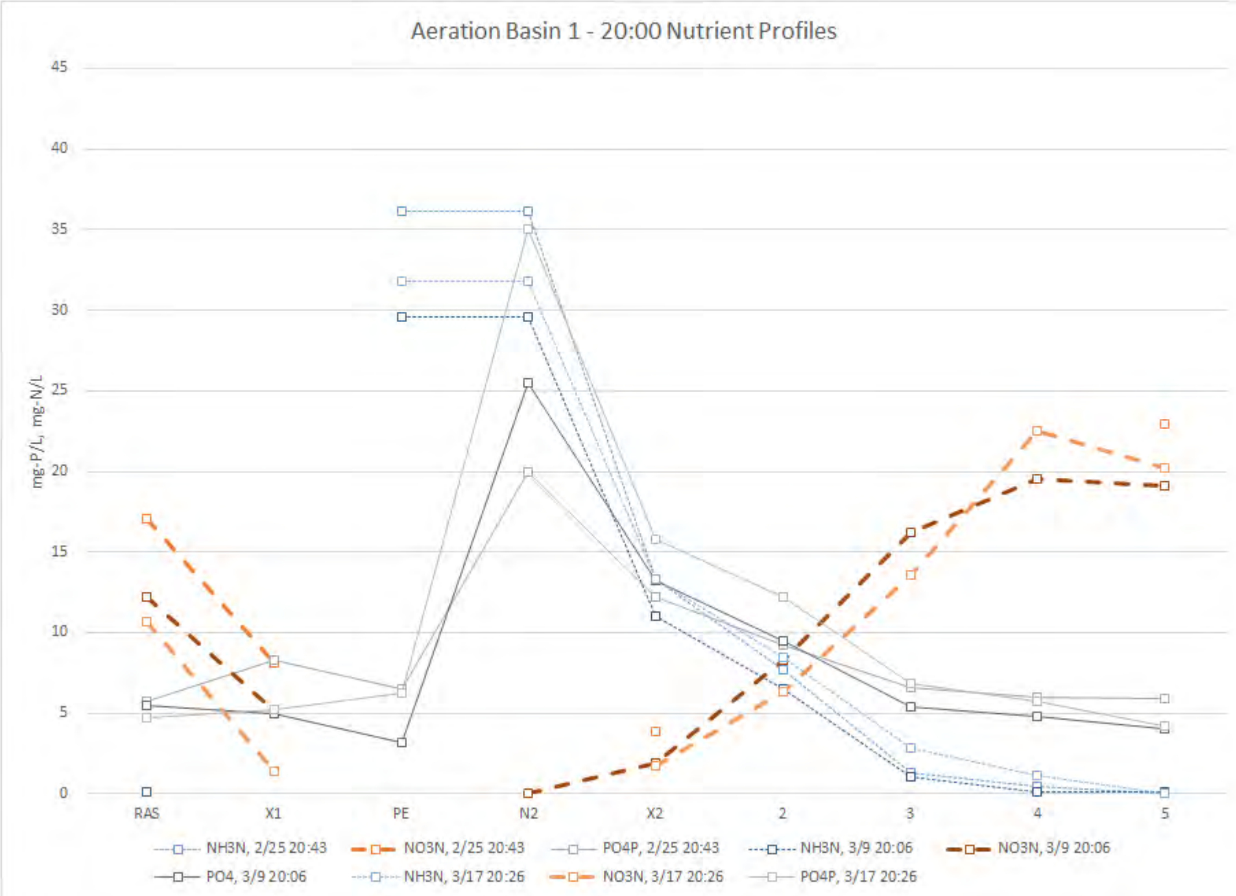



Figure 24. West Boise WWTF – Aeration Basin 1 Nutrient Profile, 20:00 (Average PE = 8.1 MGD, Average RAS = 3.0 MGD)

On April 13, 2016 at 20:00, a nutrient profile was collected from Aeration Basin 1, Aeration Basin 2, and Aeration Basin 6. The goal of this profiling effort was to determine the differences, if any, between the three bioreactors. At the time of sample collection the total PE flow to Aeration Basin 1 was 8.67 MGD, PE flow to Aeration Basin 2 was 8.53 MGD, and PE flow to Aeration Basin 6 was 4.2 MGD. The RAS flow to each aeration basin was: Aeration Basin 1 – 3.51 MGD, Aeration Basin 2 – 3.5 MGD, and Aeration Basin 6 – 1.65 MGD. The internal mixed-liquor recycle (MLR) stream for Aeration Basin 1 and Aeration Basin 2 is set at 6.1 – 6.5 MGD (approximately 70 – 76 percent of PE flow). The MLR in Aeration Basin 6 is set at approximately 8.5 MGD (approximately 200 percent of PE flow). These nutrient profile data for the three aeration basins are presented in Figure 25.

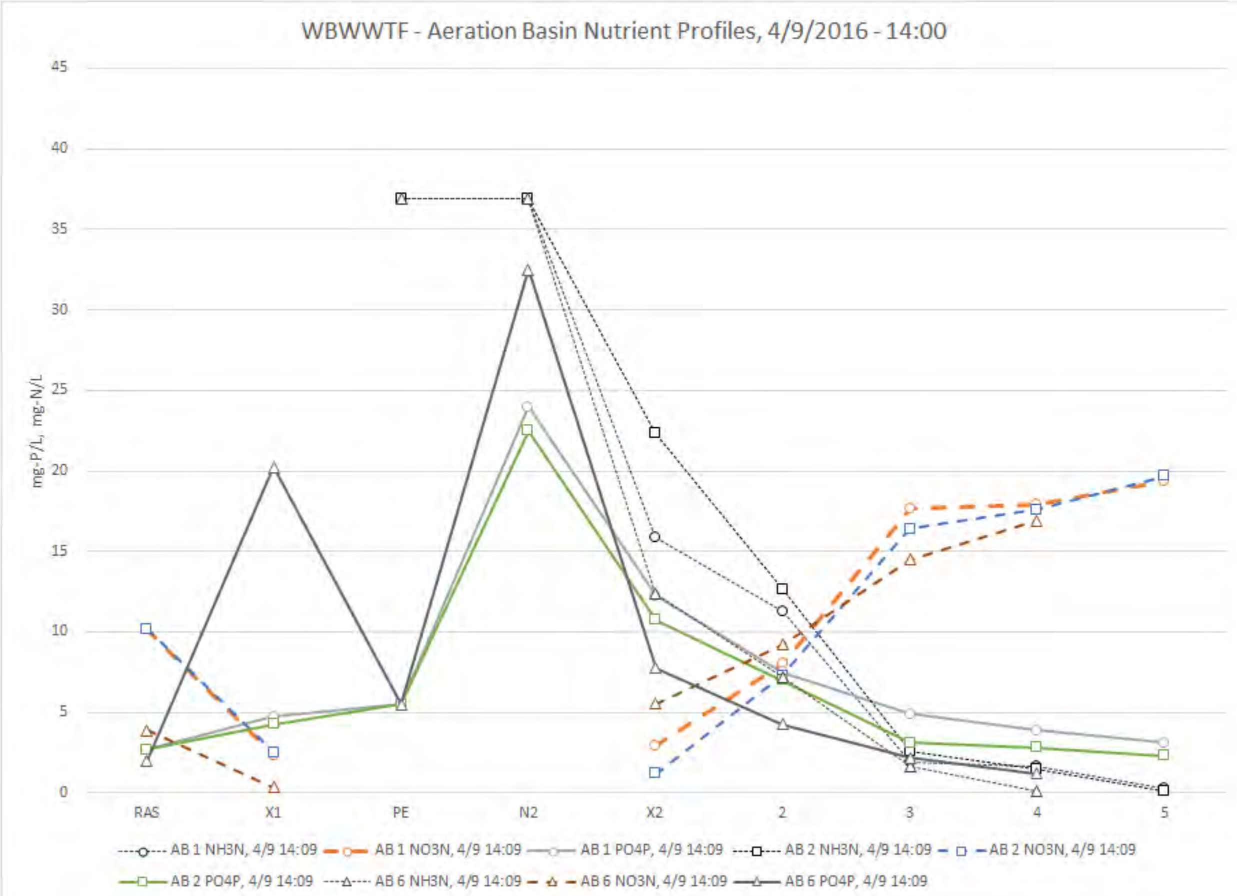



Figure 25. West Boise WWTF – Aeration Basin 1, 2 and 6 Nutrient Profiles, 4/13/2016, 14:00

The sampling data from the April 13, 2013, associated with the nutrient profiles are presented in Figure 25, are presented in Table 3.

Table 3. West Boise WWTF Aeration Basin Profiles, 4/13/2016, 14:00.

| Location | $NH_3N$ | $NO_3N$ | $PO_4P$ | $NH_3N$ | $NO_3N$ | $PO_4P$ | $NH_3N$ | $NO_3N$ | $PO_4P$ |
|---|---|---|---|---|---|---|---|---|---|
| | Aeration Basin 1 | | | Aeration Basin 2 | | | Aeration Basin 3 | | |
| PE | 36.9 | | 5.5 | 36.9 | | 5.5 | 36.9 | | 5.5 |
| RAS | | 10.2 | 2.7 | | 10.2 | 2.7 | | 3.87 | 2 |
| X1 | | 2.35 | 4.75 | | 2.54 | 4.25 | | 0.35 | 20.25 |
| N2 | | | 24 | | | 22.5 | | | 32.5 |
| X2 | 15.9 | 2.92 | 12.25 | 22.3 | 1.22 | 10.75 | 12.4 | 5.54 | 7.75 |
| 2 | 11.3 | 8.02 | 7.5 | 12.6 | 7.3 | 7 | 7.17 | 9.21 | 4.25 |
| 3 | 1.93 | 17.7 | 4.9 | 2.61 | 16.4 | 3.1 | 1.64 | 14.5 | 2.2 |
| 4 | 1.65 | 17.9 | 3.9 | 1.5 | 17.6 | 2.8 | 0.123 | 16.9 | 1.2 |
| 5 | 0.323 | 19.4 | 3.1 | 0.077 | 19.7 | 2.3 | | | |

| | Aeration Basin 1 | Aeration Basin 2 | Aeration Basin 3 |
|---|---|---|---|
| | Date: 4/13/2016 | Date: 4/13/2016 | Date: 4/13/2016 |
| | Time: 14:09 | Time: 14:09 | Time: 14:00 |
| | PE Q: 8.67 mgd | PE Q: 8.53 mgd | PE Q: 4.2 mgd |
| | MLR Q: 6.1 mgd | MLR Q: 6.5 mgd | MLR Q: 9 mgd |
| | RAS Q: 3.51 mgd | RAS Q: 3.5 mgd | RAS Q: 1.65 mgd |
| | VFA Q: 26.1 gpm | VFA Q: 31.4 gpm | VFA Q: 18.3 gpm |

## Updated Online Analyzer Data

The City of Boise updated the online monitoring of primary effluent data by including an ammonium-nitrogen probe, the HACH unit that includes their sc1000 electronics/analyzers together with an ion selective probe (AN-ISE SC series). This is located in the same area as the phosphate probe listed in the discussion previously. Together these provide the West Boise operations staff online, real-time readings of $PO_4$-P and $NH_3$-N on the primary effluent. The plant effluent also includes the online monitoring of $PO_4$-P, as presented earlier in the TM. Figure 26 presents the online measurement of $PO_4$-P and $NH_3$-N from March 31, 2016 to April 19, 2016.

