Membrane Bioreactor and High Flow Biological Treatment System for the Cox Creek WRF

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Cox Creek Water Reclamation Facility (WRF)

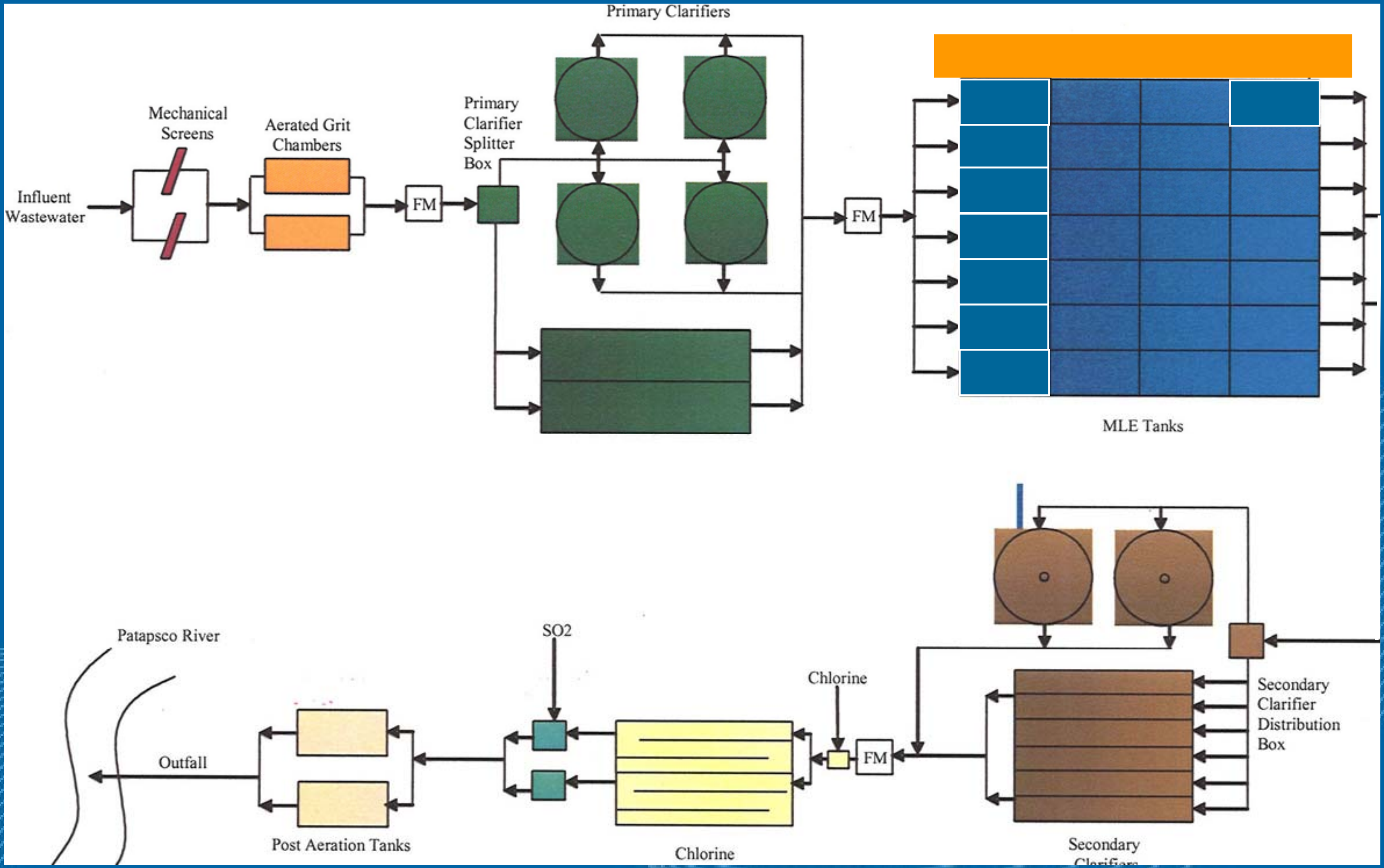
- Owned and operated by Anne Arundel County, Maryland
- Serves the Baltimore suburbs in the north central portion of the County
- Discharge to Patapsco River (tributary of Chesapeake Bay)

Facility History

- 1955: 5.0 mgd primary treatment facility constructed at current site
- 1970: Facility upgraded to secondary treatment (activated sludge) and expanded to 8.5 mgd
- 1982: Facility expanded to 15.0 mgd

Cox Creek WRF

1982 Plant Flow Schematic

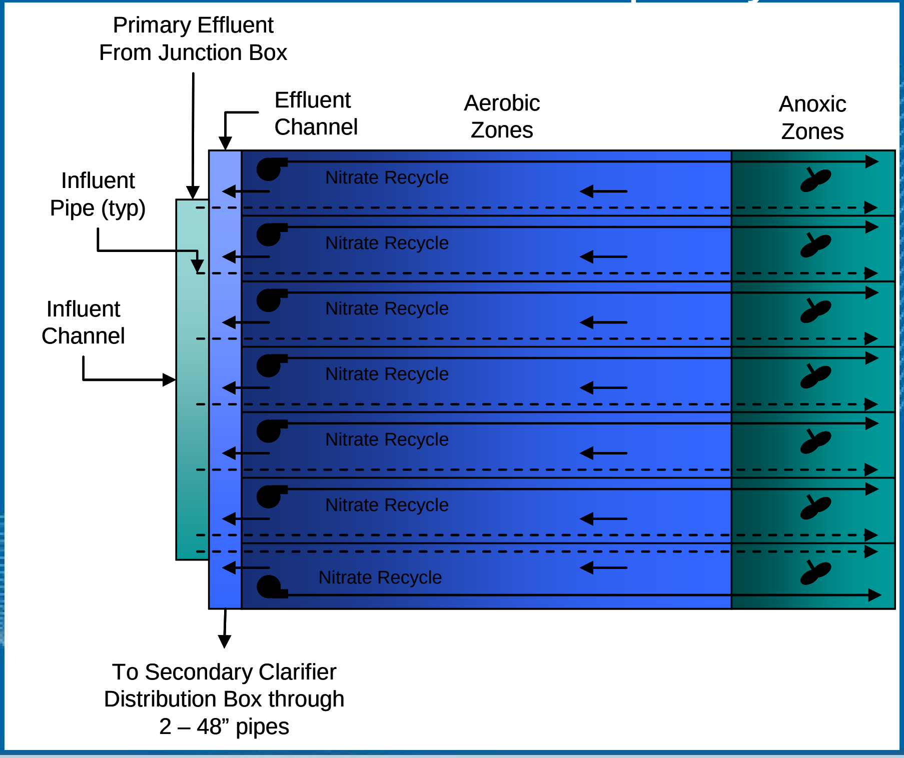


Nutrient Removal History

- Original activated sludge plant was designed for secondary BOD and TSS removal only (no nitrification)
- Ferrous sulfide addition to primary clarifiers started in mid-1980s with effluent limit of 2.0 mg/L TP
- In 1990s, MDE approached Anne Arundel County about entering a voluntary agreement to implement biological nitrogen removal (BNR) at the facility in exchange for grant funding
- The County decided to replace the surface aerators with fine bubble diffusers and convert into an MLE process in the existing reactors

BNR Upgrade (completed 2002)

- Seasonal TN Goal
  (8 mg/L May 1 – Oct 31)
- MLE configuration
- Flexibility to operate w/ Step Feed
  - During high flows from I&I
  - When one activated sludge tank is out of service
- Flexibility to increase aerobic volume and MCRT
  - Cyclic aeration of anoxic zone
  - Helps re-establish complete nitrification quickly

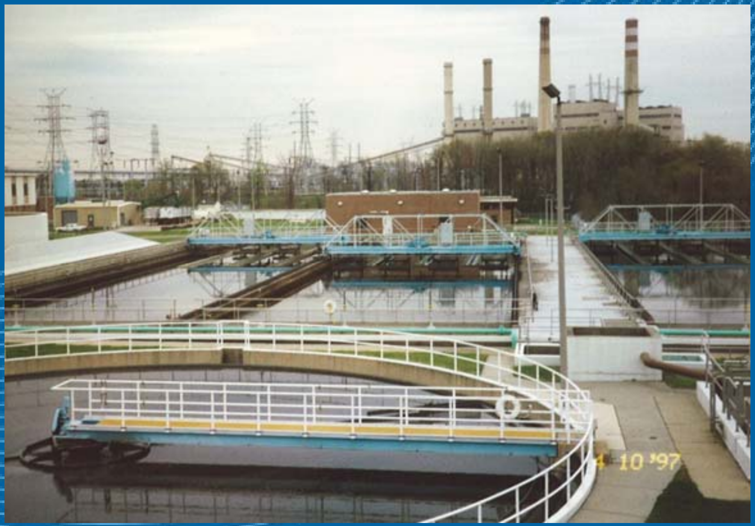


BNR Performance

- Since 2002, BNR facility has been able to achieve annual average TN as low as 8 mg/L
  - Example: 2006 Annual Average at ADF of 11.9 mgd
    - NH4-N: 0.7 mg/L
    - Organic-N: 1.3 mg/L
    - TKN: 2.0 mg/L
    - NOx-N: 5.3 mg/L
    - TN: 7.3 mg/L
    - TP: 1.1 mg/L
- However, clarifier performance limitations prevented complete nitrification under cold weather conditions

