

National Facilities Survey

O C T O B E R 1 1 , 1 9 9 6

PREPARED FOR

National Centers for
Water Treatment Technologies

A COOPERATIVE PROGRAM OF

National Water Research Institute
U.S. Bureau of Reclamation
U.S. Army

PREPARED BY

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EXECUTIVE SUMMARY

NATIONAL FACILITIES SURVEY II NATIONAL CENTERS FOR WATER TREATMENT TECHNOLOGIES

The first survey of publicly and privately owned facilities, pilot plant equipment and laboratories, in the United States was completed in 1994¹. The survey was conducted for the National Water Research Institute and the U.S. Bureau of Reclamation. Since that time, the effort has been joined by the U.S. Army. The three organizations jointly funded this survey.

The purpose of the survey is to identify research and development facilities in the United States with facilities and equipment available to aid in the development of water treatment research and development programs.

The mission of the program is unchanged:

- To facilitate, coordinate and integrate water treatment research and development to promote and develop water purification technology.

The goals of the program are the same as initially conceived:

- To develop and implement a strategy that will create and cultivate partnerships between Government, university, and industry that will facilitate research and enhance technology transfer of research products.
- To promote the cost-effective allocation of financial, human, and facilities resources.
- To establish and maintain an information and data exchange system to improve the coordination between engineering and technology research.

The ability to develop a technology transfer strategy is a key element in the successful conclusion of R&D efforts. In today's competitive economic environment, research deliverables and products must have "real world" application if the investment of resources is to be perceived as worthwhile. The initial survey was intended to identify those institutions with pilot plant equipment, considered the critical link between the laboratory and "real world" application of technology and products.

The second survey is intended to further elucidate the capabilities of major research centers and more clearly define the cost of performing research at these facilities. Each respondent was requested to submit some indication of the cost for facilities, equipment and services. Some were very specific with their costs; others chose to identify only overhead percentages.

The original survey identified 37 sites with pilot plant equipment in 15 states. Since that time, at least 3 sites have withdrawn as prospective centers and two others have been added. University owned equipment as well as commercial equipment available through private sector companies were also identified; a total of 72 facilities and com-

panies were identified. In addition to the more than one hundred institutions and agencies contacted in the initial survey, approximately 30 additional institutions and agencies were contacted during the second survey. The original respondents were all contacted to update their submittals and research positions.

The summary of sites identified to date:

Prospective national centers with pilot plant equipment:	38
Laboratory facilities with instrumentation and bench equipment:	20
Private sector companies with pilot plant equipment:	14
Total:	72

There are only 4 sites which offer the use of thermal processes and two of those are private sector companies. A fifth site is in the process of selling their thermal unit. An overwhelming majority of sites have membrane separation equipment available for testing. The membrane systems, primarily reverse osmosis, range from small laboratory size (< 1 gpm) to full commercial size (231 gpm).

Since the first survey, additional sites have shutdown their facilities and/or equipment due to lack of funding. A few of the facilities now known to be out of operation are:

- Ewa Demonstration Plant, Ewa, Oahu, Hawaii
- Los Banos Test Facility, Department of Water Resources, State of California.
- Salt Rock Water Treatment Plant, Salt Rock, West Virginia
- Water Reuse Demonstration Plant, City of Denver, Colorado

A few other facilities have put research programs on "standby" due to lack of personnel and/or funds to continue research, or have higher priorities:

- City of Cape Coral, Florida
- City of Everett, Washington
- Lake Arrowhead Facility, University of California-Los Angeles, California
- Southern Nevada Water Authority, Las Vegas, Nevada
- Town of Jupiter, Florida

One of the most completely equipped and instrumented sites in the country (City of Denver Water Reuse Demonstration Plant) has been shutdown for some time now and the equipment has been cannibalized to the point that future use of this facility will require substantial investment. Some of the equipment formerly operated at the Los Banos, California site are now being offered for sale at prices significantly lower than acquisition cost (vapor compression evaporator, Rankine cycle engine). These sites represent the unfortunate demise that many research facilities are now facing.

New facilities added for this survey include:

- University of Alaska, Fairbanks, Alaska
- Arizona State University, Tempe, Arizona
- University of Connecticut, Storrs, Connecticut
- University of Nebraska, Lincoln, Nebraska
- North Carolina State University, Raleigh, North Carolina
- University of North Carolina, Chapel Hill, North Carolina

One of the goals of this survey was to obtain more accurate information from respondents on the cost of facilities and services. The response was much better than the first survey, but many institutions are still reluctant to divulge their costs and prefer to negotiate. A few institutions, had well funded research institutes and chose not to participate in this program. Several facilities anxious to participate in the Centers program offer their facilities at no cost other than utilities and consumables at cost.

The information received from the candidate sites varied considerably, from a single faxed page to bound volumes. The information provided on the following pages is indicative of the information received.

With the addition of facilities and loss of others, the pilot plant facilities, laboratory facilities, and private sector companies represent 27 states, a few more than the previous survey.

The institutions contacted continue to express support of the Centers concept and the partnering of universities, private industry, and government, but anxiously await the next positive step forward.

¹National Centers for Separation and Thermal Systems Research - National Facilities Survey, National Water Research Institute, Fountain Valley California and U.S. Bureau of Reclamation, Denver, Colorado, September 23, 1994.

PART 1

Background

BACKGROUND

The concept for a National Centers program for water treatment technology grew from the Membrane Research and Development cooperative program between the National Water Research Institute and the U.S. Bureau of Reclamation. An initial survey of facilities was conducted in 1994. The program was joined in 1996 by the U.S. Army.

The National Centers for Water Treatment Technology is predicated on a joint venture as defined by the Steven-Wydler Technology Transfer Act of 1978, as amended. It recognizes that many organizations do not have the singular ability to underwrite the costs of research in today's economic climate. By bringing together organizations with mutual interests, a partnership can be fostered whereby cost sharing can enable projects to be funded at levels which each partner would find difficult to achieve alone. Utilization of existing facilities can be optimized by coordinating their availability to the wider research community.

The mission of the program is to facilitate, coordinate and integrate national research to develop and promote water purification technology.

The goal of the program is

- To develop and implement a strategy that will create and cultivate partnerships between Government, university, and industry that will facilitate research and enhance technology transfer of research projects.
- To promote the cost-effective allocation of financial, human, and facilities resources.
- To establish and maintain an information and data exchange system to improve the coordination between engineering and technology research.

The National Centers for Water Treatment Technology Research Concept (see figure) is predicated on a joint venture as defined by the Steven-Wydler Technology Transfer Act of 1978, as amended. It recognizes that many organizations do not have the singular ability to underwrite the costs of research in today's economic climate. However, by bringing together organizations with mutual interests, a partnership can be fostered whereby cost sharing can enable projects to be funded at levels which each partner would find difficult to achieve alone. Utilization of existing facilities can be optimized by coordinating their availability to the wider research community.

Principal partners in the National Centers program are the National Water Research Institute, U.S. Bureau of Reclamation, and the U.S. Army. The program envisions three levels of associate partners: governments, universities, and industry. The government partners, e.g. Environmental Protection Agency, National Institute of Standards and Technology, National Institutes of Health, as well as the university and industry partners will all be contributing members to the Centers.

A key element within this concept is the technology transfer strategy. Research deliverables or products must have "real world" application if the investment of resources is to be perceived as worthwhile.

It is envisioned that a number of Centers could be established throughout the country and made available to the partners. Here are some examples:

- U.S. Bureau of Reclamation has two facilities, the Research and Engineering Laboratory in Denver, Colorado, and the recently established Water Quality Improvement Center at the Yuma Desalting Plant, Yuma, Arizona. These facilities can contribute small and large-scale pilot testing, research, operational, and field testing capabilities.
- Orange County Water District's Water Factory 21 facilities, would be made available as well as its research, testing, and operational capabilities.
- The U.S. Army is constructing a new research facility in Michigan which will house the existing activity currently housed at the Fort Belvoir, Virginia location. A laboratory is included.

This is an important moment in the history of our Nation's research programs. A decisive step is required to redesign the manner in which national research is carried out in order to maintain the quality of research. The concept of National Centers is not new, but joint venture partnerships can provide a viable alternative to single source funding. The National Water Research Institute, using private funds, has been very successful in partnering research funds and has funded about \$15 million in research in its initial five years of existence.

There are significant benefits and values of the National Centers Concept:

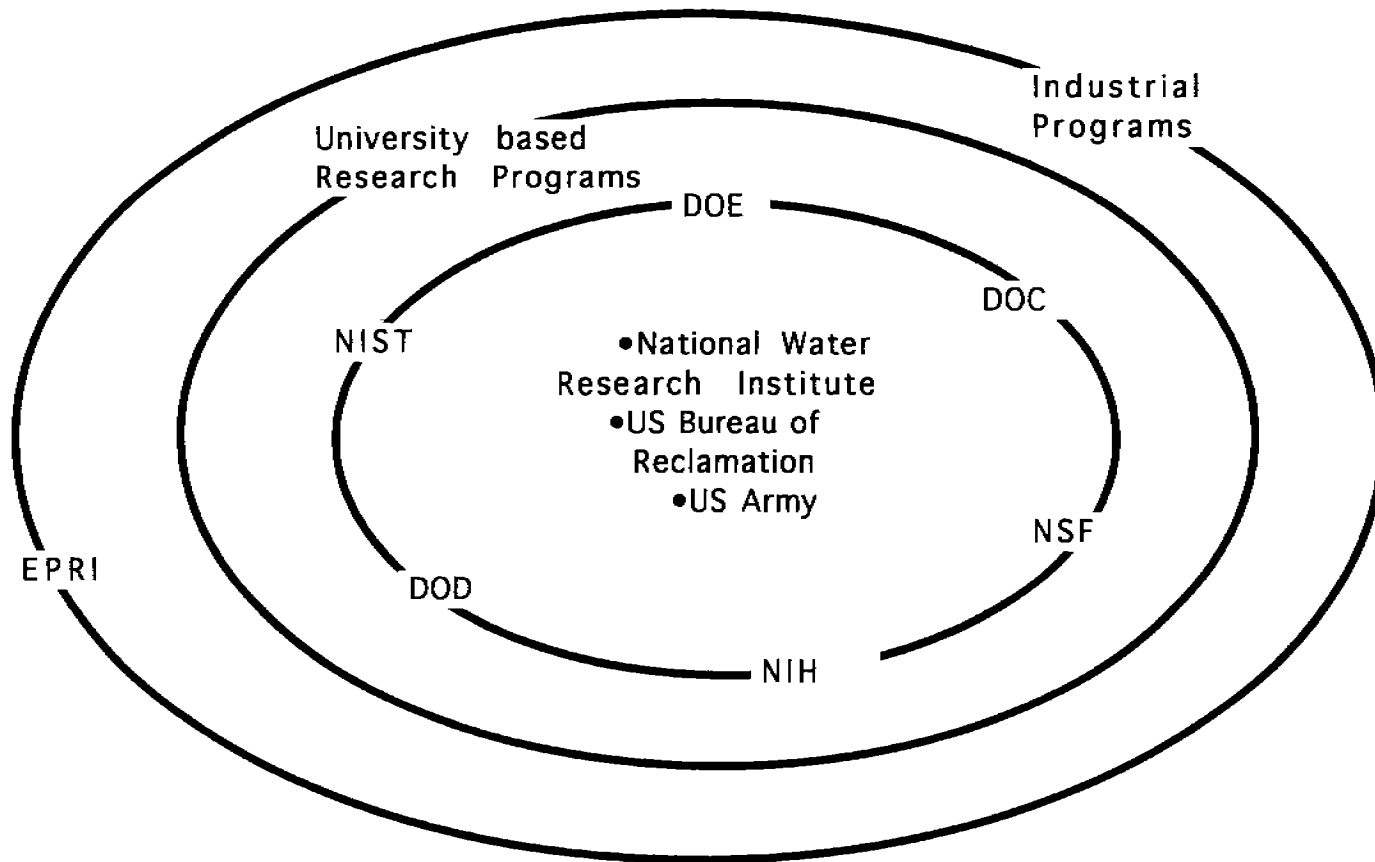
- Shared Resources
- Enhanced technology transfer
- Shared information and data
- Avoidance of duplicate research
- Advancement of science and engineering

The strategy to accomplish these goals is outlined;

- Establish an inventory of facilities, personnel, and financial resources involved in water treatment technology research.
- Identify and organize a consortium of partners (investors) to cost share in the development of the National Centers program
- Identify and describe the set of current and projected annual needs.
- Develop a financial strategy based on the principles of asset allocation including selection criteria and methodologies.
- Design a methodology to track, measure, and document accomplishments on a regular basis.

The Centers concept is an important step to bring together universities, industry, and federal agencies, to concentrate on common goals. Bringing diverse sources of funding together and encouraging the use of under utilized existing facilities will foster the initiation of significant water-related research and development.

NATIONAL CENTERS FOR WATER TREATMENT TECHNOLOGIES



PART 2

Pilot Plant Facilities

PILOT PLANT FACILITIES

The facilities listed in this section represent a wide cross section of water utilities, municipalities, state owned sites, federal facilities, and universities. Each has pilot plant equipment on site which can be made available for research projects. It is believed that the pilot plant step in proving the proof of concept is essential in the development of a process or product.

There was a considerable difference in the attitudes of the respondents with regard to cost of facilities. Many were reluctant to reveal "hard numbers," preferring to negotiate the cost of facilities and services as each research project is developed. The response was much better than experience with the first survey, and there is now a fair estimate of the cost of utilizing the majority of the sites.

ARIZONA

SCOTTSDALE, CITY OF

Water Resources Department
9388 E. San Salvador Drive
Scottsdale, Arizona 85252

Administrator: Marty Craig
Telephone: 602-391-5684
Fax: 602-391-5615

The City of Scottsdale embarked on a research program to determine the efficacy of microfiltration followed by reverse osmosis or nanofiltration for treatment of municipal wastewater effluent. To accomplish their goals, a test site was erected which houses two microfiltration skids, chlorine disinfection, and a reverse osmosis skid capable of testing three reverse osmosis or nanofiltration combinations concurrently. The pilot plant equipment is placed in a compact area (Figure 1).

The Water Campus Pilot Plant is located at the southeast corner of the intersection of Scottsdale Road and Mountain View Road. A 3" influent line comes from the Gainey Ranch Water Reclamation Plant to a 2,145 square foot concrete slab, shade structure, chemical storage area with secondary containment, potable water system, sewer, 480-volt power supply, trailer, security system, and outdoor lighting.

A summary of equipment at this site is presented in Table 1. The pilot plant computer, PLC, and variable frequency pump drives are located inside the trailer. Office space and supplies, laboratory equipment, and restroom facilities are also located inside the trailer.

The first priority for the water campus pilot plants is to complete their on-going research project. Decisions on further testing or maintaining active equipment and facilities will depend upon the immediacy of proposed research programs.

Table 1. City of Scottsdale: Equipment, Instrumentation and Controls

1. Microfiltration
 - Two Memcor model 60M10C units arranged in parallel with automatic flow control and automatic air backwash. The units are currently operated as 4M10c's to better match the flows required for current testing. Two cartridges on each unit are not in service.
2. Reverse Osmosis
 - Three parallel trains
 - 2:1 arrays
 - 20' long pressure vessels accommodate six 40" or four 60" membrane elements
 - Pressure vessels rated at 600 psi
 - Membranes available:
 - Fluid systems CA elements 4" x 40", 18 total
 - Fluid Systems low pressure CA ROGA elements, 4" x 60", 12 total
 - Fluid Systems Thin Film Composite elements, model TFCLHR, 4" x 40", 18 total
 - FilmTec polyamide nanofiltration elements, model NF70, 4" x 40", 18 total
 - FilmTec polyamide thin film composite elements, model BW30-4040, 18 total
 - Piping flexibility allows operation of one train in 4:2:1 array.
3. Membrane cleaning
 - Cleaning system pump
 - 2-chamber wash/flush tank
 - Flexible hoses and quick disconnects
4. Post treatment
 - one DeLoach decarbonation tower (not currently in use)
5. Pre treatment auxiliary equipment
 - 2 air compressors
 - One 200 gallon air receiver
 - One backwash surge tank
6. Instrumentation and controls
 - Flowmeters
 - Pressure sensors and transmitters
 - Differential pressure transmitters
 - Pressure gages
 - Pressure switches
 - automatic air backwash controls for microfiltration
 - Automatic flow control for microfiltration filtrate flow
 - Automatic RO shutdown controls for high/low pressure and high/low pH
 - Automatic flushing sequencer for RO train shutdown
 - Automatic VFD pacing
7. Analytical instrumentation
 - Low range turbidity analyzers
 - Surface scatter turbidity analyzer
 - Conductivity analyzer/transmitter
 - pH sensors and analyzers/transmitters
 - Chlorine residual analyzers
 - Temperature transmitter
 - Silt density index analyzer
 - Spectrophotometer
 - Colorimeter

CITY OF SCOTTSDALE WATER CAMPUS Pilot Plant Equipment Layout

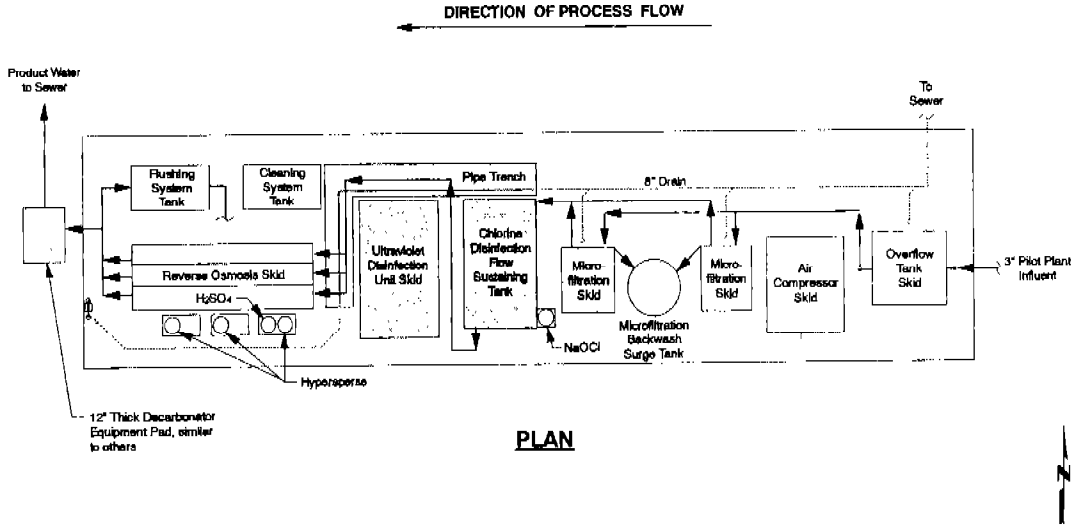


Figure 1. City of Scottsdale Water Campus: Pilot Plant Equipment Layout

BG
VH

Revised May 2, 1994

CITY OF SCOTTSDALE WATER CAMPUS Pilot Plant Schematic

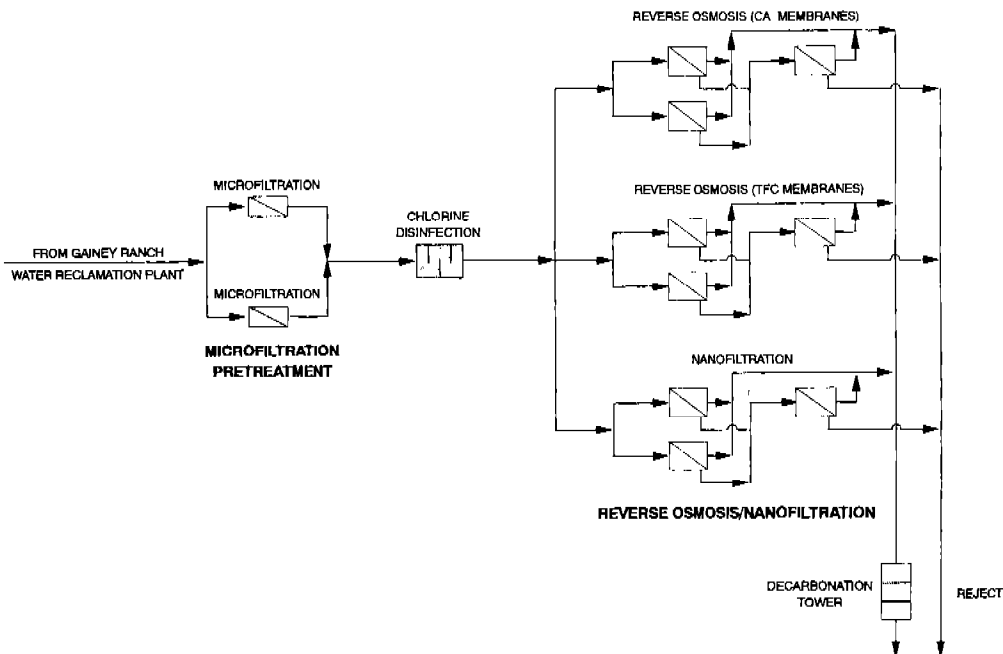


Figure 2. City of Scottsdale Water Campus: Pilot Plant Schematic

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VH

Revised May 2, 1994

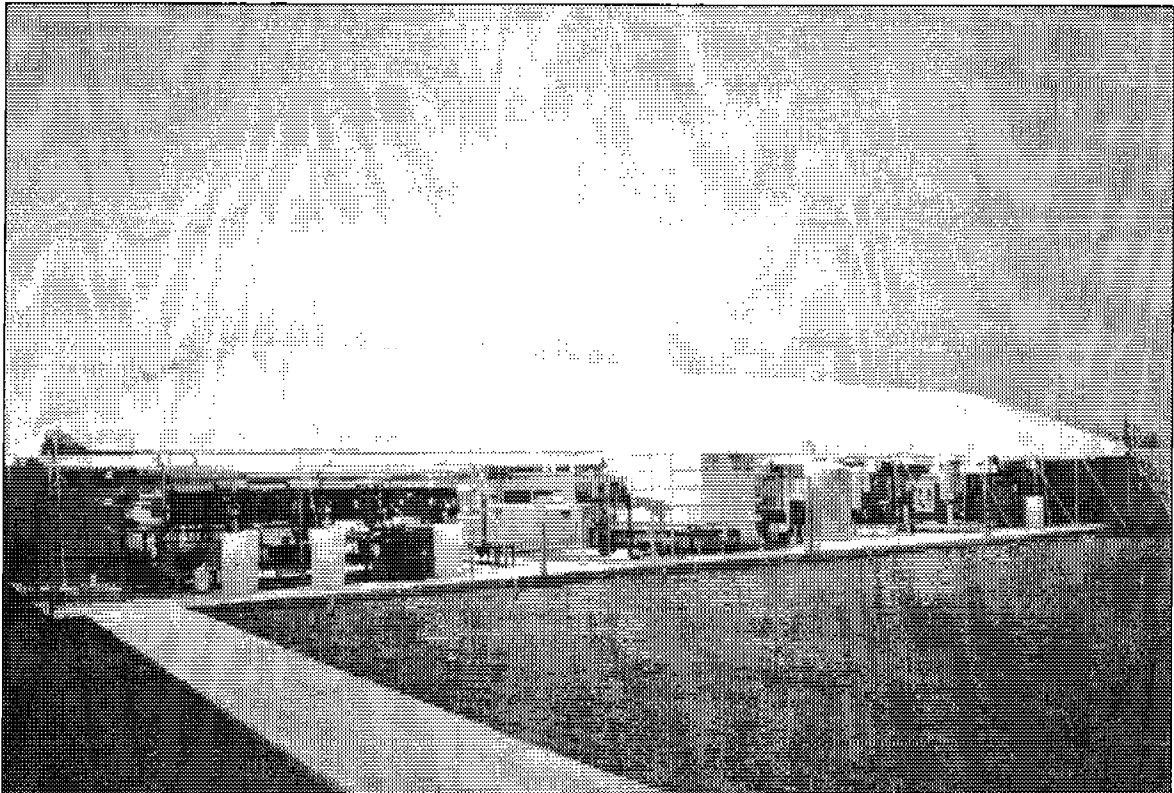


Figure 3. City of Scottsdale Water Campus

7/88; Edn. Pleasant View Road
Scottsdale, Arizona 85208

ARIZONA

US BUREAU OF RECLAMATION

Water Quality Improvement Center
Yuma Desalting Plant
P.O. Box D
Yuma, Arizona 85366

Administrator: Paul McAleese
Telephone: 520-343-8229
Fax: 520-343-8320

Desalination research and development has been conducted at the US Bureau of Reclamation (USBR) Denver laboratories since the late 1950's. However, a more recent USBR desalination R&D effort has been conducted at the Yuma Desalting Plant (YDP) at what is called the Water Quality Improvement Center (WQIC).