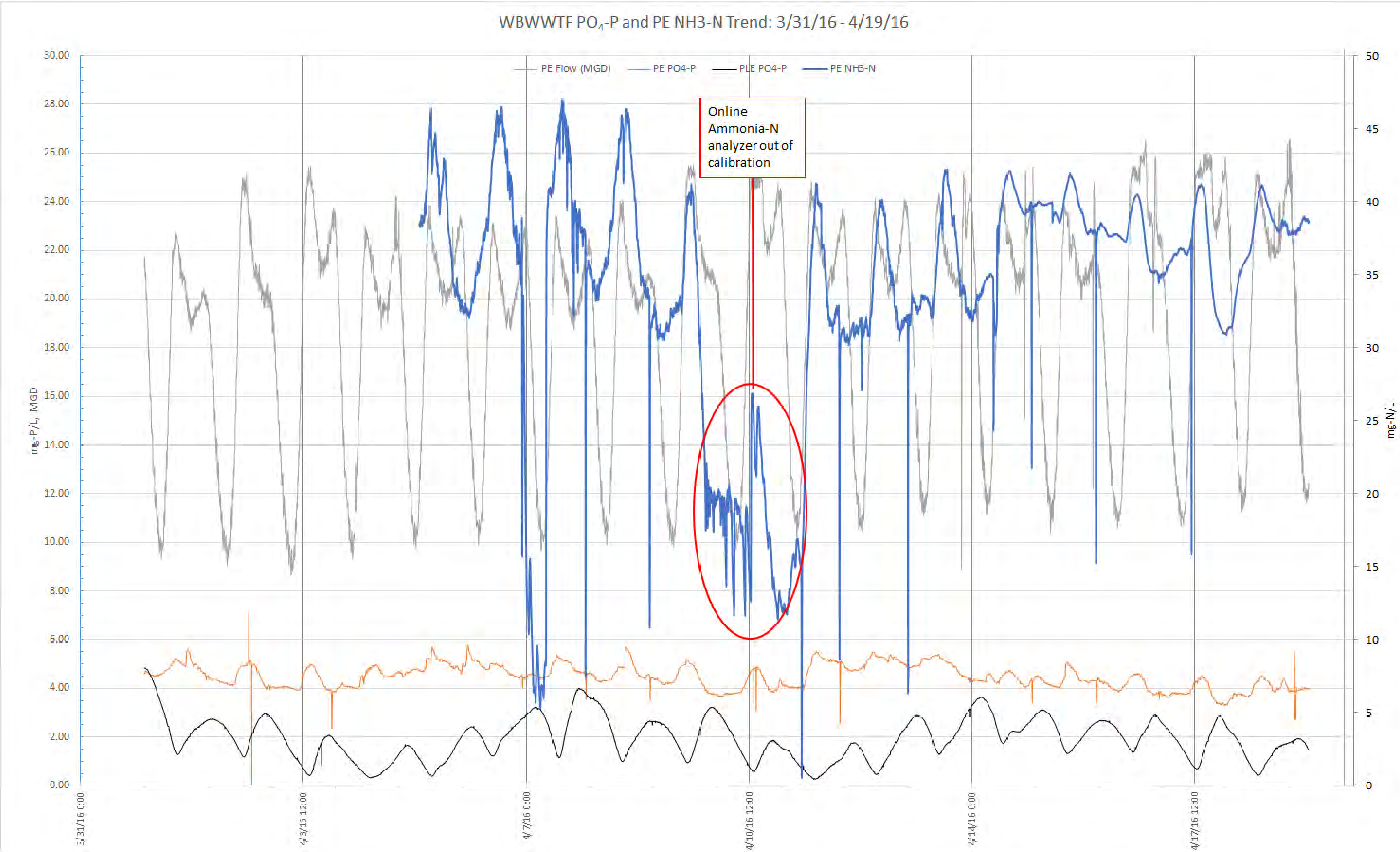



Figure 26. West Boise WWTF – Online Monitoring for PE $PO_4$-P, PLE $PO_4$-P and PE $NH_3$-N

# Discussion

A discussion of the results is framed as they relate to the prerequisites listed in the TM earlier for optimal and reliable EBPR performance. The top six prerequisites identified by Jeyanayagam (2015) are:

- Feed the PAOs
- Protect the anaerobic zone
- Maximize P uptake in the aerobic zone
- Maximize solids capture
- Minimize recycle loads
- Minimize competition

In addition to these items, there are other considerations to review given the complex nature of the EBPR process. Of particular interest at the West Boise WWTF is the impact of the dewatering filtrate return with the additional loading from the Lander Street WWTF. There is also a consistent trend of higher loading conditions weekends, contributing to the overall impacts on the secondary treatment process.

## Feed the PAOs

As discussed previously, a reliable EBPR system requires a constant feed of carbon to act as the “food” source for the PAOs. The PAOs utilize short chain VFAs, but also are dependent on fermentable COD (fermented COD [VFAs] and fermentable COD are both included in the readily biodegradable COD fraction [rbCOD]). Minimum substrate requirements are published to provide guidelines as to amenability of a given wastewater to EBPR. Table 4 provides a summary of the substrate to TP ratio for the bioreactor influent wastewater.

Table 4. Minimum Substrate Requirement for EBPR

| Substrate | Substrate to TP Ratio | Comments |
|---|---|---|
| cBOD5 | 25:1 | Provides rough, initial estimate |
| COD | 45:1 | More accurate than cBOD5 |
| VFA | 5:1 to 15:1 (4:1 to 5:1 with VFAs fed directly to the anaerobic zone) | More accurate than COD |
| rbCOD | 15:1 | Most accurate, includes fermented (VFA) and fermentable substrate |

Adapted from Jeyanayagam, 2015

The recent sampling campaign from January 2016 provides a measurement of the COD:TP ratio for the bioreactor influent (raw sewage + plant drain loads), averaging 50:1. However, diurnal variations range from 18:1 to 80:1. While the diurnal range is high, the average values indicate that the COD:TP ratio is within the range typically required for EBPR.

The VFA:TP ratios are calculated for the October 2015 and November 2015 sampling campaign. These are presented in Table 5 for each aeration basin in service, the PE VFA:TP ratio and AN 1 VFA:TP ratio are shown.

Table 5. West Boise WWTF – VFA:TP Substrate Ratios (October to November 2015).

| | PE VFA:TP (average) | AN 1 VFA:TP (average) |
|---|---|---|
| AB 1 – October 2015 | 7.2:1 | 5.6:1 |
| AB 1 – November 2015 | 5.5:1 | 3.5:1 |

Table 5. West Boise WWTF – VFA:TP Substrate Ratios (October to November 2015).

| | PE VFA:TP (average) | AN 1 VFA:TP (average) |
|---|---|---|
| AB 2 – October 2015 | 7.1:1 | 5.5:1 |
| AB 2 – November 2015 | 5.5:1 | 3.5:1 |
| AB 6 – October 2015 | 6.7:1 | 5.1:1 |
| AB 6 – November 2015 | 6.3:1 | 4.5:1 |

These data indicate that the average VFA:TP ratio is about what is expected for municipal wastewater without a high industrial component. The October 2015 values, where the PE flow distribution is 10:60:30, compared to the November values (PE distribution of 10:45:45), is slightly higher in AN 1. The diurnal comparison of these ratios, together with the online measured effluent $PO_4$-P values are shown in Figure 27.

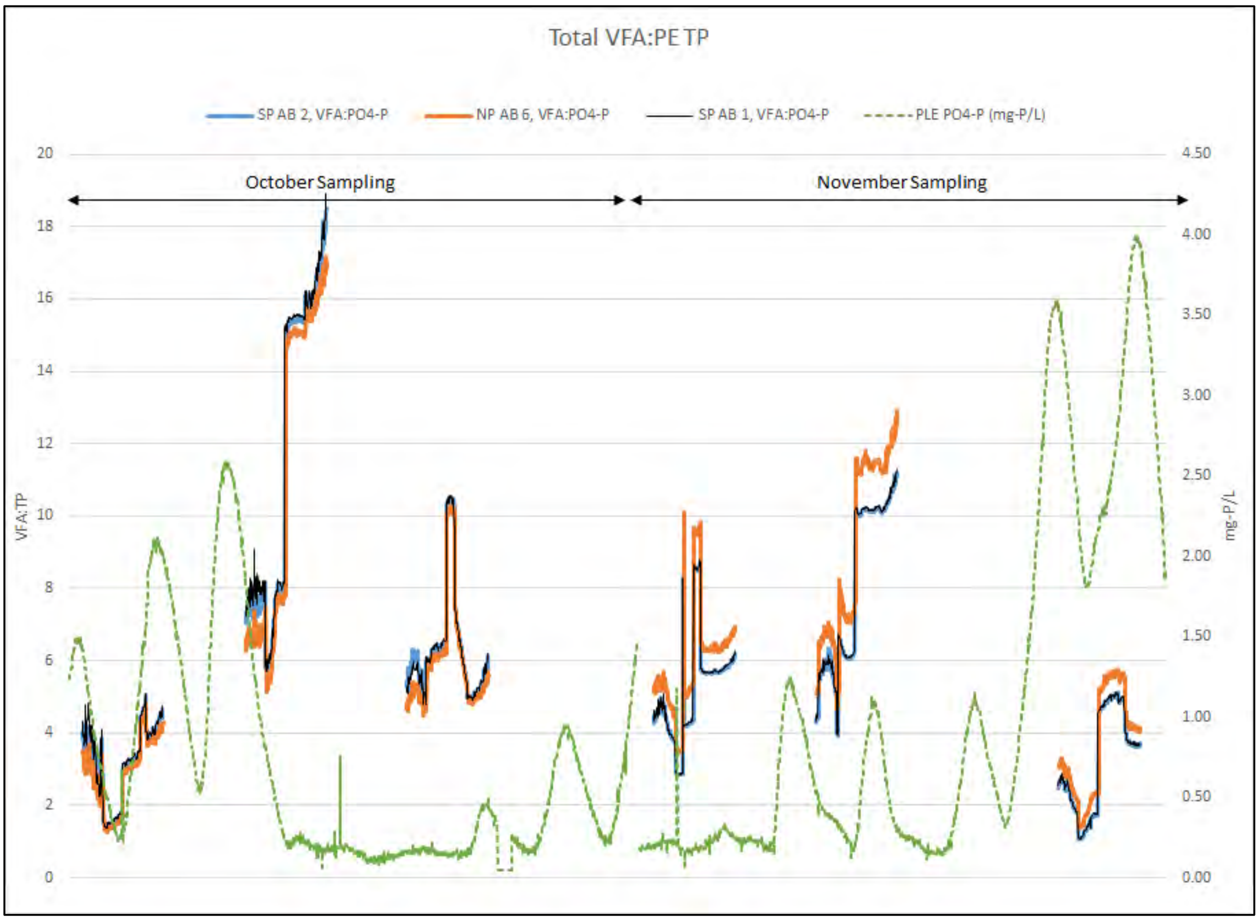



Figure 27. West Boise WWTF – Diurnal Variation of PE VFA:TP Ratio with Effluent $PO_4$-P