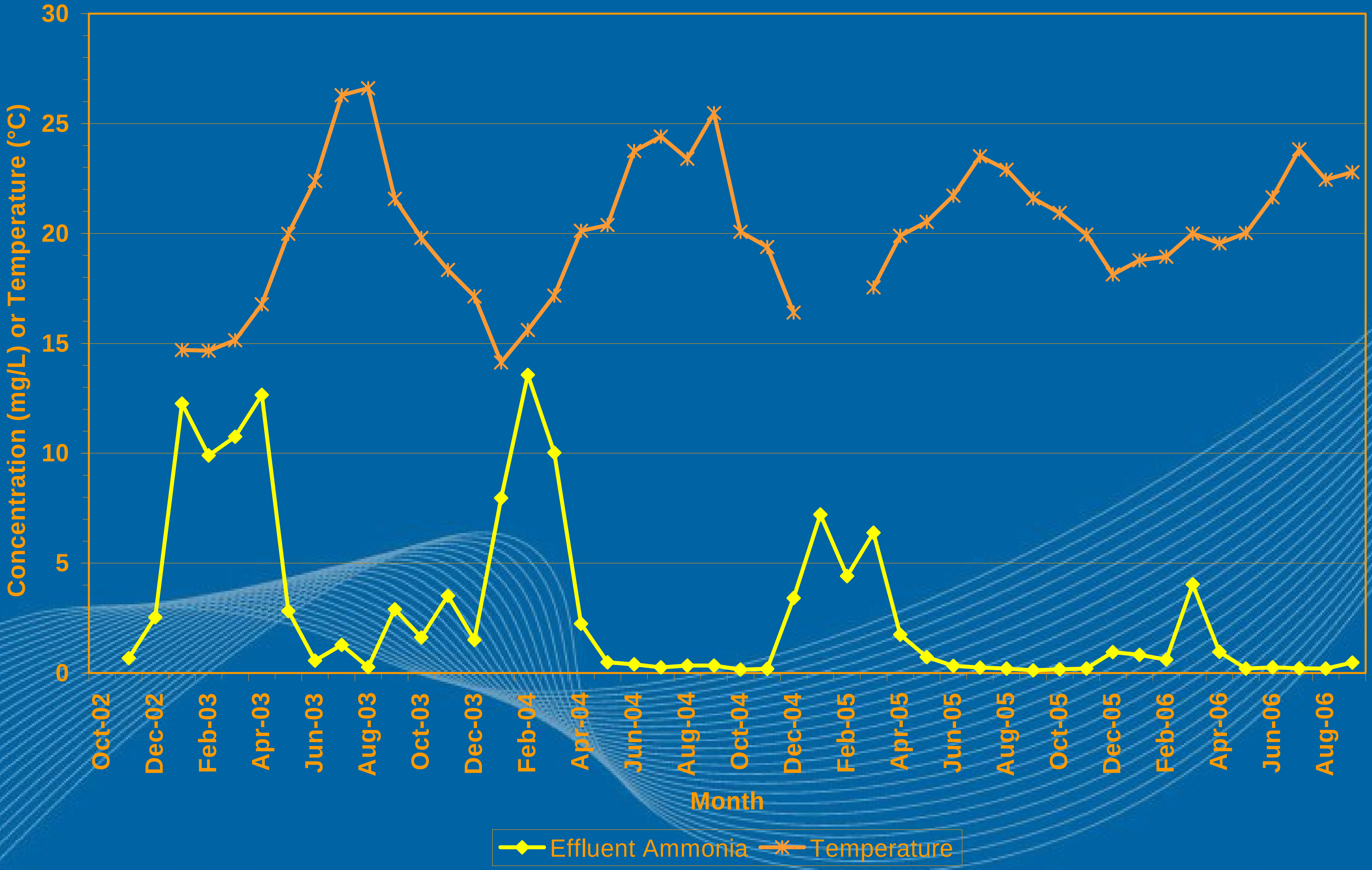
Final Clarifier Limitations

- Max MLSS = 3,000 mg/L / SOR = 300 gpd/SF
- If MLSS >, then RAS plugs – loose clarifier
- 15 to 25 mg/L effluent BOD and TSS with solids settling in Chlorine Contact tanks
- Poor seasonal SVI
- Polymer required



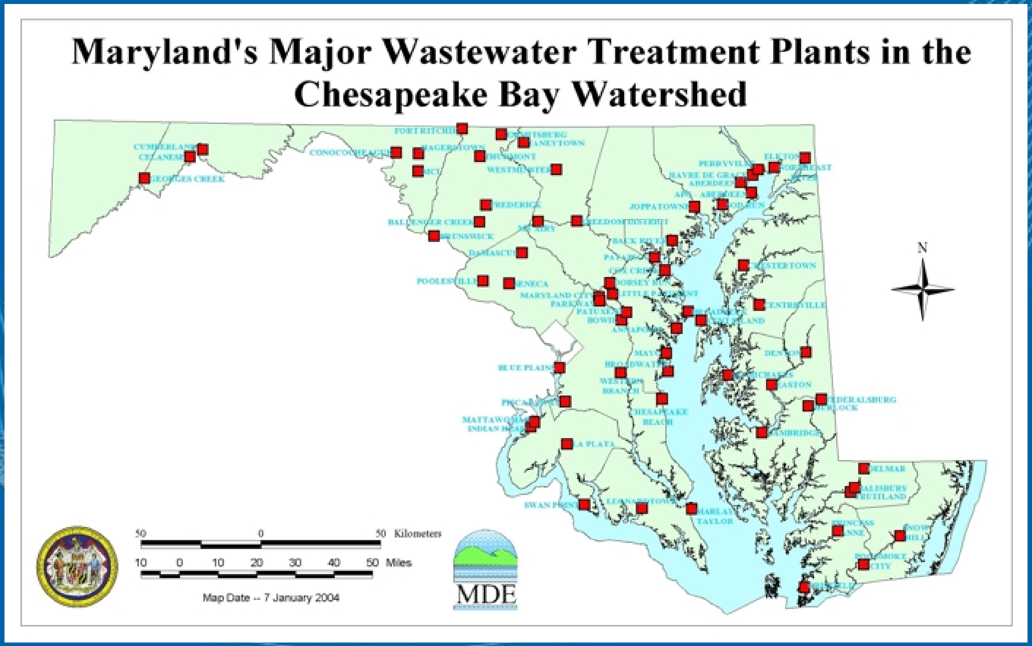
Historical Plant Performance

- Loss of nitrification during cold weather conditions



ENR Upgrade

- MDE's ENR Program required upgrade to 3 mg/L TN and 0.3 mg/L TP at all 66 major municipal WWTPs in the State.
- Anne Arundel County designated Cox Creek as the first of their 7 plants to be upgraded for ENR because it had the higher current nutrient loading and most to gain from ENR



ENR Design Criteria

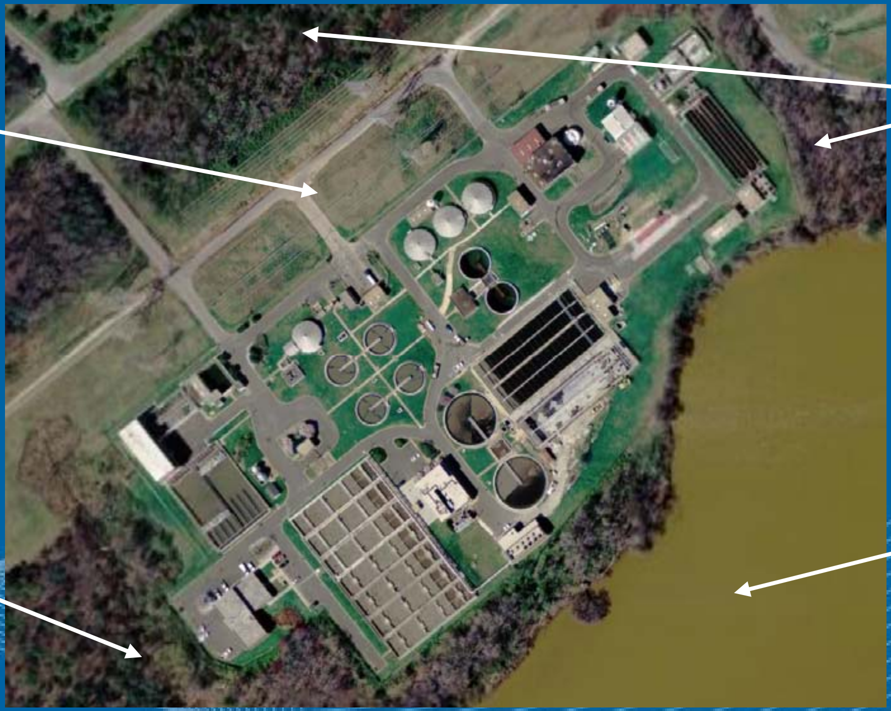
- Average Daily Flow: 15.0 mgd
- Maximum Month Flow: 19.4 mgd
- Peak Hour Flow: 45.0 mgd
  - Accommodate peak hour without equalization
- ENR Limits (1)
  - < 4 mg/L TN annual average
  - < 3 mg/L TN May-October average
  - < 0.3 mg/L TP annual average

Note

1. Actual ENR Limits in the County's draft watershed permit are based on an annual average discharge equivalent to 4.0 mg/L TN and 0.3 mg/L TP at the MDE approved design capacity for each of five (5) County-operated WRFs in the watershed, including the Cox Creek WRF.

Technical Issues

Limited space available for new construction



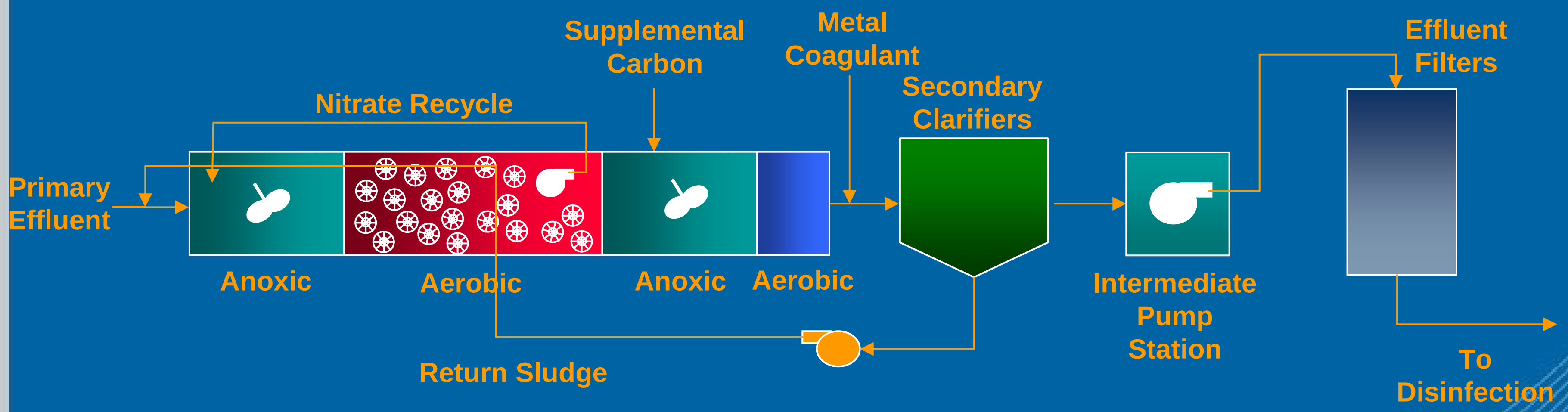
ENR Process Selection Procedure

- Develop ENR Evaluation Matrix
- Develop 5 general ENR categories to include all application ENR processes
- Use Evaluation Matrix to complete Initial ENR Screening to shortlist down to 3 general ENR categories
- Develop multiple ENR alternatives for each general ENR category
- Use ENR Evaluation Matrix to select one ENR alternative to evaluate from each general ENR category
- Develop a preliminary design, site plan, and cost estimate for selected ENR alternative
- Make final ENR Process selection based on capital and O&M cost estimates as well as non-cost criteria

