Wastewater Nutrient Removal

An overview of phosphorus and nitrogen removal strategies

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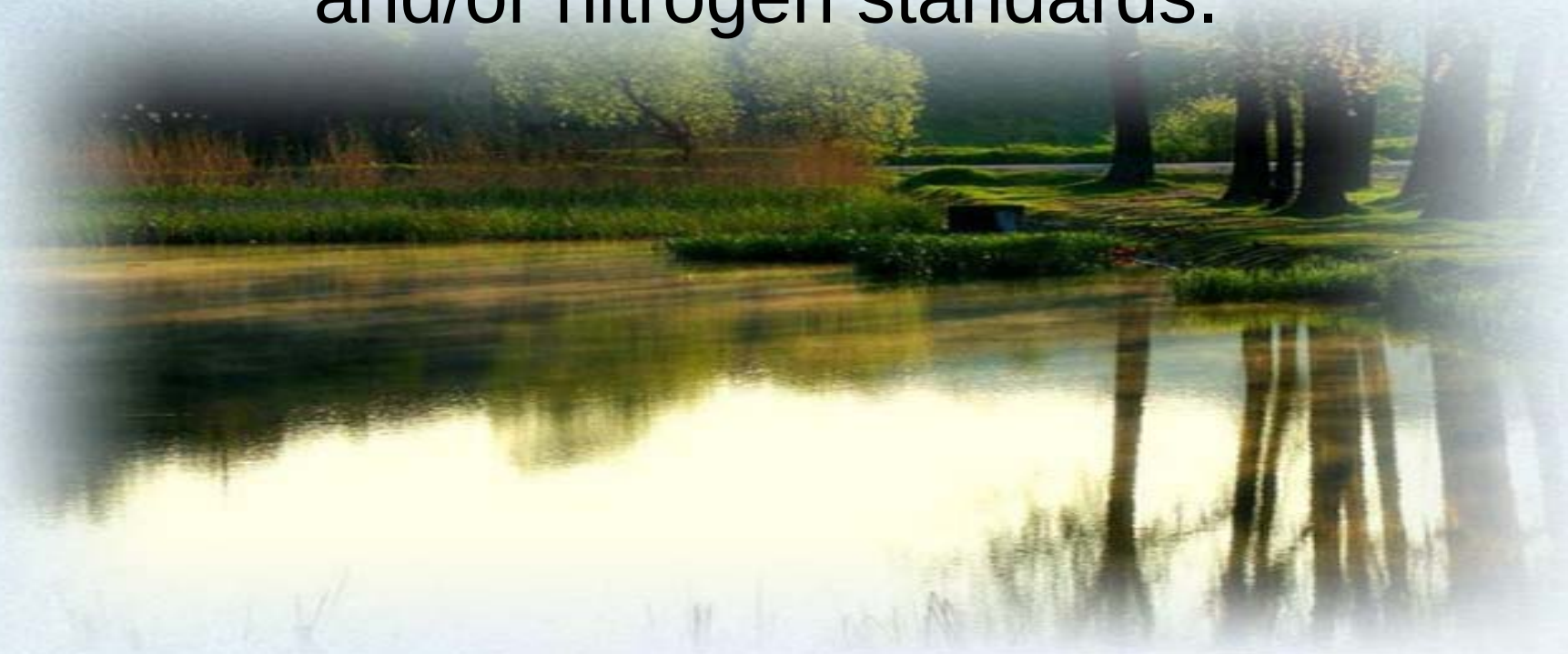
Why are nutrients an issue in the environment?

- Stimulates algae and plant growth
- Creates dissolved oxygen issues
- P – limiting fresh water nutrient
- N – limiting marine water nutrient

Nutrient standards are coming!

Water quality concerns will result in many treatment facilities receiving phosphorus and/or nitrogen standards.



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Overview of phosphorus removal strategies

Typical wastewater phosphorus concentrations

		% Removal
Typ. Infl. Sewage	7ppm	
Typ. Sec'd. Effl.	5ppm	30%
Level 1-P Removal	1.0ppm	86%
Level 2-P Removal	0.5ppm	93%
Level 3-P Removal	0.2ppm	97%
Level 4-P Removal	0.1ppm	98.5%
Level 5-P Removal	0.05ppm	99.3%

Phosphorus removal through secondary treatment

- Some P reduction occurs in every secondary treatment system
- Between 1 to 6 mg/l or 1/3 reduction can be attributed to:
  - Settling of insoluble P
  - Cell Growth

Microbiology and biochemistry

Typical Cell

Carbon$_5$	5 x 12.0 =	60
Hydrogen$_7$	7 x 1.0 =	7
Oxygen$_2$	2 x 16.0 =	32
Nitrogen$_1$	1 X 14.0 =	14
Phosphorus$_{0.07}$	0.07 x 31.0 =	2.17
Total: $C_5H_7O_2NP_{0.07}$	=	115.17

% Phosphorus = 2.17/115.17 = 1.9

How to obtain additional phosphorus removal

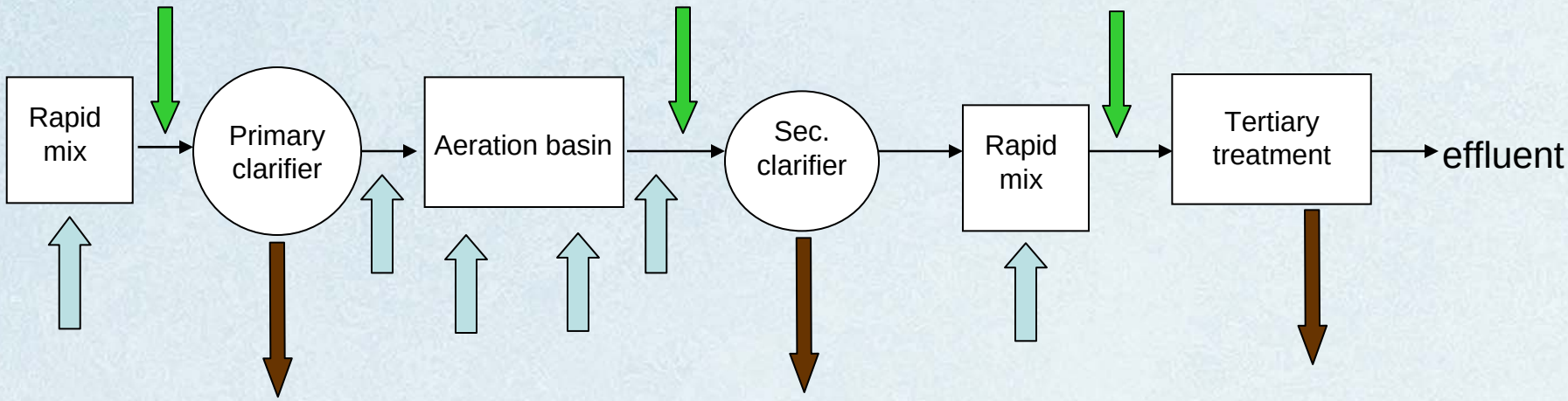
1. Convert soluble P to insoluble P (chemically or biologically)
2. Capture insoluble P (in clarifier or some other solids removal system)

How does chemical phosphorus removal work?

$$M^{+3} + PO_4^{-3} \text{--->} \quad MPO_4 \text{ (insoluble)}$$

- A soluble metal (M) is added which combines with soluble orthophosphate to form an insoluble compound (precipitate)
- Chemical Options
  - Aluminum– Alum, Aluminate, PACl
  - Iron– Ferric Chloride, Ferric Sulfate, Ferrous Sulfate/Chloride
  - Calcium--Lime

Chemical application points



Alum or ferric addition

Flocculant aid addition

Sludge

Chemical phosphorus removal – pros and cons –

Pros

- Simple controls systems
- Inexpensive to install
- Improves settling
- Reliable
- Can achieve low P levels

Cons

- Chemical costs
- More sludge generated
- Sludge can be more difficult to dewater

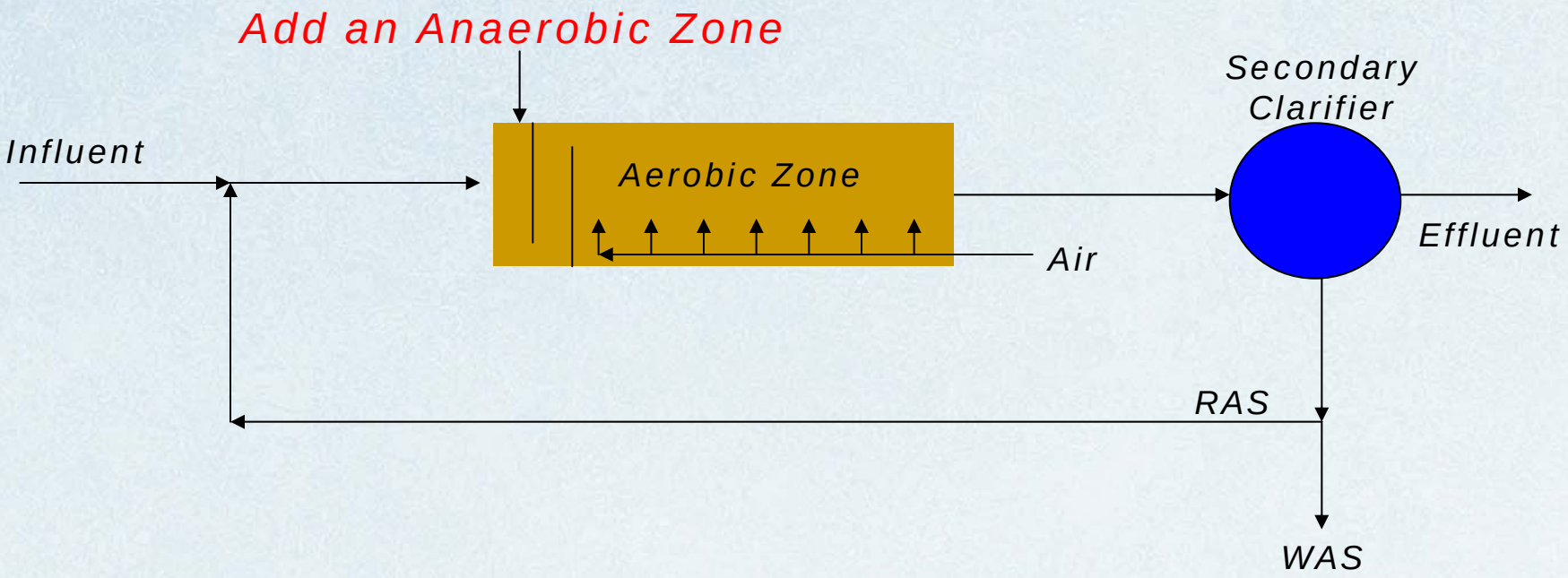
Biological phosphorus removal

- Enhanced Biological Phosphorus Removal

  Process to grow Poly-P heterotrophic bacteria that can accumulate excess phosphorus, (Typ. 3-15% by weight of biomass volatile fraction)

- Poly-P heterotrophic bacteria require:
  - Anaerobic-aerobic sequencing
  - COD:P ratios>45
  - Excess phosphorus

How do you make your plant a Bio-P plant?