The diurnal variations of the VFA:TP ratio are significant, and the highest ratio in October 2015 does appear to contribute to one of the lower effluent $PO_4$-P values at the time. Recent samples from March 2016 indicate that the primary effluent VFA concentration averages 20 mg/L, which is slightly lower than the values presented in Figure 18. The lower primary effluent VFA may be the result of the spring influent flow conditions, which is typically higher given the influent from the increase in Boise River flow. The primary effluent VFA concentrations will continued to be monitored, helping WWTF staff understand when this may be affecting EBPR performance.

The PSD fermentation system has generated an adequate supply of VFAs, as shown in Figures 13 and 19. Figure 13 highlights that during the summer months a higher level of VFAs was being generated. The higher level of VFA generation from the fermentation system is expected given the warmer wastewater temperatures at the time. Figure 13 also highlights how the VFA generation is trending down from an average around 1,600 mg/L in the summer to 1,100 mg/L average in the colder months. While there is a potential to generate more VFAs with a longer SRT in the Fermentation Tank (currently at approximately 4 days), the existing PSD pumping is not sized to turn down to the flow required. These pumps are scheduled for replacement or modification, which may be able to help reduce the associated PSD flow to the fermentation tank (and increasing the SRT). A second fermentation tank is available, but at this time, it is not warranted to bring this tank into service given the ongoing optimization of the facility. When compared to the design loadings anticipated from the PSD Fermentation system, the actual values are lower but still in the range necessary to drive the EBPR process.

An evaluation of the VFA feed system (designated as “VFLT” piping identifier) is ongoing to ensure even distribution of VFAs between the aeration basins. During the November 2015 sampling, a higher percentage of VFA was sent to the North Plant. This imbalance was corrected by manually throttling a valve, but the discrepancy remains a concern, potentially indicating that the distribution system is limiting the amount of VFAs that can be sent from the PSD Fermentation Tank. Another feature in the VFA distribution system is the connection of the VFLT into AB 5 and AB 6 when compared to AB 1 and AB 2. The VFLT is connected directly to the PE piping in AB 5 and AB 6, which may be more efficient than the VFLT connection through the wall into AB 1 and AB 2. An investigation into the optimal location of the VFLT connection is warranted, because there may be a number of approaches to potentially improve this system (e.g., move the VFLT in AB 1 and AB 2 into the PE piping as per AB 5 and AB 6 or move the VFLT closer to the influence of the bioreactor mixer).

The large impact of the PE VFAs on the system is of interest. As shown in Figure 18, there is a large VFA load from the PE, subject to the diurnal variations of the influent. The associated PE flow distribution to the aeration basins may be affected by this variation. Additional investigation is warranted to determine the optimal PE distribution into the bioreactor. The implementation of RAS/mixed liquor (ML) fermentation has been investigated at other facilities operating configurations similar to the Westbank process used at West Boise (Barnard et al., 2010; Cavanaugh et al., 2012; Tremblay et al., 2005). This type of system diverts most (if not all) of the PE past the anaerobic zone to the anoxic environment that follows. The concept is to have the VFA within the PE provide carbon required for the denitrification process. The RAS anoxic environment, followed by the anaerobic environment where the VFAs from the PSD fermentation process are introduced, allow for the required PAO development and associated $PO_4$-P release for EBPR. It may be warranted to move the PE distribution from the current 10:30:60 (AX 1:AN 1:AX 2) closer to this 0:0:100 distribution. It is recommended that the City gradually move to this distribution, potentially starting with a 10:20:70 PE distribution. An important feature with any of these adjustments is the associated RAS rate. The optimal RAS/ML fermentation approach uses a relatively low RAS rate, in the range of 30 percent of the PE. Process simulations using CH2M’s Pro2D2™ indicate that this lower RAS rate provides a benefit in the overall performance of EBPR. The City is currently operating around a 40 percent RAS rate, and it is recommended that this be reduced to the extent possible.

A review of the VFAs available to the PAOs indicates that the current substrate ratio is within the range expected for this type of system. It does not appear that the readily available carbon in the system is the primary factor limiting EBPR performance at the WWTF, but there may be issues during the peak influent loading conditions. Even with the periods of lower VFA:TP ratios, the anaerobic zones in all of the aeration basins consistently see a relatively high release of $PO_4$-P (as shown in Figures 14, 15, and 16). As discussed previously in the TM, the release of $PO_4$-P in the anaerobic zone is a key function of EBPR and it appears that this has been relatively consistent at the WWTF. The release of $PO_4$-P, while actually on the higher side at times when compared to other EBPR facilities, does vary throughout the date. The recent aeration basin nutrient profiles (Figures 22, 23, 24, and 25) do highlight this variation from the lower influent flow and loading periods to the higher influent flow and loading conditions. The ongoing optimization effort will focus on addressing the higher loading periods, seeing if there are options to improve the EBPR performance at these times.

## Protect the Anaerobic Zone

The anaerobic zone must be protected against the detrimental impacts of DO and $NO_3$-N. These constituents adversely affect the EBPR process, because the PAOs will no longer have a selective advantage, as other heterotrophs will propagate and out-compete the PAOs for the readily available carbon (VFAs). Sampling has not detected DO within the anaerobic zones so this issue does not appear prevalent at the WWTF. However, higher $NO_3$-N levels in the RAS flow (and AX 1) have been periodically detected. The higher level of $NO_3$-N entering the anaerobic zone will reduce the overall performance of EBPR at the facility. One of the more beneficial improvements to the EBPR process at West Boise was the operation of the swing zones in an anoxic environment, increasing the size of AX 2. This change helped increase denitrification through the system, reducing the overall $NO_3$-N inventory. As the wastewater cooled (reaching 14 degrees Celsius [°C]), the swing zones had to be returned to an aerobic configuration to sustain nitrification in the colder weather. The operations staff monitored the aeration basin effluent $NH_3$-N concentrations. When a few values approaching 4.0 mg-N/L were recorded during the peak loading conditions, they elected to change the swing zone to be aerobic. The maximum daily limit established in the NPDES permit was never reached, but the staff did not want to risk any nitrification issues. This change to the aerobic swing zone occurred in early January 2016, which can be easily identified in Figures 10 and 11, because this corresponds to the large increase in effluent $PO_4$-P. The $NO_3$-N values within AX 2 during the baseline sampling campaign (see Figures 14, 15, and 16) were very low, with the average values approximately 1.0 mg-N/L. When the swing zone was converted to aerobic operation, this $NO_3$-N value in AX 2 increased to approximately 8.0 mg-N/L. At this same time, the $PO_4$-P concentration within the anaerobic zone dropped to approximately 16.0 mg-P/L. This highlights the importance of optimizing the denitrification process in the system, ensuring that the anaerobic zone is protected against high levels of $NO_3$-N. The recent aeration basin profiling effort has helped confirm the importance on denitrification process, as higher $NO_3$-N concentrations in AX 1 and AX 2 result in reduced EBPR performance.

There was a discussion of increasing the overall aerobic SRT in the system to improve nitrification during the colder conditions, while maintaining the swing zones in the anoxic environment. The North Plant (AB 5 and AB 6) has two secondary clarifiers (SC 5 and SC 6), and the South Plant (AB 1 and AB 2) has four secondary clarifiers (SC 1, SC 2, SC 3, and SC 4). Currently, AB 6 and SC 6 are in service and the mixed-liquor suspended solids (MLSS) within AB 5 had a January 2016 average of 3,200 mg/L. This correlates to a solids loading rate (SLR) of 11 pounds per day per square foot (lbs/day-$ft^2$), which is well below the limiting condition. The South Plant has AB 1 and AB2 in service along with three secondary clarifiers. The January 2016 MLSS concentration in AB 1 and AB 2 averaged 3,700 mg/L, corresponding to a SLR in the secondary clarifiers of 27 lbs/day-$ft^2$. Theoretically, there is additional capacity available in the South Plant clarifiers, but this is closer to the limiting condition (especially if the RAS rate is reduced from the current level). The mixed-liquor is not connected between the two plants, allowing use of the additional clarifier capacity on the North Plant. As a result, the City does not prefer increasing the MLSS and associated SRT to manage the winter nitrification. The option of bringing AB 5 into service during the winter was discussed, as this would allow for an increase in aerobic SRT while still maintaining the swings zone anoxic. At the time, the City prefered managing the swing zone under a periodic anoxic/aerobic operation instead of bringing AB 5 into service.

There is an opportunity to turn off the air in the swing zones periodically during colder conditions, allowing for an anoxic environment at times. The need for the additional aerobic volume is driven by the nitrification required to meet the low effluent $NH_3$-N required at the WWTF during the winter months. It may be possible to still meet this limit by only aerating during the peak ammonia-loading during the day. As shown in Figure 20, the peak $NH_3$-N loading occurs from 12:00 Noon to approximately 8:00 PM. Programming is available to set the swing zone operation on a timed schedule, which could be aligned with this period. On February 4, 2016, the City implemented a periodic anoxic swing zone operation. The aeration system was used from 10:00 AM to 10:00 PM, and then turned off for the remainder of the day. This 12-hour cyclic operation appeared to be provide a benefit at the facility, with an improvement in EBPR noted (see Figures 10 and 11). The system was monitored for potential scum/foaming on the aeration basin, as switching from an anoxic to aerobic environment may promote its formation. An increase in scum/foam formation did not occur during this periodic swing zone operation. The City was able to operate the swing zone anoxic for 24-hours per day on March 4, 2016 (corresponding to an aeration basin temperature of 16.5°C), and the bioreactors have been in this configuration since.

