RFP No. BES103

PROFESSIONAL, TECHNICAL AND EXPERT SERVICES

City of Portland, Oregon
February 17, 2010

REQUEST FOR PROPOSALS

for

Engineering Services for Columbia Boulevard Wastewater Treatment Plant Secondary Process Improvements, Project #E08909

PROPOSALS DUE: **March 18, 2010, by 4:00 p.m.**

Envelope(s) shall be sealed and marked with RFP # and Project Title.

Submit one (1) original and seven (7) complete copies of the Proposal to:

Vu Han
City of Portland
Bureau of Environmental Services
Columbia Boulevard Wastewater Treatment Plant
5001 N Columbia Blvd.
Portland, OR 97203

Refer questions to:
Vu Han
Phone: (503) 823-2635
Fax: (503) 823-2478
Email: vuh@bes.ci.portland.or.us

A PRE-SUBMITTAL MEETING has been scheduled on February 24, 2010, at 1:30 pm, at the Columbia Blvd Wastewater Treatment Plant, 5001 N Columbia Blvd, Portland OR 97203, in the Mt. Hood Conference Room.

GENERAL INSTRUCTIONS AND CONDITIONS

DIVERSITY IN EMPLOYMENT AND CONTRACTING REQUIREMENTS – The City of Portland seeks to extend contracting opportunities to Minority Business Enterprises, Women Business Enterprises and Emerging Small Businesses (M/W/ESBs) in order to promote their economic growth and to provide additional competition for City contracts. Therefore, the City has established an overall 20% utilization goal in awarding PTE contracts to ESBs. No goal is set for the use of M/WBE firms, but the City is committed to ensuring that such firms receive opportunities and equal consideration to be awarded City PTE contracts.

ENVIRONMENTALLY PREFERABLE PROCUREMENT – In accordance with the City's Sustainable City Principles and the City's Sustainable Procurement Policy, the City of Portland values the use of products and services that minimize the negative human health and environmental impacts of City operations. Therefore, proposers are encouraged to incorporate environmentally preferable products or services into their responses wherever possible. "Environmentally preferable" means products or services that have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose. This comparison may consider raw materials acquisition, production, manufacturing, packaging, distribution, reuse, operation, maintenance, or disposal of the product or service. To view the above City policies go to www.portlandonline.com and navigate to "Charter, Code & Policies Documents".

INVESTIGATION – The proposer shall make all investigations necessary to inform it regarding the service(s) to be performed under this request for proposal.

SPECIAL CONDITIONS – Where special conditions are written in the Request for Proposal, these special conditions shall take precedence over any conditions listed under the Professional, Technical and Expert Service "General Instructions and Conditions".

CLARIFICATION OF REQUEST FOR PROPOSAL – Proposers who request a clarification of the RFP requirements must submit questions in writing to the person(s) shown in the REFER QUESTIONS TO section on the cover of this RFP, or present them verbally at a scheduled pre-submittal conference, if one has been scheduled. The City must receive written questions no later than the date stated herein. The City will issue a response in the form of an addendum to the RFP if a substantive clarification is in order.

Oral instructions or information concerning the Request for Proposal given out by Bureau or Office managers, employees or agents to prospective proposers shall not bind the City.

ADDENDUM – Any change to this RFP shall be made by written addendum issued no later than 72 hours prior to the proposal due date. The City is not responsible for any explanation, clarification or approval made or given in any manner except by addendum.

COST OF PROPOSAL – This Request for Proposal does not commit the City to pay any costs incurred by any proposer in the submission of a proposal or in making necessary studies or designs for the preparation thereof, or for procuring or contracting for the services to be furnished under the Request for Proposal.

CANCELLATION – The City reserves the right to modify, revise or cancel this RFP. Receipt and evaluation of proposals or the completion of interviews do not obligate the City to award a contract.

LATE PROPOSALS – Proposals received after the scheduled closing time for filing will be returned to the proposer unopened.

REJECTION OF PROPOSALS – The City reserves the right to reject any or all responses to the Request for Proposal if found in the City's best interest to do so. In the City's discretion, litigation between the City and a proposer shall be cause for proposal rejection, regardless of when that litigation comes to the City's attention and regardless how the consultant's proposal may have been scored. Proposals may also be rejected if they use subcontractors or subconsultants who are involved in litigation with the City. Proposers concerned about possible rejection on this basis should contact the City before submission of a proposal for a preliminary determination of whether its proposal will be rejected.

CITY OF PORTLAND BUSINESS LICENSE – Successful consultant shall obtain a current City of Portland Business License prior to initiation of contract and commencement of the work.

WORKERS' COMPENSATION INSURANCE – the successful consultant shall be covered by Workers' Compensation Insurance or shall provide evidence that State law does not require such coverage.

CERTIFICATION AS AN EEO AFFIRMATIVE ACTION EMPLOYER – Proposers must be certified as Equal Employment Opportunity Affirmative Action Employers as prescribed by Chapter 3.100 of the Code of the City of Portland. The required documentation must be filed with Procurement Services, City of Portland, prior to contract execution.

EQUAL BENEFITS PROGRAM – Proposers must provide benefits to their employees with domestic partners equivalent to those provided to employees with spouses as prescribed by Chapter 3.100 of the Code of the City of Portland. The required documentation must be filed with Procurement Services, City of Portland, prior to contract execution.

CONFLICT OF INTEREST – A proposer filing a proposal thereby certifies that no officer, agent or employee of the City who has a pecuniary interest in this Request for Proposal has participated in the contract negotiations on the part of the City, that the proposal is made in good faith without fraud, collusion or connection of any kind with any other proposer of the same call for proposals, and that the proposer is competing solely in its own behalf without connection with or obligation to, any undisclosed person or firm.

CONFIDENTIALITY – All information submitted by proposers shall be public record and subject to disclosure pursuant to the Oregon Public Records Act (ORS 192.410 et seq.), except such portions of the proposals for which proposer requests exception from disclosure consistent with Oregon Law. Any portion of a proposal that the proposer claims constitutes a "trade secret" or is "confidential" must meet the requirements of ORS 192.501, ORS 192.502 and/or ORS 646.461 et seq. If the entire proposal is marked as constituting a "trade secret" or being "confidential," at the City's sole discretion, such a proposal may be rejected as non-responsive.

If a request to inspect the proposal is made, the City will notify the proposer of the request. If the City refuses to release the records, the proposer agrees to provide information sufficient to sustain its position to the District Attorney of Multnomah County, who currently considers such appeals. If the District Attorney orders that the records be disclosed, the City will notify the proposer in order for the proposer to take all appropriate legal action. The proposer further agrees to hold harmless, defend and indemnify the City for all costs, expenses and attorney fees that may be imposed on the City as a result of appealing any decision regarding the proposer's records.

The Purchasing Agent has the authority to waive minor irregularities and discrepancies that will not affect the competitiveness or fairness of the solicitation and selection process.

These Professional, Technical and Expert Services Request for Proposal "General Terms and Conditions" are not to be construed as exclusive remedies or as a limitation upon rights or remedies that may be or may become available under ORS Chapter 279.

PART I CONTRACT REQUIREMENTS

SECTION A GENERAL INFORMATION

1. INTRODUCTION

The Bureau of Environmental Services (BES) serves the Portland community by protecting public health, water quality and the environment. The Columbia Boulevard Wastewater Treatment Plant (CBWTP), where treatment of wastewater generated from dry weather and wet weather conditions occurs, are essential in allowing the Bureau to accomplish its mission.

2. BACKGROUND

During the 2008 CBWTP Facilities Plan Update work, the consultant, Brown and Caldwell, identified the Secondary Process Improvements Project as a project that would improve performance of the existing secondary treatment system, potentially delay costly construction of new secondary clarifiers, including related infrastructure to expand across North Portland Road, and allow the treatment plant to continue to meet the requirements of the existing NPDES (National Pollutant Discharge Elimination System) permit.

The objective of the project is to reduce the solids loading rate to the secondary clarifiers and reduce the SVI (sludge volume index) to allow flow through the secondary process to be maximized. Therefore, one of the project goals is to produce mixed liquor with improved settling properties.

Historically, SVI values at CBWTP have been high, which have restricted settling in the secondary clarifiers. In the recent past, mixed liquor SVI at CBWTP have exceeded 300 mL/g for months at a time, averaged over 400 for some months, and have even reached values in the 500's. The average SVI value for 2007 was 297 and the 90^{th} percentile SVI value was 428. These high SVI values are indicative of poorly settling secondary solids due to poor biological selector performance and inadequate secondary process controls. The high SVI values limit the flows that can pass through secondary treatment without violating effluent suspended solids limits. Therefore, treatment process is sensitive to flow fluctuations, including those from peak wet weather related flows. To prevent high effluent TSS (total suspended solids) in the secondary effluent, peak flows are diverted to the wet weather treatment facility, which provides primary treatment and disinfection prior to discharge.

In 2009, a full-scale pilot work to demonstrate process effectiveness of selector performance enhancements was completed. Final report of the full-scale pilot work, titled "Selector Enhancement Pilot Report" (by Brown and Caldwell), dated Oct 27, 2009, was incorporated in the CBWTP Facilities Plan Update. A copy of the Selector Enhancement Pilot Report is attached with this RFP as Exhibit D.

The pilot work report provided a number of recommendations, which serve as the basis for the scope of work for this project. However, the recommendation for additional aeration diffusers, which are being installed by the plant personnel, and the recommendation for additional selector zone baffle walls, which will be installed in the summer 2010 and by others, will not be part of the scope of work for this project.

In addition to improving the secondary process control to improve SVI, step feed mode of operation is needed to reduce solids loading to the secondary clarifiers. The existing piping network in the secondary process does allow the operation of step-feed mode. However, this mode has not been operated previously due to other deficiencies and limitations.

3. SCOPE OF WORK

The City of Portland, Bureau of Environmental Services is seeking proposals from individuals, firms, teams or consultants, hereafter called "Proposer(s)," with demonstrated experience in designing wastewater treatment plant related processes and facilities.

This project will produce the design for the construction of facilities that will improve the settling properties of the mixed liquor and reduce solids loading to the secondary clarifiers at the CBWTP. The facilities to be designed will focus on improving the performance of the secondary treatment process to consistently achieve SVI level of 200 mL/g or less, for design flowrate of 100 mgd (million gallons per day).

The scope of work for this Secondary Process Improvements project includes the following:

A. Secondary Process Control Improvements
   1. Mixing facilities for the existing primary effluent/RAS (return activated sludge) channel.
   2. Addition of DO (dissolved oxygen) analyzers in the aeration zones of the aeration basins, including replacement of the existing out-of-date DO analyzers to be consistent with new analyzers.
   3. Automation of the existing diffuser air distribution system, including air flow metering and evaluation of the system for optimized process control and energy usage.
   4. Addition of ORP (oxidation-reduction potential) instruments in the anoxic zones of the aeration basins.
   5. Evaluation and addition of on-line COD (chemical oxygen demand) analyzers for secondary influent and effluent.
   6. Solids concentration metering and automation of WAS (waste activated sludge).
   7. Solids concentration metering and flow metering for RAS to the primary effluent channel.
   8. Solids concentration metering for RAS to the aeration basins.
   9. Solids concentration metering for MLSS (mixed liquor suspended solids)

B. Step Feed Operation
   1. Automation of the existing aeration basin influent gates.
   2. Automation of the existing step feed gates.
   3. Evaluation of the existing RAS system.
   4. Evaluation and recommendations for step-feed operating mode.
   5. Evaluation and modifications of aeration basin inlets, outlets, or secondary clarifier inlets as required for process improvements.

C. Computer Modeling
   1. CFD (computational fluid dynamics) modeling of the existing secondary clarifiers and provide recommendations to optimize performance.
   2. Secondary treatment process modeling using BioWin simulation and provide recommendations for optimized process operations.

D. System Integration and Other Support Services
   1. Tie-ins and integration with existing facilities/systems – structural, mechanical, electrical, instrumentation and controls.
   2. Evaluation of options, optimization, and integration of communication and control systems; options to include fieldbus technologies.
   3. Development of process control narratives to be incorporated with the overall system.
   4. Value engineering at 30% design.
   5. Preparation of construction plans and specifications.
   6. Development and preparation of construction estimates and schedules.
   7. Assistance during bidding period.
   8. Assistance with building permit and DEQ permit for construction.
   9. Support services during construction, testing and start up.
   10. Assistance with development of process O&M manual.
   11. Assistance with process control training.

4. PROJECT FUNDING

The anticipated cost for the services described herein is approximately $2 million. The Proposer's proposal shall include the Proposer's true estimated cost to perform the work irrespective of the City's budgeted funds for this work.

5. TIMELINE FOR SELECTION

The following dates are proposed as a timeline for this project:

Pre-submittal conference	February 24, 2010
Written proposals due at 4 p.m.	March 18, 2010
Selection committee recommendation	April 7, 2010
Contract negotiation with successful Proposer	April 26, 2010
Notice to proceed – work begins	July 19, 2010

The City reserves the right to make adjustments to the above noted schedule as necessary.

SECTION B WORK REQUIREMENTS

1. TECHNICAL OR REQUIRED SERVICES

The Consultant will provide the design and construction services outlined below, and comply with applicable BES standards, i.e. BES Control Systems Standards, BES front-end specifications, and CAD Standards.

1. Preliminary Design Services
    - Compile project specific data
    - Establish design criteria
    - Establish design standards
    - Evaluate step feed alternatives
    - Evaluate process control aeration requirements
    - Perform CFD modeling of the existing secondary clarifiers that incorporates flow velocities and solids settling characteristics
    - Perform BioWin modeling for the secondary treatment process
    - Confirm process improvements and modifications
    - Evaluate issues associated with long delivery equipment items and make preliminary recommendations on equipment and construction packaging, if any
    - Evaluate capacity and availability of required support systems utilities, and process interconnections.
    - Prepare and submit P&IDs and 30% design drawings
    - Prepare and submit Equipment List
    - Evaluate options for communication and control system integration
    - Budget project cost estimate and schedule
    - Conduct 30% design review meeting
    - Prepare predesign report
    - Organize and facilitate Value Engineering analysis commensurate with the final scope of the project
2. Final Design Services
    a. 60% Design
    - Provide process control strategies
    - Finalize P&IDs
    - Prepare loop narratives
    - Provide typical loop documents
    - Prepare 60% design drawings and technical specifications
    - Make final recommendations on equipment and construction packaging
    - Conduct 60% design review meeting

b. 90% Design
   - Finalize loop narratives
   - Finalize loop documents
   - Prepare 90% design drawings and technical specifications
   - Conduct 90% design review meeting

c. Final Design
   - Prepare and submit final contract documents (electronic and print ready copy format)
   - Submit final design report
   - Submit final engineer's cost estimate and construction schedule
   - Submit structural calculations and geotechnical data for building permit application

3. Bid Phase Services
   - Assist with preparing addenda
   - Assist with answering questions from contractors
   - Attend prebid conference
   - Assist with answering questions, or responding to review checksheets from Bureau of Development Services (for building permit), and DEQ, if required

4. Services During Construction
   - Provide design support services, such as submittal reviews, clarifications for RFIs, assistance as needed with design clarifications and change orders, as requested meeting attendance, and periodic site visits and inspections (BES may elect to use construction management software ConstructWare for this project)
   - Provide CAD services for drawing revisions
   - Provide assistance for BES I&C team on application software development
   - Perform final field inspection and prepare final report for building permit
   - Assist with start up and testing
   - Assist with preparation of process O&M manual and process training

2. WORK PERFORMED BY THE CITY

Bureau staff shall make available sufficient hours of staff personnel to meet with the Consultant and provide such information as required. BES has assigned a project manager who will oversee the work and provide support as needed. The Bureau has drafted a project management plan which includes the following objectives for the project:

- ➢ Manage the project decision making by consensus, as much as practicable within the accelerated design schedule.
- ➢ Manage overall project budget and schedule to ensure timely project completion within allocated budget.
- ➢ Design facilities that will meet the projected system demands and that will meet the regulatory requirements.
- ➢ Design cost-effective facilities.
- ➢ Design "good neighbor" facilities by prioritizing odor, noise, and visual mitigation.
- ➢ Plan for effective operation and maintenance, including safety and risk minimization for operation and maintenance staff, best utilization of staff resources, and optimum automation.
- ➢ Design for process reliability and flexibility, for energy efficiency and optimization of plant energy resources, and for conservation of other resources, including maximizing recycling and reuse where practical.
- ➢ Plan for minimum disruption to existing facilities, activities, and development.
- ➢ Ensure input and review by CBWTP operations and maintenance staff.
- ➢ Provide opportunities for the participation of M/W/ESB firms.

Other specific services provided by the City include:

- Survey (by Portland Bureau of Transportation)
- Application software development (i.e. PLC and iFIX programming)
- Preparation of process O&M manual
- Reproduction of bid documents

Bureau staff will provide the Consultant with access to, or copies of, the following documents:

- Columbia Boulevard Wastewater Treatment Plant Facilities Plan Update (2009), Brown and Caldwell
- Secondary System Capacity Report (2009), Brown and Caldwell
- Secondary Treatment Facilities Improvements (1992), CH2M HILL/BCC
- As-built drawings and site plan information as needed
- Plant data
- BES CAD Standards
- BES Wastewater Group Control System Standards
- COP BES Div 0 and 1 (front-end) specifications

3. DELIVERABLES AND SCHEDULE

Deliverables shall be considered those tangible resulting work products that are to be delivered to the City such as reports, draft documents, data, interim findings, drawings, schematics, training, meeting presentations, final drawings and reports. The Consultant is encouraged to provide any deliverables in accordance with the City's Sustainable Paper Use Policy. The policy can be viewed at: http://www.portlandonline.com/omf/index.cfm?c=37732 .

Deliverables for this project shall include: technical memoranda, cost estimates, schedules, predesign report, value engineering final report, final design report, construction plans and specifications (and files), structural calculations for building permit (if any), process and loop narratives (and files), and BioWin modeling files.

Submit a Monthly Subconsultant Payment and Utilization Report by the 15th of each month (reference Part II, Section C.5 of the RFP).

All deliverables and resulting work products from this contract are the property of the City of Portland.

Major milestones for this project include:

July 2010	Notice to Proceed with Design
June 2011	Bid Documents Ready
March 2013	Upgraded Secondary System in Operation

4. PLACE OF PERFORMANCE

Contract performance will take place primarily at the Consultant's facility. On occasion and as appropriate, work will be performed at City facilities, a third-party location or any combination thereof.

5. PERIOD OF PERFORMANCE

The City anticipates having the Consultant begin work in July of 2010, with submittal of final design deliverables to the City occurring no later than June 2011. An accelerated design schedule will be beneficial to the City. It is expected that all contract services will be completed by mid 2013.

6. PUBLIC SAFETY

Public safety may require limiting access to public work sites, public facilities, and public offices, sometimes without advance notice. The Proposer shall anticipate delays in such places and include the cost of delay in the proposed cost. The Consultant's employees and agents shall carry sufficient identification to show by whom they are employed and display it upon request to security personnel. City project managers have discretion to require the Consultant's employees and agents to be escorted to and from any public office, facility or work site if national or local security appears to require it.

7. INSURANCE

The Consultant shall agree to maintain continuous, uninterrupted coverage of all insurance as required by the City. There shall be no cancellation, material change, reduction of limits or intent not to renew the insurance coverage(s) without a 30-day written notice, or ten (10) days written notice for non-payment from the Consultant or its insurer(s) to the City.

Workers' Compensation Insurance in compliance with ORS 656.017, which requires subject employers to provide Oregon workers' compensation coverage for all their subject workers (firms with one or more employees, unless exempt under ORS 656.027).

General Liability Insurance with a combined single limit of not less than $1,000,000 per occurrence for Bodily Injury and Property Damage. It shall include contractual liability coverage for the indemnity provided under this contract, and shall provide that the City of Portland, and its agents, officers, and employees are Additional Insureds but only with respect to the Consultant's services to be provided under this Contract.

Automobile Liability Insurance with a combined single limit of not less than $1,000,000 per occurrence for Bodily Injury and Property Damage, including coverage for owned, hired, or non-owned vehicles, as applicable.

Professional Liability Insurance with a combined single limit of not less than $1,000,000 per claim, incident, or occurrence. This is to cover damages caused by negligent acts, errors or omissions related to the professional services to be provided under this contract. If insurance coverage is provided on a "claims made" basis, the Consultant shall acquire a "tail" coverage or continue the same coverage for three years after completion of the contract, provided coverage is available and economically feasible. If such coverage is not available or economically feasible, Consultant shall notify City immediately.

Certificates of Insurance: As evidence of the insurance coverages, the successful Proposer shall furnish acceptable insurance certificates to the City at the time signed contracts are returned to the City. The certificate will specify all of the parties who are Additional Insureds and will include the 30-day cancellation clause and 10-day non-payment clause as identified above. Insuring companies or entities are subject to City acceptance. If requested, complete policy copies shall be provided to the City. The Consultant shall be financially responsible for all pertinent deductibles, self-insured retentions, and/or self-insurance.

SECTION C ATTACHMENTS

1. INDEX

Exhibit A	First Tier Subconsultant Disclosure Form (submit with proposal)
Exhibit B	Site plan
Exhibit C	Piping and process diagrams. As mentioned in *Part I.A.3*, the existing piping network does allow for step-feed operating mode. However, due to other deficiencies and limitations, the plant has not operated in step-feed mode.
Exhibit D	Selector Enhancement Pilot Report (2009), Brown and Caldwell

2. SAMPLE CONTRACT

The Professional, Technical and Expert Services Contract is the City's standard contract and will be used as a result of this selection process. A sample contract can be viewed at: http://www.portlandonline.com/shared/cfm/image.cfm?id=27067 .

3. PROJECT DATA

The following information is available upon request by contacting Vu Han at vuh@bes.ci.portland.or.us or 503-823-2635:

- CBWTP Facilities Plan Update (2009), Brown and Caldwell
- CBWTP Secondary System Capacity Report (2009), Brown and Caldwell
- CBWTP Secondary Treatment Facilities Report (1992), CH2M HILL/BCC
- As-builts
- Plant data

PART II PROPOSAL PREPARATION AND SUBMITTAL

SECTION A PRE-SUBMITTAL MEETING/CLARIFICATION

1. PRE-SUBMITTAL MEETING

There is a pre-submittal meeting and site visit scheduled for this project on **February 24, 2010, at 1:30 pm**, at the Columbia Boulevard Wastewater Treatment Plant, 5001 N. Columbia Boulevard, Portland, Oregon 97203, in the Mt. Hood Conference Room.

This is a **non-mandatory** meeting; therefore, proposal submission is not contingent upon attendance at the meeting.

2. RFP CLARIFICATION

Questions and requests for clarification regarding this Request for Proposal must be directed in writing, via email or fax, to the person listed below. **The deadline for submitting such questions/clarifications is seven (7) working days prior to the proposal due date.** An addendum will be issued no later than 72 hours prior to the proposal due date to all recorded holders of the RFP if a substantive clarification is in order.

Vu Han
Bureau of Environmental Services
Columbia Boulevard Wastewater Treatment Plant
5001 N Columbia Blvd
Portland, OR 97203

E-mail: vuh@bes.ci.portland.or.us
Phone: (503) 823-2635
Fax: (503) 823-2478

SECTION B PROPOSAL SUBMISSION

1. PROPOSALS DUE

Sealed proposals must be received no later than the date and time, and at the location, specified on the cover of this solicitation. The outside of the envelope shall plainly identify the subject of the proposal, the RFP number and the name and address of the Proposer. It is the Proposer's responsibility to ensure that proposals are received prior to the specified closing date and time, and at the location specified. Proposals received after the specified closing date and/or time shall not be considered and will be returned to the Proposer unopened. The City shall not be responsible for the proper identification and handling of any proposals submitted to an incorrect location.

2. PROPOSAL

Proposals must be clear, succinct and **not exceed 40 pages**, excluding *Supporting Information – Resumes and References* and the *First Tier Subconsultant Disclosure Form.* Additionally, section dividers, title page, and table of contents do not count in the overall page count of the proposal. Proposers who submit more than the pages indicated may not have the additional pages of the proposal read or considered.

For purposes of review and in the interest of the City's Sustainable Paper Use Policy and sustainable business practices in general, the City encourages the use of submittal materials (i.e. paper, dividers, binders, brochures, etc.) that contain post-consumer recycled content and are readily recyclable. The City discourages the use of materials that cannot be readily recycled such as PVC (vinyl) binders, spiral bindings, and plastic or glossy covers or dividers. Alternative bindings such as reusable/recyclable binding posts, reusable binder clips or binder rings, and recyclable cardboard/paperboard binders are examples of preferable submittal materials. Proposers are encouraged to print/copy on both sides of a single sheet of paper wherever applicable; if sheets are printed on both sides, it is considered to be two pages. Color is acceptable, but content should not be lost by black-and-white printing or copying.

All submittals will be evaluated on the completeness and quality of the content. Only those Proposers providing complete information as required will be considered for evaluation. The ability to follow these instructions demonstrates attention to detail.

3. ORGANIZATION OF PROPOSAL

Proposers must provide all information as requested in this Request for Proposal (RFP). Responses must follow the format outlined in this RFP. Additional materials in other formats, or pages beyond the stated page limit(s), may not be considered. The City may reject as non-responsive at its sole discretion any proposal or any part thereof, which is incomplete, inadequate in its response, or departs in any substantive way from the required format. Proposal responses shall be organized in the following manner *(Note: suggested section page counts are provided as a guide only)*:

1. Cover Letter (2 pages)
2. Project Team (8 pages)
3. Proposer's Capabilities (6 pages)
4. Project Approach and Understanding (14 pages)
5. Diversity in Employment and Contracting Requirements (6 pages)
6. Proposed Cost (4 pages)
7. Supporting Information – Resumes and References
8. A completed First Tier Disclosure Form (refer to Part II.C.5)

SECTION C PROPOSAL CONTENT

1. COVER LETTER

By submitting a response, the Proposer is accepting the General Instructions and Conditions of this Request for Proposal (reference second page of the RFP) and the Standard Contract Provisions of the Professional, Technical and Expert Services contract. The Cover Letter must include the following:

- RFP number and project title
- name(s) of the person(s) authorized to represent the Proposer in any negotiations
- name(s) of the person(s) authorized to sign any contract that may result
- contact person's name, mailing or street addresses, phone and fax numbers and email addresses

A legal representative of the Proposer, authorized to bind the Proposer in contractual matters must sign the Cover Letter.

BUSINESS COMPLIANCE

The successful Proposer(s) must be in compliance with the laws regarding conducting business in the City of Portland before an award may be made. The Proposer shall be responsible for the following:

Certification as an EEO Affirmative Action Employer

The successful Proposer(s) must be certified as Equal Employment Opportunity Employers as prescribed by Chapter 3.100 of the Code of the City of Portland prior to contract award. Details of certification requirements are available from Procurement Services, 1120 SW Fifth Avenue, Room 750, Portland, Oregon 97204, (503) 823-6855, website: http://www.portlandonline.com/omf/purchasing

Non-Discrimination in Employee Benefits (Equal Benefits)

Proposers are encouraged to submit the Equal Benefits Compliance Worksheet/Declaration Form with their response. If not submitted, you will be contacted and required to provide this form prior to contract award; otherwise your proposal may be rejected. If your company does not comply with Equal Benefits and does not intend to do so, you must still submit the Form. The Equal Benefits

Compliance Worksheet/Declaration Form can be obtained from the following web site: http://www.portlandonline.com/omf/purchasing

- Fill out the form properly. You may call Procurement Services at 503-823-6855 to ensure you correctly complete the form. You may also call the contact listed on the front page of this solicitation document for assistance.

- There are five options on the Worksheet/Declaration Form to pick among. They range from full compliance (Options A, B, C), to one that requires advance authorization by the City (Option D – Delayed Compliance), to Non Compliance. Select the option that is true of your company's standing at the time you submit your proposal. You cannot change your answer after you submit the Worksheet/Declaration Form.

- Option D is only used if you have an official waiver from the City. Waivers are only issued by Procurement Services.

- The Form provides the City with your declared Equal Benefit status. However, the City issues the final determination of your Equal Benefit status for purposes of contract award.

If information on your form is conflicting or not clearly supported by the documentation that the City receives, the City may seek clarification to ensure we properly classify your compliance.

Business License
The successful Proposer(s) must be in compliance with the City of Portland Business License requirements as prescribed by Chapter 7.02 of the Code of the City of Portland prior to contract award. Details of compliance requirements are available from the Revenue Bureau License and Tax Division, 111 SW Columbia Street, Suite 600, Portland, Oregon 97201, (503) 823-5157, website: http://www.portlandonline.com/omf/index.cfm?c=29320

If your firm currently has a business license and is EEO certified, include in the Cover Letter your firm's City of Portland Business License number as well as the Equal Employment Opportunity (EEO) expiration date.

2. PROJECT TEAM

The proposal shall, at a minimum, include the following information:

- Approximate number of people to be assigned to the project;
- Extent of company's principal member's involvement;
- Team qualifications and experience on similar or related projects:
  - Qualifications and relevant experience of prime consultant
  - Qualifications and relevant experience of sub-consultants, if any
  - Project manager's experience with similar projects;
- Names of key members who will be performing the work on this project, and:
  - Their responsibilities on this project
  - Current assignments and location
  - Experience on similar or related projects
  - Unique qualifications
  - Percentage of their time that will be devoted to the project
- Management Approach
  - Describe or provide a detailed description of your approach to overall management and integration of all activities required by the scope of work, including the management objectives and techniques that demonstrate how the work requirements will be met.

- Key Personnel
    - o Describe the education background, directly related work experience, professional development, and demonstrated performance record of the proposed key personnel.

Include resumes for key personnel in the *Supporting Information* section of the proposal.

3. PROPOSER'S CAPABILITIES

Describe your capabilities and resources in relation to this project. At a minimum, include the following information:

- Similar projects performed within the last 5 years, which best characterize capabilities, work quality and cost control.
- Similar projects with other government agencies
- Resources available to perform the work for the duration of the project and other on-going projects.
- Internal procedures and/or policies associated or related to work quality and cost control
- Management and organizational capabilities

Provide at least 3 references for similar projects. Include project references in the *Supporting Information* section of the proposal. References must include the contact person's name, company/agency name, address, telephone number, the name of the project, and when the work was done.

4. PROJECT APPROACH AND UNDERSTANDING

Describe your proposed approach to the project:

- Describe the tasks and activities, the methodology that will be used to accomplish them, and which team members will work on each task;
- Describe the products that would result from each task or activity;
- Identify points of input and review with staff; and
- The time frame estimated to complete each task.

5. DIVERSITY IN EMPLOYMENT AND CONTRACTING REQUIREMENTS

The City is committed to increasing contracting opportunities for State of Oregon certified minority, women and emerging small business (M/W/ESB) enterprises. The City values, supports and nurtures diversity, and encourages any firm contracting with the City to do the same, maximizing M/W/ESB business participation with regard to all City contracts. As such, the City has established an overall 20% utilization goal in awarding PTE contracts to State of Oregon certified emerging small business (ESB) enterprises. The City has assigned at least 15% of the total points available on this solicitation to determine the award of this contract. No goal is set for the use of minority (MBE) and women business (WBE) enterprises, but the City is committed to ensuring that such firms receive opportunities and equal consideration to be awarded City PTE contracts.

All Proposers shall address the following in their proposals:

a. Indicate if your firm is currently certified in the State of Oregon as an MBE, WBE and/or ESB, or if your firm has applied for certification with the State of Oregon's Office of Minority, Women and Emerging Small Business (OMWESB). Provide a copy of the State of Oregon certification letter confirming receipt of application or copy of the approval letter certifying your firm.

b. Identify your current diversity of workforce and describe your firm's commitments to providing equal employment opportunities. Include in your response:
    - Number of total employees and description of type of work performed.
    - Number of minorities and women within your current workforce, broken out by ethnicity and positions held.

- Any underutilization of minorities or women within your workforce and your firm's efforts to remedy such underutilization.
- Any plans to provide innovative mentoring, technical training or professional development opportunities to minorities and women in your workforce in relation to this project, or plans to employ minorities and women to work on this project.
- Description of the process your firm uses to recruit minorities and women.

c. Have you subcontracted or partnered with State of Oregon certified M/W/ESB firms on any project within the last 12 months? If so, please describe the history of the firm's subcontracting and partnering with certified M/W/ESB firms. Include in your response:
   - List of State of Oregon certified M/W/ESB firms with which your firm has had a contractual relationship during the last 12 months.
   - Any innovative or successful measures that your firm has undertaken to work with M/W/ESB firms on previous projects.
   - Any mentoring, technical or other business development services your firm has provided to previous or current M/W/ESB subconsultants or partners, or will provide in relation to this project.

d. Are you subcontracting any element of your proposal? Describe your firm's plan for obtaining maximum utilization of State of Oregon certified M/W/ESB firms on this project. Include in your response:
   - Subcontracting opportunities your firm has identified in the scope of this project.
   - Efforts made relating to outreach and recruitment of certified M/W/ESB firms. Did your firm advertise contracting opportunities in the *Daily Journal of Commerce, Skanner, Oregonian, Observer, El Hispanic News, Asian Reporter*, and/or other trade publications? Did your firm conduct any outreach meetings? Did your firm use the State's OMWESB certification list, or other source, as a basis for direct outreach? What were the actual results of any of the above efforts?
   - Any proposals received from certified M/W/ESB firms. If any such proposals were rejected, provide reasons for rejection.
   - Other efforts your firm used or proposes to use in relation to this project.

e. If your firm will be utilizing State of Oregon certified M/W/ESB firms on this project, please list those firms and detail their role within your proposal. In addition, **all Proposers must submit Exhibit A - First Tier Subconsultant Disclosure Form 1** in their proposal, which requires Proposers to identify the following:
   - The names of **all** subconsultants to be used on this project with subcontracts greater than or equal to $10,000.
   - The names of all State of Oregon certified MBE, WBE and ESB firms. If firms have more than one certification (i.e., ESB and MBE, and/or ESB and WBE) note that on the form so that proper credit can be given for the ESB goal and for tracking MBE and WBE utilization.
   - The proposed scope or category of work for each subconsultant.

   If Proposers will not be using any subconsultants that are subject to the above disclosure requirements, Proposers are required to indicate **"NONE"** on the First Tier Subconsultant Disclosure Form 1.

The City expects thoughtful consideration of all of the above Diversity in Employment and Contracting criteria in the preparation of proposals. The City will enforce all diversity in workforce and M/W/ESB commitments submitted by the successful Proposer, and the successful Proposer will be required to submit a completed Monthly Subconsultant Payment and Utilization Report to ensure that subconsultants are utilized to the extent originally proposed and submitted in its proposal. The successful Proposer will not be permitted at any time to substitute or add a subconsultant without the prior written approval of the Purchasing Agent. ALL subconsultants, including M/W/ESB firms, and first tier subconsultants shall be reported on the Monthly Subconsultant Payment and Utilization Report as well as contract amounts and payments. For reference, a copy of this form may be obtained at: http://www.portlandonline.com/shared/cfm/image.cfm?id=119851 .

6. PROPOSED COST

The proposal shall include the Proposer's true estimated cost for the proposed project approach irrespective of the City's anticipated cost. Additionally, this cost shall include the hourly rates of each person associated with the project as well as the estimated number of hours each staff member will be expected to work on each task.

