Optimizing Nutrient Removal in Oxidation Ditches

US EPA sponsored webinar for Wastewater Treatment Plant Operators
January 27, 2022

Grant Weaver, PE & wastewater operator
President
Grant Tech, Inc.
Grant@GrantTechSolutions.com

Optimizing Nutrient Removal & Wastewater Excellence

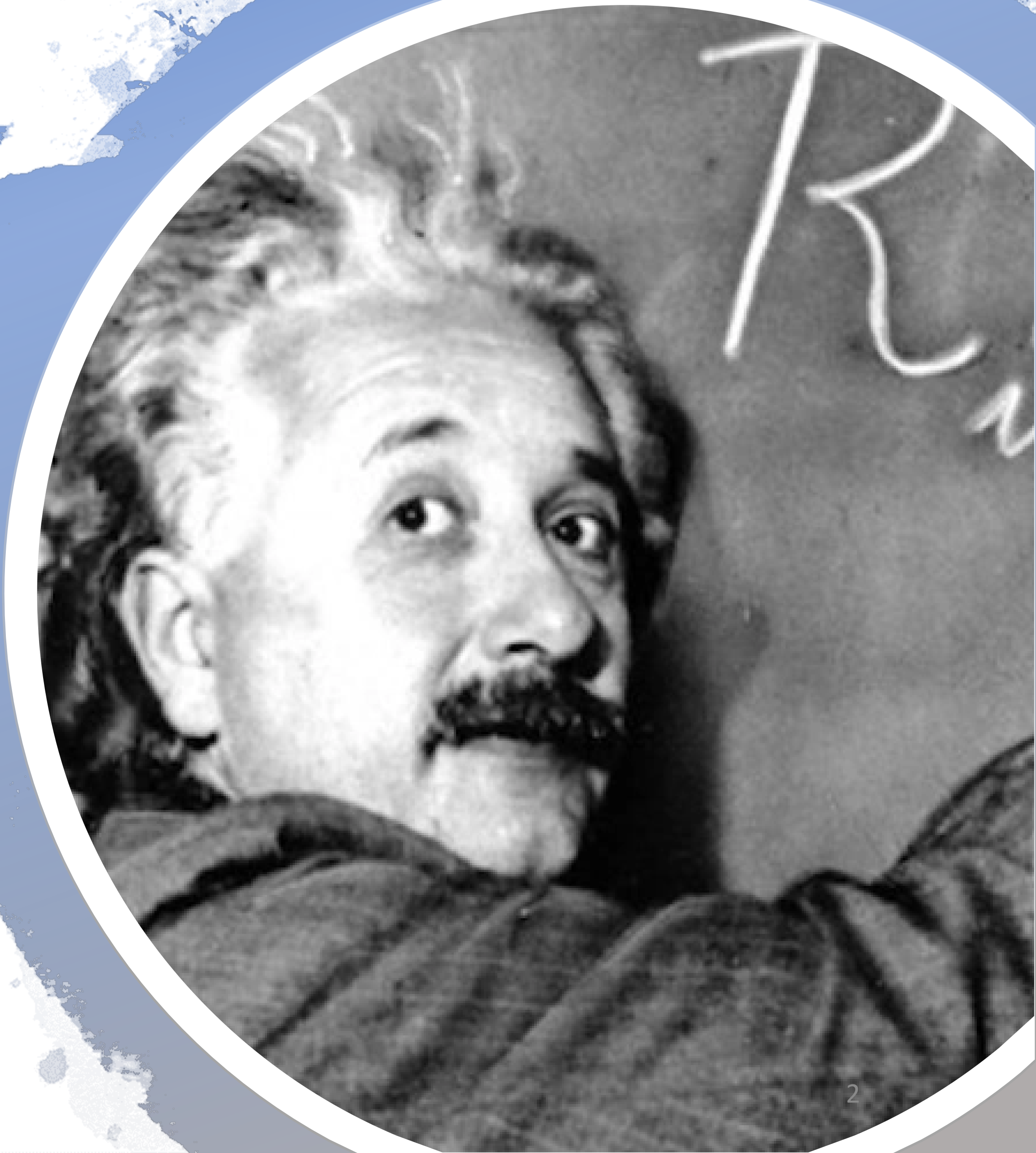
Optimizing Nutrient Removal in:

Oxidation Ditches
(Today)

Sequencing Batch Reactors
(February 17, 2022)

Conventional / Extended Air Activated Sludge
(March 31, 2022)

Transitioning from Permit Compliance to Wastewater Excellence
(April 28, 2022)



TODAY

Optimizing Nutrient Removal in Oxidation Ditches

Review

Biological Nutrient Removal

- Nitrogen Removal
- Phosphorus Removal

Oxidation Ditch Design Concepts

Case Studies

Wastewater treatment plants operating differently than designed to improve N&P removal

- Cookeville, Tennessee
- Chinook, Montana
- Great Bend, Kansas
- Oneida, Tennessee
- Basehor, Kansas

Discussion

KEEP
CALM

AND

BLAME
ME FOR EVERYTHING

Acknowledgements

BASEHOR, KANSAS Gene Myracle, Jr.

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GREAT BEND, KANSAS Jason Cauley, Reuben Martin, April Batts & James Gaunt

ONEIDA, TENNESSEE Greg Burchfield, Chad McDowell & Greg Overton

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TENNESSEE Karina Bynum, Tim Hill & Mark Valencia (**TDEC**), Brett Ward (**UT-MTAS**), Dewayne Culpepper (**TAUD**)

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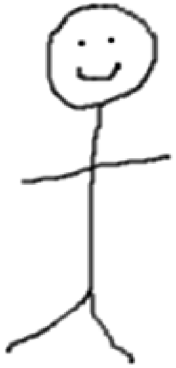
MONTANA Paul LaVigne (retired), Pete Boettcher, Josh Viall, Darryl Barton, Bill Bahr (retired), Dave Frickey (retired) & Mike Abrahamson (**DEQ**)



7

N

Nitrogen

Step 1: Convert Ammonia (NH_4) to Nitrate (NO_3)

Oxygen-rich Aerobic Process

Don't need BOD for bacteria to grow

Bacteria are sensitive to pH and temperature

Step 2: Convert Nitrate (NO_3) to Nitrogen Gas (N_2)

Oxygen-poor Anoxic Process

Do need BOD for bacteria to grow

Bacteria are hardy

Ammonia Removal - 1st Step of N Removal

Ammonia Removal

Ammonia (NH_4) is converted to Nitrate (NO_3)

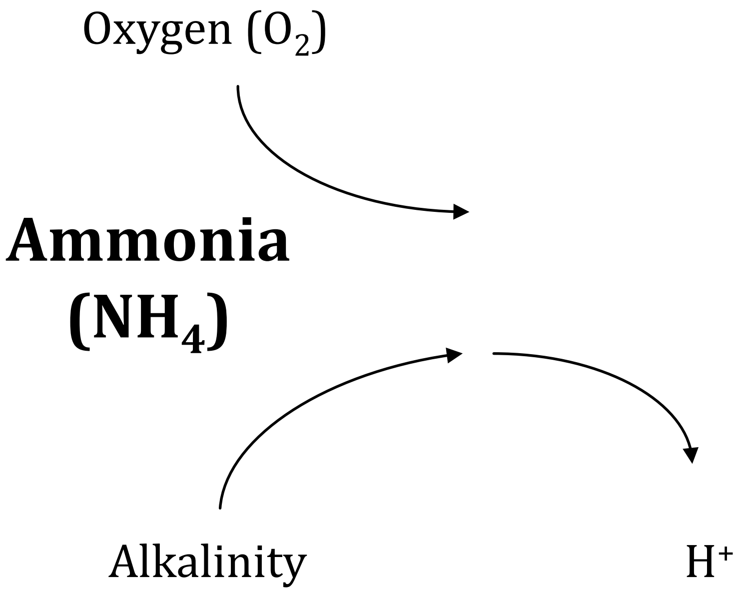
Ammonia
(NH_4)

Ammonia Removal

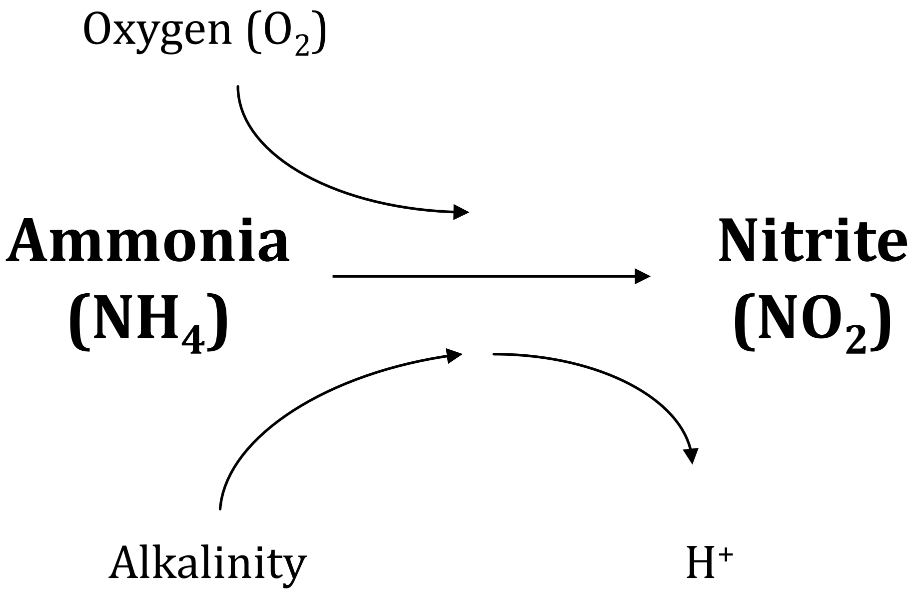
Oxygen (O_2)

Ammonia (NH_4)