The WWTF staff have also worked to optimize the RAS system to minimize the return of $NO_3$-N to the aeration basins. The South Plant (AB 1 and 2) RAS system was adjusted to provide a low flow base value, which helped the flow distribution in AX 1. As noted earlier, the RAS had been operated at 50 percent of the PE flow during this optimization effort. This value is flow-paced against the PE flow, with a low-value set point in place. It may be warranted to reduce this RAS rate further, and will be a topic of investigation moving forward with the EBPR optimization. The lower RAS flow may lead to other issues at the WWTF, especially in the summer with warmer wastewater. On March 16, 2016, the RAS rate was reduced to 40-percent of the PE flow. EBPR performance has stabilized since this change in RAS rate, but there has not been a significant reduction in effluent TP at this time. The RAS rate is still a key focus at the WWTF, and will be adjusted further as the optimization effort continues.

A number of EBPR facilities have found that a key to phosphorus removal is generally the control of the nitrogen inventory. This appears to be a significant factor at the West Boise WWTF. With an optimized denitrification system, the $NO_3$-N being returned in the RAS is significantly reduced. When the swing zones were operated as anoxic zones, this configuration change did result in improved TP removal performance at the facility. The monitoring of $NO_3$-N is a good operational tool for the WWTF staff. Some initial areas for monitoring would be the RAS, AX 1 and/or AX 2. In general, a $NO_3$-N concentration at the end of AX 2 at about 1.0 mg-N/L is a good target, helping maintain good EBPR performance. It is also recommended that the MLR be evaluated further to determine the optimal setpoint. This has not been a focus of the work to date, but there is a difference between the MLR on the North Plant (200 percent of PE) to South Plant (90 percent of PE). There are limitations on the North Plant MLR system in that this is set at its minimum value. It may be possible to increase the MLR on the South Plant, for a potential improvement in denitrification.

## Maximize P Uptake in the Aerobic Zone

The discussion of the EBPR mechanism cites a healthy uptake of $PO_4$-P in the aerobic environment being crucial for efficient EBPR. It has been shown that once the mixed-liquor enters the aerobic zone, the immediate and rapid uptake of $PO_4$-P is required for optimal EBPR. The bulk-liquid DO in this zone must be greater than 2 mg/L to ensure this occurs. Up to 85 percent of the P-uptake can occur in the first 66 percent of the aeration basin volume, as cited by Jeyanayagam (2015), and shown in Figure 28.

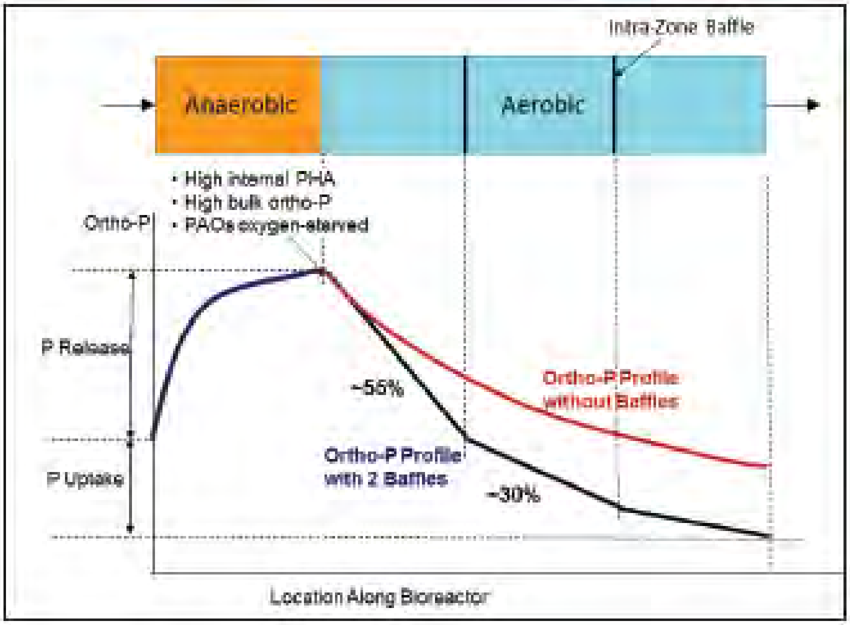



Figure 28. EBPR Mechanics – Impact of Intra-Zone Baffles on Aerobic $PO_4$-P Uptake

The aerobic uptake of $PO_4$-P was also cited as a key factor in the performance of the Durham facility operated by Clean Water Services (Johnson et al., 2006; Narayanan, et al., 2006). It was determined that aerobic $PO_4$-P uptake in the initial aerobic zones was the strongest indicator of the health of an EBPR system. In addition to the DO concentration averaging above 2 mg/L in this initial aerobic zone, this concentration should be relatively consistent and not subject to excessive variations. The DO concentration in the initial aerobic zone (Aerobic Zone 2 [AER 2]) at Aeration Basin 1 and Aeration Basin 6 are evaluated to compare against the baseline sampling campaign. The DO trends for October 23, 2015, November 17, 2015, and December 15, 2015 from 8:00 AM to 4:00 AM (on the following day) are presented in Figures 29, 30, and 31, respectively. The EBPR performance on these days is presented earlier in Figures 14, 15, and 16. The effluent $PO_4$-P concentration in Aeration Basin 1 varies during these three days. However, Aeration Basin 6 effluent $PO_4$-P values stay relatively low during October 23, 2015 and November 17, 2015, but vary throughout the day on December 15, 2015. The DO concentrations shown for Aeration Basin 1 do appear to be consistent, close to the 2.0-mg/L setpoint, for all of the days in questions. For Aeration Basin 6, the DO does hold consistent at 2.0 mg/L for October 23, 2015 and November 17, 2015, but appears to vary significantly on December 15, 2015. While there is not enough detail with this comparison to determine if the DO concentration in the first aerobic zone is limiting the $PO_4$-P uptake in the system, this does seem to warrant additional investigation into aeration system performance at the facility. When EBPR is again in relatively consistent operation at the West Boise WWTF, additional investigation into the aerobic P-uptake potential of the system is recommended. This additional investigation will continue to include profiles of $PO_4$-P throughout the aerobic zones, allowing determination of the associated P-uptake rates.

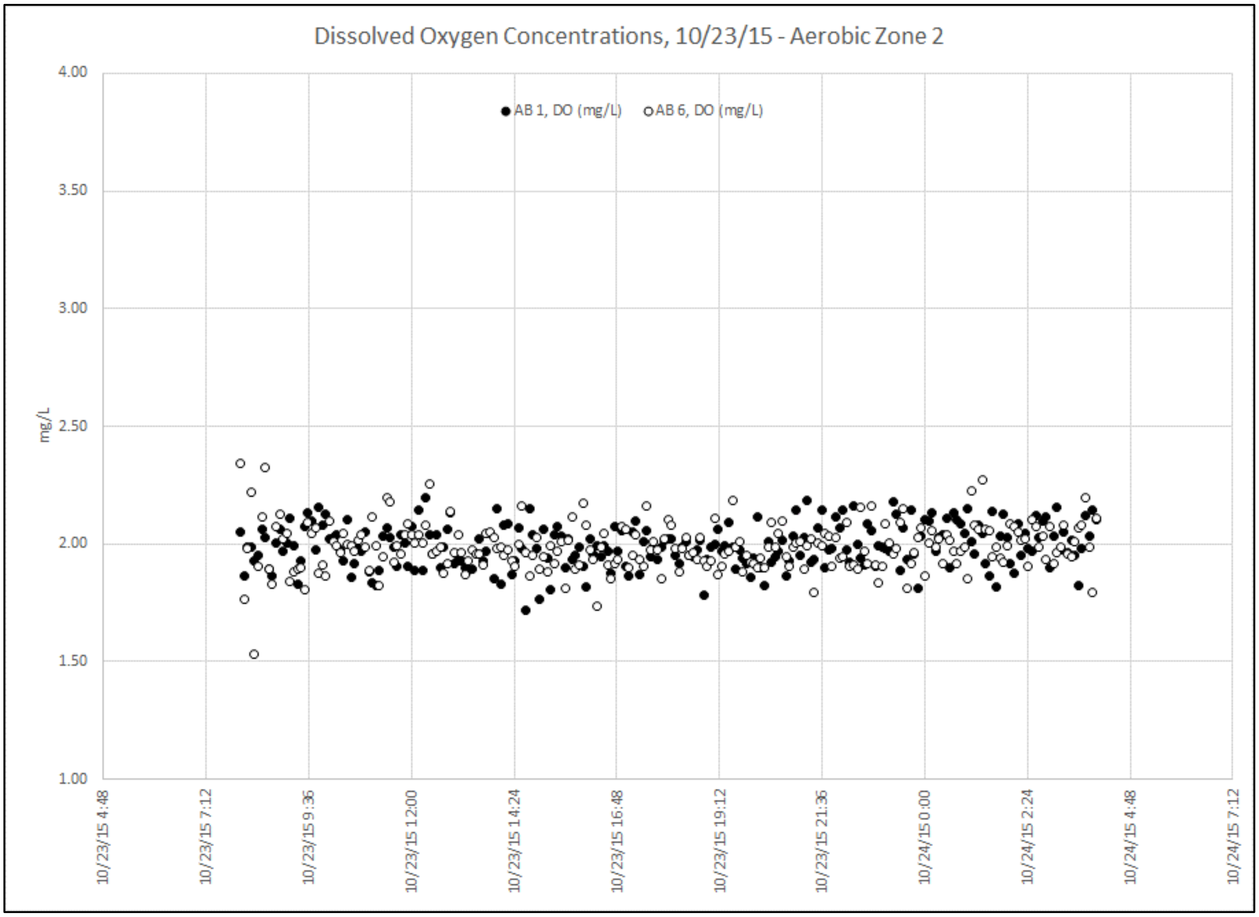



Figure 29. Aeration Basin Dissolved Oxygen Concentration – Aerobic Zone 2, October 23, 2015

