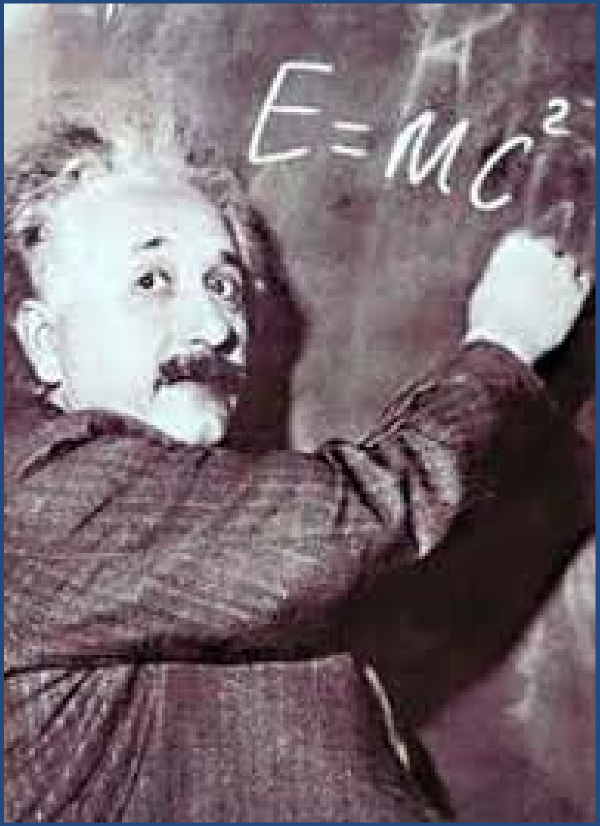
RE-ENGINEERING O&M PRACTICES TO GET NITROGEN & PHOSPHORUS REMOVAL WITHOUT FACILITY UPGRADES

GRANT WEAVER, PE & WASTEWATER OPERATOR

WISCONSIN WASTEWATER OPERATORS ASSOCIATION
WISCONSIN DELLS, WI – OCTOBER 11, 2012

THE WATER PLANET COMPANY

Re-Engineering O&M to get N+P Removal



Nitrogen Removal

Science

Design Theory

Phosphorus Removal

Science

Design Theory

O&M Strategies

Case Studies

Traditional Approach

Cost of Facility Upgrades

$85 billion taxpayer dollars
spent building 15,000 wastewater treatment plants (1972-Present).

$250 billion
“needed” to fix existing treatment plants and CSO pollution (2010 EPA 20-year Needs Assessment).

Wastewater One-Percenters

Connecticut's Nitrogen Trading Program (2002-2012)

1% of the Capital Cost

No Facility Upgrade
10 of 80 plants: Process changes @ $50,000 per plant
6 mg/L total-N

99-Percenters; Everybody Else

Facility Upgrades
48 of 80 plants: N-Removal upgrades @ $6.15 Million per plant
6 mg/L total-N

Phosphorus Experience

Re-Engineering

Existing equipment is used differently to provide better habitats.
Making the treatment plant a good "home" for bacteria.

BOD/TSS Removal

Biological Nitrogen Removal
- Aerobic -Ammonia Removal
- Anoxic - Nitrate Removal

Biological Phosphorus Removal
- Anaerobic - VFA production
- Aerobic - bio-accumulation

How to make any treatment plant remove Nitrogen & Phosphorus

- Oxygen-Rich, low BOD environment
  - Nitrogen
    - Ammonia Removal – Nitrification
  - Phosphorus
    - Dissolved Phosphorus converted to TSS (particulate Phosphorus)
- Oxygen-Poor, high BOD environment
  - Nitrogen
    - Nitrate Removal – Denitrification
  - Phosphorus
    - Volatile Fatty Acid (VFA) production; if anaerobic/fermentative
- TSS Removal
  - Nitrogen
    - 12% of MLSS is Nitrogen (8 mg/L TSS = 1 mg/L total-N)
  - Phosphorus
    - 3-5% of MLSS is Phosphorus (2 mg/L TSS = 0.1 mg/L total-P)

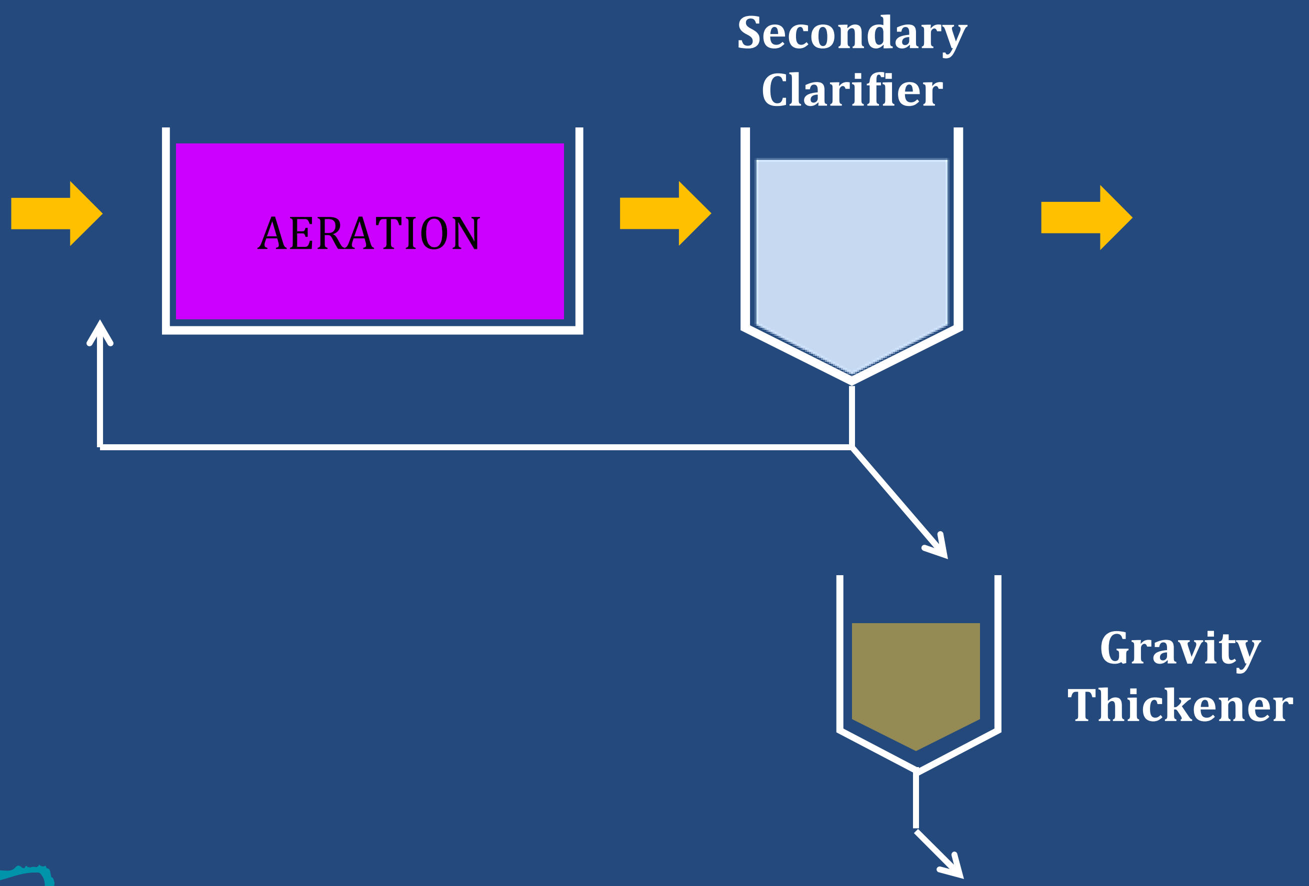
Case Study
Plainfield (CT) Village Plant – ReEngineered for N&P Removal

Design Flow: 0.5 MGD
Actual: 0.2 MGD

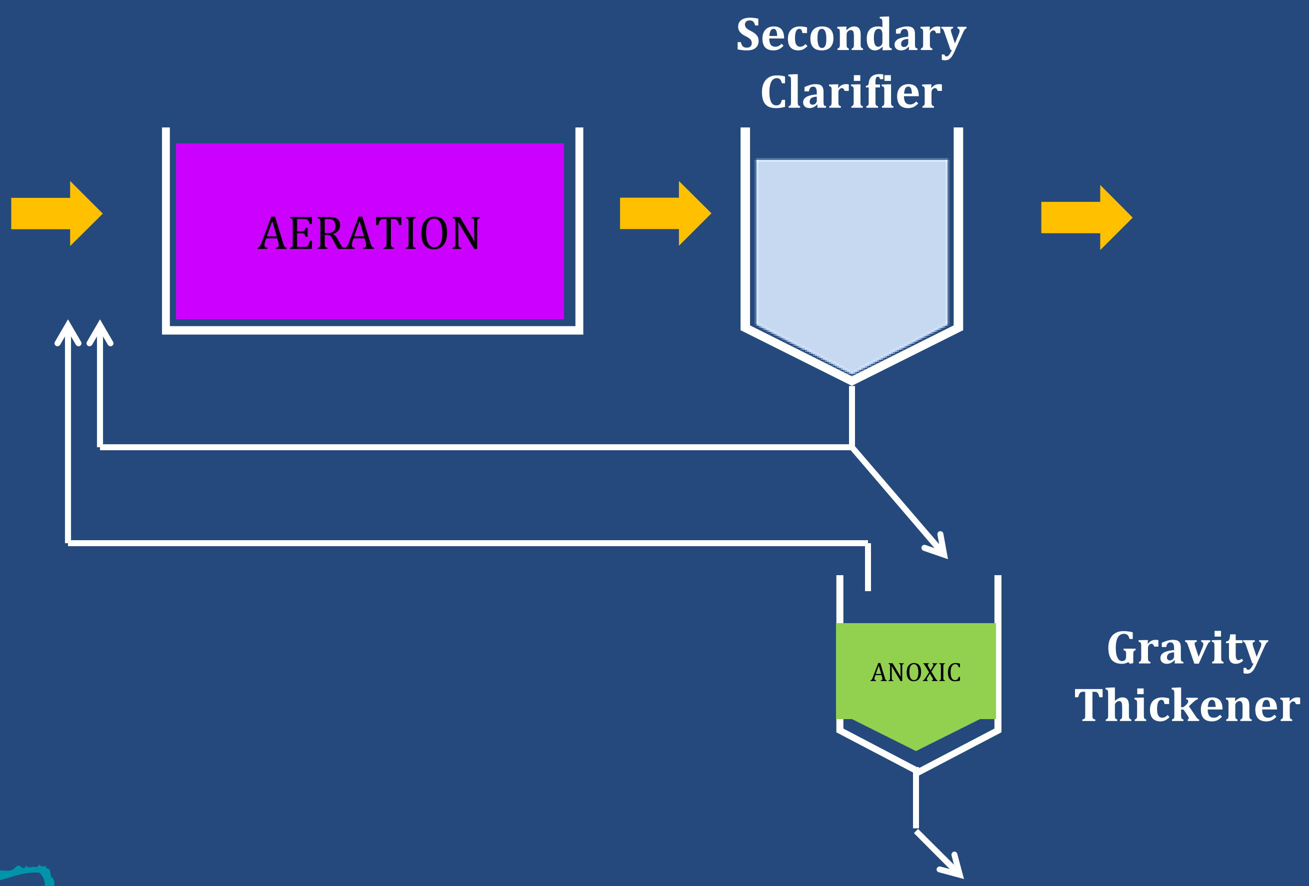
Effluent total-N
- Before Changes: 20 mg/L
  (10 TKN, 8 Ammonia, 10 Nitrite + Nitrate)
- After Changes: 6 mg/L
  (2.5 TKN, 0.5 Ammonia, 3.5 Nitrite + Nitrate)

Effluent total-P
- Before Changes: 3 mg/L
- After Changes: 0.75 mg/L

Plainfield Village



Plainfield Village
Gravity Thickener as Post-Anoxic Denitrification

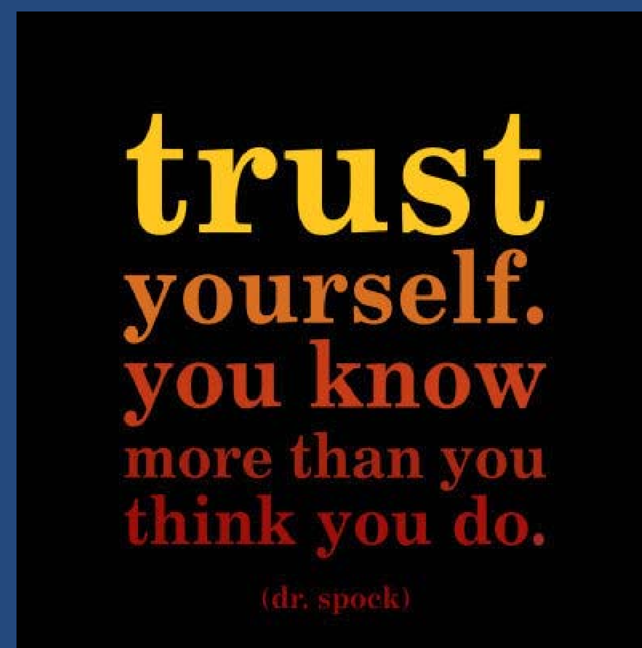


Nitrogen and Phosphorus Removal

Costly Facility Upgrade!

... or ...

Process Changes?