Biological phosphorus removal – pros and cons –

Pros

- Less sludge production
- Less chemical costs
- Can be coupled with chemical P removal
- Can achieve 0.5 mg/l P levels
- Improved process stability

Cons

- Capital costs
- More complex process control
- Cannot achieve real low levels

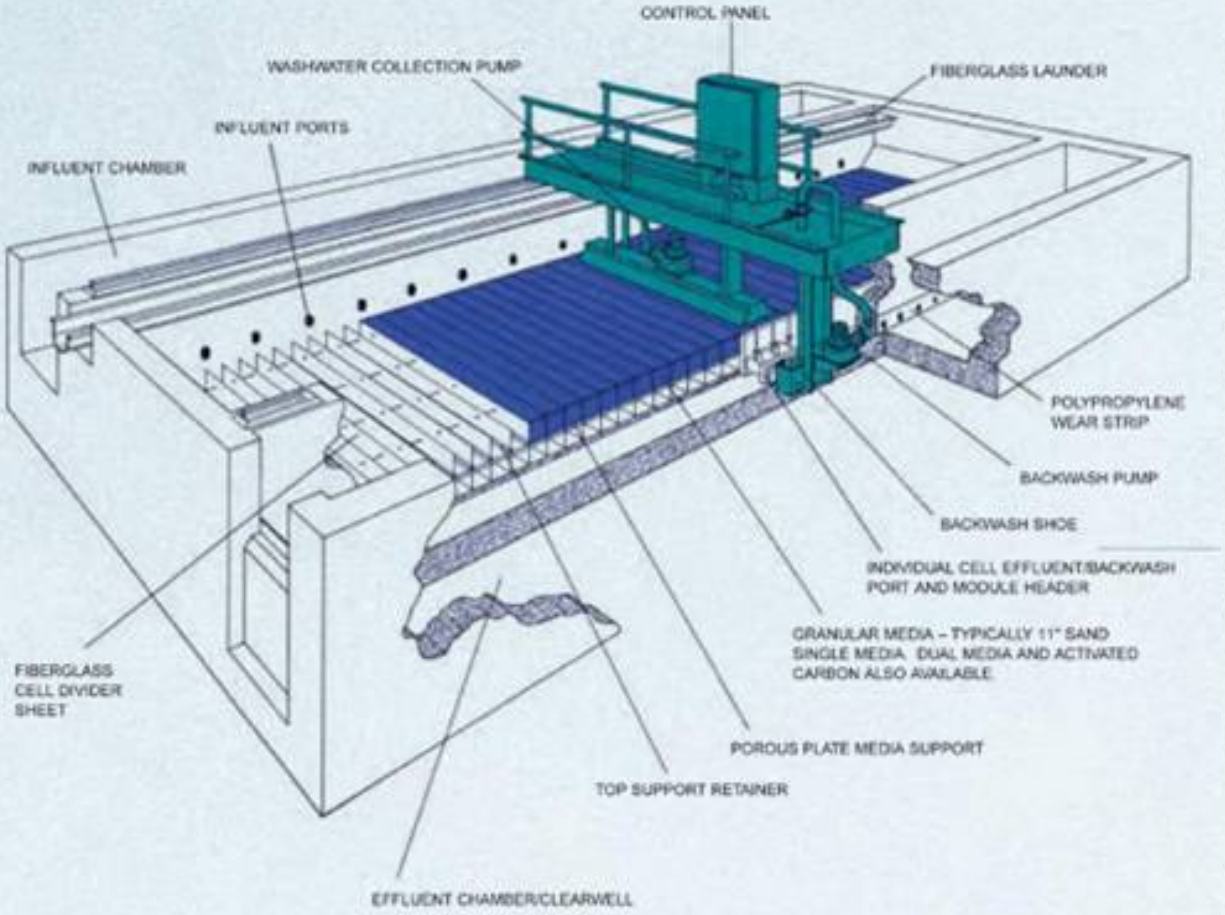
Phosphorus removal – solids capture

After the phosphorus is converted to an insoluble form (chemically or biologically), the solids have to be captured.

Solids capture options

	Achievable P Level (mg/l)
• Typical secondary clarifier	0.50 - 1.0
• Filtration (Following Clarification)	<0.2
• Filtration preceded by high rate settlers	<0.1
• Dual Filtration systems	<0.1
• Ballasted clarification	<0.1
• Dissolved air floatation	<0.1
• Membrane systems	<0.05
• Combinations of Systems	<0.05

Filtration process traveling bridge filter



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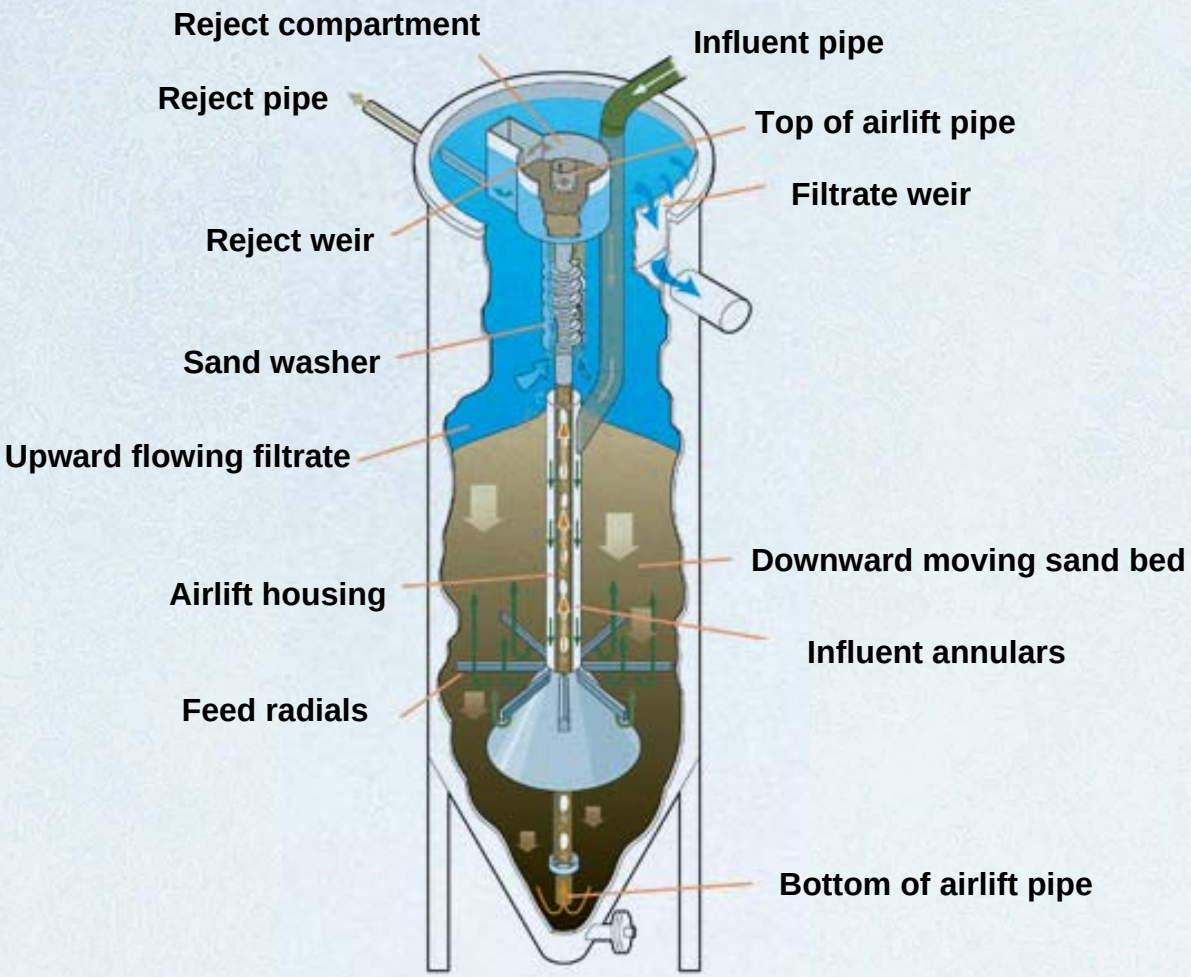
Upflow continuous backwash filter DynaSand



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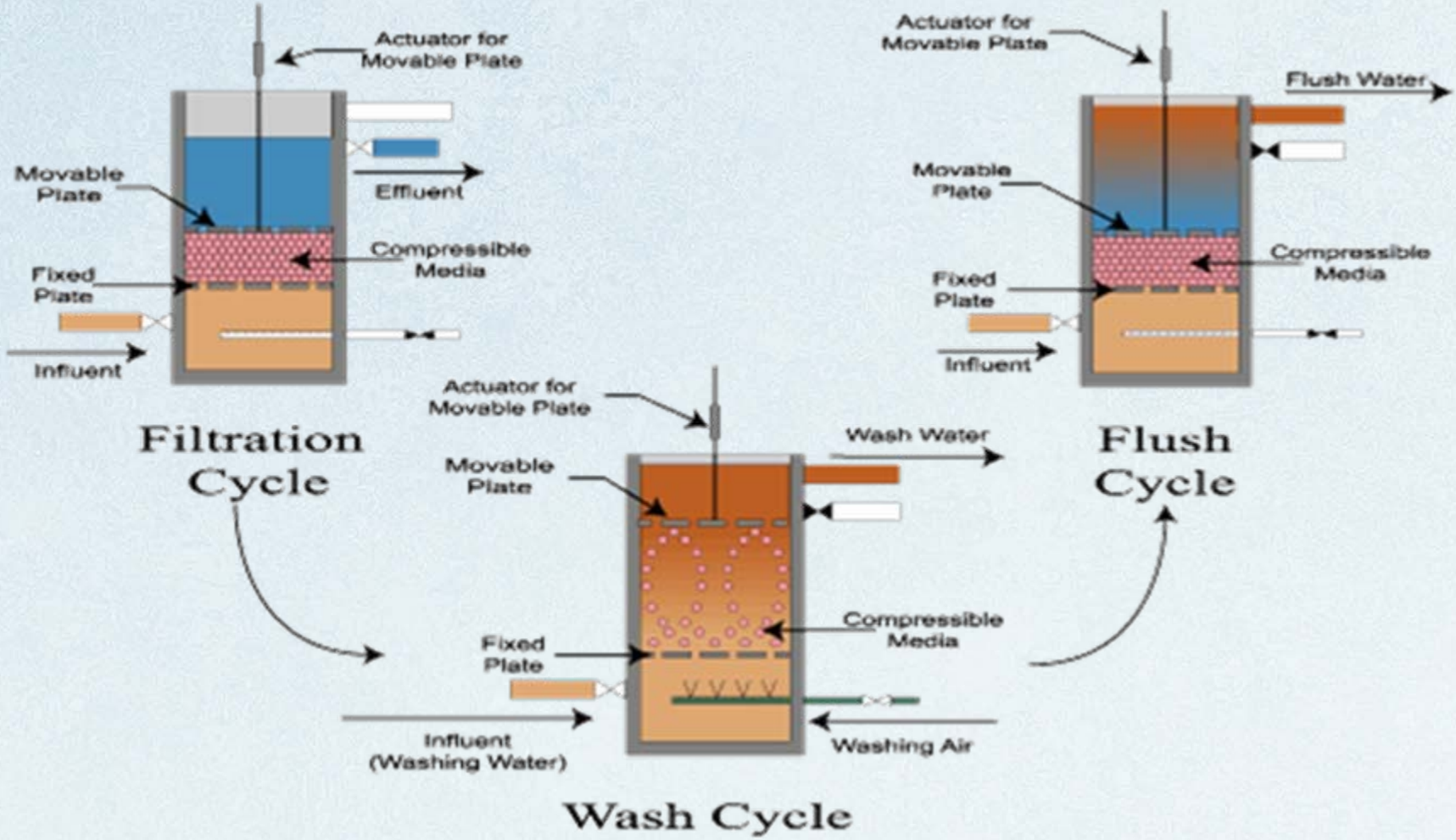
Filtration process
Schreiber's fuzzy filter