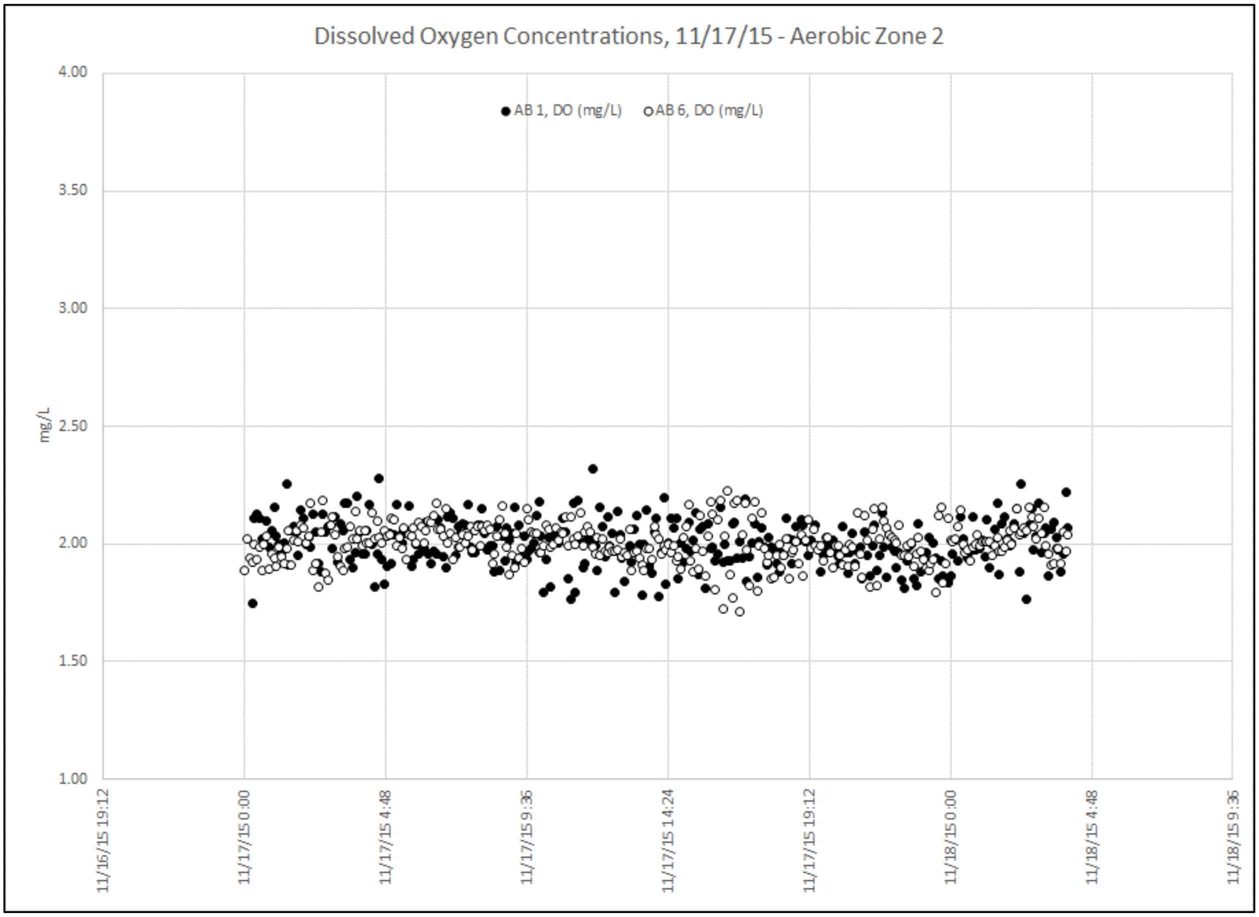



Figure 30. Aeration Basin Dissolved Oxygen Concentration – Aerobic Zone 2, November 17, 2015

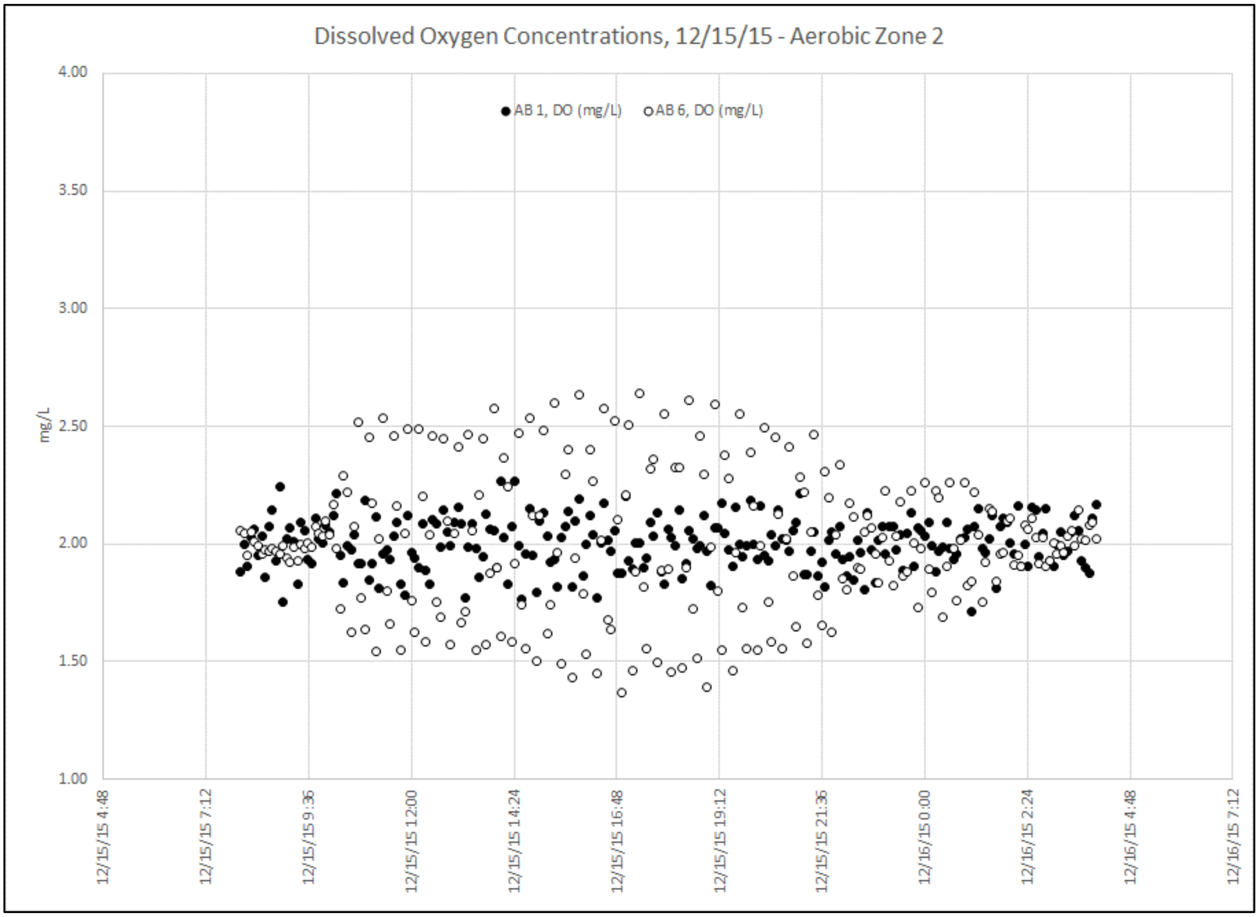



Figure 31. Aeration Basin Dissolved Oxygen Concentration – Aerobic Zone 2, December 15, 2015

## Dissolved Oxygen Control Strategy

The existing control strategy for the DO within the aeration basins includes a methodology common for activated sludge facilities. The aeration basins have designated airflow control valves, airflow meters, and DO monitoring for each aerobic zone. The operators have the ability to establish a setpoint for the DO concentration within each DO zone. As the aerobic $PO_4$-P uptake is investigated, the process control approach for the aeration system will be optimized to maximize EBPR. In the near-term, the DO concentration setpoint in the first aerobic zones may be increased to help with the $PO_4$-P uptake. Another refinement within the aeration system is potentially to reduce the DO setpoint in the last aerobic zone (to approximately 1.25 mg/L). While we have not seen evidence of DO being returned in the MLR system, this would reduce the potential for having DO adversely affect the anoxic environment. This has been successful at other EBPR facilities, reducing the DO in the MLR while also improving the overall energy efficiency in the system.

The bulk-liquid DO concentration was increased in the aeration basins starting in January 2016. The intent was to ensure a residual DO of 2.0 – 3.0 mg/L was held in the initial aerobic zone, maximizing the aerobic uptake of $PO_4$-P. The nutrient profiles through each zone are used in part to determine the aerobic uptake capacity in the system. The data from profiles taken during the low-flow and loading periods (8:00, shown in Figure 22) indicate good aerobic uptake with removals approaching 95% through the first two aerobic zones. The higher flow and loading periods, however, indicate reduced aerobic P-uptake during the initial aerobic zones. As a result, the overall $PO_4$-P removal from the bioreactor during these higher flow and load periods is reduced.

## Maximize Solids Capture

The EBPR process results in high levels of P stored in PAOs as Poly-P granules. The P-content in the WAS is therefore relatively high (6 to 15 percent). Figure 32 shows how the WAS P-Content and associated effluent TSS concentration can affect the resulting effluent particulate fraction of TP. As per the example in the figure, with an effluent TSS concentration of 15 mg/L and a WAS P-Content of 6 percent, the effluent particulate P concentration is 0.9 mg/L. It is important to note that the effluent TSS concentration in an EBPR system has a direct effect on the effluent TP concentration.

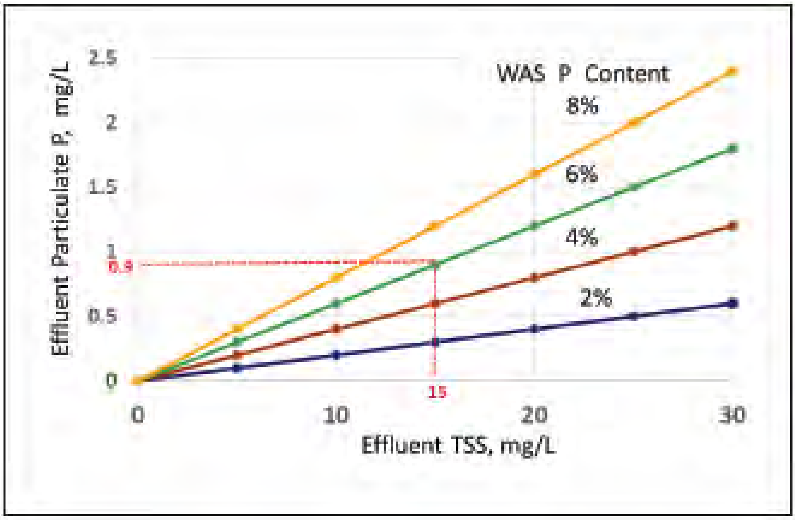



Figure 32. EBPR Mechanics – Correlation between Effluent TSS and Particulate P

The operations and maintenance staff have done an excellent job in managing the secondary clarification process. The performance of the secondary clarifiers is a significant component of a reliable EBPR system. West Boise WWTF had exceptionally low effluent TSS during this EBPR startup and optimization period, with historically low values (averaging < 5 mg/L) in December 2015. Recently, the effluent TSS has increased to 10 – 15 mg/L, which is common for the WWTF during the spring months. The SVI values during this optimization period have averaged approximately 90 mL/g. The MLSS concentration in the bioreactors has steadily increased given the colder weather, with the associated SLR for the clarifiers increasing accordingly. Aeration Basins 1 and 2 are receiving most of the PE, and the resulting SLR on the secondary clarifiers is 27 gallons per day per square foot (gpd/$ft^2$). With only Aeration Basin 6 and one secondary clarifier in service on the North Plant, the SLR is 11 gpd/$ft^2$.