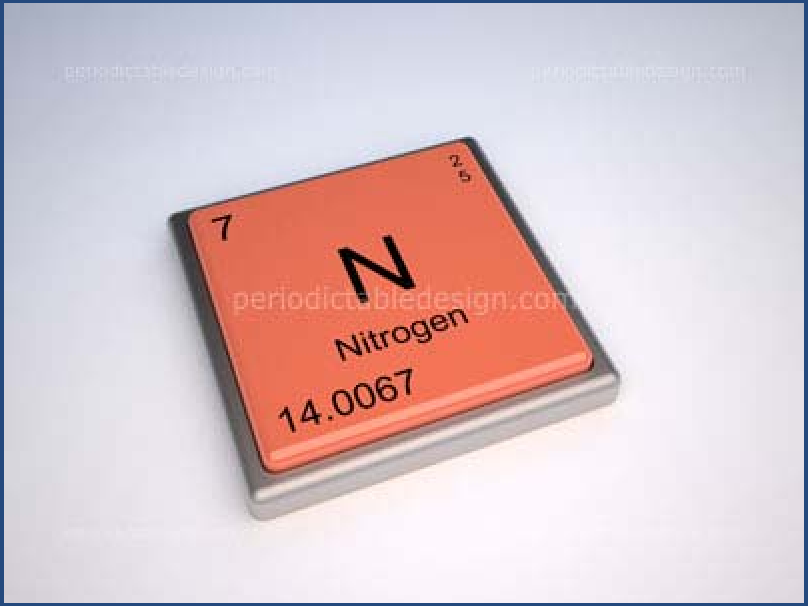


Compliance may be easier and

and more affordable than you've

been led to believe...


Let's
begin


7
2
5
N
Nitrogen
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Biological Nitrogen Removal

Organic-Nitrogen (org-N)

↓

Ammonia (NH_3)

↓

Nitrate (NO_3)

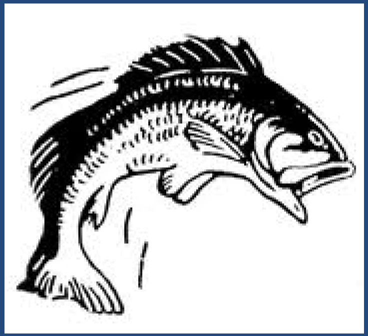
↓

Nitrogen Gas (N_2)

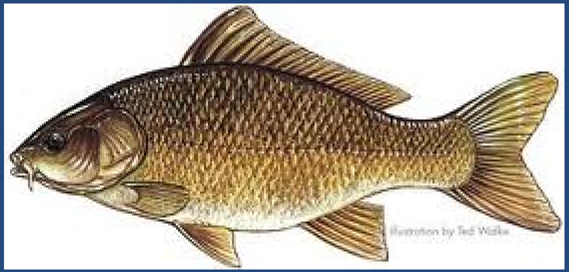
Ammonia Removal - Nitrification:
Bacteria Convert Ammonia to Nitrate

Nitrate Removal - Denitrification:
Bacteria Convert Nitrate to Nitrogen Gas

Re-Engineering O&M for Nitrogen Removal



Ammonia Removal



Nitrate Removal

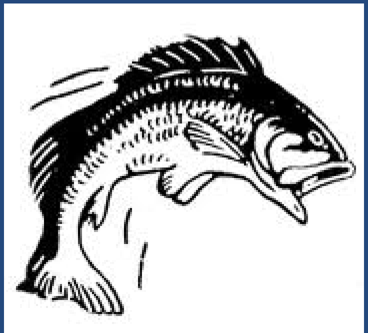
Ammonia Removal

Oxygen

Oxygen

Ammonia → Nitrite → Nitrate

Alkalinity



Ammonia Removal - Nitrification

Create a Habitat to motivate and support Bacteria that remove Ammonia (NH_3)

- Dissolved Oxygen (DO)
- +100 ORP
- Low BOD
- Old Sludge (High MLSS, High MCRT/SRT; Low F:M)
- Alkalinity to keep pH from dropping
- Time (HRT)
- Temperature

Ammonia Removing Technologies

Extended aeration

Dissolved Oxygen (DO) & ORP

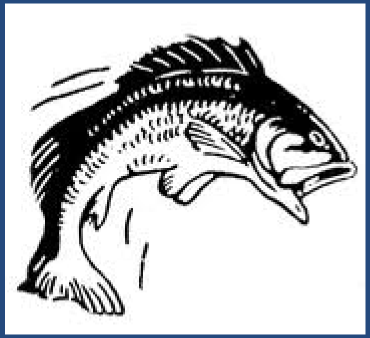
Old sludge (High MLSS / MCRT / SRT; Low F:M)

Low BOD

Time (HRT)

Alkalinity to keep pH from dropping

Two-stage trickling filter



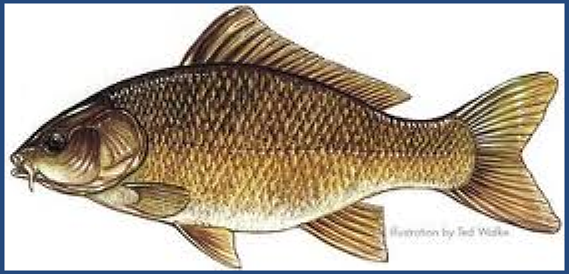
Nitrate Removal

BOD

Oxygen

Nitrate → Nitrogen Gas

Alkalinity



Nitrate Removal - Denitrification

Create a Habitat so the Bacteria that Remove Nitrate (NO_3) will be motivated to do it…

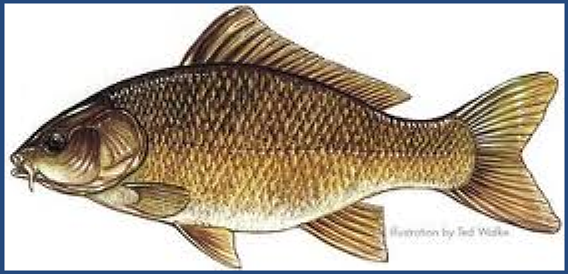
Little to Zero DO

-100 ORP

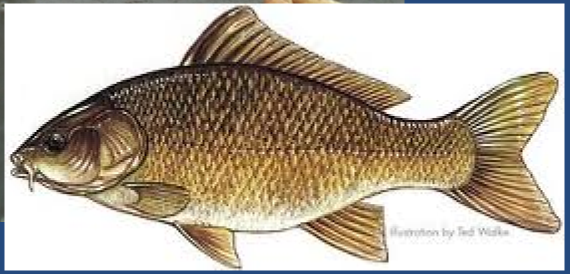
Surplus BOD (High F:M)

Time (HRT)

They give back one-half of the
Alkalinity that the Nitrifiers removed



Nitrate Removal Habitats



Nitrate Removing Technologies

Post-Anoxic Denitrification

Pre-Anoxic Denitrification (MLE: Modified Ludzack-Ettinger)

SBR, or Cycling between Nitrification and Denitrification

Oxidation Ditch (Bardenpho)

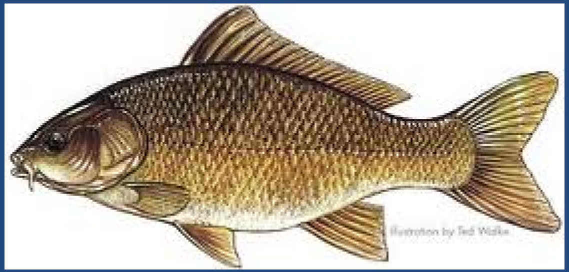
HABITAT

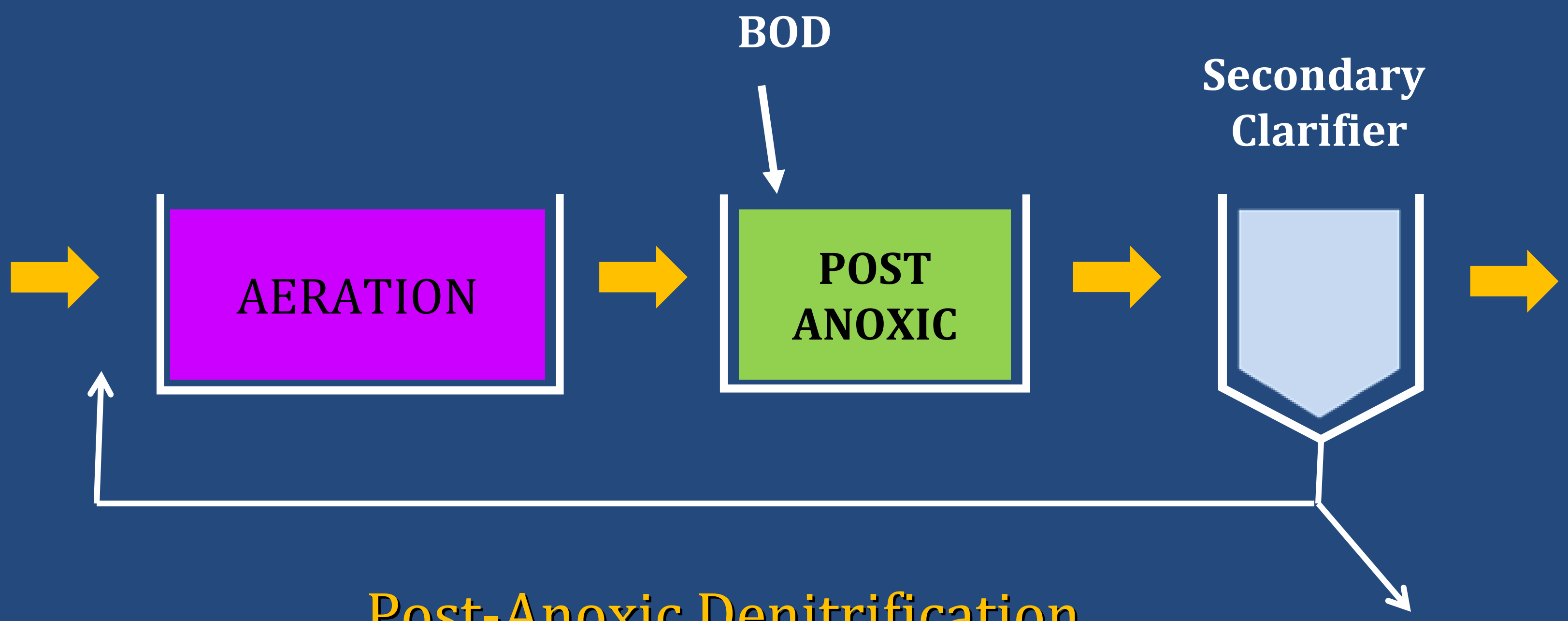
Little to Zero DO

-100 or lower ORP

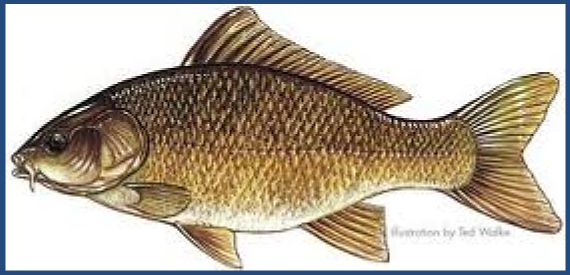
Surplus BOD (High F:M)

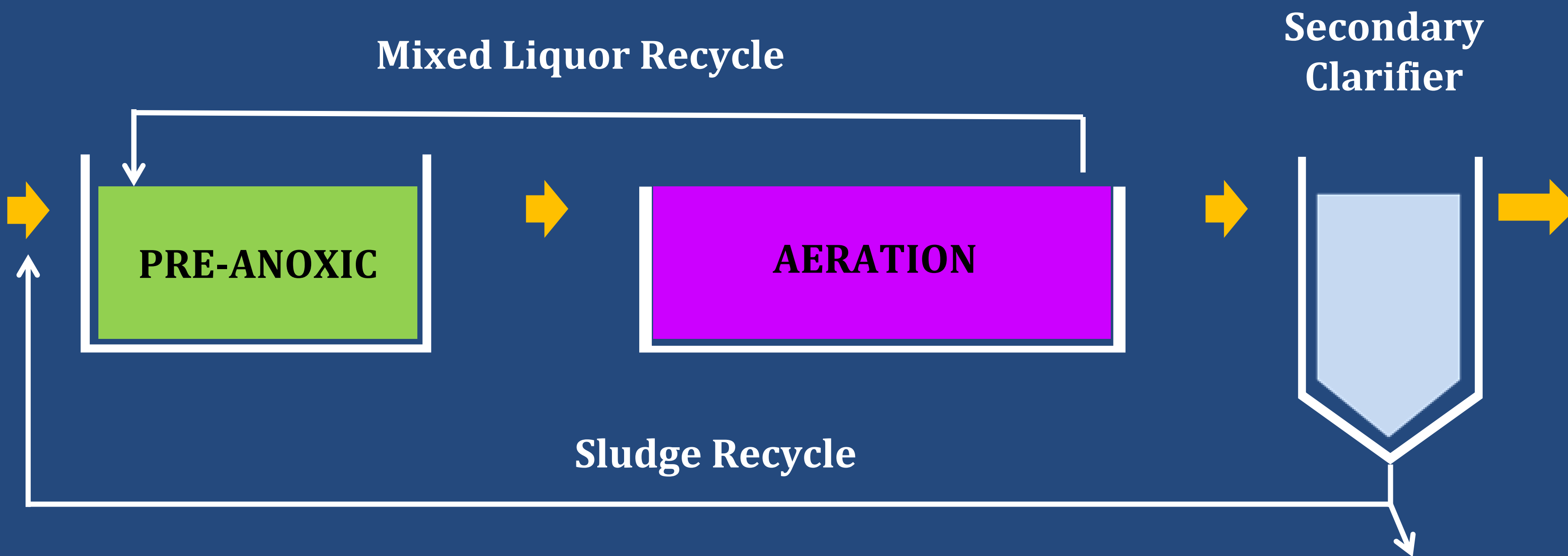
Time (HRT)



