evoQUA

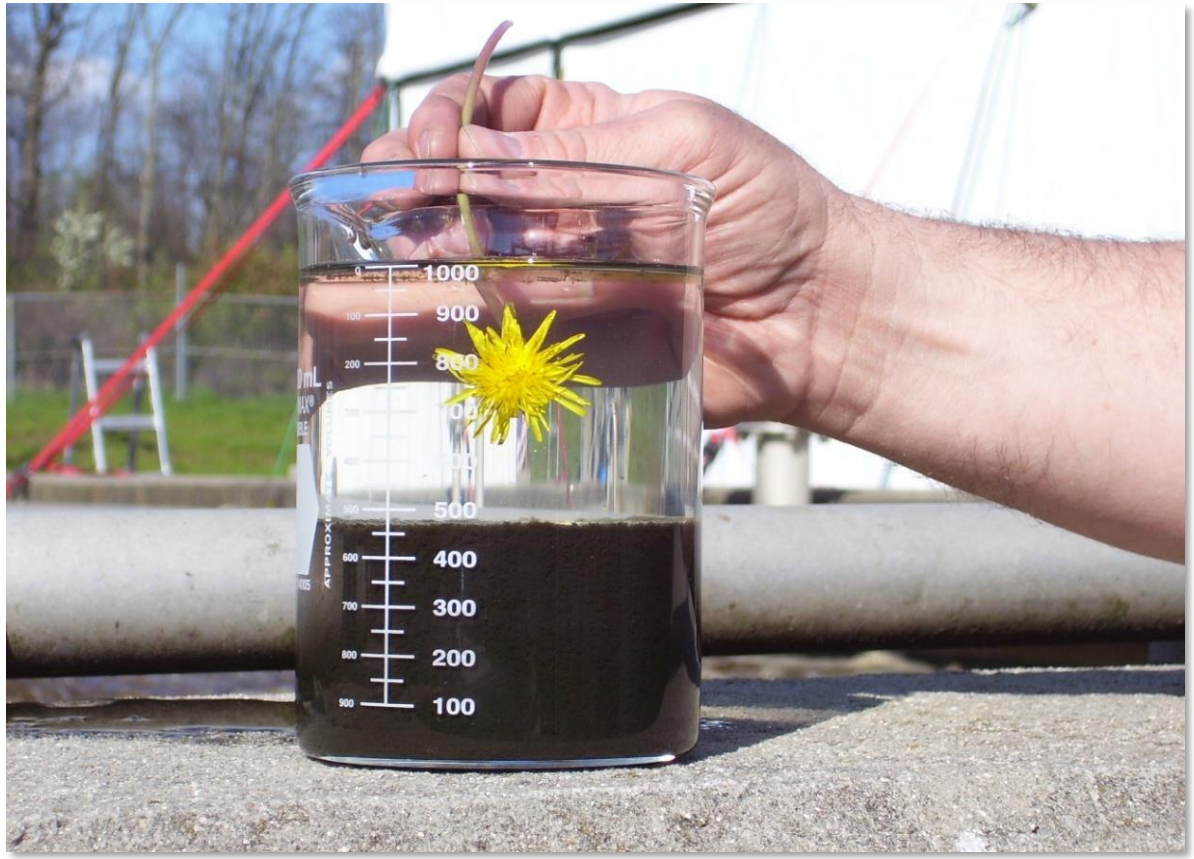
WATER TECHNOLOGIES

BIOMAG® SYSTEM

ADVANCED SEPARATION

Agenda

Advanced Separation Overview



- Ballasted Systems & Magnetite
- BioMag® System & Equipment
- Installations and Benefits
- Questions and Answers

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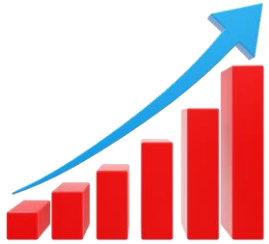
WATER TECHNOLOGIES

Evoqua Water Technologies

BioMag® System Drivers

Reduce Footprint

Increase Capacity



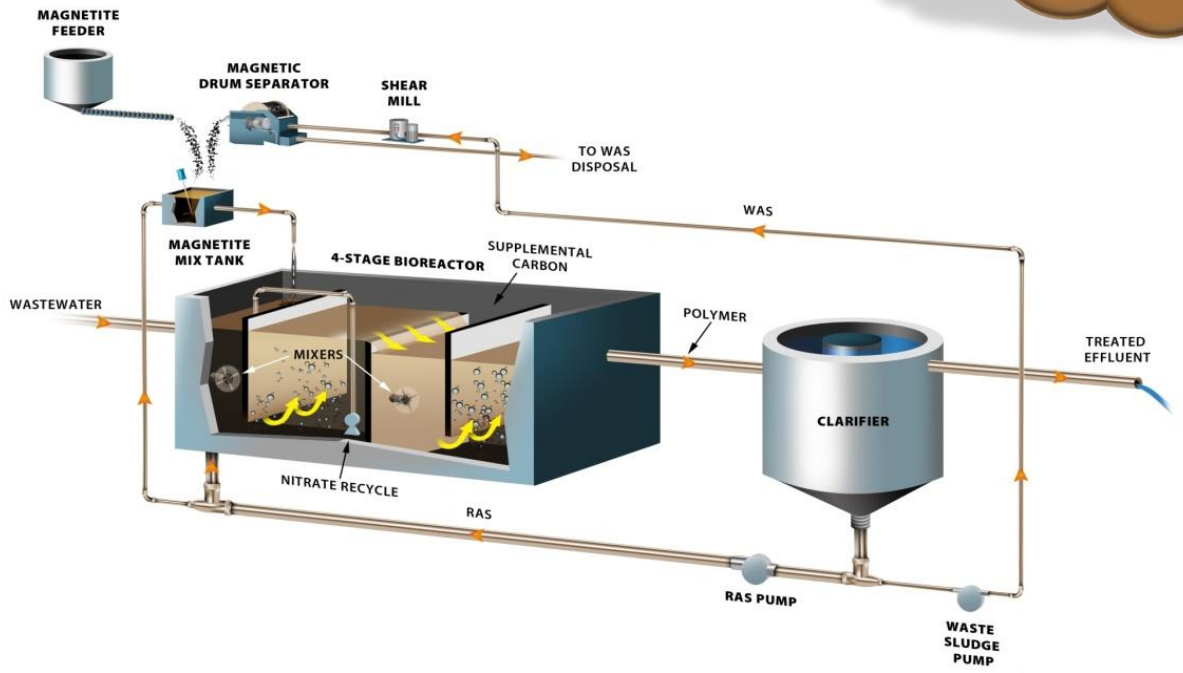
Enhance Stability & Balance

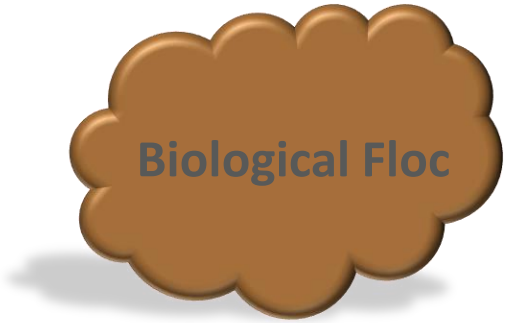
Improve Performance

EVOQUA WATER TECHNOLOGIES

BioMag® System

Advanced Biological Treatment

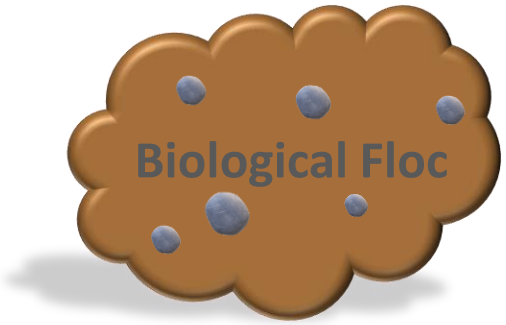


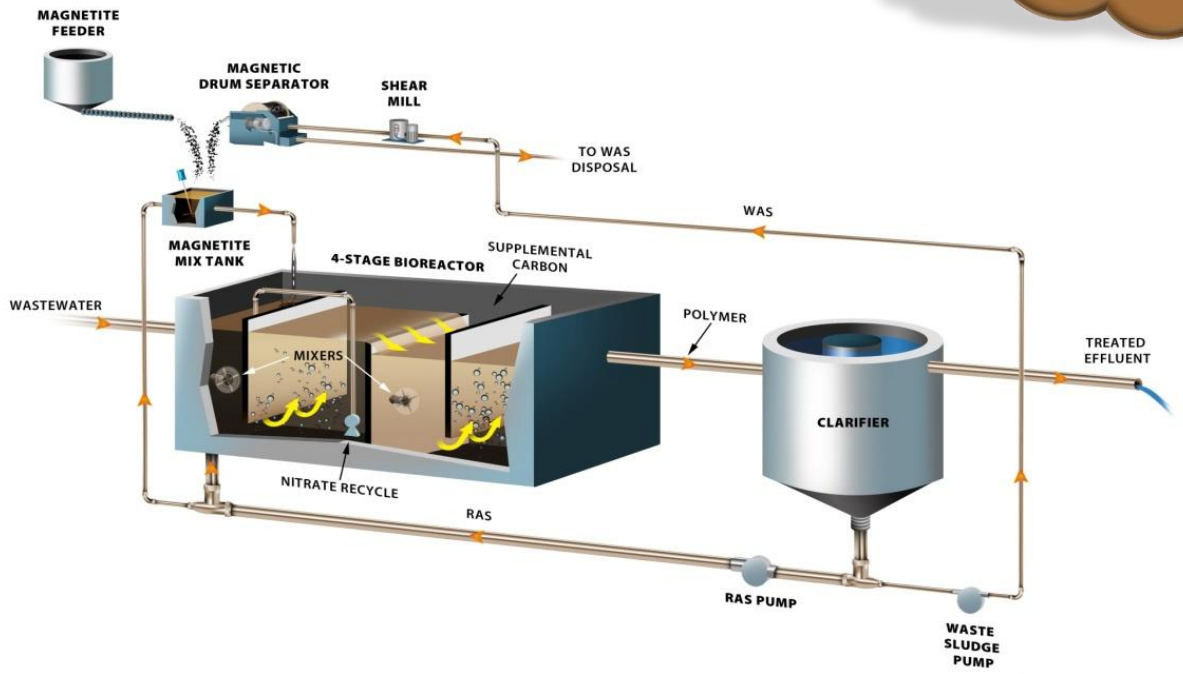


Magnetite Particles

BioMag® System

Advanced Biological Treatment





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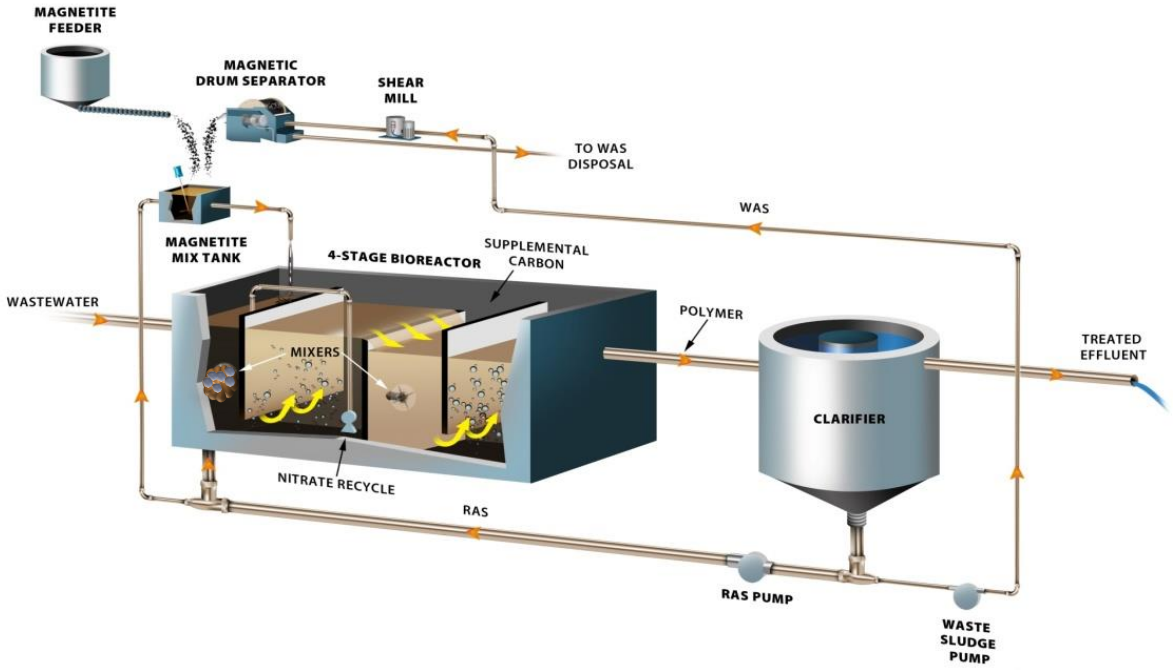


Intensification Process

Benefits

- More flow & load
- Better treatment
- Better use of tankage

Implementation

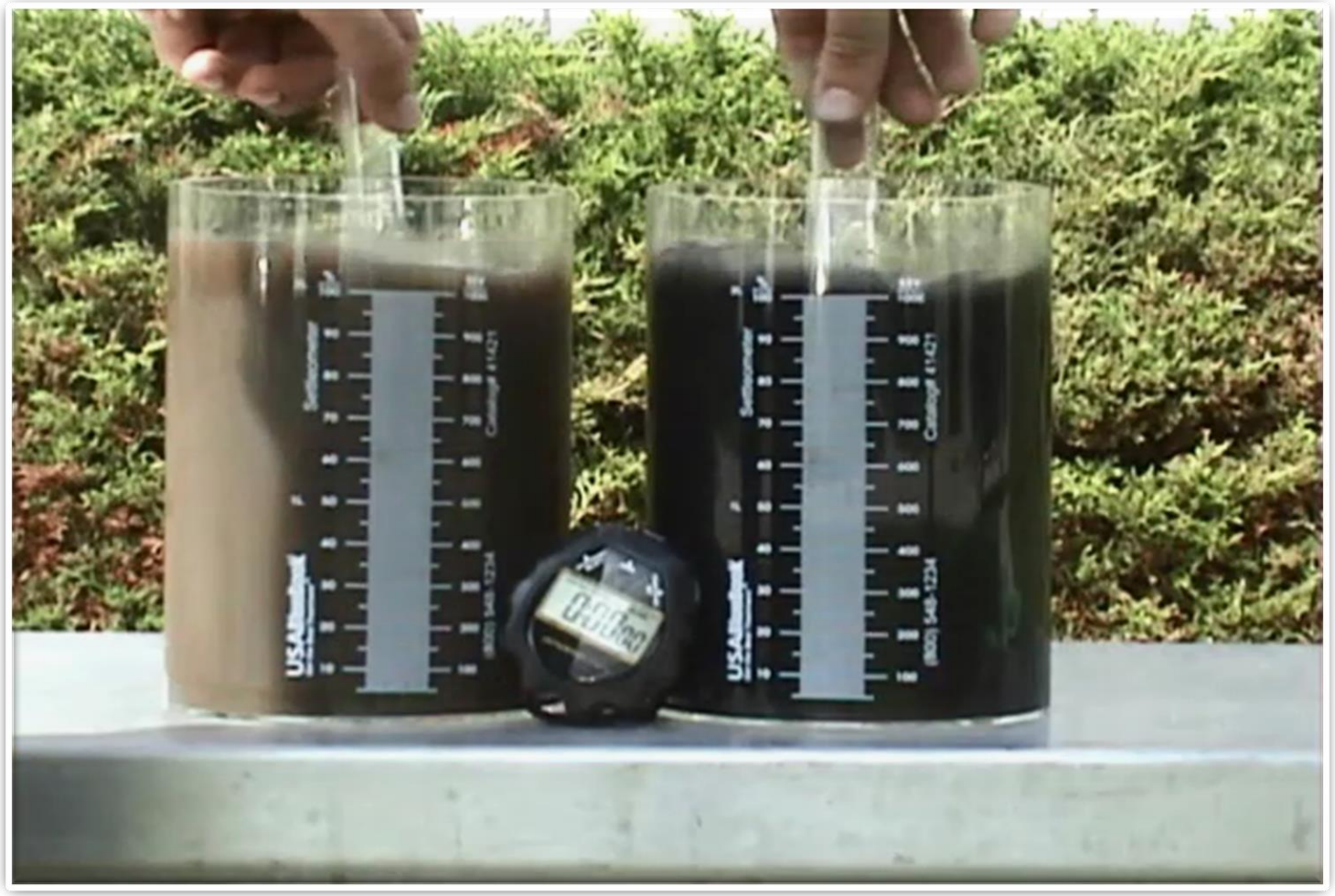
- Retrofit
- Green field plants

Advanced Separation - BioMag® Settling

Embrace Gravity

Conventional

Ballasted



Advanced Separation Timeline

How did we get here?

