DO Control
Ammonia Based Process Control

On-line Analyzer Workshop
DCWASA
September 15, 2008

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BIOCHEM® TECHNOLOGY, INC.

Agenda

- Non-steady-state plant operating conditions
- ASM and feed forward control
- Aeration control
- Aeration energy
- Case Study - Phoenix

Biological Nutrient Removal

- Microorganisms do all the ‘dirty’ work
- To *optimize* their unique abilities we must supply them with the *appropriate environment* as they are carried through the biological reactor

What *environmental* factors can be controlled in a waste water treatment plant?

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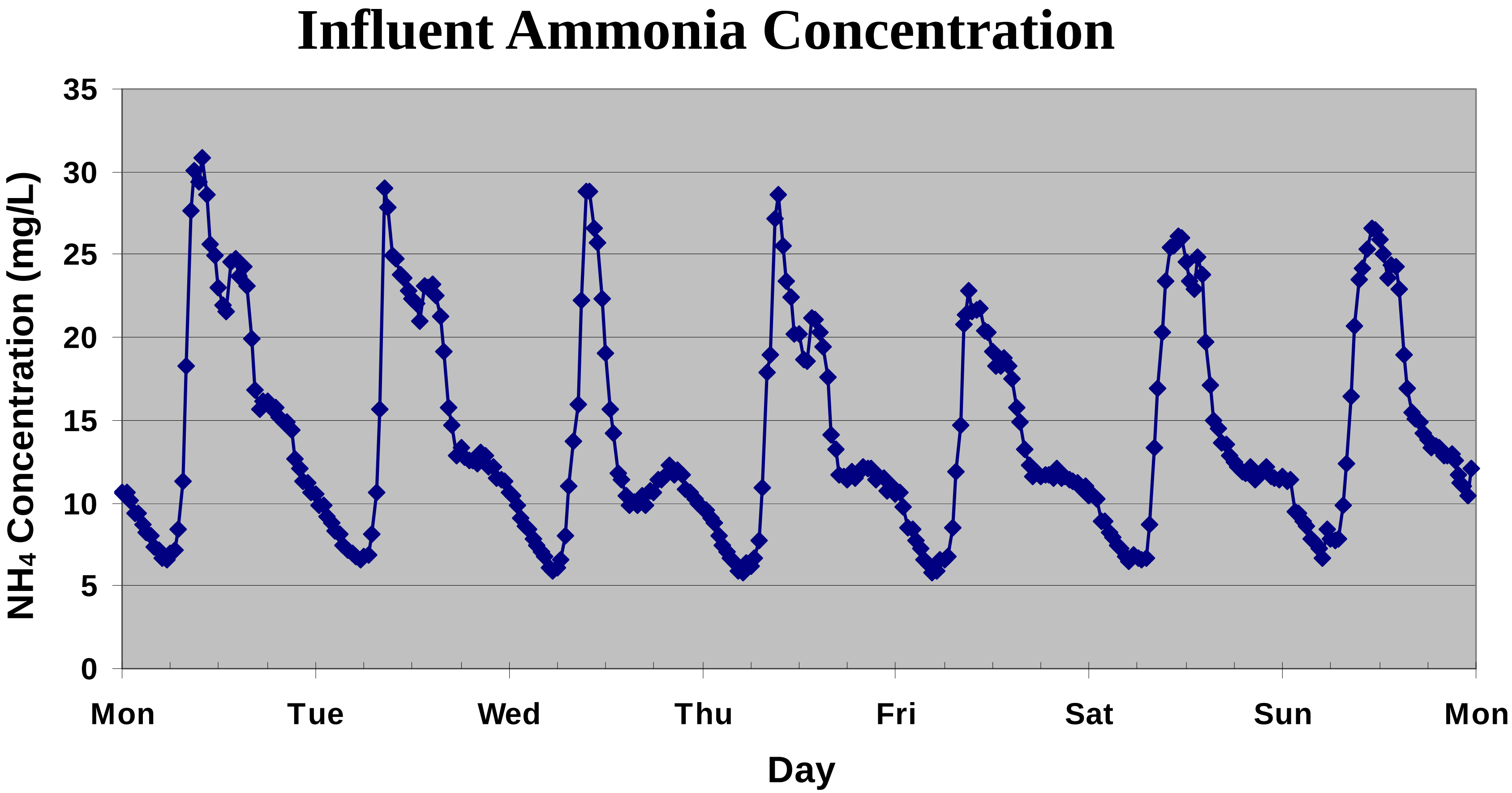
Diurnal Plant Loading



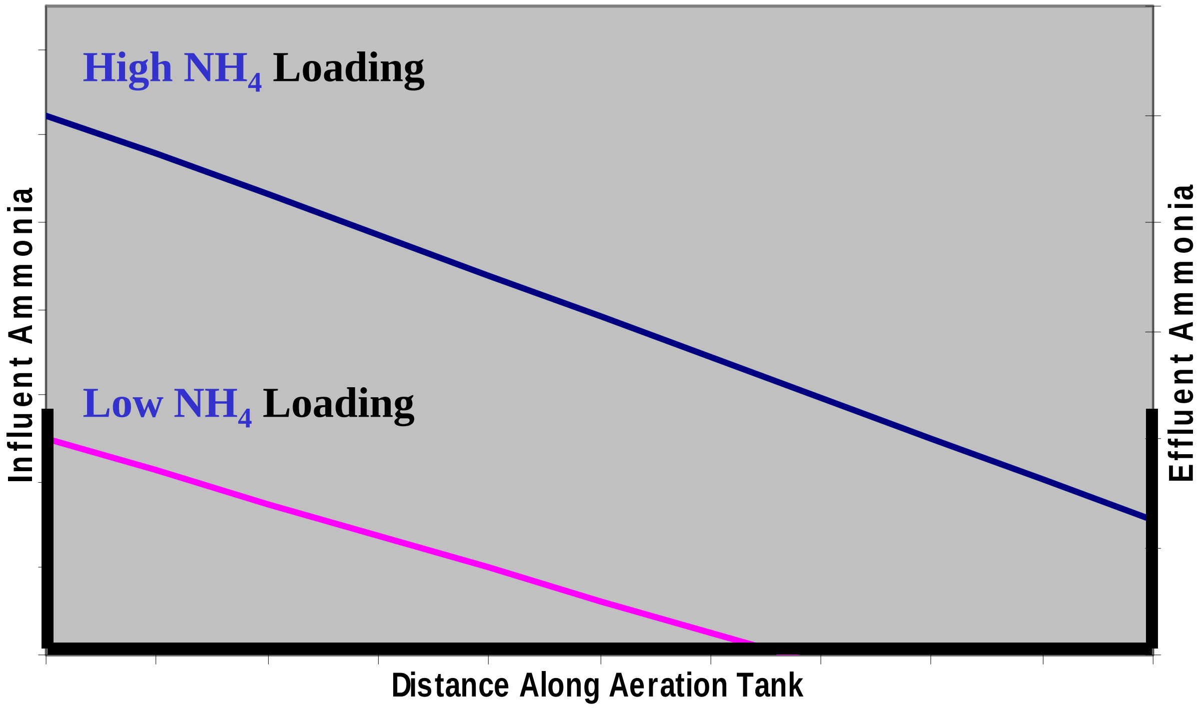
Current Control Practices

The SCADA controls the plant according to:

- Fixed DO set-points
- Fixed IRQ ratio
- WAS rate to achieve a fixed SRT
- Fixed or uncontrolled centrate return

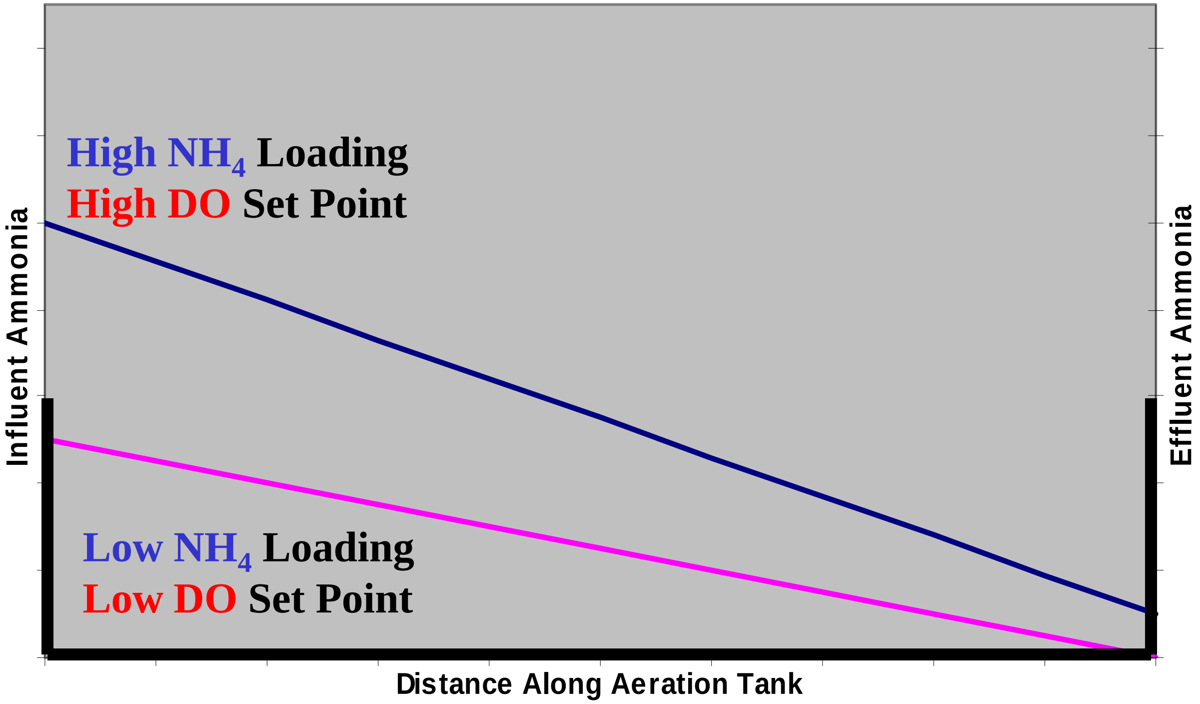
All are based upon peak loading and do not take into account diurnal fluctuations.

Ammonia Profile
Fixed DO Set-Point



- Ammonia bleed through during peak loading
- Wasted power during low loading

Ammonia Profile
Dynamic DO Set-Point



- Ammonia bleed through during peak loading is dampened
- Lower power required during low loading
- Stabilized process

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Feed-Forward vs. Feed-Back Control

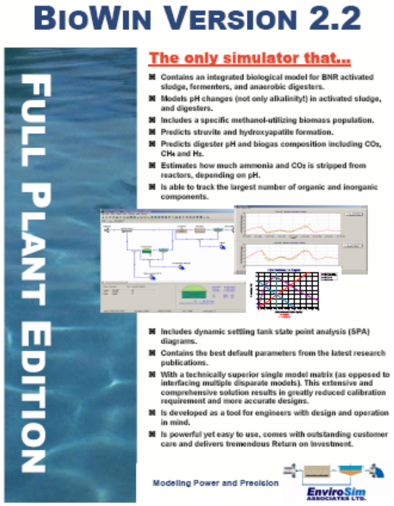
Feed-Forward Control

- Proactive
- Necessary when there are delays between the process input and process output
- Requires a model

Feed-Back Control

- Reactive
- Applicable when there is little time lag between the process input and process output
- Does not need a model
- Often use PID loops

Activated Sludge Model - ASM



BioWin Version 2.2

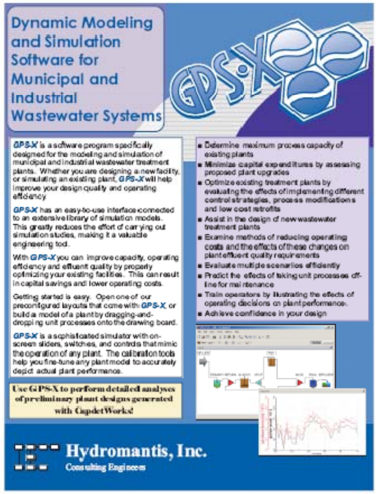
FULL PLANT EDITION

The only simulator that…

- Contains an integrated biological model for BNR activated sludge, fermenters, and anaerobic digesters.
- Models pH changes (not only alkalinity!) in activated sludge, and digesters.
- Includes a specific methanol-utilizing biomass population.
- Predicts struvite and hydroxyapatite formation.
- Predicts digester pH and biogas composition including CO_2, CH_4 and H_2.
- Estimates how much ammonia and CO_2 is stripped from reactors, depending on pH.
- Is able to track the largest number of organic and inorganic components.
- Includes dynamic settling tank state point analysis (SPA) diagrams.
- Contains the best default parameters from the latest research publications.
- With a technically superior single model matrix (as opposed to interfacing multiple disparate models). This extensive and comprehensive solution results in greatly reduced calibration requirement and more accurate designs.
- Is developed as a tool for engineers with design and operation in mind.
- Is powerful yet easy to use, comes with outstanding customer care and delivers tremendous Return on Investment.

Modeling Power and Precision

EnviroSim ASSOCIATES LTD.



