Membrane Bio-Reactors (MBRs) – The Future of Wastewater Technology, Science and Economy Aspects

Glen T. Daigger, Ph.D., P.E., DEE, NAE
Senior Vice President and Chief Technology Officer
CH2M HILL

Presented at
EFCA 2005 General Assembly Meeting & Conference
Krakow, Poland
30 May, 2005

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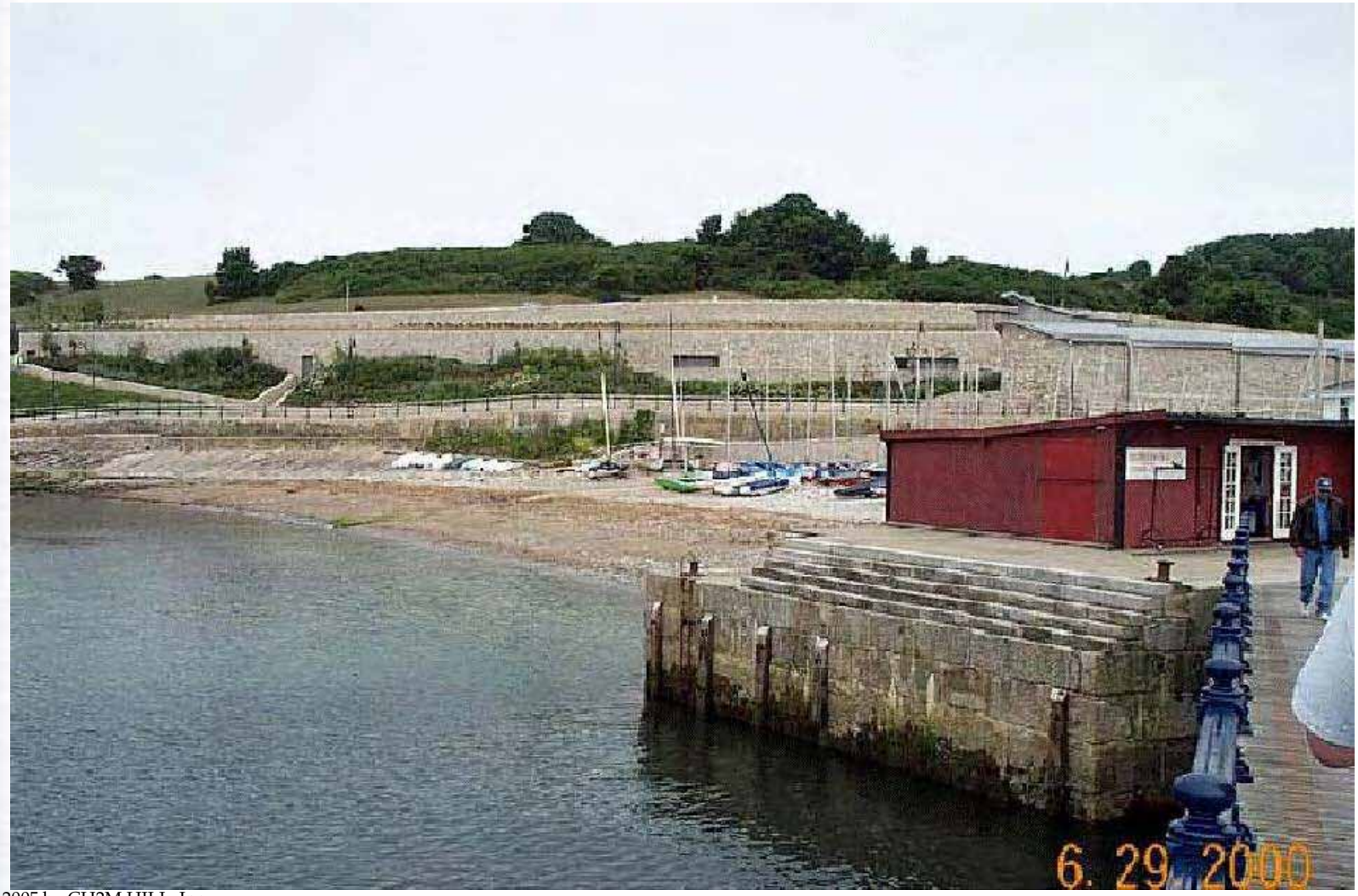
Can You Tell Me Where the 12,500 m^3/day Swanage WWTP, UK is?



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Do You Believe, Structure on Left is a Wastewater Treatment Plant?

3,400 m^3/day Hamptons WRF, Cumming, GA, USA

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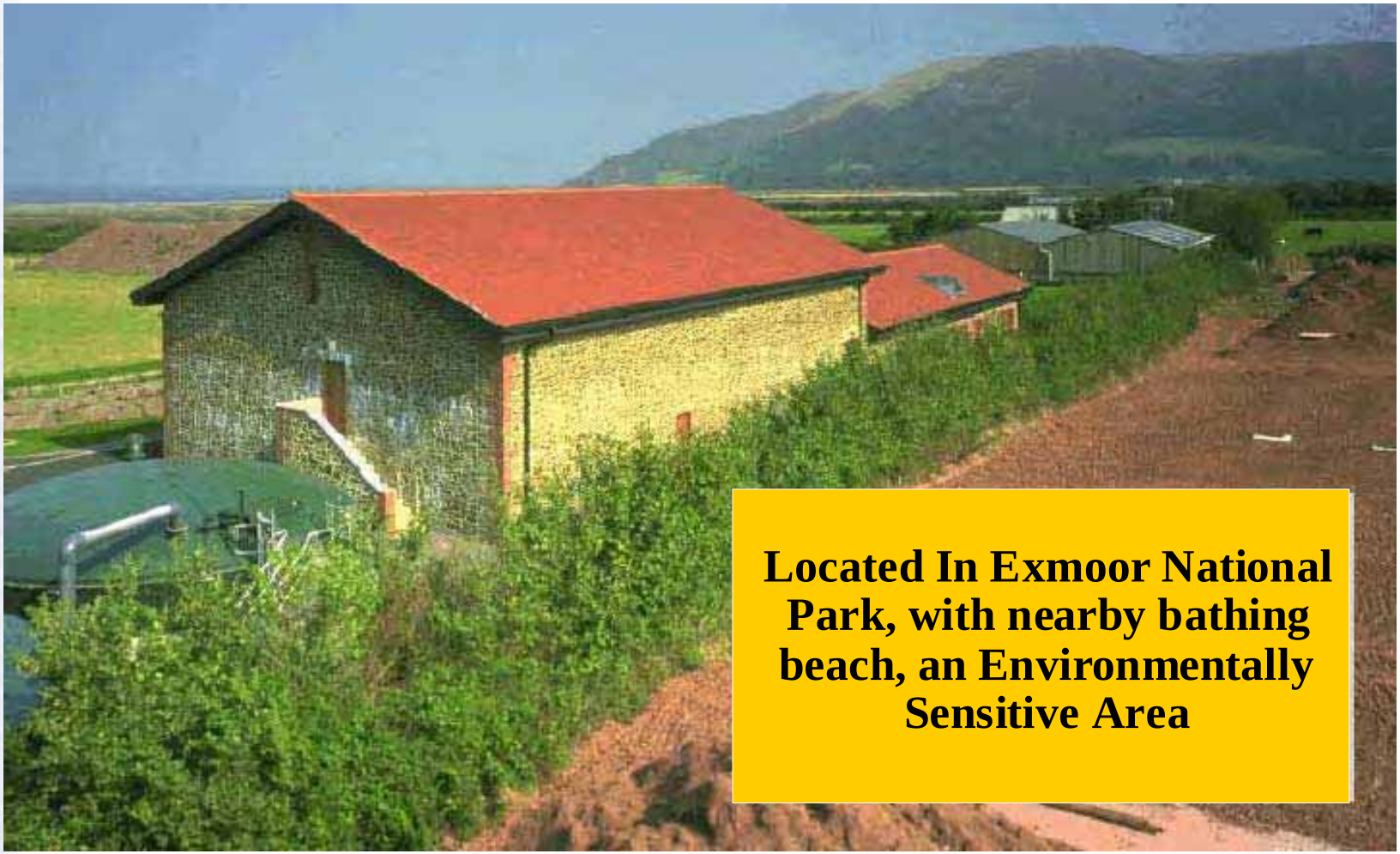
Porlock WWTP, UK (2,000 m^3/day)



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And, Here is the Effluent Quality That Can be Produced!

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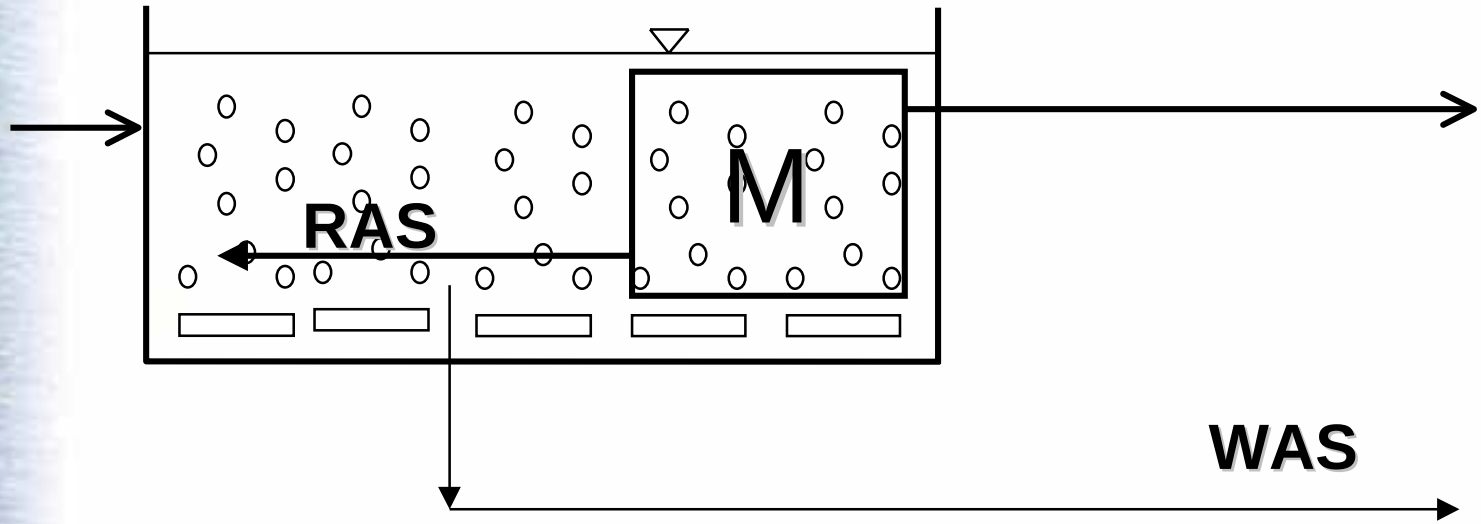
MBRs Incorporate Membranes Into Activated Sludge Process



