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**ZeeWeed<sup>®</sup> Immersed Membrane  
Technology and Innovations for Drinking  
Water and Wastewater Treatment**

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Terry Matthews  
(Zenon Environmental Inc., Canada)

# **ZeeWeed® Immersed Membrane Technology and Innovations for Drinking Water and Wastewater Treatment**

**by Terry Matthews  
ZENON Environmental Inc.**



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# Outline

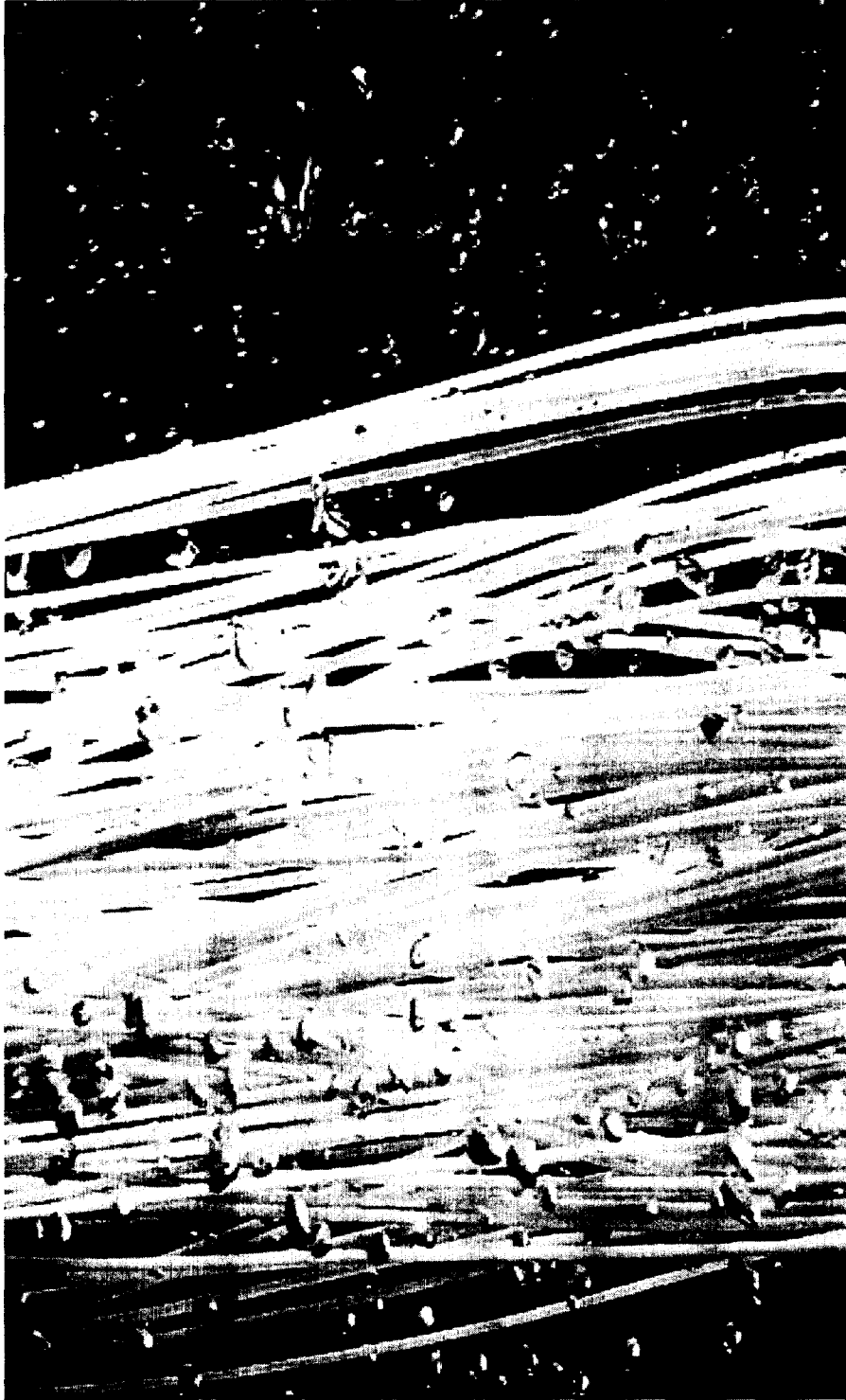
- **The ZeeWeed® immersed membrane**
- **Historical development of ZeeWeed® modules**
- **ZeeWeed® / ZenoGem® for membrane bio-reactor applications**
- **The evolution of ZeeWeed® for MBR applications**
- **ZeeWeed® system design concepts**
- **ZeeWeed® for filtration applications**
- **ZeeWeed® 1000: a glimpse at the future**
- **The evolution of ZeeWeed® for filtration applications**
- **Conclusions**



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# The ZeeWeed® Membrane



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# The ZeeWeed® Membrane

- **Hollow fibre with outside-in flow (0.9 mm ID, 1.9 mm OD)**
- **Chlorine-resistant polymeric membrane**
- **Pore size of 0.04 µm nominal in the ultrafiltration range**
- **Permeate drawn by suction on the permeate side**
- **Air bubbling induces turbulence to keep membrane clean**



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# ZeeWeed® / ZenoGem® for Membrane Bio-reactor Applications

