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EASTERN MUNICIPAL WATER DISTRICT RO TREATMENT/SALINE VEGETATED WETLANDS PILOT STUDY

Final Report

Water Treatment Technology Program Report No. 16

September 1996

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
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13. ABSTRACT (Maximum 200 words)

The Bureau of Reclamation and the Eastern Municipal Water District in southern California conducted a jointly-funded research study to investigate the use of reverse osmosis (RO) to desalt San Jacinto Basin groundwater for municipal and industrial uses, and also to evaluate the use of the RO concentrate (reject) for sustaining saline vegetated wetlands to provide irrigated green belts, open spaces, and wildlife habitat.

Two separate low-pressure RO membrane elements were evaluated using a total of 18 elements in a 2-to-1 array operating at 75-percent recovery. Two local brackish wells were used as feedwater Sources: first, the Moreno Highlands well for an 1860-hour test using FilmTec's BW30-2540 elements; and second, the Dairyland well for a 1000-hour test using Desal 3LP (SG2540) elements. Both wells have salinities of approximately 1000 mg/L TDS (total desolved solids). Test results arc summarized in terms of average NDP (net driving pressure) and NPF (normalized permeate flow). RO reject flows were directed to the saline vegetated wetlands throughout the testing.

Four salt-tolerant plant species, native to southern California, were evaluated in the saline wetlands: alkali bulrush (*Scirpus robustus*), creeping spikerush (*Eleocharis palustris*), marsh smartweed (*Polygonum muhlenbergii*), and Pennsylvania smartweed (*Polygonum pensylvanicum*). The growth, establishment, and health of the plants were monitored from the initial planting. In addition, toxicological data were collected and analyzed, and observations of wildlife visitations were made. Conclusions are presented regarding the sufficiency of the data collected and the advisability of pursuing full-scale development of saline wetlands.

14. SUBJECT TERMS
--water treatment/groundwater/desalting/reverse osmosis/saline wetlands/*Scirpus robustus*/ *Eleocharis palustris*/*Typha spp* /heavy metals/Eastern Municipal Water District/Water Treatment Technology Program

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by

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Denver, Colorado

September 1996

UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION

ACKNOWLEDGMENTS

We would like to thank all of the people at the Eastern Municipal Water District who made this pilot study a success. Special thanks go to Steve Crombie and Stella Denison for their diligence and hard work in operating the test facility and monitoring results for the past 2 years. We would also like to thank Christie Crother for coordinating many of the study activities and for running interference for us when necessary, John Ward for his efforts during the design and construction phase, and S. Mark Nelson for his monitoring advice and invertebrate identification throughout the life of this project.

Mission Statements

U.S. Department of the Interior

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity: preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

National Biological Service

The National Biological Service, soon to be merged with the U.S. Geological Survey, works with others to provide the scientific understanding and technologies needed to support the sound management and conservation of our Nation's biological resources.

Disclaimer

CONTENTS

CONTENTS — Continued

Page

TABLES

FIGURES

FIGURES - Continued

APPENDIXES

ACRONYMS AND ABBREVIATIONS

CA	cellulose acetate
CDA	cellulose diacetate
cfu	colony forming units
CTA	cellulose triacetate
EC	electrical conductivity
EMWD	Eastern Municipal Water District
EPA	Environmental Protection Agency
FRP	fiber-reinforced plastic
GAC	granular activated carbon
HCl	hydrochloric acid
HPC	heterotrophic plate count
Ix	ion exchange
LSI	Langelier saturation index
MCL	maximum contaminant level
M&I	municipal and industrial
NBS	National Biological Service
NPF	normalized permeate flow
NDP	net driving pressure
ntu	nephelometric turbidity unit
PA	polyamide
PCB	polychlorinated biphenyls
PID	proportional integral derivative
PVC	polyvinyl chloride
RO	reverse osmosis
RWRF	regional water reclamation facility
scu	streaming current unit
SDI	silt density index
SEM	scanning electron microscopy
SR	salt rejection
SRPA	Small Reclamations Projects Act
TCF	temperature correction factor
TDS	total dissolved solids
TFC	thin-film composite
TOC	total organic carbon
UV	ultraviolet

CHEMICAL FORMULAS

Al^{+3}	aluminum ion
B^{+3}	boron ion
Ba^{+2}	barium ion
$BaSO_4$	barium sulfate
Ca^{+2}	calcium ion
$CaCO_3$	calcium carbonate
CaF_2	calcium fluoride
$CaSO_4$	calcium sulfate
Cl^-	chloride ion
Cl_2	chlorine
CO_2	carton dioxide
Cu^{+2}	copper ion
F	fluoride ion
Fe^{+2}	ferrous iron
Fe^{+3}	ferric iron
H^+	hydrogen ion
n c o ,	bicarbonate ion
Hg	mercury
H_2S	hydrogen sulfide
H_2SO_4	sulfuric acid
K^+	potassium ion
Mg^{+2}	magnesium ion
$Mg(OH)_2$	magnesium hydroxide
Mn^{+2}	manganese ion
N_2	nitrogen
Na’	sodium ion
NaCl	sodium chloride
NH_4^+	ammonium ion
NO,	nitrate ion
O_2	oxygen
O_3	ozone
PO_4^{-3}	phosphate ion
s	elemental sulfur
Se	elemental selenium
SiO_2	silica
SO_4^{-2}	sulfate ion
Sr^{+2}	strontium ion
$SrSO_4$	strontium sulfate

SI METRIC CONVERSIONS

From	TO	Multiply by
ft	m	*3.048 000 E-01
in	m	*2.540 000 E-02
ft^2	m^2	'9.290 304 E-02
kgal	m^3	3.785 412
Mgal	m^3	3.785 412 E+3
acre-ft	m^3	1.233 489 E+3
lb/in^2	kPa	6.894 757
°F	°C	$t_C = (t_F - 32)/1.8$

1. EXECUTIVE SUMMARY

The Bureau of Reclamation (Reclamation) and the Eastern Municipal Water District (EMWD) of San Jacinto, California, are involved in a cooperative research and demonstration project to evaluate the integration of multipurpose wetlands with wastewater and groundwater quality improvement, environmental enhancement, education and recreation, and. ultimate reuse of reclaimed water. Several predesign investigations and pilot studies were performed as part of the second phase of this project, and some are still ongoing at this writing. The pilot studies include the construction, testing, and evaluation of: (1) eight wetland research cells that are fed secondary treated municipal wastewater directly; and (2) a reverse osmosis desalination/saline vegetated wetland system.

EMWD is interested in reverse osmosis (RO) for desalting San Jacinto Basin water, exploring possible beneficial uses for the RO reject (concentrate)[1] generated with this process, and methods of reducing the concentrate volume prior to final disposal. One beneficial use that is being evaluated as part of this study is using RO reject to sustain saline vegetated wetlands. The wetlands reduce the volume of the reject through plant uptake and evaporation, then final evaporation ponds are used to further reduce the volume of the residual brine prior to disposal. The combination of low-pressure RO treatment of brackish groundwater and saline wetlands has the potential of providing high quality potable water at *a* reasonable cost for the needs of the San Jacinto Valley, as well as irrigated green belts, open spaces, and habitat areas.

An RO/saline vegetated wetlands research facility was constructed in San Jacinto, California, immediately west of the Hemet/San Jacinto Regional Water Reclamation Facility (RWRF). The research facility includes a 6 gal/min pilot RO system designed and built at Reclamation's Denver laboratories, two 20-foot by 80-foot by 2-foot-deep lined saline vegetated wetlands (marshes), and two similarly sized lined evaporation ponds (cells). The pilot RO system was installed and vegetation planted in the saline wetlands during the month of April 1993 by Reclamation and the National Biological Service (NBS) Denver Office personnel. Four salt-tolerant plant species which are attractive to wildlife were planted in horizontal bands in each of the two wetlands: alkali bulrush (*Bolboschoenus robustus*), creeping spikerush (*Eleocharis palustris*), marsh smartweed (*Polygonum muhlenbergii*), and Pennsylvania smartweed (*Polygonum pensylvanicum*). For 6 weeks, the plants received fresh water to promote growth. Then, shortly after pilot plant operations began on June 4, 1993, RO reject was added to the wetlands.

Three separate well waters were used in the pilot study. Originally, it was planned that all RO testing would be performed using the nearby Walker Duck Club well water. This well was selected because of its elevated total dissolved solids (TDS): 1,905 mg/L and its proximity to a future wetlands development site (Bureau of Reclamation and Eastern Municipal Water District, 1991). Two separate l,OOO-hour tests were to be conducted using the following low-pressure RO elements: FilmTec's BW30-2540 and Desalination System's 3LP (SG2540). However, subsequent to the building of the pilot plant and the completion of

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[1] Throughout this report, the terms "reject" and "concentrate" are used interchangeably to refer to the waste stream exiting the reverse osmosis process; whereas, the term "brine" is used for the more highly saline water flowing from the wetlands into the evaporation ponds.

RO reject-regenerated ion exchange pretreatment experiments (see appendix A), the Walker Duck Club well was abandoned as a source of feedwater because of severe flooding and access problems. The nearby Moreno Highlands well (975 mg/L TDS) was then selected by EMWD as an interim feedwater source to begin testing of the FilmTec elements. After 1,860 hours of operation, the Moreno Highlands well pump failed due to electrical problems. Because of tbe anticipated high cost of repair, along with legal problems associated with a recent change in ownership of the well, EMWD switched to yet another feedwater source. After almost 6 months of down time, the EMWD-owned Dairyland well (1,049 mg/L TDS) was selected as a replacement. The Desal 3LP elements were then loaded, and testing began anew. Operations continued with these elements through November 1995; however, this report documents the results of only the first 1,000 hours of testing.

The average feed and permeate TDS for the FilmTec BW30 element testing, using the Moreno Highlands well water, were 988 and 14.2, respectively. Overall TDS rejection was 97.1 percent., Boron, a trace metal of concern in the saline wetlands, was rejected at an average of 74.4 percent and was measured in the RO reject at a concentration of 1.2 mg/L (based on a single chemical analysis at 561 hours of operation).

Because of high heterotrophic plate counts (HPC) measured in the RO feed and reject tanks (heterotrophic plate counts: >5,700 cfu/mL), a regimen of weekly element flushing with a 1 percent solution of the biocide Minncare™ was initiated. Followup samples indicated significant reductions in the HPCs; however, it was later discovered from noticeable increases in normalized permeate flow (NPF) and permeate conductivity that some membrane damage was occurring. Minncare™, which contains hydrogen peroxide (a strong oxidant) as a principal ingredient, was suspected. The disinfection protocol was subsequently changed to include less frequent flushing with Minncare™; i.e., 30 minutes once a month, and weekend storage of the elements in 1 percent sodium bisulfite to inhibit microbial growth. Scanning electron microscopy (SEM) imaging was later used on an autopsied first stage lead element to determine if membrane surface damage could be visually detected. The SEMs showed conclusively that surface penetrations of the membrane developed within and along the edge on the Vexar (concentrate spacer) imprints. Two explanations were considered for this localized degradation: first, that the damage was caused solely by the repeated pressure cycles of operating in a daily on-off mode; and second, that Minncare™ contributed to (accelerated) the damage, possibly by being adsorbed onto trapped particles at the points of Vexar contact.

The average feed and permeate TDS for the Desal-3LP element testing, using the Dairyland well water, were 993 and 20.6 mg/L, respectively. Average salt rejection for the first 1,000 hours of testing was 98.0 percent. Boron was rejected at 38.8 percent, with concentrations of boron in the RO reject of 2.3, 2.0, and 2.5 mg/L (measured during three separate chemical analyses). Ultraviolet (UV) disinfection combined with monthly 30-minute flushings with a 1 percent solution of Minnicare™ and storage of the elements in dilute sodium bisulfite during weekend shutdowns appears to have effectively controlled biological fouling. There was no evidence of undue fouling or membrane degradation. during the first 1,000 hours of testing.

The growth, establishment, and health of the plants in the saline vegetated wetland cells have been monitored since the initial planting. In addition, some toxicological data have been collected and analyzed, and observations have been made regarding wildlife visitation and use.

The alkali bulrush and spikerush survived in both vegetated wetlands, and once cattail (*Typha spp.*) invaded, it survived and thrived in the north wetland, but was inhibited in the south. Watergrass (*Echinochloa crusgalli*), quillwort (*Isòetes spp.*), and California bulrush (*Schoenoplectus californicus*) plants emerged in the fresher north wetland only. As the constituents of the water changed in the two vegetated wetlands, so did the plant response. Bach time fresh water was added (rainwater or potable water) to either wetland, the plants responded by having a growth spurt and became greener.

The plant communities existing at the end of the 1995 growing season in the north (control) wetland and the south saline wetland differed from each other after a year of maintaining fairly consistent water sources for both. Although the plants propagated rapidly each spring in the south saline vegetated wetland, they turned brown much earlier in the growing season than did plants in fresher wetlands on the San Jacinto Wildlife Refuge, 12.9 kilometers (8 miles) north of this pilot site (Stella Denison, personal communication, 1994). Alkali bulrush quickly became the dominant plant species, outcompeting the spikerush, and remained dominant throughout the study period. In the north vegetated wetland cell, the cattails spread to such a degree that they created more of a mixed plant community with the alkali bulrush, but with time, they may displace most of the other smaller species. Long term evaluation using the appropriate water is necessary to accurately assess the establishment of the plant communities and their successional patterns.

Wildlife usage: of the saline vegetated wetlands was documented on numerous occasions throughout the: period of this study. Tracks, scat, sounds, carcasses, nests, and actual sightings of m-al, rodent, amphibian, bird, and invertebrate species were observed regularly. Reptiles were observed occasionally.

During the period of about 6 months, when both vegetated wetlands were receiving fresh water, the south wetland contained a total of 15 invertebrate taxa, while the north wetland contained 18. One year later, the south wetland contained 12 invertebrate taxa, and the north wetland contained 11. These taxa numbers illustrate only that the south wetland was never so saline that it seriously restricted the invertebrates that could live there. When comparing the taxa, a few trends can be discerned, such as absence or reduced numbers of intolerant taxa from the saline wetland and presence in the control wetland. The sporadic and infrequent nature of invertebrate sampling makes definitive conclusions impossible.

Using the data that were received from EMWD, there are some trace metals that warrant concern for the health and well-being of visiting wildlife but, at this time, there appear to be no serious threats to wildlife using the saline vegetated wetland cells. However, it should be noted that the available data are very limited, so no definite conclusions on the longer term impact can be drawn. Because of data sparsity, it is not recommended that a larger saline wetland system be created to reduce RO reject (concentrate) volumes or to create green space and wildlife habitat until more stable water quality conditions are achieved and further data are collected and analyzed. It must be remembered that within this reported sampling period, the south saline wetland received a constant flow of RO reject from only July 21, 1994, through the May 1995 sampling date. Therefore, long range effects or accumulations have not yet been adequately addressed. Monitoring should be continued and more samples should be collected and analyzed before any conclusions can be drawn about the feasibility of using wetlands for concentrate reuse and disposal.

The objective of the evaporation ponds (cells) at this pilot facility was to determine the degree to which the effluent volume from the saline vegetated wetlands could be further reduced to minimize the cost of RO reject/brine disposal. However, due to the limited amount of data available from the evaporation ponds, conclusions on long term conditions and impacts cannot yet be drawn. Since it is very important to know what, if any, hazards exist for wildlife using evaporation ponds associated with constructed saline wetlands, more data collection and careful analysis are essential before a full-scale RO system with saline vegetated wetlands and evaporation ponds is built.

Although no flow or volume data were recorded, the saline vegetated wetlands appeared to reduce the volume of reject from the RO unit. Since there are insufficient data to determine whether or not the saline vegetated wetlands and associated evaporation cells were harmful to the wildlife that used them, a full-scale development project is not recommended at this time. Additional monitoring is highly recommended.

2. INTRODUCTION

2.1 Background

The Bureau of Reclamation (Reclamation) is involved in a cooperative effort with the Eastern Municipal Water District (EMWD) of San Jacinto, California, to evaluate the effectiveness and feasibility of integrating constructed wetlands with wastewater and groundwater quality improvement, environmental enhancement, and ultimate reuse of reclaimed water. The overall program, entitled "Multipurpose Wetlands Research and Demonstration Project," contains five phases. The first phase, which has been completed for some time and documented in a November 1991 report, included the development of specific goals and objectives, agency responsibilities, site review and selection, a detailed plan of study, and preliminary cost estimates and time schedules. Several predesign investigations and pilot studies were performed as part of the second phase, and some are still ongoing. These include the construction, testing, and evaluation of eight research cells, which are fed secondary treated wastewater directly, and a reverse osmosis desalination/saline vegetated wetland system (subject of this report). The final three phases incorporate the design, construction, and operation and monitoring of a 45-acre demonstration wetlands facility, which is being funded under the Small Reclamation Projects Act (SRPA) loan program and the Wetlands and Riparian Initiative. The final designs, environmental assessments, construction, and planting of vegetation have been completed, and operations and monitoring are underway.

The total water management cycle shown in figure 2.1 illustrates EMWD's concept for the integration of multipurpose wetlands into the district's comprehensive water management planning. Reclaimed or treated wastewater represents an underused but readily available source of "new" water for the district that could help meet water demands if more cost-effective ways could be found to treat and store the water produced. EMWD is already supplying reclaimed water for irrigation and other nonpotable uses through a secondary distribution system (Bureau of Reclamation and Eastern Municipal Water District, 1991). Constructed wetlands, a heretofore overlooked resource for achieving high levels of treatment, are viewed as a potentially important part of the district's water resource management plan. When applied as an advanced water treatment process, wetlands become part of the water supply, use, treatment, storage, recovery, and reuse cycle.

The pilot and demonstration studies described above are being conducted at the EMWDAJSBR Wetlands Research Facility, which is located at the San Jacinto Regional Water Reclamation Facility (RWRF), approximately 85 miles east of downtown Los Angeles. Figures 2.2 and 2.3 show the location of the EMWD in western Riverside County and a detailed map of the district, respectively.

2.2 Purpose and Scope of Study

EMWD is interested in reverse osmosis (RO) desalting for the treatment of brackish groundwater in the San Jacinto Basin for municipal and industrial (M&I) applications and for

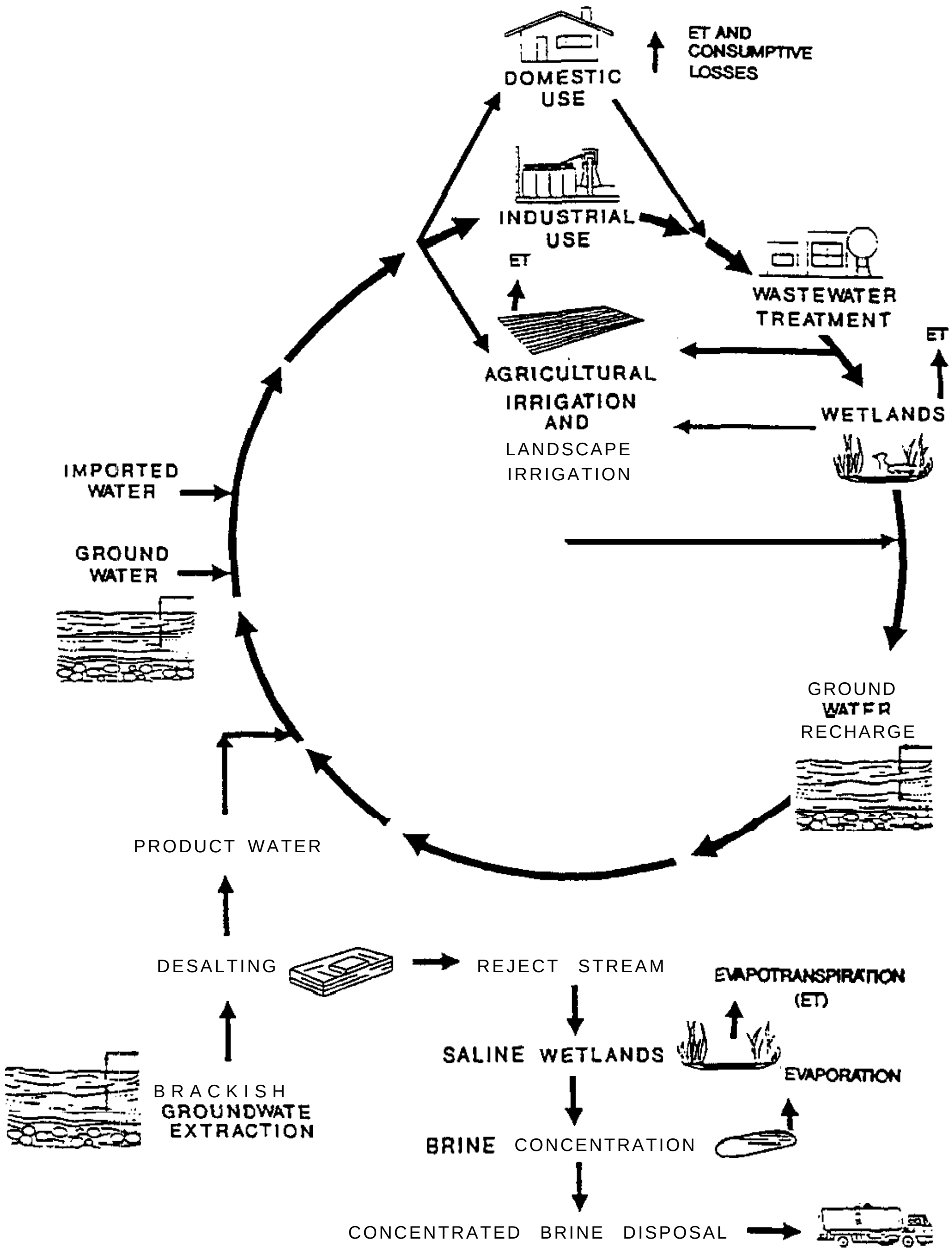

Figure 2.1 .—EMWD's proposed total water management cycle.

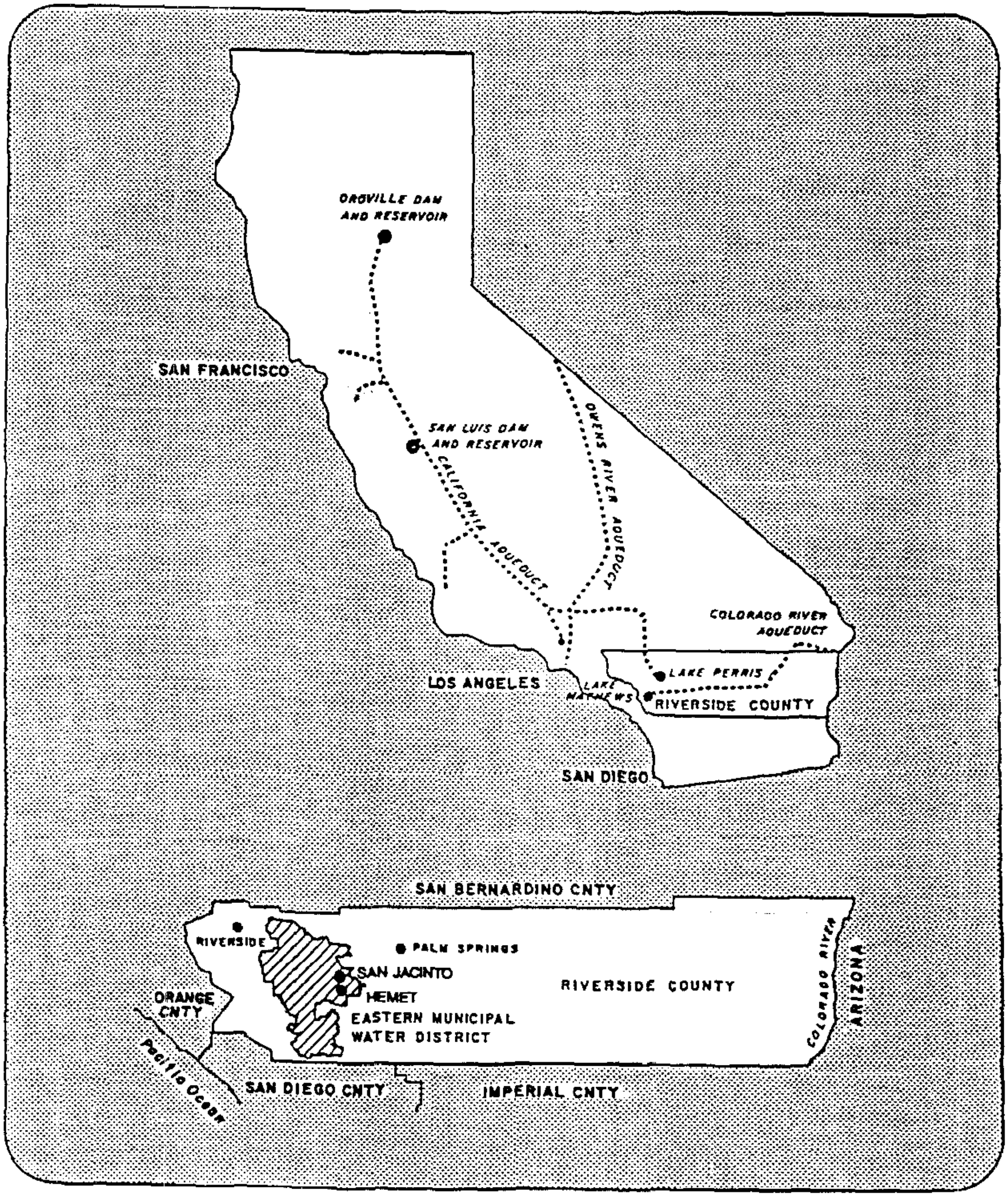

Figure 2.2.—State map showing the location of the Eastern Municipal Water District.

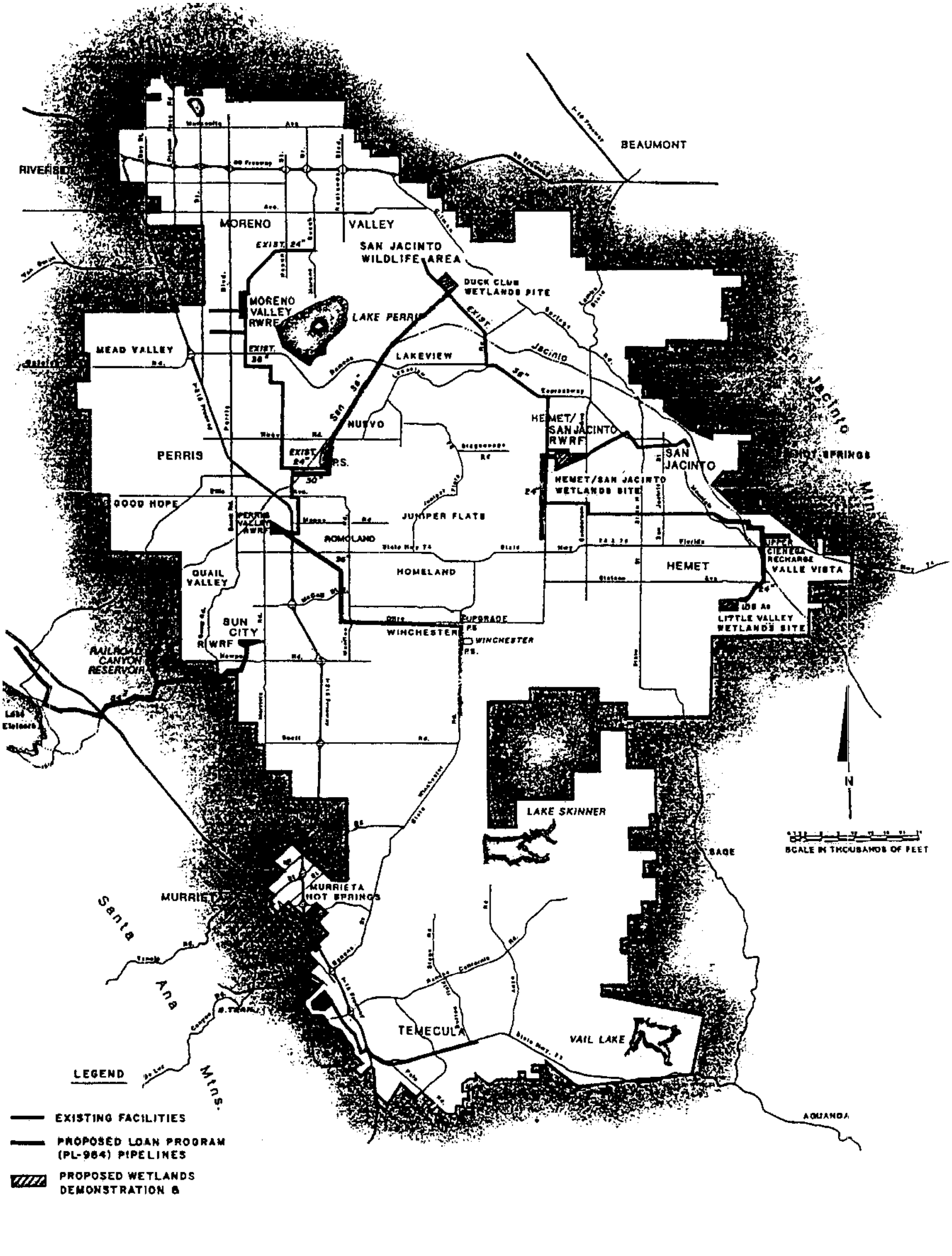

Figure 2.3.—Map of the Eastern Municipal Water District,

groundwater recharge. The pilot study described herein was undertaken to determine the performance of an RO system for improving the quality of San Jacinto Basin water to potable standards. The district is also exploring possible beneficial uses for the concentrate generated with this process and methods for reducing its volume prior to final disposal. One such beneficial use is being evaluated as part of this study, that of using RO reject (concentrate) to sustain saline vegetated wetlands. The wetlands reduce the volume of the concentrate through plant uptake and evaporation, then final evaporation ponds are used to reduce the volume of residual brine[2] flowing from the saline wetlands even further. The successful demonstration of these processes could lead to the use of RO treatment for the production of high quality water at a reasonable cost for the needs of the San Jacinto Valley and, at the same time, provide saline water for the irrigation of green belts, open spaces, and habitat areas.

2.3 Specific Test Objectives

Referring to the bottom of figure 2.1, the pilot study focused on brackish groundwater extraction, desalting, the use of desalting system reject for the support of saline wetlands, and brine concentration in solar evaporation ponds. Specific test objectives for the study are described as follows:

- **Reverse osmosis desalination** - to evaluate the use of low-pressure RO desalting for improving the quality of brackish groundwater in the Lower San Jacinto Basin to Federal and state drinking water standards, and to monitor the RO system rejection of selected constituents that are known to be detrimental or toxic to plants.

- **Saline vegetated wetlands *(marshes)* -** to determine whether the reject stream of a desalination process can be used to sustain a variety of flora and fauna in saline vegetated wetlands, and to determine whether these saline wetlands will or will not accumulate toxic materials or result in hazards to wildlife due to water quality.

- **Evaporation ponds** -to determine the effectiveness of pond design and engineering in discouraging use by wildlife, and to determine whether toxic substances are present and concentrated to significant levels. The original test plan included the evaluation of evaporation enhancement techniques; however, this was not accomplished for reasons explained later in section 7.1.2.

2.4 General Description and Layout of Test Facility

A conceptual diagram of the RO/saline wetlands test facility and a construction plan view are shown in figures 2.4 and 2.5, respectively. The research facility is composed of a 6-gal/min pilot RO system designed and built at Reclamation's Denver laboratories, two 20-foot by SO-foot by 2-foot-deep lined saline vegetated wetland cells (marshes), and two similarly sized lined evaporation ponds. Referring to figure 2.4, well water is first treated by RO to reduce the total dissolved solids (TDS) content of the feedwater to well below the

[2] Throughout this report the terms "reject" and "concentrate" are used interchangeably to refer to the waste stream exiting the reverse osmosis process; whereas, the term "brine" is used for the more highly saline water flowing from the wetlands into the evaporation ponds.

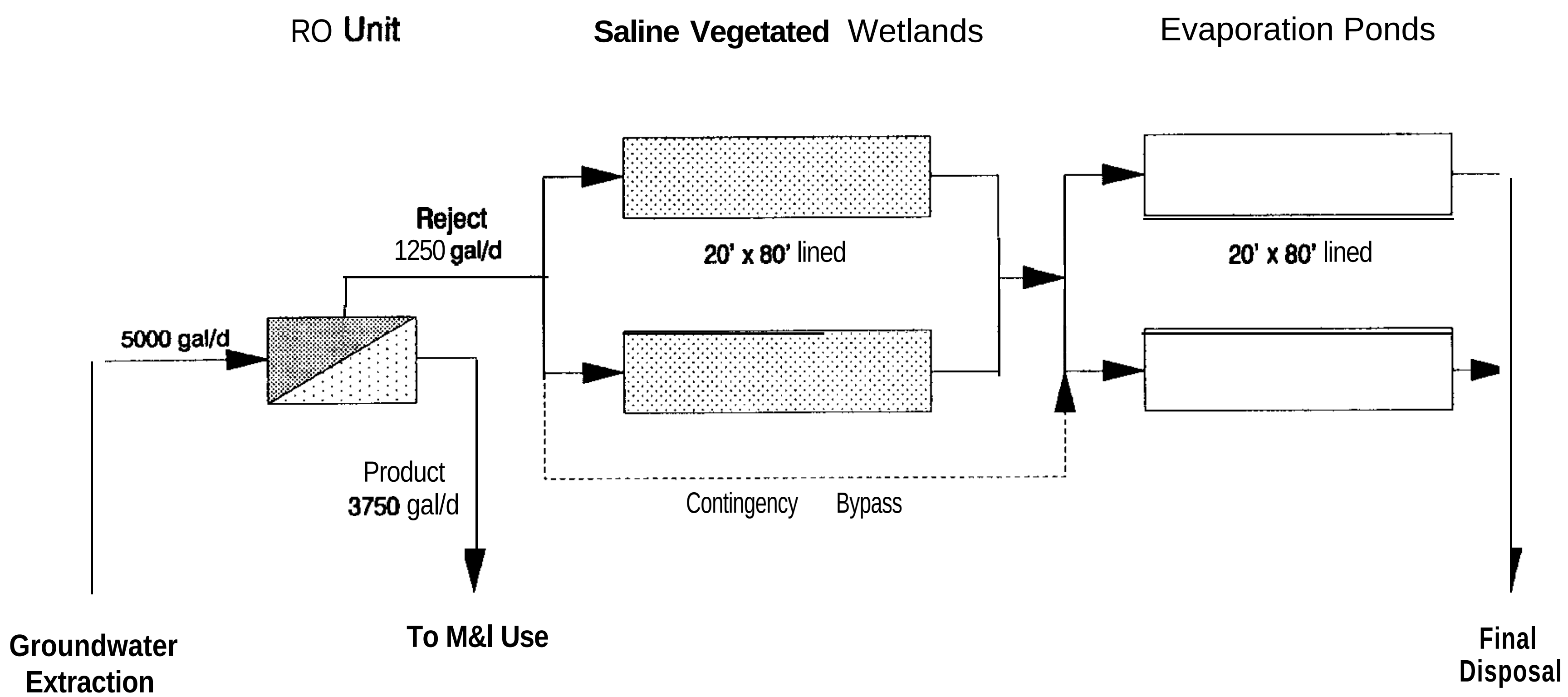

Figure 2.4.—Conceptual diagram of the RO/saline vegetated wetlands test facility.

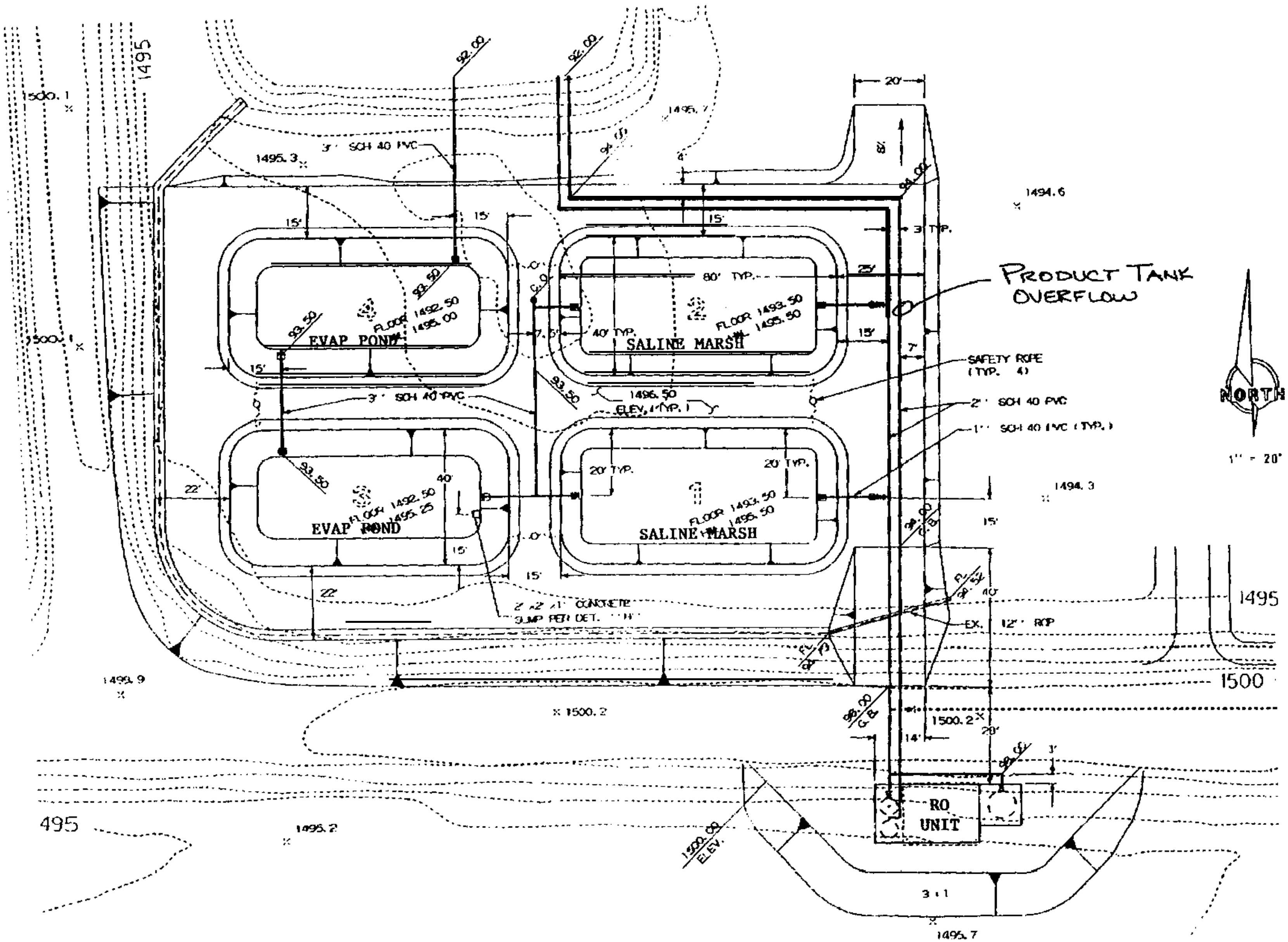

Figure 2.5.—RO/saline vegetated wetlands test facility construction drawing (plan viewj.