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MBRs Provide Several Significant Benefits

- Complete Retention of Particulate Matter - Effluent TSS is Very Low
- High MLSS/Long SRT - Compact Bioreactor
- Complete Biomass Retention
- Small Footprint - Small Bioreactors with No Clarifiers or Filters
- Automated Operation

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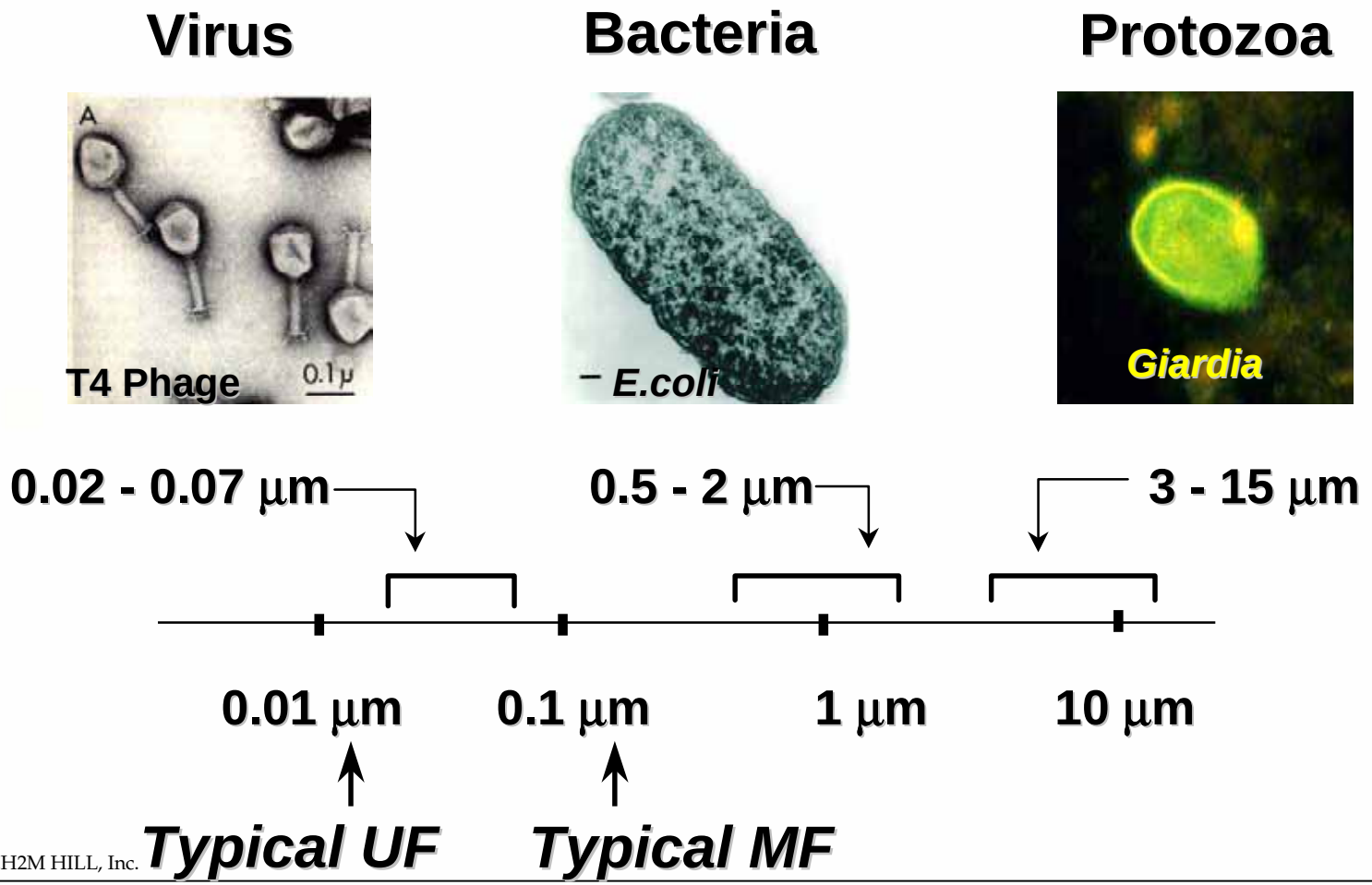
Membranes Can Remove Wide Range of Pathogens



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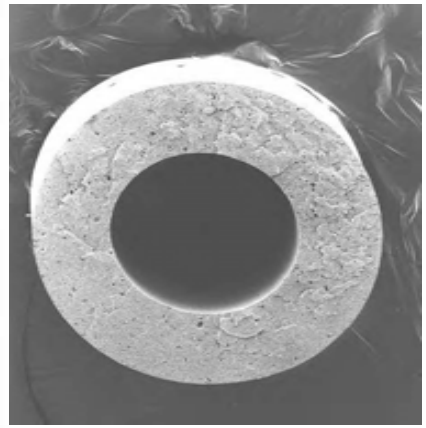
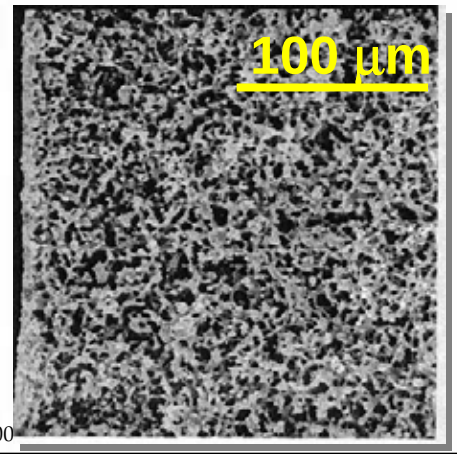
Everything Begins with the Membrane

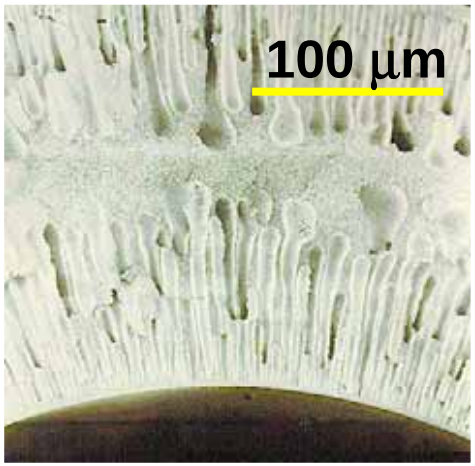
Hollow Fibre

Symmetric





Asymmetric



Flat Sheet

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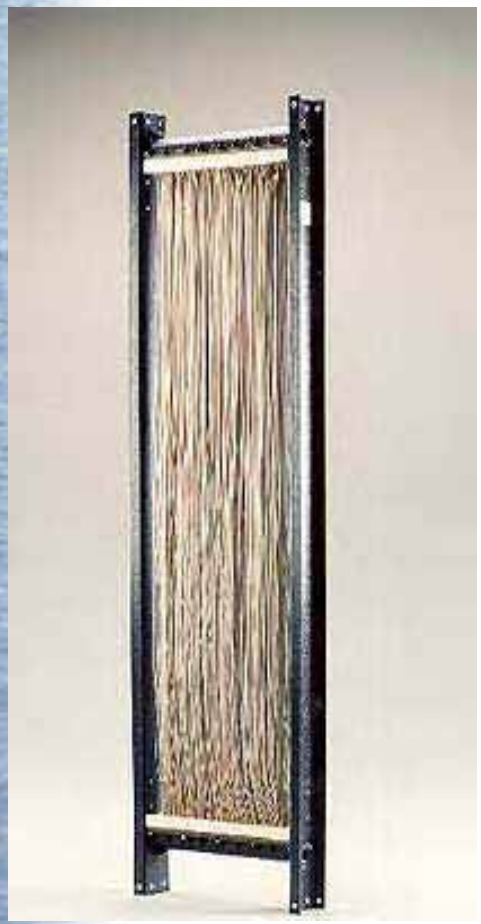
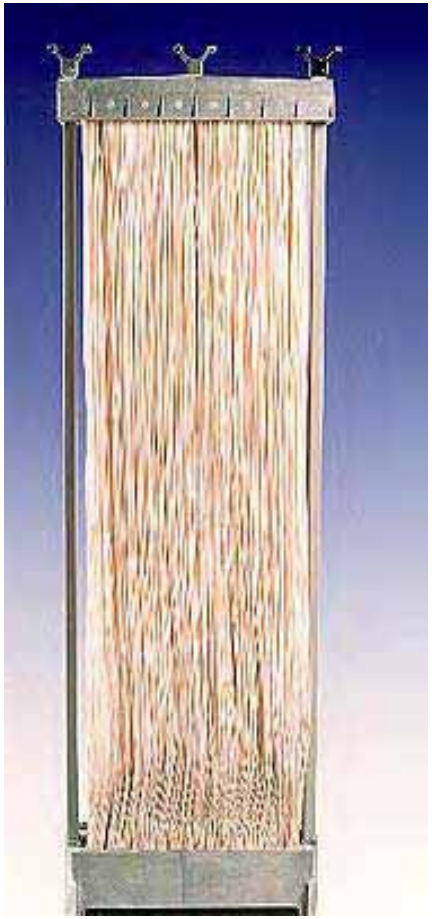
Membrane Elements are Assembled into Modules, Then Into Casettes





