Denitrification Filter Technology

Achieving Low Effluent Nutrient Requirements

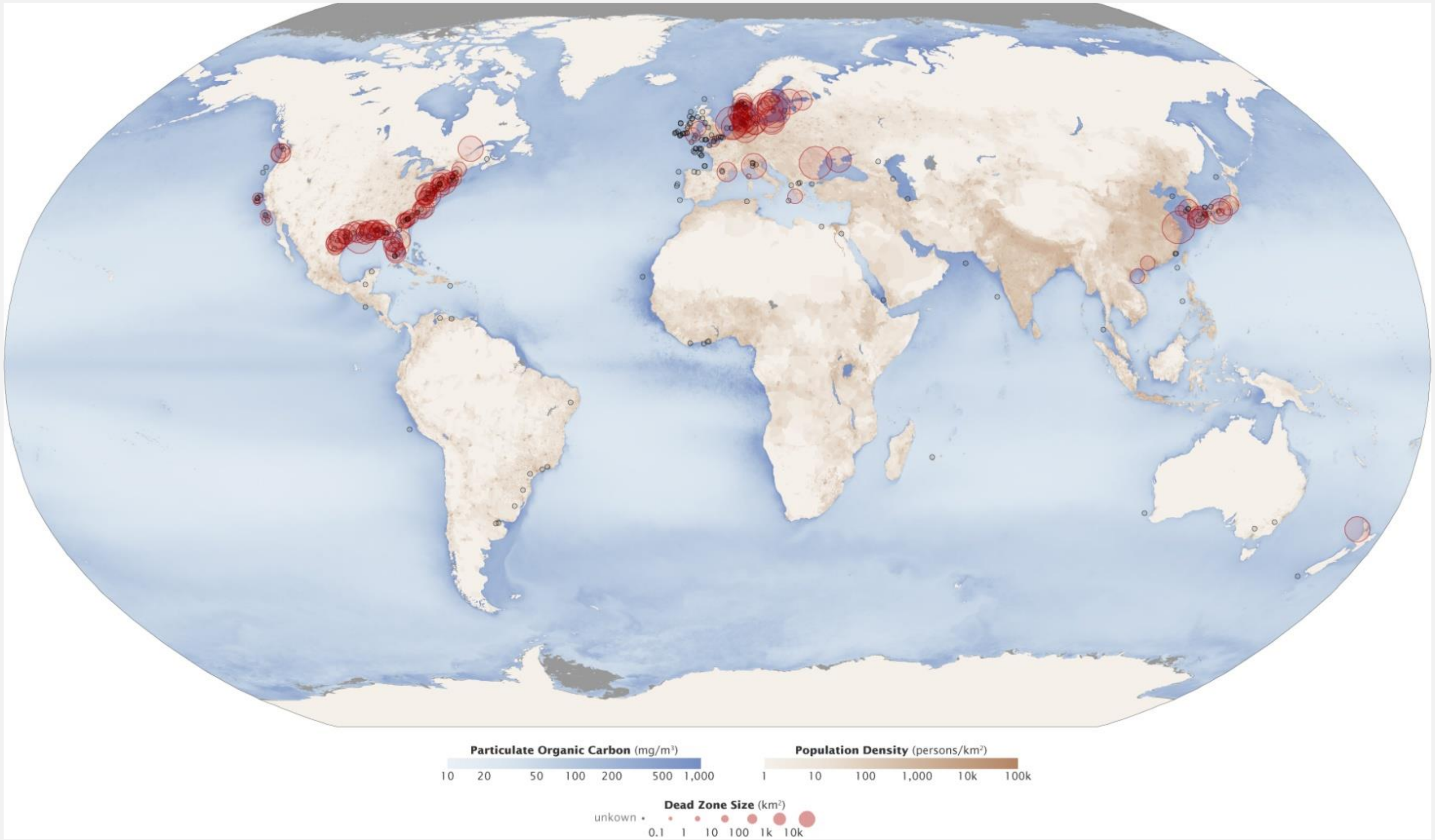
HAZEN AND SAWYER
Environmental Engineers & Scientists

File location name here.ppt

Agenda

- Why nutrient removal?
- Nitrogen cycle basics
- Nitrogen removal at WWTP
- Denitrification filter technology basics
- Deep bed denitrification filters

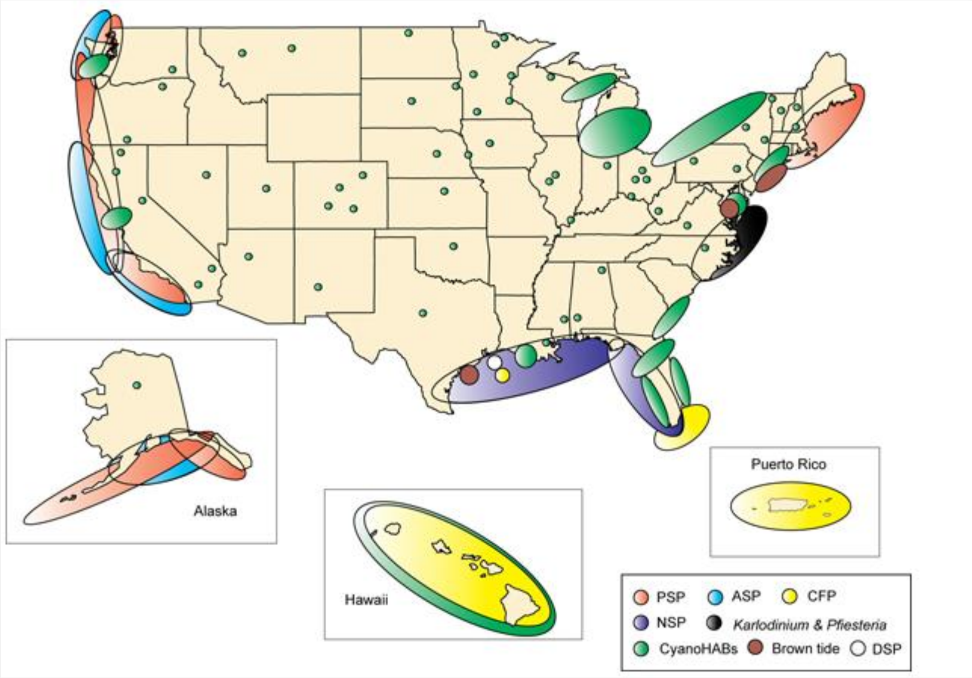
Excess Nutrients are a Global Concern



NASA Earth Observatory

Extent of N&P Impacts

- 14,000 Nutrient-related Impairment Listings in 49 States
- ~80% of Assessed Continental U.S. Coastal Waters exhibit eutrophication
- ~50% of streams have medium to high levels of nitrogen and phosphorus



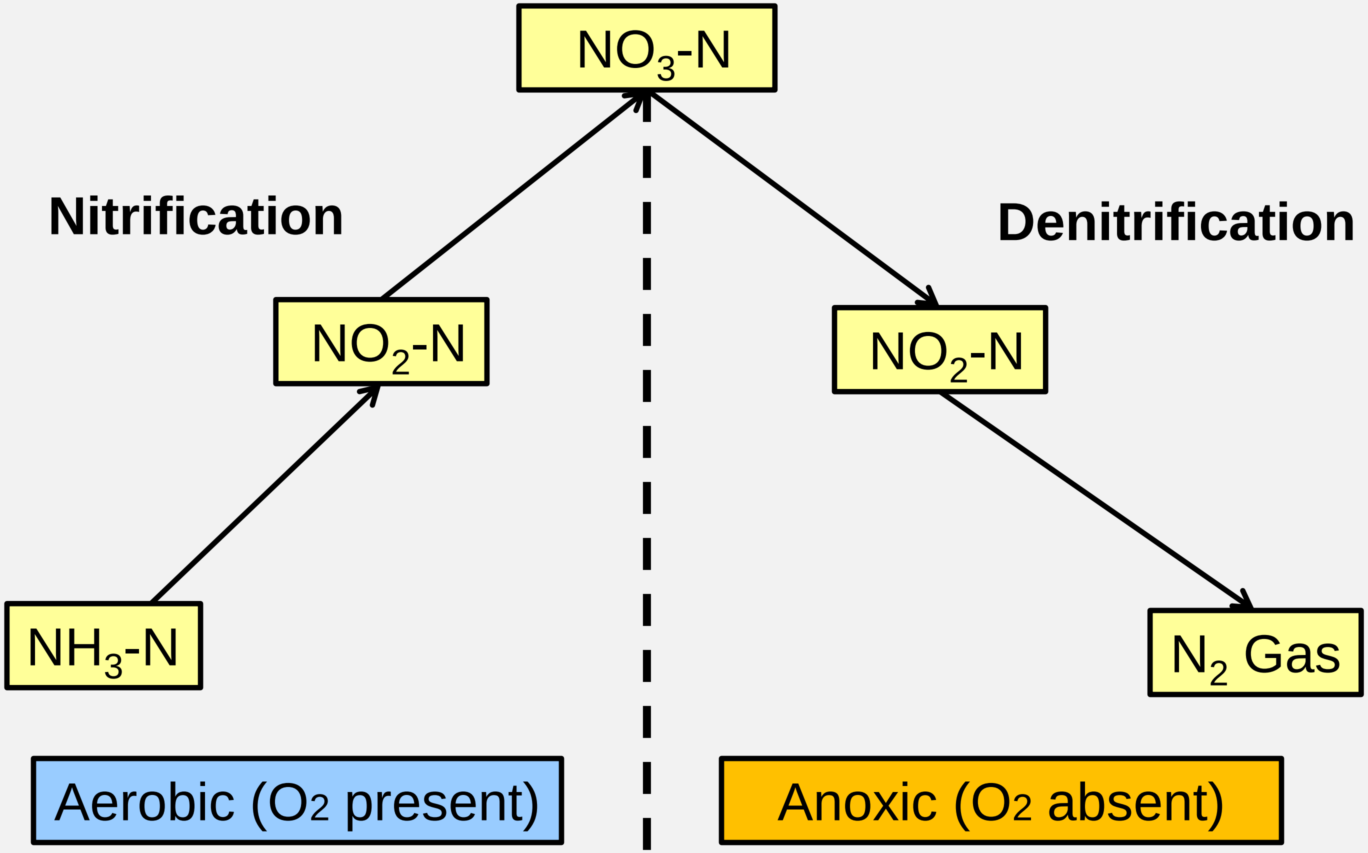
Occurrence of Algae throughout the U.S.