Environmental Protection Agency (EPA) drinking water guidelines. Next, concentrate from the RO process is directed to the saline marshes where it is used to sustain selected salt-tolerant plants and, at the same time, undergoes a reduction in volume as it passes through rhe marshes by both plant uptake and evaporation. *Outflows* from the saline marshes are then directed to the evaporation ponds where final brine concentration is achieved. The reject line from the RO system is plumbed such that flows can be directed to either or both of the marshes. The two saline marshes are shown in the foreground of figure 2.6, and the RO pilot plant is shown in both figures 2.6 (background) and 2.7 (closeup).

Installation of the pilot RO system and planting of vegetation in the saline wetlands were accomplished during April 1993 by Reclamation and National Biological Service (NBS) Denver Office personnel.

Figure 2.6.—RO pilot plant with saline wetlands shown in the foreground.

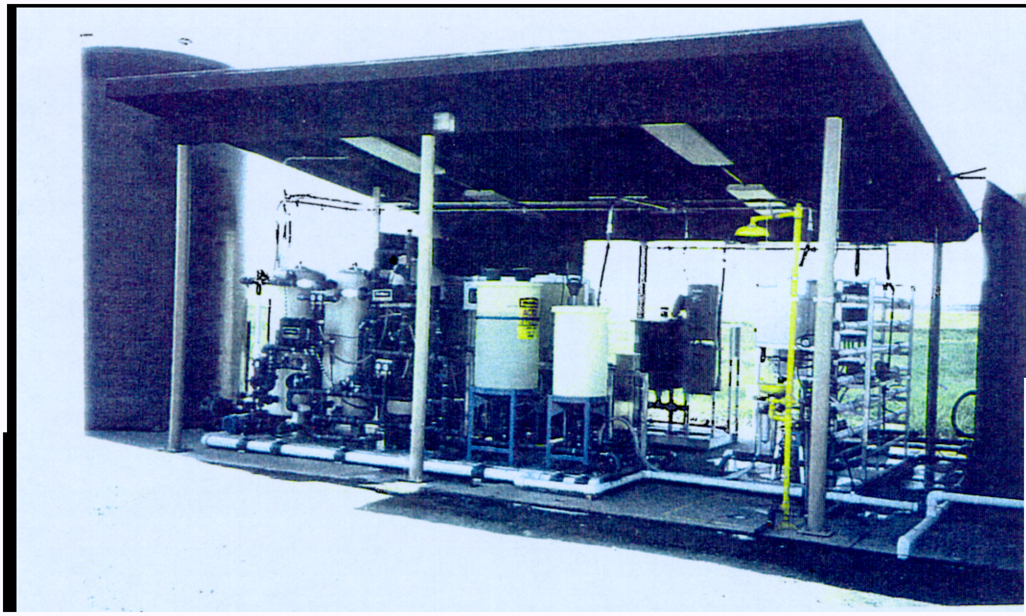

Figure 2.7.—Closeup view of the RO pilot plant.

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3. WELL SELECTION AND GROUNDWATER QUALITY

3.1 Wells Selected for Testing

Originally, it was planned that RO testing would be performed using the nearby Walker Duck Club well water. This well was selected because of its elevated TDS, access, and proximity to the wetlands site. However, due to unforeseen events that will be described later in the report, groundwater from two additional wells was also included in the testing: Moreno Highlands well and Dairyland well. The following paragraphs describe the location, construction details, yields, and water quality of these wells. Table 3.1 presents the most recent chemical analyses available (prior to this test program) for the three wells.

3.1.1 Walker Duck Club well.-The privately owned Walker Duck Club well is located 7.5 miles northwest of the wetlands research facility, adjacent to the San Jacinto Wildlife Area (California Department of Fish and Game). The well was completed in October 1984 to a total depth of 1,035 feet. The diameter of the bore is 24 inches. A 12-inch-diameter steel casing extends to a depth of 1,035 feet, with perforations below 735 feet. The annulus is packed with #5 gravel. A 32-hour pump test yielded 1,600 gal/min with zero drawdown. The static water level was reported to be 155 feet.

3.1.2 Moreno Highlands well.-The Moreno Highlands well, owned by the Alta Dena Dairy, is located approximately 11 miles northwest of the wetlands research facility on the southwest comer of Alessandro and Virginia, near the town of Moreno. The well was completed in October 1980 to a total depth of 1,110 feet. The diameter of the bore is 26 inches with a 3/8-inch gravel pack. A 16-inch-diameter steel well casing extends to a depth of 1,080 feet. The casing is perforated below 504 feet. The well was pump tested for 48 hours at a flow rate of 500 gal/min. Initial and final reported water levels were 106 and 152 feet, respectively.

3.1.3 Dairyland well.-The Dairyland well, owned by EMWD, is located about 1-1/2 miles northwest of the wetlands research facility, along Warren Road, a mile south of the Romona Expressway, in the city of San Jacinto. The well was completed in April 1994 to a total depth of 850 feet. The diameter of the bore is 42 inches to a depth of 50 feet and 28 inches from 50 feet to 800 feet. A 34-inch steel casing was used in the upper 50 feet, and 16-inch alternating steel and stainless steel casings **were** used from 50 feet to 800 feet. The annular till material is cement (10 sack) from 0 to 350 feet, and #8 gravel from 350 to 800 feet. The stainless steel sections of the casing are perforated at depth intervals of 400 to 460 feet, 490 to 520 feet, and 550 to 780 feet. A 72-hour pump test yielded an estimated 1,200 gal/min with a total drawdown of 72 feet. The static water level depth was measured at 195.5 feet:.

Table 3.1 .-Groundwater analyses available for the three wells prior to testing

Constituent		Units	Walker Duck Club	Moreno Highlands	Dairyland
Calcium	Ca^{+2}	mg/L	82	23	89
Magnesium	Mg^{+2}	mg/L	21	3.6	17
Sodium	Na^{+}	mg/L	490	2%	219
Potassium	K+	mg/L	7	1.1	7.0
Aluminum	Al^{+3}	mg/L	<0.1	0.28	<0.1
Barium	Ba^{+2}	mg/L	0.8	0.07	<0.1
Boron	B	mg/L	0.6	0.31	
Iron, dissolved	Fe^{+2}	mg/L			<0.02
Iron, total	Fe	mg/L	w.35	w.74	*1.9
Manganese	Mn^{+2}	mg/L	*0.30	*0.07	0.04
Strontium	Sr^{+2}	mg/L	1.0	0.48	0.55
Total Cations		meq/L	27.4	14.3	15.6
Bicarbonate	HCO_3^-	mg/L	808	234	104
Sulfate	SO,”	mg/L	<1	152	*300
Chloride	Cl^-	mg/L	*490	*264	*310
Nitrate	NO_3	mg/L	3	1.8	0.9
Phosphate	PO_4^{-3}	mg/L	0.07	0.3	
Fluoride	F^-	mg/L	0.4	2.4	0.60
Total Anions		meq/L	27.1	14.5	16.7
Silica, dissolved		mg/L	28		20
Silica, total	SiO_2	mg/L	29	23.2	18
Carbon Dioxide	CO_2	mg/L	nd	3.5	
Hydrogen Sulfide	H_2S	mg/L	0.05	<0.1	
Dissolved Oxygen	O_2	mg/L	3.8	1.5	
Ammonium	NH_4^+	mg/L	8.4	<0.1	
Total Organic Carbon	TOC	mg/L	31	5	2.1
Heterotrophic Plate count	HPC	cfu/mL	125	13	
Specific Conductance		µS/cm	2500	1550	1530
Total Dissolved Solids	Sum	mg/L	1905	975	1049
Turbidity		ntu	14	2.1	9.4
Temperature		°C	28	29	
pH			7.7	8.0	8.1

nd - none detected
* - exceeds State and Federal secondary drinking water standards

3.2 Comparison of Groundwater Constituents for the Selected Wells

Bar graphs are presented in figure 3.1 that depict the major ion concentrations (meq/L) far the three well waters. The predominant ions in each of the waters are sodium (Na^+) and chloride (Cl). The major ions of concern, however, are usually calcium (Ca^{+2}), sulfate (SO,“) and bicarbonate (HCO_3^-) because they can contribute to the formation of calcium sulfate ($CaSO_4$) and calcium carbonate ($CaCO_3$) scaling in an RO element's concentrate channel. Solubility calculations must be performed, as part of the RO design process, to determine the degree to which each of these constituents can be concentrated before scaling occurs.

As shown in figure 3.1, the TDS level for the Walker Duck Club well is considerably higher than the other two wells, which made it a good candidate for testing. Note also that the SO_4^{-2} concentration for this well is extremely low, which would preclude the possibility of $CaSO_4$ scaling. However, as will be discussed later in section 4.2.2, pretreatment would be required for Walker Duck Club well water to reduce the potential for $CaCO_3$ scaling. The Moreno Highlands and Dairyland wells have similar TDS levels; however, the Dairyland well has a fairly low Ca^{+2} concentration, while the Moreno Highland well contains higher concentrations of both Ca^{+2} and SO_4^{-2}. There are, of course, other constituents in the well waters that could contribute to the scaling or fouling of RO membranes. These will be addressed in detail in sections 4.2.2 through 4.2.4, along with pretreatment options.

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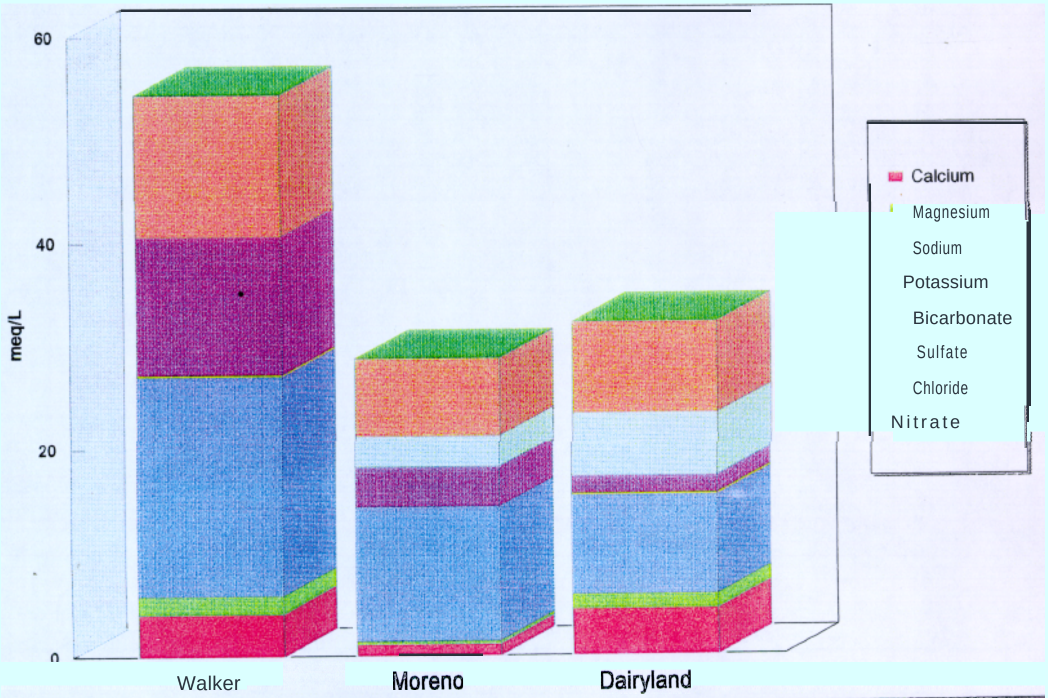

Figure 3 1 —Comparison of the three well waters used in the pilot study

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4. REVERSE OSMOSIS DESALINATION

4.1 Reverse Osmosis Process Description

Reverse osmosis (RO) is a process used for desalting water by the application of hydrostatic pressure to drive feedwater through a semipermeable membrane. A major portion of the water's impurity (dissolved salts) remains behind and is discharged as concentrate, while relatively pure product water (permeate) emerges at near atmospheric pressure. A typical operating pressure range for RO is 200-400 lb/in^2 for brackish water and 800-1,000 lb/in' for seawater desalination. However, recently developed ultra-low pressure RO elements are available with an operating range of 75-150 lb/in* for brackish water applications. Ion rejections achieved with RO usually exceed 90 percent.

Membranes are manufactured from a variety of materials, such as cellulose acetate (CA):, cellulose diacetate (CDA), cellulose triacetate (CTA), polyamide (PA), other aromatic polyamides, polyetheramides, polyetheramines, and polyetherurea. Thin-film composite (TFC) membranes may be made from a wide variety of polymers consisting of several different materials for the substrate, the thin film, and other functional layers in the membrane (Parekh, 1988). Each of these types of membranes will have a unique response and varying tolerances to feed concentration, composition, pressure, temperature, and pH. Depending on the level of these operating parameters, each membrane will perform differently in terms of: water flux (quantity of water passing through a membrane per unit area and time, $gal/ft^2/day$); salt rejection (measure of the amount of salt rejected in the concentrate, %); and water recovery (permeate recovered from a single element compared to the feed flow rate, %).

Four RO membrane configurations are currently manufactured: spiral-wound, hollow tine fiber, tubular, and plate and frame. Of these, only the spiral-wound (considered in this study) and hollow fine fiber types are used for municipal water treatment. A spiral-wound membrane, shown in figure 4.1, consists of two flat sheets of membrane separated by porous support or backing sheets sealed on three sides to form an envelope. The fourth side is attached with an adhesive to a hollow plastic tube that collects the product water. Typically, two or more of these membrane envelopes are glued to the product water collection tube and rolled up in the form of a spiral. Multiples of the spiral-wound modules or elements are usually connected in series in a fiberglass pressure vessel. These pressure vessels are then arrayed in both series and parallel configurations to form a desaltmg system, depending on the product water flow and percent recovery required (Conlon, 1990).

4.2 Pretreatment Considerations

4.2.1 General,.-The life and performance of desalting membranes can be adversely affected by the presence of scaling and/or fouling components in the feedwater. Membrane scaling can occur when dissolved salts in the feed are concentrated beyond their solubility limit and precipitate from solution in the element's concentrate channels. Typical scales of concern are calcium carbonate ($CaCO_3$), calcium sulfate ($CaSO_4$), barium sulfate ($BaSO_4$), strontium sulfate ($SrSO_4$), and silica (expressed as SiO_2 [silicon dioxide]). SiO_2 has a solubility that is

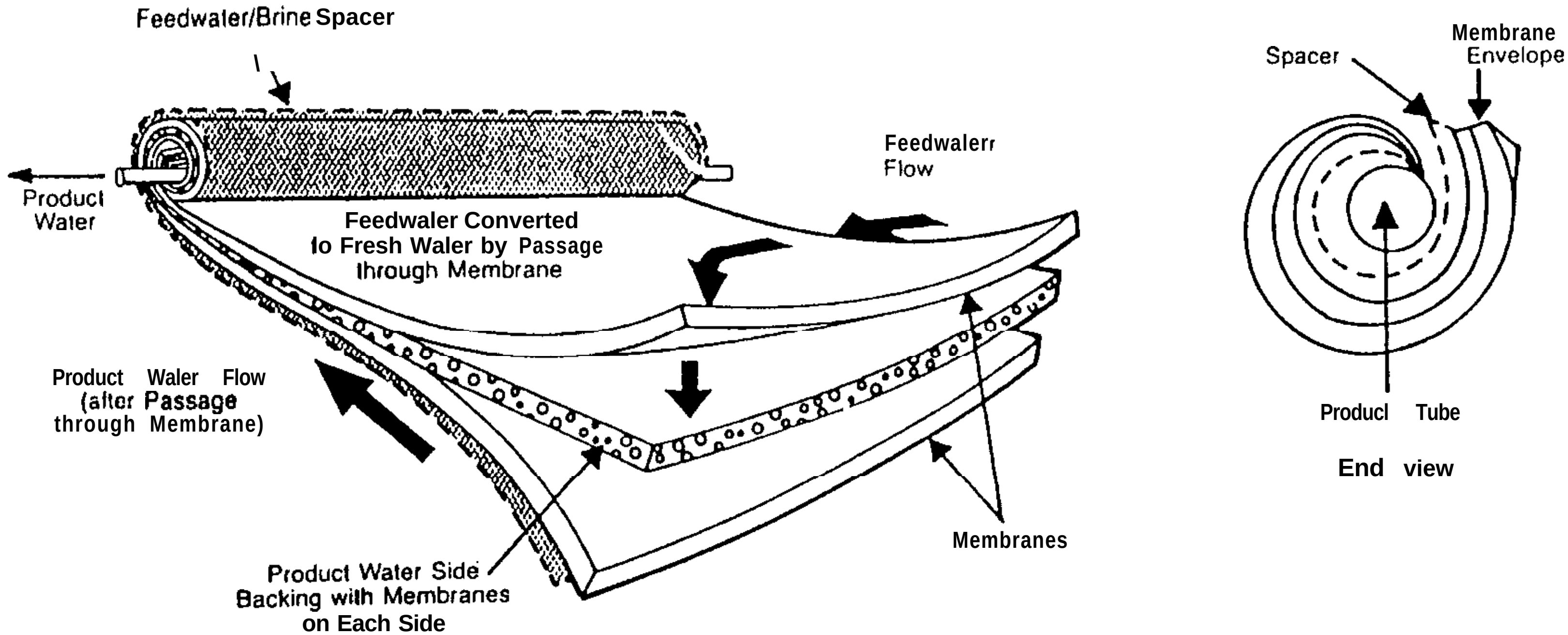


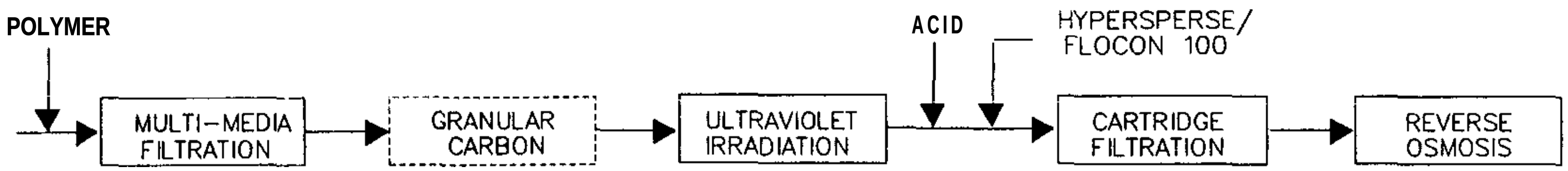
Figure 4.1.—Cutaway diagram of a spiral-wound RO element [Conlon, 1990].

directly proportional to temperature and that increases substantially with pH from a minimum at around 7.0-7.8. When supersaturated, SiO_2 can polymerize to form insoluble colloidal silica or silica gel which will cause scaling. Additionally, the solubility of SiO_2 can be dramatically reduced by the presence of metal oxides, which can complex with SiO_2 and lead to the formation of metal silicates. Scaling can usually be avoided by taking one or more of the following actions: (1) limiting the product recovery of the desalting system; (2) removing scaling components from the feedwater during pretreatment (e.g., using lime softening or ion exchange); or (3) adding acid and/or scale inhibitor to increase the solubility limits of the scaling compounds.

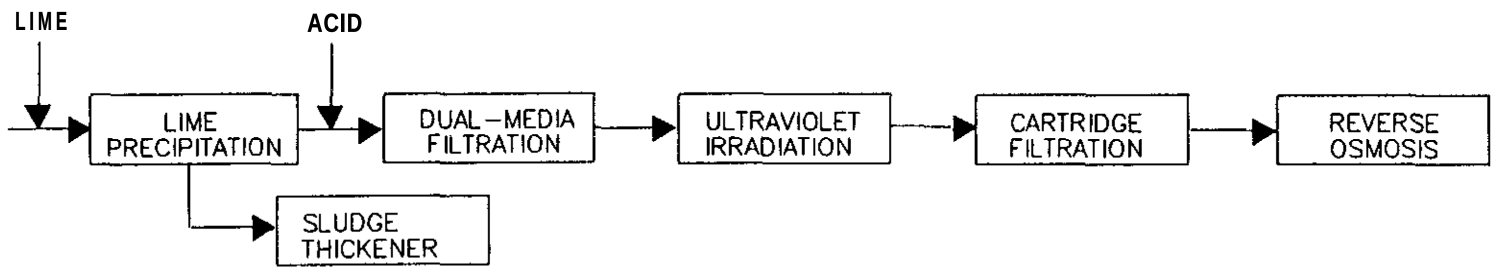
Fouling involves the trapping of materials on the surface or within the pores of the membranes. These foulants generally include colloidal materials (clays, iron corrosion products, etc.), biological growth, oxidation products of iron and manganese (metal oxides), and oxidized hydrogen sulfide (elemental sulfur). Pretreatment may be necessary to reduce the concentration of these materials and/or to inhibit biological growth. Noncellulosic membranes (used in this study) offer good biological stability and are not degraded by bacteria. However, given the right circumstances, a "biofilm" can develop from the colonization of bacteria on the surface of the membrane, which can cause significant flux decline. High pH cleaning with a detergent/surfactant and chelating agent is usually required for removal of this biofilm. Heterotrophic plate counts (HPC) can be used to assess the fouling potential of bacteria in water. Also, total organic carbon (TOC) has been shown to correlate with direct counts (Paul, 1990).

4.2.2 **Walker Duck Club** well.-Because of the low SO_4^{-2} concentration in this well water, there is virtually no potential for $CaSO_4$ scaling. The Marshall program (based on the Debye-Huckel equations) indicates that a 99.7 percent product recovery is achievable at an assumed RO feed temperature of 25 °C. However, because of the high HCO_3^- level in the raw water, $CaCO_3$ scaling will occur. The concentrate Langelier Saturation Index (LSI) was calculated at 2.12, assuming 75 percent recovery. In addition, $BaSO_4$ poses a problem with a projected percent saturation of 6,500. Three pretreatment options were considered for the prevention of $CaCO_3$ scaling, as shown in figure 4.2. The first involves the addition of acid and antiscalant to inhibit $CaCO_3$ precipitation, and the latter two involve the removal of Ca^{+2} from the well water using either lime softening or strong acid ion exchange (IX), making use of the RO reject for regeneration of the resin. The antiscalant and IX options would each effectively control $BaSO_4$ scaling as well. Because of the considerable quantity of acid required for the first option (about 85 mg/L of 93 percent sulfuric acid [H_2SO_4]), it was decided that brine-regenerated IX feasibility experiments would be performed. These experiments are discussed in section 4.5.1, and a concluding report is presented in appendix A.

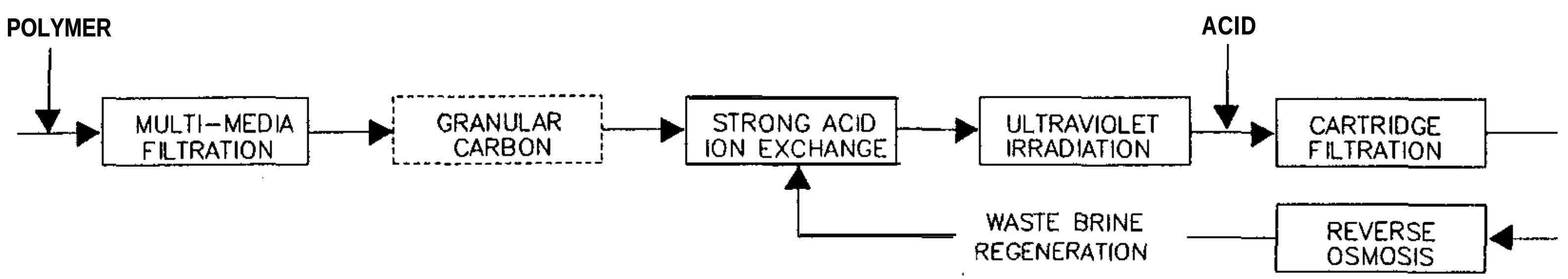
Turbidity seems to be highly variable in this well, ranging in the samples tested from 0.9 ntu (November 30, 1992) to 14 ntu (December 10, 1991), depending on the pumping regimen. The well was pumped for 40 minutes prior to the 14 ntu reading, and overnight prior to the 0.9 ntu reading. RO feedwater turbidity should be limited to 1 .0 ntu. Three silt density index (SDI) measurements were performed in the field on January 30, 1992, resulting in values of 6.12, 5.34, and 5.74 (SDI is a measure of the colloidal fouling potential of the water). Most membrane manufacturers recommend an SDI below 5.0 in the feedwater, and preferably closer to 3.0. The 0.35 mg/L of iron shown in table 3.1 is slightly higher than the 0.3 mg/L



Option 1 - Acid & Anti-scalant



Option 2 - time Softening



Option 3 - ton Exchange with Waste Brine Regeneration

Figure **4.2.—Pretreatment** options considered for RO operations.

recommended for RO feedwater; however, because the water is being trucked to the site, most of the iron will oxidize to Fe^{+3} in transit and should be removed during filtration. Dual-media or multimedia filtration is included in each of the pretreatment options. Polymer is added in options 1 and 3 to remove turbidity/colloidal materials and in option 2 for removing carryover precipitates from the lime process.

A considerable amount of air entrainment was observed in the well water during the SDI measurements. Dermis Watt, Hydrologist with Reclamation's Lower Colorado Regional Office, commented (memorandum dated February 24, 1992) that air belching from the well may indicate well damage, particularly if the well seems to be pumping too much sand, or a water table decline. A 64-minute pump test on March 6, 1992, resulted in a 61-foot drawdown, from a level of 263 feet to 202.4 feet, and some very fine sand was observed in the water (the well is screened below a depth of 735 feet). Some H_2S odor was noticed during this pump test (17 minutes after the pump was turned on), but all concentrations reported in the well analyses were at or below 0.05 mg/L. Perhaps this occurred because of infrequent pumping. If concentrations of H_2S were present in the well water, most of it would probably be lost during transit, and any residual elemental sulfur (S) would be removed during filtration.

The SiO_2 concentration of 29 mg/L (table 3.1) limits the achievable product recovery to roughly 75 percent. Silica can be removed during pretreatment, but only by using heroic measures such as coprecipitation with magnesium hydroxide ($Mg(OH)_2$) during high-pH lime softening.

Ammonia (NH_4^+) was measured at 8.4 mg/L, but NO,' was present at only 3 mg/L.

A heterotrophic plate count (HPC) run on this well water indicated 125 cfu/mL (cell forming units per milliliter). Two methods were considered for the control of biofouling: chlorination followed by dechlorination; and ultraviolet (UV) disinfection. Because of the low bacterial population, UV was selected with an estimated 99 percent plus kill probability. Since TFC membranes are highly susceptable to damage from strong oxidants, the use of chlorine (Cl,) was considered an unnecessary risk.

Granular activated carbon (GAC) was included in the pilot plant design because of the 3 1 mg/L TOC measured in this well water (table 3.1). However, based on the concerns of membrane manufacturers regarding the possible carryover of carbon fines to the RO elements, it was decided that the GAC would not be used until it was proved necessary.

Based on the outcome of the RO reject-regenerated IX experiments and the desire, by all parties concerned, to avoid the copious production of lime sludge (and the disposal requirements that result), it was decided that the pretreatment should consist of polymer addition followed by direct filtration, GAC (if required), acid and antiscalant addition, UV disinfection, and finally cartridge filtration. Because of the need for chemical compatability, Filtermate-150™ (polymer) and Hypersperse-150™ (anti-scalant), both marketed by Argo Scientific, were selected.

42.3 Moreno Highlands well.—Ca^{+2} concentration is relatively low in this water, compared to the other two wells, which allows an achievable recovery of 97.4 percent based on $CaSO_4$ solubility (Marshall Program). However, the 23.2 mg/L SiO_2 does limit product recovery to 75 percent. The HCO_3^- concentration is not nearly as high as in the Walker Duck Club well water, but still results in a positive concentrate LSI of 1.23 (at 25 "C). Argo Scientific: recommended the addition of 6.6 mg/L Hypersperse-150™ and operation at pH 7.5 to control $CaCO_3$, as well as $BaSO_4$ and CaF_2 scaling (at 75 percent recovery, the degree of saturation for $BaSO_4$ was calculated to be 11.18).

Direct filtration with polymer addition, which was originally designed to accommodate the Walker well water, was determined to be appropriate for this water as well. Direct filtration is recommended for use at turbidities of 15 ntu or less. Argo Scientific determined the: optimum Filtermate-150™ dosage to be 2 ppm. Again, the total iron concentration of 0.74 mg/L is above the 0.3 mg/L recommended by membrane manufacturers; but, as pointed out previously, it most likely will be oxidized in transite and removed during filtration.

Because of the low HPC of 13 cfu/mL, UV disinfection was again considered adequate to control biofouling. Periodic shock treatments with the biocide Minncare™ during extended shutdown periods were included as additional protection. The H_2S and TOC levels in the well water were low, <0.1 and 5 mg/L, respectively.

4.2.4 Dairyland well.—Of the three wells, Dairyland has the highest Ca^{+2} and SO_4^{-2} concentrations (refer to table 3.1 and figure 3.1), yet the Marshall program indicated an achievable product recovery of 88.8 percent based on $CaSO_4$ solubility. However, 20 mg/L SiO_2 limits product recovery to roughly 80 percent. HCO_3^- concentration is the lowest of the three wells, but still results in a positive concentrate LSI of 1.66 (at 25 "C) because of the higher Ca^{+2} level. Argo Scientific recommended the addition of 6.6 mg/L Hypersperse-150™ and operation at pH 7.5 to control $CaCO_3$, as well as $BaSO_4$ and CaF_2 scaling (at an assumed 75 percent recovery, the degree of saturation for $BaSO_4$ was calculated to be 20.88).

Argo Scientific determined the optimum Filtermate-150™ dosage for direct filtration to be 2 ppm, based on zeta potential measurements. Sample turbidity delivered to Argo Scientific was 8.9 ntu, which compares to 9.4 ntu in table 3.1. Total iron is high (1.9 mg/L), but dissolved iron is very low (<0.02 mg/L); therefore, Fe+' would be easily removed during filtration.

No H_2S or HPC data were provided for this well water.

4.3 Pilot Plant Design and Construction

The pilot plant is composed of three subsystems, each mounted on a separate equipment skid: pretreatment,, RO, and membrane cleaning. A process and instrumentation diagram of the combined system is shown in figure 4.3.

4.3.1 Pretreatment subsystem.-The unit processes on the pretreatment skid (figure 4.3) include the following:

- Polymer addition (Filtermate-150™)
- Direct 2-stage filtration

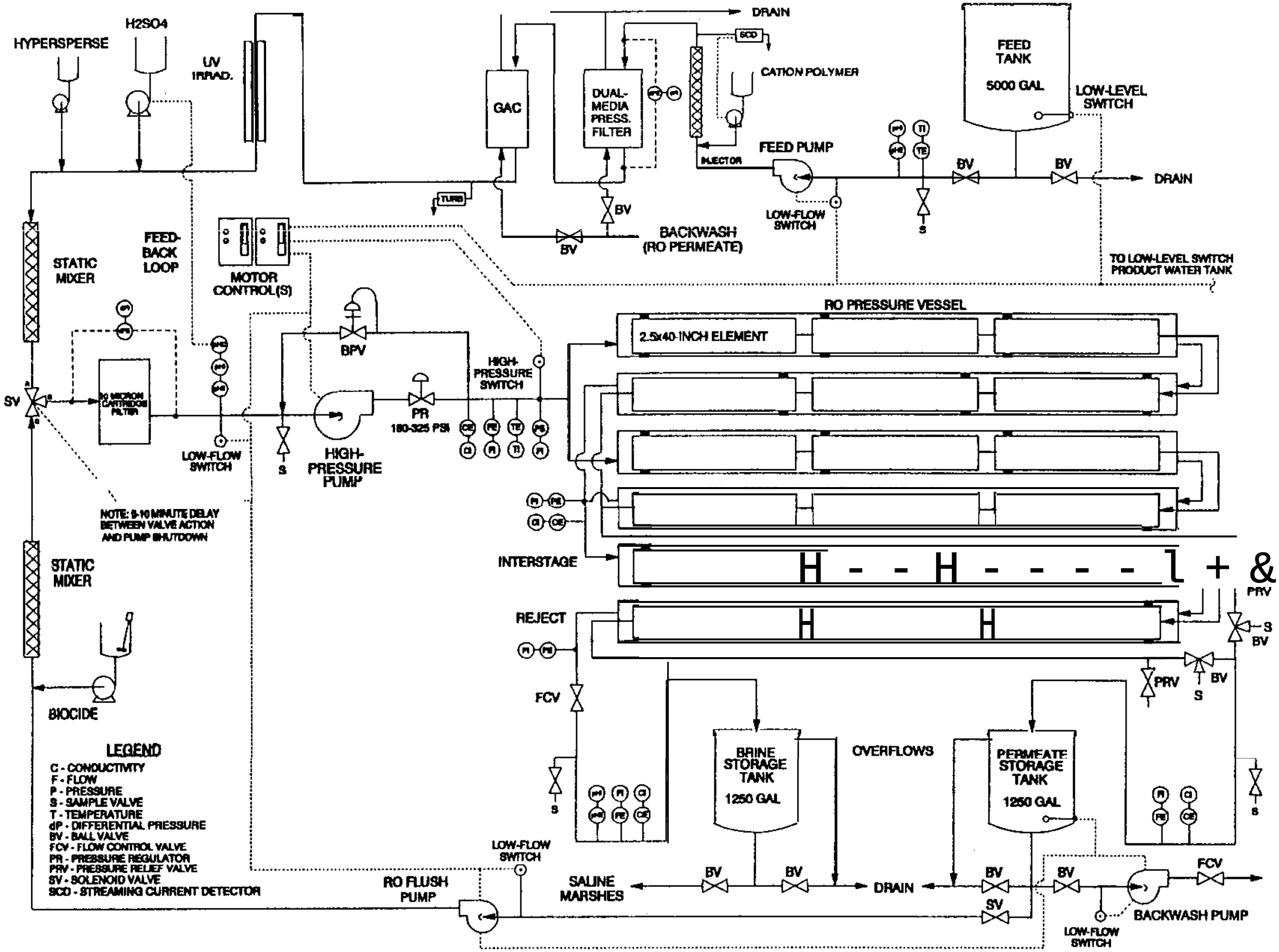


Figure 4.3—RO system process and instrumentation diagram.

- Granular activated carbon (GAC)
- Ultraviolet (UV) disinfection
- Acid addition (H_2SO_4)
- Anti-sealant addition (Hypersperse-150™)
- Cartridge filtration (10 pm)

Polymer dosage was controlled using a Milton Roy model SC 5200 streaming current detector, and filter effluent turbidity was monitored using a Hach model 1720C low range turbidimeter. Acid and antiscalant were added at concentrations determined by Argo Scientific, using Liquid Metronics, Inc. (LMI) chemical feed pumps. A proportional integral derivative (PID) controller was used to control acid addition to maintain the required feed pH. Although GAC was available as part of the pretreatment system, its use was not recommended by the membrane suppliers because of the possibility of carbon fines carrying over to the RO elements. The backwash cycle for the pressure filter was initiated manually at a preselected differential pressure (AP). Pretreated water was provided to the RO skid at a flowrate of 6.0 gal/min.

A separate 30-gallon mix tank, mixer, and pump were provided on the pretreatment skid for preparing and applying biocideibiostat (sodium bisulfite) solutions to the RO elements during weekend and other extended system shutdowns.

It should be noted that at the time the design and construction of the pilot plant was underway, the planned feedwater was to come from the Walker Duck Club well. Consequently, the design of the pretreatment system and chemical feed rates were based on the requirements of this feedwater. Fortunately, when it was necessary to switch to alternate feedwater sources later in the program, it was possible to use the same process configuration with only minor changes in chemical feed rates.

4.3.2 RO subsystem.-The reverse osmosis skid included the following equipment:

- High pressure feed pump (normally operating at 200-225 lb/in^2)
- Six three-element pressure vessels (for 2.5-inch RO elements)
- RO flush and filter backwash pumps
- Pump controls for the high pressure and feed forwarding pumps
- Instrumentation, relays, timers, etc.
- Data acquisition system (data logger, disk drive, and modem)

The RO system was operated at 75 percent recovery, yielding 4.5 gal/min of product water and 1.5 gal/min of concentrate. Two 1,250-gallon fiber-reinforced plastic (FRP) tanks were provided for the storage of product and concentrate flows. The concentrate was then used to support the saline vegetated wetlands (marshes), while the product water was used for filter backwash, element flushing, chemical dilutions, and other maintenance activities.
Because the system operated intermittently (nightly and weekend shutdowns), which is uncharacteristic of most RO plants, extra care had to be taken to avoid biological fouling of the membranes. Besides the online UV disinfection and provisions for periodic flushing of the elements with a biocide/biostat during extended shutdowns, the system was also (designed to automatically flush the elements with RO permeate (product) for 10 minutes at the end of every operational cycle (triggered when the 5,000-gallon feed tank emptied).

4.3.3 Membrane cleaning subsystem.-A separate membrane cleaning skid was provided in the event the removal of scaling and/or fouling components from the elements was necessary. The 50-gallon cleaning solution tank is equipped with a variable-speed mixer and Chromalox 7.5-kW immersion heater to maintain solution temperature. An inline 10-μm cartridge filter is also included to remove cleaning residue in the recirculating solution.

4.3.4, Membrane selection.-The main treatment objective was to achieve as high a product recovery as possible at minimum cost. To accomplish this, two separate thin-film composite membrane elements were chosen for testing: FilmTec's BW30-2540 and Desal's X2.540. Both have relatively low operating pressures and provide good productivity and high TDS rejection. It should be noted, however, that other membrane elements are available which would provide equally satisfactory results.

4.4 Test Procedures

4.4.1 Schedule.-A comparison of the original test program and the actual testing completed is shown on the schedule in figure 4.4. As was mentioned previously, at the time the design and construction of the pilot plant was underway, the planned feedwater was to come from the Walker Duck Club well. The original test plan included a 6-week checkout of the pilot plant, using a partial compliment of 6 RO elements, followed by two 1,000-hour tests, the first using FilmTec BW30-2540 elements and the second using the Desal SG2540 elements. Then, based on a comparative analysis of the two tests, a final report was to be: written. Operation of the RO unit was to continue in support of the saline marshes for an additional 12 months. Again, all operations were to be accomplished using the Walker Duck Club well water.

Subsequent to the building of the pilot plant and the completion of RO reject-regenerated ion exchange pretreatment experiments (discussed in section 4.5.1 and appendix A), the Walker Duck Club well was abandoned as a source of feedwater because of severe flooding and access problems. The Moreno Highlands well was suggested by EMWD as an interim source until a permanent replacement could be found. As shown in figure 4.4, this "interim" well was used for approximately 1,860 hours of testing.

On February 4, 1994, pilot plant operations were discontinued because of electrical problems with the Moreno Highlands well pump. Due to the anticipated high cost of repair and legal problems associated with a recent change in ownership of the well, EMWD decided to switch to yet another feedwater source. After almost 6 months of down time, a new well (Dairyland) was identified. On July 21, 1994, the Desal SG2540 elements were loaded and the system restarted. Operations continued with these elements through November 1995; however, this report documents the results of only the first 1,000 hours of testing.

