Optimizing Nutrient Reduction in Small Wastewater Treatment Plants

Operator Training Committee of Ohio Webinar

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Division of Environmental and Financial Assistance

Compliance Assistance Unit

The Plan

- The Three Environments
- What goes wrong
- Troubleshooting systems
- Case studies
- Questions and Comments

The Basics of BNR

Biological Nutrient Removal

2 Processes

Biological Nitrogen Removal

- **Denitrification**
- **Nitrogen Gas leaves the System**

Biological Phosphorus Removal

- **Orthophosphate is taken up by Phosphorus Accumulating Organisms (PAOs)**
- **PAOs are wasted from the System**

The Basics of BNR

2 Zones for Biological Phosphorus Removal

Anaerobic Zone
Oxic Zone

Each zone requires a specific <u>environment</u> that will get the bacteria to do a specific job.

The Basics of BNR

2 Zones for Biological Nitrogen Removal

Anoxic Zone
Oxic Zone

Each zone requires a specific <u>environment</u> that will get the bacteria to do a specific job.

The Basics of BNR

3 Zones for Biological Nutrient Removal:

Anaerobic Zone

Anoxic Zone

Oxic Zone

Each zone requires the proper specific environment that will get the bacteria to do a specific job.

The Basics of BNR

The Anaerobic Zone:

1. Relatively small volume
2. Mixed without diffused air (mechanical mixer)
3. Combines influent wastewater with RAS
4. Needs **Soluble Carbon** to drive the reaction

The Basics of BNR

The Anaerobic environment

1. No dissolved oxygen

2. No nitrate

3. Low energy mixing

The Basics of BNR

The Anoxic Zone:

1. Larger volume
2. Mixed without diffused air (mechanical mixer)
3. Combines influent wastewater with nitrified mixed liquor (or RAS) from the Oxic tank

The Basics of BNR

The Anoxic Environment

1. No dissolved oxygen
2. Nitrate Available (i.e., Combined Oxygen, NO_3-N)
3. Low Energy Mixing
4. Needs **Soluble Carbon** to drive the reaction

The Basics of BNR

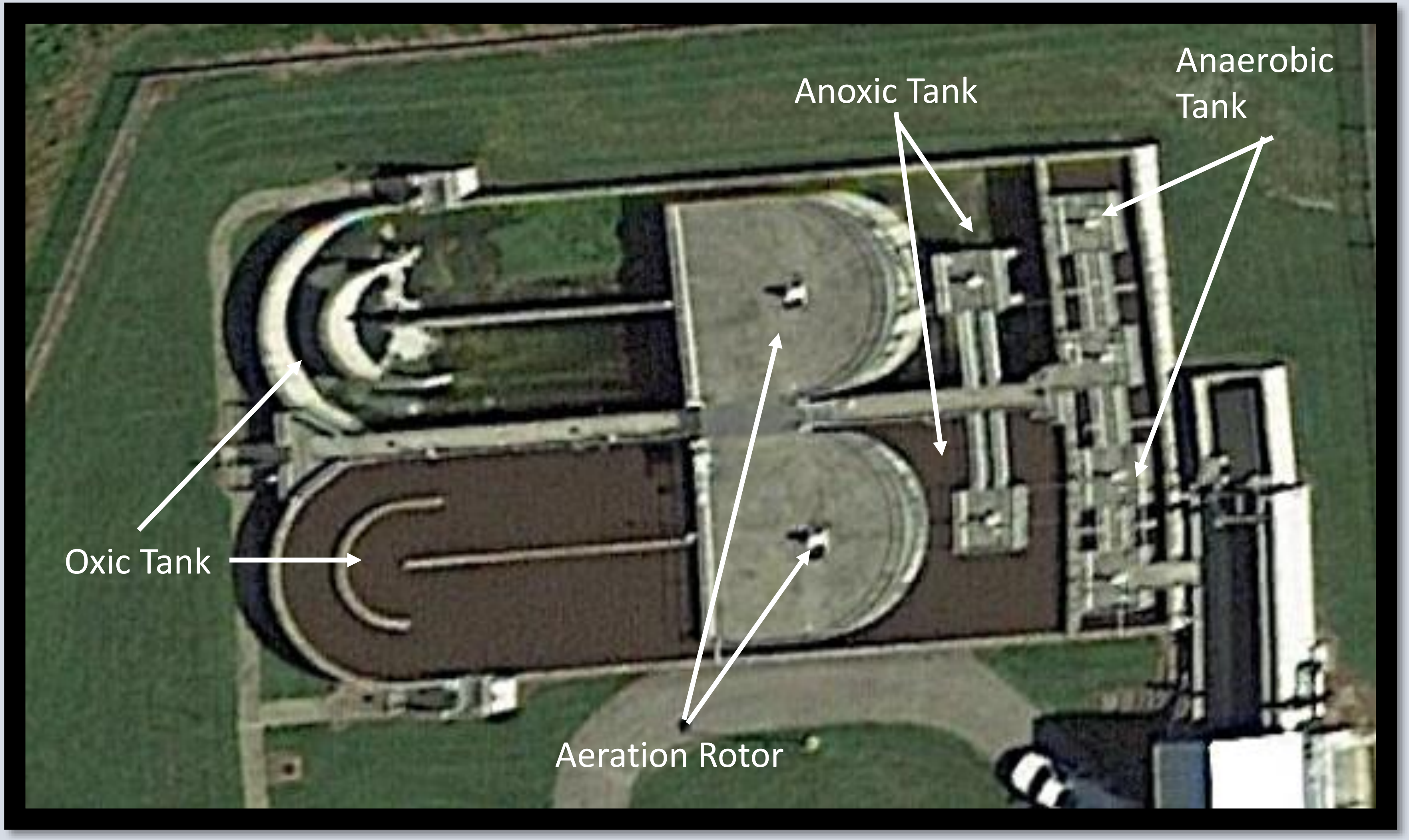
The Oxic Zone:

The Oxic Environment

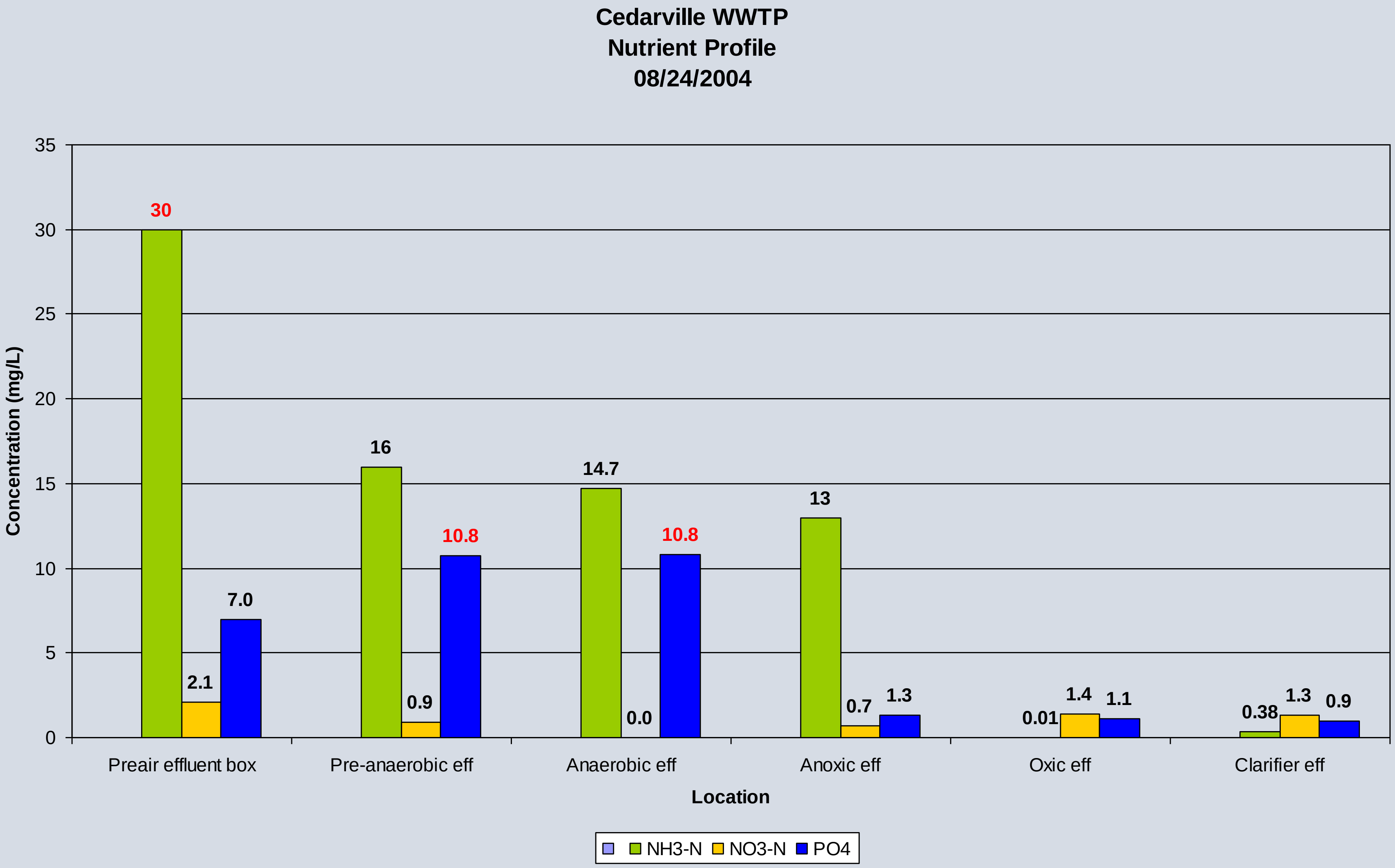
1. Dissolved oxygen present
2. $cBOD_5$ is converted into bacteria and CO_2
3. Ammonia converted to Nitrate
4. Ortho P released in Anaerobic zone is taken up, and more

The Basics of BNR

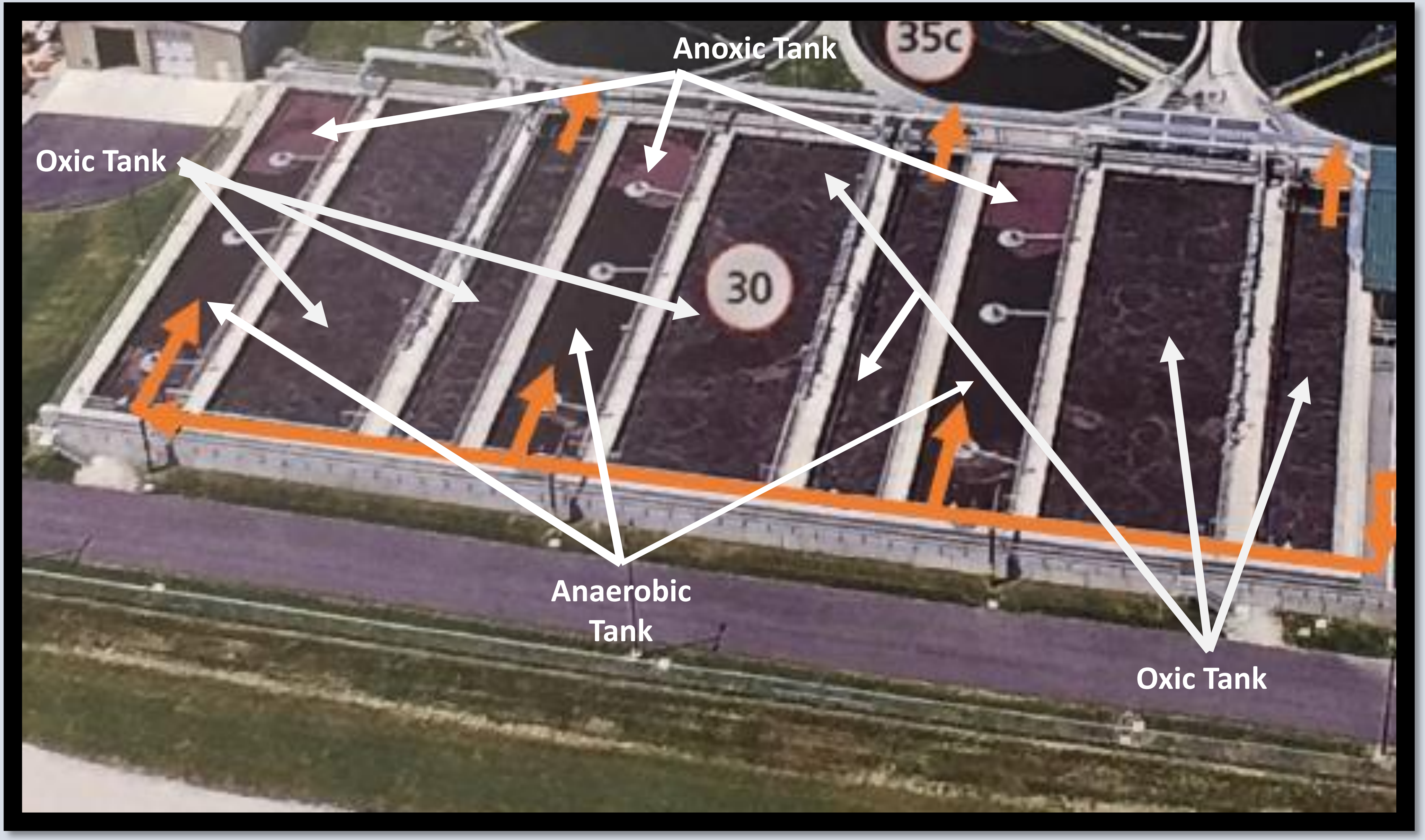
The Basics of BNR



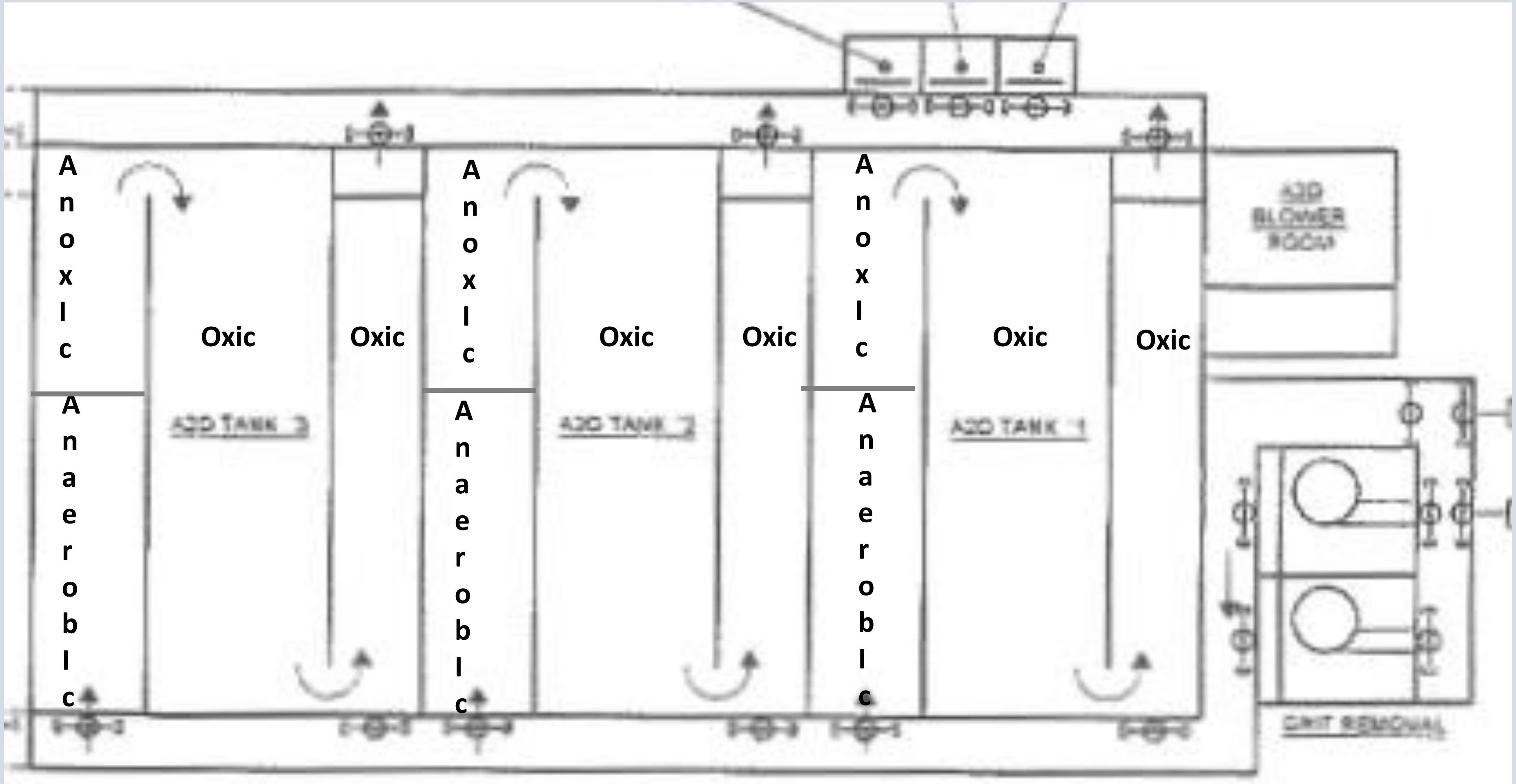
Troubleshooting Systems



The Basics of BNR



The Basics of BNR



What goes wrong…

Permit Limits change, and the WWTP doesn’t

Nutrients in the natural waters are causing problems

WWTPs are easy to regulate

So, **Nutrient limits for WWTPs are tightening….**

What Goes Wrong

What Goes Wrong

What goes wrong…

Nutrient Control:

Cyanobacteria utilize nitrogen and phosphorus

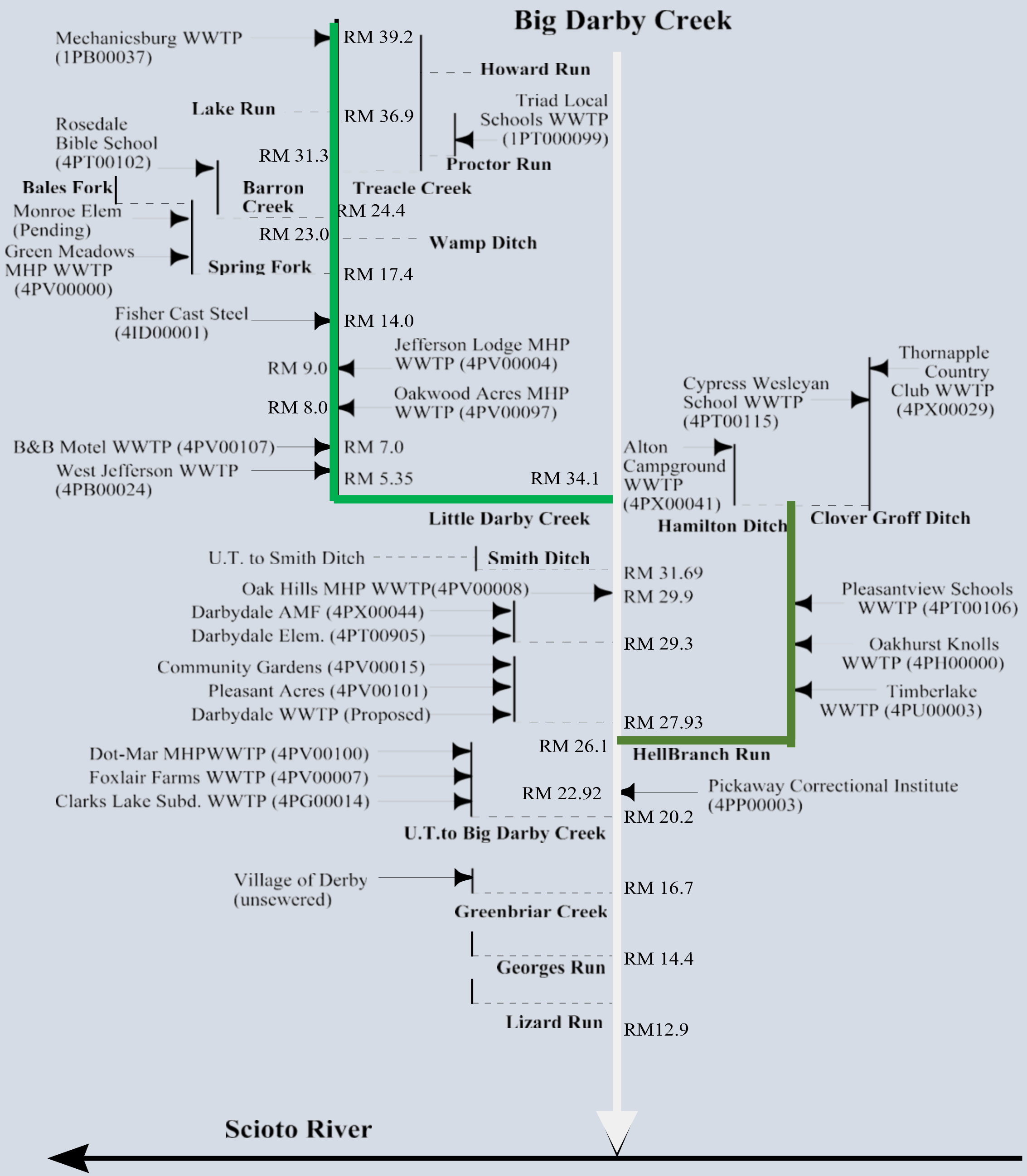
Tend to flourish when water is warm and nutrients are plentiful

Produce liver toxins, neurotoxins and dermatoxins in the water column

What goes wrong…

One town’s downstream is the next town’s upstream

Lower Big Darby Creek
Little Darby Creek
Hellbranch Run



What goes wrong…

Permit Limits change, and the WWTP doesn’t

Land Application of Treated Wastewater Rules Implemented 2014

- WWTPs encouraged to avoid discharging to Waters of the State
- Eased limits since they discharged to impoundments
- WWTPs not designed to meet 10 mg/L TIN in effluent

What goes wrong…

Effluent limits tighten statewide

Tighter TP limits for some dischargers to Ohio River Basin

Nitrate limits on the horizon?

What goes wrong…

Design is important

But often design is by the book (and bacteria can’t read)

Inattention to influent waste streams will create havoc with BNR

Especially influents with weak organic loadings

What goes wrong…

Disconnect between design and operation

Design is important

But when design doesn’t include operational flexibility,

the hands of the operator are tied

(operators don’t get to chose what comes down the pipe)

Troubleshooting Systems

Process Control is **essential**

Check the chemical trails that the biology leaves behind

Field test equipment

Grab samples, sometimes lots of grab samples

Cheap, easy, and effective

Troubleshooting Systems

Toubleshooting Systems

Troubleshooting Systems

If the conditions are right, the bacteria will perform

Ammonia, nitrate, and orthophosphate in the inputs to the tanks

Ammonia, nitrate, and orthophosphate in the outputs from the tanks

Measure, don’t guess…

Manufacturing Facility Wastewater Treatment Plant

- Design
  - 1500 gallons per day
  - 6000 gallons per day rate (peak hourly flow capacity)

- Influent Characteristic
  - Ammonia: 121 mg/L
  - $cBOD_5$: 517 mg/L
- All Sanitary Waste
  - Full first shift, small second shift, maintenance on third shift.

Spray Irrigation Field

Manufacturing Facility Wastewater Treatment Plant

Sample ID: **Effluent**

Lab Sample # **MP11-17377-01**

The Fecal was analyzed at our Mansfield facility.

Analyte	Results	Units	PQL	Method	Analyst	Extraction Date	Analysis Date/Time
Ammonia-N	0.16	mg/L	0.05	EPA 350.1	TLL		09/26/2011 15:12
Carbonaceous BOD	4.7	mg/L	4.0	SM-5210 B	TLL		09/21/2011 18:00
	Estimate; lab control standard exceeded method limits.						
Nitrite-N	0.98	mg/L	0.05	EPA-353.2/ SM4500NO3	TLL		09/21/2011 17:45
Nitrogen, Total Inorganic	9.65	mg/L	0.20	Calculation	RCM		10/04/2011 15:00
Nitrate/Nitrite-N	9.49	mg/L	0.50	EPA-353.2/ SM4500NO3	TLL		09/27/2011 13:14
Nitrate-N	8.51	mg/L	0.100	EPA-353.2/ SM4500NO3	RCM		10/04/2011 15:00
Total Suspended Solids	27	mg/L	1.0	SM-2540 D	TLL		09/23/2011 16:45
E.Coli	<1.00	MPN/100 mL	1.00	SM 9223B	GLM		09/21/2011 15:10
Total Coliform	1.00	MPN/100 mL	1.00	SM 9223B	GLM		09/21/2011 15:10
Fecal Coliform	<9.0	per 100mL	9.0	SM-9222D	MC		09/20/2001 16:35

Flow Equalization Tank converted into Anoxic Tank

Flow Equalization / Anoxic Tank

Aeration Tank

Aeration Tank Baffle Installed to Prevent Short Circuiting from Splitter Box to Clarifier

Aeration Tank Baffle and Geyser Pump for Nitrate Recycle to Anoxic Tank

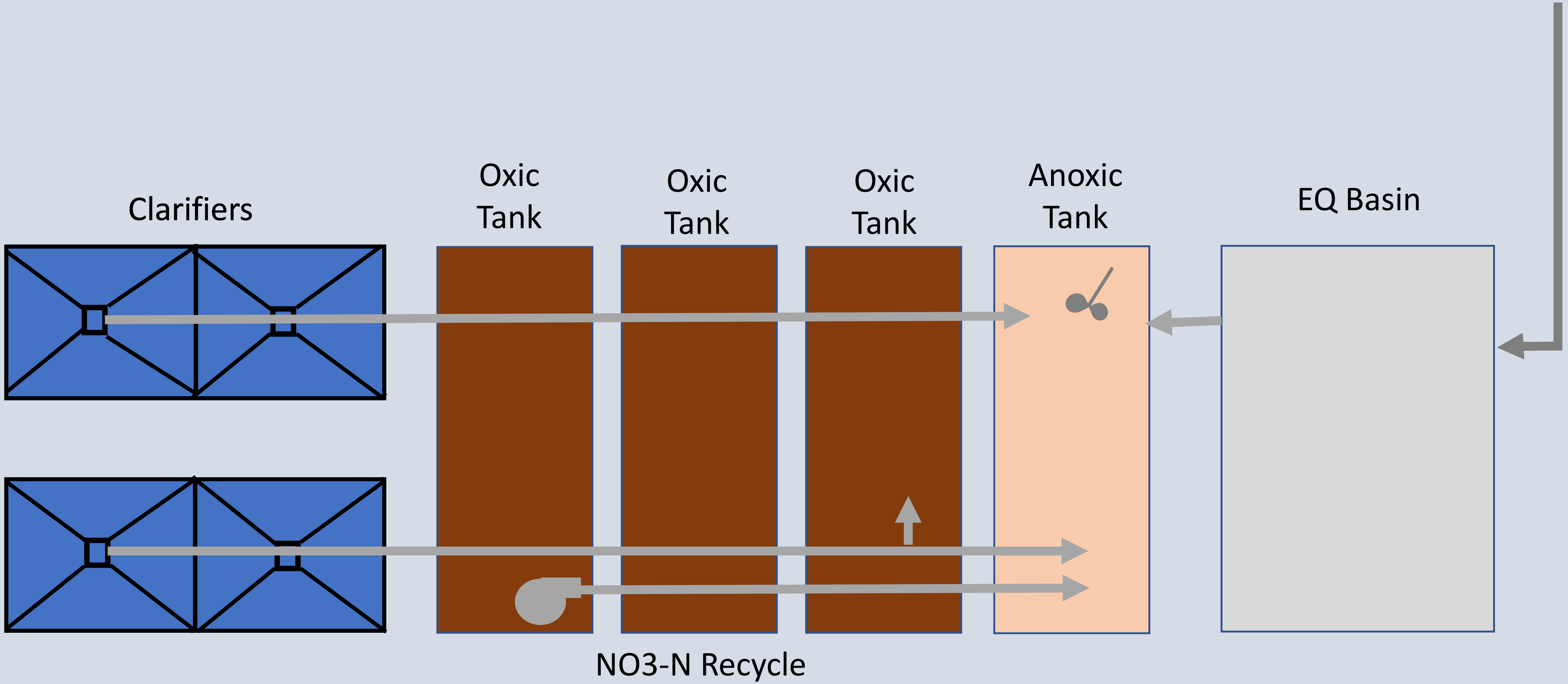

pump

?

Glycerin Feed to Supplement Organic Loading of Anoxic Tank

Case Study: Firestone Trace WWTP

Case Study: Firestone Trace WWTP



Firestone Trace WWTP

We found:

Everything was running full throttle!

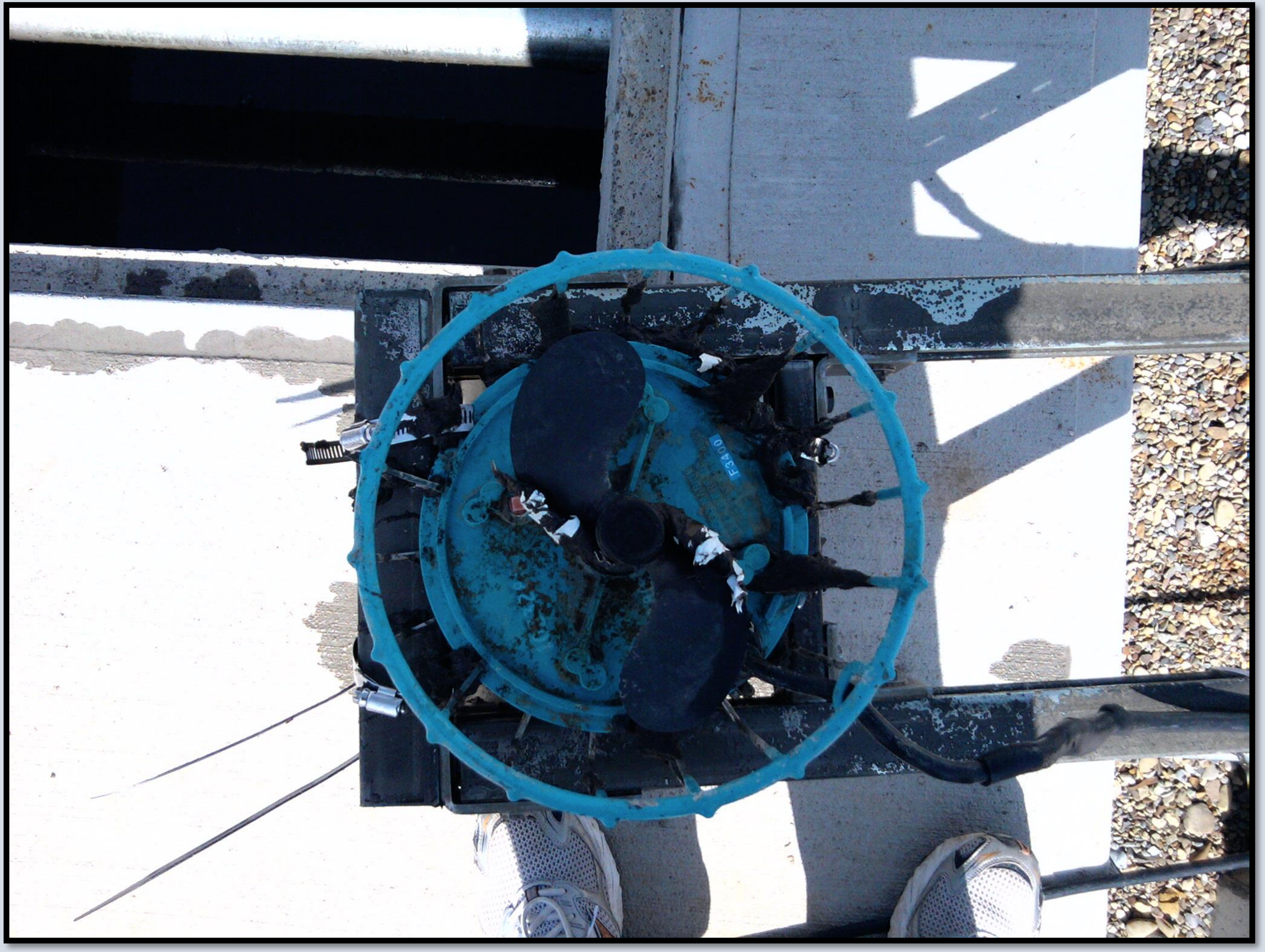
Nitrates are high (anoxic and effluent)

- Turn the Nitrate Recycle Pump down to 15 min ON, 45 min OFF (96 pin timer!)