The initial research activities were the investigation into the most effective pretreatment methods, proper long term storage procedures for membranes, and optimization of the reverse osmosis process for the YDP. The YDP is the world's largest reverse osmosis facility rated at 73 mgd. A successful research program was carried out to determine the cause of "front-end" deterioration of cellulose acetate membrane elements. The likely cause was found, a remedy was established, and a potential major problem was averted.

Current research activities at the WQIC include not only desalination research related to the YDP but also for outside entities. The WQIC serves as a field site to investigate new and improved water treatment technologies including pretreatment associated with desalination. The intent is to make pilot water research and field testing more cost effective and practical for entities such as the U.S. Government, desalting researchers, universities, water treatment companies, municipalities, private industries, and foreign governments. The WQIC is available for research and development projects to further the desalination state of the art on a cost-shared or cost-reimbursed basis.

The WQIC is a cornerstone of the Centers for Water Treatment Technology initiated by the Bureau of Reclamation and the National Water Research Institute (NWRI). Until now no united means existed to coordinate the water quality research efforts of government, academia, and private industry in order to efficiently advance this research.

Services provided at the WQIC to benefit our customers include:

- Experienced maintenance workers and 24-hour licensed water treatment operators.
- Engineering and technical staff with expertise in water treatment processes and instrumentation, including services relating to computer control and data acquisition systems.
- Fully staffed and licensed State of Arizona environmental laboratory that can conduct drinking water and waste water analyses, bacteriological analyses, and analyses of major inorganic constituents of water.
- Fully furnished office facilities with utilities including telephone, fax, and computer data transfer lines.
- Discharge and waste permits in place.
- Classroom and hands-on operator training programs.
- Cooperative R&D agreements can be implemented to handle the individual needs of an entity taking into account such concerns as patenting rights and non disclosure of proprietary data.

Water Quality Improvement Center

WQIC technical information and features include:

- Various brackish water process trains- one at 600 gpm, two at 50 gpm, 600 gpm connection to an on-site groundwater well.
- Process trains include- sedimentation lime softening (rapid mix, flocculation, and clarification), chemical addition, media filtration, microfiltration, ultrafiltration, nanofiltration, and reverse osmosis membranes.
- A range of brackish feedwater salinities can be made available for testing.
- Chemical processes include- disinfection, chlorination/dechlorination, ammonia/chloramination, other biocides and methods of disinfection are available.
- Processes are fully instrumented and feature a networked Supervisory Control and Data Acquisition (SCADA) computer system with Internet access to data files.
- A 11' x 15' computer control room and a 11' x 20' wet laboratory room are available.

- Because there is sufficient clear space at the WQIC, other types of customer-supplied small pilot scale plants or desalination processes can be tested.

Costs:

The following are some general costs for facilities and services. Actual costs are determined after examining the needs of the research project and then a research agreement is established on this basis.

1. Plant operator, maintenance worker, or engineering technician: \$25.00/hour
2. Process engineer \$45.00/hour
3. 150 square foot office space \$125.00/month
4. Complete inorganic laboratory water analysis \$100.00/analysis
(includes TDS, major ions, pH, and turbidity)

Table 2. USBR WOIC Equipment

ARIZONA

Table 2. USBR WOIC EQUIPMENT					
CENTER: US BUREAU OF RECLAMATION - WATER QUALITY IMPROVEMENT CENTER					
LOCATION:	Yuma, Arizona				
Feed streams:	Brackish irrigation return flow Well Water (Colorado River Water) A range of brackish feedwater salinities can be made available.				
Equipment:					
	Reverse Osmosis Test Units	Dual Media Gravity Filters	Solids Contact Reactors	Clearwells	Element Check Apparatus
No. of Systems	8	3	3	3	2
Average feed flow, gpm	1@350 1@200 6@12	1@600 2@50	1@600 2@50		1@85 1@50
Pressure, psi	450				
Size, gallons			1@135,000 2@5500	1@60,000 2@75	
Number of stages	up to 2				1
Elements per stage	varies from 1 to 7				1
Recovery, %	varies up to 80%				up to 10%
Element size, inches	1.5, 4.0, 8.5, 12.0				8.5, 12.0

CALIFORNIA

ARLINGTON DESALTING PLANT

Santa Ana Watershed Project Authority

11615 Sterling Avenue

Riverside, CA 92503-4979

Administrator: Neil Cline, G.M.

Telephone: 909-785-5411

Fax: 909-785-7076

The Arlington Desalting Plant is owned by the Santa Ana Watershed Project Authority. It operates a 6 mgd reverse osmosis desalter, with the concentrate disposed to the Santa Ana Regional Interceptor, which conveys wastes to the Orange County Sanitary District for treatment and ocean disposal. The plant utilizes brackish groundwater with micron filtration and was installed to reduce the level of nitrates in the groundwater.

Sufficient space is available on-site for conduct of pilot plant testing with telephone and fax available. Although the availability of on-site research support is uncertain at this time, office space is available.

Previous pilot plant studies have been carried out at the plant, including one with a new electro dialysis membrane. The general manager has been a long time proponent of technological advancement and would welcome additional research efforts. The cost of facilities is negotiable and institutions or companies wishing to engage in R&D would be expected to assume any costs incurred by SAWPA in support of the R&D effort. The site would provide a good test site with supportive management.

Estimated cost:

It is anticipated that the facilities will be made available at direct cost with no additional overhead charges.

CALIFORNIA

CALIFORNIA - LOS ANGELES, UNIVERSITY OF

Lake Arrowhead Community Services District Facility

#1 Pilot Rock Road, Grass Valley WWTP

Lake Arrowhead, California 92352

Administrator: Prof. Michael Stenstrom

Telephone: 310-825-1408

Fax: 310-206-5476

The University of California at Los Angeles, Department of Civil Engineering, owns and operates a fully equipped pilot for reclaiming municipal secondary effluent at the Lake Arrowhead Community Services District Facility.

Equipment available:

- Denitrification
- Clarification

- Filtration
- Carbon adsorption
- Ozonation (10,000 gpd)
- Ultrafiltration (4,500 gpd)
- Reverse osmosis (3,000 gpd)

Instrumentation:

- G.E. Fanuc automation with programmable logic controllers

Analytical equipment:

- GC/MS
- IC
- AA
- Visible spectrum UV spectrophotometry
- Biological testing

Wastewater effluent is available at the site and the equipment is in excellent condition.

Both PC and Mac computer facilities are available with telephone and fax communication. The university is currently in the process of disassembling and re-assembling the pilot facilities.

Although it is not currently available for external research, it may be in the future.

CALIFORNIA

CAMBRIA COMMUNITY SERVICES DISTRICT

2200 Center Street

Cambria, California

Administrator: David Andres; Dan Hartman

Telephone: 805-927-3050

Fax: 805-927-0178

The Cambria Community Services District is constructing a 1 mgd seawater reverse osmosis facility, which will be built in three phases: 300, 200, 200 gpm. Alternative phases 2 and 3 will consider groundwater recharge with effluent recovery using brackish water reverse osmosis. This alternative was piloted earlier with a 10 gpm packaged reverse osmosis unit, which is now available for use.

The facility will be housed in a 72' x 210' building. Approximately 72' x 30' will be available for pilot plant testing after phase one is installed. Four office cubicles will be available for researcher use with access to telephone, fax, and computer terminal. The facility is located in a quiet preserve, with ideal conditions for research.

The following feed sources are available at the site:

- Seawater
- Wastewater effluent
- Brackish well water
- Wastewater effluent processed and percolated, recovered from wells
- Pre-treated seawater

Equipment available:

- 100 or 200 gpm trains for seawater desalination
- 10 gpm brackish water reverse osmosis packaged unit, 2 stage

Laboratory facilities:

- Laboratory facilities with standard process analysis
- Bench space available for portable analytical equipment

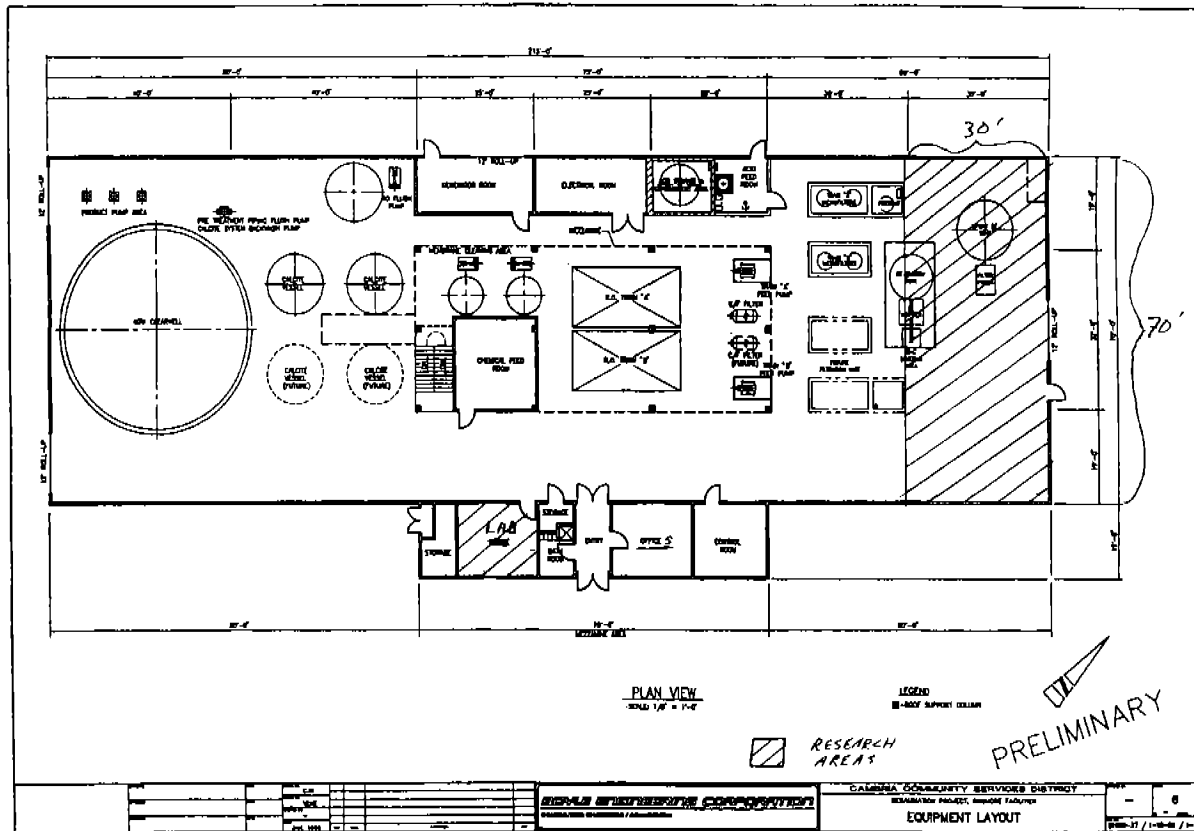


Figure 4. Cambria Seawater Desalination Facility Layout

CALIFORNIA

CONTRA COSTA WATER DISTRICT

Water Quality section

201 Bates Ave.

Concord, California 94520

Administrator: Larry J. McCollum

Telephone: 510-674-8127

Fax: 510-689-5936

The Contra Costa Water District has a modular pilot plant which is a scaled down version of their existing plant and is located adjacent to the main plant. It is a dual train system capable of 9 gpm through each train through the flocculation step. Thereafter it is reduced somewhat. It also contains a full scale sedimentation section. The dual train was established to facilitate parallel studies. For example, studies were conducted comparing alum and ferric hydroxide treatment. Granular activated carbon filters are available as well as ozonation.

Equipment:

- Ozone
- Flocculation
- Sedimentation
- Sand filtrations
- Granular activated carbon
- Ultrafiltration pilot plants

Limited laboratory and office space are available.

Estimated cost:

The water district is amenable to establishing collaborative research programs with their staff and facilities representing in-kind contributions to the cost of the research program. Their overhead rates are about 30 %.

CALIFORNIA

DEPARTMENT OF WATER RESOURCES

3374 E. Shields Ave.

Fresno, California 93726

Administrator: Kurt Kovac, Sr. Engr., DWR, Dr. Larry Owens, CSU Fresno

Telephone: 209-445-5509

Fax: 209-445-5370

The California DWR maintains a small test facility at their Adams Avenue site in conjunction with Fresno State University. a small volume (10-15 gpm) of agricultural drain water of about 10,000 ppm is available for testing. Several small (2gpm) reactors are available for conducting tests. They are upflow, fluidized bed reactors, designed to investigate the reduction/removal of selenium from agricultural drainage.

Although the test facility at a Los Banos has been closed and is being dismantled, a vapor compression evaporator rated at 50,000 gpd is available at nominal cost. Originally purchased at a cost of \$600,000 plus installation, the plant may require tube replacement and would require moving from the premises. The DWR is anxious to cooperate in order to facilitate its use in further research efforts.

The electro dialysis reversal unit installed at Los Banos is also available, but the wear and tear from exposure to the elements probably make refurbishment more costly than a new pilot plant.

Also available from DWR are a 1,210 gallon clarifier and a 10 kw Rankine cycle engine.

Facility cost:

Nominal, direct cost of utilities

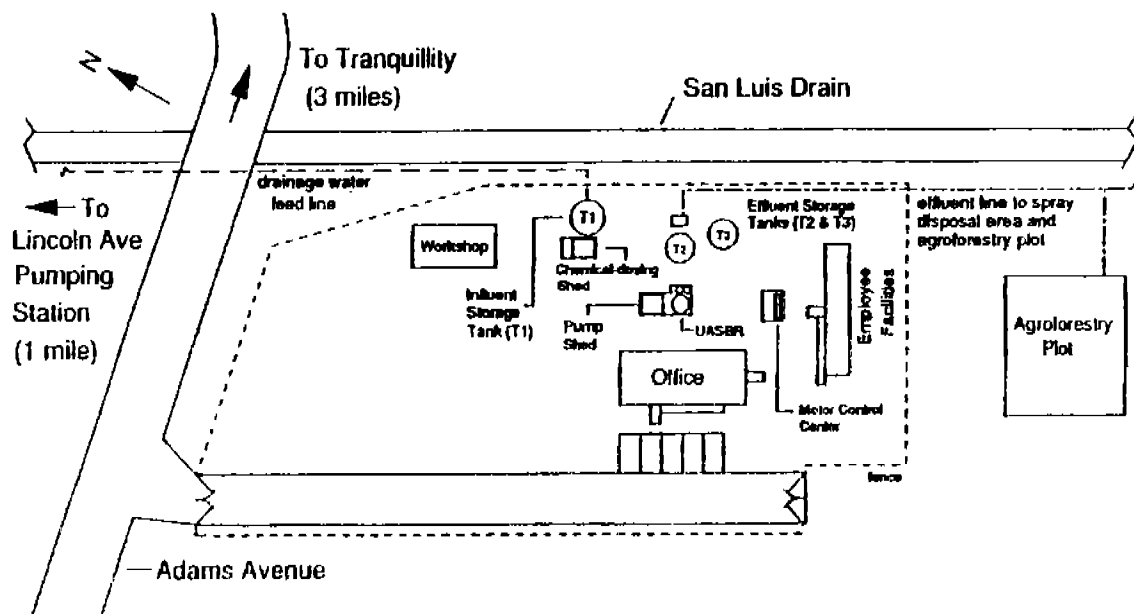


Figure 5. California DWR: Adams Avenue Test Facility Layout

CALIFORNIA

IRVINE RANCH WATER DISTRICT

Organic Removal Pilot Facility
3232-1/2 So. Greenville
Santa Ana, California 92704

Administrator: Kenneth A. Thompson
Telephone: 714-453-5620
Fax: 714-453-0228

The Irvine Ranch Water District established a water research test facility at a site with access to a highly colored groundwater aquifer, the Dyer Road Well Field. The Organic Removal Pilot Facility was designed and constructed in 1992 to examine the feasibility of turning this highly colored groundwater into high quality potable water. The facilities are comprised of the following unit Processes:

- Conventional ozonation
- In-line ozonation
- Membrane separation
- Granular activated carbon adsorption
- Biological activated carbon filtration
- Conventional clarification
- Deep-bed filtration

The process characteristics and description are summarized in the following table. Pre-treatment for the membrane section is by cartridge filter, acid and/or anti-scalant addition. Post-treatment is by ozonation and chemical addition. A skid mounted unit is available for membrane cleaning.

On-line continuous monitoring of low rate, color, turbidity, pH, electrical conductivity, temperature, ozone residual, percent ozone, and pressure levels from multiple sample locations is provided. The control system is comprised of a Modicon 984-685 PLC that collects instrumentation signals and a PC operating with Wonderware In-Touch Operator Interface Package and Microsoft Excel. The system has three functions: data acquisition, displays of all current values, and data logging every 10 minutes into a master spreadsheet and optionally logged at desired frequencies into three other spreadsheets.

Analytical equipment:

- Amicon UF separation
- UV/VIS HP spectrophotometer
- Cole Parmer pH meter
- Turbidimeter
- Alkalinity, hardness, dissolved oxygen and ozone kits
- Silt density index kit

Feed water sources:

- 2 groundwater wells
- Wastewater effluent

Telephone and fax are available on-site for communication and PC computers are available. Limited office space is available and excellent support staff present, including process engineers, full service laboratory staff, and supervisory engineers. Special disciplines include advance water and wastewater treatment, environmental engineering, microbial and biologic sciences, regulatory compliance, project management.

The study of colored groundwater treatment was conducted with a grant from the National Water research Institute¹.

Estimated costs:

- Supervisory labor: 60 % OH
- Non-supervisory labor: 60 % OH
- Facilities: \$478 per day (all inclusive)

Table 3. Irvine Ranch Water District

Table 3. Irvine Ranch Water District								
CENTER:	ORGANIC REMOVAL PILOT FACILITY							
LOCATION:	Santa Ana, California							
FEED STREAMS:	Groundwater							
PROCESS:	Ozone Contactors	GAC Filtration	Ozone Reactor	Coag/Floc/Sed	Filter	Micro-filtration	Membrane Unit	Single Element Bench Scale Unit
No. of systems	2	4	1	1	6	1	1	1
Type	Bubble diff.		Eductor	Roberts filter		Memcor 4M1		
Avg feed flow, gpm				40		2		
Capacity, lb/d	7							
Dimensions	0.75'id x 16'	0.33'id x 20'	1.3'id x 16'		0.3' x 20'			
Media type	ceramic disk				mono/dual			
Filtration rate, gpm/sf		2-8		1.5	4-12			
Contact materials	acrylic/PVC	clear PVC	PVC		clear PVC			
No. of stages							2	1
Elements per stage			40				6	1
Recovery, %							75-90	10-30
Element type							spiral	spiral
Pore size, mm						0.2		
CONTROL SYSTEM:	24 hour a day operation. Controlled by Wonderware							

¹Thompson, K., et al, "A membrane Pilot Study on Highly Colored Groundwater in Southern California, Irvine Ranch Water District, 1993.