Major Forms of Nitrogen

Nitrogen Form	Abbreviation	Physical Form
Organic Nitrogen	Org-N	Solid or liquid
Ammonia	NH_3-N	Liquid
Nitrite	NO_2-N	Liquid
Nitrate	NO_3-N	Liquid
Nitrogen Gas	N_2	Gas

- Wastewater treatment converts nitrogen among various forms
- Biological processes
  - Nitrification: $NH_3\text{-N} \rightarrow NO_3\text{-N}$
  - Denitrification: $NO_3\text{-N} \rightarrow N_2$
- Nitrification & denitrification required for TN removal

Simplified Nitrogen Removal



Three Ingredients for Nitrogen Removal

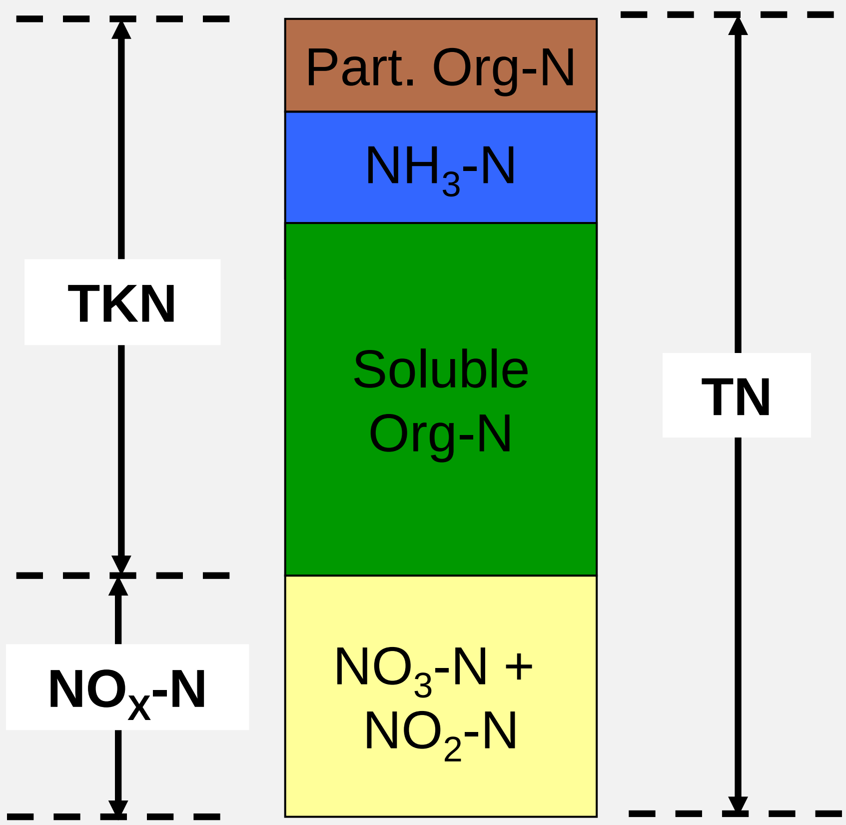
Nitrification improves oxygen in receiving waters:

Ammonia + Oxygen —(Autotrophs)→ Nitrate

Denitrification removes nitrogen:

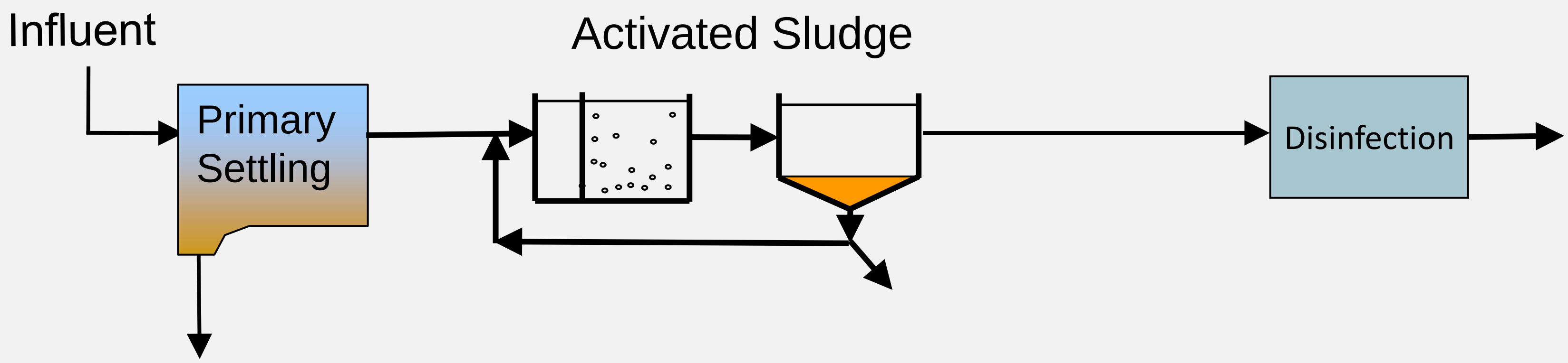
Nitrate + Food —(Heterotrophs)→ Nitrogen gas ↑

Effluent TN Characteristics



- Effluent TKN: 1 – 2 mg/l
- Limit of technology (LOT) requirements TN ≤ 3 mg/l
- Effluent TN is function of denitrification capability of the WWTP
- Typically requires “add-on” treatment process to achieve LOT for TN

Typical BNR Configuration



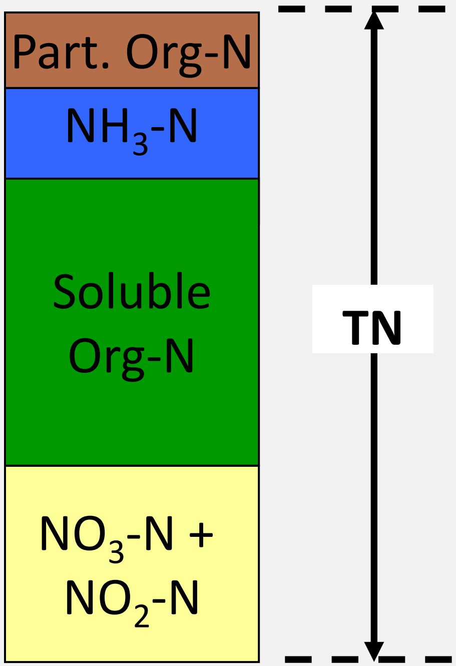
Activated Sludge (Anaerobic/Anoxic/Aerobic)

Nitrogen: 35 mg/L → 6 – 8 mg/L

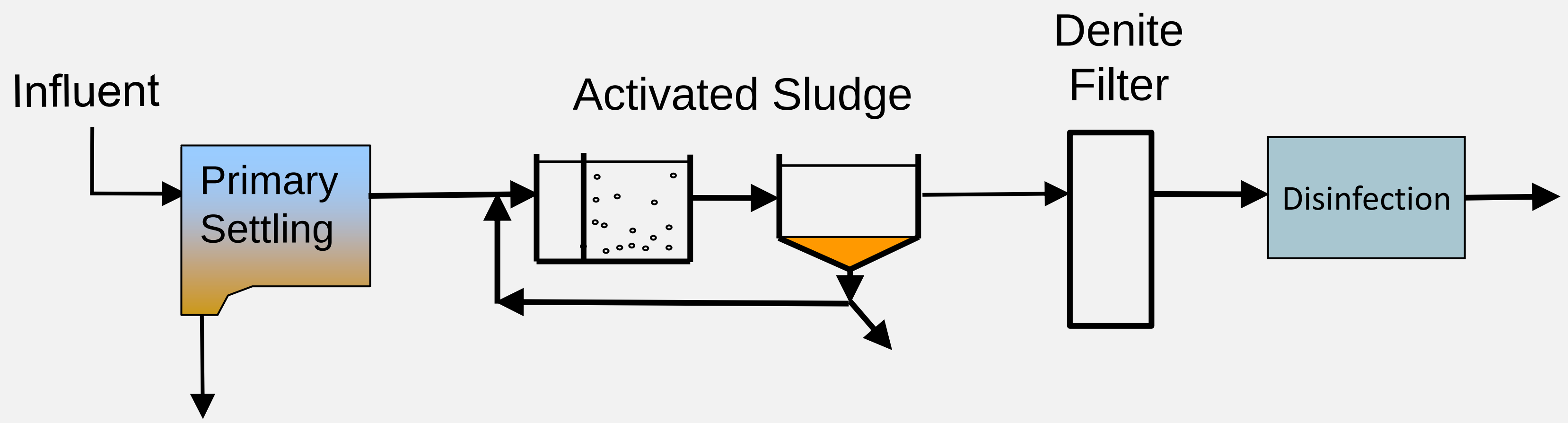
Phosphorus: 7 mg/L → 0.5 mg/L

Why Denitrification Filters?