ZW 500c Cassette

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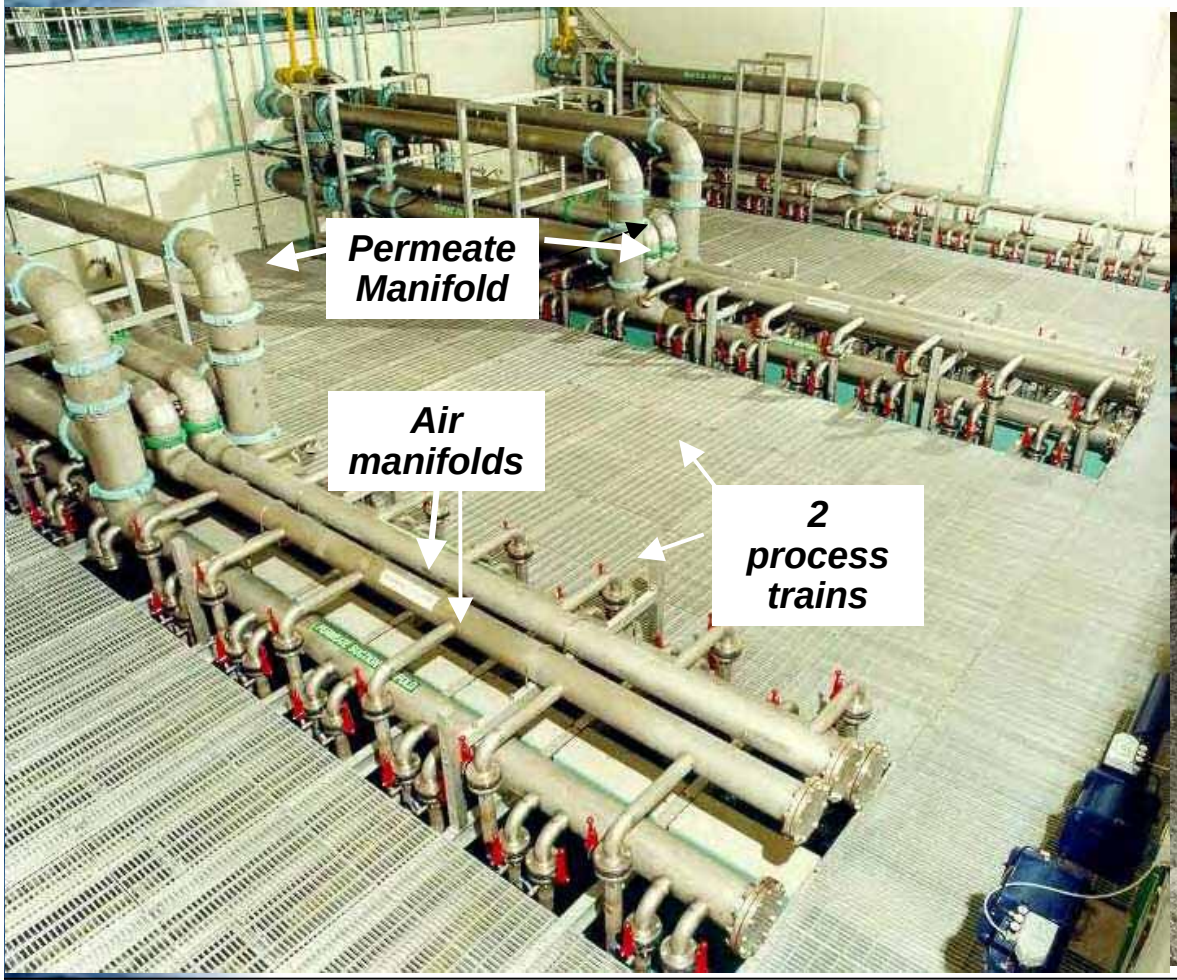
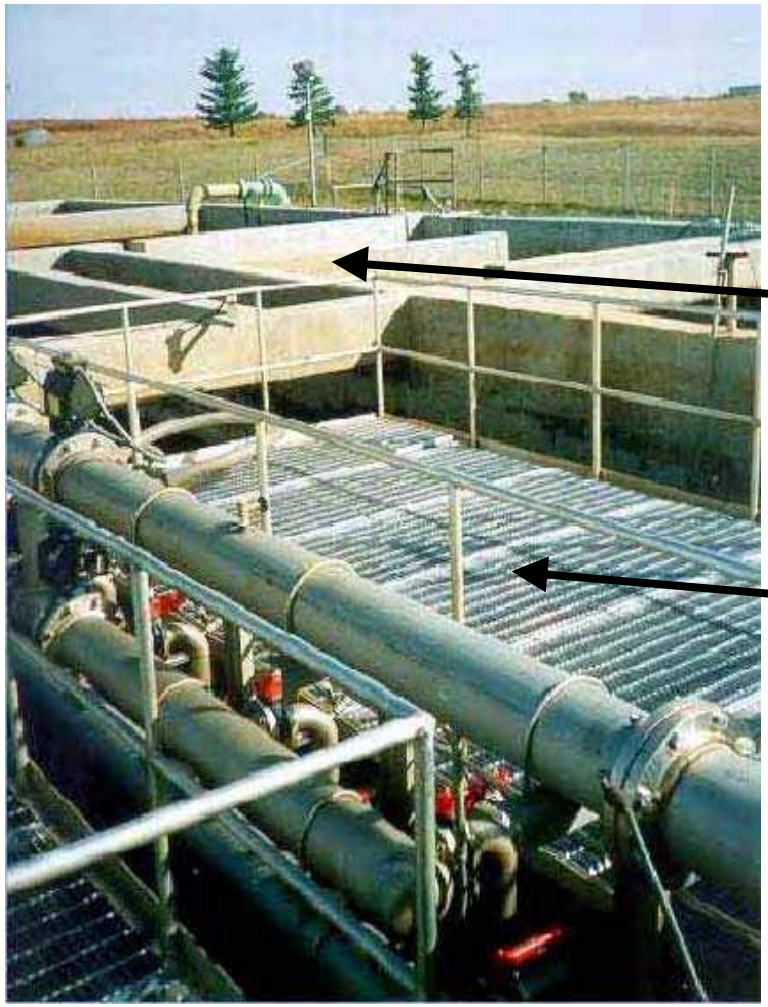
Casettes are Inserted Into Process Trains



Membrane Trains are Then Integrated with Bioreactor



Arapahoe County, Colorado

Main Bioreactor

Membrane Section

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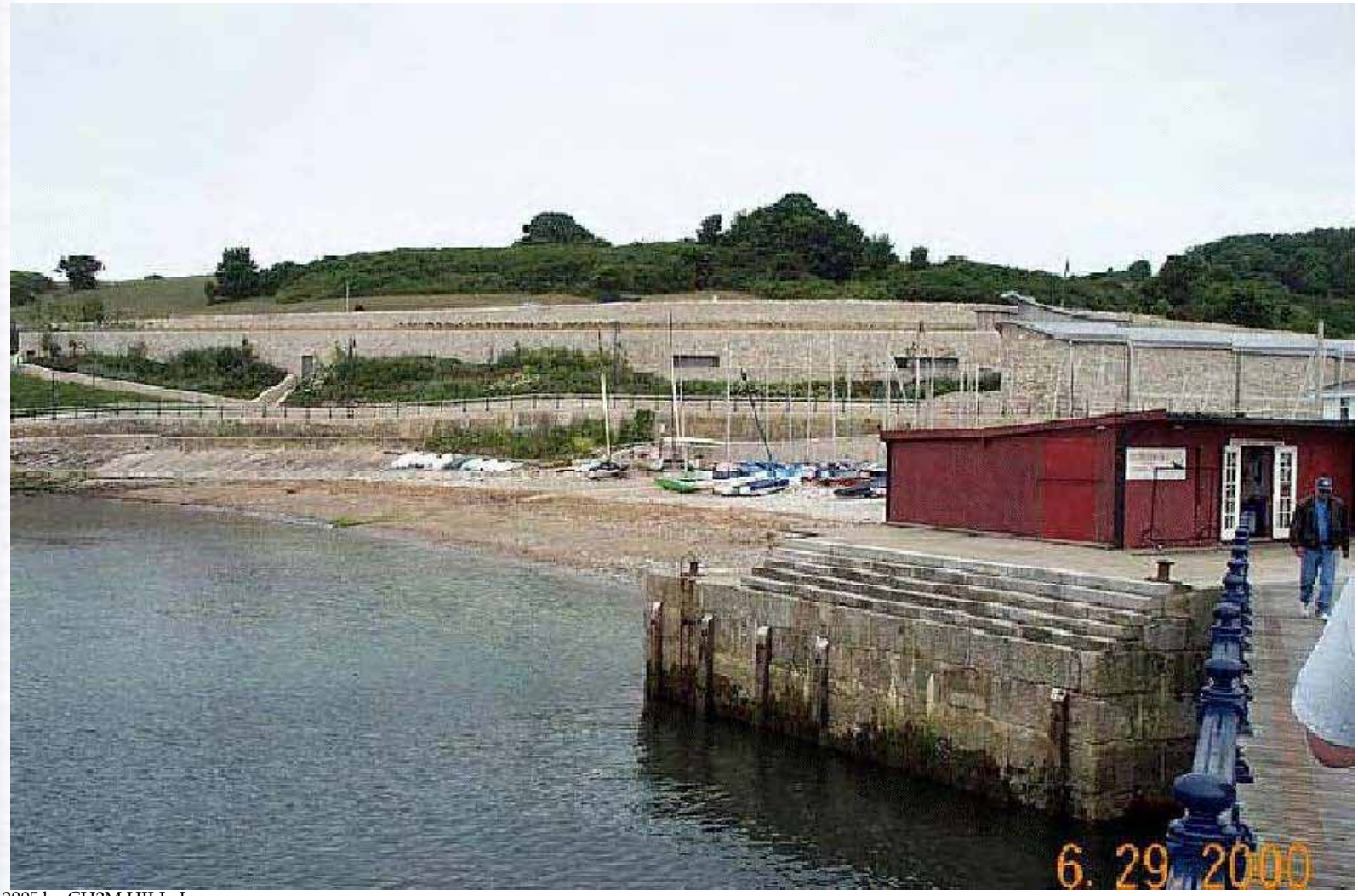
Swanage WWTP, UK (12,500 m^3/day)