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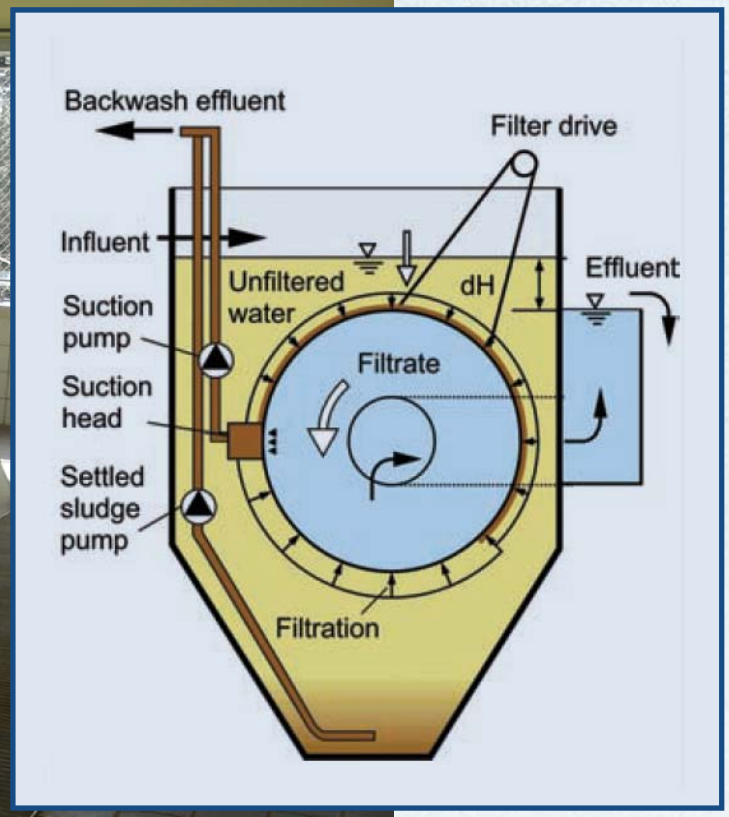
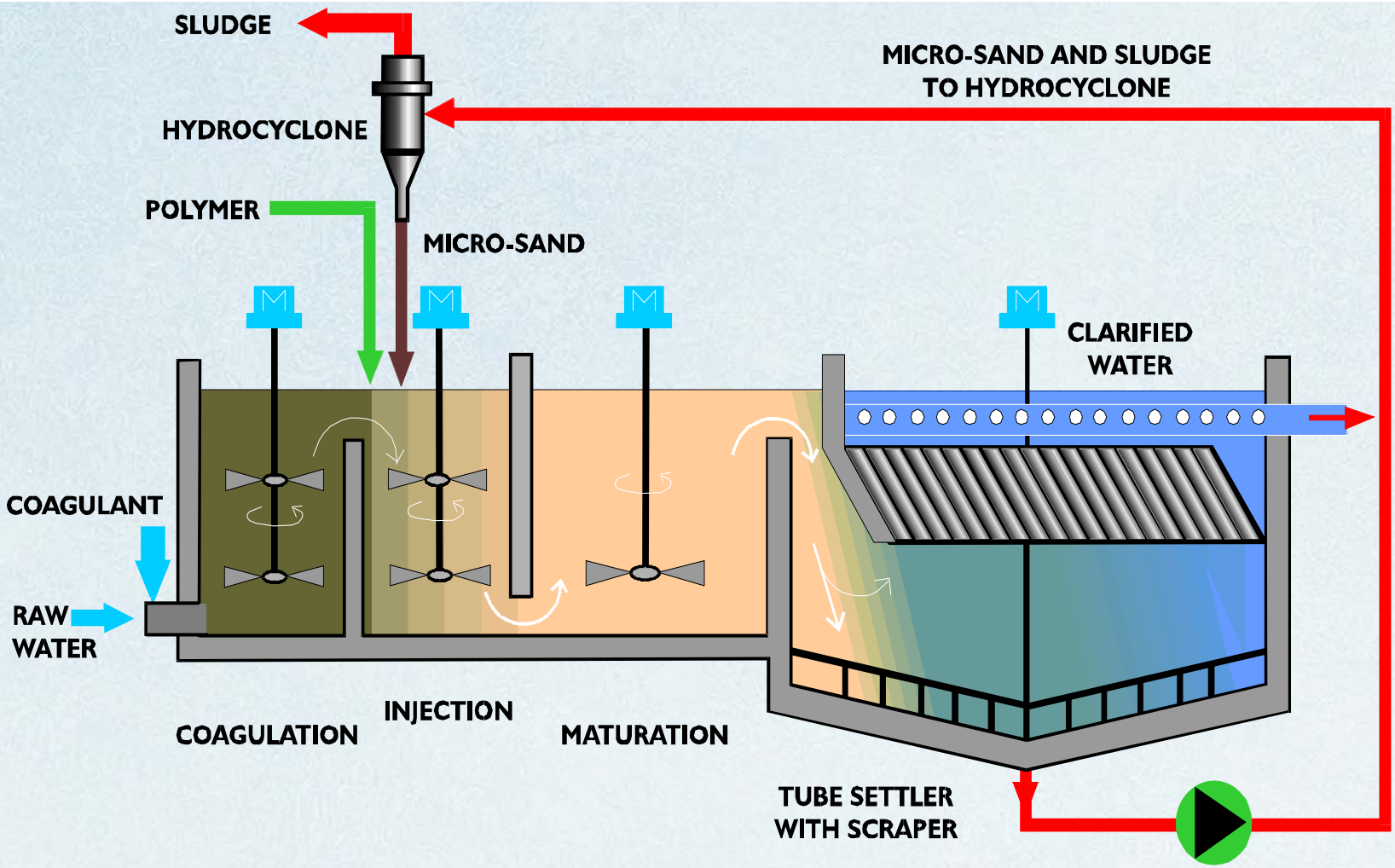
Filtration processes – disk filter



Ballasted clarification ACTIFLO process



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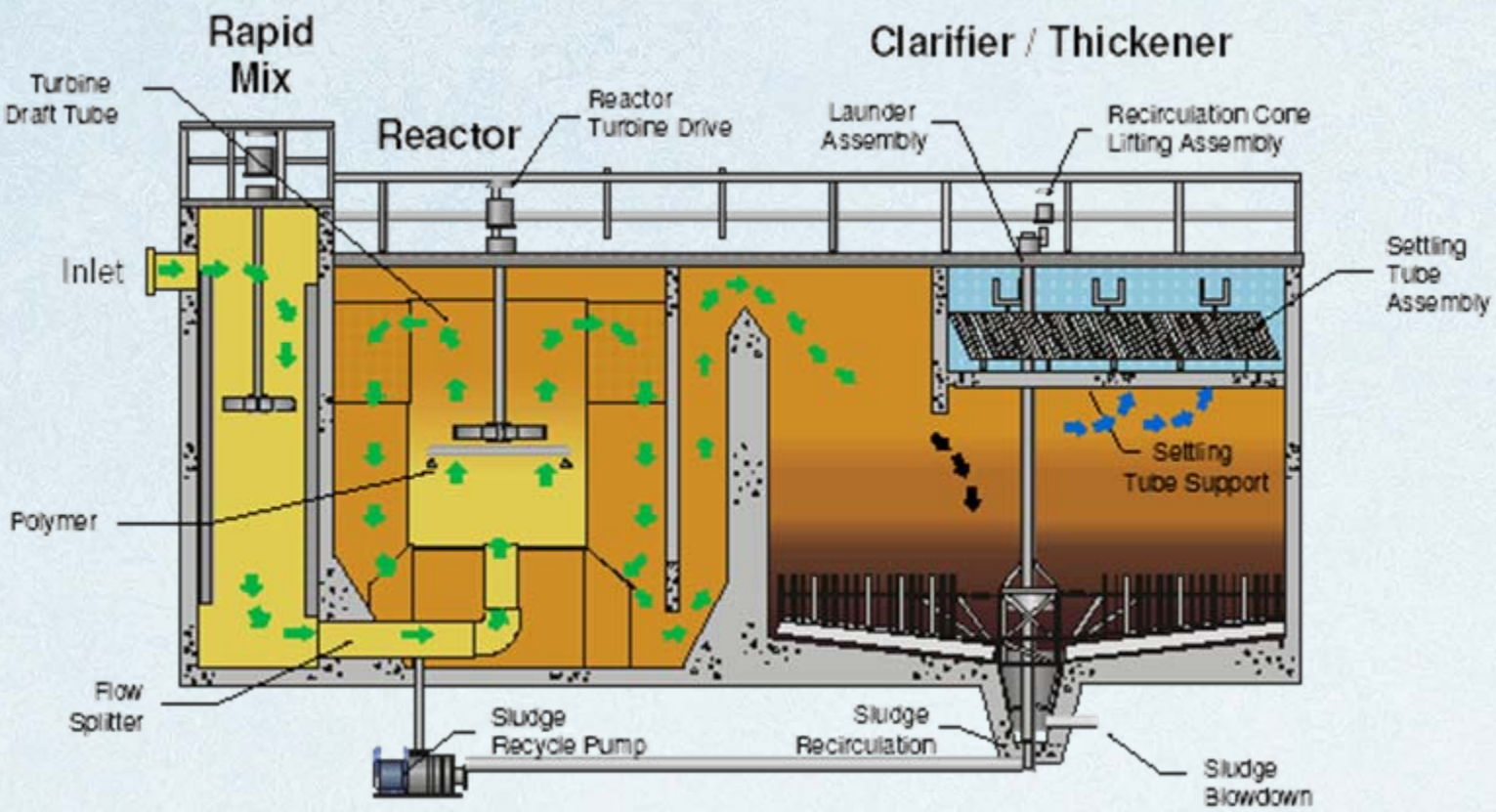
Ballasted clarification DENSADEG process