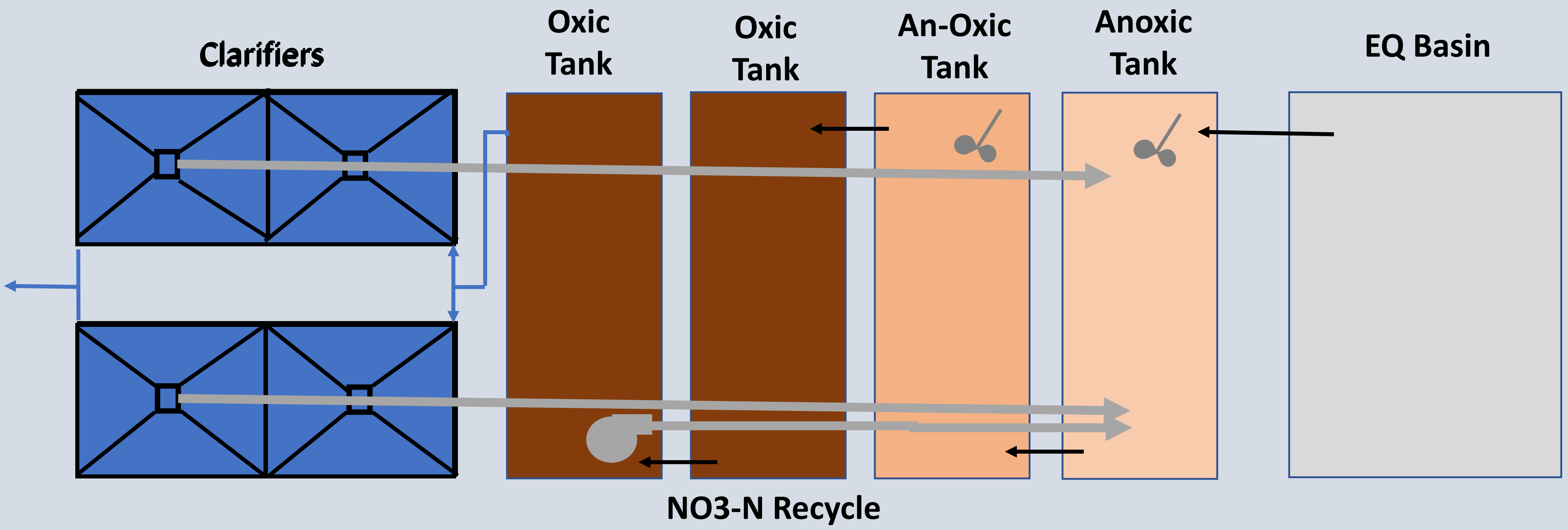
Influent COD is low

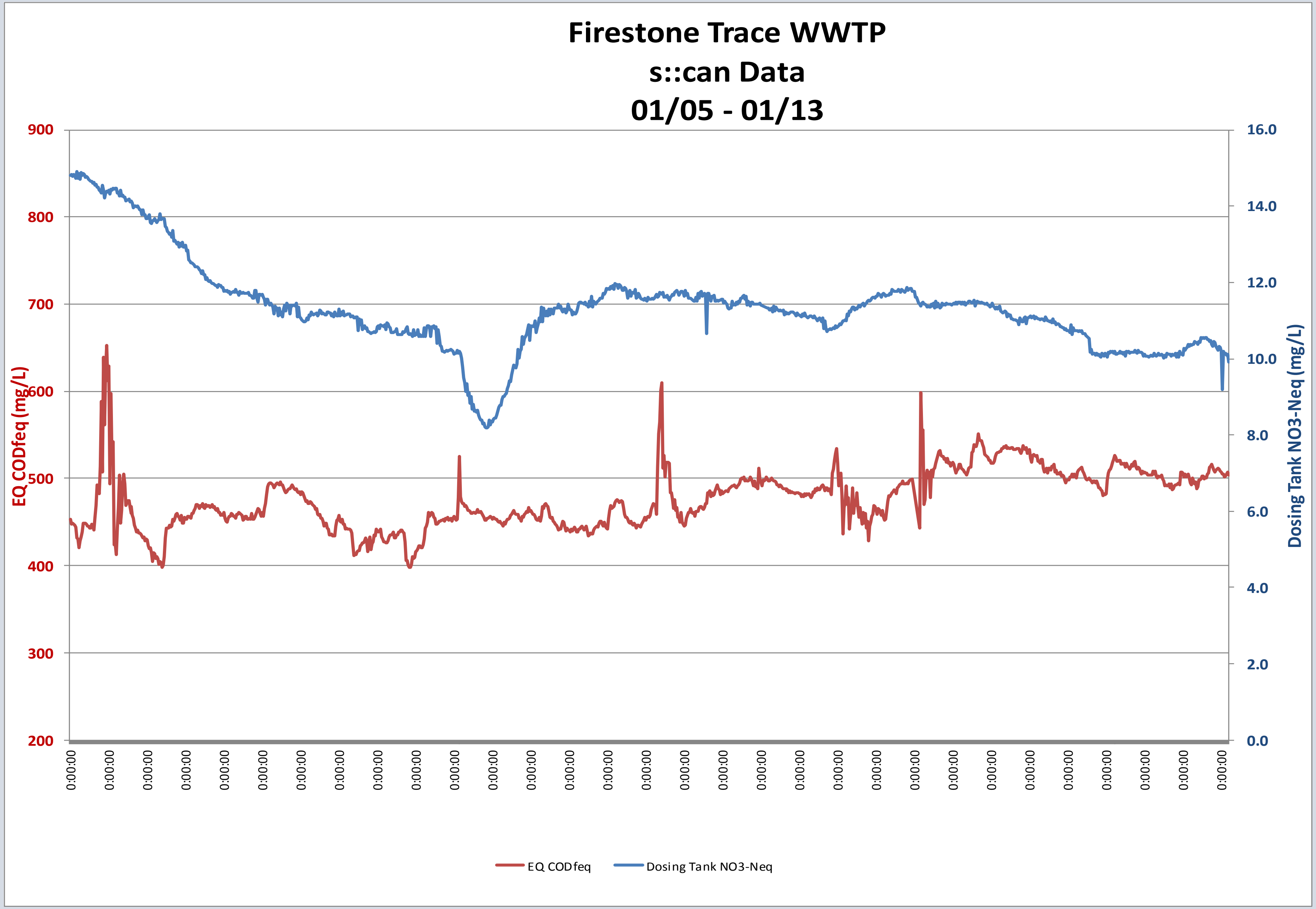
Aeration tanks are very aerobic (NH_3-N ~ 0.00 mg/L)

Expand the Anoxic Tank?


F3400

Troubleshooting Systems





Firestone Trace WWTP
s::can Data
01/05 - 01/13
900
800
700
600
500
400
300
200
EQ CODfeq (mg/L)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Dosing Tank NO3-Neq (mg/L)
0:00:00
EQ CODfeq
Dosing Tank NO3-Neq

Firestone Trace WWTP

Continued to run with two anoxic tanks for through the summer of 2011

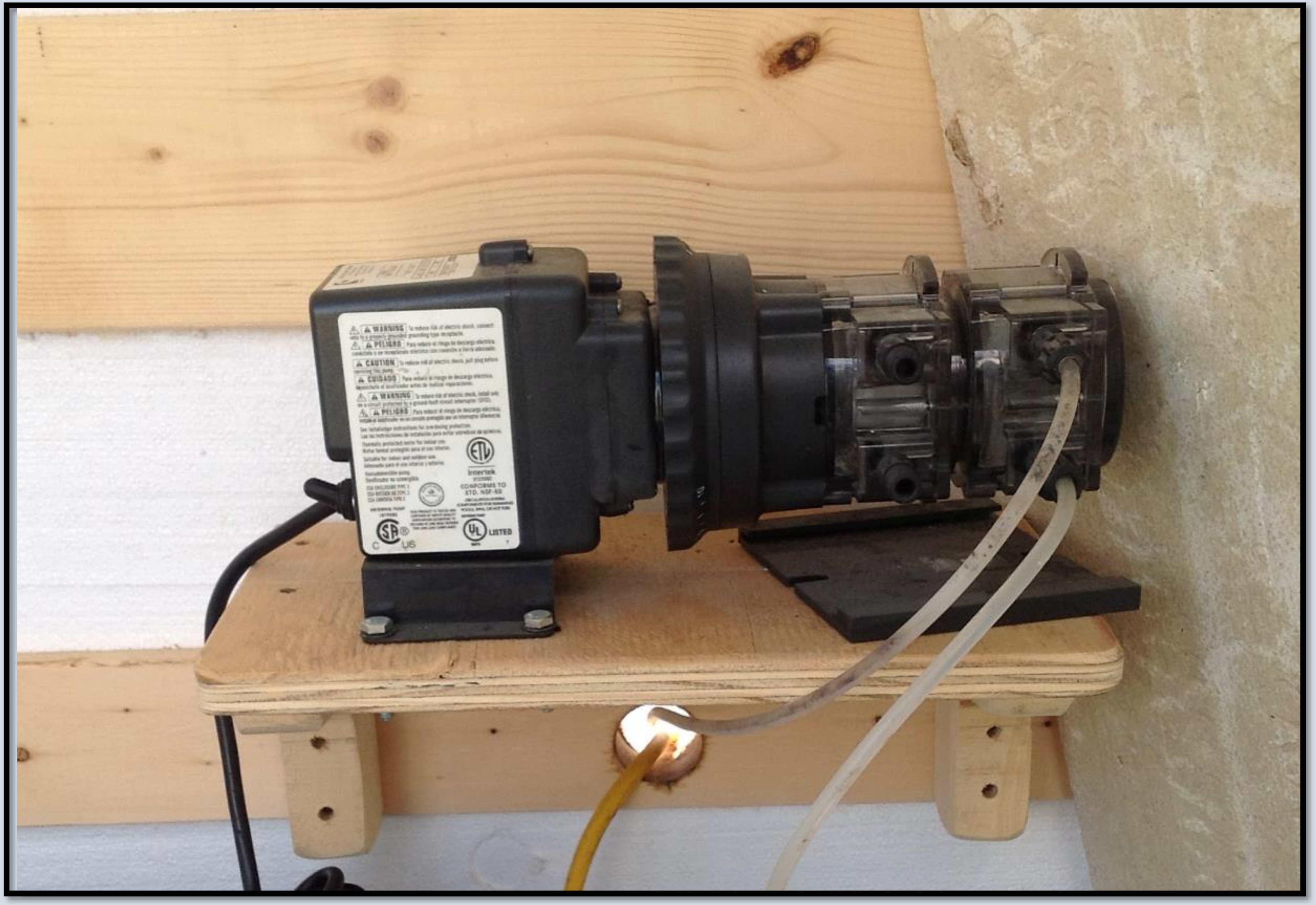
Flirted with Noncompliance for TIN all summer

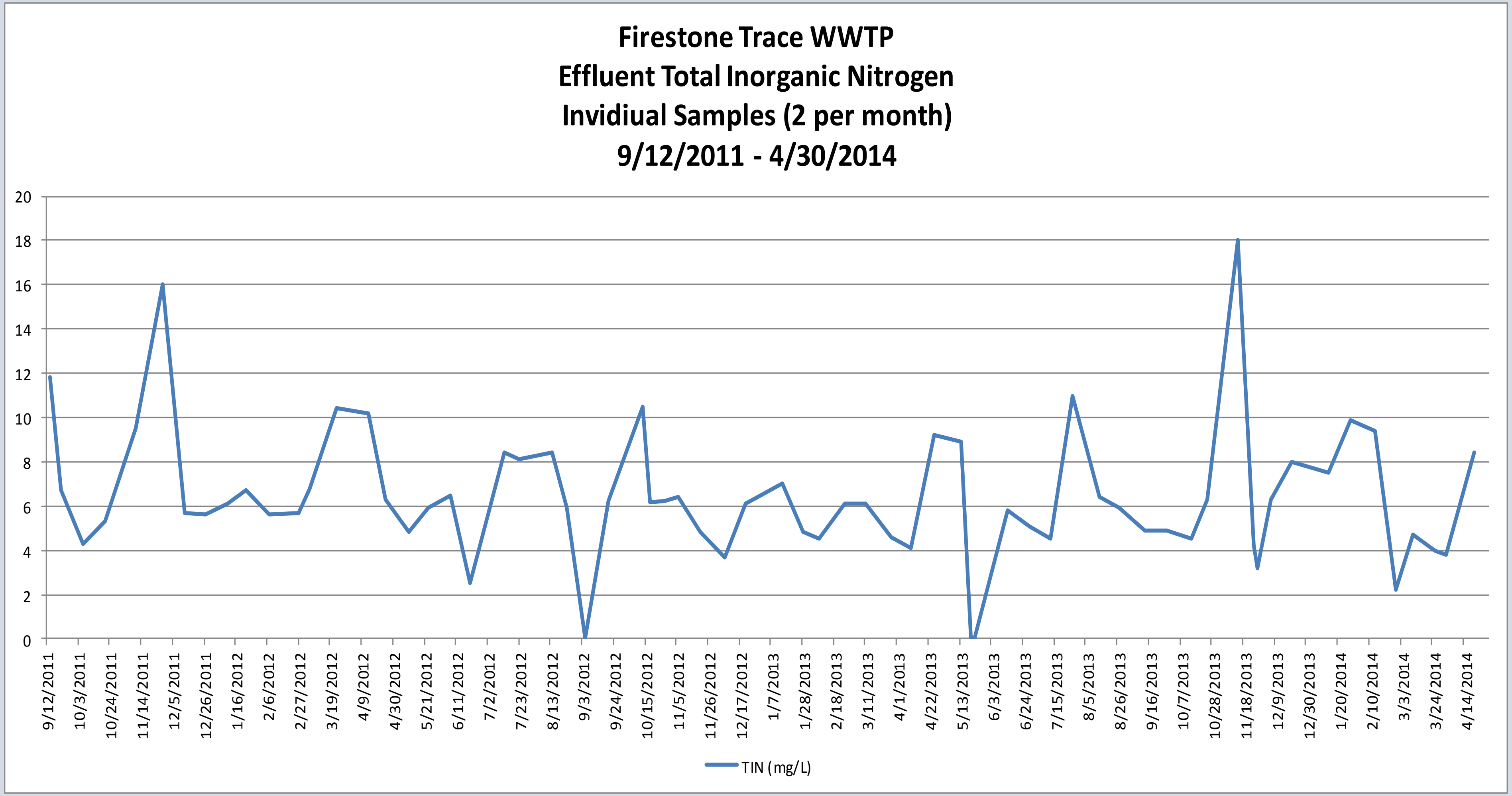
Pretty certain that carbon was the limiting factor

