MBR Activated Sludge Truths: The Real Information Concerning the O&M Associated with MBR Activated Sludge

OWEA State Conference

June 20, 2012

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When evaluating using the MBR process it is important to look at the capital and o/m costs for the WHOLE plant not just the membranes.

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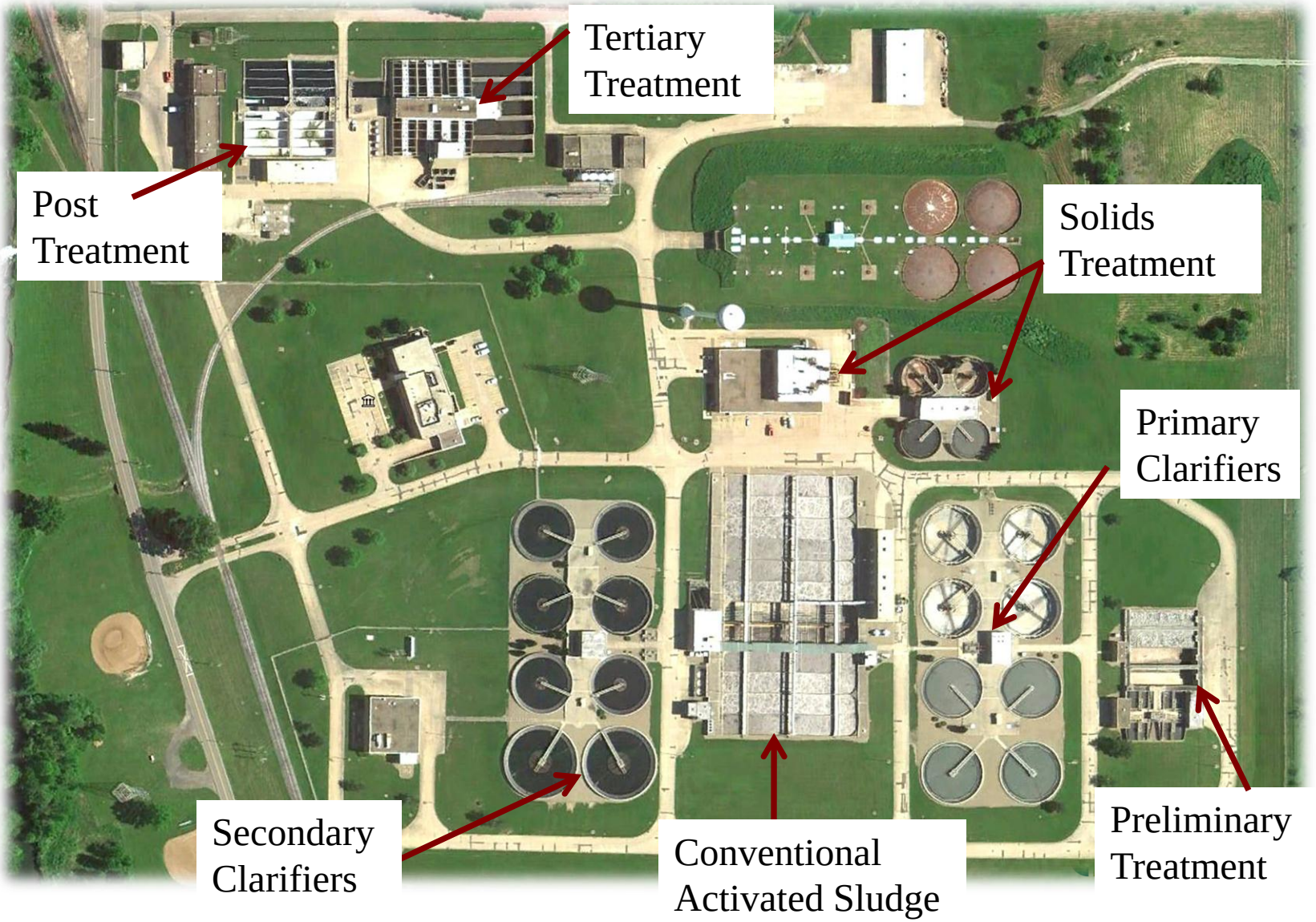
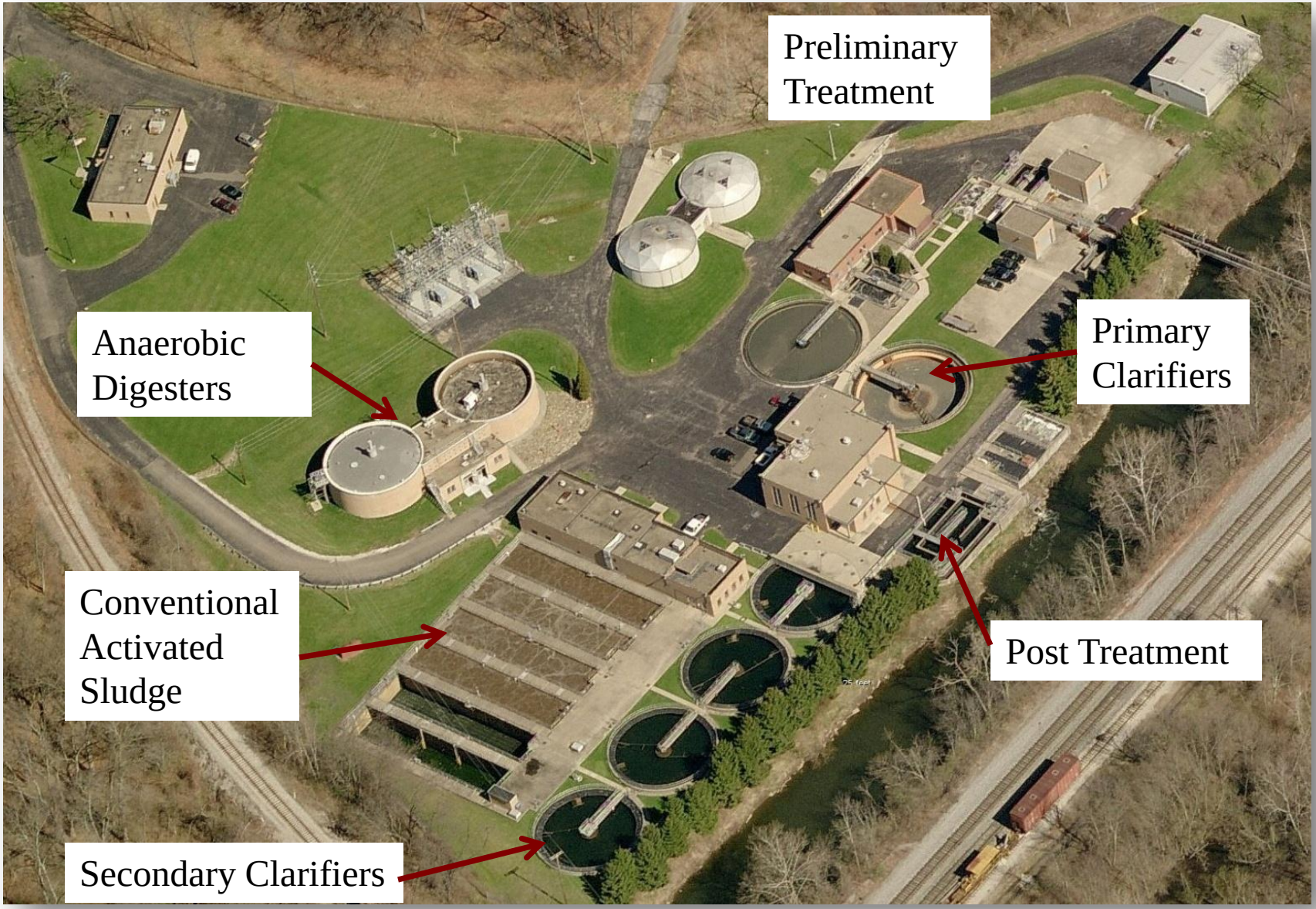
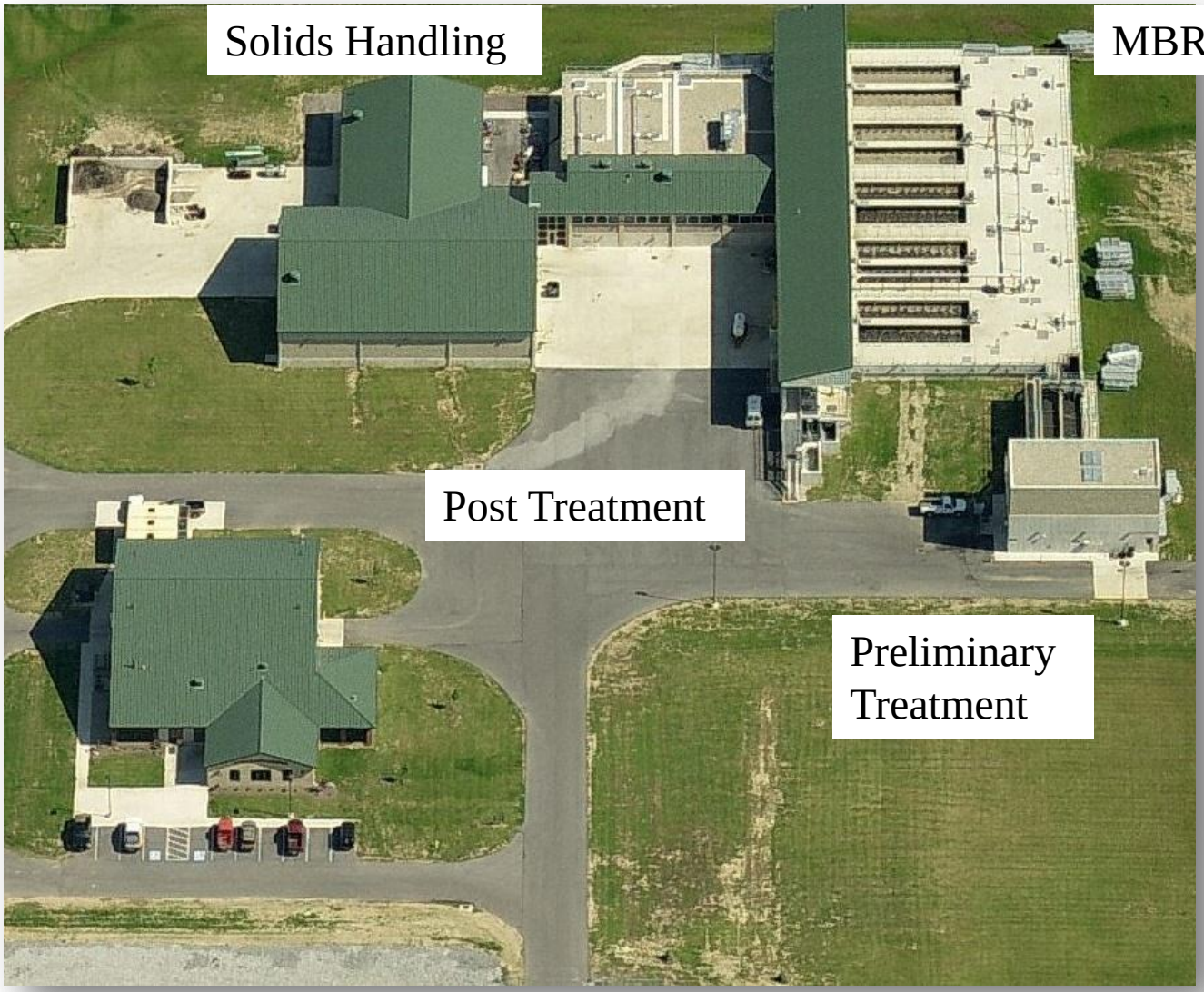
Conventional Wastewater Plant