- Stringent TN requirements
  - Removes solids (reduces particulate org-N fraction)
  - Removes nitrogen (reduces NO_x-N fraction)
- Stringent TP requirements
  - Removes solids (reduces particulate P)
  - Consumes soluble P
- Limited land availability
- Provides “two barrier” removal for TN
  - Operational flexibility
  - Seasonal TN removal strategies



BNR + Denite Filter Configuration



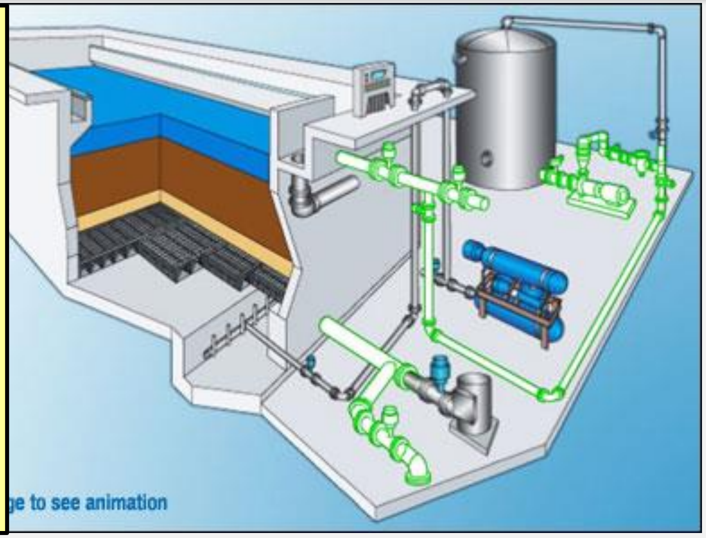
	Activated Sludge (Anaerobic/Anoxic/Aerobic)	Denite Filter
Nitrogen: 35 mg/L	6 – 8 mg/L	3.0 mg/L
Phosphorus: 7 mg/L	0.5 mg/L	0.18 mg/L

Denitrification Filters

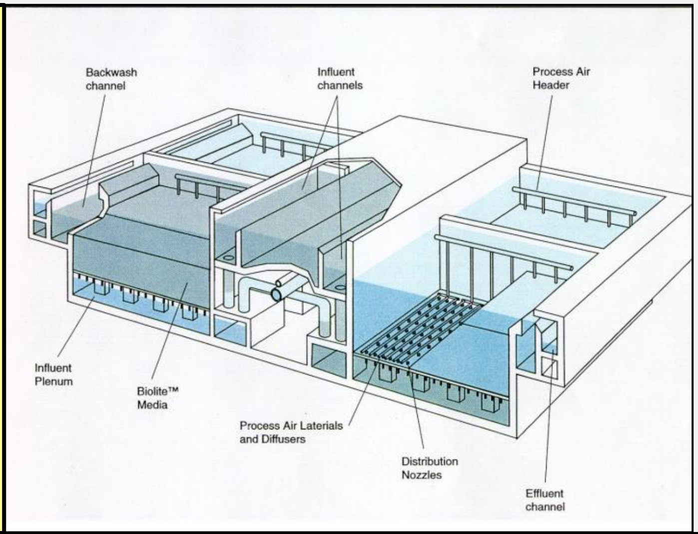
- Advanced TN removal technology
- Typically designed for effluent TN goals < 6 mg/l
- Attached growth filtration process
  - Secondary clarifier effluent applied with NO_X-N
  - External carbon addition required
  - Applied NO_X-N is converted to N_2
  - N_2 released to atmosphere
- Additional facilities required
  - Intermediate pump station (IPS)
  - External carbon addition facility

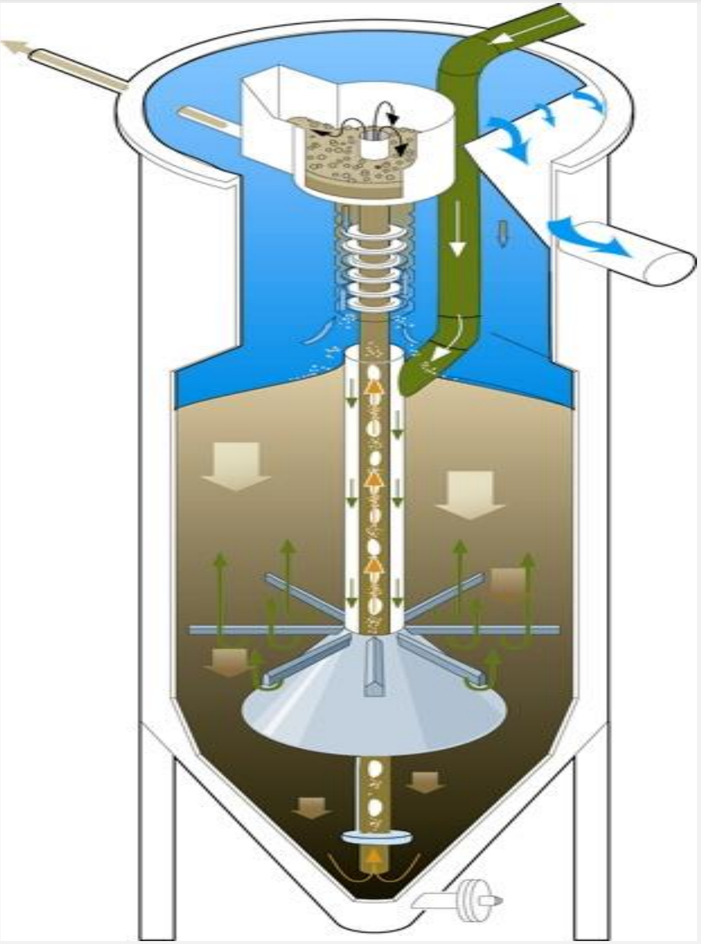
Types of Denitrification Filters

Deep Bed
Courtesy of
ITT Leopold



Biological Active Filter
Courtesy of
IDI





Continuous Backwashing
Courtesy of Parkson (Siemens)

Technology Comparison

Gravity Filter Versus Deep Bed Denitrification Filter

Feature	Gravity Effluent Filter	Deep Bed Denitrification Filter
Purpose	Solids Removal TP Removal	TN Removal Solids Removal TP Removal
Media Design	Mono Dual Multi	Mono
Media Depth	24 – 42-inches	72-inches
Media Size	0.5 – 1.8 mm	1.5 – 3.0 mm
Auxiliary Backwash Energy	Air Surface Wash	Air
Backwash Rate	8 – 25 gpm/SF	6 gpm/SF
Flow Control	Effluent	Influent

Critical Design Criteria
Deep Bed Denitrification Filters

1. Hydraulic Loading Rates (HLR)
   - Peak HLR = 6 gpm/SF
   - Avg. HLR = 2 – 3 gpm/SF
2. NO_X-N Loading Rates
   - Higher loadings require additional filter volume
3. Wastewater Temperature
   - Treatment reduction at cold temperatures
4. Organic Carbon Addition
   - Secondary effluent deficient in organic carbon