Dynamic Modeling and Simulation Software for Municipal and Industrial Wastewater Systems

GPS-X is a software program specifically designed for the modeling and simulation of municipal and industrial wastewater treatment plants. Whether you are designing a new facility, or simulating an existing plant, *GPS-X* will help improve your design quality and operating efficiency.

GPS-X has an easy-to-use interface connected to an extensive library of simulation models. This greatly reduces the effort of carrying out simulation studies, making it a valuable engineering tool.

With *GPS-X* you can improve capacity, operating efficiency and effluent quality by properly optimizing your existing facilities. This can result in capital savings and lower operating costs.

Getting started is easy. Open one of our preconfigured layouts that come with *GPS-X*, or build a model of a plant by dragging-and-dropping unit processes onto the drawing board.

GPS-X is a sophisticated simulator with on-screen sliders, switches, and controls that mimic the operation of any plant. The calibration tools help you fine-tune any plant model to accurately depict actual plant performance.

Use GPS-X to perform detailed analyses of preliminary plant designs generated with CapdetWorks!

- Determine maximum process capacity of existing plants
- Minimize capital expenditures by assessing proposed plant upgrades
- Optimize existing treatment plants by evaluating the effects of implementing different control strategies, process modifications and low cost retrofits
- Assist in the design of new wastewater treatment plants
- Examine methods of reducing operating costs and the effects of these changes on plant effluent quality requirements
- Evaluate multiple scenarios efficiently
- Predict the effects of taking unit processes off-line for maintenance
- Train operators by illustrating the effects of operating decisions on plant performance.
- Achieve confidence in your design

Hydromantis, Inc.
Consulting Engineers

BioWin™ **GPS-X™**

Feed Forward Controller

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Kinetic Expression of Nitrification Rate & Ammonia Utilization Rate

$$NR = 4.24\mu_A X_A = 4.24\mu_{\max\_A} \frac{S_{NH_4}}{K_{NH_4} + S_{NH_4}} \frac{S_{O_2}}{K_{O_2} + S_{O_2}} \frac{\cdots}{\cdots} X_A$$

$$AUR = NR + 0.022\mu_H X_H = NR + 0.022\mu_{\max\_H} \frac{S_{COD}}{K_{COD} + S_{COD}} \frac{S_{O_2}}{K_{O_2} + S_{O_2}} \frac{\cdots}{\cdots} X_H$$

- **NR: Nitrification rate**
- **AUR: Ammonia utilization rate**
- **Key parameter:**
  μ_{max_A} and K_{O2} need to be calibrated

Calculation and Optimization

Historical Influent Conditions

Fixed Set-points

Off-Line

BioWin^{TM}

GPS-X^{TM}

Effluent Characteristics

Actual Influent Conditions

Effluent Targets

Real-Time Feed Forward

Dynamic Controller

Optimized Set-points

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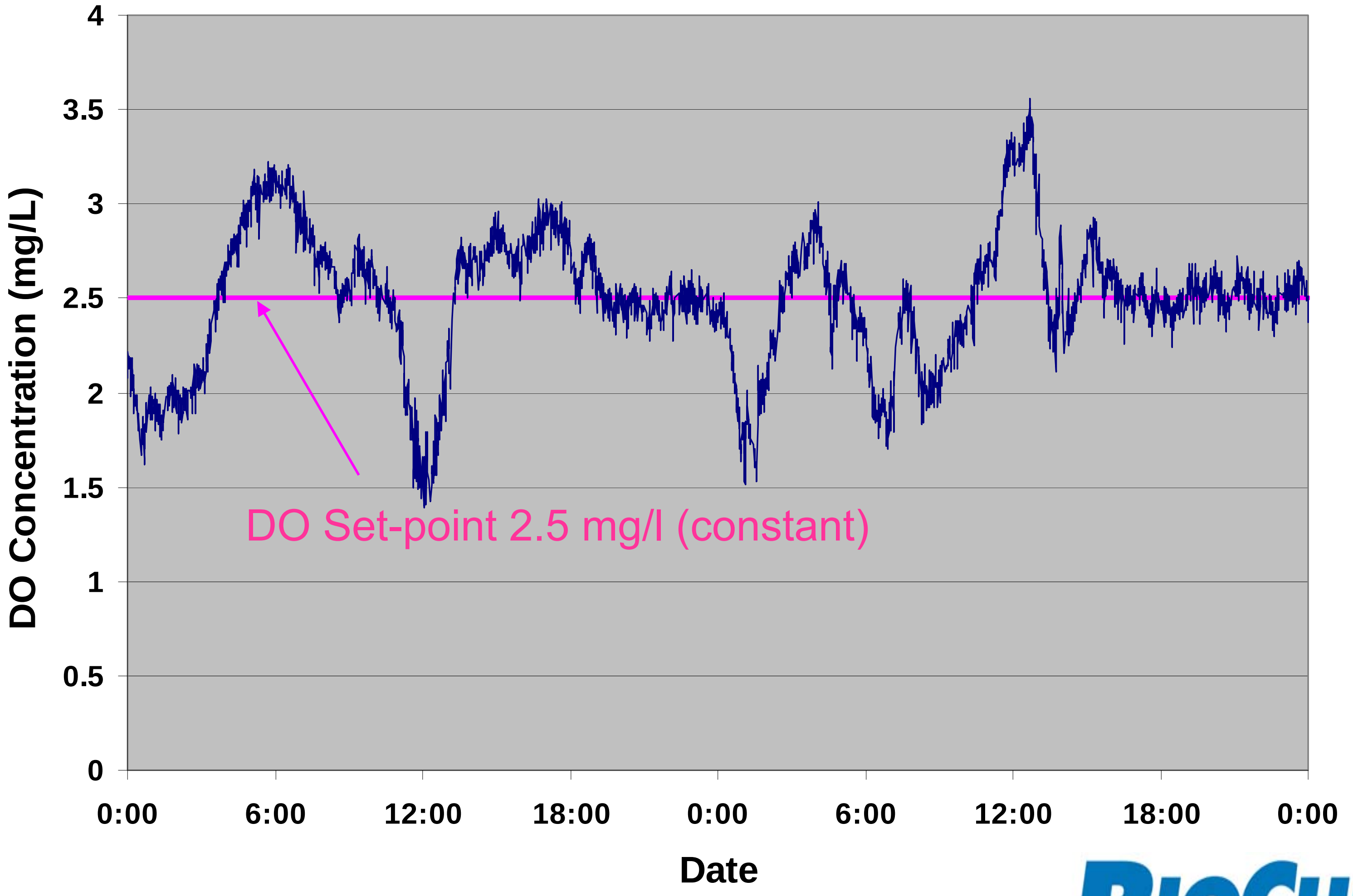
Typical DO Control Based on Constant Gain



