

Background

This project focused on optimizing chemical ortho-phosphate removal at the Arlington WWTF using automated alum dosing and process control.

Current Alum Dosing Challenges

- Operator-adjusted dosing setpoints
- Constant 24-hour dosing schedules increased risk of chemical overdosing
- Elevated membrane fouling potential in the MBR system
- Increased operational and maintenance costs

Environmental Impact

Excess phosphorus discharge contributes to eutrophication, oxygen depletion, and aquatic ecosystem degradation.

Project Objectives

- Develop a control strategy for alum dosing system.
- Minimizing chemical usage.
- Consistently meeting effluent total phosphorus permit limit 1mg/L monthly average.
- Improve operational reliability while reducing operating costs.

Methods Summary

Model Validation

Seasonal Trends

- Plant operating data 2022
- BioWin simulation results

→ Comparative analysis and calibrated the BioWin model to perform similarly to plant conditions.

Dosing Location Evaluation

Locations

- S – Swing Zone
- ML – Mixed Liquor
- FL – Filtrate Line
- RAS – Return Activated Sludge
- WAS – Waste Activated Sludge

Model Baseline Conditions

- Liquid Temperature → 18°C
- Influent OP → 5.08 mg/L

Each location was simulated under minimal equivalent constant dosing conditions.

→ Identify most promising configurations that maximize chemical efficiency and biological removal.

Developed Preliminary Control Strategies

Configurations	Evaluation
1 ML + WAS	3 Effluent targets
3 S + RAS	Chemical efficiency
2 WAS + FL	Variation in seasonal control
4 RAS + FL	

→ Determine most promising dosing configuration.

Refine Control Strategy

→ Tune Controllers → Changes to influent conditions → Sensitivity analysis

Dosing Location Evaluation

ML + WAS	WAS + FL	S + FL	RAS + FL
43% Reduction	44% Reduction	39% Reduction	56% Reduction
Shortest dead time	Targets high-P stream	Supports EBPR	Best optimization
Membrane fouling	Digester inhibition	Lowest reduction	Longer dead time

RAS + FL for Further Refinement

This configuration utilizes the benefits of the WAS and S locations to achieve the highest alum reduction without inhibiting biological phosphate removal.

Modeling Results

Baseline Controls

AVG Weekly Trend: Summer

0.61 mg/L EFF TP | 47% Alum Reduction

Legend: Plant Flow, FL Flow, RAS Flow, EFF TP Conc.

FF → Predictive → low gain, high reset
FB → Reactive → high gain, low reset

→ Apply controls under varying INF conditions and tune controller parameters.

Refined Controls

Effluent TP Week Trend

Season	% Alum Reduction	AVG Monthly TP EFF Conc.
Winter	59%	0.34 mg/L
Spring	25%	0.43 mg/L
Summer	52%	0.78 mg/L
Fall	82%	0.45 mg/L

→ Perform sensitivity analysis for summer and fall conditions.

≥ 0.22 mg/L Margin | Stable PI control

Model Conditions

Seasonal Trends

Season	Liquid Temp. (°C)	INF OP Conc. (mg/L)	Flow
Winter	13.55	3.56	High
Spring	15.53	4.63	Decreasing
Summer	22.94	5.72	Low
Fall	17.11	4.48	Increasing