BES Multiplier Policy
The multiplier applied to salaries shall not exceed 3.1. The multiplier shall include the following non-reimbursable expenses: fringe benefits, payroll bonuses, autos and other defined perquisites, telecommunications, facsimile services, overhead expenses including but not limited to local and long distance telephone, parking, delivery/courier, general business and professional liability insurance, advertising costs, postage, internal copying, lease of office equipment, mileage and other local travel costs, information technology (including computer time and CAD services and other related highly specialized equipment), all other direct costs not identified as reimbursable, other indirect costs and profit.

Standard Reimbursable Costs
The following costs will be reimbursed without mark-up.

- Out-of-Town Travel. Travel (transportation, lodging and per diem) of successful Proposer and/or experts when specified in the contract or requested by BES, directly attributed to specific tasks and when to a location outside a 100 mile radius of successful Proposer's project office. Travel costs will be reimbursed in accordance with the City's Travel Expense Guidelines, which are based on the General Services Administration (GSA) per diem rates.
- Photocopying/Reproduction Costs. Reproduction of required drawings, reports, specifications, bidding documents, in excess of the number required as part of the contract excluding the cost of reproduction for successful Proposer's or sub's own use.

Subconsultant Costs
Compensation for subconsultants shall be limited to the same restrictions imposed on the Consultant. The maximum markup on subconsultant services shall not exceed 5%. Consultants are not guaranteed the maximum mark-up will be allowed, it may be less or none at all. The actual rate will be determined during contract negotiations.

Adjustment of Hourly Rates Due to Inflation
Annual adjustment of hourly rates will be considered upon written request from the Consultant. Approval of a request for rate increases is solely within the City's discretion and under no circumstances is the City obligated to approve such a request.

Rate increases are subject to the following limitations:

- No increases will be granted before the one-year anniversary of the contract;
- No more than one increase shall be granted per contract year;
- Rate increases may not exceed the then-current average inflation rate for the Portland Metropolitan Area (as determined from the US Department of Labor statistics and certified by the City of Portland Auditor);
- Rate increases shall not be retroactive..

Other than the impact of inflation as described above, hourly rates may not be increased.

7. SUPPORTING INFORMATION – RESUMES AND REFERENCES

In this section, provide resumes for key personnel *(see Section II.C.2)* and project references *(see Section II.C.3)*. The pages in this section will not count against the page limit set for the proposal.

PART III PROPOSAL EVALUATION

SECTION A PROPOSAL REVIEW AND SELECTION

1. EVALUATION CRITERIA SCORING

Each proposal shall be evaluated on the following evaluation criteria, weighting and maximum points, as follows:

	Criteria	Maximum Score
a.	Cover Letter	0
b.	Project Team	25
c.	Proposer's Capabilities	15
d.	Project Approach and Understanding	30
e.	Diversity in Employment and Contracting	15
f.	Proposed Cost	15
	Total Points Available	100

2. PROPOSAL REVIEW

An evaluation review committee will be appointed to evaluate the proposals received. For the purpose of scoring proposals each of the committee members will evaluate each proposal in accordance with the criteria and point factors listed above. The evaluation committee may seek outside expertise, including but not limited to input from technical advisors, to assist in the evaluation process.

The successful Proposer shall be selected by the following process:

a. An evaluation committee will be appointed to evaluate submitted written proposals.
b. The committee will score the written proposals based on the information submitted according to the evaluation criteria and point factors.
c. The committee will require a minimum of 15 working days to evaluate and score the written proposals.
d. A short list of Proposers, based on the highest scores, may be selected for oral interviews if deemed necessary. The City reserves the right to increase or decrease the number of Proposers on the short list depending on the scoring and whether the Proposers have a reasonable chance of being awarded a contract.
e. If oral interviews are determined to be necessary, the scores from the written proposals will be considered preliminary. Final scores, based on the same evaluation criteria, will be determined following the interviews.

All communications shall be through the contact(s) referenced in Part II, Section A.2 of the RFP. At the City's sole discretion, communications with members of the evaluation committee, other City staff or elected City officials for the purpose of unfairly influencing the outcome of this RFP may be cause for the Proposer's proposal to be rejected and disqualified from further consideration.

For contracts over $100,000, the evaluation committee's recommendation for contract award will be submitted to the Portland City Council for approval. The City has the right to reject any or all proposals for good cause, in the public interest.

NOTE: In the City's discretion, litigation between the City and a Proposer shall be cause for proposal rejection, regardless of when that litigation comes to the City's attention and regardless how the Proposer's proposal may have been scored. Proposals may also be rejected if they use subcontractors or subconsultants who are involved in litigation with the City. Proposers concerned about possible rejection on this basis should contact the City before submission of a proposal for a preliminary determination of whether its proposal will be rejected.

3. CLARIFYING PROPOSAL DURING EVALUATION

During the evaluation process, the City has the right to require any clarification or change its needs in order to understand the Proposer's view and approach to the project and scope of the work. While clarification is being requested, no other changes or substitutions will be allowed to proposals.

SECTION B CONTRACT AWARD

1. CONSULTANT SELECTION

The City will negotiate and, if successful, award a contract to the highest scoring Proposer. Should the City not reach a favorable agreement with the highest scoring Proposer, at the City's sole discretion, the City shall terminate negotiations and commence negotiations with the second highest scoring Proposer and so on until a favorable agreement is reached. A consultant selection process will be carried out under Portland City Code Chapter 5.68.

2. CONTRACT DEVELOPMENT

The proposal and all responses provided by the successful Proposer may become a part of the final contract. The form of contract shall be the City's Contract for PTE Services.

3. AWARD REVIEW AND PROTESTS

REVIEW:
Following the Notice of Intent to Award, the public may view proposal documents. However, any proprietary information so designated by the Proposer as a trade secret or confidential and meeting the requirements of ORS 192.501, 192.502 and/or ORS 646.461 et seq., will not be disclosed unless the Multnomah County District Attorney determines that disclosure is required. At this time, Proposers not awarded the contract may seek additional clarification or debriefing, request time to review the selection procedures or discuss the scoring methods utilized by the evaluation committee.

PROTESTS OF CONTRACT AWARDS:
Protests may be submitted to the Purchasing Agent only for contracts in excess of the formal limit established by the City Auditor (reference http://www.portlandonline.com/omf/index.cfm?a=74585&c=27353), and only from those Proposers who would receive the contract if their protest were successful.

Protests must be received by the Purchasing Agent within seven (7) calendar days UNLESS OTHERWISE NOTED following the date of the City's Notice of Intent to Award was issued. The protest must specifically state the reason for the protest and show how its proposal or the winning proposal was mis-scored or show how the selection process deviated from that described in the solicitation document. No contract will be awarded until the protest has been resolved.

Timely protests must include all legal and factual information regarding the protest, and a statement of the form of relief requested. Protests received later than specified or from other than the Proposer who would receive the contract if the protest was successful will not be considered. The exercise of judgment used by the evaluators in scoring the written proposals and interviews, including the use of outside expertise, is not grounds for appeal.

The Purchasing Agent may waive any procedural irregularities that had no material affect on the selection of the proposed contractor, invalidate the proposed award, amend the award decision, request the evaluation committee re-evaluate any proposal or require the bureau to cancel the solicitation and begin again to solicit new proposals. In the event the matter is returned to the evaluation committee, the Purchasing Agent shall issue a notice canceling the Notice of Intent to Award.

Decisions of the Purchasing Agent are final and conclude the administrative appeals process.

EXHIBIT A

CITY OF PORTLAND
PROFESSIONAL TECHNICAL & EXPERT (PTE) SERVICES
FIRST TIER SUBCONSULTANT DISCLOSURE FORM

CITY PTE DISCLOSURE REQUIREMENTS

The City's disclosure program was adopted to document the use of subconsultants on City projects over $100,000; particularly Oregon certified Minority, Women and Emerging Small Businesses (M/W/ESBs).

This Request for Proposal requires submission by the Proposer of the First Tier Subconsultant Disclosure Form. When the contract amount of a first-tier subconsultant furnishing services, labor or labor and materials would be greater than or equal to $10,000, the Proposer must disclose the following information about such subconsultants:

1) The subconsultant's contact information
2) State of Oregon M/W/ESB designation
   (Verify certification status with the Office of Minority, Women and Emerging Small Business at http://egov.oregon.gov/DCBS/OMWESB/index.shtml)
3) The proposed scope or category of work that the subconsultant will be performing
4) The amount of the subconsultant's contract

If the Proposer will not be using any subconsultants that are subject to the above disclosure requirements, the Proposer is required to indicate **"NONE"** on the accompanying form.

ATTACHMENTS: Form 1: City of Portland PTE First Tier Subconsultant Disclosure Form

CITY OF PORTLAND
PTE FIRST TIER SUBCONSULTANT DISCLOSURE FORM
(FORM 1)

This Request for Proposal requires submission by the Proposer of the First Tier Subconsultant Disclosure Form. When the contract amount of a first tier subconsultant furnishing services, labor or labor and materials would be greater than or equal to $10,000, the Proposer must disclose the following information about that subconsultant.

Proposer Name: ______________________ **Proposed Cost:** ______________________

RFP Number: ____BES103____________ **Project Name:** ______________________

SUBCONSULTANT INFORMATION (Please Print)	M/W/ESB	SCOPE/TYPE OF WORK	SUBCONTRACT AMOUNT
Firm Name: Phone #: Fax #:			$
Firm Name: Phone #: Fax #:			$
Firm Name: Phone #: Fax #:			$
Firm Name: Phone #: Fax #:			$
Firm Name: Phone #: Fax #:			$
Firm Name: Phone #: Fax #:			$

NOTE:

1) **If the Proposer will not be using any subconsultants that are subject to the above disclosure requirements, the Proposer is required to indicate "NONE" on this form.**
2) **All subconsultants with contracts $10,000 or over must be listed on this form. Leave M/W/ESB column blank if firm is not confirmed certified through the *State of Oregon Office of Minority, Women and Emerging Small Business:* *http://egov.oregon.gov/DCBS/OMWESB/index.shtml*.**

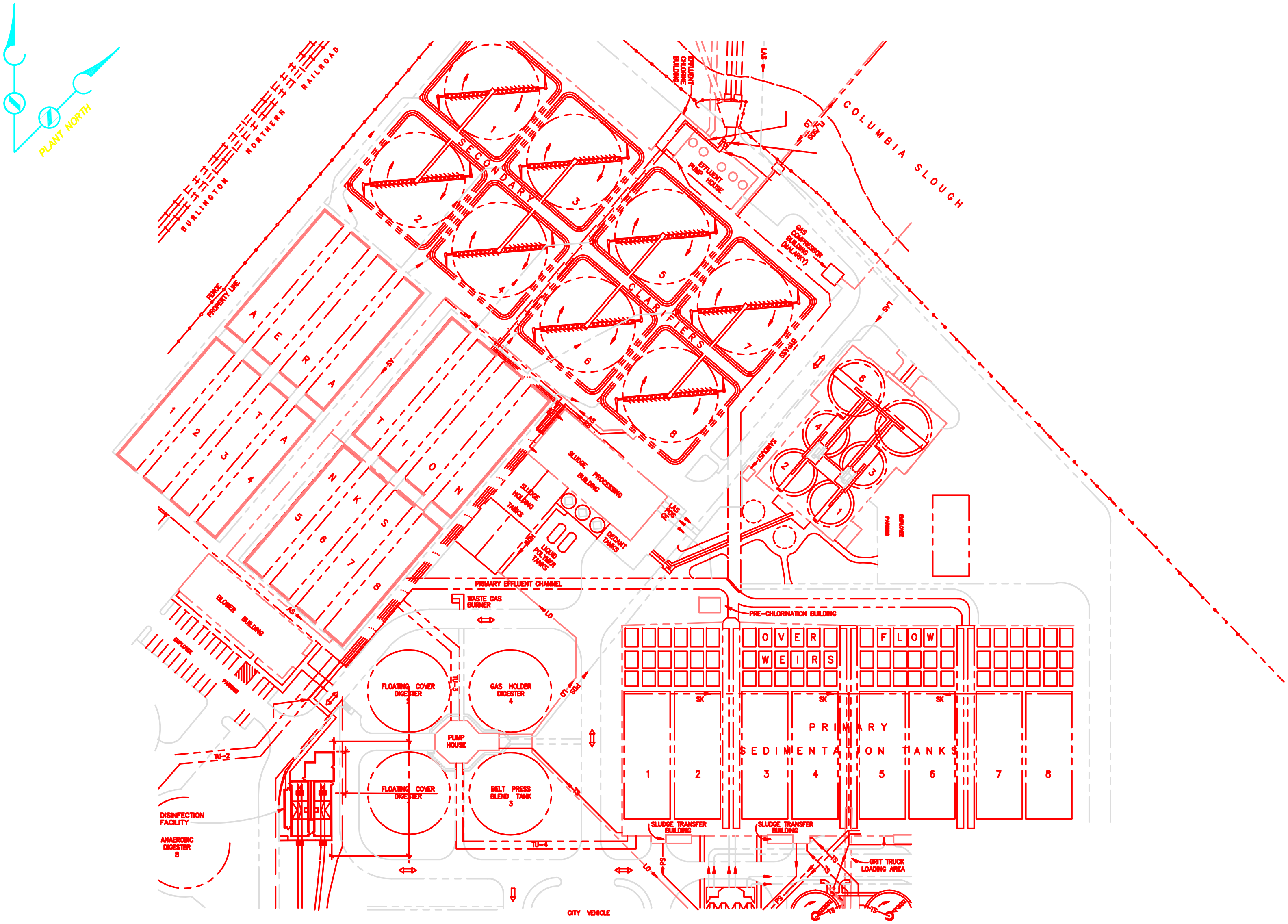


EXHIBIT B

SITE PLAN

09-15-93

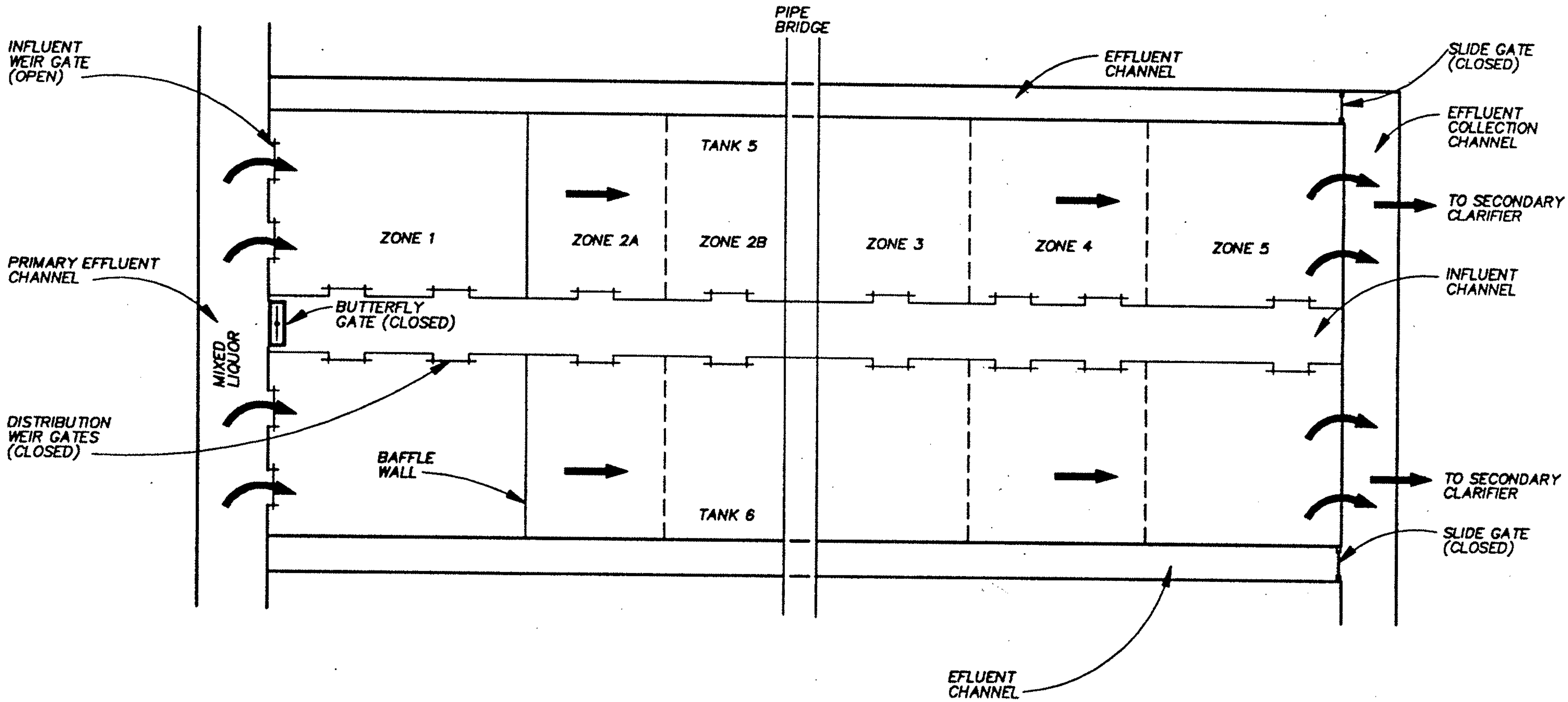


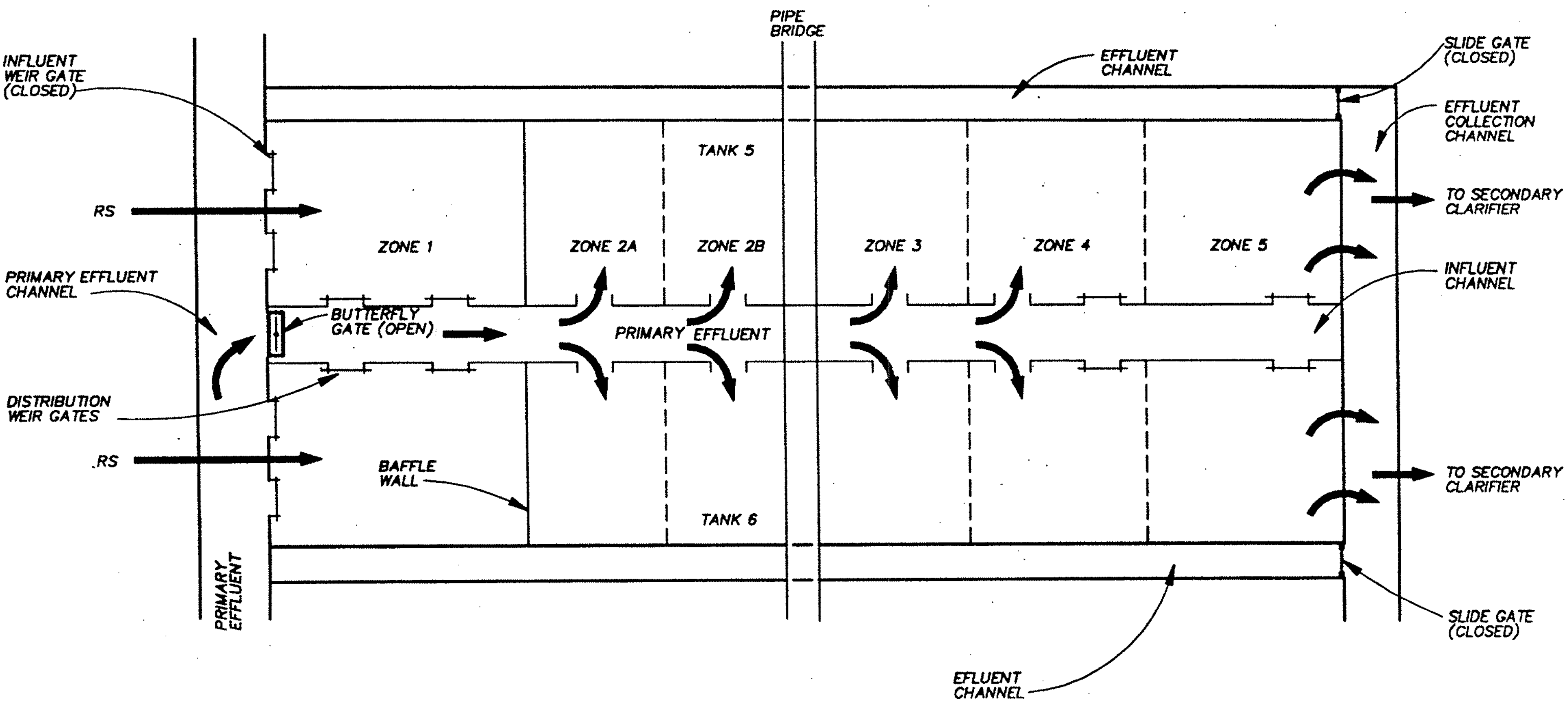
EXHIBIT C

FIGURE 2-2
PLUG FLOW/ANOXIC MODE OF OPERATION

CH2M HILL

I:\32146\CAD\2146F202.DWG

09-10-93



RS IS DISTRIBUTED INDIVIDUALLY TO THE FIRST ZONE OF EACH TANK VIA SEPARATE PIPELINES.

EXHIBIT C

FIGURE 2-3
STEP FEED MODE OF OPERATION

CH2M HILL®

I:\32146\CAD\2146F203.DWG

Y CONG 2146F206
09-13-03

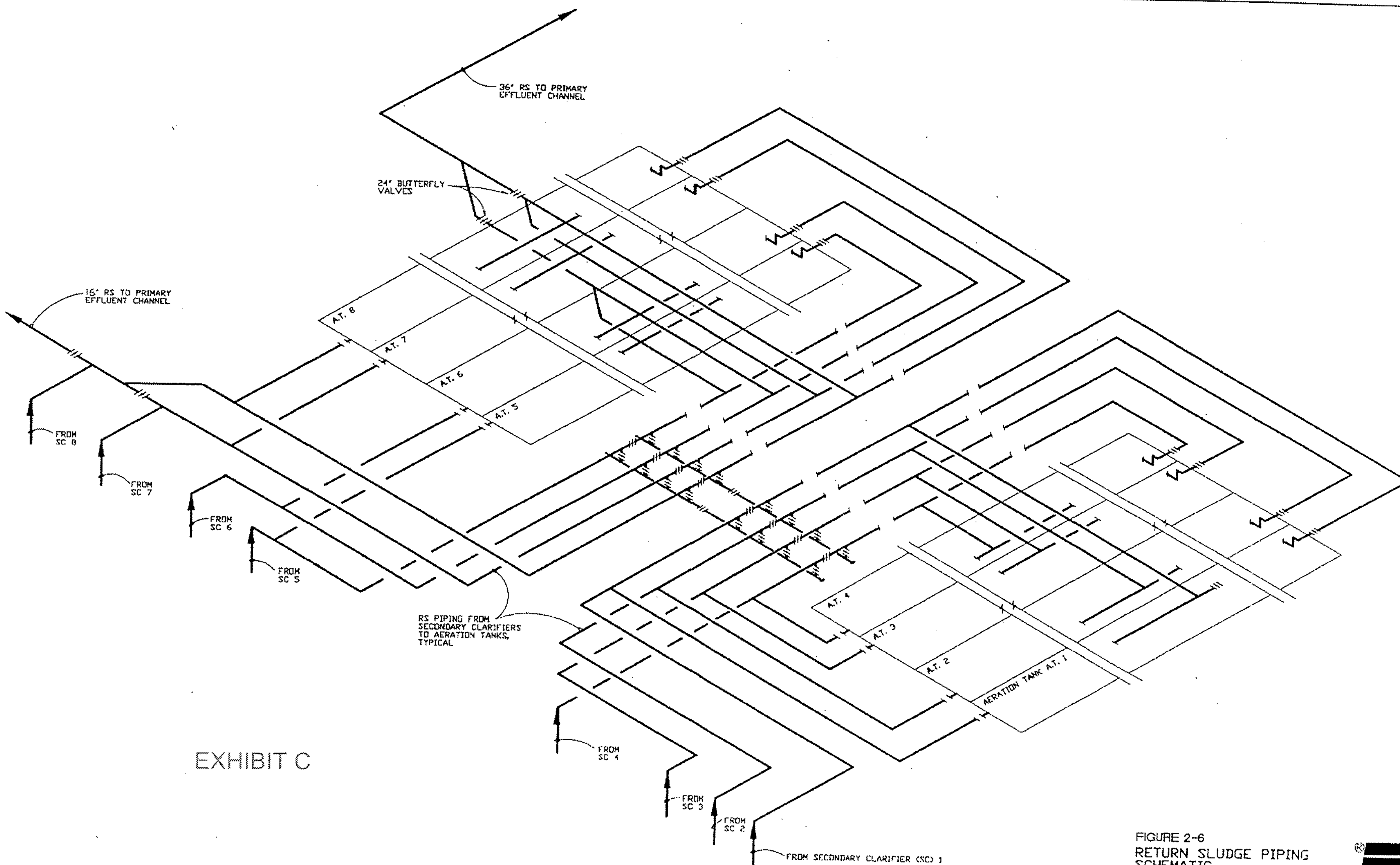


EXHIBIT C

FIGURE 2-6
RETURN SLUDGE PIPING SCHEMATIC

CH2MHILL

J:\32146\CAD\2146F206.DWG

EXHIBIT D

Final Report

CBWTP Facilities Plan Update

TO:	Garry Ott, City of Portland, Bureau of Environmental Services
COPIES:	Steve Simonson, City of Portland, Bureau of Environmental Services File
FROM:	Daria Wightman, Brown and Caldwell
PREPARED BY:	Adam Klein, Brown and Caldwell
REVIEWED BY:	Henryk Melcer, Brown and Caldwell Denny Parker, Brown and Caldwell
DATE:	October 27, 2009
PROJECT NO.:	129055 Task 006 City Project 7847
SUBJECT:	CBWTP Selector Enhancement Pilot Project Using Indicator SVI Results and Recommendations

CONTENTS

SUMMARY AND CONCLUSIONS

The objective of the Selector Enhancement Pilot Project was to demonstrate the feasibility of improvements that would lower the operating sludge volume index (SVI) below historical records. Achieving lower SVIs of 150 mL/g for 100-mgd secondary treatment (per the Contract Amendment for pilot testing) would postpone the need for expansion of the secondary clarifier system until after 2015 based on growth projected in the CBWTP Draft Facilities Plan Update, January 2008 (Facilities Plan Update).

The full-scale pilot trial attempted to isolate one secondary treatment train consisting of one aeration tank and one secondary clarifier (the pilot) from the remaining seven trains (the control). Supplementary diffusers were installed in the first stage of aeration downstream of the selector to increase oxygen transfer in that zone and a baffle wall was installed to divide the existing anaerobic selector zone into two smaller zones in the pilot train. The City simultaneously adjusted the air distribution in the control trains in the first stage of aeration downstream of the selector. The pilot testing was conducted from December 20, 2008, to April 9, 2009. The full-scale pilot test findings include the following:

- A full assessment of operational changes was not possible due to a series of problems associated with maintaining separation between the pilot and control trains.
- Performance of the pilot train was hampered by an inability to control solids transfer. The pilot train was not able to achieve lower SVIs (100 to 150 mL/g) for 100-mgd secondary treatment. During the 4-month pilot study, the 90th percentile SVI for the pilot train was 321 mL/g.
- Modifications to process aeration and operation at a higher solids residence time (SRT) appear to have improved mixed liquor settling in the control train. The 90th percentile SVI for the control train was 261 mL/g.
- The true impact of these changes is confounded due to cross-connections between the control and the pilot trains.

Compared to the historical record, the lower SVI in the control train is attributed to operation at a slightly higher SRT, the redistribution of air to the control trains, and the extra attention given to overall process control associated with the pilot study. Since conclusion of the pilot operation, the plant has maintained an SVI of less than 200 mL/g.

Based on the pilot test results, it is reasonable to assume that long-term operation at an SVI of 200 to 250 mL/g is achievable. At a design SVI of 250 mL/g, four new secondary clarifiers would be required by 2011 (bringing the total to 12 clarifiers). Up to four additional secondary clarifiers (eight existing and up to eight new for a total of 16), would be needed by either 2015 or 2023, depending on how much and at what rate flow is allowed into the secondary system during the winter. If long-term operation at an SVI of 200 mL/g were achieved (potential based on operation post-pilot testing), then only two clarifiers would be needed by 2011 and up to four additional clarifiers by 2015 depending on how much flow is allowed into the secondary system during the winter. SVI declined in the aftermath of most storms during the pilot testing.

The recommendations for operational changes and capital improvements to more reliably achieve the SVI of 200 mL/g are summarized below.

- Install additional aeration diffusers downstream of the selector in all basins
- Install an intermediate baffle to divide the selector into two zones in all basins
- Operate at a higher SRT
- Operate with a minimal clarifier solids blanket.
- Install automated dissolved oxygen (DO) control
- Install permanent DO sensors downstream of the selector
- Install permanent oxidation reduction potential (ORP) sensors in the selector
- Install in-line solids concentration sensors for the mixed liquor suspended solids (MLSS) and waste activated sludge (WAS) streams
- Provide automated solids wastage
- Conduct daily total and soluble chemical oxygen demand (COD) measurement of the primary effluent
- Measure daily total and floc filtered effluent COD (ffCOD) in concert with the influent COD measurements
- Conduct regular phosphorus profiling across the secondary system.
- Renovate the return activated sludge (RAS) system with valve replacement and automation.

OVERVIEW

Project Objective

The purpose of this project was to test whether modifications to the secondary process tanks and the secondary process operating strategy could improve mixed liquor settling in order to postpone the secondary expansion.

Historical Plant Performance

The Facilities Plan Update demonstrated the sensitivity of the liquid stream treatment process capacity to activated sludge mixed liquor settling characteristics as measured by the SVI; lower SVI means better settling and greater capacity. Desirable settling behavior is observed at an SVI in the 100 to 150 mL/g range. CBWTP has a history of a highly variable SVI and has normally operated outside the desirable range as shown in Figure 1.

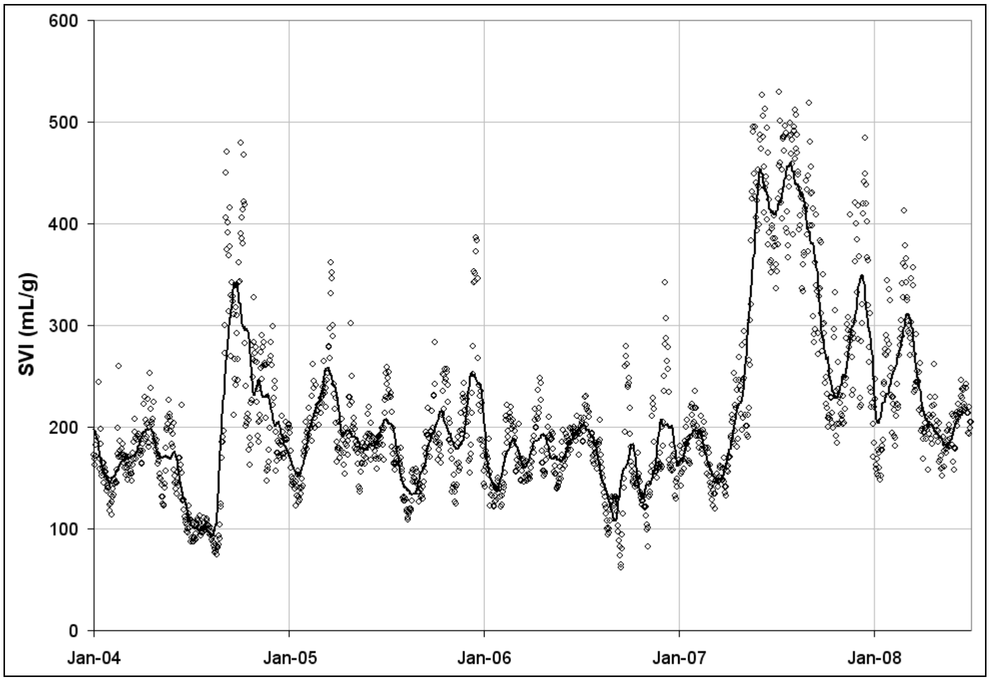


Figure 1. Historical Record of SVI
(solid line is running 30-day average)

Assuming that settling properties would mirror those observed historically (mixed liquor SVI periodically exceeding 300 mL/g), the Facilities Plan Update projected a need to increase the size of aeration basins through conversion of the existing 8 secondary clarifiers, and provide 12 new secondary clarifiers across the railroad tracks for potential ultimate expansion in 2040. In contrast, demonstrating the control of mixed liquor settling to the desirable SVI operating range (100 to 150 mL/g) would render expansion of secondary clarification beyond the existing eight units unnecessary until 2040.

PILOT TEST IMPLEMENTATION

Secondary Treatment Train Modifications

The test isolated one of the eight secondary process trains from the others, so that it could be modified and used as a test train (referred to herein as the pilot train) to compare its performance against the remaining seven trains (referred to collectively as the control). Pilot train modifications were intended to encourage the growth of biological phosphorus removal (bio-P) microorganisms. A benefit accruing from the presence of bio-P organisms is that they are dense and settle well. Because the bio-P organisms settle well, a large population of bio-P organisms will result in improved mixed liquor settling.

Modifications to the pilot train included the following:

- Isolation of the pilot train (one aeration basin plus one secondary clarifier) from the rest of the Plant through the following:
  - Separate feed primary effluent pumping from the dry weather primary clarifiers. Figure 2 shows the temporary motor-driven pumps that allowed the primary effluent to bypass the point where RAS mixes with the primary effluent prior to entering all the aeration basins.
  - Closing all gates between the pilot train and the rest of the plant.
  - Isolating solids recycle pumping from the pilot clarifier to the pilot aeration basin.

Figure 2. Temporary Primary Effluent Pumping to the Pilot Train

- Installation of a baffle to divide the aeration basin selector into two compartments (in the pilot train only. Figure 3 shows the newly installed baffle in the pilot train between the head of the aeration basin and the existing selector baffle.

Figure 3. Installation of Mid-Selector Baffle in the Pilot Train

- The bio-P organisms do not function well when oxygen is present. Plant staff reported that storm-induced high flows introduced DO into the selector because of the well oxygenated state of the influent under those conditions. The second baffle was introduced to ensure that no oxygen migrates into the second compartment of the selector, thereby protecting the integrity of the anaerobic environment that promotes bio-P organisms in that part of the selector.

- Modifications to the aeration diffuser grids were implemented to increase the mass of oxygen delivered at the upstream end of pilot train aerated zones and downstream of the selector (Figure 4). This was accomplished by adding diffusers to the available spare ports. If aeration downstream of the selector is limited, this can give rise to the growth of filamentous organisms, which impair mixed liquor settling.

- Also, to boost the aeration rate in this location, the distribution of air to the aeration basin was modified to direct more air to the influent end of the aerated zones of the basin. The air redistribution was also made for the other (control) aeration basins.

- Operation at higher SRT. The bio-P organisms require a higher SRT than the typical heterotrophic activated sludge organisms, in the range of 2.5 to 3.0 days at the prevailing plant operating temperature.