1999 — CoMag® System Concept

Based on a concept used for decades in coal cleaning processes, the ballasted settling idea is generated, and pilot plant discussions begin

2002 — Concept Demo Plant

The concept pilot is started at Concord MA WWTP with oversight and guidance from top engineering firms

2005 — BioMag® System Concept

With a well running pilot for chemical floc, why not apply this concept to biological floc in an activated sludge system? Ballasting expands into activated sludge.

2008 — BioMag System Full-Scale Pilot

Sturbridge MA pilots BioMag System to help them meet TSS, nitrogen and TP limits.

2010 — 1st BioMag System Install

Allenstown NH BioMag plant comes online as the first BioMag plant to help overcome the shallow 7'SWD secondary clarifiers

2016 — 1st UK Project

Initially with CoMag System but quickly followed with BioMag System the ballasted technologies have become a proven choice for UK utilities

2019 — 1st US DW CoMag System

White Tanks AZ CoMag System drinking water plant comes online as a 33 MGD facility pretreating drinking water

2020 — 100B+ gal treated & 75+ installations

With a variety of plants across municipalities and industrial customers, the technologies growth and acceptance continues to evolve

CoMag System

BioMag System

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Advanced Separation - Two products, One Ballast

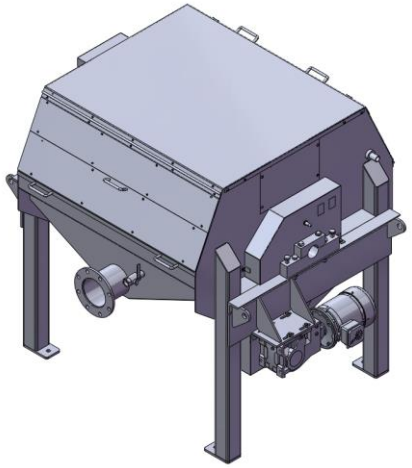
Ballast is added to improve the specific gravity of floc, to more efficiently use gravitational separation

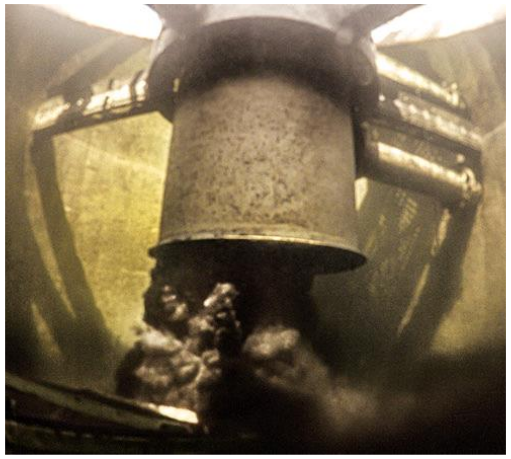
Commonalities

- Magnetite is added as a ballast
- Magnetite ratio is monitored
- Magnetite is recovered for reuse
- Resultant floc is much heavier and settles more reliably

Differences

- **Bio**Mag® System targets activated sludge systems
- **Co**Mag® System targets chemical floc systems





Ballast

Magnetite

- Chemical formula: Fe_3O_4

  Inverse spinel compound – highest state of oxidation

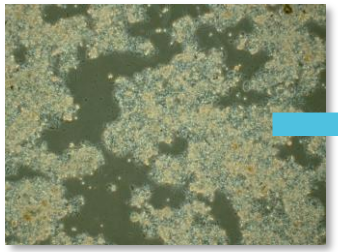
- High specific gravity: 5.2

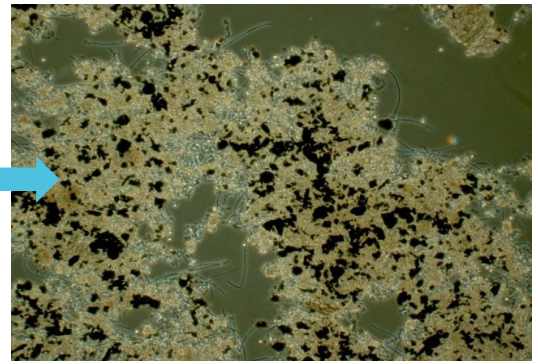
  Water: 1.0, Sand: 2.6, Lead: 11.34, Gold: 19.32

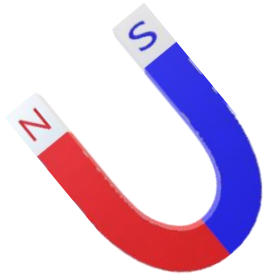
- Small particles: 10-40 µm

  Talcum power: ~26.5 µm, human hair: ~50 µm

- Readily available & Inexpensive
- Inert & NSF certified for drinking water use
- Magnetically recoverable







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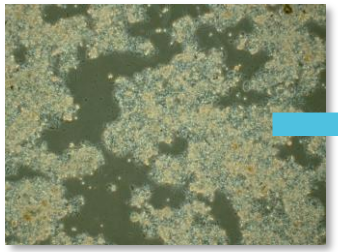

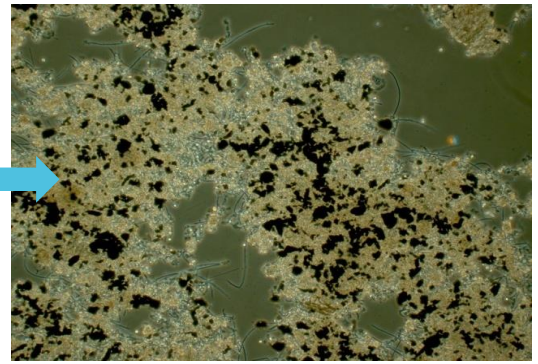

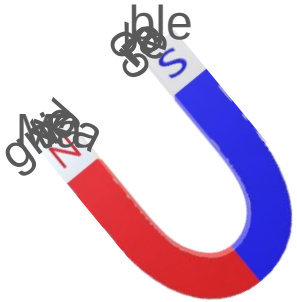

Ballasted Systems

The Keys to implementing and running a successful ballasted system

Add it!

Measure it!

Recover & Reuse it!

Ballast Feed

KEY 1 – Add it!

Conveying

- Manually
- Auger system
- Pneumatically

Magnetite Measuring & Ratios

KEY 2 – Measure it!

Meter

- Instantaneous readout on local LCD
- Can be setup for remote monitoring
- Benchtop or inline measuring
- ~30 seconds to complete test

BioMag® System

- Magnetite:CAS = 1:1 Ratio
- Secondary measuring = %VSS (TSS:VSS ratio)

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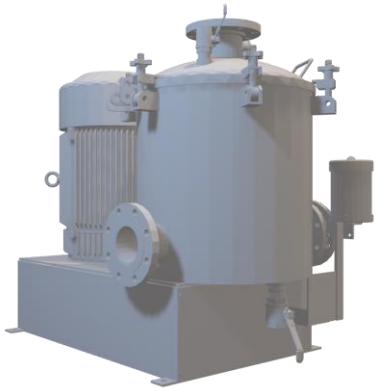
Recover & Reuse

KEY 3 – Recover & Reuse

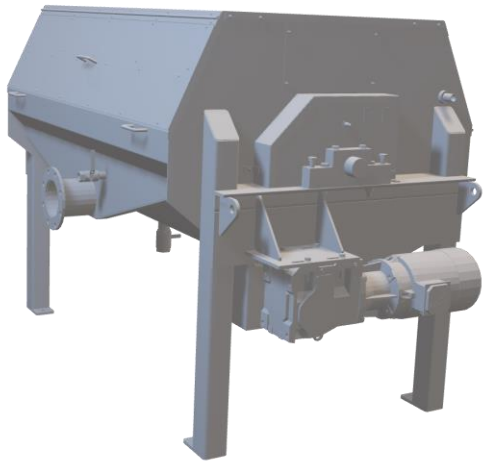
Step 1

- A shear device is used to liberate the magnetite from the floc before separation



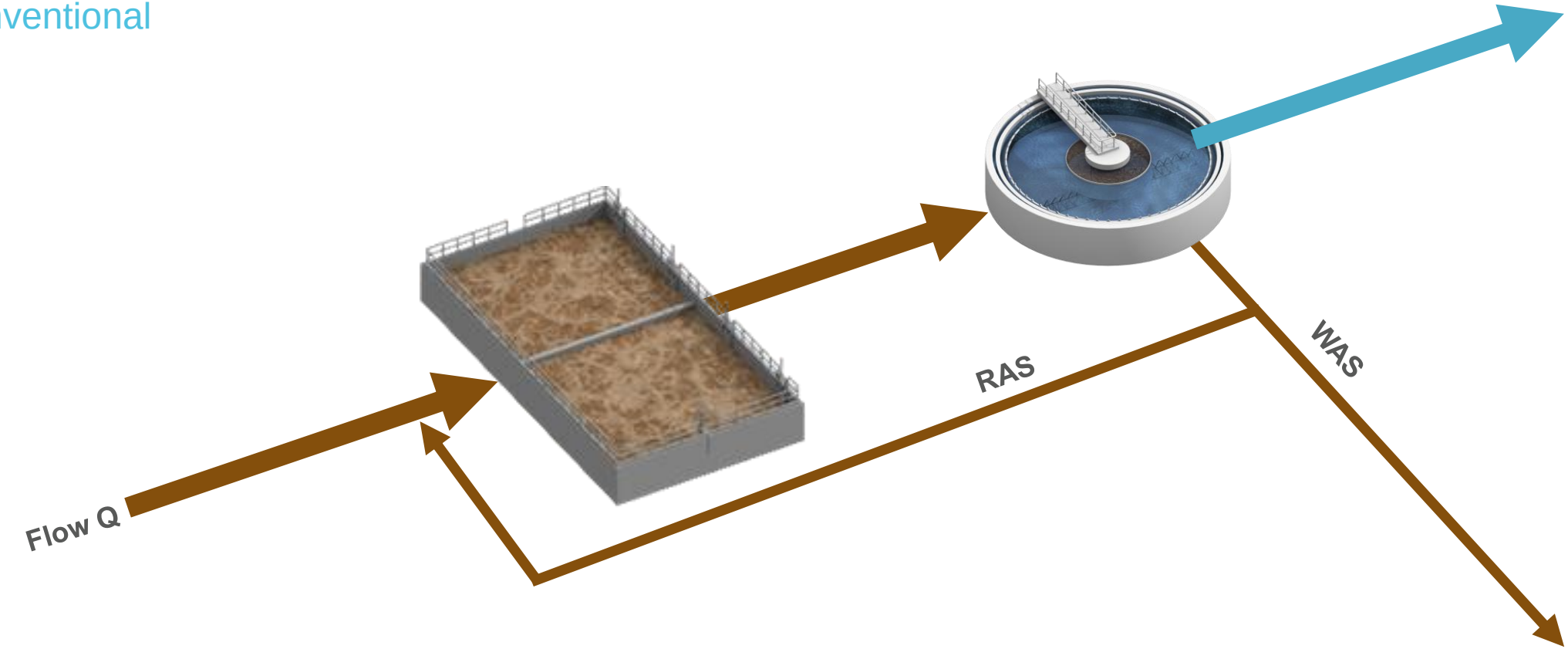
Step 2

- Magnetic Recovery Drum is utilized to recover the magnetite from the waste liquid for reuse