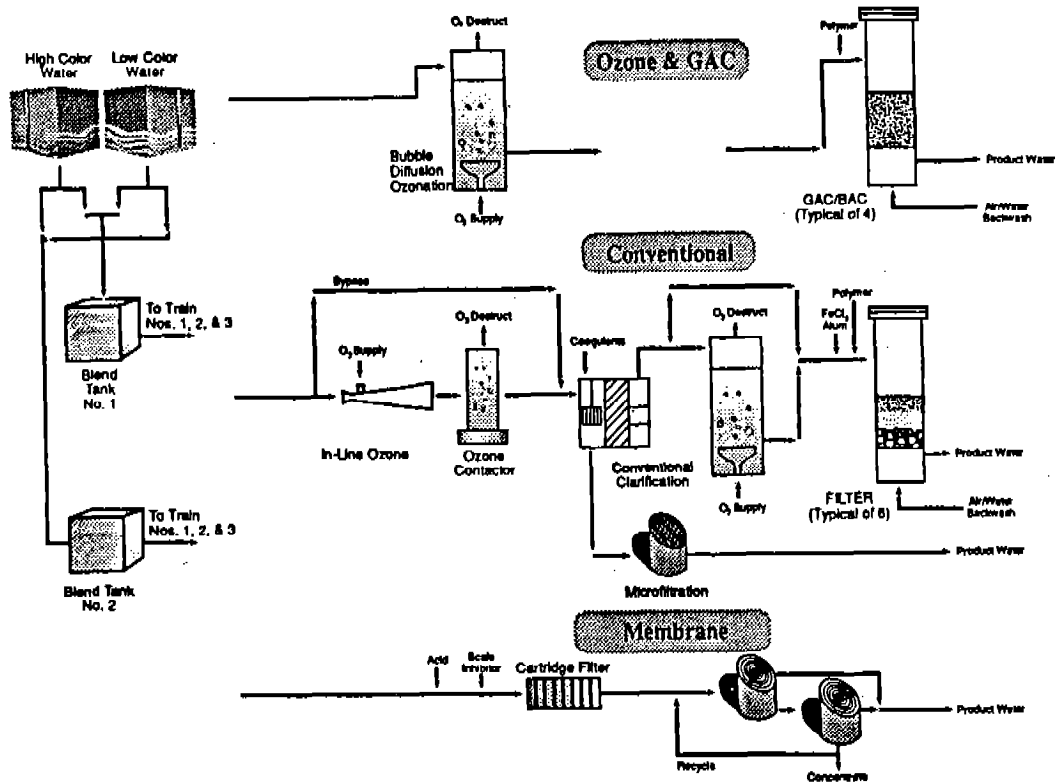


Figure 6. IRWD: Organic Removal Pilot Testing Equipment

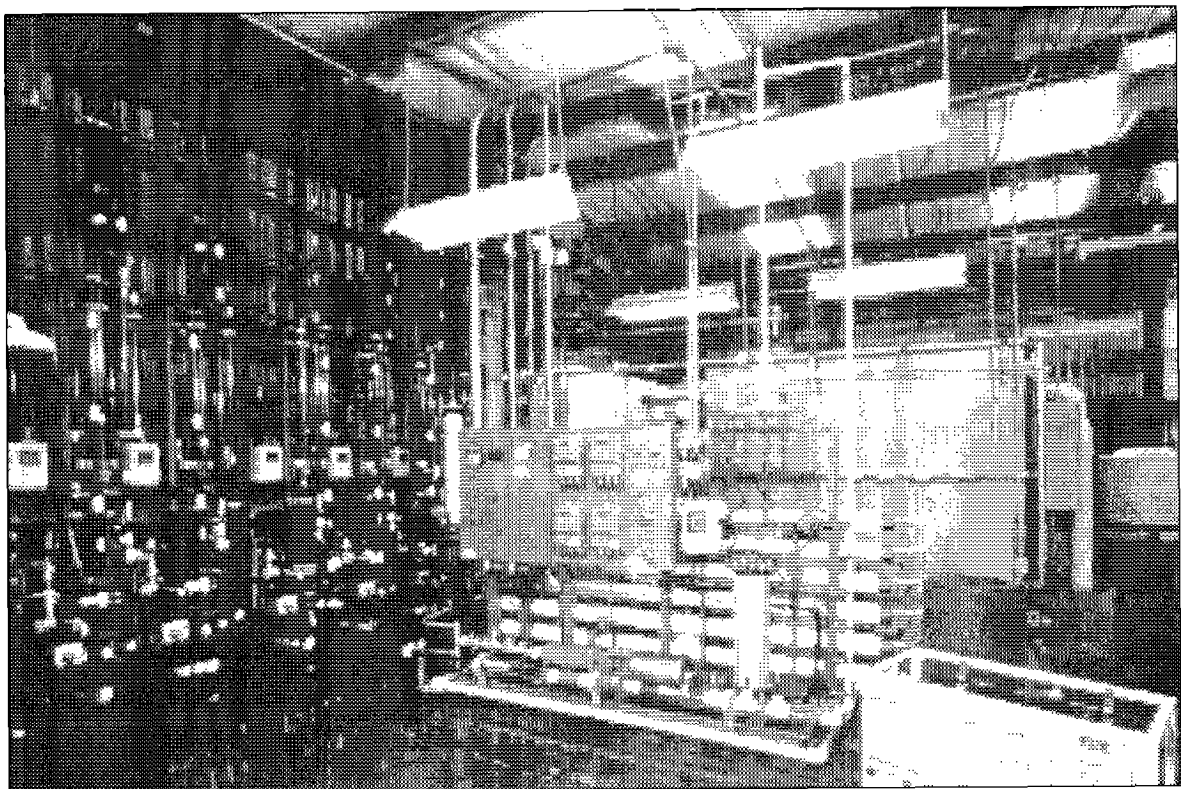


Figure 7. IRWD: Process Treatment Trains

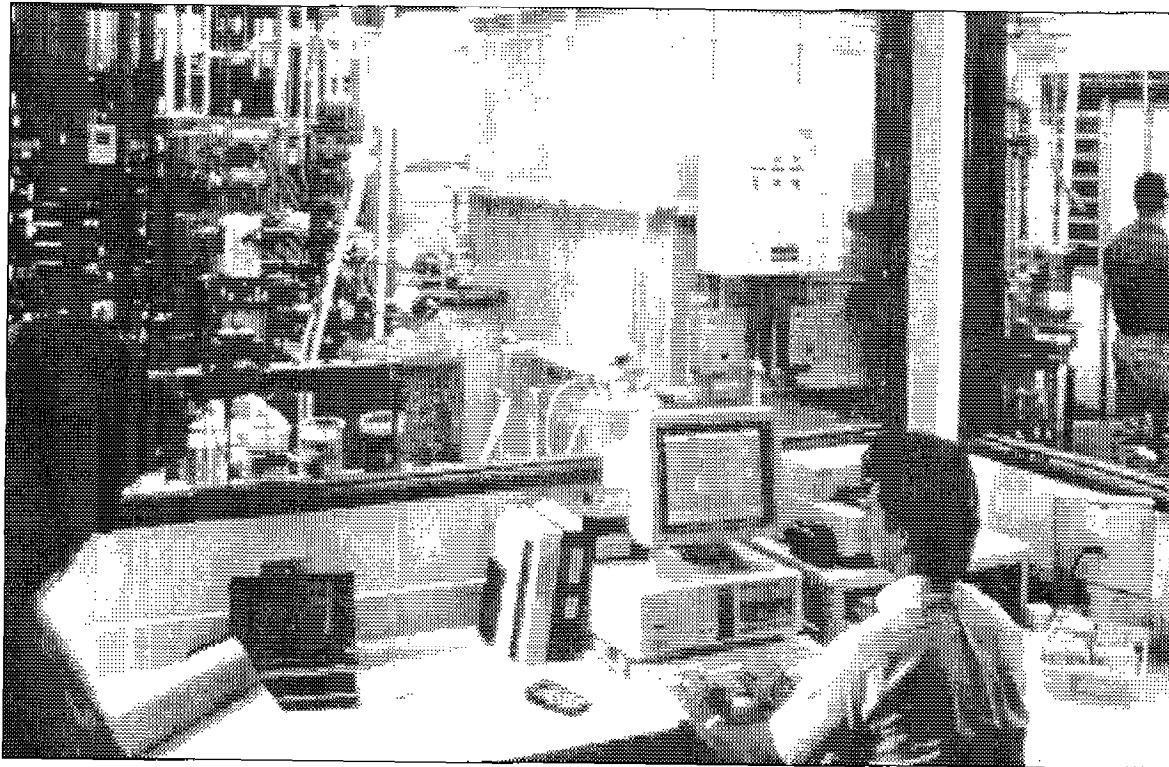


Figure 8. IRWD: Control Center for Data Acquisition & On-Line Monitoring

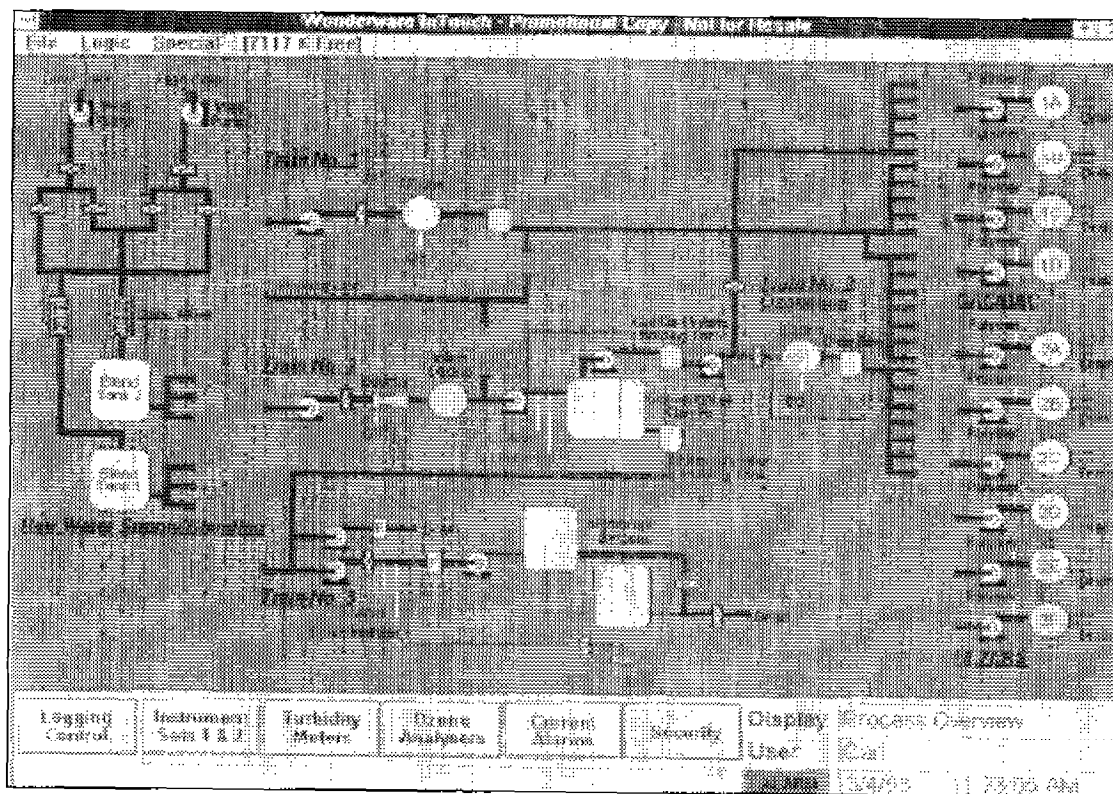


Figure 9. IRWD: Process Control Computer Display

CALIFORNIA

LOS ANGELES, CITY OF

WWRG, WESD, Bureau of Sanitation

Terminal Island Treatment Plant

5555 Terminal Way

San Pedro, CA 90731

Administrator: Kris Flaig

Telephone: 310-548-7767

Fax: 310-548-7772

The Terminal Island treatment Plant (TITP) Pilot Test Facility (PTF) was developed in 1992 to provide support for a study that tested and compared five (5) media filters. The Los Angeles Department of Water and Power recently used the TITP PTF to test and verify the capability of microfiltration to adequately provide pre-treatment for reverse osmosis. Other research efforts have included evaluations of state of the art analyzers and instrumentation as part of the on-going Wastewater Engineering Services Division research program.

Originally a small office, five media filter pilot plants, two 6,000 gallon mixing vessels, other tanks, pumps and several turbidimeters were installed on the 30'x60' concrete pad. The office contains two computers and many meters, by which the combined processes were monitored. Presently the office, concrete pad, power (120, 240, 480v), water and drainage remain in place, and the tertiary pilot unit and appurtenant equipment remain installed.

The facilities will be made available as finances allow and with management approval.

Supporting instrumentation:

- Nissin electric BOD-2000 on-line
- Alka-Pro multi-line alkalinity analyzer on-line
- Respirometer to determine BOD and toxicity
- Particle counter
- Turbidimeters
- Flow meters
- Hach analysis kits
- Fluorometer
- Samplers

All equipment is in good condition and wastewater and wastewater effluent are readily available as feed source. Other feedstreams can be accommodated. PC computer facilities are utilized and communications include phone and fax.

Research support is available including supervision, staff, caretakers and maintenance. Limited office space is available. The daily rate for facilities is negotiable and support services may be available at cost, including standard overhead.

CALIFORNIA

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

La Verne Water Treatment Plant

700 Moreno Ave.

La Verne, California 91750

Administrator: Dr. Sun Liang

Telephone: 909-392-2914

Fax: 909-392-5246

At their La Verne facility, the Metropolitan Water District maintains pilot plant membrane equipment for testing.

Equipment:

- Single element membrane test unit, 350 psi, approximately 2 gpm product
- Mobile RO test unit, 1200 psi
 - 5 μ cartridge filters
 - chemical cleaning
 - flowmeters, chlorine analyzer, conductivity meter, pressure gages
- Membranes on hand include nanofiltration and ultrafiltration

Analytical equipment:

- Chlorine analyzer
- Turbidimeter
- Conductivity meter
- pH meter

Both PC and Mac computers are available as is office space. Research support is available with two associate engineers, one assistant engineer, one engineering technician as well as senior and associate engineers for supervision. Facility and equipment are maintained by staff technicians. All of the staff members have extensive water treatment backgrounds with some having additional background in membrane processes.

Telephone, facsimile and e-mail services are on-site.

The equipment is normally reserved for use by one of MWD's member agencies. It may be available to others when not in use by member agencies, at a cost to be negotiated.

CALIFORNIA

ORANGE COUNTY WATER DISTRICT

WATER FACTORY 21

10500 Ellis Ave., P.O. Box 8300

Fountain Valley, California 92728-8300

Administrator: William R. Mills, Jr., G.M.; Bill Dunivin, Plant Manager

Telephone: 714-378-3266

Fax: 714-378-3374

Water Factory 21, owned and operated by the Orange County Water District has become the premier advanced wastewater treatment facility in the U.S. The District has consistently been on the leading edge of technology in finding improved methods for water reclamation. Through a pro-active strategy with regulators and legislators, they were the first to obtain a permit for direct injection of reclaimed water into groundwater aquifers. Their concept of injecting reclaimed water into barrier wells to prevent the intrusion of seawater has served as a model throughout the Los Angeles basin.

Equipment:

- 5 mgd reverse osmosis plant featuring
 - extensive membrane testing and evaluation facilities
 - state certified analytical laboratory
 - Biotechnology Research Department with active research programs in bacterial attachment and biofilm formation on membranes

- Pilot plants, 1 to 500 gpm:
 - Reverse osmosis
 - Microfiltration
 - Ultrafiltration
 - Nanofiltration
 - Vacuum distillation
 - Ozonation
 - Filtration processes

- Membranes
 - Cellulose acetate membranes
 - Thin film membranes
 - Polyamide membranes
 - Experimental polymers

- Elements
 - Spiral wound
 - Hollow fiber
 - Flat sheet
 - Alternative flow spacer designs and module configurations

- Supporting equipment
 - High pH lime clarification
 - Disinfection (UV, O3, CL2)
 - Microfiltration
 - Multi-media filtration
 - Cleaning skids

- State certified analytical laboratory

Feed water sources:

- Brackish water (well)
- Seawater (limited quantity)

- Wastewater
- Wastewater effluent
- Groundwater

Concentrates are disposed via city sewer. The Orange County Wastewater Treatment Plant is next door.

Excellent computer facilities are available including PCs. The equipment on-site is all in excellent condition and is well maintained. The facility is serviced by 3 shifts of operations and maintenance. Supervision is available, but limited. The Biotechnology Research Group provides exceptional capabilities. Office space is limited.

Cost:

Facilities: Cost of expendable supplies (chemicals, power, etc.)

Supervisory and non-supervisory personnel: Direct salaries of personnel utilized.

No overhead costs are anticipated for research at OCWD.

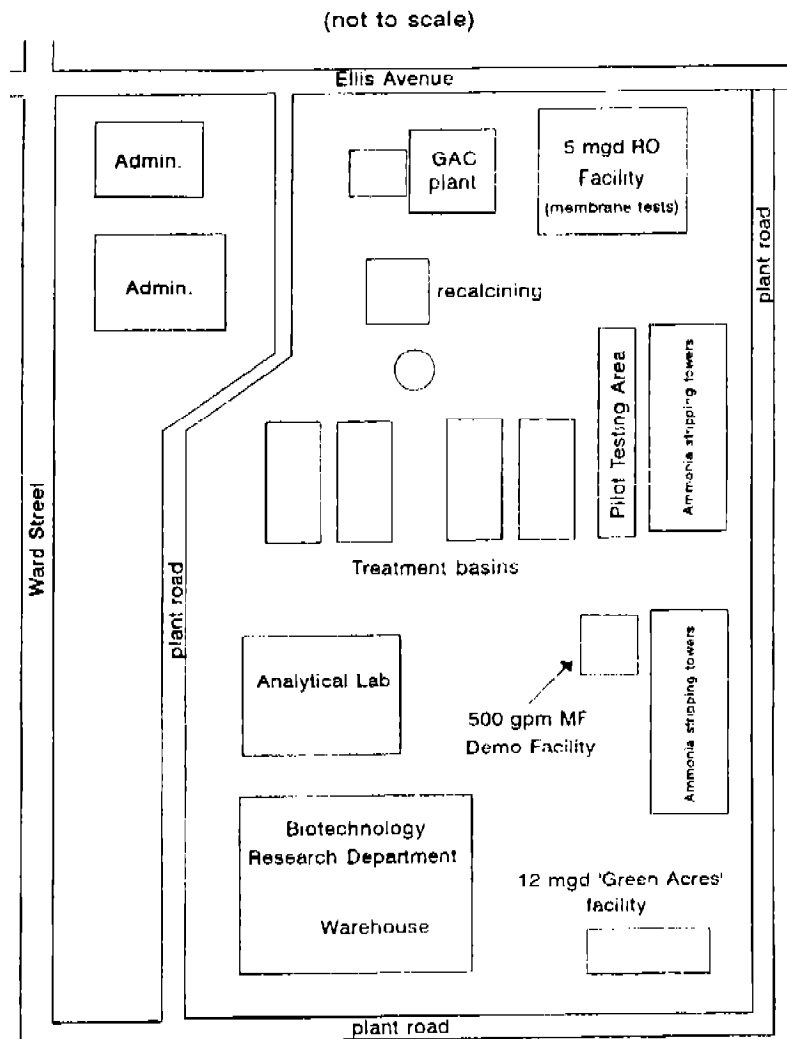


Figure 10. OCWD: Water Factory 21 Facilities Layout

CALIFORNIA

ORANGE COUNTY WATER DISTRICT WATER FACTORY 21

Biotechnology Research Department Facilities
10500 Ellis Ave., P.O. Box 8300
Fountain Valley, California 92728-8300

Administrator: Dr. Harry F. Ridgway, Director

Telephone: 714-378-3266

Fax: 714-378-3374

Several research and development programs related to membrane separations are currently underway within the Biotechnology Research Department. these programs include

- (1) studies on the identification and analysis of chemical biocides for retarding biological fouling of membranes,
- (2) analysis of biocide penetration and transport in membrane biofilms, and
- (3) investigation of the mechanism of bacterial attachment and biofilm growth in membrane systems.

The department is a state-of-the-art facility designed to meet the needs of scientists and engineers engaged in fundamental and applied studies related to water treatment and groundwater management.

Analytical capabilities:

- Digital confocal microscopy coupled with 3D specimen reconstruction/manipulation
- Conventional epifluorescence light microscopy
- Attenuated total reflection Fourier transform infrared spectrometry
- Electronic particle distribution analysis
- Ion chromatography
- Total organic carbon and organohalide analysis
- Spectrofluorometry
- Digital image processing and analysis
- Protein and nucleic acid electrophoretic separations
- Ultracentrifugation
- Gene probing and other molecular genetic techniques
- Electron microscopy is performed in the Department of Biology, University of California, Irvine, approximately 10 minutes from OCWD

Approximately 15 scientific and technical personnel comprise the Biotechnology Research Department. Education backgrounds range from the bachelors to the doctoral degree in microbiology and chemical engineering.

CALIFORNIA

PADRE DAM MUNICIPAL WATER DISTRICT

Santee Water Reclamation Facility
c/o Padre Dam MWD, P.O. Box 719003
Santee, California 92072

Administrator: Harold Bailey
Telephone: 619-258-4689
Fax: 619-258-8774

The Padre Dam Municipal Water District owns a 4 mgd secondary plant (of which 1 mgd is currently utilized), followed by oxidation pond effluent polishing. They also have a 2 mgd "Bardenpho" process consisting of flocculation/clarification, denitrification filters, phosphorous precipitation, chlorine contact, and dechlorination with sulfur dioxide.

The facility has two concrete tanks available, concrete pads, and 40 million gallons oxidation ponds. A control/office building is on site. A basic water and wastewater laboratory conducts all of the analysis required on-site. The equipment is being upgraded. Both wastewater and wastewater effluent are available as feed water sources.

Telephone, fax, and e-mail communications are available. Supervision and facilities caretakers and maintenance are available. Office space is available.

CALIFORNIA

SAN DIEGO, CITY OF

San Pasqual Aquatic Treatment Facility (Aqua III)
Department of Water Utilities
14103 Highland Valley Road
San Diego, California 92128

Administrator: Mr. Paul Gagliardo
Telephone: 619-668-2072
Fax: 619-668-2062
Voicemail: 619-538-8184

The City of San Diego has been active in the development of processes for wastewater reclamation since the late 1960's when a tubular reverse osmosis system was installed at Point Loma Wastewater treatment Plant for treatment of raw sewage. Through the years, other processes such as ultrafiltration and water hyacinths have been examined. A small facility was built in Mission Valley (Aqua II) to demonstrate the applicability of water hyacinths as a natural secondary wastewater treatment process prior to use of reverse osmosis.

After successful operation in Mission Valley, a new, larger facility was built in the San Pasqual area, on Highland Valley Road in north San Diego (Aqua III). The equipment from Aqua II was moved to the new site to accommodate additional research to support the new Aqua III facility. The Aqua II equipment has been renovated and is

in working condition. It was utilized successfully in the 1995 Water Repurification pilot testing of CA and TFC membranes.

The Aqua II pilot plant equipment consists of 2 - 4" vessels and 3 - 8" vessels. additional equipment on site includes clarification, dual media filters, UV, GAC and an air stripper. a cleaning skid is available on site. The equipment is installed on a concrete pad with a protective roof.

The site provides an excellent opportunity to perform R&D using residential wastewater. Secondary and tertiary effluent are available on site.

In 1996, in support of the Water Repurification Project a new testing facility was installed. It consists of a tertiary filter, 2 - 40 gpm membrane pretreatment units (ultrafiltration and microfiltration) and two reverse osmosis skids, each containing 6 - 4" vessels. In addition, the system incorporates ion exchange and an ozonator.

The City is willing to make electricity and space available for R&D, as long as it does not interfere with on-going activities. Laboratory, limited office facilities and a conference room are available. PC computers are on site and some supervision is available. Facility caretakers and maintenance are available on site. Telephone, facsimile, e-mail are available.

No specific charges have been established for use of the facility. The City would probably not charge for electricity and space as long as the research does not encroach upon daily requirements of existing staff. They would consider exchange of facilities for data acquisition depending upon the circumstances.