Top 3 ENR Alternatives

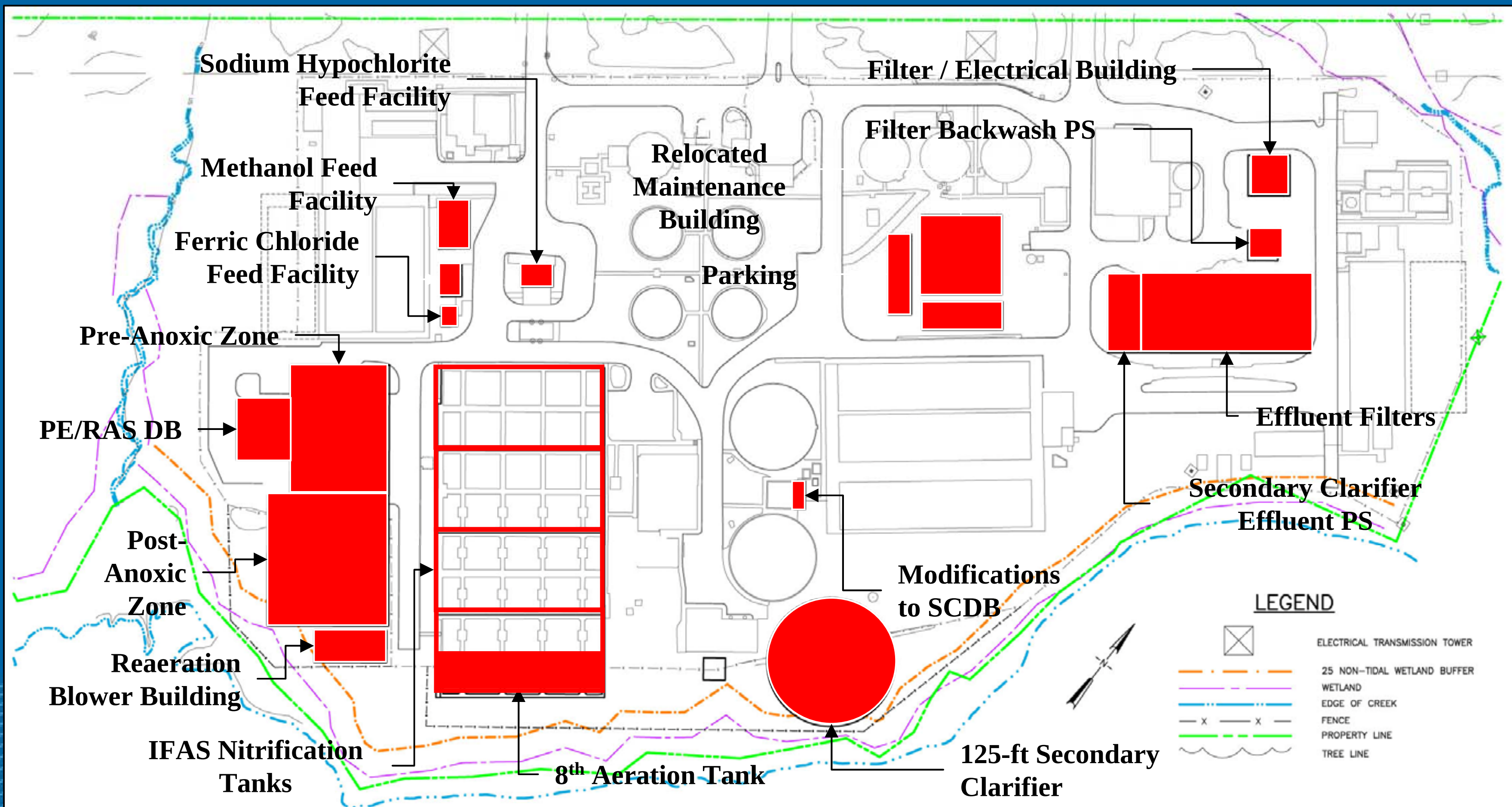
- Alternative A: Single-Stage Activated Sludge Process
- Alternative B: Parallel Suspended Growth Process
- Alternative C: Single-Stage MBR

Alternative A: IFAS with Effluent Filters

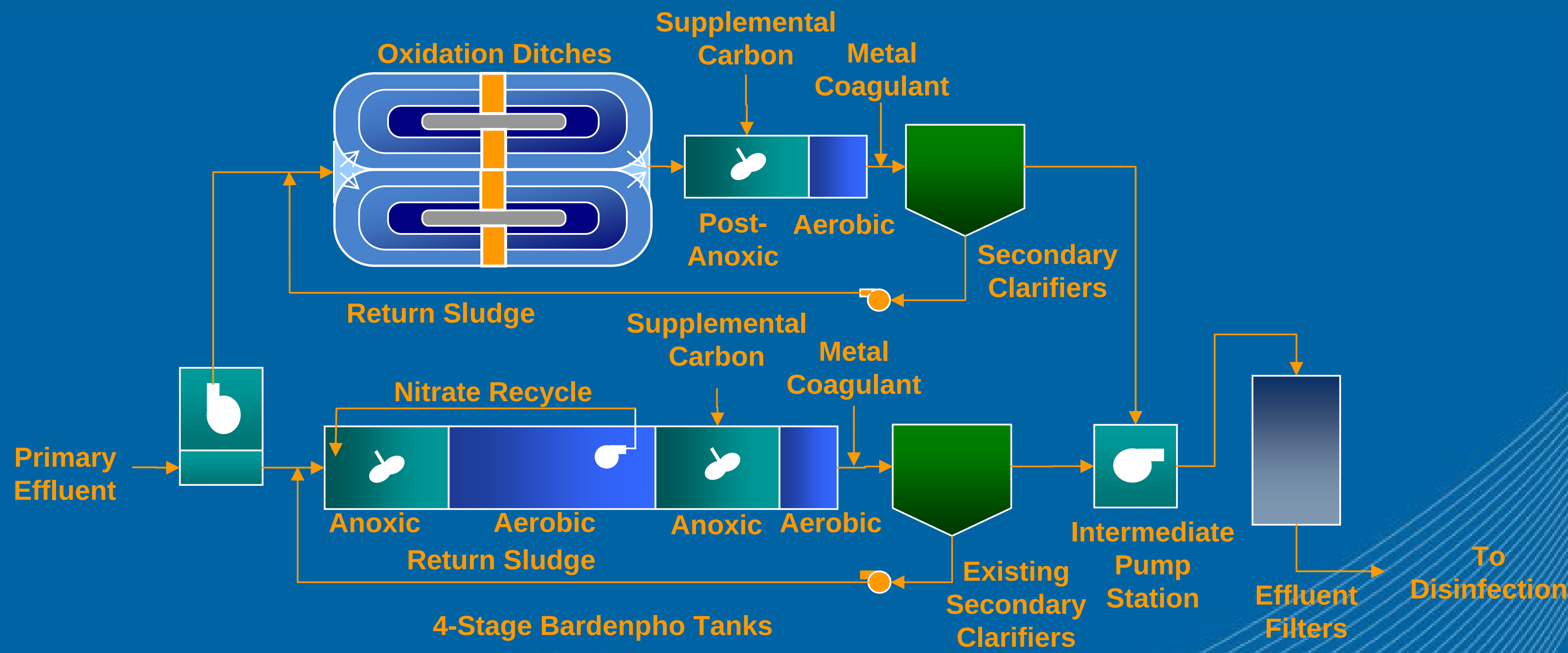


- Modify the existing BNR reactors and construct one additional reactor to create four (4) two-pass IFAS nitrification tanks
- Build new pre-anoxic, post-anoxic and reaeration tanks at the site of the existing Maintenance Building to create 4-Stage Bardenpho process
- Build new 125-ft secondary clarifier
- Construct deep-bed sand filters