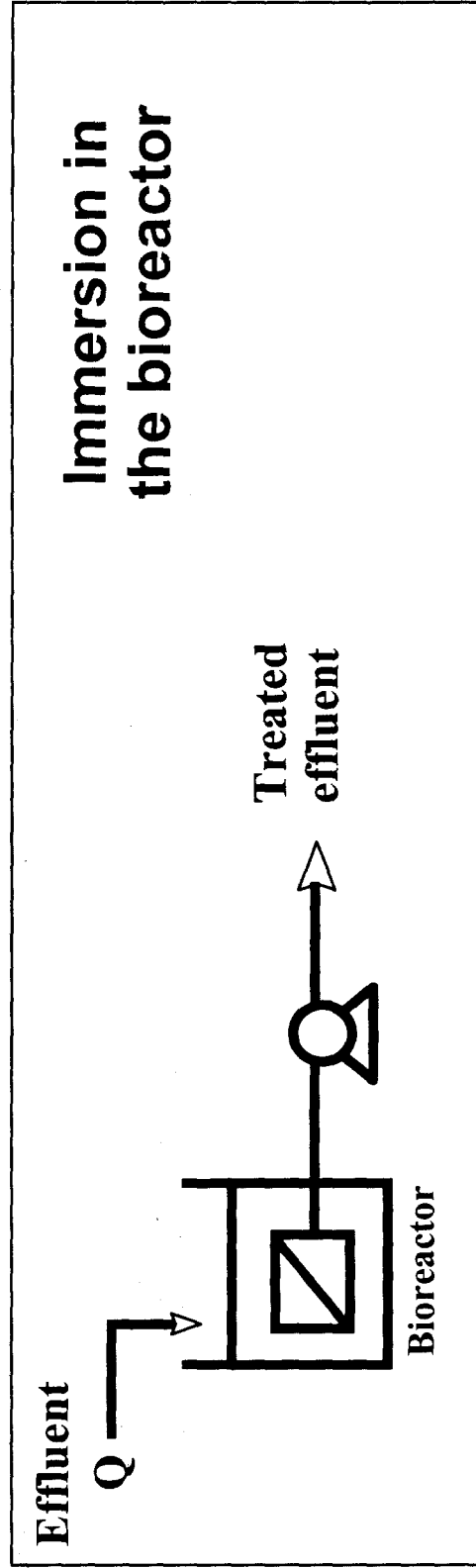
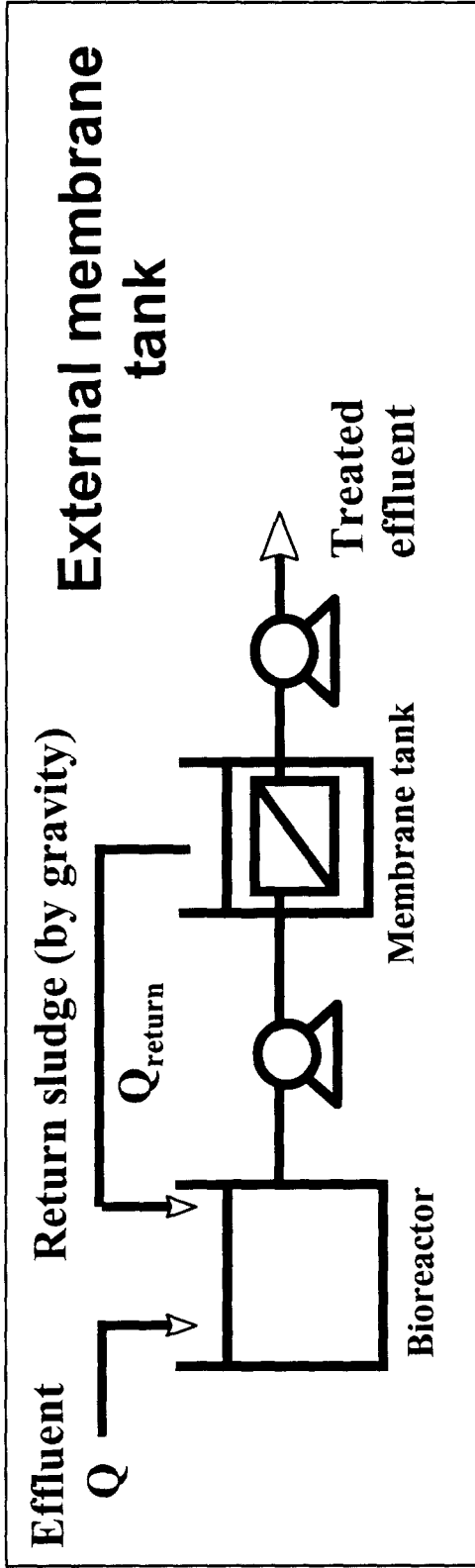
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# Immersed Membrane Bioreactors



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# ZenoGem® Effluent Quality

- **BOD<sub>5</sub> < 5 mg/L**
- **Turbidity < 0.5 NTU**
- **Ammonia-Nitrogen < 1 mg/L**
- **Total Phosphorus < 0.1 mg/L**
- **Total Nitrogen < 10 mg/L**  
(moderate climate)
- **Total Coliform < 100 CFU/100 mL**
- **Fecal Coliform < 10 CFU/100 mL**
- **Total Nitrogen < 3 mg/L**  
(warm climate)
- **SDI 1-3**