Deep Bed Denitrification Filters

United States Market

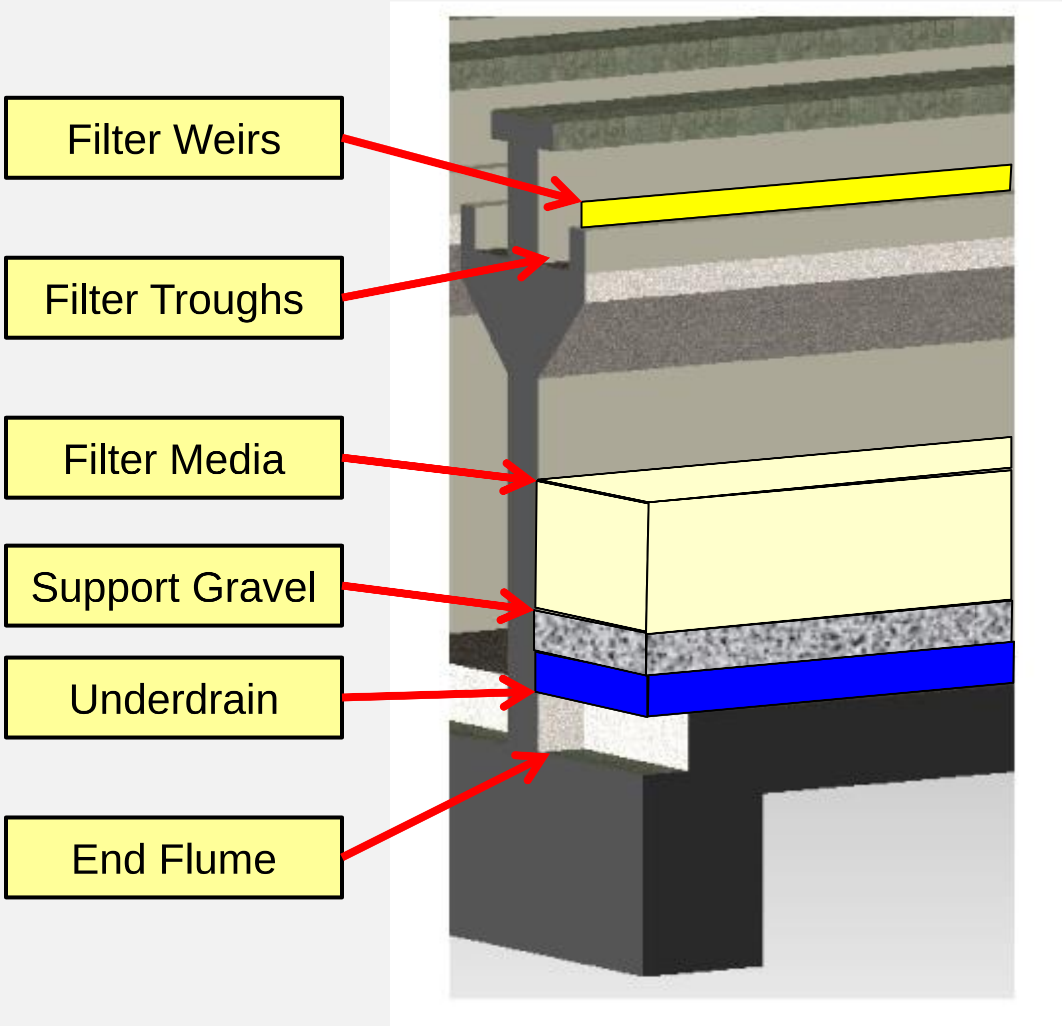
Design Criteria	Criteria
Hydraulically Limited Designs	~95%
NO_X-N Loading Limited Designs	~5%
Critical Wastewater Temperature	<15 °C (lower performance)

- Two major U.S. suppliers of technology
  - ITT Leopold
  - Severn Trent Services
- Significant differences between suppliers
  - Physical layout
  - Operations
  - Control strategies

ITT Leopold Elimi-Nite®

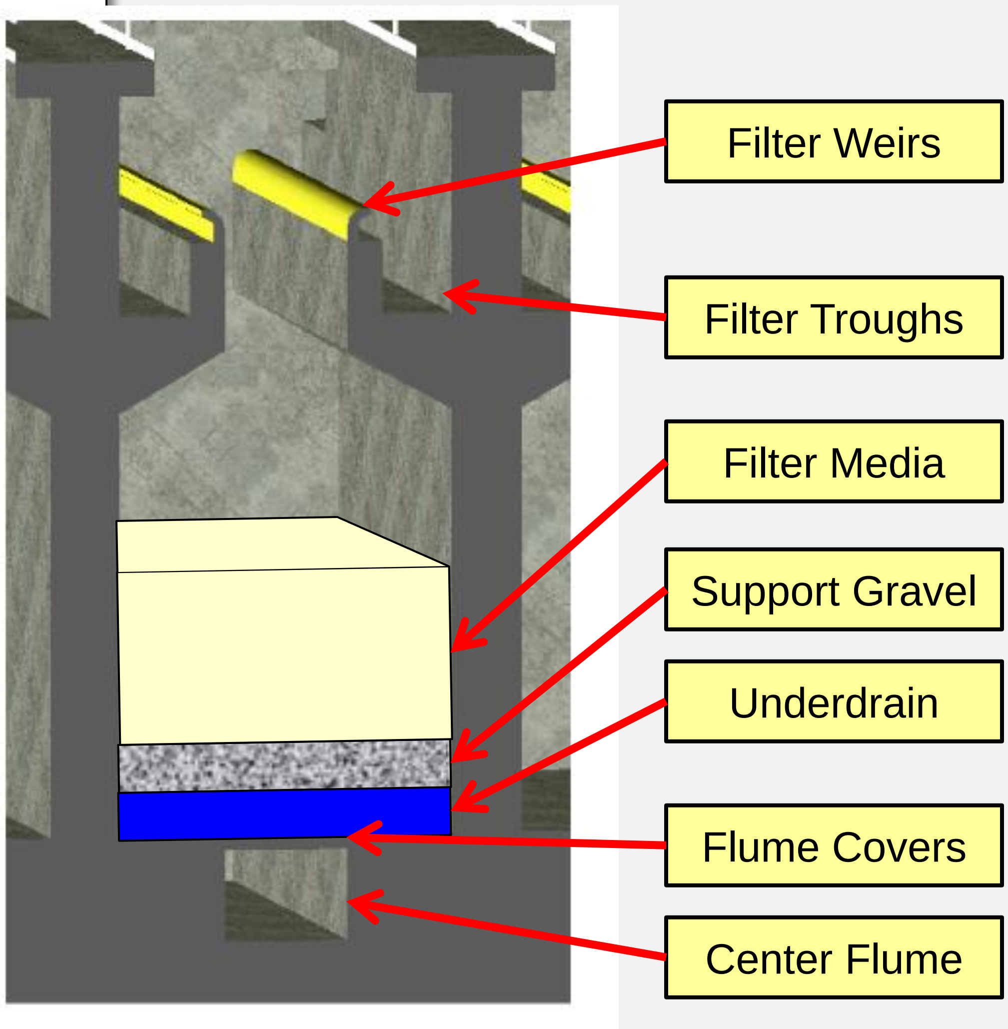
Specific Filter Internals

Internals	Criteria
Filter Weirs	SS
Filter Media	1.5 – 3 mm
Filter Media Depth	72 inches
Support Gravel	15 inches
Underdrain	Dual Parallel
Max. Filter Length	40 feet
Max. Filter Area	520 SF



Severn Trent Tetra Denite®

Specific Filter Internals



Internals	Criteria
Filter Weirs	Concrete
Filter Media	2 – 3 mm
Filter Media Depth	72 inches
Support Gravel	15 inches
Underdrain	T-Block
Max. Filter Length	100 feet
Max. Filter Area	1,167 SF

Supplier Comparison

Physical Design Characteristics

Internals	Leopold	Severn Trent
Filter Weirs	Stainless Steel	Concrete
Filter Media	1.5 – 3 mm	2 – 3 mm
Filter Media Depth	72 inches	72 inches
Support Gravel	15 inches	15 inches
Underdrain	Universal Type S Continuous lateral Parallel to filter length	T-Block Individual blocks Parallel to filter width
Flume	End	Center
Max. Filter Length	40 feet	100 feet
Filter Width (typical)	13 feet	11.67 feet
Max. Filter Area	520 SF	1,167 SF

Deep Bed Denitrification Filters

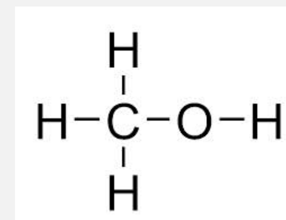
Process Operation

- External carbon added, typically methanol
- Attached biomass converts NO_X-N to N_2
- Biomass growth + TSS removal
  - Increases headloss
  - Requires filter backwashing
  - Air/Water backwash
  - 24 – 48 hour run time
- N_2 collects in media pores
  - Increases headloss
  - Requires filter “bumping”
  - Water backwash
  - 6 – 8 times per day

Deep Bed Denitrification Filters

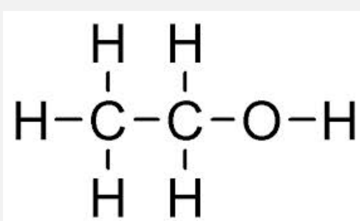
Organic Carbon Dosing Strategy

- Methanol (MeOH) preferred (pure or reclaimed)
  - Specific type of microorganisms use methanol for denitrification
  - Less methanol goes to biomass growth (i.e. lower yield)
    - Less solids accumulation
    - Less frequent backwash required
    - Stable operation

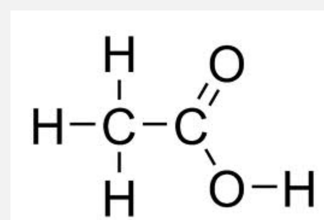


Methanol

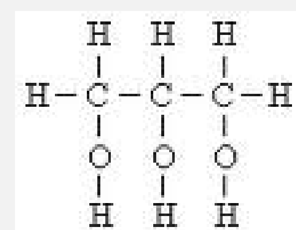
- Limited success with alternative carbon sources
  - Micro-C (proprietary)