Conventional Wastewater Plant



MBR Wastewater Plant



MBR Activated Sludge

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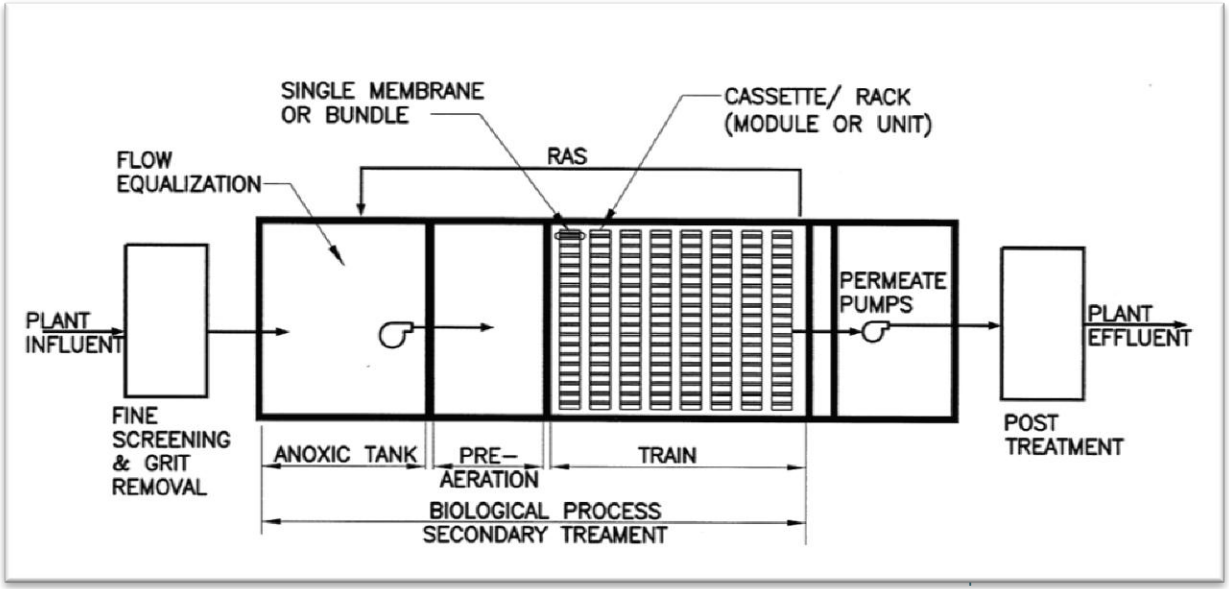
Definition of MBR

- The membranes are submerged in the activated sludge tanks to perform the critical solids separation process that clarifiers and tertiary process units perform in conventional treatment plants
- Processes with an anoxic zone, aeration zone, and a membrane zone. Sometimes an anaerobic zone if biological nitrogen removal is required.



Conventional Plants	MBR Plants
Influent Pumping	Influent Pumping
Grit and Grease	Grit and Grease
	Fine Screens
Primary Settling	
Conventional Activated Sludge	MBR Activated Sludge
Secondary Clarifiers	
Tertiary Filters	
Disinfection	Disinfection?
Solids Handling	Solids Handling

MBR TRUTHS

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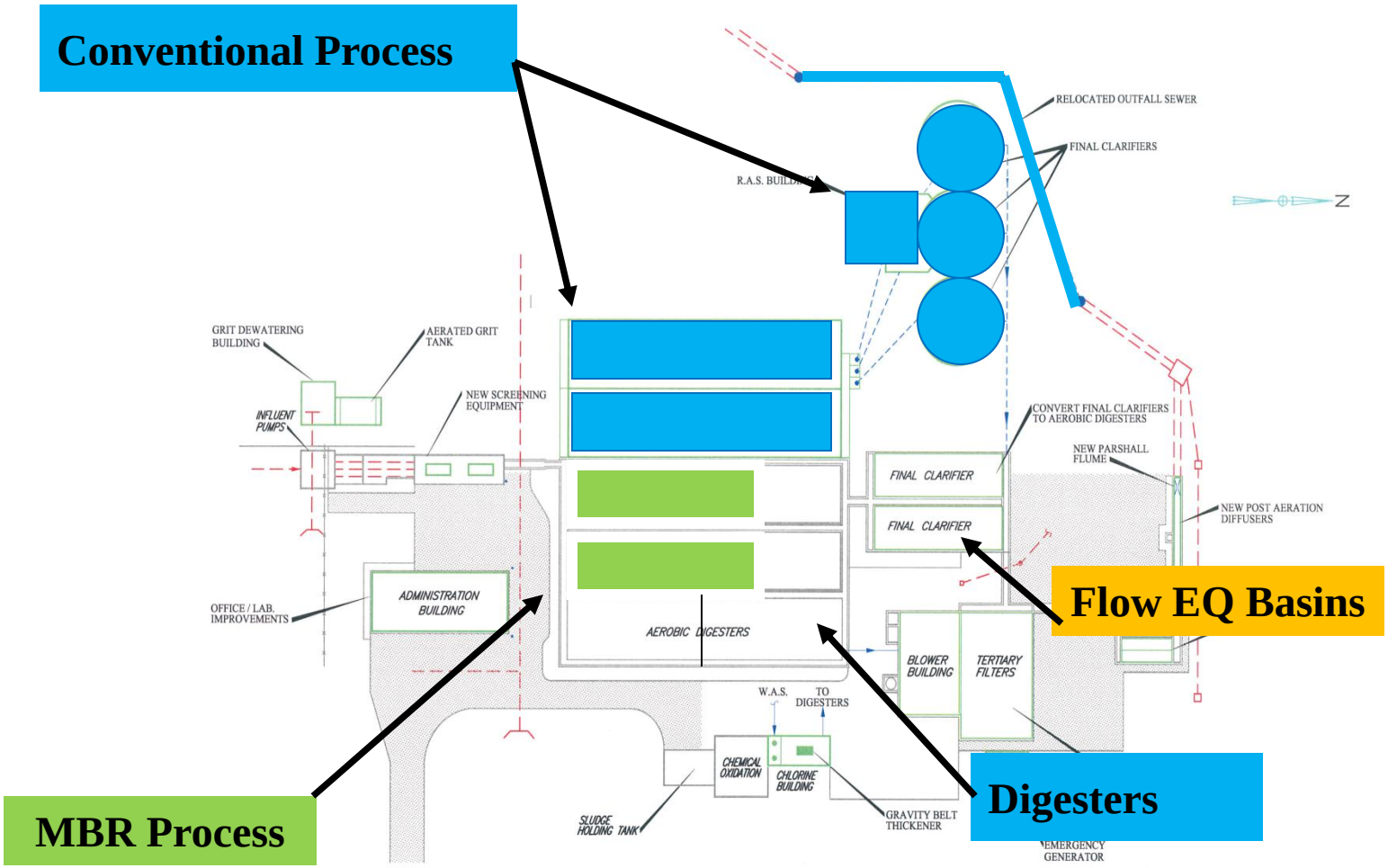
MBR Plants have a SMALLER Footprint