Secondary P-release can occur in secondary clarifiers, causing an adverse impact on the effluent TP concentration. The release of $PO_4$-P occurs within the secondary clarifiers because of the anaerobic conditions that can occur while VFAs are absent. Secondary P-release can result from high sludge blanket depths, where the long SRT in the clarifier can create an anaerobic environment. The blanket depth should be managed accordingly to avoid this issue. The City typically operates with a relatively thin sludge blanket in the secondary clarifiers. The $NO_3$-N concentration within the RAS is a good identifier of the potential for secondary $PO_4$-P release. With a level of $NO_3$-N present in the RAS, there is likely minimal secondary $PO_4$-P release. The West Boise staff have been diligent in monitoring the secondary clarifiers for secondary P-release and monitoring the $NO_3$-N concentration in the RAS stream. Secondary $PO_4$-P release does not appear to be an issue at the facility.

## Minimize Competition

Glycogen accumulating organisms (GAOs) have a metabolism similar to PAOs and can utilize the VFAs in the anaerobic environment. These use glycogen as the energy source (where PAOs use Poly-P, releasing $PO_4$-P into the anaerobic zone). As a result, the GAOs do not exhibit anaerobic P-release and the subsequent P-uptake in the aerobic environment. The GAOs compete directly with the PAOs for VFAs. If GAOs are the dominant organisms in the anaerobic environment, the performance of EBPR is compromised. The factors responsible for the PAO-GAO competition are carbon source composition, temperature, and pH. These parameters are presented schematically in Figure 33, showing the interaction between the PAO and GAOs as temperature, pH and VFA type vary.

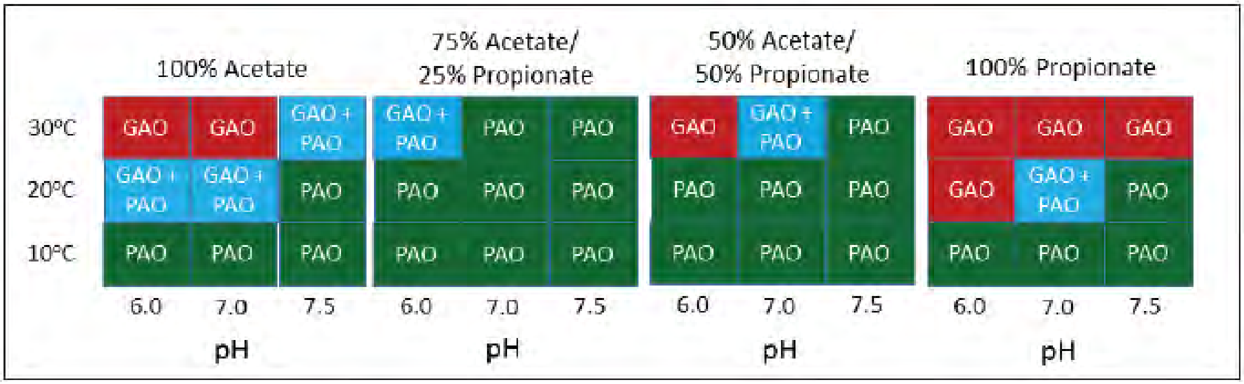



Figure 33. Population Distribution of PAOs and GAOs

Figures 18 and 19 highlight the composition of the VFAs at the West Boise WWTF, from both the PE and PSD Fermentation system. The VFA composition falls into the 75 percent Acetate/25 percent Propionate range, based on the sampling of PE VFA and fermented primary sludge VFA during the October 2015 to December 2015 baseline sampling campaign. The wastewater temperature stays below 30 °C throughout the year at West Boise, with the annual average being below 20 °C. As a result, West Boise WWTF characteristics are favorable for PAO dominance. The competition from GAOs is an unlikely candidate for being an issue at the West Boise WWTF.

## Other Considerations

### Dewatering Filtrate and Struvite Recovery

The influence of dewatering anaerobically digested sludge from West Boise together with anaerobically digested sludge from Lander Street at the West Boise WWTF is a significant component for the optimization of EBPR. The reduction of $PO_4$-P in the dewatering filtrate is key to successful EBPR at the West Boise facility. The result of having a higher $PO_4$-P load in the PE could be presented in the discussion on feeding PAOs, because a higher P load in the filtrate reduces the associated substrate to TP ratio. Early planning for this project indicated that the additional $PO_4$-P load from the Lander Street WWTF would be a significant issue, which led to the installation of the Struvite Production Facility. This facility has the unique capability of being able to remove $PO_4$-P from the wastewater, through the production of a sustainable nutrient recovery byproduct. The Struvite Production Facility has been in operation since 2012, but did not receive the higher $PO_4$-P loads from the dewatering filtrate and WAS $PO_4$-P Release filtrate until this past summer. Optimization of the struvite recovery process has been an ongoing task throughout the EBPR commissioning period. At times, this facility has been bypassed, but it achieves the required reduction of $PO_4$-P in the dewatering filtrate when in operation. Figure 20 provides a graphical example of the performance of the struvite recovery process. During the first part of the sampling period, the Struvite Production Facility was offline, causing high recycle stream $PO_4$-P loads (up to 1,000 lbs-P/day) in the process drain. When the facility was returned to operation and optimized for performance, the resulting $PO_4$-P load in the process drain dropped to 200 lbs-P/day.

The dewatering system at the West Boise WWTF was installed in the late 1990s, and its age has mandated a relatively high, regularly required level of maintenance. The West Boise WWTF staff undertook some work over this optimization period to improve the overall performance of the dewatering system. Early in the commissioning period, disruptions to the dewatering process were identified to have an adverse effect on the EBPR process. Any sludge that had to be bypassed around the dewatering system had to go directly to the process drain, resulting in a higher bioreactor influent TP loading. The dewatering operation has also been a subject of discussion, because this is currently established based on the truck loading and disposal schedule. Work is ongoing to determine the best operational practice for the dewatering system.

### Influent Diurnal Loading

The $PO_4$-P data in Figures 10 and 11 indicate a consistent effluent peak aligning with the higher PE loadings. It appears that the increase in plant influent loadings on weekends, coupled with the increase in process drain loadings, has an adverse effect on EBPR performance. The sampling data indicate that the $PO_4$-P release in the anaerobic zones does stay consistently high, even with these increased PE loadings. As discussed previously January 2016 proved to be the most challenging month with respect to EBPR performance, as the colder temperatures required the swing zone to be operating in an aerobic condition to ensure compliance with the winter $NH_3$-N effluent limits. CH2M's Pro2D2™ dynamic process simulator was calibrated against the January 2016 data. This process simulation had been calibrated and validated against other historical performance data, and updated to reflect the current operating conditions. Figure 34 shows the results of this calibration effort against actual values from January 2016.

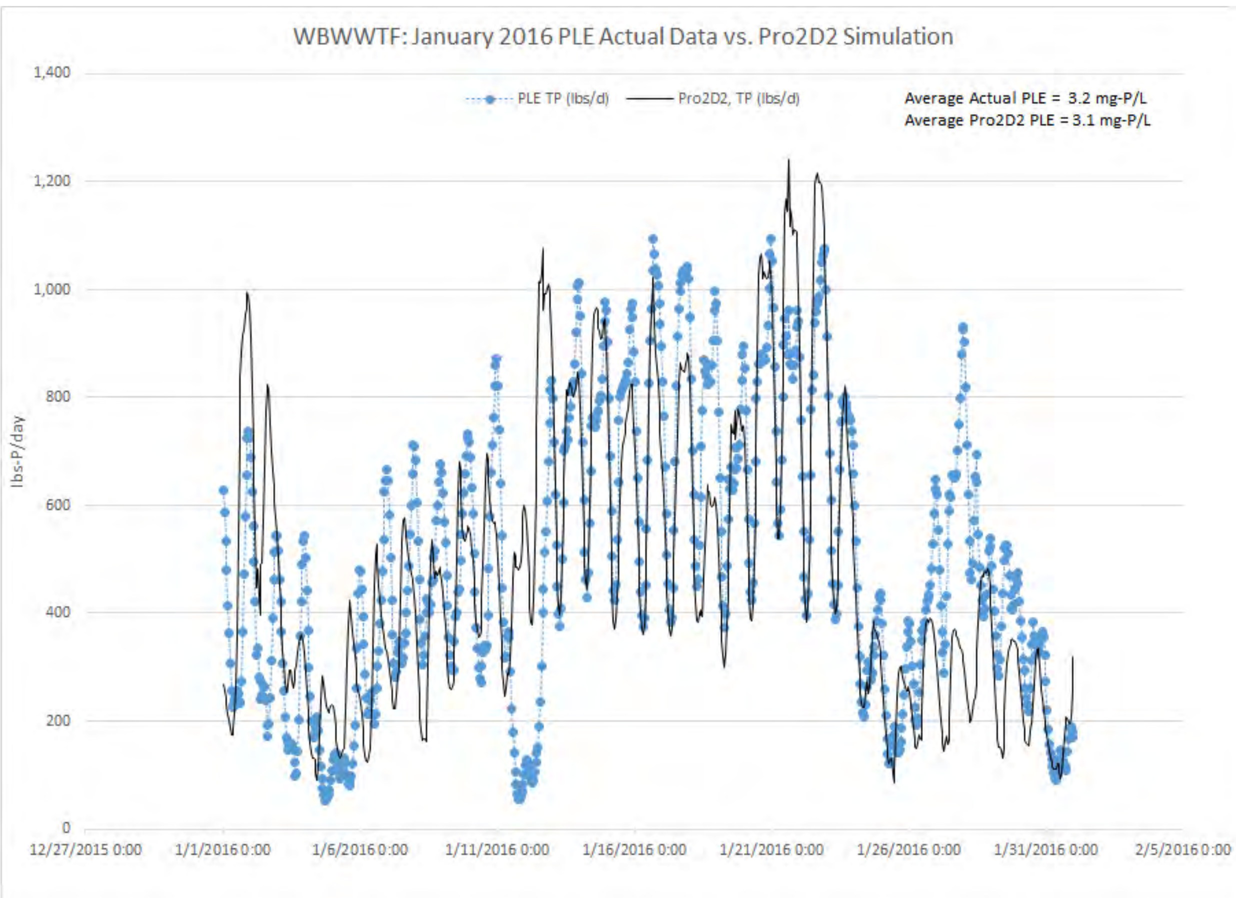



Figure 34. Modeling Calibration – Actual WWTP data compared against Process Simulation data

The dynamic process simulation is being used as a tool to help predict some of the operational adjustments that help improve EBPR performance. A number of parameters are being evaluated with the process simulation, some of which include a look at diverting influent flow and loads during peak conditions, adjustments in VFA quantities between bioreactors, RAS rate adjustments, and modifications to the MLR rates.