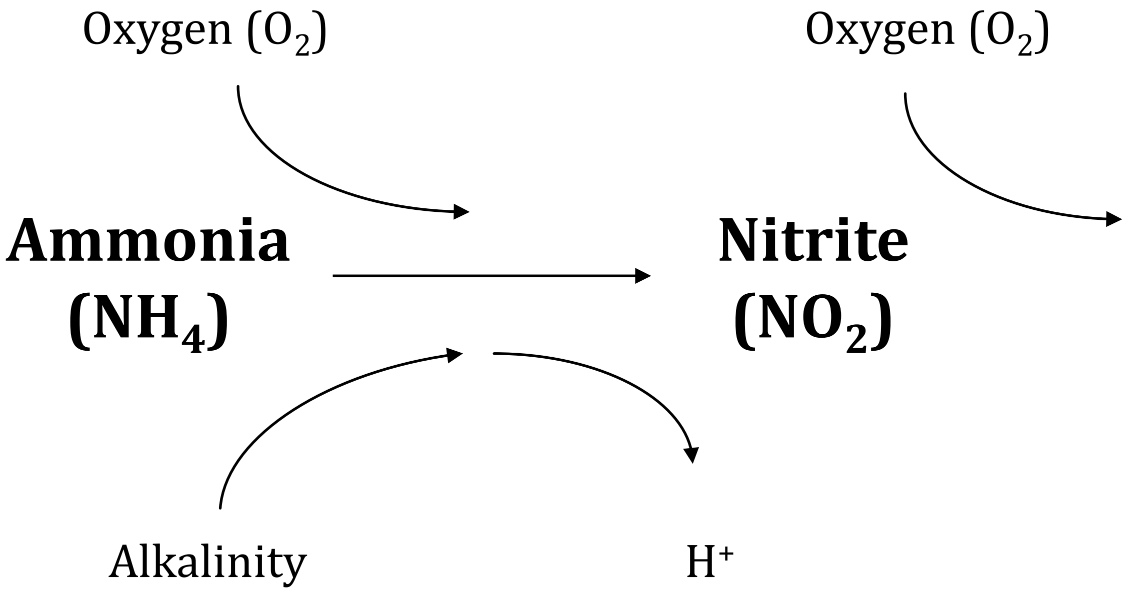
Ammonia Removal



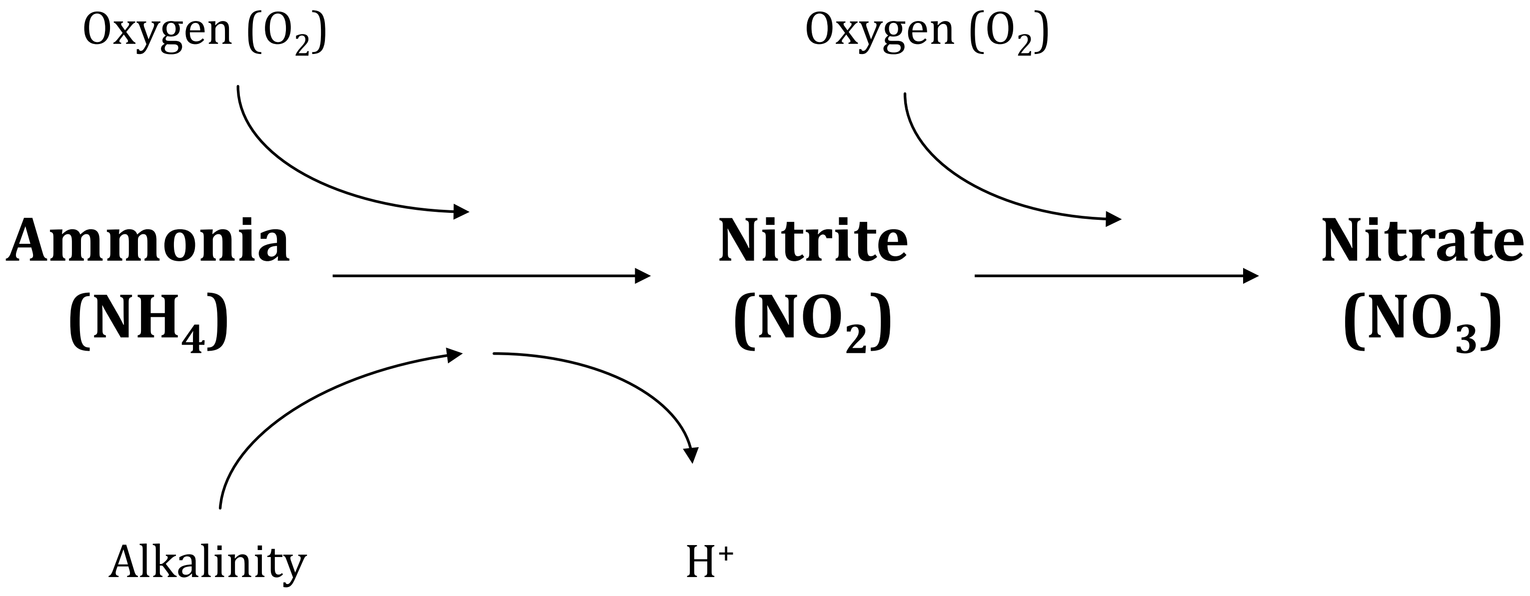
Ammonia Removal



Ammonia Removal



Ammonia Removal



Nitrate Removal - 2nd Step of N removal

Nitrate Removal

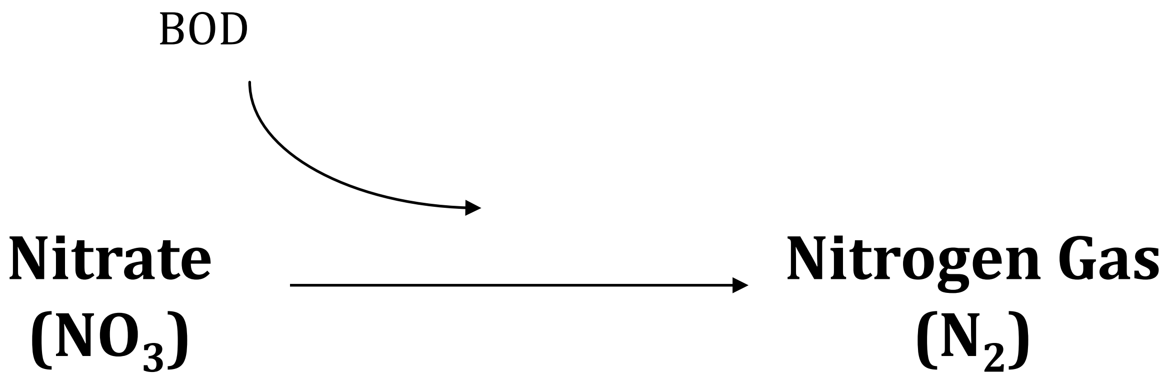
Nitrate
(NO_3)

Nitrate Removal

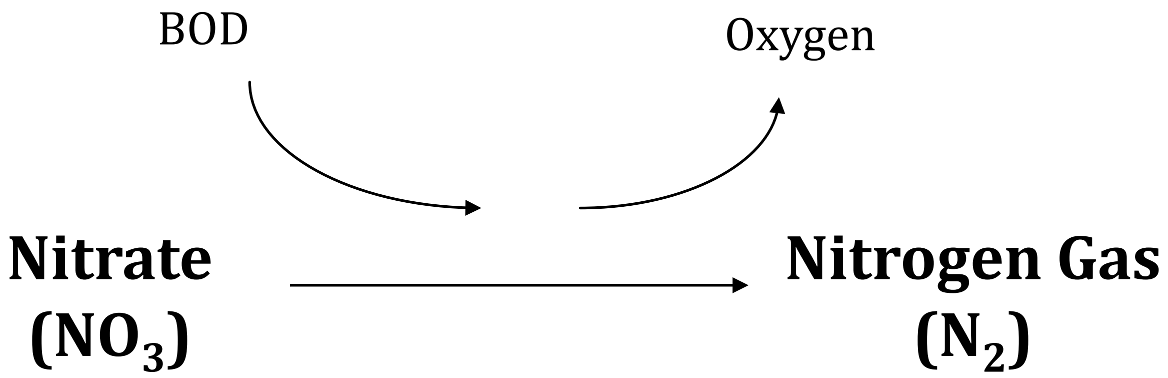
BOD

Nitrate (NO_3)

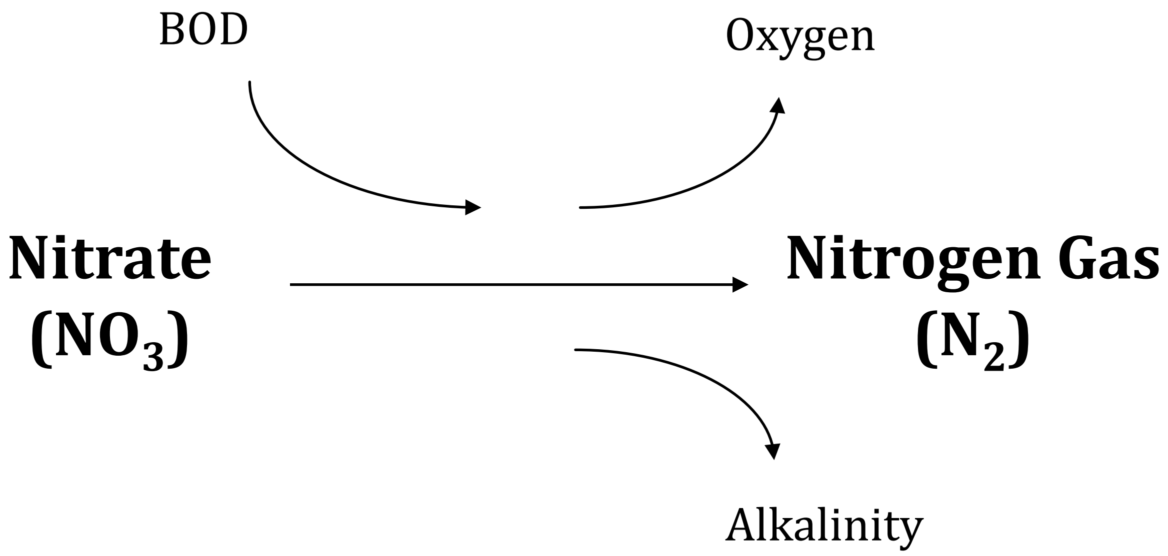
Nitrate Removal



Nitrate Removal



Nitrate Removal



Questions?
Comments?


VOTE
VOTE
VOTE
VOTE
VOTE
VOTE
VOTE
VOTE
VOTE

Phosphorus

15

P

30.974

Phosphorus Removal:
What an Operator needs to know

ONE. Convert soluble phosphorus to TSS (total suspended solids)…

Biologically

Chemically

TWO. Remove TSS

Biological Phosphorus Removal

Step 1: prepare "dinner"

VFA (volatile fatty acids) production in septic conditions

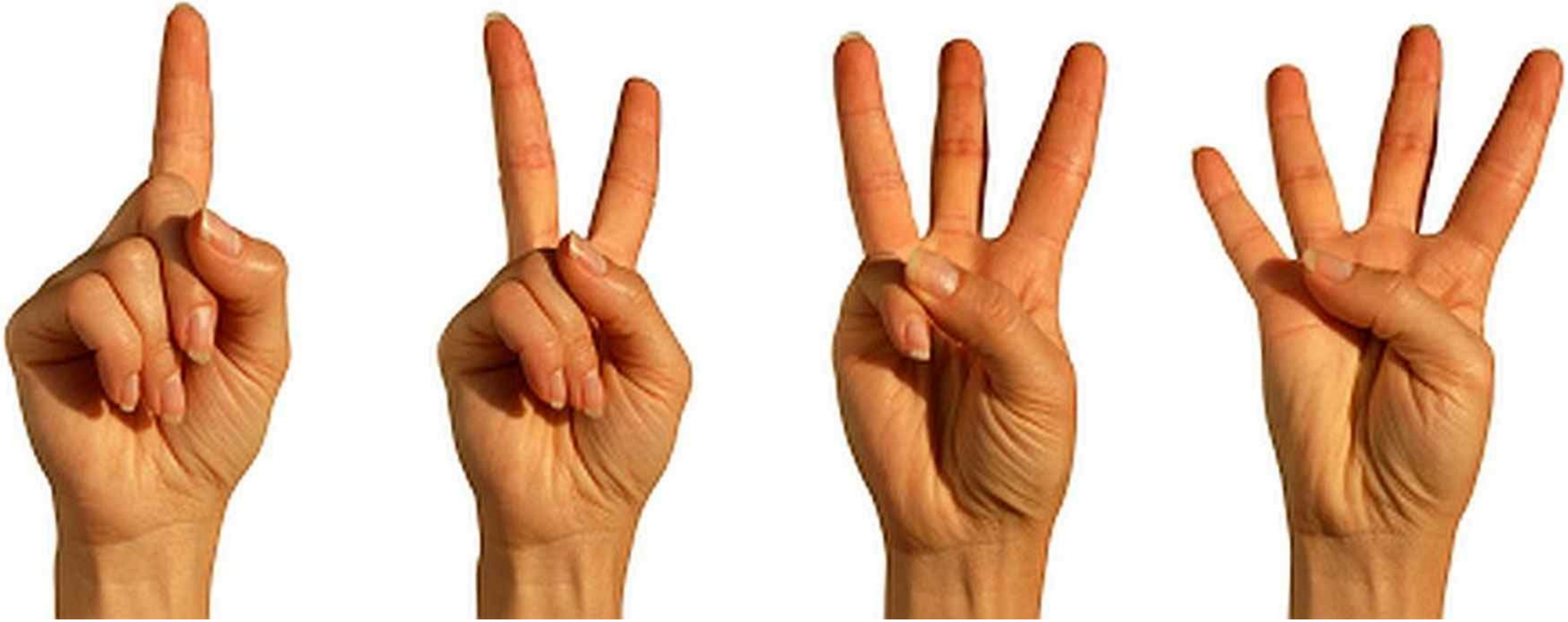
Step 2: "eat"

Bio-P bugs (PAOs, "phosphate accumulating organisms") eat VFAs in septic conditions … temporarily releasing more phosphorus into the water

Step 3: "breathe" and grow

In oxygen-rich conditions, bio-P bugs (PAOs) take in almost all of the soluble phosphorus as they reproduce and grow

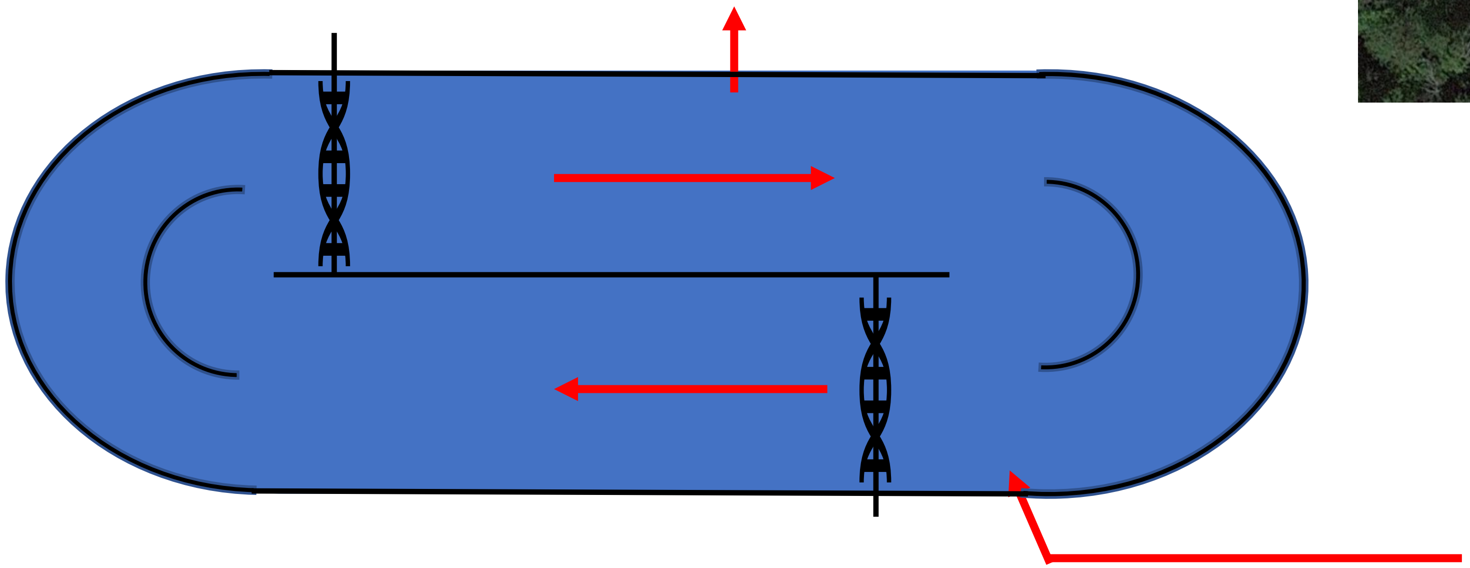
Questions?
Comments?