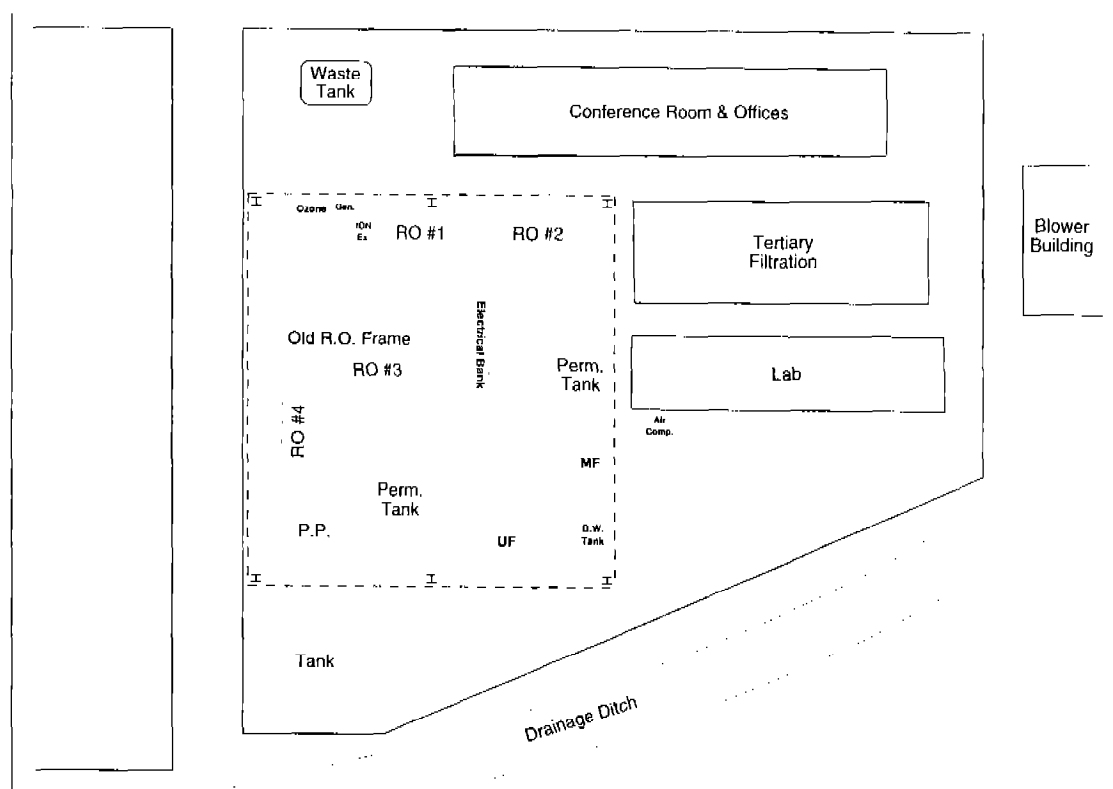


Figure 11. San Diego: AWT Process Pilot Plant Layout

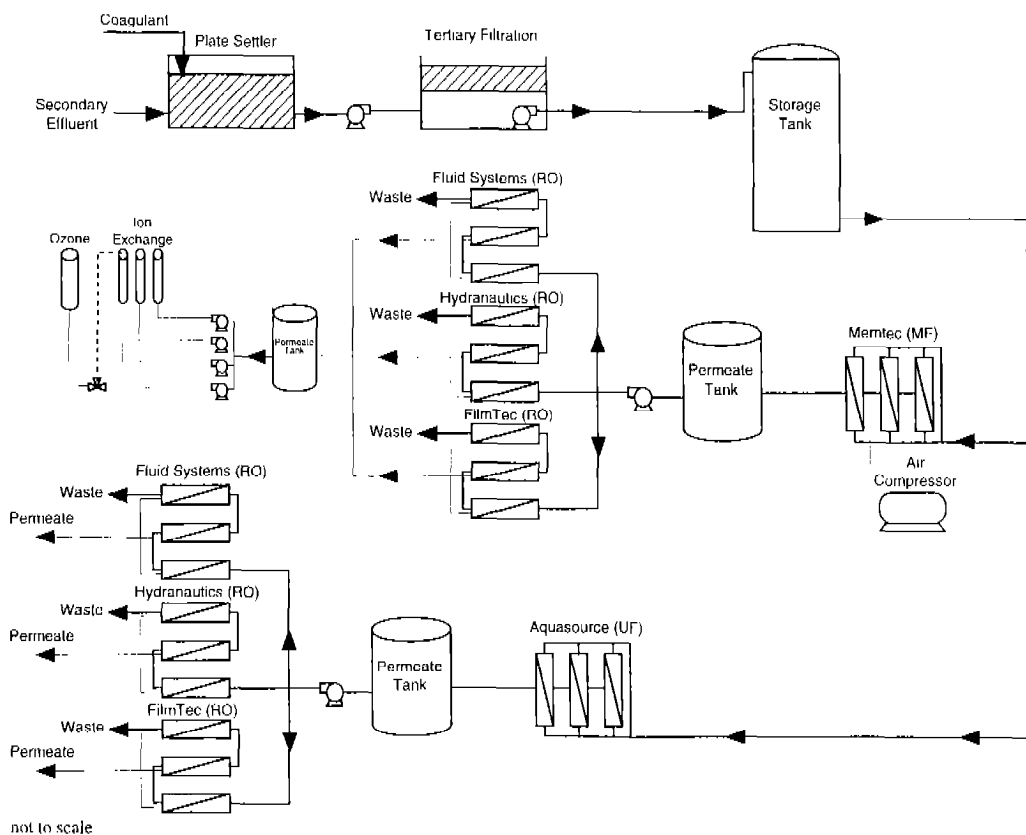


Figure 12. San Diego: AWT Process Pilot Plant Schematic

CALIFORNIA

SAN FRANCISCO, CITY AND COUNTY OF

Southeast Water Pollution Control Plant

Reverse Osmosis Pilot Plant

750 Phelps St.

San Francisco, CA 94124

Administrator: Paul Pitt

Telephone: 415-648-6882

Fax: 415-282-5280

The City and County of San Francisco owns a 30 gpm reverse osmosis pilot plant and a 30 gpm microfiltration pilot plant at their Southeast Water Pollution Control Plant. They are fed with chlorinated/dechlorinated secondary effluent. Instrumentation, controls, and analytical equipment include chlorine analyzers, turbidimeters, programmable logic controllers for both MF and RO, pH analyzers, and reverse osmosis software. Computer facilities for both PC and Mac are available. All equipment is in good condition.

Communications include telephone and fax. Research support is available with staff support, supervision, facility caretakers and maintenance. Both environmental and mechanical engineers are available on-sit. Office space is available. Use and cost of facilities must be negotiated with the City and County of San Francisco.

CALIFORNIA

SANTA CLARA VALLEY WATER DISTRICT

5750 Almaden Expressway

San Jose, California 95118

Administrator: Ms. Sandy Oblonski

Telephone: 409-927-0710

Fax: 408-268-7687

The Santa Clara valley Water District conducted pilot plant tests at their Los Gatos pumping plant to determine viability of using ozone for disinfection. This was done to determine the future direction required to meet DBP regulations.

Equipment available:

- Ozonation system, 3 train, 0.5 lb/day
- Modular sections accommodate 4 gpm per train
- Parallel or series operation

The equipment is in (satisfactory, excellent, ?) condition and is available at the pumping plant for additional testing.

CALIFORNIA

U.S. NAVY

NAVAL FACILITIES ENGINEERING SERVICE CENTER

1100 23rd Avenue

NCBC

Port Hueneme, California 93403

Administrator: Ted Kuepper

Telephone: 805-982-1631

Fax: 805-982-1641

The Seawater Desalination Test Facility, located at the Naval Facilities Engineering Service Center, provides facilities, equipment and support for desalination technology research and development test programs for a wide variety of customers. Past and present customers include all the military services within the U.s. Department of Defense (DOD) and numerous commercial equipment developers from around the world. The SDTF is unique because it is fully instrumented for evaluating water treatment processes and because of its seawater access to the Pacific Ocean. The SDTF has been a key testing facility, especially for the evaluation of reverse osmosis (RO) systems and related components. However with the facility's automated data collection and permanent seawater access for 24-hour operation, the SDTF provides a test-bed for evaluating all technologies related to seawater desalination.

Being able to evaluation equipment with natural seawater allows data to be collected under "real world" conditions and allows water treatment prototypes that utilize new technology to be directly compared to more traditional hardware. Data are collected by SDTF staff who have worked with virtually all types of water treatment processes.

Because the SDTF is unique in the U.S., testing for commercial companies is routinely performed and typically comprises about 15 % of yearly test work. The SDTF is especially designed to perform the accurate evaluations necessary to help manufacturers develop marketable products from prototype equipment. The SDTF provides a cost effective form of Technology transfer to the commercial sector by providing a detailed evaluation of prototype equipment during the crucial optimization phase associated with new product development.

The facility is 3,000 square feet in size and consists of a wide variety of equipment and test beds. The seawater intake is an underwater pipe which reaches out only 15 feet from shoreline and lies about 12 feet deep. In spite of this nearness to shore, little variation in TDS is noted. The main seawater intake pump is capable of delivering 300 gpm (432,000 gpd). This site produces real world situations including the worst case condition of "red tide" which occurs once or twice a year for one or two weeks duration.

The reverse osmosis test units are U.S. Army Reverse Osmosis Water Purification Units (ROWPU). At the present time two are being operated in parallel for a test. Ten additional ROWPUs are available. All of the units are modified slightly to allow safe 24 hours per day unattended operation. Each unit comes packaged with its own operational controls and safeguards.

The facility has a permit to re-combine the product with the brine and discharge back into the ocean. A complete water analysis laboratory is located on the premises, equipment with most of the standard analytical instrumentation.

The facility is flexible in developing a working relationship with outside parties. They are amenable to providing only space, electricity, feed stream and monitoring personnel to companies desiring to bring in their own complete units.

Costs:

1. Facilities: There is no cost associated with using the Seawater Desalination Test Facility
2. Equipment: There is no cost associated with using specific equipment in the Facility such as:
 - Pretreatment systems
 - Cartridge filter test stand
 - Single & dual element RO test stands
 - 600 gph ROWPU
 - 1200 gph ROWPU
3. Utilities: Electricity cost is \$0.10 per kilowatt hour for electrical devices associated with testing a particular piece of equipment
4. Labor: \$75 per hour of actual labor required for:
 - Equipment installation operation and maintenance
 - Test stand modifications

Data collection and data analysis
 Analytical instrumentation operation

5. Consumables: Materials and consumables associated with testing a particular piece of equipment are charged accordingly
6. Exceptions: If test work being conducted complements an ongoing investigation at the test facility for the Department of Defense, then some or all of the required labor charges for test work may be waived.

Table 4. U.S. Navy Pilot Plant Equipment

CALIFORNIA

Table 4. U.S. Navy Pilot Plant Equipment								
CENTER:	U.S. NAVY FACILITIES ENGINEERING SERVICE CENTER							
LOCATION:	Port Hueneme, California							
FEED STREAMS:	Seawater							
PROCESS:	Reverse Osmosis (a)	Reverse Osmosis (a)	Cartridge Filter Test	Single Element Test Stand	Dual Element Test Stand	Multi-media Filtration	Cartridge Filters	
	1200 gph	600 gph						
No. of systems	1	8	1	1	1	9	2	1 several
Avg feed flow, gpm	70	33		24	44			
Dimensions						30" & 36"d		
Media type						varied		
No. of stages	1	1		1	2			
Elements per stage	9	9	1	1	6		12	3
Recovery, %	varies	varies		varies	varies			
Element type	8"x40"TFC	6"x40"TFC		6"x40"	Two 6"x40" One 8"x40"	40"	20"	10", 20"
CONTROL SYSTEM:	24 hour a day operation. Automatic shutdown on hi/lo pressure.							
(a) Each ROWPU is skid mounted and packaged with a multi-media filter and cartridge filter which matches the throughput of the RO unit.								

Table 5. U.S. Navy Laboratory Instrumentation and Specialized Equipment

- Particle size distribution Analyzer
 - Hiac/Royco Model 8000 with automatic batch sampler, 1-150 micron size range sensor
- Turbidimeters
 - Hach ratio 2000 (process style)
 - Hach Model 1720C - low range (process style)
 - Hach Ratio/XR (laboratory style)
 - H F Instruments, Model DRT 200A (process style)
- Conductivity Meters
 - YSI - Model 34 (laboratory style)
 - Rosemount - Model 1054C (process style)
 - Great Lakes - Model 671 (process style)
 - Amber Science - Model 605 (laboratory style)
 - Balsbaugh - Model 910 (process style)
 - Balsbaugh - Model 1200 (process style)
 - Lakewood (hand-held)
- pH Meters
 - Great Lakes - 671 (process style)
 - Hach Model 2278 (laboratory style)
 - Rosemount - Model 1054pH (process style)
 - Chemtrix - Type 40 (laboratory style)
 - Beckman - Model 960 (process style)
- Silt Density Index test Apparatus (2 units)
- Data Loggers
 - Orion - Model 3530
 - Metrosonics - Model 714
- Phipps & Bird Jar Test apparatus
- Variety of Pressure, Flow, and Temperature Instruments
- Analytical Equipment
 - Atomic absorption spectrophotometer
 - UV/VIS/NIR spectrophotometer, Lambda 9
 - Infrared spectrometer (FTIR)
 - X-Ray spectrometer, TN5502 (Noran)
 - X-Ray spectrometer, Delta XRF
 - Emission spectrometer, Plasma 40
 - Gas chromatograph
 - Ion chromatograph, Dionex
 - Scanning electron microscope
 - Thermal gravimetric analyzer
- Special facilities
 - Seawater corrosion facility
 - Salt spray test chamber
 - Cold temperature test chamber

COLORADO

COLORADO STATE UNIVERSITY

Engineering Research Center
Fort Collins, Colorado 80523

Administrator: Prof. David W. Hendricks

Telephone: 303-491-8273

Fax: 303-484-3899

The Colorado State University Engineering Research Center includes pilot plant equipment based upon the original design of the Denver Water Reuse Demonstration Plant, but at smaller volumetric flow. The processes include ozonation, carbon absorption, air stripping, rapid mixing, flocculation, settling, filtration, ion exchange and membrane separation. Individual processes or the entire treatment train can operate at flow up to 20 gpm (28,800 gpd). The processes can be tested individually or in various combinations.

The primary feed stream is from Horsetooth Reservoir, adjacent to the campus, which is a drinking water reservoir. The pilot facilities were build with funds provided by the U.S. Army Corps of Engineers, but belongs to CSU. The original purpose was to study advanced treatment technologies for removal of contaminants including toxic organic compounds, metals, and conventional contaminants such as viruses, bacteria, cysts, biodegradable organic compounds and salts.

During the initial Facilities Survey, it was stated that secondary effluent might be available from a nearby facility, but that does not appear to be feasible. They would normally "spike" feedwater with chemical or particulate contaminants.

The equipment is nearly new, most of it having been built in 1993, with the exception of the filter columns constructed in 1985. The equipment is laid out in an orderly, easily usable, configuration.

The administrator is Dr. David Hendricks, who most recently completed a study of nanofiltration for low turbidity waters. He has good working relationships with professors and scientists at the University of Colorado, the City of Denver Water Utilities Department, and others in the water treatment community.

The facility offers good analytical support, communications facilities, computer facilities, and office space. The facilities are outstanding and the process control is excellent; it should allow conduct of water treatment research at a reasonable cost.

Estimated cost:

CSU prefers to develop a joint research contract, manage the research with a faculty member, with most of the work done by graduate students.

Overhead rate:	45 %
Supervisory personnel:	\$15,000 per month
Graduate students:	\$1400-2000 per month
Facilities:	\$5000 per project.

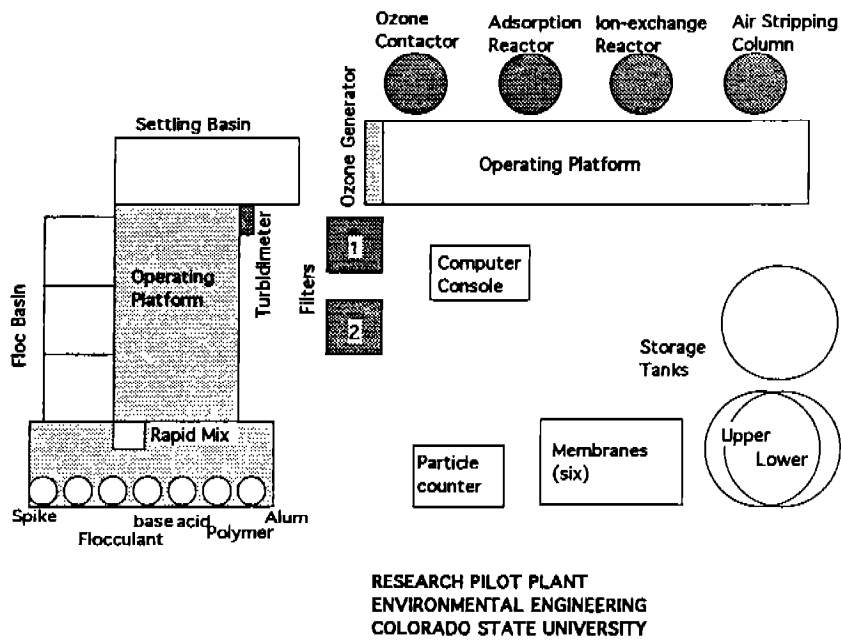


Figure 13. Colorado State University: Research Pilot Plant Layout

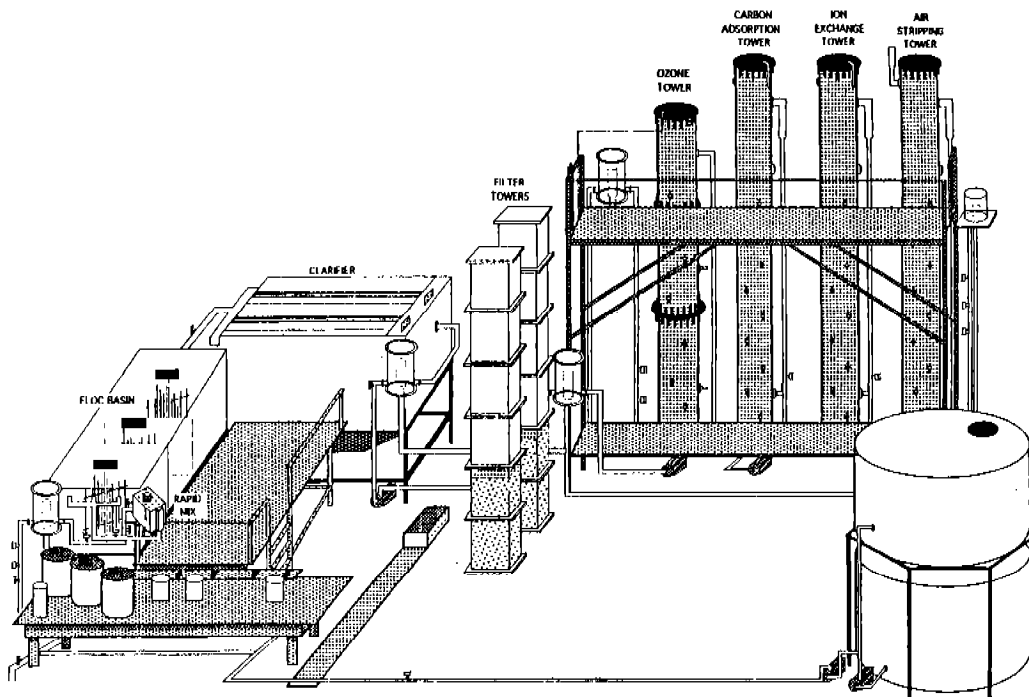


Figure 14. Colorado State University: Advanced Water Treatment Pilot Plant

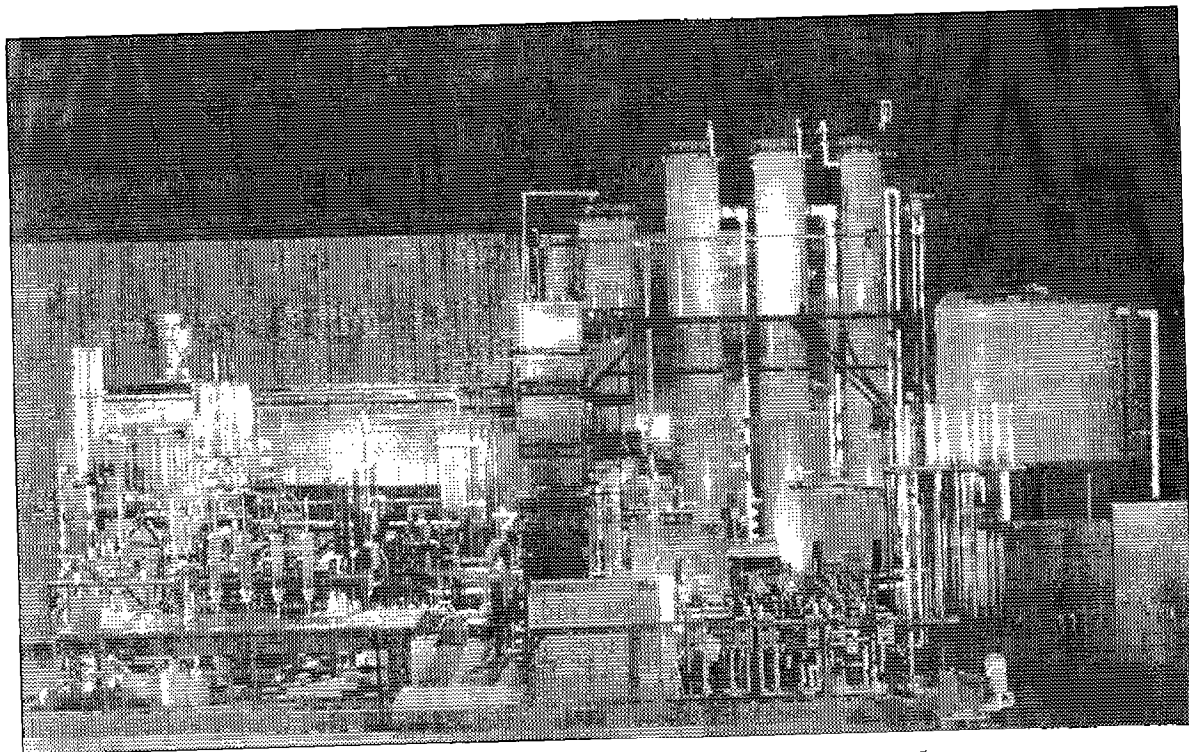


Figure 15. Colorado State University: AWT Pilot Plant

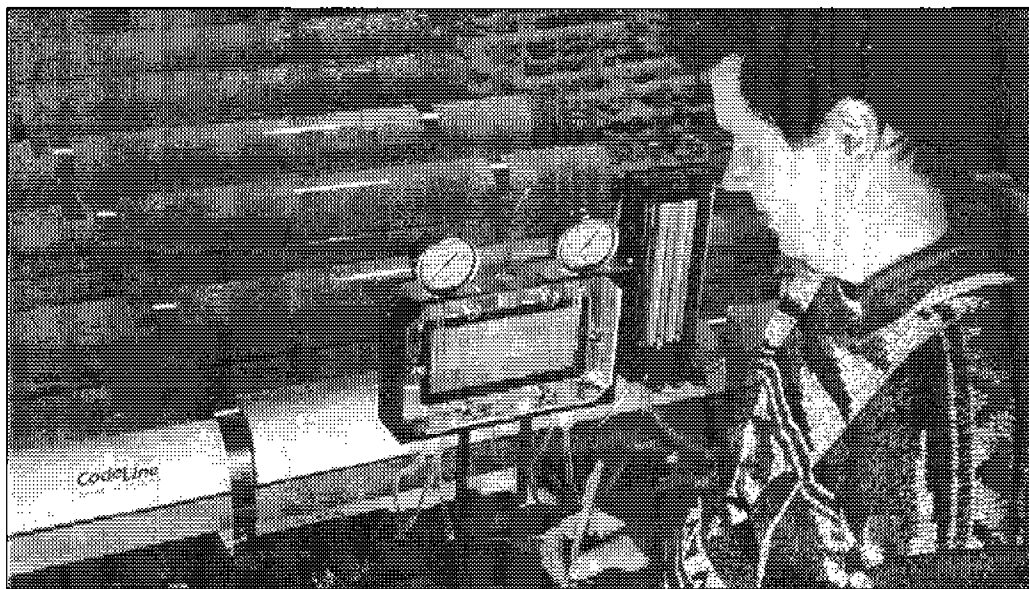
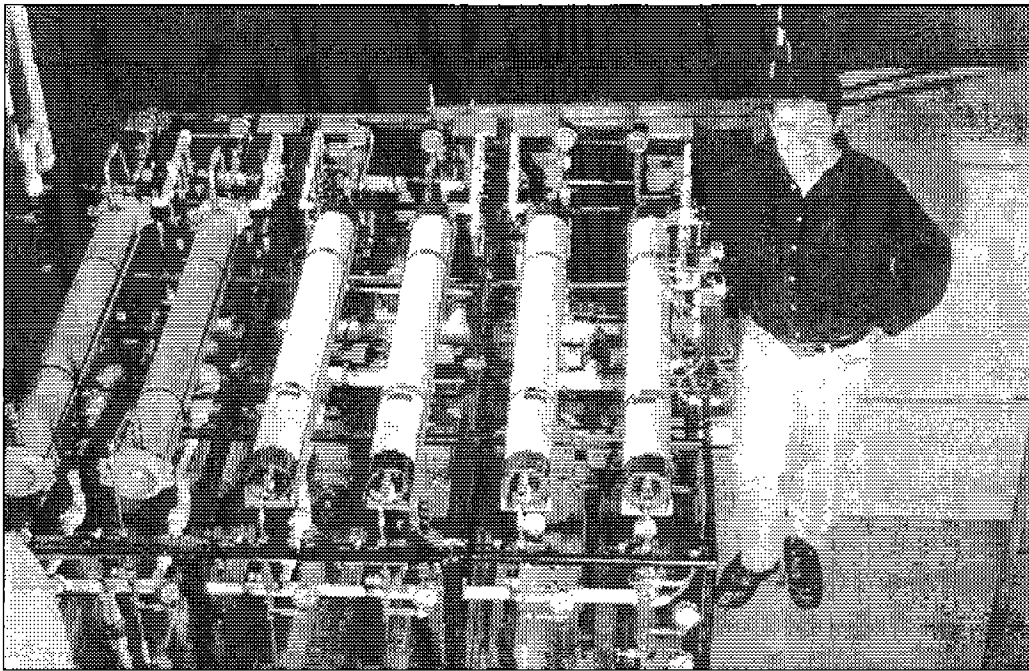