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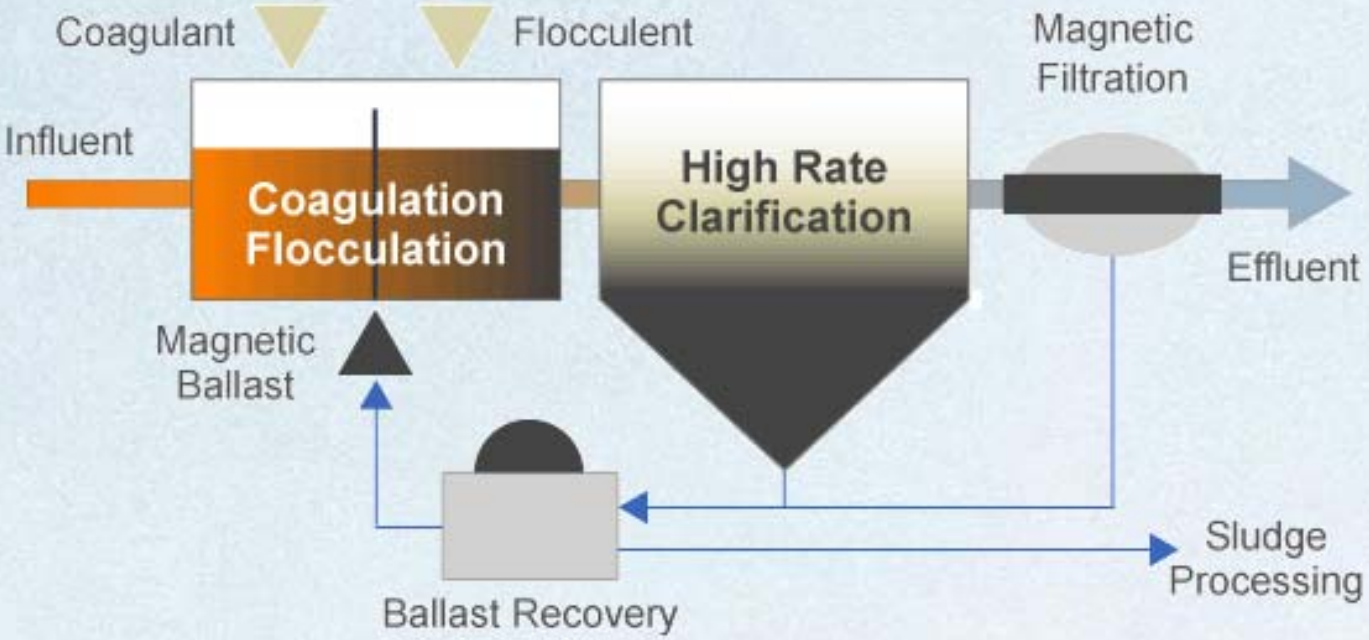
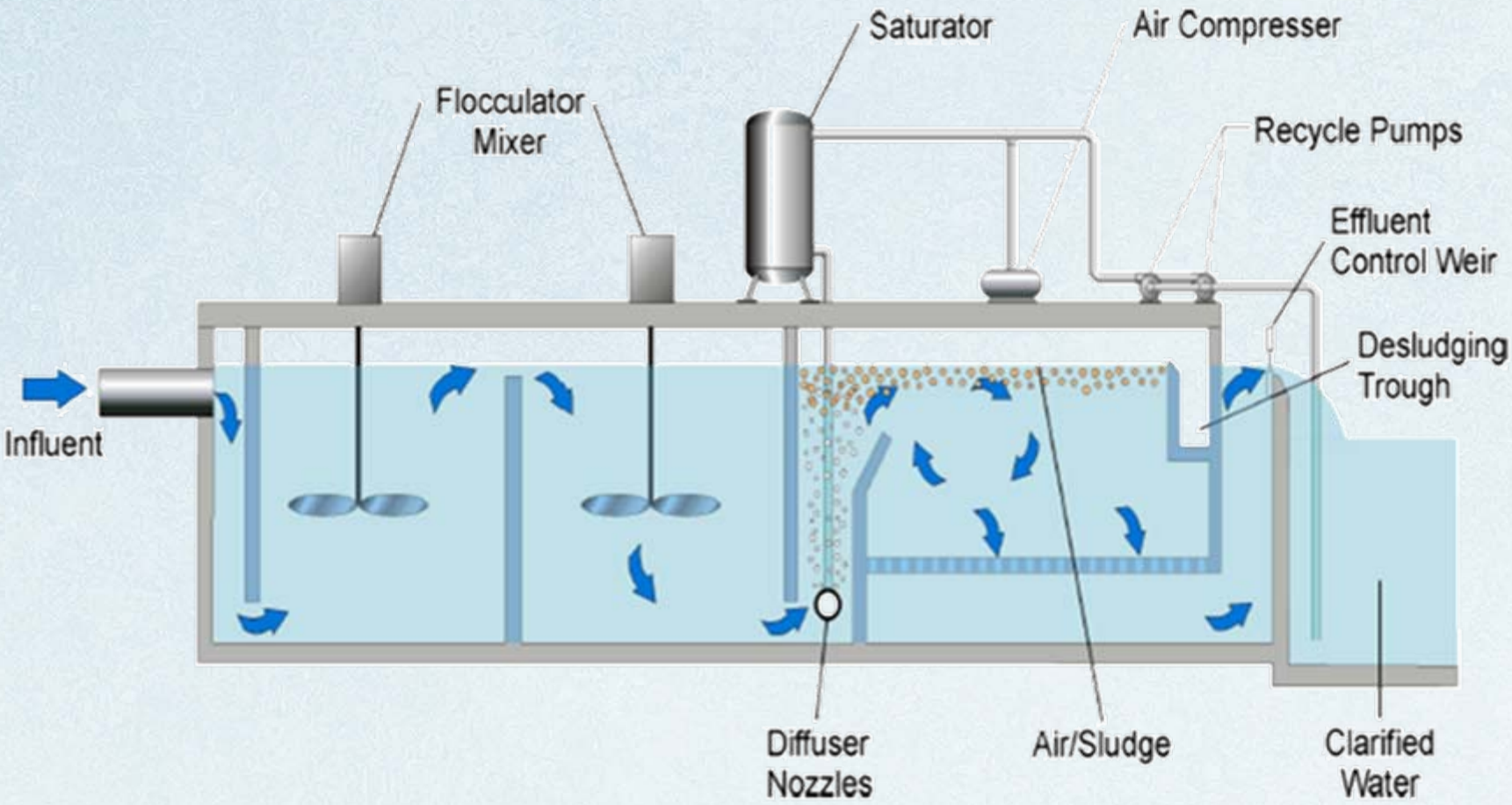
Ballasted clarification
CoMag process



Dissolved Air Flotation (DAF)



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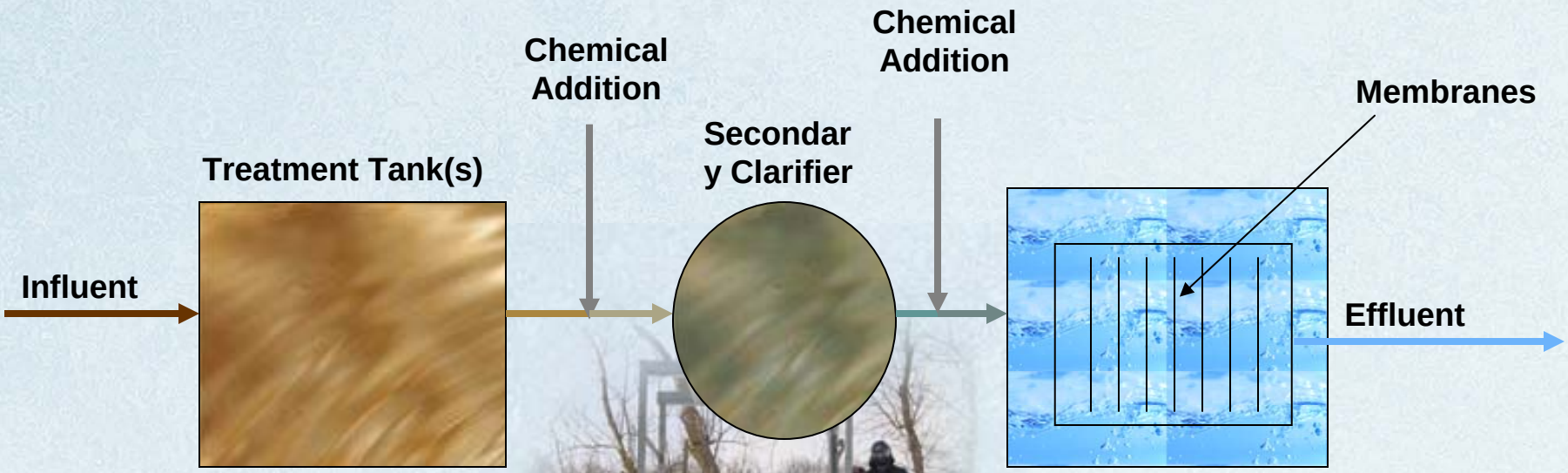
Membranes



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Overview of nitrogen removal strategies

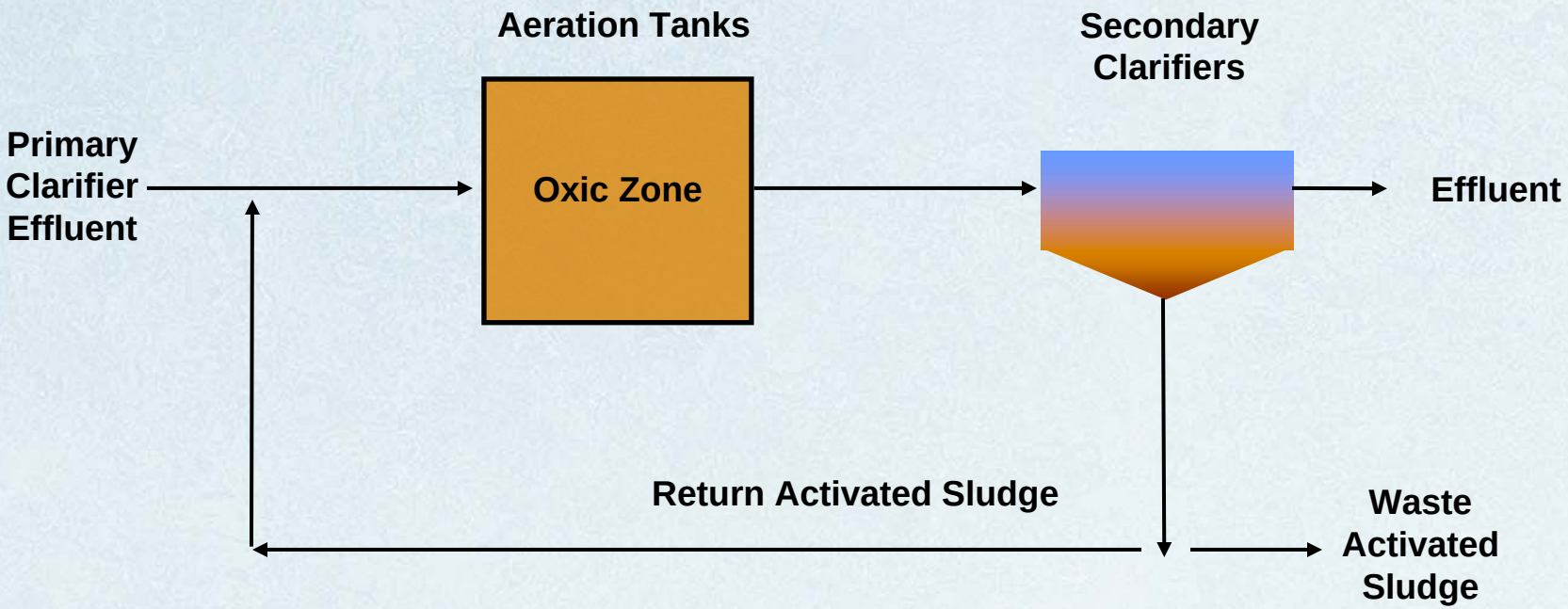
Typical wastewater nitrogen concentration

		% removal
Typical influent sewage	40 ppm	
Typical secondary effluent	32 ppm	20%
Level 1-N removal	8 ppm	80%
Level 2-N removal	5 ppm	87.5%
Level 3-N removal	3 ppm	92.5%