Ammonia Based Aeration Control

- The Aeration Control System is based on the ASM feed-forward model
- Oxygen requirement increases with NH_3 loading
- Calculated airflow rates are based on real time oxygen requirements and the deviation from the dynamic DO setpoint
- The ABAC controls the blower to provide the required airflow and the air distribution system to deliver the air according to the calculations

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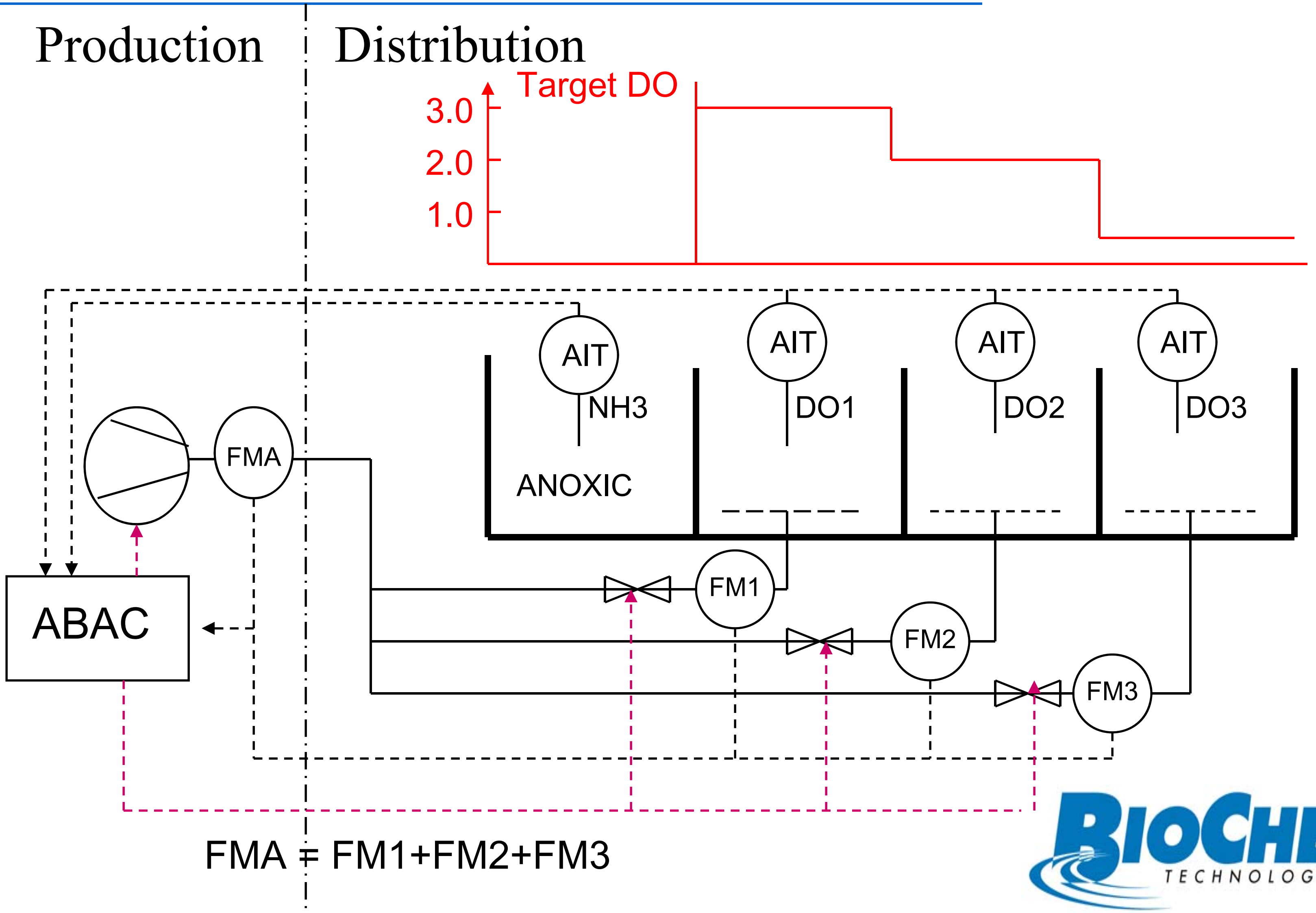
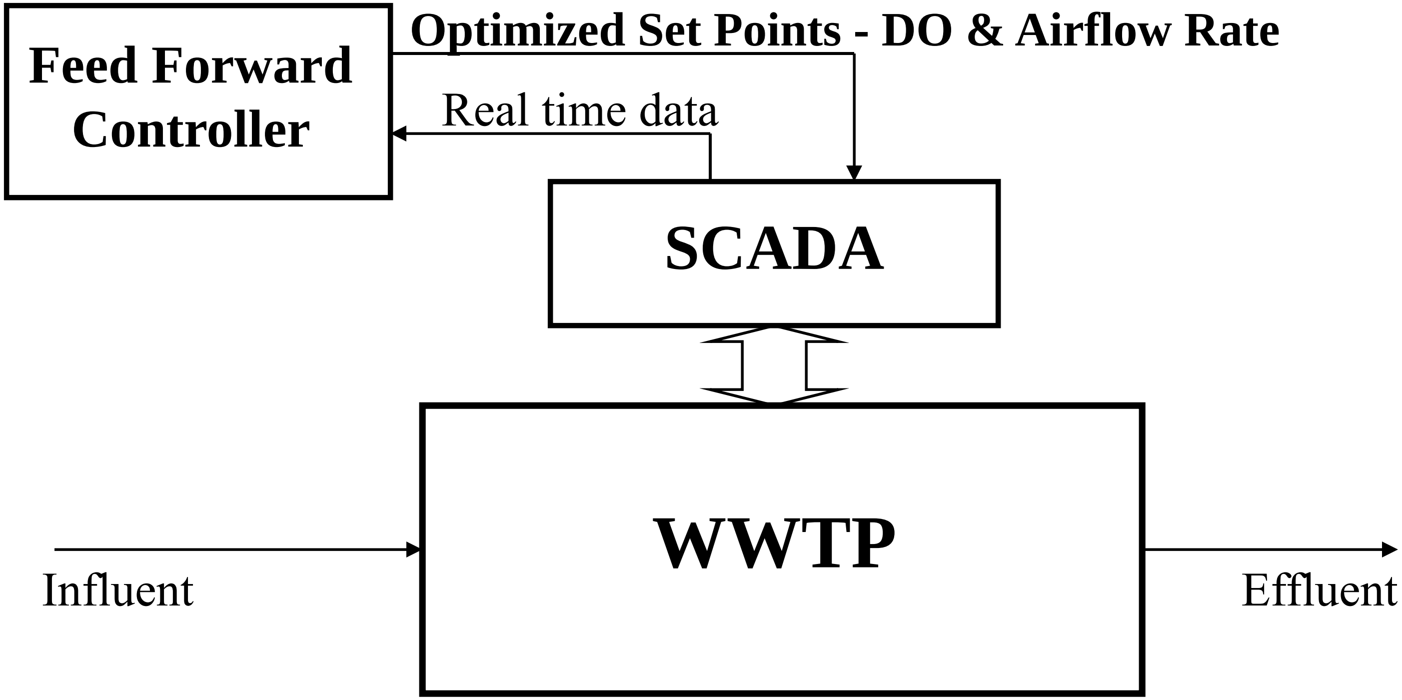
Aeration Control