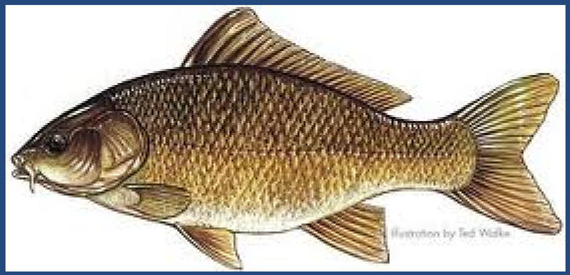


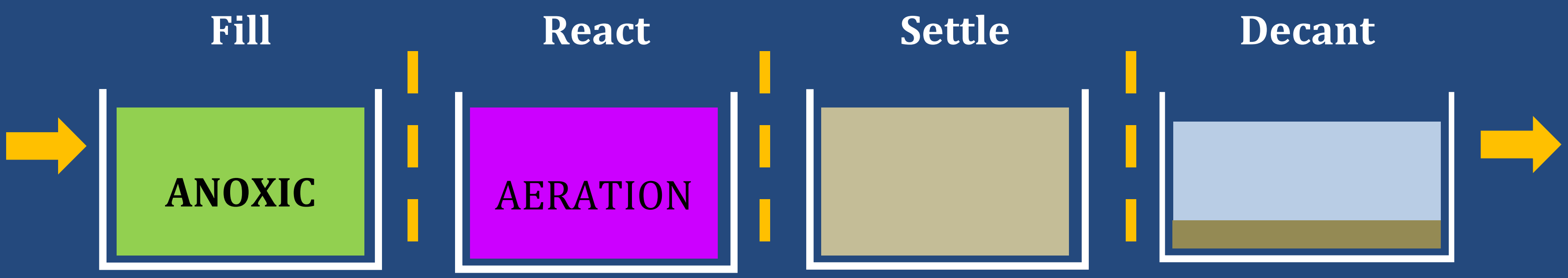
Post-Anoxic Denitrification



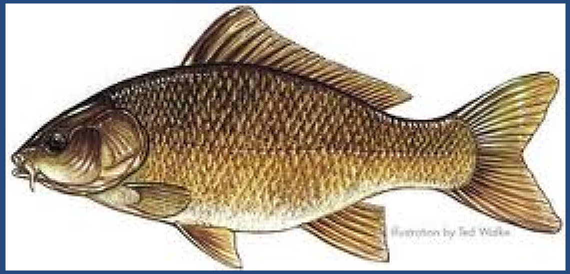


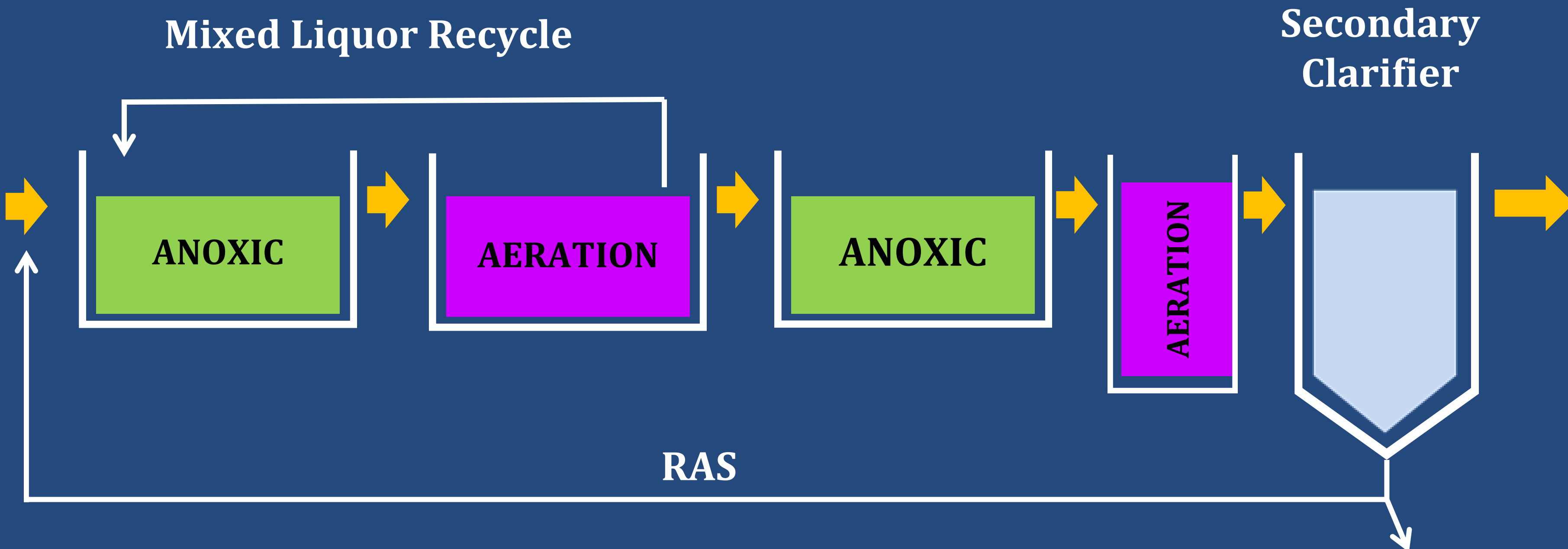
Pre-Anoxic: MLE Process



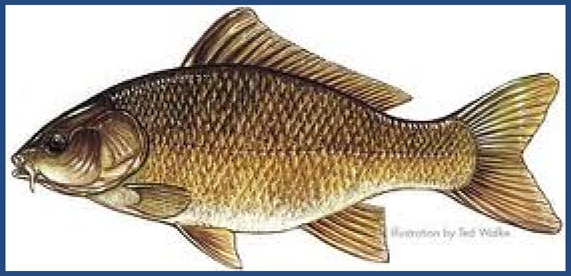


Sequencing Batch Reactor (SBR)

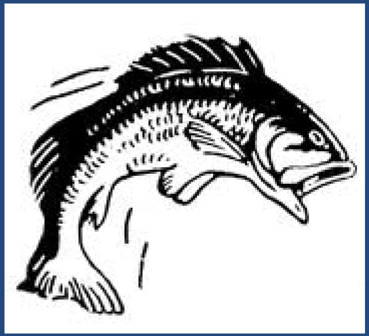




Oxidation Ditch: Bardenpho Process

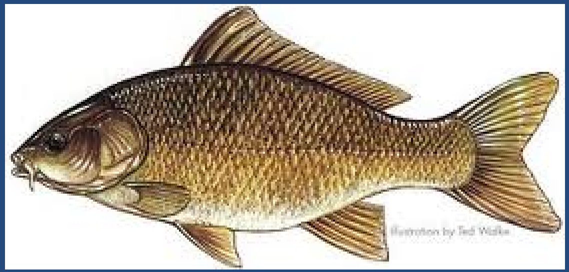


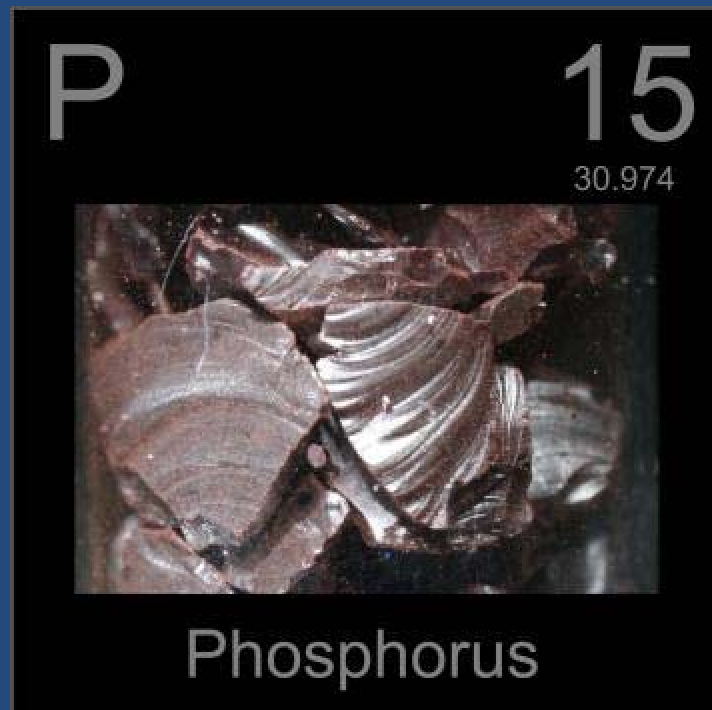
Nitrogen Removal Simplified



Ammonia Removal - Nitrification
- High DO / ORP
- Low BOD
- Plenty of Alkalinity
- High Sludge Age
- Long Retention time

Nitrate Removal - Denitrification
- Low DO / ORP
- High BOD
- Long Retention time
- Gives back alkalinity

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Phosphorus

Phosphorus: Soluble and Particulate

- Soluble Phosphorus
  - Convert to TSS (Particulate)
    - Biological P removal
    - Chemical P removal
- Particulate Phosphorus
  - Remove phosphorus by removing TSS

Phosphorus Removal Strategy

Convert up to 0.05 mg/L of Soluble Phosphorus to TSS (Particulate)

- Biologically
- Chemically

Particulate Phosphorus

- Remove as much TSS as necessary to meet Phosphorus Limit
  - Rule of Thumb: 2 mg/L TSS = 0.1 mg/L t-P

TSS Removal Requirements

If all but 0.05 mg/L of Soluble Phosphorus is Converted to Particulate Phosphorus (Biologically and/or Chemically)

And, if Effluent TSS is 5% total-Phosphorus, Effluent TSS cannot exceed the numbers shown in the table…

P Limit	max TSS
0.1	1
0.2	3
0.3	5
0.4	7
0.5	9
0.6	11
0.7	13
0.8	15
0.9	17
1.0	19
1.1	21
1.2	23
1.3	25
1.4	27
1.5	29

Habitats

Anaerobic Zone

Volatile Fatty Acid (VFA) production

... followed by ...

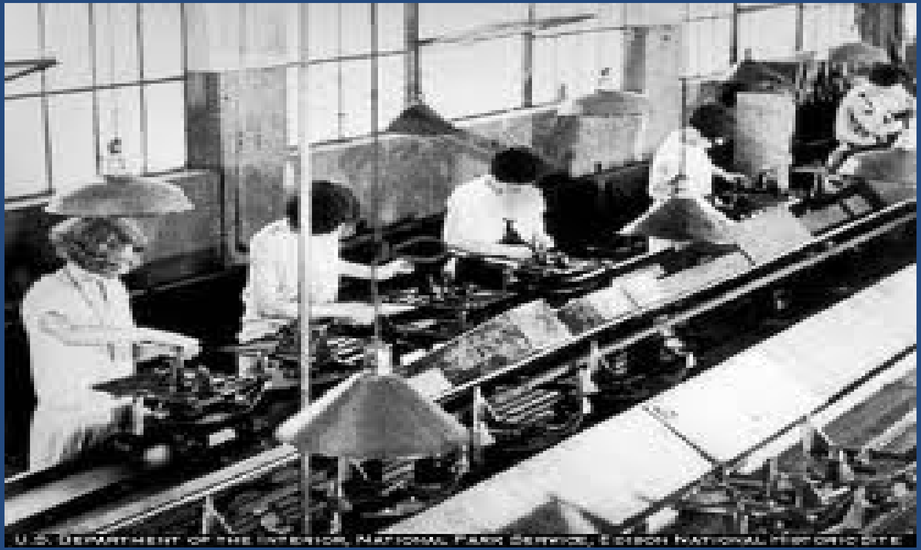
Aerobic Zone

Phosphorus Uptake by PAOs ("Luxury Uptake")

Anaerobic Zone - Volatile Fatty Acid (VFA) formation

Bacteria create VFAs . . . .

AND



. . . . In the process, the Bacteria release some of their cellular Phosphorus into solution

Aerobic Zone

Phosphorus Accumulating Organisms (PAO) concentrate soluble Phosphorus.

PAOs contain 3 times as much Phosphorus as “regular” bacteria do. The phosphorus concentration in the mixed liquor increases from <2% total-P to as much as 5% total-P.

Biological Phosphorus Removal

ANAEROBIC zone for VFA production

… followed by

AEROBIC zone for Phosphorus uptake by PAO bacteria

Anaerobic Zone (Fermentation)

<u>Mainstream</u>

Pre- Anaerobic Zone

Modify Pre-Anoxic

Modify Existing Tanks

<u>Sidestream</u>

RAS piping

Gravity Thickener

Primary Sludge

WAS

Combined Primary & Secondary

Sludge Storage

Septage

Chemical Phosphorus Removal

Soluble ortho-Phosphate is taken out of solution and made into TSS .
The particulate Phosphorus is settled.