- MLSS is 3-4 times higher for MBR facilities
  - Conventional: 2,000 – 4,000 mg/l
  - MBR: 8,000 – 12,000 mg/l
- Membranes are submerged in the Activated Sludge process

Expansion from 1.2 to 1.8 MGD; New Limits



McFarland Creek MBR vs Conventional Expansion

MBR Footprint Advantages

- No impact to adjacent property value
- Odors are negligible
- Environmental impact and approvals avoided
- Excavation, erosion control, restoration avoided
- Land reclamation for other use

RAS Recycle Rate

- Conventional: 0.5 - 1.5 Q
  - Return bugs back from clarifiers to head of activated sludge
- MBR: 2 - 4 Q
  - Return bugs back
  - Keeps basins in suspension
  - High RAS rates naturally increases nutrient removal since bugs are fighting for more of the oxygen and food

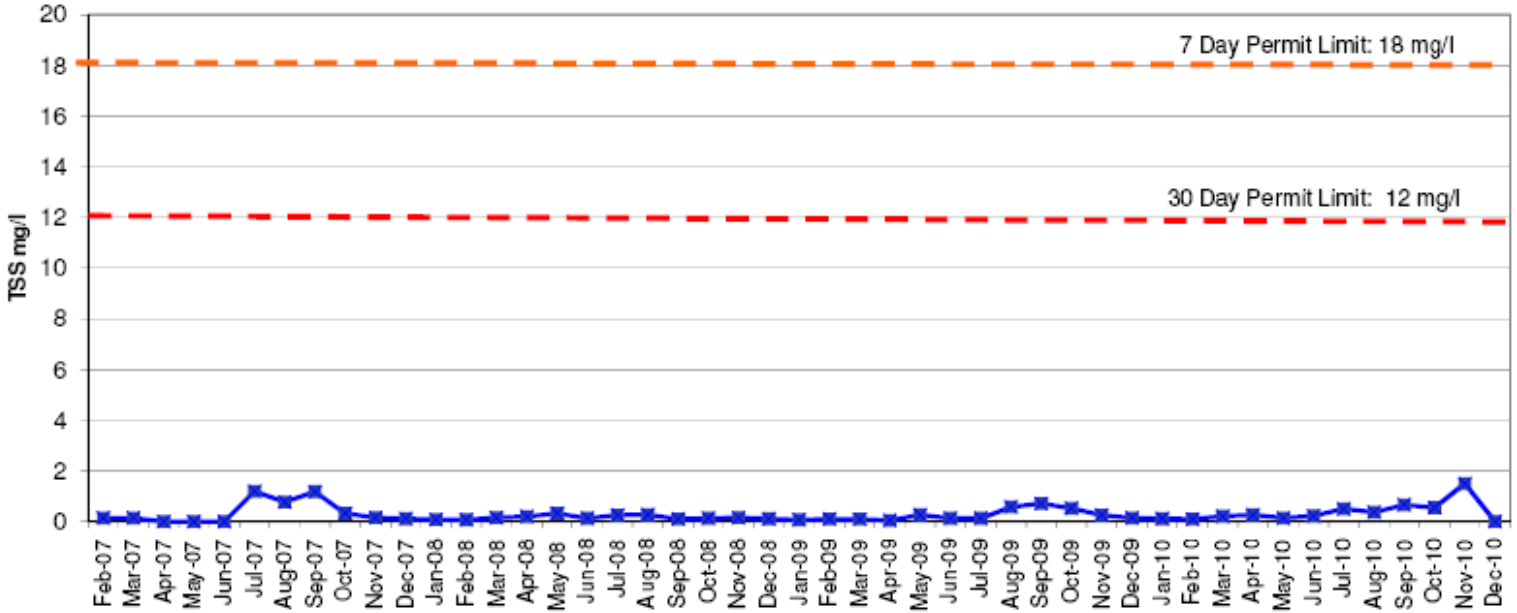
SRT – Solids Retention Time

- Conventional
  - Varies to suit effluent requirements (ammonia)
  - An ammonia limit requires a higher SRT
  - Ammonia limits require more power (need to increase air demand)
- MBR
  - Requires Higher SRT (2-3 times higher)
  - Ran higher to create a sludge that is less likely to stick to the membranes
  - Side benefit is that the higher SRT causes ammonia reduction

Permeate Quality Benefits

Parameter	Secondary Treatment	Tertiary Treatment	MBR
CBOD (mg/l)	25 - 10	10	<5
TSS (mg/l)	30 - 12	12	<5
Fecal Coliform (CU/100 mL)	1,000	1,000	<1
Metals	Proportional to TSS	Same	Less
Bio P without chemicals (mg/l)	3-1	2-1	0.5