Oxidation Ditches Designed for Neither Nitrogen Removal nor Phosphorus Removal

Oxidation Ditch with no Anoxic Zone and no Anaerobic Zone

Oxidation Ditch



Oxidation Ditch:
BOD and Ammonia removal (Nitrification)

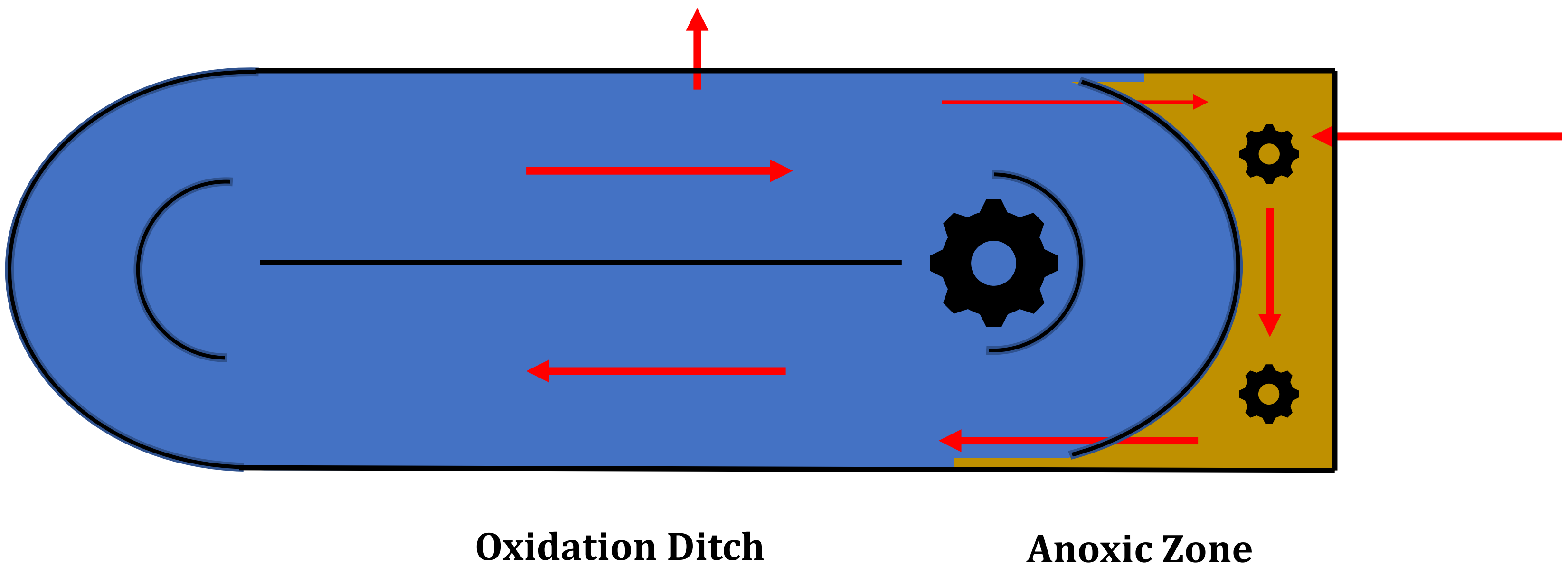
2

Oxidation Ditches Designed for Nitrogen Removal but not for Phosphorus Removal

Oxidation Ditch with Anoxic Zone

Anoxic Zone:
Nitrate removal (Denitrification)

Oxidation Ditch:
BOD and Ammonia removal (Nitrification)



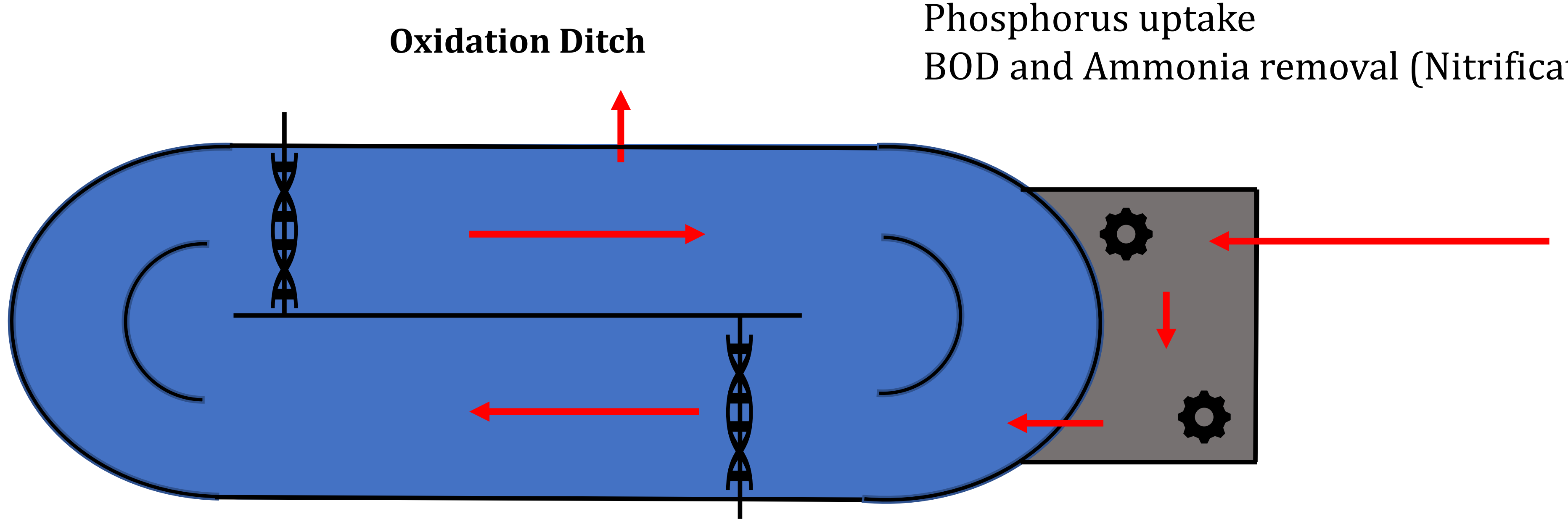
3

Oxidation Ditches Designed for Phosphorus Removal but not Nitrogen Removal

Oxidation Ditch with Anaerobic Zone

Anaerobic Zone:
VFA production / VFA uptake / Phosphorus release

Oxidation Ditch:
Phosphorus uptake
BOD and Ammonia removal (Nitrification)



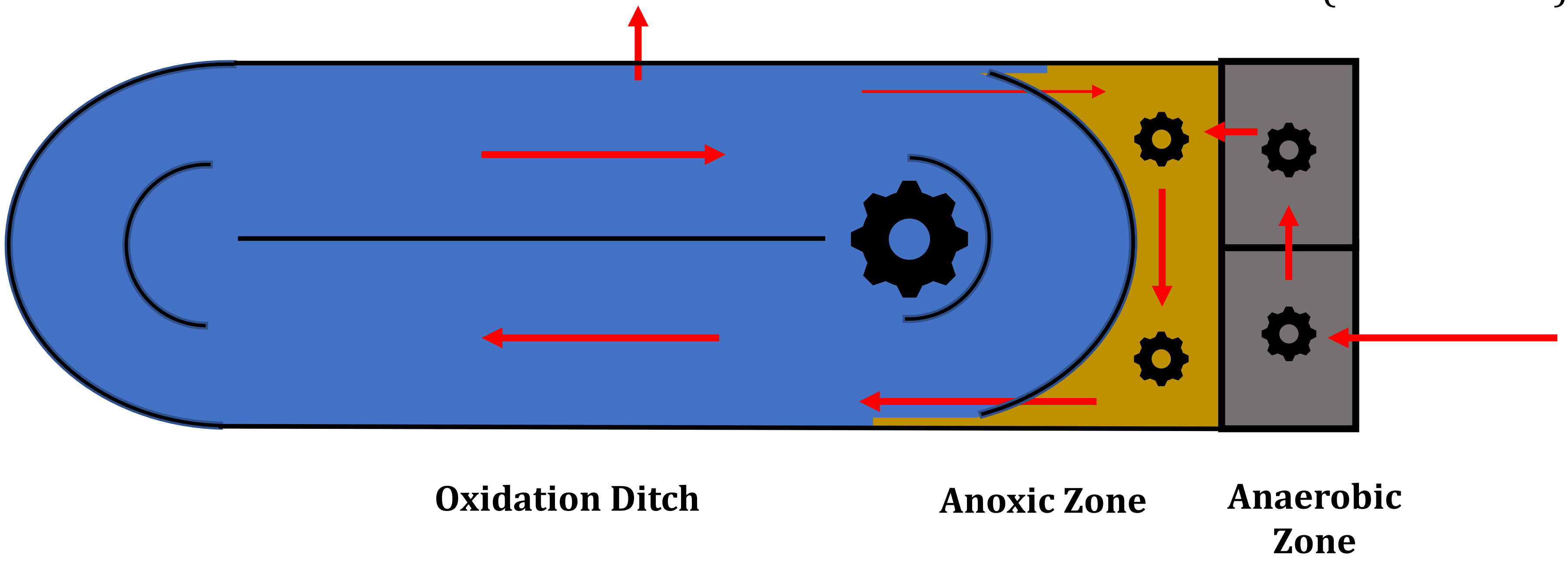
Oxidation Ditches Designed to Remove both Nitrogen and Phosphorus

Oxidation Ditch with Anaerobic and Anoxic Zones

Anaerobic Zone:
VFA production / VFA uptake / Phosphorus release

Anoxic Zone:
Nitrate removal (Denitrification)

Oxidation Ditch:
Phosphorus uptake
BOD and Ammonia removal (Nitrification)



Orbal Oxidation Ditch


Questions?
Comments?


VOTE
VOTE
VOTE
VOTE
VOTE
VOTE

N

7

Nitrogen

Options for Optimizing Nitrogen Removal in Oxidation Ditches

1. Create Zones

Oxygen-rich aerobic zone(s) for ammonia conversion to nitrate

Oxygen-poor anoxic zone(s) for nitrate conversion to nitrogen gas

2. Cycle Air On & Off

Aerate long enough to convert ammonia to nitrate

Air-off long enough to convert nitrate to nitrogen gas

Options for Optimizing Nitrogen Removal in Oxidation Ditches

1. Create Zones

Oxygen-rich aerobic zone(s) for ammonia conversion to nitrate

Oxygen-poor anoxic zone(s) for nitrate conversion to nitrogen gas

2. Cycle Air On & Off

Aerate long enough to convert ammonia to nitrate

Air-off long enough to convert nitrate to nitrogen gas

Cookeville, Tennessee Population: 33,500 15 MGD design flow


Cookeville


TREATMENT PLANT OPERATOR
tpo
LET'S BE CLEAR:
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TECH TALK:
A new approach to flood protection | 14
From Learner to Mentor
MICHELE HIGDON SAYS THANKS FOR HER SUCCESS BY GIVING BACK AS A VOLUNTEER | 10
SPECIAL FEATURE:
PLANT PROFICIENCIES
PAGE 31