Figure 4. Increased Aeration Diffuser Density Downstream of the Selector (pilot shown)

In order to improve operational efficiency and monitor the test program, DO and ORP probes were installed in the pilot train as shown in Figure 5, and detailed wastewater sampling and laboratory testing were carried out periodically from December 20, 2008, to April 8, 2009. The DO probes monitored the level of DO that was carried into the selector during elevated storm flow conditions and the degree to which an adequate level of DO was maintained downstream of the selector. The ORP probes provided data on the suitability of the microbial environment for growing bio-P organisms.

Figure 5. DO and ORP Probes in the Pilot Train

The changes to the pilot train are schematically expressed in Figure 6.

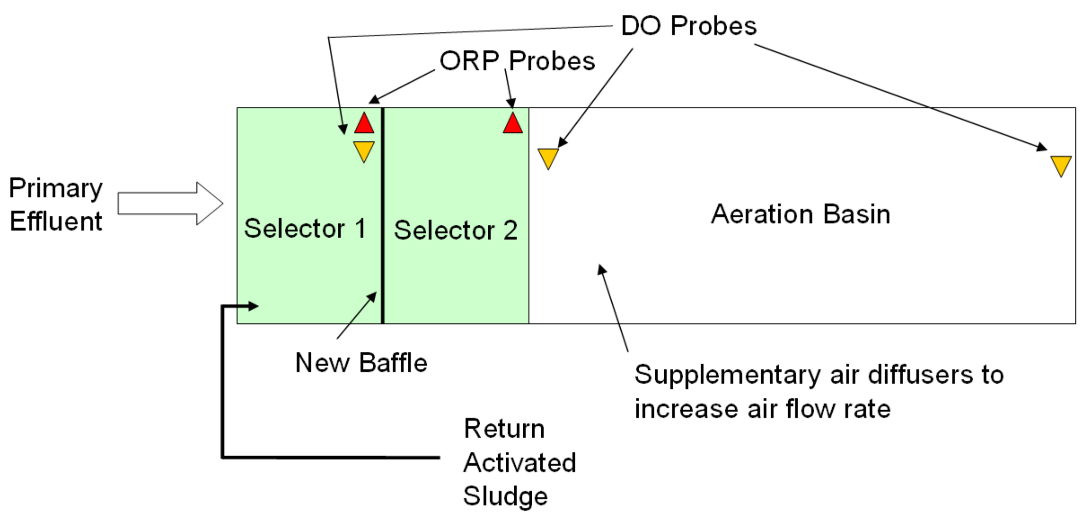


Figure 6. Modifications to the Pilot Train

Test Schedule

The test was conducted from mid-December 2008 through the beginning of April 2009. In order to assess the performance of the pilot train, the following items were monitored:

- **SVI**. The goal of the test was to achieve an SVI in the pilot train of 150 mL/g or less.
- **Phosphorus profiles.** Because the bio-P organisms are involved in phosphorus removal, the levels of phosphorus at different places along the treatment train provide an indirect measure of the size and strength of this population. A healthy bio-P population leads to high phosphorus concentrations in the selector, and low phosphorus concentrations in the aeration basin, secondary clarifier, and effluent.
- **Wastewater characteristics in both pilot and control trains.** A complete record of these data, upon which the figures presented in this memorandum are based, is provided in Appendix A. Similarly, a summary of the operational monitoring data provided by the CBWTP operations staff is provided in Appendix B.

From February 23, 2009, onward, conference calls were held almost daily between CBWTP and Brown and Caldwell staff to discuss changes in operational strategies to respond to the changing conditions that are described in this memorandum. Minutes of these calls were issued the day after the call. The essential information relating to plant operations was extracted from these minutes and inserted in Appendix C to provide a record of how changes in performance and operational strategies (as discussed later in this memorandum) were developed.

The full test plan is included in Appendix D.

Chronology of Events During the Test

At the onset of testing, the SRT of the pilot train was set approximately 1 day higher than that of the control train (3.5 days pilot, 2.5 days control). However, SRT control was initially hampered by an accumulation of solids in the pilot clarifier (see lower panel in Figure 7).

In spite of efforts to control blanket depth by increasing the RAS flow rate (pilot RAS set at 60 percent of pilot influent; control RAS set at 35 percent of control influent), the pilot clarifier maintained a solids blanket approximately 2 feet deeper than the control clarifiers throughout most of December 2008. As the automated WAS control system was based on the mean cell retention time (MCRT), which considers both solids in the aeration basins as well as solids in the clarifiers, the accumulation of solids in the pilot clarifier resulted in a higher WAS flow setting, which effectively decreased the pilot SRT to 2.0 to 2.5 days.

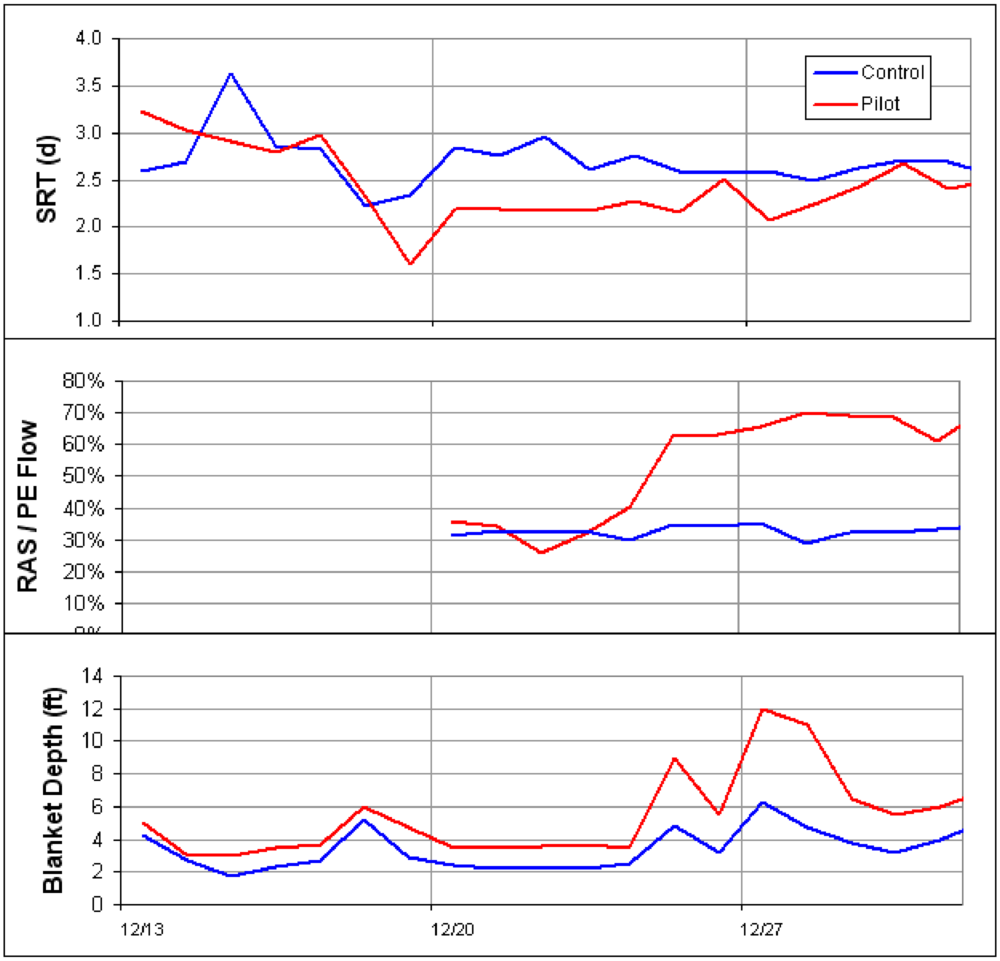


Figure 7. December 2008 Process Parameters

Impact of Winter Holiday Storms

In late December 2008, a major storm system passed through the area and significantly increased influent flow rate as shown in Figure 8. This was accompanied by an influx of solids into the pilot clarifier. Solids inventory in the pilot train increased from 55,000 lb to 80,000 lb from December 26, 2008, through January 2, 2009, with the initial increase observed in the clarifier. The pilot SVI, which had tracked closely with the control SVI to this point, increased to 390 mL/g on the first day of the storm event.

After the storm, the SVI in both trains decreased to less than 150 mL/g. Staff report that SVI typically declines in the aftermath of storms. This may be related to a ballasting effect caused by the influx of inert solids and grit as the storm flow scours the collection system and primary sedimentation basins. These solids accumulate and agglomerate mixed liquor solids, resulting in increased settling velocities and a reduction in the SVI. Regular volatile suspended solids (VSS) measurement, which would allow for the calculation of inert solids, would allow this hypothesis to be tested over time.

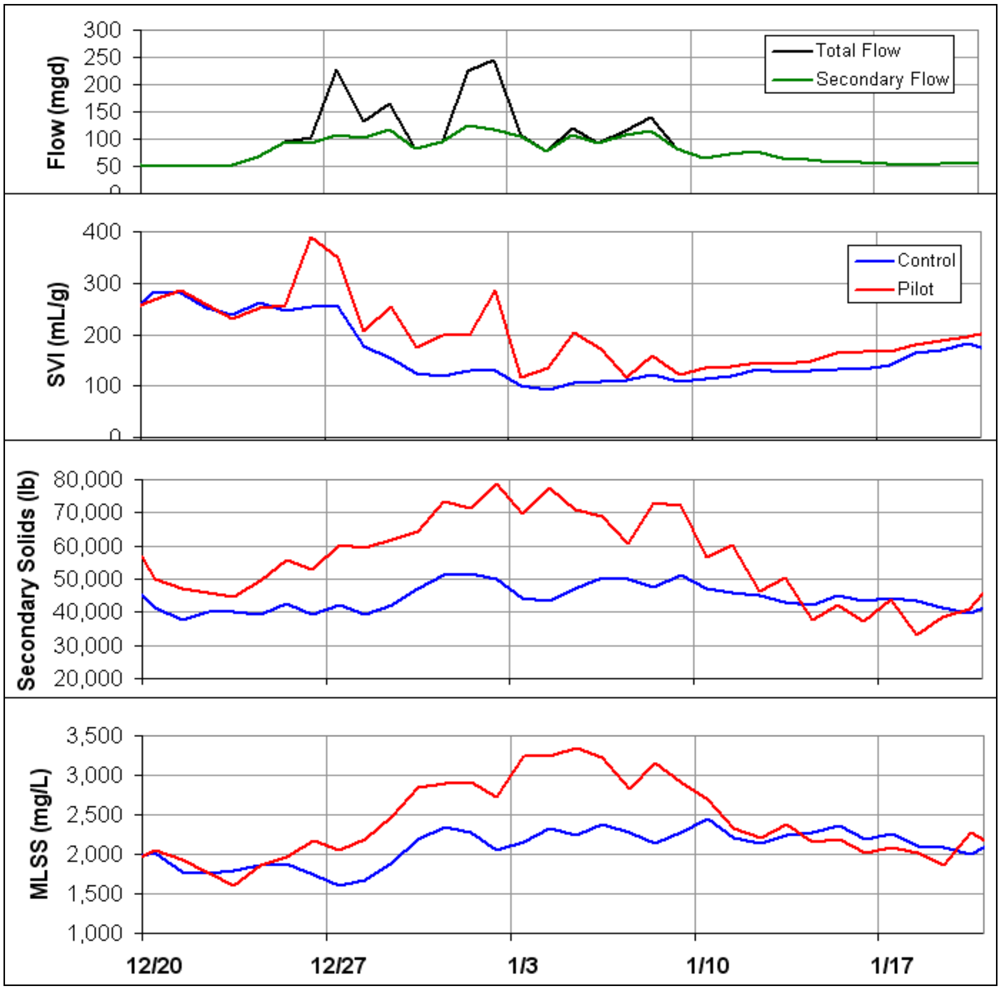


Figure 8. Late December 2008/ Early January 2009 Process Parameters

The MLSS of the pilot train increased steadily in the wake of the storm, as solids appeared to have migrated from the pilot clarifier to the aeration basins. Pilot MLSS peaked at 3,340 mg/L on January 4, 2009. Throughout this period, the SRT setting did not change, and both trains operated near 2.5 days. Further information on the staff-reported historical relationship between stormflow and settling is presented later in this report.

A high pilot MLSS (above 3,000 mg/L) was maintained through most of the first 2 weeks of January 2009. During this time, both pilot and control SVIs maintained a value near 150 mL/g. This period was marked by the high flows to the Plant. ORP readings in the pilot selector indicated a slightly less anaerobic condition, particularly in the first selector zone as shown in Figure 9. To be truly anaerobic, the ORP needs to be in the -250 to -350 mV range. However, bio-P activity can continue with ORP values in the -50 to -150 mV range. These data show that the first selector zone had some brief periods where conditions would not be suitable for bio-P activity, but the second selector zone conditions should have been able to support bio-P activity throughout the period of record.

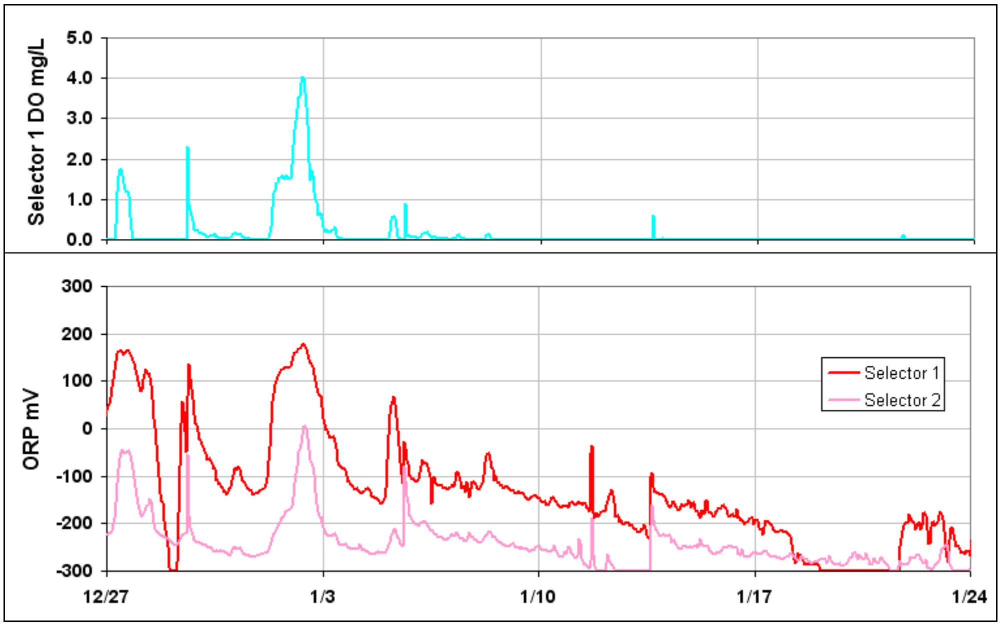


Figure 9. Early January 2009 Oxygen and ORP Conditions for Selector Zones in Pilot Train

The reduction in influent ffCOD and soluble chemical oxygen demand (sCOD) during the storm (Figure 10) is likely a combination of a dilution effect, along with decreased collection system residence time, with the consequence of less degradation and fermentation in the collection system. These reductions would limit the availability of substrate for bio-P organisms in the selector, and could therefore be implicated in reduced settling efficiency during storms. However, the data suggest that, of the reduced amount of substrate reaching the selector, very little was actually being utilized. The best indicator of substrate utilization is the ffCOD, which measures the truly soluble fraction of substrates. In Figure 10, the ffCOD values are scattered during the storm period, and do not develop into a pattern indicating utilization across the selector until January 15.

The sCOD data demonstrate a similar pattern, without some of the scatter observed in the ffCOD data as shown in Figure 10. sCOD is a less accurate measure of readily biodegradable substrates, because it includes the colloidal fraction of substrate, and is therefore subject to flocculative removal in addition to microbial utilization. However, sCOD is often used as a surrogate for ffCOD. This is because ffCOD tends to be more difficult to assess in the laboratory, as borne out by the ffCOD data quality issues observed during this study. For example, 44 out of the 60 samples analyzed from the selector and aerated zones recorded higher levels of ffCOD than sCOD, which is theoretically not possible, since ffCOD is a fraction of the sCOD. In this case, the sCOD data mirror the ffCOD data, suggesting little utilization within the selector during the period from late December through mid January (Figure 10).

Phosphorus data (Figure 10) substantiate a reduction in bio-P activity through January 12. During this time, selector orthophosphate was reduced from 25 mg/L to 5 mg/L, indicating very little phosphorus release.

As plant flows decreased through the end of January 2009, the pilot MLSS gradually decreased from 3,000 mg/L on January 9 to 2,000 mg/L by January 18 (Figure 8). The SVI of both pilot and control trains increased steadily over that same period, from 120 mL/g on January 9 to roughly 200 mL/g on January 20. As the selector become anaerobic, the phosphorus profile reflected a more active bio-P population. Selector orthophosphate increased from 5 mg/L on January 10 to 20 mg/L on January 20, and substrate utilization patterns (ffCOD and sCOD) demonstrated a consistent reduction from the first selector zone to the second selector zone to the aerated zone (Figure 10).

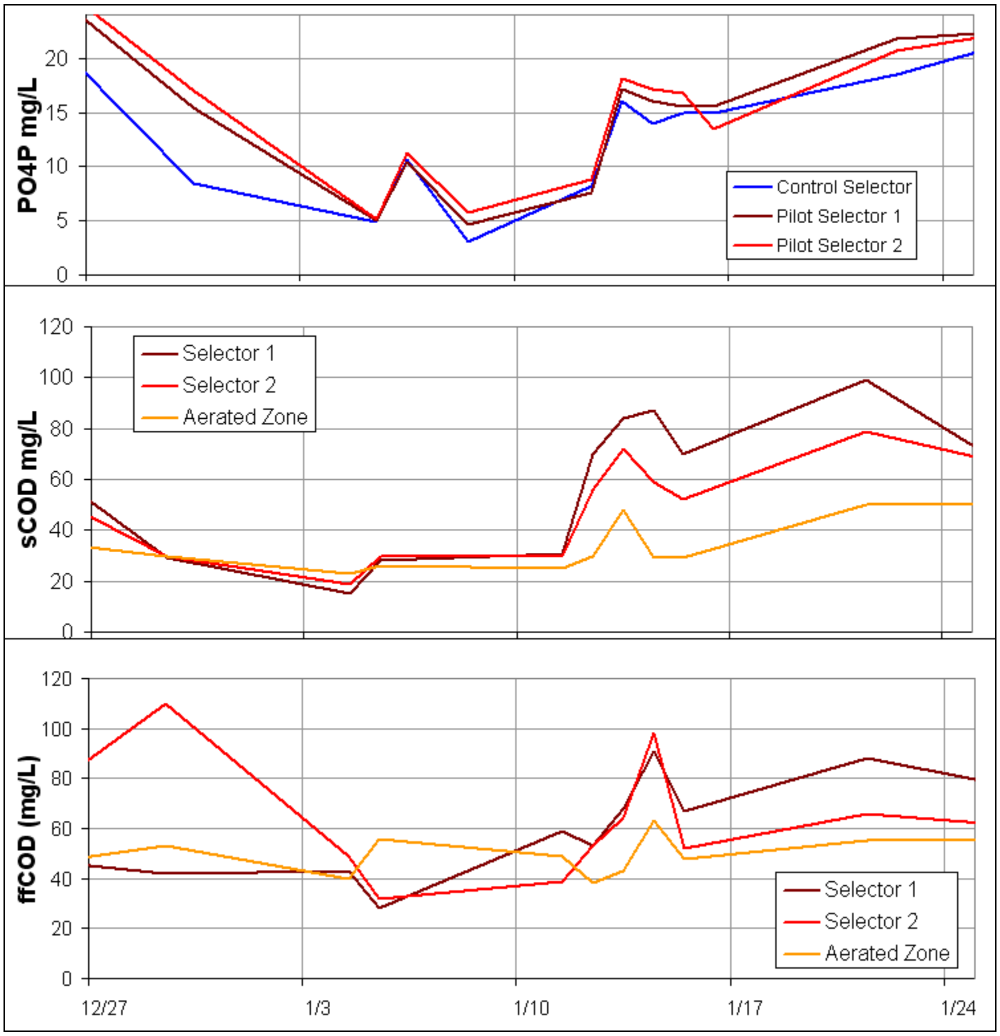


Figure 10. Early January 2009 Selector Zone Parameters

Effect of RAS Rate Increase on Pilot Performance

By the end of January 2009, a sample sent to Dr. Michael Richards was reported to have abundant bio-P organisms and a healthy filament profile. Pilot and control SVI were holding near 200 mL/g, and both SRTs were set near 3.0 days (Figure 11). Given the apparent stability of the process, a decision was made to increase the RAS flow rate in the pilot train in an effort to reduce the solids blanket in the clarifier (holding between 2-3 feet) and further stimulate the bio-P population by eliminating phosphorus release in the clarifier.

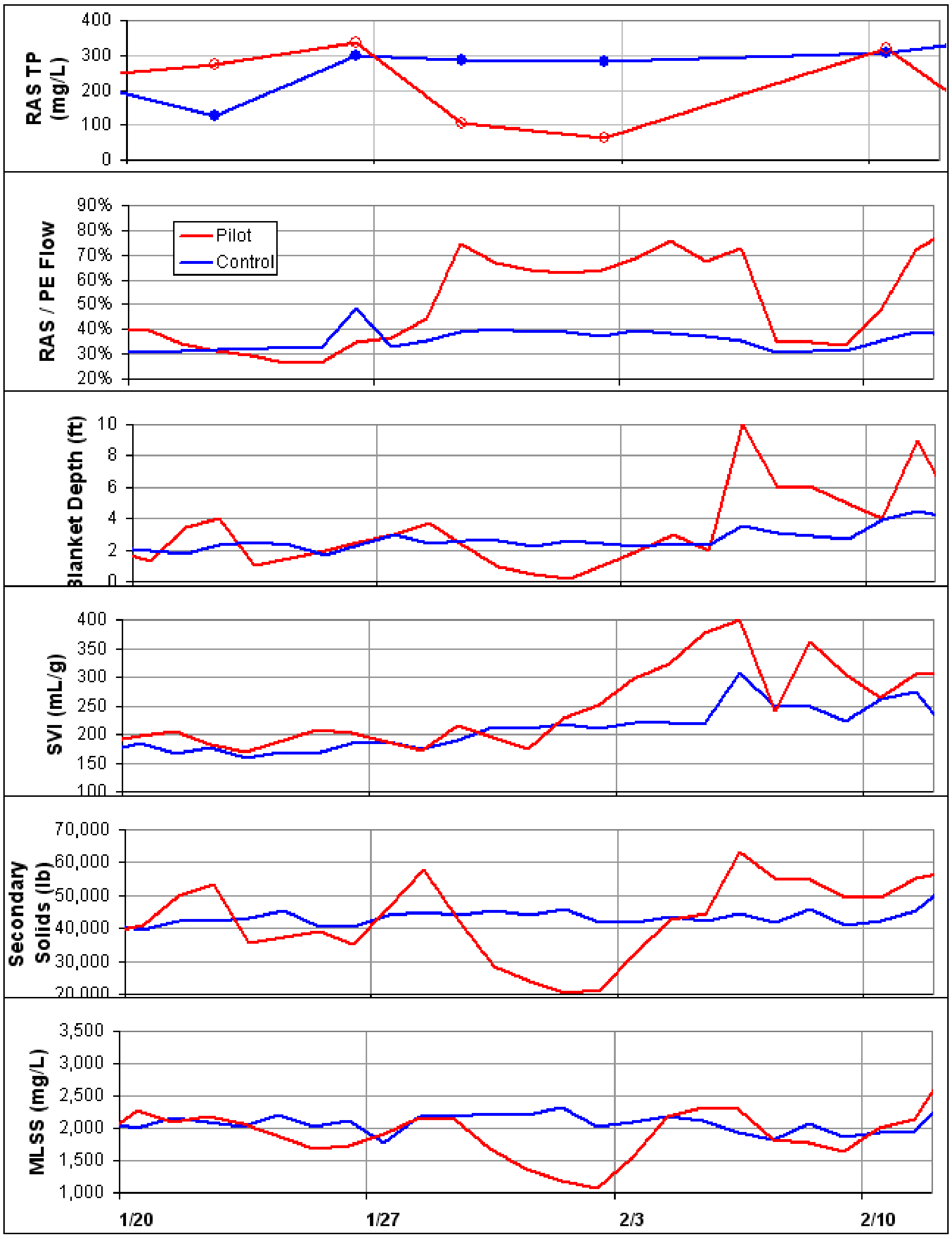


Figure 11. End of January 2008, Early February 2009 Process Parameters

Concern over phosphorus release in the clarifier was related to the phosphorus content of the RAS, which was averaging from 200 to 400 mg/L throughout late January (Figure 11). Phosphorus release in the secondary clarifier would cause a reduction in bio-P activity in the selector, as organisms returning in the RAS would already have taken up substrate. The result of this would be a reduction in selector substrate utilization and increased potential for readily biodegradable substrate release into the aerated zone, which could cause an outbreak of filamentous organisms in the basin.

The RAS flow rate in the pilot train was increased to 75 percent of pilot influent on January 29, 2009 (Figure 11). Over the next 4 days, the pilot MLSS decreased from 2,100 mg/L to 1,100 mg/L. The pilot clarifier blanket reduced from 3 feet to 0.2 feet, and the total solids in the pilot train declined from 42,000 lb to 20,000 lb. On February 1, 2009, the pilot SVI began to increase. After averaging near 200 mL/g over the previous 2 weeks in January, the SVI increased to 228 mL/g on February 1, 251 mL/g on February 2, 322 mL/g on February 4, and 400 mL/g on February 6, suggesting washout of the bio-P organisms and/or the establishment of a filament population. The calculated SRT of the pilot train remained stable between 3 to 4 days throughout this period, as active MCRT control was maintained (the pilot WAS rate was reduced in line with the reduction in MLSS).

Although the control MLSS remained relatively constant during this period, near 2,100 mg/L, the control SVI began to increase on February 6. From its baseline near 200 mL/g, the SVI increased to 307 mL/g on February 6, and then held near 250 mL/g for the next few days.

During this period, bio-P activity appeared to reduce in the pilot train (Figure 12). Selector orthophosphate decreased from 22 mg/L to 14 mg/L and final effluent orthophosphate increased from 1 mg/L to 3 mg/L, confirming the supposition that bio-P organisms were being washed out of the system. The control train continued to exhibit healthy bio-P activity at this time.

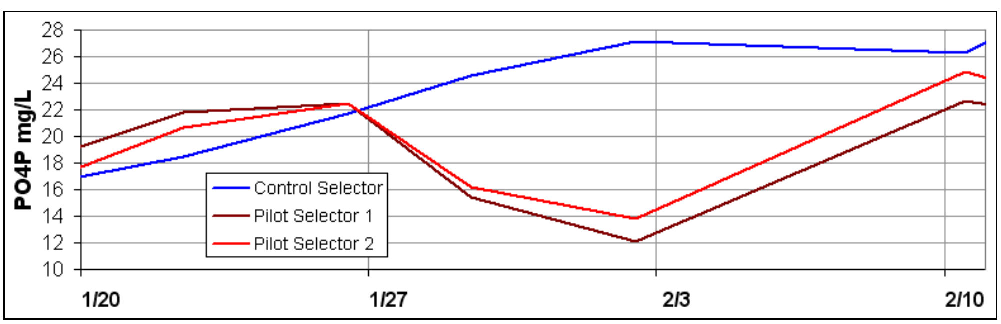


Figure 12. Early February 2009 Orthophosphate (PO4P) Profile for Selector Zones

Abnormal Influent Loading

An extended reduction in aeration basin DO concentration during February 2 through 6, 2009, suggested an abnormal loading of some kind. Figure 13 shows a decline in DO concentration in the zone downstream of the selector and in the last zone of the aeration basin.

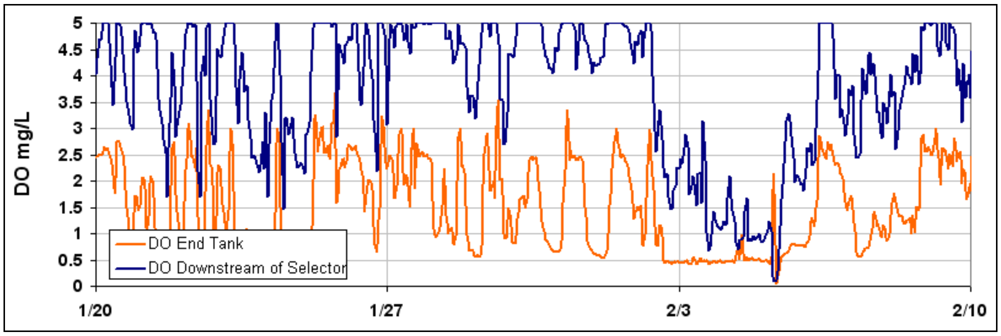


Figure 13. Early February 2009 DO Concentration Profiles, Pilot Train

Raw influent BOD increased from a baseline of 300 mg/L in the last week of January 2009 to 390, 420, 560, and 530 mg/L on February 2, 3, 4, and 5, respectively. Also, the pH of the raw influent decreased from a baseline of 7.2 to 6.8 on February 2, 4, and 6.

On February 6, 2009, staff reported heavier than normal foaming throughout the aeration basins (control and pilot), and microscopic examination was consistent with a filamentous outbreak. This condition persisted, with gradual abatement, through the middle 2 weeks of February. During this time, an effort was made to build solids in the pilot train. After bottoming out at 1,100 mg/L on February 2 (Figure 11), the pilot MLSS rebounded to 2,500 mg/L by February 12, and was maintained in the range, 2000 to 2,500 mg/L through February 23 (Figures 11 and 14).

While the pilot MLSS returned to a level similar to that observed in late January, two disturbing trends were noted in the data at this time. First, the SVI of the pilot train grew quite erratic, fluctuating between 250 to 350 mL/g, while the control SVI re-stabilized near 200 mL/g. Second, the pilot MLSS, while improving, still failed to exceed the control MLSS from the beginning of March, in spite of a reduced WAS flow rate and increased RAS flow rate.

Isolation Gate Failure during Storm

On February 23, 2009, a storm event increased flow throughout the plant, causing the failure of an isolation gate between the control and pilot trains. Solids in the pilot clarifier increased from 6,000 lb to 23,000 lb over a 2-day period (Figure 14). The WAS flow rate in the pilot train was increased in an effort to deal with the increased solids, but extremely dilute WAS solids led to very little solids being wasted, and an extremely high calculated SRT. In the aftermath of this event, bio-P activity in both the pilot and control trains reduced substantially. Selector orthophosphate decreased from 30 mg/L in both trains on February 19 to 5 mg/L on March 2 (Figure 15).

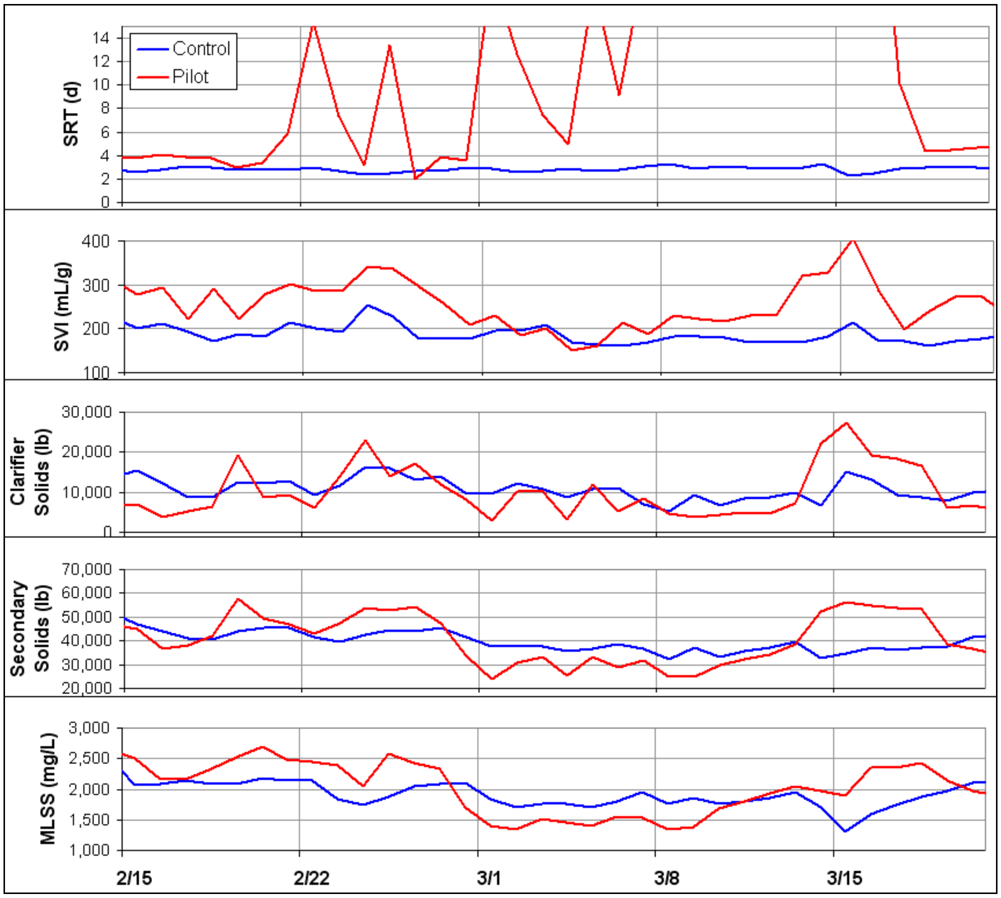


Figure 14. February/March 2009 Process Parameters

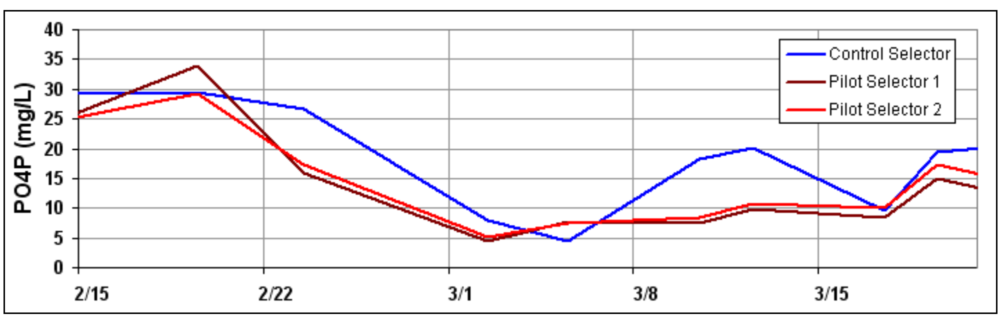


Figure 15. February/March 2009 Orthophosphate Profile in Selector Zones

On February 27, 2009, the pilot MLSS decreased from 2,500 mg/L to 1,500 mg/L, where it remained through March 10 (Figure 14). Efforts to increase the MLSS in the pilot through a reduction in WAS flow were ineffective. On March 1, the pilot WAS flow was reduced from 0.38 to 0.16 mgd. On March 7, it was reduced further to 0.06 mgd. On March 10, the pilot WAS valve was closed, and the WAS flow rate remained at zero from March 10 through March 15.