TSS Effluent Concentration

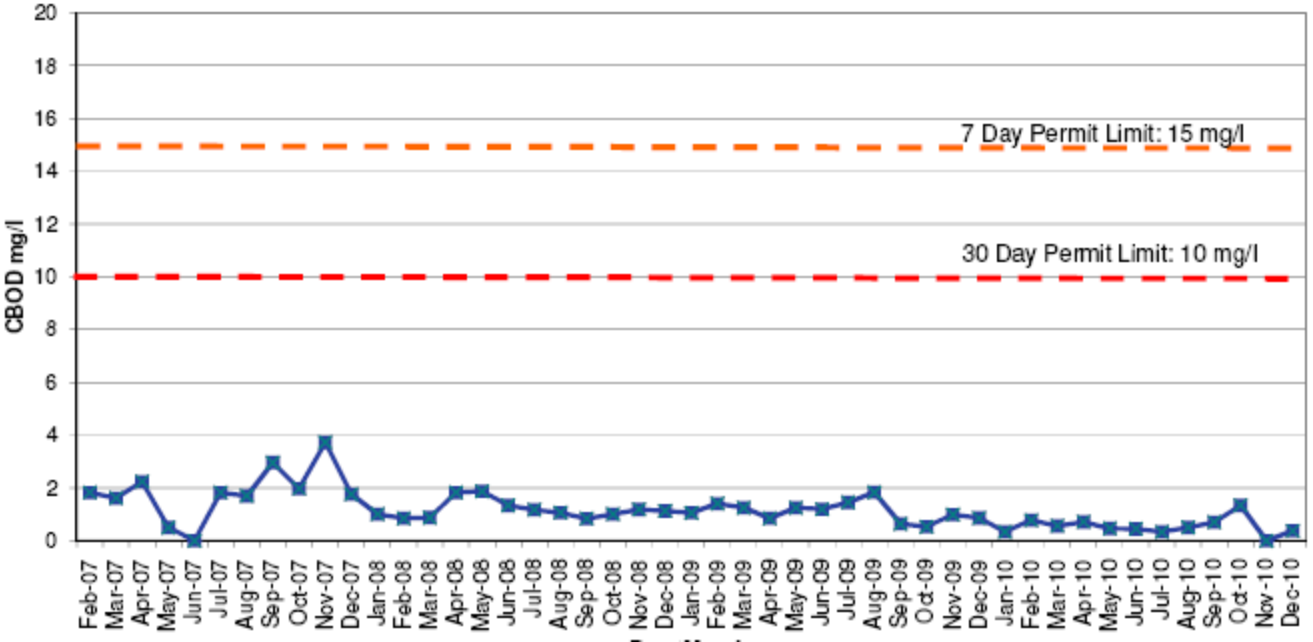


2007-2010

DELPHOS

"America's Friendliest City"

CBOD Effluent Concentration



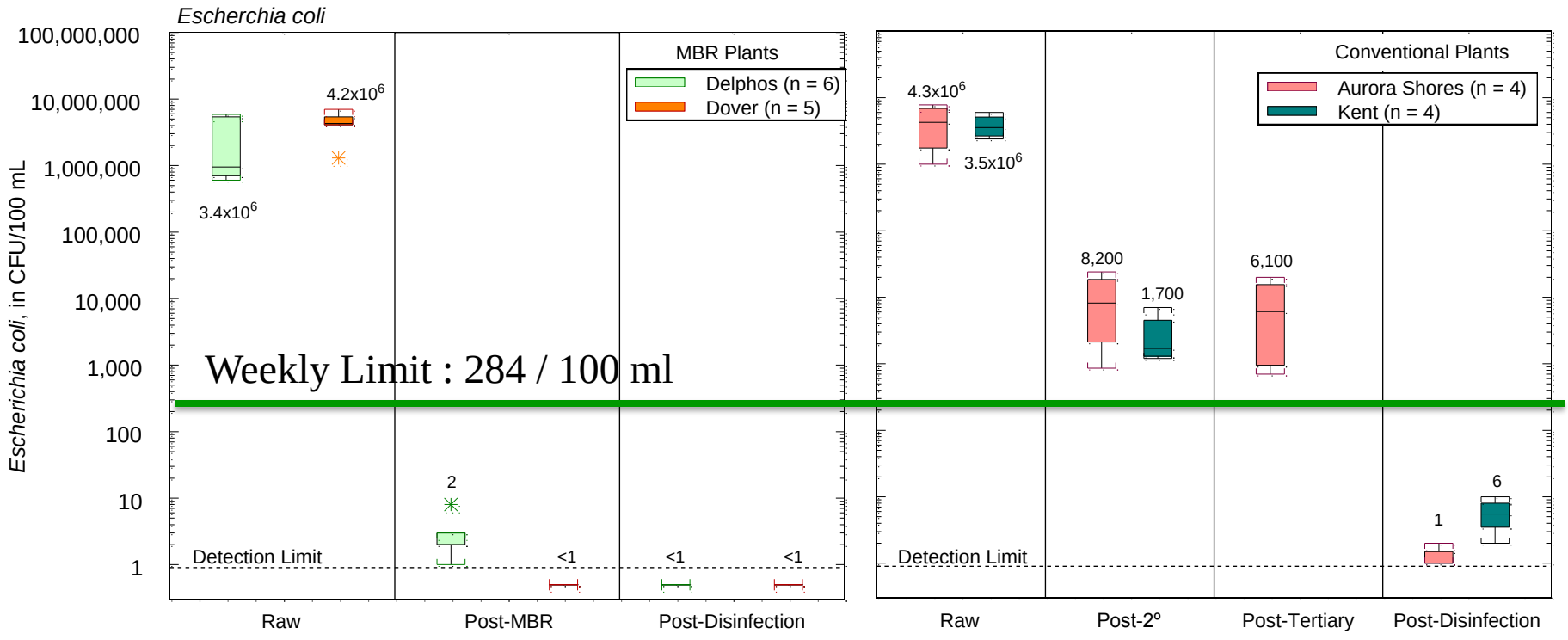
Need for Disinfection?

Does MBR treatment provide the same level of public health protection from microorganisms as that found for conventional systems that use disinfection after secondary treatment?

Samples were analyzed for...

- Bacterial Indicators
  - E.coli, Fecal Coliform, Enterococci
- Somatic and F-specific Coliphage
- Enteric Viruses by qPCR
- Enteroviruses, Noroviruses, Adenoviruses, Rotaviruses, and Hepatitis A Virus
- Culturable Viruses

E. Coli Results



(Median values are shown; CFU/100 mL, colony-forming units per 100 milliliters)

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Conclusions of Study

- Membranes remove fecal coliform and E.coli to levels equivalent to conventional plants and after disinfection
- Membranes remove viruses to similar levels as seen by conventional plants after disinfection
- The removal amount of fecal coliform, E. coli, and viruses by disinfection at MBR plants is insignificant

Using Membranes for Disinfection

- Eliminates additional Capital and O/M Costs
- Reduces Environmental Impacts
- Improves Plant Safety Conditions
- Provides NPDES Permit Compliance
- Provides comparable results for Fecal Coliform and E.coli removal as existing BADCT disinfection systems

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Capital Costs

UV O/M Costs

- Electrical Power Cost
- Bulb Replacement
- Quartz Sleeve Replacement
- Ballast Replacement
- Wiper Ring Replacement

Chlorine O/M Costs

- Sodium Hypochlorite ($0.65 - $1.10 per gallon)
- Sodium Bisulfite ($1.50 per gallon)
- Tank Replacement
- Chemical Pump replacements

Effluent Quality – Water Reuse

- Revenue possibilities
  - Sell to others
  - Industrial – make up, cooling, process
- Use water to reduce other O/M costs for city
  - Any non potable water uses
  - Landscape Irrigation
  - Maintenance cleaning, sewer jetting
  - Toilet flushing
  - Fire protection