Cookeville, Tennessee

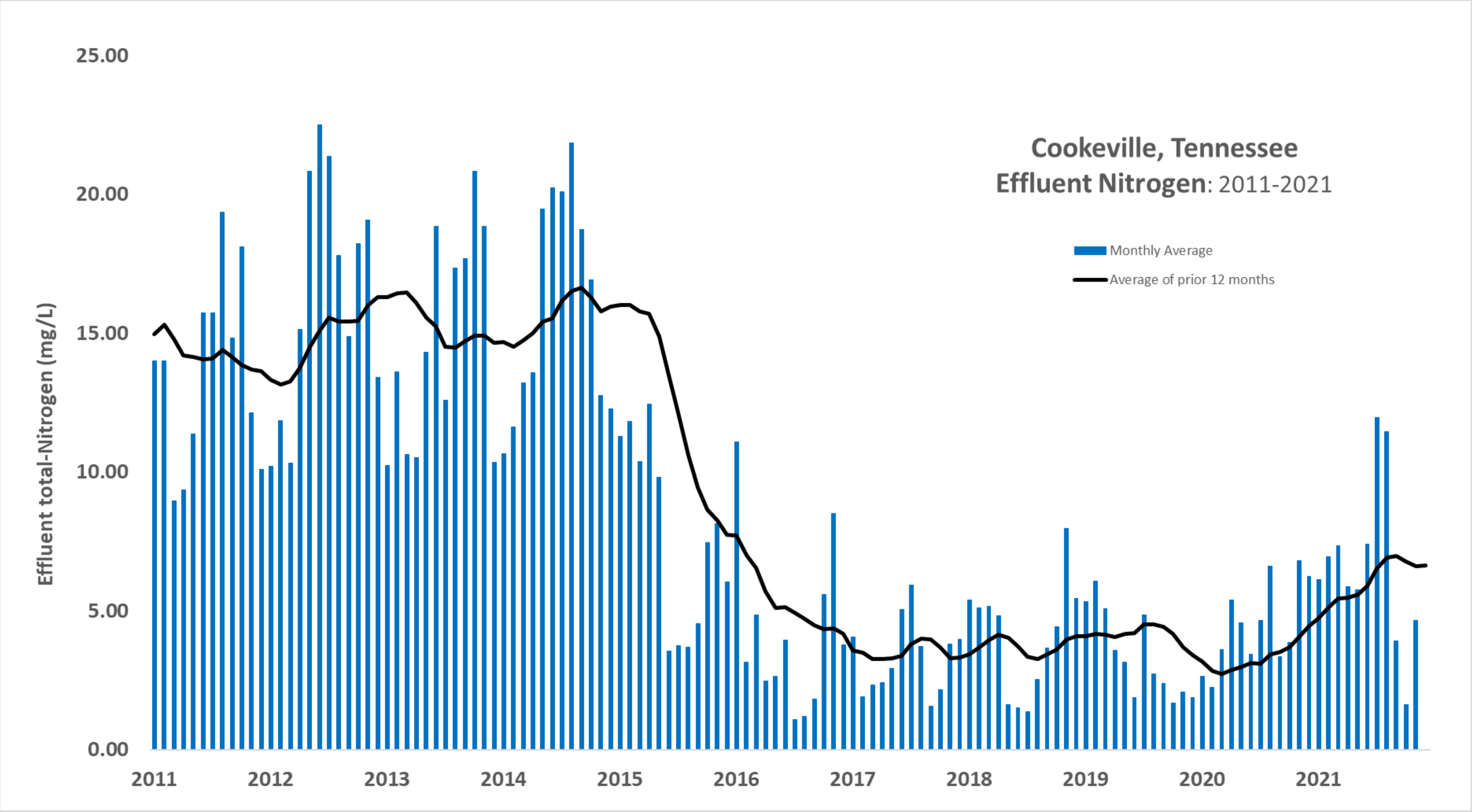

Cookeville, Tennessee


Cookeville, Tennessee

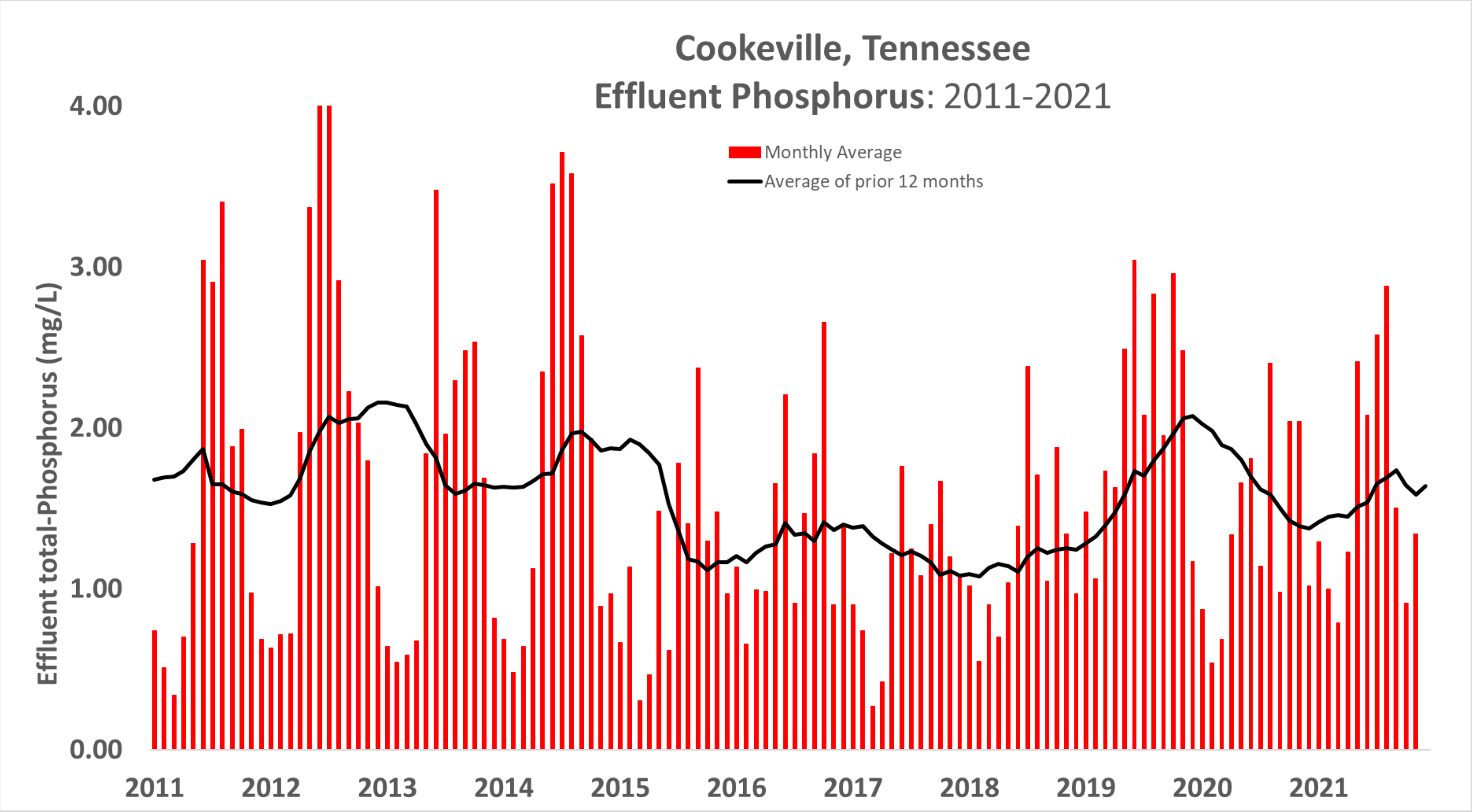

Cookeville, Tennessee


Cookeville, Tennessee


Cookeville, Tennessee



Cookeville, Tennessee
Effluent Nitrogen: 2011-2021
Monthly Average
Average of prior 12 months
Effluent total-Nitrogen (mg/L)
25.00
20.00
15.00
10.00
5.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021


Cookeville, Tennessee
Effluent Phosphorus: 2011-2021
Monthly Average
Average of prior 12 months
Effluent total-Phosphorus (mg/L)
4.00
3.00
2.00
1.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

Cookeville, Tennessee

Nitrogen

Now: 5.5 mg/L

Was: 15 mg/L

Phosphorus

Little to no change: 1.5 mg/L

Sustainable

No new construction

Less electricity is used

Ratepayer savings

$10,000 investment in aeration timers and in-house lab equipment

$250,000 per year electrical savings

$4+ million facility upgrade no longer necessary

Questions?
Comments?

Options for Optimizing Nitrogen Removal in Oxidation Ditches

1. Create Zones

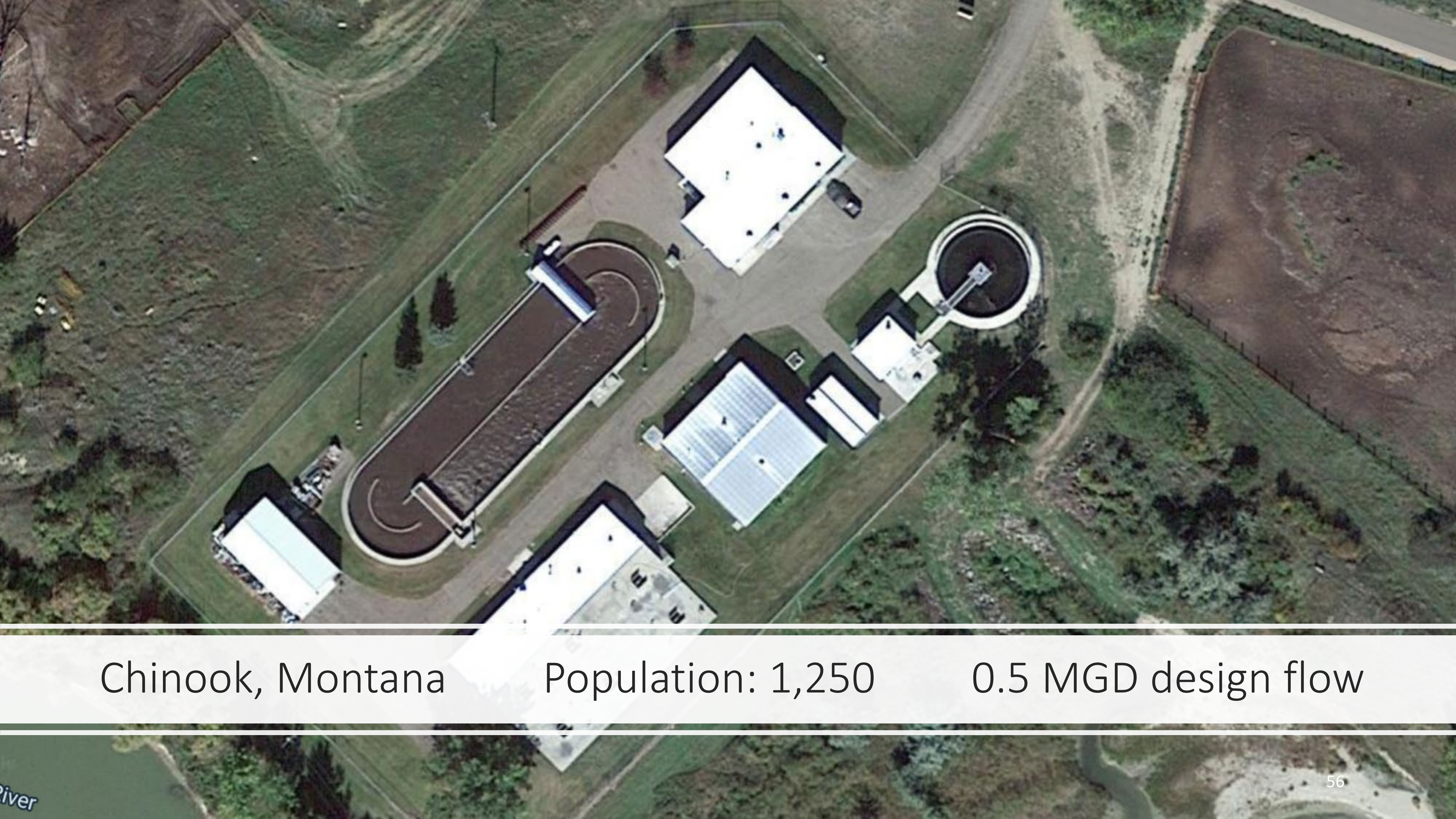
Oxygen-rich aerobic zone(s) for ammonia conversion to nitrate

Oxygen-poor anoxic zone(s) for nitrate conversion to nitrogen gas

2. Cycle Air On & Off

Aerate long enough to convert ammonia to nitrate

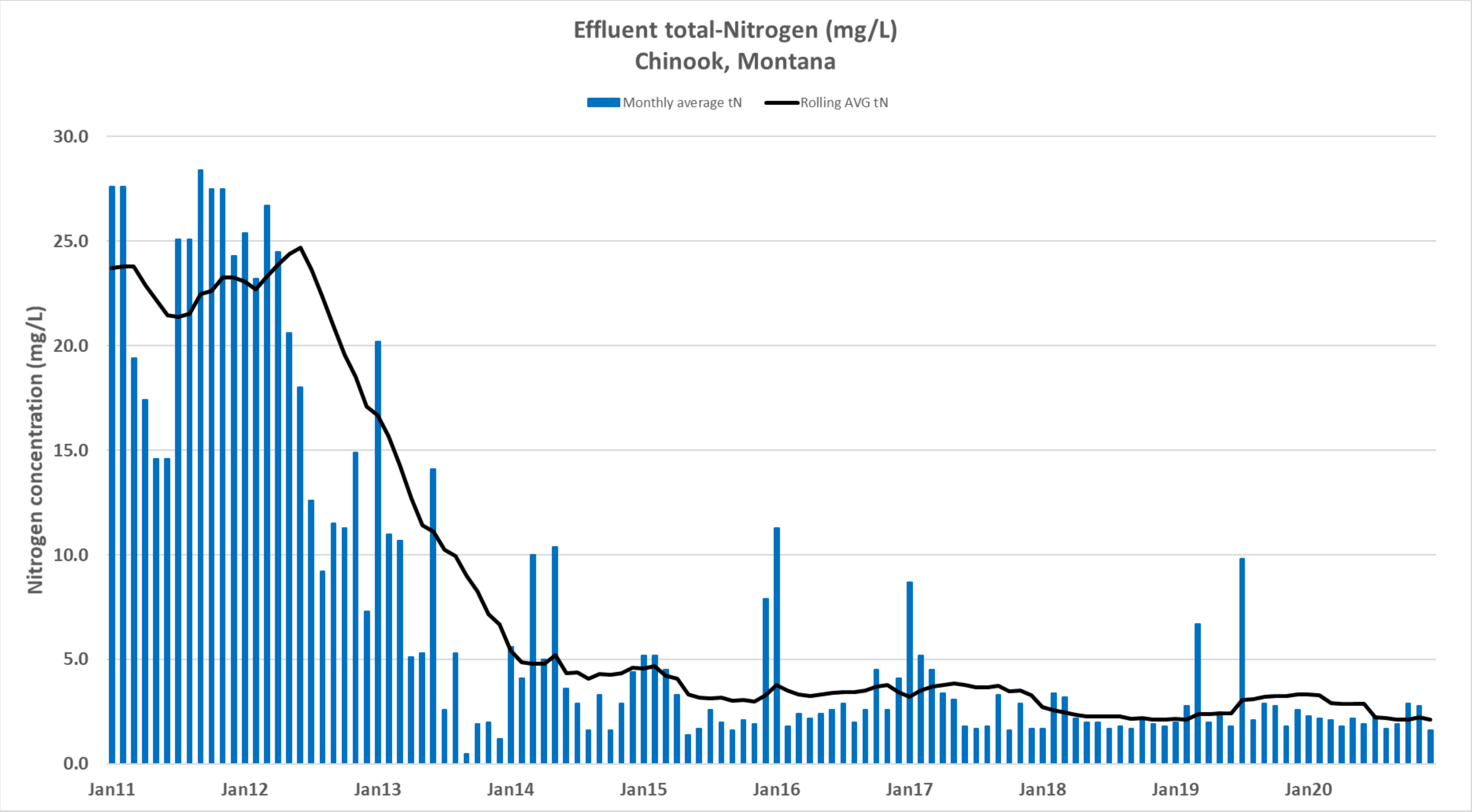
Air-off long enough to convert nitrate to nitrogen gas



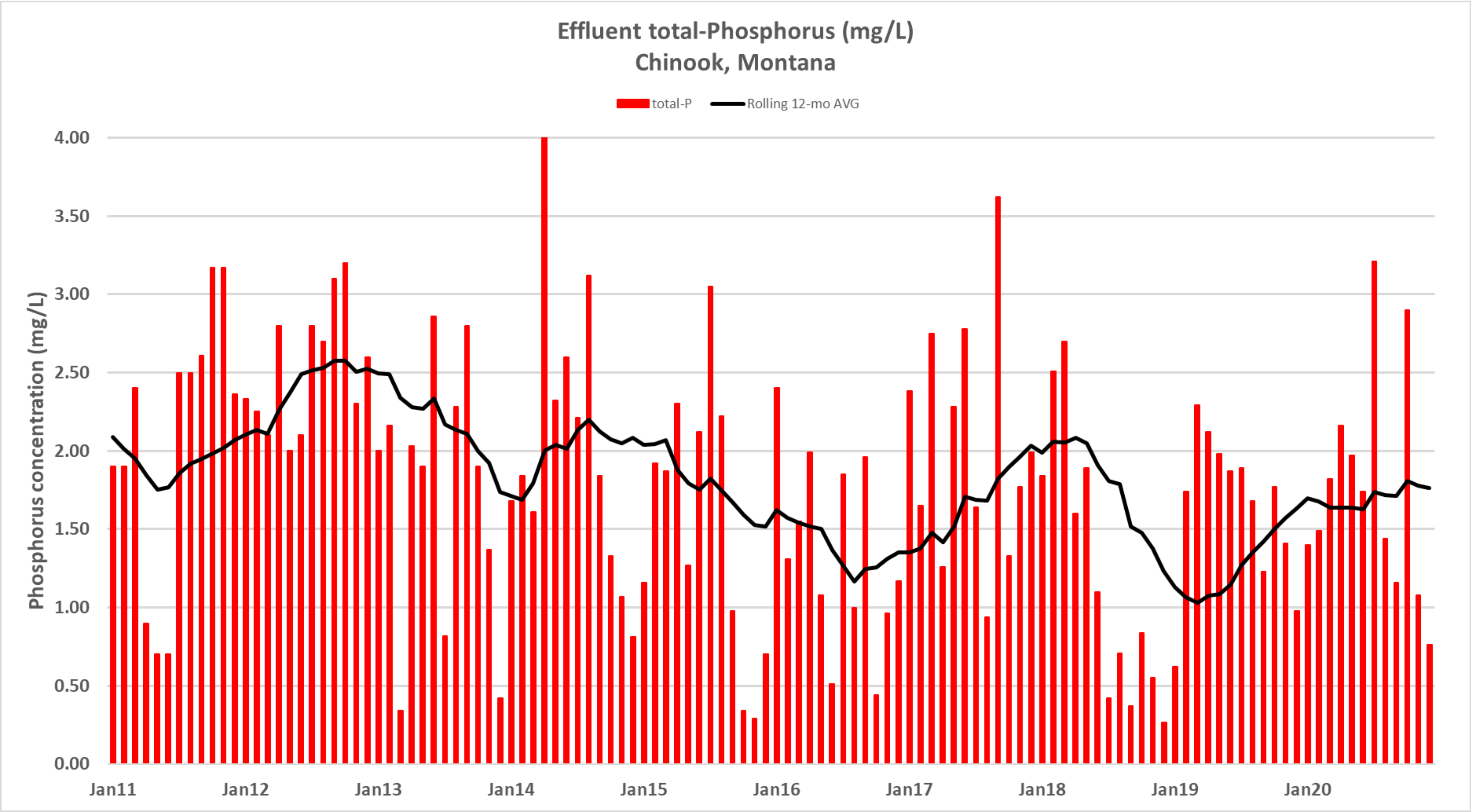
Chinook, Montana Population: 1,250 0.5 MGD design flow