4.4.2 Pilot plant operations.-Approximately 5,000 gallons of RO feedwater was trucked to the site each weekday from one of the nearby brackish wells discussed above (figure 4.5). The water was first pretreated to:

- Remove suspended materials; i.e., silts, clays, etc.
- Kill microbial organisms to prevent biofouling of the RO membranes
- Suppress the scaling tendencies of selected minerals

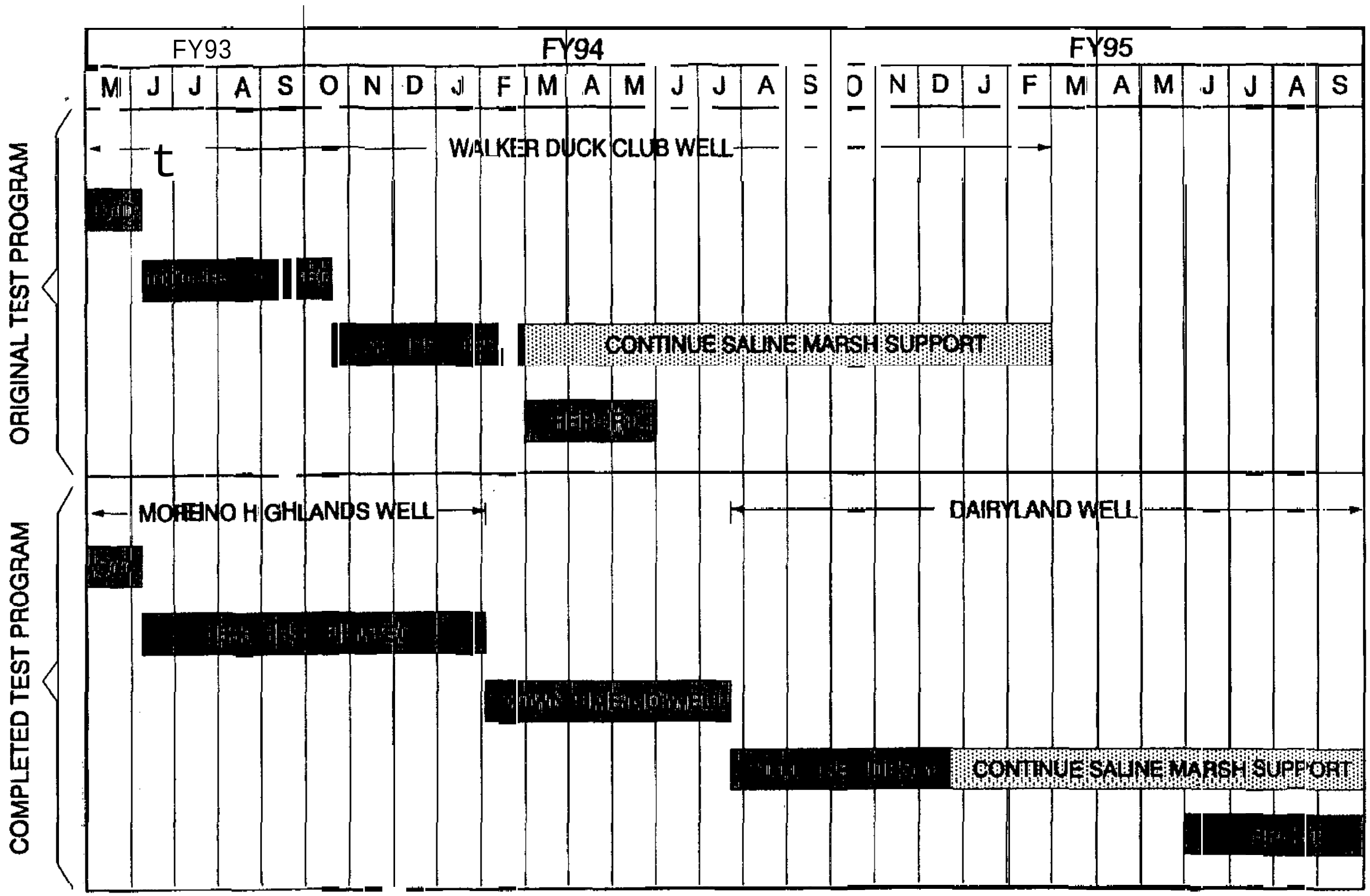


Figure 4.4.–Comparison of original versus completed RO test program.

The unit processes involved in pretreatment included: basket strainer and polymer addition (figure 4.6), two-stage pressure filtration (figure 4.7), UV disinfection and acid/antiscalant addition (figure 4.8), and cartridge filtration. The RO system then desalted the pretreated water using TFC membrane elements at an operating pressure of about 225 lb/in*. Operating at 75 percent recovery, the RO system yielded 4.5 gal/min of product (fresh) water and 1.5 gal/min of concentrate. A total of about 1,250 gallons of concentrate was produced and stored each weekday to support the saline vegetated wetlands. Figure 4.9 shows the RO equipment skid and the 1,250-gallon permeate and concentrate tanks. The RO system control and instrumentation panel is shown in figure 4.10.

4.4.3 Process data collection and recording.-System operation was continuously monitored using a Molytek 32-channel datalogger (figure 4.11). A total of 18 channels were active, receiving 4-20 mA signals from process instruments. Channel assignments and engineering units were as follows:

Channel 1 - Streaming current, SCUs
Channel 2 - Turbidity, ntu
Channel 3 - RO feed conductivity, μS/cm
Channel 4 - RO interstage conductivity, μS/cm
Channel 5 - RO reject conductivity, μS/cm
Channel 6 - RO permeate conductivity, μS/cm
Channel 7 - Raw feed pH
Channel 8 - RO feed pH
Channel 9 - RO reject pH
Channel 10 - RO feed flow, L/min
Channel 11 - RO reject flow, L/min
Channel 12 - RO permeate flow, L/min
Channel 13 - RO feed pressure, kPa
Channel 14 - RO interstage pressure, kPa
Channel 15 - RO reject pressure, kPa
Channel 16 - Raw feed temperature, °C
Channel 17 - RO feed temperature, °C
Channel 18 - Atmospheric temperature, °C

Every 15 minutes, an instantaneous value was recorded from each channel by a Molytec 9903 disk recorder. In addition, selected channels were plotted as trends on strip chart paper providing visual data for operating and troubleshooting the system. Channels 2 (turbidity) and 8 (RO feed pH) have alarm shutdowns triggered by "out-of-spec" operating conditions. The alarm notifies the operator who isolates the fault(s) and manually restarts the system.

4.4.4 Sampling and analyses.-Pretreatment effectiveness was monitored using pressure filter effluent turbidity and daily silt density index (SDI) measurements (figure 4.12). As was mentioned previously, SDI is a measure of fouling potential of the feedwater from colloidal-size materials. SDIs were initially run only on samples collected upstream from the cartridge

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Figure 4.5.—Well water being pumped into the 5,000.gallon RO feed tank.

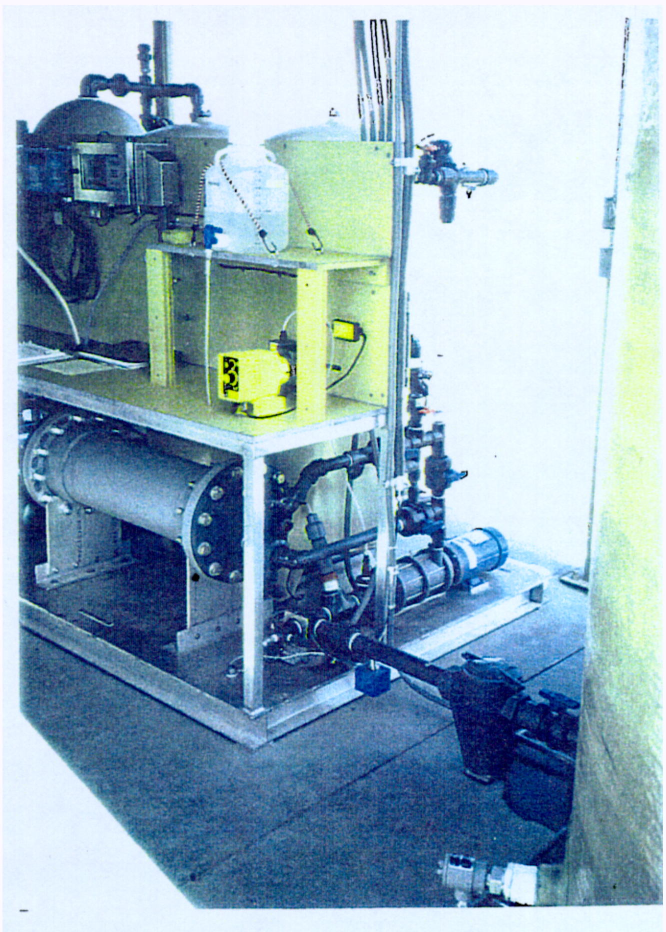

Figure 4.6-View showing basket strainer and polymer addition.

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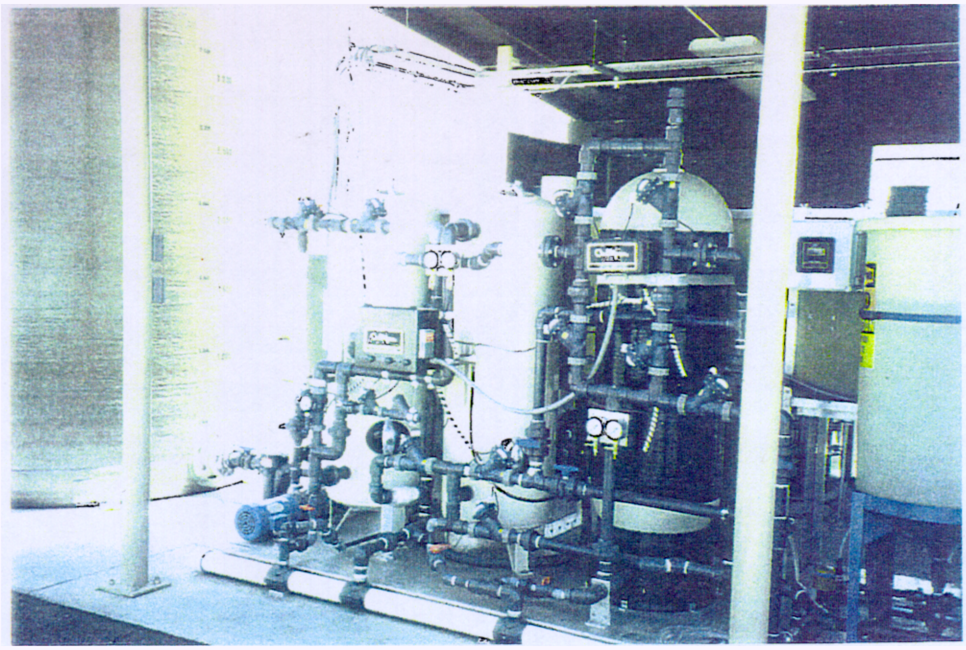

Figure 4.7.—View showing the sand clarifier, pressure filter, and GAC column.

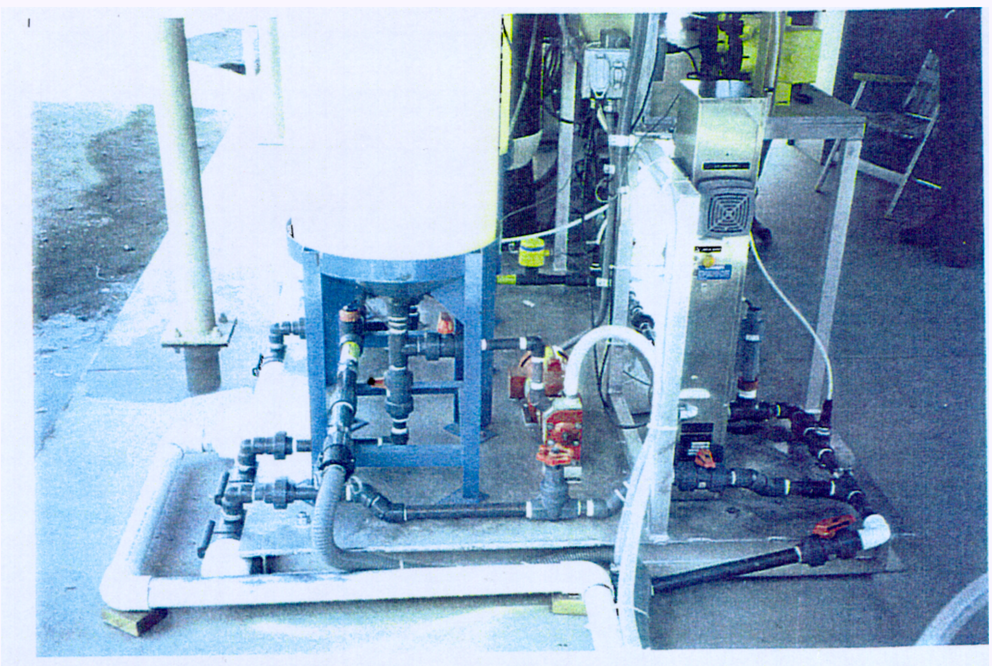

Figure 4.8.—View showing acid feed tank and UV (ultraviolet) sterilizer to the right.

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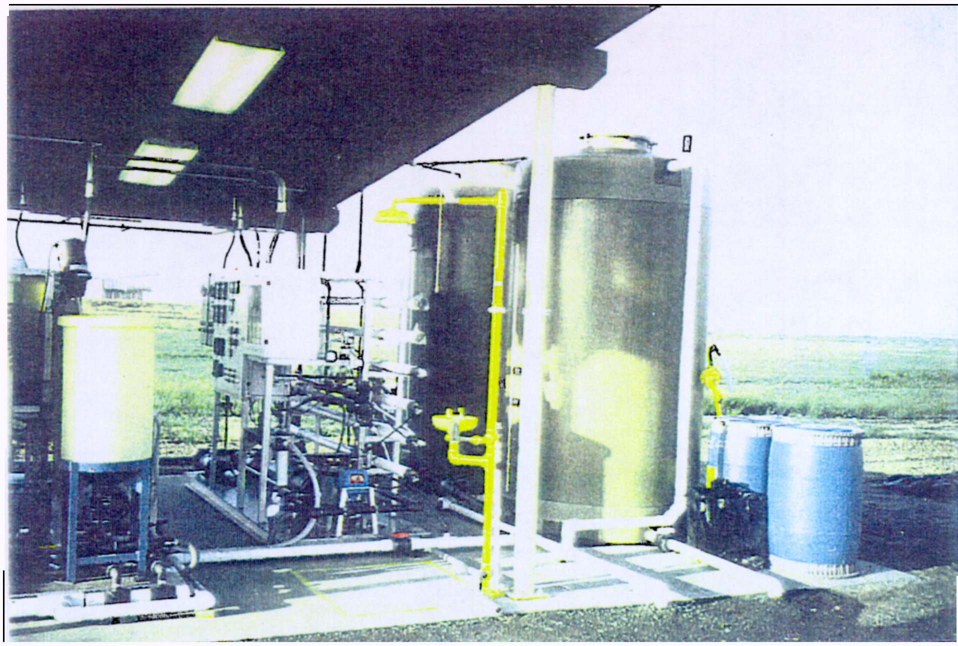

Figure 4.9.—RO equipment skid next to the 1,250-gallon permeate and concentrate tanks.

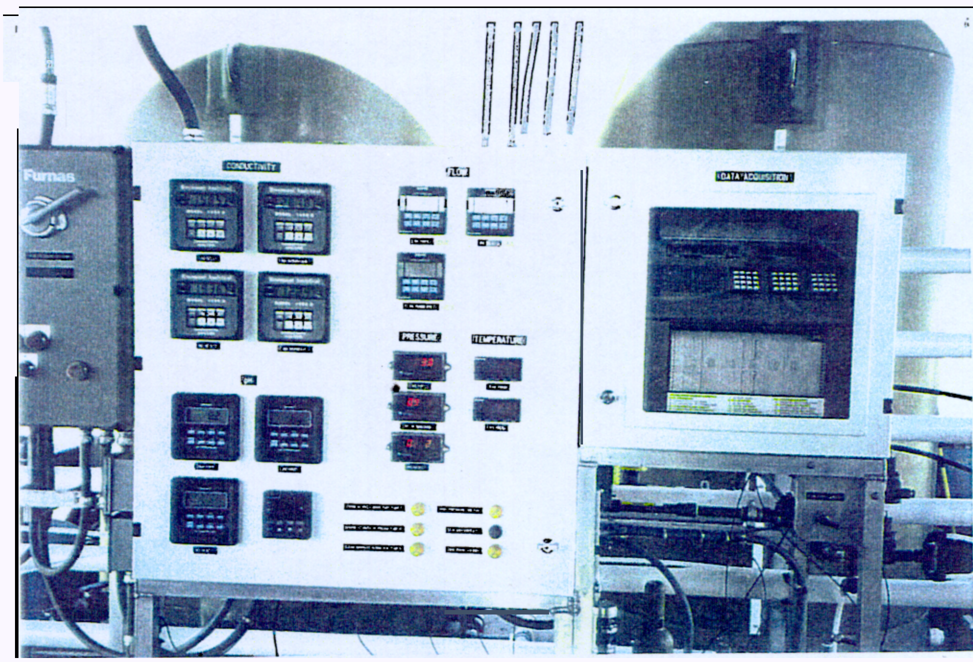

Figure 4.10.—RO system control and instrumentation panel with data acquisition to the right.

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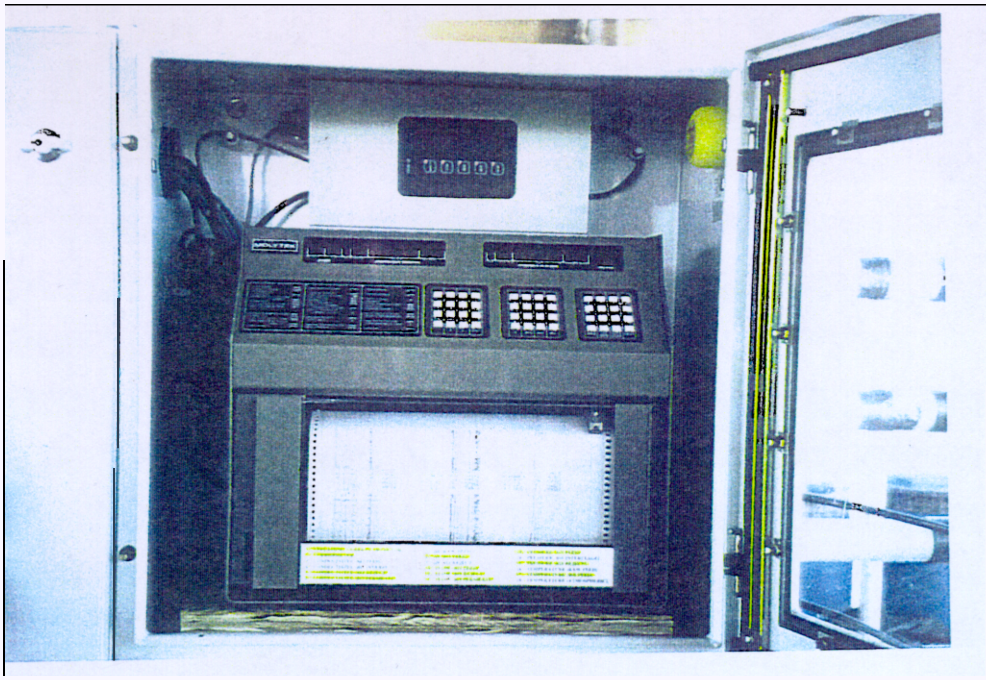

Figure 4.1 I-Closeup view of the 32-channel Molytec recorder and disk drive unit.

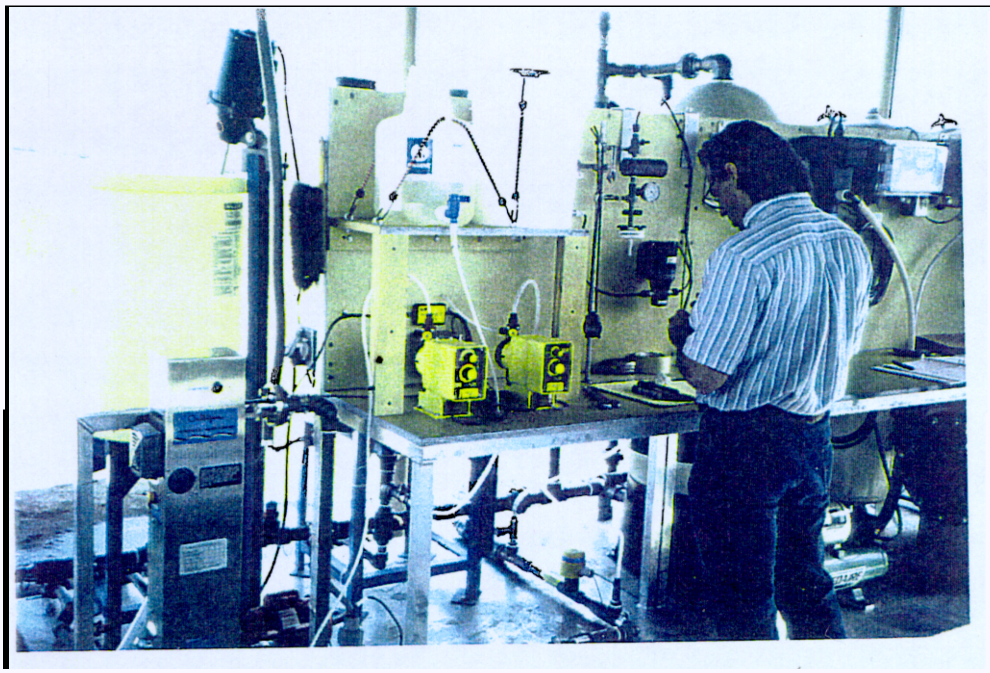

Figure 4.12.—EMWD operator performing daily silt density index (SDI) measurements.

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filter. However, recent measurements have been taken on both upstream and downstream samples for comparison (downstream values reflect what the lead RO elements are seeing). Samples were collected periodically from the feed, interstage (Desal 3LP testing only), reject, and permeate streams and chemically analyzed to determine specific ion rejections and to calculate mass balance calculations. The constituents measured included major ions, SiO_2, HPC, TOC, and selected metals (refer to appendices C and G).

4.4.5 Data reduction and interpretive methods.-A generalized RO process diagram is presented in appendix D which was used during data reduction for mass balance calculations. Two methods of data reduction are typically used for interpreting RO data. The first and more rigorous method involves the calculation of water transport (A, 10^{-12} m/s·Pa) and salt transport (B, 10” m/s) coefficients. The second involves the calculation of net driving pressure (NDP) and normalized permeate flow (NPF). The latter is the more common method and is used herein.

4.5 Results and Discussion

4.5.1 RO reject-regenerated ion exchange experiments-Bench-scale tests were conducted in anticipation that RO operations would be performed using the Walker Duck Club well water. They basically consisted of laboratory experiments to evaluate reject-regenerated IX (ion exchange) as a pretreatment process. Because of the high concentrations of Ca^{+2} (calcium) and HCO_3^- (bicarbonate) in the Walker Duck Club well water, it would have been necessary to add a considerable amount of acid plus antiscalant to avoid the precipitation of $CaCO_3$ (calcium carbonate) in the RO elements. IX experiments were conducted using a strong acid cation exchange resin operated in a sodium cycle to remove calcium. Regeneration of the resin was attempted using a solution synthesized to duplicate the anticipated RO reject (concentrate) stream. These experiments were completed in April 1992, and the results were documented in a memorandum report (Included as appendix A to this report). Subsequent to these experiments, the Walker Duck Club well was abandoned as a potential RO feedwater source because of severe flooding and access problems.

4.5.2 FilmTec BW30 element evaluation.—On June 6, 1993, a full load of 18 FilmTec BW30-2540 elements was installed in the pressure vessels (refer to appendix E for loading pattern and serial numbers). During the following 8 months, a total of 1,860 hours of operation were logged. In that time, 2,530,000 L (670,000 gal) of Moreno Highlands well water was desalted, yielding 1,900,000 L (502,000 gal) of product water and 634,000 L (167,000 gal) of concentrate. Average feed and product concentrations were 988 and 14.2 mg/L TDS, respectively.

4.5.2.1 *Operational* data--Operational data collected during this test period by the plant operators, along with other calculated values, are tabulated in appendix B. Flow, temperature, conductivity, and pressure data are also graphically depicted on figures 4.13 *through 4.18.*

Figures 4.13 and 4.14 show the process flow and temperature data. The feed and reject flows were: held constant at 22.7 L/min (6.0 gal/min) and 5.7 L/min (1.5 gal/min), respectively,

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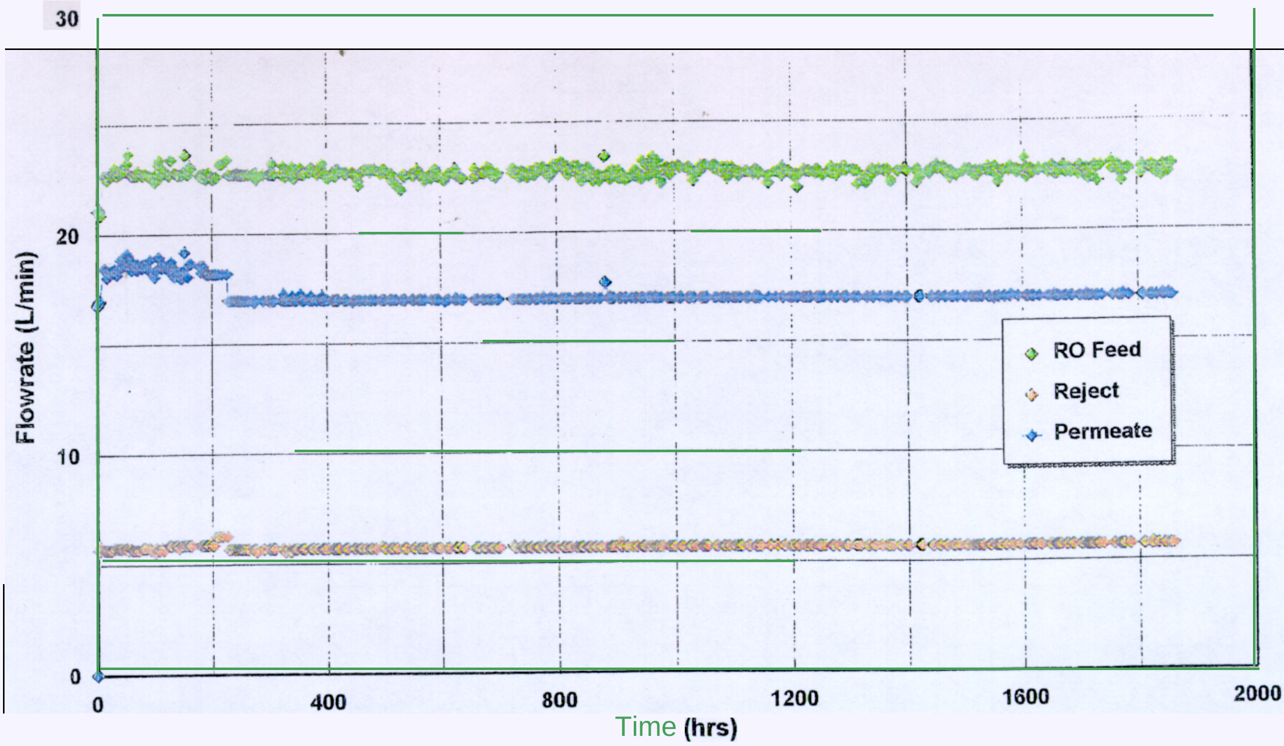

Figure 4.13.—System flowrates (FilmTec BW30).

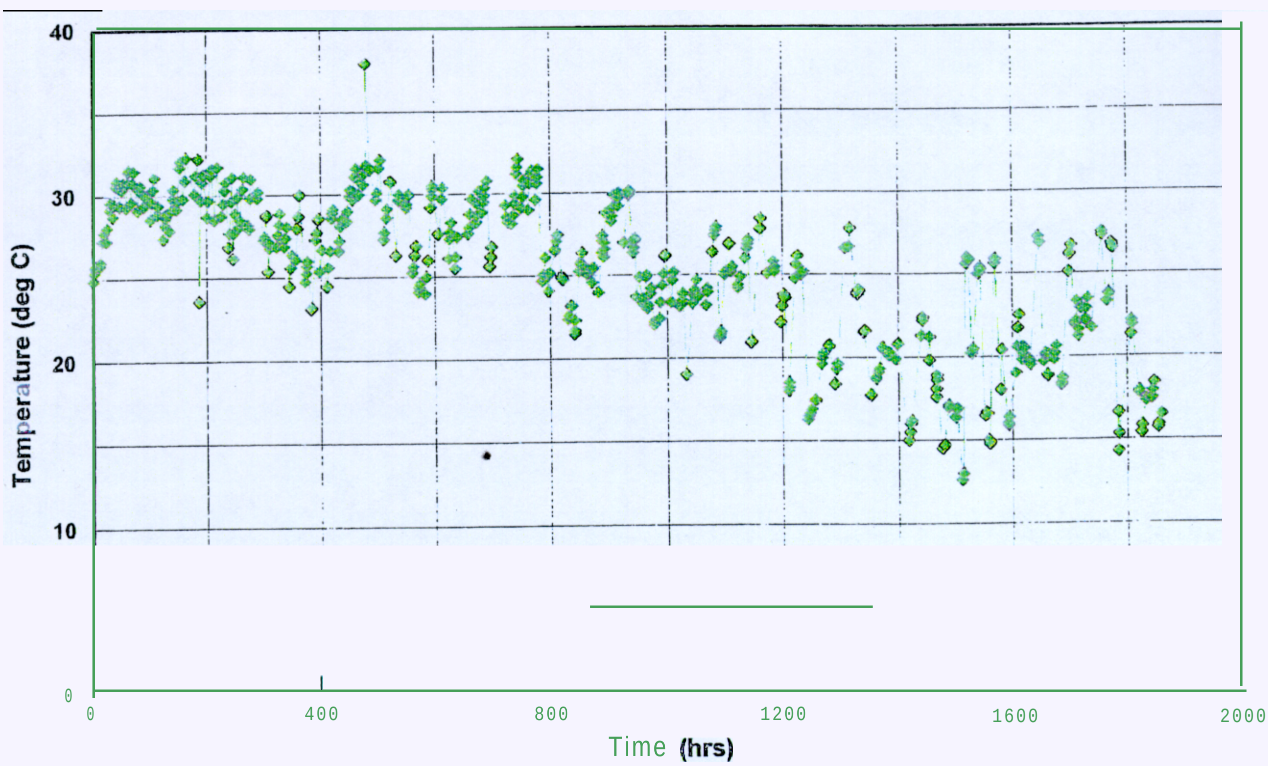

Figure 4.14.—Feed temperature.

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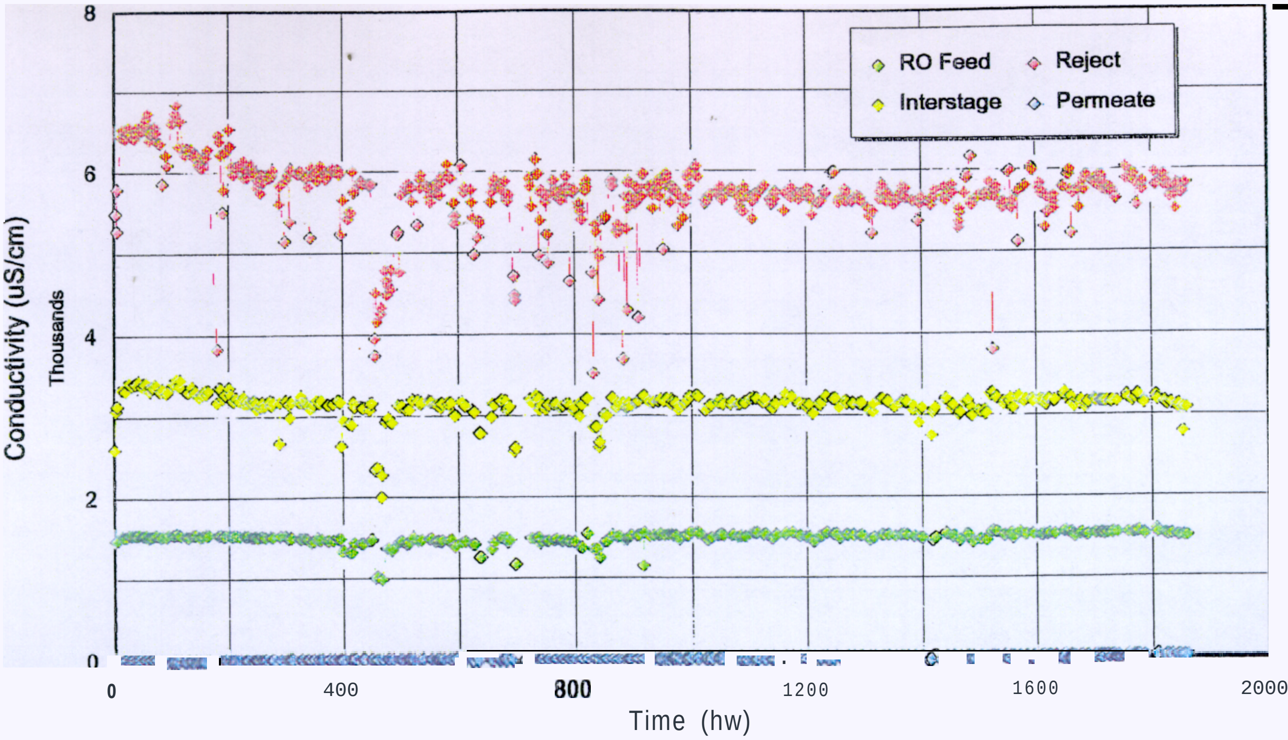

Figure 4.15.—System conductivities.

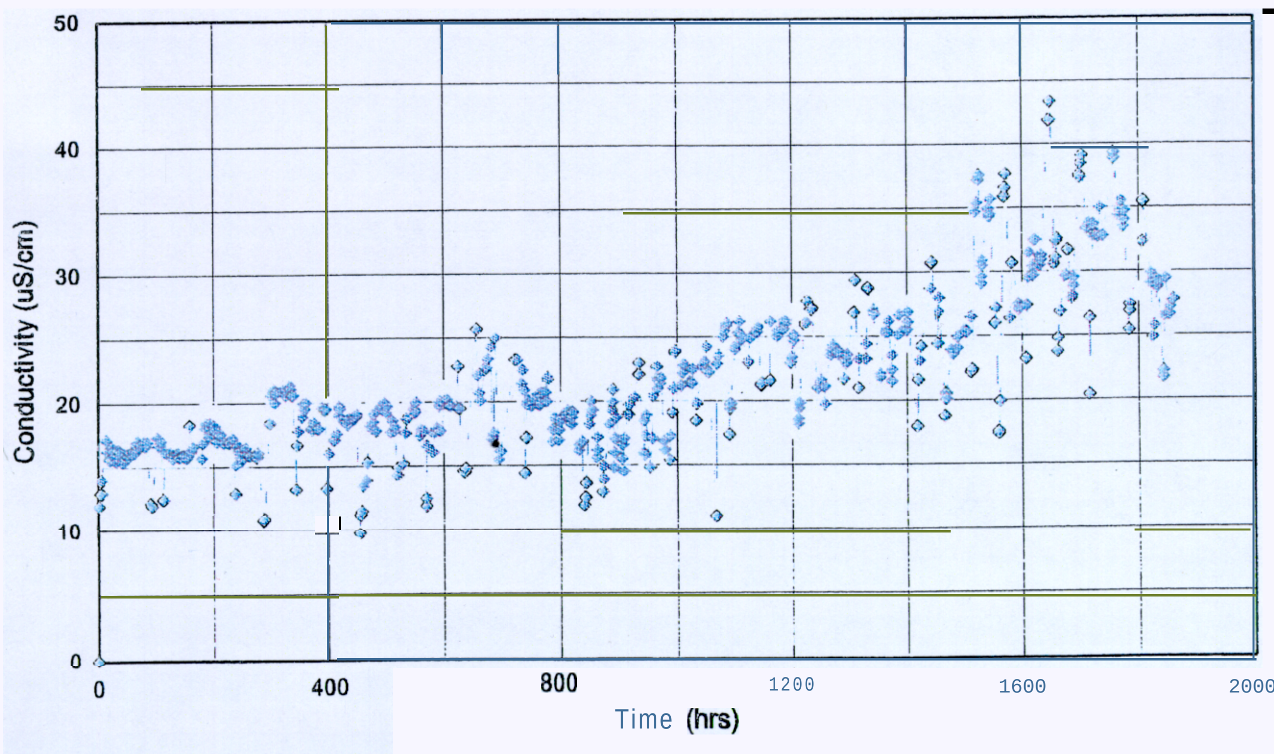

Figure 4.16.—Permeate conductivity.