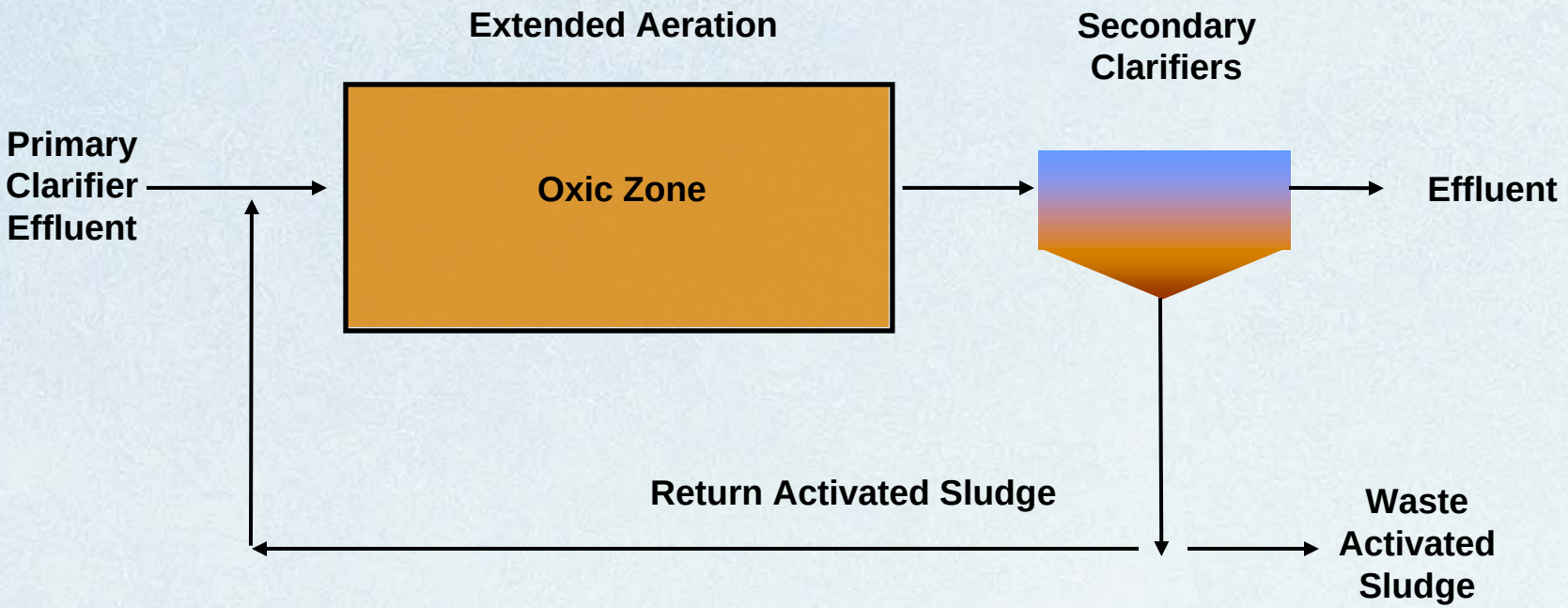
Nitrogen removal

1. Convert ammonia (NH_3) to nitrate (NO_3) under aerobic conditions
2. Convert nitrate (NO_3) to nitrogen gas (N_2) under anoxic conditions

Conventional activated sludge



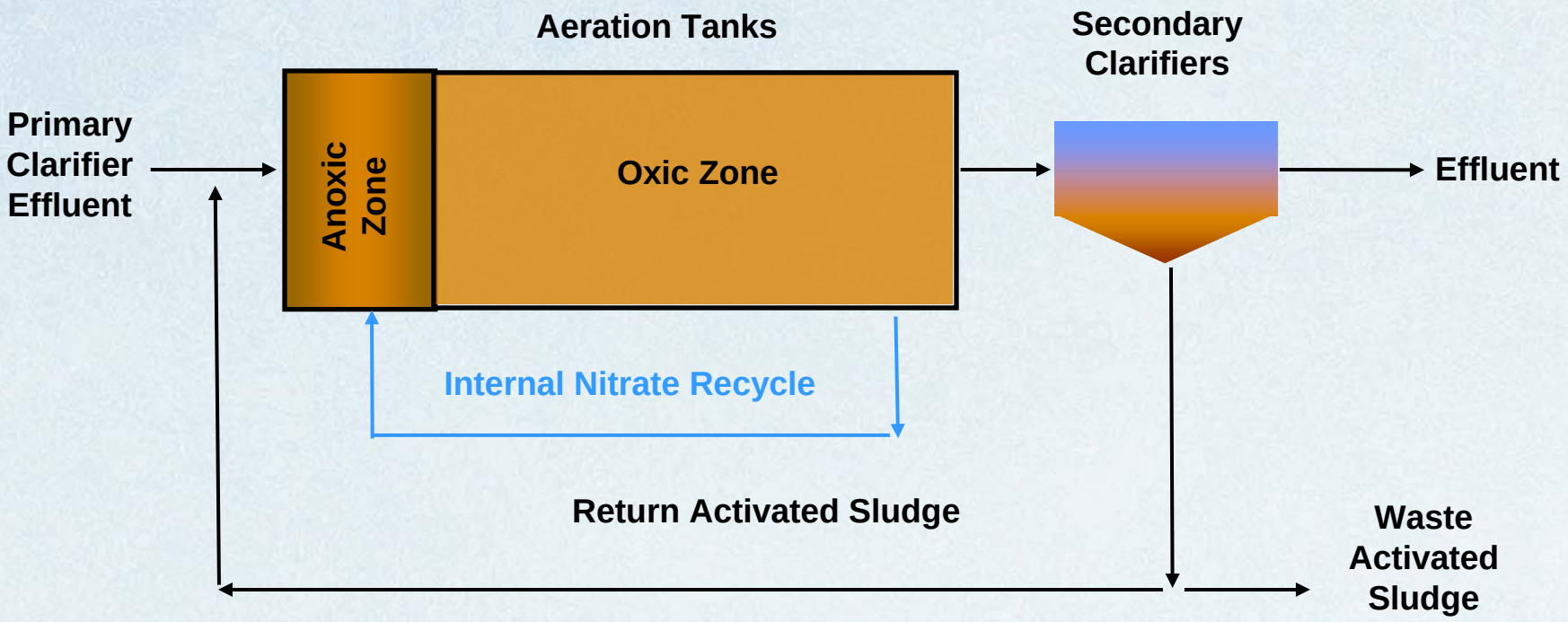
How to upgrade for ammonia removal



How to upgrade for TN removal

(8 mg/l TN limit)

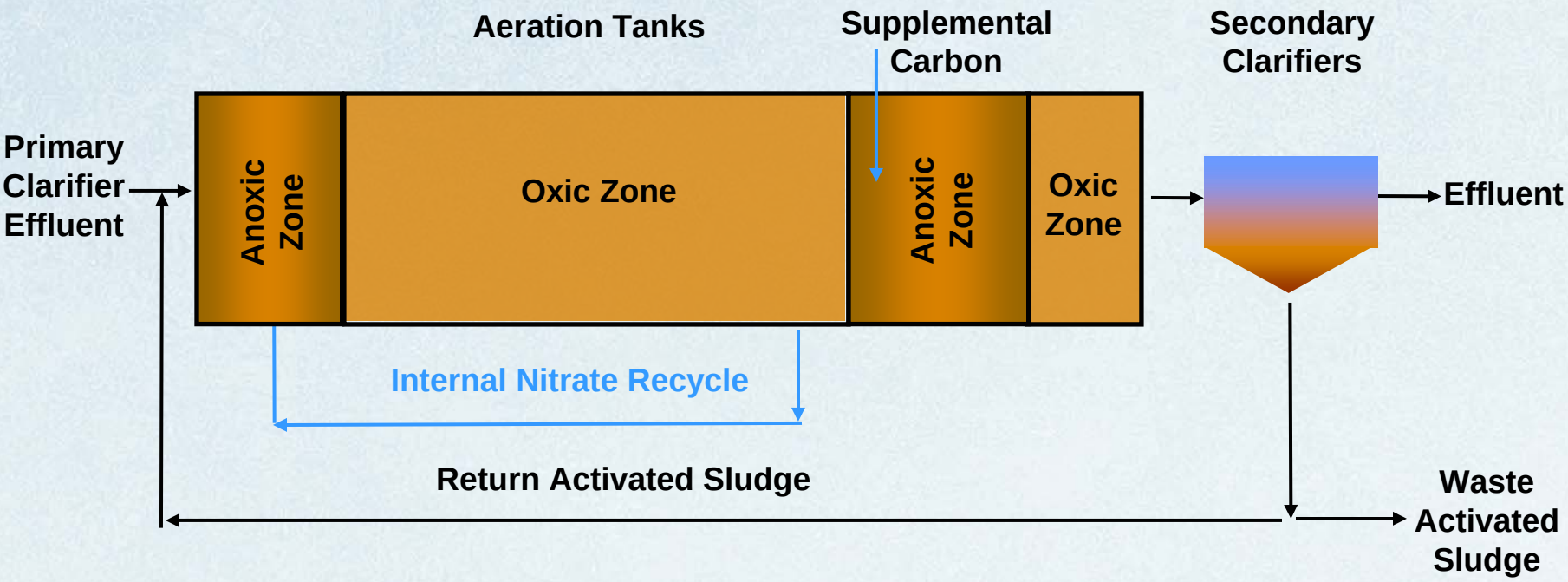
MLE Process



How to upgrade for higher TN removal

(3 to 5 mg/l TN)

Four-Stage Bardenpho Process



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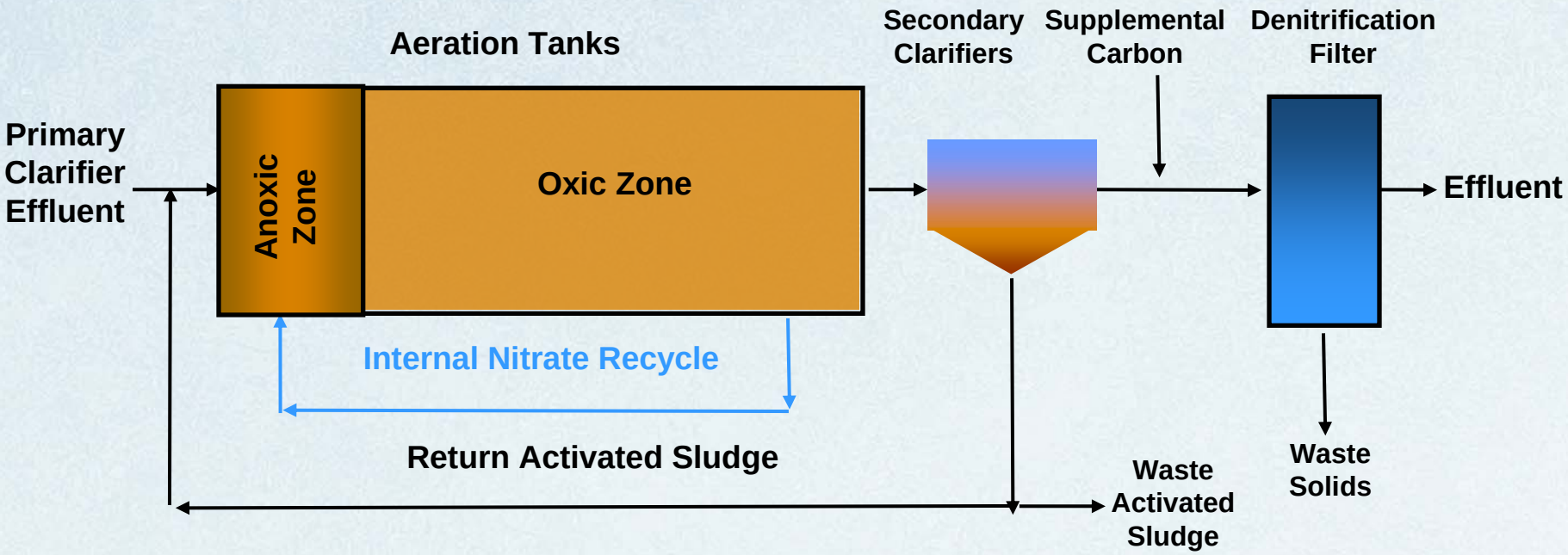
Alternative approach to TN limits