FMA = FM1+FM2+FM3

Ammonia Based Process Control System Diagram



Feed Forward Controller

Optimized Set Points - DO & Airflow Rate

Real time data

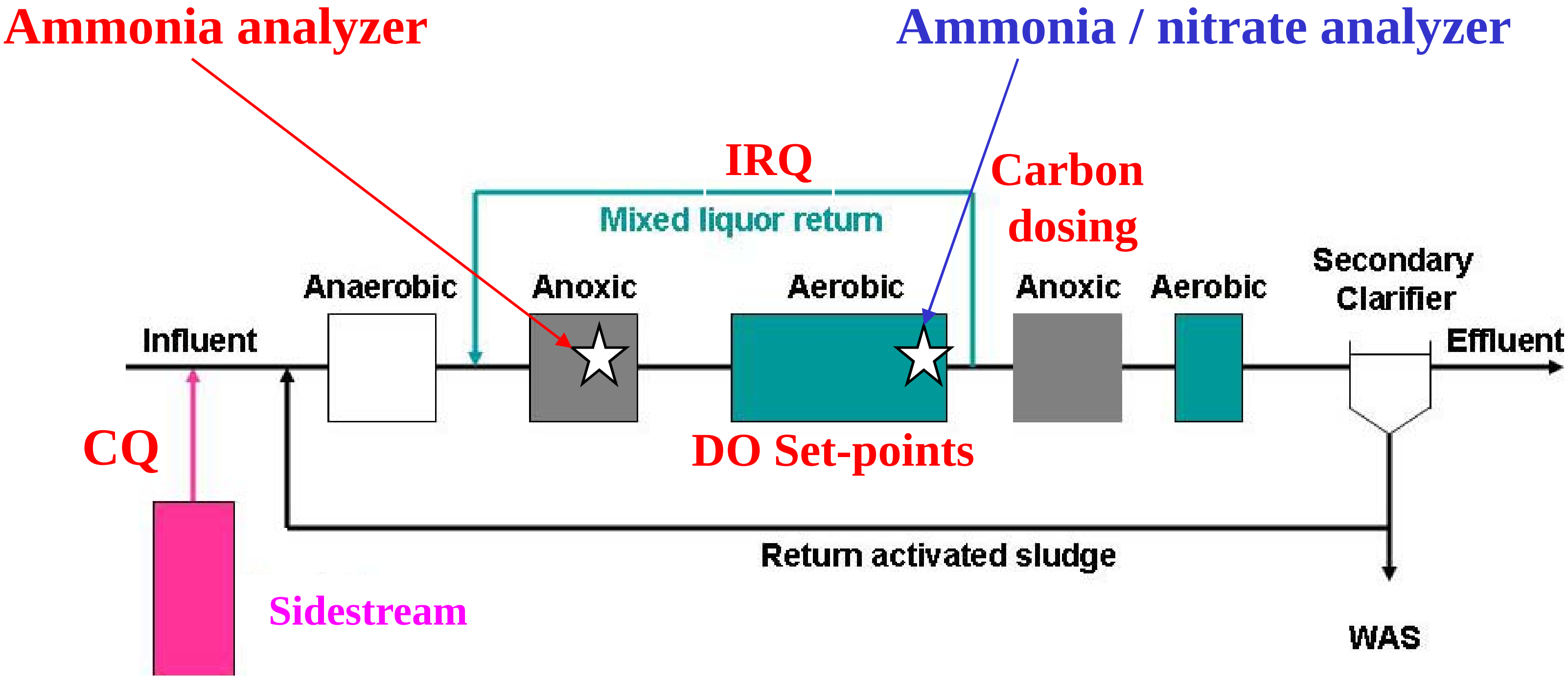
SCADA

WWTP

Influent

Effluent

Bardenpho 5-Stage Treatment Process



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Oxygen Transfer Efficiency OTE