Solids Inventory Control

Several theories were proposed to explain the failure to build solids in the pilot train. These included a faulty WAS flow meter, fugitive losses into the control RAS pipeline, and process inhibition. While the WAS flow meter was never calibrated, the failure to build solids despite completely shutting off the WAS valve suggested that other factors were at play. Manual inspection of all potential cross-connections between the pilot and control RAS pipelines indicated no apparent losses, although further testing (e.g., dye testing) was not carried out. Process inhibition was ruled out as the control train continued to build solids as expected during this time frame.

The accepted explanation for the failure to build solids is related to the isolation gate between the pilot and control channels just downstream of the aeration basins. This gate "failed" on February 23, 2009, and efforts to repair this gate were ultimately unsuccessful. The gate was not designed to effect a tight seal, and staff believes that some degree of leakage was likely occurring throughout the entire trial. On February 23, the gate became unseated, with heavy leakage. Although staff was able to reseat the gate, continuing leakage could not be prevented without a gate replacement.

Leakage across the gate also appeared to be related to the static head on each side of the gate, which is related to the water surface elevation. During high plant flows, when flow to the control train exceeds flow to the pilot train, the difference in water levels on either side of the gate is thought to have induced flow from the control to the pilot train. This correlates with the repeated instances of solids build-up in the pilot clarifier during storm events. During low flow periods, when the flow to the pilot train tended to be slightly higher than flow to the control train, there appeared to have been flow from the pilot to the control train. This correlates with the inability to build solids in the pilot train. Process modeling suggested that even as little as 1 percent cross-flow between the pilot and control trains would be enough to significantly alter the SRT and MLSS of the pilot train.

By the end of March 2009, efforts to maintain a stable MLSS concentration in the pilot train by controlling the WAS flow had failed, and the pilot system was trending toward failure. Pilot SVI had increased to 400 mL/g, and the pilot clarifier effluent solids were increasing above 30 mg/L. The bio-P population in the pilot train was minimal, with selector orthophosphate values near 10 to 15 mg/L (compared to 20 mg/L in the control). The decision was made to end the test in the first week of April. Data were collected through April 9, 2009.

PROCESS SIMULATION

Throughout the trial period, biological process modeling was conducted to evaluate system performance. A BioWin model was developed and calibrated as part of the planning phase of this project. Model calibration is discussed in detail in the September 19, 2008, Technical Memorandum by Brown and Caldwell attached in Appendix E.

The model was loaded with actual flows and loadings to the aeration basin, and set up using actual process parameters (RAS flow, WAS flow, DO control) used during the trial. Model MLSS is compared with actual values in Figure 16.

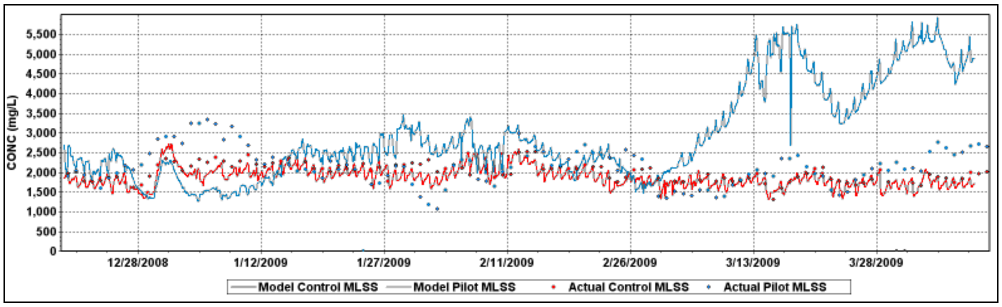


Figure 16. Model versus Observed MLSS During Pilot Trial Period

During the high flow period in late December 2008/early January 2009, the model predicted a lower pilot stream MLSS than was observed. This discrepancy appears to be the result of presumed solids transfer from control to pilot during high flows. After the isolation gate failure in late February, the model projects very high MLSS values in the pilot train (exceeding 5,500 mg/L). During this period, solids transfer appears to have occurred primarily from the pilot train to the control train, as the pilot train failed to build solids in the face of a very low wasteage rate.

The model demonstrates the impact of solids transfer on performance. When the model was adjusted to allow for 5 percent transfer of mixed liquor from the pilot to the control, commencing on February 23, 2009, the plot changes to that depicted on Figure 17. In this case, the model pilot MLSS is somewhat lower than observed values. This suggests that less than 5 percent of transfer between trains led to the severe controllability issues observed during the trial.

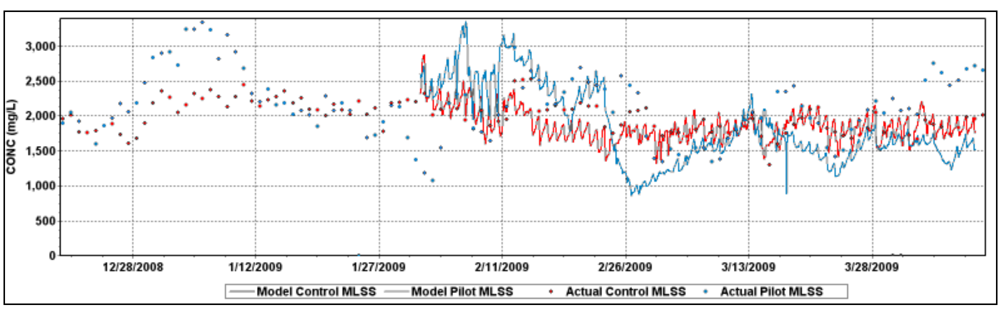


Figure 17. Model versus Observed with Five Percent Mixed Liquor Transfer from Pilot Train to Control Train

PILOT STUDY RESULTS

A plot of the SVI for the pilot and control systems throughout the entire test period is provided on Figure 18, and a plot of the respective phosphorus profiles is provided on Figure 19.

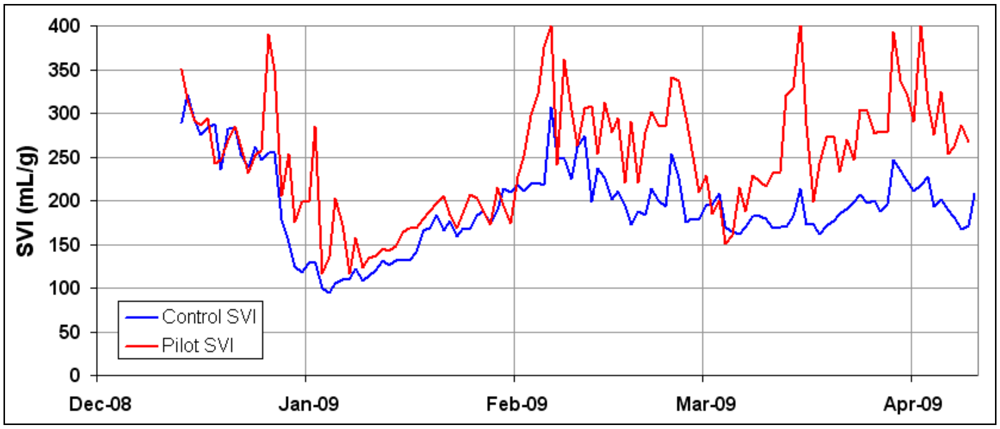


Figure 18. Pilot and Control SVI for the Entire Test Period

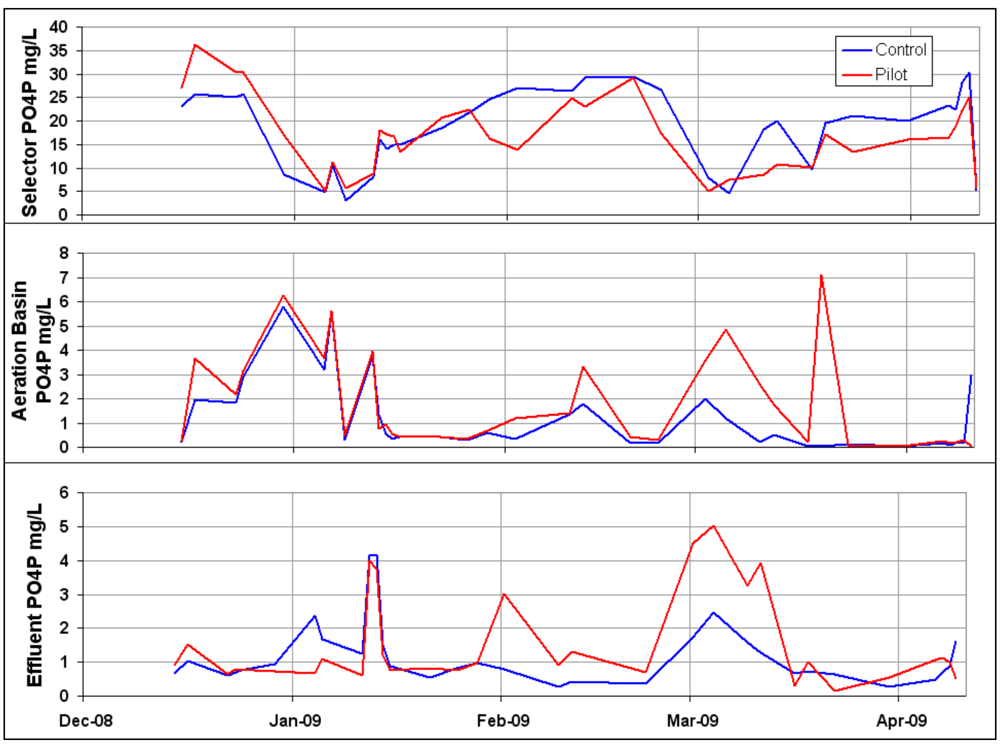


Figure 19. Pilot and Control Orthophosphate Profiles

The SVI of the pilot train was consistently higher than that of the control train, and also more erratic. Peak values reached as high as 400 mL/g, indicative of an unstable bio-P population. The orthophosphate profiles confirm this (Figure 19). Levels of orthophosphate in the selector varied from 5 mg/L to 35 mg/L, where a healthy bio-P population would be expected to generate stable levels between 20–40 mg/L. Aeration basin and effluent orthophosphate levels were also quite variable, especially in the pilot train. Effluent orthophosphate reached 3 mg/L on three occasions in the pilot train; the low phosphorus removal indicates a poorer ability to take up phosphorus in the aeration basin. Also, the higher soluble orthophosphate concentration in the final effluent compared to the aeration basin orthophosphate indicates that phosphorus release was occurring in the secondary clarifier sludge blankets for the pilot train all of the time and in the control for part of the time. Phosphorus release and uptake were stronger and more consistent in the control train.

The results suggest a weak and unstable bio-P population in the pilot train. During the test, it became clear that separation of the pilot train from the rest of the plant was very difficult to achieve. Persistent leakage across isolation gates resulted in fluctuating periods of solids loss and solids gain, which appears to be tied to the respective flow rates in each of the trains. The solids transfer between pilot and control trains made it impossible to control the SRT, and efforts to manually control solids inventory led to wide swings in operating conditions, with harmful effects on the bio-P population. The relative stability of the control train may be attributed to its larger volume, which buffered the impact of solids exchange. In fact, the control train performed quite well during this test, indicating that the small changes undertaken as part of the test (redistributed aeration downstream of selector, and operation at a slightly higher SRT) may have improved settling compared to the historical record. In the months following the test (April 11 through July 9, 2009), the 90th percentile SVI has been 196 mL/g.

Comparing SVI values during similar time frames from past years as listed in Table 1, the current achievable SVI represents the lowest 90th percentile SVI of the past 6 years.

Table 1. 90th Percentile SVI—April 11 through July 9

Year	90th Percentile SVI, mL/g
2004	208
2005	230
2006	210
2007	487
2008	229
2009	196

DISCUSSION

The goal of this project was to determine whether a set of mechanical and operational changes could improve settling at the plant. A full assessment of operational changes was not possible due to a series of problems associated with maintaining separation between the pilot and control trains during the test. Mechanical adjustments associated with process aeration, and operation of the control train at a slightly higher SRT than usual, appear to have had a positive effect on settling in the control train.

With respect to the Facilities Plan Update, the selection of a design SVI is one of the critical outcomes of this assessment. Prior to testing, an examination of the historical record suggested an inability to control settling over the long term (Figure 1). The 90th percentile SVI value is typically used for design. The 90th percentile SVI value from 2006–2008 was 405 mL/g. The maximum month SVI during that period was 441 mL/g. During the 4-month pilot study, the 90th percentile SVI for the control train was 261 mL/g, and the 90th percentile SVI for the pilot train was 321 mL/g. The lower SVI compared to the historical record is attributed to the process aeration modifications, operation at a slightly higher SRT, and the extra attention given to overall process control associated with the pilot study. After discontinuing the pilot operation, the plant has maintained an SVI less than 200 mL/g.

Accounting for some degree of process destabilization related to the pilot setup and cross-connections with the control train, long-term operation at an SVI in the range of 200 to 250 mL/g appears to be a reasonable design assumption. The strength of this assumption will be amplified if the set of recommendations detailed below are carried out. These recommendations will provide staff with more current, accurate, and reliable feedback on process control, and will improve operational control and flexibility to the point that the plant could operate with a target SVI of 200 mL/g.

FINDINGS AND CONCLUSIONS

The following findings and conclusions were derived from the pilot test:

- A full assessment of operational changes was not possible due to a series of problems associated with maintaining separation between the pilot and control trains.
- Clearly, a viable population of bio-P organisms could be grown and maintained in the CBWTP. The presence of a healthy population of bio-P organisms is essential to maintaining the integrity of the anaerobic selector.
- The contribution of a viable anaerobic selector to maintaining a stable SVI at a target of 200 mL/g was clearly demonstrated, as evidenced by improved conditions in the control trains during the test.
- Performance of the pilot train and its ability to demonstrate long-term successful implementation of anaerobic selector operation was hampered by an inability to control solids inventory.
- Modifications to process aeration and operation at a higher SRT appear to have improved mixed liquor settling in the control train.
- The true impact of these changes is likely diluted due to cross-connections between the pilot and the control trains.
- It is reasonable to assume that long-term operation at an SVI of less than 250 and as low as 200 mL/g is achievable through improved plant controllability and other modifications to the system.

RECOMMENDATIONS

The following modifications are recommended, based upon operational experience generated during this study:

- Additional aeration diffusers. Install additional aeration diffusers downstream of the selector in all basins. Aeration will help prevent low-DO bulking. When the oxygen supply in the post-selector zone is limited, it favors the growth of filamentous organisms, which preferentially degrade readily biodegradable substrate escaping from the selector. Supplementing aeration in this area will help prevent such an occurrence. This is especially important as data collected during the pilot study suggested exactly such an outbreak during the first week of February 2009, when the plant experienced an unusually high strength influent load.

- Baffle wall. Install an intermediate baffle to divide the selector into two zones in all basins. During the pilot study, there were periods where the ORP in the first zone of the pilot selector became aerobic. Installation of an intermediate baffle, as was done in the pilot train, ensures that at least a portion of the selector remains anaerobic most of the time. This is particularly important during and after storm events. Maintaining anaerobic conditions provides a competitive advantage to the bio-P organisms the selector aims to grow.

- In-line solids concentration sensors for the MLSS and WAS streams. These will allow for better control of the system, giving operators a real-time estimate of the sludge inventory and therefore of the SRT. This would allow for the automatic control of the wasting rate based on a target SRT.

- Automated solids wasteage. The WAS valves and flow meters should be calibrated to respond to a real-time calculation of SRT based on in-line solids and flow data. This will allow for improved and up-to-the-minute process control, giving operators more leverage to control the system based on changes in loading or Plant conditions.

- Daily total and soluble COD measurement of the primary effluent. COD can be analyzed within three hours of sampling, providing operators with same-day estimates of the food-to-microorganisms ratio (a key operational parameter), as well as allowing for same-day response to slug loads of highly concentrated waste streams. During testing, at least two such incidents provoked destabilization of the process with long-lasting impacts.

- Measurement of daily total and soluble effluent COD in concert with the influent COD measurements would allow measurement of the readily biodegradable COD fraction that is required for inducing the selector effect.

- Permanent dissolved oxygen sensors downstream of the selector. Failure to provide sufficient oxygen in this area is linked to filamentous bacteria outbreaks, which impair mixed liquor settling.

- Automated DO control. During the trial, large fluctuations in DO concentration across the aeration tank were noted. In part, this appeared to be related to large changes in influent loading which may be attributed to the large industrial flow component to this Plant. Automated DO control will allow the aeration system to react in real-time to loading changes. This will limit the occurrence of low DO concentration periods associated with filamentous outbreaks and poor settling, and will also limit the waste of energy associated with oversupply during low load periods.

- Permanent ORP sensor in the selector. The ORP meters can be used to assess the strength of the bioP population, allowing operators to manage the SRT accordingly.

- Regular phosphorus profiling across the secondary system. Phosphorus profiles can gauge the strength of the bioP population, and also give evidence of harmful phosphorus release in the secondary clarifier blanket.

- Operation at a higher SRT. With improved aeration downstream of the selector, the risk of filament outbreak is reduced, allowing for more flexibility in operating at higher SRTs. The secondary processes should be operated near a 2.5 to 3.5 day SRT in order to ensure the viability of the bioP population, the value adjusted according to season of operation.

- Operation with a minimal clarifier solids blanket. Efforts should be made to prevent the formation of deep clarifier solids blankets. Blanket depth of no more than 1-2 feet should be a goal, in order to prevent premature phosphorus release by the bioP population.

- RAS valves. Renovate the RAS return system with valve replacement and automation. The existing RAS valves are corroded. RAS control was impeded by the condition of the RAS valves and RAS could not be returned to the entrance to each train. This would allow decoupling the RAS flow from the primary effluent flow and provide more RAS capacity.

Additional Recommendations

Additional recommendations are included in Appendix G. These recommendations were not tested as part of the pilot testing but resulted from observations and/or additional recommendations based on the pilot test findings.

APPENDIX A

Special Sampling Data

Table A-1. Primary Effluent

Date	TSS	VSS	COD	SCOD	ffCOD	VFA	BOD	TKN	NH_3-N	NO_2-N	NO_3-N	TOT-P	PO_4P	Alkalinity
12/14/2008	144	132	360	100	88		260	44.7	37.3	0.15	<0.10	8.07	6.62	
12/15/2008														
12/16/2008				190								7.25	5.58	
12/22/2008			320	140				37.8	29.7	0.56	<0.10	6.75	5.26	
12/23/2008	82	74		160								6.49	5.13	
12/29/2008			190	71	54				10.7	0.43			2.15	
1/4/2009	93	69	220	80	43	3.35	110	26.8	20.8	0.69	0.73	4.92	4.1	119
1/5/2009			300	100	71		142					5.21	3.77	118
1/11/2009	115	102	310	130	86			33.1	26.7	0.17	0.30	6	4.48	156
1/12/2009			350	150	96		182					7.44	5.71	170
1/13/2009	99	85	400	210	120		200	38.9	32.1	0.096	<0.10	6.77	5.14	173
1/14/2009			440	190	130		275					5.97	4.1	162
1/15/2009	167	148	450	220	130		260	36.5		0.032	<0.10	5.61	3.6	160
1/21/2009	168	140	480	190	140		275	54.2	39.9	0.026	<0.10	9.41	6.53	200
1/25/2009				160								6.93	5.17	
1/28/2009	156	130	440	160	120		205	48.9	36.5	0.051	<0.10	9.09	6.58	195
2/1/2009				180								9.78	8.11	
2/9/2009	110	97	430	160	140		240	56.1	40	0.025	<0.10	9.58	7.35	200
2/11/2009				180								7.65	6.53	
2/18/2009	74	67	430	190	170		188		40.7	0.014	<0.10	10.2	7.35	202
2/22/2009	105	101	360	160	120		202		38.6	0.011	<0.10	8.21	6.81	192
3/1/2009	120	100	330	140	83		176		28.6	0.072	0.11	6.81	5.02	152
3/4/2009				240								9.37	7.42	
3/9/2009	83	72	360	150	92		164	37.7	28.4	0.099	0.16	6.12	4.66	155
3/11/2009				240								8.13	5.83	
3/16/2009	88	66	280	96	67		126	26.6	19.1	0.11	0.56	4.02	2.94	108
3/18/2009				210								7	5.75	
3/22/2009	90	76	300	100	69		154	41.2	31.4	0.038	<0.10	6.94	5.4	169
3/30/2009	104	93	360	150	110		195	39.5	27.5	0.072	<0.10	6.17	4.39	161
4/5/2009	95	83	380	170	100	<50	193	44.2	32.2	<0.010	<0.10	6.96	5.32	174
4/6/2009			420	200	120		210					7.52	5.66	181
4/7/2009	90	81	470	220	130		205	60.9	45.6	0.016	<0.10	9.9	8.38	226
4/8/2009			460	220	130		212					11.4	9.49	226
4/9/2009	154	138	430	190	120	30	178	35.4	25.6	0.052	0.17	7.06	5.12	138

Table A-2. Control Train

	Selector 1		Oxic 2				Secondary Effluent								RAS			
Date	TP	PO4P	TSS	VSS	PO4P	TP	TSS	VSS	cBOD	NH_3N	NO_2N	NO_3N	TP	PO_4P	TSS	VSS	TP	PO4P
12/14/2008							27	24		17.4	0.023	0	1.54	0.66				
12/15/2008	47.3	23	1,340	1,080	0.23	52	15	13							8,800	6,940	289	40.1
12/16/2008			1,370	1,140			14	12					1.55	1.03	8,480	6,930		
12/17/2008	46.7	25.7	1,450	1,180	1.94	54.2	10	9							8,110	6,430	317	36.6
12/18/2008			1,630	1,310			17	14							8,970	6,760		
12/19/2008			1,430	1,160			16	16							10,500	8,540		
12/20/2008			1,490	1,250			12	12							9,060	7,480		
12/21/2008			1,420	1,210			12	10							8,120	6,790		
12/22/2008							10	8		27.5	0.089	0	0.93	0.6				
12/23/2008	45.3	25	1,380	1,170	1.83	58.6									7,320	6,160	309	42.7
12/24/2008		25.8			2.89									0.77				51.9
12/29/2008										12.1				0.94				
12/30/2008		8.51			5.77													34.4
1/4/2009							15	12	12	19.8	0.023	<0.10	2.64	2.37				
1/5/2009	41.7	4.88	1,990	1,300	3.21	45.1	20	14					2.14	1.68	6,460	4,240	123	14.5
1/6/2009	47.5	10.6	2,270	1,540	5.59	51.4	26	20							8,600	5,740	74	30.8
1/7/2009			1,960	1,370											10,500	7,220		
1/8/2009		3.09			0.29										9,400	6,450		
1/9/2009							27	24										
1/10/2009			1,820	1,320											11,100	7,850		
1/11/2009			1,770	1,330			26	23	13	25.1	0.019	<0.10	2.21	1.26	10,400	7,700		
1/12/2009	56.3	8.23	1,680	1,310	3.76	49	20	18					4.87	4.15	9,440	7,180	271	57.2
1/13/2009	44.5	16	1,730	1,350	1.35	50.5	89	85	17	27.6	0.088	<0.10	4.38	4.17	9,870	7,570	295	56.3
1/14/2009	41.4	14	1,820	1,420	0.56	51	29	25					2.19	1.51	10,400	8,200	294	55.7
1/15/2009	44.4	15	1,760	1,380	0.36	51.7	24	21	12	23.1	0.019	<0.10	2.09	0.87	10,100	7,840	341	65.8
1/16/2009	40.7	14.9	1,690	1,360	0.41	52	23	20							8,950	6,860	276	19.2
1/17/2009			1,580	1,290			92	83							10,000	8,230		
1/18/2009			1,510	1,250											9,110	7,400		
1/21/2009							40	34	13	26.6	0.043	<0.10	3.74	0.54				
1/22/2009	48.9	18.5	1,780	1,430	0.44	60.3	46	39							8,330	6,680	128	36.3
1/23/2009			1,560	1,260			52	48							8,360	6,710		
1/24/2009			1,680	1,360			25	21							8,590	6,900		
1/25/2009			1,550	1,240			81	77					2.01	0.83	7,990	6,400		
1/26/2009	49.5	21.7	1,730	1,400	0.3	72.4	36	32							7,730	6,220	297	22.4
1/27/2009			1,550	1,300			31	27							8,250	6,600		
1/28/2009			1,710	1,420			100	91	49	25.1	0.025	<0.10	3.02	0.97	8,040	6,570		
1/29/2009	59.4	24.6	1,910	1,580	0.59	84.2	44	40							7,450	6,110	287	32.6
1/30/2009			1,850	1,510			26	24							8,710	7,150		
1/31/2009			1,690	1,380			22	22							7,460	6,050		
2/1/2009			2,070	1,660			18	18					1.52	0.79	7,230	5,910		

Table A-2. Control Train

	Selector 1		Oxic 2				Secondary Effluent								RAS			
Date	TP	PO4P	TSS	VSS	PO4P	TP	TSS	VSS	cBOD	NH_3N	NO_2N	NO_3N	TP	PO_4P	TSS	VSS	TP	PO4P
2/2/2009	56.6	27.1	1,620	1,270	0.35	72.1	20	17							7,520	6,050	284	29
2/3/2009			1,500	1,370			56	51							6,950	6,070		
2/4/2009			1,510	1,340			72	66							6,330	5,410		
2/5/2009							34	29										
2/6/2009			1,810	1,550			71	63							5,110	4,380		
2/7/2009			1,580	1,310			38	33							7,900	6,630		
2/8/2009			1,510	1,250			26	22							7,870	6,430		
2/9/2009			1,450	1,150			42	37	19	31.3	0.041	0.18	1.72	0.27	7,570	6,120		
2/10/2009	53.1	26.3	1,550	1,260	1.37	68.6	51	44							7,460	6,150	309	37.5
2/11/2009			1,640	1,350			52	47					2.25	0.43	5,900	4,880		
2/12/2009	69.7	29.3	1,850	1,480	1.78	71.3	32	29							8,450	6,720	334	28.2
2/13/2009			1,900	1,560			28	25							7,600	6,210		
2/14/2009			2,070	1,640			53	48							8,720	7,010		
2/15/2009			1,700	1,350			36	32							7,290	5,890		
2/16/2009			1,540	1,240			45	40							6,790	5,520		
2/17/2009			1,700	1,380			18	18							9,730	7,840		
2/18/2009			1,630	1,320											6,490	5,230		
2/19/2009	62.9	29.5	1,620	1,300	0.18	73.6									8,060	6,510	383	37.1
2/20/2009			1,660	1,330											7,510	6,070		
2/21/2009			1,670	1,330			32	29							7,250	5,810		
2/22/2009			1,950	1,670			29	26	7	29	0.032	0.13	1.56	0.38	6,970	5,710		
2/23/2009	61.4	26.7	1,380	1,130	0.18	72.7	16	16							5,280	4,550	298	20.7
2/24/2009			1,450	1,150			16	13							4,490	3,570		
2/25/2009			1,520	1,130			20	18							5,320	4,060		
2/26/2009			1,810	1,400			24	22							6,070	4,690		
2/27/2009			1,580	1,240			64	61							6,630	5,160		
2/28/2009			2,260	1,790			19	19							5,230	4,130		
3/1/2009			1,950	1,560			29	26	15	27.8	0.025	<0.10	2.58	1.75	6,830	5,520		
3/2/2009	66.4	7.89	1,580	1,290	2.02	54	25	23							5,000	4,150	175	21.1
3/3/2009			1,740	1,400			21	17							5,070	4,130		
3/4/2009			1,600	1,270			21	19					3.16	2.48	6,550	5,170		
3/5/2009	62.3	4.56	1,830	1,480	1.18	60.5	19	19							6,270	5,010	177	27.2
3/6/2009			2,000	1,630			12	12							6,900	5,630		
3/7/2009			1,820	1,500			10	10							6,740	5,510		
3/8/2009			1,740	1,450			9	9							6,190	5,110		
3/9/2009			1,710	1,450			11	10	8	27.7	<0.010	<0.10	2.13	1.57	6,420	5,380		
3/10/2009	73.3	18.2	1,820	1,510	0.23	73.3	12	10							6,330	5,310	230	25
3/11/2009			1,740	1,520			10	8					2.14	1.27	6,240	5,390		
3/12/2009	64.9	20.1	1,850	1,600	0.53	67.1	12	11							6,730	5,750	233	34.9
3/13/2009			1,930	1,630			14	12							6,930	5,910		

Table A-2. Control Train

	Selector 1		Oxic 2				Secondary Effluent								RAS			
Date	TP	PO4P	TSS	VSS	PO4P	TP	TSS	VSS	cBOD	NH_3N	NO_2N	NO_3N	TP	PO_4P	TSS	VSS	TP	PO4P
3/14/2009			1,600	1,360			18	15							6,570	5,510		
3/15/2009			1,240	1,090			20	16							5,060	4,370		
3/16/2009			1,640	1,360			20	16	12	16.7	<0.010	<0.10	1.39	0.68	7,070	5,850		
3/17/2009	52.5	9.68	1,880	1,500	0.051	53.4	20	16							5,670	4,530	156	18
3/18/2009			2,040	1,620			16	13					1.29	0.72	7,000	5,570		
3/19/2009	62.2	19.5	2,150	1,720	0.062	69.9	18	16							7,870	6,300	248	37.2
3/20/2009			2,260	1,880			16	13							7,680	6,330		
3/21/2009			1,980	1,640			14	12							6,620	5,520		
3/22/2009			1,760	1,470			12	10	6	29.6	0.015	<0.10	1.13	0.64	6,280	5,270		
3/23/2009	69.6	21.1	1,410	1,180	0.11	58.4	16	13							1,770	1,520	71.7	0.57
3/24/2009			1,800	1,500			11	10							6,110	5,120		
3/25/2009			1,750	1,470			21	18							6,280	5,410		
3/26/2009			1,860	1,590			10	8							6,890	5,900		
3/27/2009			1,870	1,600			11	10							6,670	6,290		
3/28/2009			1,900	1,640			24	21							6,600	5,680		
3/29/2009			1,730	1,460			11	9							5,460	4,650		
3/30/2009			1,910	1,580			10	8	4	25.5	0.016	<0.10	0.72	0.27	6,520	5,520		
3/31/2009	64.8	19.9	1,590	1,340	0.033	58.3	10	9							5,780	4,870	254	28
4/1/2009			1,790	1,550			14	7							6,140	5,320		
4/2/2009			1,600	1,350			16	10							5,000	4,220		
4/3/2009			1,900	1,600			12	10							5,540	4,650		
4/4/2009							10	7										
4/5/2009			1,720	1,470											5,780	5,020		
4/6/2009	66.5	23.4	1,690	1,480	0.15	65.4	9	8	9	29.1	0.013	<0.10	1.03	0.49	6,080	5,240	236	22.7
4/7/2009	61.9	22.4	1,660	1,420	0.088	64.4	12	10	7		0.031	<0.10	1.27	0.71	5,650	4,880	206	21.8
4/8/2009	80.4	28.1	1,890	1,630	0.22	79	11	10					1.43	0.89	6,380	5,490	269	32.9
4/9/2009	84.5	30.4	1,830	1,570	0.17		13	11			0.012	<0.10		1.6	5,720	4,900	285	29.5
4/10/2009		5.19	1,910	1,610	2.97										4,260	3,600		16

Table A-3. Pilot Train

Pilot	Selector 1					Selector 2					Oxic 1				Oxic 2		
Date	sCOD	ffCOD	PO4P	TP	VFA	sCOD	ffCOD	PO4P	TP	VFA	sCOD	ffCOD	VFA	PO4P	TP	TSS	VSS
12/14/2008																	
12/15/2008	36	45	31.8	72.7		37	42	27	73.5		29	35		0.25	63.3	1,550	1,270
12/16/2008																1,760	1,470
12/17/2008	80		37.9			60		36.2			39			3.66		1,920	1,610
12/18/2008																1,780	1,440
12/19/2008																1,730	1,450
12/20/2008																1,820	1,540
12/21/2008																1,770	1,490
12/22/2008																	
12/23/2008	46	51	29.6			50	47	30.4			32	41		2.18		1,550	1,310
12/24/2008	82		29.3			67		30.3			38			3.15		1,510	1,320
12/29/2008																	
12/30/2008	29	42	15.4			30	110	17			30	53		6.25			
1/4/2009																	
1/5/2009	15	43	5.02	92	4.58	19	49	5.14	85.3	2.51	23	40	2.43	3.66	84.7	3,240	2,030
1/6/2009	28	28	10.4	88.5		30	32	11.3	90.5		26	56		5.63	94.2	3,100	2,000
1/7/2009																2,480	1,670
1/8/2009			4.68					5.7						0.48			
1/9/2009																	
1/10/2009																2,380	1,710
1/11/2009																2,170	1,590
1/12/2009	31	59	7.55	174		30	39	8.83	67.2		25	49		3.96	65.3	2,200	1,640
1/13/2009	70	53	17.2	62.7		56	53	18.1	60.8		30	38		0.75	66.8	2,380	1,840
1/14/2009	84	68	16.1	65.9		72	64	17.2	67		48	43		0.92	66.9	2,380	1,870
1/15/2009	87	91	15.5	64.2		59	98	16.8	61.6		29	63		0.57	62.9	2,230	1,760
1/16/2009	70	67	15.6	57.9		52	52	13.5	62.5		29	48		0.41	62.6	2,020	1,610
1/17/2009																1,930	1,580
1/18/2009																1,790	1,500
1/21/2009																	
1/22/2009	99	88	21.8	71.7		79	66	20.7	70.6		50	55		0.42	68.5	2,060	1,690
1/23/2009																1,890	1,550
1/24/2009																1,850	1,520
1/25/2009																1,610	1,320
1/26/2009	70		22.5	97.1		68		22.5	66		50			0.33	69.7	1,720	1,410
1/27/2009																1,780	1,460
1/28/2009																1,830	1,520
1/29/2009	72	71	15.4	77.9		63	59	16.2	76		49	56		0.68	85.5	1,830	1,540
1/30/2009																1,420	1,190
1/31/2009																1,090	954
2/1/2009																1,110	934

Table A-3. Pilot Train

Pilot	Selector 1					Selector 2					Oxic 1				Oxic 2		
Date	sCOD	ffCOD	PO4P	TP	VFA	sCOD	ffCOD	PO4P	TP	VFA	sCOD	ffCOD	VFA	PO4P	TP	TSS	VSS
2/2/2009	75		12.1	39.7		65		13.8	41.9		42			1.2	43.1	1,050	894
2/3/2009																1,370	1,250
2/4/2009																1,800	1,670
2/5/2009																	
2/6/2009																2,000	1,740
2/7/2009																1,630	1,410
2/8/2009																1,670	1,430
2/9/2009																1,590	1,310
2/10/2009	79	56	22.7	70.7		67	60	24.9	74.8		44	46		1.4	79.2	1,740	1,430
2/11/2009																2,010	1,650
2/12/2009	57		21.7	115		49		23.1			32			3.34	98.7	2,670	2,130
2/13/2009																2,100	1,730
2/14/2009																2,170	1,760
2/15/2009																2,140	1,730
2/16/2009																1,970	1,620
2/17/2009																1,940	1,580
2/18/2009																2,130	1,740
2/19/2009	80	88	34	115		59	81	29.3	134		36	63		0.44	90	2,160	1,730
2/20/2009																2,440	1,980
2/21/2009																2,300	1,850
2/22/2009																1,470	1,230
2/23/2009		74	15.9	99.2			260	17.3	145		30	190		0.31	96.7	2,110	1,730
2/24/2009																1,780	1,460
2/25/2009	46					46										2,530	1,920
2/26/2009																2,370	1,770
2/27/2009																2,090	1,670
2/28/2009																1,750	1,420
3/1/2009																1,300	1,080
3/2/2009	49	79	4.39	35.7		50	49	5.1	33.8		47	53		3.58	35	1,210	1,020
3/3/2009																1,440	1,190
3/4/2009																2,320	1,850
3/5/2009	95		7.78	37.3		89		7.56	39.8		57			4.85	43.6	1,380	1,160
3/6/2009																1,490	1,220
3/7/2009																1,470	1,220
3/8/2009																1,340	1,120
3/9/2009																1,320	1,120
3/10/2009	67	77	7.43	40		63	86	8.51	45		37	48		2.6	45.7	1,560	1,310
3/11/2009																1,650	1,420
3/12/2009	100		9.78	49.5		86		10.7	48		46			1.73	45.5	1,790	1,560
3/13/2009																1,970	1,710