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Inside of Plant Showing Top of Bioreactor Area

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Area Adjacent to MBR

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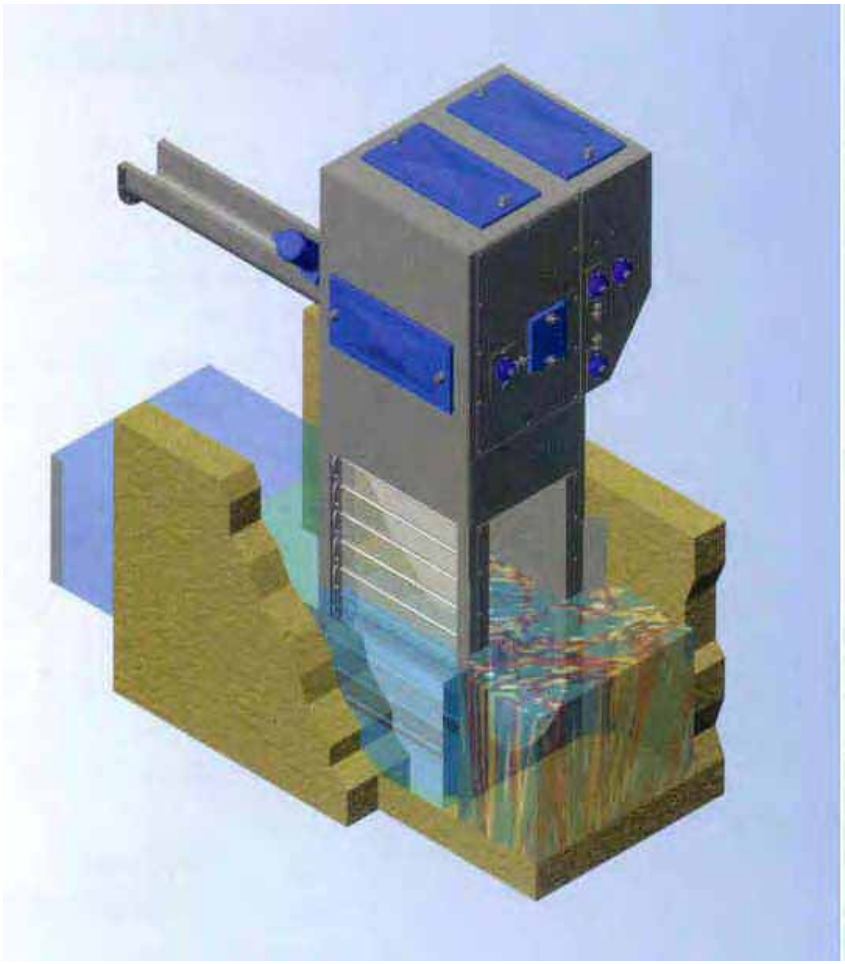
Proper Pretreatment Extends Membrane Life and Performance



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MBR Advantages Lead to Specialised Applications

- Remote Facilities Requiring High Reliability and Simple Operation
- High Quality Effluent:
  - TP < 0.1 mg/L
  - Extensive TN Removal
- Water Reclamation
- Micro-pollutant Removal

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First Conceived in Mid-1960's, MBRs Have Evolved

- First Developments by Dorr-Oliver, Transferred to Japan in Early 1970's
- Thetford Systems "Cycle-Let", Acquired by Zenon Enivornmental
- Parallel Development of Submerged MBR
  - MITI-Funded R&D Program in Japan in Late 1980's, Early 1990's
  - Zenon Development in Canada
- Membrane Costs Decrease Dramatically
- Three Generations Have Occurred and Entering Fourth Generation

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Key Changes in Transition From First to Fourth Generation

- Scale
  - Small Package Plants to Major Facilities
- Method of Implementation
  - Package Plants to Custom Designs
- Treatment Objectives
  - Treatment and Sludge Storage to Nutrient Removal and Water Reclamation
- SRT
  - Sludge Storage to Economical Process Requirements
- MLSS
  - Reduced to Maximize Membrane Capacity

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Three North American (USA) Fourth Generation Facilities:

- Broad Run Water Reclamation Facility (WRF), Loudoun County Sanitation Authority (LCSA), Virginia
  - New 45,000 m^3/day (Max Month) – 95,000 m^3/day Peak Capacity, Expandable to 136,000 m^3/day (Max Month)
  - Water Reclamation and Environmental Protection

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Broad Run WRP Will Protect Public Health and Environment

	OCCOQUAN APPROACH
BOD (mg/L)	NA
COD (mg/L)	10
TSS (mg/L)	1
TN (mg/L)	3
TP (mg/L)	0.1
MBAS (mg/L)	0.1
Turbidity	0.5 NTU
Coliform	2

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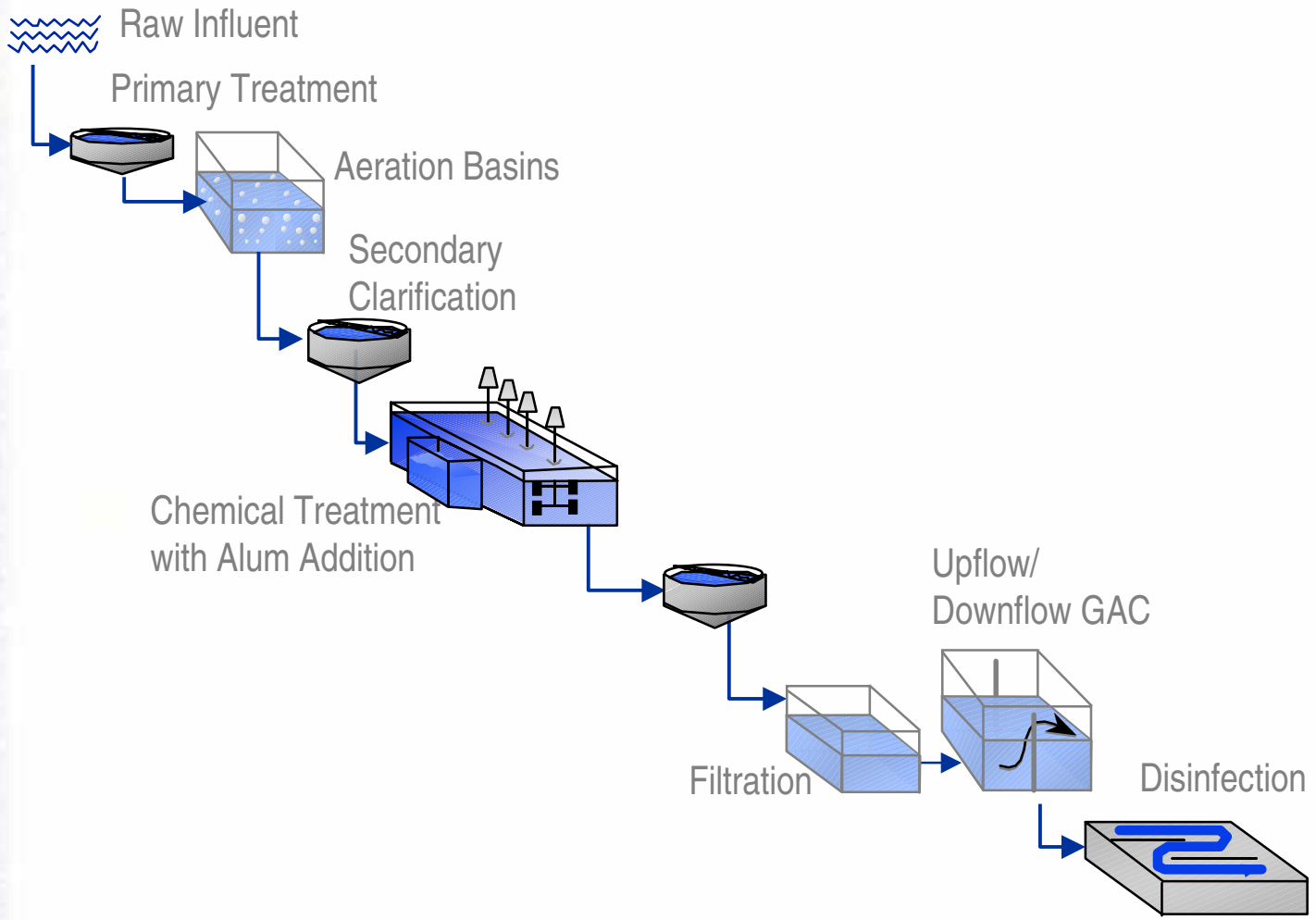
Mulit-Point Alum Addition was Best Conventional Option