Alternative A:
IFAS with Effluent Filtration

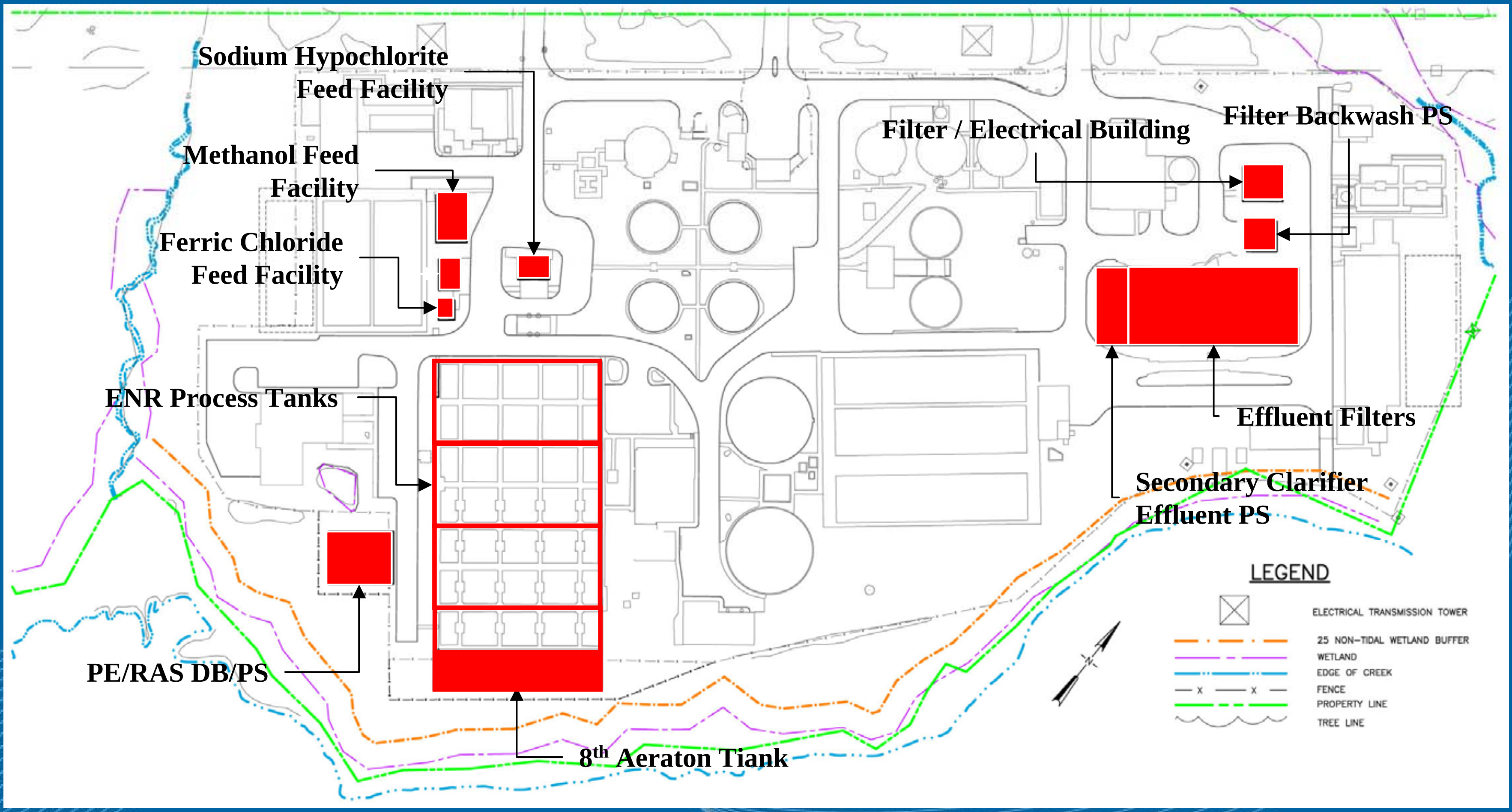


Alternative B: Parallel Train

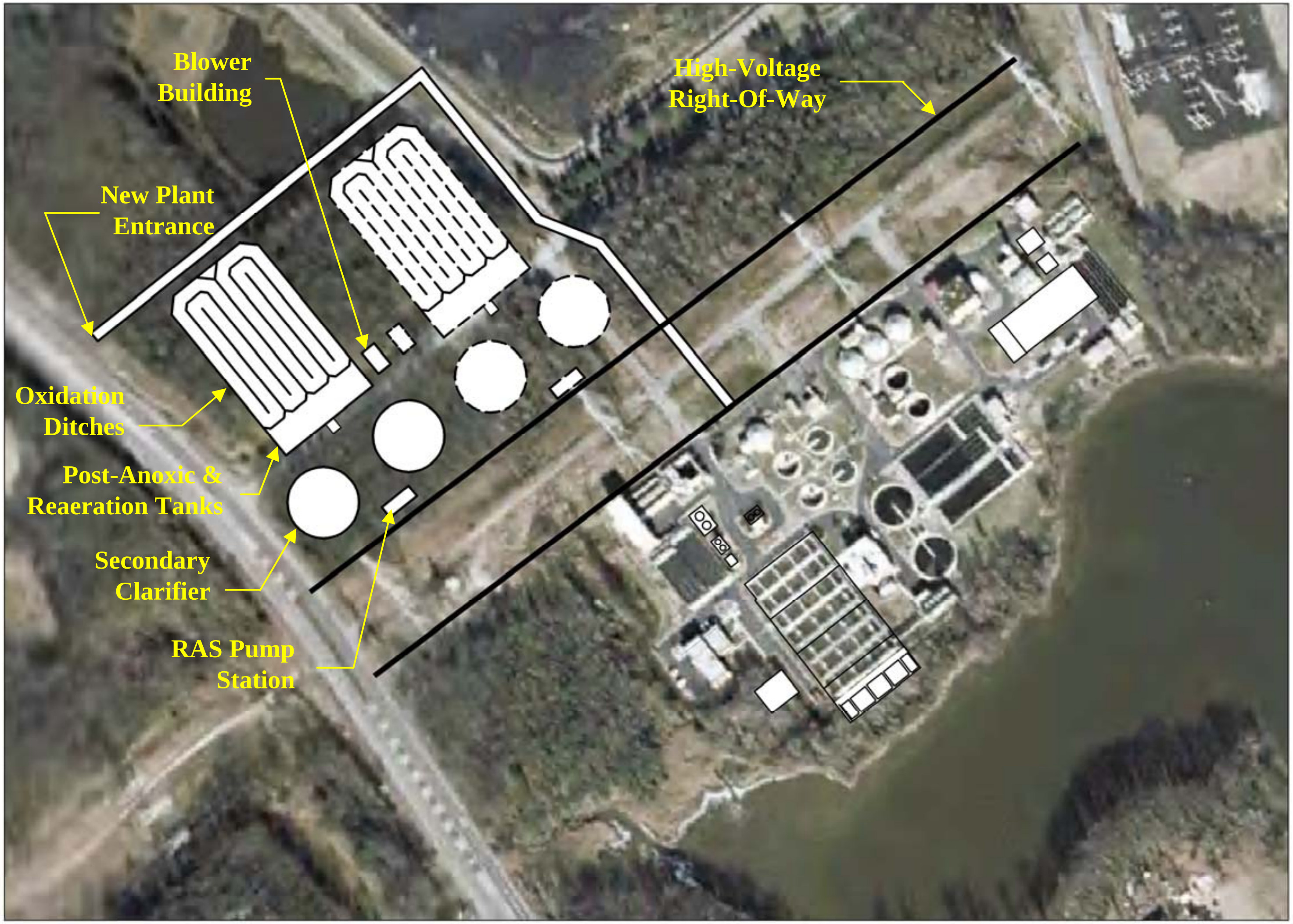


- De-rate existing facility to 7.5 mgd, modify the existing Bardenpho and construct one (1) additional reactor to create four (4) two-pass 4-Stage Bardenpho tanks
- Construct a new pump station to convey primary effluent to oxidation ditches
- Construct parallel oxidation ditches, post-anoxic and reaeration tanks and secondary clarifiers
- Construct a new secondary clarifier effluent pump station
- Construct deep-bed sand filters

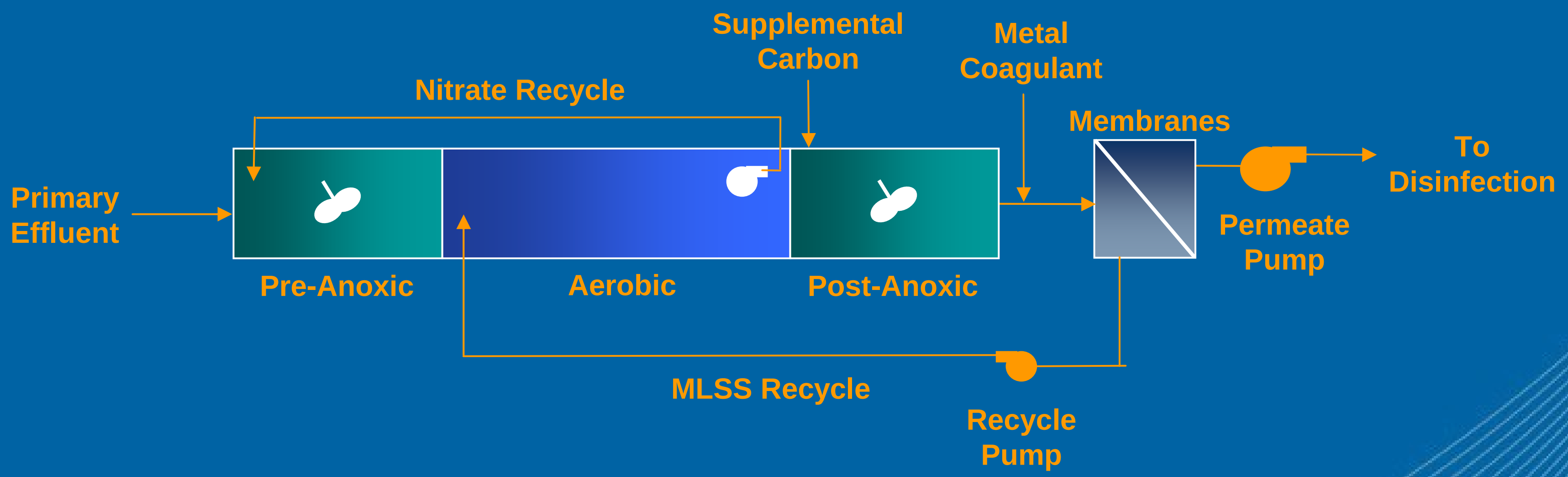
Alternative B: Parallel (Partial Site Plan)