Table A-3. Pilot Train

Pilot	Selector 1					Selector 2					Oxic 1				Oxic 2		
Date	sCOD	ffCOD	PO4P	TP	VFA	sCOD	ffCOD	PO4P	TP	VFA	sCOD	ffCOD	VFA	PO4P	TP	TSS	VSS
3/14/2009																1,780	1,510
3/15/2009																1,780	1,480
3/16/2009																2,360	2,000
3/17/2009	39	91	8.46	62.8		39	97	10.1	64.8		28	59		0.2	59.7	2,040	1,700
3/18/2009																2,520	2,030
3/19/2009	78		14.9	67.7		68		17.2	67.4		47			7.11	71.3	2,270	1,830
3/20/2009																2,030	1,700
3/21/2009																1,860	1,560
3/22/2009																1,540	1,310
3/23/2009	38	40	10.9	60.3		37	44	13.3	59.7		28	44		0.1	84.1	2,150	1,780
3/24/2009																1,340	1,140
3/25/2009																1,680	1,430
3/26/2009																1,850	1,600
3/27/2009																2,050	1,780
3/28/2009																2,070	1,780
3/29/2009																1,750	1,490
3/30/2009																2,180	1,830
3/31/2009	48	250	14.4	75.5		45	200	16	69.9		33	280		0.052	77.4	2,020	1,780
4/1/2009																2,090	1,860
4/2/2009																1,690	1,450
4/3/2009																2,370	2,000
4/4/2009																	
4/5/2009																2,350	1,990
4/6/2009								16.4	90.5					0.25	78.1	2,400	2,040
4/7/2009								18.8	91.1					0.19	78.6	2,570	2,160
4/8/2009								22.1	111					0.21	94.2	2,420	2,070
4/9/2009								25	67.6					0.31	99	2,220	1,920
4/10/2009								5.71	94.5					0.023		2,270	1,900

Table A-4. Pilot Train

	Secondary Effluent								RAS			
Date	NH3N	cBOD	NO3N	NO2N	PO4P	TP	TSS	VSS	PO4P	TP	TSS	VSS
12/14/2008			0	0.03	0.9	1.25	6	6				
12/15/2008							15	12	42.6	338	8,740	6,920
12/16/2008			0	0.031	1.52		12	10			9,160	7,320
12/17/2008							8	8	41.4		9,720	7,980
12/18/2008							7	6			8,080	5,940
12/19/2008							9	8			9,040	7,460
12/20/2008							10	9			8,340	7,180
12/21/2008							10	9			8,200	6,880
12/22/2008			0	0.084	0.65		9	8				
12/23/2008			0	0.031	0.78		10	8	42		8,240	6,960
12/24/2008									47.7			
12/29/2008				0.011	0.72							
12/30/2008									22.2			
1/4/2009	19.7	8	<0.10	0.016	0.68	1.01	13	10				
1/5/2009					1.11	1.69	14	11	13.8	156	7,360	4,690
1/6/2009							16	11	23	88.6	7,580	4,920
1/7/2009							8	6			7,360	4,960
1/8/2009											7,190	4,920
1/9/2009							11	9				
1/10/2009											9,660	6,780
1/11/2009	25.7	8	<0.10	0.072	0.61	0.98	14	12			8,290	6,020
1/12/2009					3.99	4.55	19	16	36.4	218	7,600	5,750
1/13/2009	28	6	<0.10	0.017	3.74	3.33	19	15	36.9	256	8,660	6,630
1/14/2009					1.23	1.94	27	22	45	263	9,940	7,720
1/15/2009	19.9	17	<0.10	0.02	0.77	1.56	29	24	18.1	205	7,100	5,560
1/16/2009							26	21	11.4	218	7,120	5,790
1/17/2009							15	14			7,590	6,310
1/18/2009											7,530	6,270
1/21/2009	28.7	10	<0.10	0.011	0.82	1.59	20	16				
1/22/2009							24	19	32.7	274	9,690	7,910
1/23/2009							24	20			9,130	7,500
1/24/2009							23	20			9,360	7,030
1/25/2009			<0.10	<0.010	0.76	1.53	18	15			9,150	7,530
1/26/2009							20	16	24.2	337	9,290	7,630
1/27/2009							22	17			8,950	7,190
1/28/2009	25.9	8	<0.10	0.014	0.97	2.02	19	15			9,150	7,470
1/29/2009							22	20	14.2	106	2,850	2,430
1/30/2009							22	21			1,830	1,600
1/31/2009							24	22			2,200	1,990
2/1/2009			<0.10	<0.010	3.01	3.93	26	22			1,900	1,650

Table A-4. Pilot Train

	Secondary Effluent								RAS			
Date	NH3N	cBOD	NO3N	NO2N	PO4P	TP	TSS	VSS	PO4P	TP	TSS	VSS
2/2/2009							25	22	12.2	63.2	1,850	1,610
2/3/2009							33	29			2,980	2,720
2/4/2009							20	18			3,380	3,070
2/5/2009							24	21				
2/6/2009							15	13			4,410	3,910
2/7/2009							19	17			8,170	7,110
2/8/2009							15	14			7,810	6,720
2/9/2009	33.4	10	<0.10	0.018	0.9		16	12			7,010	5,950
2/10/2009							12	11	37.6	318	8,070	6,760
2/11/2009			<0.10	0.025	1.32	1.89	12	9			4,460	3,730
2/12/2009							14	12	14	178	5,010	4,060
2/13/2009							12	12			4,370	3,680
2/14/2009							14	12			3,610	2,960
2/15/2009							12	10			3,580	2,960
2/16/2009							12	10			3,050	2,520
2/17/2009							11	11			2,750	2,320
2/18/2009											4,030	3,310
2/19/2009									33.2	335	7,670	6,280
2/20/2009											3,940	3,240
2/21/2009							9	9			3,800	3,100
2/22/2009	34.8	4	<0.10	0.012	0.71	1.28	9	9			3,320	2,860
2/23/2009							8	7	6.87	147	3,220	2,790
2/24/2009							6	6			3,730	3,050
2/25/2009							7	6			4,260	3,240
2/26/2009							9	8			4,310	3,430
2/27/2009							17	14			3,310	2,640
2/28/2009							16	15			3,250	2,630
3/1/2009	32.3	20	<0.10	0.023	4.5	4.99	19	18			1,690	1,430
3/2/2009							19	18	13.6	118	3,050	2,590
3/3/2009							22	20			3,880	3,210
3/4/2009			<0.10	<.01	5.02	5.61	54	50			1,300	1,100
3/5/2009							36	33	8.64	52.2	2,740	2,300
3/6/2009							22	22			2,620	2,160
3/7/2009							22	22			2,280	1,900
3/8/2009							17	17			2,840	2,400
3/9/2009	26.5	9	<0.10	0.018	3.26	3.85	16	14			1,800	1,530
3/10/2009							15	14	15.5	83.9	3,040	2,580
3/11/2009			0.40	0.056	3.94	4.99	22	20			2,740	2,360
3/12/2009							24	22	16.8	87.5	3,100	2,760
3/13/2009							24	22			3,670	3,200

Table A-4. Pilot Train

	Secondary Effluent								RAS			
Date	NH3N	cBOD	NO3N	NO2N	PO4P	TP	TSS	VSS	PO4P	TP	TSS	VSS
3/14/2009							18	16			9,150	7,800
3/15/2009							13	11			5,320	4,440
3/16/2009	16.6	5	<0.10	0.013	0.31	0.6	10	8			5,160	4,400
3/17/2009							10	9	13.6	146	5,200	4,260
3/18/2009			<0.10	0.035	1.02	1.33	10	10			4,680	3,810
3/19/2009							21	18	15.3	123	4,280	3,470
3/20/2009							20	16			3,240	2,700
3/21/2009							14	12			2,760	2,320
3/22/2009	29.6	7	0.17	0.052	0.15	0.71	13	10			2,160	1,880
3/23/2009							18	16	29	218	7,240	5,920
3/24/2009							12	9			2,560	2,190
3/25/2009							14	12			2,750	2,330
3/26/2009							13	10			3,450	3,020
3/27/2009							12	10			3,680	3,160
3/28/2009							10	9			3,660	3,160
3/29/2009							8	7			4,470	3,780
3/30/2009	26.5	<6	0.14	0.062	0.54	0.89	9	8			3,790	3,220
3/31/2009							10	9	11.8	152	3,780	3,250
4/1/2009							52	41			3,560	3,230
4/2/2009							32	25			3,740	3,220
4/3/2009							12	9			4,480	3,820
4/4/2009							12	9				
4/5/2009											4,460	3,800
4/6/2009	27.2	9	0.24	0.16	1.06	1.78	16	15	8.5	143	4,320	3,680
4/7/2009		5	0.61	0.23	1.14	1.55	12	11	9.6	142	4,500	3,830
4/8/2009					1.01	1.53	13	12	18.1	183	4,840	4,160
4/9/2009			<0.10	0.076	0.51		8	8	13.4	180	4,180	3,620
4/10/2009									8.54		3,820	3,260

APPENDIX B

Monitor Data (24-hour averages)

Table B-1. Monitoring Data (24-Hour Averages)

	Pilot flow, mgd	Total flow, mgd	Pilot flow/ total flow	Pilot RAS, mgd	Temp, °C	DO oxic 1, mg/L	ORP selector 1	ORP selector 2	DO selector 1, mg/L	Pilot RAS/ pilot flow	Pilot WAS, gpm	DO end tank, mg/L
12/20/08	7.6	52.1	14.5%	2.71	16.1	4.3	-261	-276	0.0	35%		
12/21/08	7.6	52.1	14.6%	2.61	15.6	4.0	-296	-268	0.0	33%		
12/22/08	8.0	54.9	14.7%	2.07	15.6	3.8	-288	-261	0.0	25%		
12/23/08	8.1	55.5	14.6%	2.57	15.7	2.8	-300	-277	0.0	31%		
12/24/08	8.4	69.5	13.0%	3.38	15.4	3.8	-300	-269	0.0	39%		
12/25/08	9.8	98.0	10.2%	6.11	12.5	4.4	-211	-244	0.0	63%		
12/26/08	9.4	88.4	11.5%	5.91	12.4	4.2	-238	-250	0.0	63%		
12/27/08	9.8	110.1	8.9%	6.42	8.4	4.7	129	-117	0.6	66%		
12/28/08	9.8	108.6	9.0%	6.84	10.6	3.0	2	-192	0.0	70%		
12/29/08	9.8	114.5	8.6%	6.72	11.4	4.7	-84	-223	0.3	69%		
12/30/08	9.8	94.1	10.5%	6.67	13.1	5.0	-87	-254	0.1	68%		
12/31/08	9.8	99.8	9.9%	5.98	13.5	5.0	-113	-261	0.1	61%		
1/1/09	9.8	118.5	8.3%	6.83	11.5	5.0	36	-218	1.0	70%		
1/2/09	9.6	121.4	7.9%	6.85	9.3	4.7	137	-89	2.3	72%		
1/3/09	9.8	113.5	8.6%	5.65	12.0	3.5	-50	-233	0.1	58%		
1/4/09	9.6	83.6	11.9%	4.88	13.5	4.5	-137	-258	0.0	51%		
1/5/09	9.8	108.3	9.0%	6.73	11.5	3.9	-46	-207	0.2	69%		
1/6/09	9.4	99.6	9.5%	6.12	13.5	4.7	-104	-212	0.1	28%		
1/7/09	9.3	103.2	9.4%	4.93	14.2	5.0	-118	-228	0.0	47%		
1/8/09	9.7	121.7	8.0%	6.27	13.5	4.4	-101	-233	0.0	65%		
1/9/09	9.8	91.3	10.8%	5.11	14.2	4.4	-138	-251	0.0	52%		
1/10/09	9.0	68.2	13.5%	3.41	14.8	4.0	-157	-258	0.0	37%		
1/11/09	9.4	75.2	12.8%	3.33	14.8	3.2	-154	-271	0.0	35%		2.6
1/12/09	9.7	82.2	12.0%	3.53	14.9	3.5	-177	-295	0.0	43%		2.2
1/13/09	9.0	67.1	13.6%	2.88	15.6	4.5	-182	-265	0.0	32%		2.3
1/14/09	8.9	64.0	14.3%	2.92	15.5	4.7	-159	-239	0.0	33%		1.7
1/15/09	8.6	60.3	14.3%	2.73	15.8	4.4	-171	-252	0.0	32%		1.9
1/16/09	8.4	59.1	14.4%	2.63	15.8	4.5	-185	-258	0.0	31%		1.3
1/17/09	6.3	56.6	11.4%	2.28	15.7	4.8	-207	-267	0.0	39%		2.6
1/18/09	6.0	54.8	10.9%	2.38	15.5	4.2	-265	-274	0.0	42%		2.3
1/19/09	6.1	57.0	10.8%	2.39	15.4	4.3	-298	-281	0.0	43%		2.4
1/20/09	7.4	56.8	12.6%	2.98	15.6	4.3	-300	-273	0.0	45%		2.1
1/21/09	8.9	56.6	15.8%	3.03	15.6	4.0	-275	-287	0.0	34%		1.4
1/22/09	8.4	59.2	14.3%	2.65	15.6	4.0	-201	-280	0.0	32%		1.8
1/23/09	8.6	56.7	15.1%	2.56	15.7	3.8	-237	-284	0.0	30%		1.2
1/24/09	8.4	53.1	15.9%	2.23	15.6	3.0	-291	-300	0.0	26%		0.9

Table B-1. Monitoring Data (24-Hour Averages)

	Pilot flow, mgd	Total flow, mgd	Pilot flow/ total flow	Pilot RAS, mgd	Temp, °C	DO oxic 1, mg/L	ORP selector 1	ORP selector 2	DO selector 1, mg/L	Pilot RAS/ pilot flow	Pilot WAS, gpm	DO end tank, mg/L
1/25/09	8.9	63.5	14.9%	2.39	14.8	4.4	-300	-300	0.0	26%		2.2
1/26/09	8.5	54.0	16.9%	2.95	15.0	4.4	-300	-300	0.0	33%		2.1
1/27/09	8.8	71.7	13.3%	3.21	14.6	4.8	-300	-300	0.0	36%		2.3
1/28/09	8.9	58.3	15.5%	3.99	14.7	4.7	-299	-300	0.0	43%		1.6
1/29/09	8.6	57.2	15.2%	6.42	15.4	4.2	-300	-300	0.0	78%		1.5
1/30/09	8.8	55.6	15.8%	5.88	15.5	4.8	-300	-300	0.0	67%		1.5
1/31/09	8.4	54.1	15.6%	5.34	15.5	4.7	-300	-300	0.0	67%		1.7
2/1/09	8.3	52.7	15.9%	5.18	15.5	4.7	-300	-300	0.0	68%		1.7
2/2/09	8.6	55.1	15.8%	5.54	15.5	3.3	-300	-300	0.0	68%		1.1
2/3/09	8.7	54.8	15.9%	5.97	15.7	1.9	-300	-300	0.0	72%		0.5
2/4/09	8.7	55.5	15.9%	6.57	16.1	1.1	-300	-300	0.0	79%		0.5
2/5/09	8.5	56.0	15.2%	5.74	16.2	1.6	-300	-300	0.0	67%		0.7
2/6/09	8.1	68.0	12.7%	5.87	15.8	3.7	-300	-300	0.0	78%		1.9
2/7/09	9.1	55.3	17.3%	3.23	15.9	3.5	-300	-300	0.0	35%		1.1
2/8/09	9.3	60.2	17.2%	3.22	15.8	3.9	-300	-300	0.0	34%		1.5
2/9/09	9.2	59.0	16.5%	3.08	15.4	4.5	-253	-300	0.1	33%		2.4
2/10/09	9.0	77.3	13.4%	4.33	14.5	4.8	-127	-300	0.2	47%		2.1
2/11/09	9.4	72.0	13.2%	6.77	13.6	4.6	-110	-300	0.0	73%		1.8
2/12/09	8.2	57.1	14.4%	6.57	15.5	3.8	-180	-300	0.0	86%		1.2
2/13/09	8.9	61.6	14.5%	6.48	15.4	4.3	-226	-300	0.0	73%		1.1
2/14/09	7.7	55.5	14.0%	6.48	15.6	4.3	-296	-300	0.0	90%		1.9
2/15/09	8.0	59.8	13.6%	6.48	15.2	4.6	-298	-300	0.0	87%		2.4
2/16/09	7.9	56.3	14.0%	6.48	15.4	4.5	-300	-300	0.0	88%		2.1
2/17/09	7.9	55.6	14.3%	6.48	15.8	4.6	-300	-300	0.0	87%		1.6
2/18/09	8.1	55.7	14.5%	6.35	15.9	3.9	-300	-300	0.0	84%		0.9
2/19/09	7.9	56.0	8.4%	5.01	15.9	4.7	-299	-300	0.1	68%		2.0
2/20/09	7.6	55.1	13.9%	5.99	16.0	4.0	-300	-300	0.1	85%	161	1.1
2/21/09	7.6	53.4	14.2%	6.16	16.0	3.7	-300	-300	0.0	88%	168	1.6
2/22/09	7.5	53.4	14.1%	6.15	15.8	3.8	-300	-300	0.0	92%	100	1.8
2/23/09	8.4	77.6	11.6%	6.33	15.0	4.5	-273	-300	0.0	83%	118	2.7
2/24/09	8.3	105.1	7.9%	6.83	13.2	4.6	-245	-295	0.0	98%	277	3.2
2/25/09	5.6	91.6	6.2%	6.39	13.8	3.3	-300	-300	0.0	115%	220	3.0
2/26/09	7.6	75.4	10.3%	6.50	14.3	4.9	-299	-300	0.0	94%	340	4.3
2/27/09	7.4	61.4	4.9%	6.05	15.1	4.8	-300	-300	0.0	87%	230	2.2
2/28/09	8.7	58.3	15.2%	6.77	14.7	5.0	-300	-300	0.0	79%	264	2.7
3/1/09	8.1	60.9	14.3%	6.77	15.0	5.0	-300	-300	0.0	89%	112	3.4

Table B-1. Monitoring Data (24-Hour Averages)

	Pilot flow, mgd	Total flow, mgd	Pilot flow/ total flow	Pilot RAS, mgd	Temp, °C	DO oxic 1, mg/L	ORP selector 1	ORP selector 2	DO selector 1, mg/L	Pilot RAS/ pilot flow	Pilot WAS, gpm	DO end tank, mg/L
3/2/09	9.4	75.5	13.3%	6.26	14.1	4.7	-293	-300	0.0	67%	81	3.1
3/3/09	9.7	90.8	11.6%	5.74	13.7	4.6	-296	-300	0.0	59%	114	2.5
3/4/09	8.5	61.0	14.0%	5.82	15.3	4.9	-186	-249	0.3	73%	215	1.6
3/5/09	8.8	75.1	12.3%	5.74	15.3	4.9	-99	-219	0.2	68%	45	1.8
3/6/09	8.5	61.2	14.0%	6.02	15.0	4.1	-131	-235	0.0	75%	89	1.6
3/7/09	8.1	57.0	14.2%	5.47	15.7	3.8	-179	-248	0.0	72%	44	2.1
3/8/09	8.7	63.2	13.9%	5.47	15.2	3.8	-206	-230	0.0	65%	52	1.7
3/9/09	8.4	74.4	12.2%	5.47	14.8	4.5	-247	-250	0.0	69%	30	2.8
3/10/09	8.4	59.6	14.0%	5.47	14.8	3.8	-294	-271	0.0	68%	0	2.1
3/11/09	8.3	57.5	14.4%	5.46	15.5	3.3	-300	-291	0.0	69%	0	1.3
3/12/09	8.2	57.0	14.4%	5.47	15.6	2.5	-300	-300	0.0	70%	0	0.8
3/13/09	8.0	56.1	14.3%	4.43	15.8	2.7	-245	-292	0.1	60%	0	1.3
3/14/09	8.1	72.1	12.1%	3.40	15.3	4.3	-160	-267	0.1	39%	0	2.3
3/15/09	9.8	113.9	8.6%	5.00	11.5	4.9	-23	-214	0.7	51%	0	4.8
3/16/09	9.7	97.4	10.5%	4.93	12.9	4.8	-119	-246	0.0	51%	23	4.2
3/17/09	9.8	95.4	10.3%	5.22	13.7	4.5	-153	-234	0.1	53%	73	2.8
3/18/09	8.9	64.7	13.9%	6.13	15.0	4.8	-278	-292	0.0	71%	159	2.2
3/19/09	8.8	62.4	14.2%	5.76	15.7	4.8	-300	-300	0.0	67%	155	1.2
3/20/09	8.7	64.4	13.8%	5.76	16.0	5.0	-300	-300	0.0	68%	150	1.9
3/21/09	8.2	58.6	14.2%	5.76	15.9	5.0	-300	-300	0.0	74%	170	2.1
3/22/09	8.0	61.9	13.3%	5.67	15.6	5.0	-300	-300	0.0	77%	153	2.6
3/23/09	8.2	69.6	12.5%	5.47	15.3	5.0	-230	-299	0.1	72%	105	2.5
3/24/09	8.6	62.3	14.0%	5.47	15.1	4.6	-125	-299	0.1	66%	62	2.1
3/25/09	8.7	73.6	12.6%	5.49	15.3	4.9	-175	-300	0.0	65%	34	2.4
3/26/09	8.2	59.0	13.9%	5.58	15.7	4.2	-285	-300	0.0	72%	59	1.9
3/27/09	8.0	56.5	14.2%	5.51	16.1	4.6	-300	-300	0.0	73%	30	2.0
3/28/09	8.5	85.0	11.0%	5.62	14.9	4.7	-244	-300	0.1	71%	5	3.6
3/29/09	9.5	77.2	12.6%	5.74	14.3	4.9	-300	-300	0.0	61%	20	3.2
3/30/09	8.3	58.2	14.3%	6.05	15.5	4.8	-300	-300	0.0	76%	23	2.1
3/31/09	8.9	66.2	14.0%	6.05	15.5	4.6	-241	-300	0.1	69%	26	2.2
4/1/09	8.7	81.9	11.5%	6.05	14.7	4.7	-161	-295	0.1	73%	19	2.6
4/2/09	9.4	96.0	10.1%	5.84	13.8	4.7	-216	-286	0.1	64%	33	3.5
4/3/09	9.2	69.2	13.6%	5.47	15.0	4.3	-300	-300	0.0	60%	68	2.4
4/4/09	5.9	56.3	10.9%	5.47	15.5	4.5	-300	-300	0.0	97%	142	2.3
4/5/09	5.5	56.7	10.1%	5.47	15.8	4.4	-300	-300	0.0	99%	162	2.5
4/6/09	7.4	57.7	12.8%	5.47	16.0	4.4	-300	-300	0.0	80%	23	2.5

Table B-1. Monitoring Data (24-Hour Averages)

	Pilot flow, mgd	Total flow, mgd	Pilot flow/ total flow	Pilot RAS, mgd	Temp, °C	DO oxic 1, mg/L	ORP selector 1	ORP selector 2	DO selector 1, mg/L	Pilot RAS/ pilot flow	Pilot WAS, gpm	DO end tank, mg/L
4/7/09	8.2	59.2	13.9%	5.42	16.3	4.2	-300	-300	0.0	69%	3	2.0
4/8/09	8.3	59.1	14.0%	5.47	16.6	4.7	-225	-283	0.1	69%	77	2.4
4/9/09	8.9	65.2	14.0%	5.47	16.5	4.9	-172	-283	0.1	63%	108	3.1

APPENDIX C

Daily Phone Records

February 23, 2009

The pilot train is currently foaming. SVI of the pilot is holding around 280 mL/g. The blanket meter indicates only 0.5 ft of blanket, but core samples suggest a thicker blanket. Suspect a large amount of fluff in the clarifier. The WAS solids concentration is around 0.2 percent.

February 24, 2009

Flow increased over the night as a result of precipitation. This resulted in some apparent spillage of mixed liquor from train 8 into the pilot train. Inspection revealed that one of the isolation gates in the combined aerator effluent channel lost its seal, resulting in a flow of mixed liquor into the pilot train. The gate is being fixed to prevent any further spillage.

The pilot clarifier has filled with solids. The solids inventory in the clarifier increased from 6,000 lb yesterday, to an estimated 26,000 lb today. This massive increase is likely caused by the spillage described above. The clarifier blanket current stands at 10 feet, with effluent TSS reaching 128 mg/L in the morning. Microscopic analysis revealed high filament load.

February 25, 2009

The isolation gate seal preventing spillage from the aerator effluent channel into the pilot train has not yet been fixed. Staff are working to get it sealed by the end of the day. To compensate, WAS and RAS flows remain elevated. The chlorine feed to the RAS lines should be operable tonight, and staff plan to commence RAS chlorination overnight.

The solids content of the pilot clarifier has been reduced through RAS and WAS pumping, with the blanket reduced from 10 feet to 6.5 feet. However, the cost is an excessively diluted WAS (0.11 percent). The system has begun to respond to the increased solids and returns with an elevated MLSS (2,574 mg/L). SVI of the pilot train continues to track approximately 100 mL/g higher than control.

February 26, 2009

The isolation gate between the pilot train and the aerator effluent channel is still undergoing repair. Spillage of mixed liquor into the pilot train continues, making it impossible to establish equilibrium. Staff have responded by maintaining high rates of wastage and return (WAS rate at 145–414 gpm, RAS rate at 4,760 gpm). The WAS rate averaged 145 gpm on February 25, but was adjusted to 414 gpm (90 percent open) by the morning of February 26. RAS chlorination commenced the evening of February 25, at a rate of 700 gpd. Foam in the pilot train is somewhat reduced, although still abundant. Foam is worse in pilot than in control, and covers both selectors as well as the aerated zones. Samples of foam and mixed liquor were sent to Dr. Richard on February 26. Flow to the pilot train has been reduced by shutting off the fixed speed pump. The blanket in the pilot clarifier is reduced to 5 feet, and WAS solids have increased to 0.43 percent. SVI of the pilot train is still high, at 292 mL/g. Staff note that it takes a few days for chlorination to take effect. Final effluent solids is reduced to 10 mg/L.

March 2, 2009

Flow has been elevated due to recent precipitation. The isolation gate appears to be adequately sealed, although this will need to be tested once the flows come down and a visual observation can be made. Over the weekend, the SVI of pilot and control trains came down to 200 mL/g. Foaming in the pilot train has ceased (although some foam persists on the control train). The MLSS of the pilot train has dropped from 2,600 to 1,350 mg/L since February 26. The Core solids in the pilot had dropped from 2,200 to 220 mg/L, before increasing to 844 mg/L today. Likewise, the WAS solids in the pilot had reduced to as low as 0.08 percent over the weekend. Currently, the blanket is 3.5 feet deep in the pilot.

March 3, 2009

The leaking gate has been contained because there was no increase in solids inventory overnight.

Examination of mixed liquor under the microscope showed minimal reduction in filaments.

Continuing to chlorinate. This method of adding chlorine takes up to 14 days to be effective (not being added to RAS). Mike says that subsequently, the staff has to wean the plant off the chlorine to avoid another bloom occurring. He believes that the slowly declining SVI is not completely attributable to the action of chlorine because this is only day 5 of addition. We agreed that the chlorine be stopped at the end of the week.

Mike Richard reported that the presence of N. limicola was attributable to the presence of organic acids. Both Mikes reported their observation of higher septicity of the influent after off site storage was brought online – Swan Island and the tunnel. Presumably, the raw sewage solids sit in the bottom of these facilities and ferment producing VFAs. We have not received any more VFA data since the January 6 data set to verify that they are indeed appearing in the primary effluent.

The plant received rain showers last night that translated to a rapid increase in flow over a 2-hour period reaching 130 mgd before declining over several hours. The surge in flow resulted in the secondary clarifier blankets building up to 4 ft overnight from about 1 ft the day before, indicating the inability of the RAS pumps to keep pace with the transfer of solids to the clarifiers from the aeration tanks.

Mike Ciolli volunteered that the discharge end of the aeration tank had registered DO values less than 1.0 mg/L frequently in the past 2 to 3 weeks, unlikely the control aeration tank. Apparently, the redistribution of air so that plenty of air was sent to the zone immediately downstream of the selector robbed air from the discharge end. Both Mikes were going to investigate how they might redistribute the air and Steve was going to add the discharge end DO probe data to our online data set.

March 4, 2009

Having solved the issue of the isolation gate, the focus has turned to restoring stable operation of the pilot train. SVI in both trains has been restored to 200 mL/g (200/g mL pilot, 208 mL/g control), and filament analysis suggests a healthy population of bio-P organisms. The foaming in the pilot train has been reduced to typical levels.

March 5, 2009

Having solved the issue of the isolation gate, the focus has turned to restoring stable operation of the pilot train. SVI in both trains has been restored to 150 mL/g, and filament analysis suggests a healthy population of bio-P organisms. The foaming in the pilot train has been reduced to typical levels. The WAS pumping rate was turned down over the night, resulting in solids build-up in the pilot clarifier. Core solids are currently 1,022 mg/L. However, the mixed liquor solids have remained low, 1,450 mg/L at the last reading. WAS solids are increasing slowly, up to 0.25 percent on March 5.

Operators note that there is the possibility of WAS solids back-feeding into the pilot clarifier. The solids pipeline has no check valve, and if the pressure condition in the S1-S2 WAS storage tank reaches a certain level, the solids may feed back into the pilot clarifier. This appears to be associated with high flow events, when the RAS pumping in the control clarifier is turned up.

March 6, 2009

In the last report, it was erroneously stated that solids may back-flow from the WAS storage area into the pilot clarifier. Further investigation shows this to be impossible. However, it is now suspected that, at times, WAS from the pilot train may become entrained into the RAS flow from the control trains. On March 5, the WAS flow averaged 45 gpm. At an average concentration of 0.25 percent, this would equate to just 1,300 lb of solids wasted over the day. However, only a small increase was seen in the MLSS (1,400 to 1,500 mg/L), and a decrease was seen in the clarifier core solids (900 to 600 mg/L). In total, the mass of solids in the pilot train decreased, in spite of the low wasting. The calculated SRT on this day was 18 days.

March 9, 2009

Over the weekend, the WAS valve was kept at 25 percent open, meaning WAS flow was minimal throughout the period. In spite of this, there was a net loss of solids from the pilot train. By Sunday, the MLSS in the pilot train was reduced to 1,350 mg/L, with a clarifier blanket less than 2 feet deep. All told solids in the pilot train reduced by 12 percent from March 6 to March 8. During this period, a reduction in solids in the control train was also noted. This reduction was mainly in the clarifier, where the CTSS reduced from 900 to 430 mg/L, with basically no change in the MLSS concentration. All told, solids in the control train were reduced by 16 percent from March 6 to March 8.

March 10, 2009

The WAS valve was kept closed for the past day. The mixed liquor solids concentration in the pilot train increased from 1,350 mg/L to 1,786 mg/L. It therefore appears as though solids were being lost through the WAS valve, even when it was only left slightly open. It is unclear whether these solids are being entrained into the control trains, or simply being wasted. The possibility of a RAS-to-RAS cross connection was ruled out through inspection of the two butterfly valves locking out the pilot train.

March 12, 2009

The WAS valve continues to be kept closed in order to build solids in the pilot train. Solids appear to be accumulating at a rate of approximately 6,000 lb/d, which is slightly slower than anticipated. Staff note that solids in the control train is also unusually low, and appears to be on a downward trend.

The ORP and selector DO meters were cleaned on March 4, and this is reason for the sudden increase in ORP noted at that time. Operators state that biofilm growth on the surface of the meters was most likely interfering with the signal. Given the rate at which the ORP declined after cleaning, it was decided to implement twice-weekly cleaning of these meters.

March 13, 2009

The WAS valve continues to be kept closed in order to build solids in the pilot train.

March 16, 2009

In spite of being held at zero flow from March 9–12, the total solids in the pilot train had only increased by a total of 9,500 lb over the 4-day period. Modeling suggested an increase of 7,000 lb/d would be more likely. The rate of solids increase dropped from March 9 through March 12, with only 2,000 lb being added on the last day. During the March 13 meeting, a decision was made to reduce the pilot RAS flow, and place the pilot RAS rate in step with the control RAS rate. The reasoning behind this decision was that, having failed to increase solids by shutting off the WAS valve, perhaps some solids were still being lost through the RAS pipeline, especially at the high RAS flow being employed at that time.

On March 13 (Friday), the SVI of the pilot train increased from 233 to 320 mL/g, and increased further to 406 mL/g by Sunday.

On the evening of March 14, a storm event occurred, with high flows registered at the plant through Sunday.

On March 14, 13,500 lb of solids accumulated in the pilot train, mostly in the clarifier. The clarifier blanket increased to 10.5 feet by Sunday, with a core solids of 2,253 mg/L.

Throughout this period, the control train experienced only a small increase in SVI (to 214 mL/g), coupled with a modest increase in clarifier solids (blanket depth 5.7 feet, core solids 1,238 mg/L).

March 17, 2009

The WAS valve was left open for approximately 4 hours, with a flow averaging 150 gpm during that time. RAS flow was also increased to 4000 gpm. In spite of these actions, total solids in the pilot system increased to 61,000 lb, with nearly half of that in the clarifier. Staff report that a check valve has successfully been installed onto the WAS line from the pilot train.

March 18, 2009

The WAS valve was left open for approximately 4 hours, with a flow averaging 150 gpm during that time. RAS flow was also increased to 4000 gpm. In spite of these actions, total solids in the pilot system increased to 61,000 lb, with nearly half of that in the clarifier. Staff report that a check valve has successfully been installed onto the WAS line from the pilot train.

March 19, 2009

This morning, operators report a significant reduction in clarifier solids. The core TSS has decreased from 1,372 mg/L to 486 mg/L. With a relatively stable MLSS, this equates to a net solids loss of approximately 13,000 lb. The SVI of pilot train has been fluctuating. Last night, it was 179 mL/g, this morning it was 295 mL/g. The control train has been steadily increasing its solids over the past few days.

March 25, 2009

From March 9–16, the WAS rate in the pilot train was held at zero. During that period, the total solids in the pilot train increased from 25,000 to 56,000 lb. Pilot solids increased at rate of 2,000–5,000 lb/d, with the exception of March 14, when solids increased by 13,500 lb overnight. The cause of the rapid increase in solids has been attributed, in part, to a storm event on the evening of March 14, and also, in part, to a reduction in the pilot train RAS flow, starting on the afternoon of March 13. The apparent association between RAS flow and pilot solids has not yet been fully evaluated.