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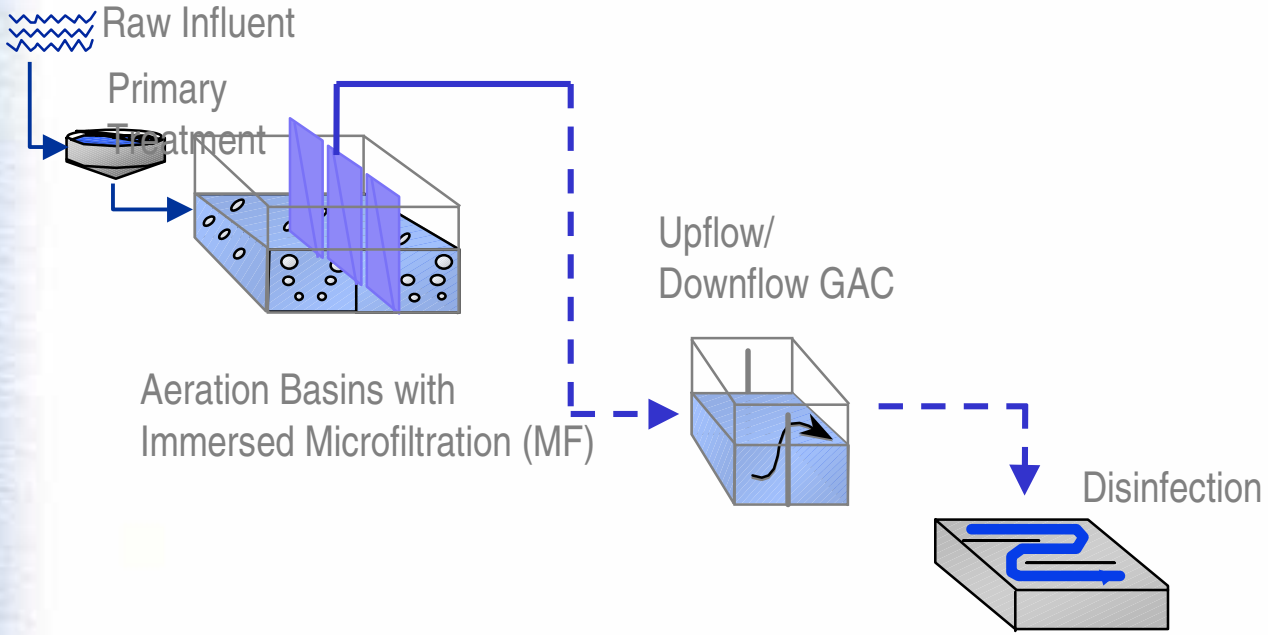
Membrane Bioreactor Eliminates Clarifiers and Filters



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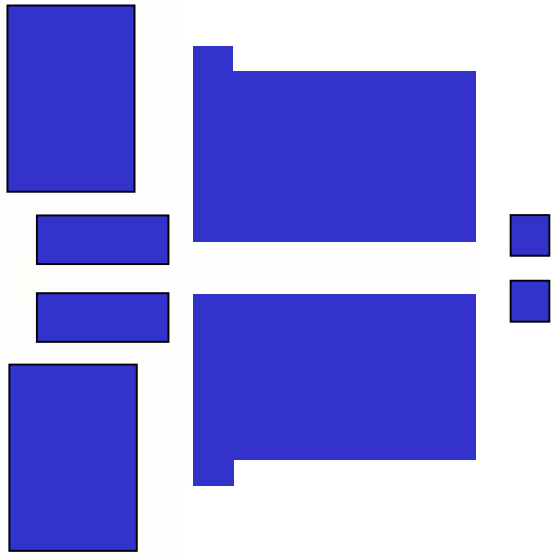
Membrane Bioreactor Takes Less Land and is Simpler



Required plant area 8 Hectares

New plant area 3 Hectares

Broad Run WRF at 136,000 m3/day Loudoun County, VA

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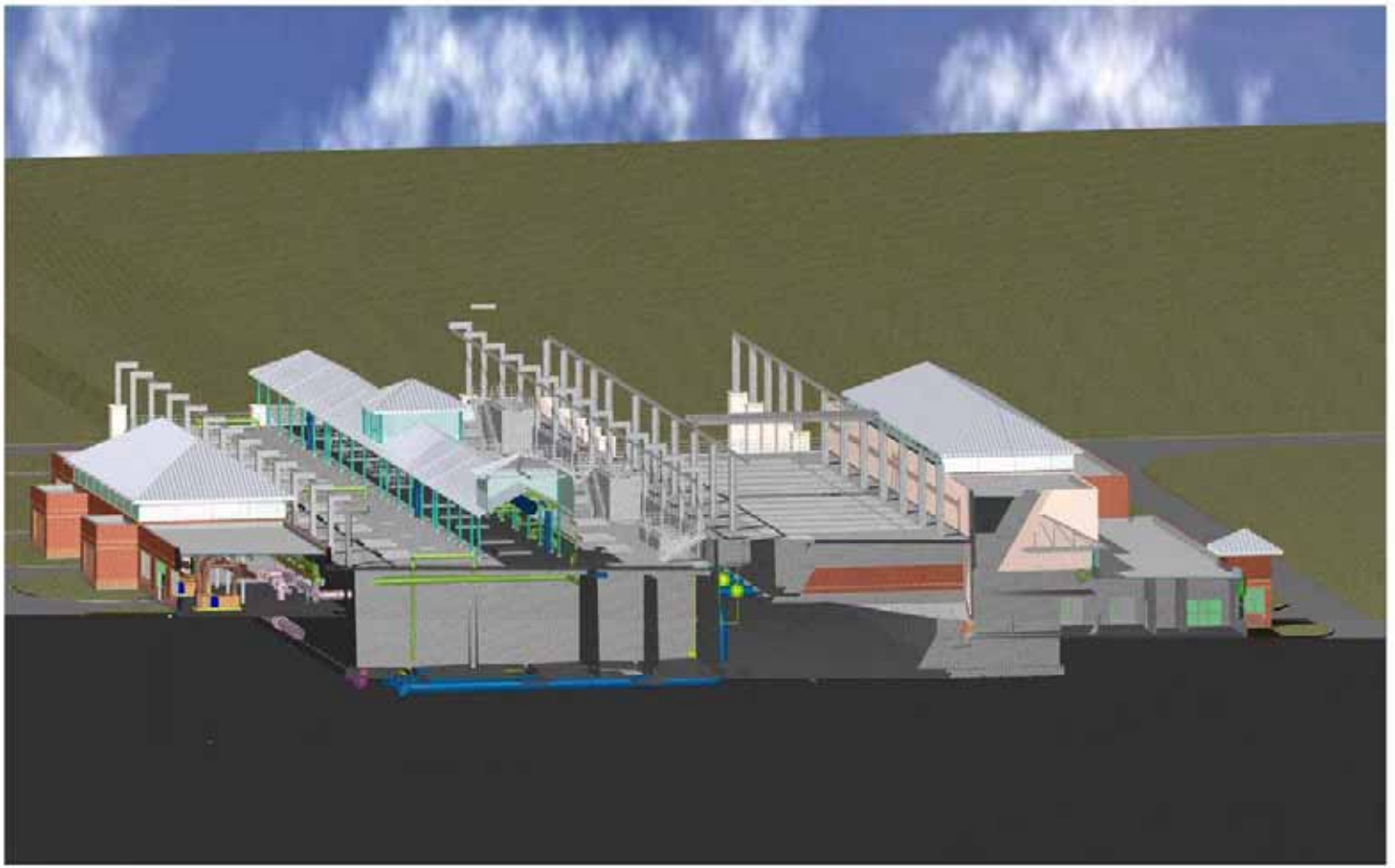
Loudoun County Represents New Generation of MBRs



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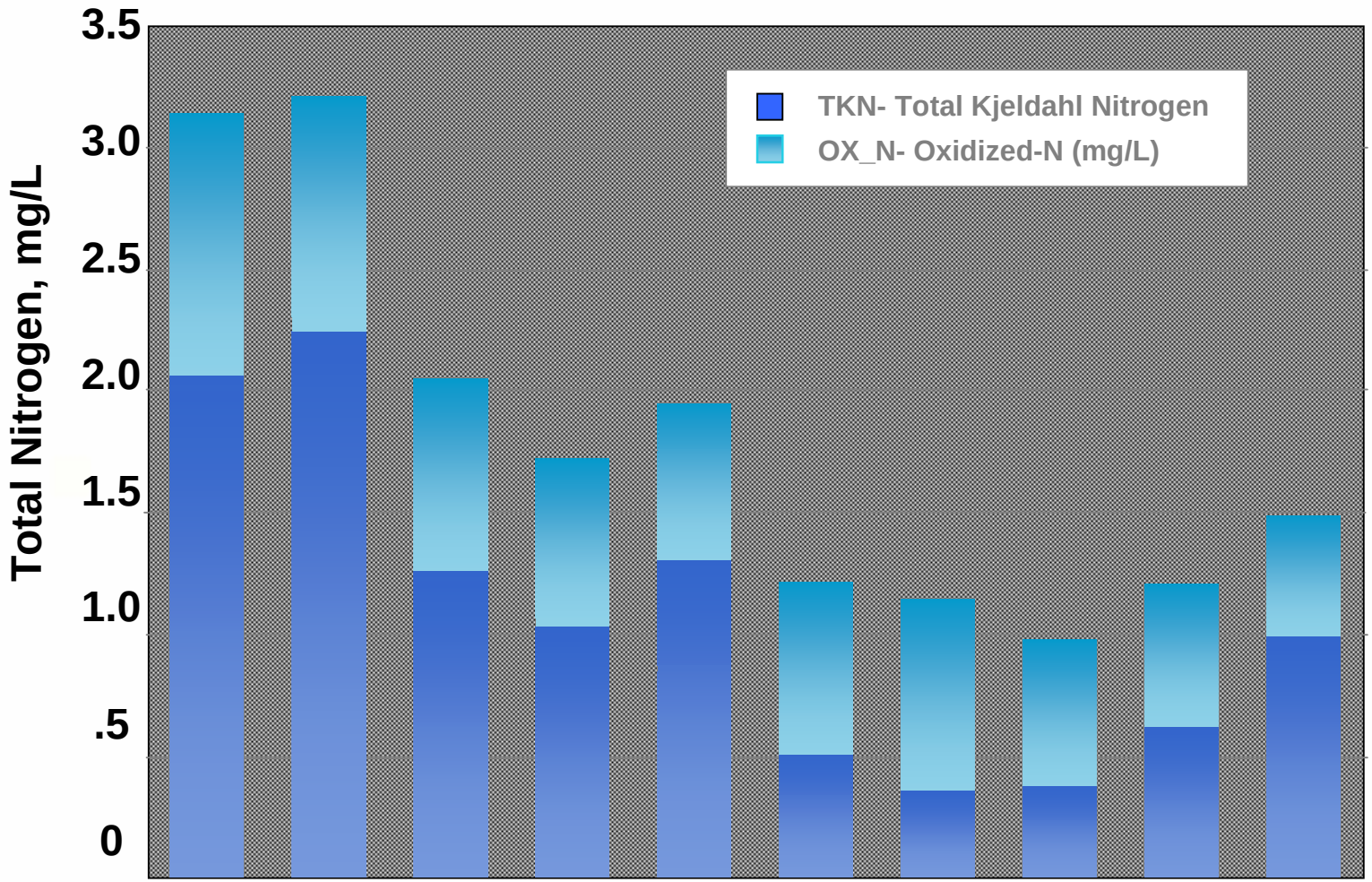
Low Effluent TN Achieved with Methanol Addition



