Membrane Filtration Application from Inside to Outside

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NEWFOUNDLAND DESIGN ASSOCIATES LIMITED
CONSULTING ENGINEERS

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Presentation Topics

- What membrane processes are relevant?
- What is their development history and growth in water treatment?
- What are the drivers for their application?
- How are they applied now and in the future? (focus on MF/UF)
- What are typical costs?
- Questions

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“Time is on my side….”
- Rolling Stones

- Time has indeed been a friend
- New chemical-free systems are now available for treating drinking water
- Membranes are leading the way

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Process and Characteristics

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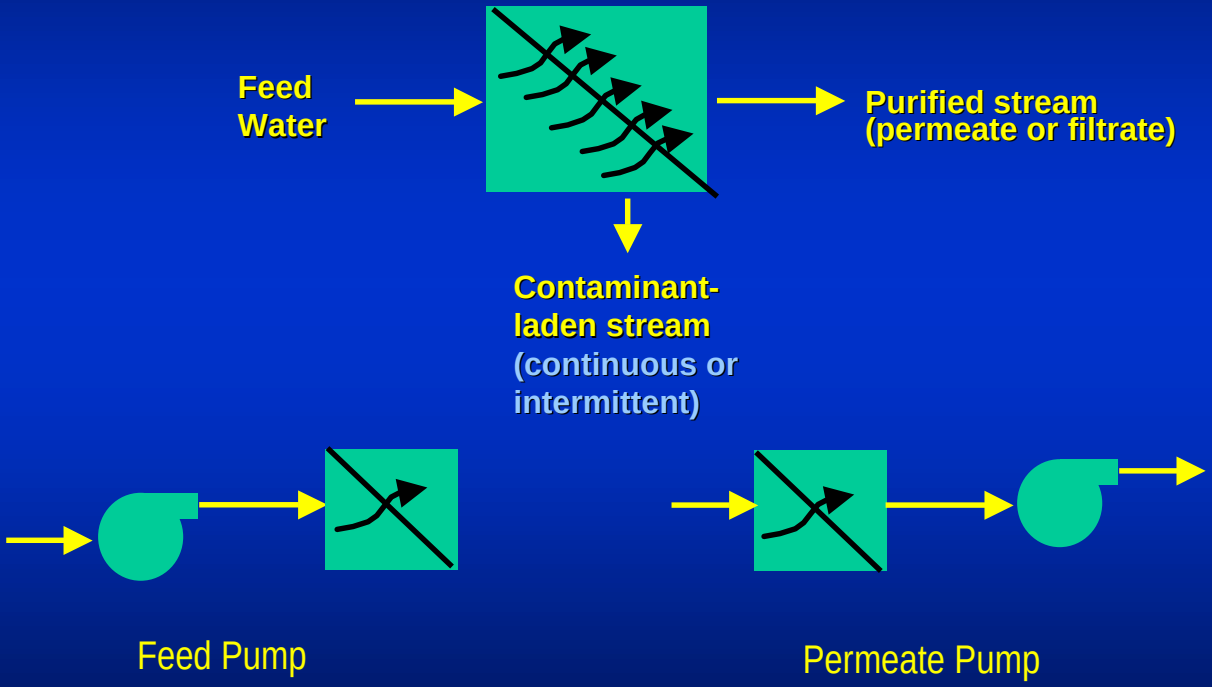
PD processes use pressure to separate contaminants from water



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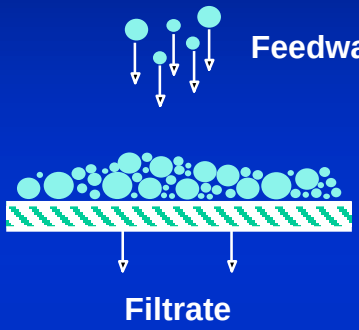
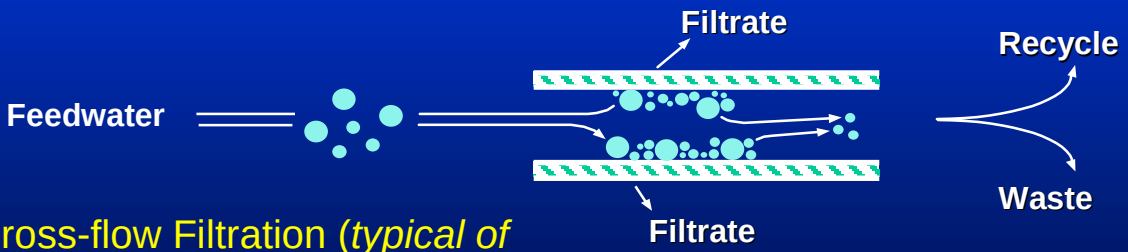
Separation is achieved either by dead-end or cross-flow filtration



Direct (Dead-end) Filtration
(*typical of MF and some UF*)



Cross-flow Filtration (*typical of some UF, NF and RO*)

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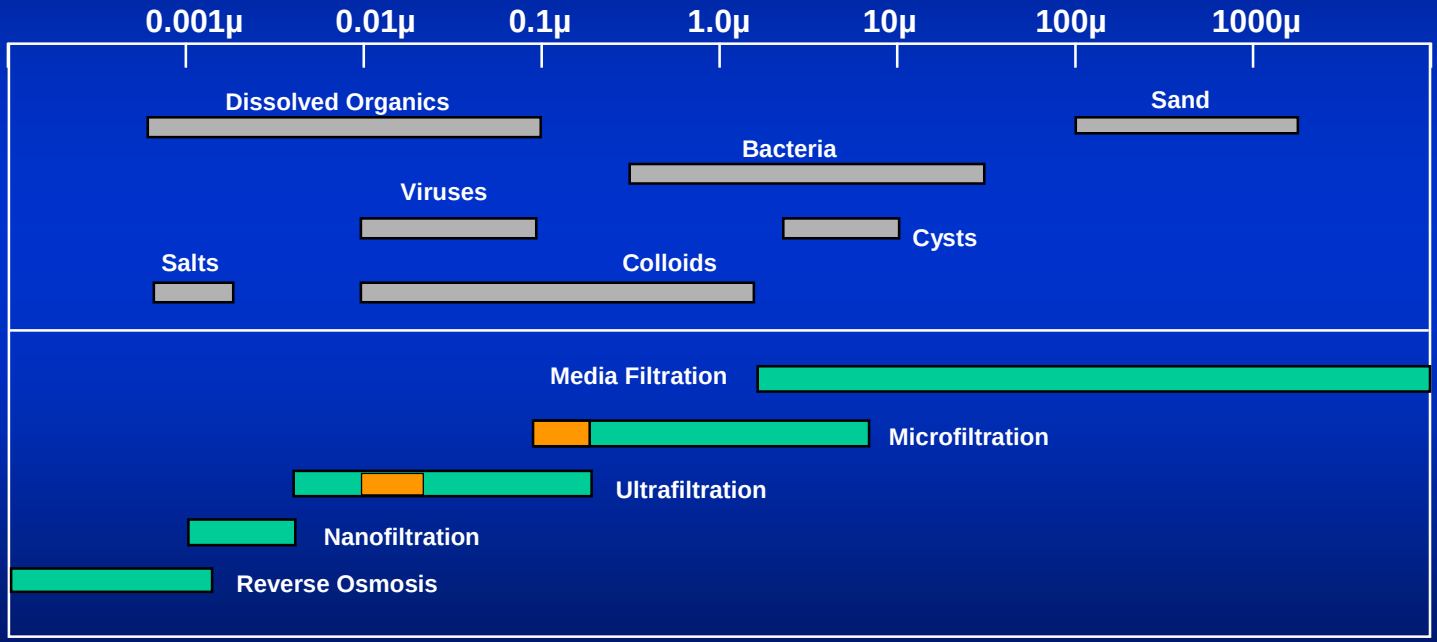
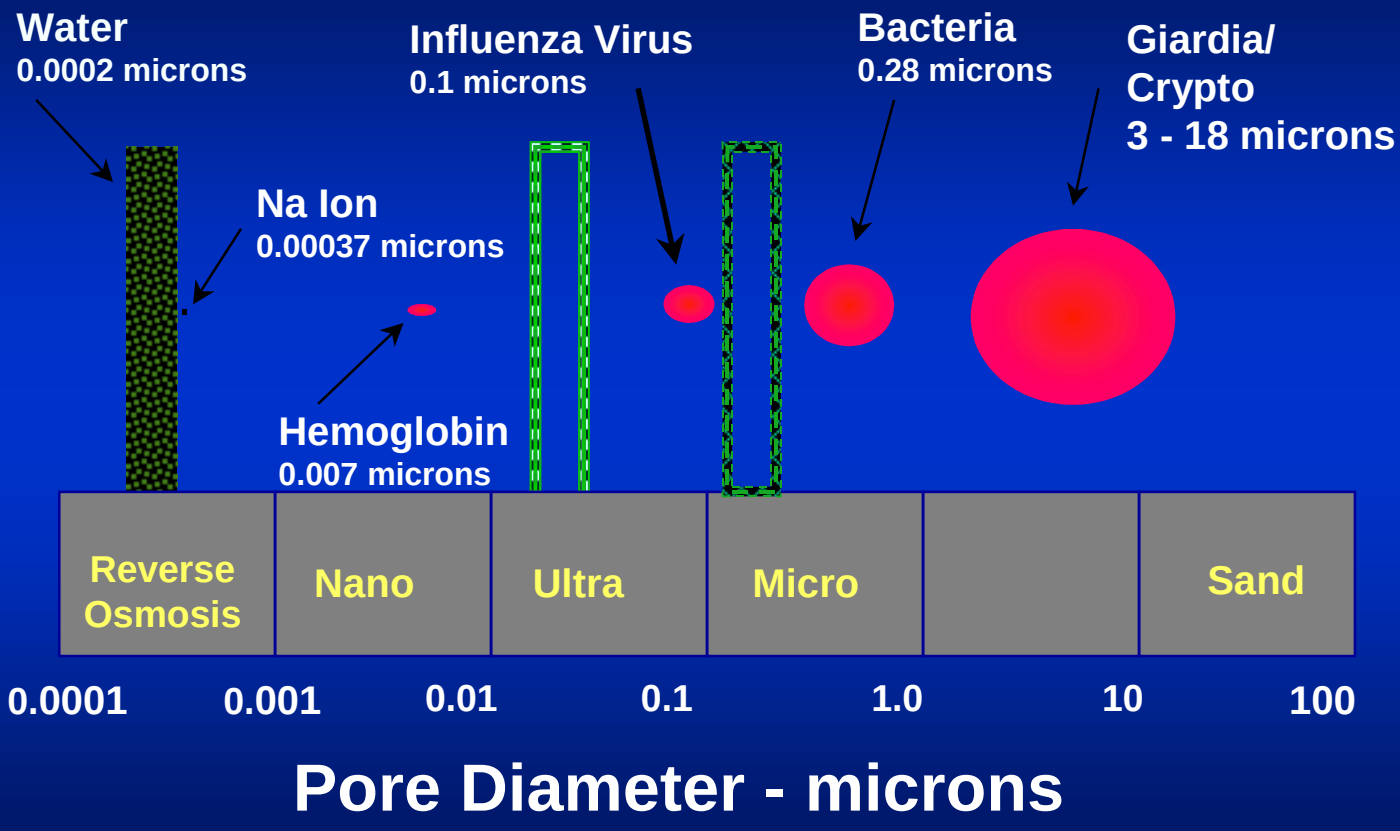
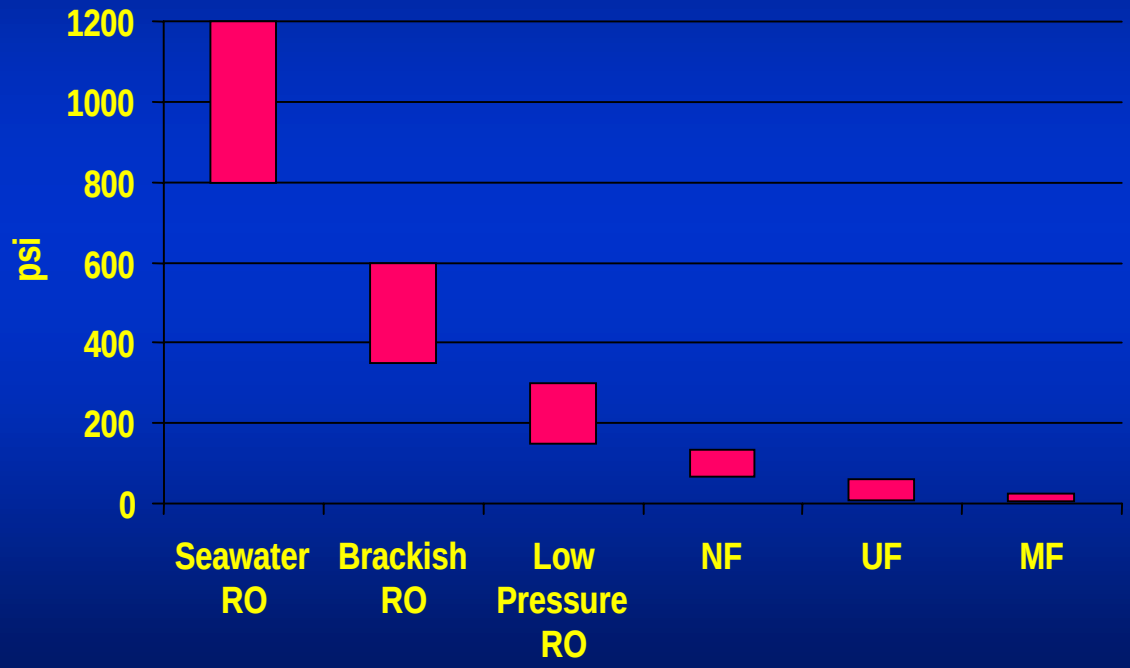
Degree of contaminant separation is direct function of membrane pore size