Ethanol



Acetic Acid



Glycerol

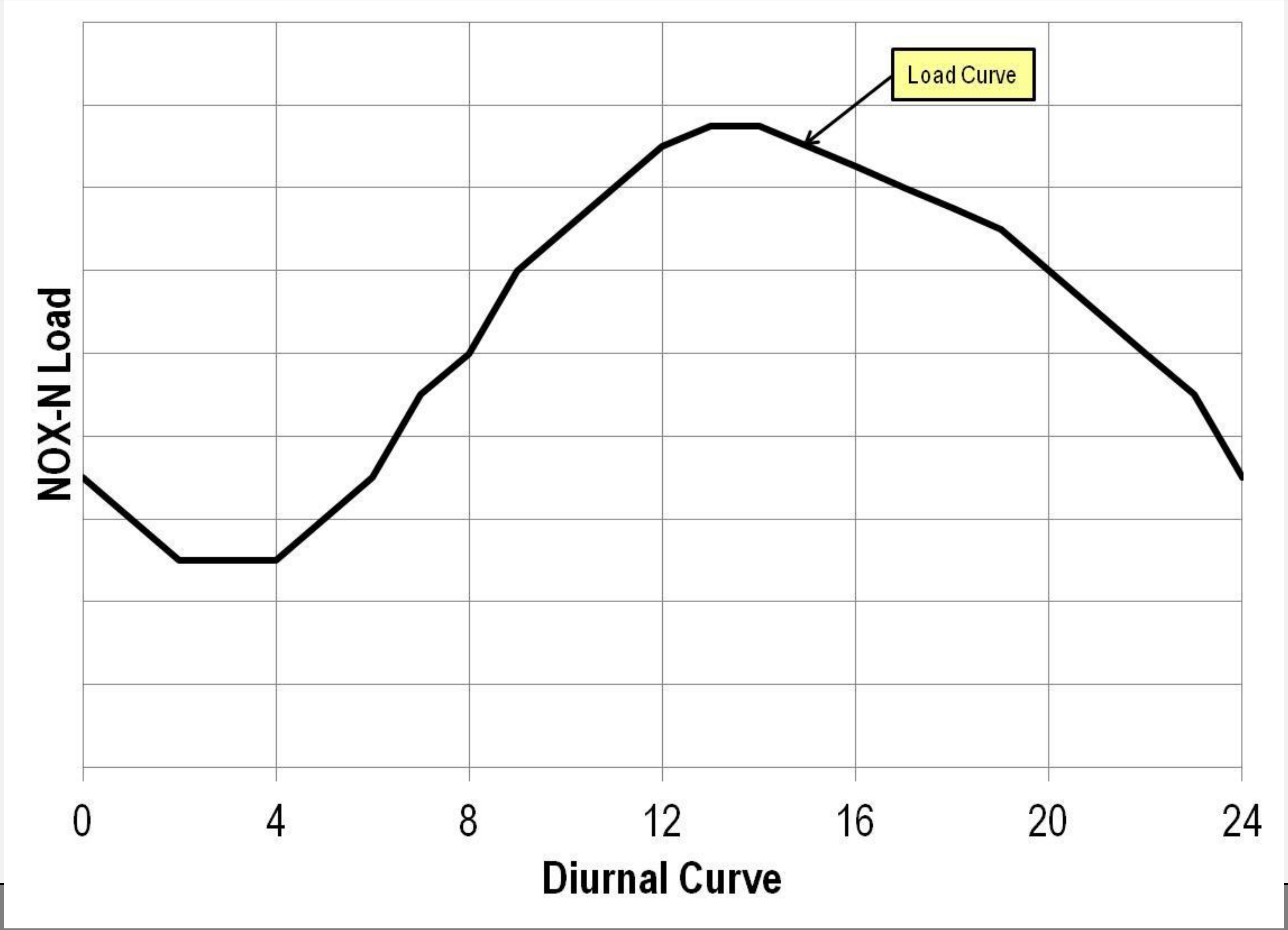
Deep Bed Denitrification Filters

Organic Carbon Dosing Strategy

- 100% MeOH dosing: ≤ 3.5 lb MeOH / lb NO_X-N removed
- Design approach – Dose dilute MeOH (reduces facility fire rating)
- Sophisticated methanol dosing controls required
  - Over dose: Increases effluent BOD
  - Under dose: Incomplete denitrification
    Effluent NO_2-N accumulation (nitrite-lock)

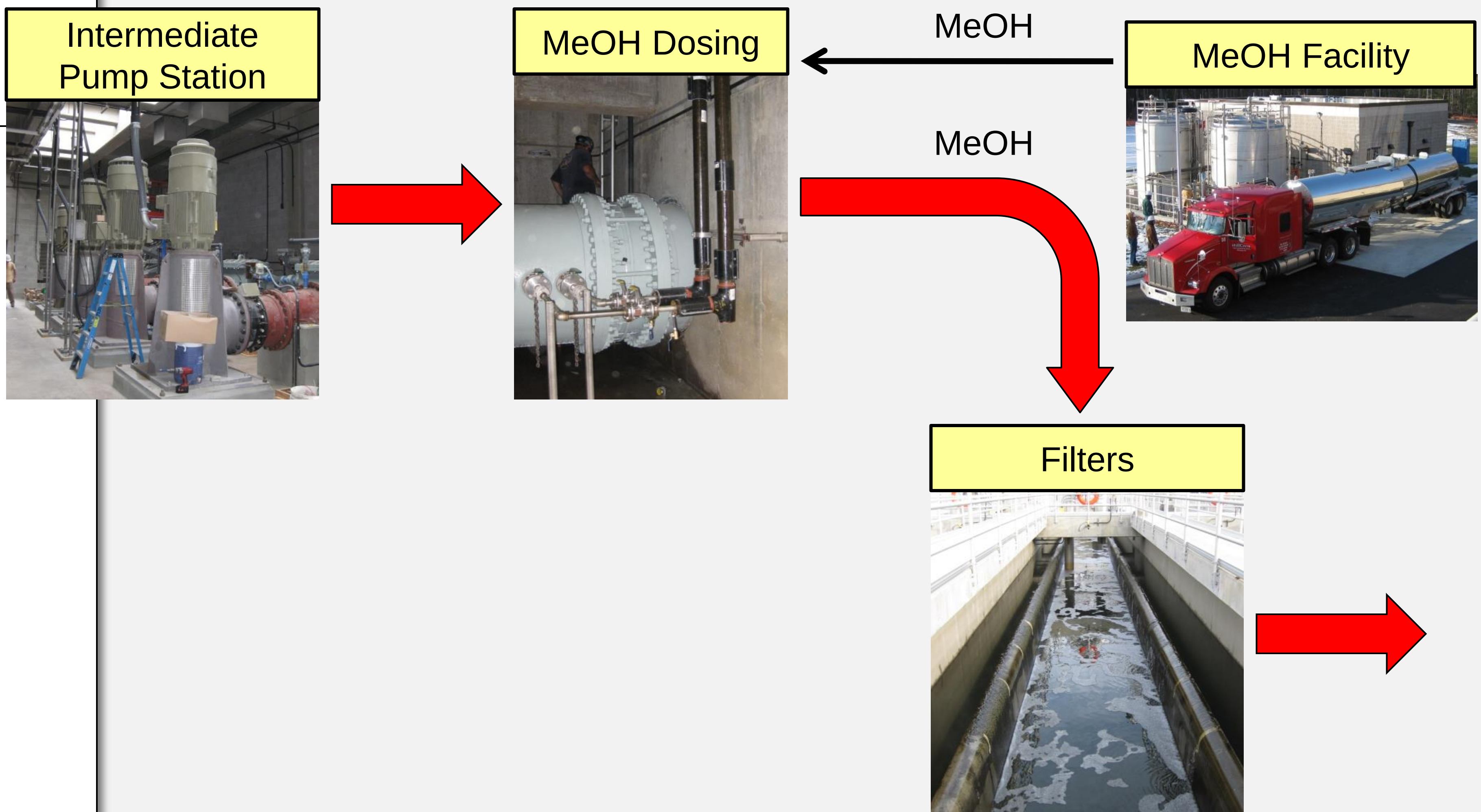
Control Level	Dosing Strategy
Level 0	Manual
Level 1	Flow Paced
Level 2	Feed Forward
Level 3	Feed Forward / Feed Back