Process Flow Diagram

Conventional



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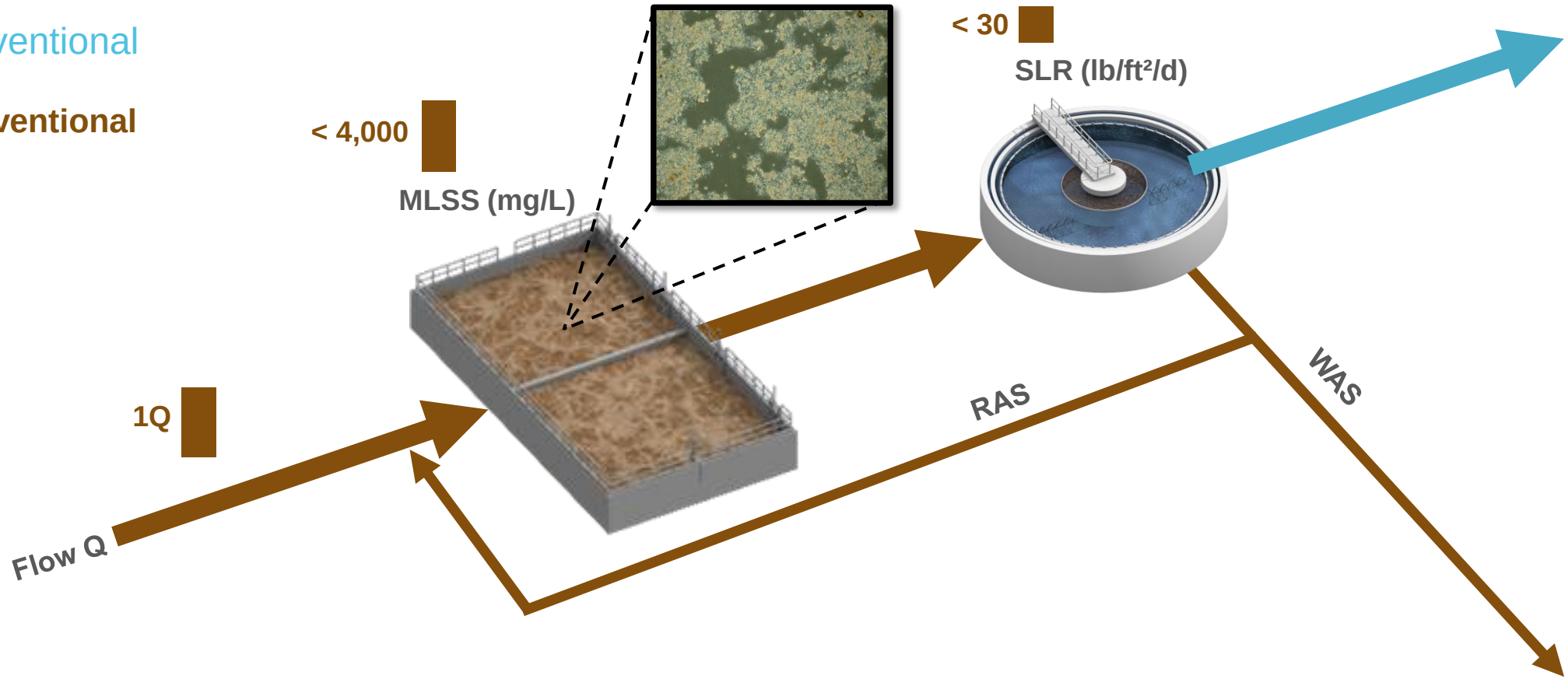
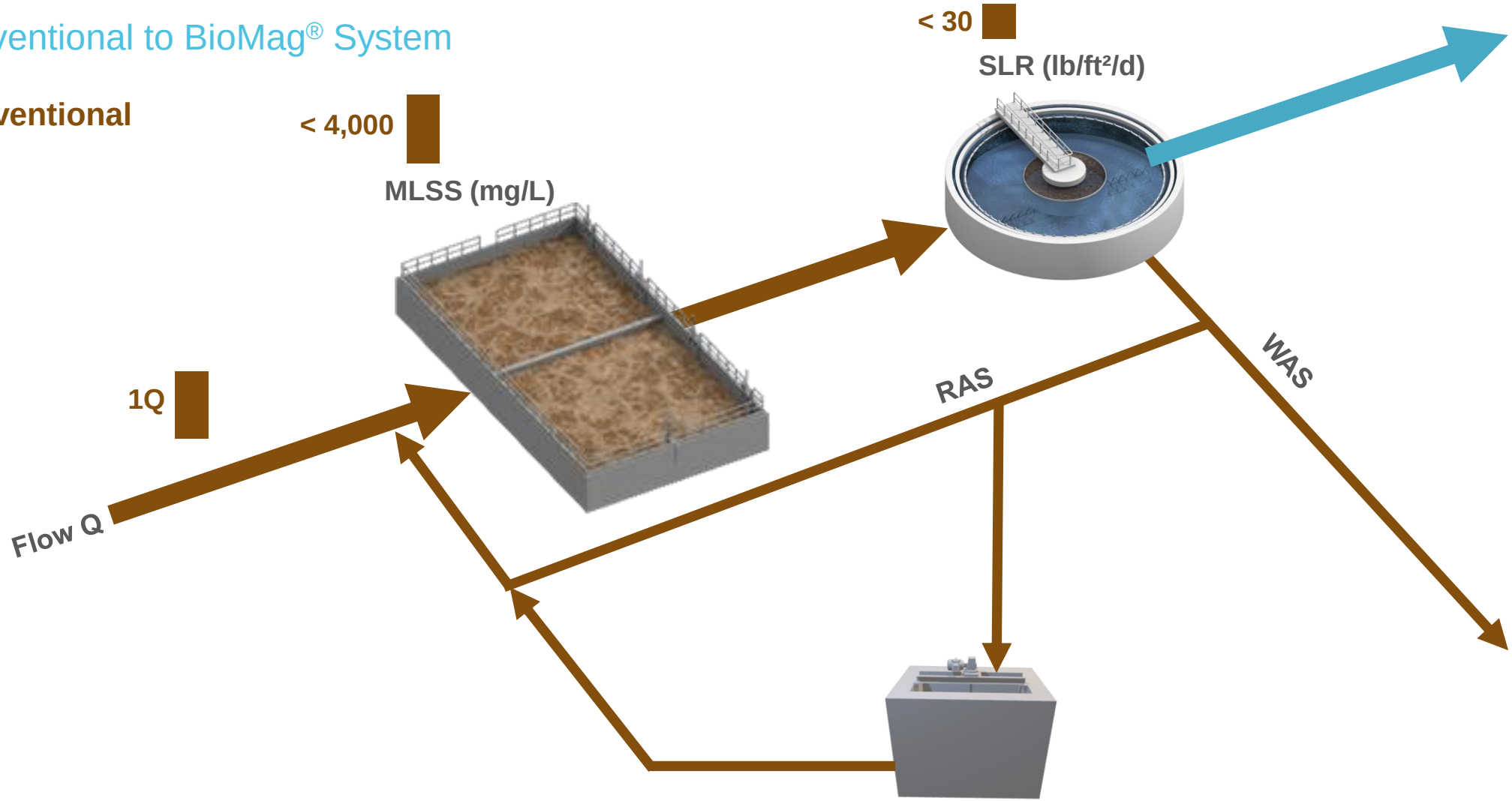


Process Flow Diagram

Conventional to BioMag® System



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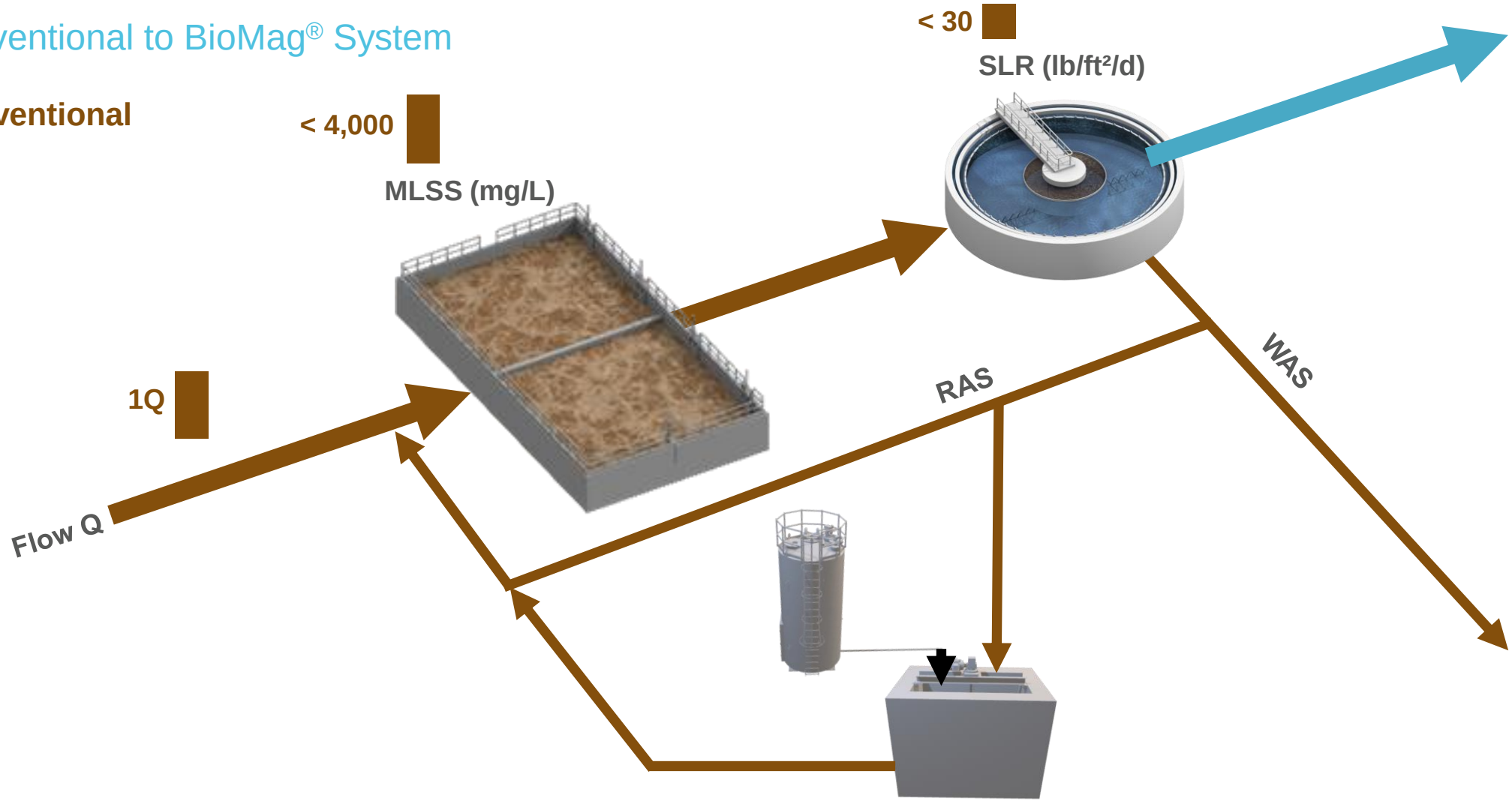

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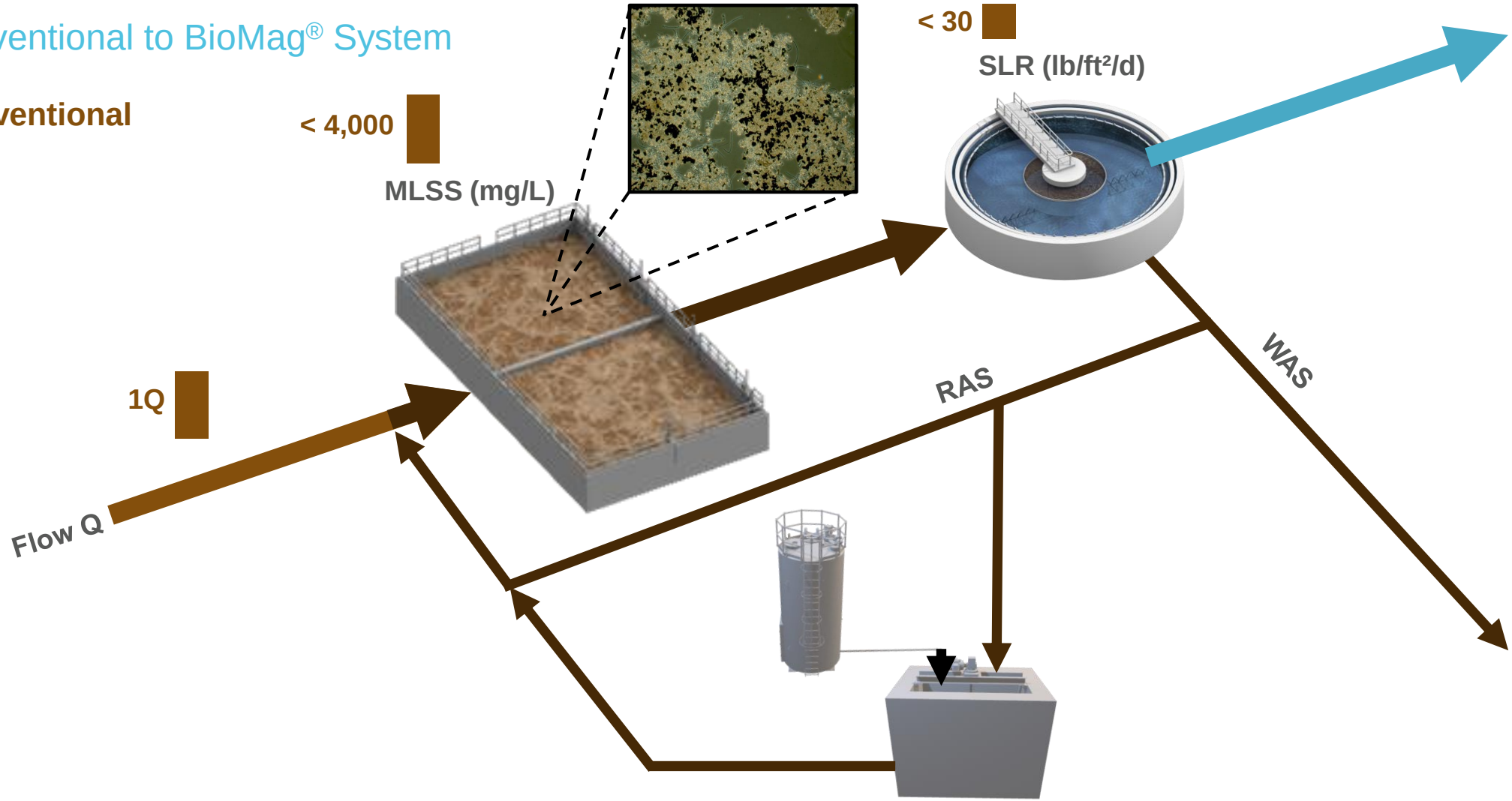

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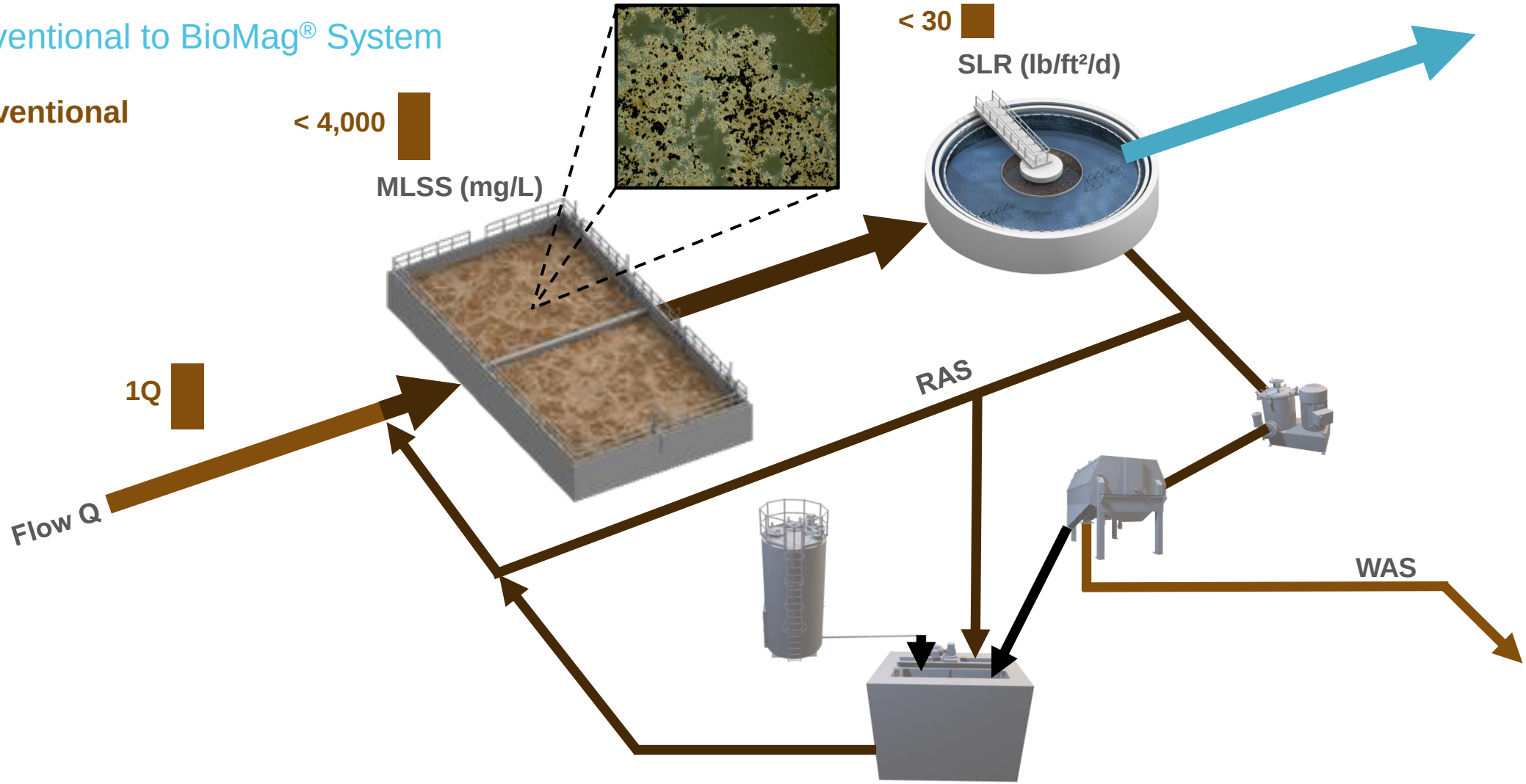