Water
0.0002 microns
Na Ion
0.00037 microns
Hemoglobin
0.007 microns
Influenza Virus
0.1 microns
Bacteria
0.28 microns
Giardia/
Crypto
3 - 18 microns
Reverse Osmosis
Nano
Ultra
Micro
Sand
0.0001
0.001
0.01
0.1
1.0
10
100
Pore Diameter - microns

Separation of ions requires greater pressure than separation of particles



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History and Growth

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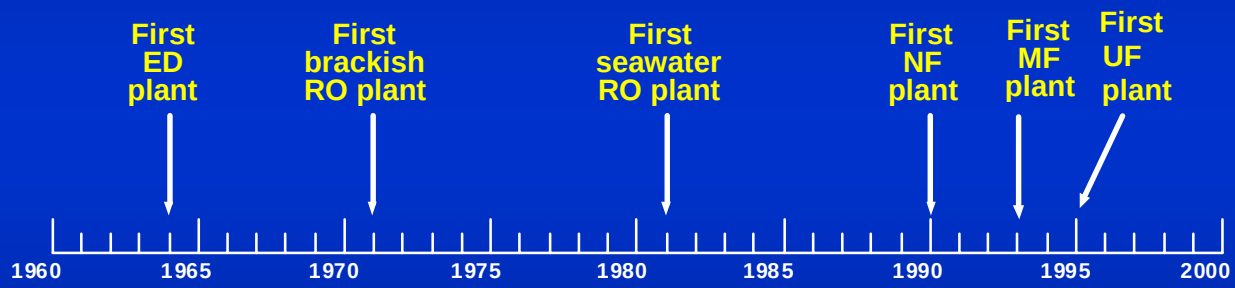
Commercial Timeline of Membrane Processes



Note: plant capacity 1 mgd or greater

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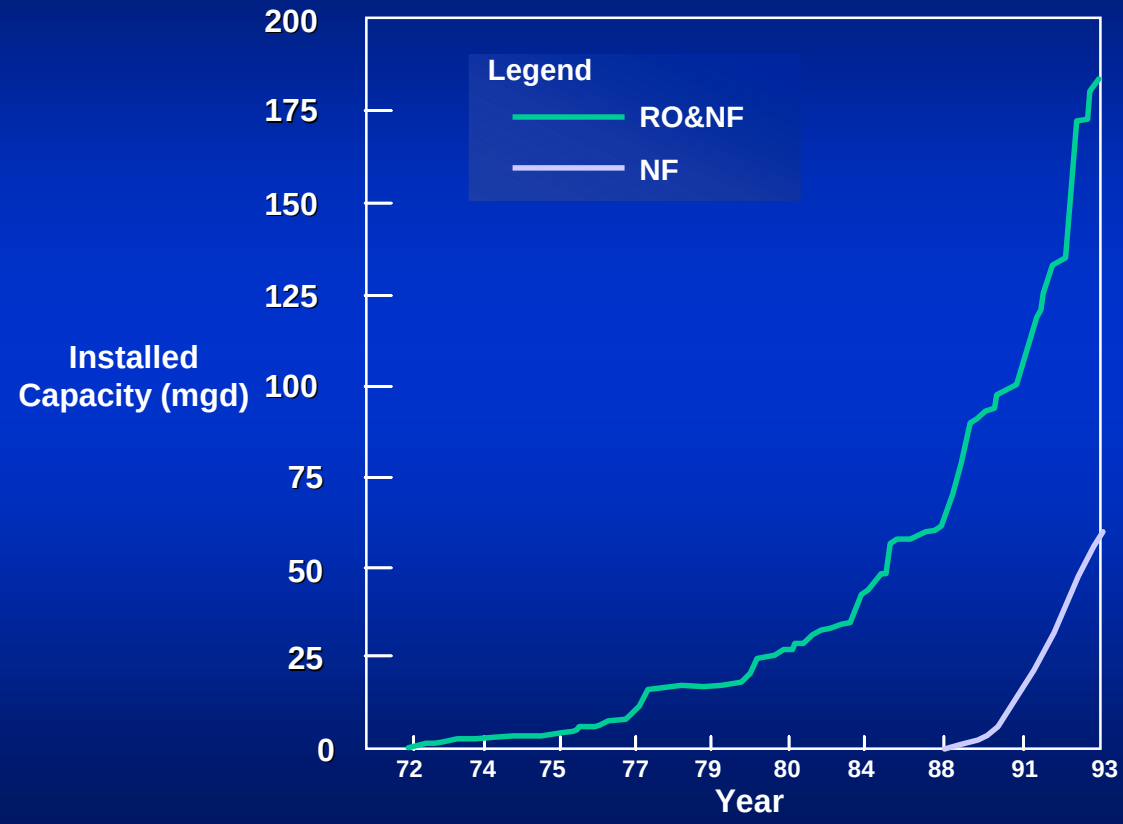
RO and NF growth



(Adapted from Wangnick, 1994)

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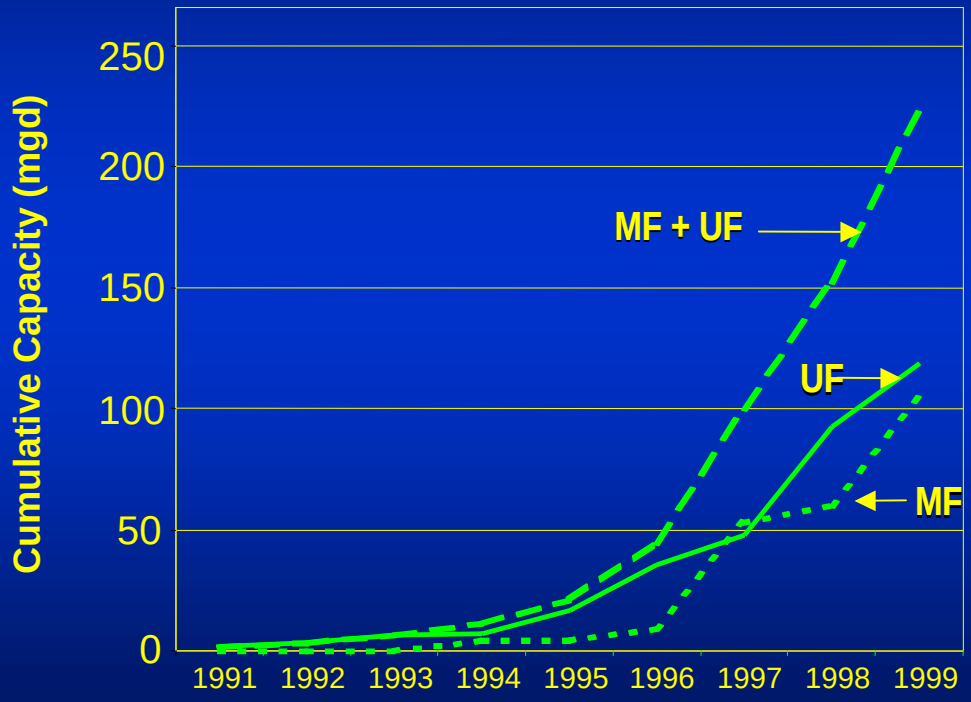
MF & UF growth is increasing rapidly