Iron

- *Ferric*
- *Ferrous*

Aluminum

- Alum
- PAC
- Sodium Aluminate

Phosphorus Removal

Convert soluble Phosphorus to particulate Phosphorus

- Biological: Anaerobic (Fermentation) followed by Aerobic
- Chemical: Iron or Aluminum compound

Remove the TSS that contains the particulate Phosphorus

Achieving low total-P compliance requires …

- Low to almost zero soluble P
- Low to almost zero effluent TSS

Case Studies

Greater than 50% Nitrogen Reduction

Greater than 50% Phosphorus Reduction

Capital Cost: as little as ZERO

- No New Tanks

O&M: generally, a cost SAVINGS

- No Chemicals

Carbon Footprint: REDUCED

Re-Engineering O&M – Optimizing Existing Equipment

Ongoing Monitoring of …

- Ammonia
- Nitrite + Nitrate
- Alkalinity
- ORP

Using …

- In-line instrumentation connected to SCADA
- Hand-held equipment
- Field Test Kits such as Test Strips

And …

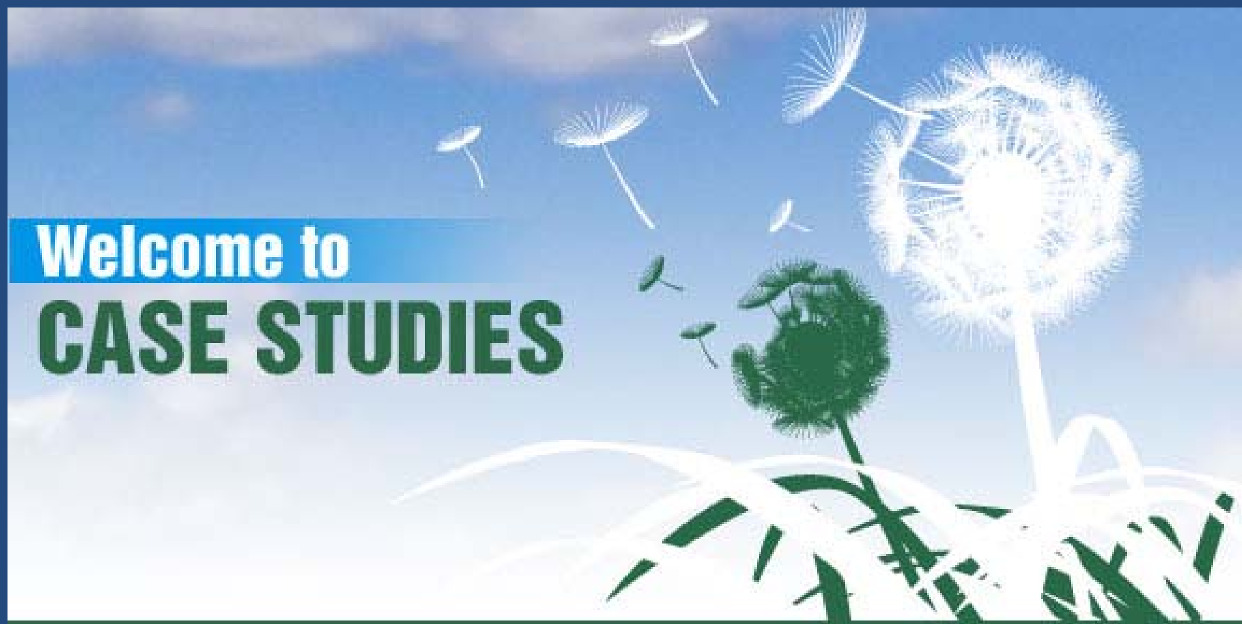
Ongoing Process Changes to Optimize Habitats

Re-Engineering for Nitrogen Removal

	t-N Before	t-N After
Suffield, CT	6.7	2.0
Montague, MA	11	3.5
Windsor Locks, CT	6.5	4.5
East Hampton, CT	11	5.5
Plainfield Village, CT	20	6.0
Manhattan, MT	12	7
Conrad, MT	12	7
Amherst, MA	25	8
Plainfield North, CT	15	8
Farmington, CT	12	8
Chinook, MT	25	12

Re-Engineering for Phosphorus Removal

	t-P Before	t-P After
Keene, NH	3.0	0.2
East Haddam, CT	3.5	0.4
Montague, MA	5.5	0.6
Suffield, CT	3.0	0.7
Plainfield Village, CT	3.0	0.8


Welcome to
CASE STUDIES

Trickling Filters, Lagoons, etc.

Case Study – Nitrogen & Phosphorus Removal
Plainfield, Connecticut
Village Plant

Design Flow: 0.5 MGD
Actual: 0.2 MGD

Effluent total-N

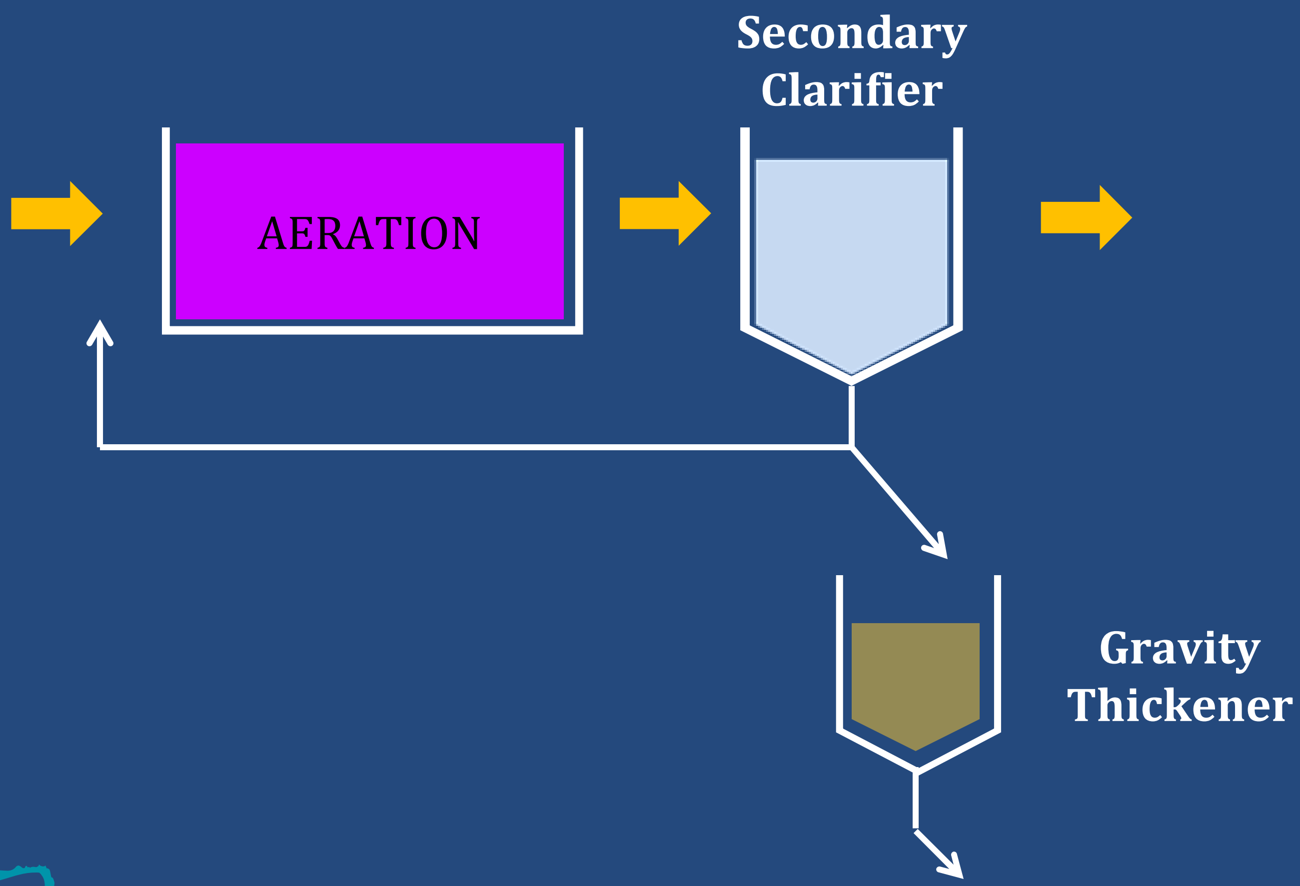
Before Changes: 20 mg/L
(10 TKN, 8 Ammonia, 10 Nitrite + Nitrate)

After Changes: 6 mg/L
(2.5 TKN, 0.5 Ammonia, 3.5 Nitrite + Nitrate)