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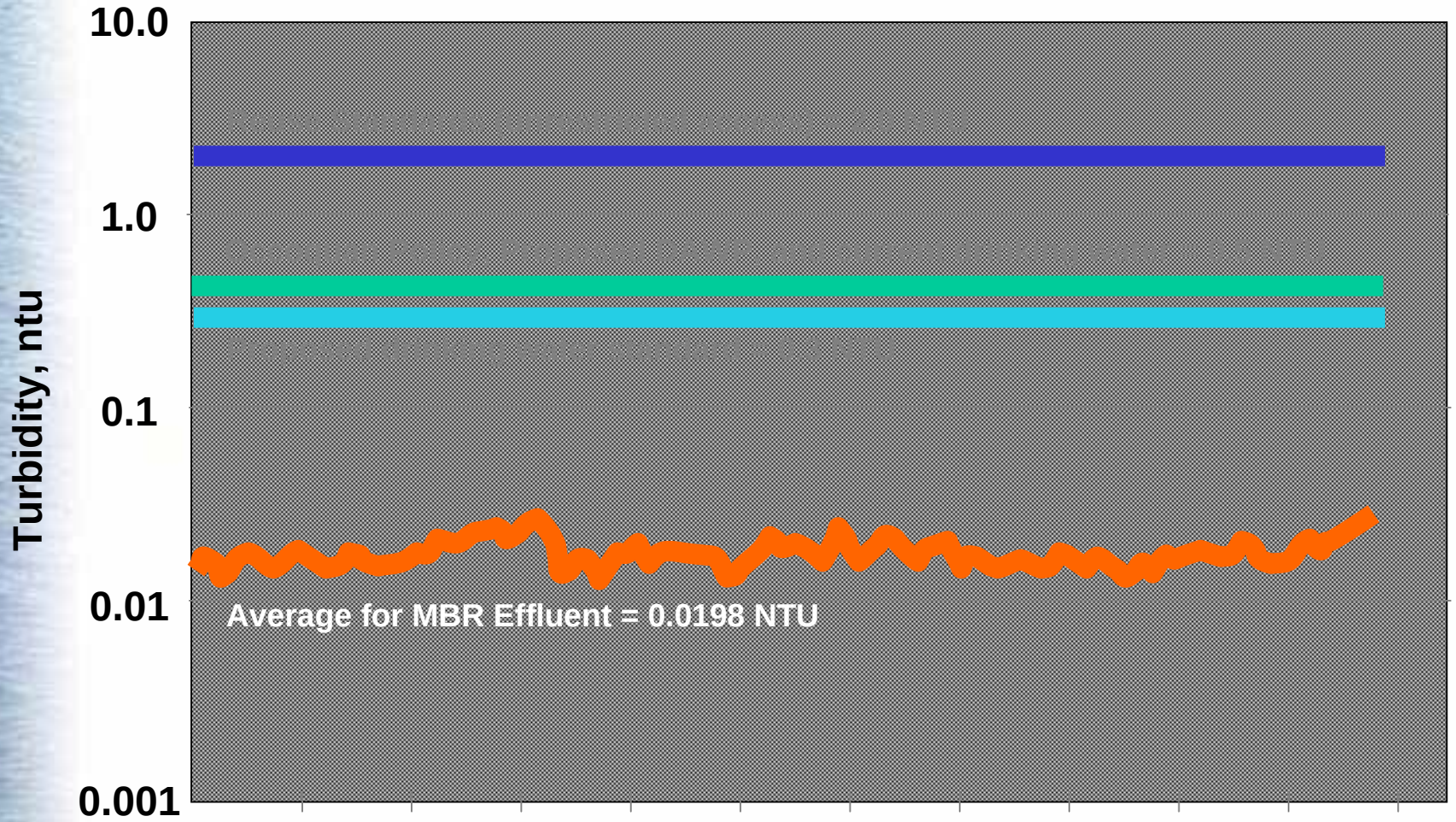
Effluent Turbidity Exceeds Recognized Standards



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Virus Challenge Results Demonstrate Pathogen Control

- 5-Log Removal in First-Stage Bioreactor
- 0.9-Log Removal in GAC Column
- *Cryptosporidium* and *Giardia* Control

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Three North American (USA) Fourth Generation Facilities:

- Broad Run WRF
- Traverse City (Michigan) Regional Wastewater Treatment Plant (WWTP)
  - Expand Existing Plant
    - *19,000 m^3/day (Max Month) Current*
    - *32,000 m^3/day (Max Month) – 68,000 m^3/day Peak Capacity*
  - High Quality Effluent to Enhance Environmental Protection
  - Design-Build
  - Largest Operating MBR in North America

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Voluntary Discharge Standards More Stringent Than Required

Item (mg/L)	MDEQ	Voluntary
BOD_5	25	4
TSS	30	4
NH_3-N	11	1
TP	1	0.5

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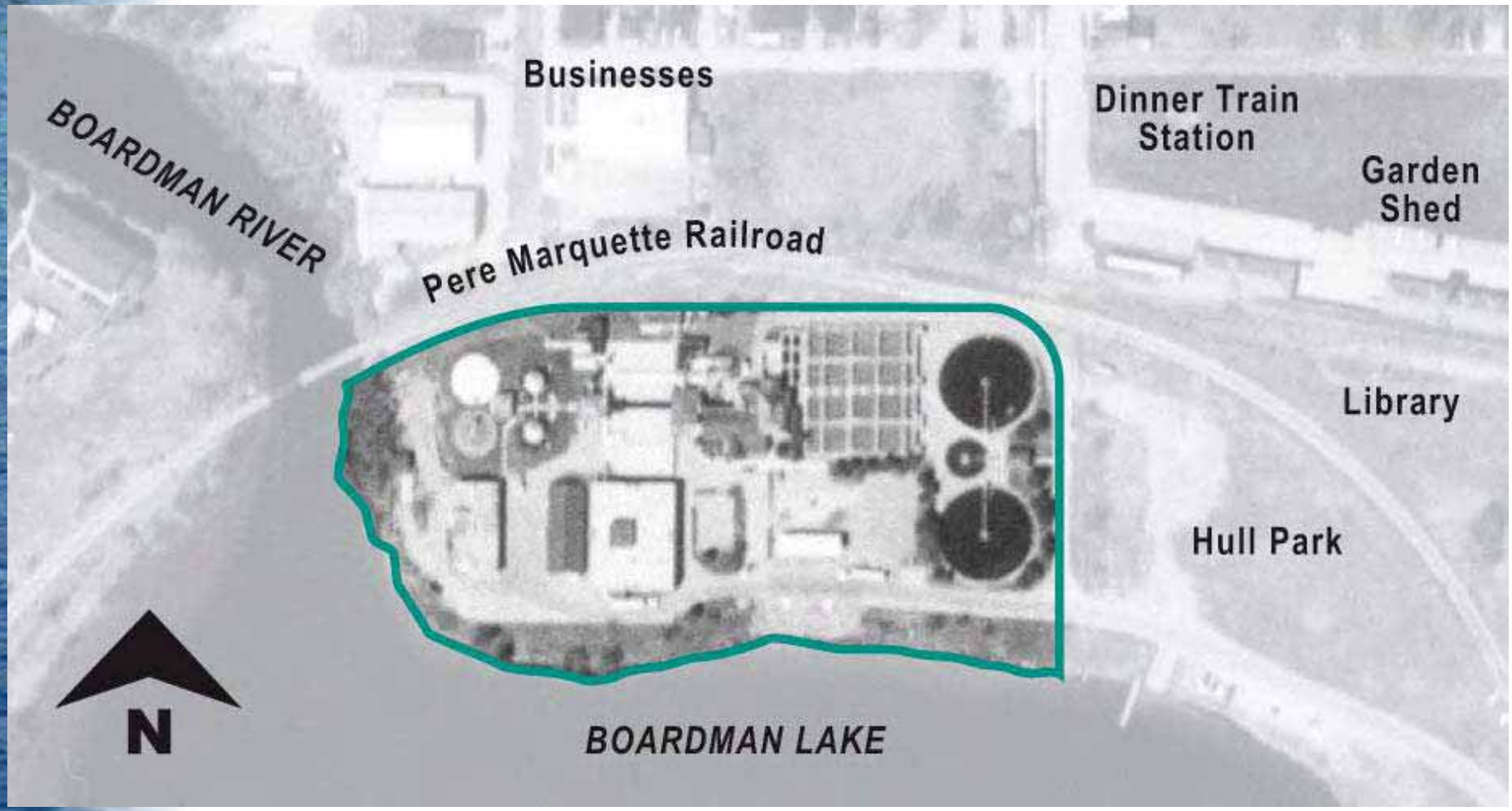
The Traverse City Available Site is Limited