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Sludge Production

- MBR Plants have less sludge than Conventional Plants – Use 20% Less for Studies
  - Union Rome used to dewater 4 days a week now only 4 days a month
  - Union Rome also has installed membrane thickening for their sludge. Increases solids concentration from 1%-4%
  - Union Rome also increased the belt press from a 0.5 meter to a 1 meter

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Union Rome Sludge Production Manpower Savings

Conventional Plant

Dewater: 4 days a week or 16 days a month

16 d/m* 12 m/yr *8 hr/day

Labor– 1,536 hours

MBR Plant

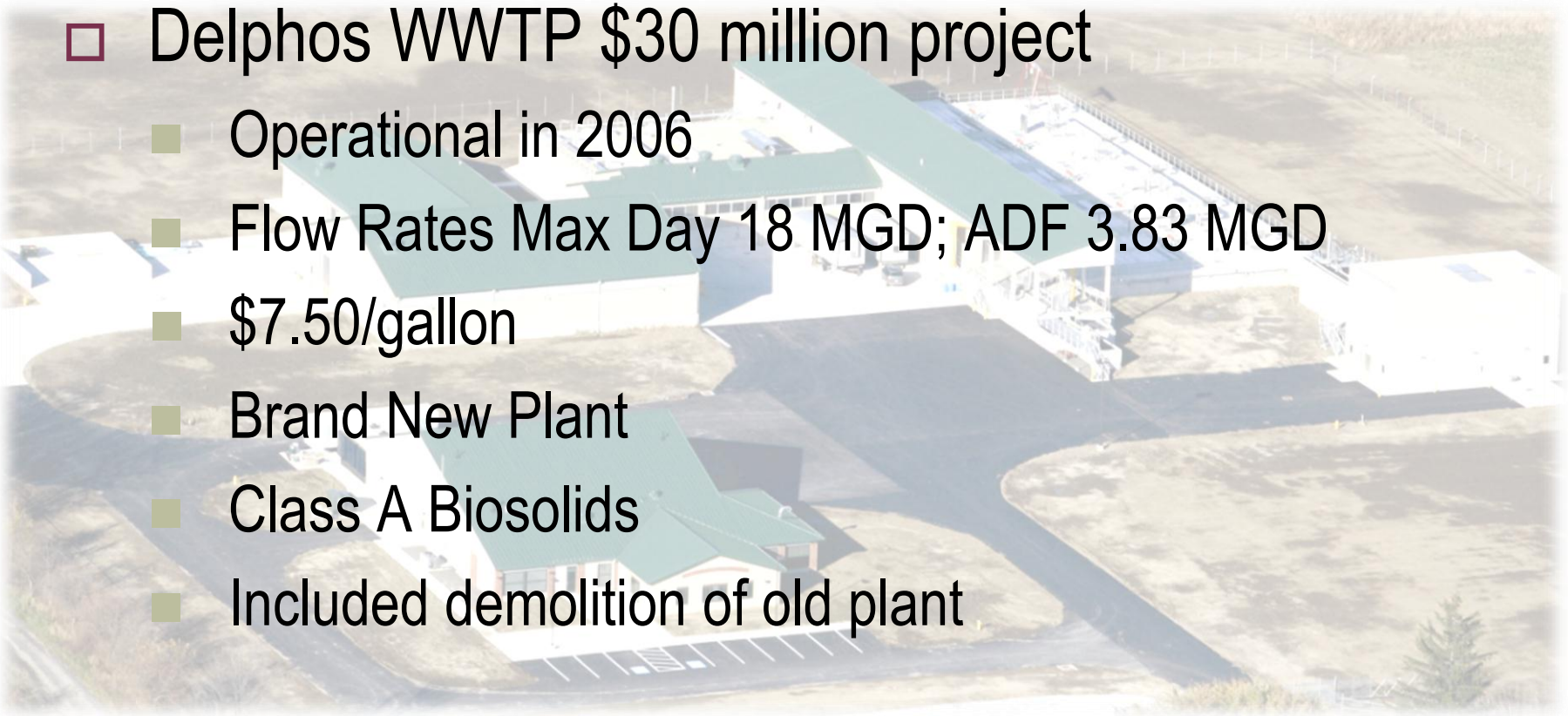
Dewater: 4 days a month

4 d/m* 12 m/yr**8 hr/day

Labor – 384 hours

An additional 1,152 hours per year (22 hours per week) for the staff to be more productive

Capital Costs



- Delphos WWTP $30 million project
  - Operational in 2006
  - Flow Rates Max Day 18 MGD; ADF 3.83 MGD
  - $7.50/gallon
  - Brand New Plant
  - Class A Biosolids
  - Included demolition of old plant

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Capital Costs

- Union Rome WWTP $20 million project
  - Operational in 2009
  - Flow Rates: Max Day 7 MGD, ADF 2 MGD
  - $10/gallon
  - Brand New Plant
  - Completely under roof
  - Odor Control
  - Increase of Capacity and New limits