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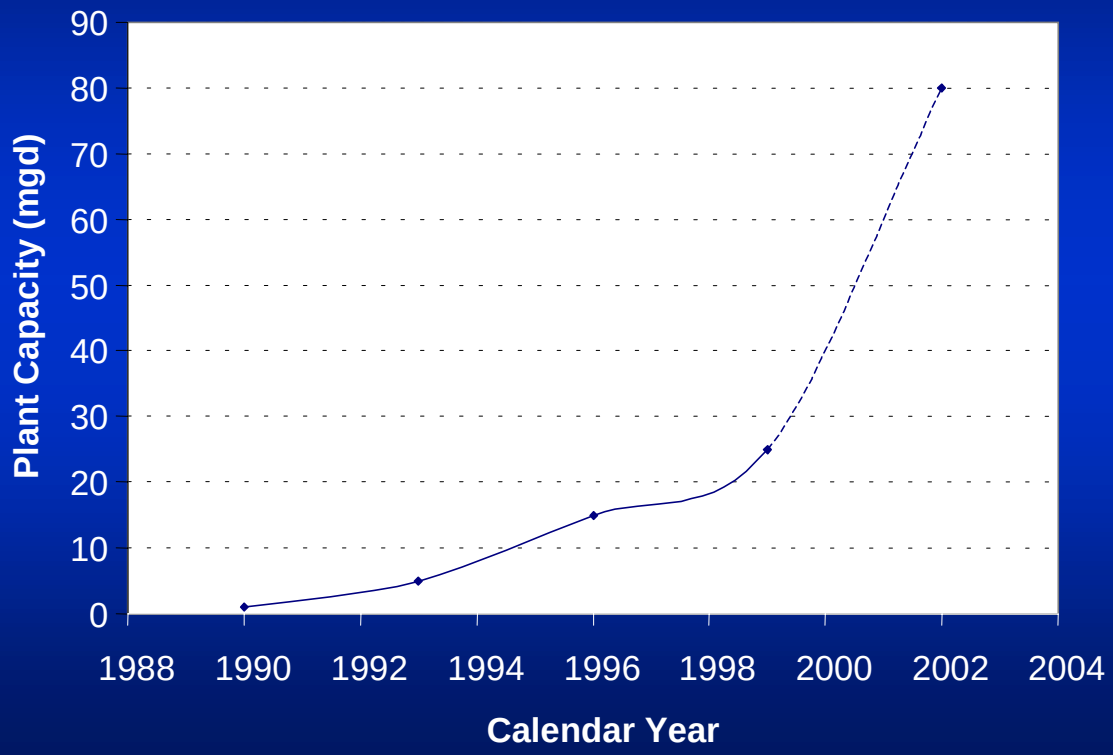
MF/UF plant capacity is also steadily increasing



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Why the increased growth in membranes?

- Capability to address increasing number and more stringent drinking water regulations
- Public and utility sensitivity to the risk of microbial outbreaks (e.g., *Cryptosporidium*)
- Decreased equipment and operating costs
- Reduced footprint
- Increasing use of lower quality water sources

Membrane processes can address a wide range of contaminants

Application	Process					
	MF	UF	NF	BW RO	SW RO	ED
TDS Reduction (brackish/seawater)	●	●	●	●	●	●
Specific Ion Removal (NO_3, F, As)	●	●	●	●	●	●
Hardness Removal	●	●	●	●	●	●
TOC, DBP Precursor Removal	●	●	●	●	●	●
Particle Removal						
Turbidity, Bacteria, Protozoan Cysts	●	●	●	●	●	●
Viruses	●	●	●	●	●	●

Legend: ● Excellent ● Good ● Fair ● Poor ● None

MF/UF treatment meets SWTR/ESWTR requirements while minimizing disinfection

- **Provides superior particle removal**
  - **filtrate turbidity <0.1 NTU**
  - **particle counts <5/mL**
  - **>5 log removal of *Giardia*, *Cryptosporidium* and bacteria (MF and UF)**
  - **>5 log removal of viruses (UF)**
- **Free chlorine CT for full or partial virus inactivation is low, minimizing DBPs**

MF/UF for SWTR/ESWTR compliance is established and fastest growing market segment

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Pressure Driven Membrane and Module Characteristics

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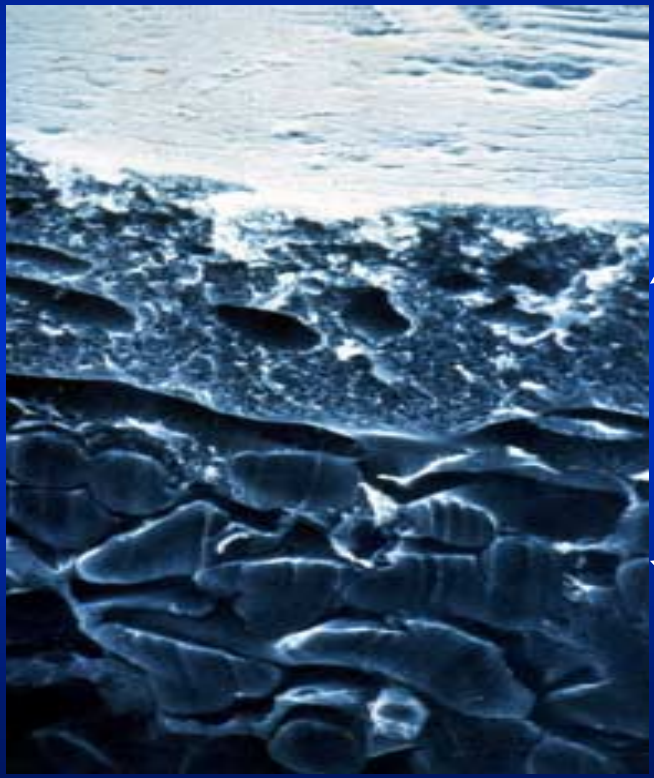
RO and NF use flat sheet non-porous membranes of cellulosic or polyamide polymers



Contaminant rejecting layer (polyamide)

Support layer (polysulfone)