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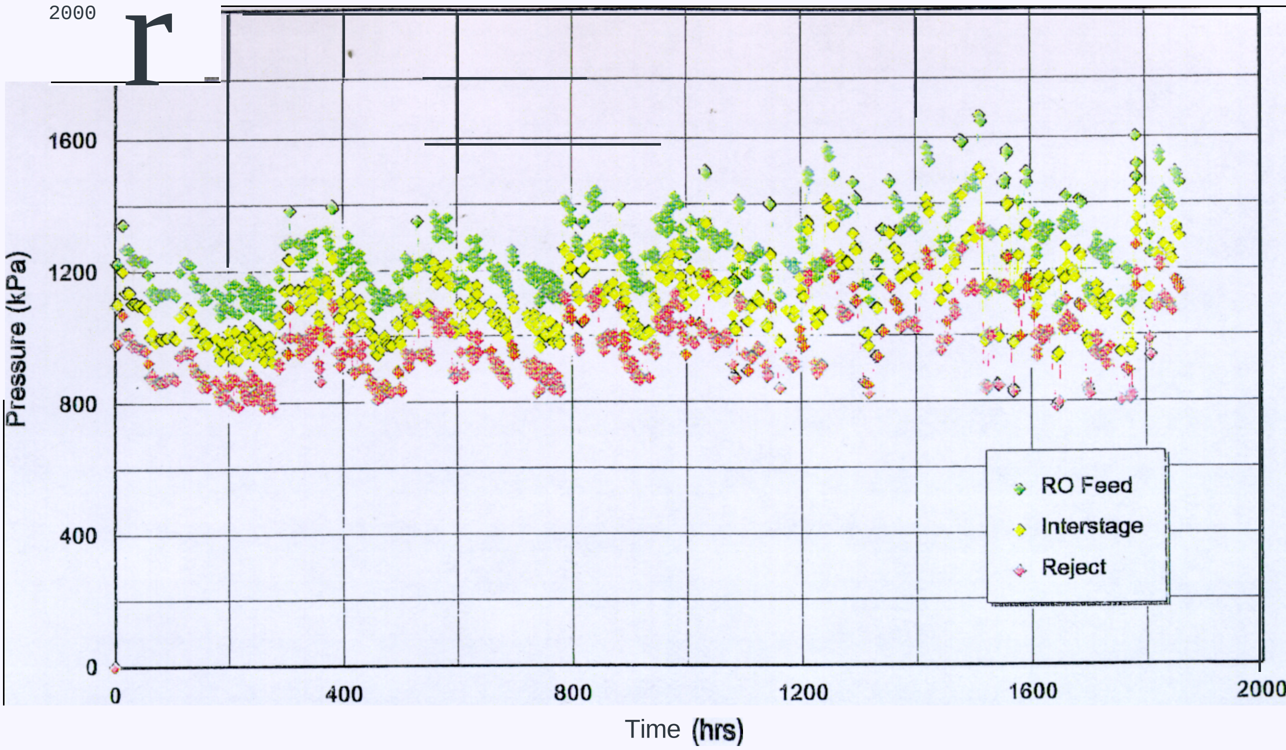

Figure 4.17.—System pressures

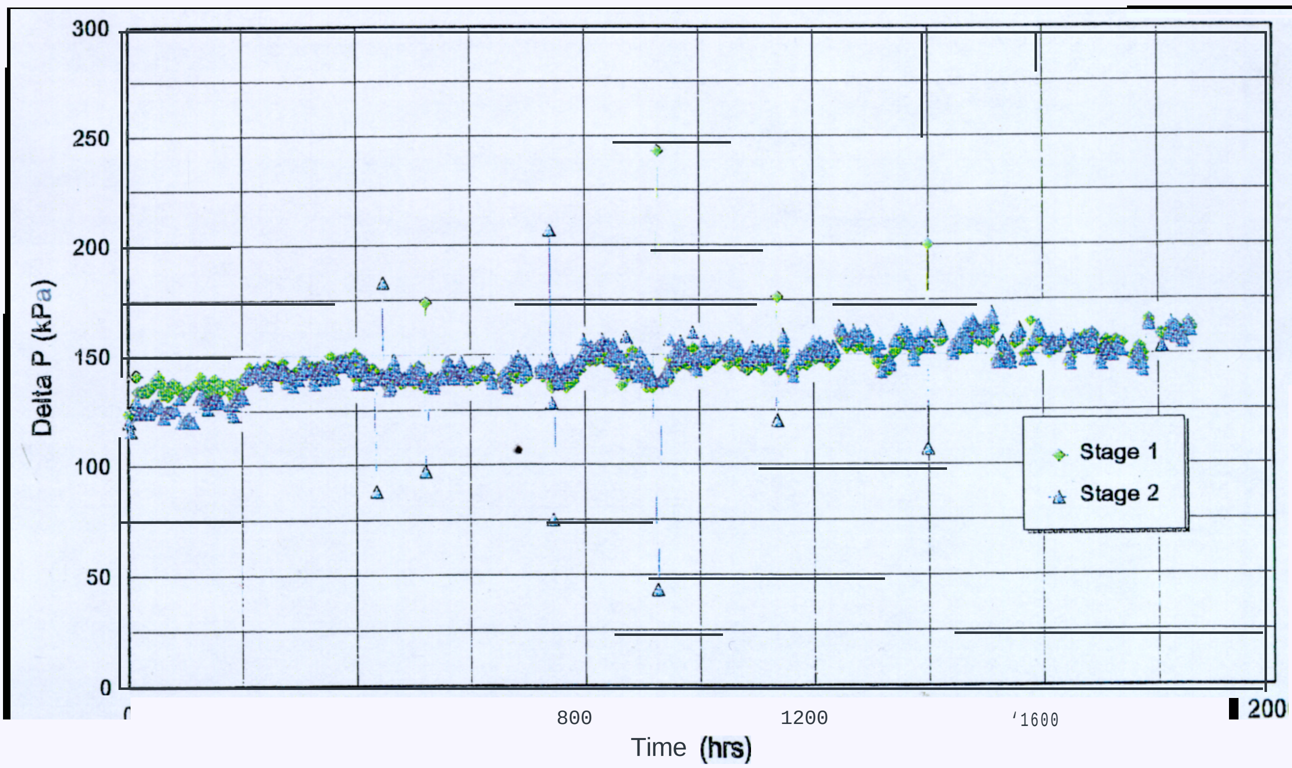

Figure 4.18.—Stage pressure drops

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yielding a 75 percent recovery of desalted water (permeate). The discontinuity in the permeate data during the first roughly 200 hours of operation resulted from instrument calibration error. Both diurnal and long term variations in feed temperature are indicated in figure 4.14. This measurement, which was taken at the feed end of the first stage, has a significant effect on membrane performance and is used in later calculations of net permeate flow which is normalized to 25 °C.

Figure 4.15 displays system conductivities as microSiemens per centimeter (µS/cm). Also, for better resolution, figure 4.16 shows an expanded view of the permeate conductivities. Note that the erratic spikes in the curves (figure 4.15) mirror one another. This would indicate that the concentration of the feedwater delivered to the site was not consistent. This is particularly noticeable at about 465 hours of operation, where it appears that the feedwater conductivity dropped by about 25 percent. Note also the gradual increase in permeate conductivity throughout the test period (figure 4.16). The suspected cause of this increase will be addressed later in section 4.5.2.2.

Figure 4.17 shows the RO feed, interstage, and reject operating pressures in kilopascals (kPa). In addition, pressure drops for each of the two stages are shown in figure 4.18. The gradual increase in the curves in figure 4.17 result, as expected, from a gradual decrease in feed temperature. For the most part, the two pressure drop curves in figure 4.18 mirror one another, indicating no differential buildup of fouling or scaling components (colloidal and biological fouling usually manifest themselves in the leading elements of the first stage, whereas scaling predominantly occurs in the trailing elements of the second stage). RO feed pressure averaged 1,267 kPa (184 lb/in^2) during the 8 months.

Complete chemical analyses were performed at 561 hours of operation on the three separate process streams (RO feed, permeate, and reject) for the following constituents:

- Cations (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+})
- Anions (HCO_3^-, Cl^-, SO_4^{-2}, NO_3^-, NO;, F^-)
- Metals (Al^{+3}, Ba^{+2}, Sr^{+2}, Fe^{+2}, Fe (total), Mn^{+2}, B'", Cu^{+2}, Se, Hg^{+2})
- Silica (as SiO_2)
- Total organic carbon (TOC)
- Heterotrophic plate count (HPC)

Results of these analyses are shown in appendix C.

Table 4.1 summarizes percent salt rejections (%SR) for selected ions and for TDS that were calculated from the concentration data in appendix C. The values shown as ≥ result from the permeate concentration falling below the detection limit. All ions, with the exception of B^{+3} (boron) and Cu^{+2} (copper), were rejected at or above 93 percent. Boron and copper, which can be toxic to wetlands vegetation at elevated concentrations, were rejected at 74 and 85 percent, respectively. The average reduction in TDS is slightly greater than 97 percent.

The HPCs, which were taken on August 13, 1993, indicated very high readings in the RO feed and reject tanks (>5,700 cfu/mL). Unfortunately, these values were not reported to the Denver Office until September 2, 1993. It was suspected at the time that the high plate

Table 4.1 .-Percent salt rejection data for the FilmTec BW30 (Moreno Highlands well) testing

SALT REJECTION (%)	
Constituent	561-Hour
Calcium	≥99.7
Magnesium	≥97.6
Sodium	98.6
Potassium	≥92.9
Boron	74.4
Copper	≥85.0
Selenium	-
Bicarbonate	97.7
Chloride	99.4
Sulfate	99.6
Fluoride	98.3
Nitrate	94.7
Silica (total)	≥95.6
TDS	97.1

Note: All ≥ rejection values above were based on permeate concentrations that were at or below detection limit for the analytical method used.

counts in the reject tank might have resulted from feedwater seeping through the system from the head differential, i.e., after the water was delivered but before system startup. The truck driver was advised to shut the effluent valve on the feed tank before tilling it. In addition, the array was flushed with a 1 percent solution of the biocide Minncare™ and allowed to sit over the weekend. Minncare" was selected because of its advertised compatablity with TFC membranes. From that point on, a regimen of weekly flushing with 1 percent Minncare™ was included in the operation and maintenance (O&M) procedures. Followup samples taken on September 7, 1993, indicated significant HPC reductions; i.e., 1 and 528 cfu/mL in the product and feed tanks, respectively.

A total of 165 SDIs were performed during the 1,860 hours of FilmTec BW30 testing (June 7, 1993 to February 3, 1994). The values ranged between 0.41 to 6.16, with an average and standard deviation of 2.33 and 1.47, respectively. All were measured upstream from the cartridge filter for this test phase. Keep in mind, however, that the SDIs will be lower downstream from the cartridge filter, and it would be the downstream readings that should fall below the recommended maximum allowable SDI of 5.0.

Figures 4.19 and 4.20 present the average net driving pressure (NDP) and normalized permeate flow (NPF) for this test phase. Average NDP is the pressure available to force water through the membrane and is calculated as follows:

$$NDP = P_f - P_p - P_o$$

where: P_f = Average feed pressure (average of feed and reject pressures)

P_p = Pressure in the permeate line (gauge pressure)

P_o = Average osmotic back pressure of the feedwater (estimated by averaging the feed and reject concentrations and dividing by 100)

NPF is the total permeate flow adjusted to standard temperature (25 "C) and to normalized NDP at startup and is calculated as follows:

$$NPF = NDP_{startup}/NDP_{today} \times TCF \times F_p$$

where: TCF = Temperature correction factor

F_p = Permeate flow

The NPF graph (figure 4.20) can be used as a diagnostic tool to estimate the degree to which membranes are being fouled or to determine if damage is occurring. The NPF graph is commonly used to determine the time at which membranes should be chemically cleaned. Some drop in NPF with time is expected. For the TFC membranes used in this study, a 15-20 percent decline over a 3- to 5-year period would not be unusual. This assumes, of course, that adequate pretreatment is maintained and an effective monitoring and membrane cleaning regimen is used. If NPF increases with time, as shown in figure 4.20, membrane damage is strongly expected.

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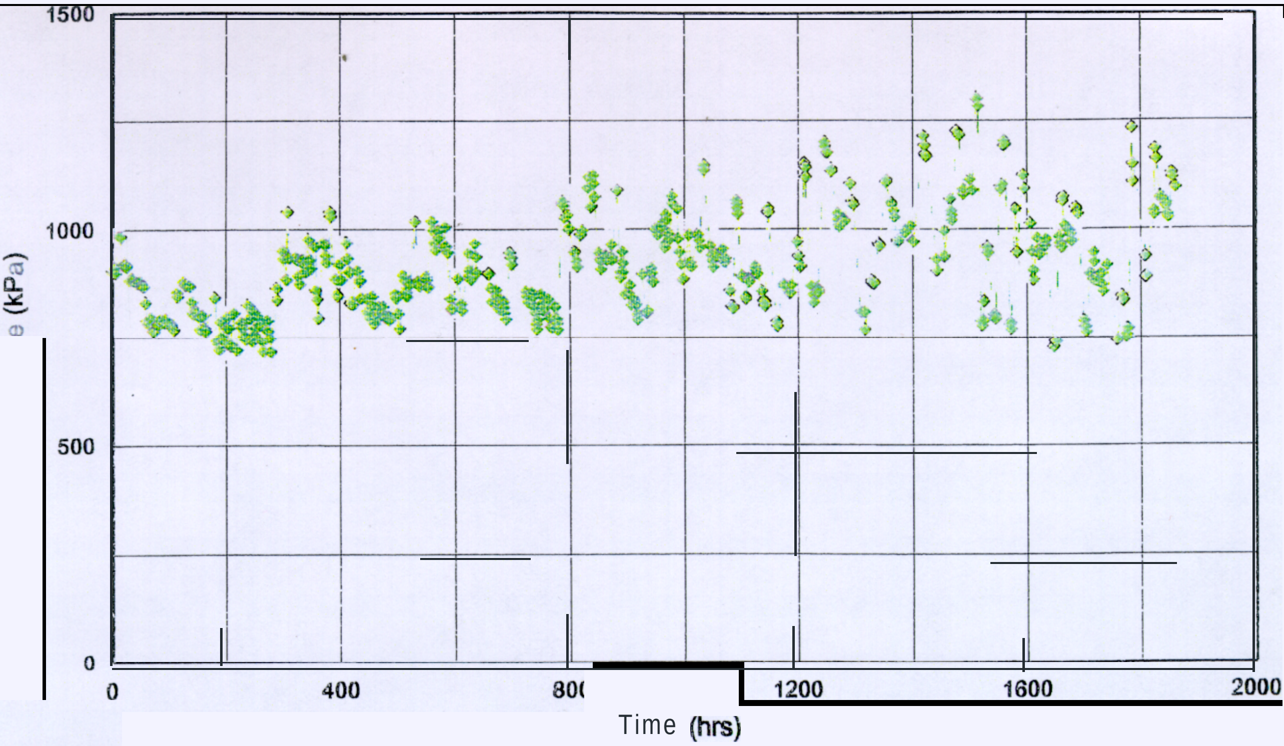

Figure 4.19.—Average net driving pressure

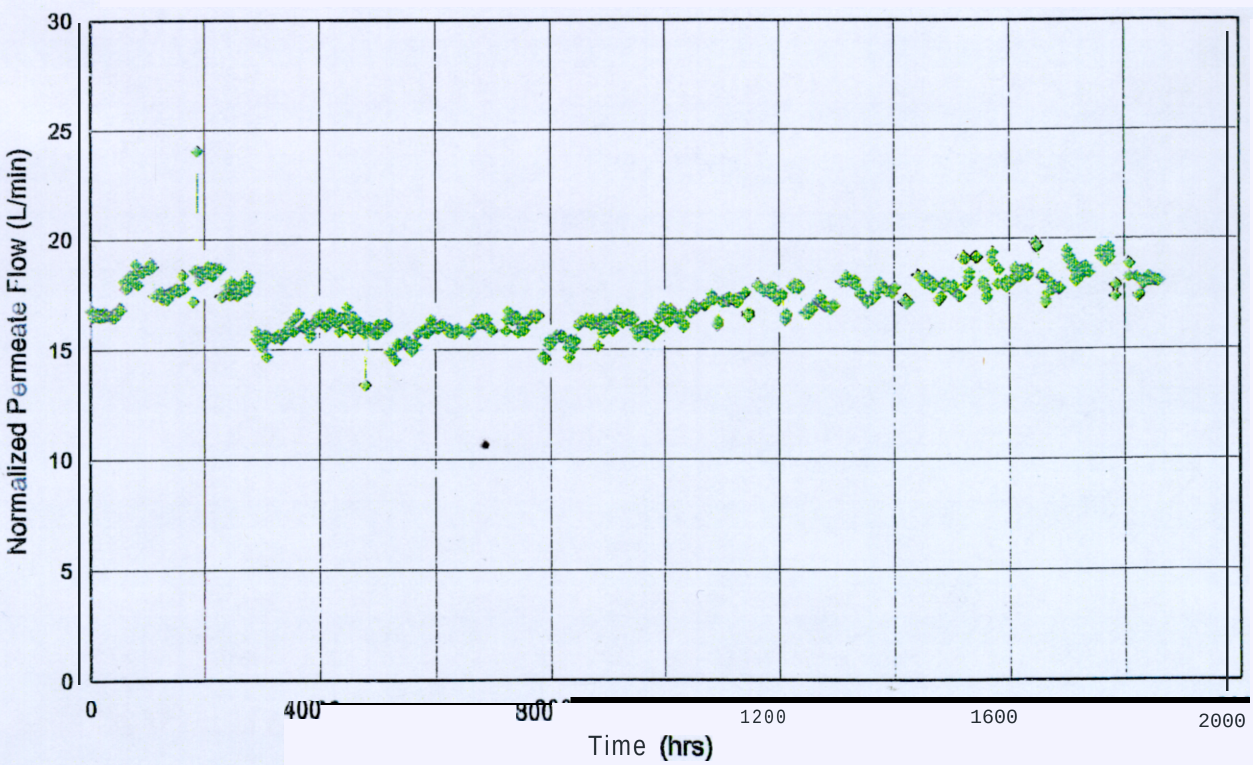

Figure 4.20.—Normalized permeate flow.

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4.5.2.2 Performance degradation.-Midway through the 1,860-hour test period, some early signs of membrane degradation were observed. The weekly use of the biocide Minncare™ was suspected as the cause of the degredation. Addition of the biocide began at about 740 hours of operation (refer to previous section), and noticable increases in NPF were observed at between 1,000 and 1,200 hours. By 1,370 hours, salt rejection had dropped slightly, by 0.35 percent, and normalized permeate flow had increased by about 8 percent. At that point, it was evident that something was causing significant membrane damage. The obvious culprit was Minncare™, which contains hydrogen peroxide, a strong oxidant, as a principal constituent. To combat or slow down this degradation, the disinfection protocol was changed to include less frequent disinfection (30 minutes flushing with 1% Minncare™ each month) and weekend storage of the elements in dilute (1 percent) sodium bisulfite to inhibit microbial growth. During the final 400 hours of operation, i.e., since the change *in* disinfection procedures, the salt rejection and normalized flows appear to have leveled out.

4.5.2.3 Membrane autopsy and scanning electron microscopy (SEM) analysis--An autopsy was performed on one of the two lead RO elements in stage 1 (serial No. Al 690782; refer to appendix E). An initial observation was that the membrane surface appeared remarkably clean, revealing no obvious fouling or scaling. Also, the Vexar™ (plastic feedwater/concentrate spacer; refer to figure 4.1) showed no signs of any buildup. After measuring the dimensions of the active membrane area, one of the membrane surfaces was irrigated with deionized water and thoroughly squeegeed to collect any adhering surface deposits. This operation yielded a small amount of light brownish material which was later determined to have a dry mass of 0.0734 grams (collected from a membrane active surface area of0.57 m’).

A dye test was used in an attempt to identify possible surface penetrations of the membane layer from chemical deterioration, pin holes, cracks, etc. A l-percent solution of congo red dye was applied to several small area of the membrane’s surface and then wiped away after a few moments. Residual (dark) dye stains or bleeding of the dye to the membrane backing material would indicate surface penetrations. No evidence of physical degradation was observed. It should be noted, however, that this dye test was originally developed for cellulose acetate (CA) membranes, which have considerably less surface roughness, and its application to TFC membranes is questionable.

Membrane samples were cut from the leaf for scanning electron microscopy (SEM) imaging, both from the lead and trailing ends of the element, to determine if surface damage could be visually detected. The samples were gold-coated to enhance imaging resolution and detail. It was suspected, prior to running the SEMs, that damage would most likely occur at the points where the Vexar™ physically contacted the membrane surface (these points were easily identified from the impressions left behind). Figure 4.21 presents four SEMs of varying magnification which show conclusively that surface penetrations have developed within and along the edge on the Vexar™ imprints. Two principal theories have been proposed to explain this localized degradation: first, that the damage was caused solely by the repeated pressure cycles of operating in a daily on-off mode; and second, that Minncare™ contributed to (accelerated) the damage, possibly by being adsorbed onto trapped particles at the points of Vexar™ contact.

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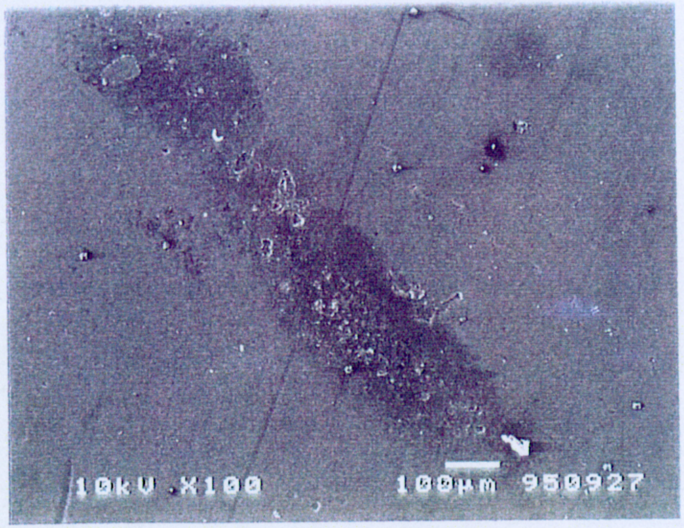
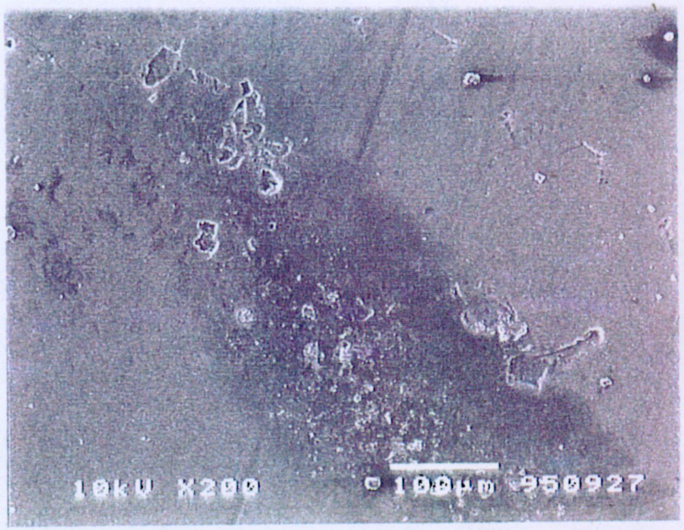
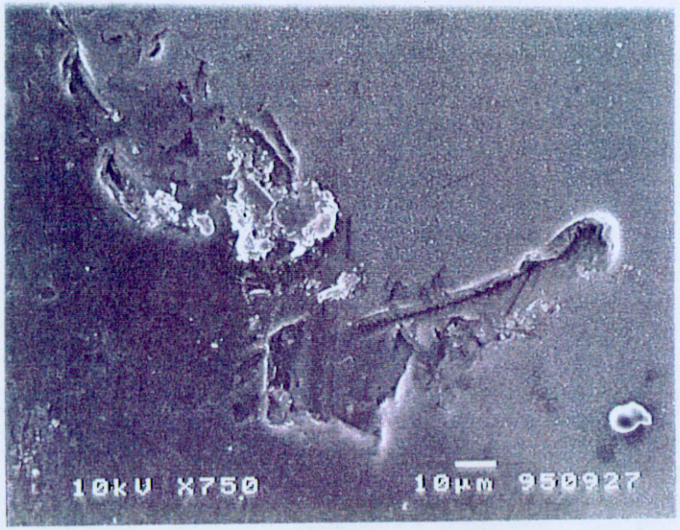


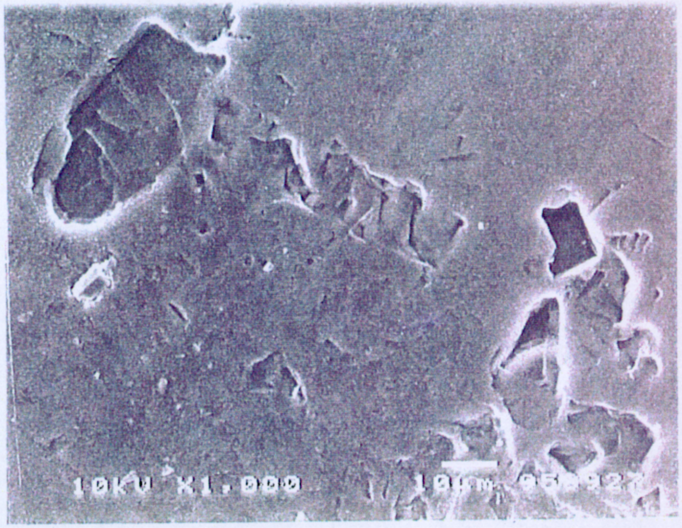
(a) View at 100x magnification showing full imprint.



(b) View at 200x magnification showing middle of imprint.



(c) Closeup view of surface penetrations at 750x magnification.



(d) Closeup view of surface penetrations at 1000x magnification.

Figure 4.21.—SEMs of Film Tec BW30 membrane surface showing localized degradation at Vexar (concentrate spacer) imprint.

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The dried sample collected from the squeegeeing operation was digested and analyzed for trace metals using inductively-coupled plasma (ICP) spectroscopy. A total of 26 metals were identified. Table 4.2 lists those found with a total mass ≥ 0.030 mg. Remember, these metals were collected from a membrane surface area of about 0.57 m^2.

4.5.3 Desal-3LP element evaluation.-& July 21, 1994, after a 5-1/2-month shutdown due to the lack of a feedwater source, a full load of 18 new Desal SG2540 elements were installed in the pressure vessels, and the system was restarted (refer to appendix E for an element loading diagram and serial numbers). As explained earlier, this report documents the results of only the first 1,000 hours of testing, even though operations continued with these elements through November 1995. During this test period, 1,363,000 L (360,000 gal) of Dairyland well water was desalted yielding 1,022,000 L (270,000 gal) of product water and 341,000 L (90,000 gal) of concentrate. Average feed and product concentrations were 993 and 20.6 mg/L TDS, respectively.

4.5.3.1 *Operational data.*—Operational data collected during this test period by the plant operators, along with other calculated values, are tabulated in appendix F. Flow, temperature, conductivity, and pressure data are also graphically depicted in figures 4.22 through 4.27.

Figures 4.22 and 4.23 show the process flow and temperature data. As before, the feed and reject flows were held constant at 22.7 L/min (6.0 gal/min) and 5.7 L/min (1.5 gal/min), respectively, yielding a 75-percent recovery of desalted water (permeate). Feed temperature dropped by about 15 °C during the 1 ,000-hour test period, which began in July and ended in December. Again, this measurement has a significant effect on membrane performance and is used in later calculations of net permeate flow which is normalized to 25 °C.

Figure 4.24 displays system conductivities as µS/cm. Also, for better resolution, figure 4.25 shows an expanded view of the permeate conductivities. Referring to figure 4.24, for some unexplained reason the feedwater concentration steadily declined during the test period by about 27 percent. As expected, this caused corresponding declines in the reject, interstage, and permeate curves as well. Since separate conductivity sensors and meters were used for each of the four streams (feed, interstage, reject, and permeate), the chances of instrument error being the cause is extremely remote.

Figure 4.26 shows the RO feed, interstage, and reject operating pressures in kPa. In addition, pressure drops for each of the two stages are shown in figure 4.27. The curves in figure 4.26 vary inversely with feed temperature, demonstrating the effect temperature has on operating pressure. For the most part, the two pressure drop curves on figure 4.27 track one another, with the first stage AP increasing at a slightly faster rate. This might indicate some early buildup of colloidal or biological fouling. RO feed pressure averaged 1,407 kPa (204 lb/in^2) during the 5 months.

Table 4.2.—Metals found on autopsied membrane surface

Metal	Percent [1,2]	Mass (mg)
Iron, Fe	2.29	1.68
Aluminum, Al	1.36	1.00
Calcium, Ca	0.84	0.62
Magnesium, Mg	0.46	0.34
Silicon, Si	0.42	0.31
Chromium Cr	0.32	0.23
Potassium, P	0.26	0.19
Zinc, Zn	0.11	0.08
Nickel, Ni	0.10	0.07
Sodium, Na	0.09	0.07
Boron, B	0.07	0.05
Molybdenum, Mo	0.04	0.03
Manganese, Mn	0.03	0.02
Barium, Ba	0.02	0.01
Copper, Cu	0.01	0.01
Lead, Pb	0.01	0.01

[1] Based on a total dry sample weight of 73.4 mg.
[2] Includes metals present at a percentage $\geq$ 0.01.

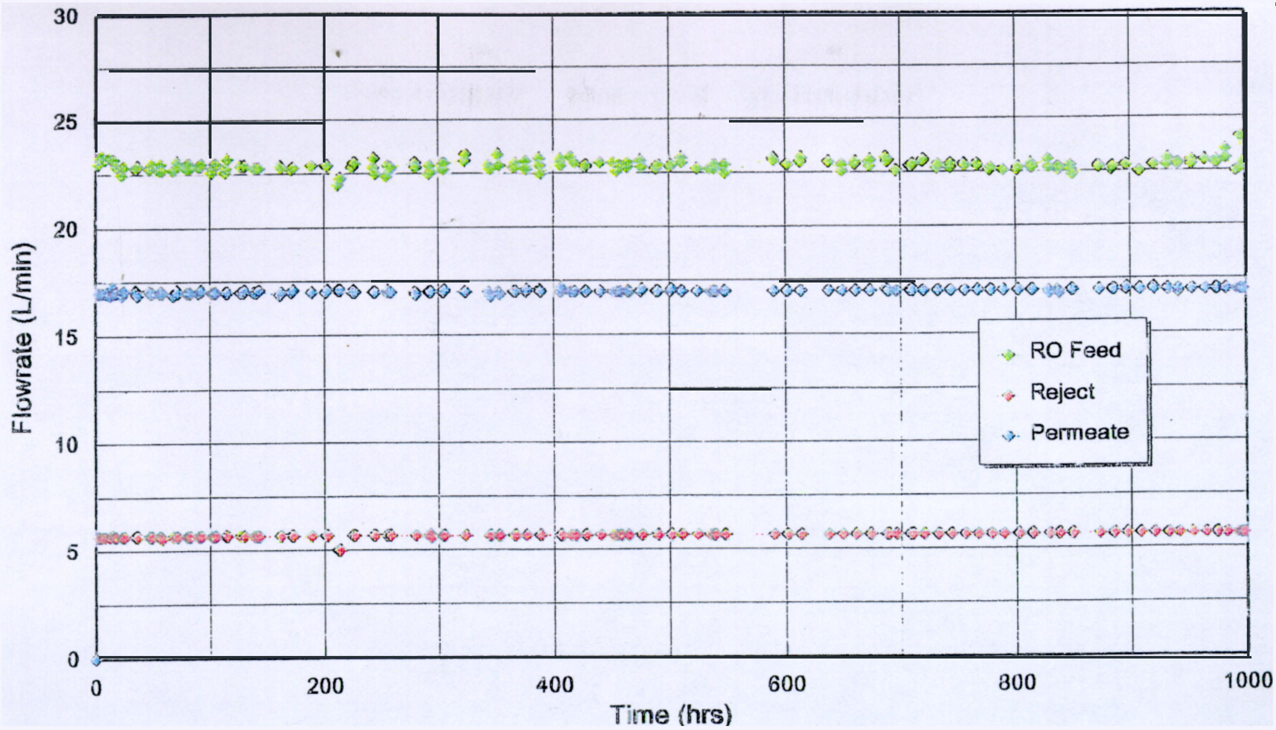

Figure 4.22.—System flowrates (Desal-3LP)

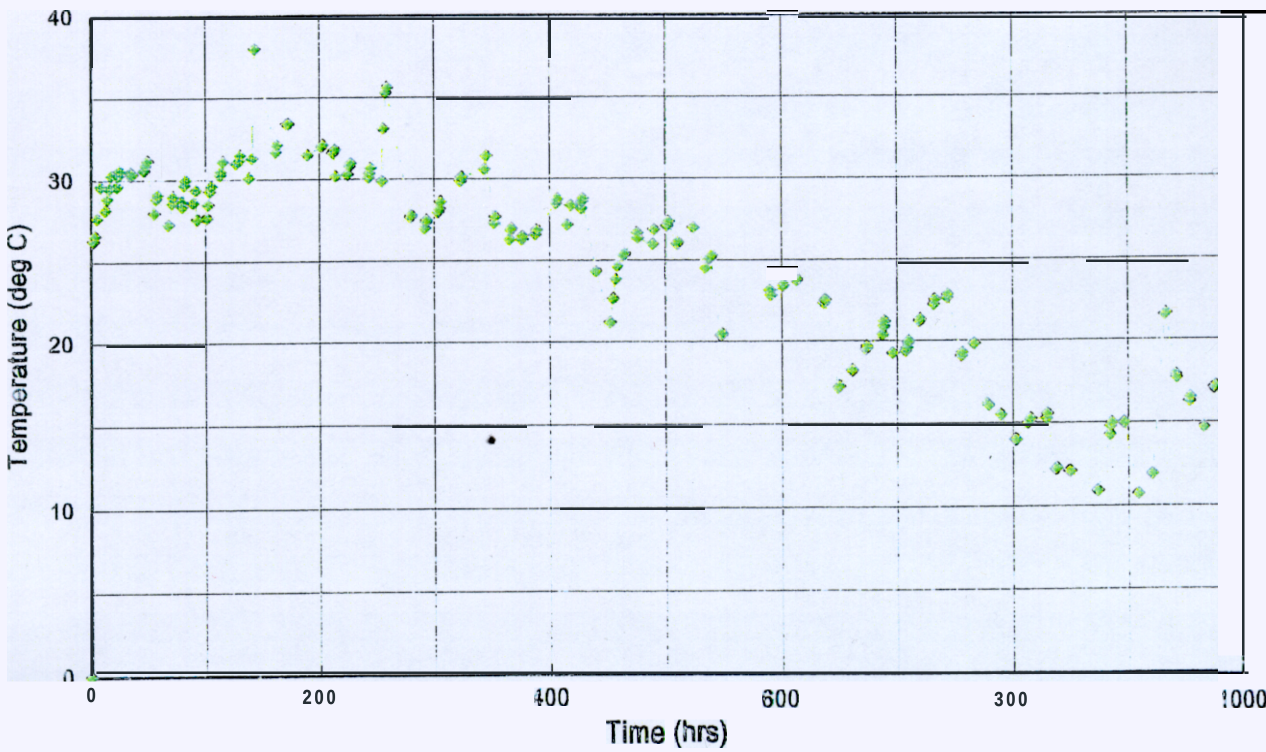

Figure 4.23.—Feed temperature

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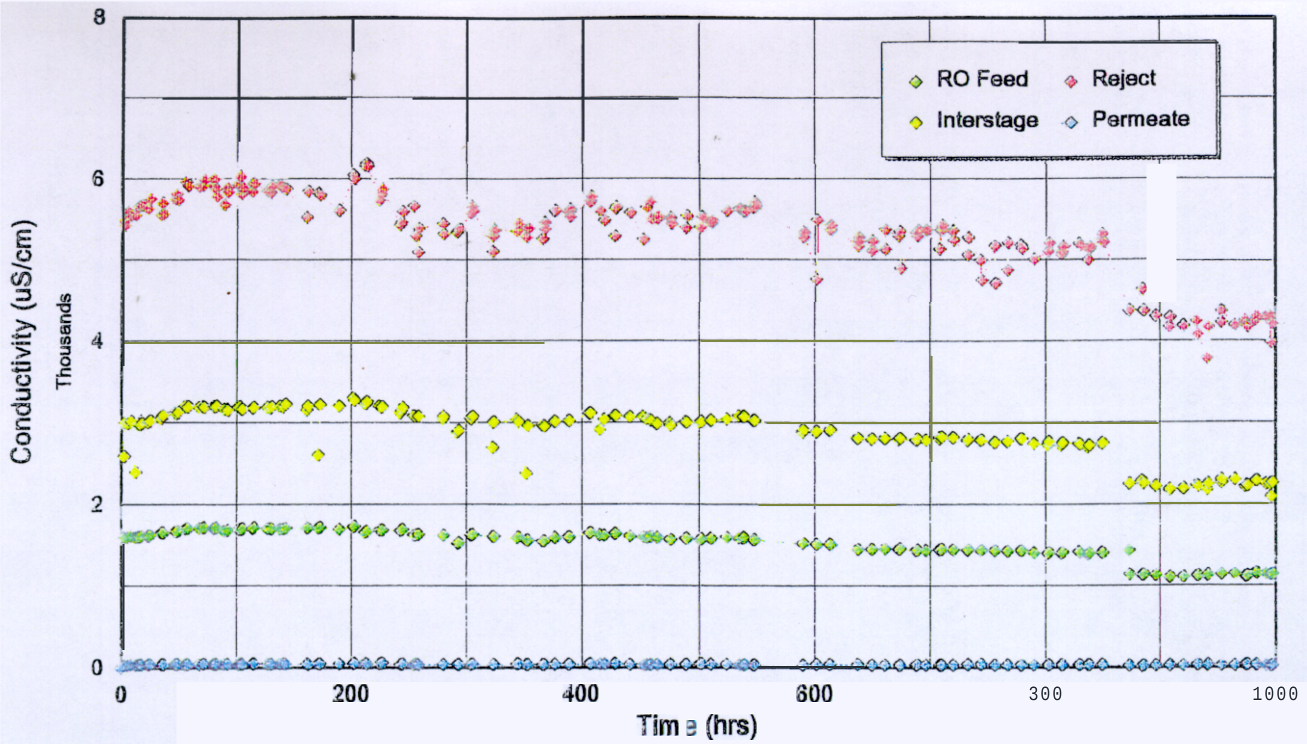

Figure 4.24.—System conductivities

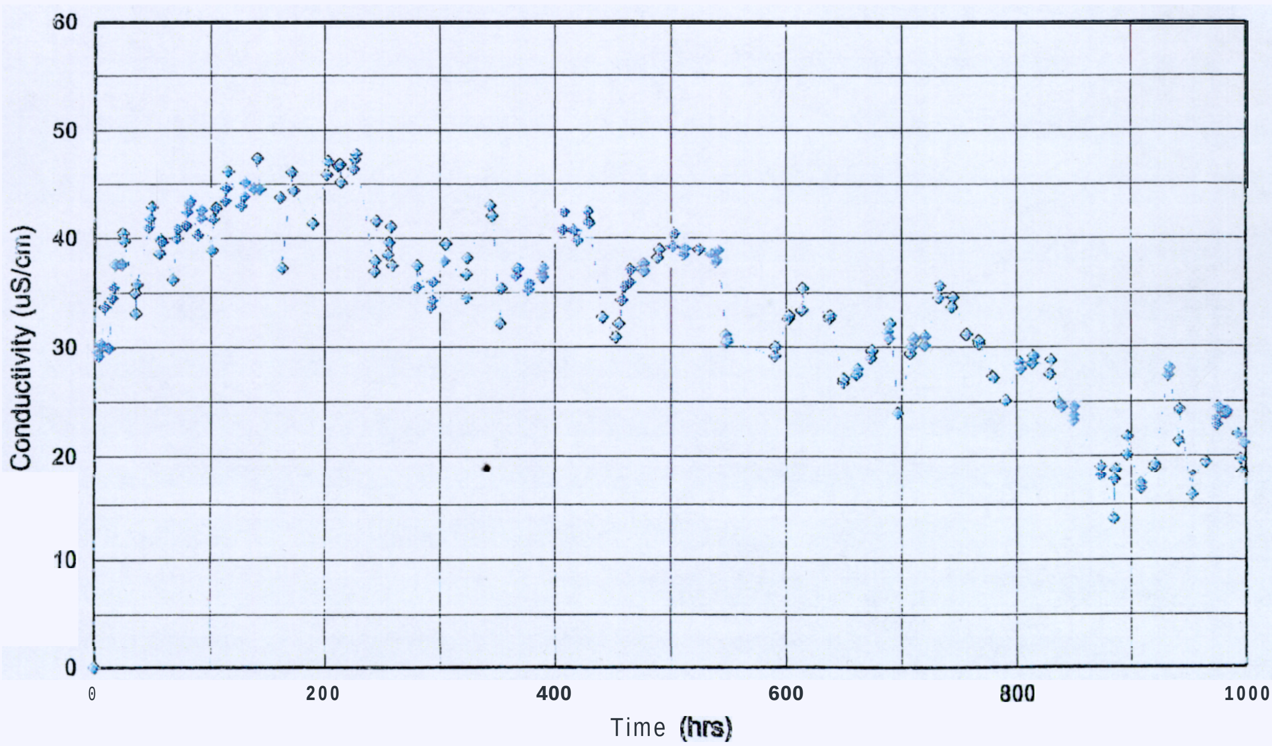

Figure 4.25.—Permeate conductivity,

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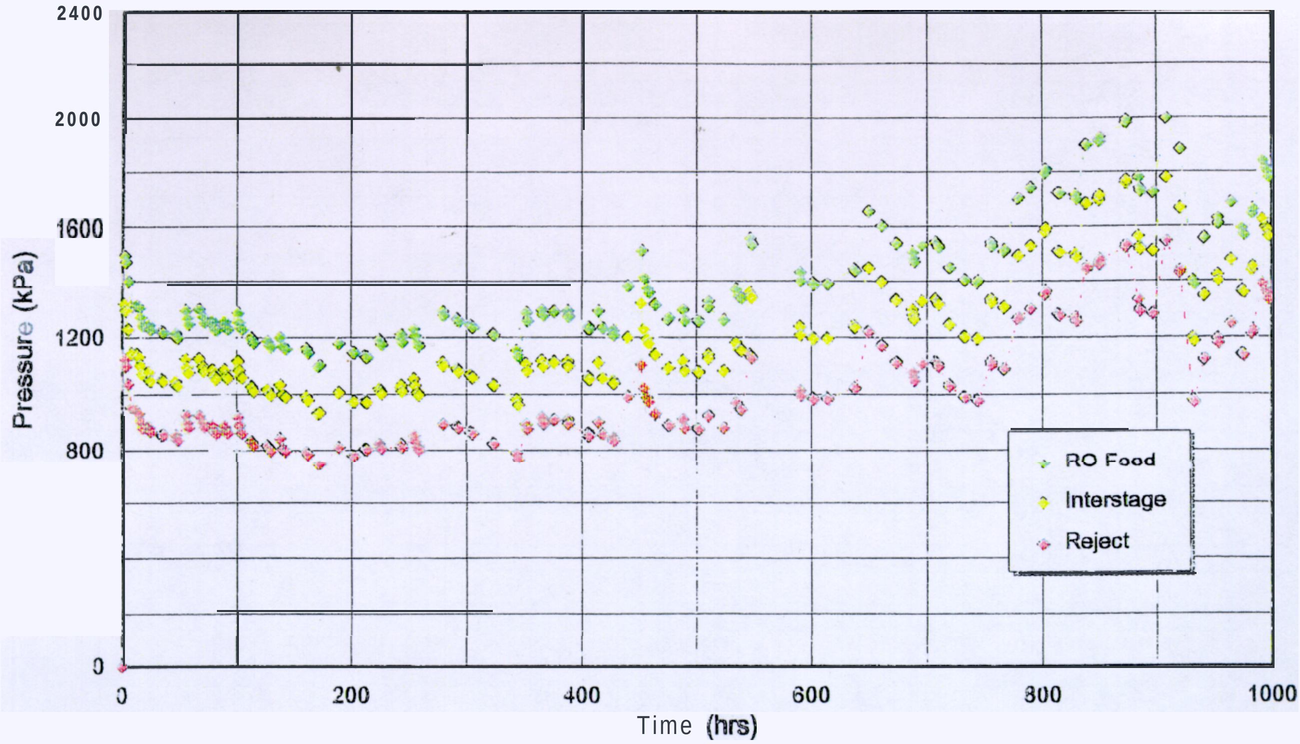

Figure 4.26.—System pressures.