In response to the rapid accumulation of solids on March 14, the RAS flow was increased back to a constant rate at close to 6 mgd (4,100 gpm), and the WAS valve was opened to allow some wastage. From March 17–23, the pilot WAS fluctuated between 150–200 gpm. During this period, the pilot solids steadily decreased, from 53,500 lb on March 18 to 27,350 lb on March 22. The rate of solids loss averaged 1,500–2,000 lb/d, which is reasonable for a system wasting at 175 gpm and 0.4 percent, given the (unusually low) rate of solids accumulation noted above (2,000–5,000 lb/d). However, there were two events of major solids which must be explained:

- March 18–19: 15,000 lb
- March 21–22: 7,000 lb

Neither of these events coincided with storm flow, or any noticeable change in either the pilot RAS or WAS flows.

In response to the decreasing solids content of the pilot train, the WAS valve was closed on March 23. However, the valve was reopened the evening of March 24, and WAS flow in excess of 300 gpm was reported during that time. After another brief period of solids loss, the WAS flow was closed again on the afternoon of March 24, and held closed until late in the day on March 25, when it was reopened slightly, to allow a flow of 75 gpm, in response to increasing SVI. Currently, solids in the pilot train has recovered somewhat, to a total of 36,500 lb.

March 31, 2009

Over the weekend, a storm event occurred, with plant flows exceeding 200 mgd. Pilot solids fluctuated widely over this period, with an increase in solids seemingly tied to both a reduction in WAS flow, and the storm event (most of which was focused on Saturday night).

Wed, 3/25:	36,589
Thurs, 3/26:	34,445
Fri, 3/27:	43,317
Sat, 3/28:	45,782
Sun, 3/29:	50,235

Notably, the control train saw much less fluctuation in solids during this period:

Wed, 3/25:	32,092
Thurs, 3/26:	34,393
Fri, 3/27:	35,322
Sat, 3/28:	36,639
Sun, 3/29:	38,439

By Monday, the pilot train solids had reduced to 46,000 lb, in spite of an average WAS flow of just 18 gpm. This had recovered, somewhat, to 49,000 lb by Tuesday, after allowing only a brief period of wasting on Monday afternoon.

The following calculations estimate the average solids generated over the past week (3/25–3/31):

Pilot WAS:	0.36 percent TS
Pilot WAS:	29 gpm/train
Pilot Flow:	8.5 mgd/train
FE TSS:	15 mg/L (assumed)

Wastage = 3,600 mg/L × 29 gpm × 1440 m/d × 8.34 ÷ 1,000,000 gal/Mgal = 1,250 lb/d
Effluent = 15 mg/L × 8.5 mgd × 8.34 = 1,060 lb/d
Solids = 32,092 lb on 3/25 to 49,000 lb on 3/31 = 16,908 lb increase 16,908 ÷ 6 days = 2,820 lb/d
Generation = 1,250 + 1,060 + 2,820 = 5,130 lb/d

Total solids in the pilot train increased by 16,900 lb. This equates to a rate of increase of 2,820 lb/day. The WAS flows measured during this period averaged 29 gpm. Based on an average WAS solids content of 0.36 percent, this equates to an average wastage of 1,250 lb/d. Assuming an effluent solids of 15 mg/L, the total amount of solids loss from the pilot train effluent averaged 1,060 lb/d.

Taken together, the rate of solids accumulation and the rate of wastage mean the pilot train was generating approximately 5,130 lb/d of solids.

Flow to the pilot train averaged 8.5 mgd during this time. The primary effluent typically averages around 200 mg/L of BOD (the month of February averaged 212 mg/L). This means the pilot train experienced an average load of 14,200 lb/d of BOD. Using typical values of cell yield (0.666 COD/COD), cell stoichiometry (1.42 lb COD/VSS), COD/BOD ratio (2.0), the system should generate over 13,000 lb/d of solids. Depending on the SRT, a certain amount of cell decay will occur, meaning the true cell yield will be somewhat lower than this number. The BioWin model estimates that, given the target SRT of 4 days, the system should generate an average of 11,654 lb/d of solids.

A number of factors can influence the rate of cell production, including various inhibitory substances in the wastewater. It is therefore useful to look at what happened in the control train during the same period.

Control WAS:	0.49 percent TS
Control WAS:	161 gpm/train
Control Flow:	8.5 mgd/train
FE TSS:	15 mg/L (assumed)

Wastage	= 4,900 mg/L × 161 gpm × 1440 m/d × 8.34 ÷ 1,000,000 gal/Mgal = 9,470 lb/d
Effluent	= 15 mg/L × 8.5 mgd × 8.34 = 1,060 lb/d
Solids	= 224,647 lb on 3/25 to 269,070 lb on 3/29 = 44,423 lb increase
	44,423 ÷ 4 days ÷ 7 trains = 1,600 lb/d/train
Generation	= 9,470 + 1,060 + 1,600 = 12,130 lb/d

During this time frame, the control train wasted an average of 9,470 lb/d/train in the WAS, and an average of 1,060 lb/d/train in the final effluent. Control solids in the aeration tanks increased by an average of 1,600 lb/d/train. As a whole, this means the control train was generating approximately 12,130 lb/d of solids per train.

The numbers suggest the solids loss continues to be a factor in the pilot train. The disposition of those solids remains a mystery. An alternative explanation would be that the pilot train is being fed with a much weaker primary effluent than that reaching the control trains. Given the location of the bypass pumping, and observations of the flow pattern in that location, the likelihood of a significant difference appears small.

SVI in the pilot train increased to 393 mL/g by March 29, while SVI in the control train exhibited a more modest increase to 246 mL/g. Both of these increases appear related to the storm event, and both have recovered to some degree by March 31 (pilot SVI = 296 mL/g).

April 2, 2009

Overnight, the pilot train experienced a redistribution of solids to the clarifier, along with a rapid deterioration in settling performance. The MLSS decreased from 2,580 to 1,624 mg/L, coupled with an increase in CTSS from 1,150 to 2,106. The clarifier had a 12 foot blanket, and effluent solids reached as high as 168 mg/L, indicating a failure condition. SVI increased from 264 to 407 mL/g by the morning of April 2. The control train experienced a much smaller increase in solids, with a CTSS of 991 mg/L and an SVI of 211 mL/g.

APPENDIX D

Sampling Plan

Technical Memorandum

CBWTP Facilities Plan Update

TO: Steve Simonson, BES

COPIES: File

FROM: Daria Wightman, Brown and Caldwell

PREPARED BY: Adam Klein, Brown and Caldwell

REVIEWED BY: Henryk Melcer, Brown and Caldwell

DATE: December 9, 2008

PROJECT NO.: Brown and Caldwell Project No. 129055 Task 006

SUBJECT: Selector Enhancement Testing Plan – Final

Background

The selector optimization investigation will compare the performance of an independent activated sludge train (aeration tank and secondary clarifier), the "pilot system", versus the remainder of the secondary system to observe how different operating conditions in the pilot system can induce improved mixed liquor settling behavior compared to the rest of the secondary system. Aeration train 4 will serve as the "control" representing the remaining part of the secondary system. The following modifications to the secondary process system will be implemented:

1. Aeration train 7 will be isolated to create a pilot activated sludge train by diverting a portion of primary effluent to the head of the train, and providing independent secondary clarification and RAS return.

2. The SRT of the pilot train will be increased to 2.75 days to induce the growth of a population of biological phosphorus removal (bio-P) organisms.

3. A baffle will be installed in the anaerobic selector of aeration train 7 to create two unaerated zones within the selector.

4. Dissolved oxygen (DO) sensors and a surface aerator will be installed downstream of the selector to guarantee a DO of at least 2.0 mg/L in that zone.

5. Oxidation-reduction (ORP) sensors will be installed in each of the unaerated selector zones to track selector function.

Two trial periods were originally planned—one in the dry weather season and the second in the wet weather season. In each case, the pilot system would be operated of up to one month to assess the impact on mixed liquor settling and secondary process performance. With the delay in baffle installation, the trial will be limited to a six week performance comparison during the winter period, December 2008/January 2009.

Test Design

The primary effluent diversion pumping system is designed to generate up to 10 mgd of flow to the pilot train. There are two pumps available. The first pump will operate at a constant speed, producing 5 mgd continuously. The second pump will operate at variable speed, and will be synchronized to the Plant's influent flow rate. Combined with the 5 mgd from the constant speed pump, the two pumps will produce a flow equal to one-eighth of the total plant flow. If the Plant flow exceeds 80 mgd, the pilot train pumps will continue to output their maximum combined flow of approximately 10 mgd. The pump curve suggests that it may be feasible to generate up to 11 mgd.

Test Performance Parameters

Ultimately, test performance will be measured in terms of the mixed liquor settling characteristics. The most basic measure of mixed liquor settling is the sludge volume index (SVI). Daily measures of SVI for both the pilot train and the control trains will be required to track system performance. Additionally, composite sampling of the effluent suspended solids concentrations from both the pilot and the control trains will be conducted daily.

At the end of each trial, it may be beneficial to carry out a set of more detailed settling tests between the two trains. These tests include:

- Flocculated Suspended Solids (FSS)
- Dispersed Suspended Solids (DSS, taken at several locations along the flow stream)
- Batch Settling Tests

These tests would allow for a more definitive measure of the impact of pilot system modifications on mixed liquor settling.

Test Optimization Parameters

In order to ensure that test conditions are fully optimized, a number of parameters will be collected to allow for real-time adjustment. In order to track the health and abundance of the bio-P population, phosphorus profiles will be taken in both the pilot and control systems:

- Primary Effluent TP
- Primary Effluent PO_4-P
- Selector Zone 1 TP
- Selector Zone 1 PO_4-P

- Selector Zone 2 TP
- Selector Zone 2 PO_4-P
- Aerobic TP
- Aerobic PO_4-P
- Secondary effluent TP
- Secondary effluent PO_4-P
- AS TP
- RAS PO_4-P

If the selector is functioning properly, the selector zone PO_4-P concentration should be high (> 15 mg/L), while the aerobic PO_4-P concentration should be close to zero. Secondary effluent TP and PO_4-P concentrations should be less than 10 percent of primary effluent values. During the two weeks of equilibrating to the new SRT, the phosphorus profile will be measured in the pilot system and in one of the other trains that will serve as the control (Aeration train 4) taken on two days per week (Tuesdays and Thursdays) as shown in Tables 1 and 2. Once equilibrated, an intensive one-week long period of testing will be carried as shown in Tables 3 and 4.

Bio-P abundance is related to the availability of readily biodegradable substrate within the selector. In order to assess the abundance of substrate, measures of volatile fatty acids (VFA), soluble COD (sCOD), and flocculated and filtered COD (ffCOD) will be taken. VFA is the best measure of substrate, but the VFA analysis is complicated, and often requires several days to obtain a result. The sCOD and ffCOD analyses are much simpler, and can return same-day results. ffCOD is a good measure of the total readily biodegradable substrate, which includes all of the VFA. sCOD is similar to the ffCOD, but includes some colloidal material. Both ffCOD and sCOD may be used as surrogates for VFA to help track the availability of substrate throughout the selector in real-time. The following analyses will be performed:

Secondary influent, selector zone 1, selector zone 2, aerobic zone downstream of selector

- VFA
- sCOD
- ffCOD

The amount of substrate in the primary effluent will help determine whether there would be any benefit to adding exogenous substrate to the system (for example, acetic acid). Once in the selector, two competing processes should occur. On the one hand, regular COD will be broken down and fermented into VFA, causing an increase in the amount of VFA across the selector. If an active population of bio-P organisms is present, these will take up the VFA, causing a drop in the VFA across the selector. Ideally, the VFA leaving the selector and entering the aerated zone will be close to zero.

In order to provide for comparison between the pilot and control trains, and in order to allow for process control, the following data will also need to be collected:

- MLSS
- MLVSS
- RAS TSS
- RAS VSS
- Primary effluent BOD
- Primary effluent COD
- Primary effluent TKN
- Primary effluent NH_3N
- Primary effluent alkalinity
- Primary effluent pH
- Secondary clarifier SBD
- Secondary effluent cBOD
- Secondary effluent COD
- Secondary effluent TSS
- Secondary effluent ffCOD
- Secondary effluent NH_3N
- Secondary effluent NO_x
- Mixed liquor temperature

Sampling Plan

The plan calls for composite sampling at four locations:

- Primary effluent at pump diversion point
- Primary effluent in aeration tank influent channel
- Secondary effluent from pilot system clarifier
- Secondary effluent from control system clarifier

The plan calls for grab sampling at the following locations:

Pilot Train (train seven)
- Selector Zone 1
- Selector Zone 2
- Aerated Zone downstream of selector
- Aerated Zone at end of train
- RAS
- WAS

Control Train (train four)
- Selector
- Aerated Zone at end of train
- RAS
- WAS

As the system starts up, a small number of parameters will be used to track performance. During this time, approximately 203 tests per week will be needed. Once the system has stabilized, a week of detailed sampling will be used to define the impact of pilot modifications. During this period, approximately 371 tests per week will be needed. The testing schedule is summarized on Tables 1-4. An overview of the sampling locations is provided in Figure 1.

On-line Measurements

The following data will be collected automatically through in-line sampling tied to the Plant's electronic recording system:

- ORP in Selector Zone 1
- ORP in Selector Zone 2
- DO in Selector Zone 1
- DO in post-selector zone (deep)
- DO in post-selector zone (shallow)
- Plant influent flow
- Flow to secondary processes
- Diversion pump speeds

Table 1. Samples per Week during Startup Period (2 Weeks)

	Pilot System (Train 7)							Control System (Train 4)			
Type:	Composite	Grab	Grab	Grab	Grab	Composite	Grab	Grab	Grab	Composite	Grab
Location:	1. Primary Eff at Diversion Pump	2. Selector Zone 1	3. Selector Zone 2	4. Aerated Zone downstream of Selector	5. Aerated Zone End	6. Sec Effluent at Pilot Clarifier	7. RAS	2. Selector Zone 1	3. Aerated Zone, End	4. Sec Effluent at Control Clarifier	5. RAS
Flow	7					7	7			7	7
TSS	1				7	7	7		7	7	7
VSS	1				7	7	7		7	7	7
COD	1										
sCOD	2	2	2	2							
ffCOD	1	1	1	1							
BOD_5	1										
$cBOD_5$						1				1	
TKN	1										
NH_3-N	1					1				1	
NO_2-N	1					2				1	
NO_3-N						2					
TP	2	2	2		2	2	2	2	2	2	2
PO_4-P	2	2	2		2	2	2	2	2	2	2
VFA	2	1	1	1							
Alkalinity	1										
pH	1										
Temp	7										
SSV30					7				7		

1. Numbers refer to location of sample point as shown on Figure 1.
2. Sample point no. 1 is the same for both pilot and control systems and is therefore shown only once.
3. Alkalinity as $CaCO_3$.

Table 2. Samples per Week during Intensive Sampling Period (One Week)

	Pilot System (Train 7)							Control System (Train 4)			
Type:	Composite	Grab	Grab	Grab	Grab	Composite	Grab	Grab	Grab	Composite	Grab
Location:	1. Primary Eff at Diversion Pump	2. Selector Zone 1	3. Selector Zone 2	4. Aerated Zone Downstream of Selector	5. Aerated Zone, End	6. Secondary Effluent at Pilot Clarifier	7. RAS	2. Selector Zone 1	3. Aerated Zone, End	4. Secondary Effluent at Control Clarifier	5. RAS
Flow	7					7	7			7	7
TSS	3				7	7	7		7	7	7
VSS	3				7	7	7		7	7	7
COD	5										
sCOD	5	5	5	5							
ffCOD	5	5	5	5							
BOD_5	5										
$cBOD_5$						3				3	
TKN	3										
NH_3-N	3					3				3	
NO_2-N	3					3				3	
NO_3-N						3				3	
TP	5	5	5		5	5	5	5	5	5	5
PO_4-P	5	5	5		5	5	5	5	5	5	5
VFA	3	3	3	3							
Alkalinity	5										
pH	5										
Temp	7										
SSV30					7				7		

1 Numbers refer to location of sample point as shown on Figure 1.
2 Sample point no. 1 is the same for both pilot and control systems and is therefore shown only once.
3 Alkalinity as $CaCO_3$.

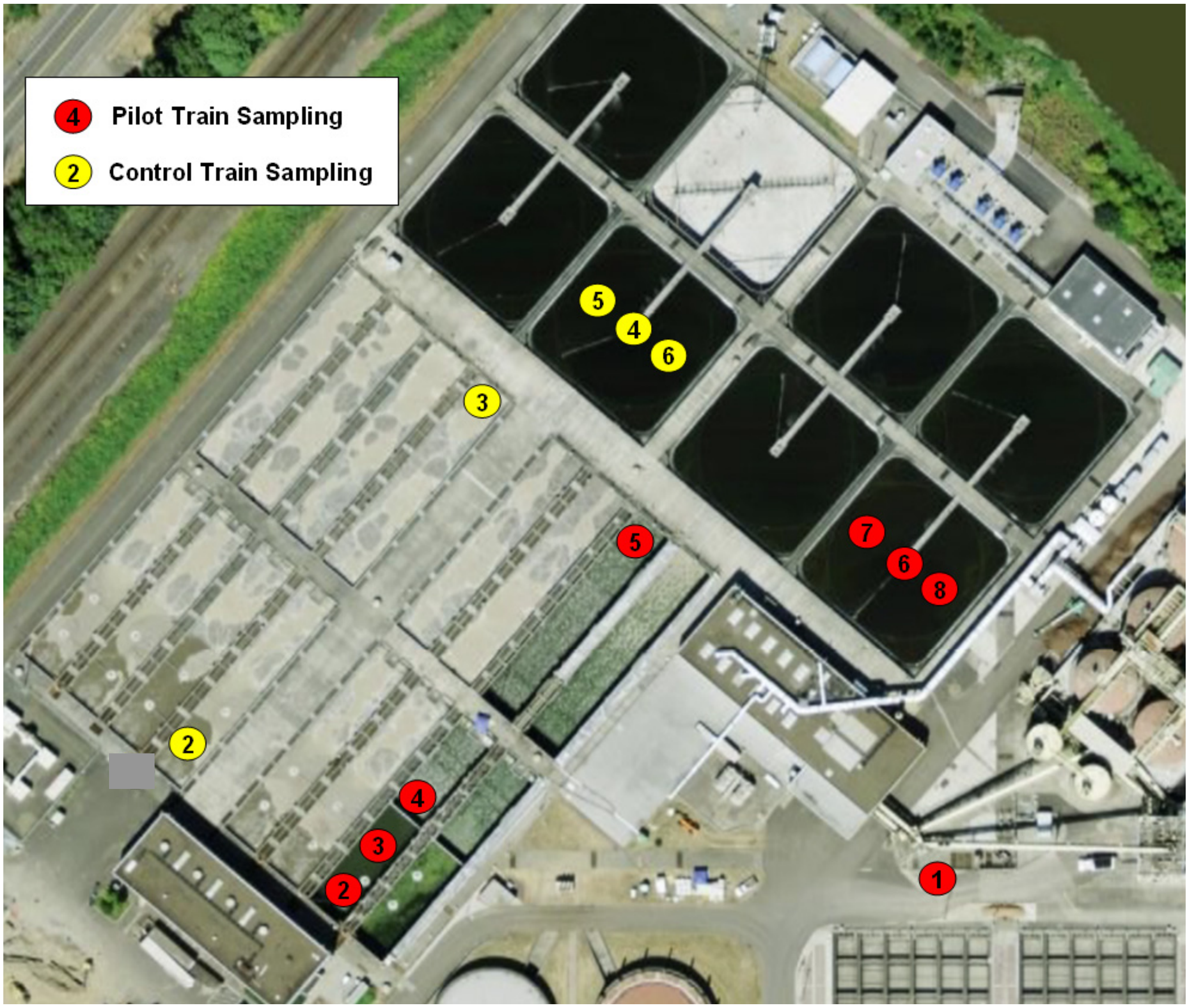


Figure 1. Overview of Sampling Locations

APPENDIX E

TM Dated September 19, 2008, on Model Calibration

Selector Optimization to Improve Mixed Liquor SVI- Process Modeling

Technical Memorandum

CBWTP Facilities Plan Update

TO: Garry Ott, City of Portland, Bureau of Environmental Services

COPIES: File

FROM: Daria Wightman, Brown and Caldwell

PREPARED BY: Adam Klein, Brown and Caldwell

REVIEWED BY: Henryk Melcer, Brown and Caldwell

DATE: September 19, 2008 (revised October 27, 2009)

PROJECT NO.: 129055
City Project 7847

SUBJECT: CBWTP Secondary Treatment Capacity Analysis Using Indicator SVI
Revision of July 8, 2008 TM: Selector Optimization to Improve Mixed Liquor SVI

CONTENTS

BROWN AND CALDWELL

BACKGROUND

The Columbia Boulevard Wastewater Treatment Plant (CPWTP) employs an eight-train aeration basin tied to eight square-sided secondary clarifiers to provide for secondary treatment and separation. The upstream quarter of each aeration basin is used as an anaerobic selector. In this region, there is no aeration, and the basins are mixed with a pair of surface mixers. A wooden baffle wall separates this unaerated zone from the rest of the aeration train.

Because it is fed in part from a combined sewer system, CBWTP typically bypasses a portion of wet weather flows around the secondary system. For this reason, flow to the secondary process tanks is limited to approximately 100 million gallons per day (mgd) CBWTP was designed to process up to 160 mgd through its secondary system, but a variety of factors have resulted in a more practical limit of 100 mgd. These factors include historically poor mixed liquor settling, inherent inefficiencies of the secondary clarifiers, and limitations in return activated sludge (RAS) pumping and return.

Biological process simulations conducted as part of the 2008 Facilities Plan Update highlighted the impact of mixed liquor settling on CBWTP capacity. In 2007, the mixed liquor sludge volume index (SVI) averaged 295 milliliters per gram (mL/g), which is indicative of poor settling. Over the past 5 years, CBWTP has experienced periodic instances where the SVI has exceeded 300, 400, and even 500 mL/g (Figure 1).

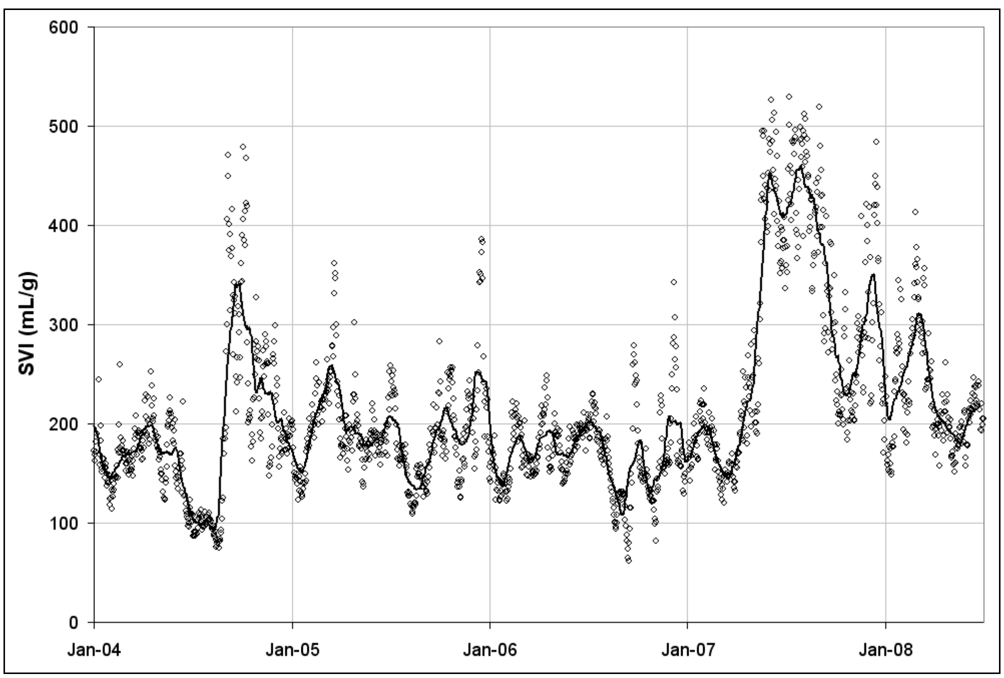


Figure 1. SVI (with 30-day moving average)

Mixed liquor settleability has a direct impact on the capacity of the secondary clarifiers to remove solids. At high SVIs, the acceptable solids loading rate to the clarifiers decreases, meaning more clarifiers are required to remove the same amount of solids (Figure 2).

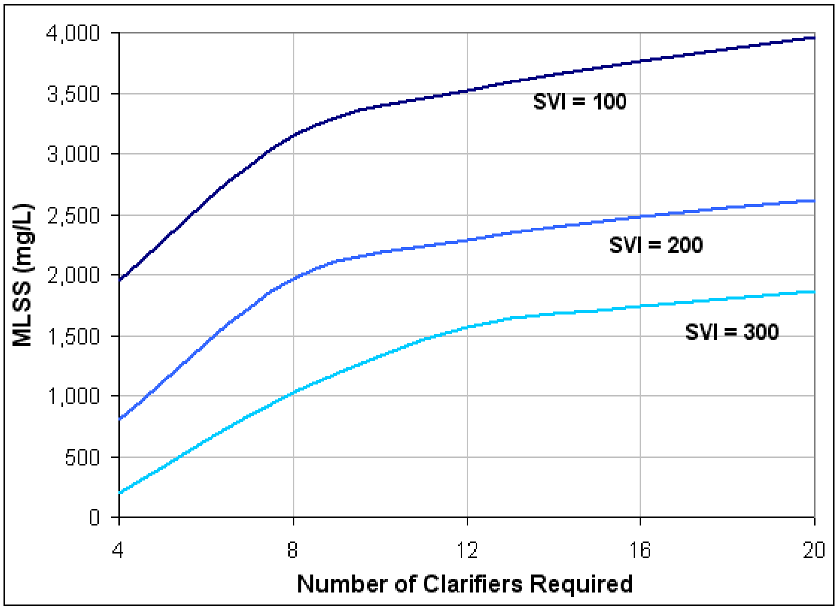


Figure 2. Relationship between SVI and Number of Clarifiers Required

In the Facilities Plan Update, it was determined that at historical SVI levels (design SVI of 300 mL/g), CBWTP would require a conversion of the existing eight secondary clarifiers into additional aeration basin volume, plus the construction of 12 new secondary clarifiers by 2040. If, on the other hand, CBWTP could control SVI to a more typical level of 150 mL/g, it could keep its secondary clarifiers, and simply add four new secondary clarifiers. The cost differential between these two options was estimated at approximately $122 million.

Based on this finding, CBWTP has decided to investigate means to improve mixed liquor settleability. The purpose of this Technical Memorandum is to investigate the cause of historically poor settling at CBWTP, and to recommend options for improving mixed liquor settling.

Biological Selectors

CBWTP currently operates with an anaerobic selector comprising the first 25 percent of its process tank. When operating as designed, the anaerobic selector should improve mixed liquor settling by fostering the growth of phosphorus-removing organisms (bio-P organisms). The bio-P organisms are able to take up simple carbon substrates such as acetic acid, and store these substrates intracellularly. Storage of these substrates allows the population to survive in the downstream aerated basins, where more rapidly growing aerobic heterotrophs dominate the food supply. The bio-P organisms influence mixed liquor settling in two ways.

First, by taking up the readily biodegradable substrates in the selector, they prevent these substrates from reaching the aerated part of the basin. In the aeration basin, substrates can promote the abundance of bulking filaments, particularly in regions where the oxygen supply is limited. In such regions, the high surface area of the filament provides it with a competitive advantage for taking up both substrate and the limited supply of oxygen. Without an ample supply of readily biodegradable substrate, the bulking filaments lose their primary food source, and are not able to persist. So, the bio-P organisms indirectly inhibit the growth of bulking filaments by removing readily biodegradable substrates from the selector.

Second, the bio-P organisms tend to be very dense, and therefore settle very rapidly. The density of the bio-P organisms is related to their uptake and storage of inorganic phosphorus. In the anaerobic selector, the bio-P organisms need to produce intracellular energy to take up these substrates, which they achieve by releasing chains of polyphosphate. In the aerated portion of the basin, the bio-P organisms use their stored substrates as food. The balance of phosphorus in the cells is restored by uptake of phosphorus from the mixed liquor. If a population of bio-P organisms is present, the phosphorus concentration in the aerated portion of the basin will be near zero. The polyphosphate chains can grow to be quite large, imparting density to the cells which makes them settle very rapidly. As these cells form flocs with other cells in the secondary clarifiers, they enhance the settling of the entire floc.

In order to generate a healthy population of bio-P organisms, the following conditions must be applied:

- Anaerobic environment
- Simple, readily biodegradable substrates in the selector
- Long enough solids retention time (SRT) to allow population growth
- Ample supply of phosphorus in the mixed liquor for uptake

Even with a healthy population of bio-P organisms, mixed liquor settling can be impaired by bulking filaments. If too much readily biodegradable substrate is present in the selector for the bio-P population to remove, this substrate can break through into the aerated portion of the basin, and promote the growth of filaments. This can be particularly important if the area downstream of the selector is not adequately aerated, creating the oxygen-poor environment which favors the filaments. CBWTP staff have reported that dissolved oxygen (DO) concentrations downstream of the selector are typically below 2 milligrams per liter (mg/L), and sometimes as low as 1 mg/L. So, two more conditions may be added to the list of factors required for optimal selector function:

- Limited breakthrough of readily biodegradable substrate into the aerated portion of the basin
- Ample oxygen supply to the basin downstream of the selector

Biological Process Modeling

The historical periods of high SVI suggest that the selector has not been functioning adequately at CBWTP. The reasons for this are linked to the conditions listed above. While some of these conditions may be assessed through an analysis of plant operational data, others require the application of biological process modeling.

The BioWin™ biological process model (version 3.0, Envirosim Ltd.) was used to model secondary processes at CBWTP. This model was calibrated against two periods of CBWTP performance—the first in July, 2007, and the second in February, 2008. During each of these periods, a detailed wastewater characterization was conducted. The results of the wastewater characterizations are summarized in Table 1.

The February 2008 record is characterized by a slightly low proportion of volatile solids (VS) in the influent (77 percent). The fraction of readily biodegradable substrates in the secondary influent was 17 percent, which is typical for municipal wastewater treatment plants. No nitrification was occurring at this time, evidenced by the effluent nitrite plus nitrate as nitrogen (NOx-N) of 0.1 mg/L. Some phosphorus removal is observed across CBWTP, but the effluent total phosphorus of 2.5 indicates weak biological phosphorus removal activity. The low selector orthophosphate concentration also points to very low activity of biological phosphorus removing organisms.

The July 2008 record is characterized by a very high influent chemical oxygen demand (COD), nearly double that of the February dataset. The COD/biological oxygen demand (BOD) ratio was 2.2, which is typical for raw influent municipal wastewaters. The ratio of volatile solids (VS) to total solids in the influent was 83 percent, which is slightly closer to typical than the February 2008 ratio. The fraction of readily biodegradable substrates in the secondary influent was 21 percent, which suggests some degree of fermentation occurring within the collection system during warmer summer conditions. Similar to the February dataset, the low effluent nitrate indicates no nitrification occurring during this time.

Table 1. Wastewater Characterization Results (Average of 10 Days of Sampling)

	February 2008				July 2007			
	Raw influent	Secondary influent	Selector	Secondary effluent	Raw influent	Secondary influent	Selector	Secondary effluent
Flow, mgd	96.4	88.3		88.3	58.4	57.5		57.5
COD	449	311		56.2	840	390		56.5
sCOD	136	135	62	26.6	208	207	72	33.7
ffCOD	76	73	61	19.9	129	107	97	25.7
BOD					379	200		8.5
cBOD	176	148		11.3	324	171		6.2
sBOD	65.1	63.7		3.0	93.7	86.6		2.3
TSS	207	100.5		22.1	460	93.3		15.8
VSS	153	76.2		15.7	391	77.3		13.3
TKN	29.6	29.8		20.6	44.4	41.2		31.1
sTKN	22.3	24.0		18.3	29.3	34.9		29.0
NH_3-N	18.6	21.6		17.7	25.8	32.3		25.5
NO_2-N						0.3		0.0
NO_3-N						0.7		0.1
NO_x-N				0.1		1.0		0.1
TP	4.6	4.8	28.7	2.5	7.0	6.6	57.6	3.8
PO_4-P		3.3	6.5	2.0		4.9	24.6	2.4
Alkalinity, mg/L $CaCO_3$		133		125		197		192
Temperature, degrees F	54.4			54.1	68.9			69.4
pH	7.3			7.0	7.2			7.3
Other parameters								
MLSS[1]	1,705				1,645			
RAS TSS[1]	5,950				5,490			
WAS flow, mgd	1.73				1.79			
RAS flow, mgd	31.6				23.3			
GBT recycle flow, mgd	0.87				0.73			

[1] MLSS and RAS TSS values taken from CBWTP daily monitoring records.

All values presented in mg/L unless otherwise noted.

Key: TSS = total suspended solids; VSS = volatile suspended solids; cBOD = carbonaceous BOD; sBOD = soluble BOD; Alk = alkalinity (mg/L $CaCO_3$); sCOD = soluble COD; ffCOD = flocculated and filtered COD; TKN = total Kjeldahl nitrogen; sTKN = soluble TKN; NH_3-N = ammonia as nitrogen; NO_2-N = nitrite as nitrogen; NO_3-N = Nitrate as nitrogen; TP = total phosphorus; PO4-P = orthophosphate as phosphorus; MLSS = mixed liquor suspended solids; WAS = waste activated sludge; GBT = gravity belt thickener

Phosphorus removal across the secondary process was similar to that observed in February, although the influent phosphorus concentrations were slightly higher. Overall, the effluent total phosphorus of 3.8 mg/L suggests weak biological phosphorus removal activity. Relatively high total and orthophosphate concentrations in the selector seem to contradict this observation, as these concentrations would suggest at least some biological phosphorus uptake and release across

CBWTP. It is possible that anaerobic conditions in the secondary clarifier and the RAS return pipeline and channel are causing phosphorus release. However, this would require phosphorus uptake in the aeration basin, which should result in a lower effluent phosphorus level.

Another possibility is that endogenous respiration within the return channel is leading to cell breakdown with subsequent release of phosphorus, although process modeling does not fully support this assertion, given a relatively high amount of substrate available in the RAS. Abnormalities in sampling within the return channel have been observed at other plants with selectors. Selector phosphorus levels have tended to be highly variable, with large differences noted between grab and composite samples taken on the same day (grab samples tend to report much lower phosphorus concentrations). Typically, the best measure of phosphorus removal activity is the effluent, which in this case indicates only a low level of activity.

Mass balances around the secondary clarifiers were used to assess the accuracy of flow data, as well as RAS and mixed liquor solids measurements. Figure 3 expresses the mass balance in the context of CBWTP process flow schematic.