Alternative B: Overall Site Plan

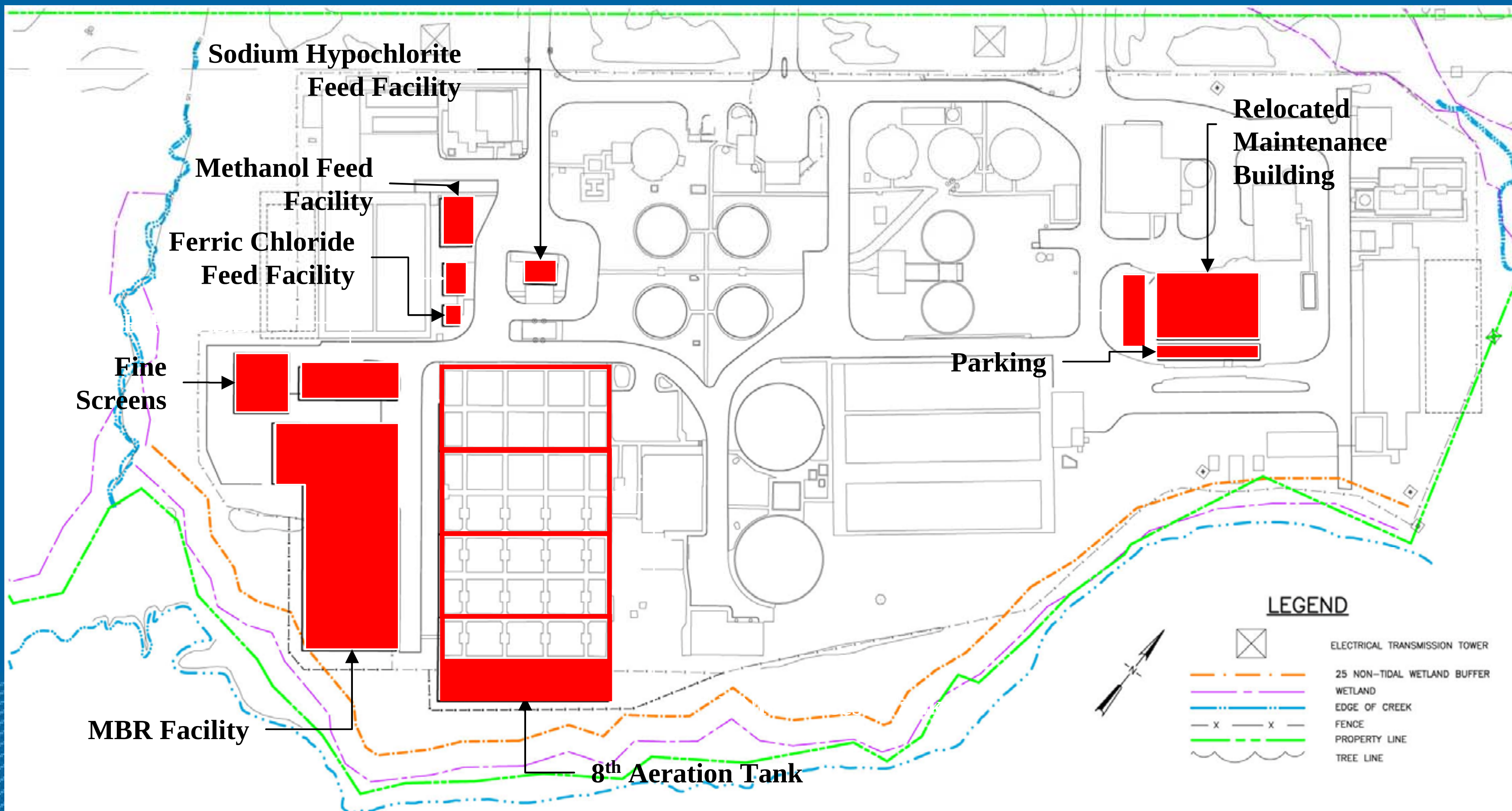


Alternative C: Membrane Bioreactor



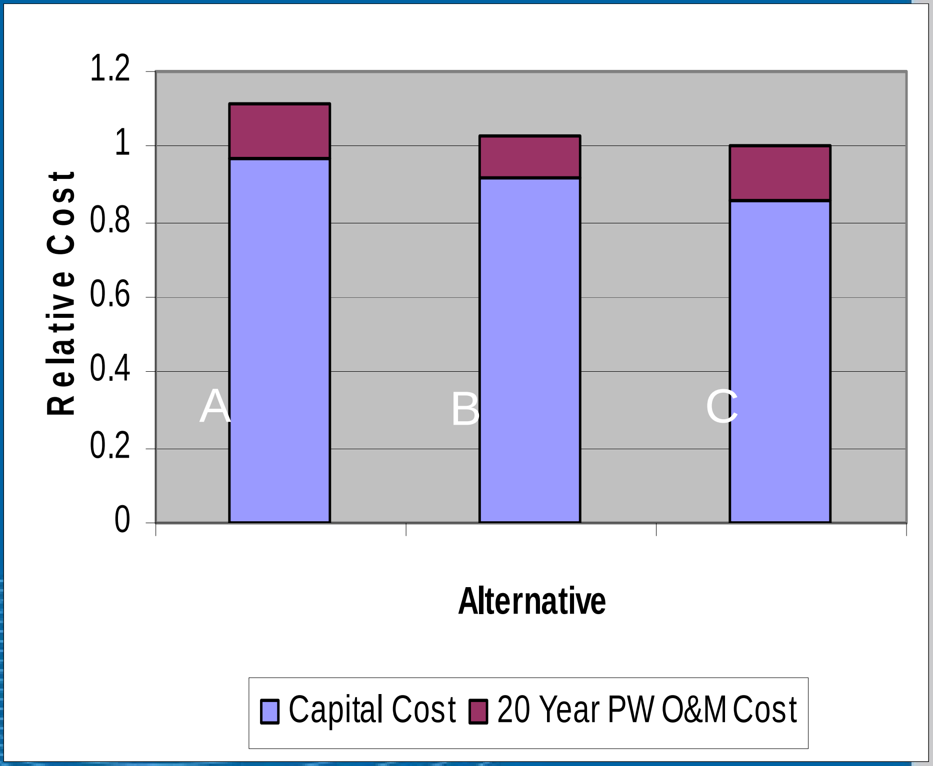
- Modify the existing BNR reactors and construct one (1) additional reactor to create four (4) two-pass modified Bardenpho tanks
- Construct new membrane tanks and building for membrane process equipment

Alternative C: MBR Site Plan



Cost Evaluation

- Estimated capital cost and 20-year present worth cost of required O&M for each Alternative.
- Alternative C had the lowest capital cost and 20-year total present worth cost.



Non Cost Factors

- Alternatives B and C have very similar non-cost criteria scores

Other Decision Factors Favoring MBR

- Recovers space on existing site for future needs
- Potential for meeting future regulatory requirements
- Increased potential for water reuse
- Sludge settleability is no longer a limiting factor
- One compact process for all TN & TP removal
- No schedule risk associated with land purchase

Cox Creek WRF:
ENR Process Selection

- Alternative C: MBR
  - Lowest Capital Cost
  - Lowest Present Worth Cost
  - Most effective use of existing site

Membrane Facility Location

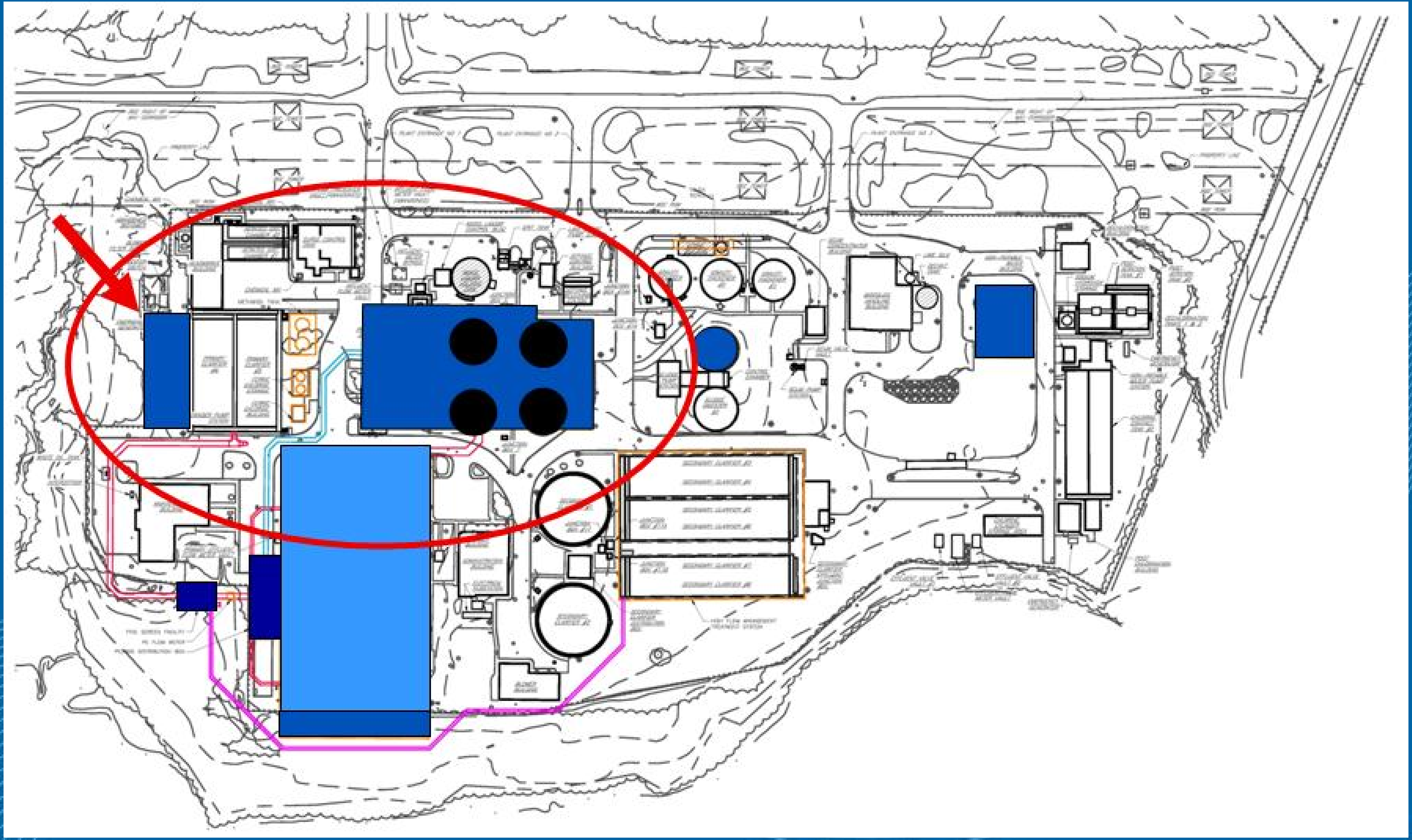
- Initial ENR Evaluation was based on relocating existing Maintenance Building to build the new Membrane Facility.
- Upon more detailed evaluation, this location had several disadvantages:
  - Requires demolition and relocation of 15 year of Maintenance Building
  - Site provides very limited space for building and equipment access
  - Site would require significant construction in Chesapeake Bay tidal wetlands buffers
  - Concern that some membrane suppliers may not be able to fit their system in this footprint (decreases competition)