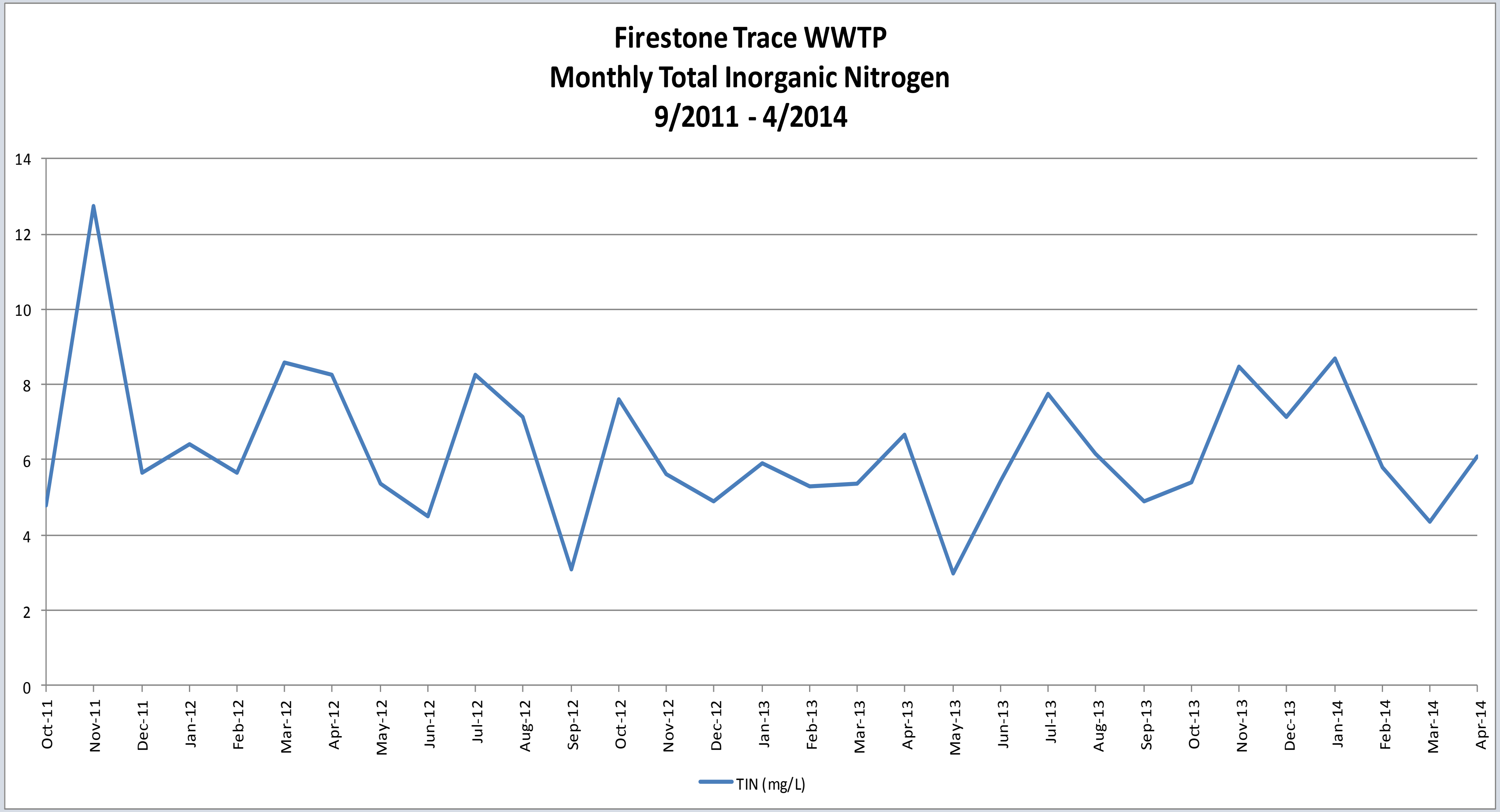
Firestone Trace WWTP

9/12/2011

A 55 gallon drum of Glycerin began to drip into the Anoxic Tank

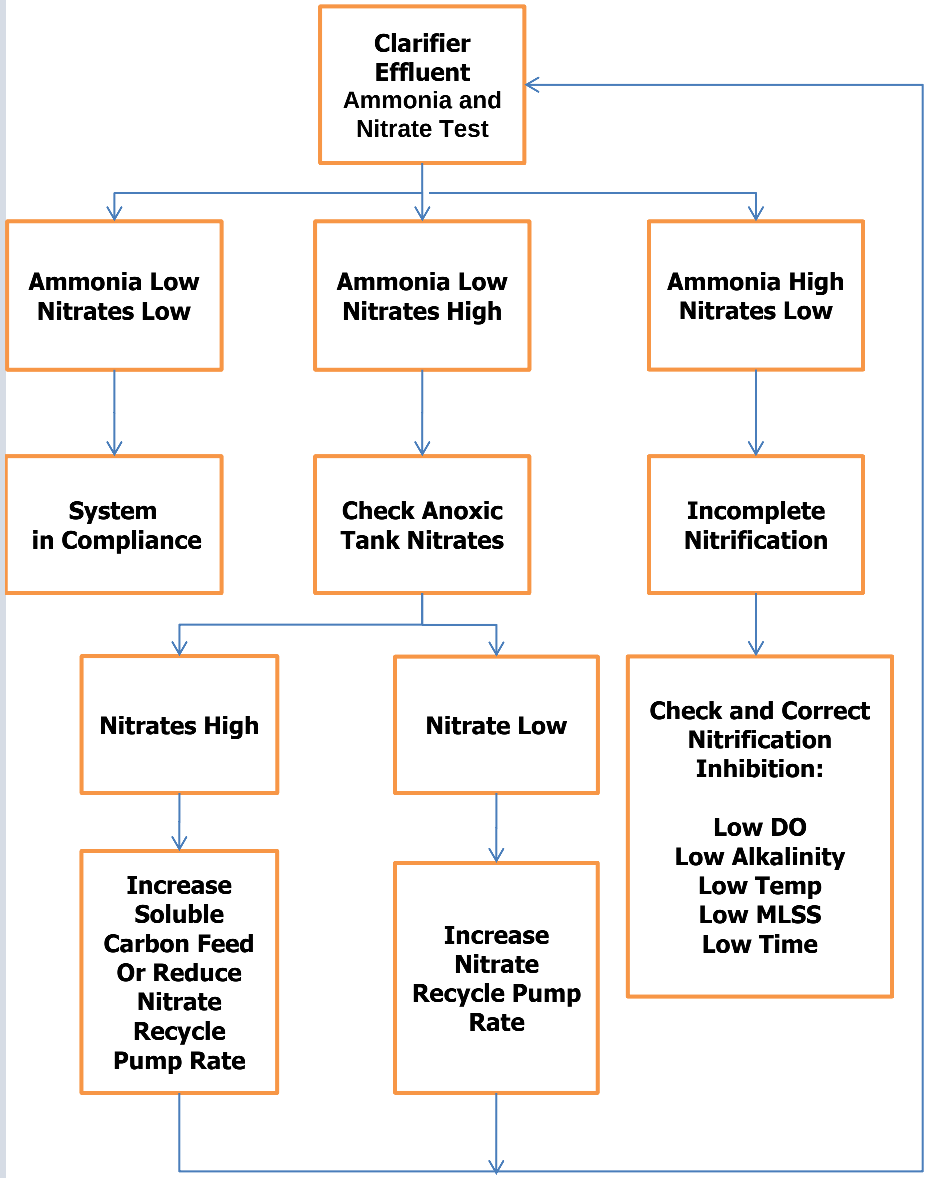

WARNING
PELIGRO
CAUTION
CUIDADO
WARNING
PELIGRO
Intertek
CONFORMS TO
STD. NSF-50
LISTED


Firestone Trace WWTP
Effluent Total Inorganic Nitrogen
Invidiual Samples (2 per month)
9/12/2011 - 4/30/2014
20
18
16
14
12
10
8
6
4
2
0
9/12/2011
10/3/2011
10/24/2011
11/14/2011
12/5/2011
12/26/2011
1/16/2012
2/6/2012
2/27/2012
3/19/2012
4/9/2012
4/30/2012
5/21/2012
6/11/2012
7/2/2012
7/23/2012
8/13/2012
9/3/2012
9/24/2012
10/15/2012
11/5/2012
11/26/2012
12/17/2012
1/7/2013
1/28/2013
2/18/2013
3/11/2013
4/1/2013
4/22/2013
5/13/2013
6/3/2013
6/24/2013
7/15/2013
8/5/2013
8/26/2013
9/16/2013
10/7/2013
10/28/2013
11/18/2013
12/9/2013
12/30/2013
1/20/2014
2/10/2014
3/3/2014
3/24/2014
4/14/2014
TIN (mg/L)



Firestone Trace WWTP
Monthly Total Inorganic Nitrogen
9/2011 - 4/2014
0
2
4
6
8
10
12
14
Oct-11
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
TIN (mg/L)

Process Control Flow Chart for Denitrification in Anoxic Tank



Firestone Trace WWTP

Optimize Anoxic Zone

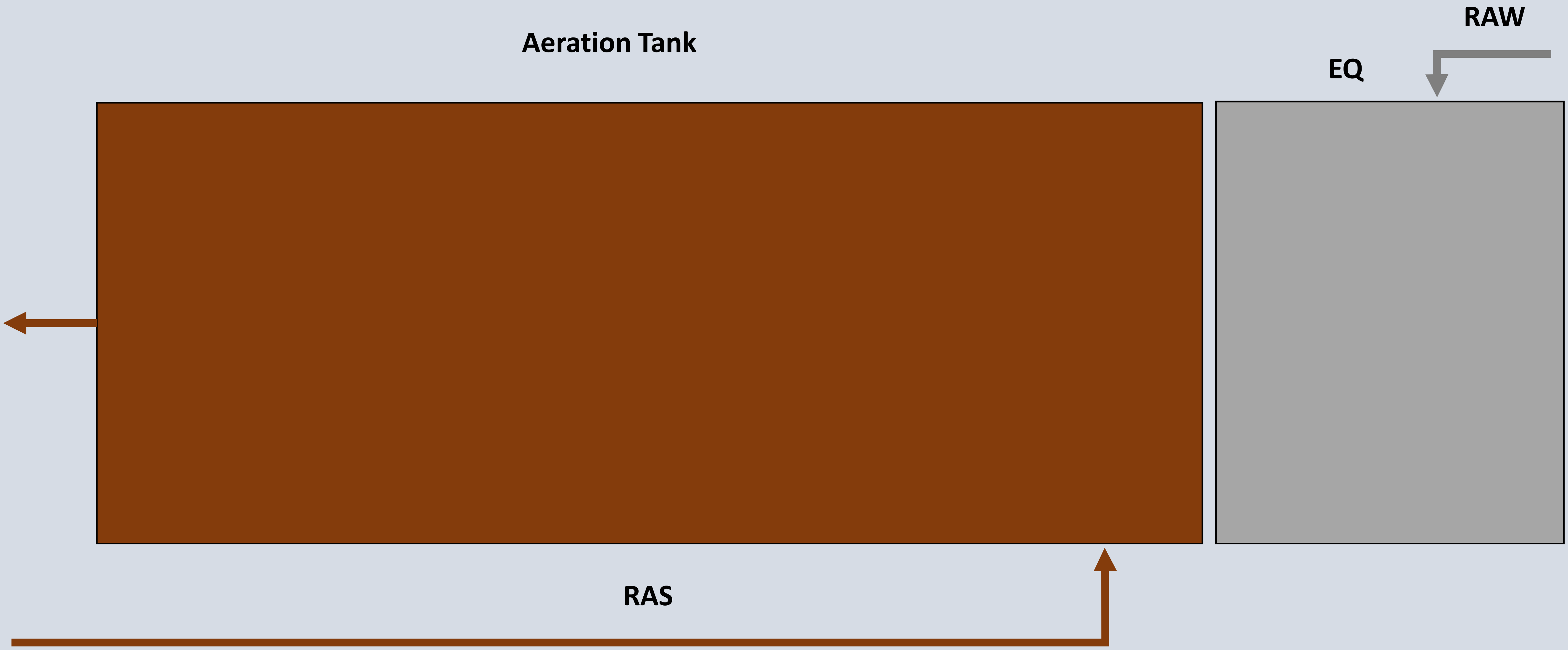
Control Nitrate Recycle

Control Soluble Carbon

Process Control:

- Anoxic Tank NH_3-N and NO_3-N
- Aeration Tank NH_3-N and NO_3-N

Case Study: Scioto Reserve WWTP



Scioto Reserve WWTP

0.423 MDG Design Flow

Operates at 50 % design flow at 100+% of online capacity

Land applies treated wastewater to an impoundment for golf course irrigation

In 2012, rules for land application change and implementation of tight limits begins

Effluent limits required 10 mg/L TIN by April 2014

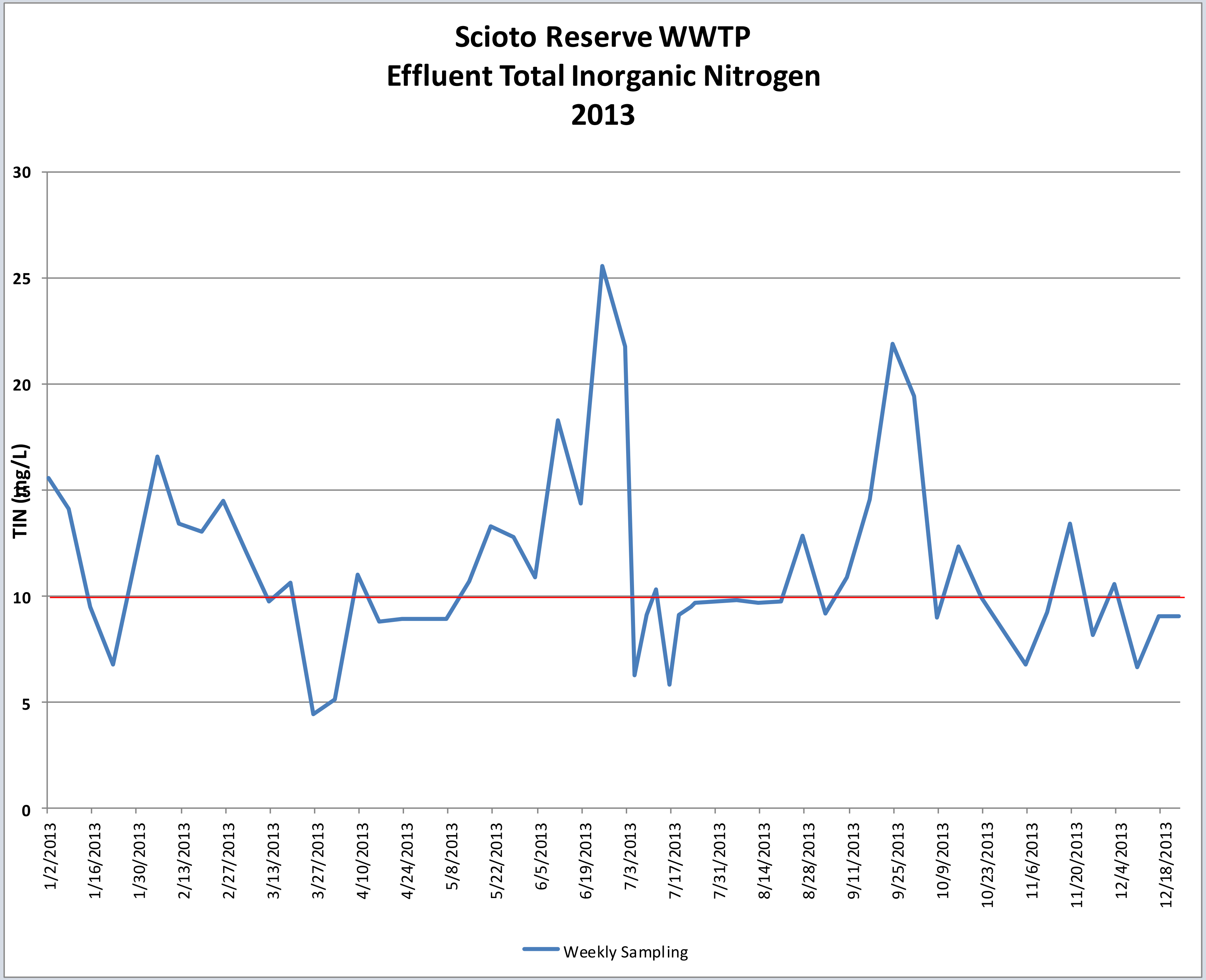
Scioto Reserve WWTP original design does not provide for denitrification

Scioto Reserve WWTP

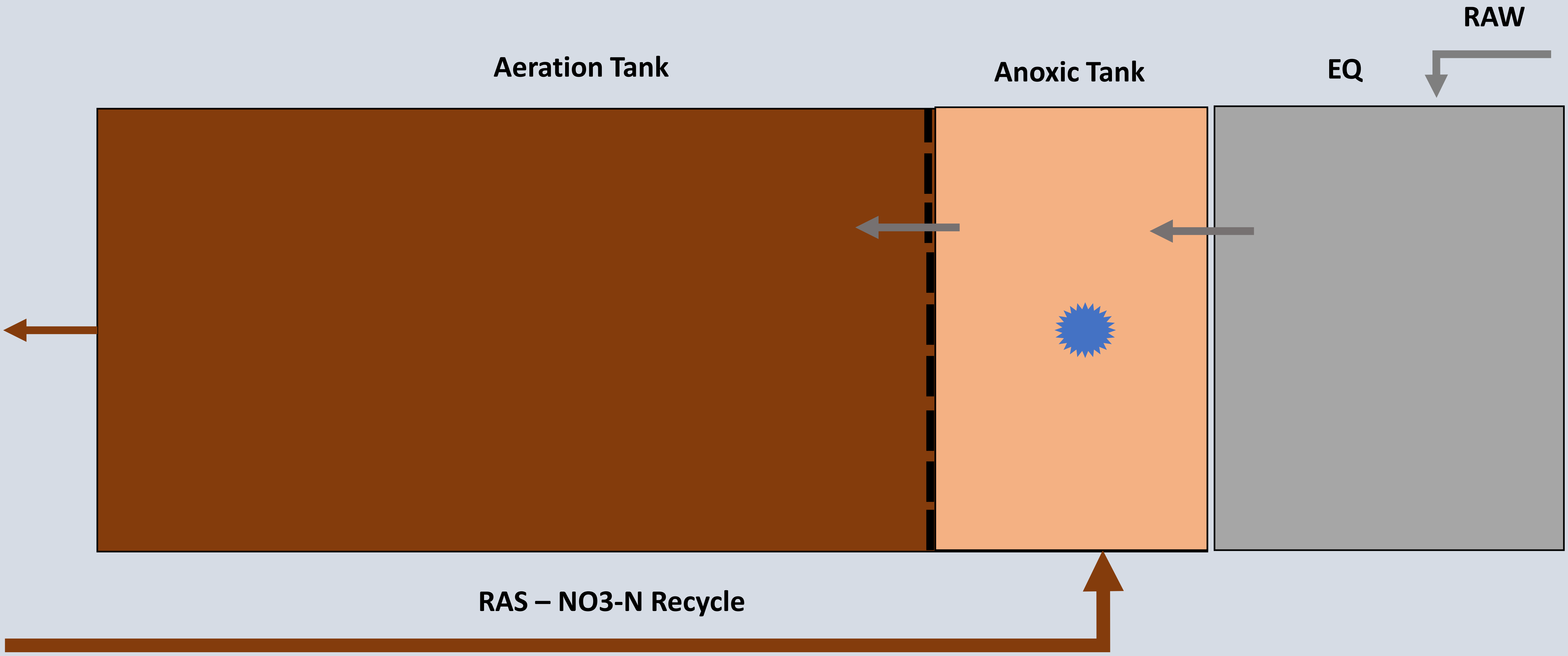
Initially, tried to ON/OFF blower operation to denitrify in the aeration tanks

Occasionally TIN would be within permit, but no consistency, no room for safety

December 2013: Drastic measures


Scioto Reserve WWTP
Effluent Total Inorganic Nitrogen
2013
TIN (mg/L)
30
25
20
15
10
5
0
1/2/2013
1/16/2013
1/30/2013
2/13/2013
2/27/2013
3/13/2013
3/27/2013
4/10/2013
4/24/2013
5/8/2013
5/22/2013
6/5/2013
6/19/2013
7/3/2013
7/17/2013
7/31/2013
8/14/2013
8/28/2013
9/11/2013
9/25/2013
10/9/2013
10/23/2013
11/6/2013
11/20/2013
12/4/2013
12/18/2013
Weekly Sampling