$$OTE_f = \alpha F\,(SOTE)\,[\beta(C_{s,T}) - C]\,/\,C_{s,T}$$

Where: α, F = are constants

$\beta = 0.95$

$C_{s,T} = 9.08$ mg/l, saturation conc. at T=20°C

C = DO concentration

SOTE = $(0.3q^{-0.15})$

for membrane disk diffuser at depth of 15ft

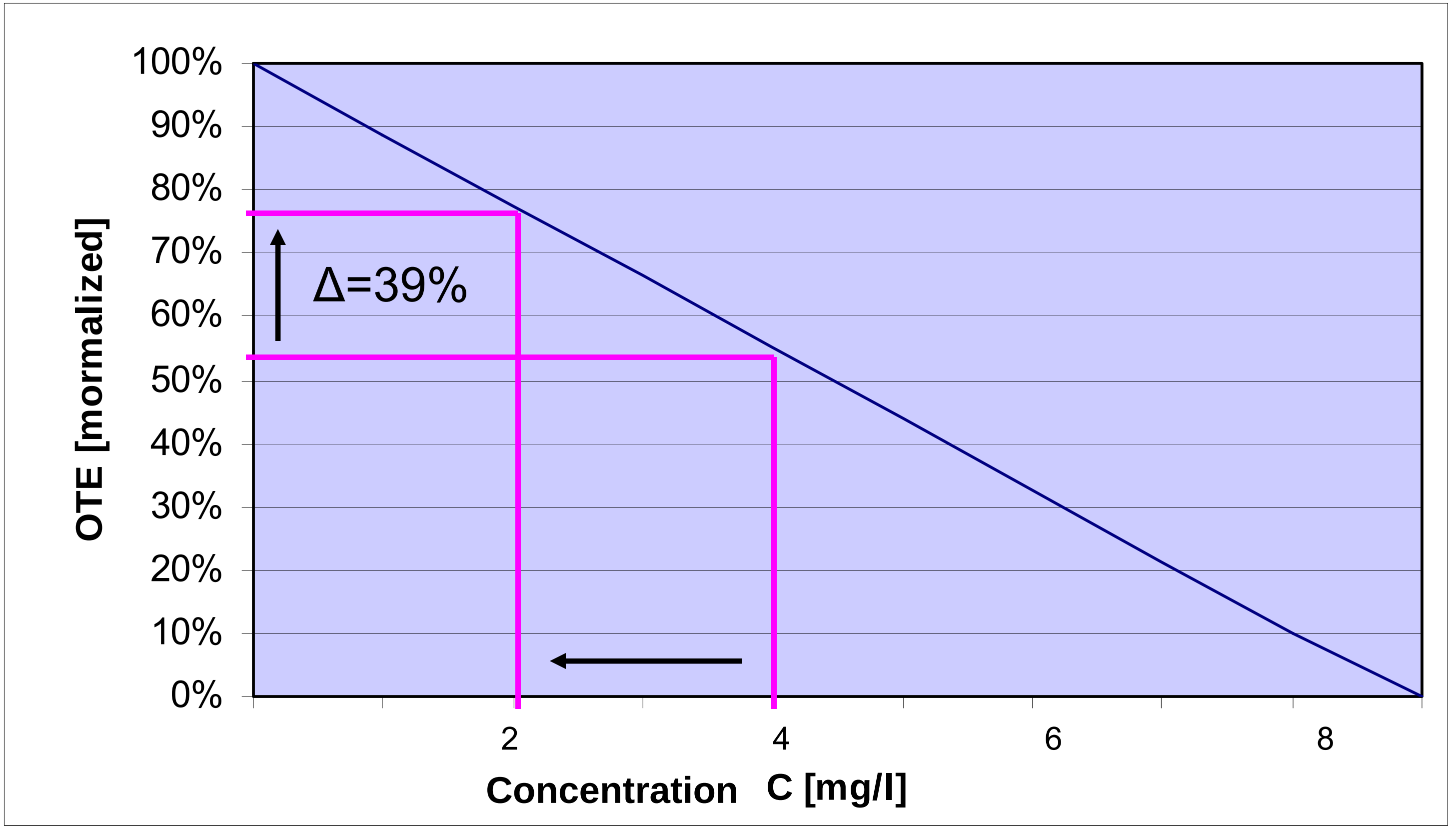
q = diffuser airflow rate

Barometric pressure = 1 atm

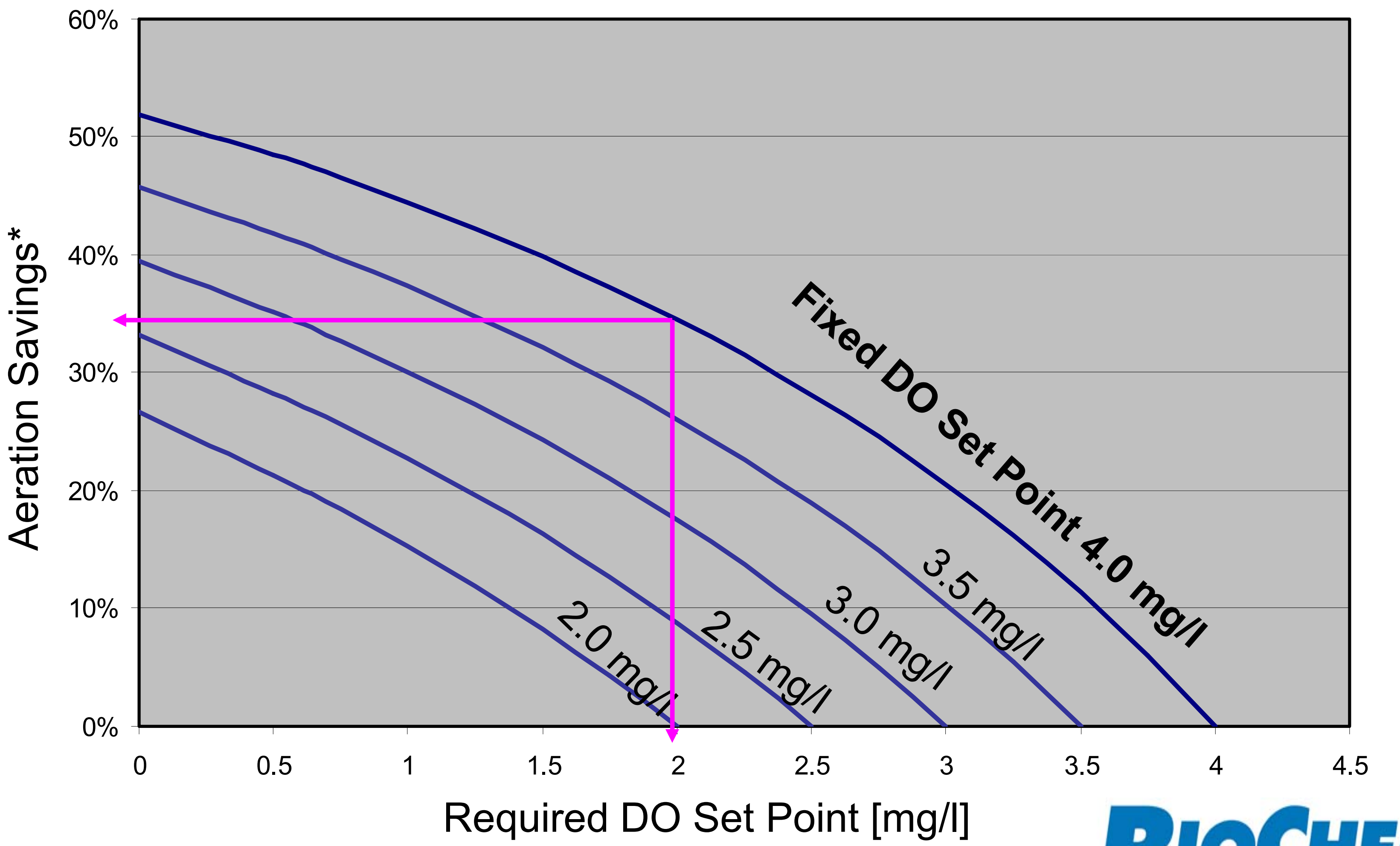
Process oxygen demand is constant

OTE as a Function of DO Concentration

OTE = k*SOTE*(C_s-C)/C_s with k*SOTE=1 and $C_{s,20}$ =9.08



Airflow Reduction as Function of DO



* Assuming constant oxygen demand

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Phoenix 23rd Avenue WWTP
Four 16 MGD Trains