(3 to 5 mg/l range)

MLE process coupled with denitrification filter



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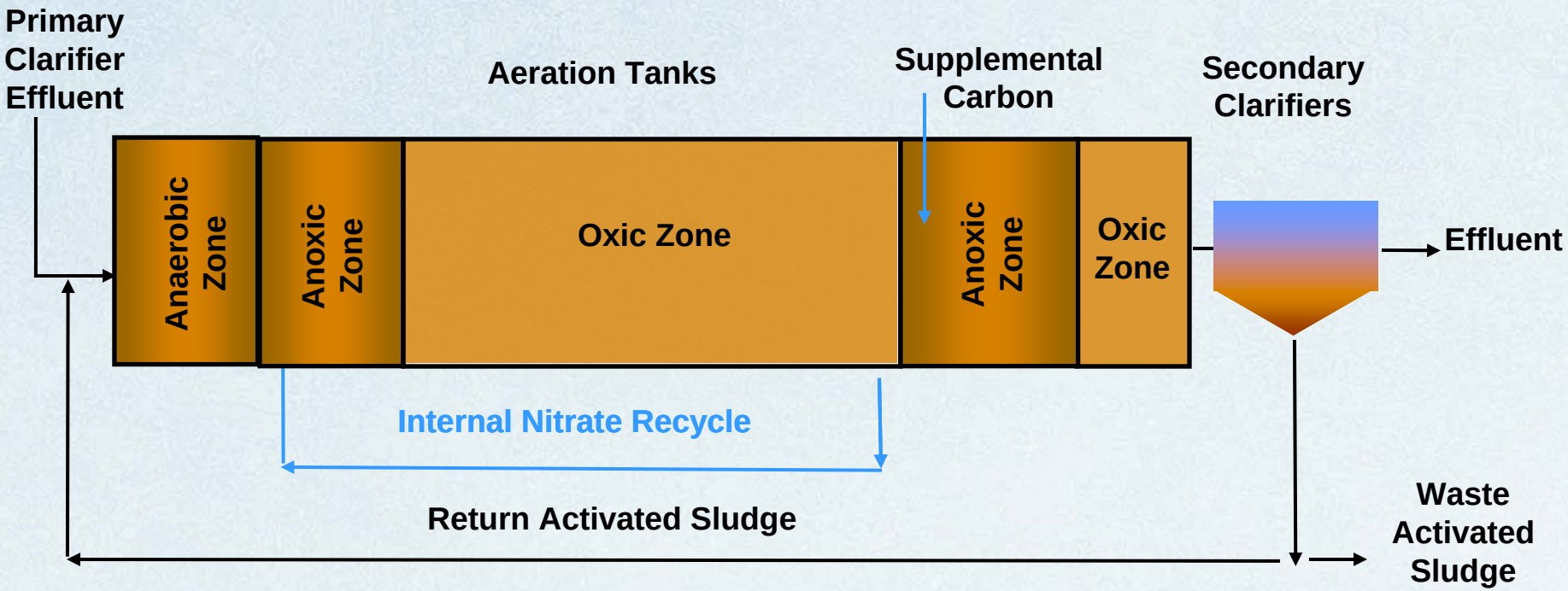
Many process configuration variations

- Sequencing batch reactors
- Oxidation ditches
- Step-feed
- Cyclic aeration processes
- Integrated fixed-film activated sludge (IFAS)
- Membrane bioreactors

Biological phosphorus removal can be incorporated with nitrogen removal

Five-Stage Bardenpho Process



Alternative discharge systems

Land disposal can be an effective nutrient management strategy

Land disposal
Slow rate land application

- Can apply to woodlands or fields
- Typically application rate 1 to 3” per week
- Seasonal application requires winter storage
- Requires much land

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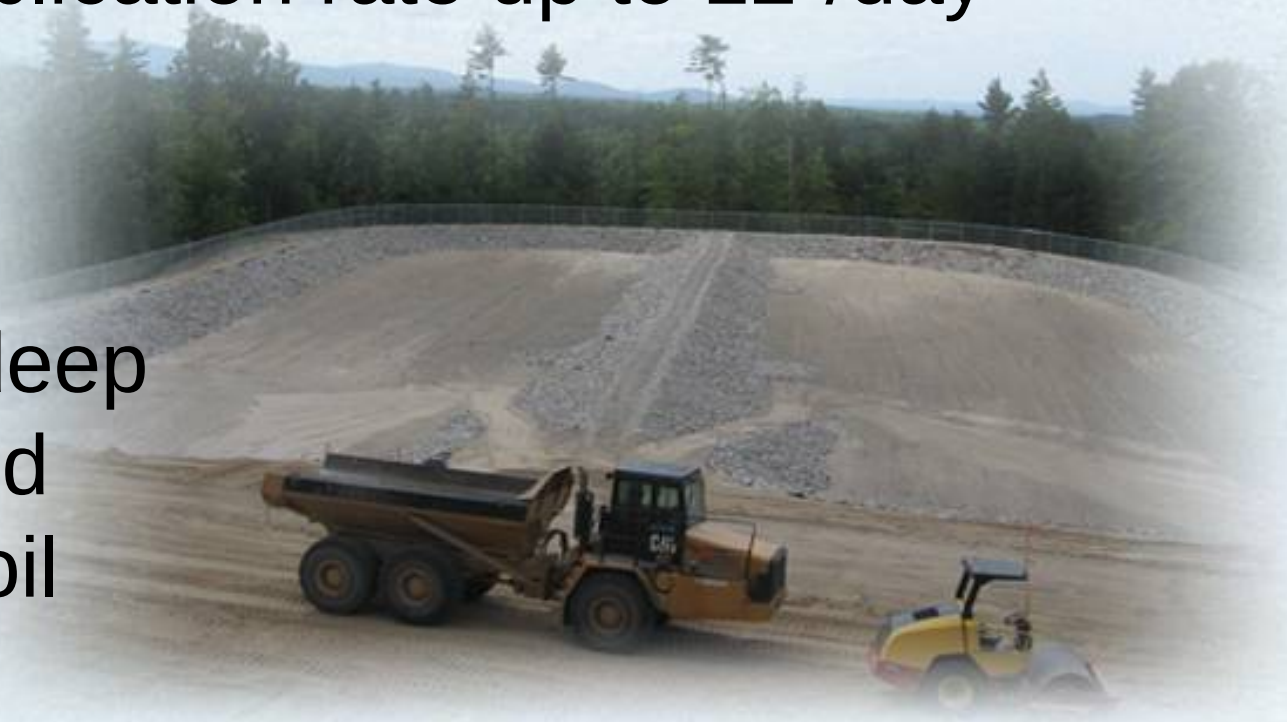
Land disposal – rapid infiltration

- Apply to prepared basins
- Typical application rate up to 12”/day
- Can apply year round
- Requires deep well drained granular soil



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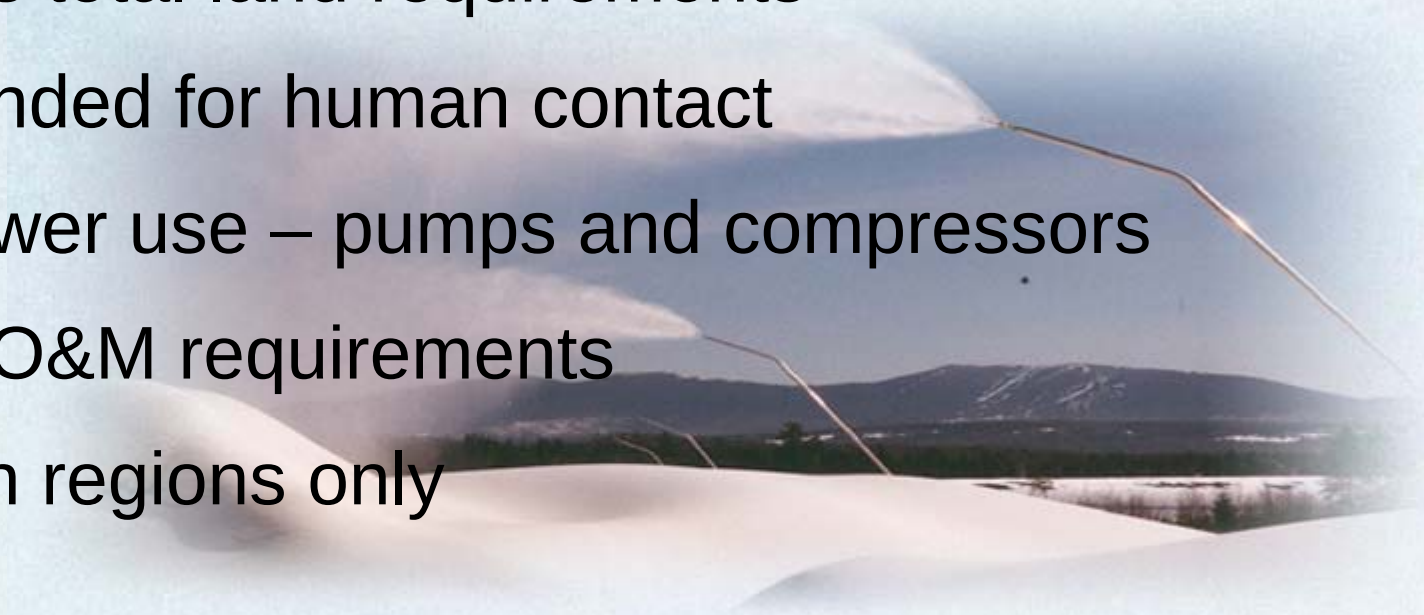
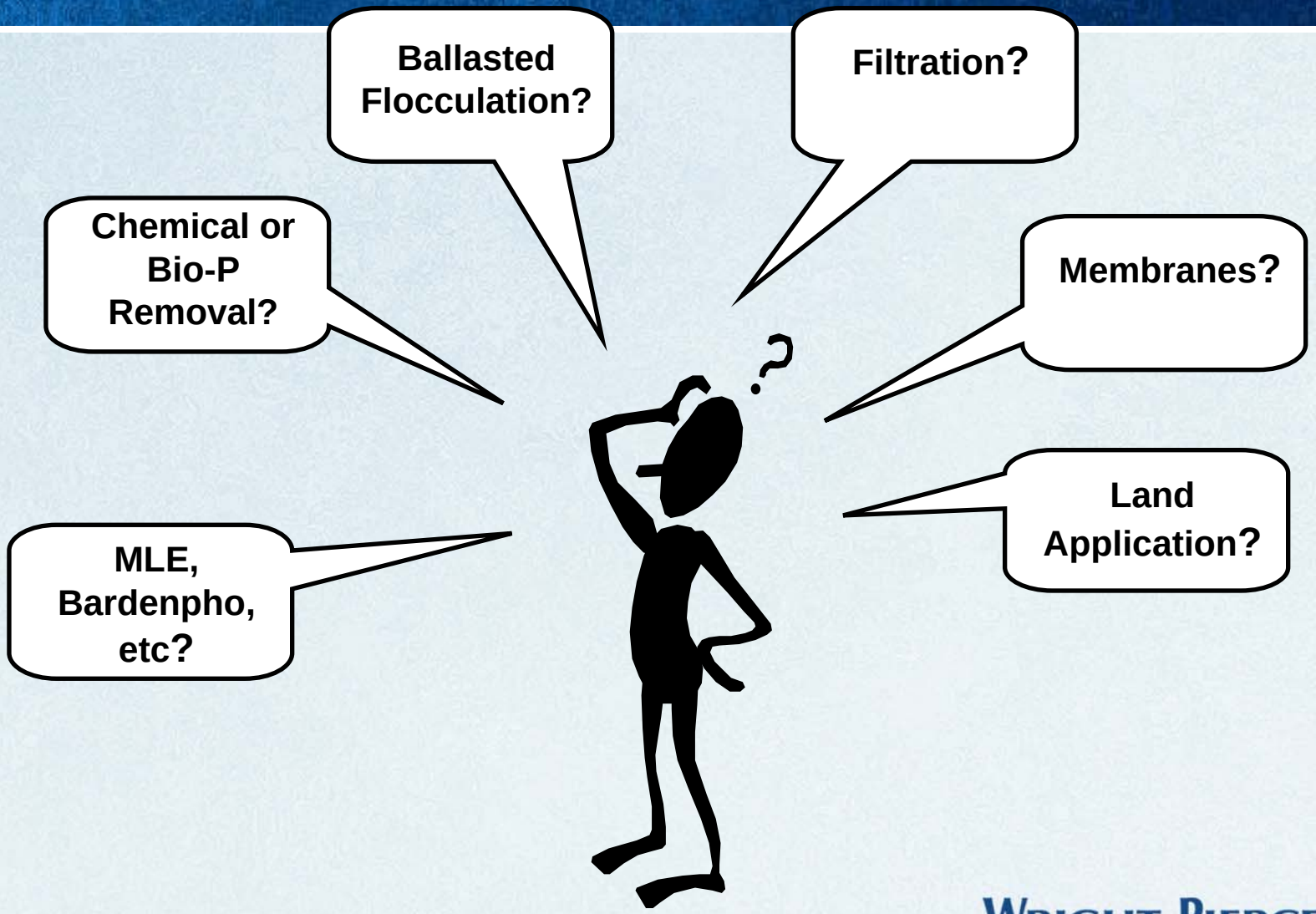
Land disposal – snow making