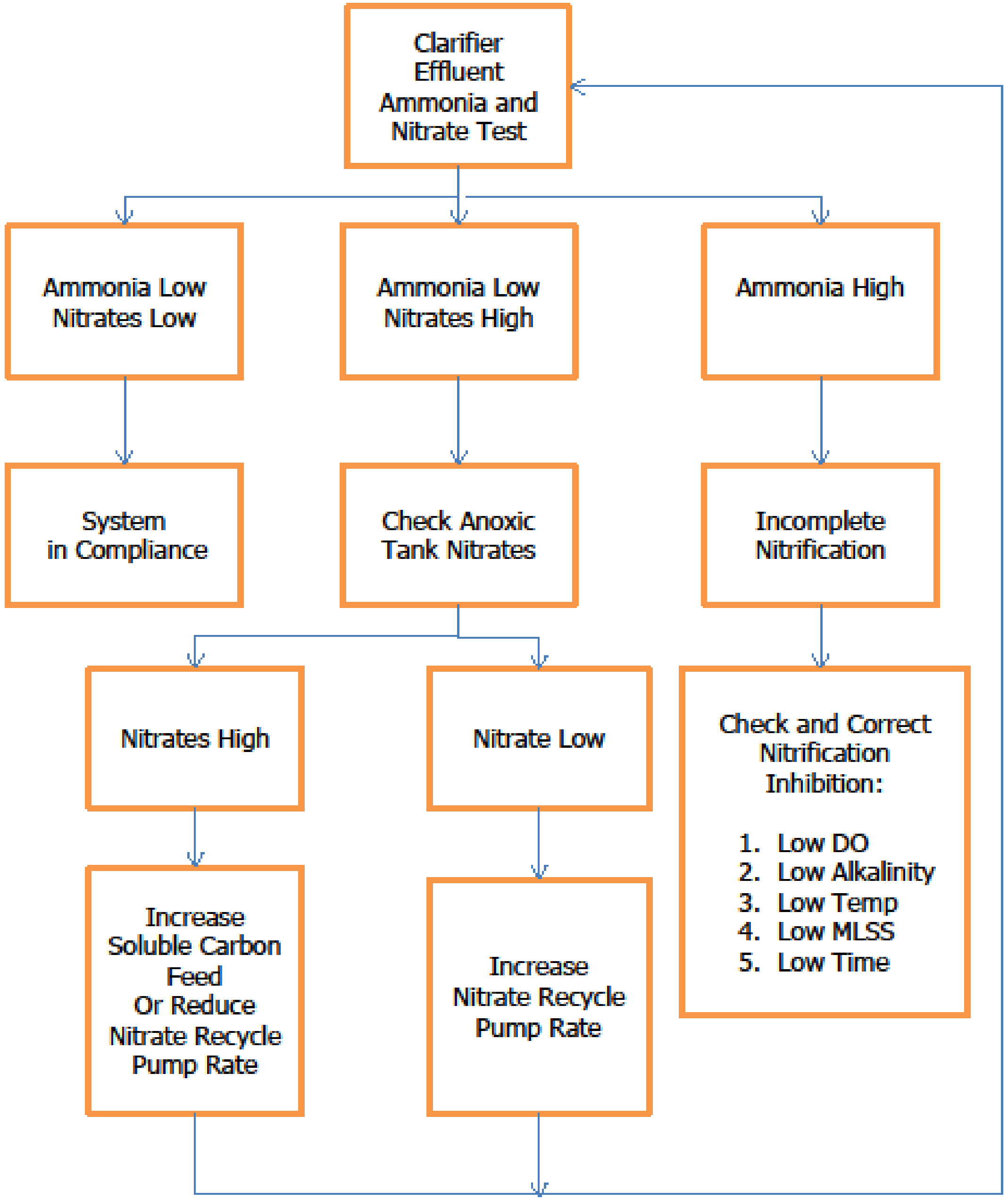
Troubleshooting Systems

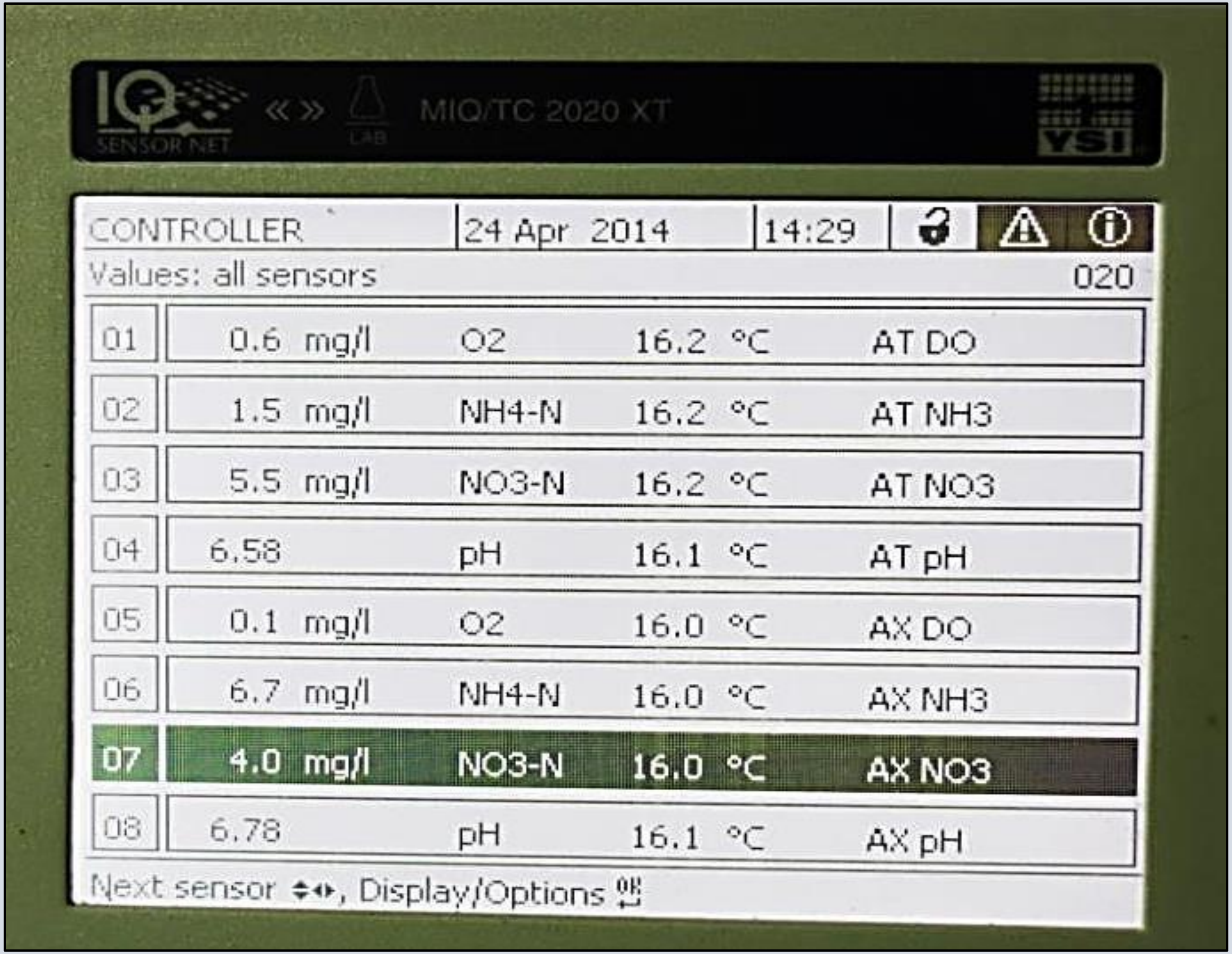


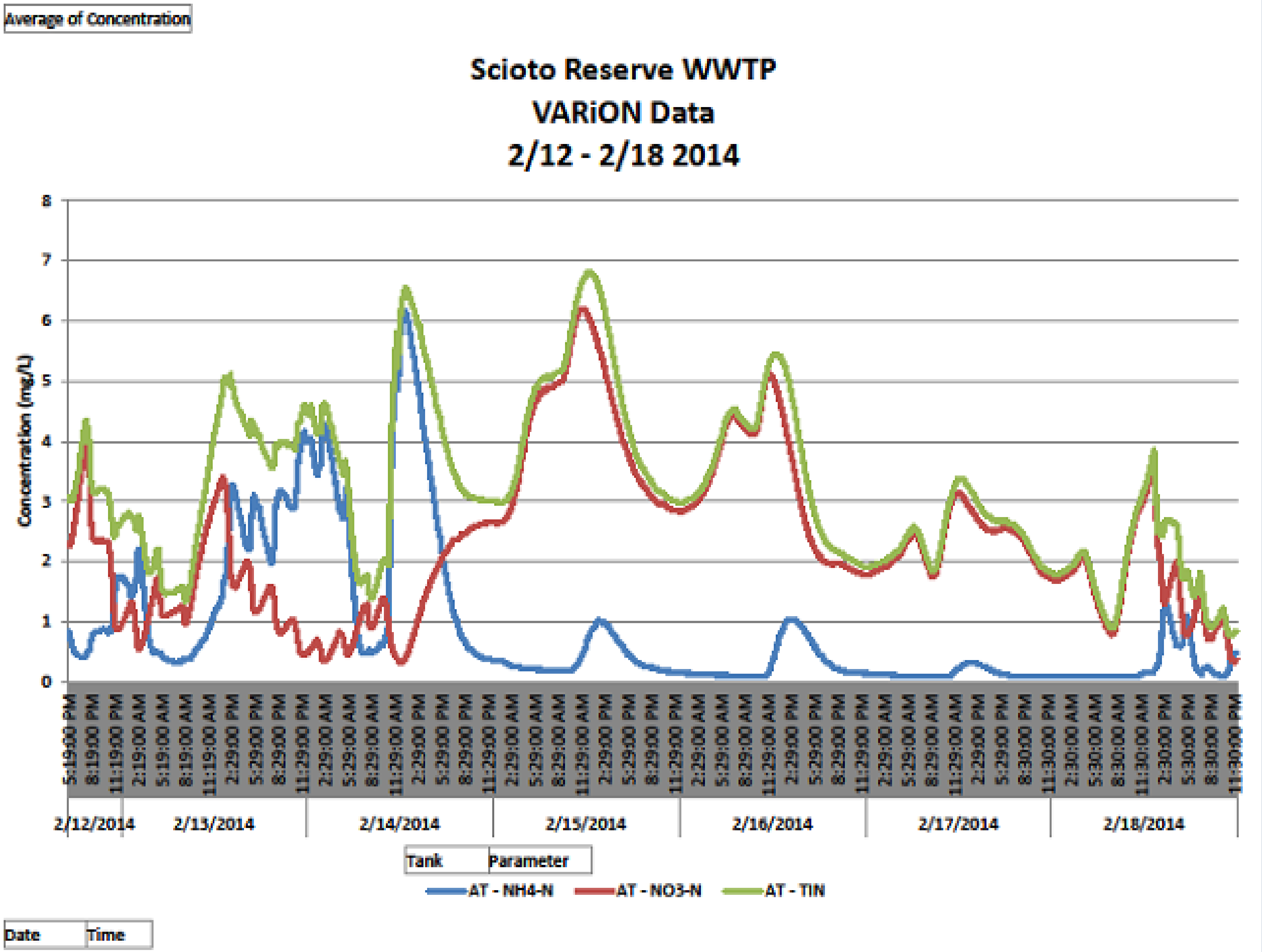

DANGER
CONFINED SPACE
ENTER BY
PERMIT ONLY


SKIMMER
SKIMMER
SLUDGE RETURN

Process Control Flow Chart for Denitrification in Anoxic Tank



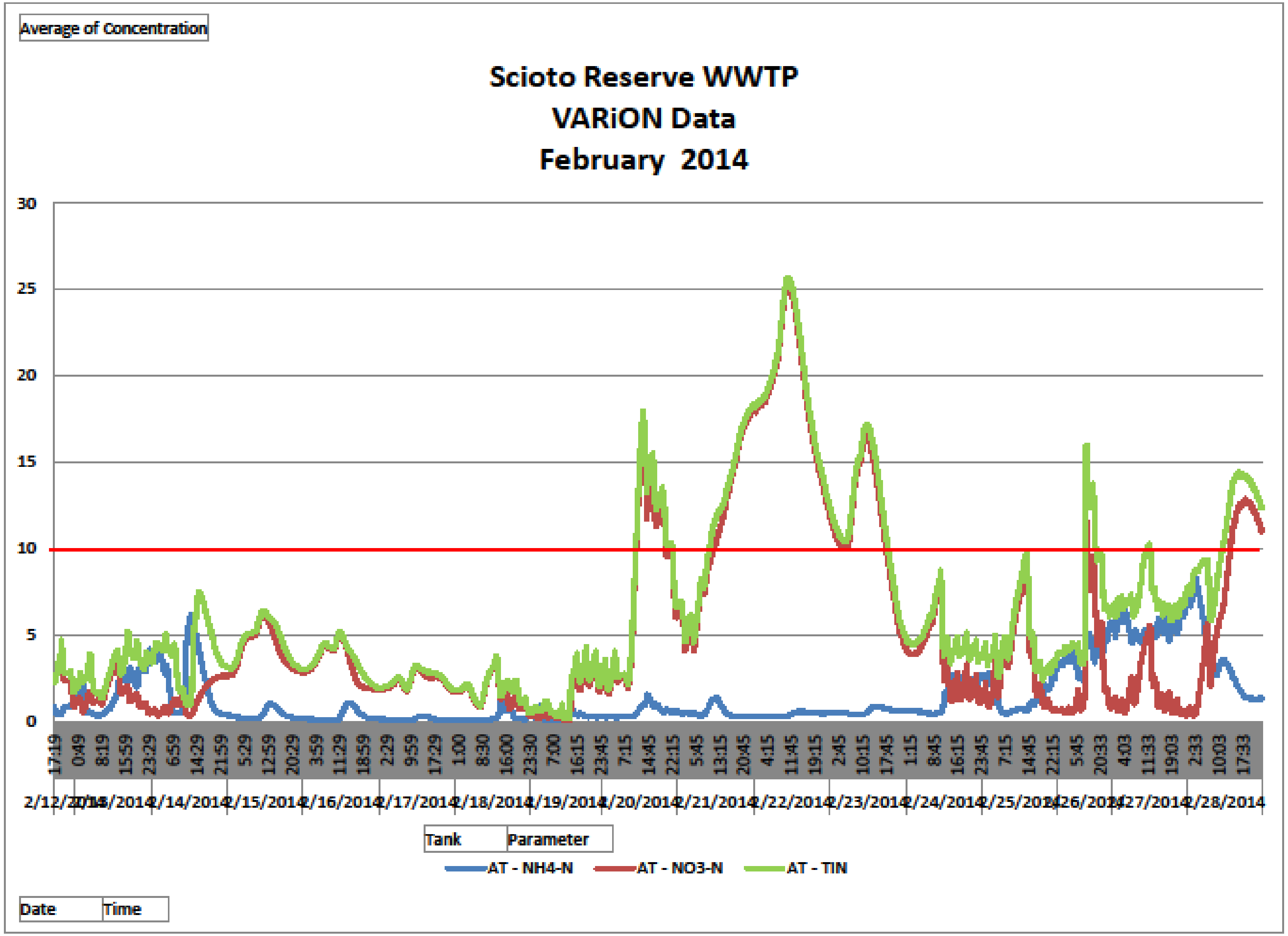

SENSOR NET
LAB
MIQ/TC 2020 XT
YSI
CONTROLLER
24 Apr 2014
14:29
Values: all sensors
020
01 0.6 mg/l O2 16.2 °C AT DO
02 1.5 mg/l NH4-N 16.2 °C AT NH3
03 5.5 mg/l NO3-N 16.2 °C AT NO3
04 6.58 pH 16.1 °C AT pH
05 0.1 mg/l O2 16.0 °C AX DO
06 6.7 mg/l NH4-N 16.0 °C AX NH3
07 4.0 mg/l NO3-N 16.0 °C AX NO3
08 6.78 pH 16.1 °C AX pH
Next sensor, Display/Options