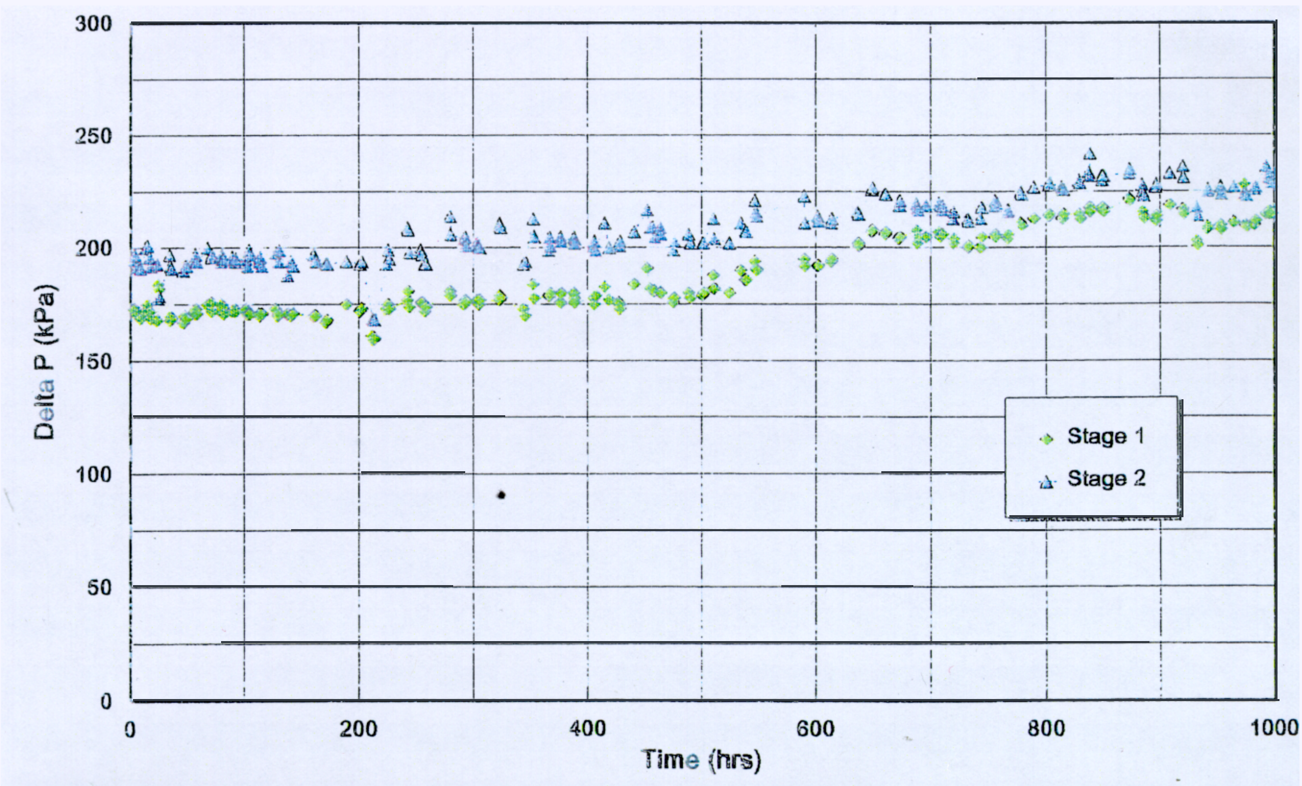

Figure 4.27.—Stage pressure drops.'

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Complete chemical analyses were performed at 5, 523, and 996 hours of operation on the four separate process streams (RO feed, interstage, permeate, and reject) for the following constituents:

- Cations (Ca^{+2}, Mg^{+2}, Na^{+}, K')
- Anions (HCO_3^-, Cl^-, SO_4^{-2}, NO_3^-, NO_2^-, F^-)
- Metals (Al", Ba^{+2}, Sr^{+2}, Fe (total), Mn^{+2}, P (total), B^{+3}, Cu^{+2}, Se, Hg^{+2})
- NH,' (ammonium)
- N (inorganic nitrogen)
- Silica (as SiO_2)
- Total organic carbon (TOC)
- Heterotrophic plate count (HPC)

Results of these analyses are shown in appendix G.

Table 4.3 summarizes percent salt rejections (%SR) for selected ions and for TDS that were calculated from the concentration data in appendix G. The values shown as ≥ result from the permeate concentration falling below the detection limit. The %SR for Cu^{+2} and Se could not be calculated because both the feed and permeate concentrations were below the detection limit. As shown, the average TDS rejection was 98.0 percent. The average rejection rate of boron (B^{+3}) was 38.8 percent, compared to 74.0 percent in the early test phase.

The HPCs (cfu/mL) measured during this test phase are summarized as follows:

	5-hour data	523-hour data	996-hour data
RO feed	>5,700	2,380	2,380
Interstage	3,021	1468	208
Permeate	78	197	14
Reject	>5,700	2,452	741

The first HPCs taken just 5 hours after system restart (following a 5-1/2 month shutdown) indicate very high plate counts from the feed and reject tanks. However, presumably because of the continuing disinfection protocol (refer to sections 4.5.2.1 and 4.5.2.2), bacterial counts dropped significantly with each succeeding sampling. As with the previous phase of testing, the RO elements were subjected to a monthly 30-minute flushing with a 1 percent solution of Minncare™ and storage in dilute (1 percent) sodium bisulfite during weekend shutdowns.

4.5.3.2 Performance summary-Figures 4.28 and 4.29 present the average NDP and NPF for this test phase. Neither of these curves show evidence of undue fouling or membrane degradation during the first 1,000 hours of operation. NPF appears to have dropped slightly, perhaps by about 5 percent. This may be considered excessive for 1.4 months (1,000 hours) of actual RO system operation, but probably not for a total in-service time of 5 months (July 22, 1994 - December 19, 1995). Generally, chemical cleaning of the elements is not necessary until NPF drops 10 to 15 percent (below an expected NPF curve for TFC membranes).

Table 4.3.—Percent salt rejection data for the Desal-3LP (Dairyland well) testing

SALT REJECTION (%)				
Constituent	5-Hour	523-Hour	996-Hour	Average
Calcium	≥99.0	≥98.8	≥98.3	-
Magnesium	≥94.1	≥94.1	≥90.9	-
Sodium	98.1	97.1	98.8	98.0
Potassium	≥85.7	≥87.5	≥83.3	-
Boron	40.0	36.4	40.0	38.8
Copper	-	-	≥69.2	-
Selenium	-	≥50.0	≥81.8	-
Bicarbonate	89.8	94.1	97.3	93.7
Chloride	98.1	97.3	98.4	97.9
Sulfate	99.3	≥99.7	99.7	-
Fluoride	≥87.5	≥80.0	≥85.7	-
Nitrate	≥92.3	≥94.4	80.0	-
Silica (total)	≥95.8	≥94.4	≥94.4	-
TDS	97.9	97.5	98.7	98.0

Note: All ≥ rejection values above were based on permeate concentrations that were at or below detection limit for the analytical method used.

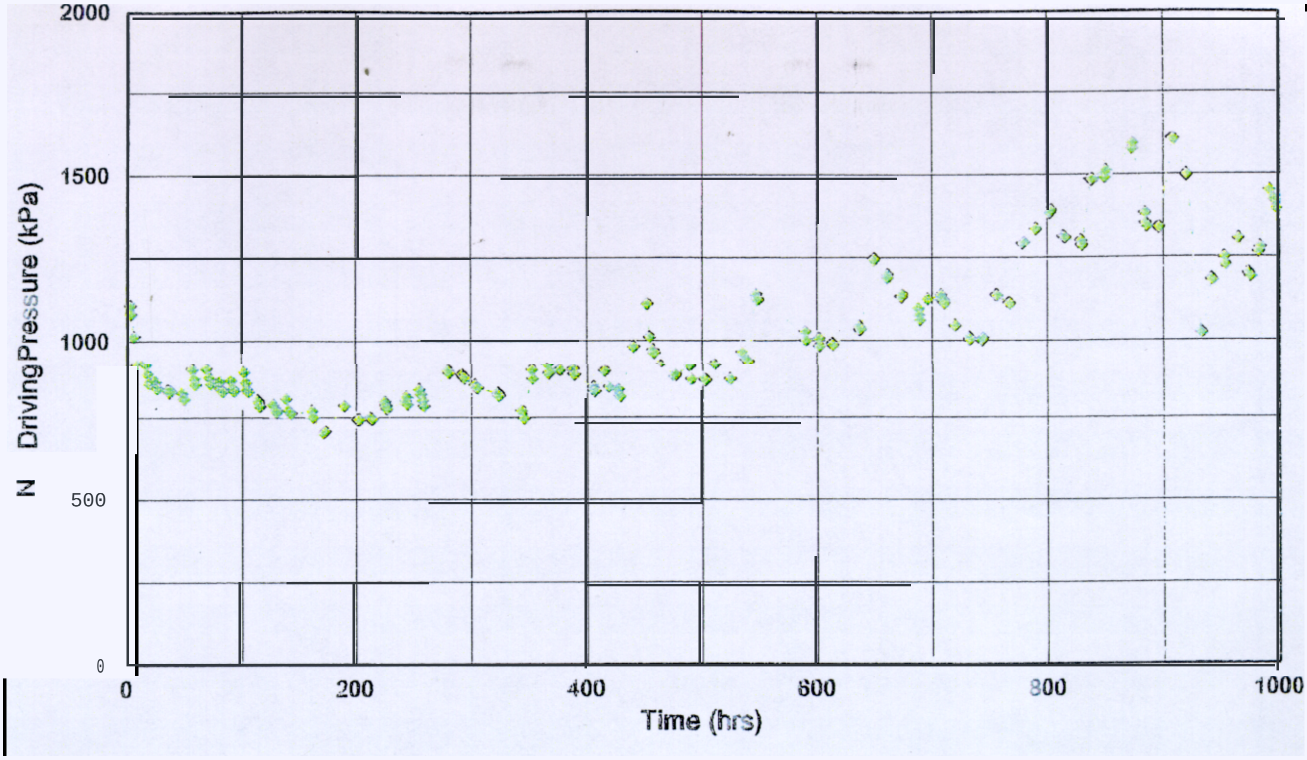

Figure 4.28.—Average net driving pressure

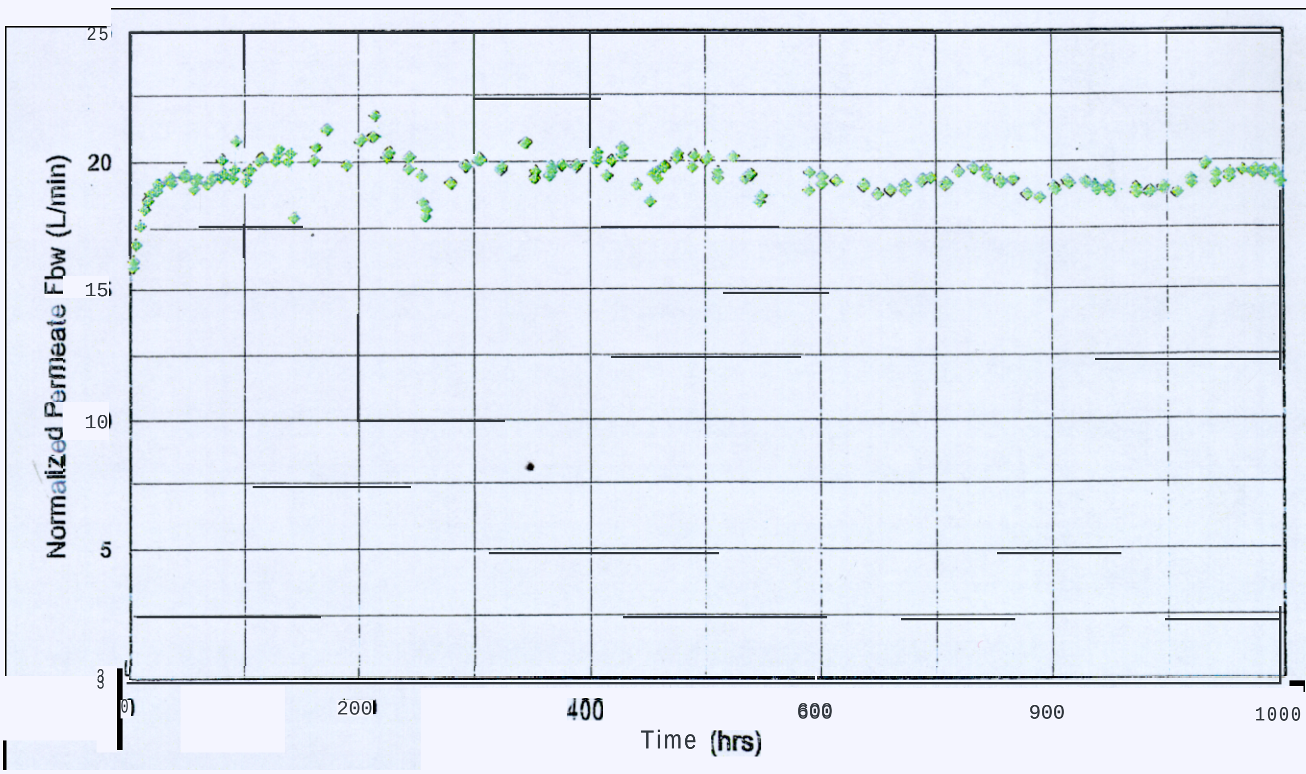

Figure 4.29.—Normalized permeate flow.

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4.6 Conclusions

Because the feedwater source was different for the two RO elements tested, it is not possible to do a side-by-side performance comparison.

4.6.1 FilmTec BW30 element testing using Moreno Highlands well water.-

- The average RO feed and permeate TDS were 988 and 14.2 mg/L, respectively. By blending the permeate with filtered well water at a ratio of about 1.04:1, a net overall recovery in excess of 87 percent could be achieved. The blended product would have a TDS of about 490 mg/L (secondary MCL is 500 mg/L) and would meet all other Federal and state drinking water standards (based on the constituents shown in appendix C).

- Overall salt rejection, calculated using the analytical data presented in appendix C, was 97.1 percent, (table 4.1). This compares to the average of 98.5 percent determined from the conductivity data in appendix B.

- Boron, a trace metal of concern in the saline marshes, was rejected at an average of 74.4 percent. The concentration of boron in the RO reject at 561 hours of operation was measured at 1.2 mg/L (appendix C).

- Because of high heterotrophic plate counts (>5,700 cfu/mL) measured in the RO feed and reject tanks on August 13, 1993, a regimen of weekly flushing with 1 percent Minncare™ was initiated. Followup samples taken on September 7, 1993, indicated significant reductions in the HPCs. However, when early signs of membrane degradation were later observed (section 4.5.2.2), the disinfection protocol was changed to include less frequent flushing with Minncare™, i.e., 30 minutes once a month, and weekend storage of the elements in 1 percent sodium bisulfite to inhibit microbial growth.

- SEMs of an autopsied first stage lead element (figure 4.21) show conclusively that surface penetrations of the membrane developed within and along the edge on the Vexar™ imprints (point of contact between the Vexar™ material and the membrane surface). Two explanations were considered for this localized degradation: first, that the damage was caused solely by the repeated pressure cycles of operating in a daily on-off mode; and second, that Minncare™ contributed to (accelerated) the damage, possibly by being adsorbed onto trapped particles at the points of Vexar™ contact.

- The use of a streaming current detector (SCD) proved to be ineffective for the automatic dosing of polymer. Calibration curves prepared with the Milton Roy Model SC5200 were not reproducable, and online readings drifted considerably. Cleaning of the SCD cell per the manufacturer's instructions did not remedy the situation.

4.6.2 Desal 3LP element testing using Dairyland well water.-

* The average feed and permeate TDS were 993 and 20.6 mg/L, respectively. By blending the permeate with filtered well water at a ratio of about 1.08: 1, a net overall recovery in excess of 87 percent could be achieved. The blended product would have a TDS of roughly 485 mg/L and would meet all other Federal and state drinking water standards (based on the constituents shown in table 3.1 and appendix G).

- Average salt rejection, calculated using the analytical data presented in appendix G, was 98.0 percent (table 4.3). This compares to an average of 97.8 percent determined from the conductivity data in appendix F.

- Boron was rejected at an average of 38.8 percent. Concentrations of boron in the RO reject were measured at 2.3, 2.0 and 2.5 mg/L during the three chemical analyses (appendix G).

- W disinfection combined with monthly 30-minute flushings with I percent Minncare™ and storage of the elements in dilute sodium bisulfite during weekend shutdowns appears to have effectively controlled biological fouling.

- There was no evidence of undue fouling or membrane degradation during the first 1,000 hours of operation.

5. SALINE VEGETATED WETLANDS

5.1 Objective

The objective of the saline vegetated wetlands (saline marshes) study was to determine the feasibility of using the reject (concentrate) stream of an RO desalting **process** for irrigating amenities such as wildlife habitat areas, green belts, and open space in arid areas. Specific areas of research included plant survival, water and soil analyses, plant and benthic invertebrate tissue analyses, and wildlife use. EMWD also hoped the wetlands would reduce the volume of the reject brine through plant uptake, transpiration, and evaporation. Final evaporation cells were designed to further reduce the volume of concentrated RO reject (brine) flowing from the saline wetlands (section 6).

5.2 Wetlands Design and Construction

The saline vegetated wetlands are composed of two 6.1-meter by 24.4-meter by 0.6-meter-deep (20-foot by 80-foot by 2-foot-deep) lined cells adjacent to and downstream of the RO pilot plant. (See figure 2.6.) The layouts are illustrated in figures 2.4 and 2.5. The complete construction design and specification document is available through EMWD, San Jacinto, California.

5.2.1 Design considerations.-The saline vegetated wetlands were designed as a pilot study to determine whether the reject stream (concentrate) produced by an RO desalting process, using local groundwater as a feed source, could sustain a variety of flora and fauna in the San Jacinto Valley. The saline vegetated wetlands were used to test the physical features of the system, the short term (three-year) flora and fauna survivability, and whether toxic materials from the reject stream would accumulate to a level that could be hazardous to wildlife using the wetlands. Adequate data must be collected and analyzed before plans to build a full-scale RO system incorporating saline wetlands for concentrating reject can be made.

The initial designs, as described in the Phase 1 Report (Bureau of Reclamation and Eastern Municipal Water District, 1991), included three 6.1-meter by 24.4-meter by 0.6-meter-deep (20-foot by 80-foot by 2-foot-deep) saline vegetated wetlands that were to be plumbed in parallel (as three replications) with a contingency bypass to the evaporation cells downstream (described in section 6). To keep costs down, the nurnber of wetland cells was reduced during final design from three to two.

Due to the nature of the RO reject stream constituents, the cells were lined with an impermeable membrane to prevent any of the stream from moving through the native soil and contaminating the groundwater below. The cells were designed to maintain an average 15-centimeter (6-inch) water depth over the surface of the soil substrate to create a free water surface wetland. The free water surface wetland, as opposed to a rock/gravel subsurface flow wetland, was employed for several reasons. The open water surface would: (1) be susceptible to greater evaporation, (2) provide better waterfowl habitat, and (3) provide more sediment and organic binding sites for certain metals. The 15-centimeter (6-inch) water depth was used to create optimal conditions for several desirable salt-tolerant, emergent wetland plant species.

5.2.2 Layout and construction.-Installation of the pilot RO system and construction of the saline vegetated wetland cells were completed during April 1993. Figure 5.1 illustrates the layout of the vegetated cells. The cells *were* lined with a high-density polyethylene (80 mil thickness) membrane, then soil was collected from nearby facility areas and deposited in each cell to a depth of about 0.6 meter (2 feet) (figure 5.2).

The reject line from the RO system was plumbed to run RO reject through a l-inch PVC pipe into the east ends of either or both of the two vegetated cells. The RO reject flowed from the pipes, which were set almost vertically in the center of each east cell wall. This design kept the line full and allowed the flow to spill out like a small fountain (figure 5.3). The outflow structures were located at the west end of each cell to force the RO reject to flow lengthwise through either or both of the saline vegetated cells. The ratio of the length to width of the cells was 4 to 1; the water depth above the substrate was 15 centimeters (6 inches). Initially, the two saline wetlands were operated in parallel (running the cells as duplicates). Outflows from each vegetated wetland went into evaporation cell number one (south cell) and then into evaporation cell number two (north cell) in series. Because the volume of reject from the RO unit did not meet the demands of the saline wetlands during peak evaporation periods (up to 1.5 cm [0.6 inches] pan evaporation per day), the underground piping and valve system was modified in September 1993, to allow the south vegetated wetland to receive all of the RO reject and the north vegetated wetland to receive RO product water as a control (figure 5.1). Plumbing modifications were also made to allow the overflow from the north vegetated wetland to flow directly into the nearby sump instead of into the evaporation cells. After modifications, a total of about 4.7 m^3 (1,250 gal) of RO reject was produced and stored each weekday to support the south saline vegetated wetland. (For more details on the construction and/or modification of the saline vegetated wetland cells, contact John Ward, engineer, EMWD, [909] 925-7676, ext. 4453.)

5.2.3 Plant species selected for evaluation.-Alkali bulrush (*Bolboschoenus robustus*), creeping spikerush (*Eleocharis palustris*), marsh smartweed (*Polygonum muhlenbergii*), Pennsylvania smartweed (*Polygonum pensylvanicum*), homed pondweed (*Zannichellia palustris*), seaside arrowgrass (*Triglochin maritimum*), and Nuttall's alkali grass (*Puccinellia nuttalliana*) were selected to be planted in the two saline wetlands (figure 5.4). The plants were chosen because they are all native to southern California (Reed, 1988), they tolerate high brine ion concentrations, tolerate 15 centimeters (6 inches) of water depth (with the exception of Nuttall's alkali grass which was to be planted around the perimeter of the cells), and are plants which wildlife use (Martin and Uhler, 1939). Unfortunately, the last three species listed above (homed pondweed, seaside arrowgrass, and Nuttall's alkali grass) were not available in the quantities that were necessary for the study, so they were not planted and are not included further in this discussion. Figure 5.4 illustrates the designed planting plan as well as the actual planting plan.

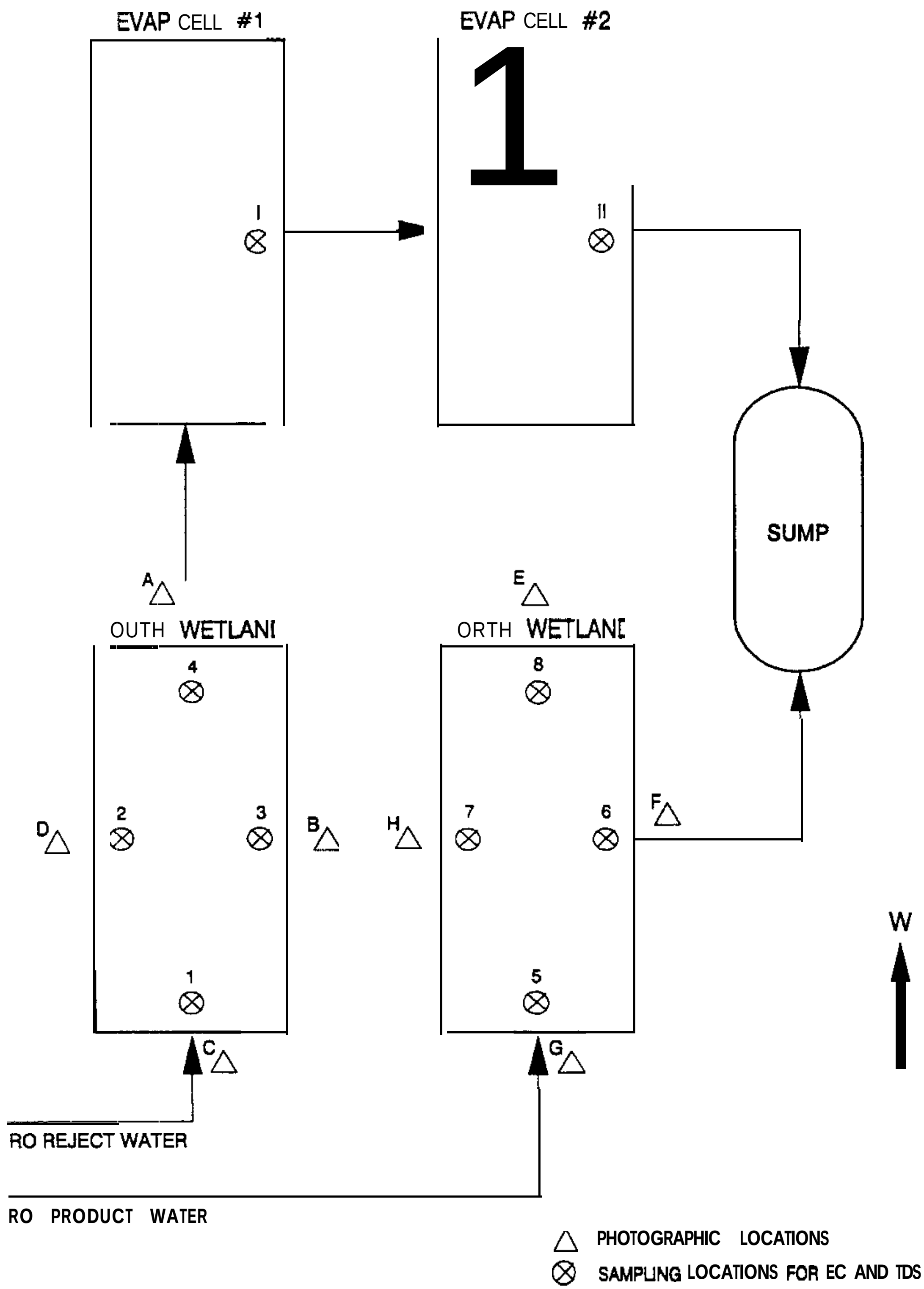

Figure 5.1 .-Flow schematic of saline vegetated wetlands and evaporation cells.

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Figure 5.2.—Soil being deposited on top of the high-density polyethylene liners in the wetland cells.

Figure 5.3.—View showing RO reject flowing into the vegetated wetland cells from pipes set in the center of each east cell wall.

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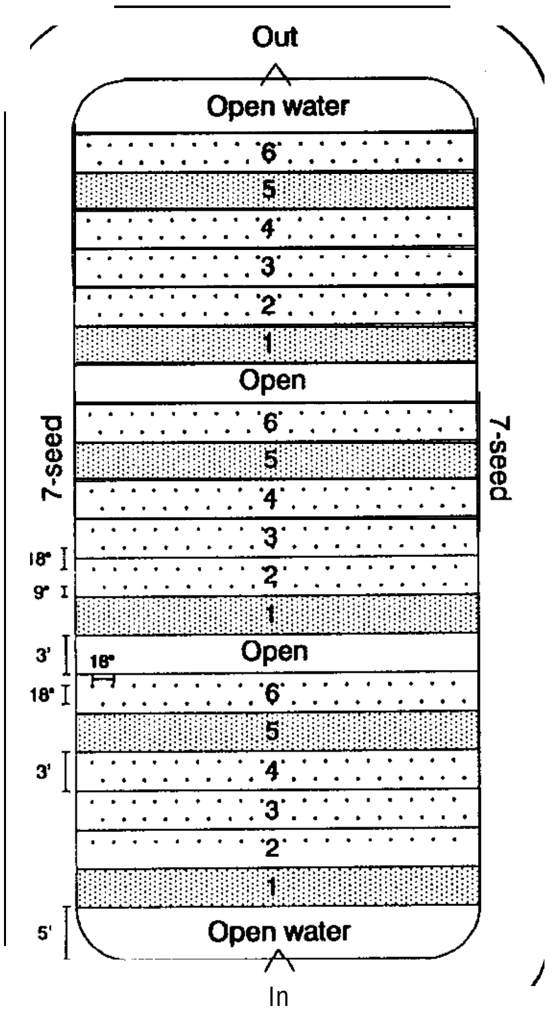
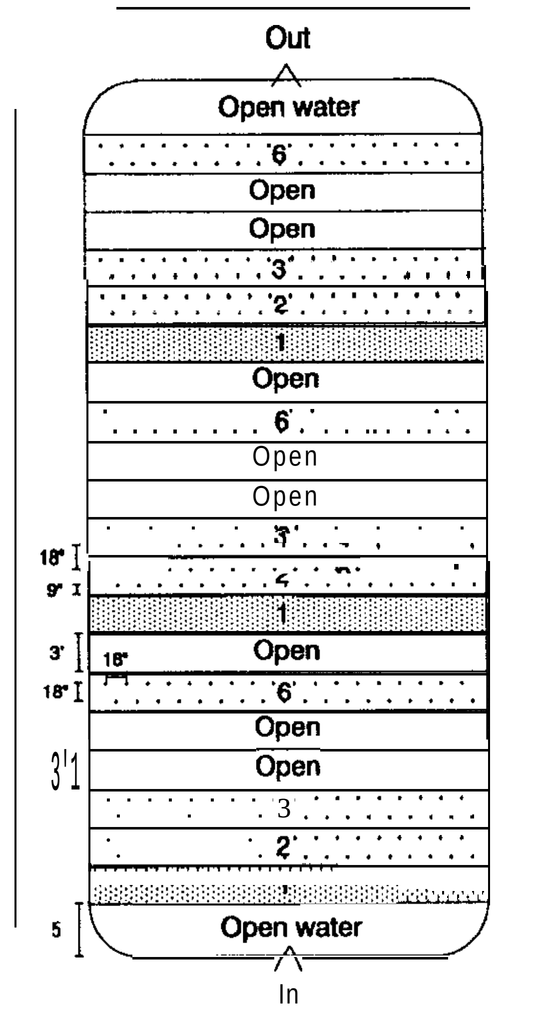


(a) Planned

1: Pennsylvania smartweed - seed
2: marsh smartweed - roots
3: creeping spikerush - plant clumps
4: homed pondweed - plants
5: seaside arrowgrass - seed
6: alkali bulrush - plant clumps
7: Nuttall's alkali grass - seed



(b) Actual

Figure 5.4.—Saline vegetated wetlands planting scheme (both cells).

5.3 Test Procedures

5.3.1 Planting of salt-tolerant species.-Alkali bulrush and creeping spikerush plants were harvested from moist-soil areas around the perimeter of a pond located on the San Jacinto Wildlife Refuge and near the San Jacinto River channel (also on the San Jacinto Wildlife Refuge), about 12.9 and 12.1 kilometers (8 and 7% miles), respectively, from the planting area. The alkali bulrush and the creeping spikerush were harvested as root/rhizome/plant clumps using shovels to dig into the soil IO- 15 centimeters (4-6 inches) and loading the clumps into the back of a pickup truck for transport. They were then planted on 45.7-centimeters (18-inch) centers in 0.9-meter- (3-foot-) wide horizontal bands (figure 5.5), and each species band was repeated three times per cell to expose the plants to different positions along the salinity gradient expected to develop as the RO reject moved from inlet to outlet within the cells (figure 5.4). The plants were watered immediately after they were planted. The marsh smartweed rhizomes and Pennsylvania smartweed seed were purchased from a nursery in Wisconsin that specializes in wetland plants. The rhizomes of the marsh smartweed were laid horizontally under the soil surface on 45.7-cm (IS-inch) centers and watered immediately. The Pennsylvania smartweed seed was broadcast in the preselected 0.9-meter- (3-foot-) wide horizontal bands after the soil was hand scarified with rakes. The seeds were then raked into the soil, pressed down, and watered in each of the two saline marsh cells. The planting was done on April 28, 1993, and for the first 6 weeks, the plants received potable water from a fire hydrant on EMWD's Hemet/San Jacinto RWR Facility. The water was delivered by an EMWD water truck (figure 5.6). The RO reject was first applied on June 7, 1993.

After the smartweed seedlings (grown from the germinated rhizomes and seeds) died back from fluctuating water management and bird predation, EMWD personnel harvested volunteer smartweed plants from around the perimeter of the EMWD/USBR Hemet/ San Jacinto RWRF wetland research cells, on August 25, 1993. The mature plants were transplanted into two 0.9-meter- (3-foot-) wide horizontal bands in each cell after the alkali bulrush was removed from those areas. Two weeks following the transplanting, all smartweed plants were pulled out. No further plantings were attempted.

5.3.2 Control of brine inflows/outflows.-About 19 m^3 (5,000 gal) of RO feedwater was trucked to the site each weekday from a nearby well (details given in earlier sections). Operating at 75 percent recovery, about 4.7 m^3 (1,250 gal) of RO reject was produced each weekday to support the saline vegetated wetlands throughout the **study period. EMWD** personnel controlled the inflow to the cells and determined that 4.7 m^3 of RO reject was not sufficient to provide enough water to both cells. It was then determined that the south vegetated wetland would receive the entire RO reject supply and the north vegetated wetland would receive water from a nearby fire hydrant, or the RO product water, beginning September 20, 1993. As explained above, the plumbing was altered, and EMWD personnel transferred the water supplies into both cells on a weekday basis until November 1995.

Figure 5.5.—Salt-tolerant wetland plants being planted on 45.7-cm (18-inch) centers in 3-foot-wide horizontal bands (refer to figure 5.4 for planting scheme).

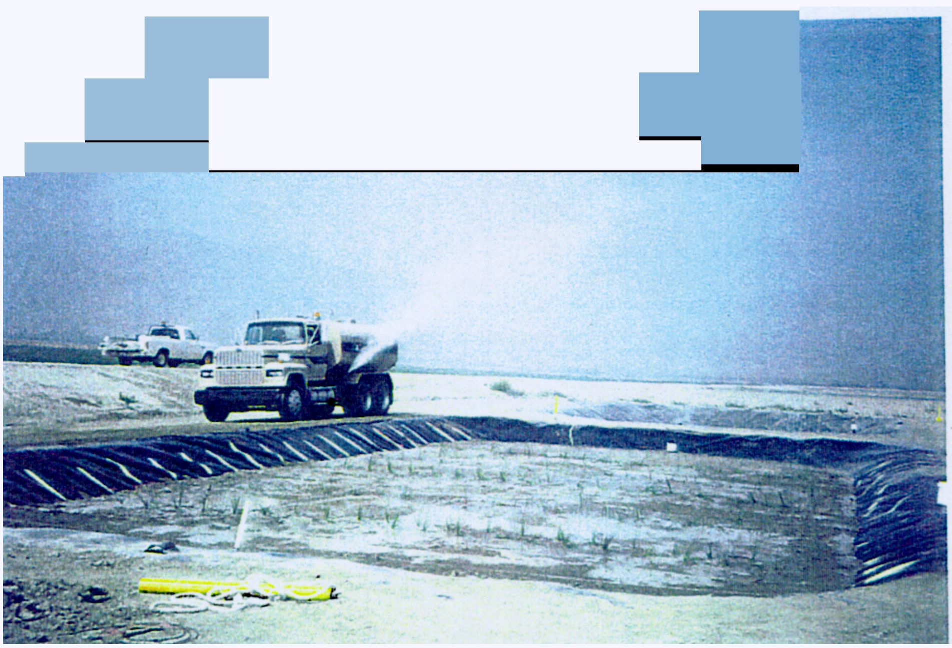


Figure 5.6.—Potable water being applied to the newly planted saline wetlands to promote plant establishment.

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Flow interruptions into the vegetated wetlands occurred occasionally due to problems preventing normal operations of the RO unit (e.g., electrical problems, compressor replacement, etc.), and a longer interruption occurred from February 9, 1994, until July 21, 1994, due to water supply problems. During the periods of flow interruption, both vegetated wetlands were kept wet either by EMWD personnel supplying fresh water via a water truck (water was obtained from a fire hydrant on the Hemet facility) or by rainfall.

5.3.3 Plant data collection and visual observations.-The "Proposed Saline Marsh Monitoring Program" document describes the plant data collection techniques and is included in appendix H.

Plant growth and survival were monitored weekly by EMWD personnel using general observations noted in a log book kept onsite and a photographic record. (Selected examples by Stella Denison and Joanna Crombie, EMWD, are shown in appendix I.) During the first winter, when the vegetation had turned completely brown, survival was determined by digging up several rhizomes and cutting them open. If root buds were present on the outside of the rhizomes and the insides were firm and fleshy, with no presence of rot, the plants were determined to be alive. As confirmation, several plants were transplanted into a glass aquarium and kept indoors in water transported from the saline wetlands. Production of new shoots was used as an indicator of plant survival.

Plant growth, establishment, and health were evaluated quarterly by National Biological Service (NBS) personnel. Quarterly monitoring was performed to determine plant survivability based on: (1) presence or absence of the planted species or natural recruits. (2) color or vitality of the vegetation (including height), (3) presence of new shoots and production of flower and seed, and (4) general observations. Photographs were taken during these visits as well.