- Augments slow rate land application – takes place of winter storage
- Reduces total land requirements
- Not intended for human contact
- High power use – pumps and compressors
- Unique O&M requirements
- Northern regions only



Which technology is right for me?



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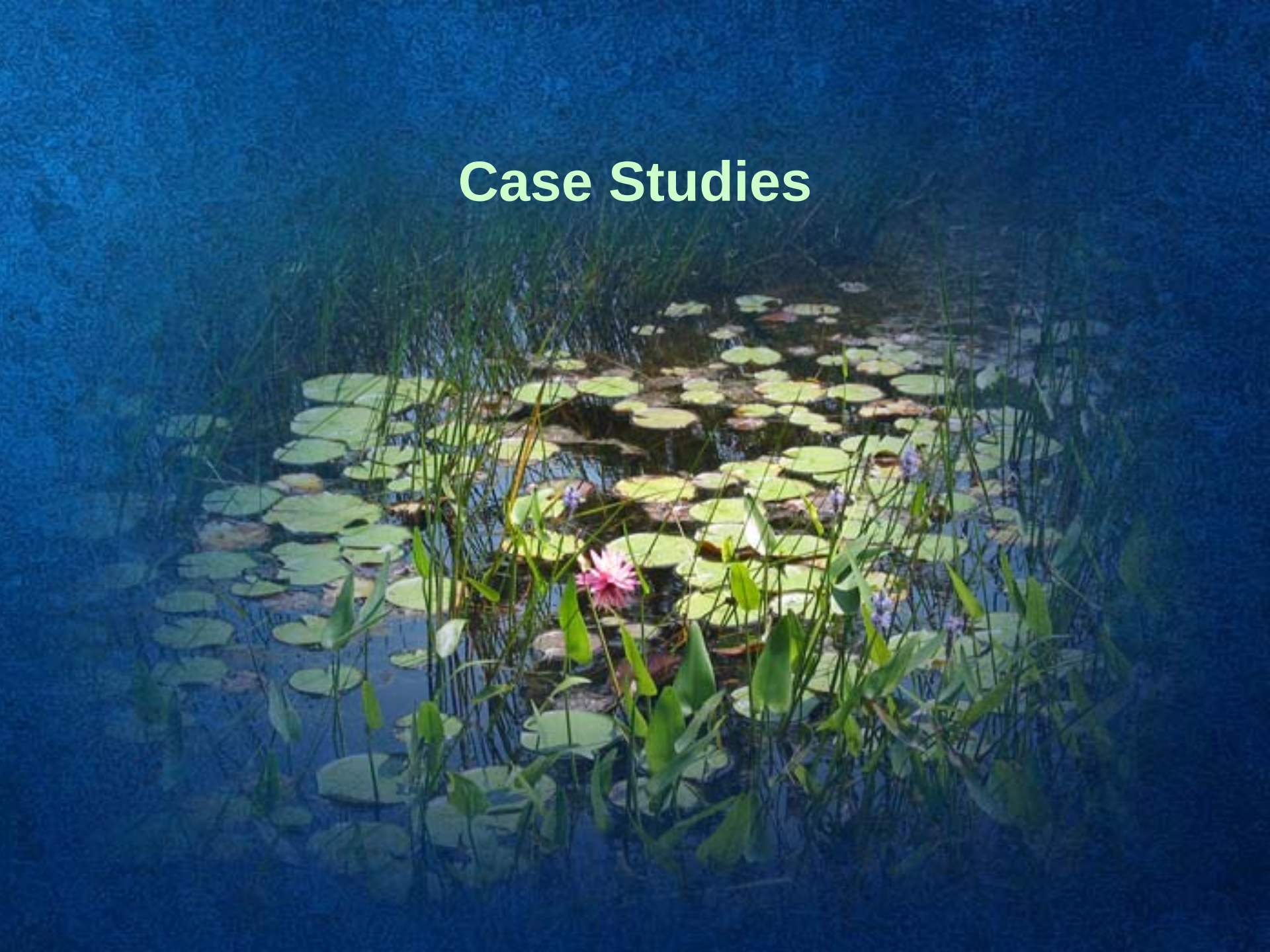
Conclusions

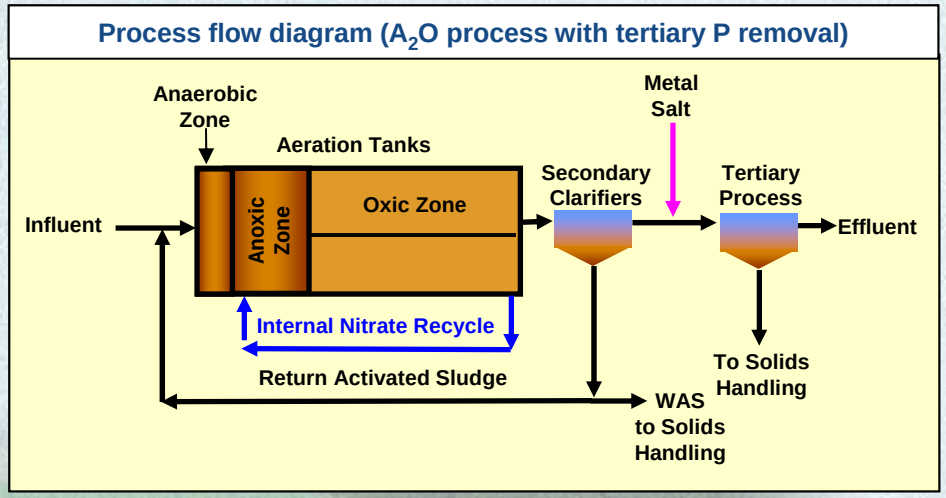
- Stringent nutrient limits are on the increase
- Many options available
- Best solution is a function of
  - The regulatory standard (proposed and likely future)
  - Site specific characteristics and constraints
- Analyze all options
- Select solution based on
  - Life cycle cost analysis
  - Operational considerations

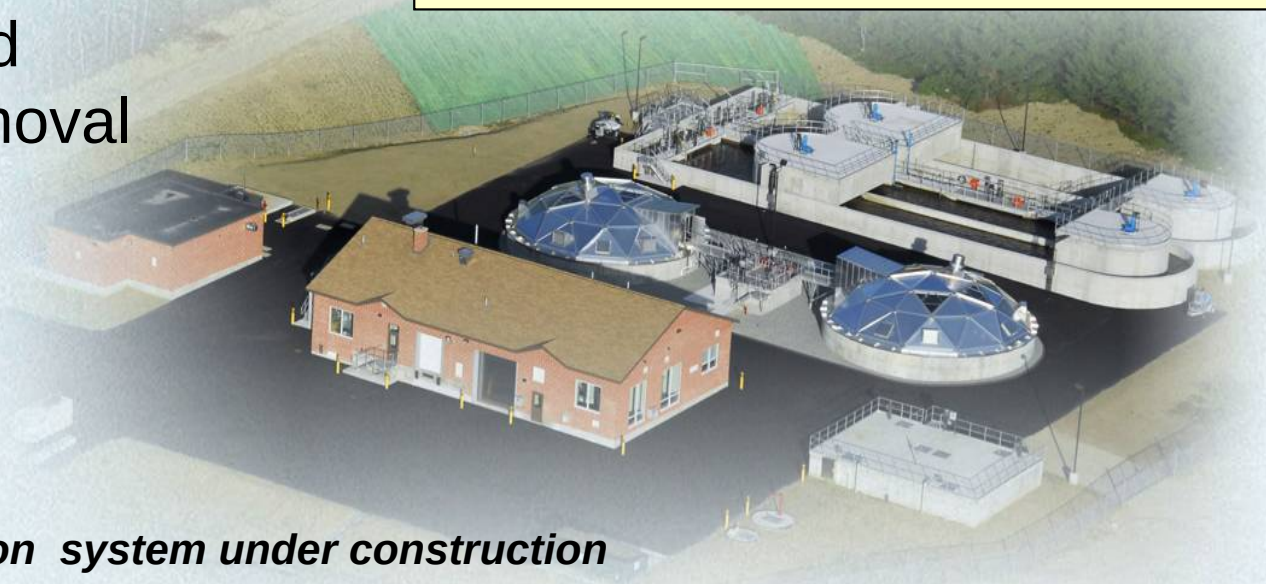
Case Studies



Jaffrey, NH Upgrade

- Upgraded lagoon facility to achieve low TN and P limits
- A_2O oxidation ditch plant followed by ballasted clarification*
- Both Bio-P and chemical P removal
- Results
  - P<0.1ppm*
  - TN<8ppm





***ballasted clarification system under construction**

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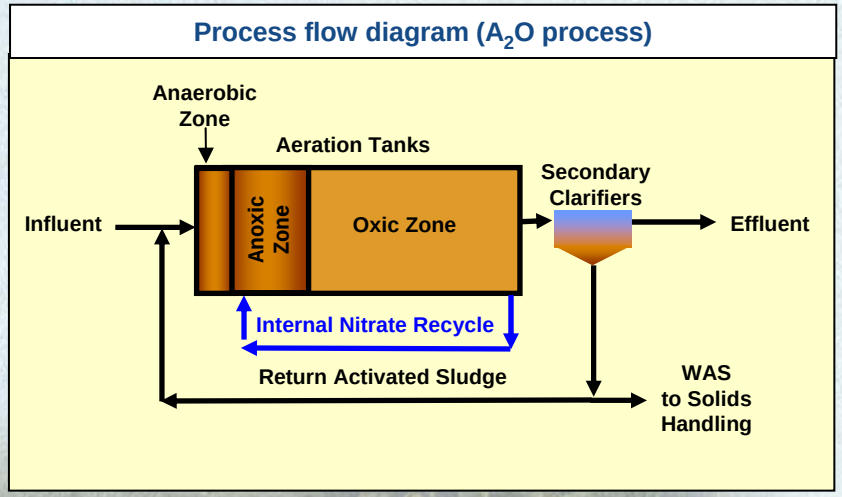
Falmouth, ME Upgrade