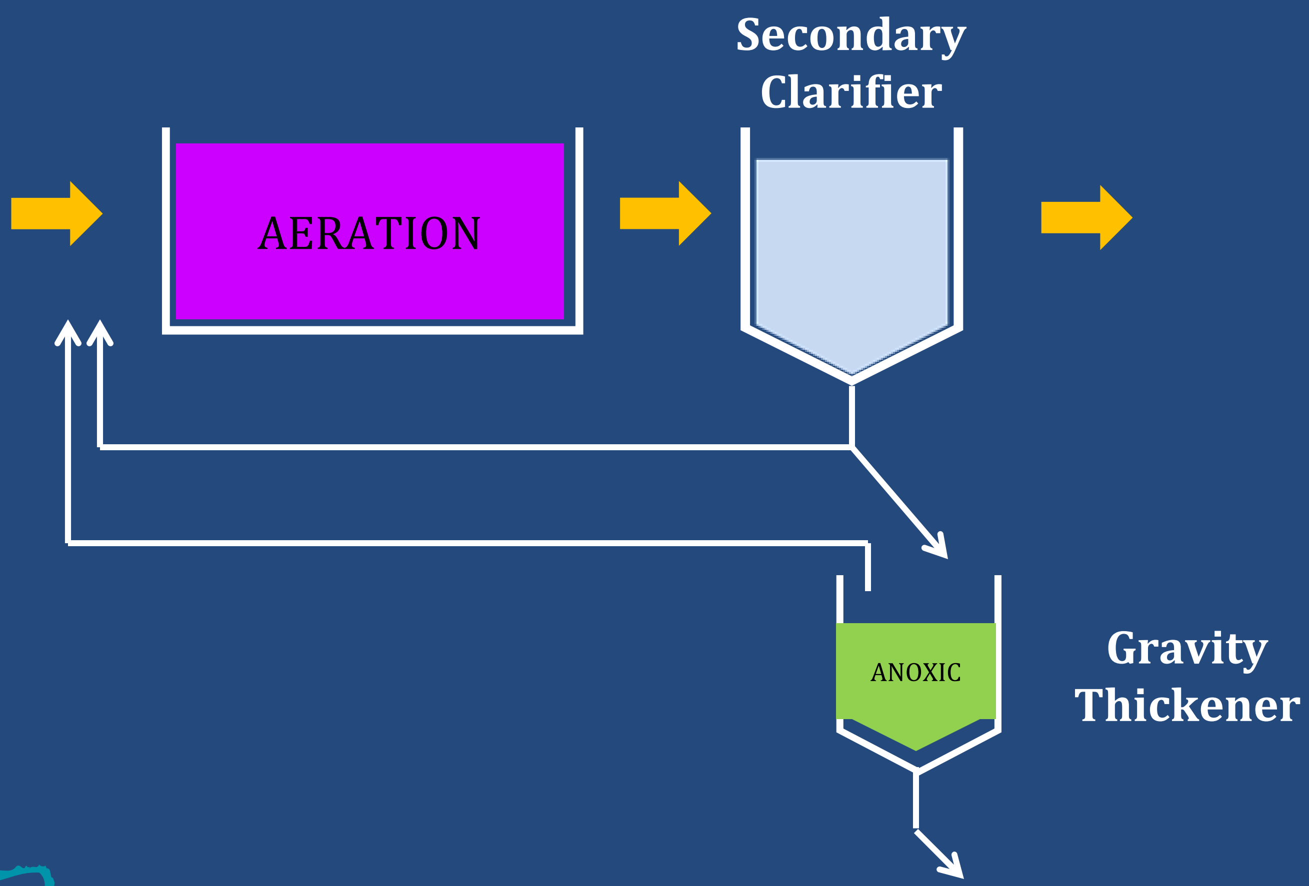
Effluent total-P

Before Changes: 3 mg/L
After Changes: 0.75 mg/L

Plainfield Village



Plainfield Village
Gravity Thickener as Post-Anoxic Denitrification



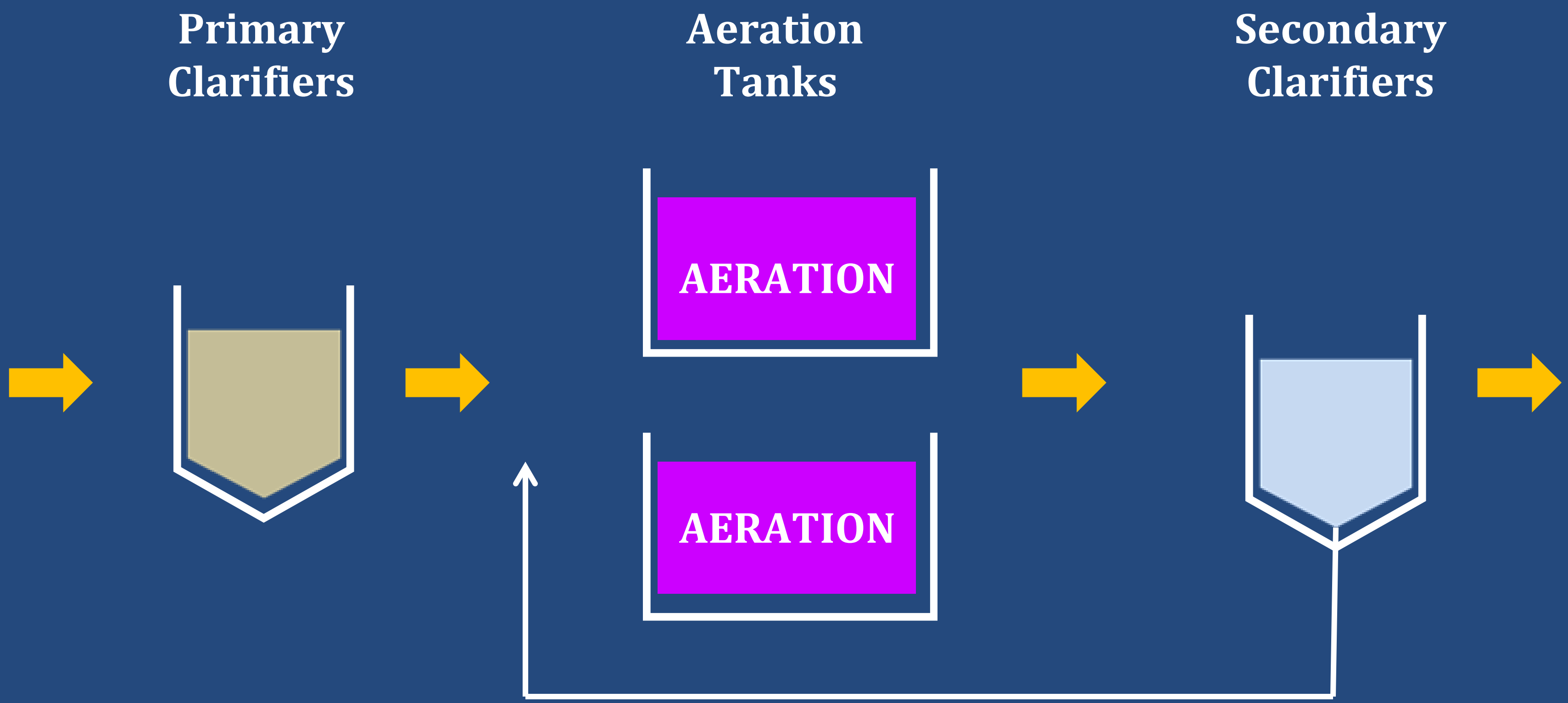
Plainfield Village

Case Study – Nitrogen & Phosphorus Removal
Montague, Massachusetts

Design Flow: 1.8 MGD
Actual: 1.0 MGD

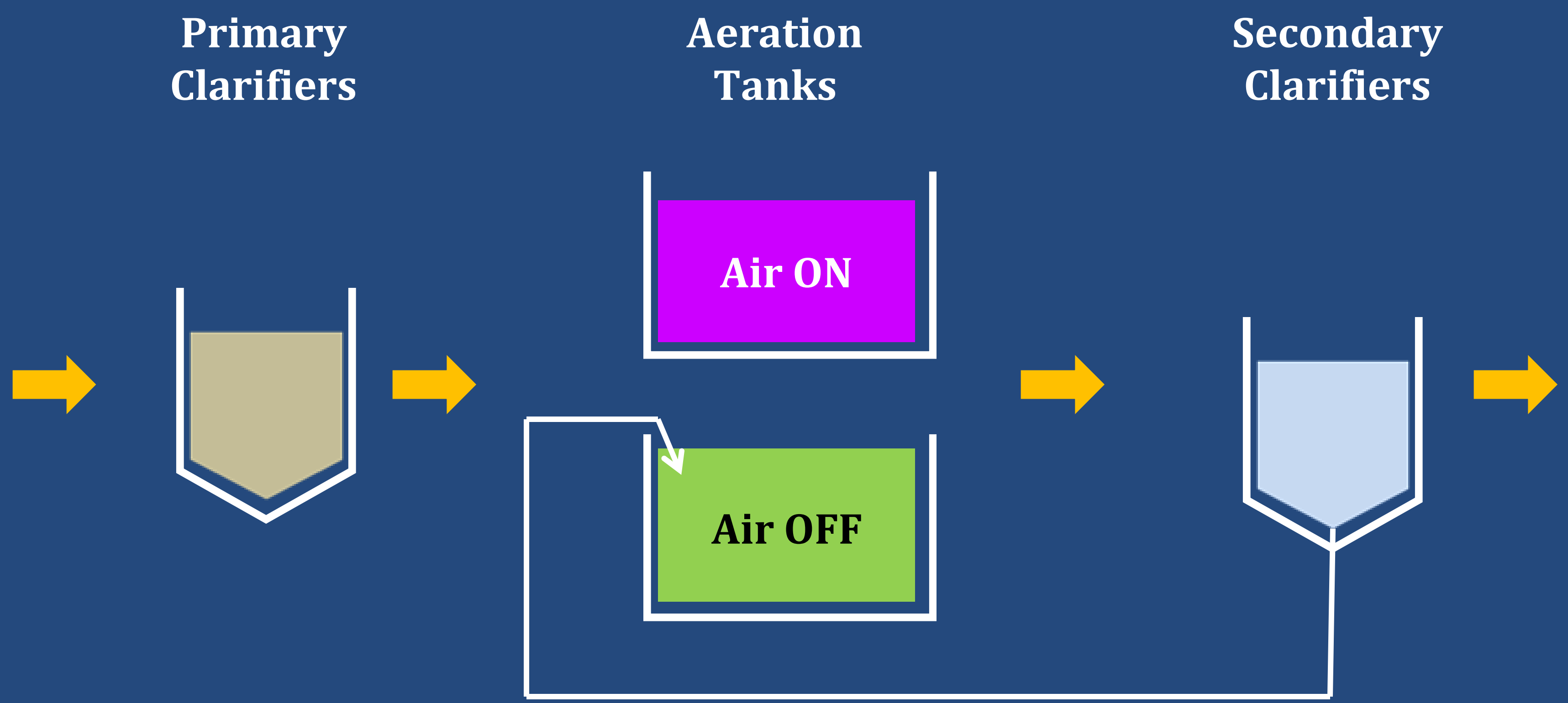
Effluent total-N
- Before Changes: 11 mg/L
  (6.0 TKN, 4.2 Ammonia, 5.0 Nitrite + Nitrate)
- After Changes: 3.5 mg/L
  (2.0 TKN, 0.5 Ammonia, 1.5 Nitrite + Nitrate)

Effluent total-P
- Before Changes: 2.5 mg/L
- After Changes: 0.6 mg/L

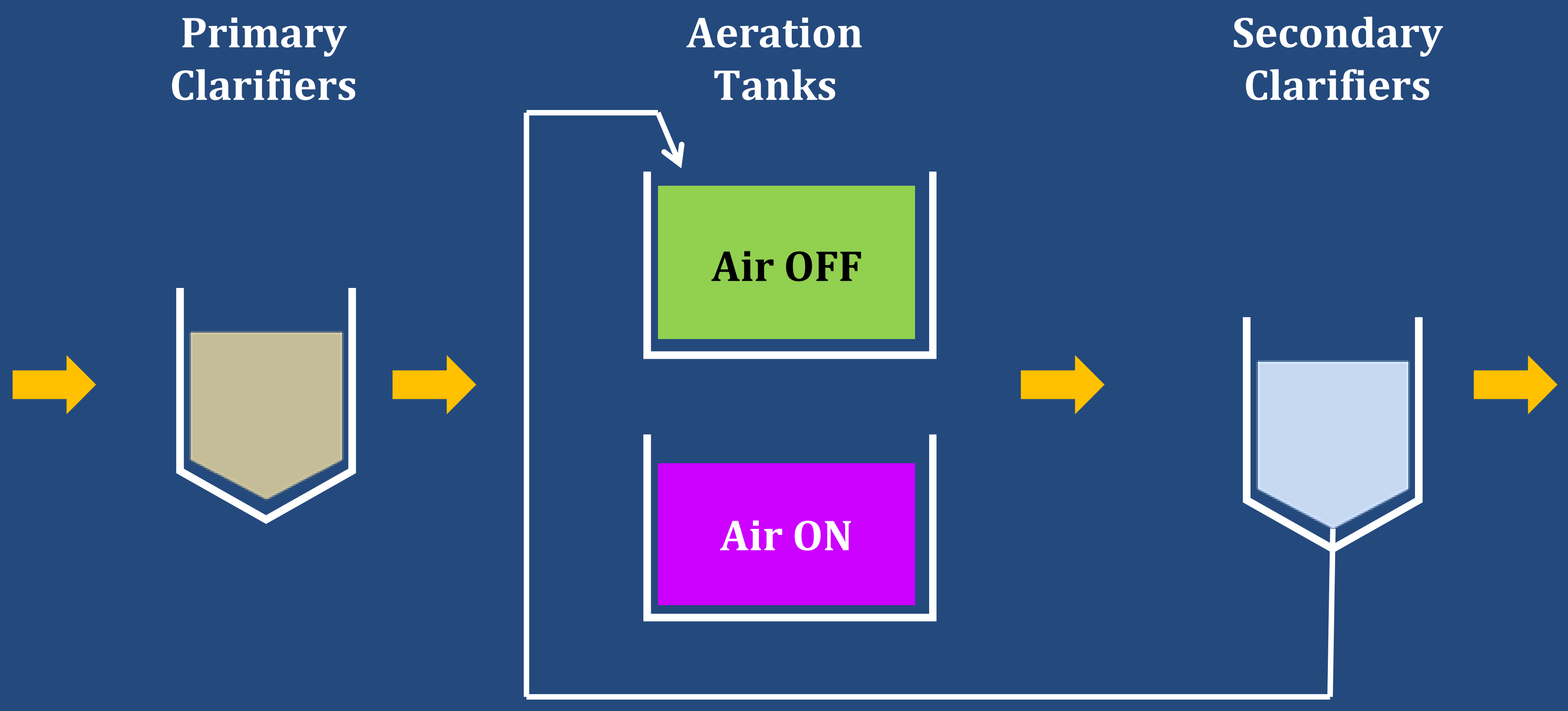


Montague, Massachusetts

Montague



Montague Process®



Montague Process®

Montague

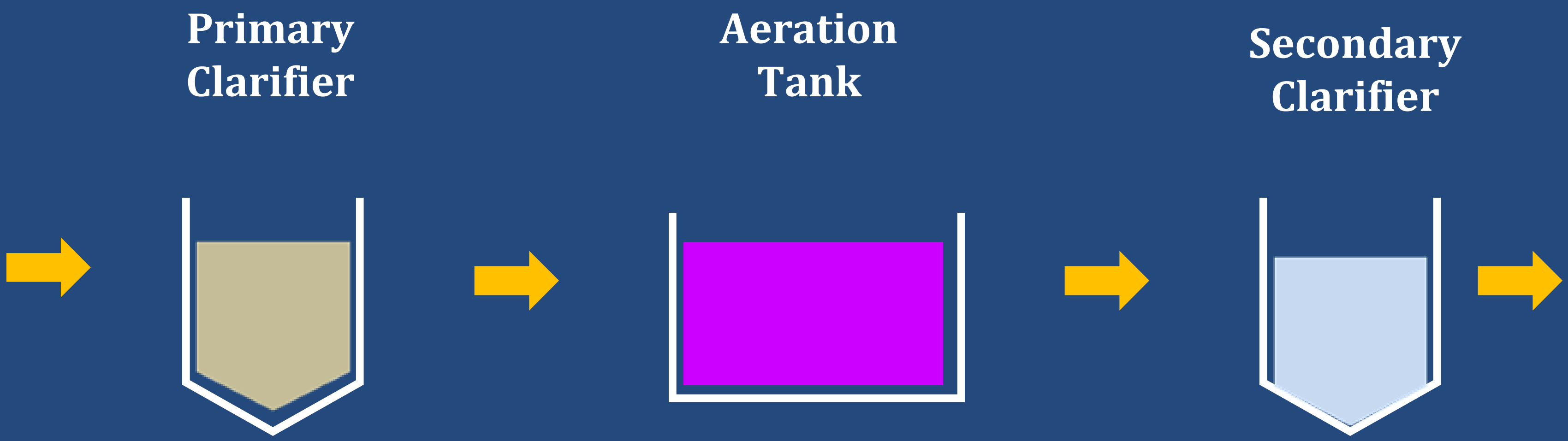
Case Study – Nitrogen Removal Plainfield, Connecticut North Plant

Design Flow: 1.0 MGD
Actual: 0.4 MGD

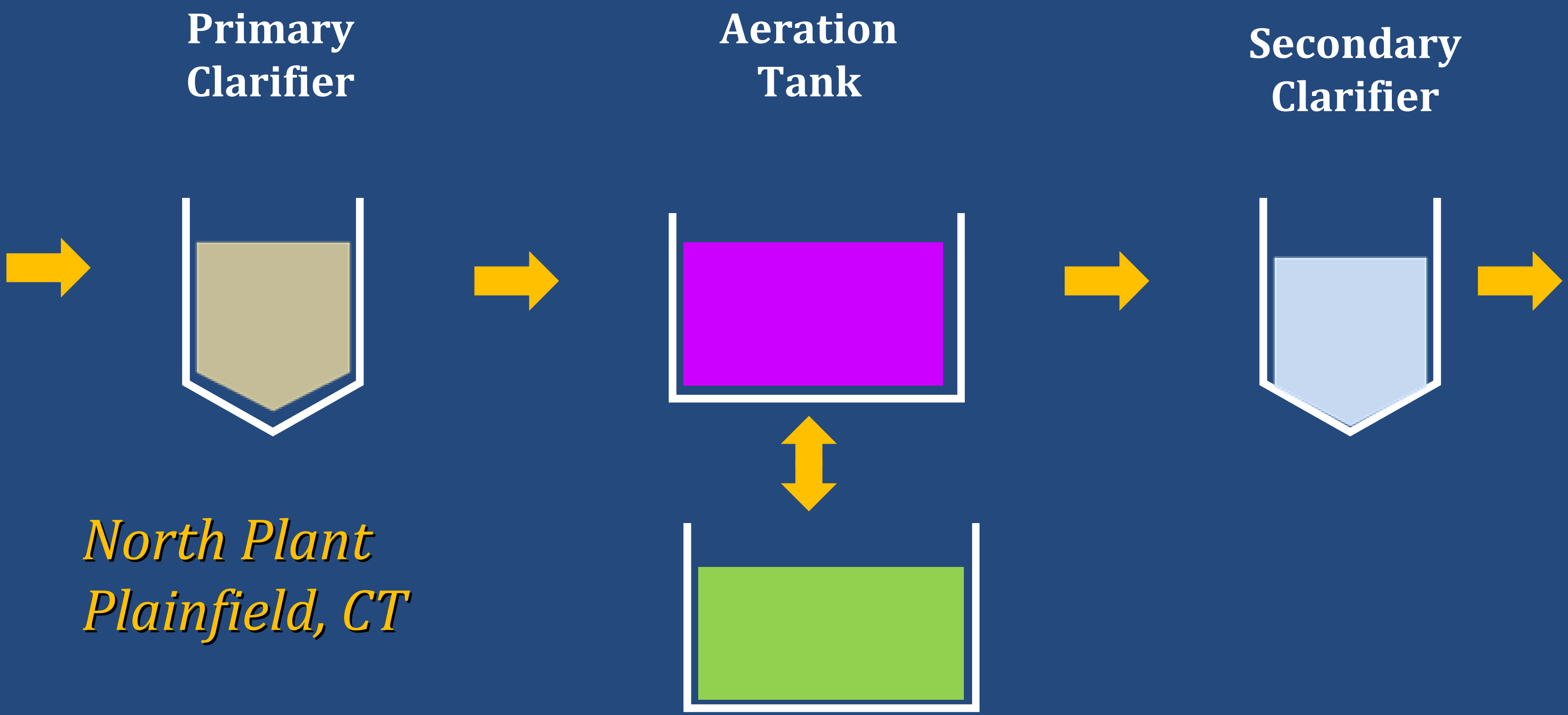
Effluent total-N
- Before Changes: 15 mg/L
- (5 TKN, 2 Ammonia, 10 Nitrite + Nitrate)
- After Phase I Changes: 8 mg/L
- (2 TKN, 0.5 Ammonia, 6 Nitrite + Nitrate)
- After Phase II Changes: 5 mg/L (anticipated)
- (2 TKN, 0.5 Ammonia, 3 Nitrite + Nitrate)