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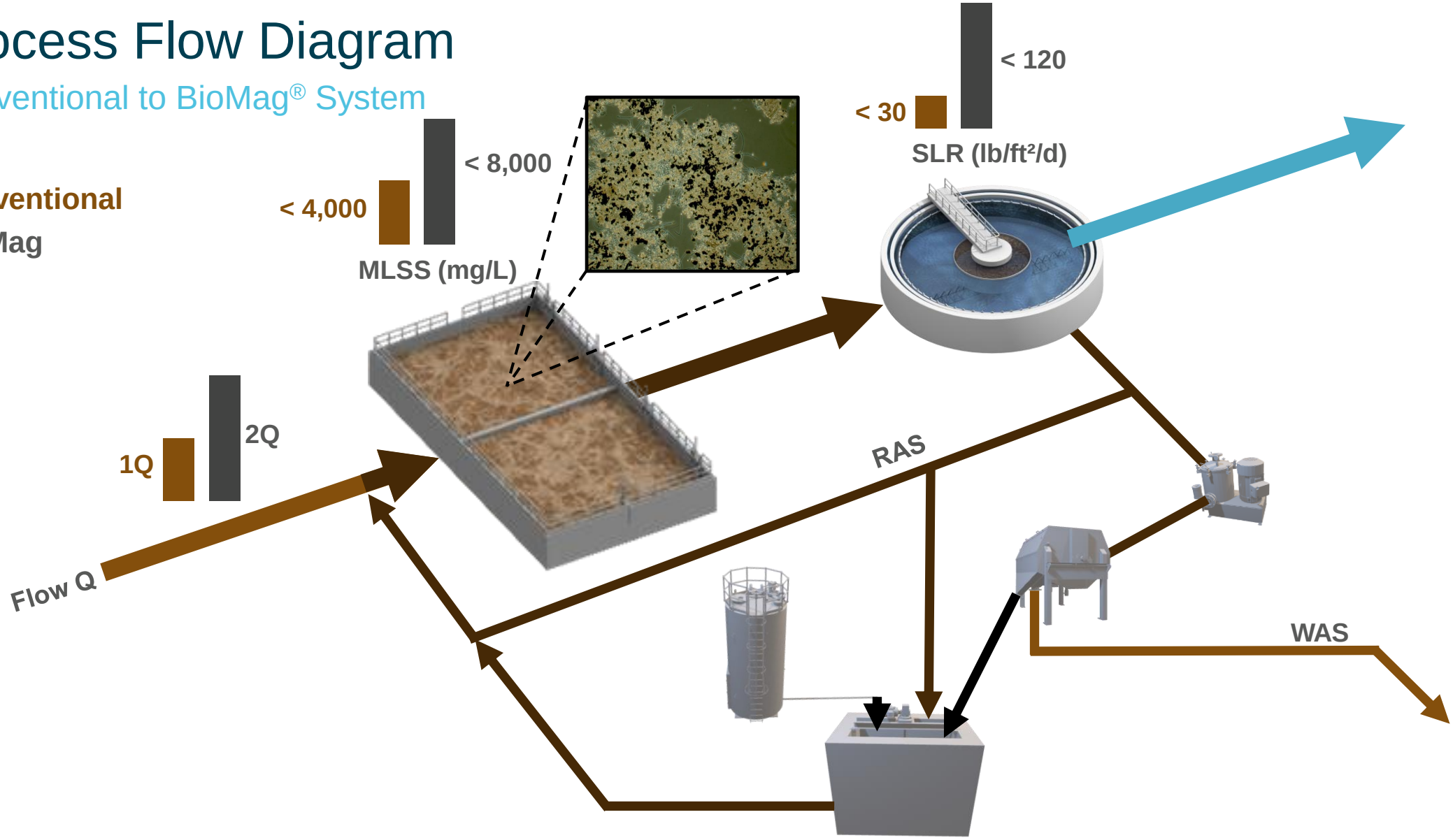


BioMag® System - Compatibility

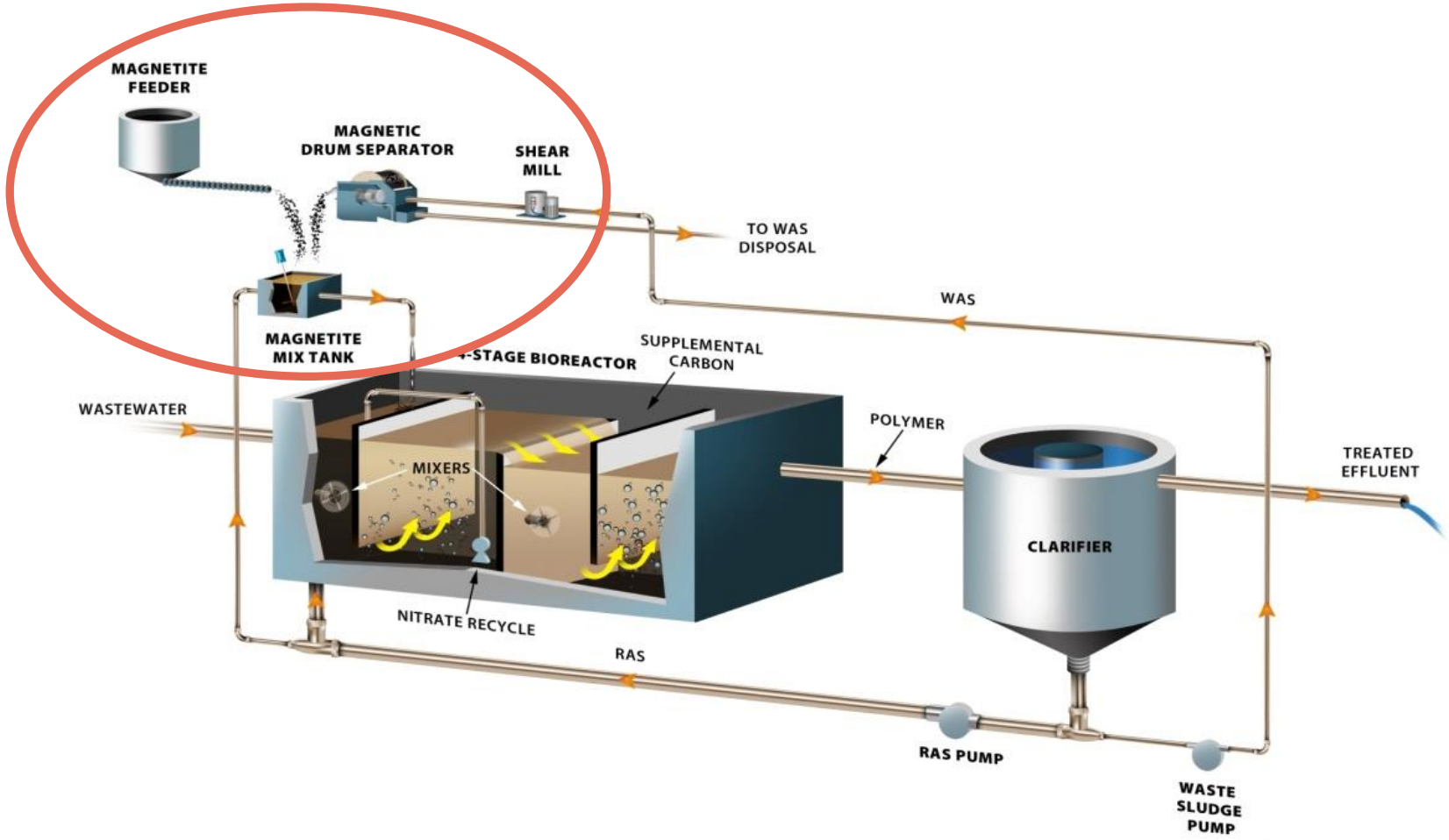
Activated Sludge

Process	Clarifier	Aeration	Pumps
Complete Mix	Plow Scraper	Fine Bubble	Centrifugal
Plug Flow	Spiral Scraper	Coarse Bubble	Submersible
Oxidation Ditch	Tow Bro Suction Header	Surface Aerators	Rotary Lobe
Multistage BNR	Chain & Scraper	Jet Aeration	Progressive Cavity
SBR		Hyperbolic	Diaphragm
Attached Growth	**Draft Tube**	✓	✓

EVOQUA WATER TECHNOLOGIES

BioMag® System Equipment

Major Components



Ballast Feed

Add it!

Manually

50 lbs

Automated Bag Feeder

1 Ton

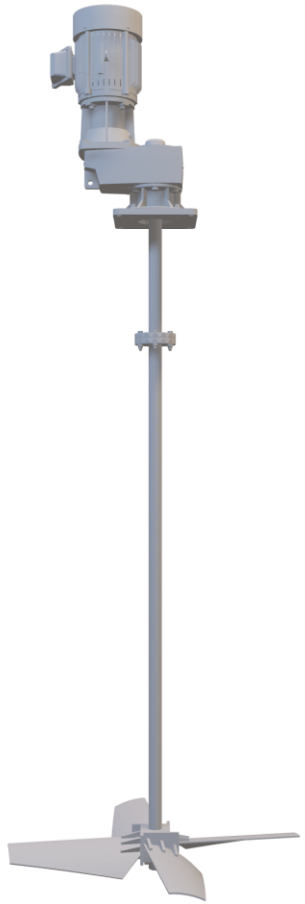
Automated Silo Feeder

25 Ton

Ballast Embedment

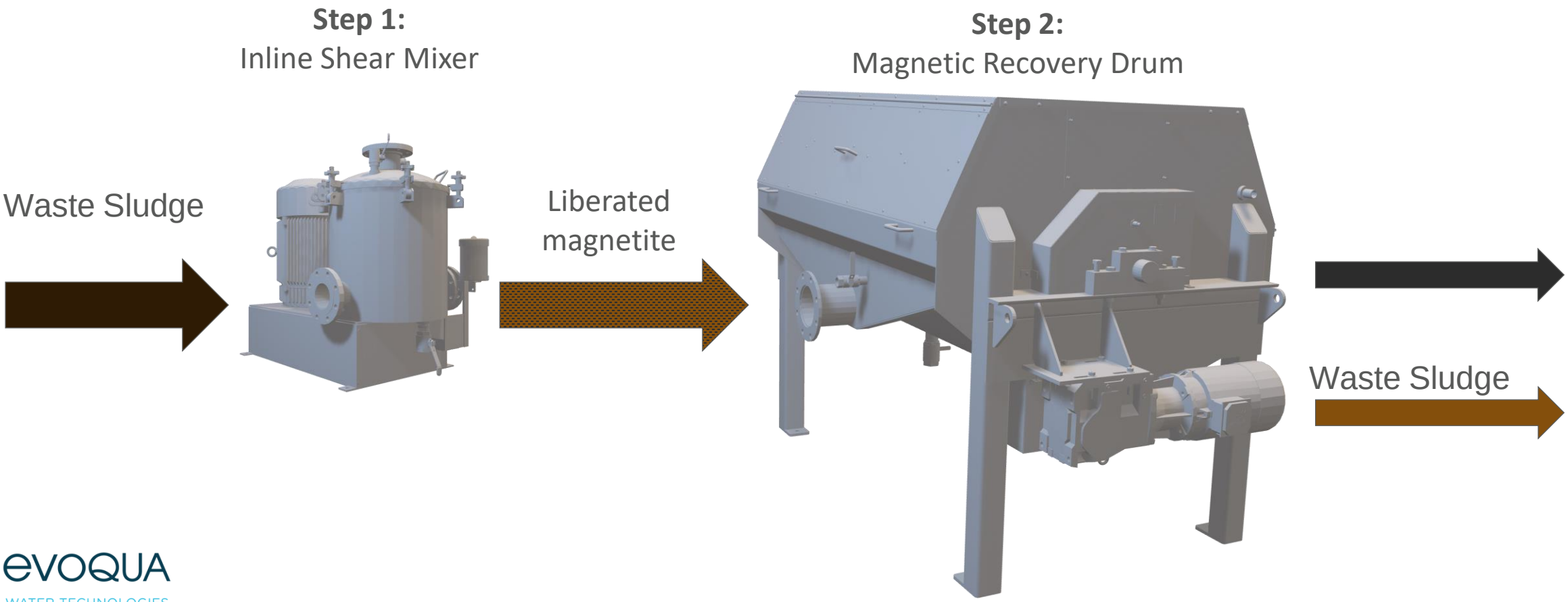
Ballast mix tank ensures contact of magnetite and floc

- Recovered and virgin magnetite
- RAS slip stream
- Ensure contact
- High specific gravity floc returned



Ballast Recovery Equipment

Waste sludge generated is processed through the recovery equipment to recover the magnetite for reuse



EVOQUA WATER TECHNOLOGIES

Ballast Recovery Equipment

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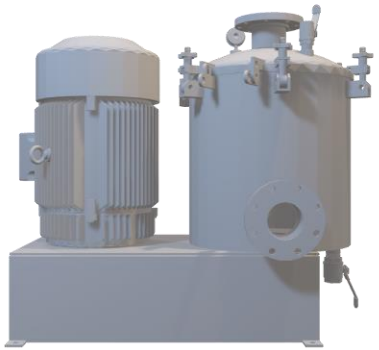
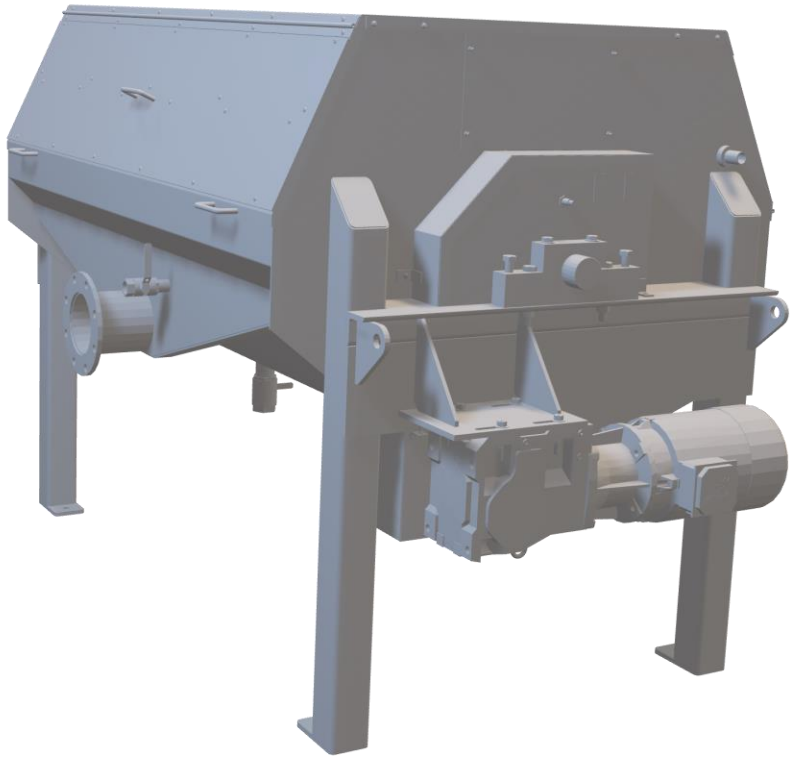
Step 1:
Inline Shear Mixer

Step 2:
Magnetic Recovery Drum

Waste Sludge



Liberated magnetite



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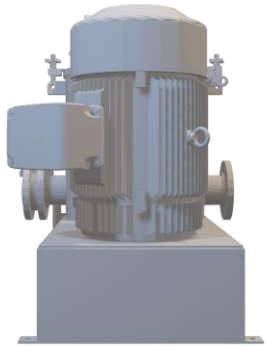