Figure 16. Colorado State University: Membrane Separation Pilot Plants

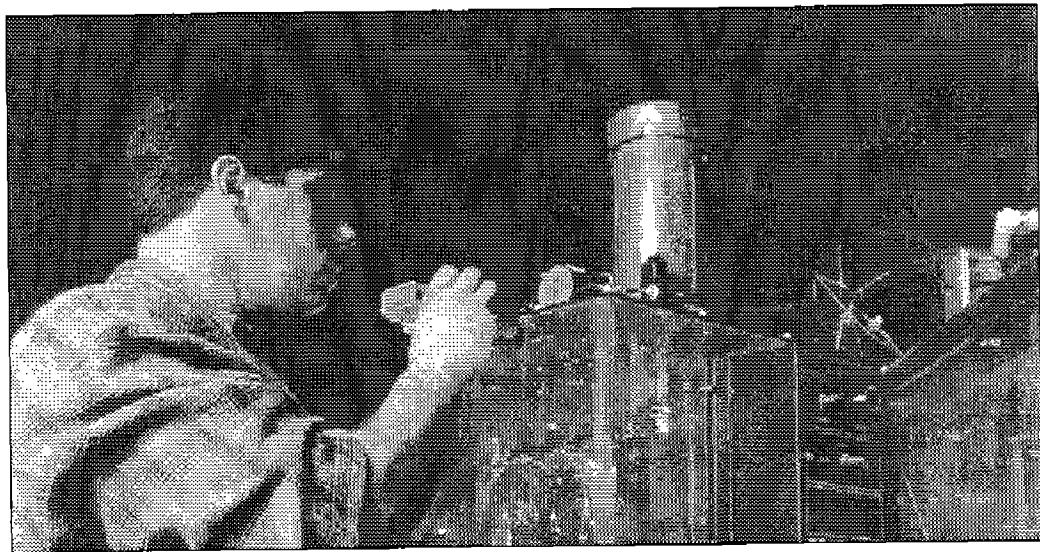
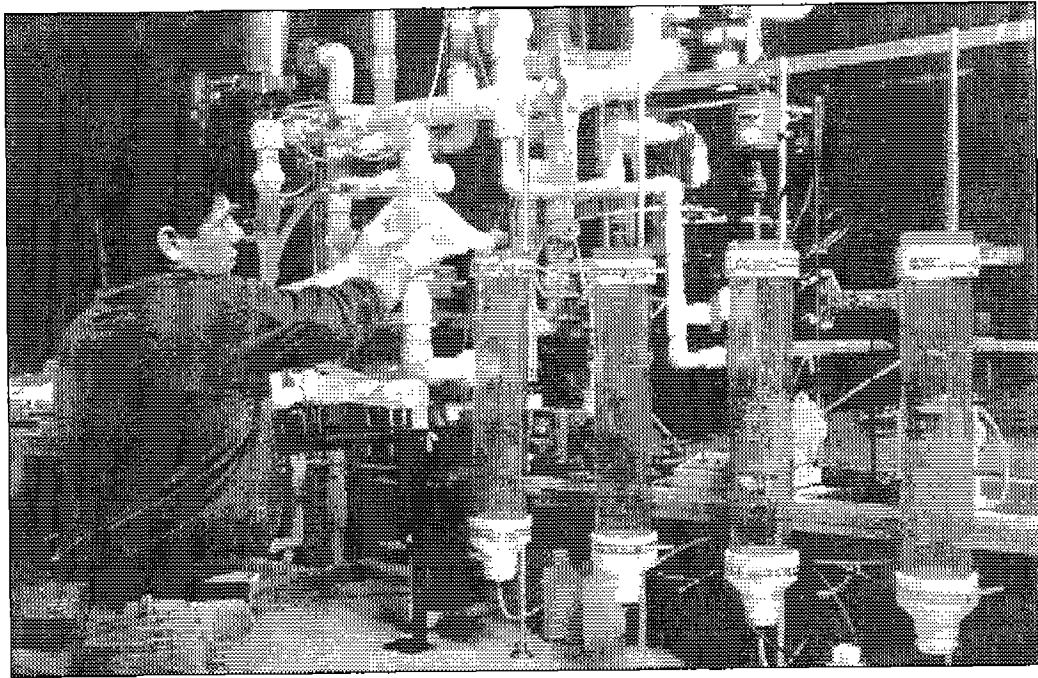


Figure 17. Colorado State University: Unit Operations within AWT Pilot Plant

COLORADO

COLORADO, UNIVERSITY OF

Civil Engineering Department
Chemical Engineering Department
Boulder, Colorado 80309-0424

Administrator: Prof. Jo Ann Silverstein, Civil Engineering
Prof. Richard Noble, Chemical Engineering

Telephone: 303-492-7211 (Civil)
303-492-6100 (Chemical)

Fax: 303-492-7317 (Civil)
303-492-4341 (Chemical)

Both the Civil and Chemical Engineering Departments of the University of Colorado are currently engaged in water resources research. The Civil Engineering Department, under direction of Dr. Silverstein, has conducted research in biological systems and have installed a pilot facility at a field location in Wiggins, Colorado. The Chemical engineering Department has established an NSF Industrial/University Center for Separations Using Thin Films, under the chairs of Drs. Krantz and Noble, where they are focused in four major areas: reversible chemical complexation, membrane morphology and performance, catalytic membrane reactors, and membrane fouling.

Both departments have extensive facilities, instrumentation and analytical tools. These include:

- Scanning electron microscopy
- Transmission electron microscopy
- Wavelength dispersive X-ray analysis
- Energy dispersive X-ray analysis
- Auger electron spectroscopy
- Low energy electron diffraction
- X-ray photoelectron diffraction
- High resolution electron energy loss spectroscopy
- Infrared thermal video imaging
- Nuclear magnetic resonance spectroscopy
- High resolution mass spectroscopy
- Automatic X-ray spectroscopy
- Fourier transform infrared spectroscopy
- High pressure liquid chromatography
- Differential scanning calorimetry
- thermal gravimetric analysis
- Ellipsometry
- Temperature programmed reaction systems
- Low and high pressure membrane flow systems
- Static chemisorption system
- Ultrasonic time domain reflectometry

Both departments support the NWRI National Centers concept and would participate in joint programs.

COLORADO

U.S. BUREAU OF RECLAMATION

Technical Service Center

Water Treatment Engineering and Research Laboratories

P.O. Box 25007

Denver, Colorado 80225-0007

Administrator: Stan Hightower

Telephone: 303-236-6203

Fax: 303-236-8862

The Bureau of Reclamation has engaged in water desalination research and development on both laboratory and pilot scale equipment in the Denver laboratories since the late 1950's. The early R&D was conducted for the Office of Saline Water and later for the Office of Research and Technology, both sister agencies within the Department of the Interior.

The facilities have since expanded their interests to general water treatment and desalination. They have an outstanding analytical laboratory for water. Their strongest asset is the research personnel which consists of 22 chemical engineers, chemists, physical scientists, environmental engineers, and chemical and civil engineering technicians. Extensive electrical/mechanical maintenance services are available through the Technical Service Center Shops personnel.

Pilot scale equipment consists of skid-mounted equipment including: reverse osmosis, pretreatment, membrane cleaning. Mobile water treatment equipment includes: granular activated carbon, slow sand filtration, pressure filtration, reverse osmosis, nanofiltration, ultrafiltration, microfiltration, ultraviolet irradiation, ozonation, greensand filtration, and ion exchange softening.

Laboratory instrumentation and specialized equipment:

- Test cell apparatus -simultaneous 4" x 6" membrane swatch testing
- Solar photovoltaic powered desalting systems for remote sites can be tested with a solar photovoltaic array mounted on the roof.
- Water storage - two 15,000 gallon storage tanks connected to outside pump and one
- Analytical instrumentation in other organizations in the laboratory that are available in support of desalting and water treatment studies:
 - Scanning electron microscope with low vacuum and EDX
 - GC/MS (gas chromatograph/mass spectrometer)
 - HPLC (high performance liquid chromatography)
 - Ion chromatograph
 - ICPMS (inductively coupled plasma mass spectrometer)
- Environmental research Chemistry Laboratory
- Completely equipped water analysis laboratory

Estimated costs:

Following are some general costs for facilities and services. Actual costs are determined after examining the needs of the research project; a research agreement is established on this basis.

- | | |
|---|-----------------------|
| 1. Plant operator, maintenance worker, or engineering technician: | \$56/hr |
| 2. Process engineer | \$71/hr |
| 3. Office space | no cost |
| 4. Laboratory analysis | dependent on analytes |

Table 6. USBR Denver Laboratories Pilot Plant Equipment

COLORADO

Table 6. USBR DENVER LABORATORIES Pilot Plant Equipment

CENTER: US BUREAU OF RECLAMATION - RESEARCH LABORATORIES

LOCATION: Denver, Colorado

Feed streams: Tapwater
Synthetic solutions
Various field locations

Equipment:

	<u>Reverse</u> <u>Osmosis</u> <u>Skid</u>	<u>Mobile Water</u> <u>Treatment</u> <u>Pilot Plant (a)</u>	<u>Reverse</u> <u>Osmosis</u> <u>Test System (b)</u>	
No. of Systems	1	1	1	2
Average feed flow, gpm	6	6	6	2-4
Pressure, psi (up to)	450	450	450	450
Number of stages	2	2	1	1
Elements per stage	6	6	6	4
Recovery, %	75	75-80	75-80	variable
Element size, inches	2.5"	2.5, 4.0"	2.5, 4.0"	2.5"
Membrane type:	TFM	TFM or CA	TFM or CA	TFM or CA

(a) Includes: chemical feed systems (lime, alum, polymer, hypochlorite, acid anti-scalant, biocide.), rapid mix and flocculation system, miscellaneous support pumps, RO, ultra- and nano- filtration skid, UV and ozonation skids, tankage, generator, greensand filter, ion exchange softener, and an Allen Bradley SLC 502 automatic process controller.

(b) Includes: An Allen Bradley SLC 500 data acquisition system.

Control system: 24 hour a day operation, automatic shutdown on hi/lo pressure.

CONNECTICUT

CONNECTICUT, UNIVERSITY OF

Environmental Research Institute (ERI)
Pollution Prevention Research and Development Center (PPRDC)
Longley Bldg. Rt 44, U-210
Storrs, CN 06269-3210

Administrator: Dr. James Fenton
Robert Carley (Analytical Laboratories)

Telephone: 860-486-4015

Fax: 860-486-5488

The University of Connecticut houses an Environmental Research Institute, which includes a pollution prevention lab. It currently occupies approximately 15,000 sq. ft. for engineering environmental studies and 12,000 sq. ft. for analytical facilities. This will expand soon to 40,000 sq ft. They currently receive \$5 MM in annual funding. ERI is active in five areas: educational activities, pollution prevention research, site remediation and recycling technology research, analytical and engineering services, and industry interactions and business services.

Some of the current water related work includes RO, EDR, and resin filled EDR. Their laboratory performs the membrane projects with equipment that includes the following:

- High pressure reverse osmosis unit, laboratory size (1/m)
- Electrodialysis set ups (6 @ 1 l/m)
- Electrowinning device (< 10 l/m)
- Analytical equipment: ICP, ICP/MS, AA, TOC, GC, GC/MS, and others

Most of their equipment is in new condition. Both wastewater and wastewater effluent are available for testing. Concentrate is disposed via sewer or other off-site methods.

They have complete computer facilities available including terminals as well as complete communications options. Research support available includes staff, supervision, facility caretakers and maintenance. Office space can be provided.

Estimated cost:

Facilities: \$49/hr

Overhead rate for support services: 40%

Analytical Laboratory Facilities Specialized Equipment:

Organics:

- Finnigan TSQ-70 Tandem Mass Spectrophotometer
- 2 Hewlett Packard Gas Chromatographs/Mass spectrophotometers
- Gas chromatograph ion trap mass spectrophotometer
- 2 High performance liquid chromatographs
- 6 Chromatographs, each equipped with specialized detectors

- Super critical fluid extractor
- PS analytical GCAFS mercury speciation system

Metals:

- Perkin-Elmer Plasma 40 sequential inductivity argon plasma spectrometer
- Perkin-Elmer 4100/PC and 5100/PC Zeeman background-corrected atomic absorption spectrophotometers
- Perkin-Elmer FIAS 100 Flow injection mercury system
- Perkin-Elmer ELAN 6000 ICP/MS

Nutrients:

- Lachat QuikChem AE automated ion analyzer (four channel analyzer equipped with high-sensitivity seawater cartridges)
- Perkin-Elmer Plasma 2400 elemental analyzer
- Dionex 4000i ion chromatograph
- OI Corporation 700 TOC analyzer

Estimated cost:

Cost of analysis dependent upon analyte.

FLORIDA

CAPE CORAL, CITY OF

P.O. Box 150027

Cape Coral, Florida 33915

Administrator: Sean Kopko

Telephone: 941-574-0536

Fax: 941-574-0882

Prior to construction of their municipal plant, the City of Cape Coral installed a single pressure vessel pilot unit with recirculation, to examine the maximum recovery achievable with their reverse osmosis system. Since the test was completed, this pilot plant has not been used, but can be made available for further research testing.

Although the extent of research may be limited by the simple design of the unit, it provides a test bed for testing new membranes, additives, and maximum recovery.

The city is currently in the process of a massive change in the PLC system for their municipal plant. They are also building a separate single element test unit for 8" diameter elements so that they can test membranes from their municipal plant.

They are not prepared to accept a research program at this time, but may be able to do so at a later date.

FLORIDA

CENTRAL FLORIDA, UNIVERSITY OF

Environmental Systems Engineering Institute
Orlando, Florida

Administrator: Prof. James Taylor

Telephone: 407-823-2785

Fax: 407-823-6562

The Environmental Systems Engineering Institute (ESEI) is a Type II institute located within the Civil and Environmental Engineering Department in the College of Engineering at the University of Central Florida. Type II institutes are not supported by any direct funding from the State of Florida. ESEI like all State University System (SUS) institutes is a non-profit organization created specifically to enhance graduate research and education, and serve society by providing access to specific resources of the State University System.

Engineering research is a primary function of ESEI, which provides a central location for coordinating environmental projects utilizing the specific expertise of CEE and other departments at UCF. The Departments of Civil and Environmental Engineering, Biology, Microbiology, Chemistry and others at UCF have conducted environmental projects individually and collectively that involved research, training, analysis, and education. UCF has significant capital resources invested in laboratory space, advance analytical equipment and computer technology that is available for environmentally oriented problem solving. Specific expertise within the CEE department includes potable water treatment, corrosion control, stormwater abatement, air dispersion modeling, noise abatement, solid waste, incineration, hazardous waste investigation, wastewater treatment and receiving water impacts.

All work conducted within ESEI must be funded by contracting organization as ESEI receives no direct state funding.

The laboratory is equipped to measure trace organic and inorganic contaminants. Equipment is housed in more than 4000 sq. ft. of laboratory space. Although a list of equipment was not submitted, it is understood that the equipment is extensive and consists of both small pilot plant equipment in addition to laboratory test cells.

The Institute was created by the UCF to enhance environmental education and services at UCF and actively seeks interaction with all government and private organizations.

Estimated cost:

Research by project or by using equipment at UCF is possible only by negotiated contract. The overhead rate is 45 % of all direct costs excluding equipment purchase on contract.

FLORIDA

JUPITER, TOWN OF

17403 Central Blvd.
Jupiter, Florida 33458

Administrator: David Brown
Telephone: 407-746-5134, x273
Fax: 407-747-5634

The Town of Jupiter acquired a reverse osmosis pilot plant of approximately 50,000 gpd capacity, to perform tests prior to construction of their full sized plant. Additional tests continue as required on the unit. The Town is willing to make the pilot plant available for research purposes as long as the project does not interfere with their day to day operations.

The pilot plant is a 2-stage unit with 4" diameter pressure vessels. It is designed for 75% recovery and has a 4:2 array of six element vessels. It is skid mounted and has rollers for portability; however, they prefer to keep the pilot plant in one locations, which is adjacent to the full-sized plant. It has adequate instrumentation and controls to allow collection of sufficient data for research projects. Thin film composite spiral wound elements are currently on hand for testing. The unit is designed for automatic operation and has safety switches to protect the system. manual adjustment is required at startup.

The feedwater can be supplied by a brackish water well, or a surficial aquifer. The former has TDS of approximately 4500 to 4800 ppm; the latter has TDS of about 450 ppm. Use of the brackish water well is very convenient; use of the surficial source would require moving the pilot plant. Waste lime and concentrate are sent to a concentrate treatment facility.

Office space is available, but limited. PC computers are available, but no main frame terminals. Telephone and facsimile service are available. Limited support staff are available.

A simple we lab is available, with an additional mini-lab for routine monitoring of the main process equipment. Simple spectrophotometric analysis are done on-site, but more sophisticated analysis are sent to a local lab.

If the research to be conducted is of benefit to the Town of Jupiter, it is likely that no charges would be incurred. If special chemicals are required, they will be the responsibility of the researchers. The following costs for labor are based on minimal requirements for testing requiring little beyond data gathering and mixing of chemicals. If the testing protocols are more demanding, the costs could increase substantially.

Estimated cost:

Staff Member	Hourly Rate <i>(including fringe benefits)</i>
Chief Operator	\$32.20
Maint. Operator	\$22.40
Operator	\$19.60
Lab Technician	\$22.40

FLORIDA

SOUTH FLORIDA, UNIVERSITY OF

College of Engineering

Tampa, Florida 33620-5350

Administrator: Dr. Robert P. Carnahan, Associate Dean

Telephone: 813-974-3786

Fax: 813-974-5094

The University of South Florida has several pilot plants, but not all of it is centrally located. A mobile trailer unit is designed to move to different sites for research and contains two 10 gpm reverse osmosis units capable of desalting seawater. The trailer also contains a 3000 gallon holding tank with temperature control. Arrays of 4" spiral wound elements or a B-9 brackish water hollow fiber permeator up to 10" diameter can be tested.

A test stand will accommodate up to 6" elements in either multi-element pressure vessels. A 100 gallons per day seawater unit for testing 2.5" elements is skid-mounted for portability. Two small hollow fiber microfilter skid-mounted units are available.

In the laboratory, two high pressure and one medium pressure cells are available for flat sheet testing with varying spacers for hydrodynamic studies. Many 2.5" diameter test cells are in place for quick tests on membranes.

For pre-treatment, clarifiers, filters, and cyclone separators are available in addition to conventional cartridge and media filtration.

Analytical instrumentation includes AA with graphite furnace, SEM, GC/MS, various microbiological tests, ion chromatography, HPLC and optical microscopy. A trailer mounted laboratory can be moved to different sites to support the reverse osmosis trailer.

Approximately 3000 sq. ft. of laboratory space is available. Six professors experienced as principal investigators and 15 to 20 graduate students provide support.

Estimated cost:

The university typically negotiates a cooperative agreement with the proposed research sponsors. Facilities, supplies, and purchases are indirect costs billed at 45% of faculty and student salaries.

Table 7. University of South Florida Pilot Plant Equipment

FLORIDA

Table 7. University of South Florida Pilot Plant Equipment							
CENTER:	University of South Florida						
LOCATION:	Tampa, Florida						
FEED STREAMS:	Seawater Brackish water (various)						
EQUIPMENT: Mobile trailer unit.....						
	Reverse	Holding	Reverse	Microfilter	Element	Membrane Flat Sheet	
	Osmosis	Tank	Osmosis	(Hollow	Test	Test Cells	
	Pilot Units		Test Unit	Fiber)	Stand		
No. of Systems	2	1	1	2	1	2	1
Average feed flow, gpm	10		0.07				
Pressure, psi	1000		1000			1000	400
Size, gallons		3000					
Number of stages	2		1		1		
Elements per stage	6				3		
Recovery, %	varies up to 80%						
Element size, inches	4" spiral		2.5"		up to 6"		
	10" hollow fiber						

HAWAII

HAWAII, UNIVERSITY OF

Water Resources Research Center
2540 Dole Street
Honolulu, HI 96822

Administrator: Dr. Roger Fujioka
Telephone: 808-956-7847
Fax: 808-956-5044
e-mail: roger@hawaii.edu

In 1990, the State of Hawaii built a demonstration plant at Ewa on the island of Oahu, with the purpose of studying the viability of reverse osmosis, electro dialysis and electro dialysis reversal desalination systems as fed by available brackish groundwater. The total capacity of the plant is 1 mgd. the plant was tested and operated part time from January 1991 until June 1995. Although currently mothballed, it is regularly maintained and might be reopened at a later date.

In 1995, the University of Hawaii Water resources Research Center purchased and installed at the Ewa Demonstration plant site a small reverse osmosis pilot plant. Later moved the Civil engineering Department hydraulics laboratory, this unit has a rated capacity of 3,000 gallons per day. It has two pressure vessels which can be operated in series or parallel. The unit uses 4" x 40" membrane elements and is pretreated with a 5 micron pre-filter, anti-scalant injection pumps, acid injection pump and pH control. Equipment exists on site to allow membrane cleaning when required. Membranes on hand include 4" x 40" spiral wound nanofilters and high flow membranes.