Effluent total-P
- Before Changes: 2.0 mg/L
- After Phase II: 0.75 mg/L (anticipated)

Plainfield North

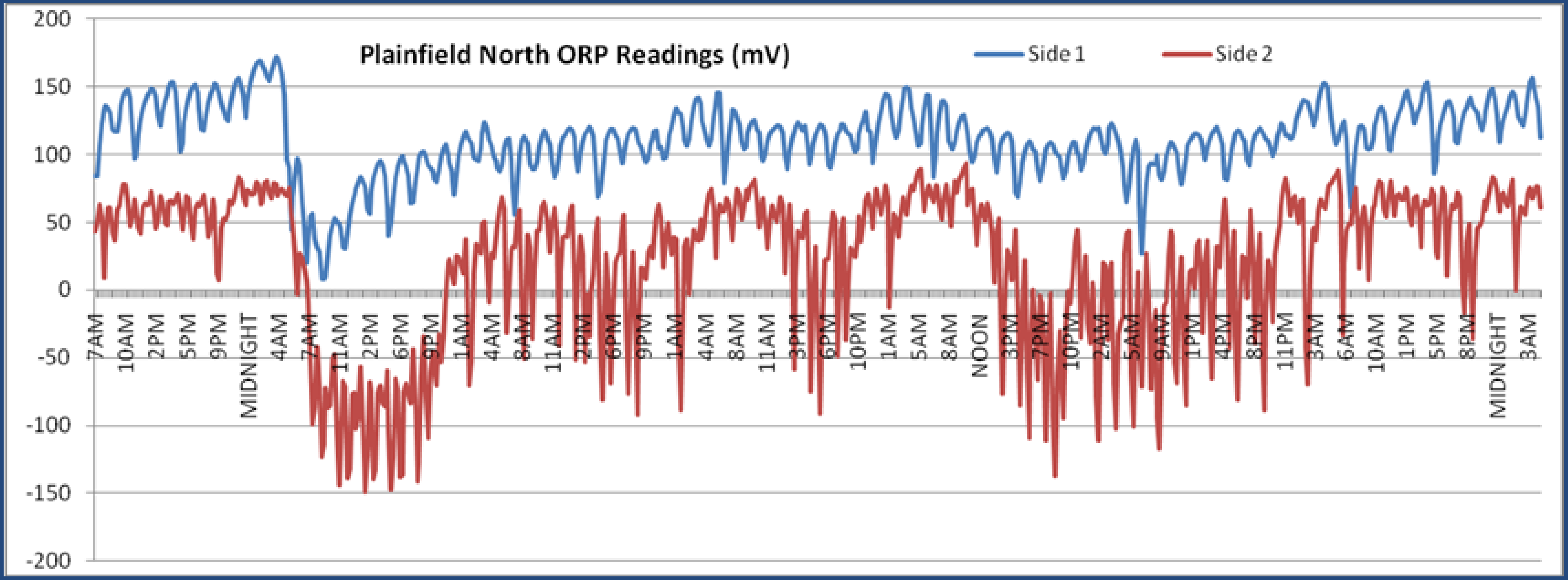


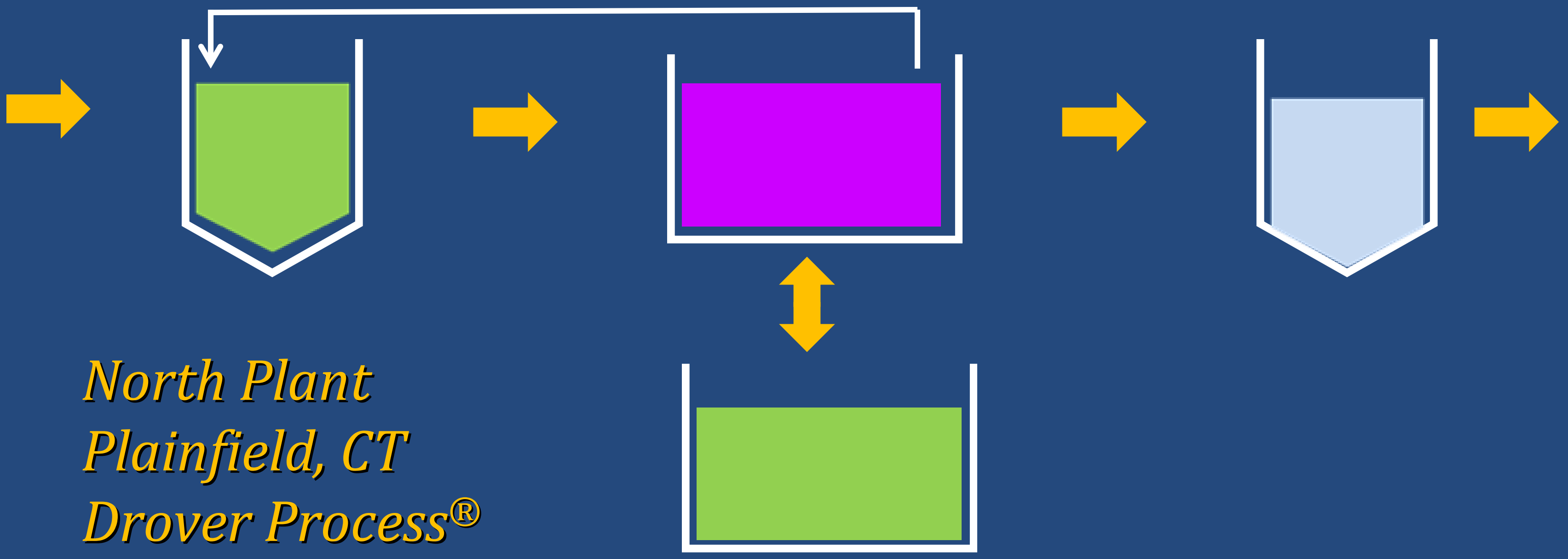
North Plant
Plainfield, Connecticut



North Plant
Plainfield, CT

Cycling Aeration to create ideal habitats for Ammonia and Nitrate removal

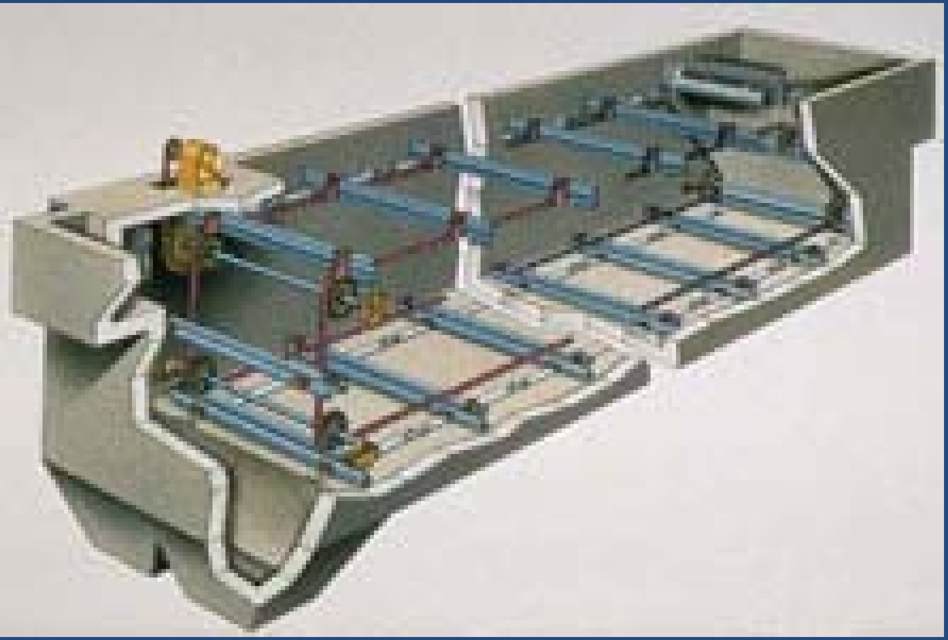




North Plant
Plainfield, CT
Drover Process®

Drover Process®

Convert Primary Clarifiers to pre-Anoxic tanks (MLE)



Case Study – Phosphorus Removal
Keene, New Hampshire

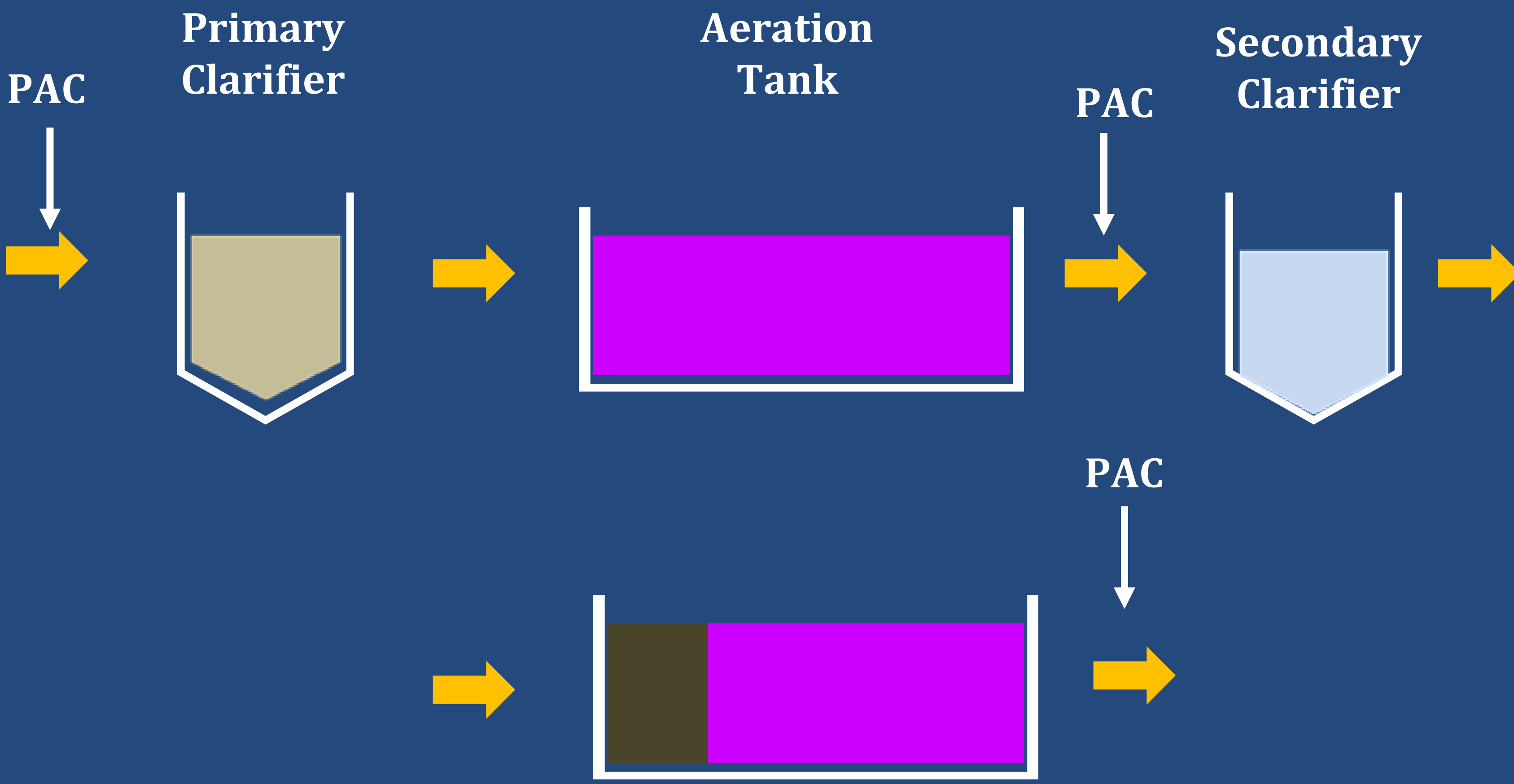
Design Flow: 6.0 MGD
Actual: 3.0 MGD

Effluent total-N

Before & After: 8 mg/L
(3.5 TKN, 1.5 Ammonia, 4.5 Nitrite + Nitrate)