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MBR Additions Include Fine Screening of Primary Effluent

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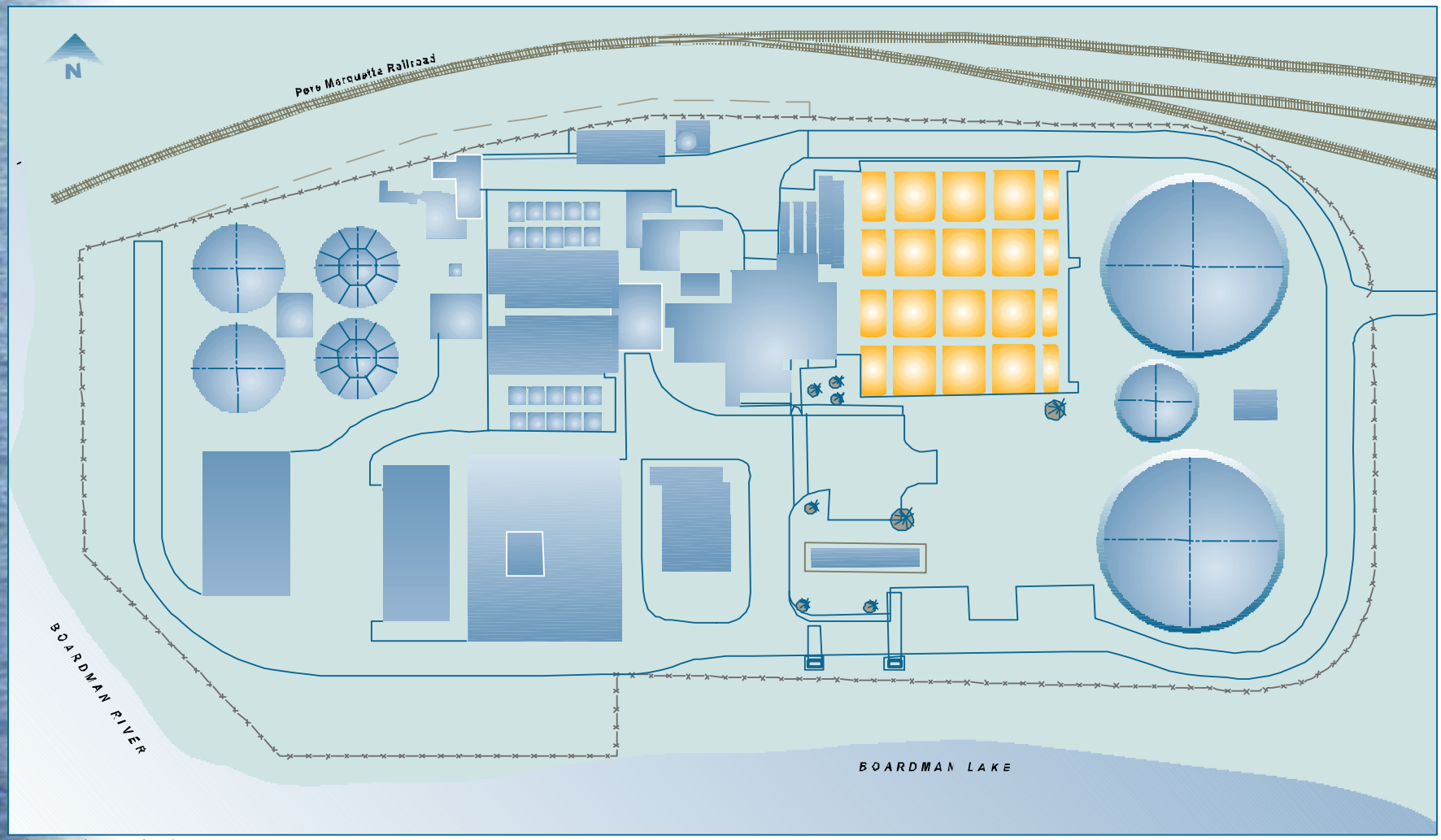
Existing Aeration Basin Sufficient But Expand Blowers



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Process Design Includes Biological Nutrient Removal

To Membrane Tanks

Membranes Will be Housed in New Tankage

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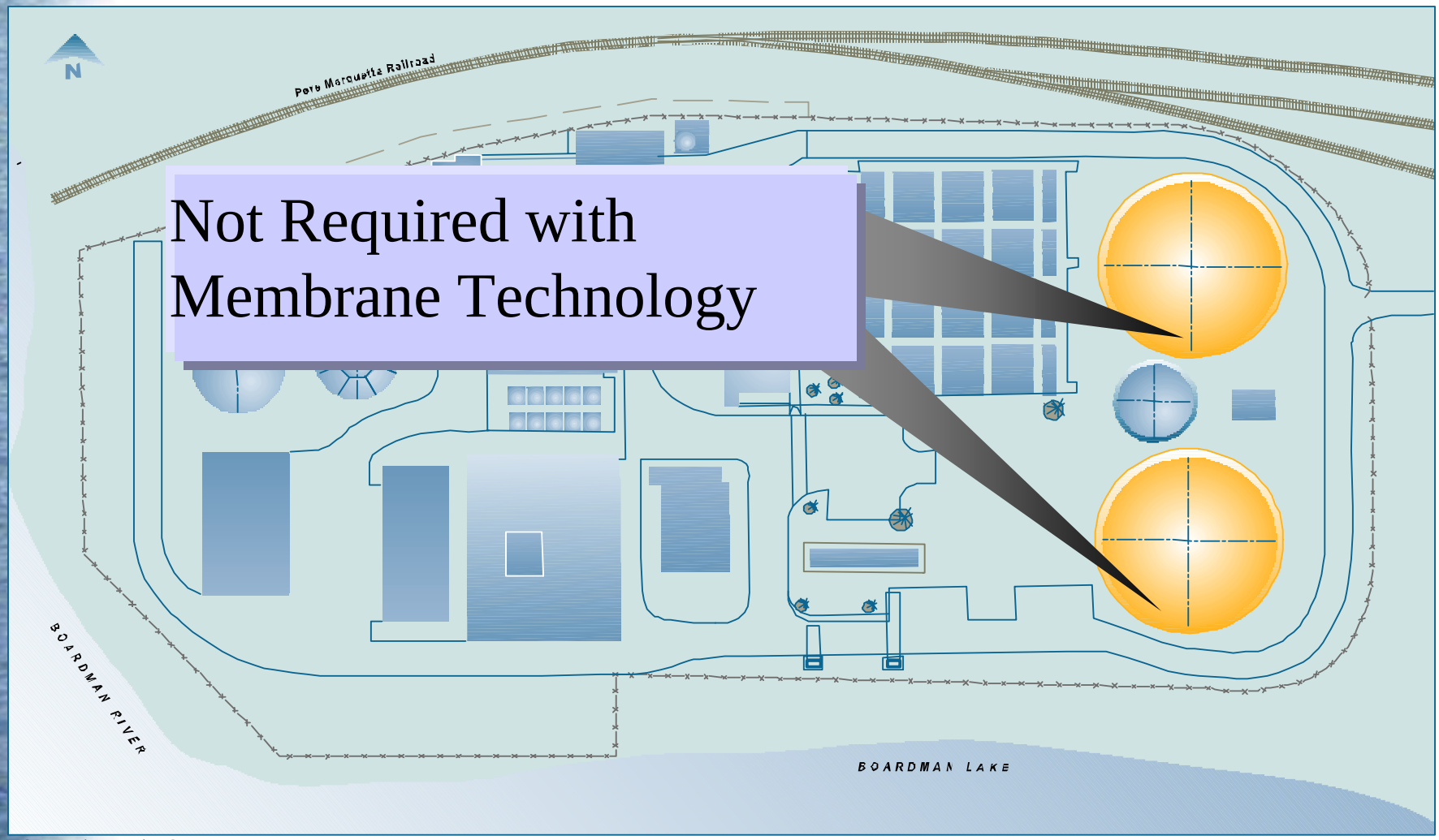
Secondary Clarifiers are Converted to Sludge Storage



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Completed Facility Showing Membrane Tanks

Copy

Three North American (USA) Fourth Generation Facilities:

- Broad Run WRF
- Traverse City WWTP
- Brightwater Wastewater Treatment Plant (WWTP), King County, Washington
  - Large Plant
    - *144,000 m^3/day Dry Weather*
    - *430,000 m^3/day Peak Wet Weather*
  - Split Flow Treatment
    - *Dry Weather Secondary*
    - *Enhanced Primary Treatment for Wet Weather*
  - Space, Odor Control, Reclamation

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Two Split Stream Alternatives Evaluated: CAS and MBR

Item		CAS*	MBR	
Secondary Capacity (m^3/day)		250,000	144,000	
Split Flow Frequency (per yr)		2-8	25-47	
Capital Cost ($M)		545	531	
O&M Cost ($M/yr)		4.5	6.7	
Present Worth ($M)				
	Average	612	631	(+ 3%)
	Best Case for CAS	651	706	(+11%)
	Best Case for MBR	643	602	(- 11%)
Surface Area (m^2)		13,000	5,600	