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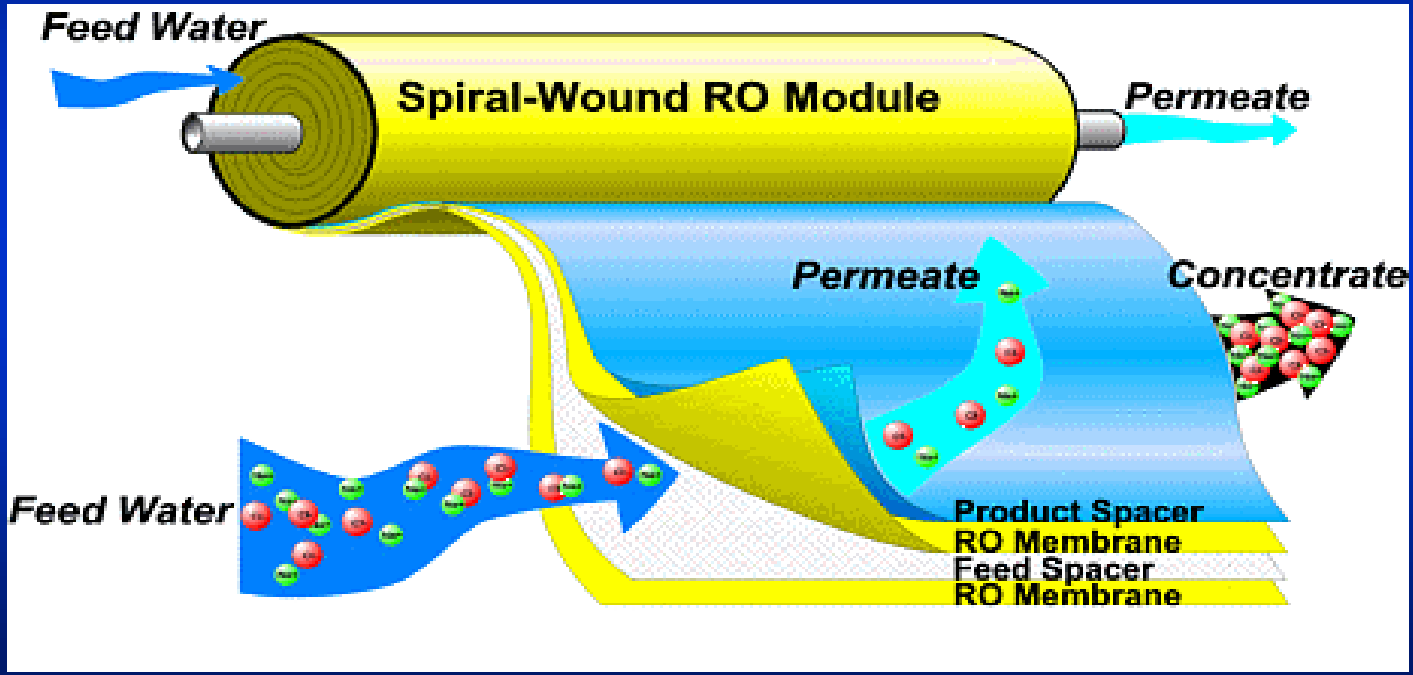
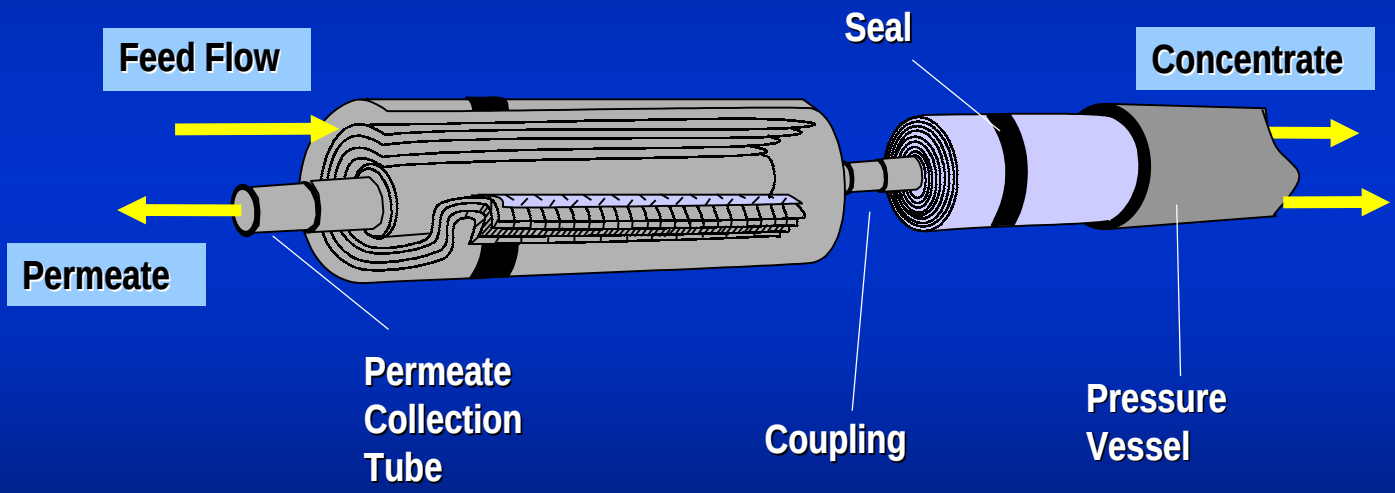
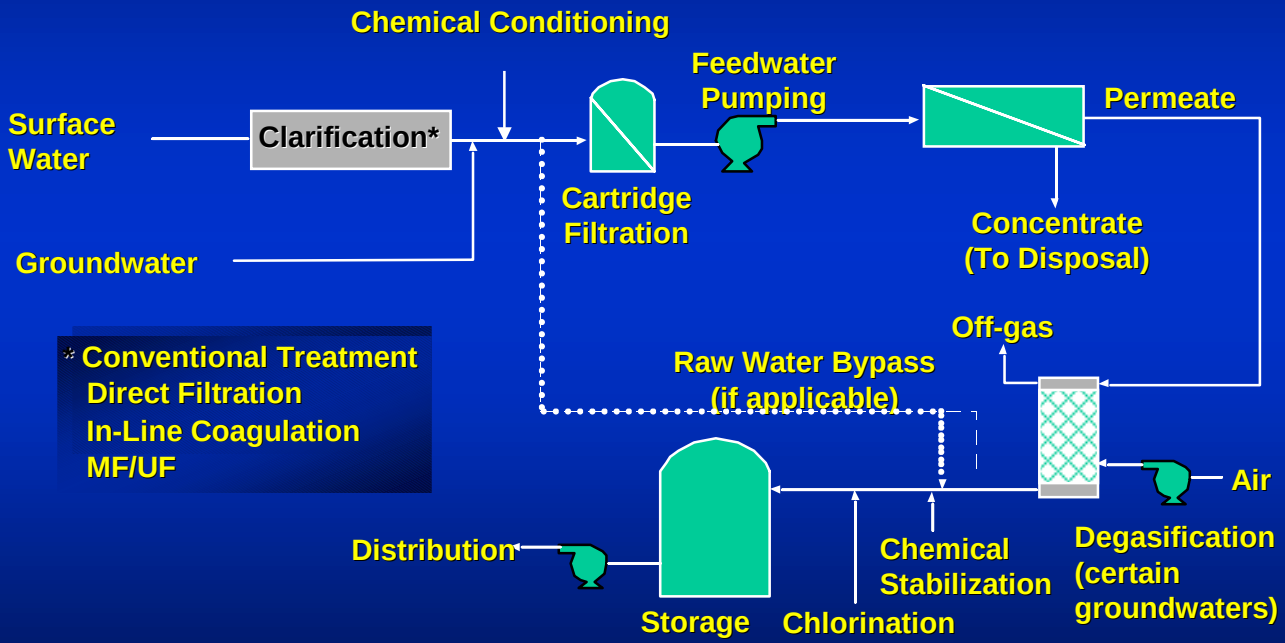
Membrane sheets are assembled into spiral wound modules



Modules are series arranged in pressure vessels



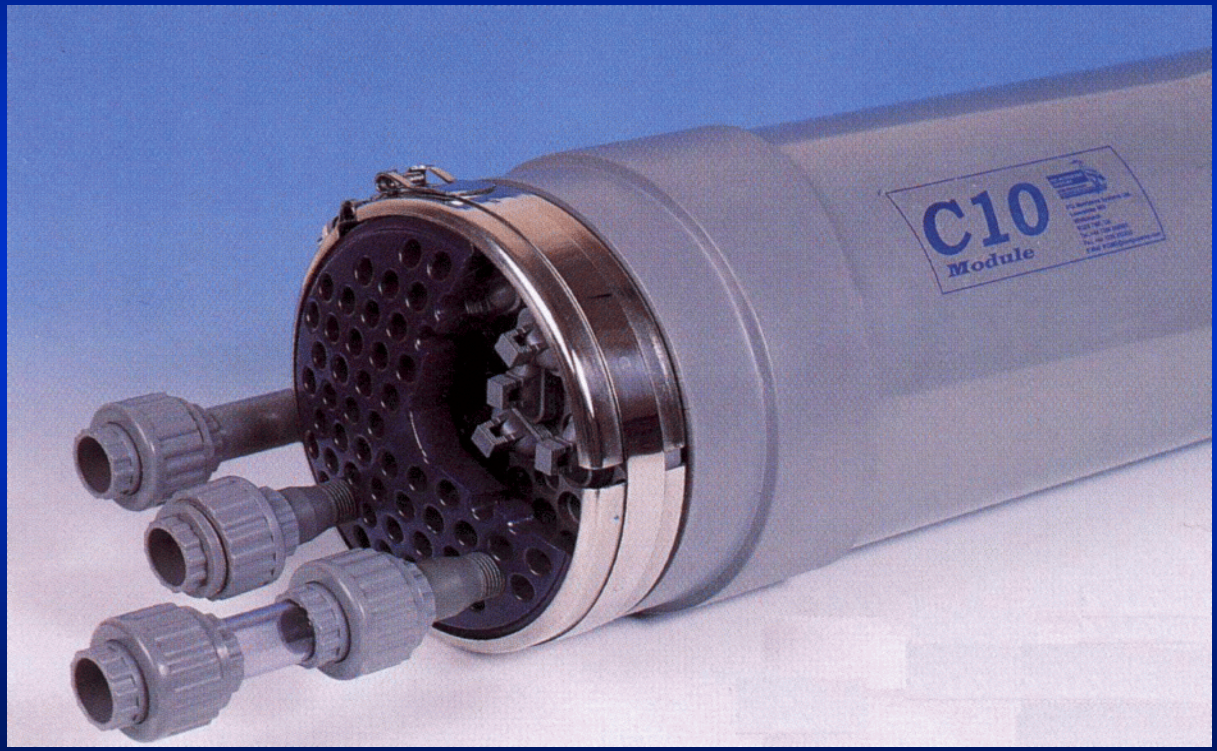
Components of a RO/NF Plant



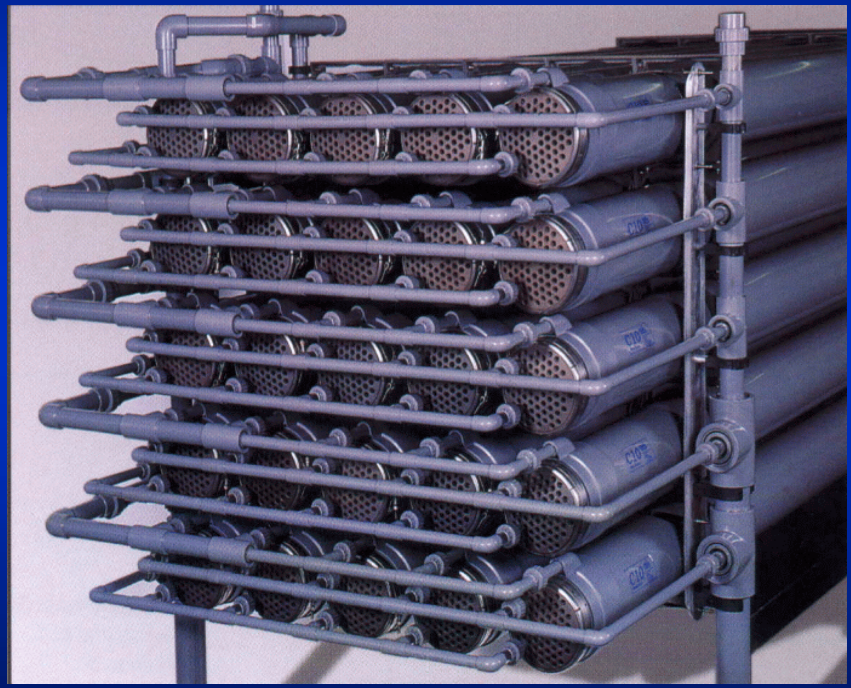
Loading 8”x 40” Spiral-Wound Membrane Elements in Pressure Vessels

Pressure vessels are arranged into skids or “trains”