The pilot plant is minimally instrumented with a watt-hour meter, pressure gages, flow meters, total volume meter and an in-line total dissolved solids meter. Adjacent WRRC laboratories have excellent analytical equipment including a carbon analyzer, ion chromatograph, HPLC, gas chromatograph, GC mass spec and atomic absorption. Conductivity meters are also available.

At the present site, feedwater must be brought in by truck. Sources are available for basal water of near-potable quality and for more saline (caprock) water.

The UH WRRC has a staff of research associates, graduate students, and faculty available to assist with the equipment. These individuals offer expertise in chemistry, civil and chemical engineering, hydrology, microbiology and economics. Both PC and Macintosh computer facilities are available along with telephone, fax and internet connections. Office space can be made available.

Estimated cost:

The pilot plant is available for projects in cooperation with U.H. WRRC researchers. There is no rental fee, but the current U.H. overhead rate is 38 % of project cost. Project Cost includes research assistants at about \$1,500 per month, additional equipment, laboratory supplies and principal investigator overload (\$6,500 per month and up).

HAWAII

MAUI DEPARTMENT OF WATER SUPPLY

614 Palapala Drive
Kahului, Hawaii 96732

Administrator: Paul L. Seitz
Telephone: 808-243-7380
Fax: 808-243-7544

The Kamole Water Treatment Plant, owned by the Maui Department of Water Supply, currently consists of a 6 mgd direct filtration water treatment facility. After testing with a microfiltration pilot plant purchased by the department, they are now installing a 6.4 mgd microfiltration plant at the Komole site and are scheduled to install a 2.4 mgd plant at another treatment plant site. The purpose for these installations is to allow them to meet the Surface Water Treatment Rule.

The 34 gpm microfiltration pilot plant has been installed in a mobile trailer and is instrumented with flow and turbidity recorders in addition to the standard controls for microfiltration.

The equipment condition is good, and fresh water supply is available for testing. Although there are no computer facilities at the site both telephone and facsimile communications are in-place. No research support staff is available, but facility caretakers, maintenance, and office space are available.

If the proposed research involves water supply and benefits the Maui area, the department will provide the equipment, facilities, and office space at no charge other than consumables and other direct expenses.

ILLINOIS

ILLINOIS, UNIVERSITY OF

Environmental Engineering and Science
Department of Civil Engineering
Newmark Civil Engineering Laboratory MC250
205 North Mathews Avenue
Urbana, Illinois 61801-2397

Administrator: Prof. Mark Clark
Telephone: 217-333-3629
Fax: 217-333-9464

The Environmental Engineering and Science program, Department of Civil Engineering, University of Illinois, is consistently one of the top four environmental engineering graduate research programs in the U.S. the normal research relationship with outside agencies and private companies is through research grants awarded to the University. the grants usually provide graduate student and faculty support, and funds for purchase of supplies and permanent equipment. there are certain indirect costs.

During the past seven years, the university has received nearly \$1 million in external grants to support membrane related research. Professors Clark, Snoeyink, and Rittmann are well known for the membrane related research. Professor Cheryan (Food Science Department) is a collaborator on some of their research and has authored a book on ultrafiltration.

The State of Illinois Hazardous Wastes and Information Center has opened extensive laboratory facilities on campus, broadening the capabilities at the university.

The EES laboratories consist of 11,000 sq. ft. of space, fully equipped for experimental research and analysis in the chemical, physical, and biological aspects of drinking water and wastewater treatment. the pilot scale equipment includes two hollow fiber ultrafiltration systems. One is fully computer assisted for on-line measurement of pressure, flow, and temperature; computer assist will automatically adjust pump voltage for constant flux operation.

The other system is an automated constant flux system with special pulse dampening capability. Other pilot scale equipment is available for test of hybrid separative systems. The units are rated between 3 and 15 gpm. Most of the work to date has been accomplished with cellulose derivative hollow fiber membranes of 0.9 mm i.d. and about 200 l/m²-hr flux. Various cartridge sizes from 20 to 100 fibers are available. Other commercial hollow fiber ultrafiltration or microfiltration membrane cartridges can be adapted to the systems.

A variety of pre- and post- treatment options are available for additional studies of complete systems. All equipment is in excellent condition. Wastewater, wastewater effluent, groundwater, and tap water sources are available for testing.

KENTUCKY

KENTUCKY, UNIVERSITY OF

Department of Chemical Engineering
Lexington, Kentucky 40506

Administrator: Prof. D. Bhattacharyya

Telephone: 606-257-2794

Fax: 606-257-7251

The University of Kentucky chemical engineering department has conducted pilot plant testing of membrane processes for more than 15 years. Concentrating primarily on application of membrane technology for industrial processes, their laboratory includes reverse osmosis and nanofiltration units (8gpm), pervaporation unit (5gpm), standard commercial grade membrane elements, and specialty products such as the Texaco spiral wound membrane for pervaporation. Configurations include spiral wound and hollow fiber.

The laboratory has the capability of pre-treatment with microfiltration, standard filtration and ozonation. a double-pass heat exchanger is used to control feed source temperature. Adsorption can be utilized for post-treatment and ozonation can be used for disinfection.

The reverse osmosis and nanofiltration units are automated and the pervaporation unit is manually controlled. The laboratory instrumentation and analytical tools include: HP GCMS, HPLC, TOC, UV/VIS, XPS, and other more conventional instruments. The condition of all equipment and instrumentation is excellent.

Industrial fluids and brackish water are readily available and wastewater feed source is possible.

Computer facilities include PC, Mac and main frame terminal. Excellent research support is available with graduate students, faculty supervision, and facility and equipment maintenance. The laboratory has telephone, telex, facsimile, Internet, and e-mail. Office space is available.

The university has other facilities available to support research through the Center of membrane Sciences and their material characterization facility.

Estimated cost:

Contracts for services can be either fixed price or negotiable. Usual rates:

Facilities: \$800-1000 per day

Support services: \$100-200 per day

NEBRASKA

Nebraska-Lincoln, University of

Institute of Agriculture and Natural Resources

Water Center/Environmental Programs

103 Natural Resources Hall

P.O. Box 830844

Lincoln, Nebraska 68583-0844

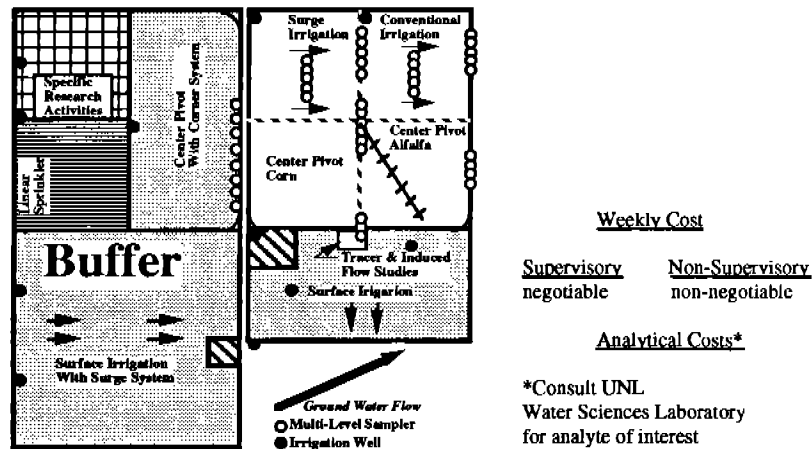
Administrator: Prof. Roy F. Spalding

Telephone: 402-472-3305

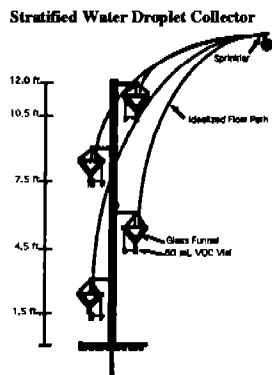
Fax: 402-472-9599

The University of Nebraska has several sites to conduct studies of groundwater recharge, nitrate remediation, source evaluation, management systems evaluation, and water sciences studies.

1. Management System Evaluation Area (MSEA), Shelton, Nebraska. Three hundred sixty acres of agricultural land available, instrumented with numerous soil and water samplers, including lysimeters, neutron probes and multi-level ground water samplers in order to evaluate agricultural management practices. The facilities are capable of conducting vadose zone and groundwater transport studies with flow capacity of 0-1000gpm and for low flow injection. Instrumentation and equipment includes: multi-level samplers, lysimeters, neutron probes, surge valves, irrigation wells, center pivots, linear sprinklers, furrow irrigation, and weather station. Special disciplines and capabilities available include hydrochemistry, engineering, agronomy, hydrology, and geology.



2. Sprinkler Remediation of VOC's, Hastings, Nebraska. A center pivot sprinkler irrigation system is available for the investigation of the efficacy of removing volatile organic compounds from groundwater. Specially designed stratified water droplet collectors which collect water samples from four fall heights beneath the sprinkler system are positioned along the sprinkler system. Special disciplines available include hydrochemistry and engineering.



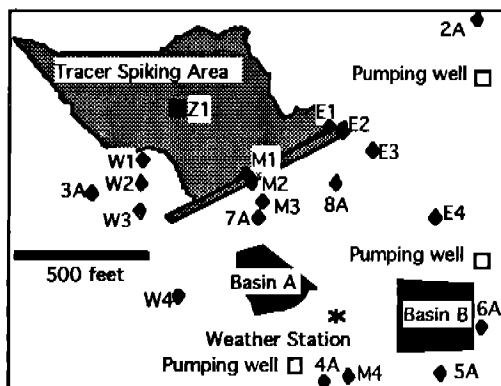
Weekly Cost

<u>Supervisory</u> negotiable	<u>Non-Supervisory</u> non-negotiable
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Analytical Costs*

*Consult UNL
Water Sciences Laboratory
for analyte of interest

3. York Recharge Site, York, Nebraska. A three hundred acre-feet impoundment for groundwater recharge is available with nested monitoring wells down-gradient, two spreading basins and a 500gpm recharge well. The site is ideal for determining surface water recharge of groundwater. Instrumentation and analytical equipment are nested monitoring wells and recharge wells and complete laboratory facilities.



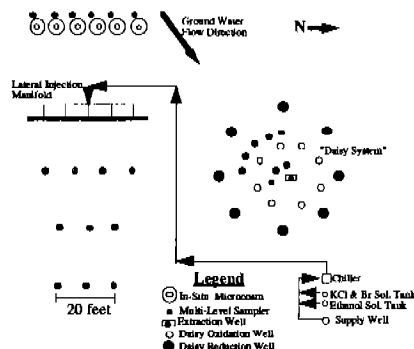
Weekly Cost

<u>Supervisory</u> negotiable	<u>Non-Supervisory</u> non-negotiable
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Analytical Costs*

*Consult UNL
Water Sciences Laboratory
for analyte of interest

4. Ground Water Nitrate Remediation Site, Central City, Nebraska. Six in-situ microcosms are available as well as an injection well with down-gradient multi-level samplers and "Daisy System" for denitrification studies. The flow capacity is 0-10gpm with low flow injection; good for in-situ and small scale aquifer denitrification study. Instrumentation and analytical equipment includes in-situ microcosms, "Daisy System", multi-level samplers, ion chromatographic ion selective electrodes, and portable laboratory facilities.



Weekly Cost

<u>Supervisory</u> negotiable	<u>Non-Supervisory</u> non-negotiable
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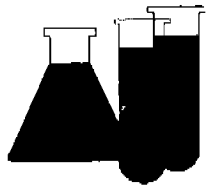
Analytical Costs*

*Consult UNL
Water Sciences Laboratory
for analyte of interest

5. Water Sciences Laboratory, University of Nebraska-Lincoln, Nebraska. This facility consists of a two story building (approximately 6000 sq. ft.) with six laboratory areas, several offices and conference room. Instrumentation and analytical equipment includes: 3 isotope-ratio mass spectrometers, 2 GC/MSD systems, 2 GC's, 2 IC's, HPLC, TOC analyzer, SFE, AA & UV-Vis spectrophotometers, multi-channel analyzer, lab robot, grinder, 3 lab balances, 2 analytical balances, water bath, 3 high vacuum preparation systems, distillation systems, and centrifuge. It is equipped with six chemical fume hoods, water purification system, and local area network. The equipment is in excellent condition having been purchased within the last 7 years.

A full range of supervision is available including full time lab manger, separations chemist, HRMS chemist, IRMS analyst, research technologist, data manager, project manager, and field manager. Special disciplines and capabilities include: environmental application of stable isotopes, environmental fate of pesticides and degradation products, environmental fate of volatile organic compounds and degradation products, and remediation techniques.

Two of the staff are shared with the Midwest Center for Mass Spectrometry. Current research involves professors from engineering, geology, agronomy, biosystems engineering, as well as researchers from the University of Waterloo and UCLA.



Analytical Costs*

*Consult UNL
Water Sciences Laboratory
for analyte of interest

Estimated cost:

The costs for these sites are highly variable. Normally to get representative results, at least two weeks at the Central City microcosm site to two years at the MSEA sites are required. Costs could vary from \$10,000 to greater than \$200,000.

NEW MEXICO

LOS ALAMOS NATIONAL LABORATORY

Industrial Wastewater Treatment Facility (IWTF)

P.O. Box 1663

Los Alamos, New Mexico 87545

Administrator: Steve Hanson

Telephone: 505-667-4301

Fax: 505-665-6320

The Los Alamos National Laboratory is a world renown laboratory facility operated by the Department of energy. The Industrial Wastewater Treatment Facility comprises 40,000 sf of laboratory space and includes parts of plant operation plus pilot test room. Both interior and exterior space is available. It is fully permitted (including

RCRA, CWA) and has analytical, engineering, design, construction, operational personnel associated with its current operations. Several other facilities exist in addition to IWTF which allow for research in other fields.

The pilot scale equipment includes electro dialysis reversal and reverse osmosis (5-10 gpm), hollow fine fiber ultrafiltration and centrifugal ultrafiltration (5-10 gpm), microfiltration and conventional filtration (5-200 gpm). Instrumentation and controls include AI (Expert) computer system, programmable logic control/monitoring. The laboratory features virtually every type of analytical equipment required for pilot plant testing including AA, ICP/MS, MS/OES, graphite furnace, radioisotope determination, etc.

The facility is in fair condition and the equipment and instrumentation is in excellent operating condition. Brackish water, wastewater, wastewater effluent and other feed sources are available for testing, making this a highly versatile pilot plant test facility. The concentrate disposal is fully permitted.

Computer facilities are outstanding and include PC, Mac and terminals for mainframe computers. All type of communications are available.

Research support is available including staff, supervision, facility caretakers and equipment maintenance personnel. Since this is a government run facility, the cost of facilities and services are based solely on the facility personnel involved. It is well known that the facility personnel embrace many special disciplines, and best known for expertise in radioactive waste handling, toxic wastes, hazardous waste, medical isotopes and risk analysis.

NORTH CAROLINA

NORTH CAROLINA AT CHAPEL HILL, UNIVERSITY OF

Department of Environmental Sciences and Engineering

CB# 7400, Rosenau Hall

Chapel Hill, North Carolina 27599-7400

Administrator: Dr. Philip C. Singer

Telephone: 919-966-3865

Fax: 919-966-7911

The Water Resources Engineering Program has analytical capabilities and laboratory facilities, including a 3700 sq. ft. high bay engineering laboratory that is available for pilot-scale testing and experimentation. The high-bay laboratory has two 3000 gallons storage tanks that can be used to supply water for preparation of test solutions or suspensions, or that can be filled with the solutions/suspensions to be tested.

The Wastewater Research Center is located at a nearby wastewater treatment plant. Raw wastewater, primary or secondary effluent, or wastewater treated for nutrient removal can be piped into the center, as can sludge from any of the units or from the anaerobic sludge digesters.

Although no permanent equipment exists, pilot scale equipment can be easily brought into the facilities to be tested on an as-needed basis. The facilities were recently used to test a buoyant coarse media flocculator at flow rates up to 30 gpm and a mixed oxidant generator, and for a membrane separation module for rejection of natural organic material.

Supporting analytical capabilities in the Department include state-of-the-art GCMS instrumentation, more than a dozen gas chromatographs, a number of liquid chromatographs, an ion chromatograph, particle counting equipment, total organic carbon analyzers, liquid scintillation counters, as well as conventional laboratory equipment. Extensive computer support capabilities and PC work stations are available.

The Department is a graduate department with 180 graduate students and 30 faculty members that cover all the major aspects of environmental sciences and engineering including water resources engineering, air pollution control, industrial hygiene, aquatic and atmospheric chemistry, aquatic and terrestrial biology, environmental policy, risk assessment, etc. Post-doctoral research associates and technicians are also employed by the Department and are supported by research grants and contracts.

Complete communications are in place including telephone, facsimile, Internet, and e-mail.

Cost:

Research contracts for testing and evaluation of equipment usually have an education component and are for a period of at least six months. The budget for each contract is developed based on the objectives of the project; the budget includes support for faculty, students, technicians and appropriate supplies and equipment. An indirect cost of 44.5% is added to the direct costs for use of the facilities.

SOUTH CAROLINA

CLEMSON UNIVERSITY

Ultrafiltration Laboratory

Clemson University

Clemson, South Carolina 29834-0921

Administrator: Prof. J.L. Gaddis

Telephone: 803-656-3294

Fax:

The Clemson University ultrafiltration laboratory conducted some of the pioneering investigations in the field of textile dye waste treatment. There is a small research facility for ultrafiltration and microfiltration testing. Pilot plant equipment with capacity up to 16 gpm includes ultrafiltration, microfiltration, and nanofiltration. A heat exchanger is piped into the loop for feed temperature control and pre-treatment consists of a cartridge filter. Disinfection is accomplished with heat or chemical addition. Membranes are cleaned chemically.

Instrumentation on the pilot equipment includes flow rate, temperature, pressure, pressure drop, pH, viscometer. Analytical equipment includes flow, conductivity, on campus support from other departments. Wastewater, wastewater effluent and process water are available feed sources. The facilities are in good condition.

Both PC and Mac computers as well as a mainframe terminal are available. Communication is by telephone, facsimile, Internet, and e-mail. Office space is available.

Research support staff is available with graduate students and faculty supervision. Facility and equipment are maintained by department technicians.

Availability of facilities and services is usually be special arrangement with an estimated cost of \$2000. Charge for facilities and services is by negotiation.

TEXAS

RICE UNIVERSITY

Department of Environmental Science and Engineering
P.O. Box 1892
Houston, Texas 77251

Administrator: Prof. Mark R. Wiesner
Telephone: 713-527-4951
Fax: 713-285-5203

The Department of Environmental Science and Engineering at Rice University has the capability for both bench scale and small volume pilot plant testing. A wide variety of membrane filtration equipment is available with flow rates from 1 to 19 liters/minute (0.26-5.02 gpm). Ceramic and polymeric membranes are available as well as hollow fiber, and tubular configurations. For pre-treatment, standard cartridge filtration with the possibility of coagulation, PAC and others are available. A separate cleaning skid is on-site. The equipment is in good to excellent condition.

Wastewater, wastewater effluent, produced waters and industrial waste water feed sources are attainable and brackish water or seawater is possible.

Both PC and Mac computer facilities are available. Communications are by telephone, facsimile and e-mail. Although office space is not available, good research support can be found. In addition to faculty supervision and graduate student help, a technical editor is on staff. Facility upkeep and maintenance of equipment is handled by graduate students and specialty campus shops.

The standard overhead rate at the department is 50%. The university would envision working on research projects in conjunction with NWRI.

TEXAS

TEXAS A&M UNIVERSITY SYSTEM

Food Protein Research and Development Center

Cater Mattil Hall

College Station, Texas 77843-2476

Administrator: Dr. S. Sefa Koseoglu, Head-Separations Science Program

Telephone: 409-845-2741

Fax: 409-845-2744

e-mail: S-koseoglu@tamu.edu

The Food Protein Research and Development Center got its name from the extensive research initiated at the university in food protein research. The pilot scale facilities have since been expanded to include water and wastewater research and development. Five separate fully-equipped pilot plant facilities are available and additional space is available for expansion and diversification of facilities. The center now has specialized discipline in membrane based separations both aqueous and non-aqueous.

Pilot scale equipment includes extraction (aqueous and non-aqueous), spray drying, membrane systems, thin film evaporators. Flow rates range from small to 150 gpm, depending upon the unit operation selected. Membranes available include microfiltration, ultrafiltration, nanofiltration, reverse osmosis in both laboratory and commercial sizes. Several multi-purpose pilot units have explosion proof capability. The laboratory also includes various types of heat exchangers, centrifuges, screens, homogenizers, ion exchange columns, carbon filtration columns. Typical disinfection is by HTST pasteurizer or chemical methods. Membrane cleaning equipment is available based on recommendations from manufacturers.

Instrumentation and controls are available. Analytical equipment includes gas chromatography, HPLC, GCMS, infrared spectrophotometry, UV-VIS, atomic absorption.

Wastewater and wastewater effluent feed streams are available as well as synthetic solutions. Samples are often shipped from point of origin to the laboratory for tests. Concentrate disposal is via city sewer.

The center has 25 full-time employees and 5 sections heads are available for supervision. Facility caretakers are on-site and the university provides 24 hr/day maintenance. Computer facilities for both PC and Mac are available as well as terminals for plug in. telephone, telex, facsimile, Internet, and e-mail are available. Office space is available.

The cost of facilities varies considerably, depending upon circumstances and the number of employees involved in the research. It ranges from \$250 to 2500 per day, which includes both facilities and support services. University rules and regulations determine the contract type as it depends upon whether it is a research or a service contract.

Table 8. Texas A&M University Pilot Plant Equipment

TEXAS

Table 8. Texas A&M University Pilot Plant Equipment									
CENTER:	TEXAS A&M UNIVERSITY								
LOCATION:	College Station, Texas								
FEED STREAMS:	Food processing								
PROCESS:	MF/UF/RO System	UF/RO System	ED System	Spray Drier	Spray Drier	Centrifuge Westfala	Pervap. Unit	Pervap. Small Lab	Decanter Sharples/Alfa-Laval
	NIRO	PCI					Texaco	Size	
No. of systems	1	1	1	1	1	1	1	1	1
Avg feed flow, gpm	30	10	1.6			6	5	0.5	10
Lbs H ₂ O/hr				65	15				
No. of stages	1	1	3	1	1, 2 or 3 phase				
Elements per stage	6	6							1
Recovery, %	varies	varies	varies				varies		
Element type	4"x40" sw	4"x40" sw	Stackpack				4" or 6" sw	flat sheet	
CONTROL SYSTEM:	24 hour a day operation. Automatic shutdown on hi/lo pressure.								

Table 9. Texas A&M University Equipment and Services

1. Pilot Plants

- Multipurpose, explosion proof, microfilter (backpulse), ultrafiltration, nanofiltration, reverse osmosis system with commercial size elements
- Multipurpose, tubular, spiral ultrafiltration and reverse osmosis system
- Spiral wound pilot size pervaporation system
- Small lab size pervaporation system
- Pilot scale electro dialysis system
- Liqui-Cel system
- Tubular, ceramic, spiral wound, hollow fiber, fine hollow fiber and disc tube membrane elements.