Effluent total-P

Before Changes: 3.0 mg/L
After Changes: 0.2 mg/L



Keene, New Hampshire

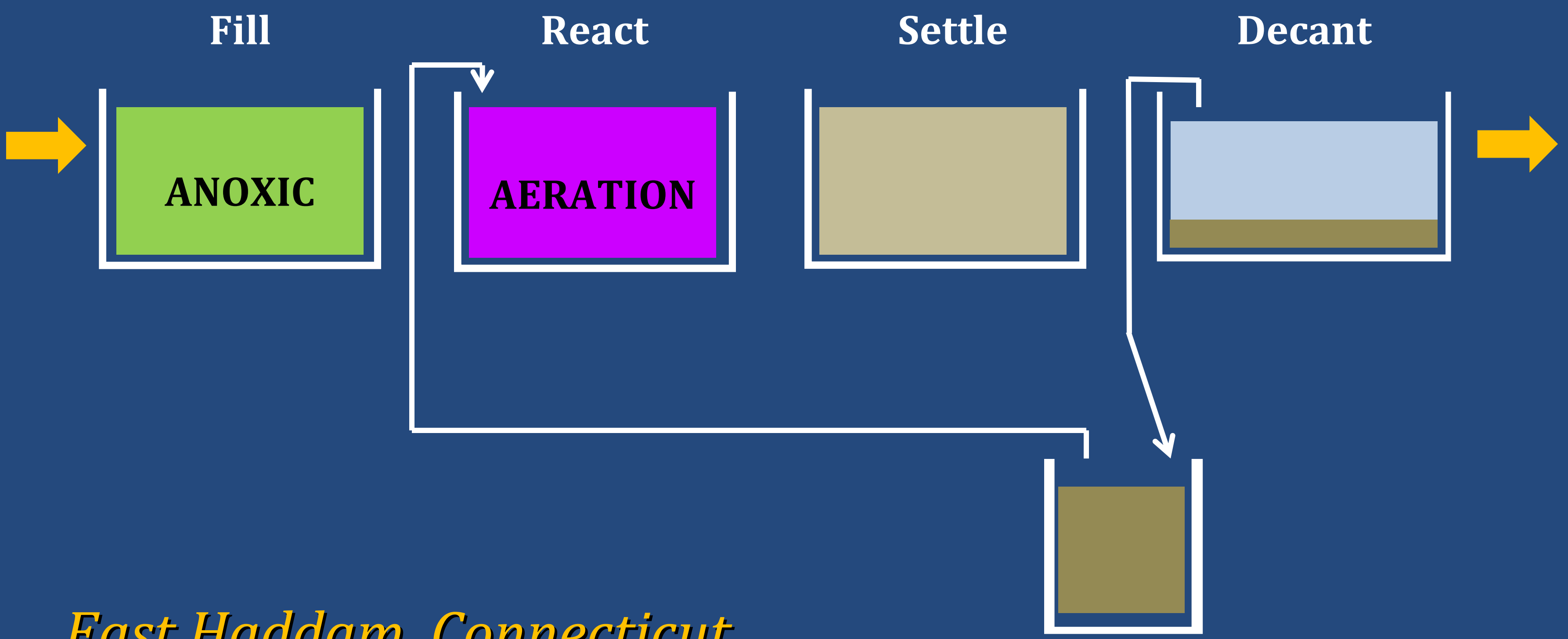
Keene, New Hampshire

Case Study – Phosphorus Removal East Haddam, Connecticut

Design Flow: 0.055 MGD
Actual: 0.015 MGD

Effluent total-N
- Before & After: 6.5 mg/L
- (2 TKN, 0.5 Ammonia, 3.5 Nitrite + Nitrate)

Effluent total-P
- Before Changes: 3-4 mg/L
- After Changes: 0.35 mg/L



East Haddam, Connecticut

East Haddam, Connecticut

Case Study – Nitrogen Removal
East Hampton, Connecticut

Design Flow: 2.0 MGD
Actual: 1.5 MGD

Effluent total-N

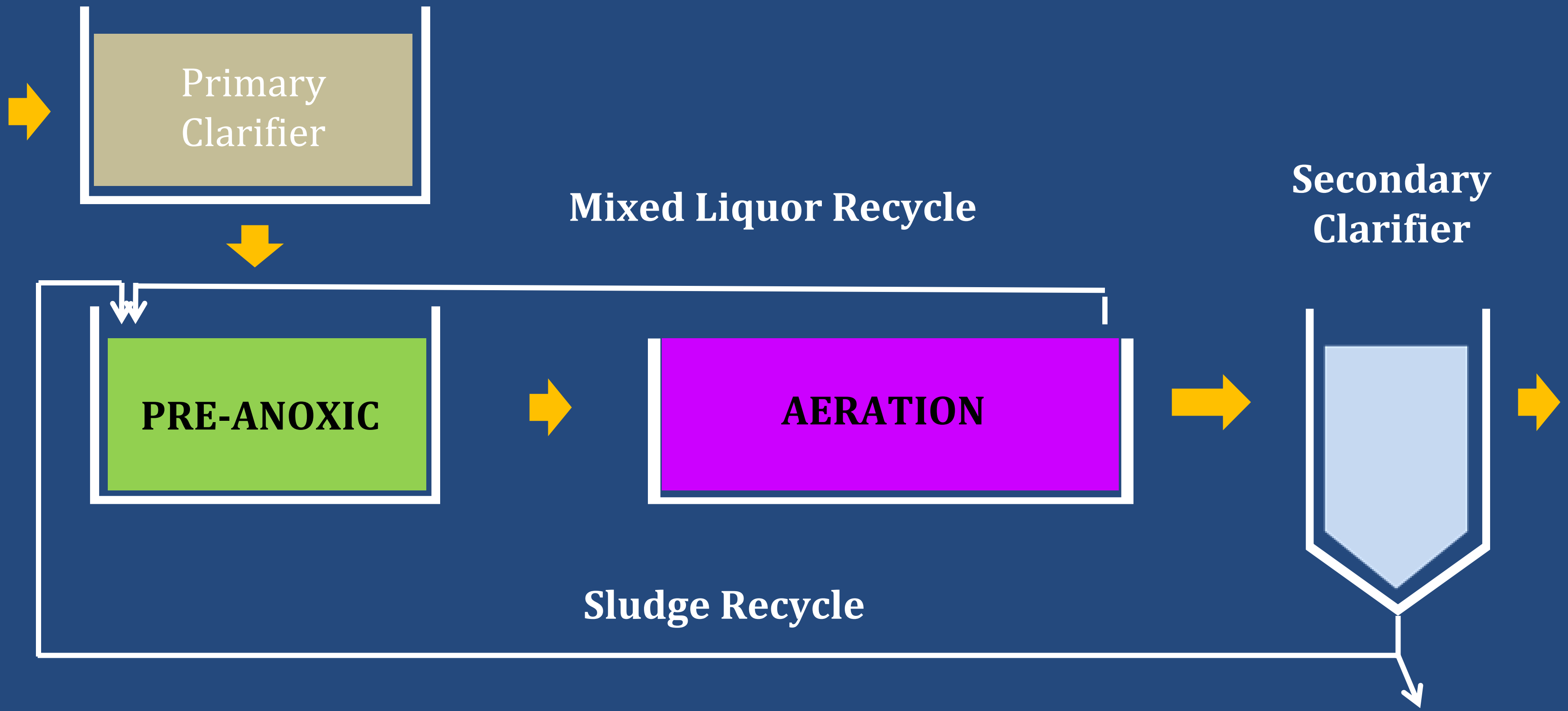
Before Changes: 11 mg/L
(2 TKN, 0.5 Ammonia, 9 Nitrite + Nitrate)

After Changes: 6 mg/L
(2 TKN, 0.2 Ammonia, 4 Nitrite + Nitrate)