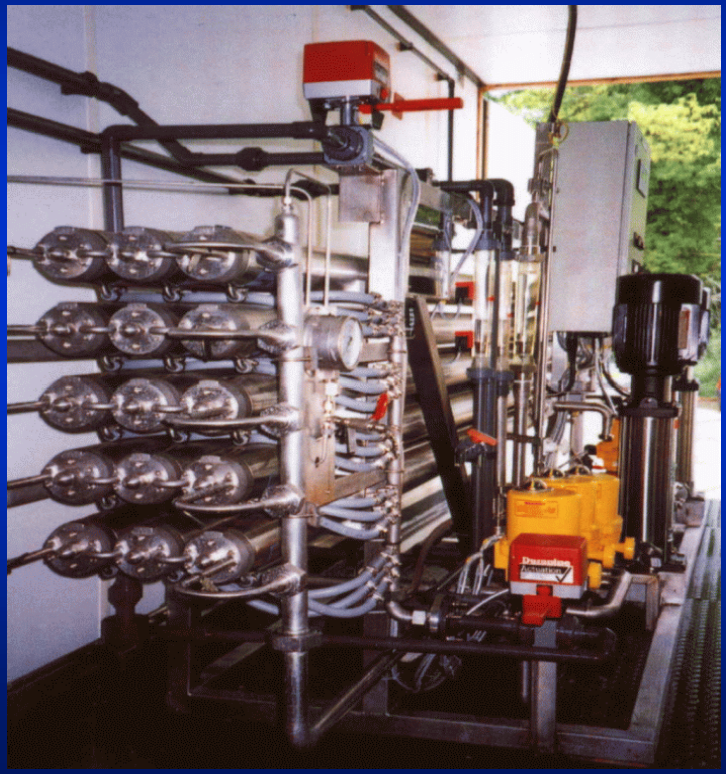
PCI Tubular NF Module



PCI Tubular NF Module in Racks and Skids



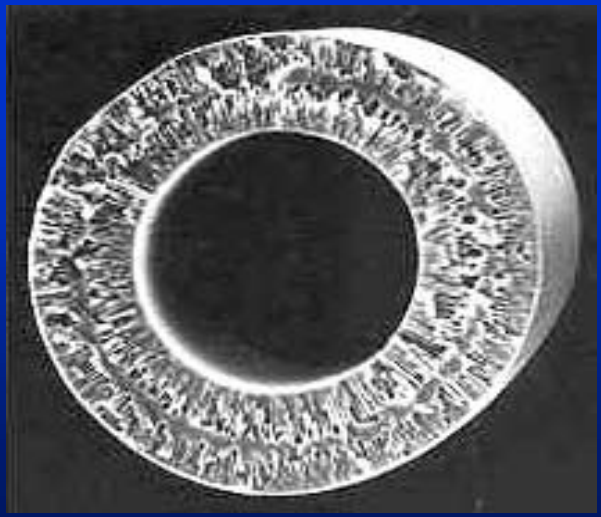
PCI Tubular - Fyne Process at Middle River, B.C.



PCI Tubular - Fyne Process at Chapel Island, N.S.

MF/UF use porous hollow fiber membranes of various materials

Koch Romicon polysulfone UF fiber (single skinned)



Pall Microza polyacrylonitrile UF fiber (double-skinned)

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Hollow fibers are configured into pressurized or vacuum-operated modules

USF Memcor M10C module

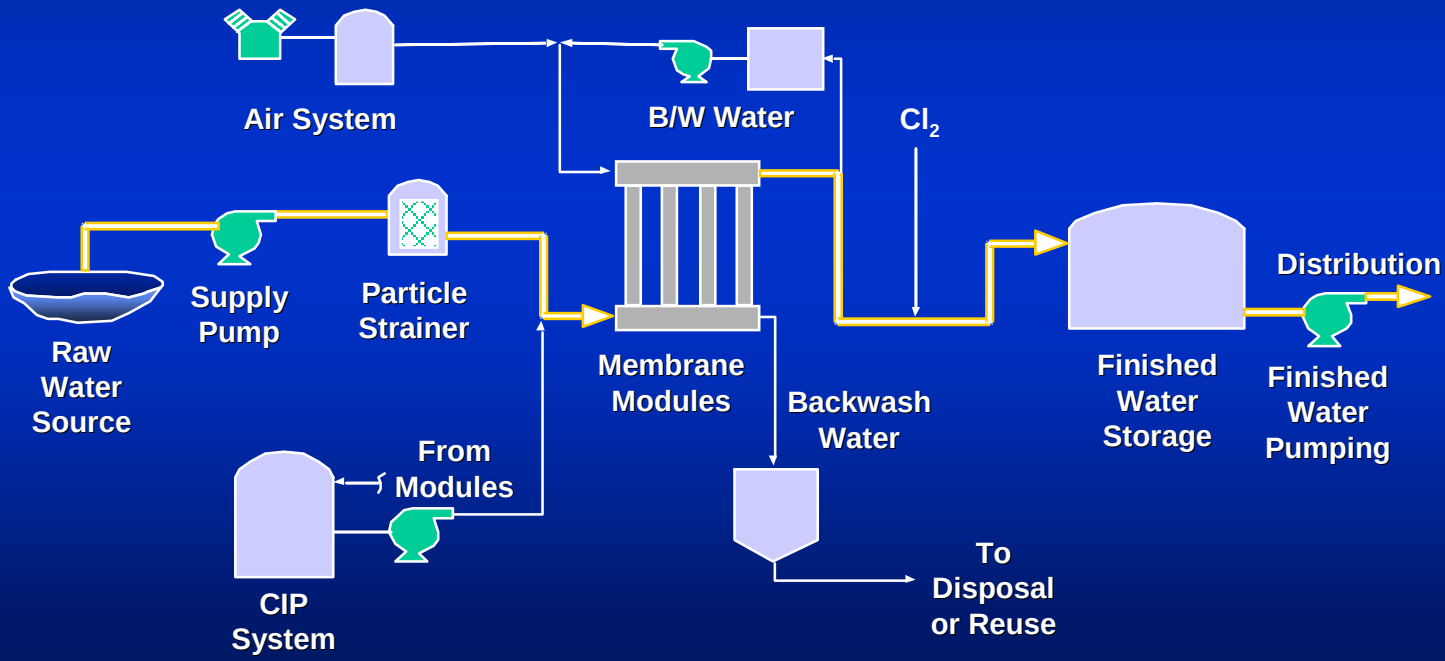
Zenon ZeeWeed ZW500 module

Modules are manifolded to form skids or trains

5 Trains of Memcor 90 M10C pressurized modules

Single cassette of 8 ZeeWeed ZW500 immersed modules

Components of a Pressure MF/UF Plant



There are some important differences in MF/UF and RO/NF systems

- RO/NF use generic system designs and similar performing membrane modules from multiple manufacturers
- MF/UF use proprietary system designs and proprietary membrane modules for each system

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What are the MF/UF Products?

	U.S. Filter/Memcor	Aquasource	Koch	Zenon (ZeeWeed)	Pall (Microza)
Configuration	Pressure	Pressure	Pressure	Immersed	Pressure
Type	MF	UF	UF	"Quasi" UF	MF
Composition	PP	CA/PS	PS	N/A	PVDF
Pore Size	0.2 μ	0.01μ 100KD	0.01μ 100K D	0.035 μ	0.1 μ
Flow Direction	Outside-in	Inside-out	Inside-out	Outside-in	Outside-in
Operation Mode	Dead-end	Cross-flow	Cross-flow	"Quasi" Cross-flow	"Quasi" Dead-end
TMP (psi)	3 – 15	5 – 30	10 – 30	1 – 7	5 – 25
Oxidant Tolerance	None	Limited	Good	Good	Good

The MF/UF field is continually expanding...

- UF
  - Hydranautics “HydraCap”
  - Leopold “Ultrabar”
  - Norit XIGA
  - Zenon ZW-1000

  MF
  - USF Memcor “CMF-S”
    - immersed, inside out, dead-end MF product
    - targeting large capacity plants at reduced cost (<$0.25/gpd equipment cost)

“Membrane Pilot World”

Case Study: Parry Sound WTP

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Parry Sound WTP Project History

- EA originally proposed conventional treatment plant
- Affordable membrane technologies emerged
- Pilot Study in 1999
- Designed as ultrafiltration plant in 1999
- Commissioned May 2001
- Plant Size 10 ML/d

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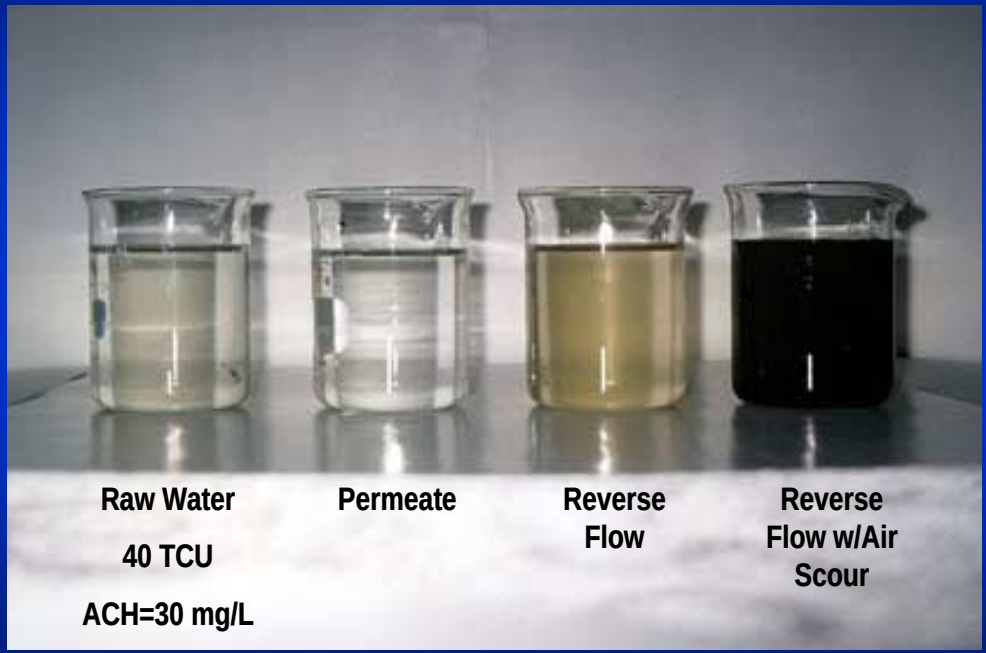
Pall stress test samples