Alternative Membrane Facility Location

- Alternative Membrane Facility Locations considered included:
  - At location of existing circular primary clarifiers
  - At location of existing stormwater management structure and dewatering truck scale
- Preliminary layouts and construction costs were done for each alternative

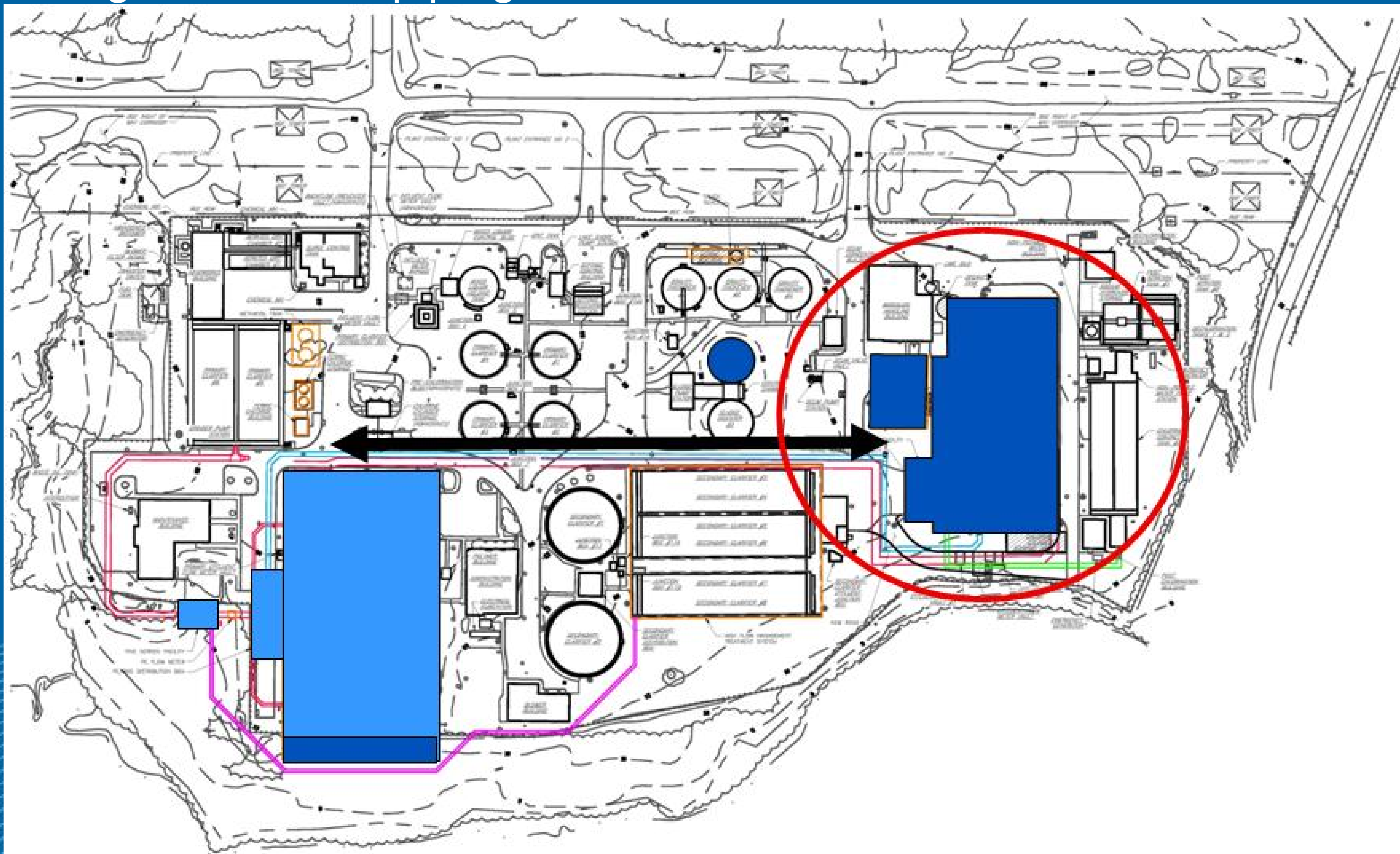
Alternative Membrane Location 2

- Required relocation of primary clarifier capacity



Alternative Membrane Location 3

- Significant site, piping, and stormwater costs



Membrane Facility Location 2 Selected

- Much less yard piping and utility relocation than Alt. 3
- Enough space and good accessibility for alternative membrane designs (unlike Alt. 1)
- Closer to reactors – more operator friendly location than Alt. 3
- Least impact into wetlands and Critical Area buffers
- Least impact on site stormwater management
- Lowest construction cost

High Flow Management Strategy

- Initial ENR Evaluation was based on sending entire 45 mgd peak flow through MBR process
- Upon more detailed evaluation, the 3:1 extended peak flow condition was dictating membrane sizing (instead of maximum month flows and loads)
- Alternatives were sought to reduce capital and operating costs

MBR Design Criteria for Initial ENR Evaluation

- Peak Wet Weather Flow Drives the Sizing/Design of the Membrane Facility

ORIGINAL DESIGN FLOW CONDITIONS	FLOW RATE
Rated Capacity, mgd (Nominal)	**15.0**
Average Daily Flow with recycles, mgd	**15.7**
Maximum Monthly Flow with recycles, mgd	**19.4**
Peak Hour Flow with recycles, mgd	**45.7**

Alternative Approach with High Flow Management Strategy

- Design the Membrane System Optimally for Maximum Month Conditions and Routine Flow Peaking Events
- Treat Excess Wet Weather Flow to a Minimum of Secondary Standards with Separate Parallel Process

  (Blending is not allowed for separated sewer systems)

What peak flow should membranes be designed to accommodate?

- Desire not to need to rely on High Flow Management Facilities under routine operation.
- Typical dry weather diurnal flow pattern varies between 40% and 150% of Average Daily Flow (ADF)
- If this pattern continues, at 19.4 mgd Max. Month ADF, the diurnal peak will be 29.1 mgd
- Size Membrane Facility for 30 mgd with one train out-of-service

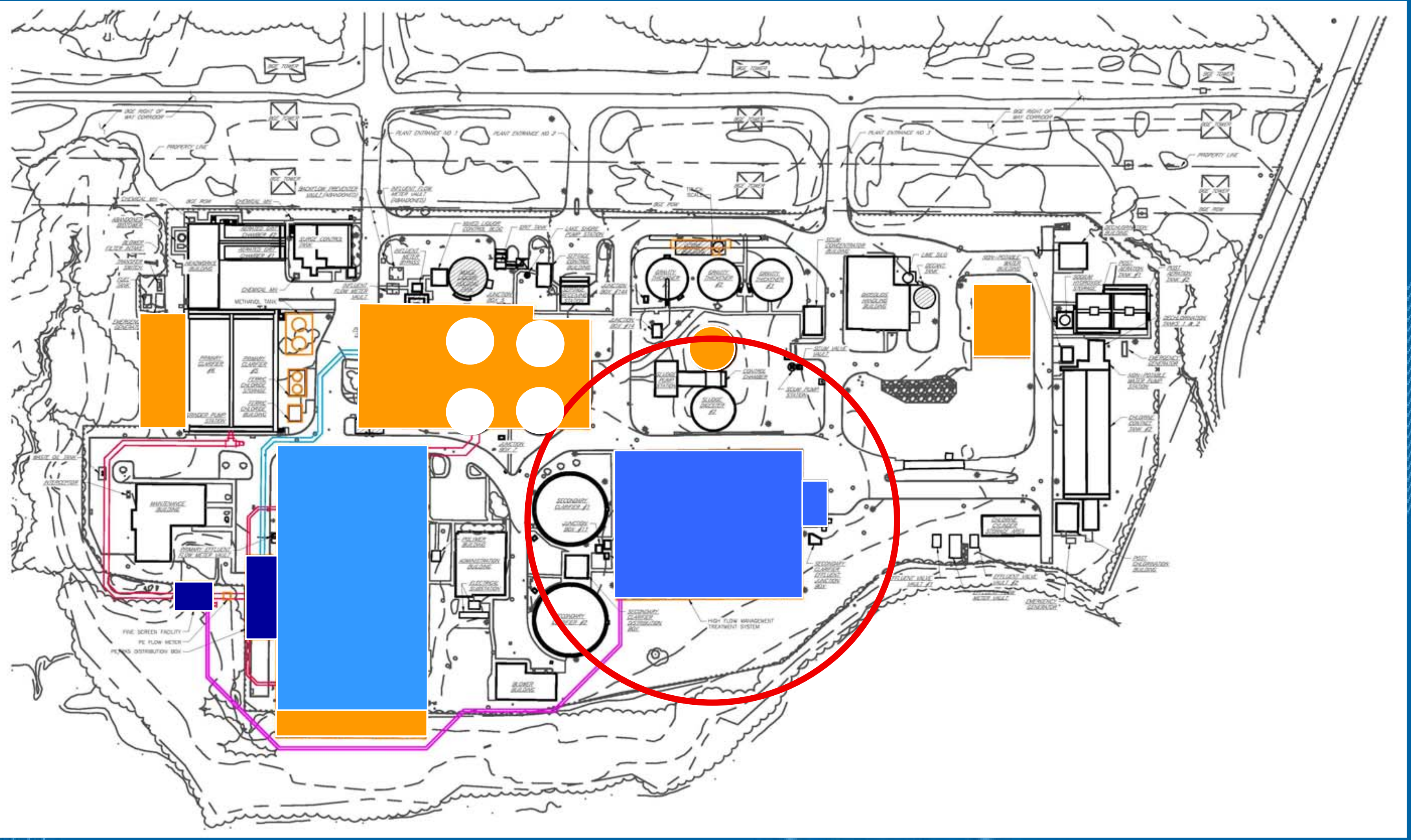
MBR Design Criteria w/ High Flow Management Strategy

- Design MBR system to accommodate 30 mgd (twice annual average daily flow)

ALTERNATIVE DESIGN FLOW CONDITIONS	FLOW RATE
Rated Capacity, mgd (Nominal)	**15.0**
Average Daily Flow with recycles, mgd	**15.7**
Maximum Monthly Flow with recycles, mgd	**19.4**
Peak Hour Flow with recycles, mgd	**30.0**

Where to locate High Flow Management Facility?