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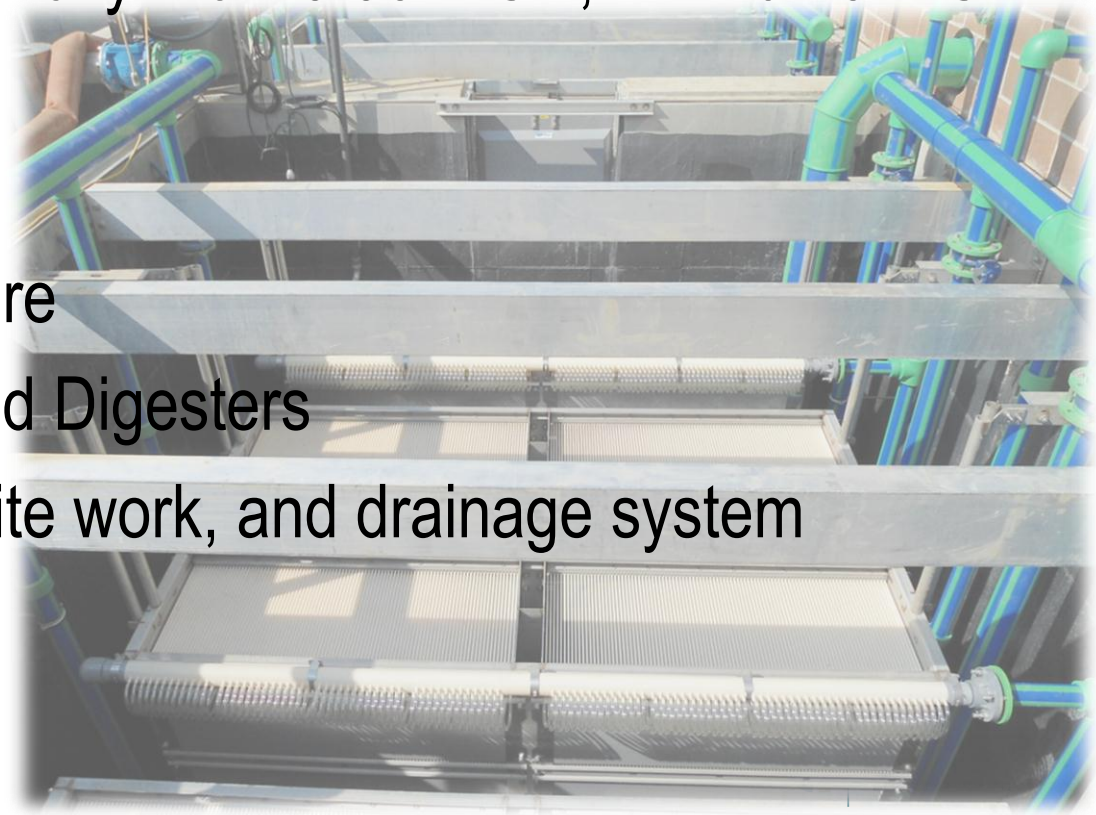
2.5-TON CAP

Capital Costs

- Carrolton WWTP $7.4 million project
  - Operational in May 2012
  - Flow Rates: Max Daily Flow 3.35 MGD, ADF 0.75 MGD
  - $9.85/gallon
  - New Headworks
  - New MBR structure
  - Retrofit for EQ and Digesters
  - New generator, site work, and drainage system



- McFarland WWTP $6.8 million project
  - Operational in Spring 2006
  - Flow Rates: Max Daily Flow 4.5 MGD, ADF 1.8 MGD
  - $3.80/gallon
  - 1.2 MGD to 1.8 MGD Expansion
  - MBR retrofit
  - Included Aerated Grit, UV Disinfection and Post Aeration, Aerobic Digesters, Site Work, and Admin Building Improvements

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Capital Cost Conclusion

- $2- $10 per gallon

OPERATION AND MAINTENANCE

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Operation and Maintenance Factors

- Power consumption
- Chemical Consumption
- Sludge Production
- Capital Maintenance
- MBR Replacement
- Staffing Needs

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McFarland Creek 1.8 MGD MBR Plant

- Preconstruction 2004 cost converted to 2006
  - $14,060/month x 1.25 / 1.1 x 6.43 / 4.8 = **$21,400/month**
- Operation in 2006
  - **$19,650/month**

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McFarland Creek Sludge Production 2004 vs 2006

Month	Cubic Yards		Dry Tons		Avg. Percent Solids	
	2004	2006	2004	2006	2004	2006
June	422	200	63.01	33.13	17.6	19.5
July	330	222	54.34	33.99	19.35	17.92
August	284	96	43.57	17.16	18.24	20.98
September	255	174	37.08	25.03	17.06	17.02
October	420	232	59.58	37.53	16.63	19.01
November	372	308	50.74	49.13	15.99	18.68
Totals	2,083	1,232	308.32	195.97	17.48	18.85

Total Polymer Cost

2004: $22,080

2006: $13,059

Difference: $9,021

Total Disposal Fees

2004: $42,000

2006: $25,000

Difference: $17,000

McFarland Creek Chemical Consumption

- Ferrous vs. Alum – More expensive but using less
- Less polymer used – Less sludge
- Sodium Hypo/Hydrochloric Acid - New
- $2,500/month increase

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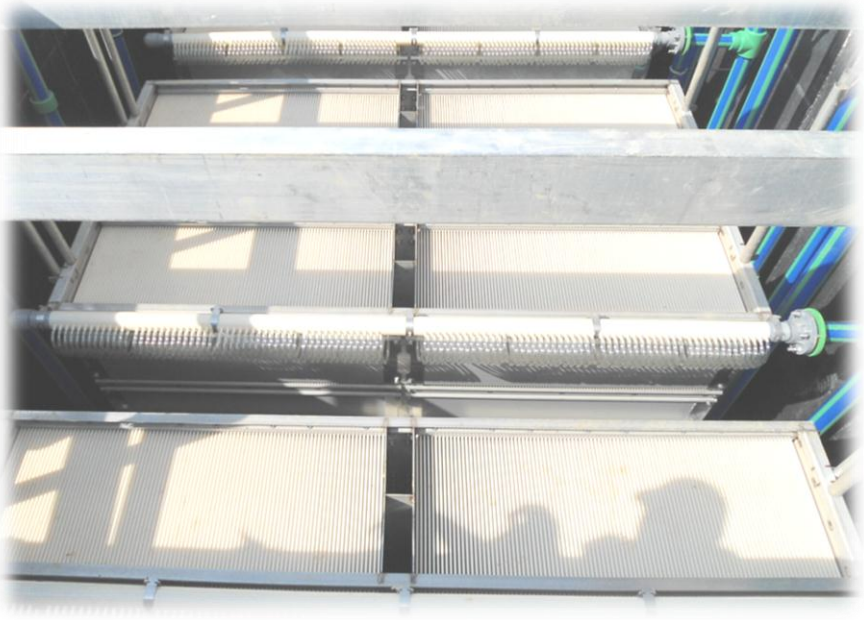
Capital Replacement – MBR Replacement

- Based on manufacturer recommendation
  - Either between years 5 and 10 or 10 and 15
  - Approximately $0.25 to $0.50 per square foot
- Diffusers- 10-20 years
- Pumps- 20 year



Staffing Demands

- More automation
- Less solids
- Smaller footprint

- Result has been that WWTP staff has had more time to be proactive

Summary of MBR vs Conventional O&M

- Power consumption is similar but should be reviewed on a case by case basis
- Chemical requirements are comparable but can be less for MBR if nutrient limits are lowered
- Sludge production is 20-30% less for MBR facilities
- Equipment replacement Costs are comparable with the exception of membrane replacement
- Staffing needs are less for MBR facilities due to automation and combined unit processes with MBR

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Final Comments

- A cost analysis is appropriate – and it should be for the whole plant
- Based on a review of both captial and O/M costs MBRs are often times a more cost effective alternative
- MBR is a system of multiple unit processes so the design and operation is unlike conventional treatment
- Upgrading to MBR when building or expanding is a worthwhile alternative to explore

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UPGRADES FOR BIOLOGICAL TREATMENT

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Biologically Enhanced Treatment

- Activated sludge process is the same
- Traditional Recycle Rates are the same: 2-4Q
- Both require internal recycle if needed
- Both may require carbon source
- Selector Processes required is the same
- Oxygen demand required is the same

Biologically Enhanced Treatment

- MLSS is still higher for MBR process
- Footprint is 1/4 size for MBR process
- Tertiary requirement for Conventional process
- Disinfection?