Best iteration | Increase upper bound

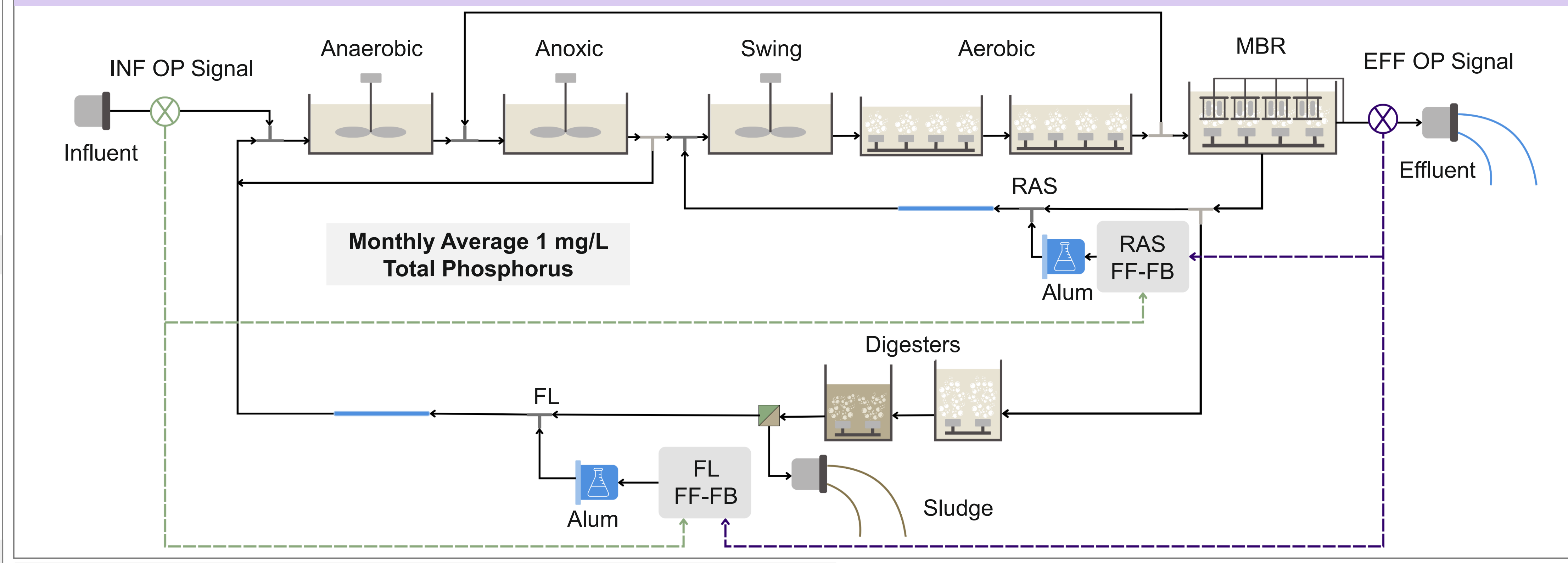
Sensitivity Analysis

Diurnal OP Loading Cycle

Control strategy stable under ± 20% influent loading variation.

- Effluent TP < 1 mg/L
- Summer → 52%-20% reduction
- Fall → 84%-80% reduction

BioWin Process Model



Control Narrative

RAS ALUM DOSING – LOC. 1-405 P-492 | OVERVIEW

AIT-538 AU	AIT-535 AU	P-492 CA	FI-490 AU
PV 45 lb/d	PV 0.65 mg/d	PV 0.83 gph	STATUS OPEN
SP 35	SP 0.95	SP 1.26	MODE: AUTO
OUT	OUT	OUT	

ALARM STATUS: TANK LVL LOW OK, EFF TP HIGH OK, FLOW LOSS OK, INSTRUMENT FAULT OK

→ Industry-standard for PLC integration and logic implementation.