Chinook, Montana
River

Chinook, Montana



Effluent total-Nitrogen (mg/L)
Chinook, Montana
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Jan11
Jan12
Jan13
Jan14
Jan15
Jan16
Jan17
Jan18
Jan19
Jan20



Effluent total-Phosphorus (mg/L)
Chinook, Montana
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jan11
Jan12
Jan13
Jan14
Jan15
Jan16
Jan17
Jan18
Jan19
Jan20

Chinook, Montana

Nitrogen

Now: 3 mg/L

Was: 20+ mg/L

Phosphorus

Now: 1.5 mg/L

Was: 2.0+ mg/L

Sustainable

No new construction

Less electricity is used

Ratepayer savings

$15,000 investment in in-line instruments and SCADA programming

Electrical savings

Reduced scope of facility upgrade


Questions?
Comments?


VOTE

Phosphorus

15

P

30.974

Options for Optimizing Phosphorus Removal in Oxidation Ditches

1. Create Zones

A. Septic conditions ahead of ditch to …

create the "food" that bio-P bugs "eat" … that is, VFA (volatile fatty acid) formation

bio-P bugs living in the MLSS (mixed liquor suspended solids) "eat" the VFAs … the bio-P bugs being PAOs, phosphate accumulating organisms

B. Followed by aerobic zone(s) in main body of ditch for for luxury uptake by energized bio-P bugs

2. Create Sludge Blankets in Ditch During Air Off cycles

Allow mixed liquor to settle during the air-off cycle and make the air-off cycles long enough for the settled sludge to go septic enough to create VFAs

When resuspended, energized bio-P bugs will pull phosphorus out of solution

3. Sidestream P Removal

Create a septic conditions in sludge holding tank and return approximately 10% of the waste sludge back into the oxidation ditch

Options for
Optimizing Phosphorus Removal in Oxidation Ditches

1. Create Zones

A. Septic conditions ahead of ditch to …

  i. create the "food" that bio-P bugs "eat" … that is, VFA (volatile fatty acid) formation

  ii. bio-P bugs living in the MLSS (mixed liquor suspended solids) "eat" the VFAs … the bio-P bugs being PAOs, phosphate accumulating organisms

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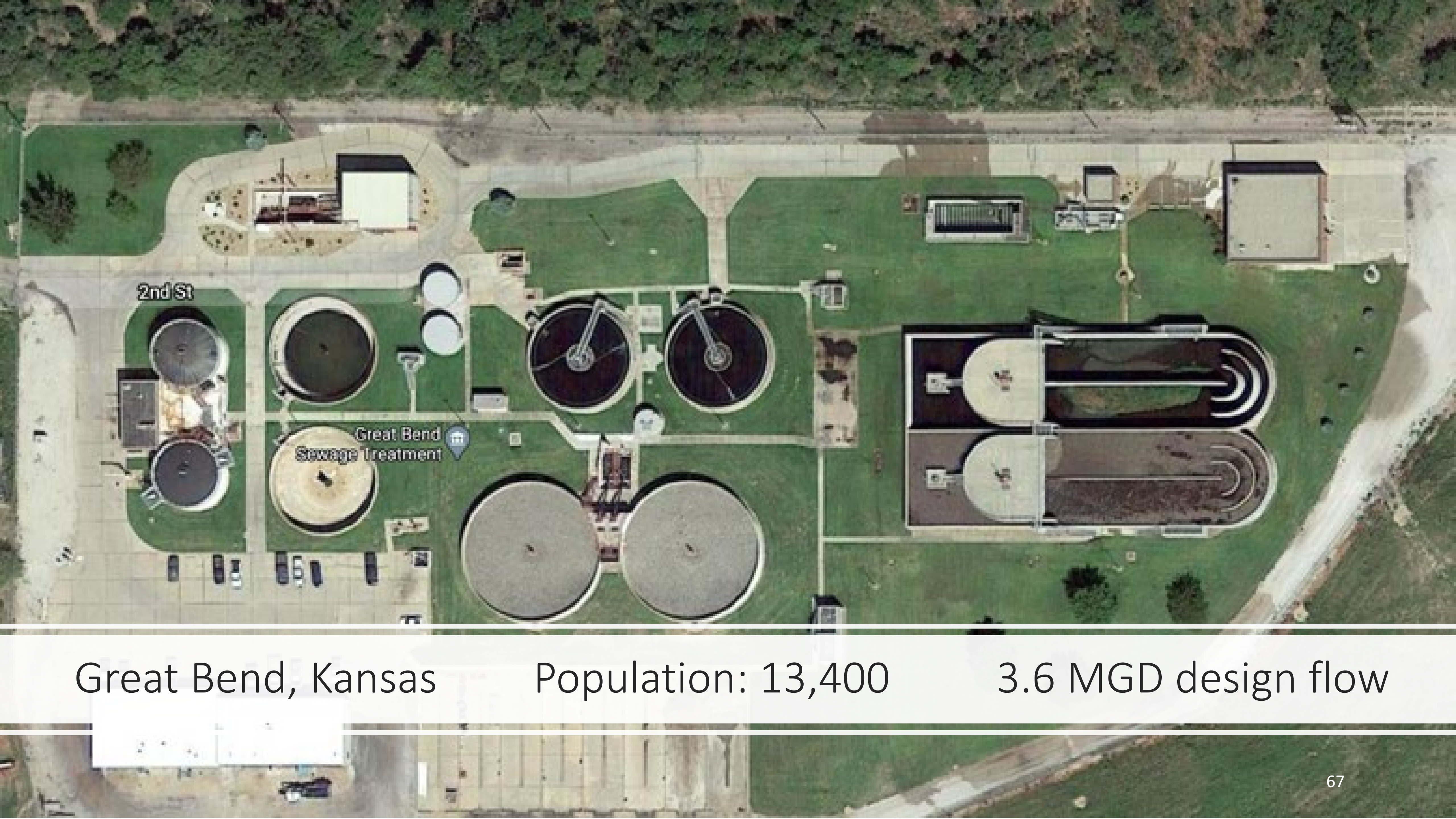
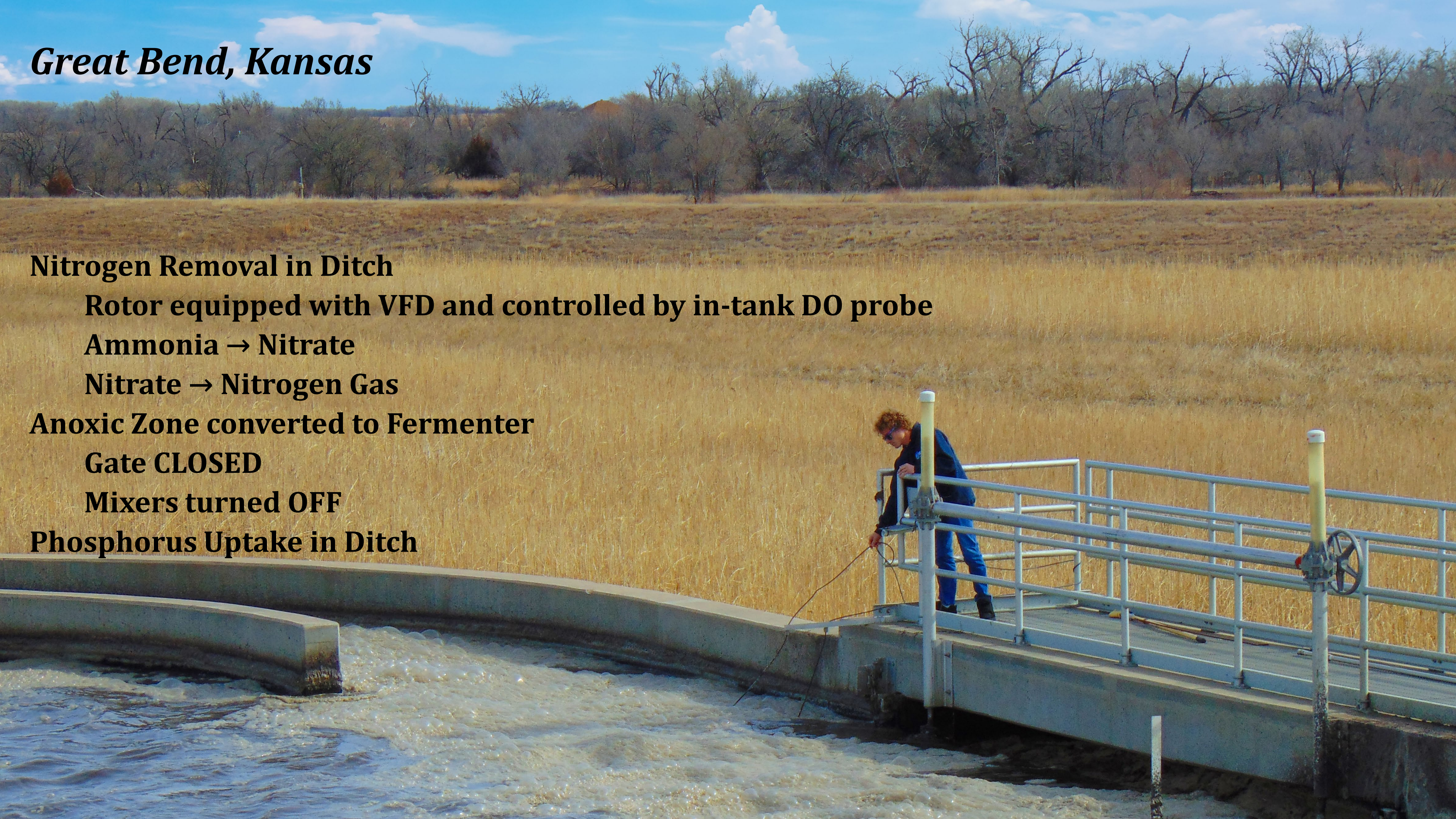
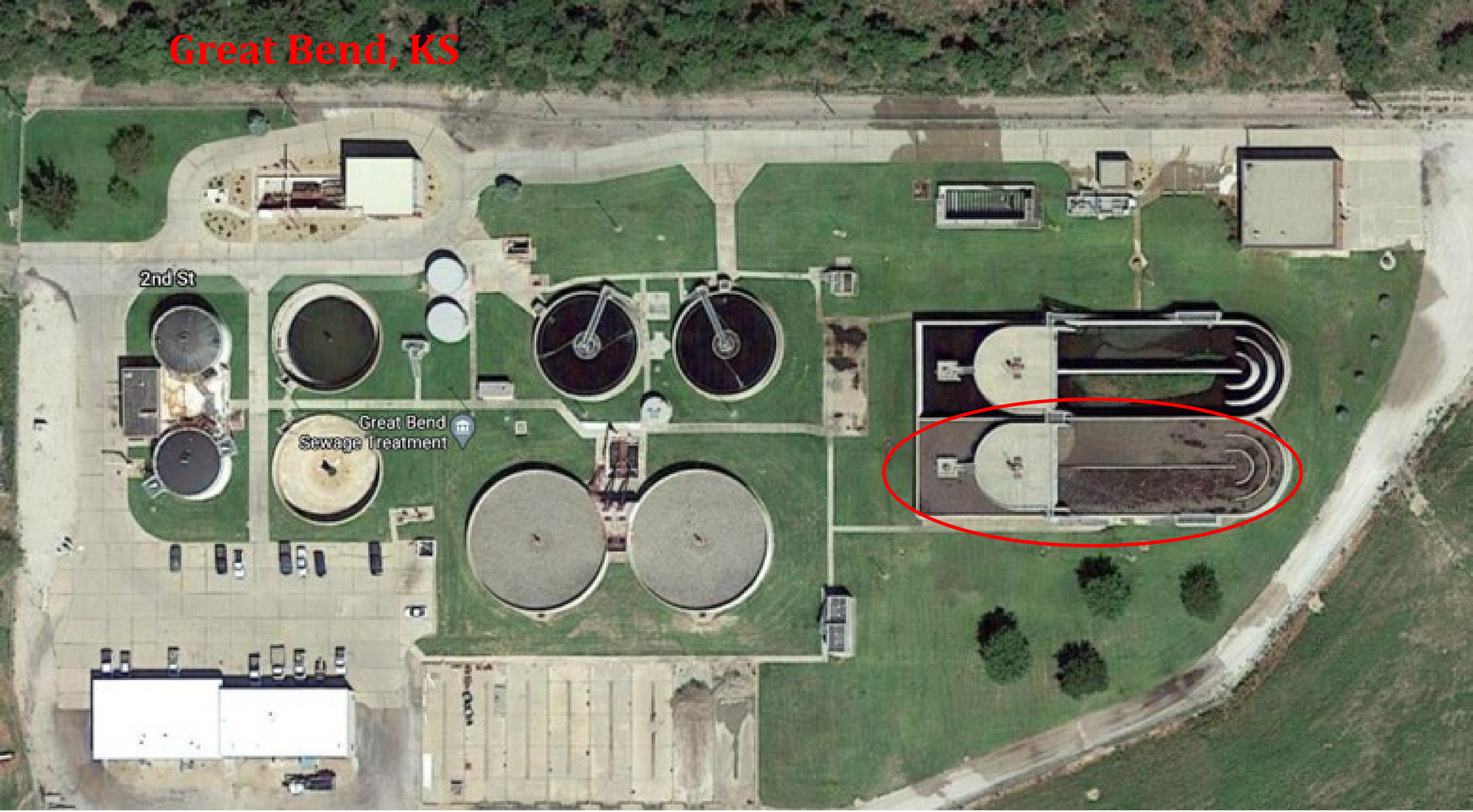