# ZenoGem® Applications

**Commercial Development**

**Industrial Wastewater**

**Municipal Wastewater**



# Commercial Development Applications

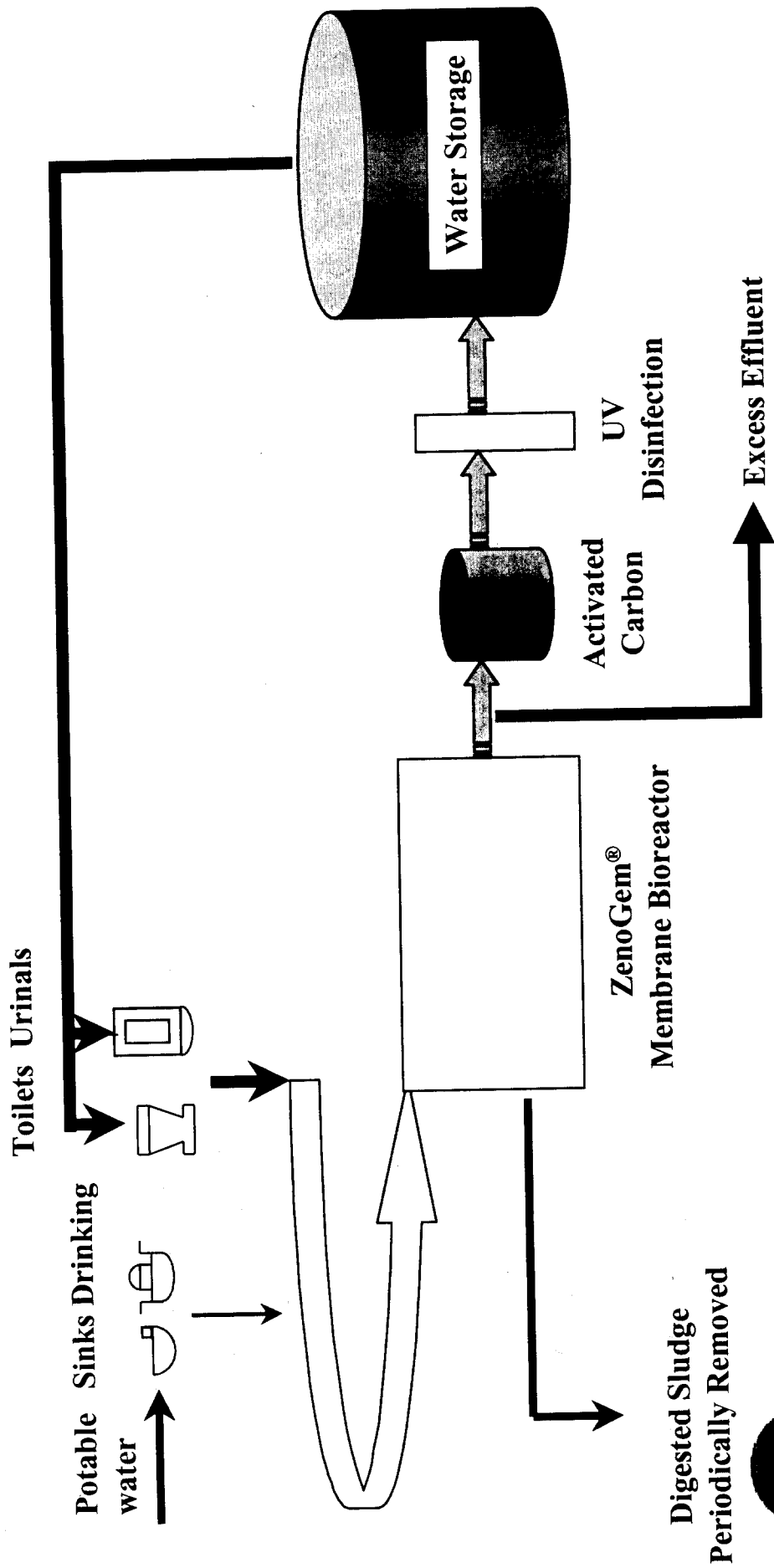
- **Started in the early 70s.**
- **Residential/office complexes, shopping centres, hotels, schools, resorts where sewage collection is not available.**
- **More than 100 plants in sizes ranging from 10-200 m<sup>3</sup>/d.**
- **Bioreactor with long HRT (up to 24h) and SRT (up to one year). Initially equipped with tubular modules; all new plants since 1994 equipped with immersed membranes.**



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# The ZenoGem® for Commercial Development



Digested Sludge  
Periodically Removed



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# Industrial Wastewater Applications

- **Started in the early 90s.**
- **Difficult wastewater such as oily wastewater and landfill leachate.**
- **Approximately 100 installations with sizes up to 30,000 m<sup>3</sup>/d**
- **Flow equalization.**



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# ZenoGem®: Typical Industrial Applications

- **Oily Wastewater** ➤ **Cosmetics Manufacturing**
- **Food Processing** ➤ **Pharmaceutical Production**
- **Landfill Leachates** ➤ **Fertilizer Production**
- **Specialty Chemicals** ➤ **Brewery Wastewater**
- **Shipboard Wastes** ➤ **Tanneries**
- **RO pretreatment** ➤ **Water Reuse**



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# Municipal Wastewater Applications

- Started in the mid 90s.
- Installations where space is limited and effluent quality requirements are high.
- 30 plants with sizes up to 20,000 m<sup>3</sup>/d.
- Membranes immersed directly in the aeration tank or in a separate membrane tank.
- Nitrification/denitrification with chemical phosphorus removal.
- Daily/seasonal flow peaking.