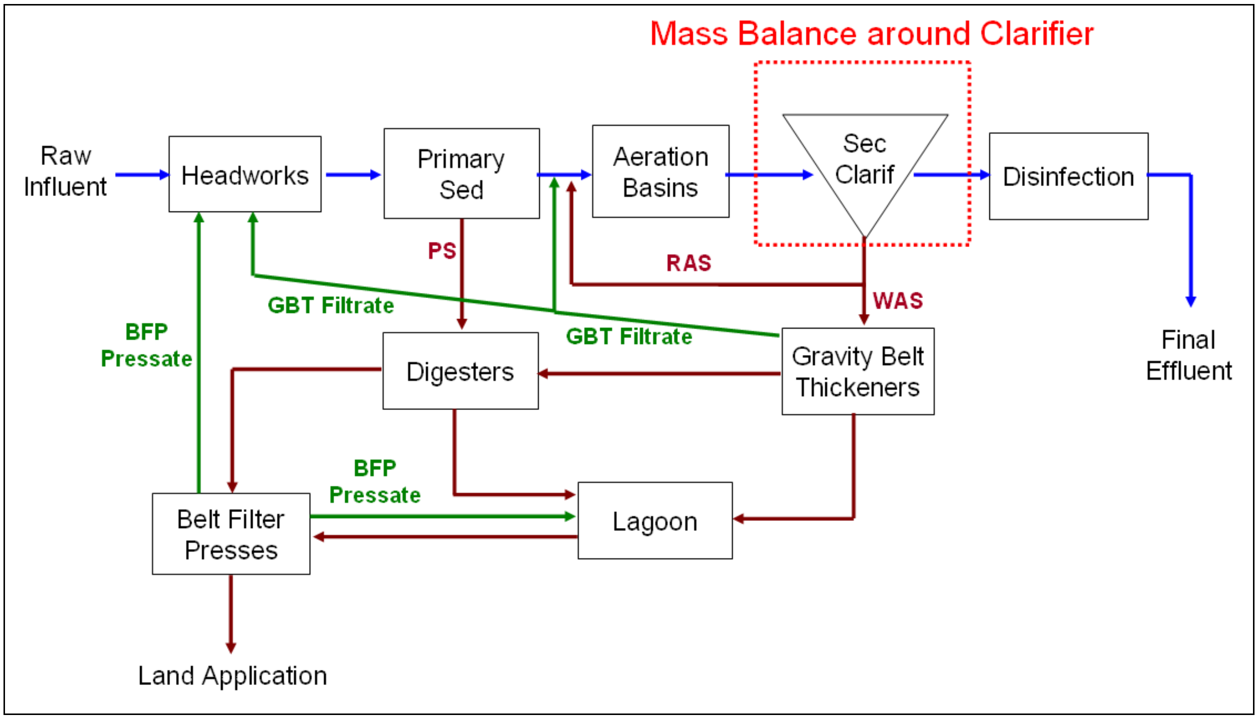


Figure 3. Process Flow Schematic with Secondary Clarifier Mass Balance

The mixed liquor flow is calculated from the dry weather primary effluent plus the RAS, plus recycle from the GBTs. GBT recycle data were available from CBWTP daily monitoring reports, from which a flow rate was estimated. Secondary clarifier underflow is a combination of RAS and WAS.

The historical mass balance around the secondary clarifiers is plotted on Figure 4. Although some variation is present, the balance stays close to 1.0, meaning the amount of solids leaving the clarifiers is equal to the amount of solids entering the clarifier. Since little to no biological activity is anticipated to occur in the clarifier, a mass balance of 1.0 makes sense.

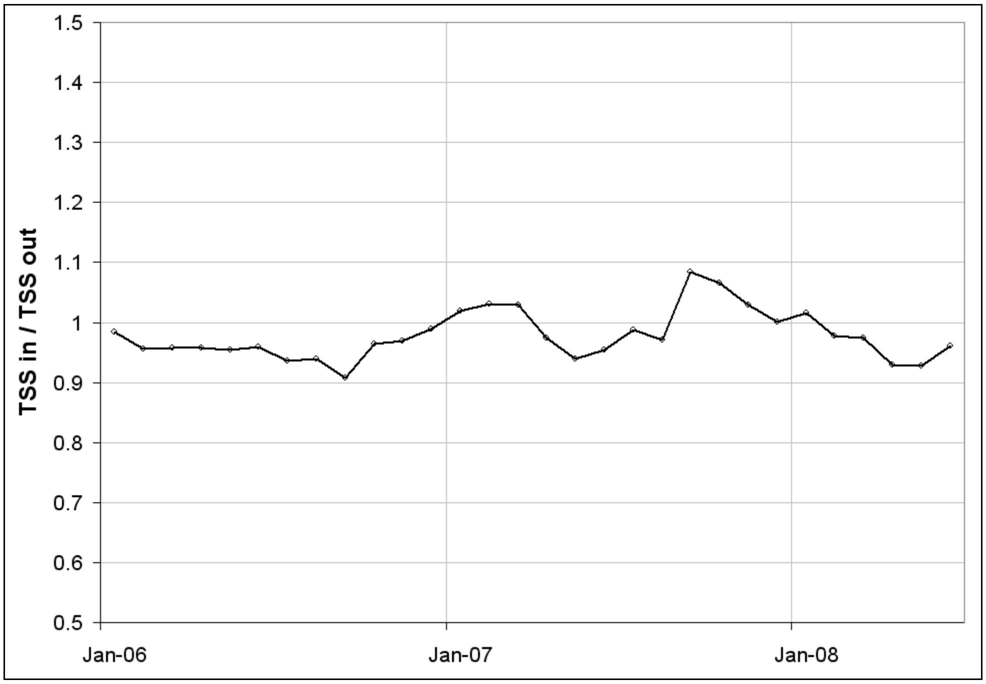


Figure 4. TSS Mass Balance around the Secondary Clarifiers

The historical mass balance suggests that RAS, WAS, and mixed liquor flow estimates are within reason, and that lab measures of mixed liquor and RAS solids are accurate.

When data from the February and July characterizations were plugged into the mass balance, a discrepancy was observed. Both balances demonstrated a significantly higher amount of solids leaving the clarifiers than were entering the clarifiers. Further data analysis uncovered a difference between the values of mixed liquor and RAS solids concentrations measuring during the special sampling campaigns, and the concentrations recorded in CBWTP's daily monitoring reports (DMRs). While the characterization concentrations resulted in mass balance ratios of 0.68 and 0.81, the DMR concentrations resulted in ratios of 1.01 and 0.95. CBWTP staff reported that the sampling locations used for the sampling campaigns were different from those typically used to collect data for the DMRs. In particular, the sample collected to measure RAS solids concentration during the sampling campaign was taken from a WAS storage well, while the samples taken to generate DMR data are drawn from the RAS return pipeline. It is possible that settling occurring in the WAS storage well led to higher reported concentrations in the characterization, which resulted in an uneven mass balance. Because CBWTP DMR data fit the mass balance, these values were used to calibrate the model, and these are the values listed in Table 1.

The BioWin model was calibrated against both the February and July datasets. A summary of the model setup and calibrated parameters is provided in Tables 2 and 3.

Table 2. BioWin Simulator Setup

Parameter	February 2008	July 2007
Tank volume, million gallons		
Mixing	0.08	0.06
Selector	3.72	2.79
Oxic 1	3.10	2.33
Oxic 2	4.30	3.23
Oxic 3	4.30	3.23
Temperature, Celsius	12.3	20.6
DO in post-selector zone	1.5	1.5
Clarifier blanket depth, percent	0.137	0.256
Clarifier reactions	off	off
Secondary influent parameters		
Flow	88.3	57.5
Total COD, mg COD/L	311	390
TKN, mg N/L	29.8	41.2
Total P, mg P/L	4.8	6.6
Nitrate N, mg N/L	0	0
pH	7.15	7.23
Alkalinity, micromols/L	2.7	3.9
Inorganic SS, mg TSS/L	24.3	16
Calcium, mg/L	80	80
Magnesium, mg/L	15	15
DO, mg/L	1	1

Table 3. BioWin Calibrated Parameters

Parameter	Default	February 2008	July 2007
Influent fractions			
Fbs, readily biodegradable	0.16	0.152	0.15
Fac, acetate	0.15	0.148	0.15
Fxsp, non-colloidal slowly biodegradable	0.75	0.6	0.42
Fus, unbiodegradable soluble	0.05	0.081	0.025
Fup, unbiodegradable particulate	0.13	0.3	0.35
Fna, ammonia	0.66	0.725	0.769
Fnox, particulate organic nitrogen	0.5	0.25	0.5
Fnus, soluble unbiodegradable TKN	0.02	0.02	0.02
FupN, N:COD ratio for unbiodegradable part. COD	0.035	0.035	0.035
Fpo4, phosphate	0.5	0.681	0.739
FupP, P:COD ratio for inf unbiodegradable part. COD	0.011	0.009	0.008
Calibrated parameters			
AOB max. spec. growth rate [1/d]	0.9	0.95	0.95
NOB max. spec. growth rate [1/d]	0.7	1	1
PAO max. spec. growth rate [1/d]	0.95	0.85	0.95
Ammonia oxidizer DO half sat. [mg O_2/L]	0.25	1	1
Nitrite oxidizer DO half sat. [mg O_2/L]	0.5	1	1
Heterotroph yield (aerobic) [-]	0.666	0.666	0.7
PAO yield (aerobic) [-]	0.639	0.639	0.7
Biological COD:VSS ratio [mg COD/mg VSS]	1.42	1.42	1.35
Particulate substrate COD:VSS ratio	1.6	2	2
Particulate inert COD:VSS ratio	1.6	2	2

In February, the model generated a close approximation to observed data. Effluent solids and cBOD were very similar to observed data (Figure 5), barring a pair of elevated cBOD samples which are within the margin of error of the recording.

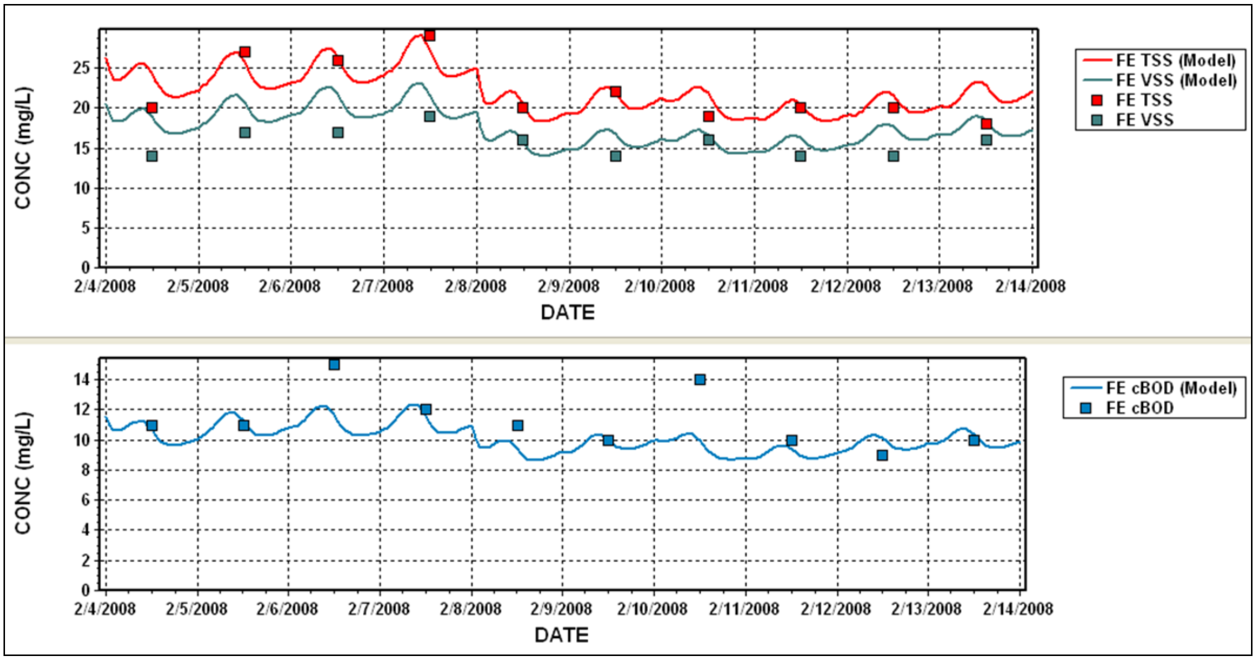


Figure 5. February 2008 Model Performance versus Observed Data, Final Effluent

Final effluent nutrient levels were modeled very close to observations. In Figure 6, the model projects no nitrification activity, and effluent phosphorus values of between 1 to 3 mg/L.

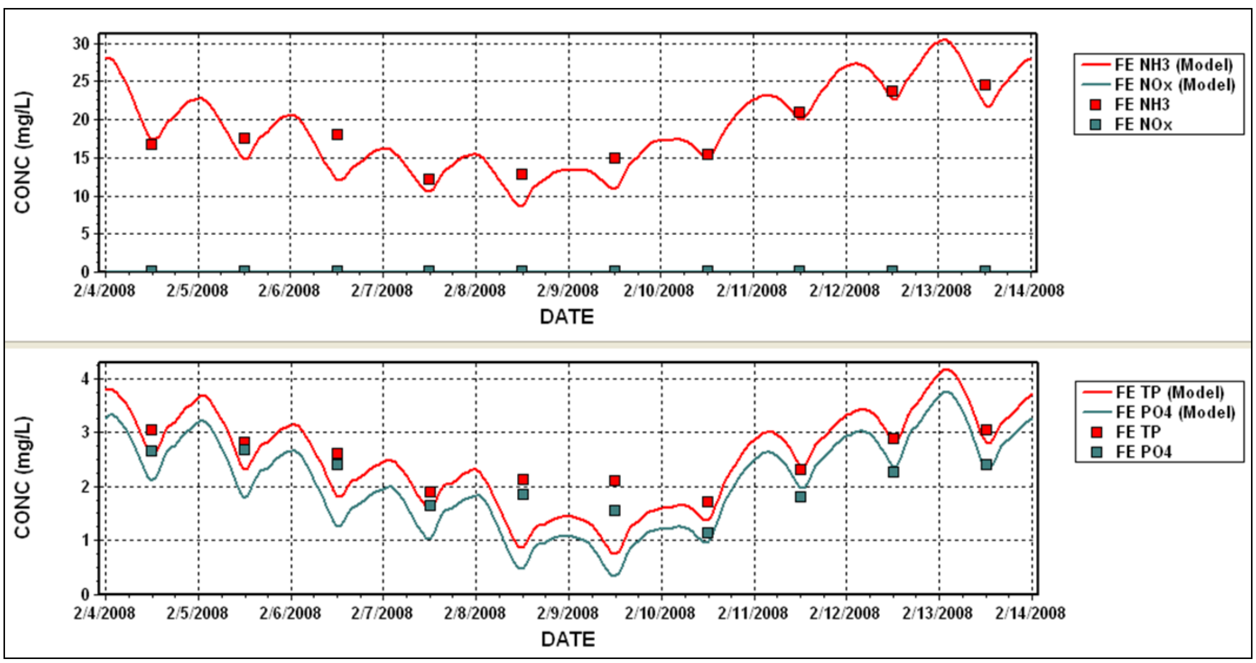


Figure 6. February 2008 Model Performance versus Observed Data, Nutrients

Parameter values in the selector tend to be highly variable. In this case, the model provided a reasonable correlation to recorded values of sCOD and phosphorus (Figure 7).

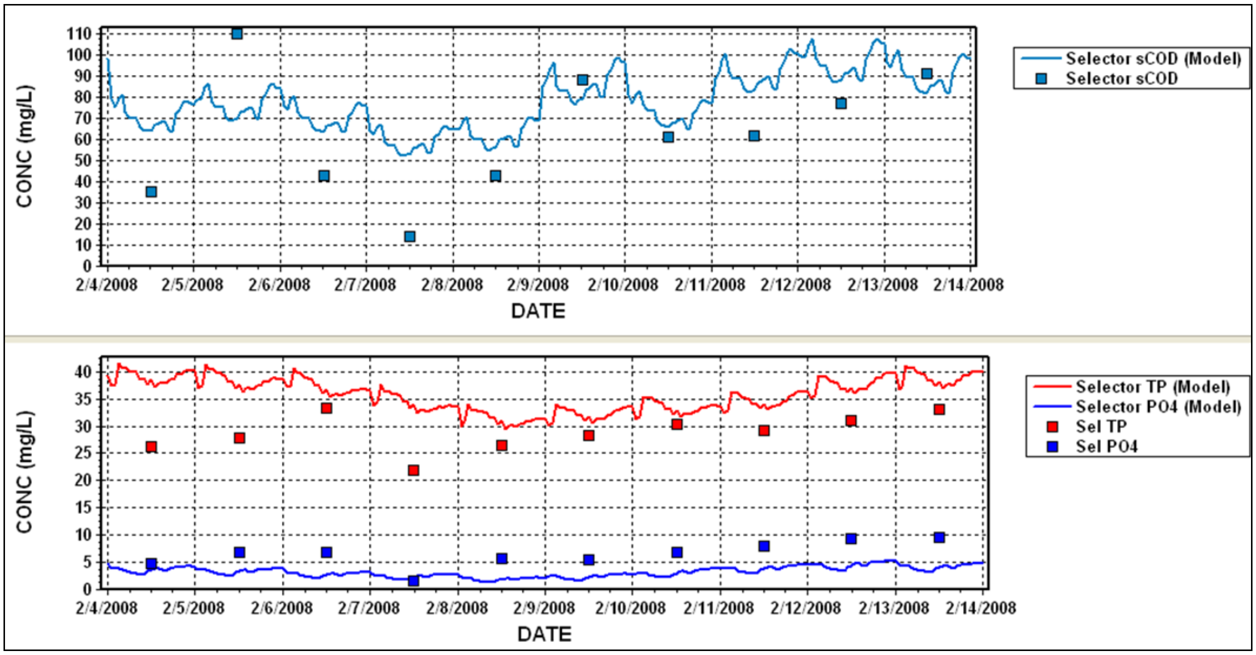


Figure 7. February 2008 Model Performance versus Observed Data, Selector

In terms of solids generated, both the MLSS and WAS solids calibrated very closely to observed values throughout the calibration period (Figure 8).

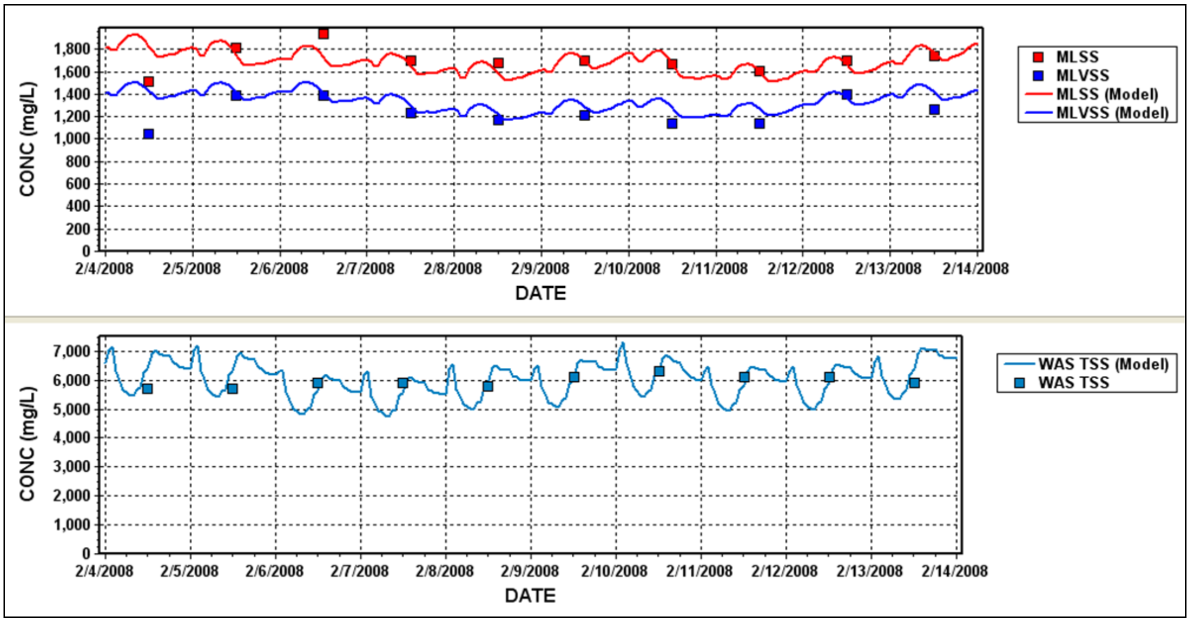


Figure 8. February 2008 Model Performance versus Observed Data, Solids

The July model was more difficult to calibrate. The solids generated in the model were consistently lower than observed, requiring in a slight increase of the biological yield coefficient and a slight reduction to the biological COD to VSS ratio. Once the calibrated parameters were entered, the model produced a good fit to effluent observations (Figure 9).

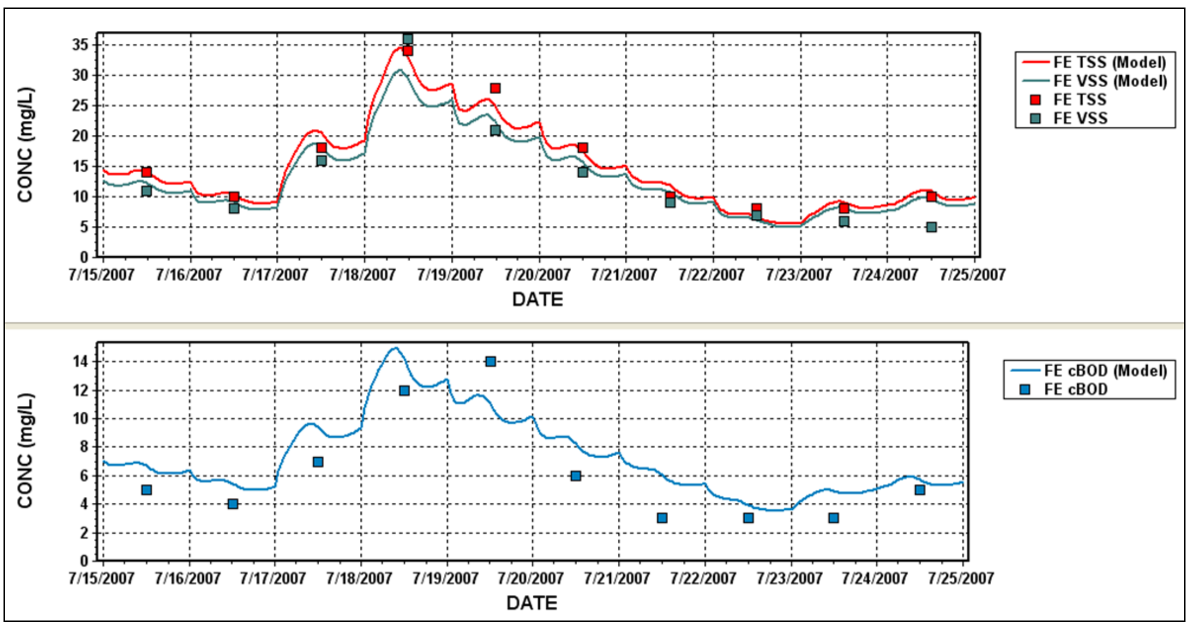


Figure 9. July 2007 Model Performance versus Observed Data, Final Effluent

The model simulated the observed effluent solids very closely (Figure 10), accurately projecting little nitrification activity, and effluent phosphorus levels of between 2 to 4 mg/L.

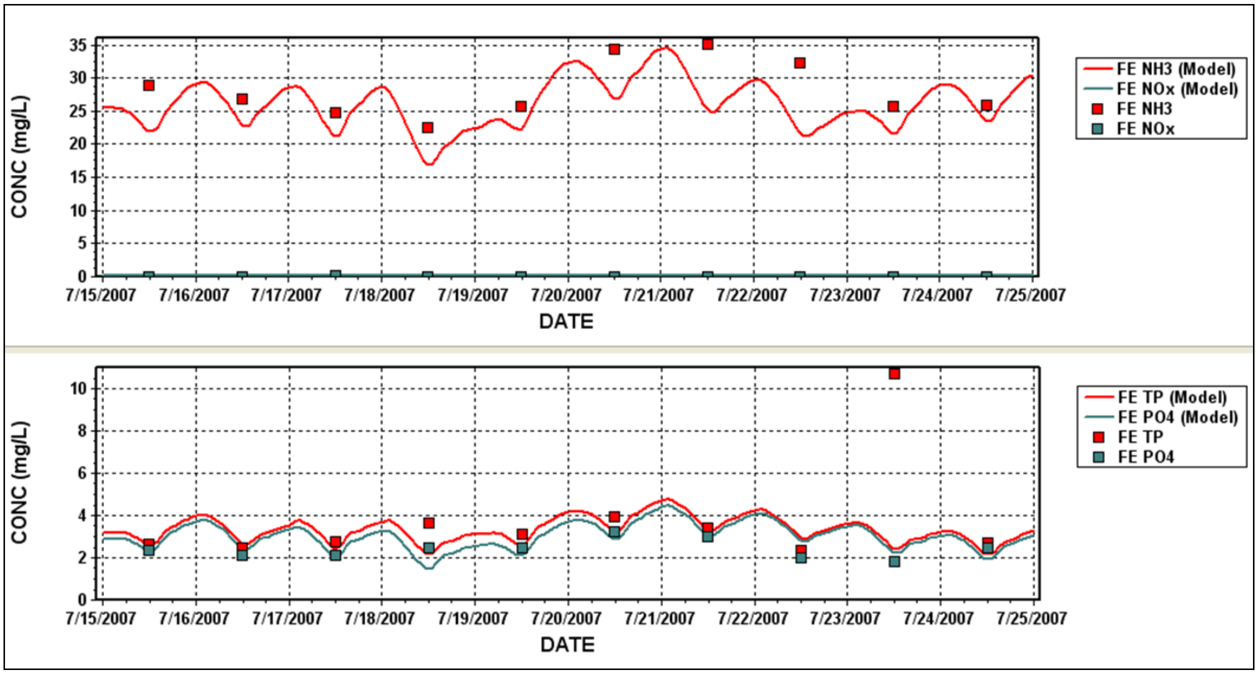


Figure 10. July 2007 Model Performance versus Observed Data, Nutrients

While the model accurately projected the soluble COD fraction in the selector, there was some discrepancy in the selector phosphorus levels (Figure 11). As discussed above, the wastewater characterization identified relatively high levels of phosphorus and orthophosphate in the selector, while only a small amount of phosphorus removal was taking place. This is counterintuitive, since high phosphorus levels in the selector would indicate that phosphorus uptake and release were occurring across the process train. If this were true, the final effluent phosphate would have to be significantly lower than observed. Staff have suggested that the relatively high orthophosphate concentration could be linked to phosphorus release in the long RAS return pipeline. Yet this also would require the presence of a bio-P population, which should not exist at the mean cell retention time experienced at the time of the characterization. At other plants, selector phosphorus levels have been known to fluctuate widely depending on the sampling location and time. Given the disparity in this piece of data, it is prudent to place more weight on the more reliable final effluent phosphorus data, and assume that the relatively high orthophosphate level in the selector is either not representative, or reflects an artifact of sample location, handling, and analysis.

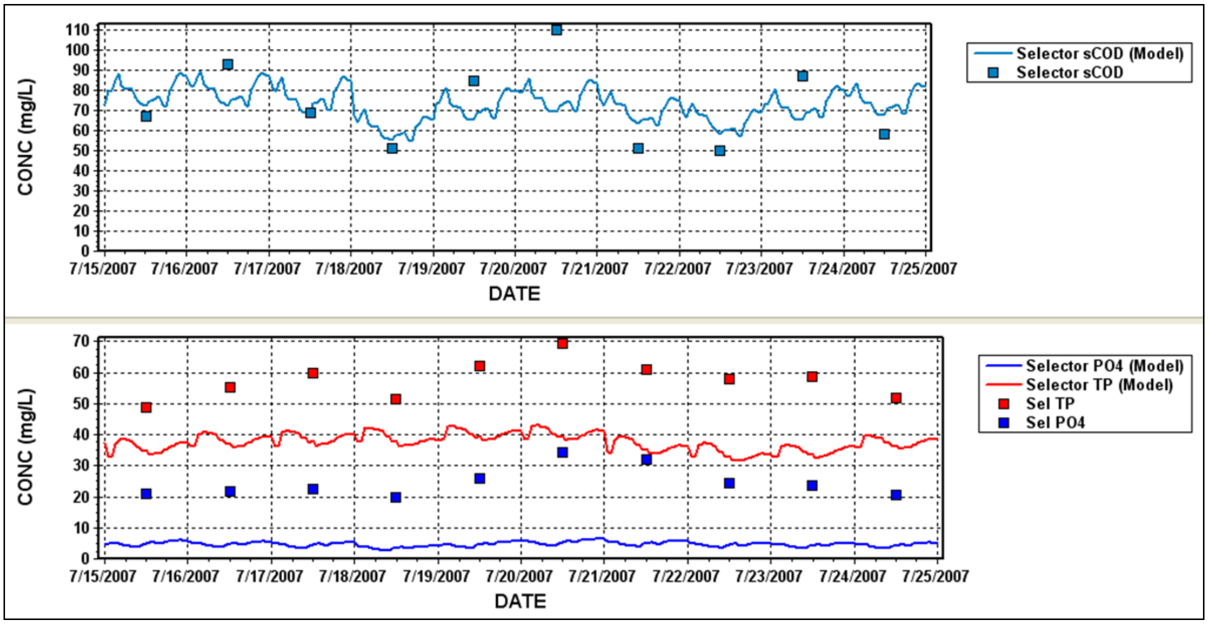


Figure 11. July 2007 Model Performance versus Observed Data, Selector

The mixed liquor and WAS solids values correlated well to observed data, with the exception of a brief period toward the end of the characterization period where model WAS concentrations did not reflect an increase noted in CBWTP data.

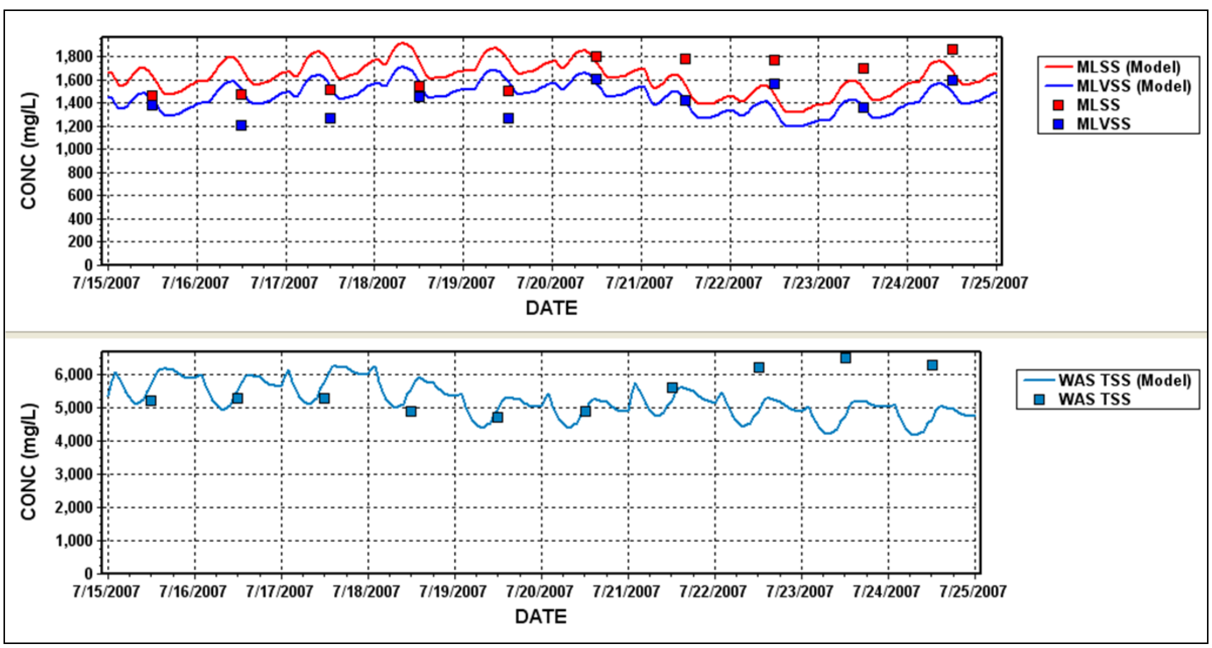


Figure 12. July 2007 Model Performance versus Observed Data, Solids

In summary, the calibrated February 2008 and July 2007 models exhibited a reasonable level of correlation to observed data. With the exception of selector orthophosphate levels measured during the July characterization, all of the key process parameters were within 10 percent of observed values for the bulk of the sampling periods. With calibration complete, the model can be applied to assess the factors that influence poor selector function at CBWTP: anaerobic environment, readily biodegradable substrate in the selector, SRT, phosphorus supply in the influent, and DO concentration downstream of the selector.

Anaerobic Environment

CBWTP employs a single-stage anaerobic selector. That is, a single baffle separates the selector from the aerated part of the basin. Secondary influent flows into the selector from a channel, passing over a weir and cascading into the process basin. As flow cascades into the basin, air is entrained. Air bubbles are visible at the head of the selector, meaning that the selector is not truly anaerobic. The presence of oxygen in the selector could limit the formation of a bio-P population by allowing the faster-growing heterotrophic bacteria to grow and compete for nutrients. Air in the selector also could promote the growth of bulking filaments, which could contribute to historically poor settling conditions.

Readily Biodegradable Substrate in the Selector

The bio-P population can take up only substrates of a very simple molecular structure. This requires that substrates are broken down or fermented prior to uptake. Often, sewage is broken down or fermented within the collection system, resulting in an adequate load of such substrate to the selector. More complex substrates reaching the selector are broken down and fermented within the selector. The longer the residence time within the selector, the more such processing can occur. In order to foster a healthy bio-P population, there must be an adequate supply of readily biodegradable substrates in the influent, or there must be sufficient residence time within the selector for the breakdown of complex substrates to occur.

The selector at CBWTP comprises 25 percent of the process tank volume. At 100 mgd, the hydraulic retention time (HRT) in the selector is approximately 40 minutes. The following model simulations (Table 4) were performed at a flow of 100 mgd, with all eight process trains in service. Summer model simulations were conducted at a mixed liquor temperature of 21 degrees Celsius (C); winter model simulations were conducted at a mixed liquor temperature of 12 degrees C. The clarifier solids blanket depth was fixed at 10 percent clarifier depth for all cases, in order to allow for equivalent comparison of the mean cell retention time (MCRT), which was fixed at 2.5 days.