5.3.4 Water/soil/plant/invertebrate sampling and analysis.-The "Proposed Saline Marsh Monitoring Program" document describes the water, soil, plant, and invertebrate data collection techniques and is included in appendix H.

Water samples collected from the RO reject line on August 13, 1993; July 22, 1994; September 27, 1994; December 19, 1994; and May 25, 1995, were analyzed to determine the chemical makeup of the inflow water entering the saline wetlands. The water sample collected on February 23, 1995, was analyzed for only three specific elements of concern to wildlife. The data are compiled in table 5.1.

In situ measurements were made within the saline vegetated wetlands for electrical conductivity (EC) and total dissolved solids (TDS). (The data are listed in appendix J.) Water samples for laboratory analyses were collected from the inflow and outflow areas of each of the wetlands on July 14, 1994; February 23, 1995; and March 29. 1995. Data are listed in tables 5.2a and b. Precipitation and evaporation data were collected from May 2 1, 1993, through October 6, 1995, and are listed in appendix K.

Table 5.1 .-Metal concentrations and ionic characterization of water samples collected from the RO reject line

Parameter	Symbol	Unit	08/13/93	07/22/94	09/27/94	12/19/94	02/23/95	05/25/95
Aluminum	Al	mg/L	<0.04	<0.1	co. 1	<0.1		<0.009
Antimony	Sb	mg/L	CO.04			co.01		0.0002
Arsenic	As	mg/L	0.006			co.01		0.011
Barium	Ba	mg/L	0.22	0.3	0.1	0.1		0.128
Beryllium	Be	mg/L	<0.002			<0.01		<0.0005
Boron	B	mg/L	1.17	2.3	2.0	2.5		1.84
Cadmium	Cd	mg/L	co.003			co.01		<0.0002
Chromium	Cr	mg/L	<0.004			<0.02		0.006
Cobalt	CO	mg/L	<0.01			co.01		
Copper	Cu	mg/L	0.01		0.0031	0.0024	0.0023	0.0044
Iron	Fe	mg/L	0.03	co.02	0.03	co.02		<0.2
Lead	Pb	mg/L	co.002			co.01		0.00013
Manganese	Mn	mg/L	0.05	0.06	0.04	0.02		0.0059
Mercury	Hg	mg/L	<0.0004		<0.0002	<0.0002	<0.0005	<0.0002
Molybdenum	Mo	mg/L	0.15					
Nickel	Ni	mg/L	co.03			co.02		co.007
Selenium	Se	mg/L	0.007		0.0048	0.0064	0.005	0.0032
Silver	Ag	mg/L	co.004			co.01		<0.0003
Strontium	Sr	mg/L		2.5	2.0	1.6		2.03
Thallium	Tl	mg/L	<0.002			co.2		<0.0001
Vanadium	V	mg/L	0.02					
Zinc	Zn	mg/L	0.05			0.03		0.0662
Hardness as CaC03		mg/L	352	1300	1030	662		950
Calcium	Ca	mg/L	111	408	308	198		285
Magnesium	Mg	mg/L	8.1	68	62	40		57
Sodium	Na	mg/L	1150	810	780	540		730
Potassium	K	mg/L	5.4	29	28	19		42
Ammonium nitrogen	NH4-N	mg/L		0.7	0.3	<0.1		co.2
Alkalinity as CaC03		mg/L		93	260	243		290
Hydrodde	OH	mg/L				<3		<3
Carbonate	co3	mg/L	0	<3	<3	<3		<3
Bicarbonate	HC03	mg/L	923	113	317	296		354
Sulfate	SO4	mg/L	736	1200	1100	770		1100
Chloride	Cl	mg/L	959	1100	1000	580		860
Nitrate nitrogen	NO3-N	mg/L	6.9	1.1	1.4	2.5		3.2
Fluoride	F	mg/L	2.9	2.3	1.9	2.1		2.5
Total phosphorus	P	mg/L		1.3	0.9	0.8		1.5
Nitrite nitrogen	NO2-N	mg/L	0.02	<0.1	<0.1	0		<0.1
Inorganic nitrogen	N	mg/L	7.5	1.8	1.7			3.2
Total silica	SiO2	mg/L	85.8	95	70	65		79
Dissolved silica		mg/L	03.2	64	70	56		77
Total organic carbon	TOC	mg/L	3.9	2.9	2.3	1.8		1.6
Heterotrophic plate count	HPC	cfu/mL	>5700	>5700	2450	741		453
Specific Conductance	C	µS/cm	7200	5600	4600	4100		4500
Total dissolved solids	TDS	mg/L	3620	3770	3780	2270		3300
Turbidity		ntu		0.5	0.2	0.1		0.5
P H			7.7	7.8	7.9	8.0		7.6
Temperature (lab)	T	deg C				13		20

Table 5.2a.--Metal concentrations and ionic characterization of water samples collected from the south (saline) vegetated wetland

Parameter	Symbol	hit	Inlet 07/14/94	Inlet 02/23/95	Inlet 03/29/95	Outlet 07/14/94	Outlet 02/23/95	Outlet 03/29/95
Aluminum	Al	mg/L	0.7		1.46	26		0.082
Antimony	Sb	mg/L	<0.01		<0.0008	co.01		<0.0008
Arsenic	As	mg/L	<0.01		0.012	<0.01		co.002
Barium	Ba	mg/L	co.1		0.117	0.3		0.0202
Beryllium	Be	mg/L	co.01		0.0032	<0.01		<0.0008
Boron	a	mg/L	0.3		1.8	0.3		1.57
Cadmium	Cd	mg/L	<0.001		0.0006	<0.01		<0.0002
Chromium	Cr	mg/L	<0.02		0.008	co.02		<0.003
Cobalt	CO	mg/L	<0.01		0.0018	<0.01		0.0006
Copper	Cu	mg/L	0.0043	0.0055	0.028	0.026	0.0022	0.01
Iron	Fe	mg/L	0.74		17	27		1.1
Lead	Pb	mg/L	co.01		0.0062	0.01		0.0004
Manganese	Mn	mg/L	0.09		0.39	0.51		0.14
Mercury	Hg	mg/L	~0.0002	~0.0005	0.0004	0.0002	<0.0005	0.0003
Molybdenum	Mo	mg/L						
Nickel	Ni	mg/L	<0.02		0.006	co.02		co.002
Selenium	Se	mg/L	<0.001	0.0022	0.0024	0.001	~0.0005	0.0006
Silver	Ag	mg/L	<0.01		0.0011	co.01		<0.0002
Strontium	Sr	mg/L						
Thallium	Tl	mg/L	co.2		0.0002	co.2		a0001
Vanadium	V	mg/L						
Zinc	Zn	mg/L	0.12		0.0993	0.29		0.0519
Hardness as CaC03		mg/L			882			659
Calcium	Ca	mg/L			266			192
Magnesium	Mg	mg/L			52			43
Sodium	Na	mg/L			670			650
% Sodium		%			62			68
Potassium	K	mg/L			15			10
Ammonium nitrogen	NH4-N	mg/L			0.6			0.4
Alkalinity as CaC03		mg/L			293			253
Hydroxide	OH	mg/L			<3			<3
carbonate	co3	mg/L			<3			30
Bicarbonate	HC03	mg/L			357			244
Sulfate	so4	mg/L			930			610
Chloride	Cl	mg/L			740			660
Nitrate nitrogen	NO3-N	mg/L			<0.1			0.2
fluoride	F	mg/L			2.1			1.9
Ortho Phosphate	P-P	mg/L			0.6			0.25
Total phosphorus	P	mg/L			2.2			0.65
Nitrite nitrogen	NO2-N	mg/L			<0.1			<0.1
Inorganic nitrogen	N	mg/L						
Total silica	Si02	mg/L						
Dissolved silica		mg/L						
Total organic carbon	TOC	mg/L						
Heterotrophic plate count	HPC	cfu/mL						
Electrical conductivity	EC	µS/cm			4200			4100
Total dissolved solids	TDS	mg/L			3000			2600
Turbidity		ntu						
Total suspended solids	TSS	mg/L			965			70
pH					7.9			8.9

Table 5.2b.—Metal concentrations and ionic characterization of water samples collected from the north (control) vegetated wetland

Parameter	Symbol	Unit	Inlet 07/14/94	Inlet 02/23/95	Inlet 03/29/95	Outlet 07/14/94	Outlet 12/14/94	Outlet 02/23/95	Outlet 03/29/95
Aluminum	Al	mg/L	1.4		0.468	14			0.33
Antimony	Sb	mg/L	<0.01		<0.0008	<0.01			<0.0008
Arsenic	As	mg/L	<0.01		<0.0004	co.01			<0.0002
Barium	Ba	mg/L	<0.1		0.0545	0.2			0.0745
Beryllium	Be	mg/L	<0.01		<0.0008	co.01			<0.0008
Boron	B	mg/L	0.1		0.519	0.3			0.488
Cadmium	Cd	mg/L	<0.01		~0.0002	co.01			<0.0002
Chromium	Cr	mg/L	<0.02		co.003	<0.02			'0.003
Cobalt	CO	mg/L	<0.01		0.0006	so.01			0.0004
Copper	Cu	mg/L	0.0031	0.0053	0.007	0.034	0.018	0.0039	0.0042
Iron	Fe	mg/L	1.9		0.0082	13			3.5
Lead	Pb	mg/L	<0.01		0.0023	"0.01			0.0007
Manganese	Mn	mg/L	0.78		0.00031	0.29			0.27
Mercury	Hg	mg/L	0.0002	<0.0005	0.0002	co.0002	<0.0002	0.0006	0.0004
Molybdenum	Mo	mg/L							
Nickel	Ni	mg/L	<0.02		0.0005	<0.02			<0.0008
Selenium	Se	mg/L	0.001	<0.0005	<0.0005	<0.001	0.0005	<0.0005	<0.0005
Silver	Ag	mg/L	<0.01		<0.0002	co.01			~0.0002
Strontium	Sr	mg/L							
Thallium	Tl	mg/L	<0.2		<0.0001	co.2			<0.0001
Vanadium	V	mg/L							
Zinc	Z"	mg/L	0.14		0.0824	0.13			0.119
Hardness as CaCO3		mg/L			44				138
Calcium	Ca	mg/L			11				45
Magnesium	Mg	mg/L			4				6
Sodium	Na	mg/L			8				46
% Sodium		%			27		59		41
Potassium	K	mg/L			3				4
Ammonium nitrogen	NH4-N	mg/L			<0.1		0.2		0.1
Alkalinity as CaCO3		mg/L			40				170
Hydroxide	OH	mg/L			<3				<3
Carbonate	co3	mg/L			<3				<3
Bicarbonate	HC03	mg/L			49				207
Sulfate	SO4	mg/L			15				32
Chloride	Cl	mg/L			<1				18
Nitrate nitrogen	NO3-N	mg/L			go.1				<0.1
Fluoride	F	mg/L			0.2				0.4
Ortho Phosphate	P-P	mg/L			co.05				01
Total phosphorus	P	mg/L			0.55		0.3		0.8
Nitrite nitrogen	NO2-N	mg/L			<0.1				<0.1
Electrical conductivity	EC	µS/cm			130				430
Total dissolved solids	TDS	mg/L			.				295
Total suspended solids	TSS	mg/L			200		20		195
pH					7.8				7.7

Three baseline soil samples were collected from each vegetated wetland cell just prior to flooding after planting on April 28, 1993. A sample was collected from each cell at the inflow area and near the outflow. The samples were placed in ziplock bags and stored at approximately 4°C (39°F) until they were analyzed for trace metals, soil particle sizes, organochloride pesticides, and polychlorinated biphenyls (PCB) by Babcock and Sons, Inc The baseline trace metal data are reported in tables 5.3a and b. Soil particle sizes and organochloride pesticides and PCB data are listed in the Bureau of Reclamation/National Biological Survey/Eastern Municipal Water District Phase II/III Report (1994).

Additional soil samples were collected by EMWD personnel using similar techniques on July 14, 1994, and March 29, 1995, and analyzed by Babcock and Son, Inc. These data are also listed in tables 5.3a and b.

One alkali bulrush sample (multiple plants throughout the cell) was collected from each cell on July 14, 1994, and May 25, 1995, and from the south cell on December 15, 1994. One creeping spikerush sample (multiple plants) was collected on July 14, 1994, from each cell, from the south cell on December 15, 1994, and from the north cell on May 25, 1995. The trace metal values contained in their tissues are listed in tables 5.4a and b.

Invertebrate samples were collected on July 14, 1994, and May 25, 1995, and analyzed by S. Mark Nelson, Bureau of Reclamation; results are listed in tables 5.5 and 5.6, respectively. The invertebrate biomass collected was insufficient for chemical analysis of the tissue.

5.3.5 Data reduction and interpretive methods.-All available data were put on a Quattro Pro for Windows (version 5.0) spreadsheet for comparisons. Sparsity of data precluded statistical analysis, so all discussion below is based on inter-comparison of the available data. The reader is cautioned, therefore, that all data discussed below should be considered as preliminary and by no means definitive.

5.4 Results and Discussion

5.4.1 Brine **use** and **physical data.—**The pilot plant performed as anticipated, with minimal interruption caused by equipment or operational difficulties. However, it was discovered through the first summer of operation that the addition of 4.7 m^3 (1,250 gal) of RO reject each weekday was not enough to keep both saline vegetated wetland cells wet. so beginning on September 20, 1993, 9.5 m^3 (2,500 gallons) of fresh water was added weekly to the north wetland,, The south wetland continued to receive the RO reject. Additionally. between February 9, 1994, and July 21, 1994, RO reject was unavailable for even the south wetland because the well pump used to supply RO feedwater developed electrical problems,

Table 5.3a.—Metal concentrations in the south (saline) vegetated wetland substrate and substrate characterization

			Inlet			Outlet		
Parameter	**Symbol**	**Unit**	**04/28/93**	**07/14/94**	**03/29/95**	**04/28/93**	**07/14/94**	**03/29/95**
Aluminum	Al	mg/kg	19200		9140	21400		7500
Antimony	Sb	mg/kg	CO.3		<0.5	co.3		<0.3
Arsenic	As	mg/kg	co.7		<8	<0.6		<5
Barium	Ba	mg/kg	273		262	279		201
Beryllium	Be	mg/kg	co.4		CI.0	0.7		<0.7
Boron	B	mg/kg	6.4		9.3	7.3		7.8
Cadmium	Cd	mg/kg	0.09		0.24	0.16		0.26
Total Chromium	Cr	mg/kg	15.2		14.1	14.6		10.3
Cobalt	CO	mg/kg	7.43		6.3	7.76		5.45
Copper	Cu	mg/kg	16.3	21	25.2	13.1	24	22.5
Iron	Fe	mg/kg	23000		22200	26000		14000
Lead	Pb	mg/kg	<5		9.92	<5		6.64
Manganese	Mn	mg/kg	400		244	430		311
Mercury	Hg	mg/kg	co.4	0.13	0.09	co.4	0.094	0.08'1
Molybdenum	Mo	mg/kg	1.2			1.5		
Nickel	Ni	mg/kg	7.4		7.3	a.9		6.4
Selenium	Se	mg/kg	<2	0.4	0.68	<2	0.5	0.4
Silver	Ag	mg/kg	0.85		1	co.02		0.7
Thallium	Tl	mg/kg	<0.5		0.31	<0.5		0.34
Zinc	Zn	mg/kg	92.9		195	76.8		93.1
Percent solids		%	100		38.2	100		61.3
Chlordane			12			ND		
pH		-			7.7			6.3
Electrical Conductivity	EC	µmho/cm			a400			6400
Sodium adsorption ratio					16			28
Cation exchange capacity					6.25			a.75
organic matter content					1.8			1
Percent sand		%			74			65
Percent silt		%			22			30
Percent clay		%			4			5

Table 5.3b.--Metal concentrations in the north (control) vegetated wetland substrate and substrate characterization

Parameter	Symbol	Unit	Inlet			Outlet		
			04/28/93	07/14/94	03/29/95	04/28/93	07/14/94	03/29/95
Aluminum	Al	mg/kg	20300		7630	20279		6150
Antimony	Sb	mg/kg	co.3		co.3	<0.3		co.3
Arsenic	As	mg/kg	co.4		<5	co.4		<4
Barium	Ba	mg/kg	274		266	251		182
Beryllium	Be	mg/kg	co.4		<0.6	1.6		<0.6
Boron	B	mg/kg	5.7		4.5	6.1		5.2
Cadmium	Cd	mg/kg	0.16		0.3	0.16		0.22
Total Chromium	Cr	mg/kg	15.4		12.9	14.2		9.5
Cobalt	CO	mg/kg	7.14		6.22	7.91		4.2
copper	Cu	mg/kg	23	21	24	19.4	20	20
Iron	Fe	mg/kg	23000		20700	27603		16900
Lead	Pb	mg/kg	<5		9.75	<5		6.66
Manganese	Mn	mg/kg	390		320	621		249
Mercury	Hg	mg/kg	<0.4	0.093	0.12	co.4	0.085	0.13
Molybdenum	MO	mg/kg	1.1			1		
Nickel	Ni	mg/kg	8.1		8	7.7		5.2
Selenium	Se	mg/kg	<2	0.4	0.2	<2	0.4	0.34
Silver	Ag	mg/kg	1.09		1.1	0.56		0.7
Thallium	Tl	mg/kg	co.5		0.3	<0.5		0.23
Zinc	Zn	mg/kg	109		119	96.3		89.2
Percent solids		%	100		65	78.9		69.7
Chlordane			19			ND		
pH		-			7.9			7.7
Electrical Conductivity	EC	µmho/cm			1300			2000
Sodium adsorption ratio					17			11
Cation exchange capacity					13			14
Organic matter content					1.1			1.4
Percent sand		%			62			65
Percent silt		%			31			31
Percent clay		%			7			4

Table 5.4.—Trace metal concentrations found in plant tissue samples collected from the vegetated wetlands

(a) South Saline Wetland

Parameter	Symbol	Unit	Alkali Bulrush 07/14/94	Alkali Bulrush 12/15/94	Alkali Bulrush 05/25/95	Creeping Spikerush 07/14/94	Creeping Spikerush 12/15/94	Creeping Spikerush 05/25/95
Aluminum	Al	mg/kg	1280	800	171	1320	1000	
Antimony	Sb	mg/kg	<8	<10	co.3	<8	<10	
Arsenic	As	mg/kg	<8	<10	<7	<8	<10	
Barium	Ba	mg/kg	48.7	20	9.02	75	30	
Beryllium	Be	mg/kg	<0.1	<5	<0.26	co.1	<5	
Boron	B	mg/kg	31	28	23.4	34	130	
Cadmium	Cd	mg/kg	<0.4	<5	co.07	co.4	<5	
Chromium	Cr	mg/kg	5	<10	<1.3	6	<10	
Cobalt	CO	mg/kg	<2	<10	co.07	<2	<10	
Copper	Cu	mg/kg	17	9.2	6.41	26	24	
Iron	Fe	mg/kg	1530	800	230	1390	1600	
Lead	Pb	mg/kg	<8	<10	<2.0	<8	<10	
Manganese	Mn	mg/kg	178	<100		289	300	
Mercury	Hg	mg/kg	0.024	0.029	0.2	0.027	0.035	
Nickel	Ni	mg/kg	2	<10	0.29	4	<10	
Selenium	Se	mg/kg	co.2	0.1	co.12	co.2	0.58	
Silver	Ag	mg/kg	<2	<10	<0.16	<2	<10	
Thallium	Tl	mg/kg	<10	<50	<0.1	<10	<50	
Zinc	Zn	mg/kg	39.1	30	30	167	120	
Percent solids (Babcock)		%			30.6			
Percent solids (U of M)		%			33.4			

(b) North Control Wetland

Parameter	Symbol	Unit	Alkali Bulrush 07/14/94	Alkali Bulrush 12/15/94	Alkali Bulrush 05/25/95	Creeping Spikerush 07/14/94	Creeping Spikerush 12/15/94	Creeping Spikerush 05/25/95
Aluminum	Al	mg/kg	1770		247	3290		410
Antimony	Sb	mg/kg	<8		co.3	<8		co.2
Arsenic	As	mg/kg	<8		<6	<8		<2
Barium	Ba	mg/kg	46.5		19	154		21
Beryllium	Be	mg/kg	co.1		<0.22	co.1		<0.16
Boron	B	mg/kg	15		24.6	16		220
Cadmium	cd	mg/kg	0.4		<0.06	co.4		co.04
Chromium	Cr	mg/kg	10		<1.1	16		0.8
Cobalt	CO	mg/kg	<2		0.08	3		0.16
copper	Cu	mg/kg	17		5.87	26		8.69
Iron	Fe	mg/kg	2370		273	5790		576
Lead	Pb	mg/kg	<8		a.7	<8		Cl.2
Manganese	Mn	mg/kg	290		53.3	1320		120
Mercury	Hg	mg/kg	0.025		co.006	0.059		0.011
Nickel	Ni	mg/kg	5		0.6	9.3		0.6
Selenium	Se	mg/kg	<0.2		0.3	0.6		co.13
Silver	Ag	mg/kg	<2		co.14	<2		<0.1
Thallium	Tl	mg/kg	<10		CO.08	<10		<0.06
Zinc	Zn	mg/kg	48.9		28.7	192		55.4
Percent solids (Babcock)		%			36.2			51.4
Percent solids (U of M)		%			33.5			45.1

Table 5.5.–Invertebrate taxa (number of individuals) collected from the vegetated wetlands on July 14, 1994[a]

Taxa	North Wetland		South Wetland	
	Sample 1	Sample 2	Sample 1[b]	Sample 2[c]
NEMATODA	1			
OLIGOCHAETA	10	3		
GASTROPODA Physidae	25	9	22	20
Cladocera		43	4	3
Ostracoda	84	26	25	21
Copepoda		1		1
Amphipoda Hyalella	39	26	45	14
Callibaetis		1	5	5
Zygoptera	4	6	5	10
Anisoptera		1	1	4
Corixidae	5	1	2	
Notonectidae	9	5	8	14
Naucoridae		1? (immature)		
Dytiscidae			1	
Helophorus	1 (adult)			
Hydrophilus		1 (adult)		
Tropisternus		1 (larva)		1 (larva)
Culex			2	2
Chironomidae	1	8	5	18
Sciomyzidae			1	
Hydracarina	1			
Total taxa	11	15	13	12
Total number	180	133	126	113

[a] Average electrical conductivity (EC) from February 15, 1994 through July 15, 1994 in the north and south vegetated wetlands was 1912 $\mu S/cm$ and 2650 $\mu S/cm$, respectively.

[b] 3 tadpoles in sample. [c] 1 tadpole in sample

Table 5.6.—Invertebrate taxa (number of individuals) collected from the vegetated wetlands on May 25, 1995[a]

Taxa	North Wetland	South Wetland
	Sample 1[b]	Sample 1
Turbellaria	3	
OLIGOCHAETA	1	
GASTROPODA Physidae	4	18
Cladocera		1
Ostracoda		19
Amphipoda *Hyalella*	52	110
Zygoptera	1	2
Anisoptera	2	
Corixidae	19	26
Notonectidae	27	
Gerridae		1 (immature)
Hydrophilidae		1
Culiseta		1
Culex	4	22
Chironomidae	10	75
Dixidae	2	
Collembola		1
Total taxa	11	12
Total number	125	227

[a] Average electrical conductivity (EC) during May 1995 in the north and south vegetated wetlands was 352 µS/cm and 6518 µS/cm, respectively.

[b] Two tadpoles and two *Gambusia* in sample.

Subsequently, the well and surrounding property were sold, so EMWD had to find a new supply well. Once that was achieved, the RO reject supply was mostly consistent with the exception of 6-½ weeks between December 22, 1994, and February 7, 1995 (due to heavy rainfall causing flooding problems); 15 working days between March 20, 1995, and April 10, 1995 (the compressor failed); and another 15 working days between May 3 1, 1995, and June 22, 1995. To keep the plants wet and the water depth constant, fresh water (rainfall or potable water) was supplied to both vegetated wetland cells whenever the RO unit was shut Off.

Electrical conductivity (EC) and total dissolved solids (TDS) were measured in situ in the vegetated wetlands. Data are listed in appendix J. The EC ranged from 65 to 4,500 µS/cm in the north vegetated wetland (after it was converted to the control cell, receiving only fresh water), and 750 µS/cm (recorded during heavy rains, with flooding, so the RO system was shut off) to 13,680 µS/cm in the south wetland, with a mean over the 2 years of approximately 1,142 µS/cm and 4,924 µS/cm, respectively. The EC and TDS decreased when fresh water was added (by rainfall or water truck) to one or both vegetated wetland cells.

5.4.2 Plant adaptation and survival.-Appendix I contains a representative selection of photographs of the vegetation in the saline wetlands, showing the progression of growth and plant establishment. By July, 1993 (3 months after planting), the alkali bulrush had spread to every available area in both cells, except for the six bands where spikerush was planted and at the inflow ends. Most of the original alkali bulrush plants planted in the six bands had flowered and turned brown, but the new plants were green, robust, flowering abundantly, and taller than the original plants (90 cm compared to 60 cm tall [≈ 3 feet to 2 feet]). The spikerush were healthy and spreading out from the planted bands and were about 60 cm (2 feet) tall in the north wetland and slightly shorter and browner in the south wetland. Flower and seed production were less in the south cell than in the north. Both smartweed species had been completely eliminated due to a combination of a lack of water (drying out some seedlings), too much water (drowning some seedlings), and bird predation. A few cattail (*Typha spp.*) recruits were growing in both wetland cells (60 to 90 cm [2-3 feet] tall in the south wetland and about 23 cm [3/4 foot] taller in the north wetland), and a few watergrass plants (*Echinochloa crusgalli*) had also established themselves. Although the cattails and watergrass appeared to be healthy, neither species spread a great deal the first year, and cattail flower production was minimal.

By November 2, 1993, it was evident that the alkali bulrush, spikerush, cattail, and watergrass had survived in both wetland cells. In the north cell, which had received only fresh water since September, the newer plants around the edges (particularly spikerush) were green, while the plants around the edges of the south cell were more chlorotic. Plants throughout the interior of both cells were mostly brown due to the colder winter temperatures. The alkali bulrush remained at about the same height since August, while the few cattails increased to about 152 cm (5 feet) tall. In many of the areas where spikerush had spread during the summer, alkali bulrush was encroaching and became an overstory for the spikerush. A quillwort (*Isòetes spp.*) mat had formed in the inflow end of the north wetland cell and appeared to be very healthy. Alkali bulrush seed was floating over the water surface in both cells.

Throughout the first growing season, some plants of each species exhibited stress, probably due to some constituents of the water (i.e., some browning, slower growth, and less seed production). But: to the casual observer, the plants appeared to be thriving. During the winter, the plants turned brown because of normal winter dormancy.

Spring 1994 growth was very lush and vigorous, and all plants appeared healthy, according to EMWD personnel. The RO reject flow into the south cell was interrupted from February 4, 1994, through July 21, 1994. Therefore, the lush growth was probably due to the fresh water supplied to both cells throughout the spring and part of summer (figure 5.7). During this period of vigorous growth, it appeared that the saline wetland plants regenerated completely by producing new growth from their rootstock. There was no evidence of wetland plant seed germination, even though alkali bulrush seed was floating over the water surface in both cells during the fall. Two species of cattail in the south cell were identified by EMWD's biologist. They were narrow-leaf cattail and broad-leaf cattail (*Typha angustifolia* and *T. latifolia*, respectively). Duckweed (*Lemna spp.*) was abundant in the north cell by April, 1994, and by August, it was evident in the south cell as well.

By September 8, 1994, the south cell had been receiving RO reject for 7 weeks. Alkali bulrush covered the entire cell and was 90-122 cm (3-4 feet) tall. Much of it was lodging (falling over). The stems were green, but the tops were brown, and heavy seeding was evident (figure 5.8). Cattail covered about 15 percent of the area, was about 2.4 meters (8 feet) tall, and was flowering. Spikemsh covered about 5 percent of the area, as the alkali bulrush outcompeted it. The spikerush was browner than in the north cell, about 30-60 cm (l-2 feet) tall, and no flowering was evident.

In contrast, the north cell, during September 1994, contained 95 percent alkali bulrush (90-137 cm [3-4-½ feet] tall), 35 percent cattail (2.7 meters [9 feet] tall), 20 percent spikerush (30-60 cm [1-2 feet] tall), and duckweed and algae floating on the open surfaces (figure 5.8). The alkali bulrush exhibited some lodging, but had green stems, brown tops, and abundant seeding. The spikerush was seeding and looked healthy and green. The vitality and health of all the plants in the cell were obviously due to the fresher (lower salinity) water.

On July 10, 1995, the south cell was still dominated by alkali bulrush (90-122 cm [3-4 feet] tall). They had brownish tips with abundant seed heads. The second most abundant species was cattail, covering about 22 percent of the area at either end of the cell (figure 5.9). The west end (higher EC) contained shorter plants with bigger catkins. The east end contained taller plants with smaller and thinner catkins. Virtually all spikerush had been displaced.

By July 1995, the north cell had become a mixed community of alkali bulrush and cattail (figure 5.9). Both species *were* flowering at that time, but alkali bulrush was predominantly brown, and the cattail was green and healthy. Spikerush could be seen only in the southeast comer (the inflow end) of the cell, and a few California bulrush (*Schoenoplectus californicus*) plants had appeared nearby. Duckweed was also present around the inflow area.

The plants responded as the constituents of the water changed in the saline vegetated wetland cells. Each time fresh water was added to one or both of the cells, the plants responded by having a growth spurt and becoming greener. At the end of the 1995 growing season, after a

Figure 5.7.—View of both vegetated wetlands during May 1994 showing very lush, vigorous, and healthy plant growth (south cell had not received RO reject since February 9, 1994).

Figure 5.8.—View of both vegetated wetlands on September 8, 1994 (the south ceil [in foreground] had been receiving reject brine for 7 weeks while the north cell continued to receive only fresh water). The photograph illustrates the additional lodging (falling over), browning, and seeding in the south wetland compared to the north.

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Figure 5.9.—View of both vegetated wetlands during July 1995 (the south cell [in foreground] had received RO reject for almost 11 months).

Figure 5.10.—Example of a waterfowl path through the spikerush in the south saline vegetated wetland.

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year of maintaining fairly consistent water sources for both plant communities, the plant community in the north (control) wetland differed from the plant community in the south (saline) wetland. Alkali bulrush was dominant in the RO reject fed (south) wetland cell and cattails were displacing most of the other smaller species in the fresher (north) wetland cell. Long term evaluation using the appropriate water is necessary to accurately assess the final outcome of this pilot study. Of course, accumulations of heavy metals or other constituents to toxic levels could change the described differences in plant communities.

5.4.3 Wildlife visitation and use.-Wildlife usage of the saline vegetated wetlands was documented on numerous occasions throughout the period of this study by EMWD personnel. Actual sightings, prints, scat, carcasses, nests, or sounds have provided evidence of usage. Raccoon and rabbit prints were observed in 1993, as well as evidence that waterfowl usage occurred (e.g., paths and tunnels through the spikerush, figure 5.10). Aquatic snails were also observed in the wetlands. In 1993, April Sleigh and Andrew Haimov, from California State Polytechnic University (CSPU) at Pomona, working under an NBS contract to count birds on the Hemet/San Jacinto RWR Facility, reported seven sightings of black phoebe (almost always on a wooden post in the vegetation), four sightings of killdeer, and one sighting of a Say's phoebe. Unfortunately, these sightings were not recorded separately for the vegetated wetlands and the evaporation ponds, but the birds were seen in the vegetated wetlands almost exclusively (April Sleigh, personal communication, 1996).

During the spring of 1994, the wildlife usage increased with the sprouting of the new plants, according to EMWD personnel. Numerous tadpoles and, later, frogs were observed. Coots, moorhens, blackbirds, black phoebes, a sora, snails, a crayfish, and a variety of invertebrates were also observed in and around the vegetated wetlands. Later in the year, opossum were observed using both wetlands on numerous occasions, and a heron frequented the north wetland. Throughout the fall, tracks of small animals (including opossum, herons, mice, skunks, small unidentified mammals [probably rodents], and cats [probably domestic]) were so abundant around the cells that it was difficult to distinguish one from another (Stella Denison, personal communication, 1994). April Sleigh and Andrew Haimov, from CSPU, recorded a total of 27 bird sightings during 1994, including: 5 sightings of black-necked stilt, 1 sighting of a willet, 1 sighting of a bank swallow, 11 sightings of least sandpiper, 1 sighting: of an American avocet, 6 sightings of black phoebe (on the wooden post in the vegetation), 1 sighting of a cinnamon teal, and 1 sighting of a common yellowthroat. It was agreed by the cooperating agencies to stock mosquitofish (*Gambusia spp.*) in the two vegetated wetlands to provide a test organism for toxicity analysis. During September 1994, 150 fish each were stocked into the south and north cells. In June 1995, fish could still be seen in both cells.

According to EMWD personnel, wildlife use during 1995 was similar to 1994. Tracks, scat, sounds, carcasses, nests, and actual sightings of the same mammal, amphibian, rodent, reptile, bird, and invertebrate species were observed. Additionally, yellow-head blackbirds were sighted regularly. April Sleigh and Andrew Haimov, from CSPU, reported 270 sightings of red wing blackbirds, 3 sightings of black-necked stilts, 1 sighting of an American avocet, 1 sighting of a loggerhead shrike, 39 sightings of tricolor blackbirds, I sighting of a common moorhen, and 4 sightings of black phoebes (on the wooden post in the vegetation) using the vegetated cells and/or the evaporation cells.

5.4.4 Invertebrate diversity data.-Invertebrate samples were collected on July 14, 1994, and May 25, 1995, and the data are listed in tables 5.5 and 5.6. At the time of the July 1994 sampling, both cells had been receiving fresh water for over 5 months. (See section 5.3.1.) Therefore, the EC of the water in the south cell was reduced and remained between 750 and 4,200 µS/cm. The invertebrates that were collected in 1994 (table 5.5) were fresh water taxa, and, therefore, neither cell was representative of the conditions of a saline vegetated wetland. The only taxon that was clearly absent from the south cell, but present in the north, was the *Oligochaeta*. This order includes the earthworms which are unable to survive in saline conditions and which have life cycles normally longer than the other invertebrates. They do not have a winged life stage to move in and out of an area quickly, so they were probably unable to populate the south cell within the 5-month period of receiving only fresh water.

For 10 months prior to the May 25, 1995, sample, RO reject flow had been fairly consistent into the south vegetated wetland. Therefore, we would expect to see species diversity differences between the sampling dates as well as between the cells. In comparing table 5.5 to 5.6, some differences were noted. There were seven invertebrate taxa collected in July 1994 that did not appear in the May 1995 sample, and there were four other taxa present in May that were not present in July 1994. However, with the exception of *Callibaetis* (*Callibaetis* is one of the major invertebrate groups least tolerant of salinities greater that 2 parts per thousand [Short et al., 1991]), each of these differing taxa was uncommon and exhibited only one or two individuals each. Since only three samples have been collected throughout the life of the project, no long term impacts on invertebrate communities can be determined from these data.

In examining the samples collected on May 25, 1995, from the north and south wetland cells, there are large differences in the *Corixidae*, the *Notonectidae*, and the *Chironomidae* taxa. *Notonectidae* occur only in fresh water (and, therefore, were found only in the north cell), while in the families *Corixidae* and *Chironomidae* (found in both cells), there are taxa that are tolerant to saline waters (Usinger, 1956). Individual chironomids were not identified to genus in order to accurately determine their saline tolerances, but their numbers are greater in the saline wetland than in the fresh water wetland. From these data, it can be deduced that these invertebrates were tolerant of higher saline concentrations (tables 5.5 and 5.6). Additional invertebrate sampling and analysis are essential to determine invertebrate community trends related to saline wetland development.

5.4.5 Toxicological data.—Collecting data to determine whether the saline vegetated wetlands are accumulating toxic materials which may be hazards to wildlife is a very important aspect of this study. Monitoring and sample collection have been performed by EMWD personnel.

In situ water analysis: The electrical conductivity (EC) and total dissolved solids (TDS) data for each vegetated wetland cell are listed in appendix J. These data illustrate how the saline wetlands gradually became more saline until they were diluted with the addition of fresh water. Measurements taken immediately after the weekly addition of fresh water to the north vegetated cell on November 3, 1993, showed that the inflow end had an EC of 2,070 µS/cm; the inflow sampling site on the south vegetated cell was 6,200 µS/cm at the same time (similar conditions occurred on July 23, 1993. and August 18. 1993). Once the RO system was shut down in February 1994, the EC levels and TDS concentrations were reduced by 50 percent (appendix J). This shutdown, plus the abundant rainfall (appendix K), freshened the water to such a degree that for 5 months the plant and invertebrate communities experienced a growth spurt. The following year (August 1994 through October 1995), EC data from the north vegetated wetland did not exceed 2,000 µS/cm and averaged 699.4 µS/cm, while EC data recorded from the south saline vegetated wetland reached 13,680 µS/cm (average 5,292.8 µS/cm).

Water analysis - RO reject: On each of 5 days, one water sample was collected from the RO reject line. (There were no replications.) Up to 22 trace elements and complete ion analyses were performed, and the data are listed in table 5.1, An additional sample, collected on February 23, 1995, was analyzed for copper, mercury, and selenium. According to the data, most of the elements analyzed were nondetectable or at levels that would not be toxic to aquatic organisms (U.S. Environmental Protection Agency, 1976 and U.S. Environmental Protection Agency, 1986). The exceptions included higher levels detected for selenium (0.0032 to 0.007 mg/L) and boron (2.5 mg/L).

Selenium levels in water that are over 0.003 mg/L exceed the criteria threshold and have shown adverse effects, such as increased risk of teratogenesis and embryo mortality, on some fish and wildlife species (Joy Gober, Reclamation memorandum dated June 14, 1993, peer-reviewed by national experts). The EPA National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (U.S. Environmental Protection Agency, 1987b) states that "freshwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of selenium does not exceed 5.0 µg/L (0.005 mg/L) more than once every three years on the average." Regardless of which criterion is applied, selenium should be monitored regularly and at a suitable detection limit to insure adequate evaluation. Since levels of 0.0032 to 0.007 mg/L selenium were detected in the RO reject going into the saline vegetated wetland, this water could potentially pose a threat to wildlife using the wetland. It is possible that higher levels could accumulate in the saline wetlands, particularly in the plants and soils.

The highest boron value found in the RO reject water samples (2.5 mg/L) may be toxic to certain crops and greenhouse plants (Csuros, 1994), but no documented boron toxicity has been found in aquatic plants (Snyder and Snyder, 1984). In hard water, the median lethal concentration to fish eggs and juveniles exposed from fertilization to 4 days after hatch ranged from 204 to 212 mg/L (Brungs et al., 1978). Although from these data, boron does not appear at toxic levels, it should continue to be monitored in the saline vegetated wetlands,,

Water analysis - saline vegetated wetland cells: Analytical results for water samples from the saline vegetated wetlands are listed in tables 5.2a and b. Many of the results are below detectable levels, and many others are at levels too low to cause any known toxic effects. The trace metals that are elevated are: aluminum (26 mg/L), copper (0.034 mg/L in the north cell). iron (27 mg/L), mercury (0.0006 mg/L in the north cell). selenium (0.0024 mg/L), and zinc (0.29 mg/L).