2. Other equipment available

- Spray dryers
- Pasteurizers, hydrogenators
- Pilot plant size solvent extraction facilities
- Disk bowl and decanter centrifuges; vibrating screens
- Thin film evaporators

3. Services available

- Pilot plant scale training to cover equipment set-up, operation, and maintenance
- Mobile trailer based on-site testing programs
- Development of membrane based processes to save energy and to eliminate waste streams
- Individualized membrane cleaning and fouling studies based on clients needs and processing streams.
- Applications screening and selection of the best commercially available membranes.

TEXAS

TEXAS-AUSTIN, UNIVERSITY OF

Separations Research Program
Chemical Engineering Bldg. 4.404
Austin, Texas 78712-1062

Administrator: Dr. James R. Fair

Telephone: 512-471-3689

Fax: 512-471-7060

The Separations Research Program at the University of Texas at Austin is a cooperative industry/university program which performs fundamental research of interest to chemical, biotechnological, petroleum refining, gas processing, pharmaceutical, and food companies. Specific areas of technology covered by the program include: adsorption/chromatographic separation, liquid/liquid extraction, supercritical fluid technology, membrane technology, flue gas desulfurization and acid gas treating, and water and wastewater treatment.

Equipment and facilities are provided in two research buildings. the Center for Energy Studies/Center for Electromechanics Building at the Balcones Research Center has administrative offices, multiple laboratories, and large-scale separations related equipment including extraction/distillation test system (18" diameter), adsorption/desorption test system (3" diameter), supercritical extraction test system (4" diameter), membrane test system, waste oxidation test systems. The membrane units include a low pressure pure water system, a high pressure water/organic system, and an industrial membrane unit.

The Chemical and Petroleum Engineering Building on the main campus also provides laboratory and office space. This building houses most of the bench-scale equipment including membrane research apparatus for liquid mixtures, high-pressure, single- and multiple-component gas permeation cells, polymer fabrication laboratory, reactors for sulfur dioxide with hydrated lime.

A highly qualified team of faculty, staff and graduate students are available to carry out fundamental separations research. Approximately 50 graduate and post-doctoral personnel are involved in the projects.

Telephone, facsimile, e-mail are accessible.

VIRGINIA

U.S. ARMY

Mobility Technology Center Belvoir
AMSTA RBWE, Bldg. 325
10115 Gridley Rd., Suite 128
Fort Belvoir, Virginia 22060-5843

Administrator: Thomas H. Bagwell, Jr.

Telephone: 703-704-3346

Fax: 703-704-2823

The U.S. Army has conducted laboratory and pilot plant testing at their Fort Belvoir location for many years. One of the most well known designs to result from their past work is the Reverse Osmosis Water Purification Unit (ROWPU), which have been extensively used in the recent middle east conflict and a disaster areas such as Somalia and Rwanda. The U.S. Army is currently constructing a new facility for their water treatment research in Warren, Michigan. The new facility should be ready for occupancy in 1997.

The new facility will contain many of the features as the Fort Belvoir facility, in addition to new equipment which is planned. The existing facility at Fort Belvoir contains a chemistry laboratory, reverse osmosis test room, an indoor test site as well as a Potomac River Test Site and a fresh water pond site. These sources provide access to a variety of water quality problems. A variety of reverse osmosis and other membrane filtration equipment is available, as well as pre-treatment and post-treatment methods. Facilities are capable of accepting other pilot plant equipment. Flow capacities up to 70 gpm are possible with existing pilot plants, which are capable of accepting commercial membranes ranging in size from 2-1/2" x 14" to 8" x 40". Gas/refrigerant, liquid/water, and titanium coil heat exchangers are available.

The equipment is instrumented for flow rate, temperature, pressure, conductivity, and pH measurement. Analytical equipment on site includes SDI, TSS, HPLC, TDS, DO, particle size distribution, pH, turbidity, chloride. Feedstreams include brackish water, seawater, and Potomac River water. Concentrate is disposed via city sewer. Equipment, instrumentation and facilities are in good condition.

Support staff is limited and researchers should anticipate providing their own supervision. Facility caretakers are available, but maintenance of equipment is the responsibility of those that come on-site. Telephone, facsimile, Internet and e-mail are on-site, but office space is not available.

Features of the new Michigan facility will be summarized and made available to interested research parties as soon as it is completed.

Cost:

Cost of facilities and limited support must be negotiated on a case by case basis.

WASHINGTON

EVERETT, CITY OF

Everett Water Treatment Plant
Everett, Washington

Administrator: Mr. Clair Olivers; Peter Berger, Plant Supervisor

Telephone: 206-259-8817

Fax: 360-793-2925

The City of Everett installed a pilot plant at their Everett Water Treatment Plant as a vehicle to determine the optimum filter media for their feed stream. Originally built at a cost of \$100,000, it consists of 4 column filters constructed of 3" PVC, 2 each 4 stage floc basins, and an ozone generation and ozonation section. the ozone process is capable of either multiple or single pass treatment. Other features include an initial flow distribution section and backwash module.

They have jointly participated with University of Washington in earlier tests. Due to the nature of the process, a strong commitment of time and manpower is required to obtain good steady state data. The equipment can be broken down into sections and used at other locations. Sections are being leased for use at this writing.

The incoming water quality at the Everett Water Treatment Plant is typically high quality, often exhibiting turbidity of < 0.5 NTU. Additional data to be attained at this site is limited, but could include analysis of DBP's from ozonation.

PART 3

Laboratory Facilities

LABORATORIES

The laboratories described in this section do not possess pilot plant scale equipment, but have excellent facilities and laboratory equipment. All of those listed indicated a desire to collaborate with partners in future research projects. Most of the laboratories identified were owned by universities, with the exception of one privately owned laboratory. All were extensively equipped with instrumentation and sophisticated analytical tools which are needed for quality research. Each is capable of providing highly qualified research staff support.

The laboratories are listed by state.

ALASKA

ALASKA-FAIRBANKS, UNIVERSITY OF

Institute of Northern Engineering

Water Research Center

529 Duckering Bldg.

University of Alaska-Fairbanks

Fairbanks, Alaska 99775-5910

Administrator: Joseph Trubacz

Telephone: 907-474-6088

Fax: 907-474-6686

The INE has been existence for 20-30 years and receives research funding from NSF, EPA, DEC (State), USGS, and \$280K in State appropriations each year. Institute staff: 3 professors, 4 research associates/assistants, 10-15 graduate students. Specializing in engineering and biology. Receive about \$1 MM in outside research funds.

Areas of interest:

1. Environmental engineering
 - cleanup at military bases
 - hydrologic linkage with arctic fresh water
 - satellite aperture reading (SAR) with NASA
2. Water quality
3. Hydrology
4. Groundwater cleanup
5. Municipal water treatment

Water Research Center is a unit within the INE. The center has no pilot plant equipment, but does have a well equipped laboratory. Their staff and students undertake field projects throughout the world (e.g. Antarctica, Russia). The WRC obtains about \$1.5 MM in funding (separate from INE funds). They have 15 faculty and 5 technicians. The professors would love to get their hands on pilot plant equipment, but have not yet received the right kind of project which will allow them to purchase it.

Other lab facilities are excellent, with a fair amount of sophisticated equipment such as GC/MS, MS for radioisotopes. He will fax a list to me. Lab has both PC and Mac capability, Internet.

Analytical Equipment:

- Atomic absorption spectrophotometer, Perkin Elmer, cation lamps, flame ionization and graphite furnaces
- pH meter/Ion analyzer, Orion Research Model 701A
- Spectrophotometer, Bausch and Lomb Spectronic 2000
- Organic carbon analyzer, Sybron Photochem
- GC/MS, Hewlett Packard 5890 Series II, flame ionization detector and single port purge and trap concentrator
- Autoclave, American sterilizer
- Isotope mass spectrometer, Sira Series II
- Autoanalyzer, Perstop Analytical (silicates, ammonia, nitrite + nitrate, phosphate)
- Two work stations: IBM Risk 6000 and data general Avion
- Two continuous fermentation chambers, New Brunswick Scientific, BioFlow III system
- Liquid scintillation counter, Beckman model 5801
- Microscope with camera, Zeiss, Inc.
- Time domain reflectometer (three) for continuous measurement of soil moisture in-situ, Textronix and Campbell Scientific
- Four temperature controlled walk-in environmental chambers for experiments of a range of -10oC to 30oC

ARIZONA

ARIZONA STATE UNIVERSITY

Environmental Engineering Research Laboratory

Arizona State University

Tempe, AZ 85287

Administrator: Prof. Larry Baker

Telephone: 602-965-0575

Fax: 602-965-0557

e-mail: lbaker@asu.edu

Over the past five years the Environmental Engineering Lab at ASU has undergone a major expansion in analytical capabilities and is now fully equipped for nearly any study in the areas of drinking water treatment, groundwater remediation, pollutant fate and transport, industrial and municipal wastewater treatment, water reuse, and regional analysis of environmental problems.

Specialized analytical instruments:

- Perkin-Elmer model 3100 atomic absorption spectrophotometer with graphite furnace and MS-100 hydride generation system
- Two Water Powerline 600 HPLCs (one with UV/VIS detector and one with a conductivity detector)

- Gow-Mac gas chromatograph
- Hewlett-Packard 5890 gas chromatograph with Tekmar LSC 2000 purge and trap accessory
- Two high capability spectrophotometers (Hewlett-Packard diode-array UV-VIS and Shimadzu UV-VIS spectrophotometer)
- Two carbon analyzers (Dohrmann Model 180 Shimadzu model TOC 5050A)
- Dionex DX40 ion chromatograph
- Brinkman Autotitration system
- Hach DR2000 spectrophotometric system
- N-CON Systems respirometer with computer control
- SRI gas chromatograph with FID/TCD detectors and auto gas sampling valve
- Lagus Autotrac SF[^] tracer gas detector
- Varian Star Workstation w/ECD/TCD/FID/PID detectors
- Tekmar purge and trap and autosampler units

Experimental apparatus

- Walk-in constant temperature room
- Walk-in cold room
- 2-D aquifer physical model
- 3-D aquifer physical model
- Large-scale aquifer recharge model
- A variety of equipment for batch and flow-through reactor studies
- Large and small scale NOM isolation/fractionation systems
- Bench-scale hollow fiber/spiral wound ultrafiltration and reverse osmosis systems (continuous or recirculating flow)
- Amicon batch ultrafiltration systems
- Ultraviolet irradiation systems

Field Equipment

Water /wastewater sampling

- Chevy Astro minivan (other vehicles available)
- 16-foot Lowe jonboat with a 30 HP outboard motor
- A variety of equipment for field sampling (field filtration apparatus: D.O. meters, Kemmerer sampler, field peristaltic pumps, bottom dredges, etc.)

Soil/groundwater

- Shallow boring and sampling equipment and geophysical equipment for surface profiling, crosshole and uphole wave velocity measurements.
- Large scale direct shear, trench shear test, anchor pullout for skin friction, downhole collapse test, and in-situ permeability
- Pressure plates and membranes, tensiometers, psychrometers, and other equipment for determining unsaturated soil properties.
- Time domain reflectometry (Environmental Sensors)
- Troxler Sentry 2000 capacitance probe
- Equipment for monitoring moisture content changes in the field.
- Apparatus for all standard index tests, compaction, direct shear, conventional consolidation, constant-rate-of-strain consolidation, vacuum triaxial, back-pressure saturated triaxial apparatus for both static and cyclic loading with microcomputer closed-loop test control and automatic data acquisition, reduction, and plotting.

Other facilities for environmental analysis at ASU

- State of the art GIS facilities
- Environmental Analysis Lab, College of Liberal Arts and Sciences (extensive water analysis capability; algal laboratory)
- Center for Solid State research (extensive array of equipment for solid phase analysis - PIXIE, SEM with ion probe, etc.)
- Geology Department (mineralogy analysis; surface analysis, etc.)

ARIZONA

ARIZONA, UNIVERSITY OF

Chemical and Environmental Engineering

Building 72, Room 306

Tucson, Arizona 85721

Administrator: Prof. Raymond Sierka

Telephone: 602-621-6044

Fax: 602-621-6048

The University of Arizona does not currently own pilot plant equipment, but space available to accommodate pilot plant units. They have extensive analytical and laboratory equipment which could support pilot plant testing. The environmental engineering laboratory covers 3000 sq. ft. on the third floor and basement of the civil engineering building on the main campus.

The university is engaged in conducting pilot plant research and development with a reverse osmosis system owned by the contracting company. The research is in the field of pulp and paper manufacturing. Extensive testing has already been conducted^{1,2}.

The general areas of expertise include physical-chemical treatment of water and wastewater for reuse purposes by adsorption with activated carbon, oxidation with ozone and other chemical oxidants, membrane processing including ultrafiltration and reverse osmosis and heterogeneous photocatalysis of toxic and hazardous pollutants.

The director of the environmental engineering program, Dr. Raymond Sierka has participated as a consultant in the development of many innovative and unique processes, including a wastewater treatment pilot system which processed all inclusive liquid wastes from an army field hospital.

Laboratory instrumentation and specialized equipment:

- Sepa cells for flat sheet testing - 138 cm².
- Membranes: all commercial flat sheet membranes

¹Sierka R.A. and H.G. Folster, J.J. Avenell, "The Treatment of Whitewaters by Adsorption and Membrane Techniques," 1994 International Environmental Conference Proceedings, Technical Association of the Pulp and Paper Industry.

²Sierka, R.A. and J.A. Avenell, H.J. Angell, "An Evaluation of Membrane Treatment of a Sulfide Kraftmill Wastewater," 1992 Environmental Conference Proceedings, Technical Association of the Pulp and Paper Industry.

- Heat exchangers: cooling water
- Pre-treatment:
 - Ozone generator
 - Hydrogen peroxide injector
 - Ultraviolet irradiator
- Disinfection:
 - Ozone generator
 - Chlorine injector
- Instrumentation:
 - Liquid chromatograph
 - Liquid scintillation counter
 - Ultra low level dissolved organic carbon analyzer
 - Low level dissolved organic carbon analyzer
 - Total organic halide analyzers
 - Gas chromatograph with ECD detector and 3390A integrator
 - Gas chromatograph with flame ionization detector and 3392 integrator
 - Atomic absorption spectrophotometer with HGA-40 graphite furnace
 - Scanning UV/VIS spectrophotometer
 - Particle counter
 - Phase contrast and epifluorescence microscopes
 - Image analysis system with 386 computer interface
 - Two ozone generators
 - Biostat MD benchtop fermentor
 - Seven benchtop fermentors
 - Biological oxygen monitor
 - Manometric respirometers
 - French hydraulic press and biological cell
 - Automatic titration pH-stat
 - Refrigerated centrifuge
 - Benchtop microcentrifuge
 - Ultrafiltration cells
 - Reverse osmosis/ultrafiltration flat sheet test cells
 - Various other lab instruments.

CALIFORNIA

CALIFORNIA, UNIVERSITY OF

Berkeley, California
Davis, California
Irvine, California
Riverside, California

The University of California system has participated in water and wastewater treatment research for many years. More than one of the above mentioned campus locations have participated with the National Water Research Institute in research programs and have indicated a strong interest in continuing the relationship. although none of the above are known to have pilot scale facilities, they have extensive laboratory facilities capable of supporting research programs and could facilitate small pilot scale experimentation.

CALIFORNIA

SAN DIEGO STATE UNIVERSITY

College of Engineering, Mechanical Engineering
San Diego, California 92182-0191

Administrator:

Telephone: 619-594-5652

Fax: 619-594-6005

Note: Due to the recent untimely and tragic death of the administrator of this program, Dr. Preston Lowrey, the future of the water purification program at SDSU is not well known. An updated report on their work will be published at a later date. Following is the report from the first survey.

The San Diego state University mechanical engineering department is engaged in the laboratory scale batch testing of a novel concept to drive distillation, using an open cycle chemical heat pump and saturated calcium chloride solutions. the laboratory testing is to prove the concept. The equipment is instrumented with data logger, pressure gages, and other necessary instruments.

The facilities are equipped with both PC and Mac equipment and the staff is composed of associate professor, graduate students, seniors and one technician. Telephone, facsimile, and e-mail comprise the laboratory communications.

The work at the university is unique and innovative; the university is actively contacting industry to market this invention³.

³Lowrey, Preston, "Salinity Powered Distillation of Freshwater from Seawater Using Plastic Sheet Heat Exchangers," San Diego State University, R/OE-18, 1990-92.

CALIFORNIA

SEPARATION SYSTEMS TECHNOLOGY

4901 Morena Blvd., Bldg. 809

San Diego, California

Administrator: Mr. Robert L. Riley

Telephone: 619-581-3765

Fax: 619-581-1211

Separation Systems Technology is one of the few privately held research laboratories. The company has a fully equipped laboratory and testing facility and occupy 2400 sq.ft. All of the equipment is of latest state of the art design and is in excellent condition.

Equipment:

- Twenty element reverse osmosis test system. The system can be operated in either once through or recalculation mode. elements, 2"x12", are tested in the parallel mode. The system is mobile and accommodates pressure up to 200 psi.
- Twelve element reverse osmosis test system. The system operates in the once through mode only. Chemical addition is optional. Usual element size is 2"x12" and normally at line pressure.
- Reverse osmosis flat sheet test cell system; brackish water and seawater testing, capable of operation up to 800 psi.
- MF, UF, RO single element test system; 2.5x40" spiral wound elements, 250 psi maximum pressure
- Spiral element rolling machine and associated equipment design and manufacture.
- Spiral element autopsy equipment for all sizes. Dye testing, vacuum testing, foulant analysis, etc. Detailed analysis reports are provided.
- Laboratory scale membrane casting machine for processing MF, UF and RO membranes.
- Continuous large scale membrane casting machine for processing MF, UF and RO membranes.
- Spiral element test systems for microbiological evaluations.
- Transparent membrane test cell system for evaluation of spiral element spacer materials, cleaning solutions, etc.

The instrumentation and analytical equipment at the facility are extensive and the office has Mac computer facilities. Communications are by telephone and facsimile. Research support is available from scientists and technicians as well as supervision by the owners. The company is owned by Bob Riley, Clyde Milstead and Ken Tagami, all well known scientists and practitioners in the membrane industry.

Limited office space is available. Additional space is available in the laboratory for placement of pilot plant skids if required. The laboratory has completed numerous membrane separations contracts for both private companies and public agencies.

The rate for facilities and services is negotiated on a case by case basis.

CALIFORNIA

STANFORD UNIVERSITY

UNIVERSITY OF SOUTHERN CALIFORNIA

Both of these prestigious private universities have extensive capabilities in water resources and water treatment research and development. Departments of both universities have participated in National Water Research Institute research projects and support the National Centers program.

ILLINOIS

ILLINOIS INSTITUTE OF TECHNOLOGY

Department of Chemical and Biological Science

Chicago, Illinois 60616

Administrator: Prof. Dale Webster

Telephone: 312-567-3491

Fax: 312-567-3494

The Institute has an extensive laboratory with state of the art instrumentation and analytical equipment. The laboratory is equipped to do biological and chemical research.

An innovative research project initiated at IIT, in collaboration with General Atomics and funded by NWRI, embraces the concept of a sodium ion pump utilizing proteins to move sodium ions. It is one of the few new, innovative approaches to separation membranes.

Wastewater, wastewater effluent and synthetic solutions can be utilized to conduct separations research. Well qualified research support staff are available including the following disciplines: biochemistry, microbiology, molecular biology and genetics, analytical chemistry.

The laboratory is fully equipped with PC, Mac and main frame computers terminals and has excellent communication facilities.

MARYLAND

JOHNS HOPKINS UNIVERSITY

Department of Geography and Environmental Engineering

Baltimore, Maryland 21218

Administrator: Dr. Charles O'Melia

Telephone: 410-516-7092

Fax: 410-516-8996

The Johns Hopkins University Department of Geography and Environmental Engineering has a complete analytical laboratory with full capability for inorganic and organic constituent analysis in water and soils. Bench-scale testing equipment is available to conduct both batch and flow reaction process research. Column-scale

testing equipment is available for simulation of groundwater flow and direct filtration processes including ultrafiltration membranes. The bench-scale equipment is capable of up to 200 m./min.

Laboratory pretreatment resulting in distilled water or deionized tap water is available at several locations. Disinfection can be accomplished with ozonation and chlorination.

They have extensive capability for organic and inorganic chemical analysis, microbiologic research, particle measurement, and radiotracer analysis. In addition to more standard instrumentation, the laboratory includes:

- Refrigerated centrifuge
- Lambda 3 spectrophotometer
- Ion chromatograph
- Particle counting and sizing analyzer
- Atomic absorption spectrophotometer with graphite furnace and auto sampler
- UV visible recording spectrophotometer
- Electrophoresis system
- Photon correlation spectrophotometer
- Liquid scintillation counter

Organic analysis instrumentation is even more extensive than the inorganic analyzers detailed above.

The environmental engineering and science laboratories total 7,000 sq. ft. Four environmental chambers are installed for controlled temperature research. Computer resources are available in the Department Computer Laboratories. Personal computers and terminals with access to ethernet and mainframe computers (IBM, Digital (VAX), and AT&T). Adequate office space is available.

MONTANA

MONTANA STATE UNIVERSITY

Center for Biofilm Engineering
409 Cobleigh Hall
P.O. Box 173980
Bozeman, Montana 59717-0398
Administrator: Nicholas Zilver
Telephone: 406-994-4770
Fax: 406-994-6098

Although the Center for Biofilm engineering does not possess pilot plant equipment, it is imminently qualified to perform biofilm research and development. The engineering research center has the capability to do bench scale evaluation of the impact of biofilms on separations equipment.

The Center's mission is to address industrial environmental and medical aspects of biofilm processes. It conducts basic and applied research to resolve industrial problems to strengthen U.S. competitiveness. Industrial participation is an essential part of research planning. Some of the Center's industrial sponsors include AWWARF,

Amoco, Aramco Services, Betz PaperChem, BHP Copper, Calgon, Chevron, Clorox, Conoco, DuPont, Exxon, Idaho National Engineering Laboratory, Nalco Chemical, NWRI, Olin, Pacific Northwest National Laboratories, Procter & Gamble, Rohm and Haas, S.C. Johnson Wax, Union Carbide, and Westinghouse Savannah River Company.

The Center specializes in interdisciplinary fundamental and applied biofilm research, measurements and simulation modeling. Approximately 30 research staff and 50 students are available to support projects, with 15 PhD principal investigators covering the disciplines of Microbiology, Chemical engineering, Civil Engineering, Chemistry, Mathematics, Physics, Computer Science, and the School of Business. Recent Center-developed advances in biofilm understanding and control include novel methods of detecting and analyzing biofilms, and biofouling work focusing on understanding and overcoming biofilm resistance to the penetration of biocides.

MONTANA

MONTANA, UNIVERSITY OF

Division of Biological Sciences
Department of Geology
Missoula, MT 59812

Administrator: Prof. Dan C. DeBorde
Telephone: 406-243-2389
Fax: 406-243-4184

The university has broad experience in water resources and hydrogeology as applied to water quality issues. The two departments are jointly engaged in an NWRI Research Project to examine the transport and fate of viruses in the vicinity of pumping wells. The university supports the National Centers concept.