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# ZenoGem® vs. Conventional Plant

	Conventional Activated Sludge	ZenoGem® Plant
<b>Clarifier</b>	Yes	No
<b>Filter</b>	Yes	No
<b>MLSS</b>	< 5,000 mg/L	> 10,000 mg/L
<b>SRT</b>	< 15 days	10 - 365 days
<b>Footprint</b>		Typically 3 to 5 times smaller
<b>Process Stability</b>	Susceptible to sludge bulking	Not susceptible to upsets



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# ZenoGem® for Water Reuse

## RO Pre-treatment in Florida

- **Location: Florida Keys**
- **Municipality required very high effluent quality, at all times to:**
  - **Protect marine life**
  - **Irrigate golf course**
- **What was considered:**
  - **Activated sludge**
  - **SBR**
  - **ZenoGem®**



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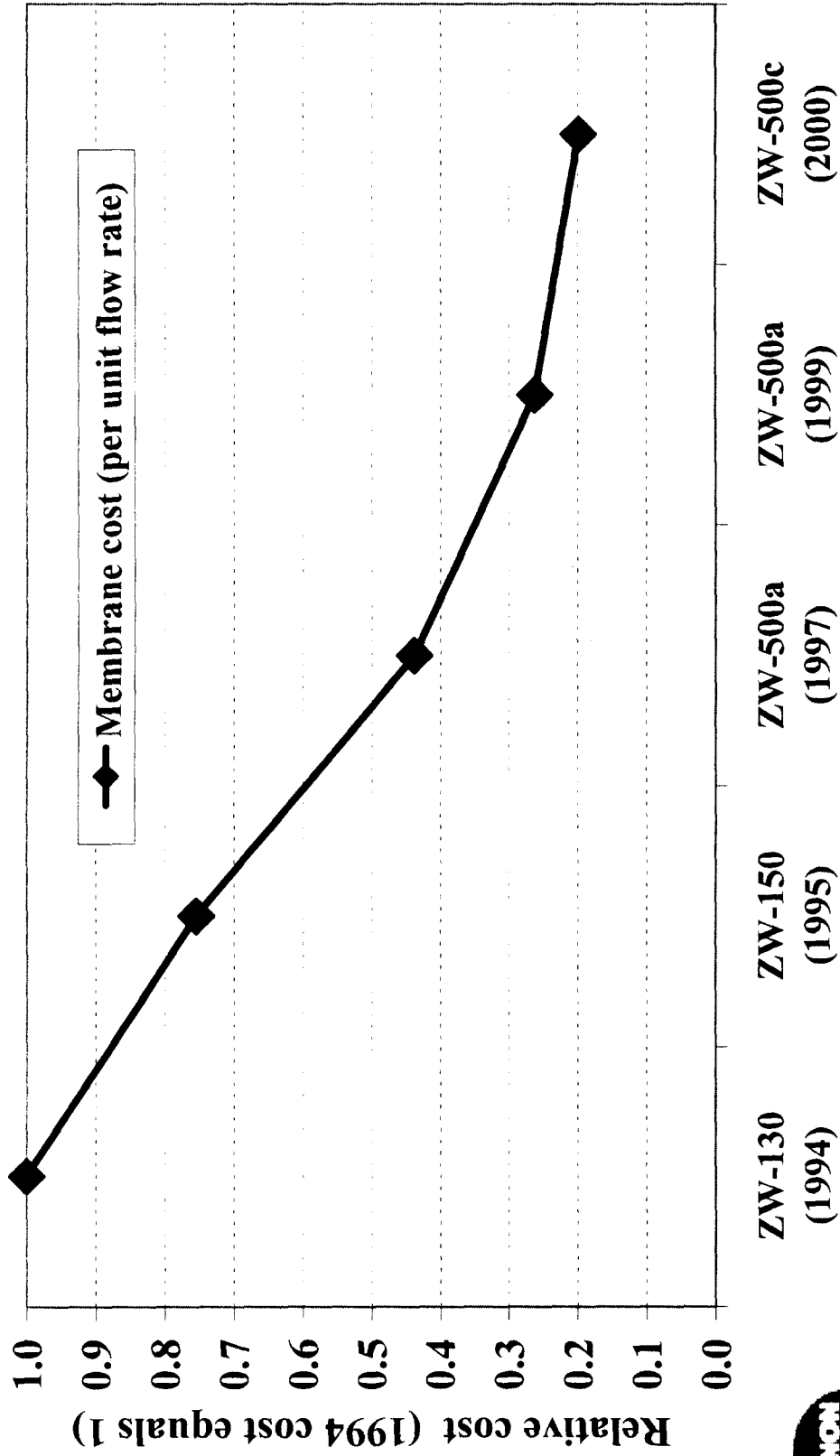
# The Evolution of ZeeWeed® for MBR Applications



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# Wastewater: Cost



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# ZeeWeed® System Design Concepts

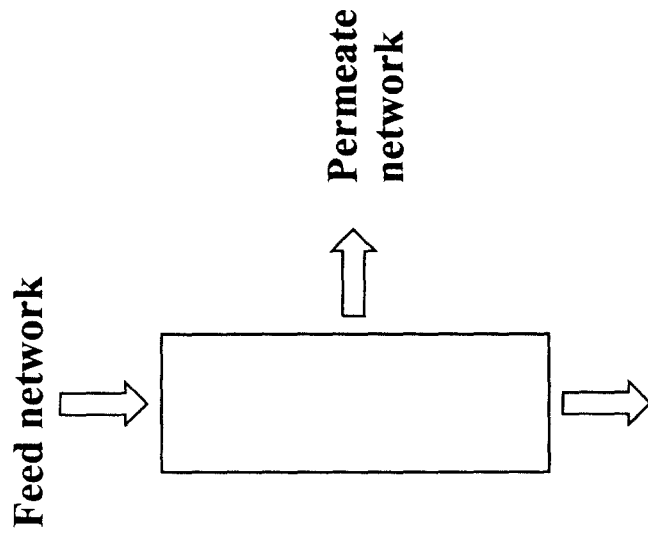


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# Turning Modules into a System