Although aluminum can cause crop problems at levels > 10 mg/L, and >1 mg/L can be toxic to fish (McKee and Wolf, 1963). aluminum effects on aquatic plants are rare, with toxicity greatly increasing at pHs less than 5, according to Gough et al. (1979). Battelle's Columbus Laboratories (197 1) showed that three species of freshwater fish could survive indefinitely at 100 mg/L, but acute toxic levels of aluminum to aquatic animals vary widely (Snyder and Snyder. 1984). Reviewing the available literature. it is doubtful whether the aluminum concentrations sampled in the wetland cells are toxic to occasional users, such as waterfowl, but since only one sample was taken at each outlet area on July 14, 1994, no definitive statements can be made. Based on a sample that was collected the following March,, aluminum levels dropped from 26 mg/L in the south cell and 14 mg/L in the north cell to below 1 mg/L. Monitoring should be continued.

The highest concentration of copper (0.034 mg/L) was found in a sample collected from the outlet of the north vegetated cell on July 14, 1994. All other samples had lower levels of copper and did not exceed the EPA National Water Quality Criteria Guidelines (U.S. Environmental Protection Agency, 1986). The copper level in the north wetland did exceed the EPA national guidelines after calculating the acceptable level using the only available measured water hardness of 138 mg/L $CaCO_3$. The measured concentration (0.034 mg/L) was about two times the accepted level for the 4-day average concentration (0.0156 mg/L). Because copper is a biocide, it should be monitored regularly.

The iron levels of 27 and 13 mg/L in the south and north vegetated wetlands, respectively, sampled on July 14, 1994, and 17 mg/L in the south cell sampled on March 29, 1995, are elevated levels. Aquatic vegetation has the ability to absorb large amounts of iron, but no information was found on toxic concentrations of iron to wetland or aquatic vegetation. Iron may actually provide protection from toxic concentrations of copper (Antonovics et al., 1971). Although the upper tolerance limit for fish under the California Water Quality Criteria (McKee and Wolf, 1963) is 50 mg/L, the 1976 EPA criterion for iron on aquatic life is 1 .0 mg/L. Therefore, it is an element that could have a negative impact on the aquatic life in the wetlands. Iron levels were also high in both wetland substrates (tables 5.3a and b) and in the plant material (tables 5.4a and b). The iron levels were not high in the influent reject: from the RO unit but were very high in the baseline soil sample prior to flooding in April 1993. The limited amount of sampling provides data which strongly suggests that iron was in the soil brought in for both vegetated wetlands. As saline water that is high in chlorides and sulfates is added to a soil high in iron, precipitates can form as ferrous/ferric ions combine with sulfate or hydroxyl ions. These precipitates could smother aquatic life (McKee and Wolf, 1963). The iron levels in the substrate and plant samples decreased with time, and by March 1995, iron concentrations had dropped to 1. 1 mg/L from 27 mg/L in the south cell and to 3.8 mg/L from 13 mg/L in the north cell. This could indicate that iron is leaching from the substrate. Monitoring should be continued.

Mercury is a highly toxic element that can both bioaccumulate and biomagnify in the food chain. Vascular plants are resistant to mercury poisoning (U.S. Environmental Protection Agency, 1973), but *Daphnia* (a common aquatic invertebrate) is immobilized by 0.006 mg/L mercury. The 1976 EPA criterion for mercury for freshwater aquatic life and wildlife is 0.00005 mg/L. However, the methylmercury form (CH_3Hg^-) is much more toxic than other forms of mercury, and the proportion of methylmercury to total mercury in *Elodea (an* aquatic macrophyte) was about 3 1 percent for the shoots and 10 percent for the roots in a study done by Mortimer (1985). Therefore, the values of 0.0002 to 0.0006 mg/L total mercury, found in the February and March 1995 south and north vegetated wetlands water samples, are probably within background levels of the system (Steven Schwarzbach, U.S. Fish and Wildlife Service [USFWS], Division of Environmental Contaminants, personal communication, 1996). Because mercury is such a highly toxic element, monitoring at detection limits no higher than 0.005 µg/L should be performed on a routine basis (Joseph Skorupa, USFWS, Division of Environmental Contaminants, personal communication, 1994). Analyses for methylmercury would be particularly useful.

Plants are able to absorb high quantities of selenium without injury, and high concentrations of sulfates will diminish the uptake of selenium and act as a partial antidote to toxicity (Bear, 1957). The south cell exhibited high sulfate concentrations in the March 1995 sample, which probably diminished the potential toxicity of the selenium concentrations of 0.0022 and 0.0024 mg/L measured in February and March 1995, respectively. However, since the newly accepted selenium level of concern for fish and wildlife in water is between 0.001 and 0.003 mg/L (Joy Gober, Reclamation memorandum, June 14, 1993), selenium must continue to be monitored. If selenium levels rise, the saline wetland could potentially become toxic to aquatic life.

The levels of zinc in waters of the south wetland, 0.12 and 0.29 mg/L where hardness measured 882 and 659 mg/L $CaCO_3$, respectively (table 5.2a), probably did not exceed the criteria levels set for aquatic organisms, as determined by the EPA formula (U.S. Environmental Protection Agency, 1987a). However, in the north wetlands, where the available measured hardness was only 44 mg/L $CaCO_3$, the zinc level of 0.14 mg/L was above criteria levels. In this case, the major source of zinc was from the substrate. The best way to determine whether zinc is toxic to aquatic organisms in this environment would be to perform onsite toxicity tests.

It is very important that additional water and plant samples be collected and analyzed to demonstrate whether the saline vegetated wetlands are accumulating toxic materials which may result in hazards to wildlife. Additionally, there may be synergistic effects of metals in combination in this water matrix. Accurately predicting those combined effects is difficult. so onsite toxicity tests should be performed to determine toxicity empirically.

Soil analyses: Data from the two wetland cells are listed in tables 5.3a and b. The baseline soil analyses, taken on April 28, 1993, showed 19 µg/kg of chlordane in the north wetland inlet area, and 12 µg/kg was present in the south wetland inlet area. No other organochlorine pesticides or PCBs were detected in the local soil prior to flooding. However, the levels of the elements cadmium, total chromium, iron (see discussion on iron in water analysis section, above). lead, nickel. and zinc in both vegetated wetland substrates were above what would be normal for crop soils (Robert Cox, personal communication, 1994). Raw data are included in appendix C of the USBR/NBS/EMWD Phase II/III Report (1994).

The next complete soil testing was performed on samples taken on March 29, 1995, almost 2 years following planting, with an additional set of samples analyzed for copper, mercury, and selenium. taken on July 14, 1994 (after 5 months of receiving only fresh water). This limited data, set makes definitive conclusions difficult. Mercury and selenium levels in these samples are below levels of concern for fish and wildlife. Copper levels are higher and appear to have increased somewhat with time in both the south and north cells. However, copper toxicity is reduced in water of high alkalinity (U.S. Environmental Protection Agency, 1976) (refer to table 5.2a).

A review of the baseline data disclosed similar concentrations of elements in both cells. This similarity strongly suggests that the metals came in with the soil. Boron, copper, and zinc increased in the saline wetland with time (possibly due to the concentrations in the RO reject), cadmium and lead increased in both wetlands, but chromium, iron, and nickel decreased. Continued monitoring is recommended.

Plant material analyses: Little information is available regarding toxic levels of heavy metals in plant tissue. In reviewing the data listed in table 5.4a and b, it appears that there are only a few elements that are of concern. Selenium levels increased slightly through time but they are below the levels of concern for consumption by waterfowl. Aluminum, barium, copper, iron, magnesium, mercury, nickel, and zinc levels were high during July 1994, but were lower in the samples collected during May 1995 in both the south and north cells. The element of most concern was boron. During December 1994, spikerush in the south cell contained boron levels of 130 mg/kg; and during May 1995, spikerush in the north (control) cell contained 220 mg/kg (table 5.4a and b). These levels of boron are toxic levels in crops; however, only one sample was collected on each date, so it is unknown whether this was typical for all the spikerush. Plants are capable of absorbing large amounts of metals, whether they need them or not (Guilizzoni, 1991), and it is still debated whether some plants are capable of concentrating high amounts in their tissues from low concentrations in the surrounding environment (Muntau, 1981 and Wells et al., 1980). Because there is no evidence of large boron levels in the water or substrate samples, and because sampled alkali bulrush contained much less boron, the spiketush may be a species capable of this phenomenon.

Sampling and analyses of plant material on an annual basis are recommended to determine if changes are occurring in the system and if the edible portions are accumulating levels of any of the RO reject constituents that could be toxic to plants, waterfowl, or wildlife feeding on these plants

5.5 Conclusions

Using the data that were received from EMWD, there are some trace metals that warrant concern for the health and well-being of visiting wildlife, but there appear to be no serious threats to wildlife using the saline vegetated wetland cells at this time. However, it should be noted that the data available are very limited, so no long term conclusions can be drawn. Due to the sparsity of the data, it is not recommended that EMWD, or any other entity, create a larger saline wetland system to reduce their RO reject volumes or to create green space and wildlife habitat until more stable water quality conditions are achieved and further data are collected and analyzed. The reader must remember that within this reported sampling period, the south saline cell received a constant flow of RO reject only from July 21, 1994, through the May 1995 sampling date. Therefore, long range effects or accumulations have not yet been adequately addressed. Monitoring should be continued, and more samples should be collected and analyzed before any definitive conclusions can be drawn about the feasibility of using wetlands for brine reuse and disposal.

6. EVAPORATION PONDS

6.1 Objective

The objective. of the evaporation ponds (cells) at this pilot facility was to determine whether the effluent volume from the saline vegetated wetlands could be reduced further to minimize the cost of concentrated RO reject (brine) disposal. In a full-scale RO facility, the cost of brine disposal could be considerable.

6.2 Evaporation Pond Design and Construction

The evaporation ponds consisted of two 6.1 x 24.4-meters by 1 .2-meters-deep (20 x 80-feet by 4-feet-deep) lined cells adjacent to and downstream from the saline vegetated wetlands (figures 2.4 and 2.5). The complete construction design and specification document is available through EMWD, San Jacinto, California.

6.2.1 Design considerations.-The evaporation ponds were made as unattractive to wildlif[redacted] as possible, since the ponds could tend to concentrate certain constituents of the saline vegetated wetland effluent to toxic or hazardous levels, if they exist in the system. The ponds were made with steep non-vegetated sides so that no food, shelter, or nesting areas were available to wildlife (figure 6.1). Without those attractions, it was hoped that transient waterfowl would be unlikely to linger around these ponds, thus limiting their exposure to any concentrated constituents

Figure 6.1 .-North evaporation pond with adjacent, upstream vegetated wetlands and RO unit in the background.

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The initial designs. as described in the Phase 1 Report (Bureau of Reclamation and Eastern Municipal Water District. 1991). included six 12.2-meter by 12.2-meter by 0.6.meter (IO-foot by IO-foot by Z-foot) deep evaporation ponds. three of which were to be fitted with sprinkling systems to further increase evaporation. These designs were modified during the final design to two. rather than six. cells. and the sprinkling systems were eliminated to keep costs down.

6.2.2 Layout and construction.-To prevent seepage of concentrated RO reject into groundwater. the evaporation cells were lined with an 80 mil high-density polyethylene liner. In April 1994. a leak formed in the north evaporation cell and. a short time later. the south cell appeared to be leaking. Both cells were drained. It was determined that the north cell was leaking because a weld along the liner seam had failed. The south cell leaked through the inlet pipe penetration. The manufacturer of the lining was called to repair the leaks. All the seams on the linings of both cells were resealed to prevent future leaks. This work was performed under warranty by the manufacturer.

Initially. outflows from each saline vegetated wetland went into evaporation cell number one (the south cell) and then into evaporation cell number two (the north cell) in series. Due to lack of sufficient reject from the RO unit to meet the demands of the saline vegetated wetlands during peak evapotranspiration periods, the underground piping and valve system was modified. in September 1993 to allow the south vegetated wetland to receive all of the RO reject and the north vegetated wetland to receive RO product water as a control. Plumbing modifications were made to allow the overflow from the north vegetated wetland to flow into a nearby sump instead of into the evaporation cells. while overflow from the south vegetated wetland continued to flow into evaporation cell number one and then into evaporation cell number two in series (figure 5.1).

6.3 Test Procedures

6.3.1 Monitoring of brine inflows and evaporation rates.—A total of about 4.7 m^3 (1.250 gal) of RO reject w-as produced each weekday to support the saline wetland. Weather. evapotranspiration. and the RO reject flow determined whether the evaporation cells received effluent from the saline wetland. Generally, during the cool, rainy season. there was enough water to accumulate in the evaporation cells. but during the dry. hot months (maximum pan evaporation was over 1.5 cm [0.6 in.] per day), there was no flow out of the saline wetland into the evaporation cells. No water volume data or flow values for the evaporation cells were recorded throughout this study period. Precipitation and evaporation pan data were collected. and the raw data are listed in appendix K.

Electrical conductivity (EC) was measured when the evaporation cells contained water. Data are listed in table 6. 1.

6.3.2 Evaporation enhancement methods.—Consideration of any further evaporation enhancement methods was dropped due to the small volume of flow the evaporation cells received from the vegetated wetlands.

Table 6.1 .—Electricl conductivity (EC) readings in the south evaporation pond

Date	EC (μS/cm)	Date	EC (μS/cm)
02/24/94	4285	01/03/95	4770
03/03/94	4285	01/10/95	3830
03/11/94	4370	01/17/95	4010
03/18/94	4560	01/24/95	3840
03/28/94	3827	02/03/95	4070
04/04/94	4100	02/10/95	4490
08/30/94	13270	02/17/95	3900
09/06/94	21000	02/24/95	3955
09/13/94	17700	03/06/95	3470
09/20/94	11460	03/24/95	3020
09/27/94	22100	03/31/95	3350
10/04/94	19240	04/14/95	3360
10/11/94	16500	06/09/95	5800
10/18/94	20220	06/16/95	6170
11/01/94	13180	06/30/95	6950
11/08/94	9510	07/07/95	7310
11/15/94	7800	08/04/95	11300
11/22/94	7160	08/10/95	12700
11/29/94	7120	09/11/95	27800
12/06/94	7200	09/22/95	37200
12/13/94	7350	09/29/95	37800
12/20/94	7500	10/06/95	38900
12/27/94	7325		

6.4 Results and Discussion

6.4.1 Brine concentration and net evaporation data.-Recorded EC measurements from the south cell are listed in table 6. 1. The examination of evaporation and precipitation data (listed in appendix K) indicated that the lower ECs occurred during times ofabundant rainfall and low evaporation. Specifically. from a low of 3.020 µS/cm in March 1995 (following a 3-week period of low evaporation and 6.4 cm [2.5 inches] of rainfall). the EC measurements (table 6.1) became exceedingly high during September and October 1995 (77.800 to 38.900 µS/cm). The high ECs occurred when precipitation was low. evaporation was high. and inflow from the wetland had stopped.

6.4.2 Wildlife visitation and use.-General observations of wildlife use were made by EMWD personnel during weekly visits. Signs of wildlife use. such as tracks and droppings. were noted. and a carcass log was used to record findings of any dead animals in or around the evaporation cells (several small animals were found dead in the cells. but it appeared they had fallen in and were unable to get back out due to the steep sides and smooth lining). The log book is available from EMWD personnel.

EMWD also observed that usage by waterfowl has been brief and transient throughout the testing period. Ducks have been observed in the evaporation cells. but they did not stay for more than 3 days. Near the end of August and into September 1994. small groups of least sandpipers. lesser yellow legs. and black-necked stilts were observed feeding from the bottom of the south evaporation cell in the sand that tilled in around the edges. They were not observed beyond mid-September.

Wildlife use during 1995 was similar to 1994. No new notations of observations were made by EMWD personnel.

6.4.3 Toxicological data.-One water sample **was** collected from each evaporation cell on February 23. 1995. and analyzed for copper. mercury. and selenium: and on March 29. 1995. 1 sample was collected and analyzed for 19 trace elements. Data are listed in table 6.2. The only element that exceeded the criteria level was zinc (0.1 19 mg/L) in the north pond (using the toxicity criteria of 0.086 mg/L for saltwater aquatic organisms [U.S. Environmental Protection Agency. 19871). However. two samples taken 5 weeks apart do not provide enough data to develop a toxicological picture of the cells through time. In this case. 2 weeks prior to the February 23 sampling. the RO system had been off for 6-X weeks due to abundant rainfall. It is. therefore. very likely that the water sampled from the evaporation cells on February 23 was heavily diluted with rain water. Although the RO system had been back on line for the 7 weeks prior to the March 29 sampling. 11.4 cm (4.5 inches) of rain had fallen within that time. Therefore. it is also very likely that the March 29 sample was heavily diluted. The EC measurement taken on March 24. 1995 (3.020 µS/cm) was the lowest EC value recorded from the evaporation cells (table 6.1). Therefore. samples were collected at a time when the evaporation ponds were experiencing very uncharacteristic operating conditions. It is logical. during the time when high ECs were recorded (August 1994 through October 199-l and August 1995 through October 1995). that the

Table 6.2.—Metal concentrations in evaporation pond water samples

	South Pond @pm)		North Pond @pm)	
Metal	2-23-95’	3-29-95’	2-23-95’	3-29-95’
Aluminum, Al		0.048		0.09
Arsenic, As		0.003		co.002
Barium, Ba		0.0507		0.0488
Cadmium, Cd		<0.0002		<0.0002
Chromium, Cr		<0.003		<0.003
Iron, Fe		0.25		0.33
Lead, Pb		0.0003		0.0007
Manganese, Mn		0.06		0.02
Silver, Ag		<0.0002		<0.0002
Zinc, Zn		0.0287		0.119
Beryllium, Be		<0.0008		<0.0008
Thallium, Tl		<0.0001		<0.0001
Nickel, Ni		0.002		0.001
Antimony, Sb		<0.0008		<0.0008
Cobalt, Co		0.0006		0.0005
Boron, B		1.26		1.23
Copper, Cu	0.0064	0.0028	0.0078	0.0073
Mercury, Hg	<0.0005	<0.0002	<0.0005	0.0003
Selenium, Se	0.001	0.001	0.001	0.001

[1] Electrical conductivity (EC) in the south evaporation pond on February 24, 1995 was 3955 µS/cm; average EC in the south vegetated wetland was 2925 µS/cm.

[2] EC in the south evaporation pond on March 24. 1995 was 3020 µS/cm; average EC in the south vegetated wetland was 3038 µS/cm.

constituents in the water were present in higher concentrations. but no samples were collected during those periods. Further sampling and analyses during other times of the year are necessary to determine ifconcentrated water in the evaporation ceils contains constituents at levels exceeding recommended criteria.

6.5 Conclusions

Due to the limited amount of data available from the evaporation cells. conclusions cannot be drawn. Since it is very important to know what. if any. hazards exist for wildlife using evaporation ponds associated with constructed saline wetlands. more data collection and careful analysis are essential before a full-scale RO system with saline vegetated wetlands and evaporation ponds is built.

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7. POTENTIAL FOR FULL-SCALE DEVELOPMENT

The data that have so far been collected from the saline vegetated wetlands and the evaporation cells are too limited to predict the potential for full-scale development. Consistent monitoring according to the July 5. 1991. proposed saline marsh monitoring program is recommended before further development is attempted. Although the plants propagated rapidly in the south saline vegetated wetland cell in the spring. they turned brown much earlier in the growing season than did plants in fresher areas (e.g.. natural alkali bulrush sites on the San Jacinto Wildlife Refuge 12.9 kilometers [8 miles] north of this pilot site). The south wetland maintained a few salt-tolerant wetland plant species. but species diversity was low: this also reduced wildlife diversity.

In summary. the saline vegetated wetlands appeared to reduce the volume of reject from the RO unit. Since there are insufficient data to determine whether or not the saline vegetated wetlands were harmful to the wildlife that used them. a full-scale development project is not recommended at this time.

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APPENDIX A

RO Reject-Regenerated ion Exchange Experiments

A. RO REJECT-REGENERATED ION EXCHANGE EXPERIMENTS

A.1 Background

Because of the concentrations of calcium (Ca^{+2}) and bicarbonate (HCO_3^-) in the Walker Duck Club well water, it would be necessary to add both acid and anti-sealant to avoid the precipitation of calcium carbonate ($CaCO_3$) in the RO elements. Computer RO performance projections run for this water indicate the need for approximately 85 mg/L of 93-percent sulfuric acid (H_2SO_4) plus about 6 mg/L of FLOCON 100/Hypersperse (anti-sealant) to achieve 75-percent product recovery.

Another way of avoiding $CaCO_3$ scaling is to reduce the concentration of either Ca^{+2} or HCO_3^- in the feedwater. Calcium, present in the Walker Duck Club well water at between 80 and 85 mg/L, can be removed by ion exchange (IX) using a strong acid cation exchange resin operated in a sodium cycle. This means that the exchange sites on the resin, which are occupied by sodium ions (Na^+) following regeneration, relinquish sodium ions in favor of calcium ions for which they have a greater affinity. Magnesium (Mg^{+2}) and other divalent cations are removed as well. The ion exchange process (sodium cycle) is shown in the following forward reaction:

$$2RzNa + Ca^{+2} \rightleftharpoons (Rz)_2Ca + 2Na^+$$

where Rz represents the functional group of the resin. Note that two sodium ions are exchanged for each calcium (or magnesium) ion.

Regeneration of the resin is usually accomplished using highly concentrated solutions of sodium chloride (NaCl), generally lo-percent. However, in RO feedwaters that have fairly high sodium levels and a favorable sodium-to-hardness ratio, i.e., high sodium concentration compared to calcium and magnesium, the possibility exists that the resin may be regenerated using the RO reject (concentrate) stream as shown on figure A. 1. This method of resin regeneration has been demonstrated in previous Reclamation research studies [1,2], but never using RO reject with as low a sodium concentration as projected for the Walker Duck Club well.

A.2 Experimental Design and Procedures

A series of laboratory experiments were conducted to demonstrate the feasibility of including reject-regenerated ion exchange as a pretreatment process at the EMWD (Eastern Municipal Water District) RO research facility.

The ion exchange test apparatus, depicted in figure A.2, included a l-inch diameter glass exchange column and the associated pumps. tanks. etc.. required to prepare and transfer feed. rinse and regenerant solutions. The column was tilled to a depth of 2 feet with Rohm and

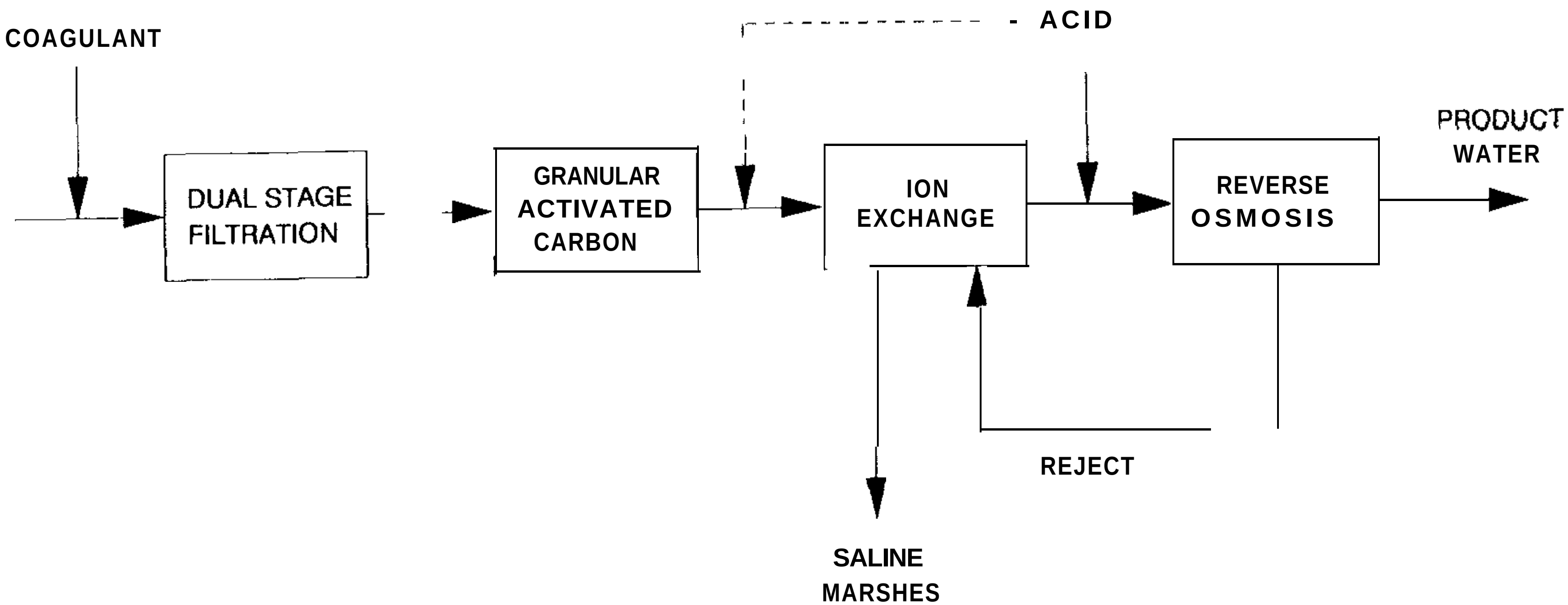


figure A.1. - RO reject-regenerated ion exchange process.

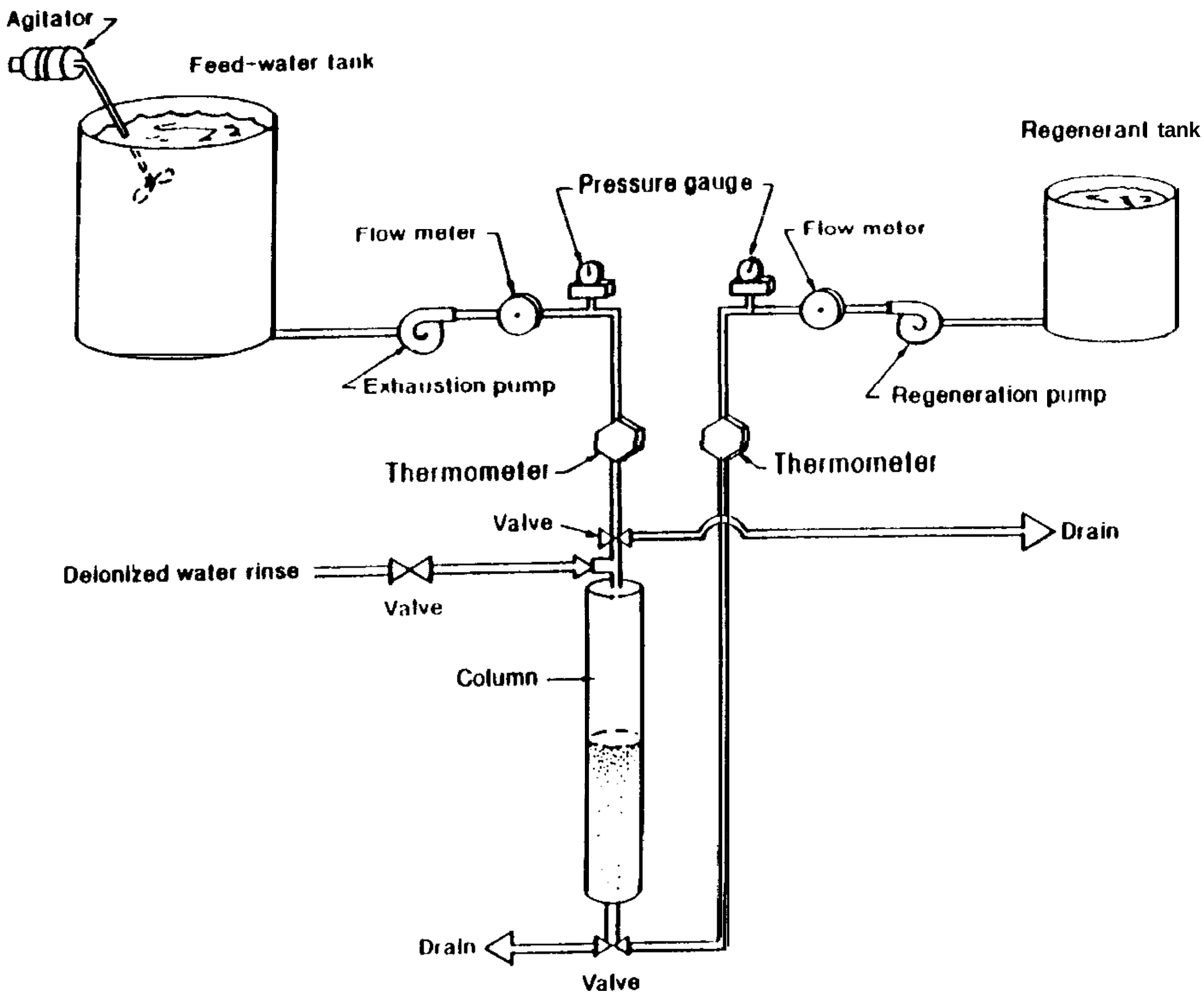


Figure A.2. - Schematic of the ion exchange test apparatus, Haas Amberlite IR-120 Plus cation exchange resin, which amounted to a resin volume of about 310 mL. Ion exchange feed and regenerant solutions were prepared to simulate the EMWD RO system raw feed and reject streams (assuming the 12/10/91 Walker Duck Club analysis). as follows:

	IX Feed		IX Regenerant	
	mg/L	meq/L	mg/L	meq/L
Calcium, Ca^{+2}	82	4.09	2	0.10
Magnesium., Mg^{+2}	21	1.73	2	0.16
Sodium, Na^{+}	490	21.32	2346	102.00
Potassium, K^{+}	7	0.18	26	0.66
Bicarbonate, HCO,	808	13.37	2739	45.40
Chloride, Cl^{-}	490	13.82	1866	53.24
Sulfate, SO_4^{+2}			202	4.21

A total of 4 exhaustions and 3 regenerations were performed. The initial exhaustion was run 50 bed volumes, past the anticipated calcium breakthrough to make sure the resin was completely exhausted prior to testing (no samples were collected during this initial exhaustion). Samples were taken at 30-minute intervals during the remaining experiments and analyzed for Ca^{+2}, Mg^{+2} and Na^{+}. A 15-minute backwash (up flow) and a 15-minute rinse were conducted, after each exhaustion and regeneration. The flowrates used in testing were as follows:

Exhaustion	83 mL/min (equivalent to 2 gal/min/ft^3)
Regeneration	21 mL/min (equivalent to 0.5 gal/min/ft^3)
Backwash	sufficient to achieve a 50-percent bed expansion
Rinse	42 mL/min (1 .0 gal/min/ft^3)

A.3 Results and Discussion

Graphs of the three exhaustion/regeneration cycles are presented on figures A.3 through A.8 in the order in which they were run. Likewise, supporting data are shown in tables A. 1 through A.6.

A.3.1 Regenerations. - Referring to the regeneration #1 graph on figure A.3, Ca^{+2} and Mg^{+2} are being displaced from the resin by the higher Na' concentration (2346 mg/L). This occurs rapidly at first:, then, towards the end of the regeneration cycle, the effluent cation concentrations slowly return to their influent levels. At this point the resin is regenerated about as completely as the regenerant sodium concentration will allow and the cycle is terminated (Note: disregard the dip in the curves at 510 min - this represents operator error and did not adversely impact the regeneration).

Because of the low concentration of sodium in the regenerant solution (0.23 percent compared to the manufacturer's recommended 10 percent), it was necessary to run the regeneration cycle

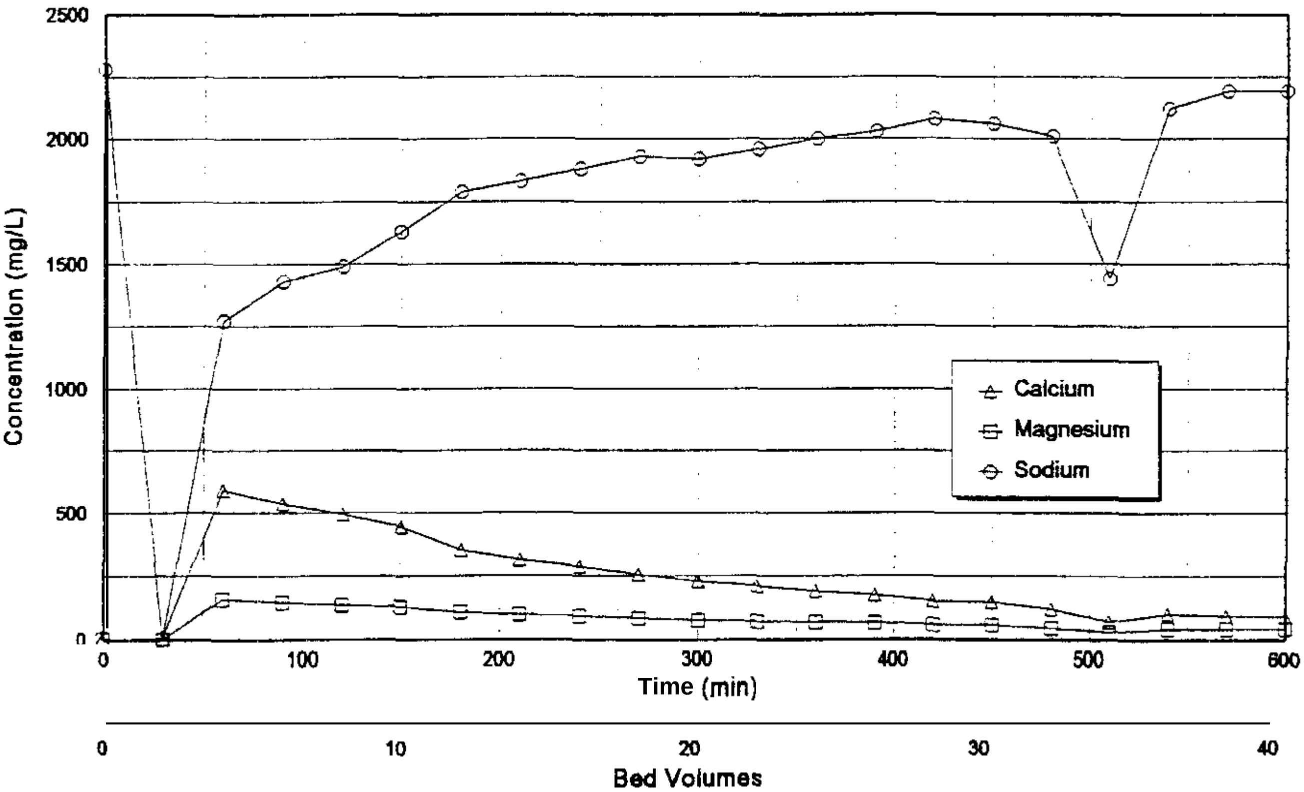


Figure A.3. - Regeneration cycle #1.

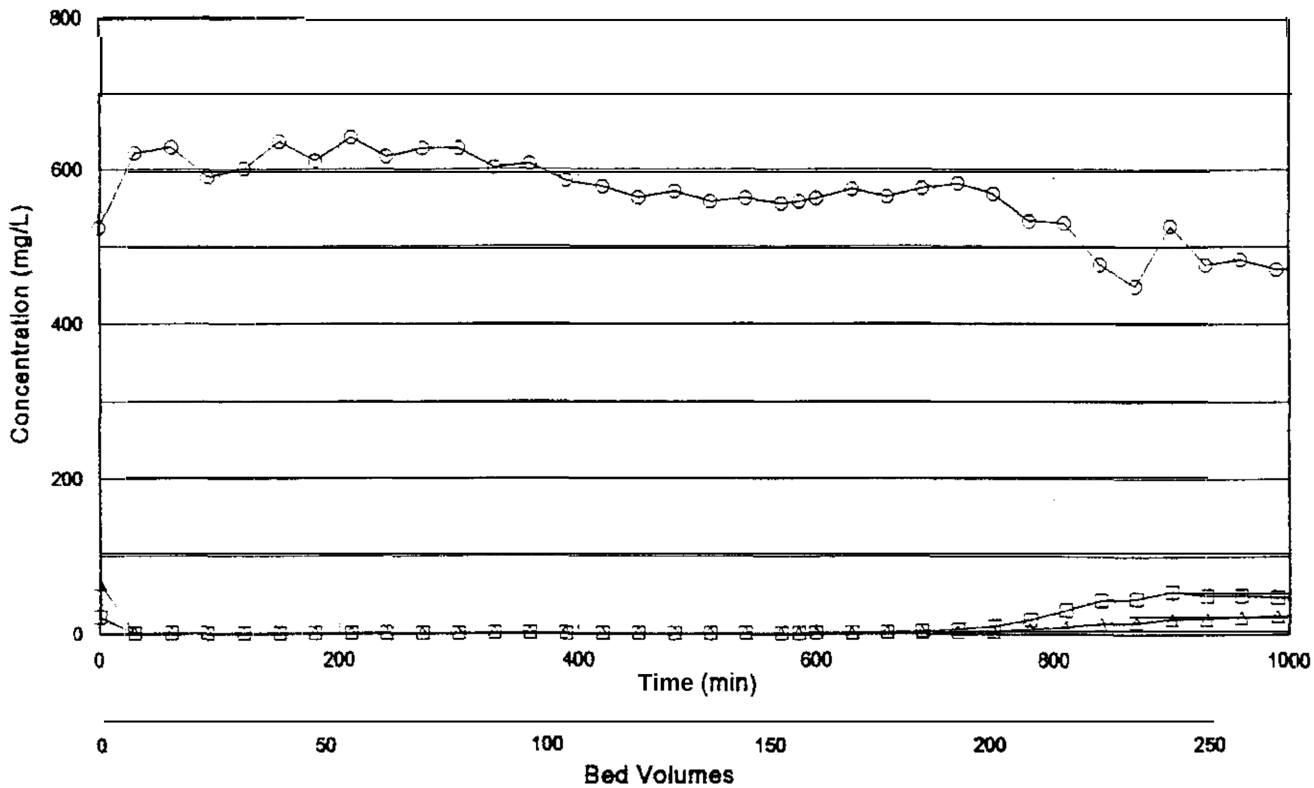


Figure A.4. - Exhaustion cycle #2.