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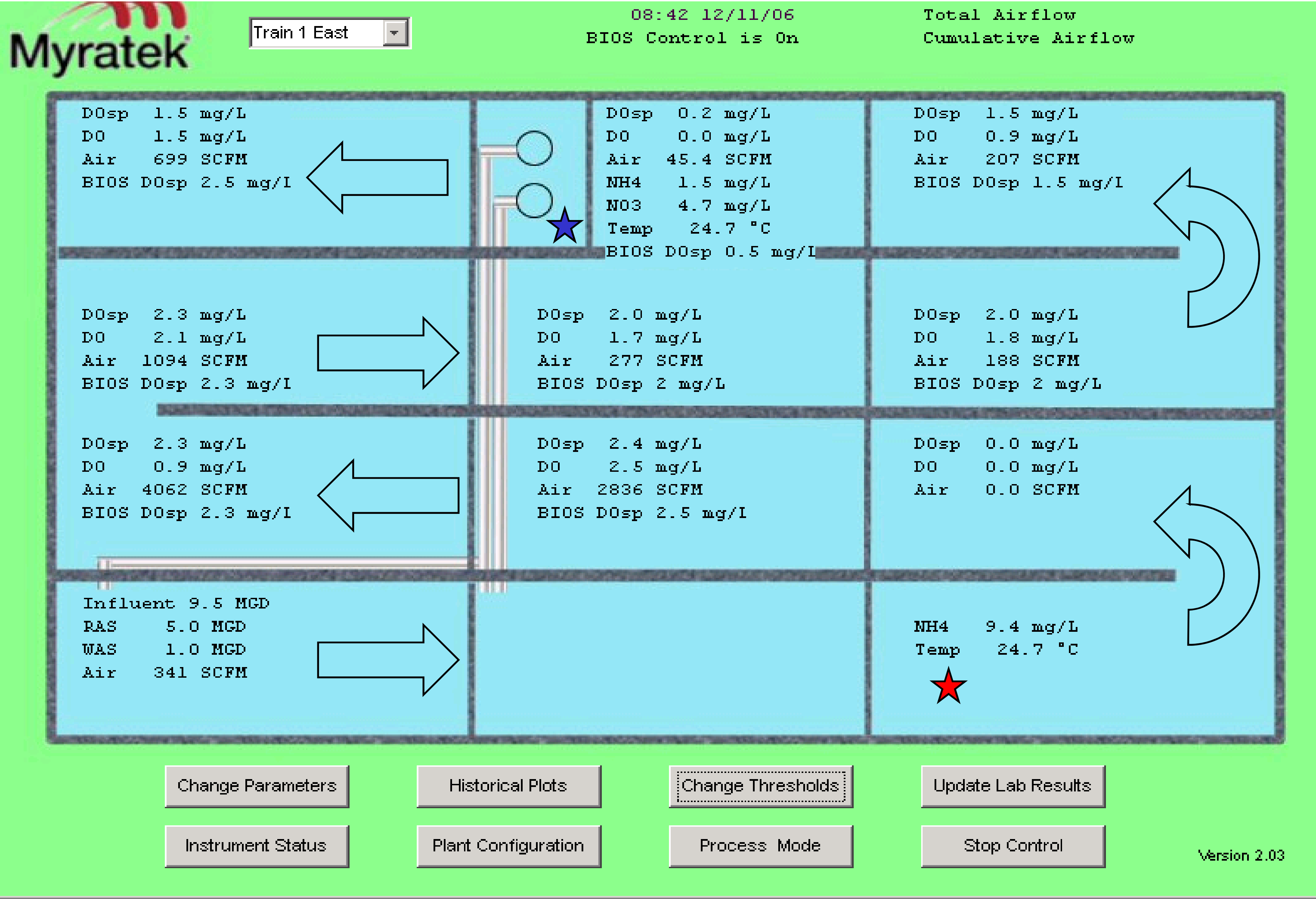
User Interface from Phoenix 23rd Ave.



08:42 12/11/06
BIOS Control is On

Total Airflow
Cumulative Airflow

DOsp 1.5 mg/L
DO 1.5 mg/L
Air 699 SCFM
BIOS DOsp 2.5 mg/l

DOsp 0.2 mg/L
DO 0.0 mg/L
Air 45.4 SCFM
NH4 1.5 mg/L
NO3 4.7 mg/L
Temp 24.7 °C
BIOS DOsp 0.5 mg/L