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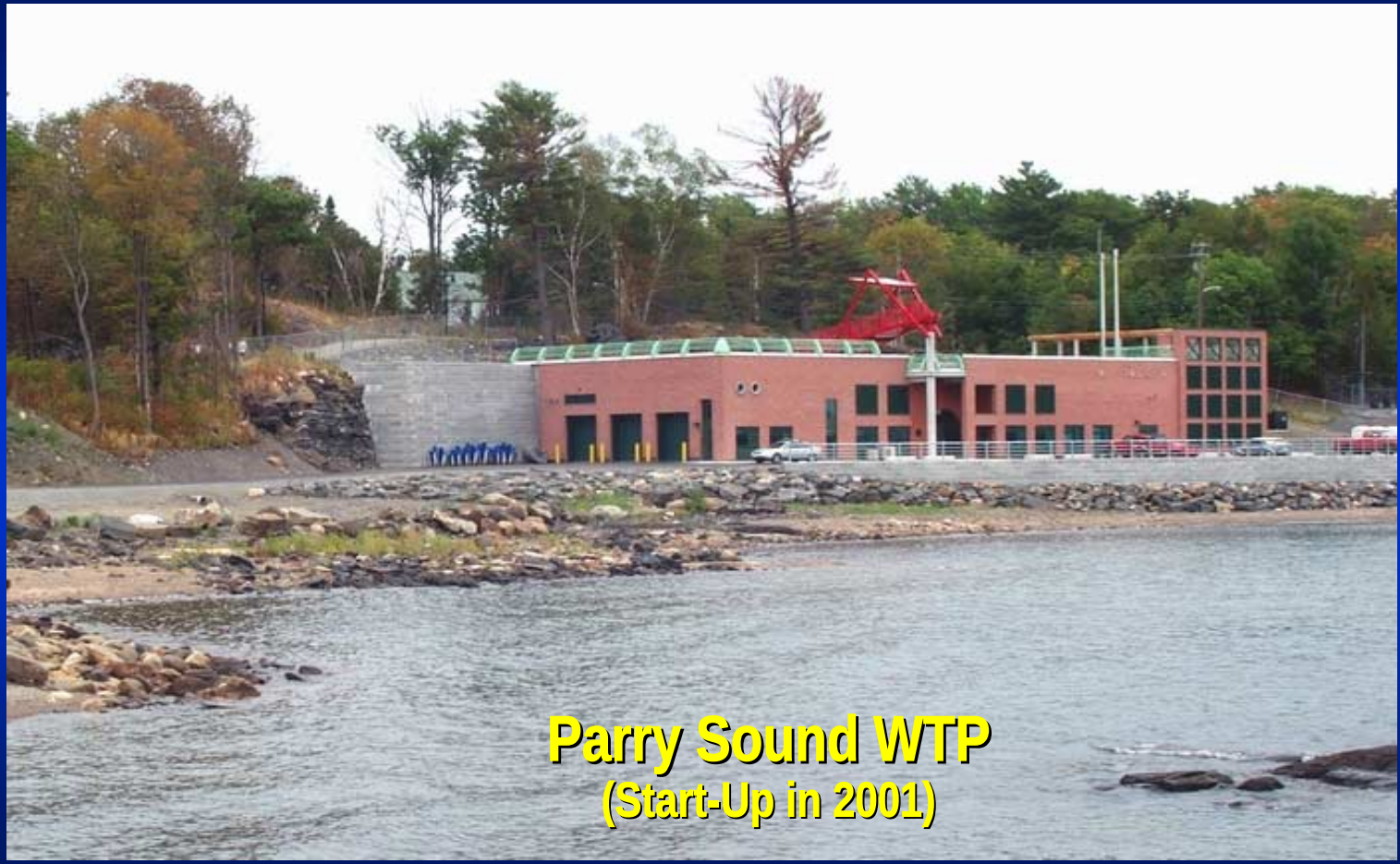
Parry Sound WTP
(Conceptual Site Rendering)

- Raw water source - eastern Lake Huron


Parry Sound WTP
(Under Construction in 2000)


Parry Sound WTP
(Start-Up in 2001)

Parry Sound WTP
(Start-Up in 2001)


Parry Sound WTP
(Start-Up in 2001)
8. 16. 2001

Parry Sound WTP
(Start-Up in 2001)

“An Architectural Challenge”

Case Study: Fairfield WTP

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Fairfield WTP Project History

- Conventional Treatment Plant proposed in early 90's deemed too expensive - project shelved
- Study in early 1997 concluded microfiltration plant at old pumping station site affordable
- Summer 1997 pilot study (Memcor vs. Zenon)
- Designed 1998, Construction began Fall 1998
- Commissioned May 2000

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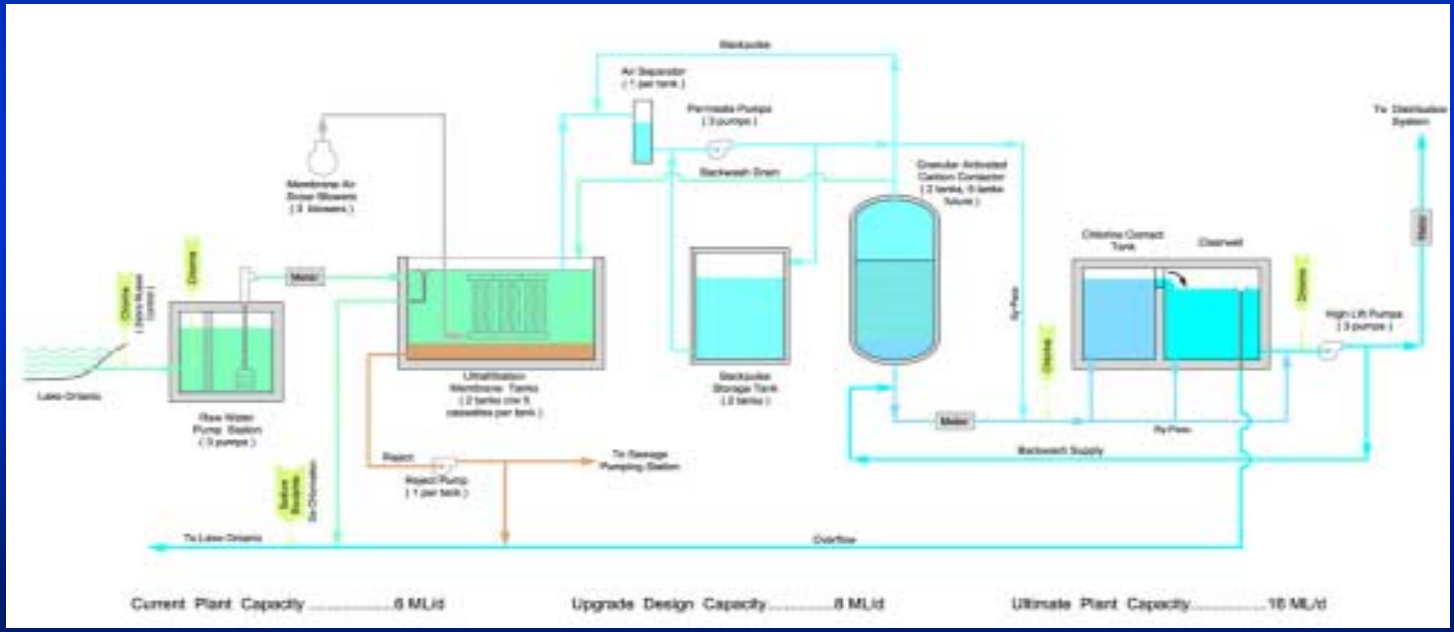
Fairfield WTP - “Stealth” Architecture

Aerial View - Fairfield WTP

Fairfield WTP Process Flow Diagram



Fairfield WTP Layout Diagram

“The Future is Now”

Case Study: Sudbury WTP

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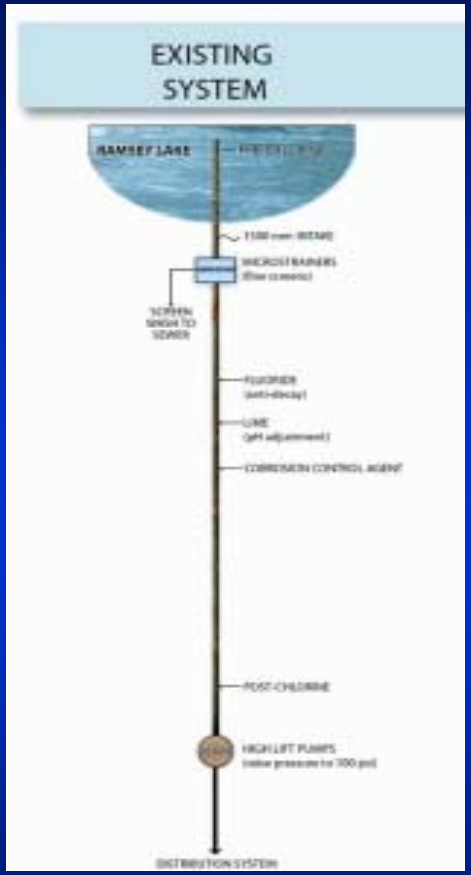
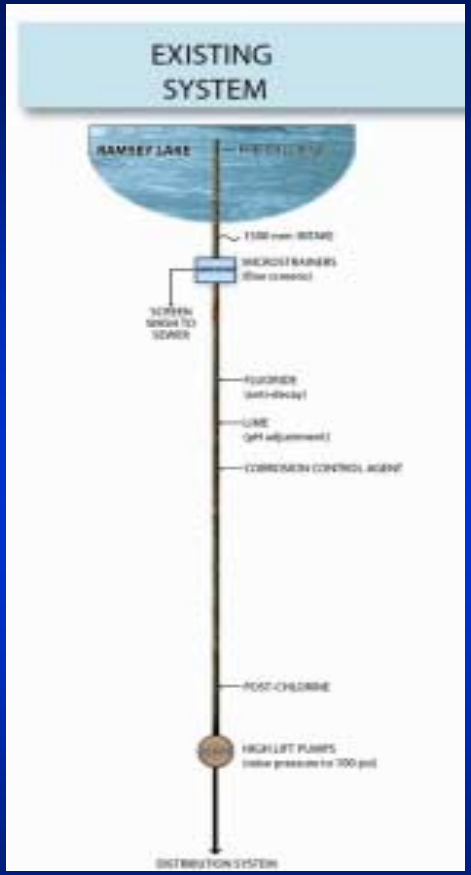
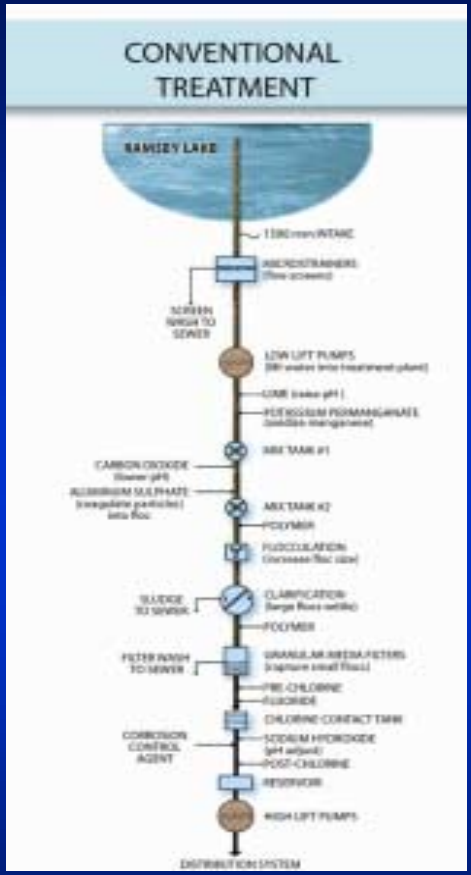