Cost Analysis

Annual Chemical Cost

- Control Strategy \$15,000
- Plant 2022 \$39,200

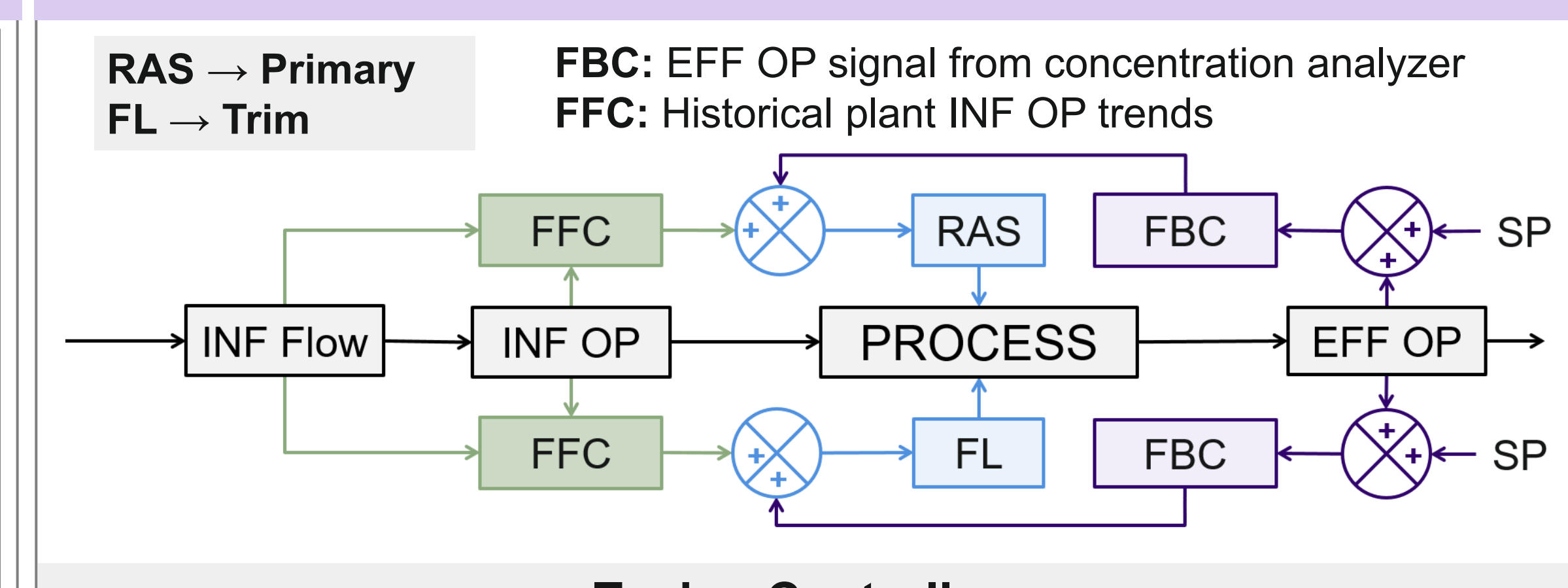
\$24,200 Annual Chemical Savings

OPEX	CAPEX
Expenses: Alum totes, OP analyzer filters, OP analyzer reagent sets	OP Analyzer 46%, Labor + OH&P 32%, Electrical 8%, PLC Integration 6%, Dosing System 5%, Demolition 4%
\$23,128 Annual Operational Cost	Total OPCC \$84,214

ROI Summary

- ~ 3.5 Year Payback Period
- 29% Annual ROI
- \$36,787 Net 5-year Savings

Control Strategy



Tuning Controllers

- P & Reset Time
- I/Step Function
- Retune in tandem

Proportional gain (P) optimized to improve response without incurring oscillations.
FBC: Integral term (I) was added to reduce steady state offset.
FFC: P divided into a step function to improve response time while minimizing overdosing.

Conclusion

Dosing Location & Control Strategy

- FL → Early alum contact increases available reaction time
- RAS → Alum recycle and redistribution
- Automated FF-FB control decreased alum usage through dynamic real-time dosing adjustment.

Increases Chemical Efficiency | 56% Annual Alum Reduction

- ↓ Alum Usage
- ↓ Membrane Fouling Potential
- ↓ Membrane Cleaning Frequency
- ↑ Effluent pH Stability
- ↑ Membrane Lifespan
- ↓ Operational & Maintenance Costs

Maintained effluent phosphorus concentrations below permit limits.

Stable phosphorus removal performance under seasonal variability.

Practical and cost-effective strategy for full-scale phosphorus control at the Arlington WWTF.

Future Work

- Foundation Hardware Development**
 - OP Analyzer Installation → OP measurement for FB control
 - SCADA Integration → chemical feed infrastructure and FF-FB controls
- Optimization Refine FF-FB Control**
 - Feedforward signal development → Further data collection
 - Controller calibration and field tuning → gain, reset time, bias parameters
- Long-term Process Chemistry**
 - Alternative coagulants → organic polymer-based options

Acknowledgements

The authors gratefully acknowledge BHC Consultants and the City of Arlington WWTF for their technical guidance, operational support, and collaboration throughout this project. Their technical expertise, operational insight, and continued engagement were invaluable to the development and evaluation of the proposed phosphorus control strategy. The authors additionally thank the University of Washington Department of Chemical Engineering for support of the industry capstone program and interdisciplinary engineering collaboration.