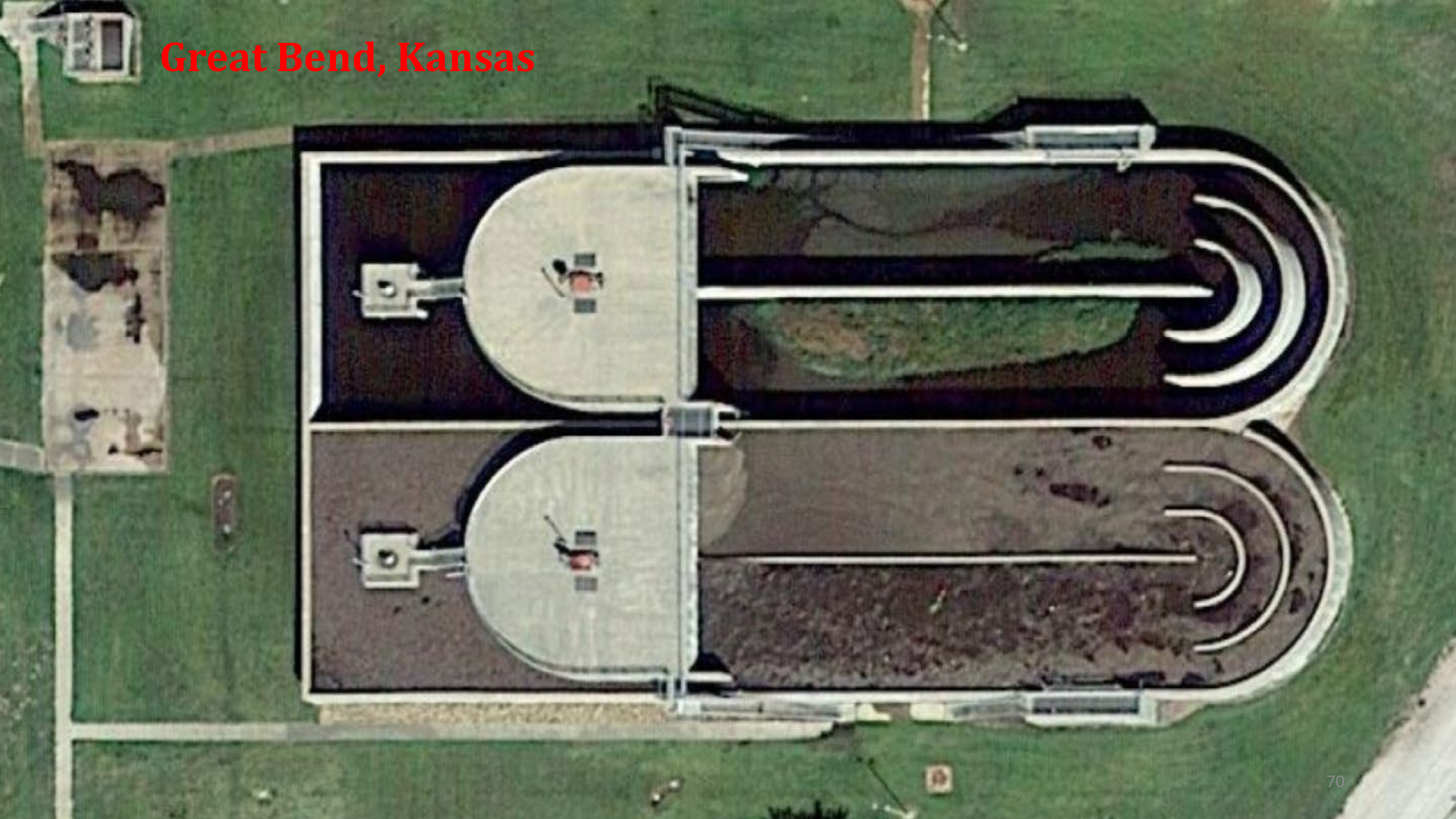
Great Bend, Kansas Population: 13,400 3.6 MGD design flow

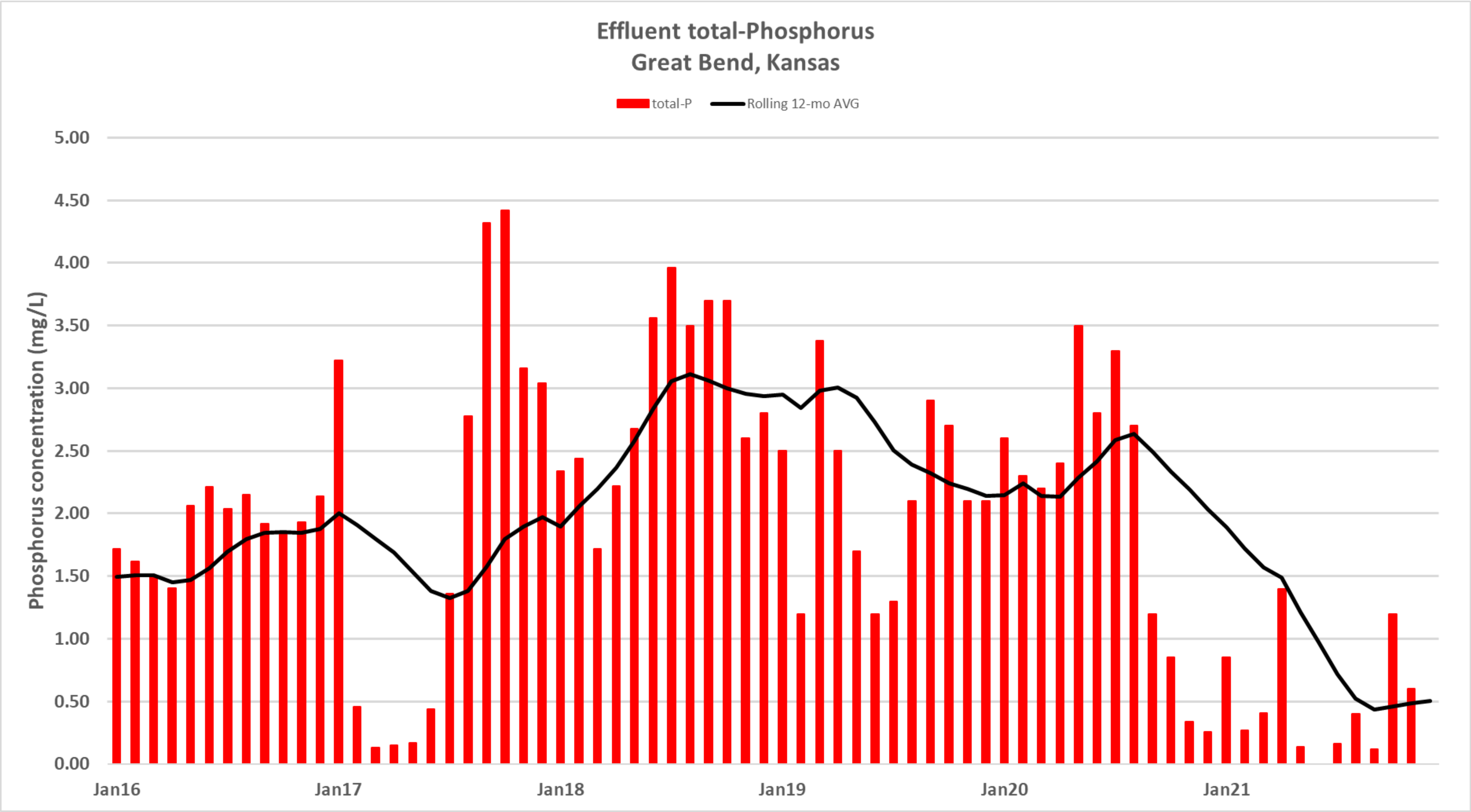

Great Bend, Kansas
Nitrogen Removal in Ditch
Rotor equipped with VFD and controlled by in-tank DO probe
Ammonia → Nitrate
Nitrate → Nitrogen Gas
Anoxic Zone converted to Fermenter
Gate CLOSED
Mixers turned OFF
Phosphorus Uptake in Ditch

Great Bend, KS

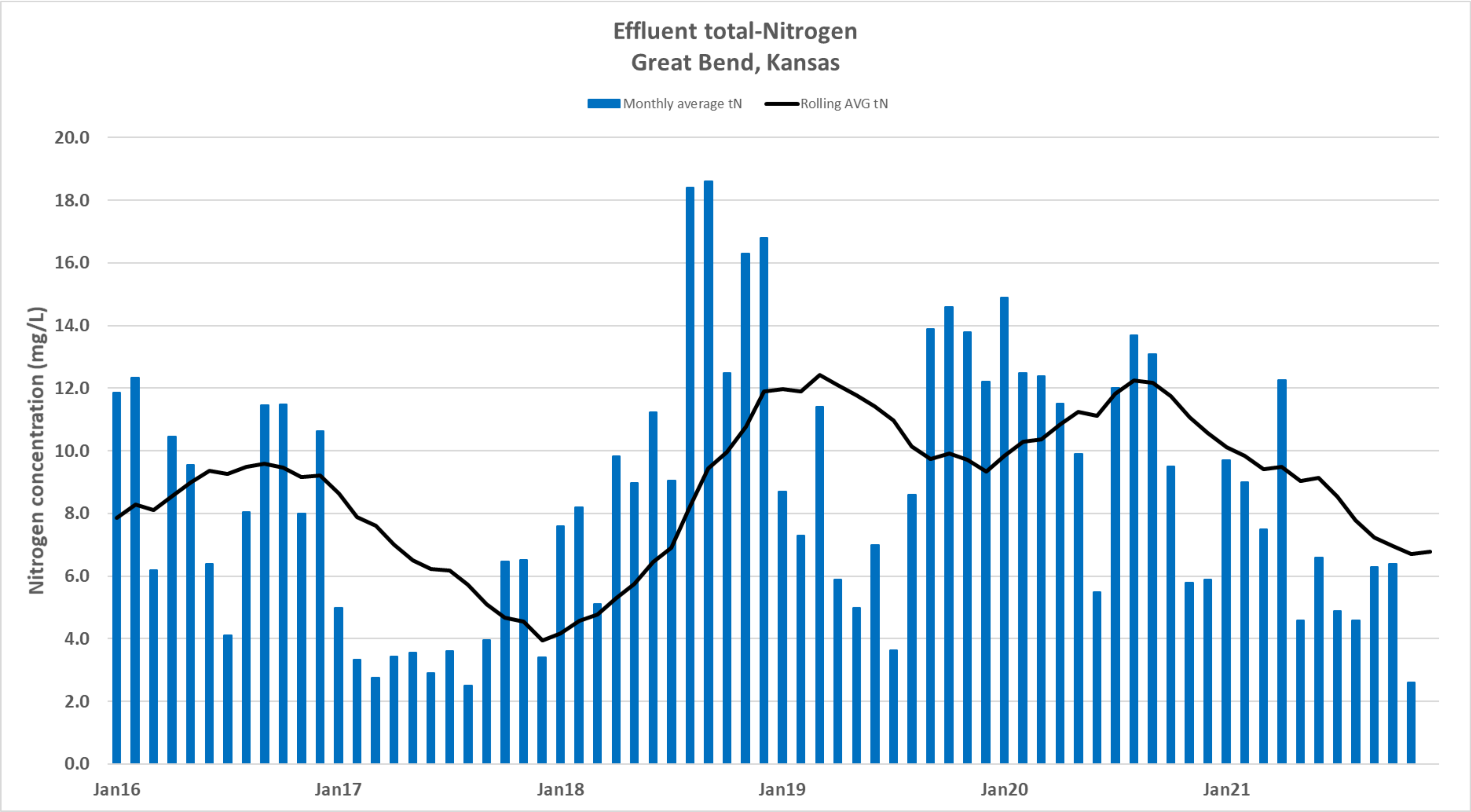


Great Bend, Kansas





Effluent total-Phosphorus
Great Bend, Kansas
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jan16
Jan17
Jan18
Jan19
Jan20
Jan21



Effluent total-Nitrogen
Great Bend, Kansas
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Jan16
Jan17
Jan18
Jan19
Jan20
Jan21

Great Bend, Kansas

Phosphorus
Now: 0.5 mg/L
Was: 2+ mg/L

Nitrogen
Now: 6 mg/L
Was: 10+ mg/L

Sustainable
No new construction
Less electricity is used

Ratepayer savings
$50,000 investment in VFD, in-line DO, and SCADA
Electrical savings
$6 million facility upgrade no longer necessary


Questions?
Comments?