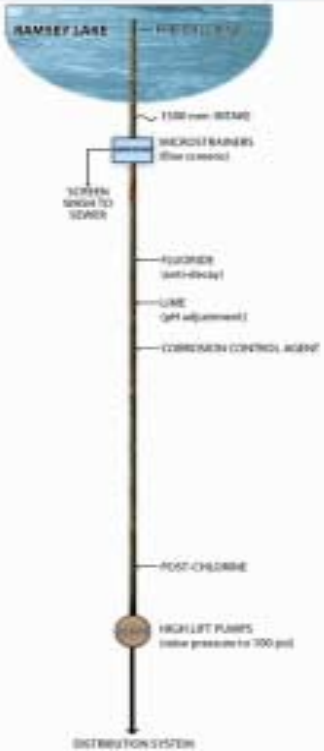
- Existing treatment system is unfiltered, fluoride, lime, chlorine
- Manganese problems summer 2000 (“black water” in distribution system)
- Quick solution needed!



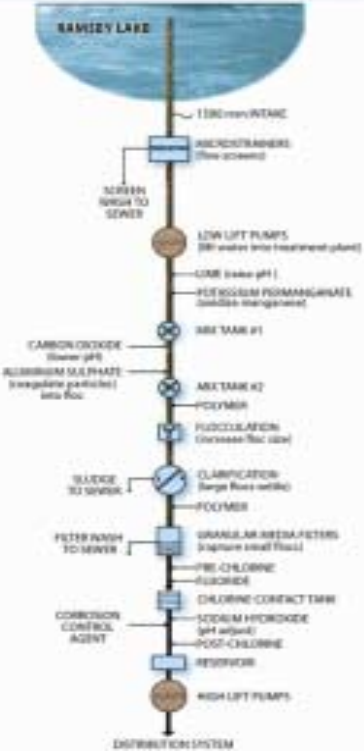


- Typical conventional treatment train
- Too big to fit on existing site for 40 ML/d capacity

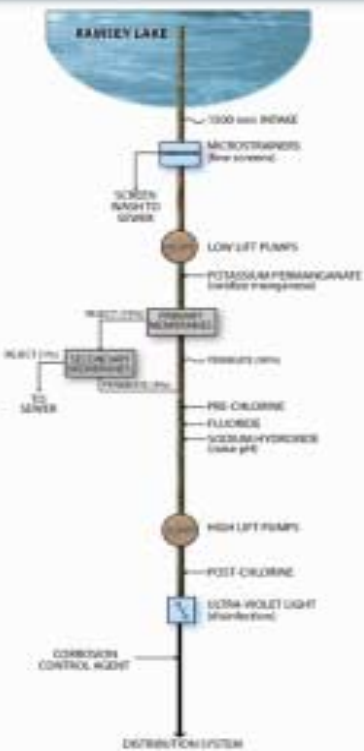
EXISTING SYSTEM



CONVENTIONAL TREATMENT



PROPOSED MEMBRANE TECHNOLOGY



- Primary Membranes
  Zenon 1000's

- Secondary Membranes
  Zenon 500c's

- Secondary Disinfection
  Trojan UV Swift

Smaller, Cheaper, Better

- Sudbury WTP's membrane design uses a "siphon" as the driving force (cheaper energy, less equipment)
- Primary and Secondary Membranes achieve >99% raw water recovery
- High Lift pumps match plant flow
- Footprint size compared to conventional is much smaller allowing use of existing site

Costs

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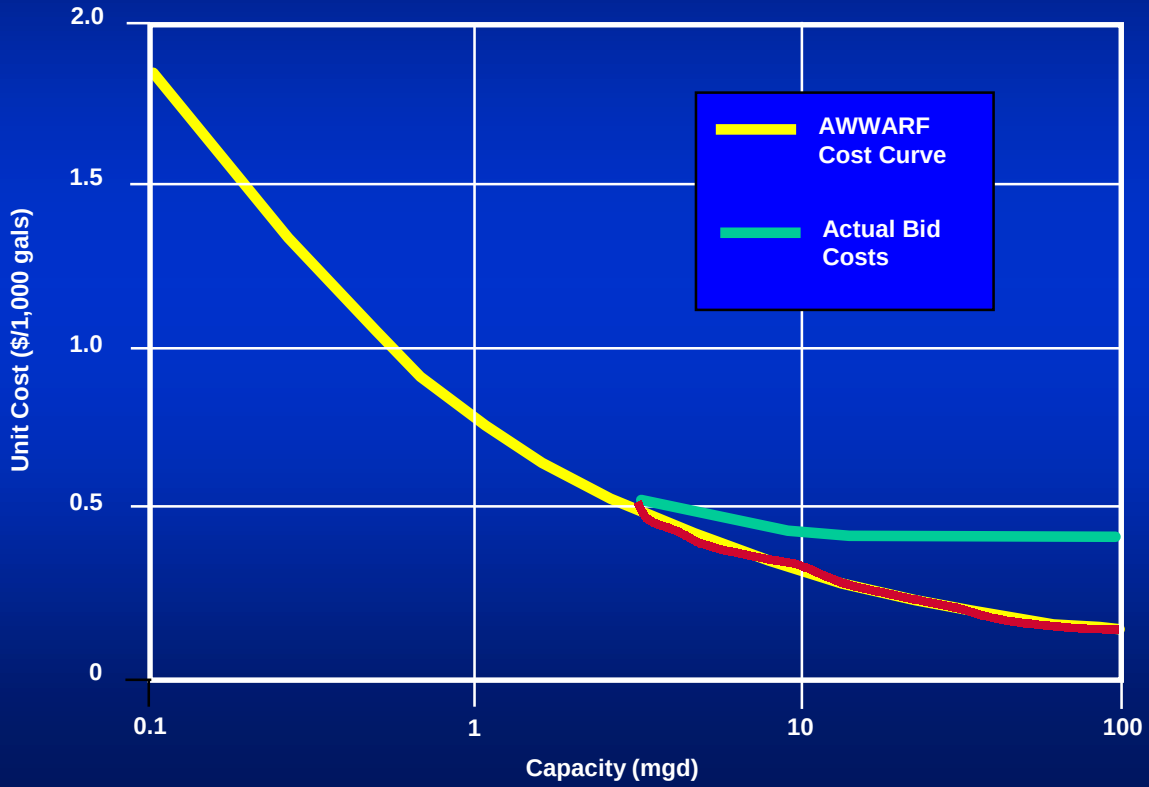
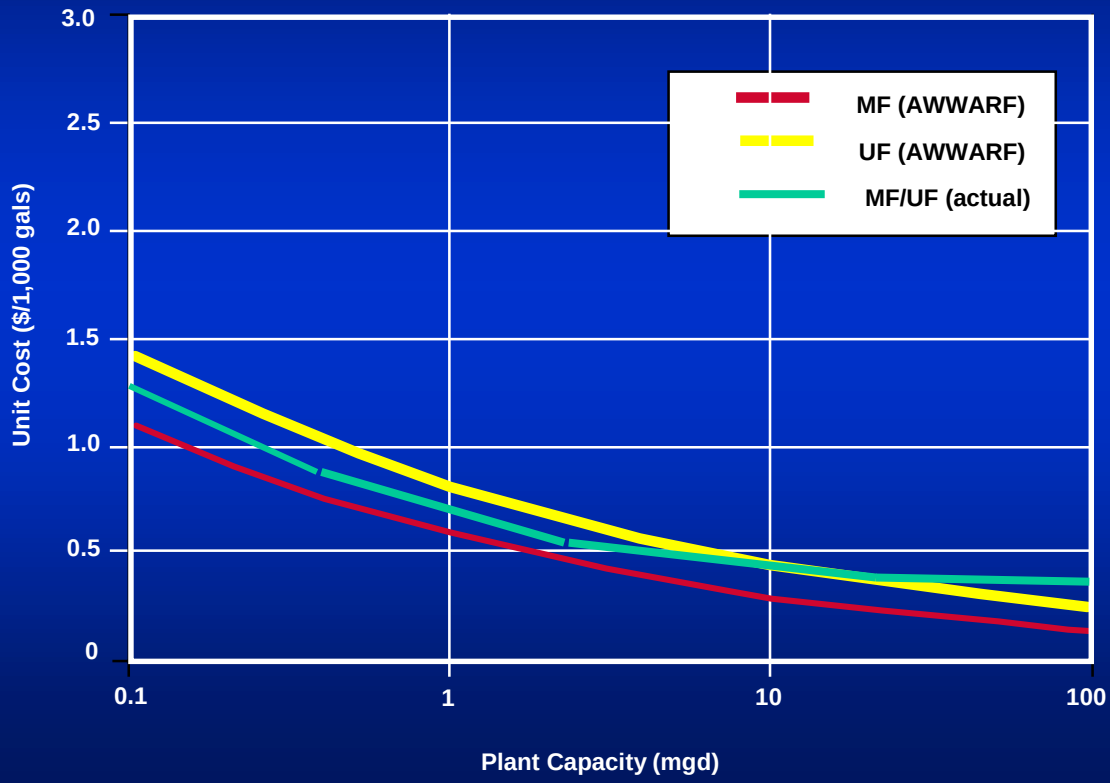
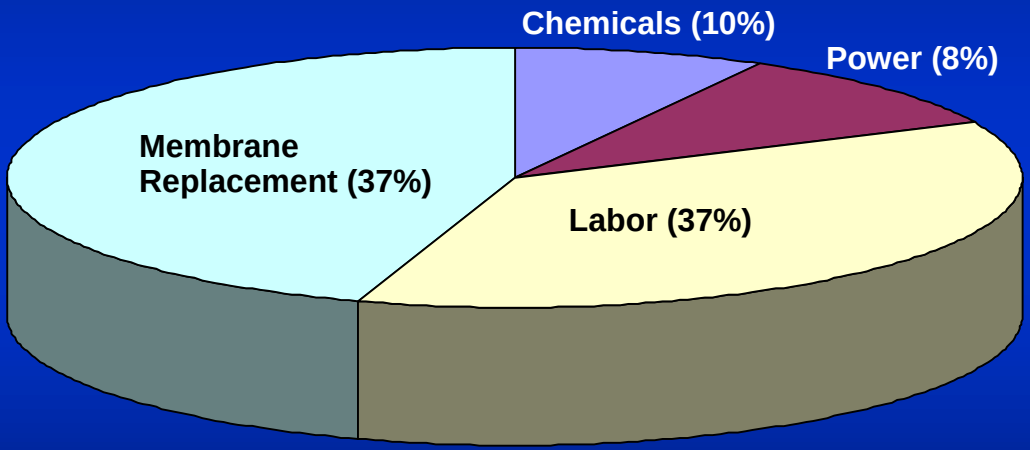
Installed Membrane Filtration Equipment Unit Costs