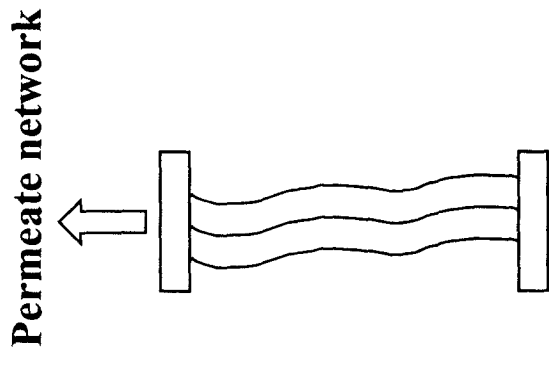
## Pressurized Module



Reject network to:

- drain
- second stage
- recirculation for cleaning

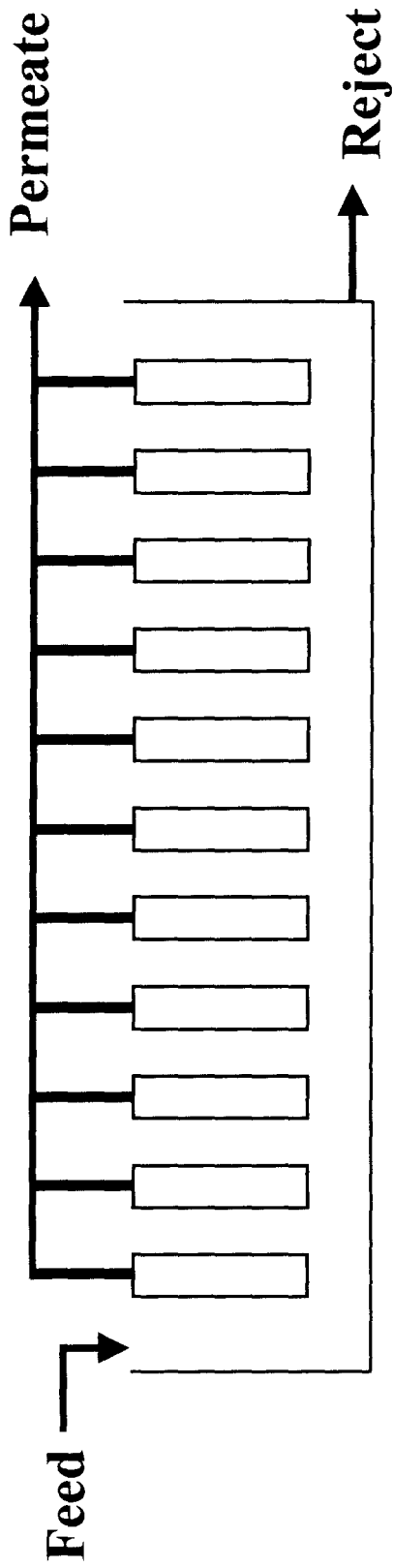
## Immersed Module



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# Immersed Membrane Tank Design with Plug Flow



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# ZeeWeed® for Filtration Applications



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# Why Immersed Membranes for Drinking Water Production?

- Simplify system to reduce capital cost
- Provide operation robustness through extensive use of membranes
- Combine separation with reactions (coagulation, precipitation, adsorption, biodegradation)
- Put membranes in existing tanks to upgrade and extend plants



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# Full-Scale Applications of ZeeWeed® for Water Filtration

- **Direct filtration of surface water**
- **Coagulation coupled with filtration for TOC and colour removal**
- **Oxidation coupled with filtration for iron and manganese removal**
- **Concentration of conventional water treatment plant residuals**
- **Pre-treatment of surface water to reverse osmosis**
- **Pre-treatment of effluents to reverse osmosis**
- **Tertiary filtration of secondary effluents for water reuse**



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# ZeeWeed® for Filtration Applications