Options for Optimizing Phosphorus Removal in Oxidation Ditches

1. Create Zones

A. Septic conditions ahead of ditch to …

i. create the "food" that bio-P bugs "eat" … that is, VFA (volatile fatty acid) formation

ii. bio-P bugs living in the MLSS (mixed liquor suspended solids) "eat" the VFAs … the bio-P bugs being PAOs, phosphate accumulating organisms

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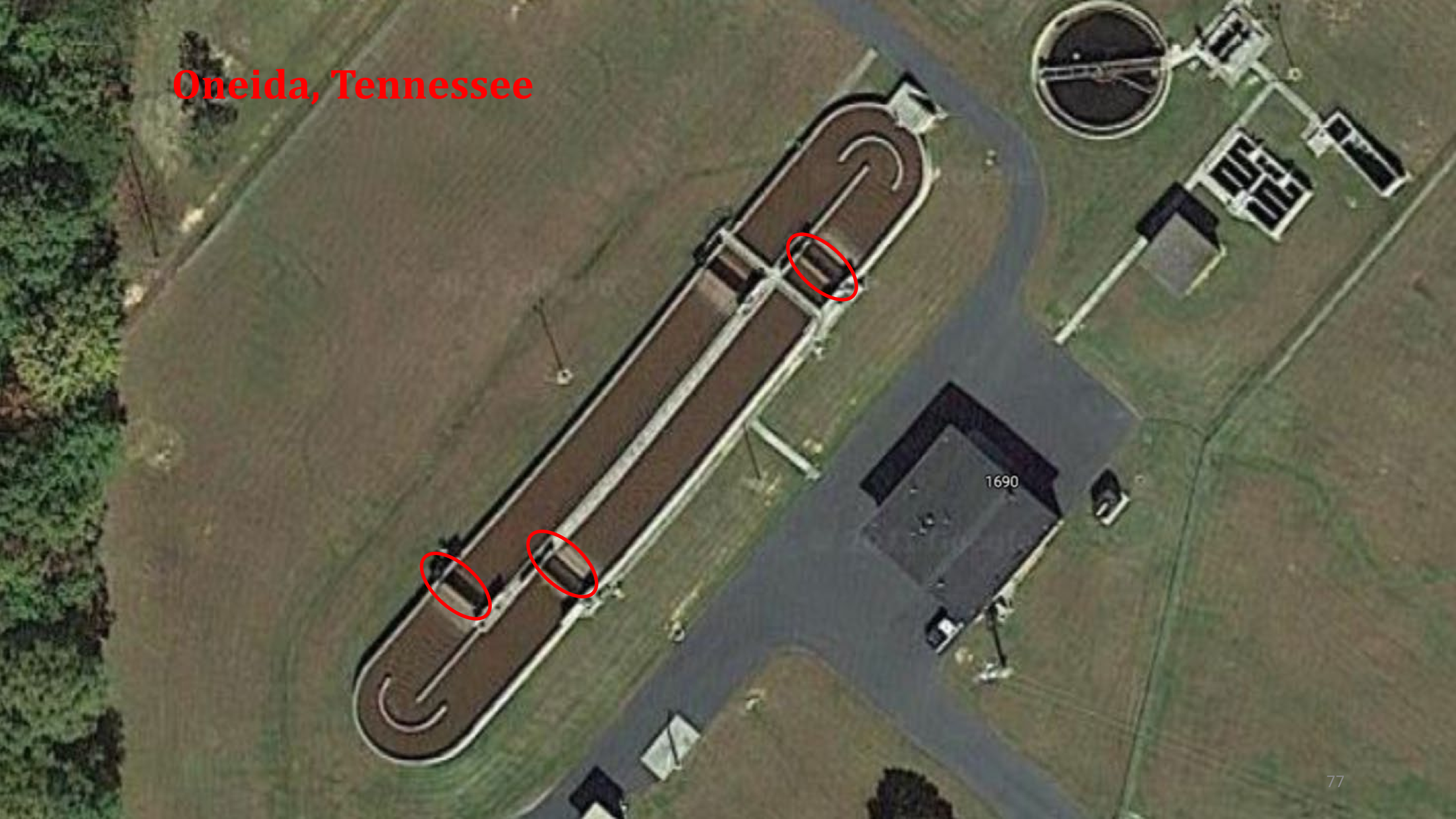
When resuspended, energized bio-P bugs will pull phosphorus out of solution

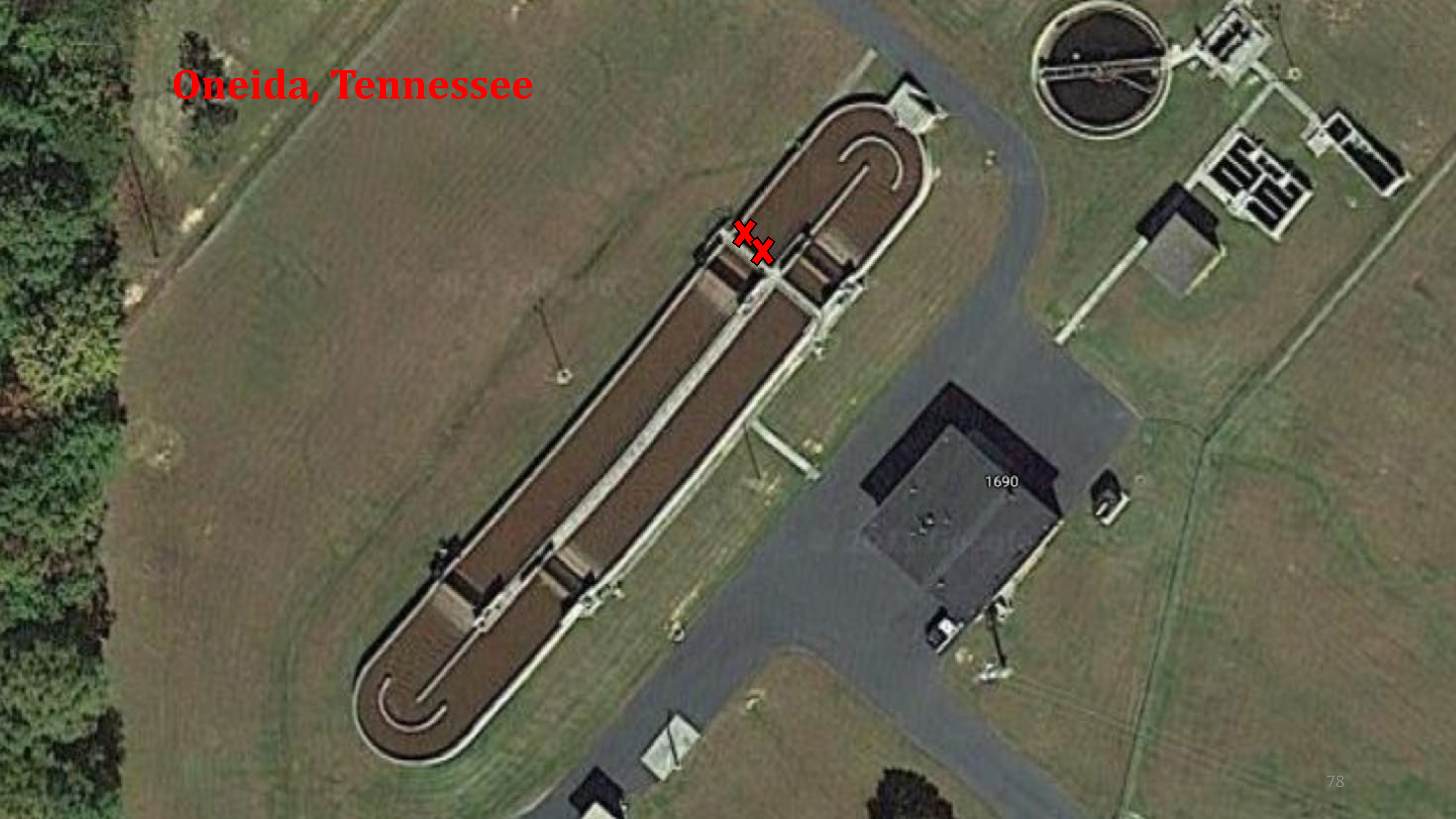
3. Sidestream P Removal

Create a septic conditions in sludge holding tank and return approximately 10% of the waste sludge back into the oxidation ditch

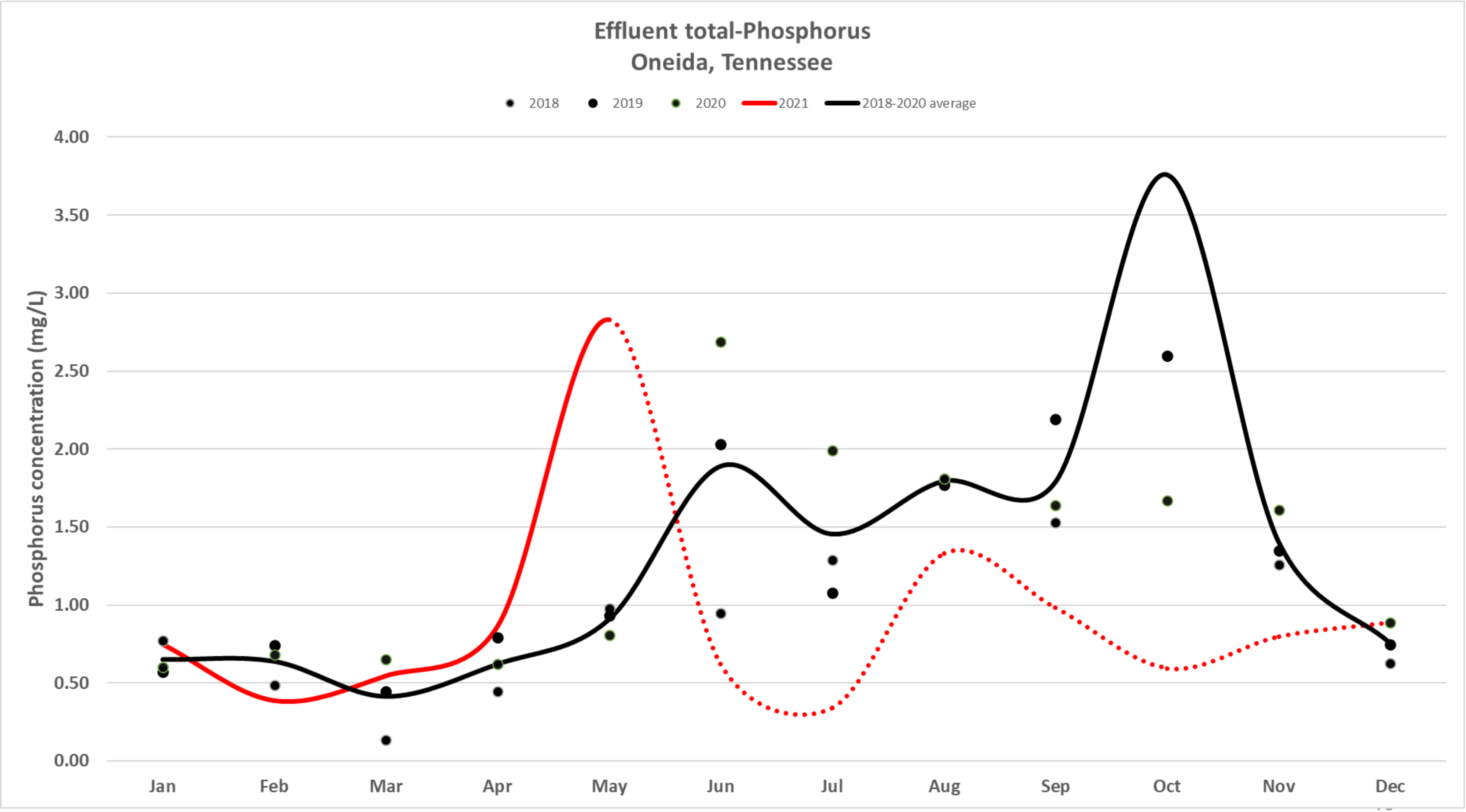
Oneida, Tennessee   Population: 3,700   0.998 MGD design flow

Oneida, Tennessee

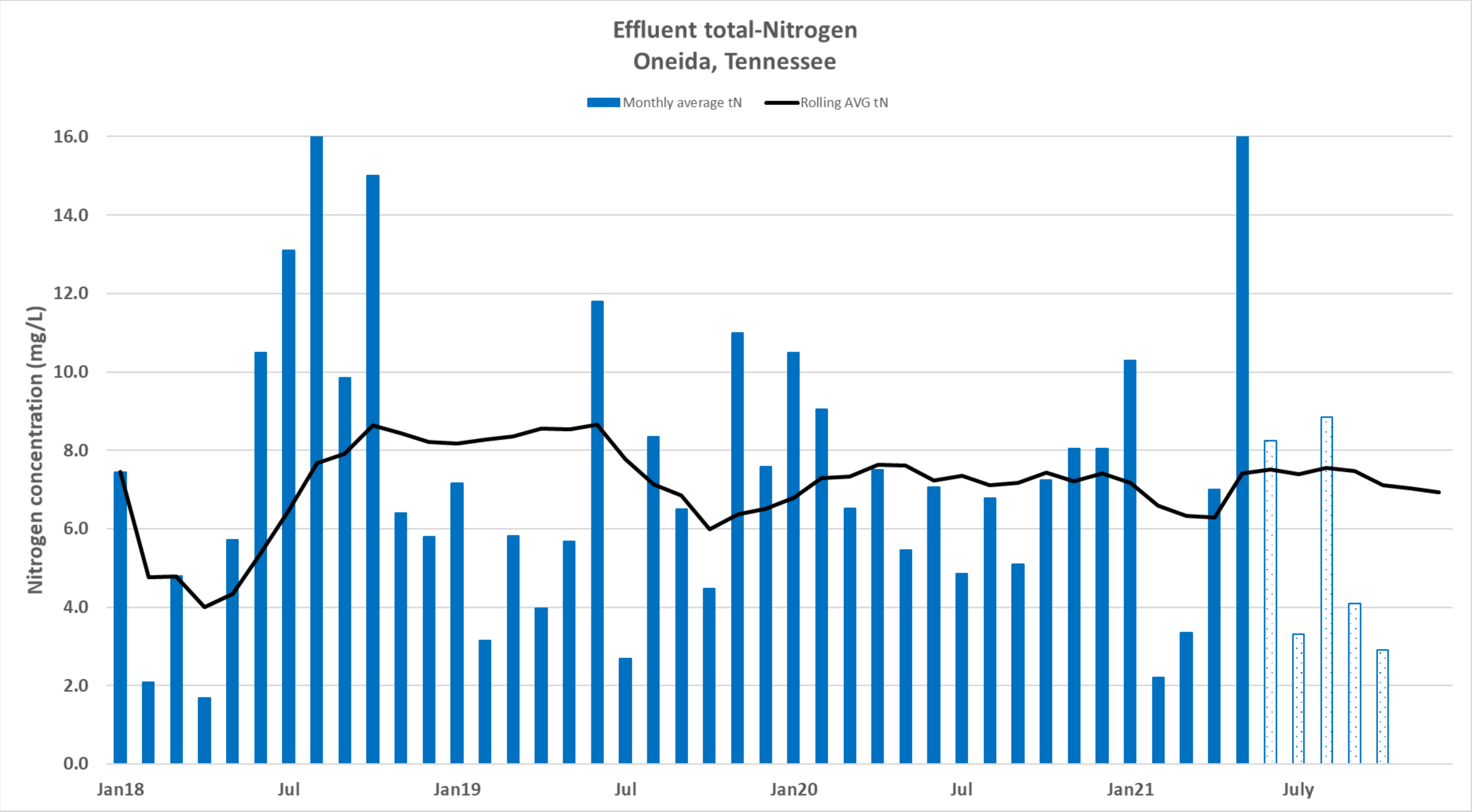




Oneida, Tennessee
1690



Effluent total-Phosphorus
Oneida, Tennessee
2018
2019
2020
2021
2018-2020 average
Phosphorus concentration (mg/L)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