- Modified existing activated sludge facility to achieve Bio-P removal and TN removal.
- Results
  - P< 0.5ppm
  - TN<8ppm



GLSD Upgrade

- Added anaerobic selector to improve process stability and obtain Bio-P removal
- Results
  - P< 0.3 ppm
  - Substantial increase in wet weather capacity

Greater Lawrence Sanitary District, North Andover, MA

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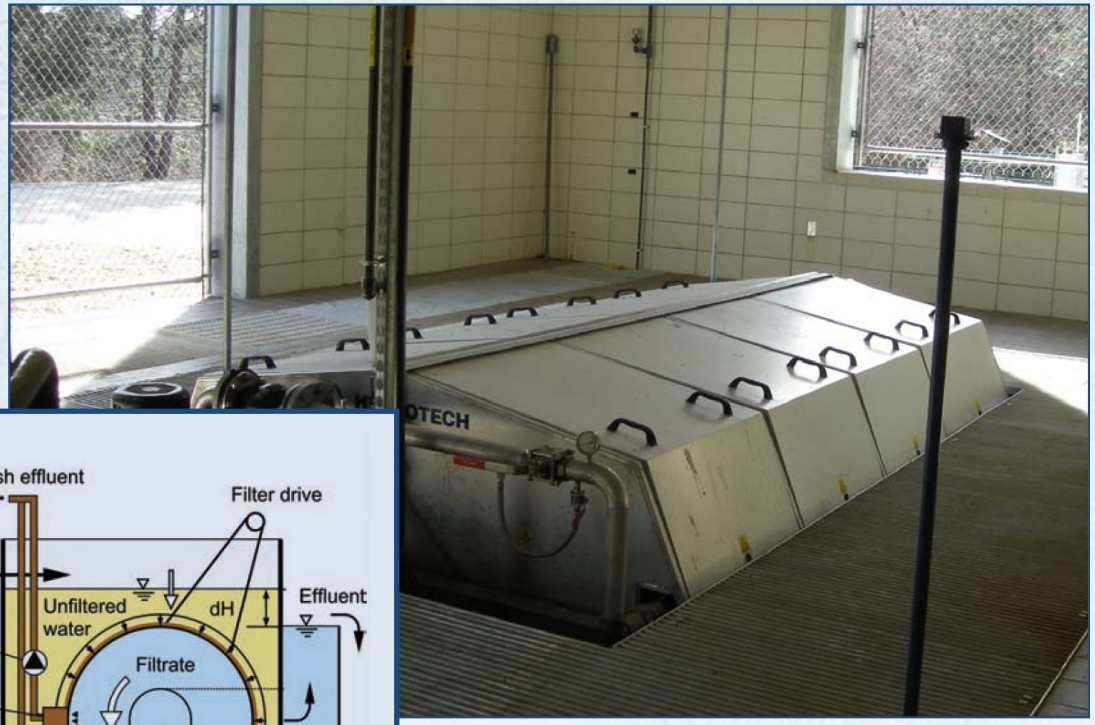
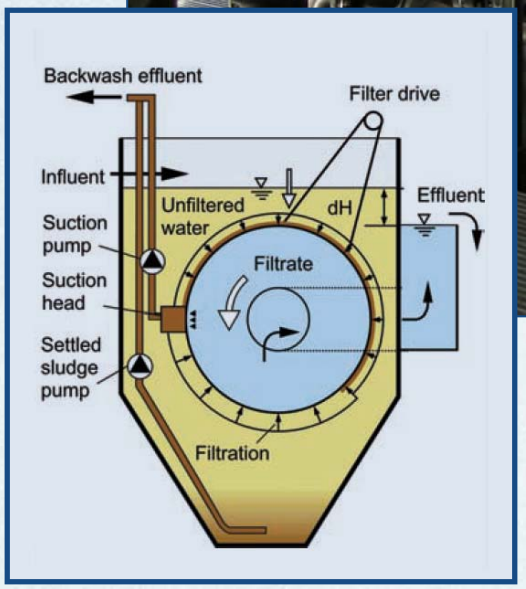
Smithfield, RI Upgrade

- Employs biological P removal and a disk filter for solids capture
- Results
  - P<0.2ppm





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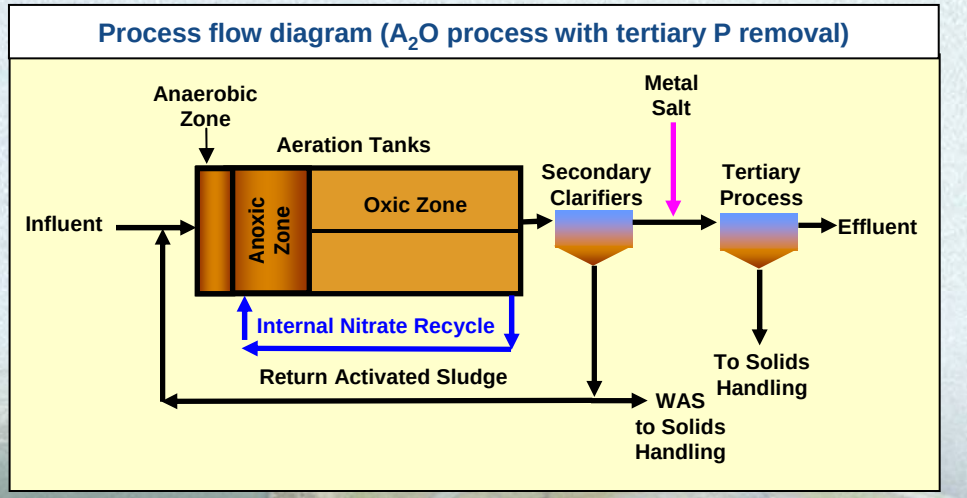
Sanford, ME Upgrade

- Upgraded lagoon facility to achieve low TN and P limits
- A2O Oxidation ditch plant followed by tertiary clarification and filtration
- Both Bio-P and chemical P removal
- Results:
  - P<0.1ppm
  - TN<5ppm



Hudson, MA Upgrade

- Chemical P removal with DAF for advanced solids capture
- Results
  - P<0.1ppm*

***currently in startup**

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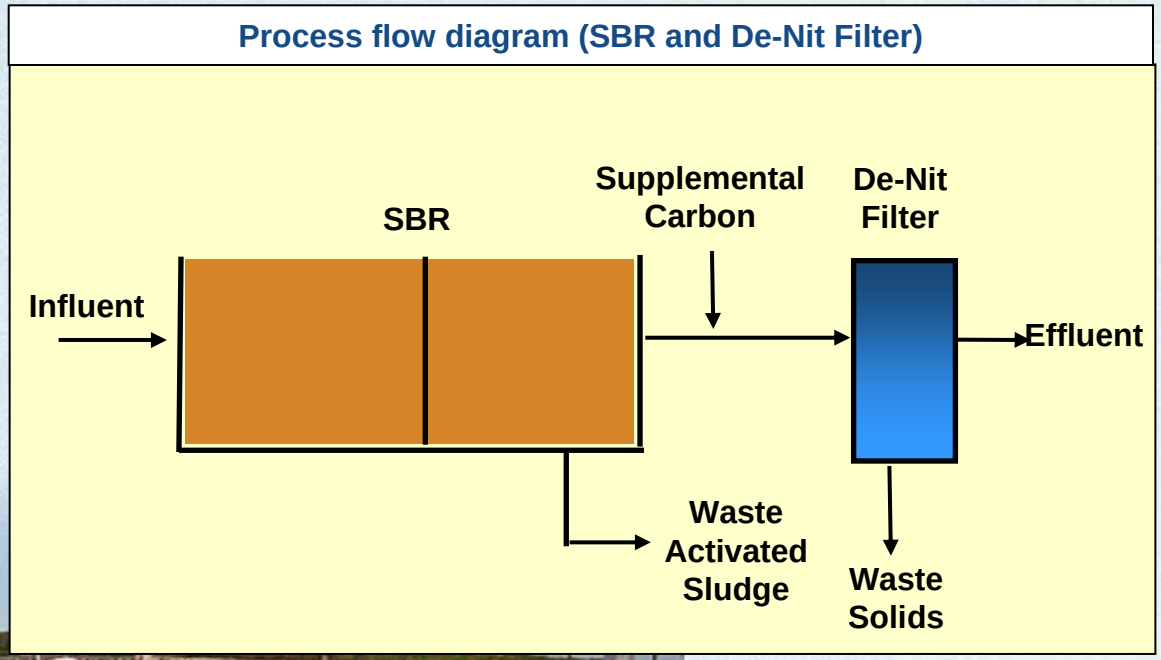
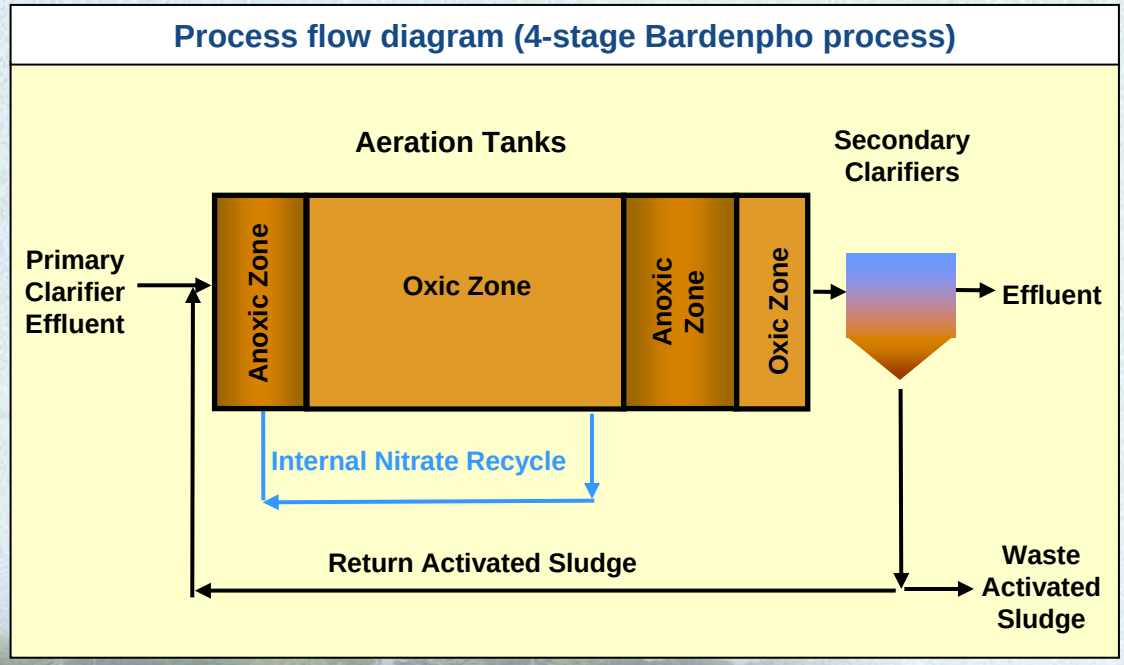
Falmouth, MA Upgrade

- Replaced lagoon treatment facility with SBR followed by De-Nit filter
- Results:
  - TN < 5 ppm after SBR
  - TN < 3 ppm after De-Nit filter



Glastonbury, CT Upgrade

- Upgraded activated sludge facility to a 4-stage Bardenpho process to achieve low TN limits
- Results
  - TN<4ppm



Questions & Answers

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