NEW YORK

RENSSELAER POLYTECHNIC INSTITUTE

Membrane Separations
Chemical Engineering Department
Troy, New York 12180-3590

Administrator: Dr. Georges Belfort
Telephone: 518-276-6948
Fax: 518-276-4030

Rensselaer Polytechnic Institute has been involved in fundamental hydrodynamic and membrane separations research for many years. Dr. Belfort is globally recognized for his work in this field. The membrane separations laboratory conducts fundamental studies with sophisticated analytical tools.

Although no pilot scale equipment is currently on-site, the facilities can be easily modified to accommodate pilot testing. The laboratory equipment includes reverse osmosis, nanofiltration, ultrafiltration, microfiltration (cross flow), Taylor Vortex Units. The flow rates are small laboratory type flows with variable cross-flow velocities. Flat sheet, tubular or any commercial membranes can be tested. The laboratory

equipment, instruments and facilities are in excellent condition.

Brackish water, seawater, wastewater, wastewater effluent and synthetic solutions are available for testing. Instrumentation and analytical equipment include ATR/IR, ESCA, SEM, UV among others.

The research staff includes one professor principal investigator and eight graduate students. Special disciplines of the staff are membrane fouling and cleaning, module design and improvement. Office space is available, but limited. All types of communications are available and both PC and Mac computers as well as terminals are on site.

Charge rates for facilities and services are by negotiated agreement with the university.

NORTH CAROLINA

NORTH CAROLINA STATE UNIVERSITY

NORTH CAROLINA-CHAPEL HILL, UNIVERSITY OF

These institutions are currently participating in a joint NWRI project, developing a new separations membrane using block polymers. Both of extensive water resources and water treatment technology laboratories and support the National Centers concept.

PENNSYLVANIA

PENNSYLVANIA, UNIVERSITY OF

Department of Mechanical Engineering

297 TB/6315

Philadelphia, PA 19124-6315

Administrator: Dr. Noam Lior

Telephone: 215-898-4825

Fax: 215-573-2065

The University of Pennsylvania was one of the early institutions to conduct experimentation for the desalination industry. Led by Professor Lior, it is also one of the few who have the capability to study evaporative processes such as flash evaporation. the department has particular expertise in desalination, heat transfer, fluid mechanics, thermodynamics, and instrumentation.

The test facility contains both small and large reactors for the fundamental study of flash evaporation, with complete instrumentation. Components for a facility for fundamental study of reverse osmosis and membrane distillation are also in place. Although currently not in use, the equipment can be made operable quickly, if funding is available.

Various heat exchangers (condensers) are available as well as complete instrumentation for precise temperature and pressure measurement, conductivity, and flow rates.

Analytical equipment includes gas chromatography and conductivity in addition to the normal analytical equipment common to modern day university laboratories.

A support staff of principal investigator, technicians, graduate and undergraduate students as well as facility and maintenance personnel are available. All communications except telex are available, and office space is available on a limited basis.

Brackish water feed source is available in addition to tap water. The cost for facilities and services is negotiated by the university on a case by case basis. The university is anxious to participate in the centers concept.

TENNESSEE

TENNESSEE, UNIVERSITY OF / OAK RIDGE NATIONAL LABORATORY

Center for Environmental Biotechnology

10515 Research Drive, Suite 300
Knoxville, Tennessee 37932-2575

Administrator: Dr. David C. White

Telephone: 423-974-8030

Fax: 423-974-8086

The Center for Environmental Biotechnology does not have pilot scale equipment, but is very much interested in continued involvement in the analysis of biofilms that foul membranes. They use the signature lipid biomarker technology developed by the Center for the in situ analysis of the viable biomass, community structure, and the nutritional/physiological status of the biofouling membranes in collaboration with samples from the Orange County Water District.

Assay types offered by the Center and their affiliated analytical company:

Microbial Insights, Inc.
201 Center Park Dr., Ste 1140
Knoxville, TN 37922-2105
Telephone: 423-966-7356
Fax: 423-966-7357
e-mail: Drewwhite@aol.com
homepage: www.microbe.com

- Phospholipid fatty acids (viable biomass, community structure, nutritional status, toxicity Eukaryote/prokaryote ratio)
- Poly fl-hydroxy alkanolate (unbalanced growth/nutritional status)
- Steroids (microeukaryote community structure, fungi, protozoa, algae)
- Lipopolysaccharide (identifies gram-negative bacteria)
- Diglyceride (DC/PFLA dead to viable cells; community structure of each)
- Triglyceride (steroid/TG eukaryote nutritional status)
- Respiratory quinones (proportions of aerobes anaerobic fermenters, and anaerobic respirers)

Cost:

Estimated cost for individual analysis is \$60-260 per sample (quantity discounts may apply).

PART 4

Private Sector Companies

COMMERCIAL COMPANIES

Many commercial companies own pilot scale equipment which they use in validating applications for their own products, or in completing engineering studies. These companies fall into the general categories of product or systems related companies and engineering consultant companies.

The companies represented below have indicated their willingness to participate in the "Centers" concept. A short synopsis of the company and/or pilot scale equipment, if available, follows. This is by no means a complete list, but the companies shown here represent the types of companies who have pilot plant equipment available.

AMERICAN ENGINEERING SERVICES

5912 Breckinridge Parkway, Ste F
Tampa, Florida 33610

Telephone: 818-357-9910

Fax: 818-357-1257

AES has manufactured membrane systems for several years. They currently have a seawater desalting pilot plant with nominal 8000 gpd capacity. It is a simple one stage system with manual controls. It rents for about \$200 per day.

DOW CHEMICAL COMPANY

Larkin Laboratory
Midland, Michigan

Telephone: 517-636-9495

The Dow Chemical Company manufactures thin film composite ultrafiltration, nanofiltration and reverse osmosis membranes. Their focus is on membrane production and distribution; most of the applications research requiring pilot plant testing is left to their OEMs. They have a 60,000 gpd trailer mounted membrane system available for rent or lease which accommodates either nanofiltration or brackish water desalting membranes. It is manually operated, with chemical pre-treatment, cartridge filtration and a cleaning skid.

DUPONT NYLON Permasep Products

P.O. Box 6101
Newark, Delaware 19714

Telephone: 302-451-3228

Fax: 302-451-9686

The DuPont Company manufactures hollow fiber reverse osmosis membrane permeators for seawater and brackish water desalination. Their current focus is on seawater membranes. Although the company does not possess pilot plant equipment for research and development, it is likely that many of their licensees do. DuPont is willing to participate in research programs which fit their current research direction.

FLUID SYSTEMS CORPORATION

10054 Old Grove Road
San Diego, California 92131

Telephone: 619 695-3840
Fax: 619-695-2176

The Fluid Systems Corporation manufactures spiral wound ultrafiltration, nanofiltration, and reverse osmosis membranes. They manufacture both cellulose acetate and thin film composite membranes. Two pilot plant skids are available which can utilize commercial membranes of 2.5" and 4" design. They contain pressure vessels in 2:2:1:1 array, each housing 3 membrane elements. This allows either parallel or series connection, with up to 75 +/- % recovery. The usual commercial rate for rental is \$1500 per month, plus the cost of membranes. Cellulose acetate membranes (4") are typically \$225 and thin film composite membranes (4") are typically \$300.

HARN RO SYSTEMS

203 S. Jackson Rd.
Venice, Florida 34292

Telephone: 813-488-9400
Fax: 813-488-9671

Harn RO has manufactured small to medium sized plants for many years and have recently manufactured multi-million gallons per day systems. Their pilot plant is nominally rated at 13-21 gpm and is a microprocessor based system, fully automated and multiple data point collection. Data can be telemetered to a central location, allowing operational flexibility. Their pilot plant systems are typically mounted on fiber reinforced plastic frames to prevent corrosion, and stainless steel tubing is electropolished. Standard rental rates are about \$5000 per month plus membrane cost.

HYDRANAUTICS

401 Jones Road
Oceanside, California 92054

Telephone: 619-901-2521
Fax: 619-901-2578

Hydranautics manufactures and sells reverse osmosis, nanofiltration and ultrafiltration membranes. They are available in flat sheet, tubular, hollow fiber or spiral wound configurations, but not all membranes are available in all configurations. Both cellulose acetate and thin film composite membranes are available. Their mobile trailer unit is a nominal 20,000 gpd unit with a simple 2:1 array. Cost of rental or lease is about \$2000 per month.

IONICS, INC.

65 Grove Street
Watertown, Massachusetts 02172

Telephone: 617-926-2500

Fax: 617-926-4304

Ionics is the pioneer in the desalting industry, beginning with the sale of electro dialysis desalting equipment in the 1950's. In recent years they have diversified by moving into reverse osmosis systems, water production, water sales, privatized plants, instrumentation and several other areas which make them a versatile company. they have several pilot plants, including both electro dialysis reversal and reverse osmosis.

OSMONICS, INC.

5951 Clearwater Drive
Minnetonka, Minnesota 55343

Telephone: 612-933-2277

Osmonics is one of the early manufacturers of cellulose acetate membranes. they have historically specialized in the industrial markets and have many pilot plants for testing purposes. In recent years they have broadened their product line to include pumps, instrumentation, cartridge filters, and other products.

ENGINEERING COMPANIES

Consulting engineers often conduct on-site pilot plant testing to verify performance prior to final design of large water treatment and purification plants. Most of the leading companies have pilot plant equipment, both skid-mounted for shipment, or mobile for rapid transfer. Although they are primarily used to aid them in customer related engineering tests, they are not always utilized. When they are not in use, they can be made available for use by researchers, on a rent or lease basis, or by negotiating a cooperative agreement.

Listed below are some of the companies known to have pilot plant equipment available. This is not a comprehensive list and there may be other companies with pilot plant equipment.

CAMP DRESSER MCKEE

Walnut Creek, California

CDM has established a capability to design and construct pilot plant facilities, and has done so for municipalities and water districts. They also maintain their own pilot plants for use at various project sites.

CH2M-HILL

Gainesville, Florida

CH2M-Hill have conducted pilot scale testing throughout the U.S. They have been particularly active in Florida, where membrane softening has become widely used for water treatment plant construction. Both skid-mounted and mobile equipment are available from this company. Typical charge for a complete, sophisticated mobile trailer mounted units is about \$4500 per month. Exact charges are a function of the situation and cooperative effort negotiated. Both conventional and advanced treatment pilot plants are available.

MALCOLM PIRNIE, INC.

Newport News, Virginia

Malcolm Pirnie has several plants which they utilize for engineering studies. They include: (1) skid mounted RO, 3 stage, nominal 30 gpm flow rate, designed for pressures up to 600-800 psi. Estimated rental fee is \$2500 per month. (2) Single element test stand for 2.5" membrane elements for testing nanofiltration or reverse osmosis membranes. (3) Microfiltration hollow fiber test skid, nominal 2 gpm flow rate. Simulates full scale operation. (4) Hollow fiber ultrafiltration membrane skid with nominal 4 gpm flow rate.

MONTGOMERY WATSON

Pasadena, California

Montgomery Watson has a wide array of pilot scale equipment available, including reverse osmosis (mobile), ultrafiltration, ozonation, ultraviolet irradiation, coagulation/sedimentation/filtration, media filters, air stripping, chlorine contact chambers, granular activated carbon. Sizes range from 5 gpm to 1 mgd. The company has an Applied Research Department, fully staffed to support research and development projects.

Table 10. Typical Commercial Pilot Plants

CENTER: LOCATION:	COMMERCIAL COMPANIES						
	United States						
COMPANY: PROCESS:	Fluid Systems Reverse Osmosis	Ham RO Membrane	CH2M-Hill Membrane	CH2M-Hill Conventional Treatment	Ionics, Inc. Electrodialysis Reversal	Memtek Microfiltration	
No. of systems	2	1	1	1	1	1	1
Skid mounted	x	x					
Mobile			x	x	x	x	x
Rated flow, gpm	15	21	15	5	17	30	30
No. of stages	4	4	3				1
Elements per stage	3	3	6				
Element Size	2.5", 4"	2.5", 4"	4"		Aquamite V	30M10	
Recovery, %	75	75	75				100
Membrane type:	CA, TFM	CA, TFM	CA, TFM		ED		
Approximate cost (per mo)	\$1500.00	\$5000.00	\$4500.00		\$7000.00	\$3000.00	

NOTE: This represents a small sampling of commercially available water purification equipment which are available for rent or lease.

PART 5

Appendix

Table 11. State or Federal Facilities

Facility	STATUS	Location	Pilot	Eq	Lab E	Feed H2	Mem	Bio	Pretr	Disin	Facility cd	Labor cost	OH rate
California DWR	ok	Fresno, CA	x	x		bw, ww		x					25%
Los Alamos National Laboratory	ok	Los Alamos, NM	x	x		bw, ww	x		x	x			TBN
US Army Tank Automotive R&D Ctr.	moving to MI	Pt. Belvoir, VA	x	x		bw, sw	x		x	x			TBN
USBR R&E Laboratory	ok	Denver, CO	x	x		bw	x			x	no cost	\$56, \$71/hr(a)	
USBR WQIC	ok	Yuma, AZ	x	x		bw, ww	x		x	x	no cost (b)	\$25, \$45/hr(a)	
USN Civil Eng. Lab.	ok	Pt. Huachuca, CA	x	x		sw	x		x		no cost	\$75/hr	

bw = brackish water; sw = seawater; gw = groundwater; ww = wastewater; surf = surface supply

(a) Technician, engineer

(b) \$125/mo for 150 sf of office space

TBN = To Be Negotiated

Table 12. City and Water District Facilities

Facility	Status	Location	PP Eq	Lab E	Feed H2O	Mem	Therm	Bio	Conv.	Pretr	Disin	Facility cd	Labor cost	OH rate
Arlington Desalting Plant	ok	Riverside, CA	space	x	bw	x				x	x	no charge	at cost	none
Cambria Community Serv. Dist.	ok	Cambria, CA	space	x	bw, sw, ww	x				x	x	TBN	TBN	
Cape Coral, City of	on hold	Cape Coral, FL	x		gw	x				x	x	TBN	TBN	
Contra Costa Water Dist.	ok	Concord, CA	x	x	surf, ww	x			x	x	x	TBN	TBN	30%
Everett, City of	on hold	Everett, WA	x	x	surf					x	x	TBN	TBN	
Irvine Ranch Water Dist.	ok	Santa Ana, CA	x	x	gw	x		x	x	x	x	\$478/day		60%
Jupiter, Town of	on hold	Jupiter, FL	x		gw	x				x	x	inclusive	\$20, \$32/hr(a)	
Los Angeles, City of	ok	San Pedro, CA	space	x	ww	x		x	x	x	x	TBN	at cost	
Maui Department of Water Supply	ok	Tampa, FL	x	x	gw, sw	x		x	x	x	x	TBN	TBN	45%
Metropolitan Water Dist of So. Ca	ok	La Verne, CA	x	x	bw, gw, surf	x				x	x	TBN	TBN	
Orange County Water Dist WF21	ok	Fountain Valley, CA	x	x	bw, sw, ww	x		x	x	x	x	consumables	at cost	none
Padre Dam Municipal Water Dist.	ok	Santee, CA	x		ww			x	x			TBN	TBN	
San Diego, City of	ok	San Diego, CA	x	x	ww	x			x	x	x	data exchange	n/a	
San Francisco, City and County of	ok	San Francisco, CA	x	x	ww	x		x	x		x	TBN	TBN	
Santa Clara Valley Water Dist.	ok	San Jose, CA	x		surf						x	TBN	TBN	
Scottsdale, City of	ok	Scottsdale, AZ	x	x	ww	x				x	x	TBN	TBN	

bw = brackish water; sw = seawater; gw = groundwater; ww = wastewater; surf = surface supply

TBN = To Be Negotiated

(a) Lead operator

Table 13. University Owned Facilities

Facility	Status	Location	Pilot E	Lab E	Feed H2O	Membr	Therm	Bio	Pretr	Disin	Facility cost	Labor cost	Oil rate
Arizona State Univ.	ok	Tempe, AZ		x	syn			x	x		TBN	TBN	
Arizona, Univ. of	ok	Tucson, AS		x	syn	x		x	x	x	TBN	TBN	
California, Univ. of	ok	Berkeley, CA		x	syn	x		x		x	TBN	TBN	
California, Univ. of	ok	Davis, CA		x	syn			x		x	TBN	TBN	
California, Univ. of	ok	Irvine, CA		x	syn			x		x	TBN	TBN	
California, Univ. of	ok	Los Angeles, CA		x	syn	x		x		x	TBN	TBN	
California, Univ. of	ok	San Diego, CA		x	sw, syn			x		x	TBN	TBN	
Central Florida, Univ. of	ok	Orlando, FL	x	x	bw, ww, syn	x		x	x	x	TBN	TBN	
Clemson University	ok	Clemson, SC	x	x	incl, syn	x				x	\$2000	TBN	
Colorado State University	ok	Ft. Collins, CO	x	x	surf, syn	x		x	x	x	\$5000-proj	\$8, \$90/hr(a)	45%
Colorado, Univ. of	ok	Boulder, CO	x	x	bw, syn	x		x		x	TBN	TBN	
Connecticut, Univ. of	ok	Storrs, CT	x	x	surf, syn	x		x	x	x	TBN	TBN	
Hawaii, Univ. of	ok	Honolulu, HI	x	x	bw, sw, syn	x				x	incl	\$9, \$39/hr	38%
Illinois Institute of Tech	ok	Chicago, IL		x	ww, syn	x		x		x	TBN	TBN	
Illinois, Univ. of	ok	Urbana, IL		x	bw, syn	x		x	x	x	TBN	TBN	
Johns Hopkins Univ	ok	Baltimore, MD		x	syn	x		x		x	TBN	TBN	
Kentucky, Univ. of	ok	Lexington, KY	x		incl, syn	x		x	x	x	\$800-\$1000/day	\$12-\$25/hr	
Montana State Univ.	ok	Bozeman, MO		x	bw, syn	x		x			TBN	TBN	
Montana, Univ. of	ok	Missoula, MN		x	gw			x	x		TBN	TBN	

bw = brackish water, sw = seawater; gw = groundwater, ww = wastewater; surf = surface supply; syn = synthetic; incl = industrial

- (a) Technician, engineer
 - (b) Estimated cost for projects
 - (c) Per sample
- TBN = To Be Negotiated

Facility	Status	Location	Pilot E	Lab E	Feed H2O	Membr	Therm	Bio	Pretr	Disin	Facility cost	Labor cost	Oil rate
Nebraska-Lincoln, Univ. of	ok	Lincoln, NE	x		gw			x	x		\$10K-\$200K (b)	TBN	
North Carolina State Univ.	ok	Raleigh, NC		x	ww, syn	x		x			TBN	TBN	
North Carolina, Univ. of	ok	Chapel Hill, NC		x	ww, syn	x		x			TBN	TBN	44.5%
Pennsylvania, Univ. of	ok	Philadelphia, PA	x	x	syn sw		x	x			TBN	TBN	
Rensselaer Polytechnic	ok	Troy, NY		x	syn	x			x		TBN	TBN	
Rice University	ok	Houston, TX		x	ww, incl, bw	x		x	x	x	TBN	TBN	50%
South Florida, Univ. of	ok	Tampa, FL	x	x	bw, sw, syn	x		x	x	x	TBN	TBN	45%
Stanford University	ok	Palo Alto, CA		x	ww, gw			x	x		TBN	TBN	
Tennessee, Univ. of	ok	Knoxville, TN		x				x			inclusive	\$60-\$260 (c)	
Texas A&M University	ok	College Station, TX	x	x	food	x	x	x	x	x	\$250-\$2500/day	incl	
Texas-Austin, Univ. of	ok	Austin, TX	x	x	bw, ww	x		x	x		TBN	TBN	

bw = brackish water, sw = seawater; gw = groundwater; ww = wastewater; surf = surface supply; syn = synthetic; incl = industrial

- (a) Technician, engineer
 - (b) Estimated cost for projects
 - (c) Per sample
- TBN = To Be Negotiated

Table 14. Privately Owned Facilities

Facility	Status	Location	Pilot	Lab	Feed H2O	Memb	Therm	Bio	Pretr	Disin	Fac & Labor Cost	Eq't Cost
American Engineering Service	ok	Tampa, FL	x		bw, sw, ww	x		x				\$200/day
Aqua chem	ok	Waukesha, WI	x	x	bw, sw, ww	x	x					TBN
Boyle Engineering Corp	ok	Newport Beh, CA	x		bw, surf	x			x			TBN
Camp Dresser McKece	ok	Walnut Creek, CA	x		bw, surf	x		x				TBN
CH2M Hill Engineers	ok	Gainesville, FL	x	x	bw, surf	x		x	x	x		\$4500/mc
Dow Chemical	ok	Midland, MI	x	x	bw, sw, surf	x						TBN
DuPont de Nemours	ok	Wilmington, DE	x	x	sw	x						TBN
Fluid Systems	ok	San Diego, CA	x	x	bw, sw, surf	x			x			\$1500/mc
Harn RO systems	ok	Venice, FL	x		bw, surf	x						\$5000/mc
Hydranautics	ok	San Diego, CA	x	x	bw, sw, surf	x						\$2000/mc
Ionics, Inc	ok	Watertown, MA	x	x	bw, sw, surf	x						\$7000/mc
Malcolm Pirnie	ok	Newport News, VA	x	x	bw, surf	x						TBN
Meco	ok	New Orleans, LA	x	x	bw, sw, surf	x	x					TBN
Montgomery Watson	ok	Pasadena, CA	x	x	bw, sw, surf	x		x	x	x		TBN
Osmonics, Inc	ok	Minnetonka, MN	x	x	bw, surf, indl	x			x			TBN
Separation Systems Tech. Inc	ok	San Diego, CA		x	surf, syn	x					TBN	TBN

bw = brackish water, sw = seawater, gw = groundwater, ww = wastewater, surf = surface supply; syn = synthetic; indl = industrial
 TBN - To Be Negotiated

Table 15. Mothballed Research Facilities

Location	Responsible agency	Process												
		ED gpm	EDR gpm	RO gpm	UI gpm	UV gpm	VCI gpm	Carbon gpm	Ozone gpm	Filtr. gpm	Clarif. gal	Demitril. gpm	Rankine cycle eng. kw	
Denver, CO	Denver Water Board			57.0	57.0	57.0		57.0	55.0					
Lake Arrowhead, CA	Univ. of California-LA			2.1	3.2			7.0	7.0	7.0	yes	7.0		
Ewa, Oahu, HI	Univ. of Hawaii	231.0	231.0	231.0										
Los Banos, CA	Dept. of Water Resources		yes				35.0				12000.0		10	
Salt Rock, WVA	Salt Rock Water Public Service	Withdrew from National Centers Program												
Cape Coral, FL	City of Cape Coral			7.5										
Jupiter, FL	Town of Jupiter			22.5										
Las Vegas, NV	So. Nevada Water Authority			10.0				10.0						
Everett, WA	City of Everett								6.0	6.0	6.0			

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2. IDA Membership Directory, International Desalination Association, Topsfield, MA. June 30, 1995.
3. AWWA Proceedings, 1995 Membrane Technology Conference, American Water Works Association, Reno, Nevada, 1995.