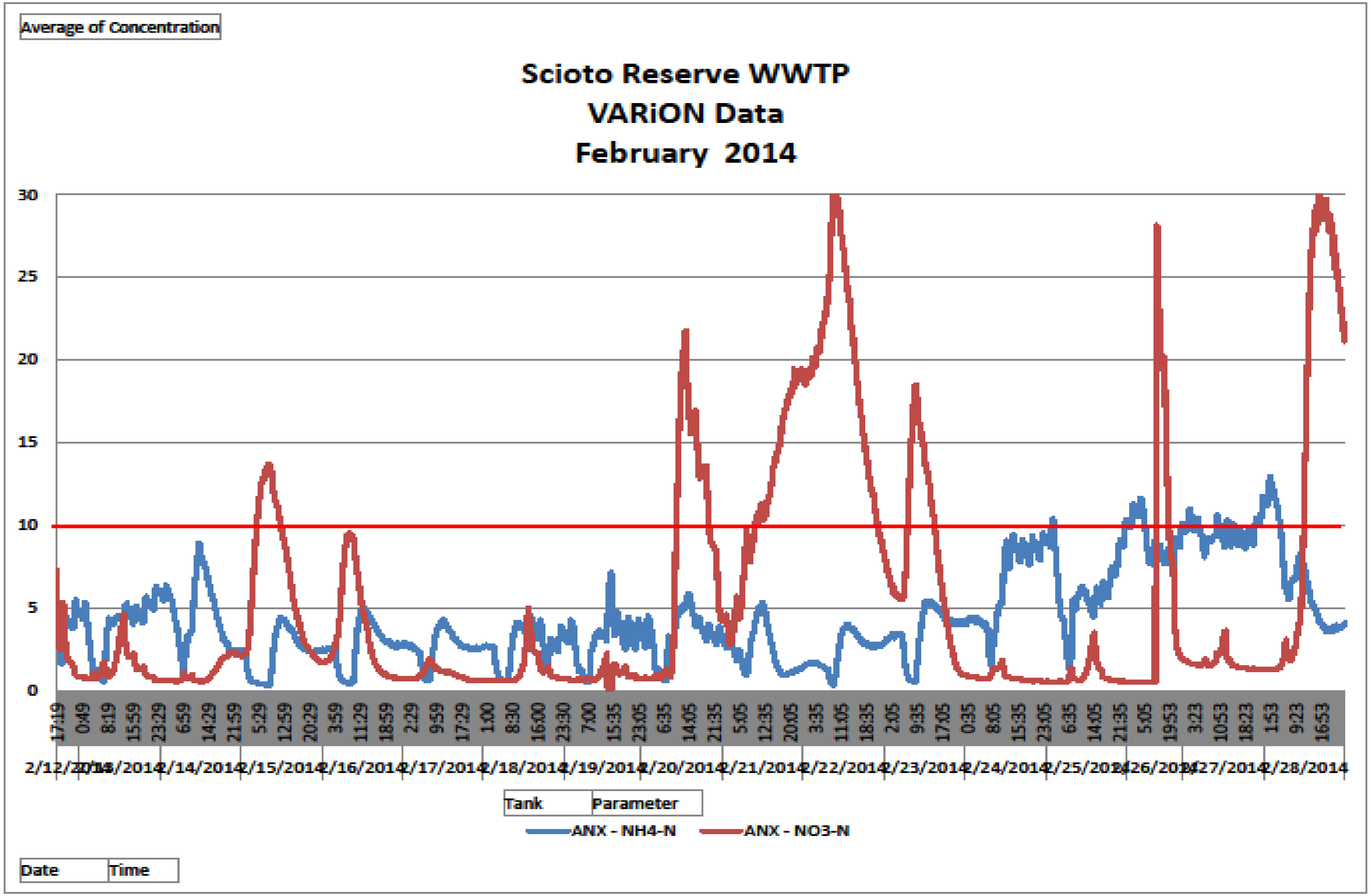


Average of Concentration
Scioto Reserve WWTP
VARiON Data
2/12 - 2/18 2014
Concentration (mg/L)
8
7
6
5
4
3
2
1
0
2/12/2014
2/13/2014
2/14/2014
2/15/2014
2/16/2014
2/17/2014
2/18/2014
Tank
Parameter
AT - NH4-N
AT - NO3-N
AT - TIN
Date
Time

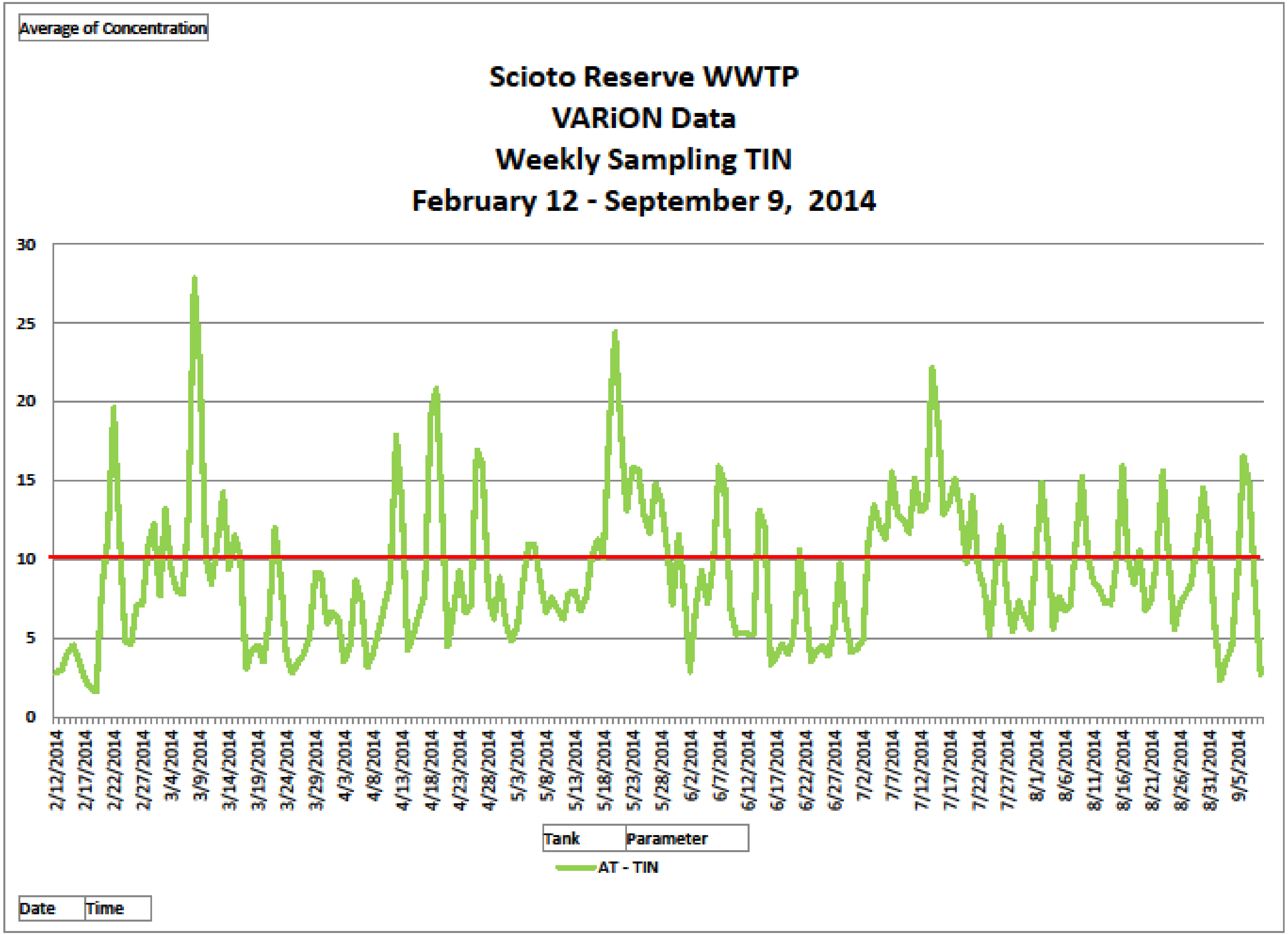
Scioto Reserve WWTP

- 1) created a mixed Anoxic Zone
- 2) relied on RAS for nitrate recycle
- 3) relied on raw wastewater for carbon source
- 4) Ran blowers ON/OFF during the week
- 5) Ran full aeration during the weekend
- **TIN < 10 mg/L**

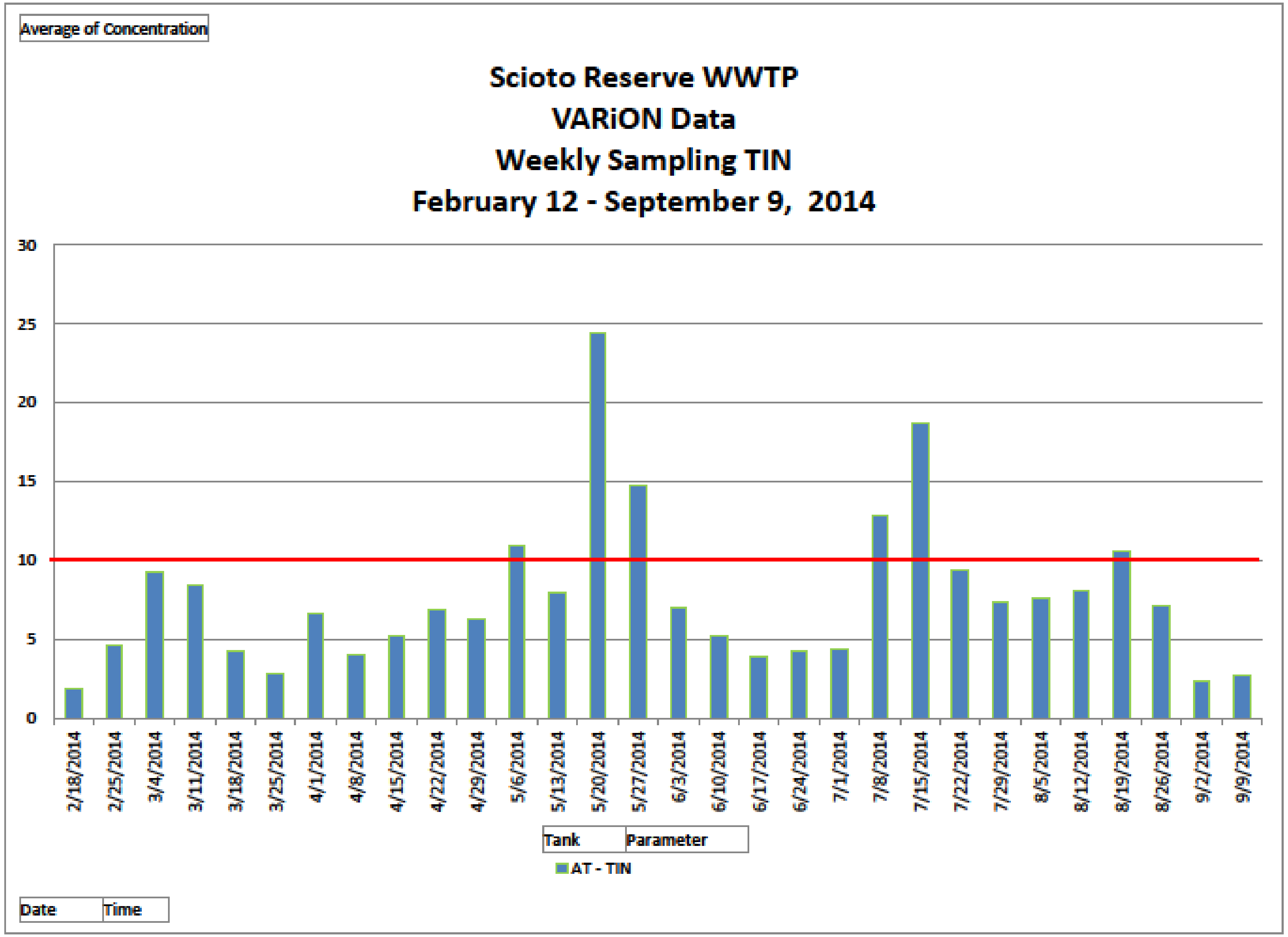

Average of Concentration
Scioto Reserve WWTP
VARiON Data
February 2014
30
25
20
15
10
5
0
Tank
Parameter
AT - NH4-N
AT - NO3-N
AT - TIN
Date
Time



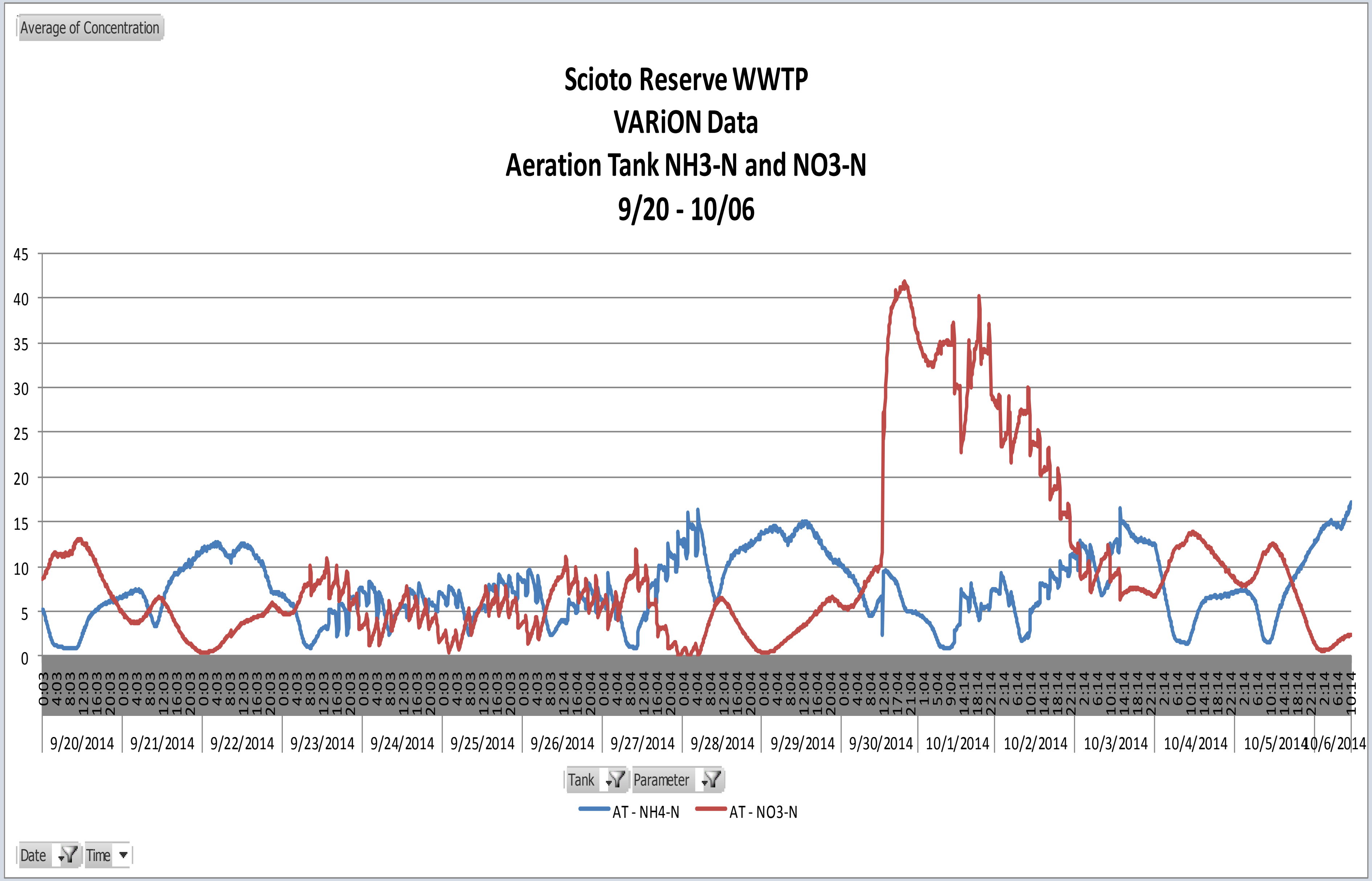
Average of Concentration
Scioto Reserve WWTP
VARiON Data
February 2014
30
25
20
15
10
5
0
Tank
Parameter
ANX - NH4-N
ANX - NO3-N
Date
Time

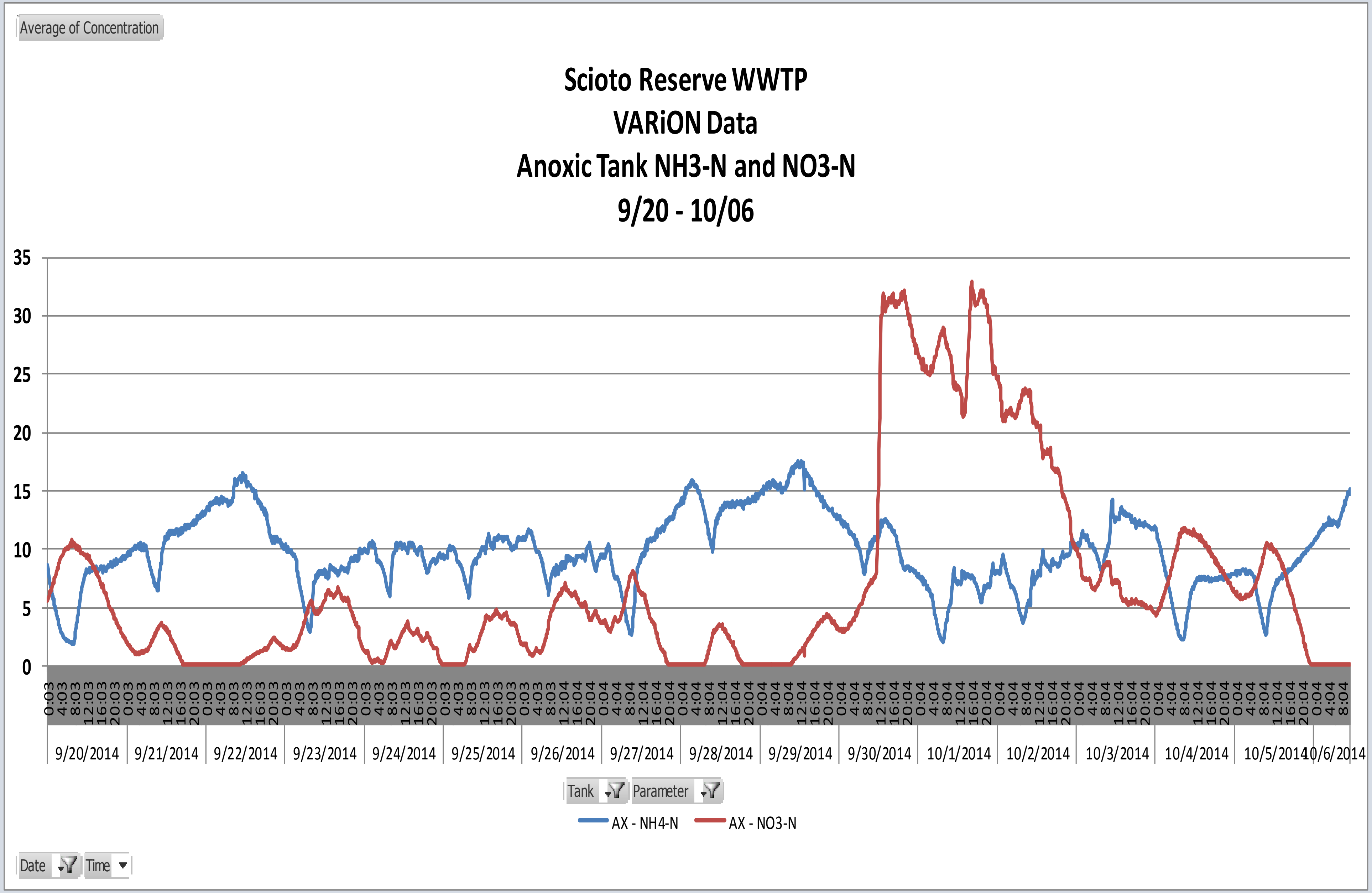


Average of Concentration
Scioto Reserve WWTP
VARiON Data
Weekly Sampling TIN
February 12 - September 9, 2014
30
25
20
15
10
5
0
2/12/2014
2/17/2014
2/22/2014
2/27/2014
3/4/2014
3/9/2014
3/14/2014
3/19/2014
3/24/2014
3/29/2014
4/3/2014
4/8/2014
4/13/2014
4/18/2014
4/23/2014
4/28/2014
5/3/2014
5/8/2014
5/13/2014
5/18/2014
5/23/2014
5/28/2014
6/2/2014
6/7/2014
6/12/2014
6/17/2014
6/22/2014
6/27/2014
7/2/2014
7/7/2014
7/12/2014
7/17/2014
7/22/2014
7/27/2014
8/1/2014
8/6/2014
8/11/2014
8/16/2014
8/21/2014
8/26/2014
8/31/2014
9/5/2014
Tank
Parameter
AT - TIN
Date
Time