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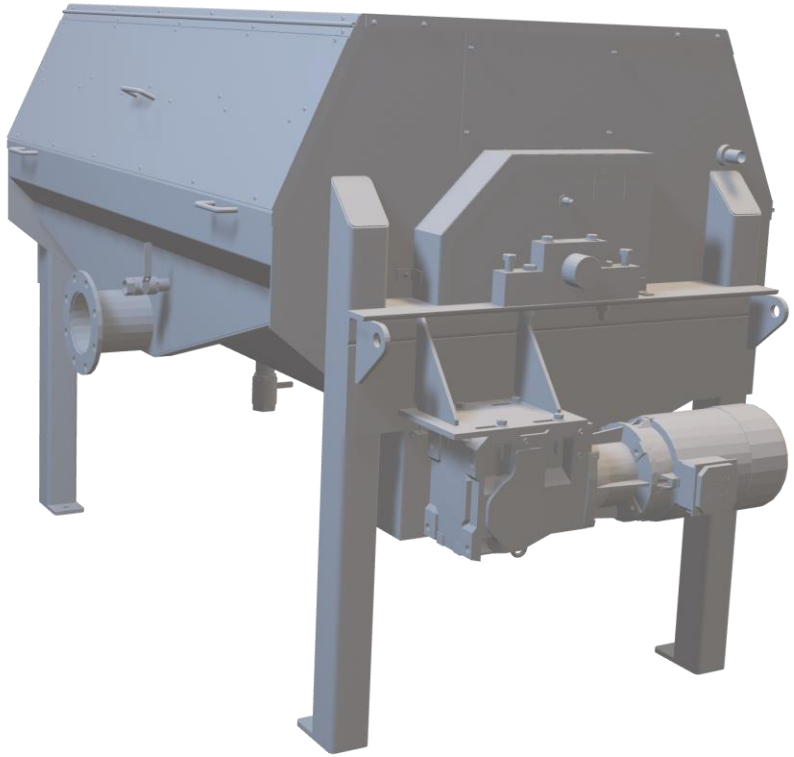

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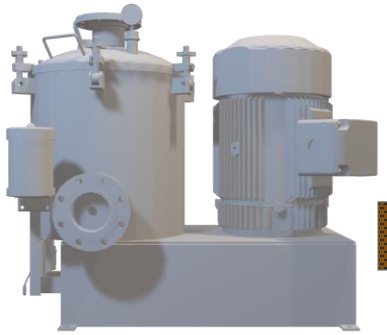

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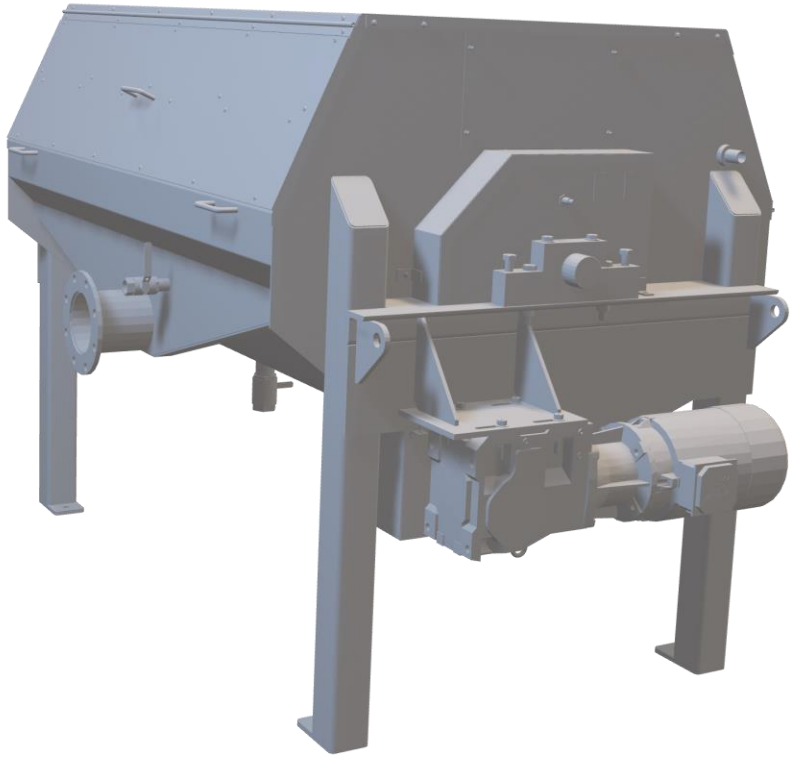

Waste Sludge

EVOQUA WATER TECHNOLOGIES

Ballast Recovery Equipment

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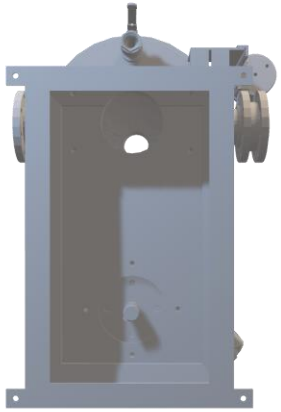
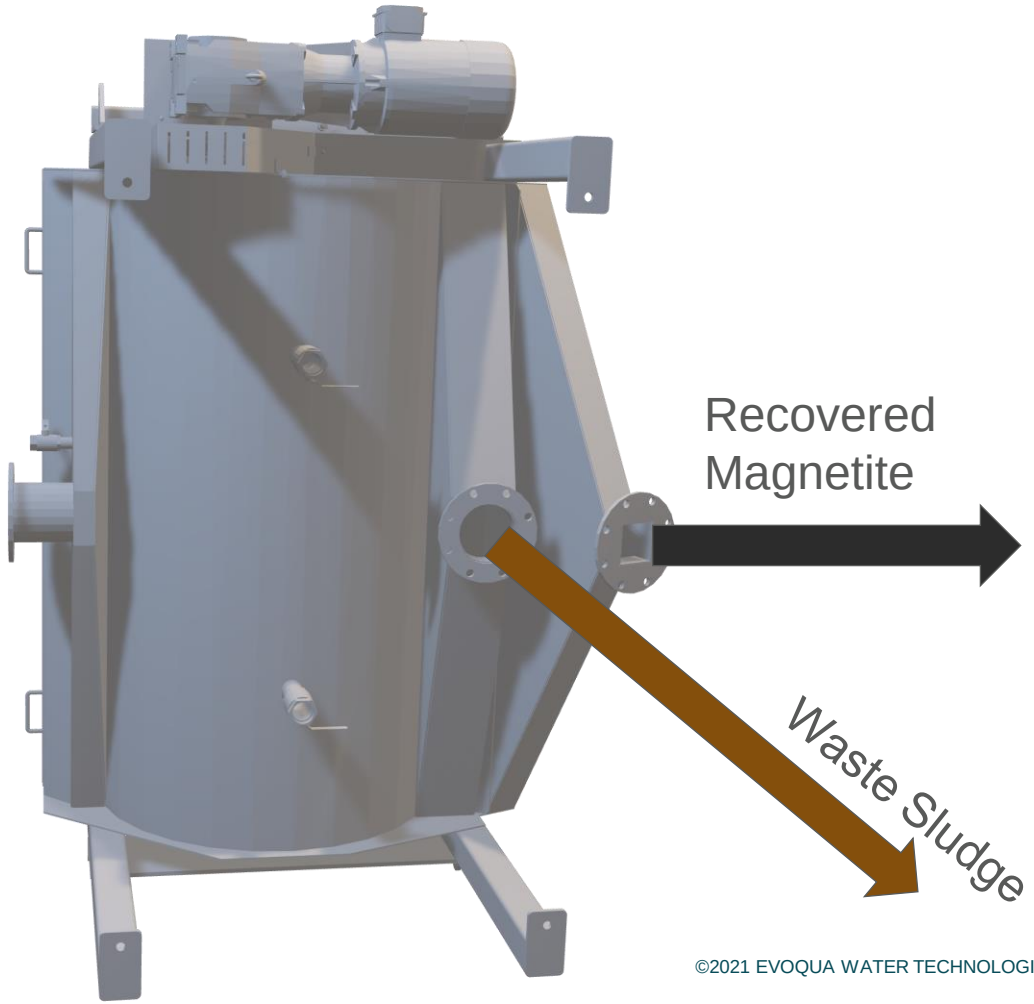


Waste Sludge

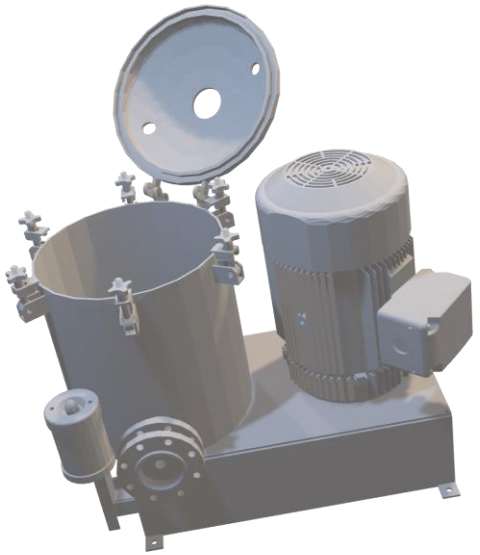
Underflow
waste Sludge



BioMag® System - Shear Mill

High speed rotor & stator designed to liberate the magnetite from the biological floc

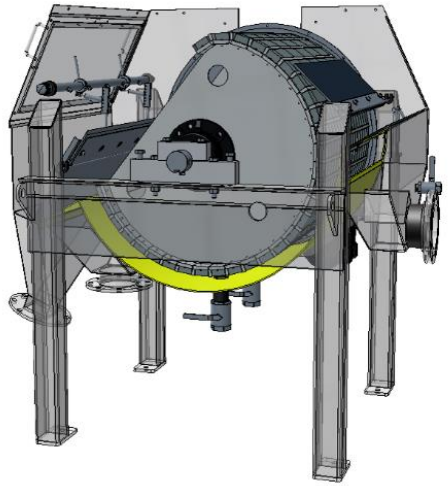
- Simple Rotor-Stator design
  - Rotor rotates
  - Stator stays
- Automatically adjusts speed to optimize power input
- Hinged top lid for cleaning & inspection
- Stainless steel construction of wetted parts for corrosion resistance and long life
- Common belt drive system



BioMag® System – Magnetic Recovery Drums

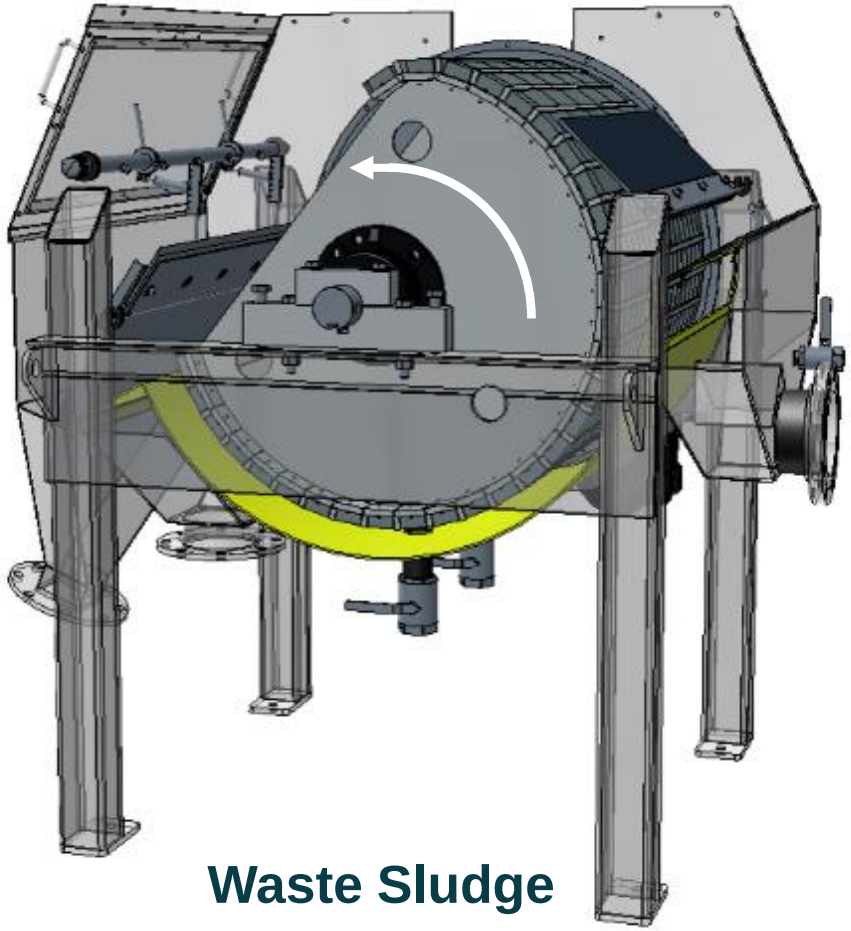
Highlights

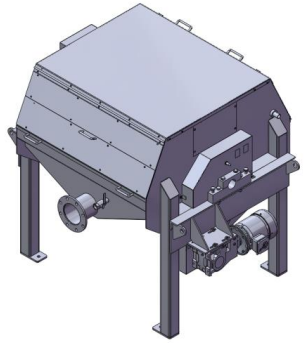
- Proven technology
- Permanent magnets – no service
- Fixed shaft, rotating outer cylinder
- Primarily stainless steel construction
- Simple chain drive