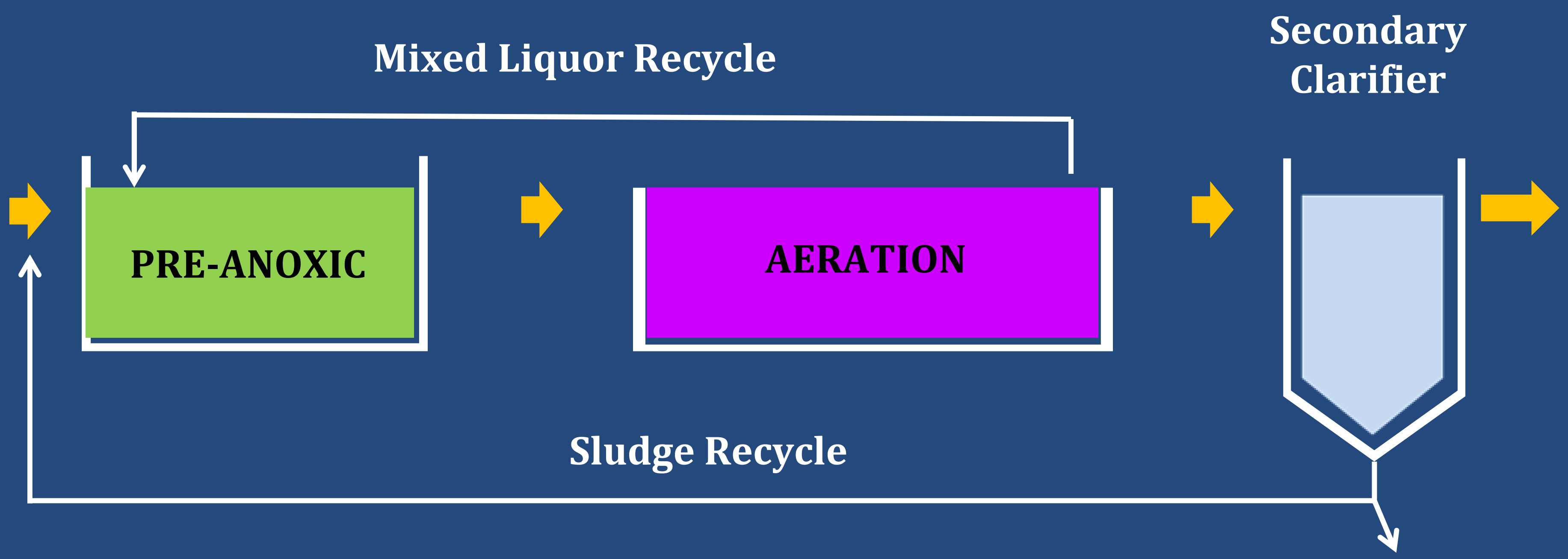
Effluent total-P

Before & After: 1-3 mg/L

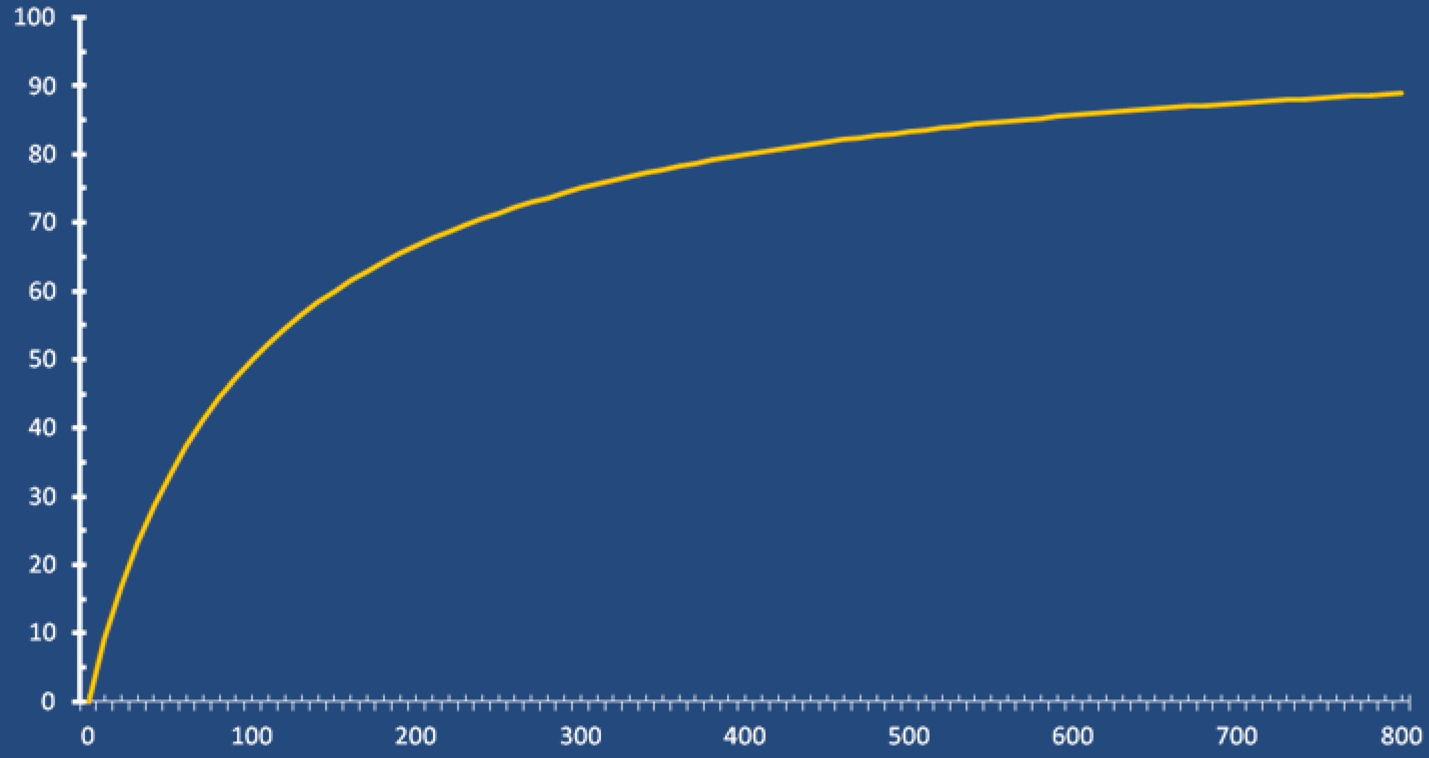
East Hampton, Connecticut

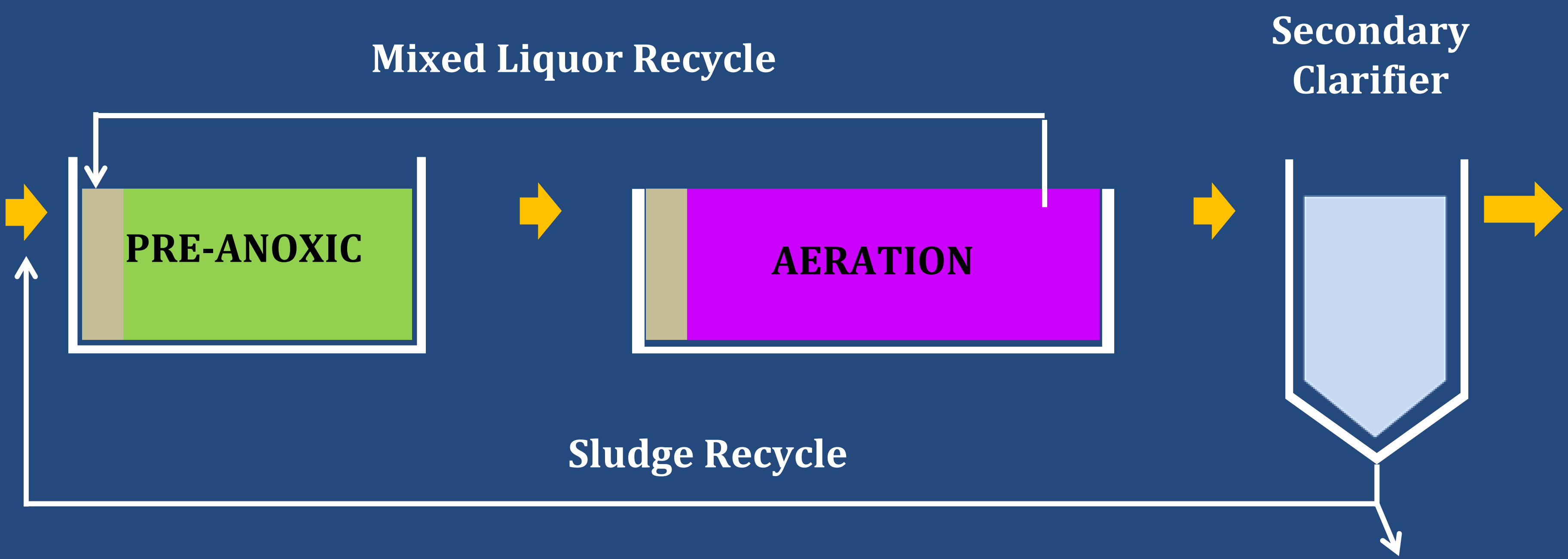


East Hampton, Connecticut

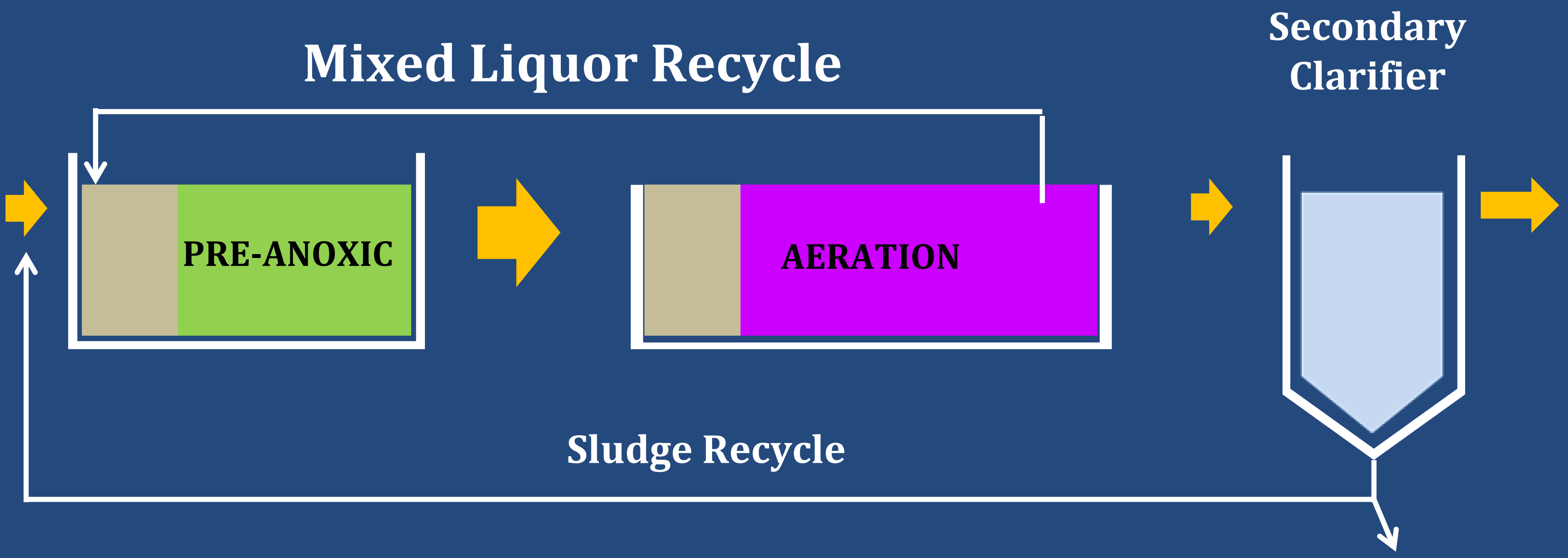

Mixed Liquor Recycle
Secondary
Clarifier
PRE-ANOXIC
AERATION
Sludge Recycle

Percent Nitrate Removal as Recycle Pump Rate Increases



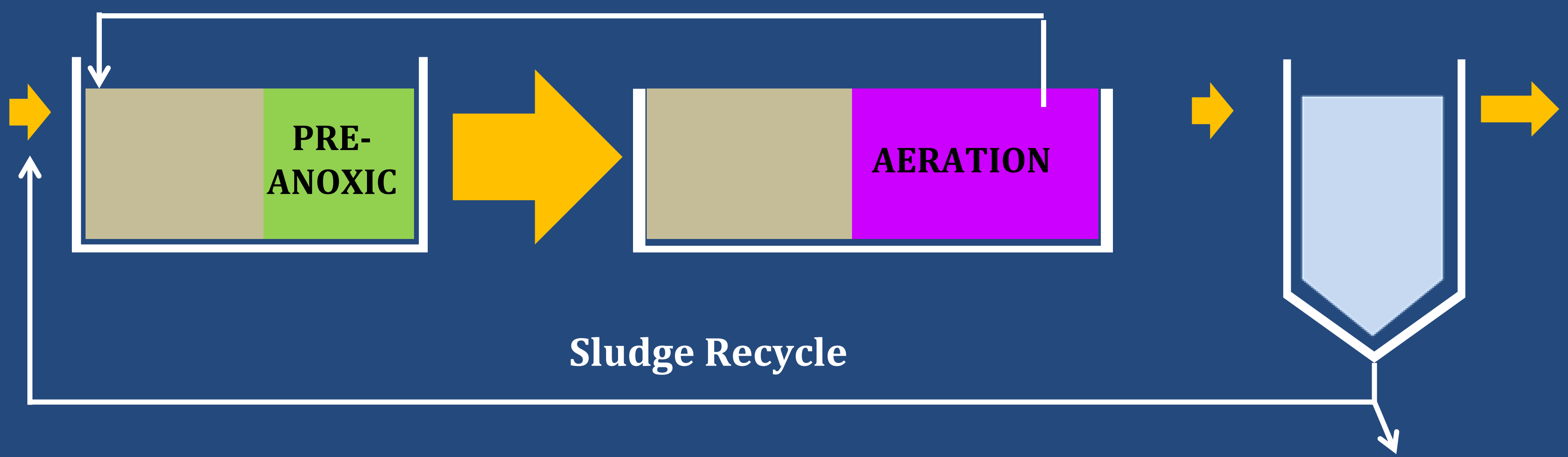


Water Planet's Observation
100% Recycle Rate



200% Recycle Rate

Mixed Liquor Recycle



300% Recycle Rate

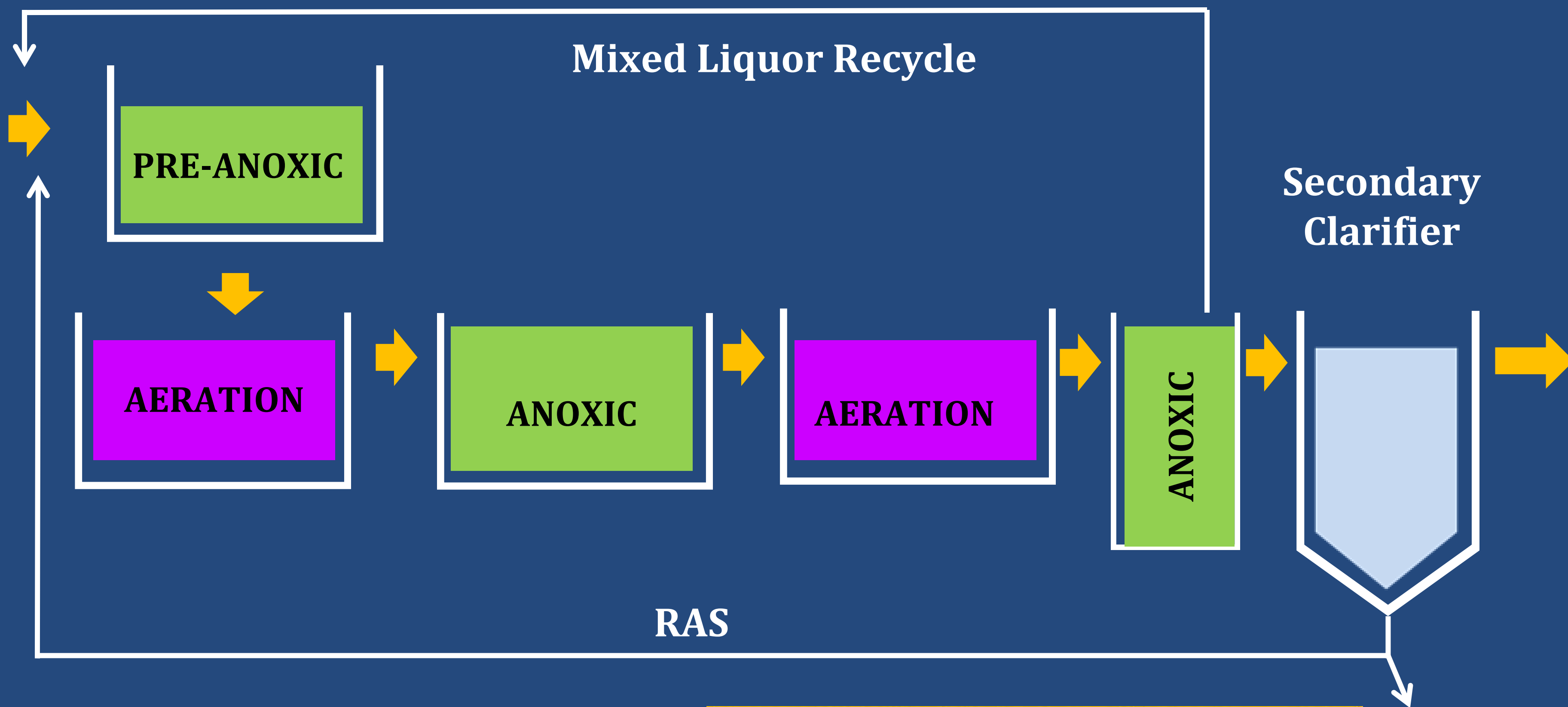
Case Study – Nitrogen & Phosphorus Removal Suffield, Connecticut

Design Flow: 2.0 MGD
Actual: 1.0 MGD

Effluent total-N
- Before Changes: 7 mg/L
  (3 TKN, 0.5 Ammonia, 4 Nitrite + Nitrate)
- After Changes: 2.0 mg/L
  (1 TKN, 0.1 Ammonia, 1 Nitrite + Nitrate)

Effluent total-P
- Before Changes: 3.0 mg/L
- After Changes: 0.7 mg/L

Suffield, Connecticut



Suffield, Connecticut

Re-Engineering O&M for Nitrogen & Phosphorus Removal

- Oxygen-Rich, low BOD environment
  - Nitrogen
    - Ammonia Removal – Nitrification
  - Phosphorus
    - Dissolved Oxygen converted to TSS (particulate Phosphorus)
- Oxygen-Poor, high BOD environment
  - Nitrogen
    - Nitrate Removal – Denitrification
  - Phosphorus
    - Volatile Fatty Acid (VFA) production; if anaerobic/fermentative
- TSS Removal
  - Nitrogen
    - 12% of MLSS is Nitrogen (8 mg/L TSS = 1 mg/L total-N)
  - Phosphorus
    - 3-5% of MLSS is Phosphorus (2 mg/L TSS = 0.1 mg/L total-P)

Questions, Comments, Discussion

THE WATER PLANET COMPANY

Making clean water affordable