Membrane Filtration Treatment Unit Costs



MF/UF O&M Cost Breakdown



Total cost = $0.10/kgals produced

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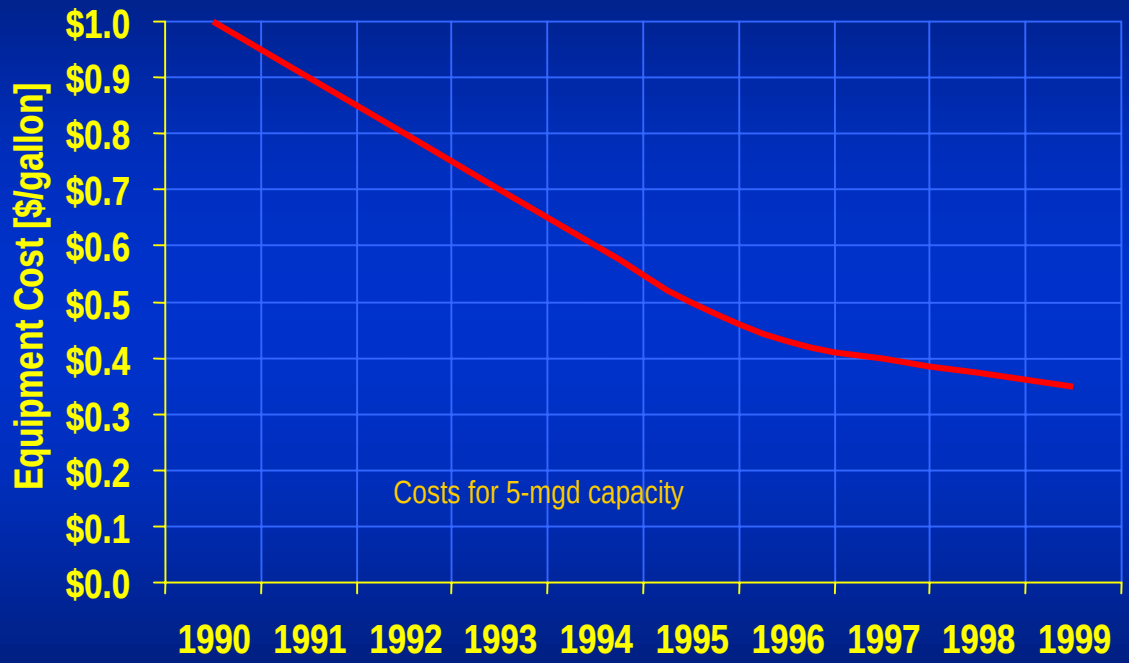
MF/UF equipment costs have decreased significantly



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Decreased costs reflect

- Increasing competition (2 suppliers in 1992; >6 suppliers in 2002)
- Decreased membrane manufacturing costs (more production installed to meet greater demand)
- Decreased module/system costs (more membrane area per module)

Where is membrane treatment headed?

- Installation of Bigger Plants
  - Up to 100 mgd under design in US for MF/UF
  - Increased use of immersed and larger pressurized modules to reduce system cost/complexity
- Increasing use of pre-clarification to reduce MF/UF plant costs
- Integration of MF/UF with chemical treatment to address full range of water quality issues
  - coagulation/PAC/pre-oxidation for control of DBPs, T&O and Fe/Mn
- Increasing use of NF for DBP reduction/colour removal

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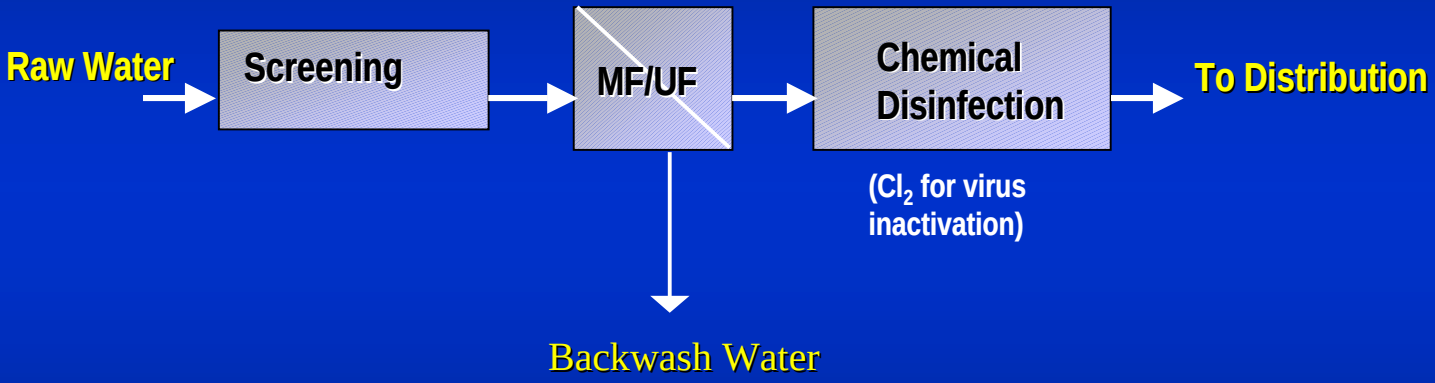
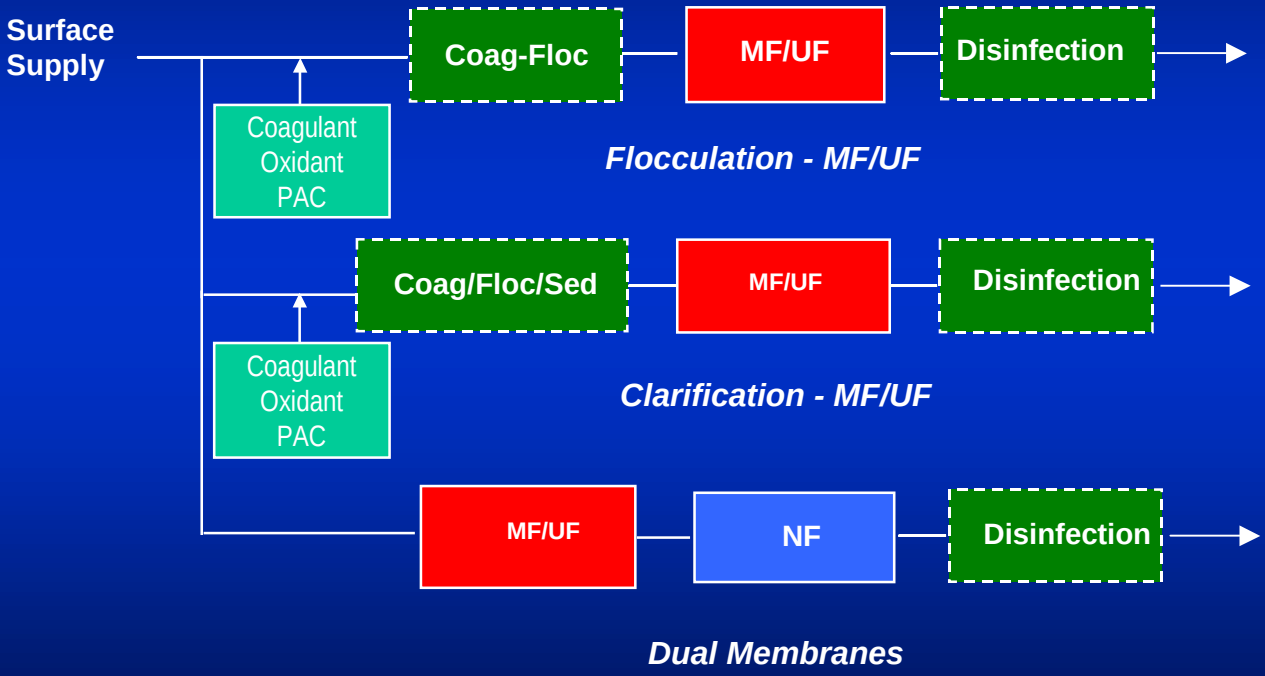
MF/UF Particle Removal Plant



This approach does not address:

- *control of aesthetic contaminants (taste and odor, iron and manganese)*
- *reduction in DBPs where free chlorine used for secondary disinfection*

How do we address more comprehensive treatment requirements? (integrated treatment)



Membrane Filtration Application from Inside to Outside

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