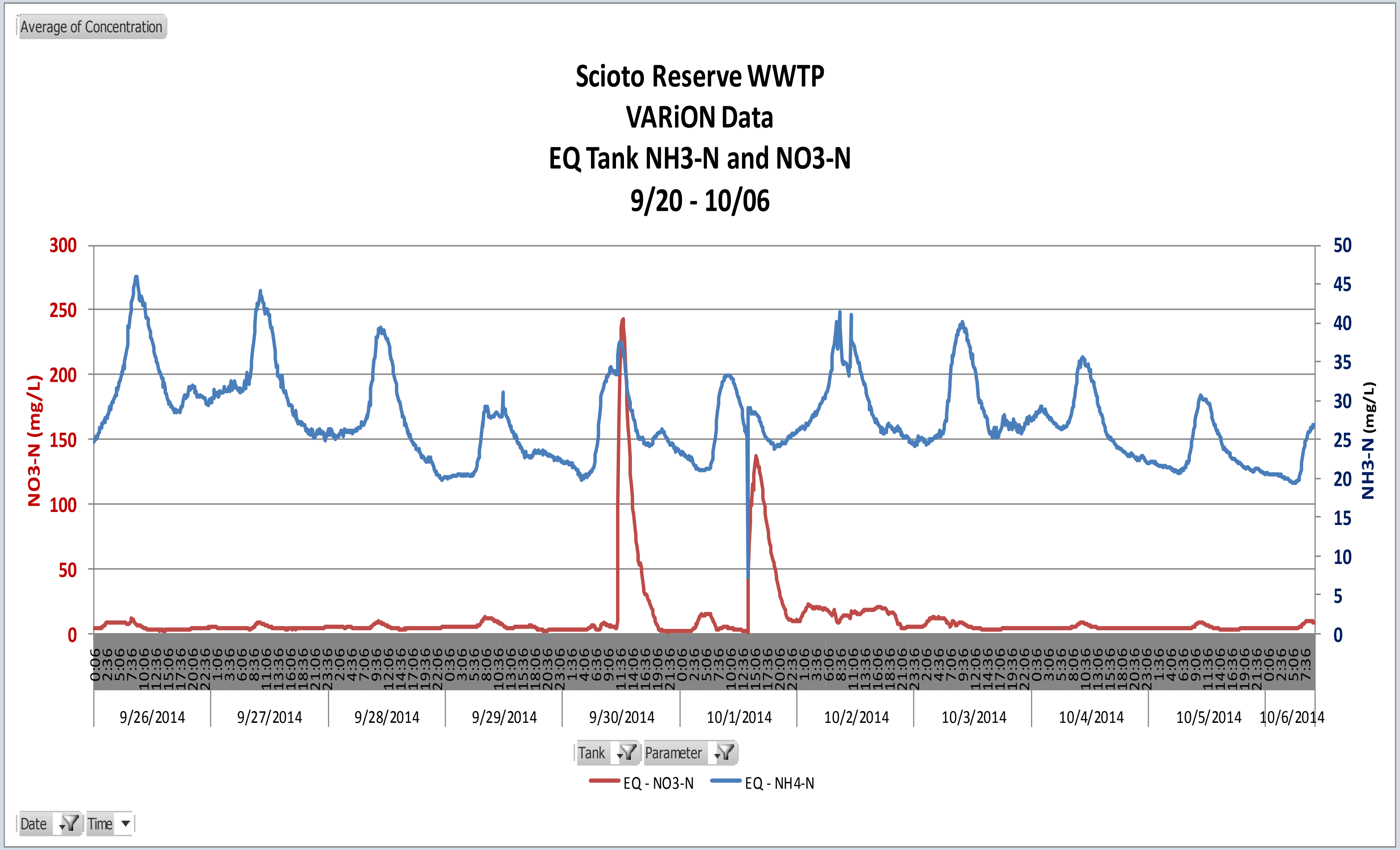


Average of Concentration
Scioto Reserve WWTP
VARiON Data
Weekly Sampling TIN
February 12 - September 9, 2014
30
25
20
15
10
5
0
2/18/2014
2/25/2014
3/4/2014
3/11/2014
3/18/2014
3/25/2014
4/1/2014
4/8/2014
4/15/2014
4/22/2014
4/29/2014
5/6/2014
5/13/2014
5/20/2014
5/27/2014
6/3/2014
6/10/2014
6/17/2014
6/24/2014
7/1/2014
7/8/2014
7/15/2014
7/22/2014
7/29/2014
8/5/2014
8/12/2014
8/19/2014
8/26/2014
9/2/2014
9/9/2014
Tank
Parameter
AT - TIN
Date
Time


Average of Concentration
Scioto Reserve WWTP
VARiON Data
Aeration Tank NH3-N and NO3-N
9/20 - 10/06
45
40
35
30
25
20
15
10
5
0
9/20/2014
9/21/2014
9/22/2014
9/23/2014
9/24/2014
9/25/2014
9/26/2014
9/27/2014
9/28/2014
9/29/2014
9/30/2014
10/1/2014
10/2/2014
10/3/2014
10/4/2014
10/5/2014
10/6/2014
Tank
Parameter
AT - NH4-N
AT - NO3-N
Date
Time



Average of Concentration
Scioto Reserve WWTP
VARiON Data
Anoxic Tank NH3-N and NO3-N
9/20 - 10/06
35
30
25
20
15
10
5
0
9/20/2014
9/21/2014
9/22/2014
9/23/2014
9/24/2014
9/25/2014
9/26/2014
9/27/2014
9/28/2014
9/29/2014
9/30/2014
10/1/2014
10/2/2014
10/3/2014
10/4/2014
10/5/2014
10/6/2014
Tank
Parameter
AX - NH4-N
AX - NO3-N
Date
Time


Average of Concentration
Scioto Reserve WWTP
VARiON Data
EQ Tank NH3-N and NO3-N
9/20 - 10/06
NO3-N (mg/L)
300
250
200
150
100
50
0
NH3-N (mg/L)
50
45
40
35
30
25
20
15
10
5
0
9/26/2014
9/27/2014
9/28/2014
9/29/2014
9/30/2014
10/1/2014
10/2/2014
10/3/2014
10/4/2014
10/5/2014
10/6/2014
Tank
Parameter
EQ - NO3-N
EQ - NH4-N
Date
Time

Troubleshooting Systems: City of Bdfrd WWTP

New WWTP came online November 2013

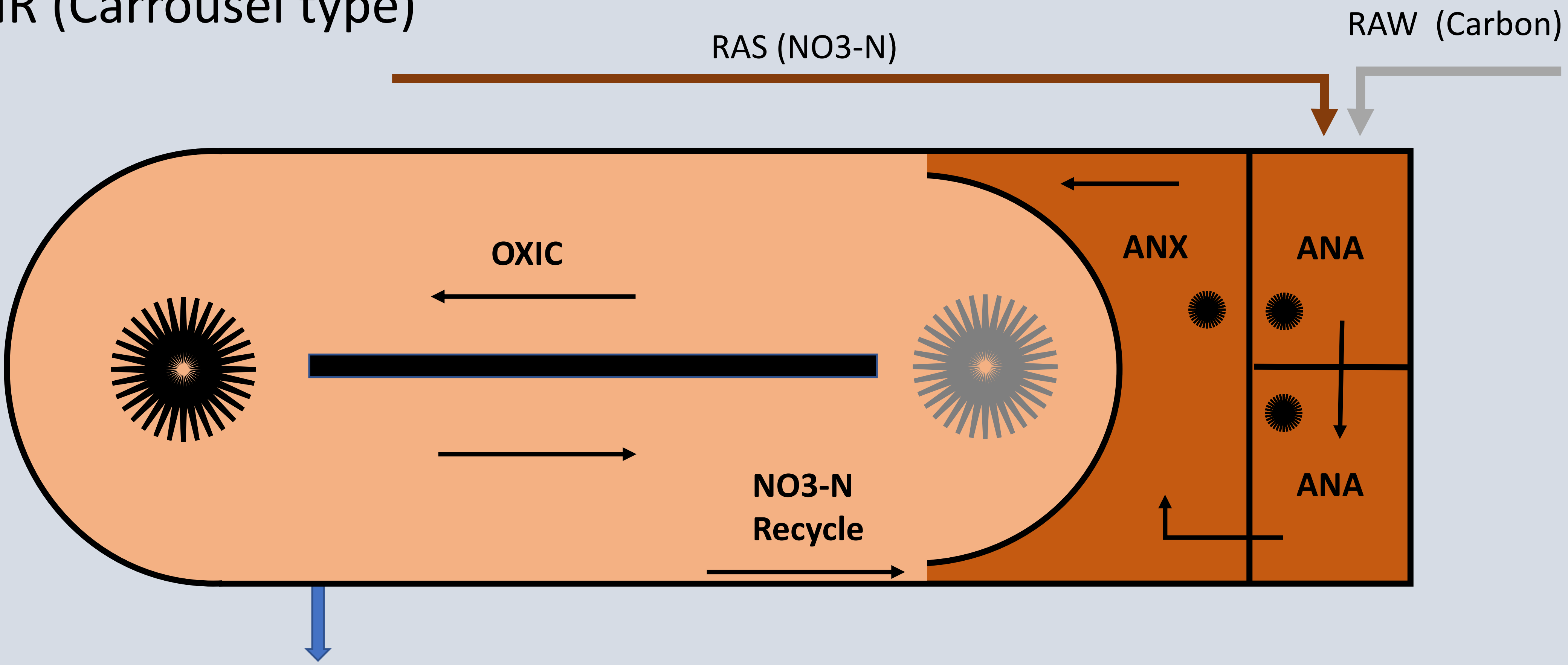
Constructed a Carrousel Type BNR System

Designed for 0.480 MGD

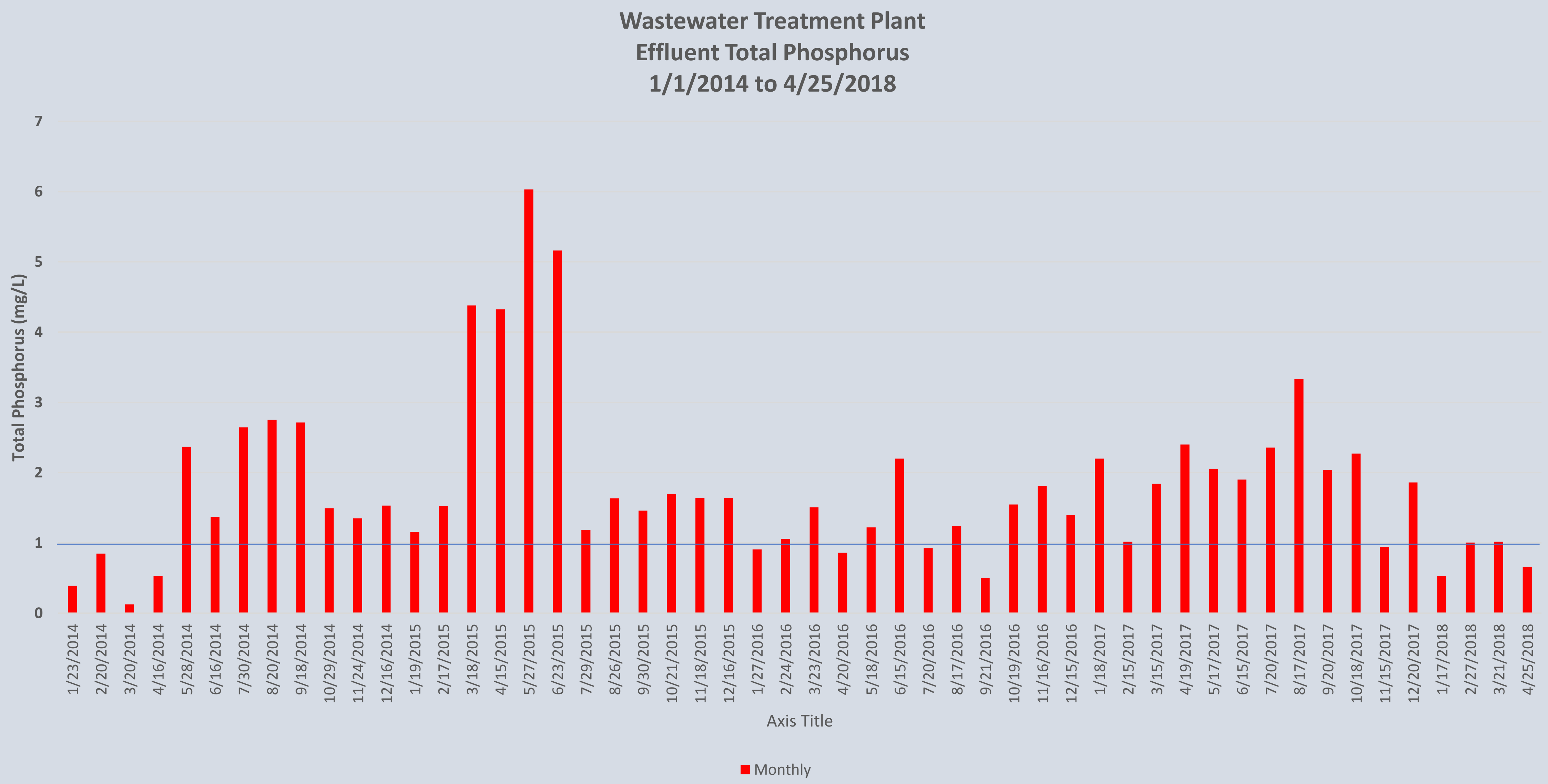
2017 average flow: ~0.550 MGD (big clarifiers!)