DOsp 1.5 mg/L
DO 0.9 mg/L
Air 207 SCFM
BIOS DOsp 1.5 mg/l

DOsp 2.3 mg/L
DO 2.1 mg/L
Air 1094 SCFM
BIOS DOsp 2.3 mg/l

DOsp 2.0 mg/L
DO 1.7 mg/L
Air 277 SCFM
BIOS DOsp 2 mg/L

DOsp 2.0 mg/L
DO 1.8 mg/L
Air 188 SCFM
BIOS DOsp 2 mg/L

DOsp 2.3 mg/L
DO 0.9 mg/L
Air 4062 SCFM
BIOS DOsp 2.3 mg/l

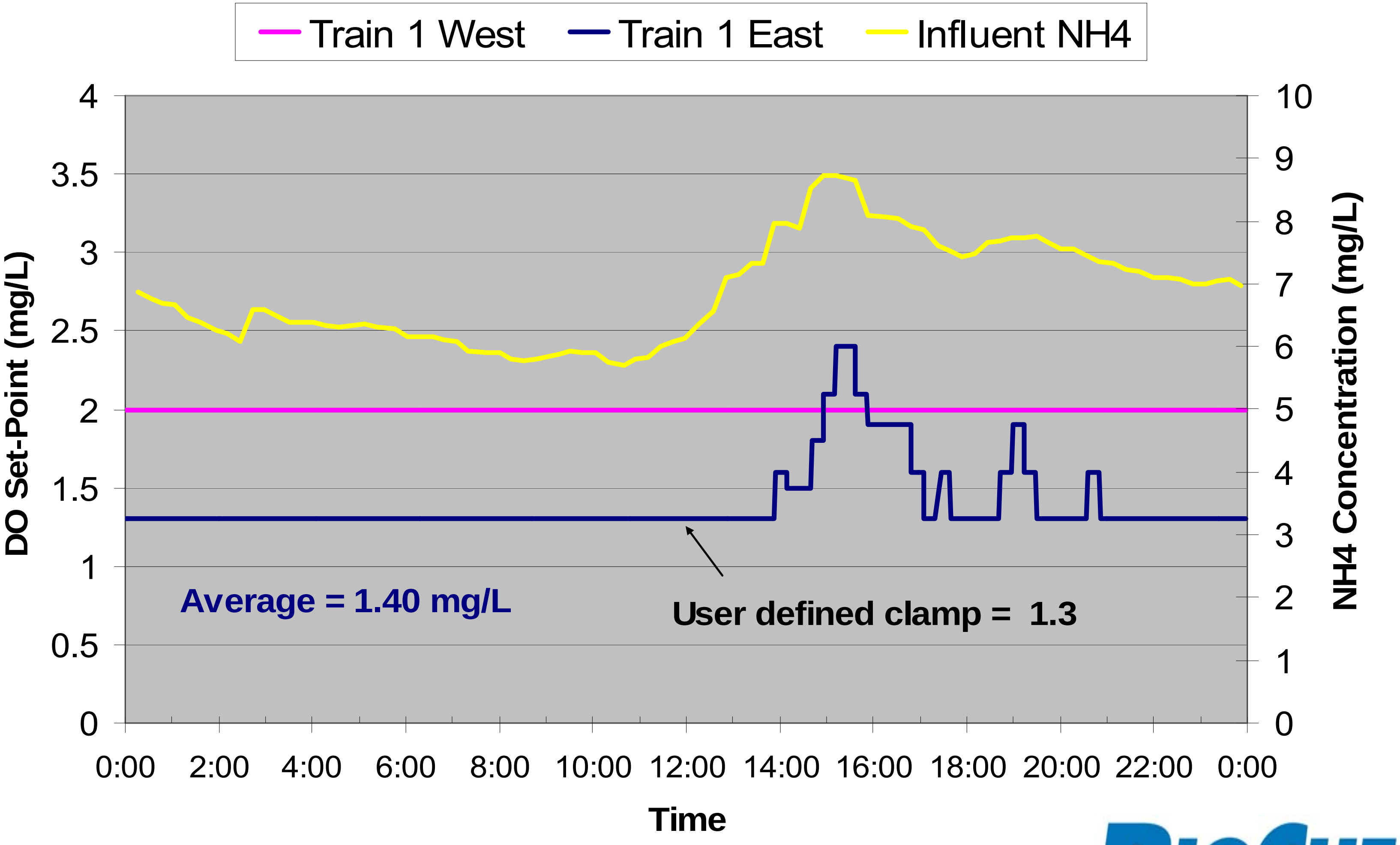
DOsp 2.4 mg/L
DO 2.5 mg/L
Air 2836 SCFM
BIOS DOsp 2.5 mg/l

DOsp 0.0 mg/L
DO 0.0 mg/L
Air 0.0 SCFM

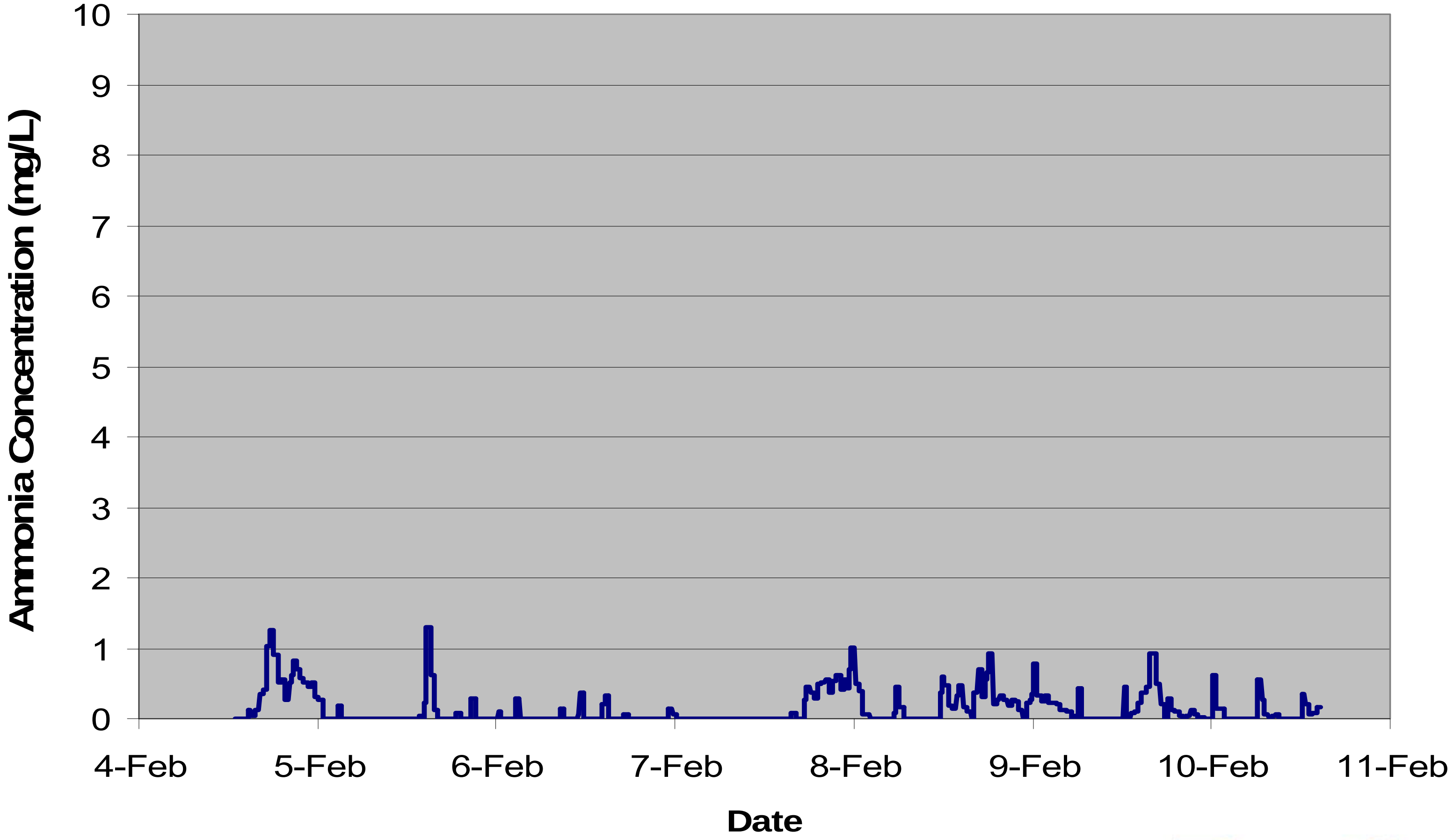
Influent 9.5 MGD
RAS 5.0 MGD
WAS 1.0 MGD
Air 341 SCFM

NH4 9.4 mg/L
Temp 24.7 °C

Aeration Zone 4
5 February 2008



Aeration Zone 8 Measured Ammonia



Annual Savings

Demonstrated Savings	**15.3%**
Current Power Usage	771.8 kWh/MG
Flow Rate	48 MGD
Estimated Power Cost	$0.12/kWh
Daily energy savings	5,557 kWh

Annual Savings of	**$243,000**
and	**2000 MWh**

Conclusions

Ammonia Based Process Control:

1. Ensures permit compliance
2. Improves process stability
3. Saves energy