* Conventional activated sludge

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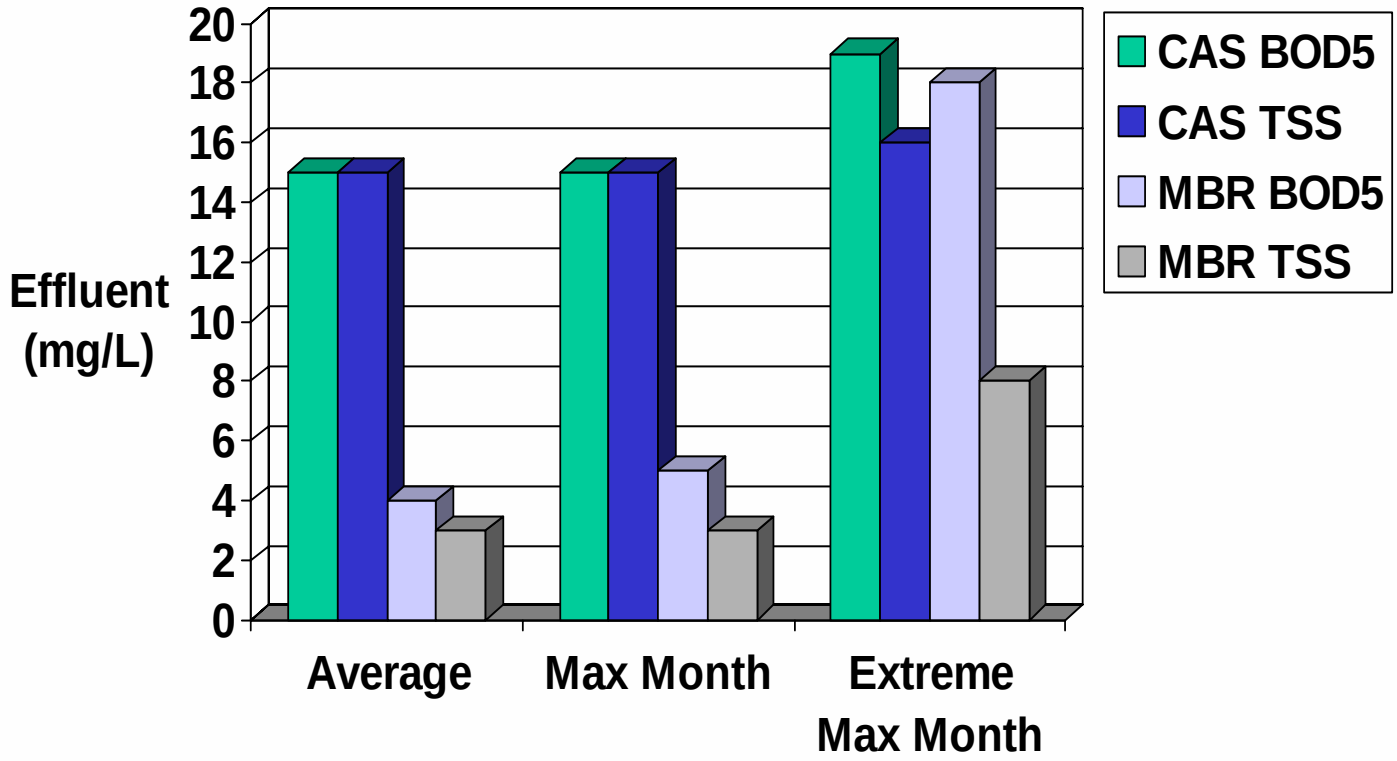
MBR Provides Superior Effluent Quality



MBR Effluent is Also Nitrified and Useful for Reclamation

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Here's What You Should Remember From This Presentation:

- MBRs are Not Just for Small Plants
- MBRs Can be Economical When High Quality Effluent and/or Small Footprint Needed
- High Quality Effluent Facilitates Reuse
- Knowledge of MBR Capabilities and Applications is Increasing Rapidly
- Manufacturers are Advancing Membrane Technology to Reduce Costs and Increase Performance

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In Singapore, Membranes are Being Used to Produce Potable Water From Wastewater

- RECYCLED WATER PASSES TASTE TEST: PUB chairman Tan Gee Paw (right) and a panel of international experts who declare reclaimed water fit to drink showed yesterday that they were ready to drink it themselves. The Straits Times hit the streets with samples on Tuesday.

  -- HOW HWEE YOUNG

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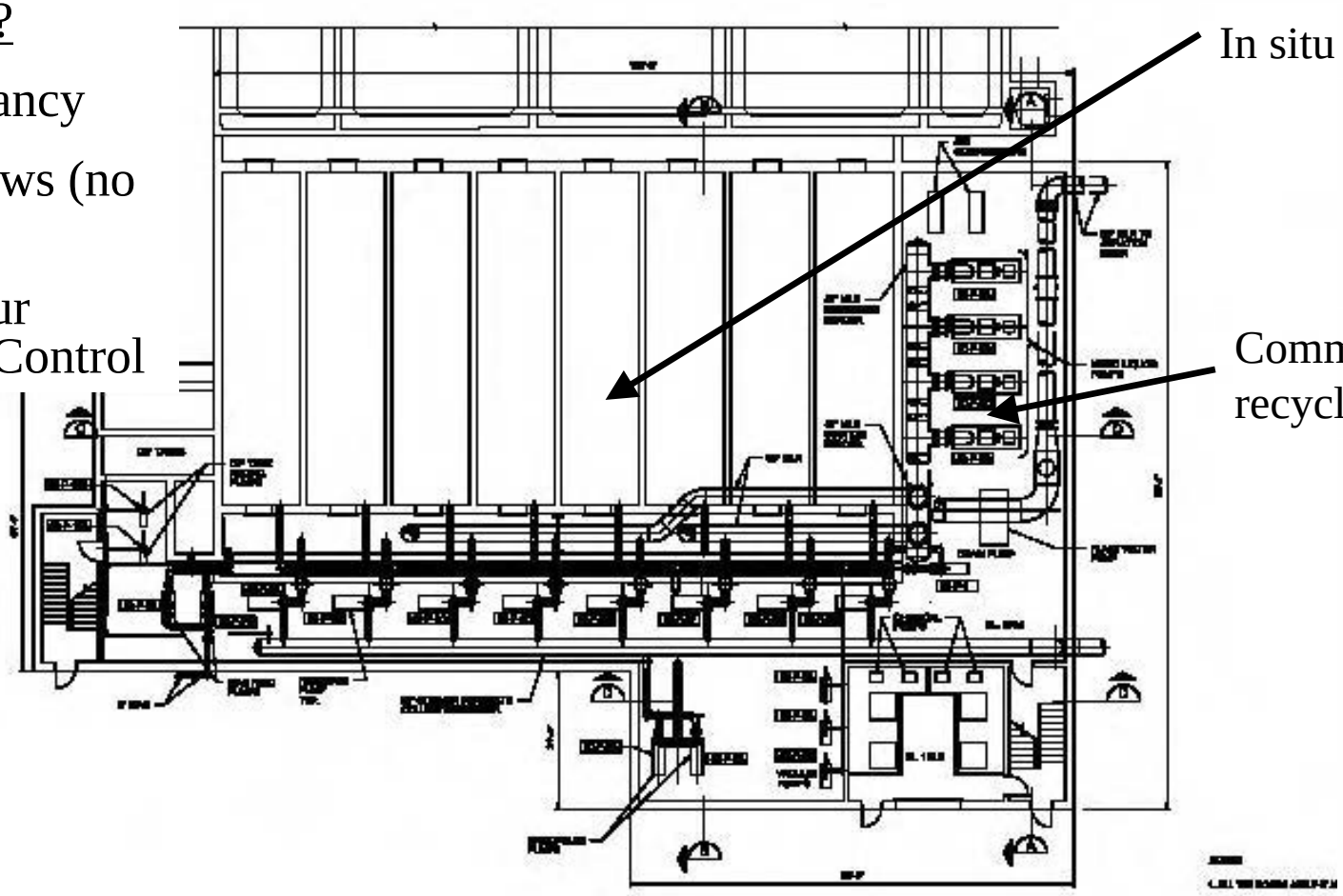
The membrane tank is divided into 8 compartments

WHY 8?

Redundancy

Peak flows (no EQ)

Air Scour Energy Control



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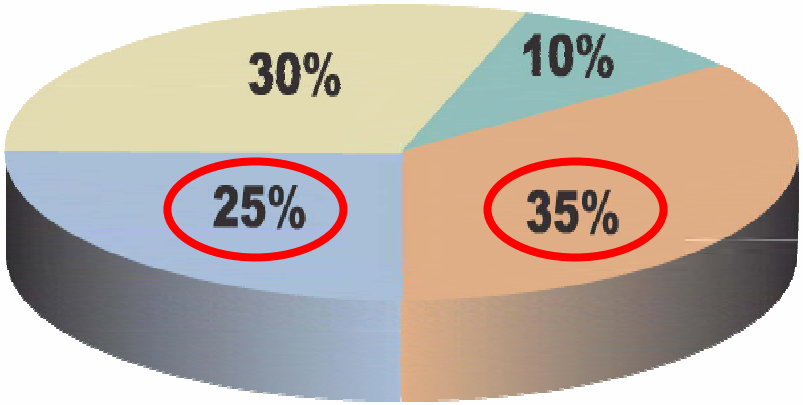
Membrane equipment costs are a significant project cost factor!

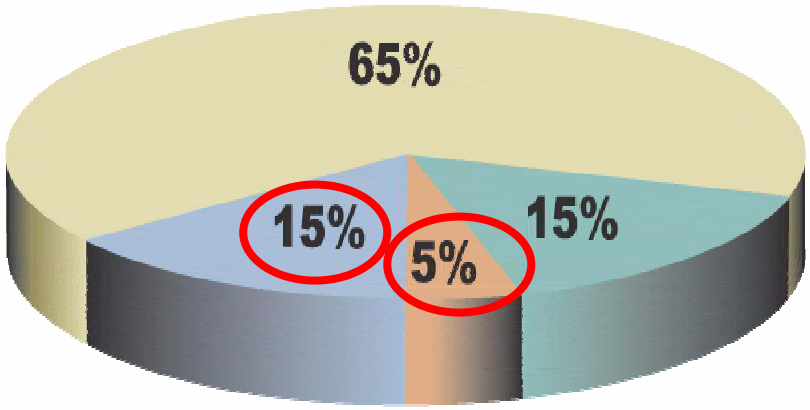
Membrane equipment capital and LCC are 50-60% of Total Costs, not 20-25%!

Fewer structures and tanks, and higher equipment costs, compared to clarifiers and filters

Membrane Bioreactor



Clarification and Filtration



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