Troubleshooting Systems: City of Bdfrd WWTP

BNR (Carrousel type)




WesTech


Wastewater Treatment Plant
Effluent Total Phosphorus
1/1/2014 to 4/25/2018
Total Phosphorus (mg/L)
0
1
2
3
4
5
6
7
1/23/2014
2/20/2014
3/20/2014
4/16/2014
5/28/2014
6/16/2014
7/30/2014
8/20/2014
9/18/2014
10/29/2014
11/24/2014
12/16/2014
1/19/2015
2/17/2015
3/18/2015
4/15/2015
5/27/2015
6/23/2015
7/29/2015
8/26/2015
9/30/2015
10/21/2015
11/18/2015
12/16/2015
1/27/2016
2/24/2016
3/23/2016
4/20/2016
5/18/2016
6/15/2016
7/20/2016
8/17/2016
9/21/2016
10/19/2016
11/16/2016
12/15/2016
1/18/2017
2/15/2017
3/15/2017
4/19/2017
5/17/2017
6/15/2017
7/20/2017
8/17/2017
9/20/2017
10/18/2017
11/15/2017
12/20/2017
1/17/2018
2/27/2018
3/21/2018
4/25/2018
Axis Title
Monthly

Nitrate Analysis

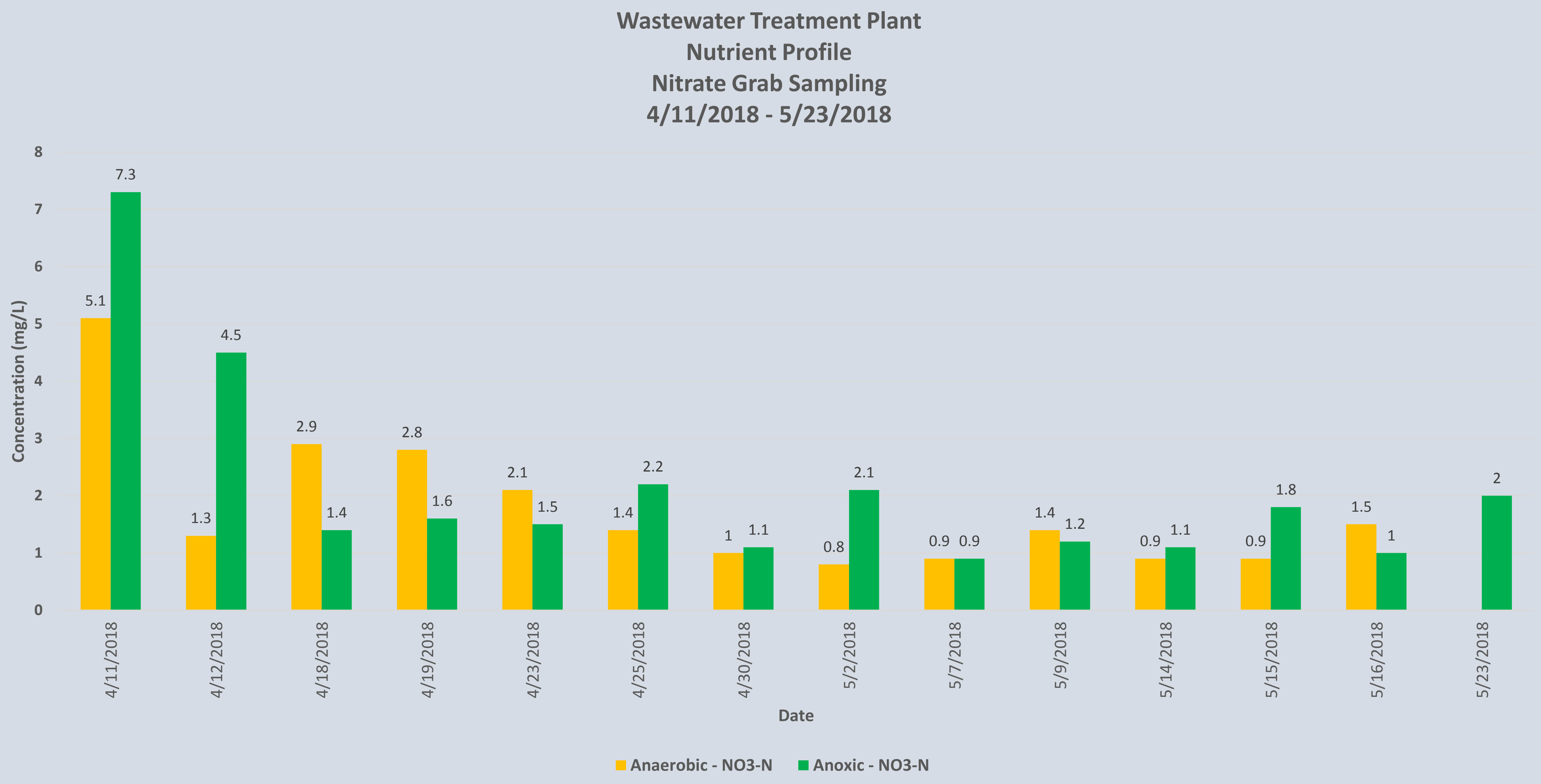
Nitrate (mg/L)				
	RAS	Anaerobic	Anoxic	Digester
3/15/2018	14.3	11.9	14.6	
3/19/2018	8.7	12.5	11.9	
3/20/2018	11.6	7.9	11.8	55.9
3/21/2018	11.5	7.5	12.0	
3/22/2018	8.6	8.2	11.1	131.5

Case Study: **City of Bdfrd** WWTP

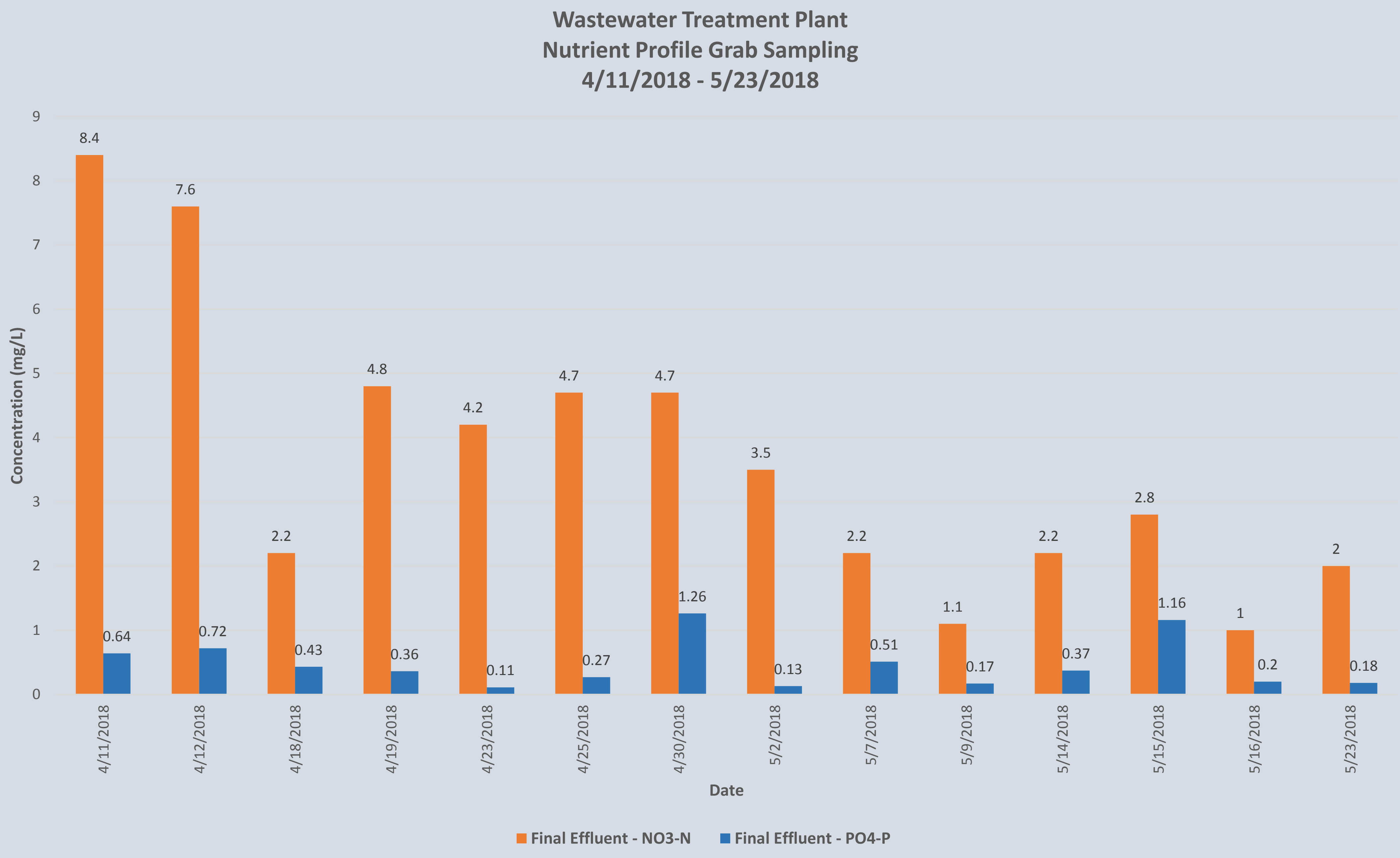
Too much Nitrate everywhere

Solution: Manage the Nitrates

1) Close the nitrate recycle gate
2) Run vertical rotor at 38 hertz
3) Turn Anaerobic Zone Mixer OFF for 3.5 hours, ON for 30 minutes
4) Turn Anoxic Zone Mixer OFF for 3.5 hours, ON for 30 minutes
5) Profile Ammonia, Nitrate, and Orthophosphate in each zone



Wastewater Treatment Plant
Nutrient Profile
Nitrate Grab Sampling
4/11/2018 - 5/23/2018
Concentration (mg/L)
0
1
2
3
4
5
6
7
8
5.1
7.3
1.3
4.5
2.9
1.4
2.8
1.6
2.1
1.5
1.4
2.2
1
1.1
0.8
2.1
0.9
0.9
1.4
1.2
0.9
1.1
0.9
1.8
1.5
1
2
4/11/2018
4/12/2018
4/18/2018
4/19/2018
4/23/2018
4/25/2018
4/30/2018
5/2/2018
5/7/2018
5/9/2018
5/14/2018
5/15/2018
5/16/2018
5/23/2018
Date
Anaerobic - NO3-N
Anoxic - NO3-N



Wastewater Treatment Plant
Nutrient Profile Grab Sampling
4/11/2018 - 5/23/2018
Concentration (mg/L)
9
8
7
6
5
4
3
2
1
0
8.4
0.64
7.6
0.72
2.2
0.43
4.8
0.36
4.2
0.11
4.7
0.27
4.7
1.26
3.5
0.13
2.2
0.51
1.1
0.17
2.2
0.37
2.8
1.16
1
0.2
2
0.18
4/11/2018
4/12/2018
4/18/2018
4/19/2018
4/23/2018
4/25/2018
4/30/2018
5/2/2018
5/7/2018
5/9/2018
5/14/2018
5/15/2018
5/16/2018
5/23/2018
Date
Final Effluent - NO3-N
Final Effluent - PO4-P


BLUE RIVER TECHNOLOGIES
NEW CASTLE, INDIANA

Case Study: **City of Bdfrd** WWTP

First April sample was high (1.25 mg/L), but the rest of the samples brought the monthly down to 0.66 mg/L

Alum feed was shut down 5/2

May 2018 another consecutive month of compliance for TP

In addition, the village was spending $800 - $1200/month for alum previously.

Electricity demand should also be reduced due to mixer turndown

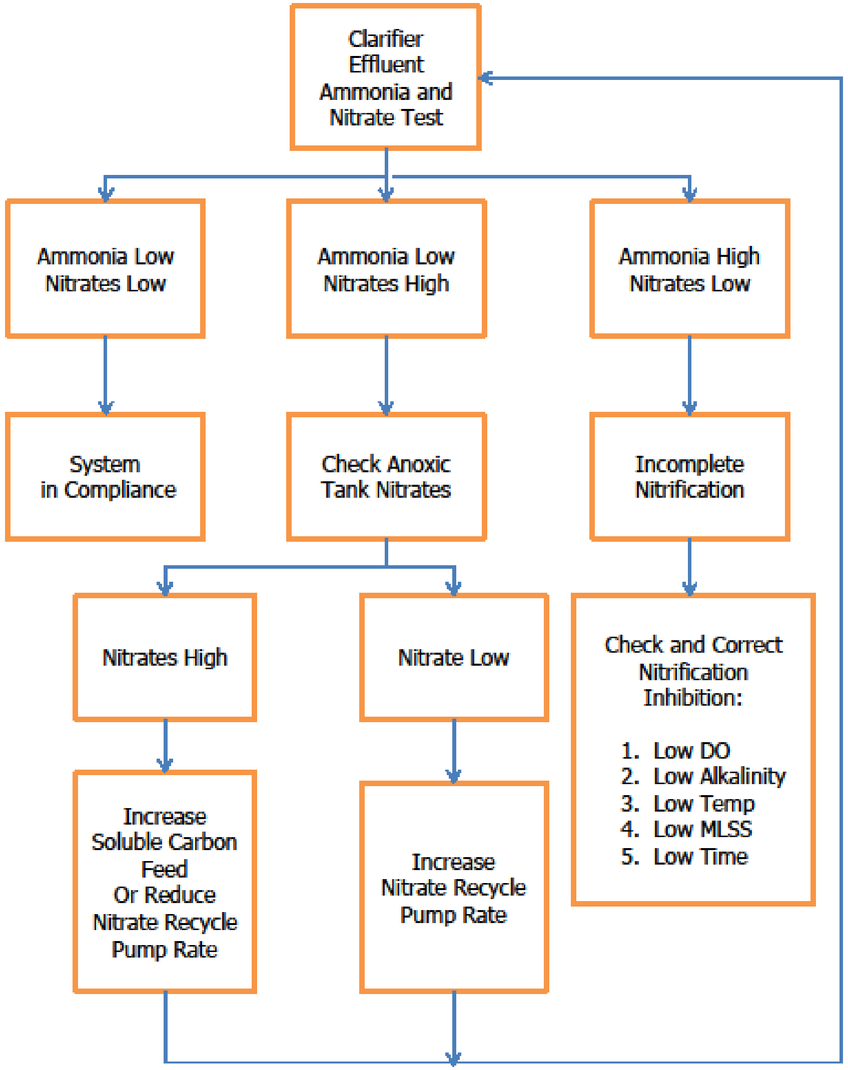
Case Study: **City of Bdfrd** WWTP

Keys to BPR:

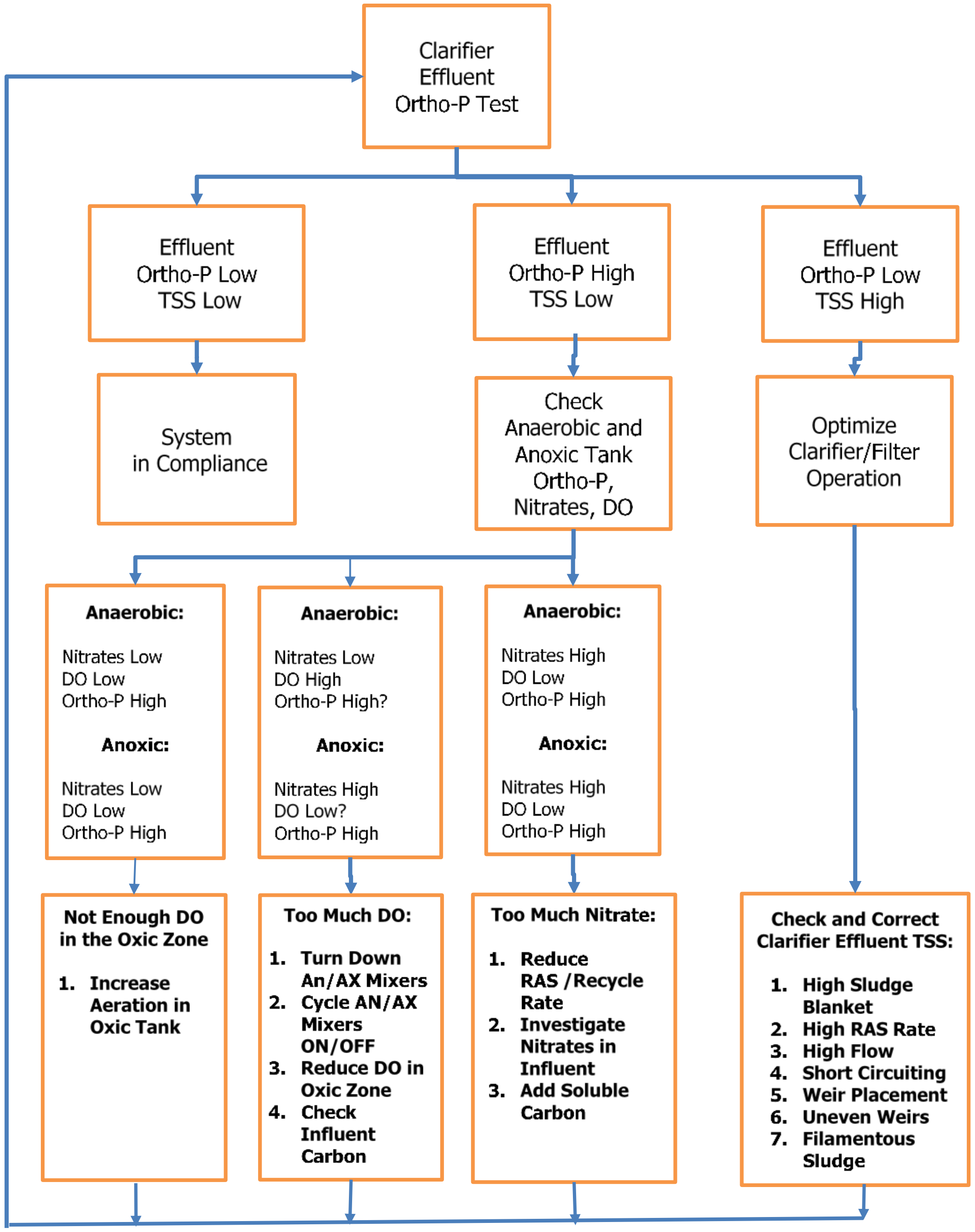
Process Control!

1) Monitor the nutrients in the Inputs to each zone
2) Monitor the nutrients in Internal Recycles (Digester Supernatant)
3) If the Chemistry is correct in the zones, the bacterial response will be compliant.
4) **Know the chemical environment in each zone of the WWTP.**

Process Control Flow Chart for Denitrification in Anoxic Tank



Process Control Flow Chart for Ortho-P Release in Anaerobic Tank



Questions?

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