Magnetic Recovery Drum

Deeper Dive





Underflow waste Sludge

Waste Sludge

Recovered Magnetite

EVOQUA WATER TECHNOLOGIES

BioMag® System Recovery

Efficiency leads to process stability

- Recovered from waste sludge
- Sustainable process
- Doesn’t degrade

BioMag Recovery
90-95%

EVOQUA WATER TECHNOLOGIES

BioMag® System Equipment

Housings and Locations

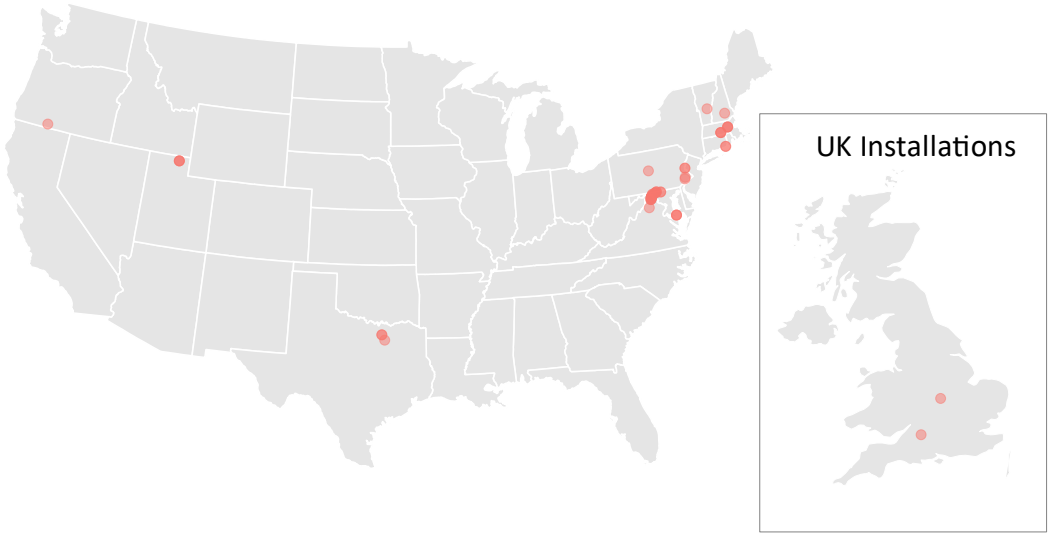
New Construction

Temp Buildings

Repurposed

BioMag® System Installations

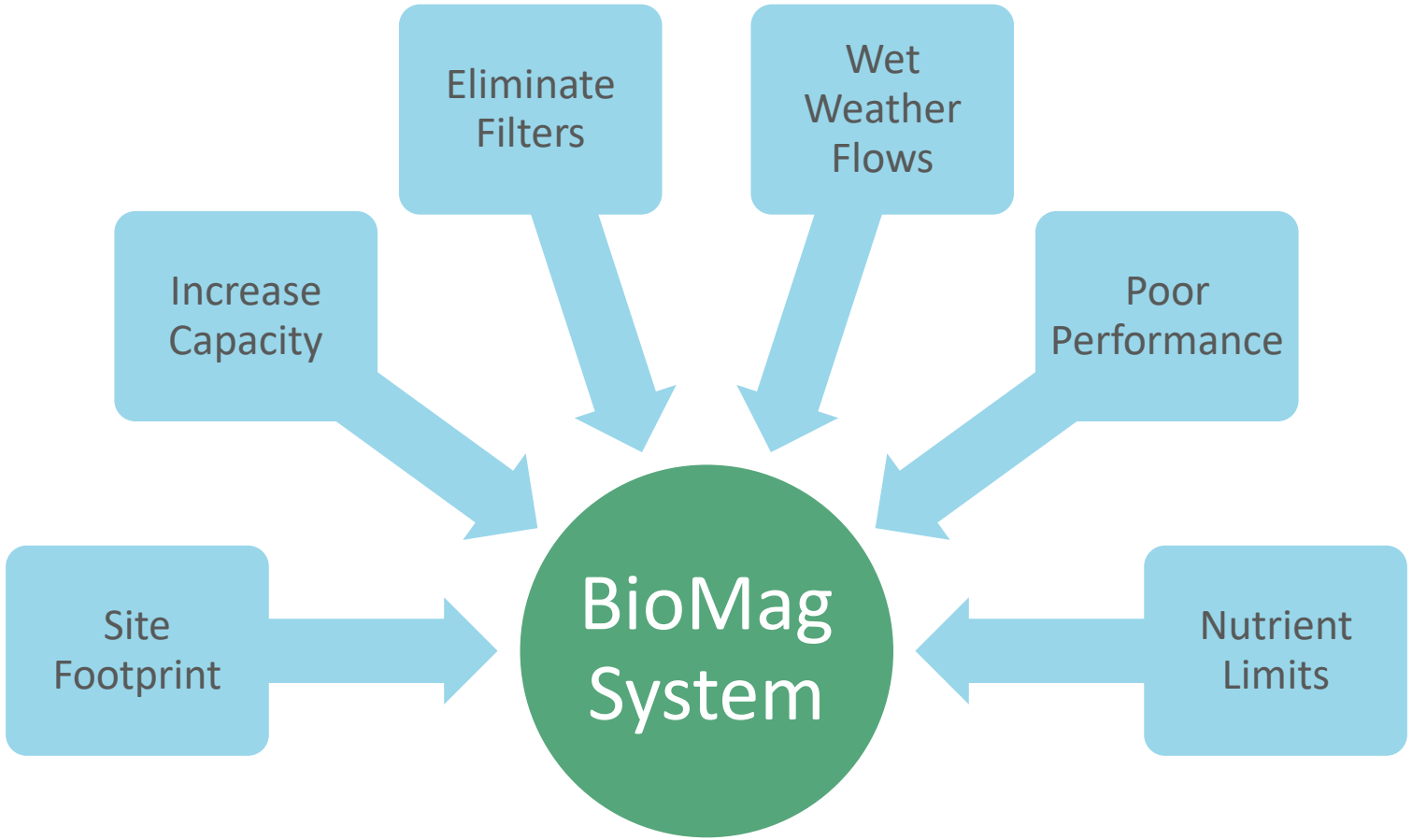
Installations	**25+**
Settling flux curves	**>1,200 tests at over 30 sites**
Full scale pilot demos	**13**
Projects in Design/Construction	**2 in the US** **1 in the UK**



EVOQUA WATER TECHNOLOGIES

BioMag® System

When is a BioMag System Applicable



BioMag® System Design

How is the system sized?

BioMag® System Design

Clarifier Sizing

Reactor

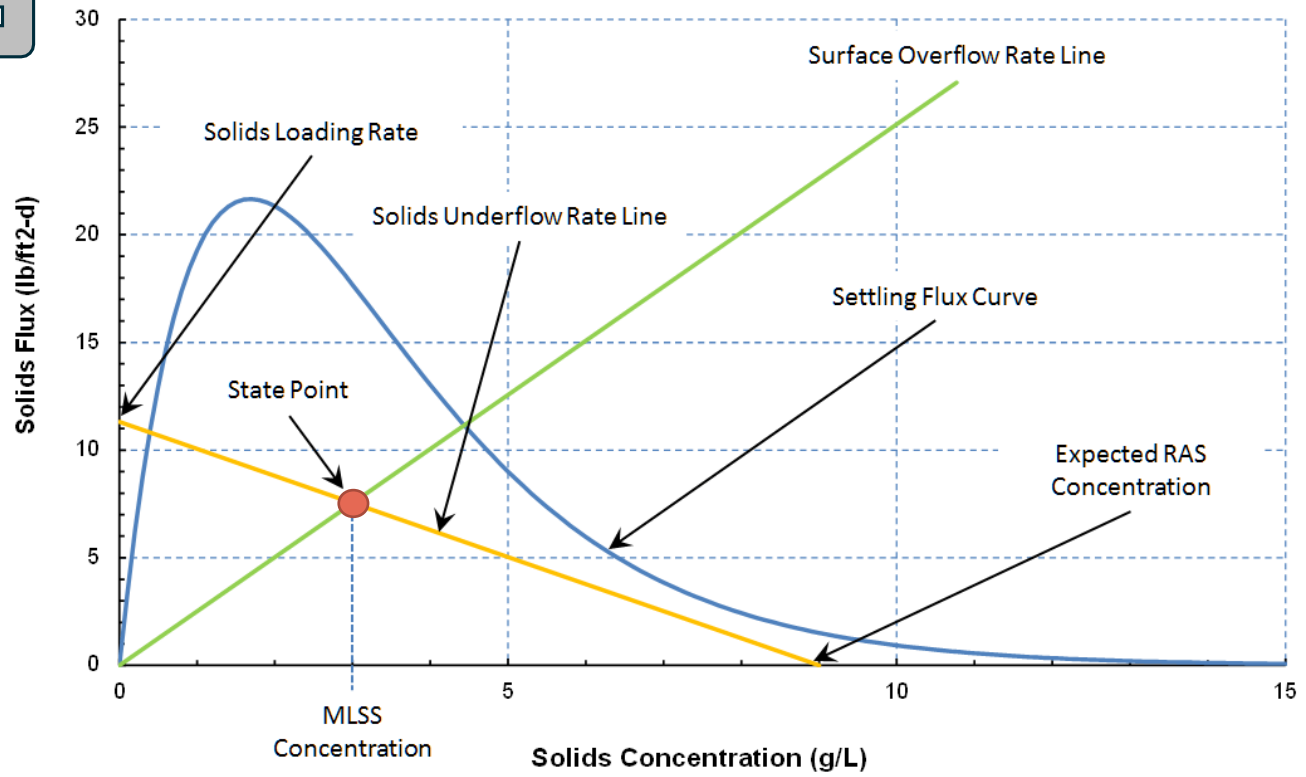
- Design Influent Flows
- Design MLSS

Clarifier

- SVI Data
- RAS Capabilities

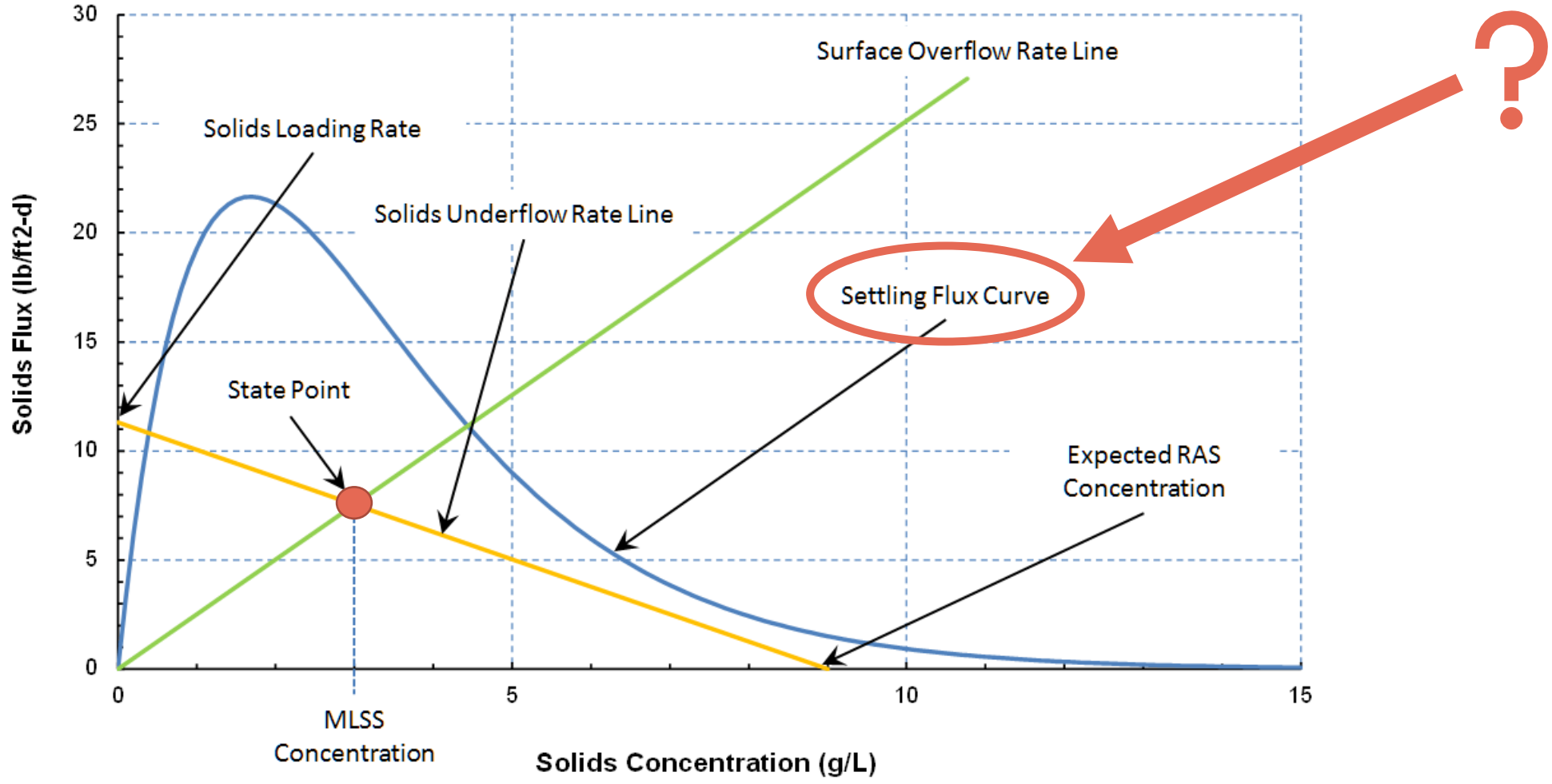
State Point Analysis

Required Clarifier Surface Area



BioMag® System Design

State Point Analysis



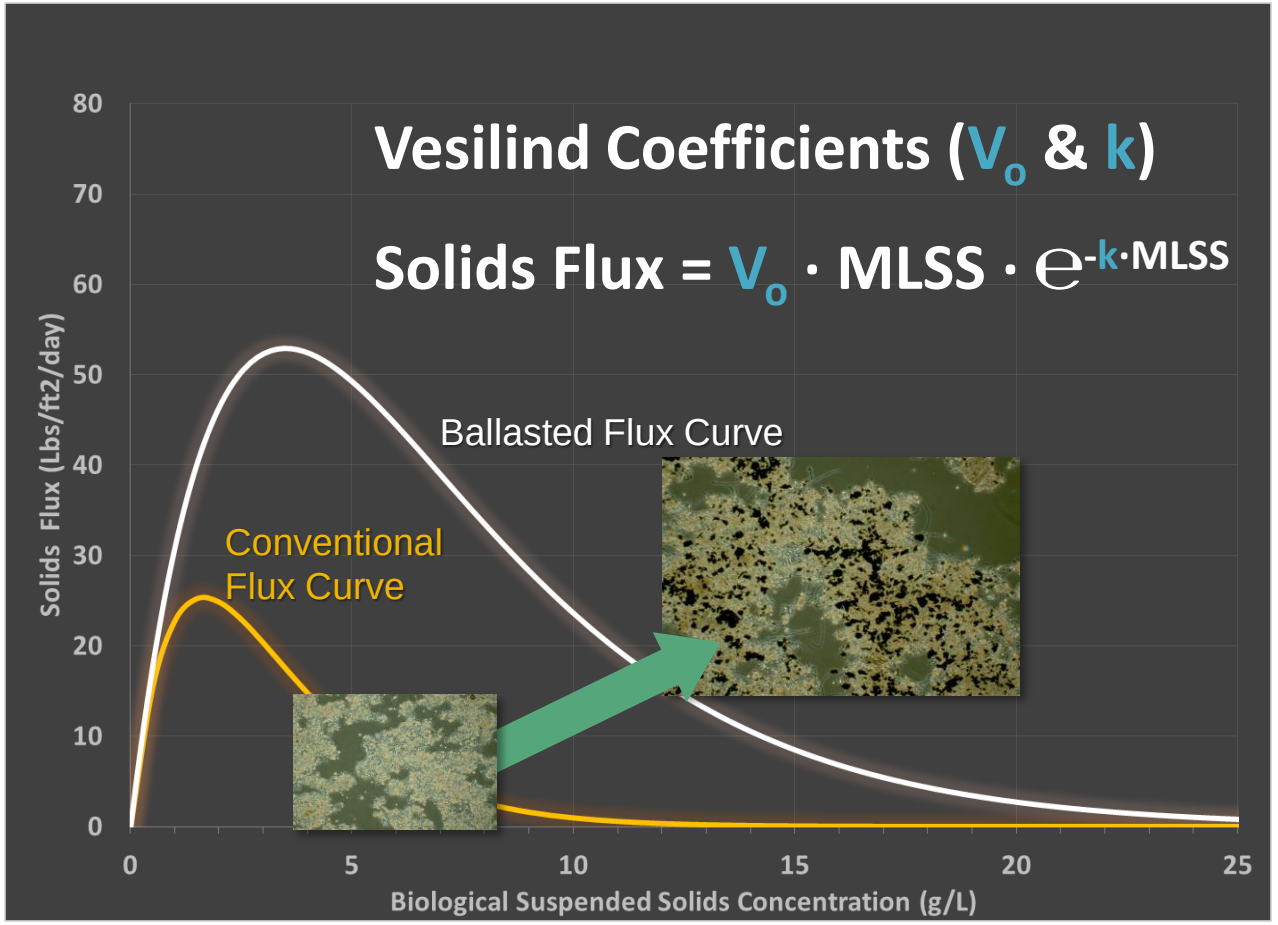
BioMag® System Design

Solids Flux Analysis

Important Features

Taller Curve
Elevates the allowable solids & hydraulic loading rates

Wider Curve
allows for higher MLSS & underflow concentrations



EVOQUA WATER TECHNOLOGIES

BioMag® System Design

Solids Flux Curve

- **Over 1,200 settling tests**
- Develop ballasted settling Vesilind coefficients
- Coefficients generate the flux curve used in state point analysis

Vesilind Coefficients:

BioMag System: V_0 = 1,000 ft/d k = 0.15 L/g

Conventional: V_0 = 511 ft/d k = 0.40 L/g

Key learning: Coefficients will vary from site to site and can depend on SVI, but all improve drastically

BioMag® System Design

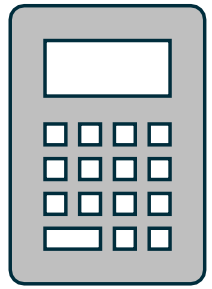
Recovery System

Biological Design

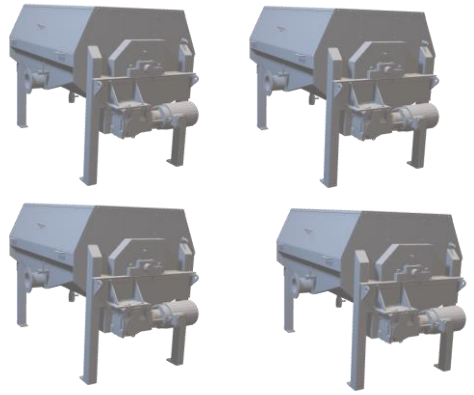
- Influent loading
- Design MLSS/SRT
- Biological Yield
- Wasting source
- WAS concentration