Table 4. Effect of Selector Volume on Selector Performance

Selector size, percent of total	**5**	**10**	**25**	**30**	**40**
Selector HRT, minutes	**8**	**16**	**40**	**48**	**64**
Summer					
Volatile fatty acid (VFA) into selector, mg/L	5	6	6	6	6
VFA leaving selector, mg/L	23	36	53	61	71
Selector acetate	12	16	20	23	26
Selector propionate	11	20	33	37	45
Selector bio-P population, mg/L	1	2	13	4	2
Final effluent total phosphorus, mg/L	3.2	3.2	3.2	3.4	3.4
Phosphorus removal, percent	51	51	51	49	48
Winter					
VFA into selector, mg/L	4	4	4	4	4
VFA leaving selector, mg/L	16	24	37	42	49
Selector acetate	9	12	15	17	19
Selector propionate	7	13	22	25	30
Selector bio-P population, mg/L	1	1	7	3	1
Final effluent total phosphorus, mg/L	2.1	2.1	2.1	2.2	2.3
Phosphorus removal, percent	57	57	56	54	52

The data in Table 4 suggest poor selector function for all of the modeled scenarios. In none of the cases does the selector bio-P population increase above 13 mg/L, and total phosphorus removal across the process train stays fixed at between 50 and 60 percent. The selector does appear to be allowing for fermentation of influent COD. In both the summer and the winter, a tenfold increase in VFA concentration is noted across the selector. While the VFA generation is proportional to the size of the selector, modest increases were observed even at very low HRTs (an eight minute HRT in the summer was enough to increase the VFA concentration from 5 to 23 mg/L). The small population of bio-P organisms generated in these cases appeared to be optimized with the existing configuration (selector equal to 25 percent of basin volume). Altogether, the results in Table 4 indicate that the size of the selector does not appear to be limiting performance at CBWTP.

To further test this hypothesis, a series of model simulations were completed with the addition of exogenous acetate. The results of these scenarios are summarized in Table 5. All of these scenarios were simulated at an SRT of 1.9 days and a flow of 100 mgd.

Table 5. Impact of Exogenous Acetate Addition on Selector Performance at 1.9 days SRT

Summer	A	B	C	D	E	F	G
Exogenous acetate, pounds per day (ppd)	0	0	0	0	501	5,007	25,036
Influent acetate, ppd	0	0	0	7,323	7,323	7,323	7,323
Influent RBCOD[1], mg/L	0.0	29.3	58.5	49.7	49.7	49.7	49.7
VFA into selector, mg/L	0.0	0.1	0.1	6.0	6.5	10.7	29.3
VFA leaving selector, mg/L	21.3	36.4	51.1	52.8	53.3	57.8	77.8
Selector acetate	7.2	11.7	15.7	20.3	20.7	25.0	43.8
Selector bio-P population, mg/L	9.0	12.2	13.6	13.0	13.0	13.0	12.8
Final effluent total phosphorus, mg/L	3.2	3.1	3.2	3.2	3.2	3.2	3.0
Phosphorus removal, percent	52	52	52	51	51	52	54
Winter							
Exogenous acetate, ppd	0	0	0	0	501	5,007	25,036
Influent acetate, ppd	0	0	0	5,840	5,840	5,840	5,840
Influent RBCOD, mg/L	0.0	23.3	46.7	39.7	39.7	39.7	39.7
VFA into selector, mg/L	0.0	0.0	0.1	4.4	4.9	9.0	27.6
VFA leaving selector, mg/L	0.0	23.4	35.8	37.4	37.9	42.5	62.7
Selector acetate	0.0	8.1	11.8	15.4	15.9	20.2	39.1
Selector bio-P population, mg/L	0.3	4.9	5.1	5.1	5.1	5.0	4.8
Final effluent total phosphorus, mg/L	3.7	2.2	2.2	2.2	2.2	2.1	2.0
Phosphorus removal, percent	23	53	55	54	55	55	59

[1] readily biodegradable chemical oxygen demand

The bio-P population is not significantly affected by the amount of acetate added in the influent at this SRT. Even with the addition of 25,000 ppd of exogenous acetate, there is no increase in the bio-P population, and no increase in phosphorus removal across CBWTP.

SRT

The bio-P population is relatively slow growing, compared to the typical heterotrophic population in a wastewater treatment plant. As a result, this population is more susceptible to the SRT. SRT is a measure of how long an individual cell remains within the treatment train. Solids stored in the secondary clarifier are not considered, since they are assumed to be relatively inactive in that environment. At low SRT, the bio-P organisms do not have enough time to grow, and are washed out of the system. Since cells grow faster in warm environments, the bio-P organisms can tolerate a lower SRT in the summer than in the winter. This relationship is demonstrated in Table 6, which summarizes a set of model scenarios simulated for an influent flow rate of 100 mgd.

Table 6. Effect of SRT on Selector Performance

Summer							
SRT, days	1.4	1.6	1.8	2.0	2.3	2.7	3.2
MCRT, days	1.7	2.1	2.3	2.6	2.9	3.4	4.1
MLSS, mg/L	1,634	1,912	2,097	2,349	2,804	3,228	3,797
Selector bio-P population, mg/L	1	2	3	37	231	328	344
Final effluent total phosphorus, mg/L	3.3	3.3	3.3	2.9	0.9	0.8	0.8
Phosphorus removal, percent	50	50	50	56	86	89	89
Final effluent NOx, mg/L	0.1	0.1	0.1	0.2	0.5	1.8	12.4
Winter							
SRT, days	1.3	1.6	1.8	2.0	2.3	2.6	3.1
MCRT, days	1.7	2.0	2.3	2.5	2.9	3.3	4.0
MLSS, mg/L	1,424	1,670	1,830	2,032	2,392	2,755	3,224
Selector bio-P population, mg/L	1	1	2	9	139	214	309
Final effluent total phosphorus, mg/L	2.4	2.3	2.2	2.1	0.8	0.6	0.6
Phosphorus removal, percent	49	53	54	55	83	87	87
Final effluent NOx, mg/L	0.0	0.0	0.0	0.0	0.0	0.0	0.1

CBWTP is permitted for BOD and TSS. Lacking an effluent nitrogen limit, CBWTP typically maintains an SRT short enough to prevent the onset of nitrification. Over the period 2006 to 2008, the SRT fluctuated between 1.75 to 2.75 days, but demonstrated a high degree of day-to-day variation (Figure 13).

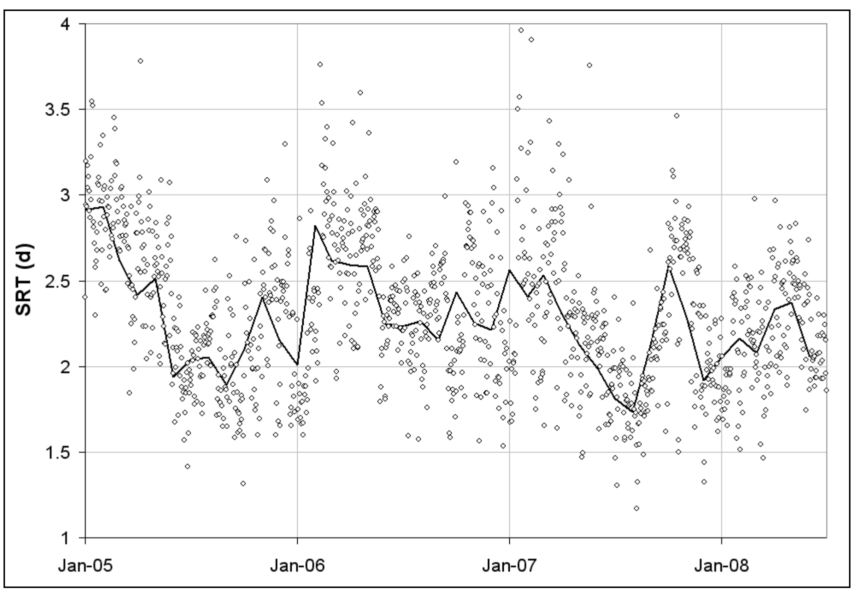


Figure 13. SRT

Figure 13 suggests that for much of the past few years, the aeration basin operation has rarely been maintained at a high enough SRT over a long enough period of time to allow the growth of a significant bio-P population. Figure 14 transposes the SVI record alongside the SRT record (Figure 14 expresses a 3-day moving average for both values). Much of period from 2005 through 2006 is characterized by the fluctuating SRT, with an SVI demonstrating periodic peaks to 300 mL/g. A large increase in SVI in 2007 is accompanied by a long-term reduction in SRT to less than 2 days. The data suggest a combination of effects. In general, the SRT has been maintained within a borderline region at which a bio-P population might begin to take hold. However, the variability of the SRT has prevented that population from growing, with periodic wash-outs accompanied by periods of poor settling.

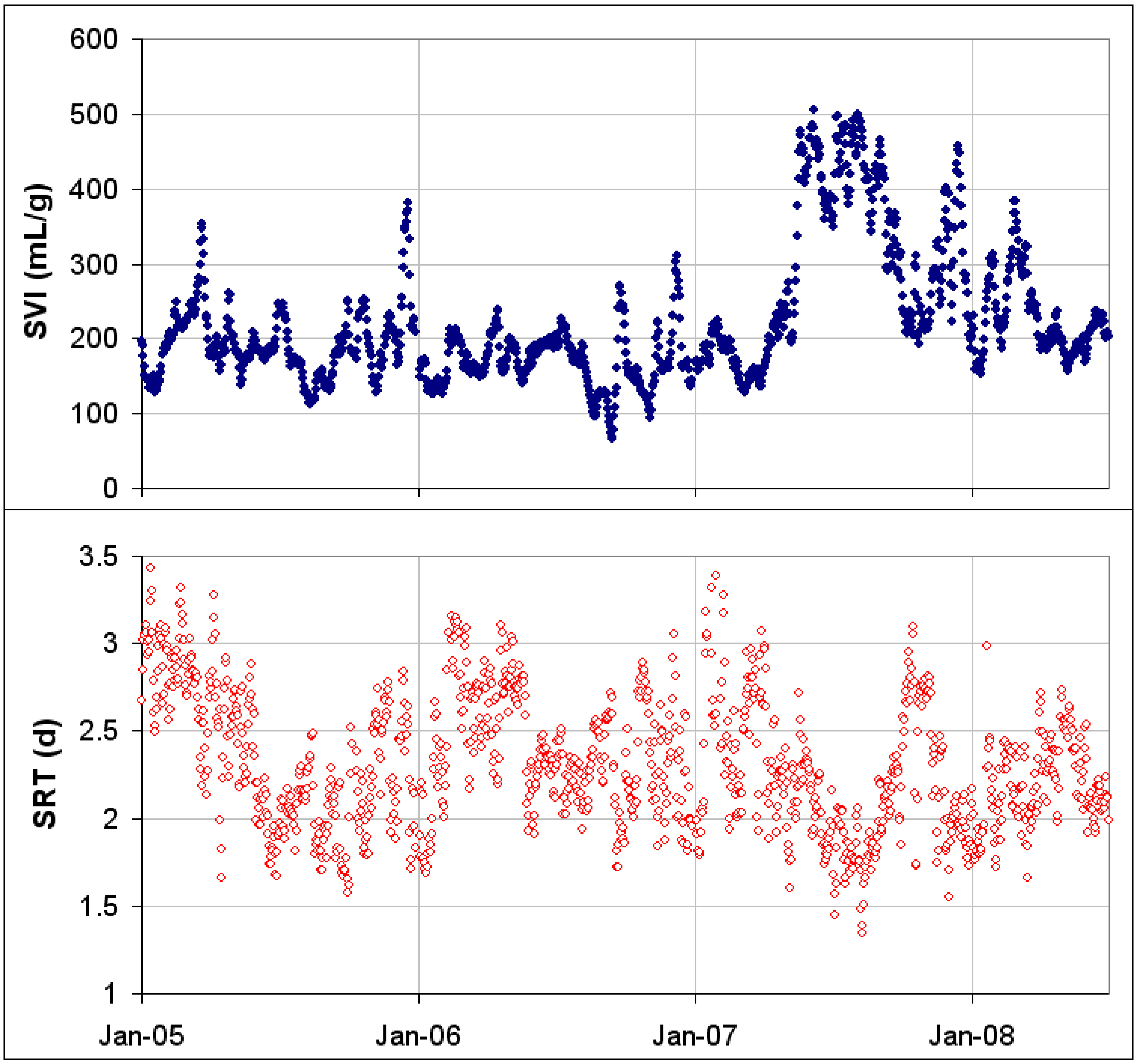


Figure 14. Correlation between SRT and SVI (3-Day Moving Average)

Given the data presented in Table 6, the SRT should be maintained in excess of 2.5 days in order to foster growth of a bio-P population. During the summer, the SRT should be balanced to prevent the onset of nitrification. In Table 6, an appreciable amount of nitrification was observed at an SRT of 3.2 days, meaning the optimal SRT window is between 2.5 and 3.2 days.

Earlier, it was determined that the amount of RBCOD or acetate entering the system had no impact on the bio-P population at an SRT of 1.9 days. It now seems clear that this is because the SRT was too low to support a population, irrespective of the influent acetate availability. This leads to the question of whether the amount of substrate plays a role at longer SRTs. In order to evaluate this, the series of model simulations outlined in Table 5 were repeated at an SRT of 2.5 days. The results of these scenarios are presented in Table 7.

Table 7. Impact of Exogenous Acetate Addition on Selector Performance at an SRT of 2.5 Days

Summer	A	B	C	D	E	F	G
Exogenous acetate, ppd	0	0	0	0	501	5,007	25,036
Influent acetate, ppd	0	0	0	7,323	7,323	7,323	7,323
Influent RBCOD, mg/L	0.0	29.3	58.5	49.7	49.7	49.7	49.7
VFA into selector, mg/L	0.0	0.0	0.0	4.7	5.2	9.1	27.3
VFA leaving selector, mg/L	10.6	13.6	18.1	16.5	16.7	19.2	41.5
Selector acetate	2.0	2.2	2.5	3.3	3.4	4.9	20.4
Selector bio-P population, mg/L	130	209	277	304	307	330	351
Final effluent total phosphorus, mg/L	1.3	1.1	1.0	1.0	1.0	1.0	1.0
Phosphorus removal, percent	81	84	85	85	85	85	85
Winter							
Exogenous acetate, ppd	0	0	0	0	501	5,007	25,036
Influent acetate, ppd	0	0	0	5,840	5,840	5,840	5,840
Influent RBCOD, mg/L	0.0	23.3	46.7	39.7	39.7	39.7	39.7
VFA into selector, mg/L	0.0	0.1	0.1	4.3	4.7	8.7	27.1
VFA leaving selector, mg/L	9.2	12.5	17.3	16.8	17.2	21.4	44.5
Selector acetate	2.3	2.5	2.9	4.3	4.5	7.3	26.2
Selector bio-P population, mg/L	69	130	174	192	193	204	203
Final effluent total phosphorus, mg/L	1.2	0.9	0.9	0.9	0.9	0.9	0.8
Phosphorus removal, percent	75	81	82	82	82	82	82

At longer SRTs, the size of the bio-P population is impacted by the amount of substrate entering the system. The effect is relatively small, however. In Table 7, the baseline scenario (scenario D, with no exogenous acetate supply, but normal levels of acetate and RBCOD in the influent) generates a bio-P population of 304 mg/L in the summer and 192 mg/L in the winter. Adding 5,000 ppd of exogenous acetate (scenario F) results in an 8.5 percent increase in population in the summer (to 330 mg/L) and a 6.3 percent increase in the winter (to 204 mg/L). Increasing the exogenous acetate further, to 25,000 ppd (scenario G), resulted in only a marginal increase (6 percent summer, zero percent winter).

In summary, the selector is not expected to perform optimally at an SRT of less than 2.5 days. At SRT values in excess of 2.5 days, the selector should generate a robust population of bio-P organisms. The size of this population would not be impacted substantially by the addition of exogenous substrate, given expected levels of RBCOD and acetate in CBWTP influent. Even if the influent acetate is taken down to zero, and the RBCOD concentration reduced by one-half (scenario B), a modest population of bio-P organisms is expected to take hold in both the summer and winter scenarios (209 mg/L bio-P in the summer, 130 mg/L in the winter).

Phosphorus Supply in the Influent

All cells require an ample supply of phosphorus in order to grow. The bio-P organisms are particularly sensitive to the influent phosphorus concentration, given their reliance on phosphorus uptake and release as part of their competitive strategy. If the level of phosphorus in the influent is low, the bio-P population will be impacted before the rest of the activated sludge organisms. This is demonstrated in Table 8, where the bio-P population had decreased to zero with only <10 percent reduction in MLSS (and much of that reduction due to the loss of bio-P organisms).

Table 8. Effect of Influent Phosphorus on Bio-P Population
Summer Scenario, 100 mgd, 2.7 day SRT

Parameter	Scenario				
	1	2	3	4	5
Secondary influent total phosphorus, mg/L	6.6	6.0	5.0	4.0	3.5
MLSS, mg/L	3,243	3,208	3,135	3,040	2,984
Bio-P population, mg/L	329	291	184	48	0.6
Percent reduction MLSS, percent	--	1	3	6	8
Percent reduction Bio-P, percent	--	11	44	85	100

DO Concentration Downstream of Selector

CBWTP staff have reported that the portion of the aeration basin downstream of the selector suffers from limited aeration. Staff cannot maintain a DO concentration of 2 mg/L in this section, and estimate that the DO can be as low as 1 mg/L at times. Bulking filaments thrive in an environment of low DO. Because of their filamentous shape, these organisms have a larger surface area than other activated sludge organisms. Bacteria take up oxygen through the cell surface, therefore organisms with larger surface areas will be able to take up more oxygen, per capita. In an environment where the oxygen supply is limited, the organisms with the largest surface area will have a competitive advantage.

Low oxygen alone will not foster the growth of bulking filaments. These bacteria also require the presence of readily biodegradable substrate. Like the bio-P organisms, bulking filaments are slow-growing, and are capable of utilizing only substrate which has already been broken down into simple components, such as acetate or other VFAs. In a properly performing selector, these substrates will be taken up and stored by bio-P organisms. If the bio-P population is large enough, very little of this substrate will leave the selector into the aerated portion of the basin. If, however, the selector is not functioning as planned, and if a bio-P population is not supported, then all the readily biodegradable substrate and VFAs will pass into the aeration basin, where they may be utilized by bulking filaments.

The combination of low oxygen plus the availability of readily biodegradable substrates creates an ideal environment for the growth of bulking filaments. These filaments interfere with mixed liquor settling in the secondary clarifiers by forming light, interwoven masses of buoyant cells. Given the historically low DO in the section of the aeration train downstream of the selector, and the evidence of little bio-P activity in the selector, it would appear as though some of the volatility in historical SVI at CBWTP could be attributed to bulking filaments.

SUMMARY AND CONCLUSIONS

Physical inspection and biological process modeling of the secondary process trains at CBWTP have identified the following factors to explain historically erratic performance of the anaerobic selector:

1. CBWTP's SRT has varied between 1.75 and 2.75 days over the past few years, with a high degree of day-to-day variation. Process modeling suggests that an SRT in excess of 2.5 days is required to foster the growth and abundance of a bio-P population.

2. The cascading flow of secondary influent into the selector has been observed to entrain air. This could result in a high enough DO concentration to limit the competitive advantage the bio-P organisms gain from an anaerobic condition.

3. Limited oxygen supply downstream of the selector, coupled with low abundance of bio-P organisms within the selector may foster the growth of bulking filaments. These filaments negatively impact settling in the clarifiers through their physical structure.

RECOMMENDATIONS

In order to improve the performance of the selector, the following modifications are suggested:

1. Increase SRT to a minimum of 2.5 days year-round. In the summer, maintain an SRT low enough to limit the onset of nitrification.
2. Install a baffle midway across the selector. This baffle will divide the selector into two parts. The first part will act to remove any residual oxygen entering the system at the influent flow cascade. The second part will be truly anaerobic, fostering the growth of bio-P organisms.
3. Install oxidation-reduction potential meters in both parts of the newly divided selector. These meters will report whether conditions in the selector are appropriate for anaerobic fermentation and growth of the bio-P population.
4. Improve the aeration downstream of the selector to ensure a minimum DO concentration of 2 mg/L at all times.
5. Install permanent DO meters downstream of the selector. These meters will verify that the aeration system is maintaining a DO concentration of 2 mg/L at all times. Meters should be installed at two depths to ensure the DO target is being met across the full depth of the tank.

In addition to the recommendations outlined above, a means for providing exogenous acetate was evaluated. A fermenter would draw primary sludge from the primary sedimentation basins, and mix it anaerobically over a period of 1 to 2 days. During this period, the primary sludge would ferment, breaking down complex organic matter into readily biodegradable substrate and VFAs. The mixture would be allowed to settle, with the supernatant fed into the head of the selector to promote the growth of a bio-P population.

Process modeling of such a system determined that the fermenter would supply only approximately 600 ppd of VFAs. Such a contribution was found to have limited impact on the bio-P population (less than 5 percent increase at expected levels of influent RBCOD, up to 20 percent increase at zero influent RBCOD). Compare the scenarios in Table 7 with 500 ppd of exogenous acetate addition with those with zero exogenous acetate addition (scenario E). In the summer, the acetate addition increased the bio-P population from 304 to 307 mg/L; in the winter the increase was from 192 to 193 mg/L. Such limited improvements do not justify the cost and complexity of installing and operating a fermenter system. If the above recommendations are adopted, and CBWTP continues to experience erratic selector performance, a more detailed analysis of influent RBCOD loadings would be recommended. If such an analysis finds period of minimal to zero RBCOD loading at the time of poor settling, further modeling and evaluation of a fermenter system would be warranted.

APPENDIX F

Tiered Recommendations and Capital Costs

For the cost estimating effort, the recommendations are grouped according to tiers, which represent the relative cost, importance, and complexity of implementation. Both operational and capital improvements are included in the tiers. Only the capital costs for the capital improvements are included.

Tier 1

The Tier 1 recommendations are as follows:

1. **Install additional aeration diffusers downstream of the selector in all basins**. Aeration will help prevent low-DO bulking. When the oxygen supply in the post-selector zone is limited, it favors the growth of filamentous organisms, which preferentially degrade readily biodegradable substrate escaping from the selector. Supplementing aeration in this area will help prevent such an occurrence. This is especially important as data collected during the pilot study suggested exactly such an outbreak during the first week of February 2009, when the plant experienced an unusually high strength influent load.

2. **Install an intermediate baffle to divide the selector into two zones in all basins**. During the pilot study, there were periods where the ORP in the first zone of the pilot selector became aerobic. Installation of an intermediate baffle, as was done in the pilot train, ensures that at least a portion of the selector remains anaerobic most of the time. This is particularly important during and after storm events. Maintaining anaerobic conditions provides a competitive advantage to the bio-P organisms the selector aims to grow.

3. **Operate at a higher SRT**. With improved aeration downstream of the selector, the risk of filament outbreak is reduced, allowing for more flexibility in operating at higher SRTs, while still minimizing the onset of nitrification. The secondary processes should be operated near a 2.5 to 3.5 day SRT in order to ensure the viability of the bio-P population, the value adjusted according to season of operation.

4. **Operate with a minimal clarifier solids blanket**. Efforts should be made to prevent the formation of deep clarifier solids blankets. Blanket depths of no greater than 1–2 feet should be a goal, in order to prevent premature phosphorus release by the bio-P population (also termed secondary phosphorus release).

Tier 2

The Tier 2 recommendations are as follows:

1. **Install automated DO control**. During the trial, large fluctuations in DO concentration across the aeration tank were noted. In part, this appeared to be related to large changes in influent loading which may be attributed to the large industrial flow component to this plant. Adding automated DO control will allow the aeration system to react in real time to loading changes. This will limit the occurrence of low DO concentration periods associated with filamentous outbreaks and poor settling and improve selection for bio-P organisms by ensuring as complete as possible phosphorus uptake while minimizing secondary

phosphorus release, and will also limit the waste of energy associated with oversupply during low load periods.

2. **Install permanent DO sensors downstream of the selector**. Failure to provide sufficient oxygen in this area is linked to an inadequate uptake of phosphorus in the aeration basin and filamentous bacteria outbreaks, which impair mixed liquor settling.

3. **Install permanent ORP sensors in the selector**. The ORP sensors can be used to assess whether the environmental conditions are conducive to the support of a robust bio-P population, allowing operators to manage the SRT accordingly.

4. **Install in-line solids concentration sensors for the MLSS and WAS streams**. These will allow for better control of the sludge inventory, giving operators a real-time estimate of the sludge inventory and therefore of the SRT. This would allow for the automatic control of the wasting rate based on a target SRT.

5. **Provide automated solids wastage**. The WAS valves and flow meters should be calibrated and automated to respond to a real-time calculation of SRT based on in-line solids and flow data. This will allow for improved and up-to-the-minute process control, giving operators more leverage to control the system based on changes in loading or plant conditions.

6. **Conduct daily total and soluble COD measurement of the primary effluent**. COD can be analyzed within 3 hours of sampling, providing operators with same-day estimates of the food-to-microorganisms ratio (a key operational parameter), as well as allowing for same-day response to slug loads of highly concentrated waste streams. During testing, at least two such incidents provoked destabilization of the process with long-lasting impacts.

7. **Measure daily total and floc filtered effluent COD (ffCOD) in concert with the influent COD measurements**. This would allow measurement of the readily biodegradable COD (RBCOD) fraction that is required for inducing the selector effect. As knowledge is gained on the variability of RBCOD, provision may need to be made for supplemental carbon addition on an as-required basis when levels fall below a critical level.

8. **Conduct regular phosphorus profiling across the secondary system**. Phosphorus profiles can gauge the strength of the bio-P population, and also give evidence of harmful phosphorus release in the secondary clarifier blanket.

Tier 3

The only Tier 3 recommendation is to renovate RAS return system with valve replacement and automation. During the trial, process control was limited by the inability to effectively separate the pilot and control trains. This brought to light the general inability to isolate individual trains and the difficulty involved in controlling the flow of RAS to each of the trains. Replacement of corroded valves and selective piping renovation would allow for each train to have a dedicated RAS return, independent of the primary effluent flow.

Long-term operation, given the above modifications, should result in reduced and more consistent mixed liquor settling. In this setting, a long-term SVI target of 200 mL/g should be achievable.

Costs of Recommendations

Table F-1 summarizes anticipated costs of each tier of recommendations. The engineering and administration markup of 45 percent is included in the capital costs for Tiers 2 and 3.

Tier 1 costs are based on the City's contract for one baffle wall that was implemented as part of the pilot testing so the contingency and contractor markups are eliminated. The City is budgeting $396,000 for the project cost (design and construction) of the seven remaining baffle walls. The costs for all eight basins are included in this estimate.

In Tier 2 costs, the estimated costs for automated DO control include installation of automated valves in the aeration supply piping, air flow meters in the aeration supply piping, and a feedback control system linking the new DO sensors in the in each train to these valves, the air flow meters and the blowers. There are five aeration grids per train. Each grid has been assumed to have its own control valve and air flow meter for a total of 40 control valves and air flow meters. Valve costs have been assumed to be $20,000 per valve (installed) and $10,000 per meter (installed). Control system upgrades were estimated to be $300,000. Total cost was estimated to be $1.5 million.

Based on the pilot trial, it was determined that one DO sensor was required to be located in zone 2A (immediately downstream of the last selector baffle wall and lower down in the aeration tank). A second DO sensor was required further down the tank in zone 4 prior to discharge from the tank. For the seven trains that still need DO sensors, this would mean a total of 14 additional DO sensors. The unit cost of a sensor with local indicator installed was estimated to be $20,000 for a total of $140,000.

Tier 3 costs include RAS replacing RAS valves. During the pilot trial, it was observed that RAS control was impeded by the condition of the RAS valves. For the whole secondary system to perform as required, it is recommended that, as a first step, the RAS be returned to the head of each train and automated RAS valves be installed at the entrance to each train. This would decouple the RAS flow from the primary effluent flow and allow for a higher RAS return to each train. The O&M manual indicates that the RAS capacity is limited to 62.5 mgd when applied to the PE channel, but can be increased to 80 mgd when RAS is applied to each train.

Table F-1. Estimated Capital Costs of Recommendations

Tier 1 Recommendations	Number	Unit cost, dollars	Total cost, dollars
Additional diffusers (City to install)	8	50,000	350,000
Intermediate baffles (design and construction)	8	56,571	396,000
Subtotal Tier 1			746,000
Total Tier 1			746,000
Tier 2 Recommendations			
Automated DO control	1	1,500,000	1,500,000
In-line MLSS meter	2	25,000	50,000
In-line WAS meter	2	25,000	50,000
DO meters	14	20,000	280,000
ORP meters	7	20,000	140,000
Subtotal Tier 2			2,020,000
Electrical	20%		404,000
Subtotal			2,424,000
Contractor markups	30%		727,200
Subtotal			3,151,200
Contingency	40%		1,260,480
Subtotal			4,411,680
Engineering and administration	45%		1,985,256
Total Tier 2			6,396,936
Tier 3 Recommendations			
Automated RAS valves	8	50,000	400,000
Subtotal Tier 3			400,000
Electrical	20%		80,000
Subtotal			480,000
Contractor markups	30%		144,000
Subtotal			624,000
Contingency	40%		249,600
Subtotal			873,600
Engineering and administration	45%		393,120
Total Tier 3			1,266,720

Table F-2 summarizes capital costs by Tier.

Table F-2. Summary of Capital Costs by Tier with Markups

Tier	Cost, dollars
Tier 1	746,000
Tier 2	6,397,000
Tier 3	1,267,000
Total, all tiers	8,410,000

APPENDIX G: TIER 4 RECOMMENDATIONS

Tier 4

If further, targeted SVI control is desired after implementing the set of recommendations that result from the pilot testing, Tier 4 recommendations may be considered:

- Install mixers in aeration basin influent channels. During the trial and the planning period leading up to the trial, staff commented that there is typically an uneven distribution of loadings to each of the eight aeration trains. The flow pattern in the aeration basin influent channel drives solids into the upstream trains (7-8), leading to a more dilute flow in to downstream trains (1-2). Installation of mixers in the influent channel will relieve this disparity, allowing for better process control and performance.

- Evaluate the effectiveness of chemically enhanced flocculation for improved mixed liquor settling during periods of increased SVI. Implementation of the above recommendations should improve selector performance, and result in reduced magnitude and frequency of periods of impaired mixed liquor settling. A supplementary approach is to employ chemicals to enhance mixed liquor flocculation and settling. Chemicals such as alum, polyaluminum chloride, and a variety of polymers can be applied to mixed liquor, inducing coagulation and improving removal in the secondary clarifiers. In plants with a history of periodic occurrences of impaired settling, particularly where difficult-to-control factors such as industrial slug loads or changes in influent characteristics may negate the ability of a biological selector to function properly, the availability of chemical flocculation may present an "insurance policy" against solids loss. Chemicals may be brought rapidly in and out of service, with nearly immediate results. Implementation of such a program would require a chemical storage location, and chemical application points in the mixed liquor channel (application points typically require service air and water). Jar testing followed by full-scale testing would determine the applicability of such a scheme to the CBWTP.

The capital costs for Tier 4 are summarized in the following Table E-1.

Table E-1. Tier 4 Capital Costs

Tier 4	Number	Unit cost, dollars	Total cost, dollars
AB influent channel mixers	8	25,000	200,000
Subtotal, Tier 4			200,000
Electrical	20%		50,000
Subtotal			250,000
Contractor markups	30%		75,000
Subtotal			325,000
Contingency	40%		130,000
Subtotal			455,000
Engineering and administration	45%		205,000
Total, Tier 4			660,000

Clarifier Testing

On March 24, 2009, a set of secondary clarifier tests were conducted on pilot and control clarifiers using Kemmerer settlers and the Wahlometer apparatus. Dispersed suspended solids (DSS) and flocculated suspended solids (FSS) tests may be used to characterize hydraulic and flocculation processes in the clarifiers. The DSS is a measure of the suspended solids concentration after 30 minutes of settling. The FSS is a measure of the suspended solids concentration after 30 minutes of flocculation, followed by 30 minutes of settling. DSS tests are carried out at the clarifier inlet and outlet. FSS tests are carried out on the mixed liquor. A sample of actual clarifier effluent suspended solids (ESS) concentration is used for comparison.

The DSS test is a measure of the maximum degree of settling that the mixed liquor sample can achieve under ideal quiescent settling conditions. Ideally, the final effluent TSS (ESS) concentration should be close to the DSS concentration and there should be a decline in DSS across the clarifier. For the FSS test, the FSS is a measure of the maximum degree of settling that can occur for a mixed liquor sample but with the benefit of a period of flocculation before settling under ideal quiescent settling conditions. The difference between the DSS and FSS measurements provides a measure of the maximum effectiveness of flocculation that the mixed liquor can effect under the conditions of growth in the aeration basin.

The results of DSS/FSS testing for the pilot and control clarifiers are summarized in Figure 20.

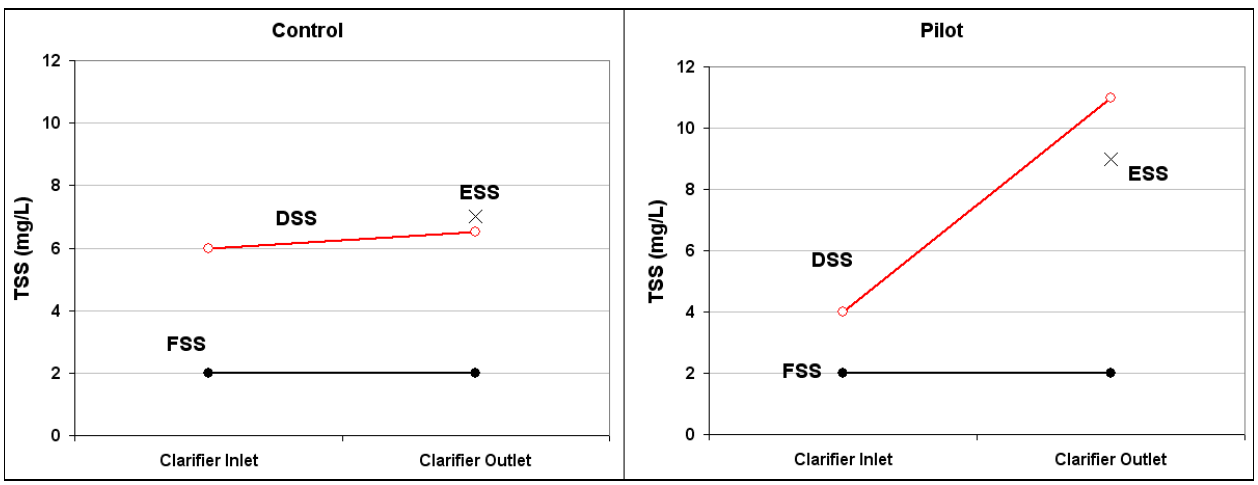


Figure 20. Results of DSS/FSS Testing, March 24, 2009

In the control clarifier (clarifier 4), the DSS was consistently higher than the FSS, with little difference between the influent and effluent DSS. The effluent DSS was nearly equal to the actual ESS. There is a 4–5 mg/L difference between DSS and FSS measurements indicating that flocculation is not as efficient as it could be in ideal conditions. One would anticipate that the DSS present in the clarifier influent might have been gathered up during flocculation processes within the clarifier with a resulting lower DSS in the effluent. However, this is a relatively small difference and a small level of inefficiency. Because the DSS does not change from the clarifier inlet to the clarifier outlet, there appears to be little flocculative action within the clarifier. With ample flocculation, the effluent should be close to the FSS value.

In the pilot clarifier, the DSS is also consistently higher than the FSS. However, in this case, the outlet DSS is much higher (7 mg/L) than the inlet DSS. There was no improvement in DSS induced by flocculation across the clarifier. This suggests that some degree of floc degradation or breakup is occurring in the clarifier.

The fact that samples from both clarifiers exhibited insufficient flocculation is supported by the absence of flocculation wells or other flocculation mechanisms in the clarifiers. Therefore, flocculation enhancement with chemical addition may be a tool to consider at CBWTP.