Effluent total-Nitrogen
Oneida, Tennessee
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Jan18
Jul
Jan19
Jul
Jan20
Jul
Jan21
July

Oneida, Tennessee

Nitrogen

Now: 8 mg/L

Phosphorus

Now: summer peaks of less than 1.5 mg/L

Was: summer peaks of more than 3.0 mg/L

Sustainable

No new construction

Less electricity is used

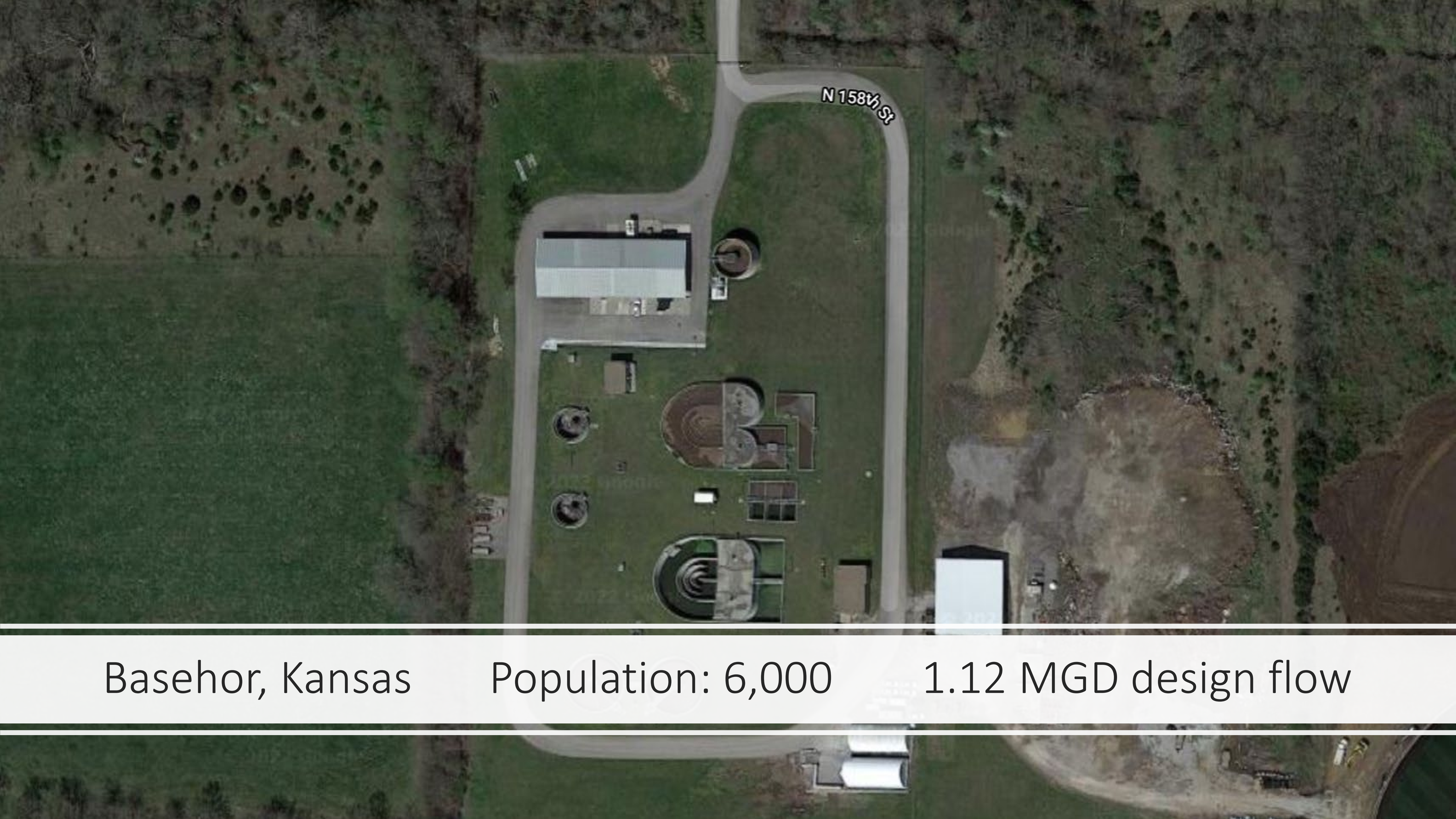
Ratepayer savings

Electrical savings

Unlikely that a facility upgrade will be required


VOTE
VOTE
VOTE
VOTE
VOTE
VOTE

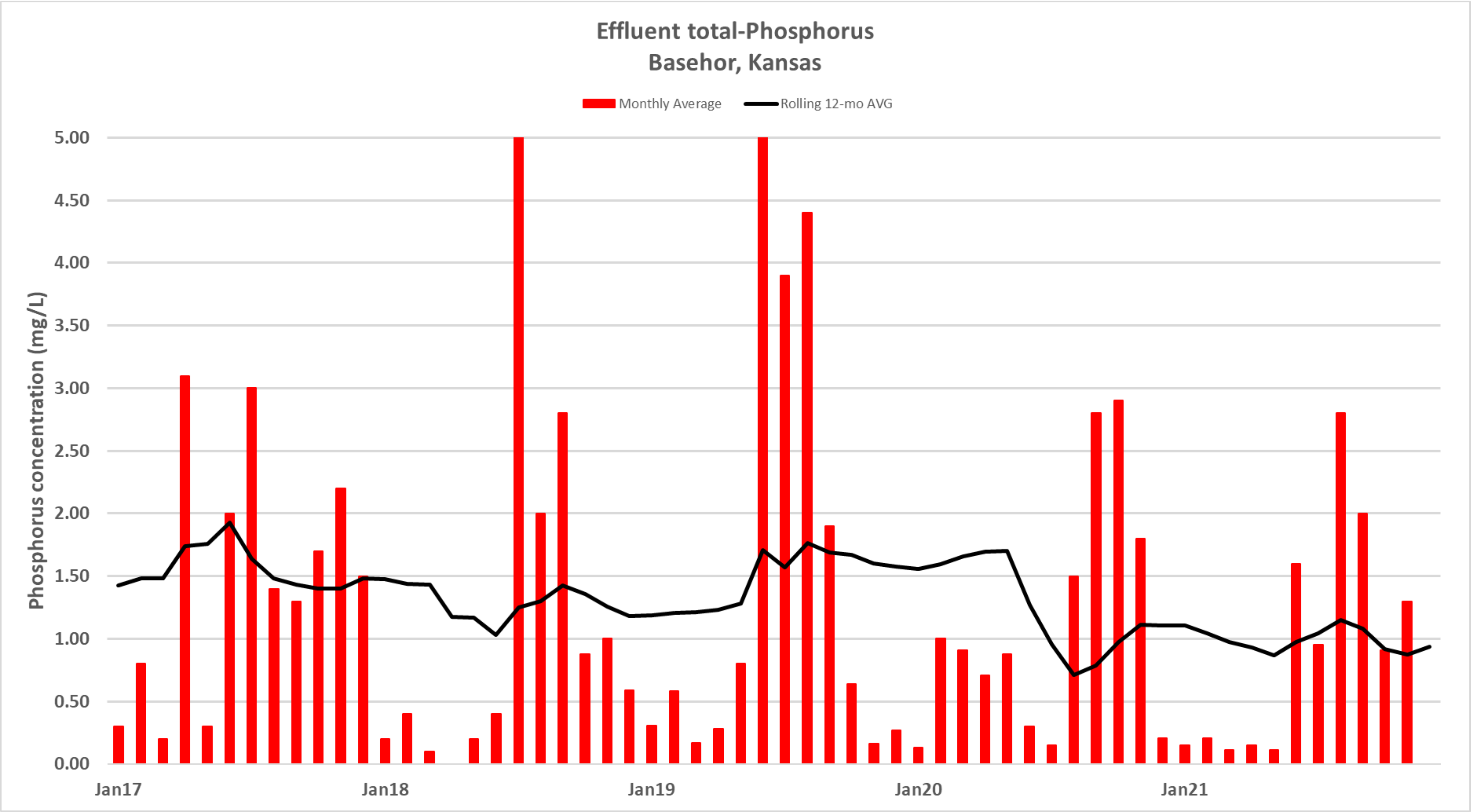
TrickedOut

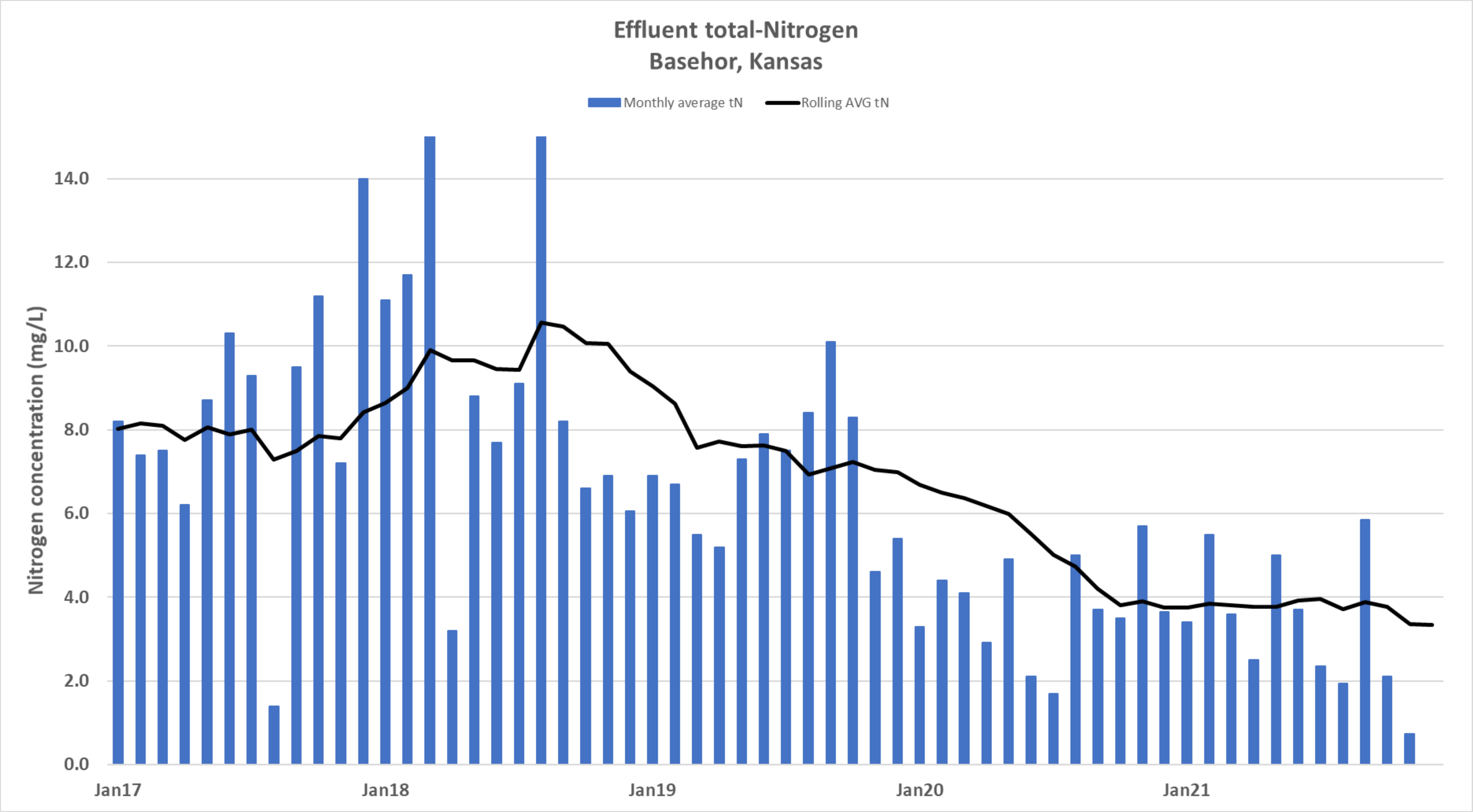


Basehor, Kansas Population: 6,000 1.12 MGD design flow


N 158th St


N 158th St


Effluent total-Phosphorus
Basehor, Kansas
Monthly Average
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jan17
Jan18
Jan19
Jan20
Jan21


Effluent total-Nitrogen
Basehor, Kansas
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Jan17
Jan18
Jan19
Jan20
Jan21

Basehor, Kansas

Nitrogen

Now: 4 mg/L

Was: 8 mg/L

Phosphorus

Now: 1.0 mg/L with summer peaks less than 3 mg/L

Was: 1.5 mg/L with summer peaks more than 3 mg/L

Sustainable

No new construction

DO control in aeration basin

Less mixing of anoxic and anaerobic tanks

Ratepayer savings

Electrical savings from less mixing

Possible elimination of near-term facility upgrade

Optimizing Nutrient Removal & Wastewater Excellence

Optimizing Nutrient Removal

February 17: Optimizing Nutrient Removal in SBRs

March 31: Optimizing Nutrient Removal in Conventional and Extended Aeration Activated Sludge wwtps

Wastewater Excellence

April 28: Transitioning from Permit Compliance to Wastewater Excellence

Comments & Questions