## Direct filtration of surface water

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# Collingwood, Ontario

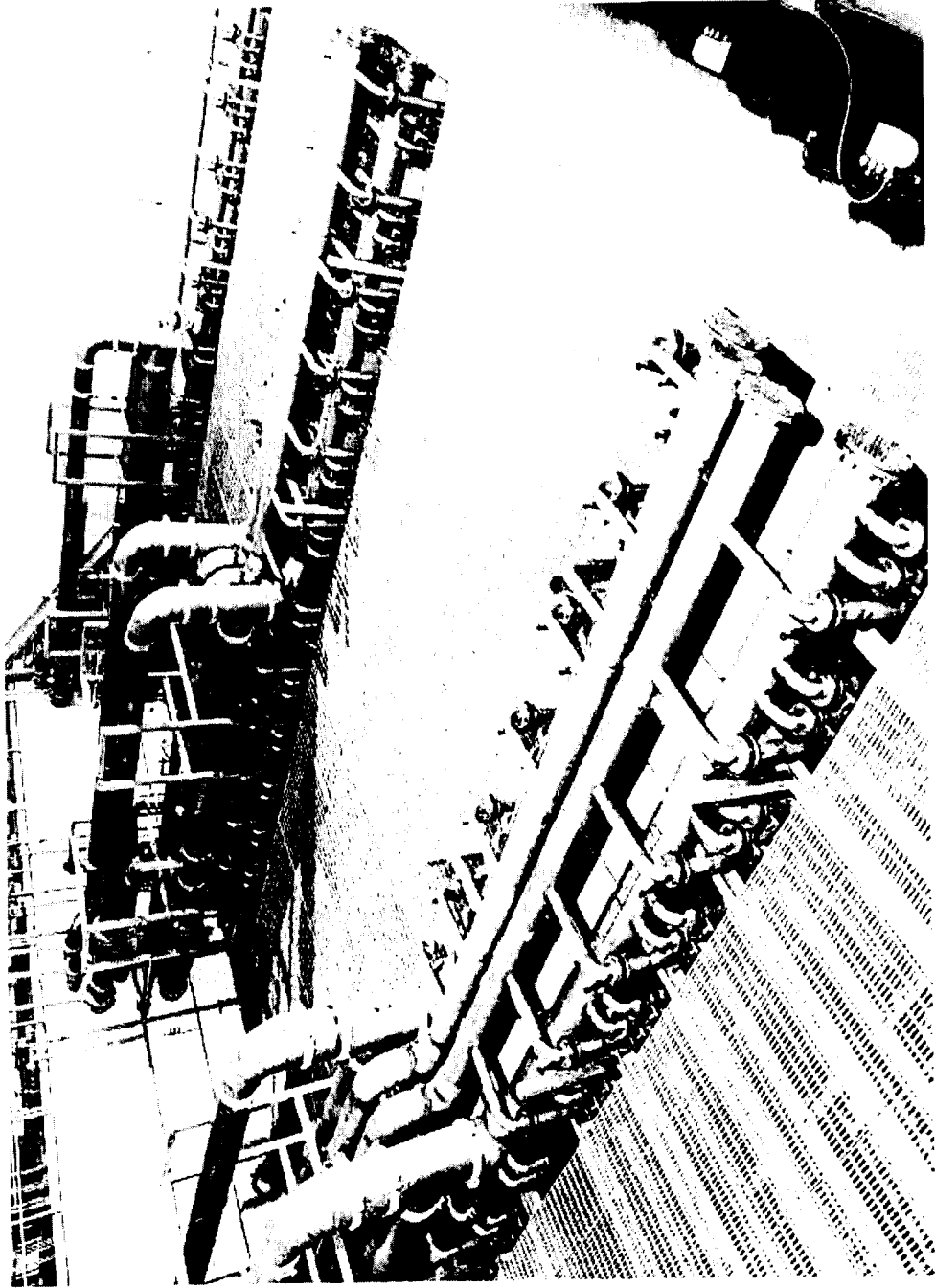
- **28,000 m<sup>3</sup>/d**
- **Georgian Bay, Lake Huron**
- **5 process trains**
- **12 cassettes/train**
- **10 ft wide basins**
- **Concrete process tanks below grade**
- **Permeate pumps are used to backpulse, gravity option**



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# Collingwood, Ontario



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# Olivenhain, California

- **100,000 m<sup>3</sup>/d (200,000 ultimate)**
- **2 stage system**
- **1st stage: 8/10 trains**
- **2nd stage: 3 trains**
- **Medium train design**
- **Gravity backpulse (centralized backpulse concept)**
- **Under construction**



# ZeeWeed® for Filtration Applications

**Coagulation coupled with filtration  
for TOC and colour removal**



# Thunder Bay Drinking Water Plant Lock Lomond Reservoir

## Water Quality

<b>TOC:</b>	<b>6 mg/L</b>
<b>DOC:</b>	<b>5.9 mg/L</b>
<b>Turbidity:</b>	<b>0.7 NTU</b>
<b>Hardness:</b>	<b>40 mg/L as CaCO<sub>3</sub></b>

## Equipment

**4 trains**  
**15 cassettes/train**  
**8 modules/cassette**  
**Total of 480 ZW-500 OCP modules**

## Design conditions

**direct filtration**  
**35,000 m<sup>3</sup>/d (at T° > 10°C)**  
**flux: 68 L/m<sup>2</sup>/h**  
**recovery: 95%**  
**pre-chlorination: 0.6 mg/L**



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# Initial UF Enhanced Coagulation Results Pilot Scale

<b>Water Source</b>	<b>Thunder Bay</b>
TOC (mg/L)	6.0
Raw Color (PCU)	33
Alkalinity (mg/L as CaCO <sub>3</sub> )	22
Raw SUVA (l/mg/cm)	1.8
Alum dose (mg/L)	40
Treated Color (PCU)	<1
% Color reduction	97
% TOC reduction	62



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# Sioux Lookout Water Plant

## Lac Seul (North of Lac Superior)

### Water Quality

	Feed
TOC (mg/L)	8.9
Colour (Pt Co units)	40
THMFP ( $\mu\text{g/L}$ )	120
Alkalinity (mg/L as $\text{CaCO}_3$ )	30

### Equipment

2 trains  
Coagulation & membrane tanks  
4 cassettes/train  
10 modules/cassette  
Total of 80 ZW-500 OCP modules

### Design conditions

Enhanced coagulation  
40-45 mg/L Alum, caustic soda for pH adjustment  
5,000  $\text{m}^3/\text{d}$  (at  $T^\circ > 10^\circ\text{C}$ )  
Flux: 58  $\text{L}/\text{m}^2/\text{h}$



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# Colour and NOM Removal at Sioux Lookout, ON

Sioux Lookout WTP	Objective	Feed	Permeate	% Removal
TOC (mg/L)	< 5.0	8.9	3.6	60%
UV at 254 nm (cm <sup>-1</sup> )		0.284	0.073	74%
Color (Pt Co units)	<5.0	40	0 – 2	100%
pH	6.5-8.5	7.0-7.2	7.5	
Alkalinity (mg/L as CaCO <sub>3</sub> )	>30	30-35	30-35	
Aluminum (ug/l)	<100	110	70	36%



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# Sioux Lookout TTHM Removal