Canton – Phosphorus and Total Nitrogen Removal Plant Upgrade

Present Worth Costs	Bio P & BNR	MBR
Capital Cost	109,425,000	72,120,000
O&M Cost	45,355,979	43,332,085
Total Present Worth	154,780,979	115,452,085

Present Worth Cost Summary N=20 yrs

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Canton - Total Equivalent Annual Costs

	Bio P & BNR	MBR
Annual Payment for Debt Service	7,086,216	4,777,020
Annual Payment For O&M	5,081,762	4,936,598
Total Annual Payment	12,167,978	9,713,618

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MEMBRANE VS. MEMBRANE

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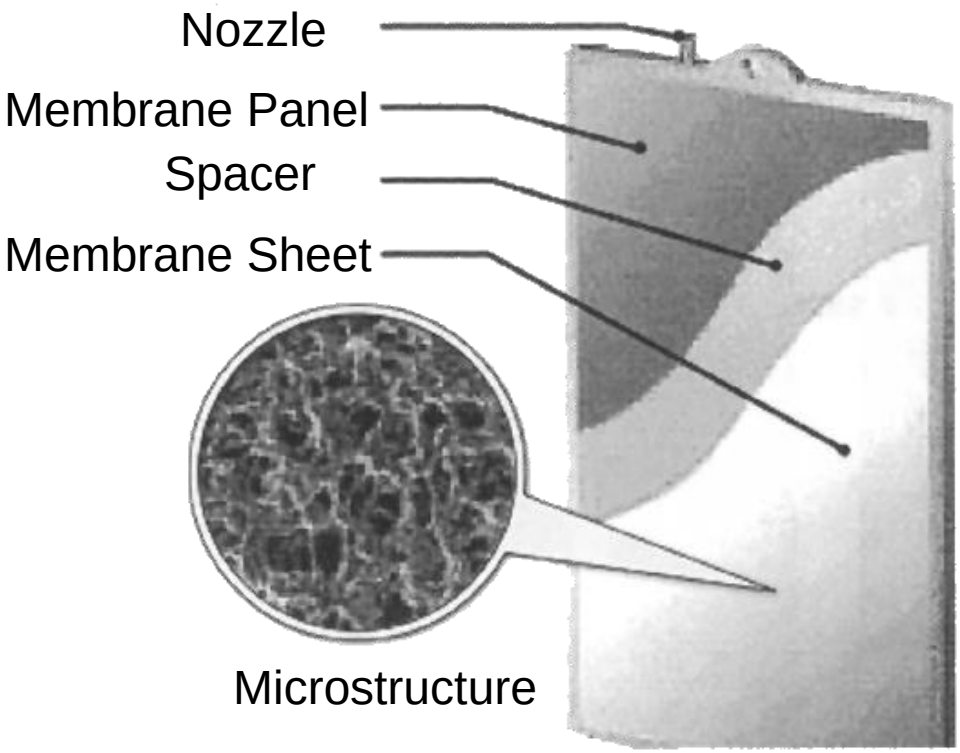
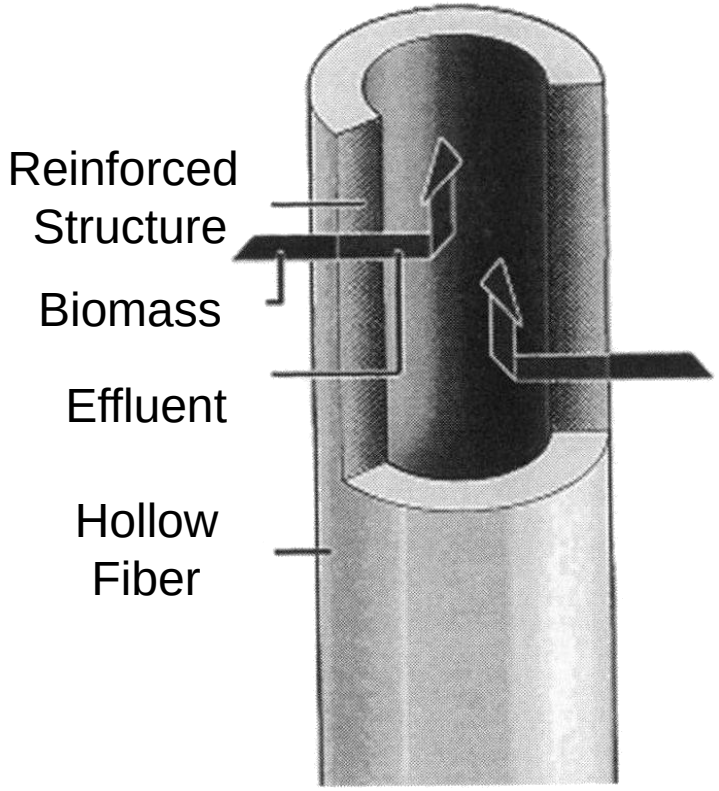
MBR Basin Size

- When first entering the market the trend was small plant applications with uniform conditions
- Now with improved systems manufacturers are able to get more membranes into an area so the membranes are more efficient for larger plant applications

Typical Types of Membranes





Flat Plate Membranes

Pore Size: 0.4 µm

Hollow Fiber Membranes

Pore Size: 0.035 µm

Summary

- More differences between membrane systems than there are similarities
- Flux rates are different based on the membrane type
- Mixed liquor concentrations vary among membrane type
- Some membranes can gravity permeate and others must pump
- Flux maintenance is different by membrane type
- Systems that support the membrane process vary
- Different types of membranes function differently on how they permeate

Questions