Typical Diurnal Load Curve



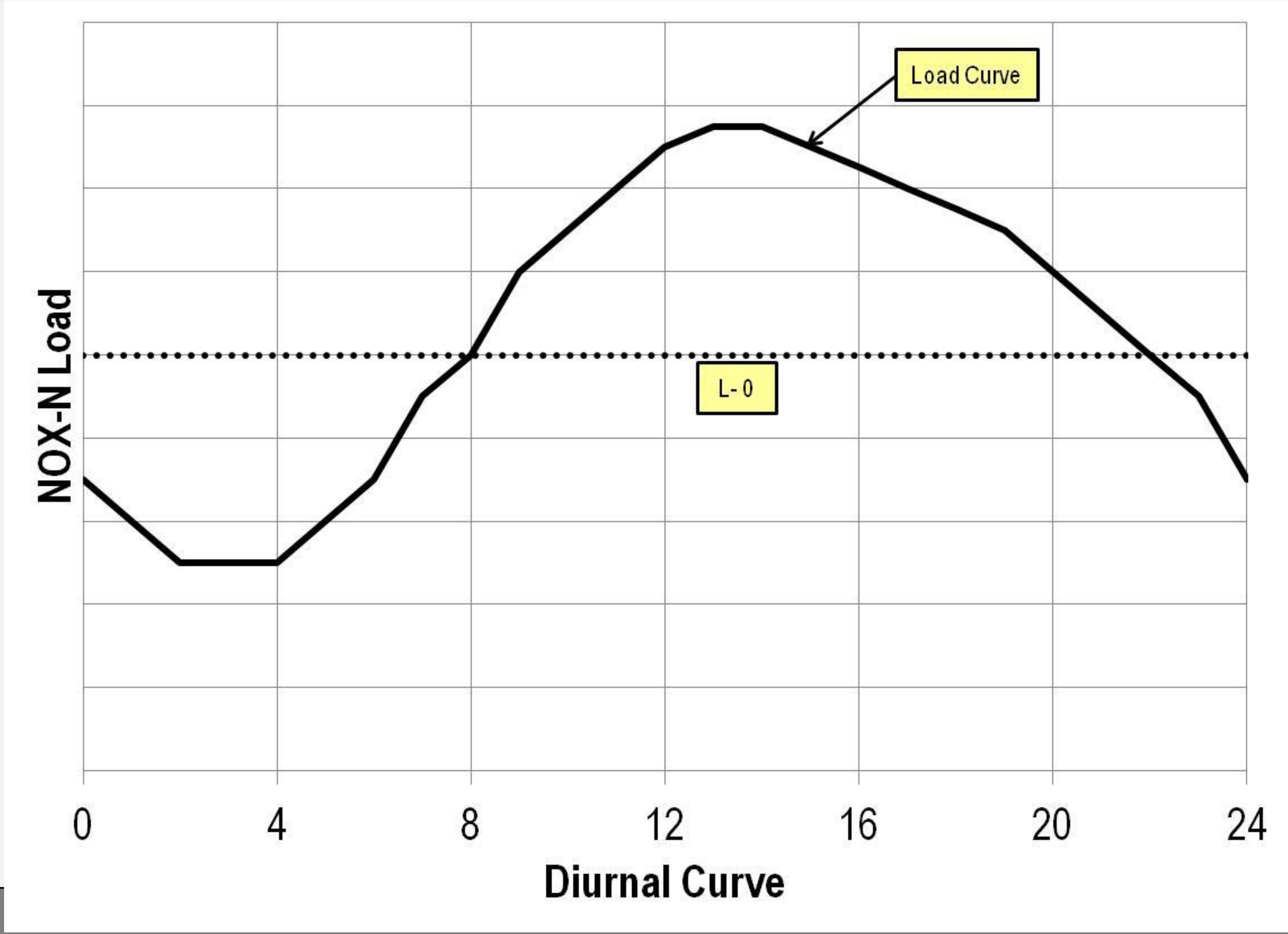
Methanol Dosing Strategy

Level 0 – Manual Control



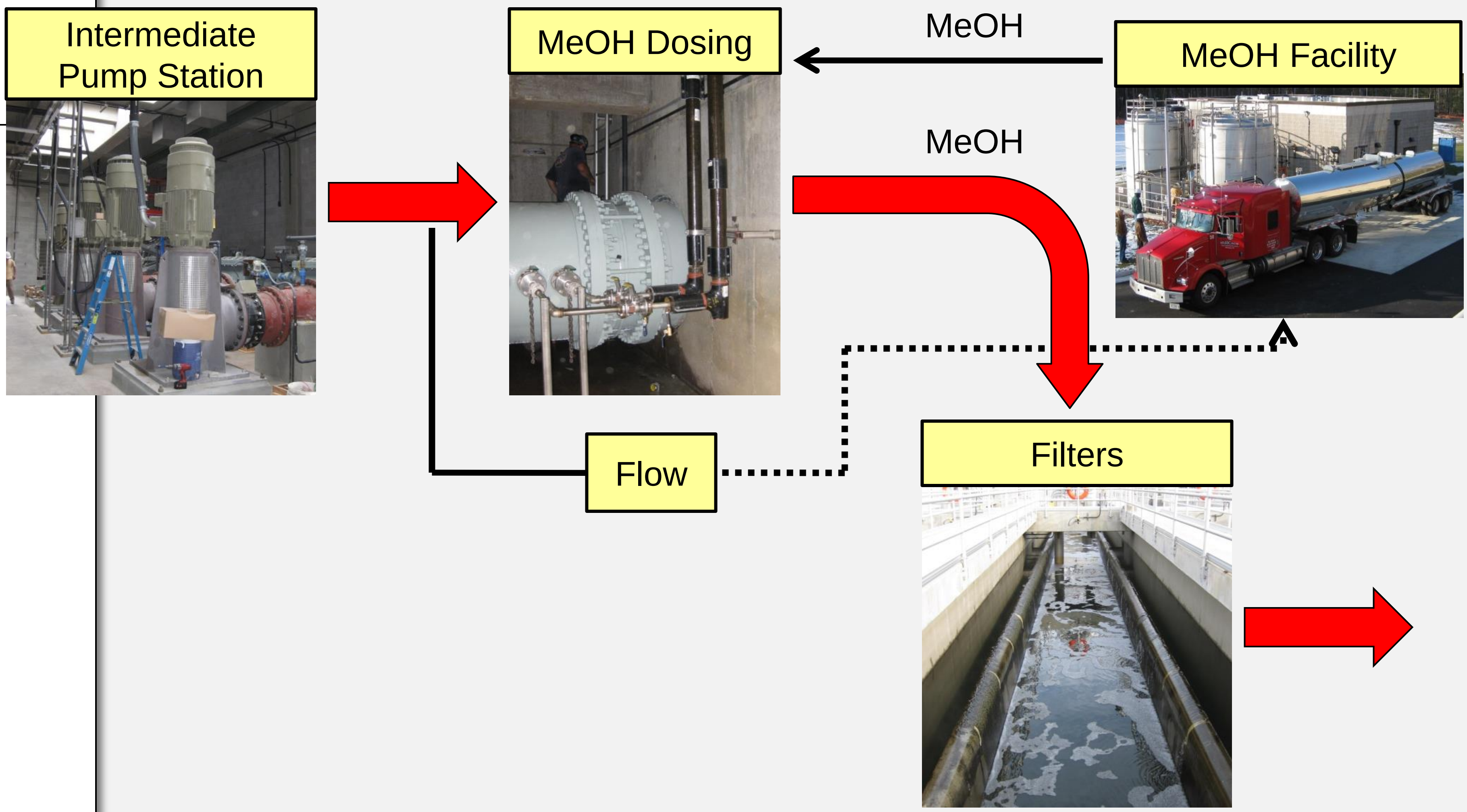
Methanol Dosing Strategy

Level 0 – Manual Control



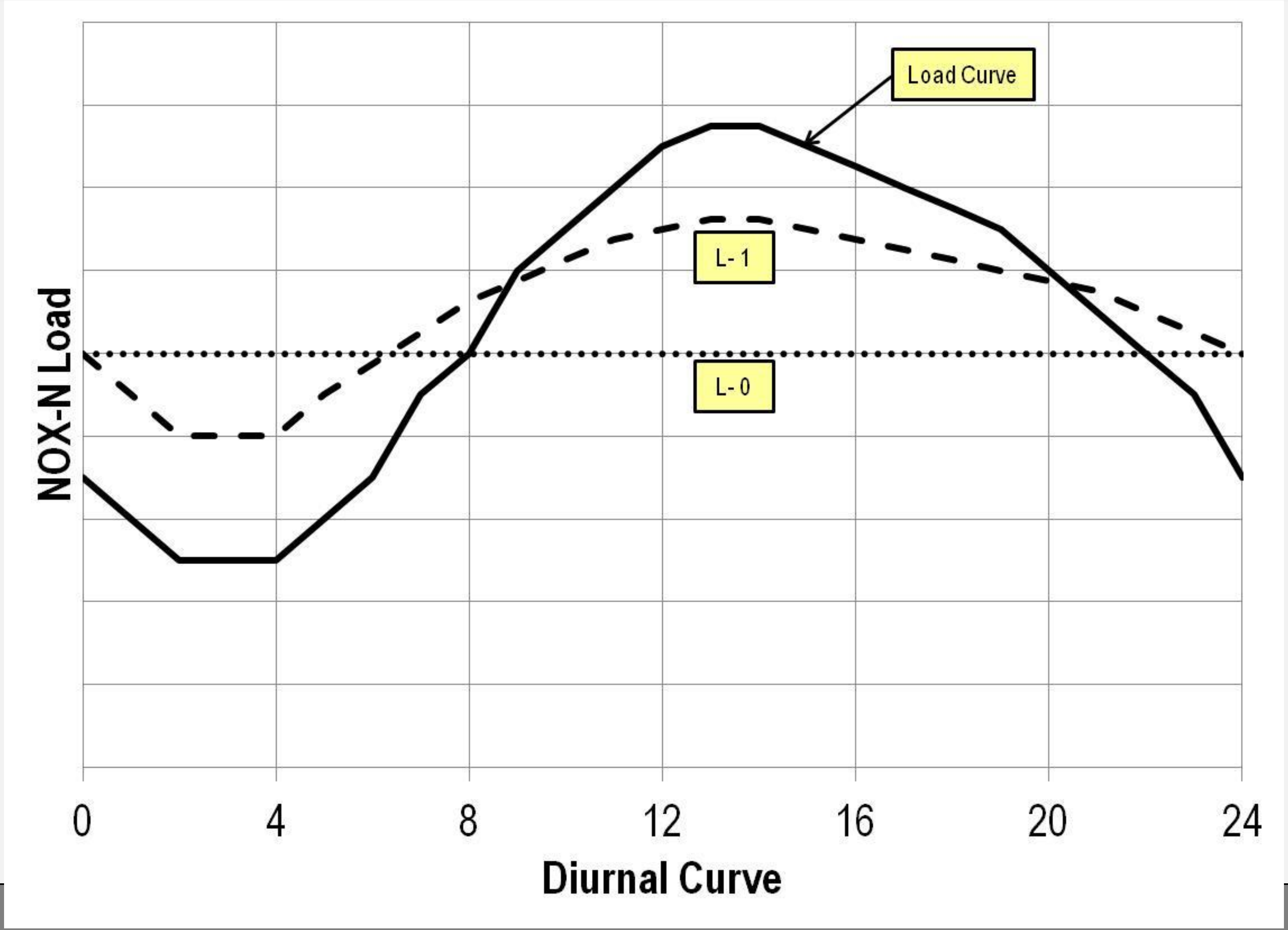
Methanol Dosing Strategy

Level 1 – Flow Paced Control

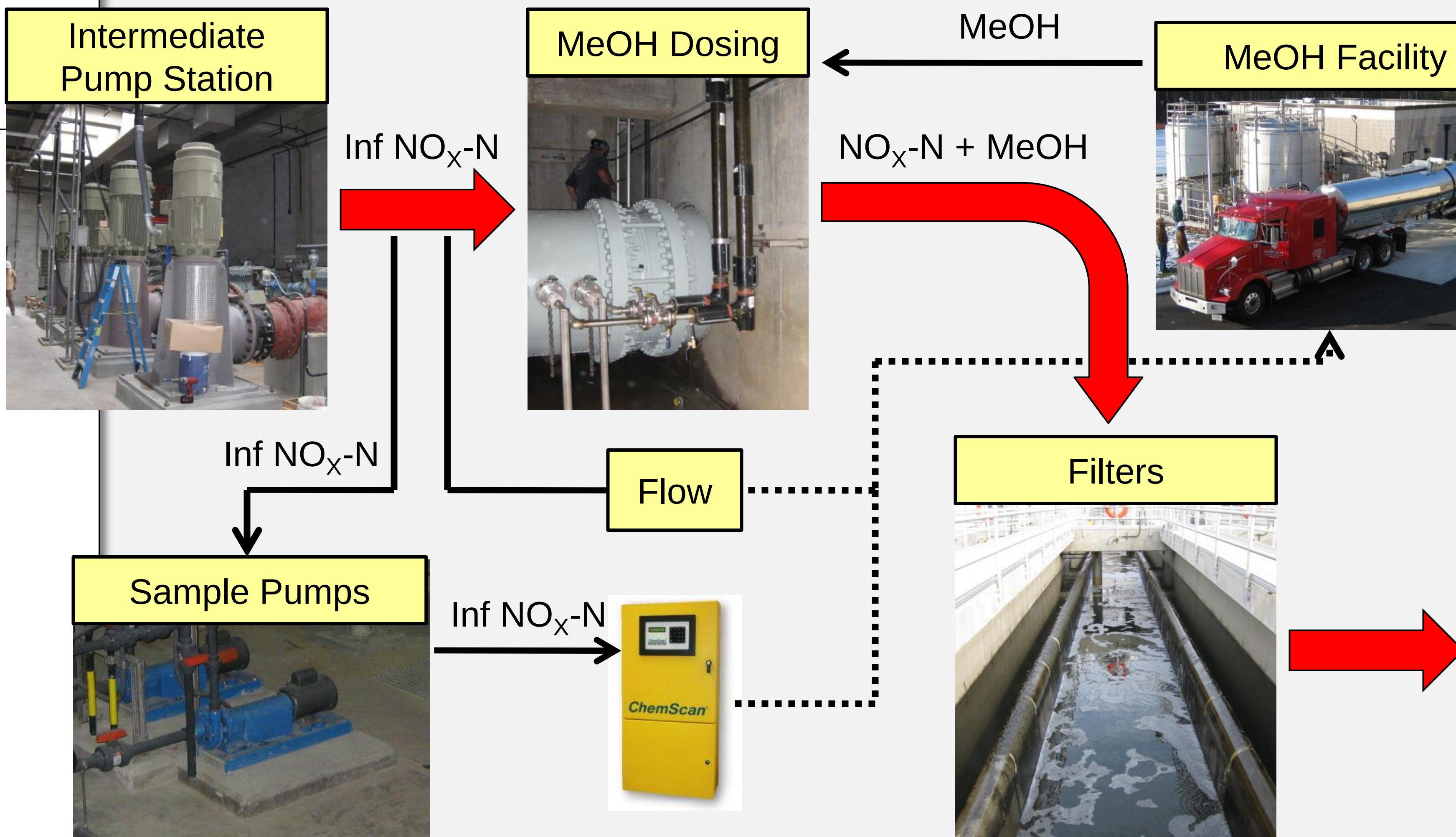


Methanol Dosing Strategy

Level 1 – Flow Paced Control

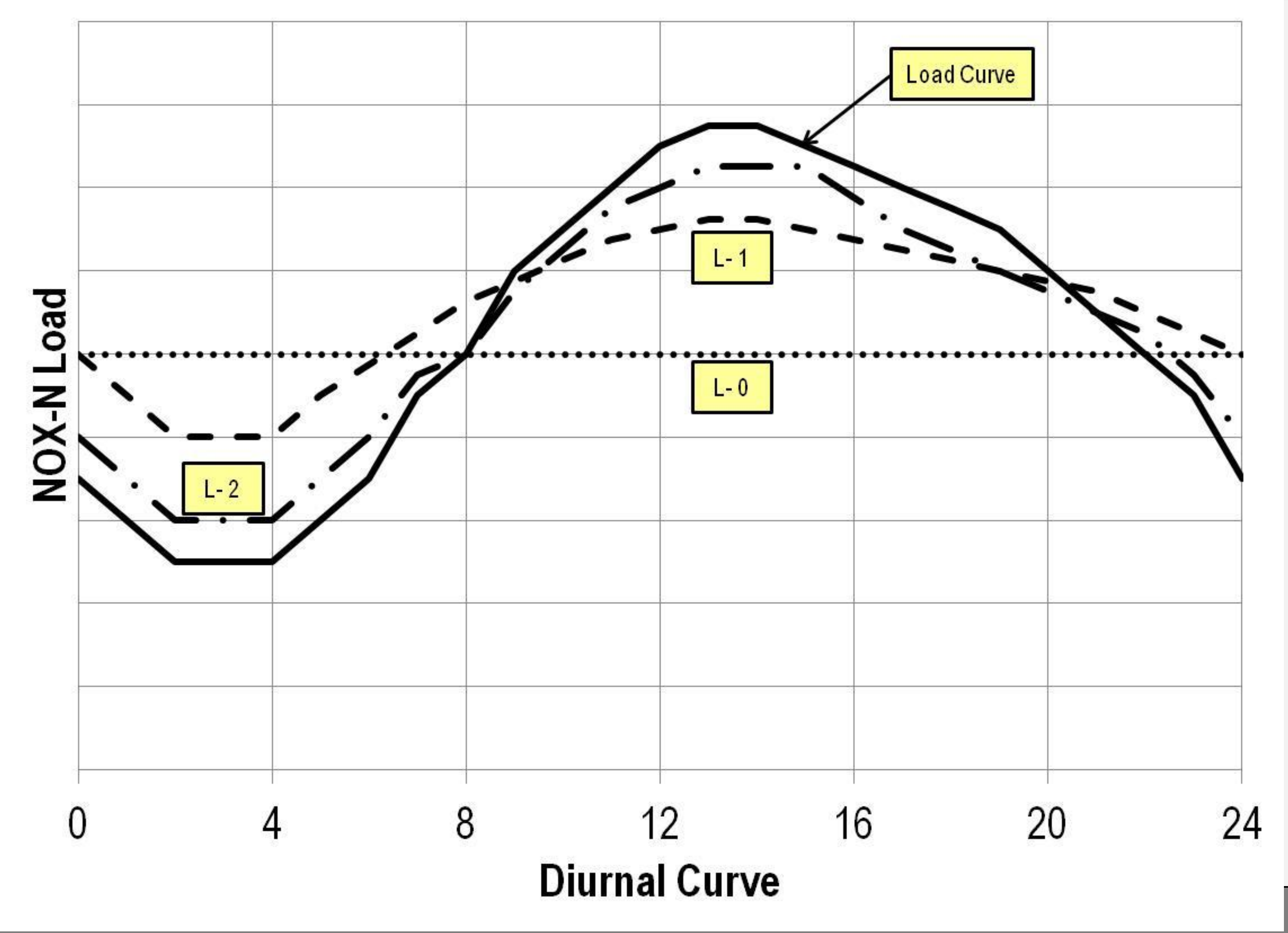


Methanol Dosing Strategy