Wasting Strategy

- Intermittent or Continuous

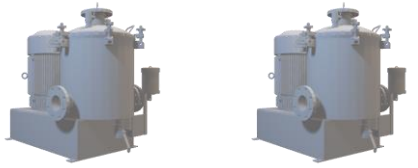


WAS Flowrate



Number/Size of Mag Drums

Number/Size of Shear Mills



BioMag® System Performance

Pushing the limits

New Hampshire	• SOR Peak:	2,520	gpd/ft2
	• SLR Peak:	106	lb/ft2/d
Texas	• SOR Peak:	2,200	gpd/ft^2
	• SLR Peak:	140	lb/ft^2/d
Ontario Canada	• SOR Peak:	1,389	gpd/ft^2
	• SLR Peak:	97	lb/ft^2/d
Tennessee	• SOR Peak:	596	gpd/ft^2
	• SLR Peak:	68	lb/ft^2/d
Texas	• SOR Peak:	1,428	gpd/ft^2
	• SLR Peak:	56	lb/ft^2/d

Conventional Loading Rates, lesser of:

SOR **Peak**: 800-1,200 gpd/ft^2

SLR **Peak**: 35 lb/ft^2/d

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BioMag® System Piloting

Setting up a full scale BioMag System demo

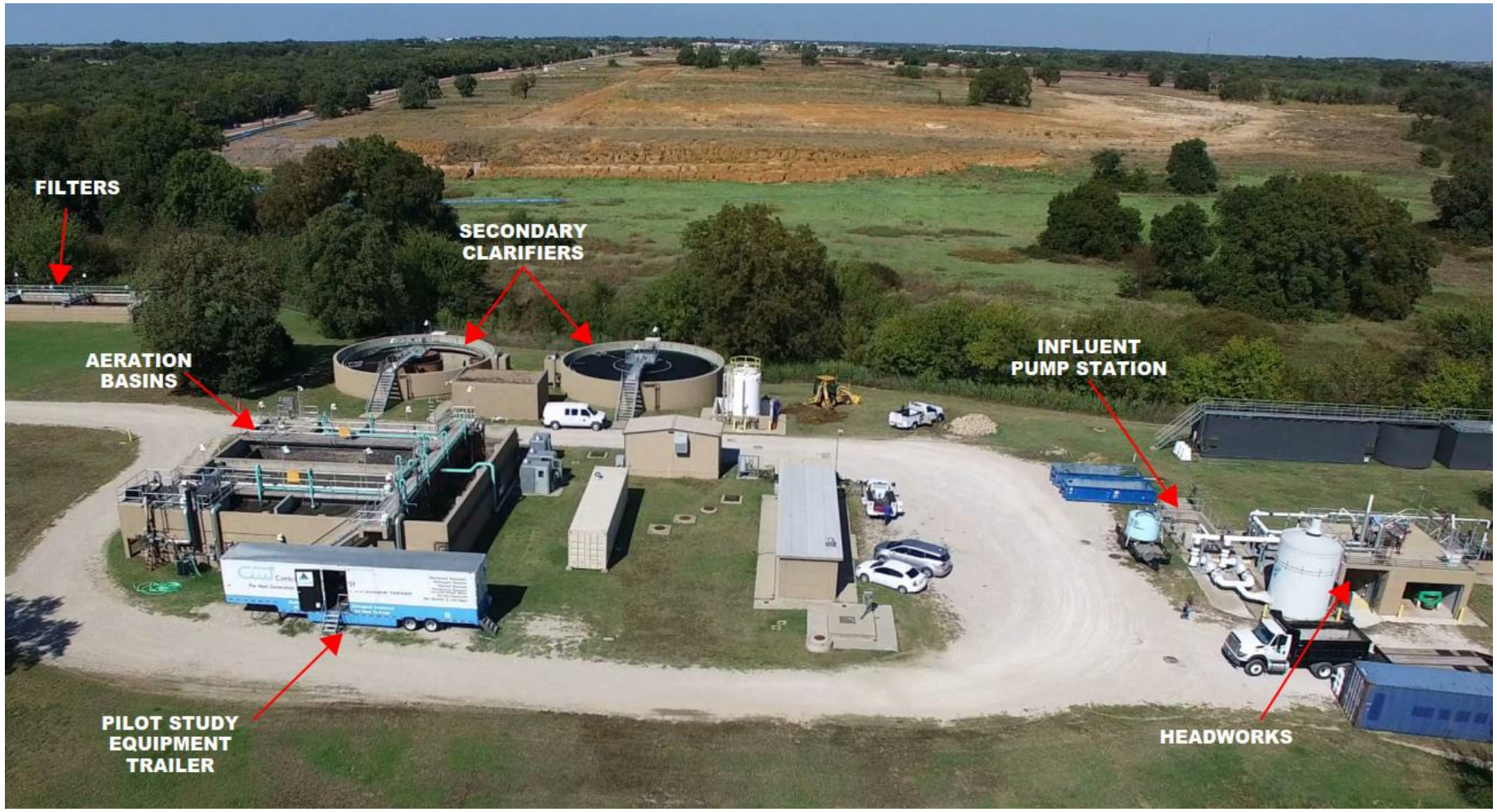


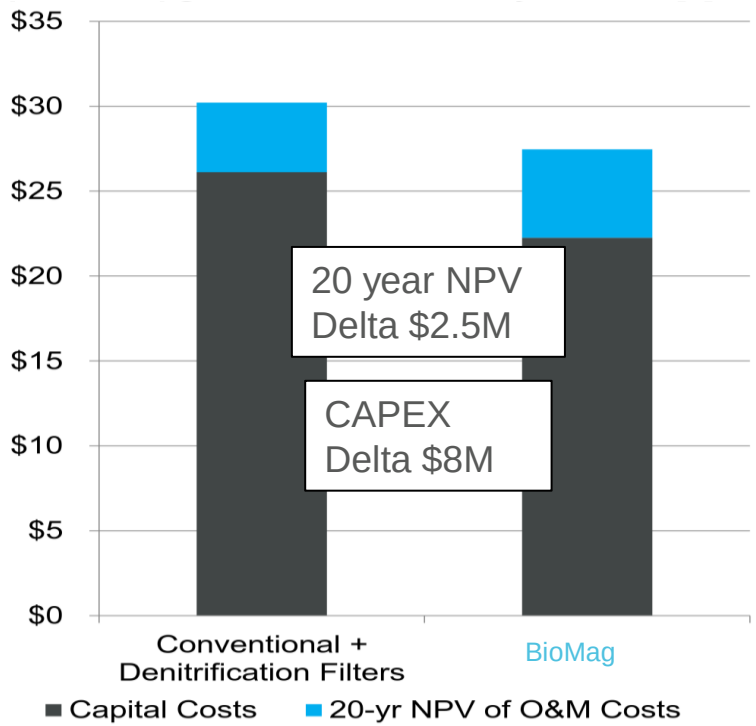
Photo courtesy of Carollo Engineers

EVOQUA WATER TECHNOLOGIES

BioMag® System Cost & Footprint Savings

Front Royal, VA

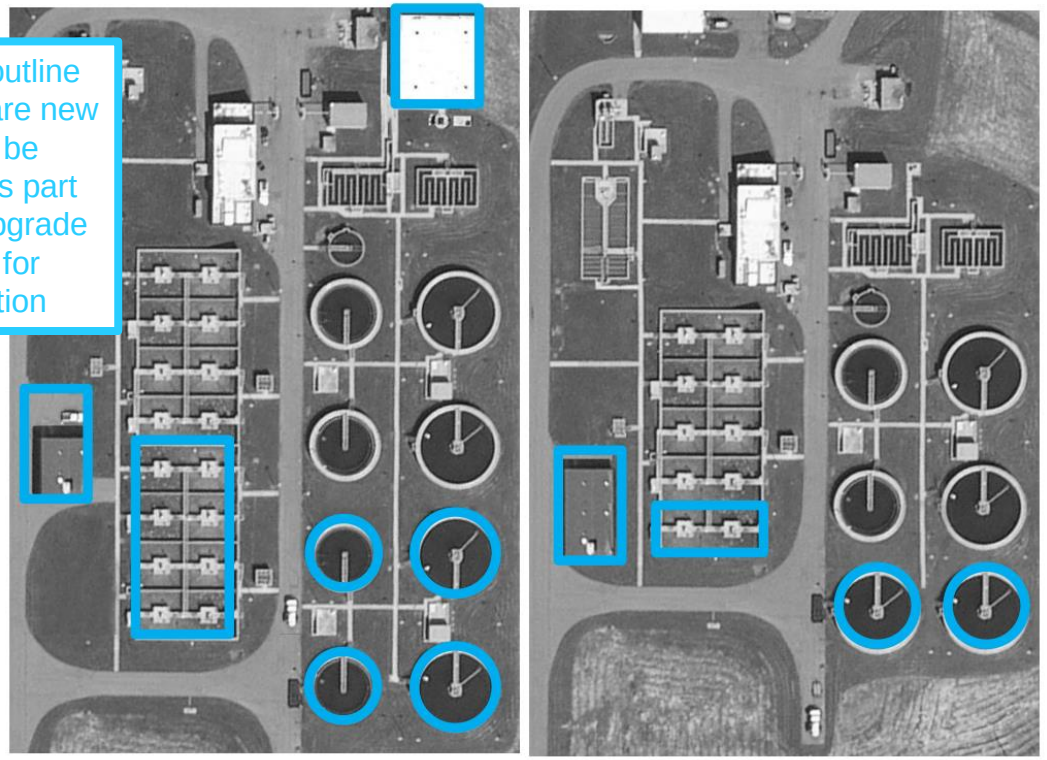
- **75% reduction on new bioreactor**
- **50% reduction on new clarifier**
- **No need for tertiary step (denite filters)**



Conventional Design

BioMag System Design

*Tanks outline in blue are new tanks to be added as part of the upgrade concept for each option



- **Expanded from 5 MGD to 8.5 MGD**
- **Nutrient removal: total nitrogen < 3 mg/L and total phosphorous < 0.22 mg/L**

Analysis courtesy of GHD Engineers

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BioMag for Nutrient Limits

Marley Taylor, MD

Schreiber Continuously Sequencing Reactor

- 6 MGD capacity

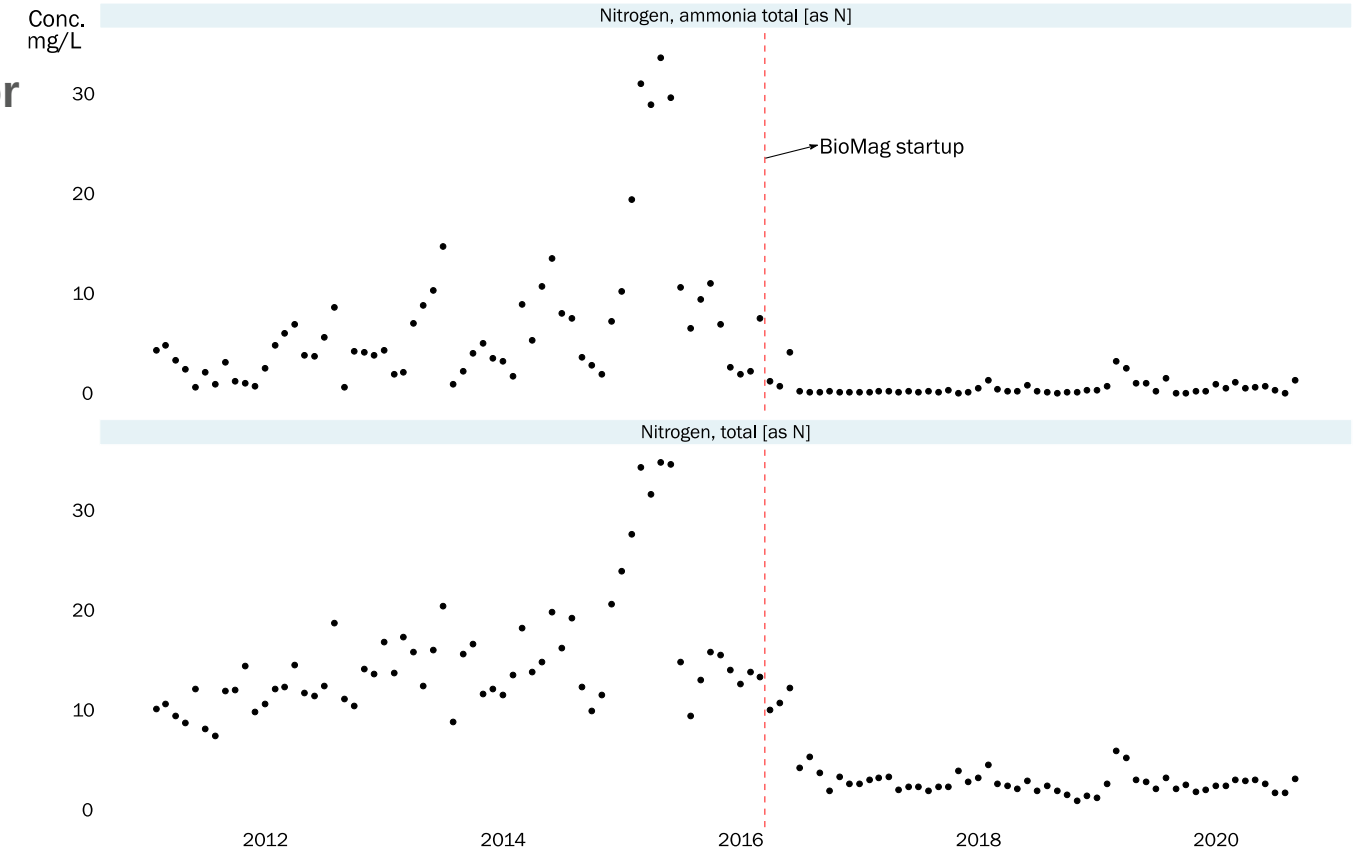
Challenge

- Lower mass based permit
- TN <4 mg/L, TP <0.3 mg/L

Solution

- Converted to 4-stage Bardenpho
- Added retrievable racks and supplemental mixing
- BioMag for intensification
- No tertiary filters required

Effluent Nitrogen Performance

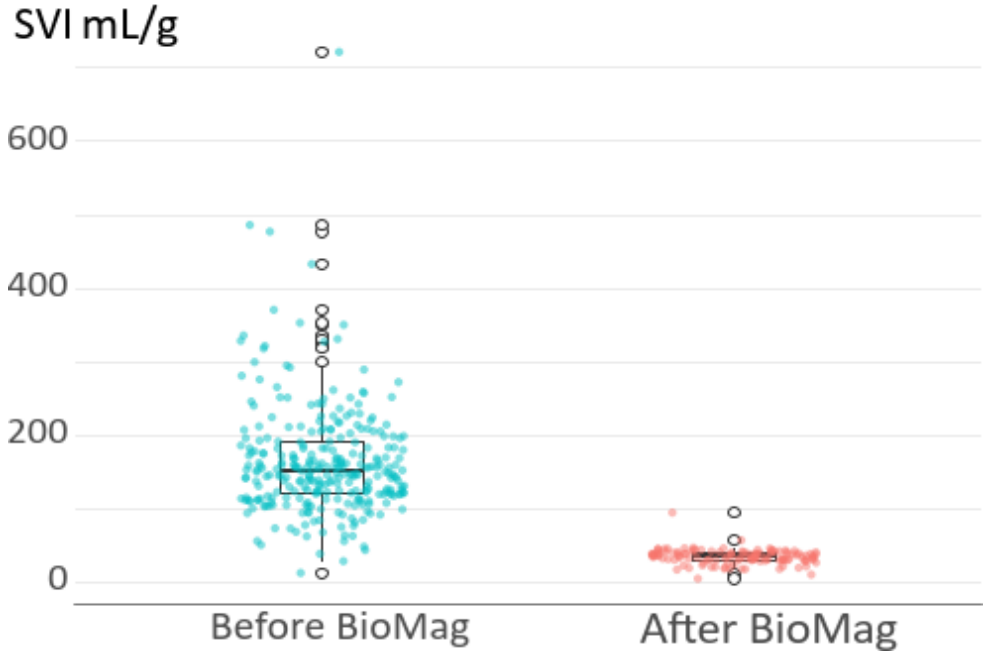


Data source: US EPA (echo.epa.gov)