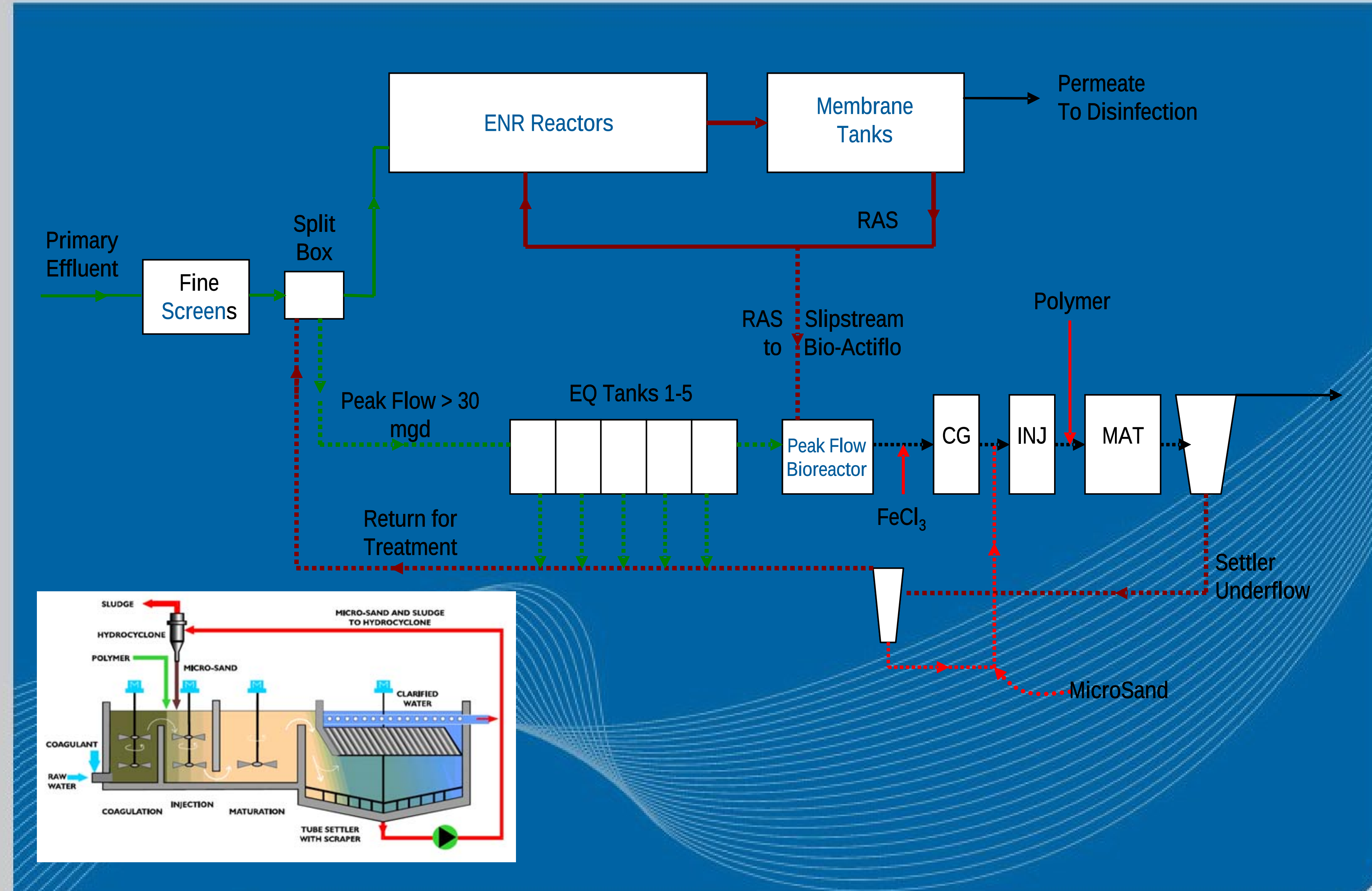
- At existing rectangular Secondary Clarifiers



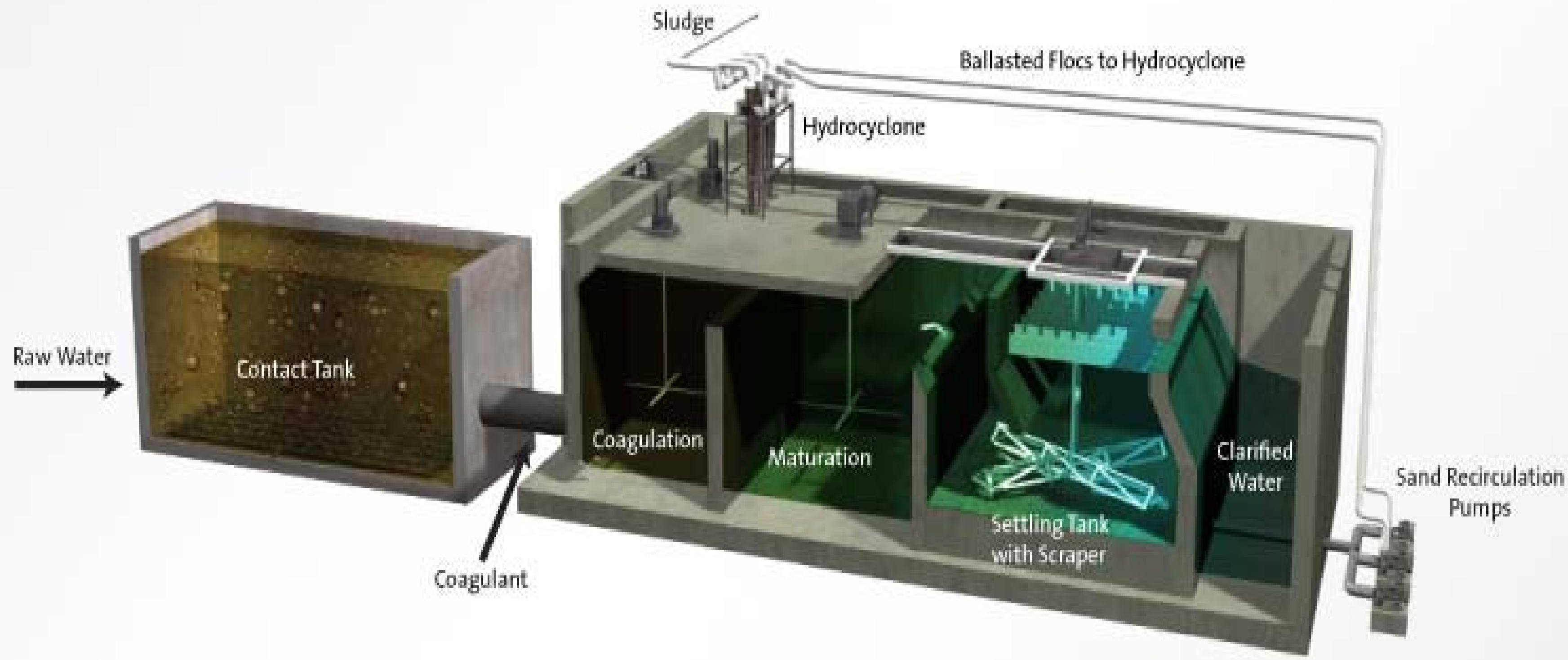
High Flow Management Approach

- Use Secondary Clarifiers Nos. 1 though 5 (2.65 Million Gallons) for short-term storage of peak flows above 30 mgd
  - Return stored flow for MBR treatment during lower flow conditions
- Construct a Contact-Stabilization Activated Sludge Ballasted Flocculated Settling System in Secondary Clarifier No. 6.
  - System will use mixed liquor from the MBR process to absorb organics and return them to MBR process for treatment

Cox Creek WRF Flow Diagram
High Flow Management



High Flow Management Process

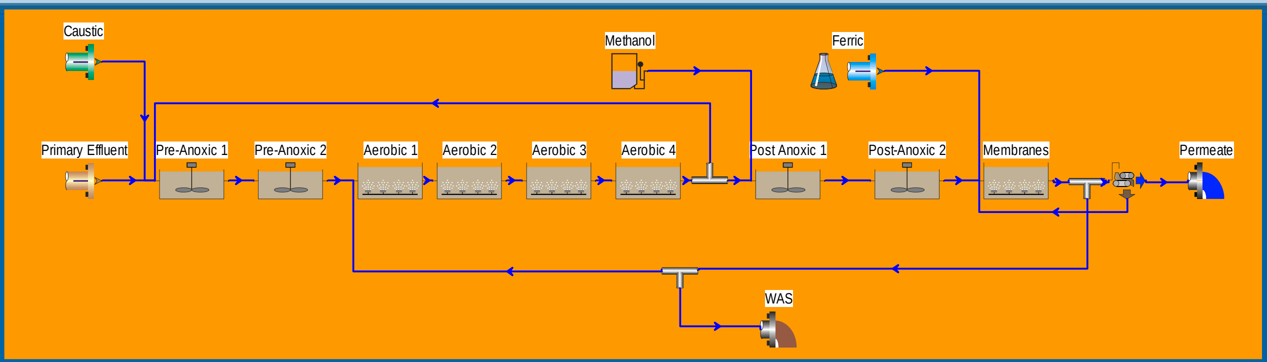


Bio-Actiflo® figure provided by Krueger

Benefits of High Flow Mgmt. Approach

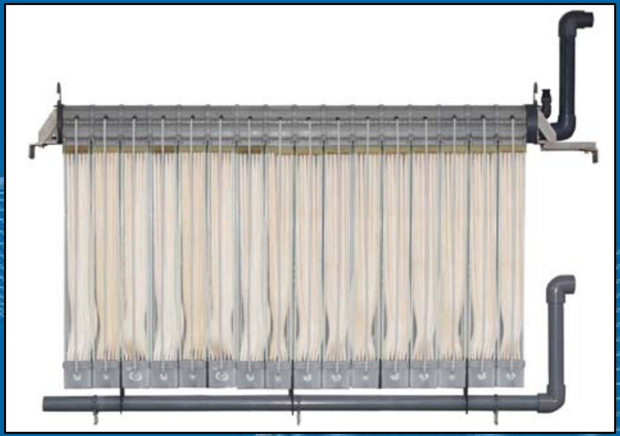
- Reduces required membrane area by 33%
- Reduces membrane tank aeration requirements (number and size of blowers)
- Reduces membrane tank and building footprint by almost 40%
- Reduces the amount of energy required to maintain off-line membrane tanks in operation
- Reduces future membrane replacement costs
- Results in net reduction of both capital and O&M costs