Influent was diverted from the West Boise WWTF to the Lander Street for a few weeks at the end of December and into January. This diversion did cause some operational concerns at Lander Street, and the relatively short duration of this experiment did not provide sufficient information to determine if it was beneficial to West Boise. However, a similar concept is being investigated with the Eagle Sewer District (District). The District sends wastewater treated in an aerated lagoon system to the West Boise WWTF, at approximately 1.9 mgd regularly. This flow has the typical nutrient values expected for municipal wastewater, but the COD had been reduced through the lagoon system. It is proposed that the District hold or minimize their wastewater flow for a few hours during the day, reducing the flow to West Boise during the peak loading conditions. The District would then increase the pumping rate to the WWTF during the off-peak hours. An initial evaluation of this strategy does appear to be feasible, and work is ongoing with the District to determine the potential for implementation. Another concept with the District that will be investigated is the complete diversion of flow around their aerated lagoon system, discharging directly to the West Boise WWTF. This would send the COD load together with the nutrient loading to West Boise, potentially providing an improvement to the EBPR system.

### Metal Salt Addition

The use of metal salts to help improve the overall removal of phosphorus has been successfully implemented at other EBPR facilities. This metal salt is incorporated to “trim” the effluent $PO_4$-P periodically. This is typically incorporated directly into the mixed-liquor, prior to secondary clarification, at low chemical dosages. The use of metal salts as a trim to EBPR was investigated during the design phase of the project, and the decision was to defer its implementation until tertiary treatment is required. The use of metal salts is still an option to consider, because this has proved to be a benefit at other EBPR facilities with only secondary treatment.

### Mass Balance

The mass balance for total phosphorus at the Lander Street WWTF and West Boise WWTF are presented in Figures 35 and 36, showing the unique interaction of the two treatment facilities. The total phosphorus values are generally from December 2015, supplemented with some sampling in internal process streams completed in January 2016. Note that some of the values are calculated and not actual samples (indicated by [*]). These mass balance figures highlight the impact the Lander Street WWTF has on the West Boise WWTF by conveying the digested solids over for dewatering. As seen in Figure 35, the Lander Street WWTF has exceptional TP removal, with approximately 480 lbs/day of TP to West Boise. Without solids dewatering at Lander Street, there is no additional TP load affecting the liquids treatment processes. In Figure 36, the West Boise WWTF mass balance shows how the 480 lbs/day of TP from Lander Street is introduced into the facility. Even with the struvite production facility, removing approximately 497 lbs/day of TP, there is still an additional TP load of 401 lbs/day being returned in the process drain. This makes up 31 percent of the TP load being treated by the liquids stream processes at West Boise.

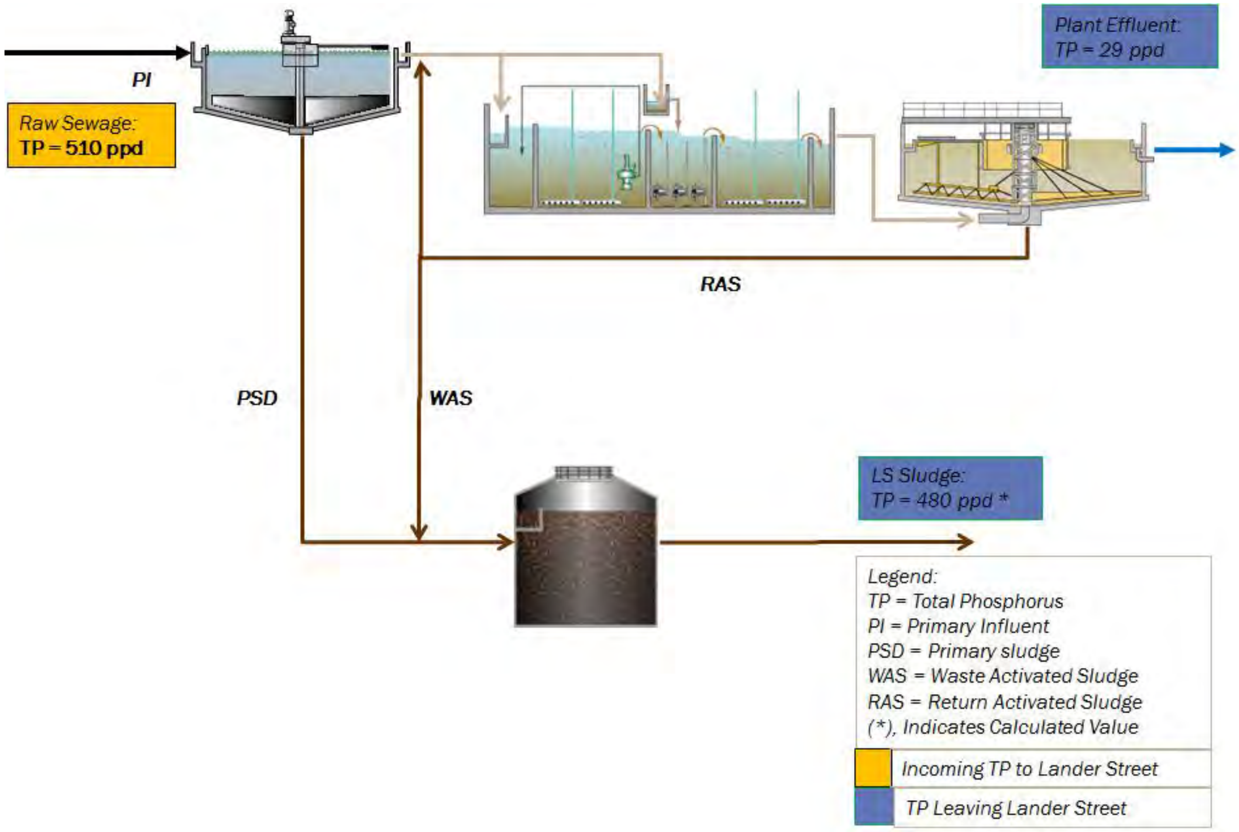



Figure 35. Modeling Calibration – Actual WWTP data compared against Process Simulation data

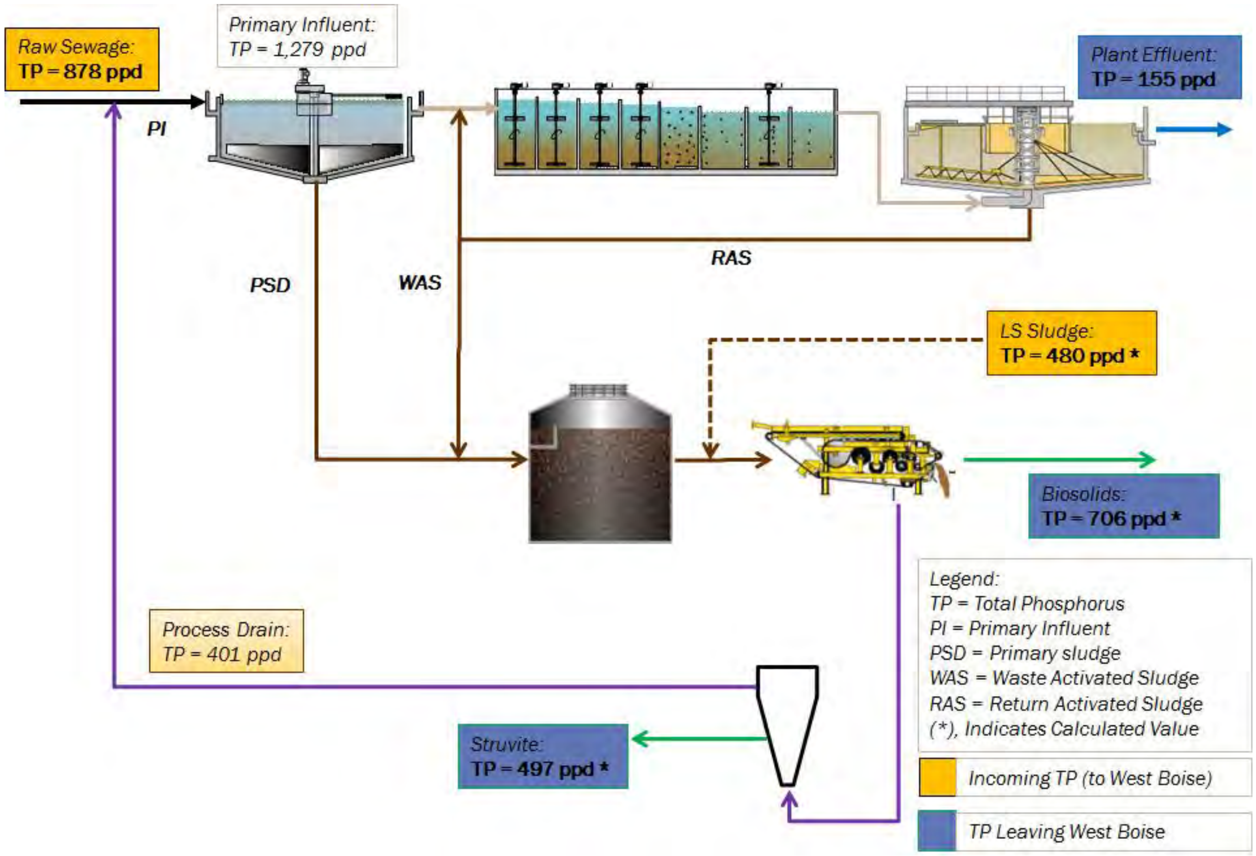



Figure 36. Modeling Calibration – Actual WWTP data compared against Process Simulation data