Sioux Lookout WTP	TOC (mg/L)	UV254 (cm <sup>-1</sup> )	Chlorine Dosage <sup>1</sup> (mg/L)	TTHM <sup>2</sup> (ug/l)	HAA <sup>2</sup> (ug/l)
<b>Before Coagulation</b>	8.9	0.284	2.9	120	n.a
<b>After Coagulation</b>	3.6	0.073	1.9	28	14.4

1. Chlorine dosage required to maintain 1 ppm residual
2. After clearwell with 3 hour contact time



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# ZeeWeed® for Filtration Applications

**Tertiary filtration of  
secondary effluents for water reuse**



# Case Study: Poland

## Secondary Effluent Reuse

- Pretreatment of municipal secondary effluent  
RO to industrial cooling circuit feedwater
- Operating since September 1999
- Plant Capacity: 5,400 m<sup>3</sup>/d
- Permeate SDI < 2



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# ZeeWeed® 1000: A Glimpse at the Future



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# ZeeWeed® 1000 Overview

- **Next generation of ZENON's immersed membrane for low solids water**
- **Quantum improvement in several properties:**
  - **Capital and operating costs**
  - **Operation simplicity**
  - **Footprint**
  - **Energy Consumption**
- **Retrofitting of sand filters and non-standard tanks**



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# ZeeWeed® 1000 Product Features

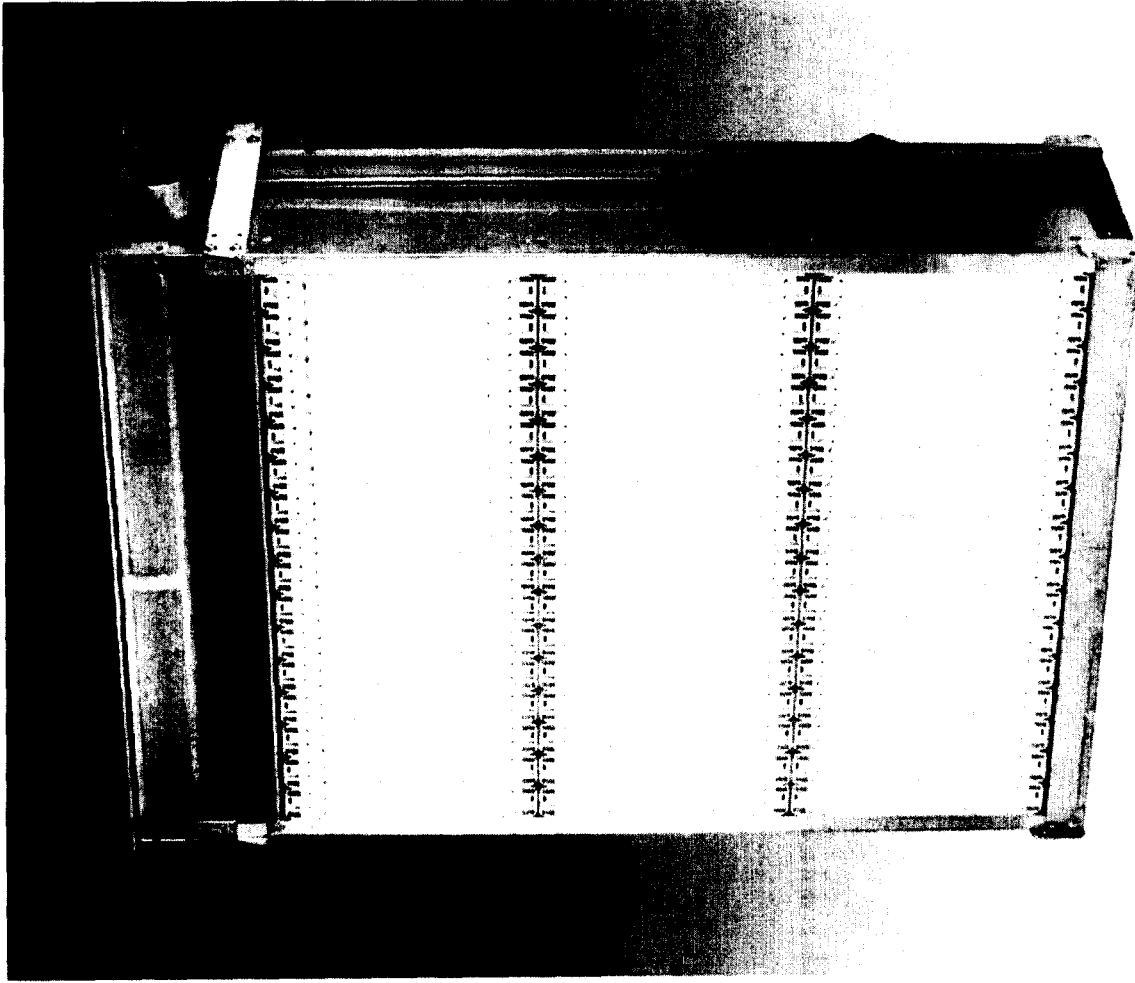
- Same membrane chemistry as ZeeWeed® 500 series
- Small diameter hollow fibre
- Virus rejecting membrane
- Rectangular building blocks to fill tanks horizontally and vertically
- Protected by existing ZeeWeed® patents and new patent applications



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# ZeeWeed® 1000 Cassette



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# **ZeeWeed® 1000**

## **Process Features**

- **Gravity feed to parallel process tanks**
- **Direct (dead-end) filtration**
- **Regular backwash**
- **Intermittent aeration**
- **Recovery 85-97% depending on water quality**
- **Membrane integrity test by pressure decay**