MBR– Final Design Criteria



DESIGN FLOW CONDITION	FLOW RATE
Rated Capacity, mgd (Nominal)	15.0
Average Daily Flow with recycles, mgd	15.7
Maximum Monthly Flow with recycles, mgd	19.4
Peak Hour Flow with recycles, mgd	30.0

GE/Zenon® ZW500d Cassette



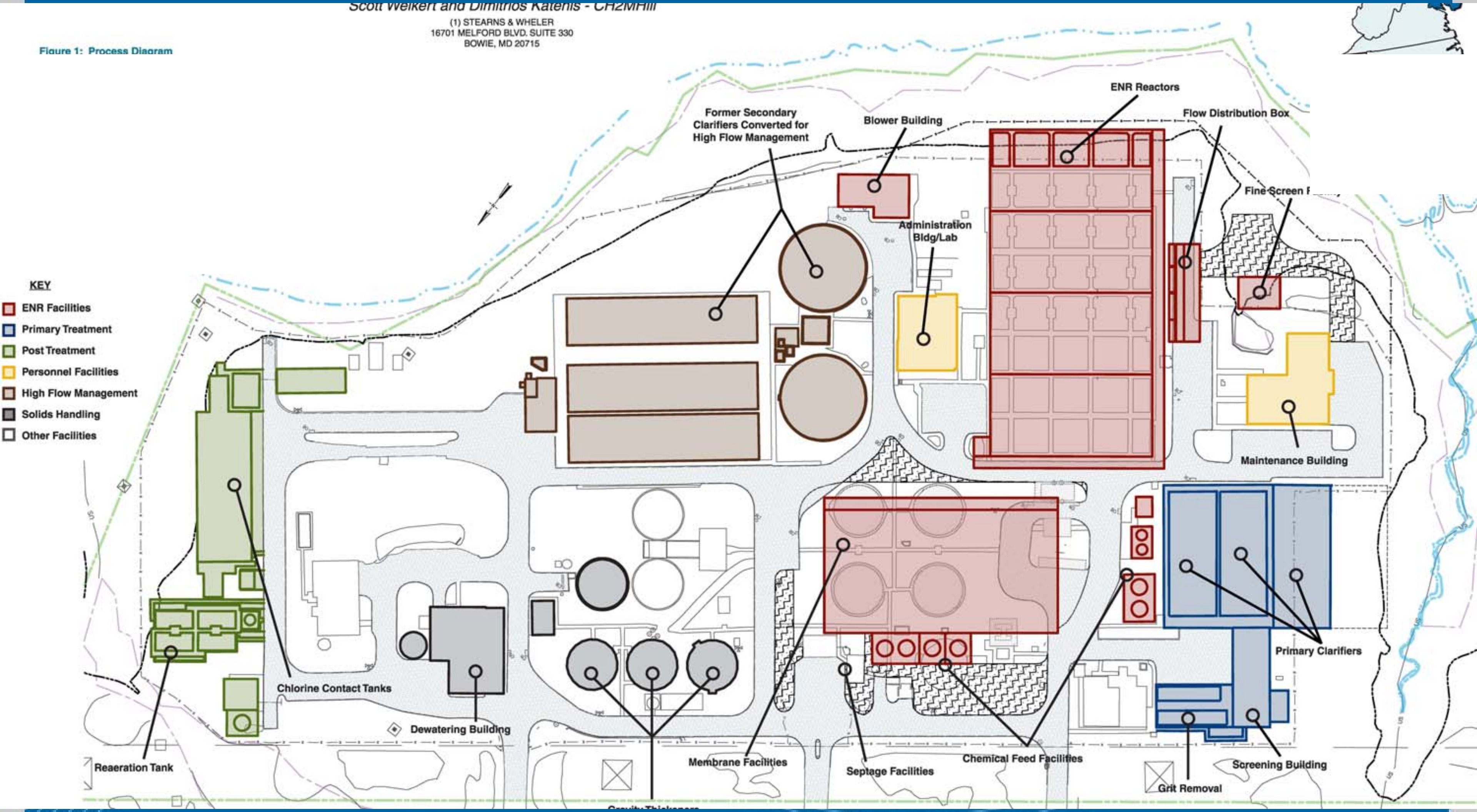
Siemens/MemJet® B30R Cassette

Enviroquip/Kubota® EW400

Pre-Selection Process

- Membrane Pre-Selection RFP Written to Encourage Open Competition
- Scope of Supply for Membrane Filtration Equipment supplier:
  - Membranes and Membrane Units
  - Permeate Pumps
  - Membrane Cleaning Systems
  - Piping and Valves
  - Instrumentation and Controls
  - Membrane Repair and Replacement Warranty
- RFP issued on April 16, 2009
- Technical and Price Proposals received on July 9, 2009
- Two firms submitted (GE/Zenon and Siemens)
- Evaluation based on 60% Cost, 40% Non-cost
- GE/Zenon selected as Membrane Supplier

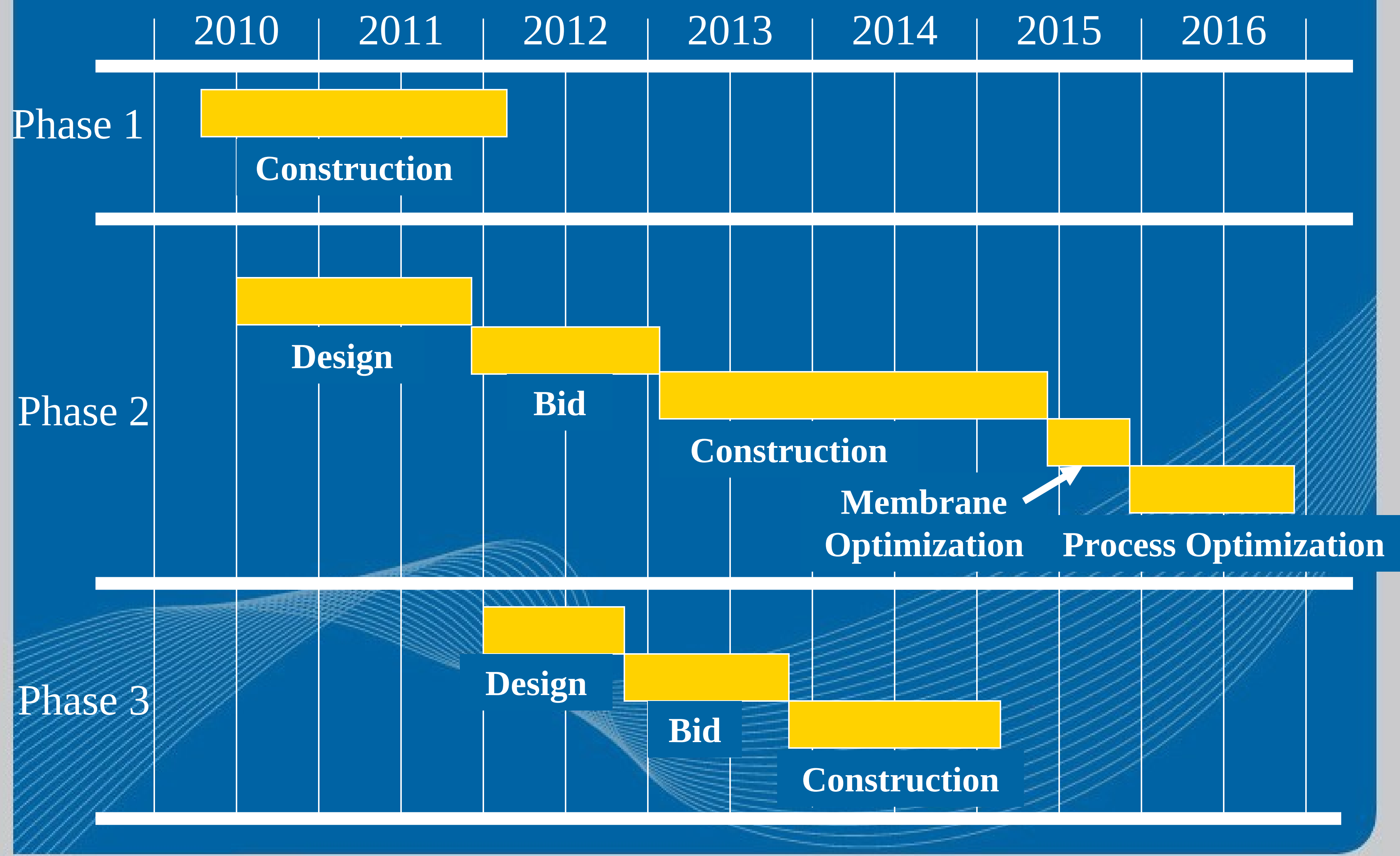
Proposed Site Plan



Current Project Status

- January 2007: ENR Process selection completed
- April 2007: Schematic Design Report completed
- June 2010: Membrane Pre-Selection Process completed
- Project implementation includes three separate construction contracts:
  - Phase 1: Primary Clarifiers and other Auxiliary Systems
  - Phase 2: Fine Screens, ENR Reactors, Membrane Tanks and Related Improvements
  - Phase 3: Non-ENR funded plant improvements (Headworks Improvements, Disinfection Upgrade, Odor Control,Thickener Improvements)
- Facility Start-up expected in 2015.

Project Schedule



Questions ?