# Summary

The West Boise WWTF has not been able to achieve the low effluent TP limit (600 µg-P/L) established in the NPDES permit. This is a challenging limit to achieve for the majority of treatment facilities that only have secondary treatment with EBPR, and presents a significant challenge for the West Boise WWTF given its unique interaction with Lander Street. However, the ongoing optimization task is working to address and improve EBPR performance to achieve the lowest level of TP this technology provides. Over the past months, a significant amount of data have been collected, helping identify the various issues adversely affecting the EBPR process. The Discussion section describes the prerequisites for reliable EBPR, and presents some of the potential limitations at the West Boise WWTF:

- **Feed the PAOs.** Adequate carbon appears available, between the PE and PSD Fermented Sludge VFA generation, to drive the EBPR process. The relatively consistent release of $PO_4$-P into the anaerobic environment leads us to conclude that the availability of carbon is not limiting at times and may not be the primary reason for the periodic diurnal increase in effluent $PO_4$-P. However, the substrate to TP ratios are very much a key component to a well-operating EBPR process, so the maintenance of an adequate VFA:TP ratio should remain a focus at the WWTF. The diurnal loading at the facility does appear to adversely impact EBPR performance, and the availability of carbon during these peak conditions is a focus of investigation. There are continuing efforts to improve the performance of the struvite recovery process and dewatering system (lowering the overall TP in the process drain). The fermentation system is providing adequate VFAs, but an opportunity may be available to work on increasing performance within this process (with a longer SRT in the PSD Fermenter during the colder months). In addition, the ongoing optimization of the VFA pumping and conveyance system is key to ensuring the readily available carbon distribution is adequate.
- **Protect the Anaerobic Zone.** The performance of EBPR is adversely impacted by the presence of $NO_3$-N in the anaerobic zone. The increase in effluent $PO_4$-P in January 2016 is primarily because of the reduction of denitrification in the system with the swing zones being operated in an aerobic configuration (as a result of the colder temperatures). The winter season $NH_3$-N limits require a robust, high level of nitrification at all times, so the swing zone will be unavailable for denitrification during cold conditions. When the wastewater temperature increased in March 2016, the swing zone was able to again be operated in an anoxic environment. Recent nutrient profiles across the bioreactors highlight the importance $NO_3$-N concentration in the anoxic environments have on EBPR performance. The reduction of $NO_3$-N is a key factor in protecting the anaerobic zone and ensuring a high level of EBPR performance in the system.
- **Maximize the P-Uptake in the Aerobic Zone.** The uptake of $PO_4$-P in the aerobic environment appears to be an issue is an area of focus moving forward, as the aerobic P-uptake mechanism may be the limiting component that is hindering reliable EBPR. The recent nutrient profiles in the bioreactors indicate that there is a reduction of P-uptake during the peak flow and loading conditions. More investigation into the aerobic $PO_4$-P capacity of the bioreactors is required.
- **Struvite Recovery and Dewatering Performance.** The WWTF staff is making progress in optimizing the process components contributing to the process drain loadings. Recent operation of the Struvite Recovery Facility has provided stable $PO_4$-P removal performance, but this system does require a high level of operator attention. The ongoing work will help to continue making this more reliable.
- **Influent Loading Variability.** The diurnal variations in PE loadings ($PO_4$-P and $NH_3$-N) appear to adversely affect $PO_4$-P removal in the system. The effluent $PO_4$-P levels rise substantially during the high load periods. This type of effluent TP variation is typical of EBPR systems, but the magnitude of the variation at Boise is substantial. Addressing this issue is a focus of the optimization task. Features that can be used to manage this variation are potentially modifying the PE distribution into

bioreactors, together with implementing changes to the RAS system. Generally having a constant RAS rate and constant PE rates, maximizing denitrification in the system, can benefit EBPR.

Following are some of the ongoing optimization tasks moving forward, along with some of the key long-term process monitoring recommendations.

### Priorities for Moving Forward:

1. Winter-time swing zone operation
2. Evaluation of aerobic P-uptake
3. Eagle Sewer District influent flow management
4. Online instrumentation investment ($NO_3$-N, $PO_4$-P, and $NH_3$-N)
5. Ongoing struvite recovery and dewatering optimization
6. VFLT distribution optimization
7. Primary effluent distribution optimization (within the bioreactors), together with RAS and MLR optimization

### Long-term Process Monitoring Summary:

1. **Control of Nitrogen Inventory**. Monitor NOx-N at the end of AX 2 (and AX 1)
2. **Aerobic P-uptake rate**. Monitor $PO_4$-P uptake rate within the first aerobic zone, which has proved to be a good measurement of EBPR health.
3. **VFA uptake**. P-removal or P-release ratio. Monitor the performance of the VFAs introduced into the basin to effluent $PO_4$-P concentration

The challenge with the West Boise WWTF is that it is unique given the interaction with the Lander Street WWTF, and the effluent criteria established are at the limits of technology for EBPR with only secondary treatment. With all of the features optimized there still may be challenges meeting this limit of technology. However, work will continue to ensure that the EBPR system at the West Boise WWTF will be optimized to the extent possible. The WWTF staff have done an admirable job working to address the EBPR limitations. They have spent countless hours on sampling, laboratory testing, operational modifications, and addressing various startup issues. While EBPR performance at the facility has not been as reliable to date, this will improve with the continuing optimization work.

# References

Barnard, J., D. Houweling, H. Analla, and M. Steichen. 2010. "Fermentation of Mixed Liquor for Phosphorus Removal". *Proceedings of the 83rd Annual Water Environment Federation Technical Exhibition and Conference. New Orleans, LA*

Benisch, M., J.B. Neethling, and P. Schauer. 2015. "Impact of EBPR on the Water Distribution in Dewatered Sludge." *Proceedings of the 88th Annual Water Environment Federation Technical Exhibition and Conference. Chicago, IL.*

Bott, C., D. Parker, J.B. Neethling, A. Pramanik, and S. Murthy. 2009. "WEF/WERF Cooperative Study of BNR Plants Approaching the Limit of Technology: II. Statistical Evaluation of Process Reliability" *Conference Proceedings Water Environment Federation 2009 Nutrient Removal Conference.* Washington, D.C.

Bott, C.B. and D.S. Parker. 2011. *Nutrient Management Volume II: Removal Technology Performance & Reliability.* Water Environment Research Foundation/International Water Association. NUTR1R06k.

Cavanaugh, L., K. Carson, C. Lynch, H. Phillips, J. Barnard, and J. McQuarrie. 2012. "A Small Footprint Approach for Enhanced Biological Phosphorus Removal: Results from a 106 mgd Full-scale Demonstration". *Proceedings of the 85th Annual Water Environment Federation Technical Exhibition and Conference. New Orleans, LA.*

Coats, E.R., D.L. Watkins, C.K. Brinkman, and F.J. Loge. 2011a. "Effect of Anaerobic HRT on Biological Phosphorus Removal and the Enrichment of Phosphorus Accumulating Organisms." *Water Environment Research.* **83** (5), 461-469.

Coats, E.R., D.L. Watkins, and D. Kranenburg. 2011b. "A Comparative Environmental Life-Cycle Analysis for Removing Phosphorus from Wastewater: Biological versus Physical/Chemical Processes." *Water Environment Research.* **83** (8), 750-760.

Drury, D., Shepherd, W., and Narayanan, B. 2005. "Phosphorus - How Low Can You Go." *Proceedings of the 78th WEF Conference and Exhibition, Washington, D.C.*

Grady, C.P.L., G.T. Daigger, N.G. Love, and C.D.M Filipe. 2011. *Biological Wastewater Treatment – 3rd Edition.* CRC Press, Taylor & Francis Group. Boca Raton, FL.

Horgan, C.J., E.R. Coats, and F.J. Lodge. 2010. "Assessing the Effects of Solids Residence Time and Volatile Fatty Acid Augmentation on Biological Phosphorus Removal Using Real Wastewater." *Water Environment Research.* **82** (3), 216-226.

Idaho Department of Environmental Quality (IDEQ). 2015. *The Lower Boise River TMDL – 2025 Total Phosphorus Addendum*. August 2015.

Jeyanayagam, S. 2015. "Knowledge-based Practices for Achieving EBPR Reliability." *Buckeye Bulletin.* Ohio Water Environment Association. (88:4). Issue 4 2015.

Jeyanayagam, S. and L. Downing. 2015. "More Efficient Enhanced Biological Phosphorus Removal." *Water Environment and Technology.* **27** (11). November 2015.

Johnson, B.R., Spani, C., Mengelkoch, M., and Baur, R. 2005. "The Reality of Attaining Plant Effluent Phosphorus Limits of Less Than 0.07 Mg P/L." *Proceedings of the 78th WEF Conference and Exhibition, Washington, D.C.*

Johnson, B.R., Baur, R. Narayanan, B., and Mengelkoch, M. 2006. "High-level Biological Phosphorus Removal Failure and Recovery" *Proceedings of the 79th WEF Conference and Exhibition, Dallas, TX.*

Khunjar, W., M. Strahota, P. Pitt, and W.J. Geller. 2015. *Evaluating the Impacts of Cold and Wet Weather Events on Biological Nutrient Removal in Water Resource Recovery Facilities.* Water Environment Research Foundation/International Water Association. NUTR1R06s.

Narayanan, B., Johnson, B.R., Baur, R., and Mengelkoch, M. 2006. "Critical Role of Aerobic Uptake in Biological Phosphorus Removal." *Proceedings of the 79th WEF Conference and Exhibition, Dallas, TX.*

Neethling, J.B., B. Bakke, M. Benisch, A. Gu, H. Stephens, H.D. Stensel, and R. Moore. 2015. *Factors Influencing the Reliability of Enhanced Biological Phosphorus Removal.* Water Environment Research Foundation/International Water Association. 01-CTS-3.

Parker, D., C. Bott, J.B. Neethling, A. Pramanik, and S. Murthy. 2009. "WEF/WERF Cooperative Study of BNR Plants Approaching the Limit of Technology: I. What Can We Learn About the Technologies?" *Conference Proceedings Water Environment Federation 2009 Nutrient Removal Conference.* Washington, D.C.

Shimp, G., J.L. Barnard, and C.B. Bott. 2013. "Seeking to Understand and Address the Impacts of Biological Phosphorus Removal on Biosoilds Dewatering." *Proceedings of the 86th Annual Water Environment Federation Technical Exhibition and Conference. Chicago, IL.*

Tremblay, S., H. Hilger, J. Barnard, C. deBarbadillo, and P. Goins. 2005. "Phosphorus Accumulating Organisms Utilization of Volatile Fatty Acids Produced by Fermentation of Anaerobic Mixed Liquor". *Proceedings of the 78th WEF Conference and Exhibition, Washington, D.C.*

Water Environment Federation (WEF). 2010. *Nutrient Removal – WEF Manual of Practice No. 34.* Alexandria, VA.