Level 2 – Feed Forward Control



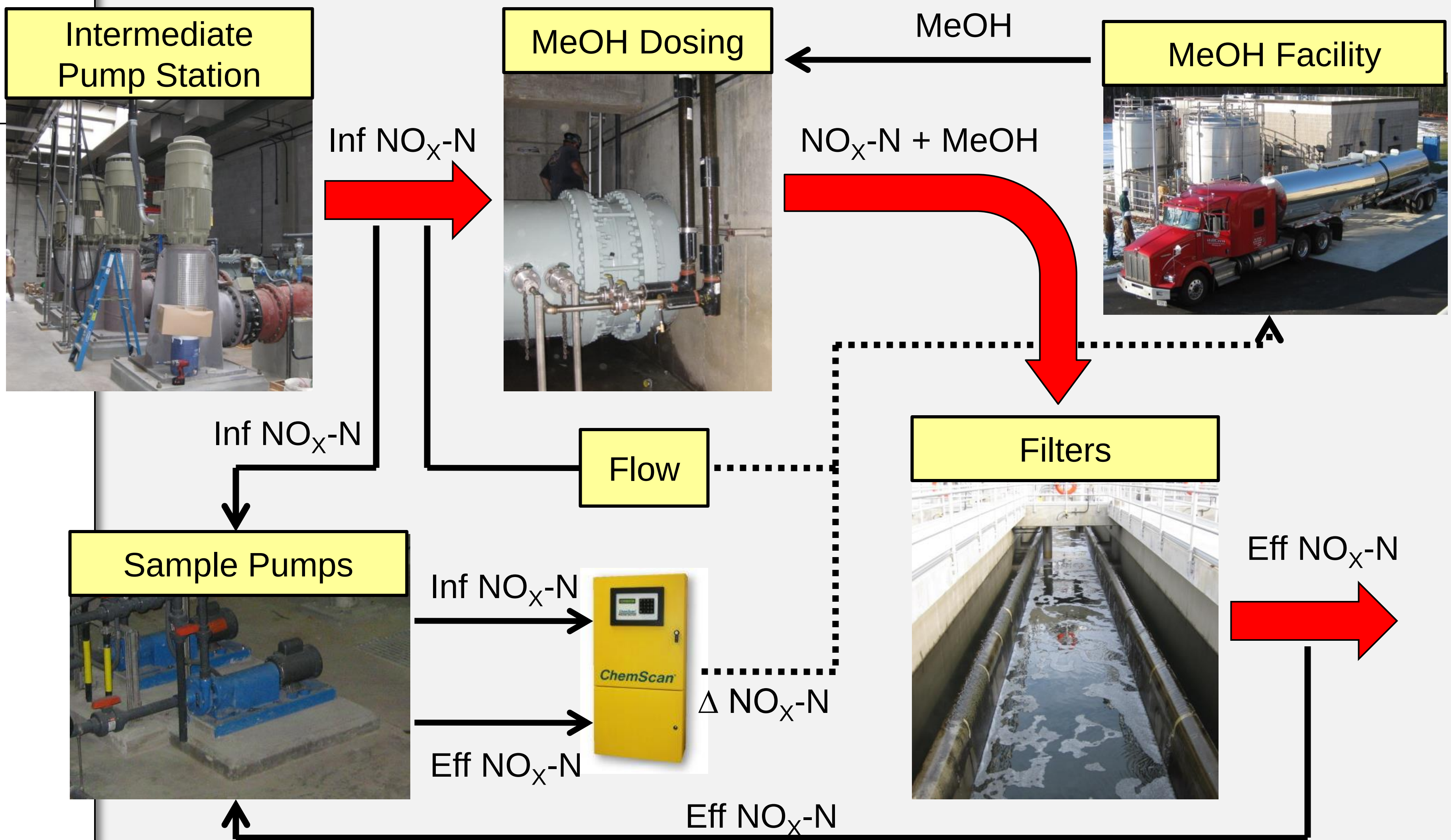
Methanol Dosing Strategy

Level 2 – Feed Forward Control



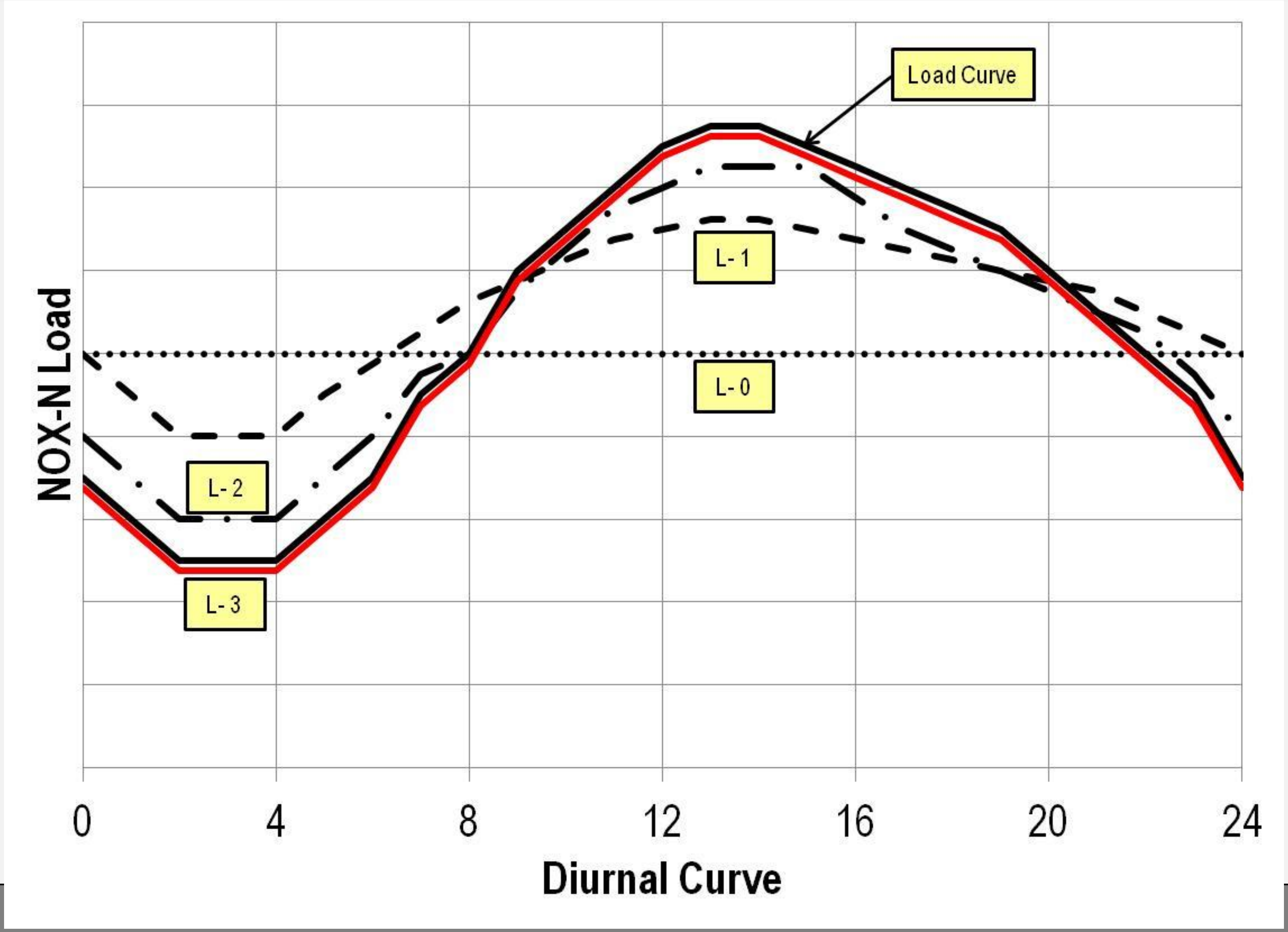
Methanol Dosing Strategy

Level 3 – Feed Forward/Feed Back Control



Methanol Dosing Strategy

Level 3 – Feed Forward/Feed Back Control



Deep Bed Denitrification Filters

Summary of Technology

- Advanced TN removal technology
- Typically designed for effluent TN goals < 6 mg/l
- Attached growth “deep bed” filtration process
- Sophisticated control system
- Additional facilities required
  - Intermediate pump station (IPS)
  - External carbon addition facility (methanol)
- Two major U.S. suppliers
  - Same biological process between suppliers
  - Differences with layouts, operations, and controls
- Recommend supplier selection prior to implementing design

Thank You!

Hazen and Sawyer, P.C.

Scott Phipps, P.E.

Associate

Columbus, OH

(614) 781-9655

sphipps@hazenandsawyer.com