BioMag® System for SVI Reductions

Allenstown, NH – 7’ SWD Secondary Clarifiers

- Low cost alternative
- Process stability
- Increased capacity
- Increased septage receiving - revenue



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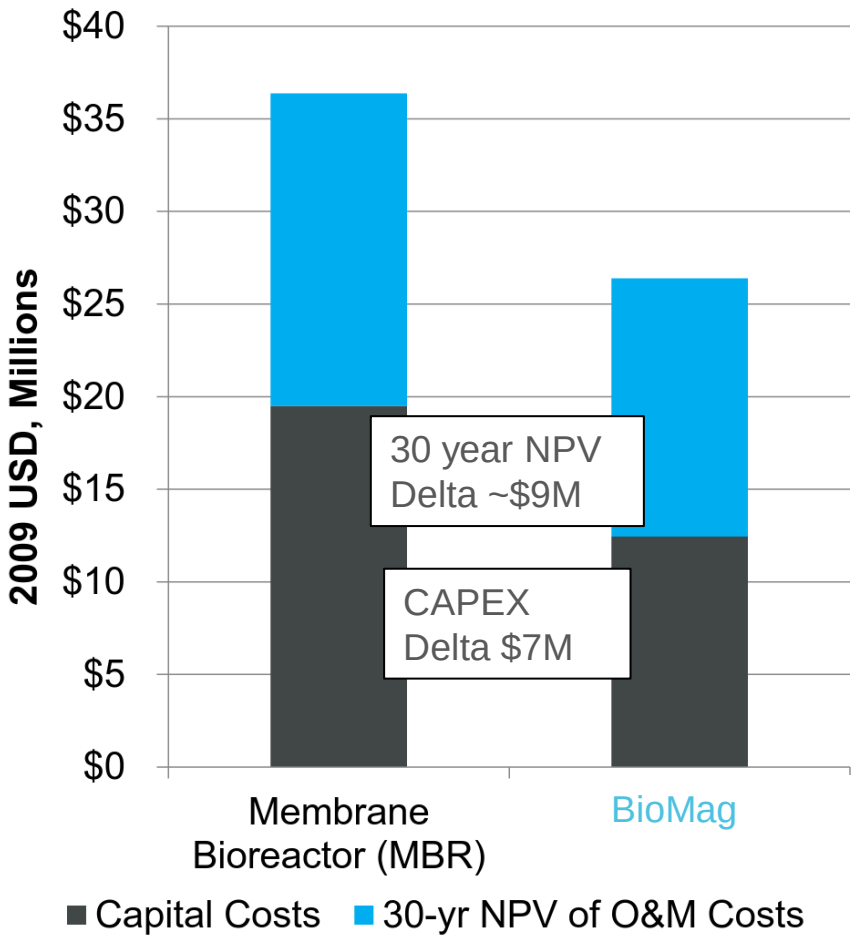
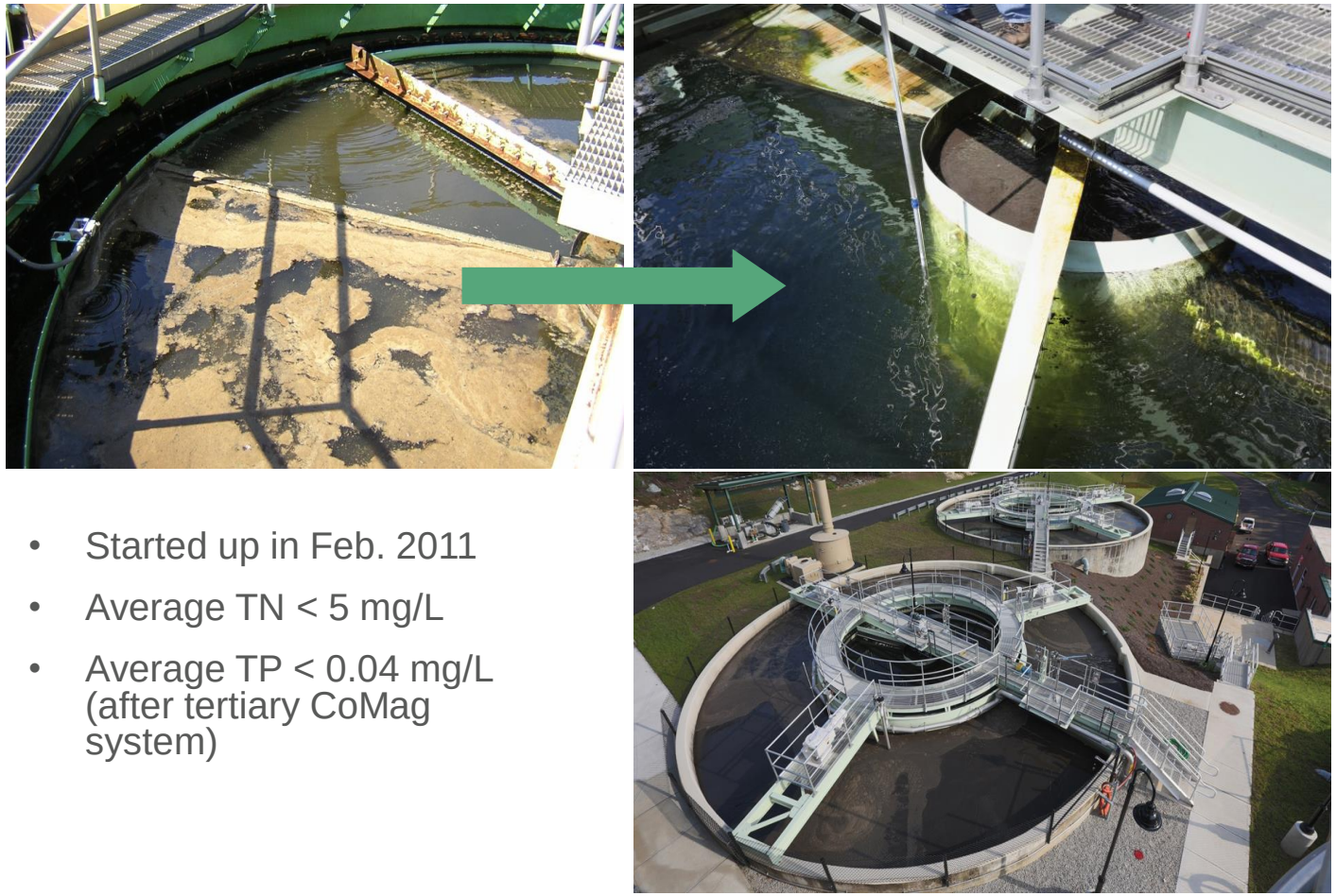
BioMag® System for Stability & Consistency

Sturbridge, MA



Before **After**

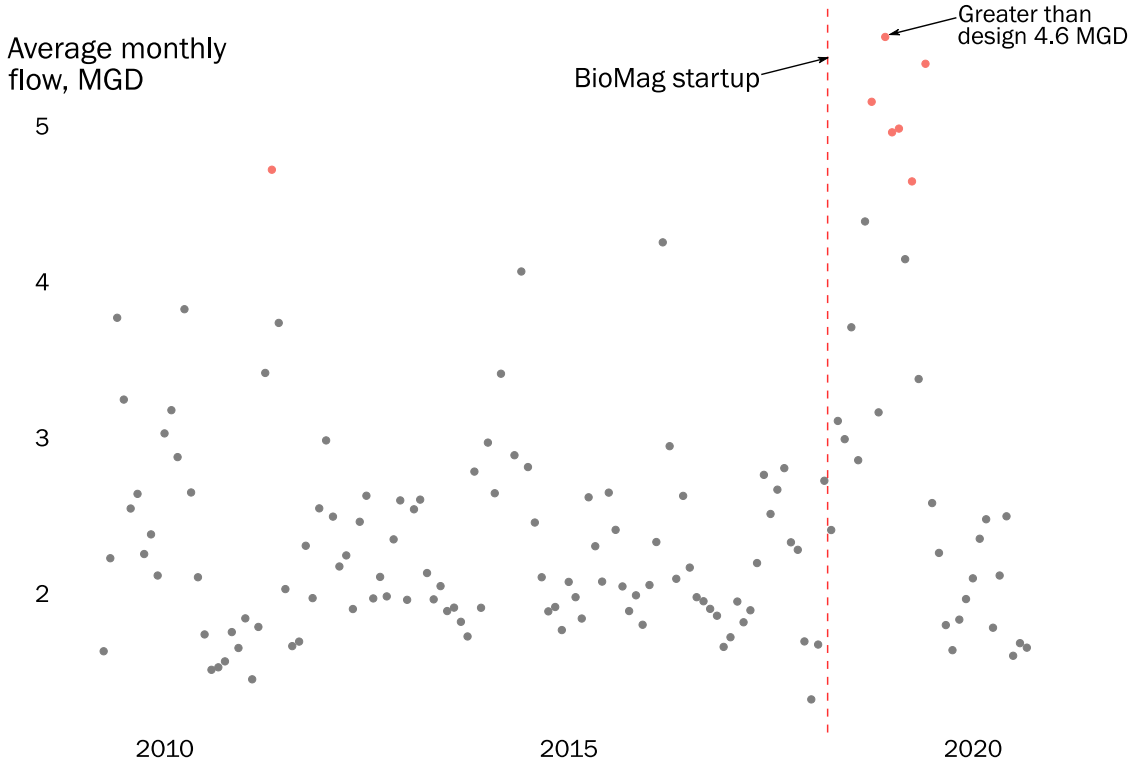


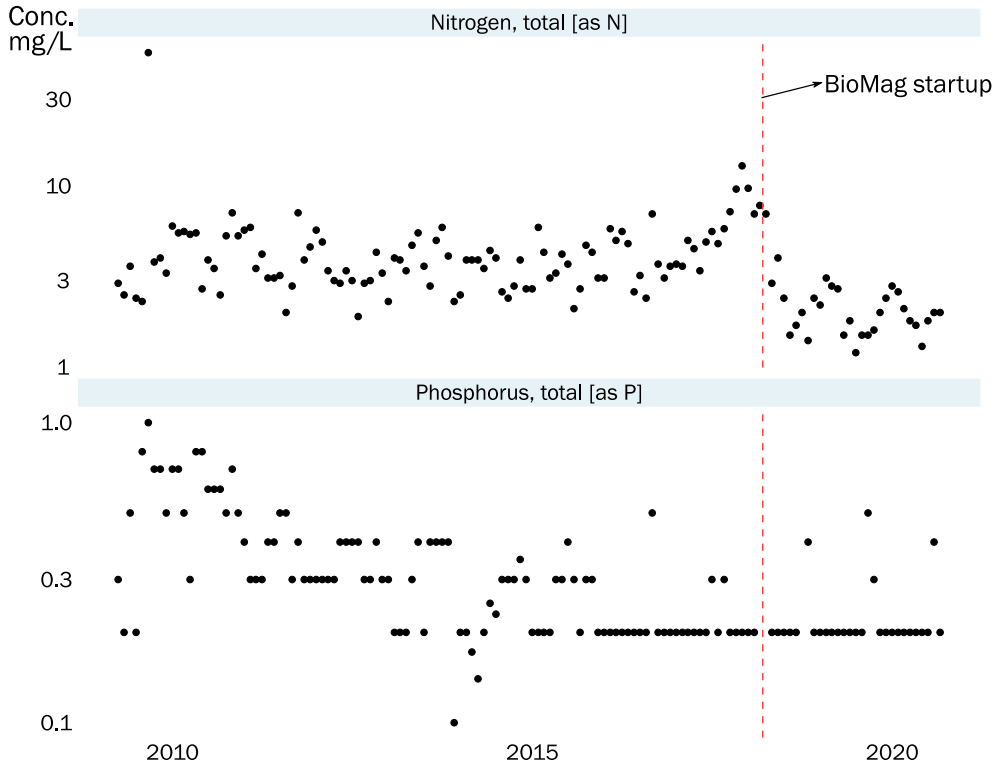
- Started up in Feb. 2011
- Average TN < 5 mg/L
- Average TP < 0.04 mg/L (after tertiary CoMag system)

NPV based on 30 year term, discount rate of 6% and inflation rate of 3.5%. Developed by Tighe & Bond.

BioMag® System Eliminates Tertiary Filters

Conococheague, MD





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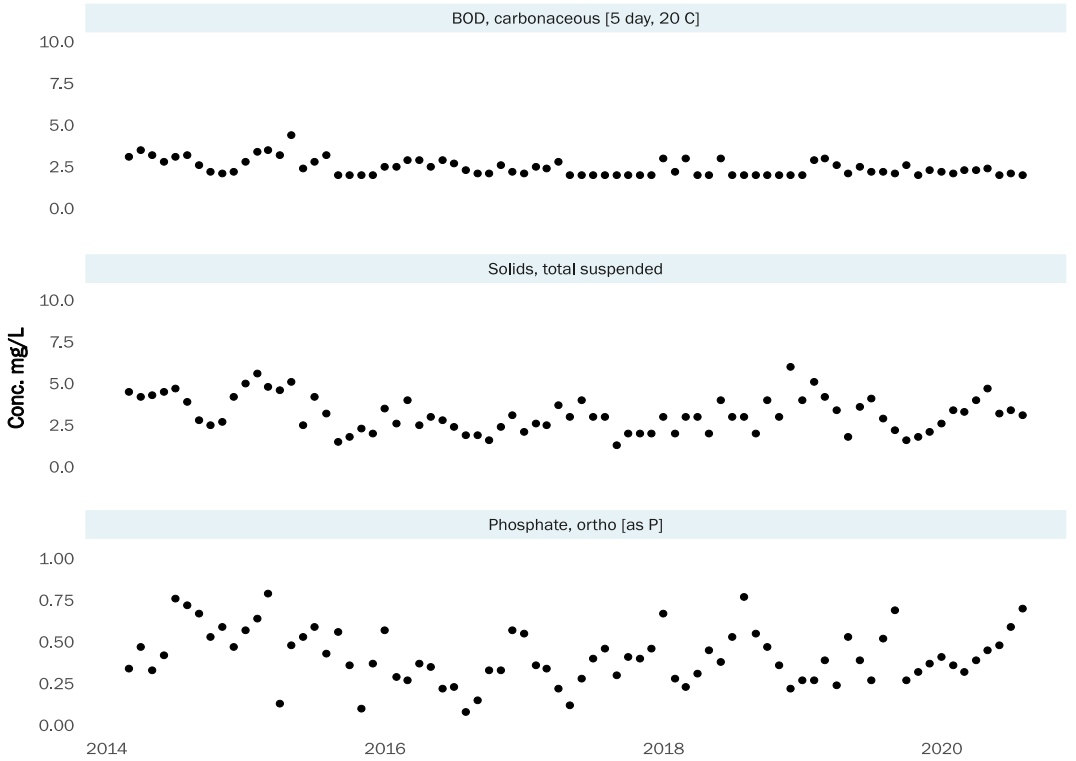
BioMag® System High Flows

Upper Gwynedd Township, PA

Peaking Factor 5-6X ADF!!!

BioMag system effluent performance since start up



Data source: US EPA (echo.epa.gov)

BioMag® System Conclusions

Takeaway Points

- ✓ Increase treatment capacity within existing tankage 2X-3X
- ✓ Achieve ENR standards **without** tertiary filtration
- ✓ Reduce costs for upgrades
- ✓ Improve clarifier performance
- ✓ Manage wet weather flows
- ✓ Provide process stability

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THANK YOU