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# Full-Scale Applications of the ZeeWeed® 500

- **Direct filtration of surface water**
- **Coagulation coupled with filtration for color and TOC**
- **Oxidation coupled with filtration for iron and manganese removal**
- **Concentration of conventional water treatment plant residuals**
- **Pre-treatment of surface water to reverse osmosis**
- **Tertiary filtration of effluents for water reuse**
- **Activated sludge coupled with filtration for wastewater treatment**



# ZeeWeed® 1000 Pilot Case Study – A0001

## Piloting Information:

- Surface water in California
- Pilot feed was not pre-chlorinated
- Feed water temperature of 17-25°C
- Pretreatment to reverse osmosis at a power plant
- Client upgrading water treatment system as part of plant expansion

## Analytical Parameters:

		Feed	Permeate
Turbidity (NTU)	Range	0.1 to 10	<0.1
	Average	4.4	
TOC (mg/L)	Range	0 to 3	0 to 3
	Average	1.8	1.6
SDI	Range	-	0.5 to 2.4
	Average		1.6



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# The Evolution of ZeeWeed® for Filtration Applications

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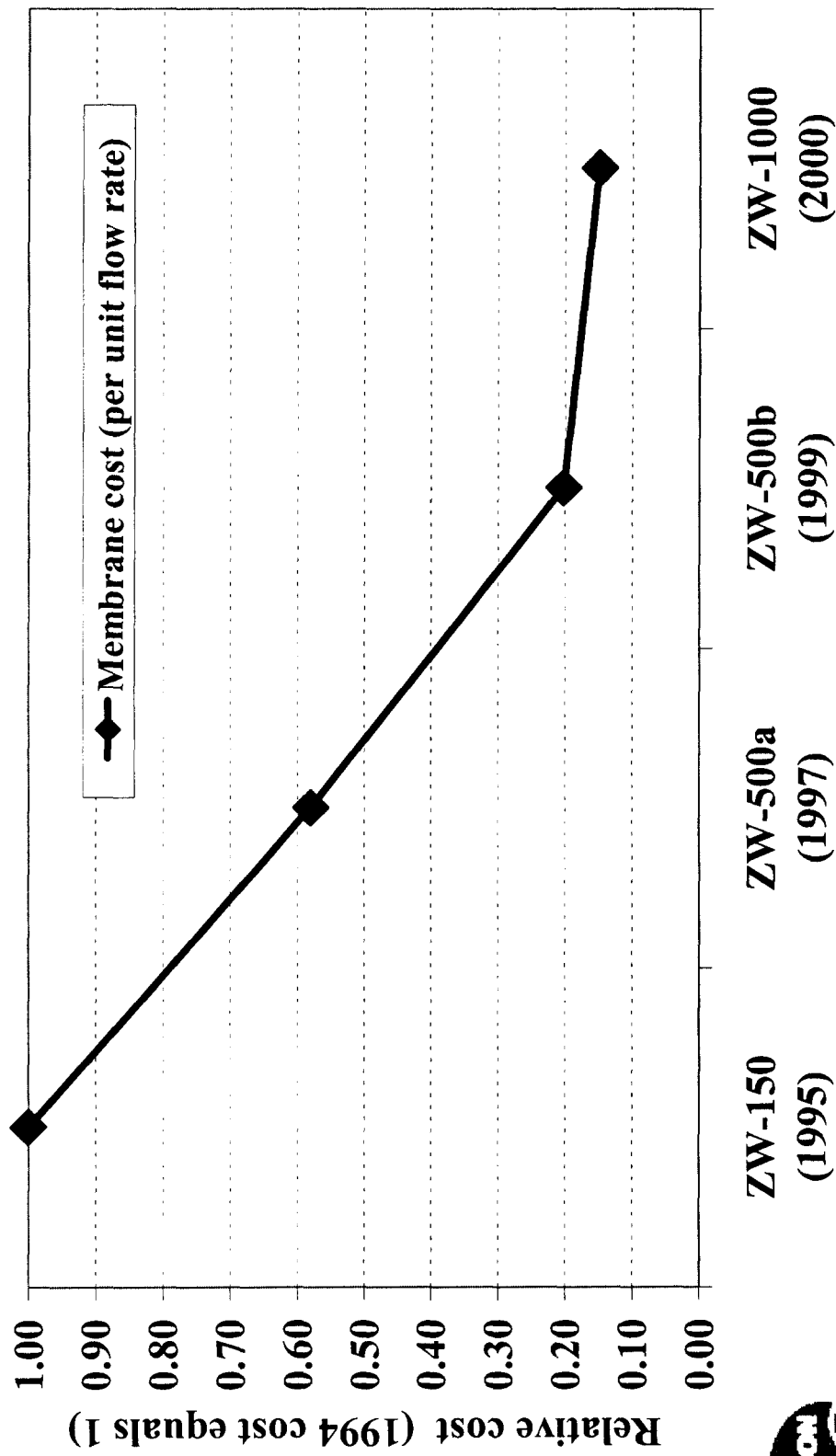


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# ZeeWeed® for Drinking Water

## Cost



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# Conclusions

- **Outside-in hollow fibres are tolerant to variable feed water quality**
- **Immersed membranes are conducive to the construction of large modules, cassettes and treatment units**
- **Low trans-membrane pressure for low fouling rates and ease of operation**
- **Immersed membranes can be used for direct filtration or coupled with oxidation, coagulation, adsorption or biological treatment for the removal of both dissolved and particulate contaminants**
- **Immersed membranes can be used to build new plants or to upgrade existing plants by immersing the membranes directly in clarifiers or sand filters**



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