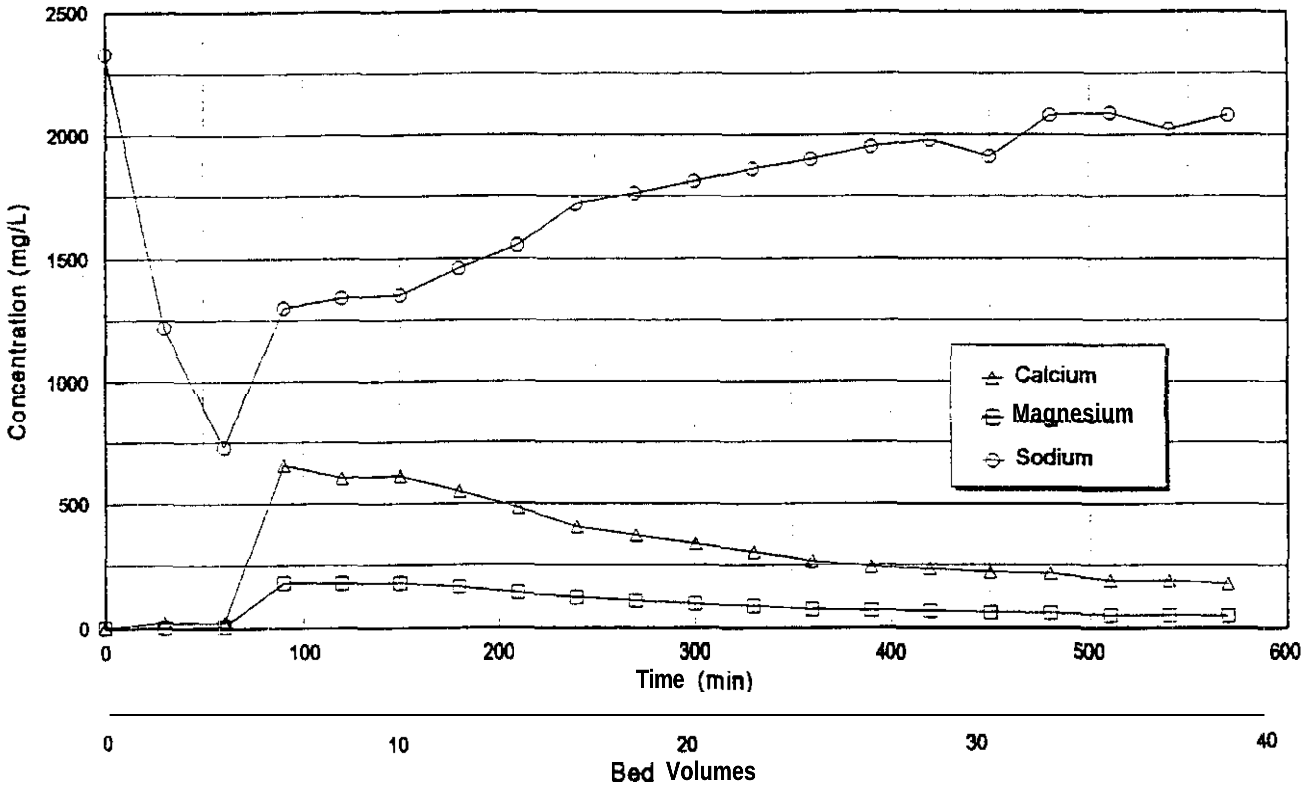


Figure A.5. - Regeneration cycle #2.

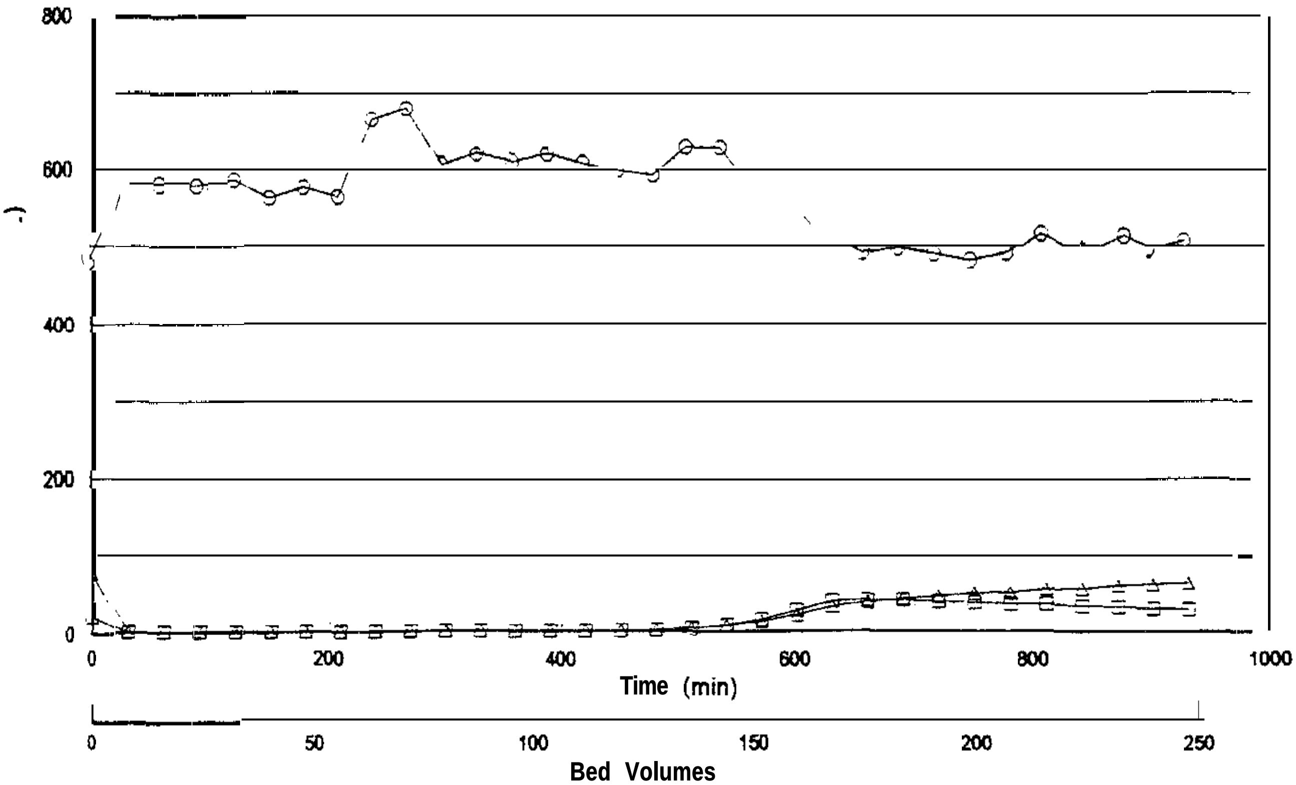


Figure A.6. - Exhaustion cycle #3.

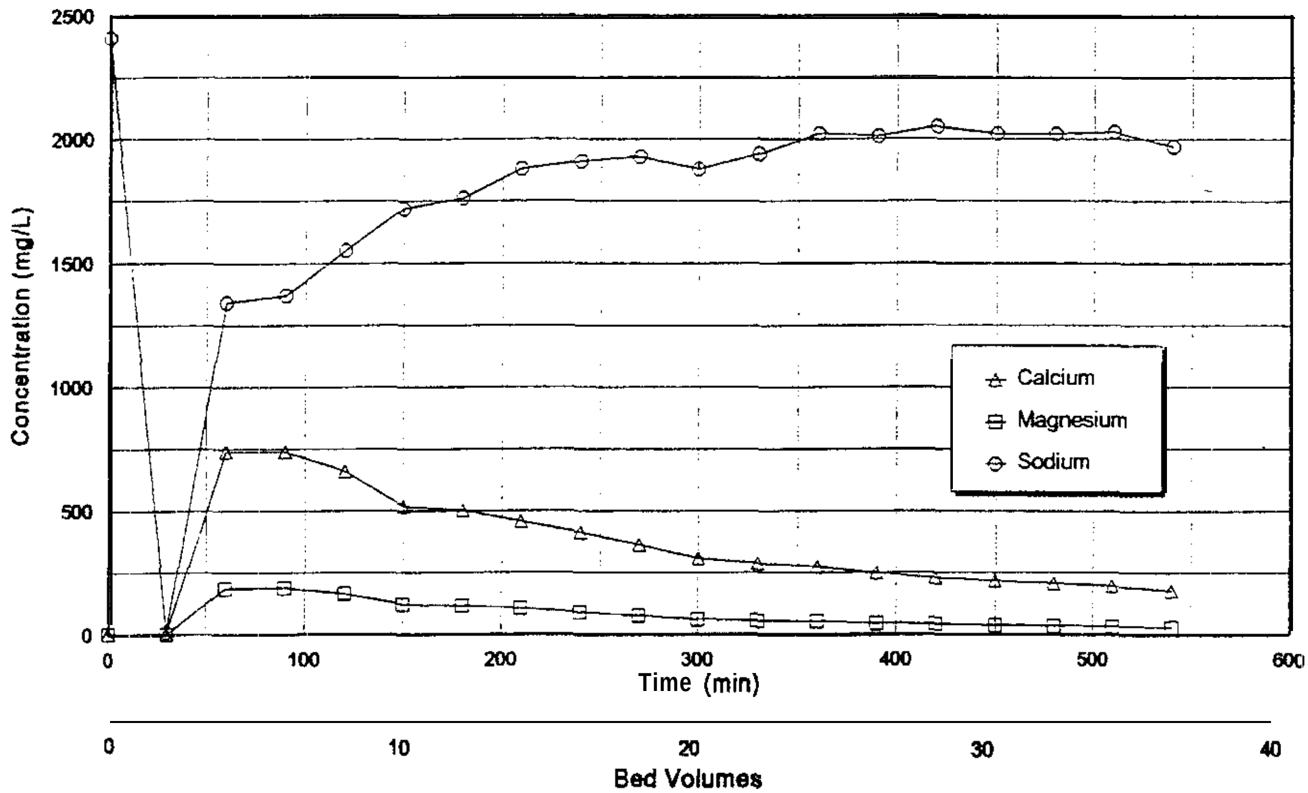


Figure A.7. - Regeneration cycle #3.

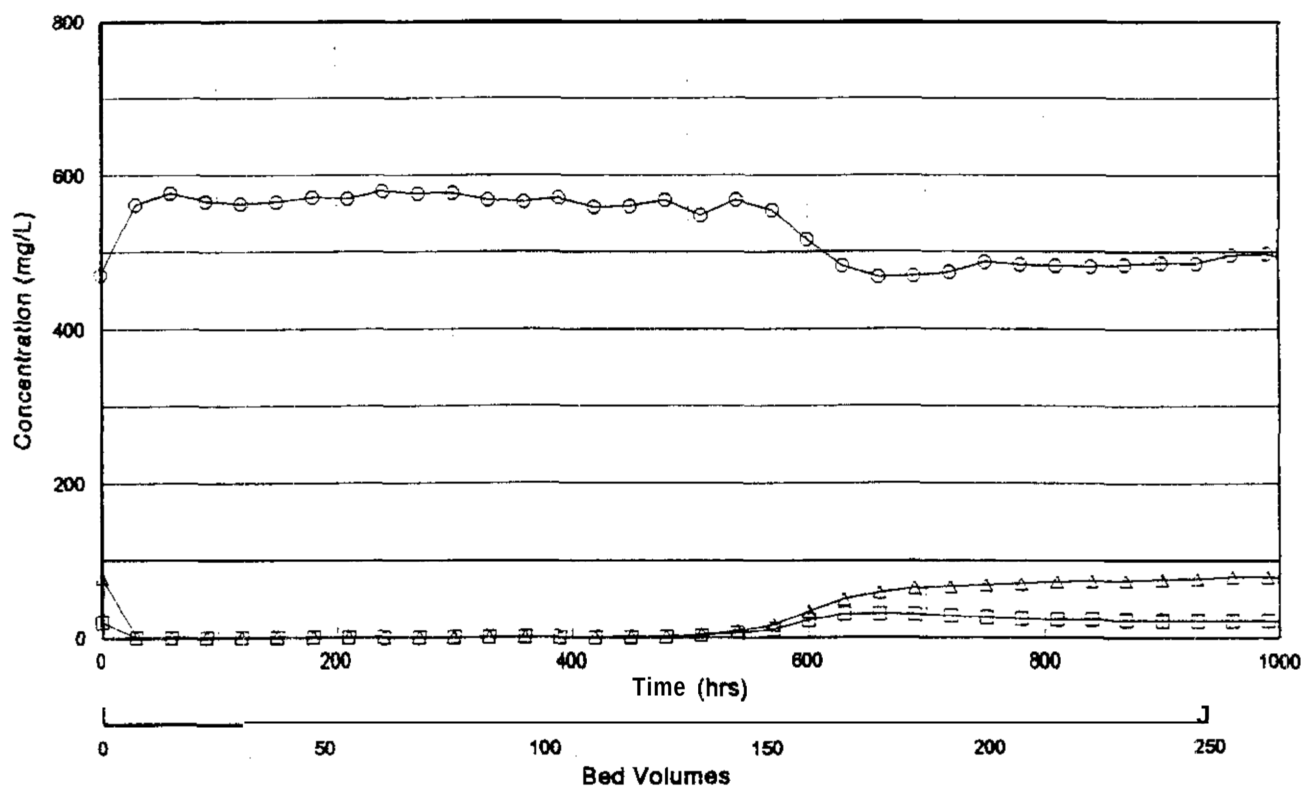


Figure A.8. - Exhaustion cycle #4.

several hours to expose the resin to a sufficient quantity of sodium. The total amount of sodium available in the RO pilot plant reject will be about 22.2 lb/day. Assuming the use of an IX column containing 3 ft^3 of resin, this is equivalent to 7.4 lb Na^+/ft^3. This is roughly 63 percent of the total amount of sodium recommended by the manufacturer for regeneration to full capacity.

Regenerations #2 and #3 are very similar to regeneration #1 except that the Ca^{+2} spikes coming off the resin at the beginning of the cycles appear to be increasing for each successive test. However, this may be an anomaly of the sampling frequency, i.e., the peak of the Ca^{+2} curve may have occurred midway between sampling points for rhe earlier regenerations.

A.3.2 Exhaustions. - Referring to the exhaustion #2 graph on figure A.4, the data points at t_0 represent the influent concentrations (sample was taken from the feed tank). The subsequent data points are column effluent values. Virtually all of the influent Ca^{+2} and Mg^{+2} is taken up by the resin during the first 690 mitt, at which time breakthrough begins to occur. During the same time interval. Na^+ is being displaced from the resin as indicated by the high effluent sodium concentrations relative to the influent level of 490 mg/L. The resin's capacity (meq hardness/mL resin) can be determined from this graph by calculating the areas between the Ca^{+2} and Mg^{+2} curves and their respective influent values. These calculations, shown in table A.2, indicate that a total of 406.9 meq of hardness was removed, which resulted in a resin capacity of 1.31 meq/mL. According to the manufacturer's literature, the maximum attainable resin capacity is 1.58 meq/mL.

The graphs for exhaustions #3 and #4, shown on figures A.6 and A.8, both exhibited breakthroughs at about 480 min (135 bed volumes), somewhat less than the 690 min achieved with exhaustion #1 The corresponding resin capacities were also lower, as indicated in tables A.4 and A.6, yielding 0.93 and 0.92 meq/mL, respectively. Since this resin capacity was obtained in two successive experiments, it probably is fairly representative of a steady state value.

A.3.3 Problem areas. - The feed solution for the first exhaustion cycle was prepared without pH adjustment (pH as tested was 8.3). Several hours into the test, $CaCO_3$ was observed precipitating in the feed tank and transfer tubes. Scale also formed in the column, both within the bed and at the surface. By the end of the cycle, the buildup was interfering with flow through the resin. A pH 5 solution, prepared with hydrochloric acid (HCI) and deionized water, was then fed to the column for 8 hours in an attempt to dissolve the scale, with little effect. The resin was subsequently replaced and the test rerun at a pH of 6.5, without scale formation.

The solution pH for the remaining experiments was set based on Langelier Index calculations. For the exhaustion cycle, the pH_S was determined to be 6.85 (assuming 70°F). The amount of acid required to adjust the feed pH from 8.3 to 6.85 was calculated to be 135 mg/L of 93-percent H_2SO_4. It is quite possible, however, that the exhaustion may work fine at a higher pH or with the addition of a small amount of anti-sealant. Additional testing would be needed to determine this.

Because of the high HCO_3^- concentration in the regenerant solution and large Ca^{+2} spike coming off the resin at the start of the regeneration cycle, the pH_S was considerably lower at 5.46. However. both pH 5.9 and 6.3 were used during regenerations #2 and #3, respectively, without problem. The amount of acid needed to adjust to pH 6.3 was calculated to be 962 mg/L of 93-percent H_2SO_4, which is considerable. Unlike the feed solution, it is not probable that this acid requirement could be reduced to any great extent.

These acid requirements, particularly for the regeneration, are far in excess of the 85 mg/L needed in the acid/anti-sealant pretreatment described earlier. Even if the regeneration could be operated at a somewhat higher pH, without scale, it is extremely doubtful that the acid dosage could be reduced sufficiently to make the process cost effective. The additional capital costs involved would also have to be factored in, which would further reduce the cost effectiveness of the process.

A.4 Conclusions and Recommendations

- Based on the second and third exhaustion cycles, it appears that a resin capacity of 0.93 meq/mL is attainable, which compares to a theoretical maximum capacity of 1.58 meq/mL.

- Assuming the 12/10/91 analysis for the Walker Duck Club well water (5.85 meq/L hardness), a total of 3.8 ft^3 resin will be required to process 4500 gal/day of feed water.

- Acid requirements to condition the regenerant stream, and most likely the feed stream, to avoid $CaCO_3$ scale are far in excess of that required for acid/anti-sealant pretreatment. For this reason, and considering the additional capital costs involved, the use of reject-regenerated ion exchange would not be recommended as part of the RO system pretreatment.

A.5 References

1. Haugseth, L. A., and C. D. Beitelshees, “Evaluation of Ion Exchange Pretreatment for Membrane Desalting Processes,” U.S. Department of the Interior, Bureau of Reclamation Report No. REC-ERC-74-26, Denver, CO, December, 1974.

2. Kaakinen. J. W., and P. E. Laverty, “Cation Exchange Pretreatment for High Recovery - Yuma Desalting Plant,” U.S. Department of the Interior, Bureau of Reclamation Report No. REC-ERC-82-11. Denver, CO, October, 1983.

Table A.l, - Regeneration #1 data.

Elapsed Time (min)	Bed Volumes	Concentration Ca (mg/L)	Mg (mg/L)	Na (mg/L)
0	0	2.54	2.42	2280
30	2.03	3.41	0.12	1.55
60	4.06	592	158	1270
90	6.10	537	145	1430
120	8.13	495	136	1490
150	10.16	447	128	1630
180	12.19	351	106	1790
210	14.23	312	96.2	1830
240	16.26	287	91.2	1880
270	18.29	256	83.2	1930
300	20.32	229	75.2	1920
330	22.35	212	71	1960
360	24.39	190	67	2000
390	26.42	175	63.4	2030
420	28.45	151	58.1	2080
450	30.48	149	55.4	2060
480	32.52	118	44.7	2010
510	34.55	70.8	27.2	1440
540	36.58	102	41.7	2120
570	38.61	92.2	40.6	2190
600	40.65	89.6	40.1	2190

Table A.2. - Exhaustion #2 data.

Elapsed Time (min)	Bed Volumes	Concentration Ca (mg/L)	Mg (mg/L)	Na (mg/L)	Ca (sum meq)	Mg (sum meq)
0	0	65.1	21.2	525		
30	8.03	0.76	0.43	621	10.09	4.22
60	16.06	0.7	0.43	629	10.10	4.22
90	24.10	0.56	0.39	590	10.11	4.22
120	32.13	0.49	0.4	601	10.12	4.22
150	40.16	0.45	0.42	636	10.13	4.22
180	48.19	0.44	0.44	611	10.13	4.22
210	56.23	0.47	0.42	641	10.13	4.22
240	64.26	0.49	0.45	616	10.13	4.21
270	72.29	0.46	0.43	627	10.13	4.21
300	80.32	0.49	0.48	627	10.13	4.21
330	88.35	0.46	0.46	602	1013	4.21
360	96.39	0.48	0.47	607	10.13	4.21
390	104.42	0.45	0.45	585	10.13	4.21
420	112.45	0.46	0.47	577	10.13	4.21
450	120.48	0.46	0.47	563	10.13	4.21
480	128.52	0.46	0.48	572	10.13	4.21
510	136.55	0.47	0.5	558	10.13	4.20
540	144.58	0.47	0.51	562	10.13	4.20
570	152.61	0.48	0.55	556	10.13	4.20
585	156.63	0.54	0.65	558	10.13	4.18
600	160.65	0.84	1.1	562	10.10	4.12
630	168.68	0.63	0.88	574	10.10	4.10
660	176.71	0.8	1.49	564	10.10	4.06
690	18474	1.24	2.82	575	10.06	3.86
720	192.77	1.95	5.4	562	9.99	3.46
750	200.81	3.12	9.85	568	9.87	2.74
780	208.64	5.38	18.1	533	9.66	1.44
810	216.87	8.67	30.8	530	9.32	-0.71
840	224.90	12.9	43	477	8.85	-3.26
870	23294	14.7	46	449	8.47	-4.82
900	240.97	19.7	55.3	527	8.05	-6.08
930	249.00	19.6	49.9	477	7.75	-6.48
960	257.03	21.4	49.7	483	7.64	-5.90
990	265.06	22.8	47.6	471	7.44	-5.67
1020	273.10	24.9	46.5	471	7.23	-5.34

Subtotals	337.13	69.73
Total		406.86
Resin Capacity (meq/mL)		1.31

Table A.3. - Regeneration #2 data.

Elapsed Time (min)	Bed Volumes	Concentration Ca (mg/L)	Mg (mg/L)	Na (mg/L)
0	0	2.61	2.58	2330
30	2.03	22.8	2.76	1220
60	4.06	20	3.39	728
90	6.10	658	161	1300
120	8.13	605	177	1340
150	10.16	613	179	1350
180	12.19	550	161	1460
210	14.23	482	140	1550
240	16.26	406	121	1720
270	18.29	373	108	1760
300	20.32	337	95.3	1810
330	22.35	304	85.2	1860
360	24.39	267	73.4	1900
390	26.42	242	66.6	1950
420	28.45	237	64.4	1980
450	30.48	222	58.4	1910
480	32.52	217	57.3	2080
510	3455	188	49.6	2090
540	36.58	189	48.4	2020
570	38.61	175	45.5	2080

Table A.4. - Exhaustion #3 data

Elapsed Time (min)	Bed Volumes	Concentration Ca (mg/L)	Mg (mg/L)	Na (mg/L)	Ca (sum meq)	Mg (sum meq)
0	0	77.1	19.9	479		
30	8.03	0.78	0.3	578	10.09	4.24
60	16.06	0.82	0.33	580	10.09	4.24
90	24.10	0.81	0.33	579	10.09	4.24
120	32.13	0.81	0.34	585	10.09	4.24
150	40.16	0.87	0.36	563	10.08	4.23
I80	48.19	0.85	0.36	575	10.08	4.23
210	56.23	0.86	0.35	564	10.06	4.23
240	6426	1.02	0.43	664	10.07	4.22
270	72.29	1.01	0.45	676	10.06	4.21
300	80.32	0.95	0.43	605	10.07	4.21
330	68.35	0.97	0.44	617	10.07	4.21
360	96.39	0.97	0.44	608	10.07	4.21
390	104.42	0.98	0.46	617	10.07	4.21
420	112.45	1.04	0.53	606	10.06	4.20
450	120.48	1.24	0.75	597	10.05	4.17
480	126.52	2.09	1.72	591	9.98	4.05
510	136.55	4.24	4.22	626	9.80	3.70
540	144.58	7.74	8.72	626	9.44	2.98
570	152.61	12.4	15.4	572	8.94	1.63
600	160.65	21.2	27.1	547	8.10	-0.05
630	168.68	32.1	38.6	511	6.88	-2.43
660	176.71	38.1	40.3	490	5.83	-3.78
690	18474	42.1	39.8	496	5.21	-3.90
720	192.77	45.1	38.3	489	4.77	-3.70
750	200.81	48.4	36.5	482	4.38	-3.36
780	208.64	49.6	35	490	4.10	-3.02
810	216.87	54.2	349	516	3.74	-2.86
840	224.90	55.6	32.4	496	3.37	-2.59
870	232.94	59.2	31.7	514	3.06	-2.26
900	240.97	61.2	29.7	496	2.71	-1.99
930	249.00	62.7	28.6	507	2.49	-1.67
		Subtotals			243.92	44.24
		Total				286.16
		Resin Capacity (meq/mL)				0.93

Table A.5. - Regeneration # 3 data.

Elapsed Time (min)	Volumes	Concentration Ca (mg/L)	Mg (mg/L)	Na (mg/L)
0	0	2.54	2.46	2410
30	2.03	1.76	0.22	9.8
60	4.06	741	187	1340
90	6.10	739	18.3	1370
120	8.13	662	166	1550
150	10.16	520	120	1720
180	12.19	504	116	1760
210	14.23	459	103	1880
240	16.26	413	89.7	1910
270	18.29	363	74.9	1930
300	20.32	310	61.3	1880
330	22.35	288	54.3	1940
360	24.39	275	50.4	2020
390	26.42	248	44.5	2010
420	28.45	231	40.5	2050
450	30.48	218	36.9	2020
480	32.52	206	33.8	2020
510	34.55	195	31.4	2030
540	36.58	179	28	1970

Table A.6. - Exhaustion #4 data

Elapsed Time (min)	Bed Volumes	Concentration Ca (mg/L)	Mg (mg/L)	Na (mg/L)	Ca (sum meq)	Mg (sum meq)
0	0	78	20.1	471		
30	8.03	0.91	0.16	561	10.08	4.27
60	16.06	0.99	0.18	577	10.07	4.27
90	24.10	0.98	0.16	566	10.07	4.27
120	32.13	0.99	0.18	562	10.07	4.27
150	40.16	I.02	0.18	565	10.06	4.27
180	48.19	1	0.17	571	10.06	4.27
210	56.23	1	0.16	569	10.06	4.27
240	6426	I.06	0.19	579	10.06	4.27
270	72.29	1.06	0.21	576	10.06	4.26
300	80.32	I.08	0.19	577	10.06	4.26
330	86.35	1.05	0.17	567	10.06	4.27
360	96.39	1.08	0.2	565	10.06	4.27
390	10442	1.12	0.2	570	10.05	4.26
420	112.45	1.22	0.28	558	10.04	4.25
450	120.48	1.51	0.47	559	10.02	4.23
480	128.52	2.42	1.05	567	9.94	4.15
510	136.55	4.85	2.64	547	9.74	3.93
540	144.58	9.03	5.66	567	9.33	3.45
570	152.61	17	11.4	554	8.57	2.56
600	160.65	33.7	22.7	516	7.04	0.81
630	168.68	49.8	30.4	482	5.00	-1.14
660	176.71	58.6	30.8	467	3.45	-1.97
690	16474	63.7	29.2	468	2.59	-1.84
720	192.77	65.9	27.7	473	2.14	-1.53
750	200.81	67.9	26.3	487	1.86	-1.23
780	208.84	70.2	24.8	463	1.61	-0.93
810	216.67	72.2	24.1	482	1.34	-0.71
840	224.90	73.6	23.3	481	1.13	-0.55
870	232.94	74.6	22.6	483	0.98	-0.40
900	240.97	75.5	22.1	486	0.86	-0.26
930	249.00	76.4	21.7	485	0.75	-0.18
960	257.03	79.5	21.9	496	0.50	-0.16
990	265.06	79.3	21.6	498	0.32	-0.15
1020	273.10	77.6	20.9	465	0.43	-0.05

Subtotals	218.48	67.74
Total		286.22
Resin Capacity (meq/mL)		0.92

APPENDIX B

FilmTec BW-30 Element Test Data

Filmtec BW-30 Element Test Data

		Elapsed	Flowrate			Conductivity				Pressure			pH			Temperature			Turbidity
Date	Time	Time (hours)	Feed (L/min)	Reject (L/min)	Permeate (L/min)	Feed (uS/cm)	Interstage (uS/cm)	Reject (uS/cm)	Permeate (uS/cm)	Feed (kPa)	Interstage (kPa)	Reject (kPa)	Raw Feed	RO Feed	Reject	Raw Feed (deg C)	RO Feed (deg C)	Ambient (deg C)	Filter Effl. (ntu)
06/07/93	11:47	1.2	21.1	5.7	16.8	1488	2598	5489	12.0	1224	1100	980	8.2	7.0	6.9	25.1	24.9	-	0.044
06/07/93	14:00	3.4	21.2	5.9	16.9	1489	3078	5489	13.0	1223	1100	980	8.1	7.0	6.0	25.4	25.4	-	0.034
06/07/93	15:30	4.9	21.1	5.7	17.0	1490	3128	5279	13.0	1224	1102	986	8.1	7.0	5.8	25.5	25.7	-	0.033
06/07/93	16:00	5.4	20.9	5.7	17.0	1491	3138	5799	14.0	1224	1102	986	8.1	6.9	5.8	25.6	25.8	-	0.032
06/08/93	09:00	13.2	22.7	5.7	18.5	1544	3338	6449	17.2	1342	1201	1072	8.2	6.9	5.4	26.0	25.8	-	0.029
06/08/93	11:00	15.2	22.7	5.7	18.5	1532	3358	6549	16.3	1342	1201	1071	8.3	7.0	5.3	26.1	26.0	-	0.027
06/08/93	14:00	18.2	22.5	5.7	18.1	1527	3328	6449	15.7	1271	1137	1013	8.2	6.9	5.3	26.9	27.3	-	0.027
06/08/93	16:00	20.2	22.7	5.7	18.3	1530	3328	6429	15.6	1269	1135	1010	8.2	6.9	5.4	27.4	27.8	-	0.027
06/09/93	09:30	24.2	22.7	5.7	18.2	1557	3418	6509	16.6	1273	1139	1015	8.3	7.0	5.4	27.3	27.3	-	0.025
06/09/93	11:00	25.7	22.7	5.7	18.4	1552	3428	6579	16.3	1269	1135	1010	8.2	7.0	5.4	27.8	28.1	-	0.024
06/09/93	16:30	30.2	22.8	5.8	18.4	1550	3388	6459	15.8	1237	1103	977	8.1	7.0	5.5	28.5	29.2	-	0.027
06/09/93	17:30	31.2	23.1	5.8	18.5	1559	3398	6479	15.5	1237	1102	977	8.1	7.0	5.6	28.9	29.6	-	0.023
06/10/93	08:30	35.6	22.7	5.8	18.2	1558	3408	6429	16.4	1239	1105	981	8.2	7.0	5.5	28.9	28.8	-	0.024
06/10/93	10:30	37.6	22.8	5.8	18.4	1550	3408	6499	16.2	1239	1103	978	8.2	7.0	5.4	29.0	29.5	-	0.024
06/10/93	14:00	41.1	22.8	5.8	18.9	1556	3428	6569	15.5	1234	1096	970	8.1	7.0	5.4	29.9	30.6	-	0.024
06/10/93	16:00	43.1	22.9	5.8	19.0	1560	3438	6519	15.4	1232	1096	968	8.1	7.0	5.4	30.2	30.9	-	0.024
06/11/93	10:18	48.4	22.9	5.8	18.7	1544	3378	6529	16.1	1237	1099	971	8.2	7.0	5.7	29.2	29.4	30.4	0.024
06/11/93	13:00	51.1	23.2	5.8	19.1	1549	3408	6599	15.9	1232	1092	964	8.2	7.0	5.7	29.9	30.4	35.8	0.024
06/11/93	15:00	53.1	23.3	5.8	19.2	1550	3408	6619	15.9	1231	1090	962	8.2	7.0	5.7	30.2	30.7	36.5	0.024
06/11/93	16:46	54.9	23.7	5.7	19.1	1557	3428	6669	16.2	1231	1090	962	8.2	7.0	5.7	30.4	30.8	38.5	0.024
06/14/93	10:30	58.9	22.7	5.8	18.8	1523	3358	6739	16.1	1191	1053	926	8.3	7.0	6.7	29.1	29.3	-	0.033
06/14/93	13:00	61.4	22.7	5.7	18.4	1529	3328	6409	16.3	1139	1008	884	8.2	7.0	6.4	30.1	30.8	34.5	0.028
06/14/93	14:30	62.9	22.7	5.7	18.7	1530	3358	6489	16.2	1136	1002	879	8.2	7.0	6.4	30.5	31.5	36.5	0.028
06/14/93	16:00	64.4	22.7	5.7	18.8	1538	3378	6509	16.9	1139	1002	880	8.2	7.0	6.5	30.8	31.6	35.0	0.027
06/15/93	11:00	67.7	22.7	5.7	18.5	1547	3368	6519	17.1	1151	1017	892	8.4	7.0	6.0	29.1	29.6	28.0	0.026
06/15/93	14:00	70.7	22.7	5.7	18.4	1552	3408	6579	16.6	1121	989	864	8.3	7.1	6.0	30.0	30.8	35.0	0.025
06/15/93	16:00	72.7	22.9	5.7	18.7	1559	3398	6509	16.8	1119	985	860	8.3	7.0	6.3	30.1	31.5	36.0	0.024
06/16/93	11:30	78.8	22.7	5.8	18.5	1529	3328	6369	17.0	1133	995	869	8.2	7.0	5.8	29.0	29.1	28.5	0.023
06/16/93	14:00	81.3	22.7	5.8	18.7	1530	3318	6309	16.7	1133	995	868	8.2	7.0	5.8	29.7	30.4	32.0	0.023
06/16/93	16:30	83.8	22.8	5.8	18.6	1540	3348	5859	17.0	1132	995	869	8.2	7.0	5.8	30.1	30.6	30.0	0.023
06/17/93	14:00	90.8	22.7	5.8	18.4	1538	3298	6219	12.2	1136	1000	869	8.3	7.0	7.3	29.0	29.4	32.0	0.042
06/17/93	16:00	92.8	22.6	5.7	18.9	1552	3318	6089	12.0	1135	1001	881	8.3	7.0	7.3	29.4	30.0	31.5	0.037
06/18/93	09:30	101.5	22.4	5.6	18.1	1562	3428	6619	17.4	1139	1007	886	8.4	7.0	6.5	28.5	28.6	28.1	0.031
06/18/93	11:30	103.5	22.8	5.8	18.4	1554	3408	6659	16.7	1135	1001	880	8.4	7.0	6.4	28.9	29.6	34.1	0.033
06/18/93	14:00	106.0	23.2	5.7	19.0	1562	3448	6739	16.8	1131	997	875	8.3	7.0	6.4	29.6	30.4	36.0	0.025
06/18/93	17:00	109.0	23.4	5.7	19.0	1569	3478	6849	17.1	1129	994	872	8.3	7.0	6.7	30.3	31.1	37.0	-
06/21/93	09:00	113.2	22.7	5.8	18.5	1555	3388	6329	12.5	1202	1066	946	8.3	7.0	7.5	28.9	28.9	21.0	0.037
06/21/93	11:00	115.2	23.0	5.7	18.7	1549	3458	6649	16.2	1200	1063	943	8.3	7.0	7.4	29.1	29.4	26.0	0.035
06/22/93	10:30	124.3	22.7	5.9	18.4	1541	3318	6229	16.2	1231	1093	962	8.4	7.0	7.5	27.5	27.4	20.0	0.027
06/22/93	13:00	126.8	22.7	5.9	18.4	1536	3308	6309	15.9	1227	1088	957	8.4	7.0	7.4	27.9	28.2	26.0	0.025
06/22/93	14:30	128.3	23.4	5.9	18.7	1530	3308	6299	15.8	1226	1085	953	8.4	7.0	7.2	28.2	28.7	28.5	0.025
06/22/93	16:00	129.8	23.4	5.9	18.8	1536	3308	6299	15.7	1226	1089	956	8.4	7.0	7.2	28.4	28.9	30.0	0.025
06/23/93	08:30	135.4	22.8	5.9	18.1	1558	3378	6299	16.1	1221	1083	954	8.5	7.0	7.6	27.9	27.9	19.0	0.026
06/23/93	12:00	138.9	22.8	5.9	18.4	1551	3308	6209	16.1	1183	1047	918	8.4	7.0	7.4	28.5	29.1	29.0	0.025
06/23/93	14:00	140.9	22.7	5.9	18.2	1551	3328	6249	15.8	1158	1025	899	8.4	7.0	7.4	29.0	29.8	33.0	0.025
06/23/93	15:30	142.4	22.7	5.8	18.3	1552	3318	6229	15.8	1155	1020	891	8.4	7.0	7.4	29.5	30.4	36.0	0.025
06/24/93	09:00	147.6	22.7	5.9	18.0	1539	3268	6089	16.0	1157	1023	893	8.4	7.0	7.6	29.0	29.2	22.0	0.025
06/24/93	10:30	149.1	22.8	5.9	18.2	1535	3248	6109	15.9	1156	1020	890	8.4	7.0	7.5	29.2	29.7	28.0	0.025
06/24/93	14:30	153.1	23.6	5.9	19.2	1540	3298	6189	15.7	1150	1010	879	8.3	7.0	7.4	30.5	31.7	38.0	0.024
06/24/93	16:00	154.6	22.9	5.9	18.5	1546	3278	6059	15.9	1113	980	851	8.3	7.1	7.4	31.1	32.1	40.0	0.024
06/25/93	08:00	158.4	22.7	5.9	18.1	1566	3328	6199	18.3	1151	1016	885	8.4	7.0	7.6	29.7	29.8	21.0	0.026
06/25/93	11:00	161.4	23.1	5.9	18.7	1548	3288	6199	18.3	1121	987	858	8.4	7.1	7.5	30.2	30.9	32.0	0.024
06/25/93	13:30	163.9	23.0	5.9	18.7	1556	3328	6289	16.6	1117	979	850	8.3	7.0	7.5	31.0	32.3	39.0	0.024
06/28/93	09:00	179.3	22.7	5.9	18.6	1551	3178	3829	15.7	1137	999	871	8.3	7.0	7.6	30.1	30.1	23.0	0.041
06/28/93	11:30	181.8	22.6	5.9	18.3	1550	3358	6469	16.9	1092	959	834	8.3	7.0	7.4	30.8	31.2	28.0	0.038
06/28/93	14:30	184.8	22.8	5.9	18.6	1555	3358	6389	18.1	1087	950	822	8.3	7.1	7.4	31.5	32.2	35.0	0.038
06/28/93	16:00	186.3	22.7	5.9	18.4	1559	3348	6219	18.5	1064	933	810	8.3	7.0	7.3	31.9	23.6	35.0	0.037
06/29/93	11:30	190.0	22.5	5.9	18.2	1537	3228	5509	18.1	1122	985	853	8.4	7.1	7.5	29.4	29.7	31.0	0.033
06/29/93	13:30	192.0	22.6	5.9	18.2	1542	3278	5789	17.5	1092	957	827	8.4	7.0	7.3	30.0	30.8	34.5	0.033
06/29/93	15:30	194.0	22.8	5.9	18.2	1547	3268	6259	18.1	1091	955	824	8.4	7.0	7.3	30.4	31.3	35.0	0.028
06/29/93	16:00	194.5	22.8	5.9	18.2	1549	3278	6259	18.4	1091	955	825	8.4	7.0	7.3	30.5	31.2	34.0	0.028
06/30/93	08:30	201.1	22.5	5.9	18.2	1559	3358	6539	18.2	1158	1018	885	8.5	7.0	7.4	29.1	28.7	20.0	0.028
06/30/93	10:30	203.1	22.5	5.9	18.2	1543	3278	6329	17.9	1126	989	858	8.5	7.0	7.3	29.4	29.7	25.0	0.026
06/30/93	14:00	206.6	22.6	6.3	18.2	1543	3198	6079	17.0	1081	941	800	8.5	7.0	7.3	30.4	31.2	35.0	0.026
06/30/93	16:00	208.6	22.6	6.3	18.2	1548	3188	5979	17.7	1080	939	799	8.5	7.0	7.3	30.8	31.6	35.0	0.027
07/01/93	09:00	213.0	23.2	6.3	18.2	1548	3228	6069	17.6	1165	1020	877	8.5	7.0	7.4	28.4	28.5	22.0	0.026
07/01/93	14:30	218.5	23.2	6.3	18.2	1529	3198	6089	16.9	1073	933	792	8.5	7.0	7.3	30.8	31.7	34.0	0.026
07/02/93	09:00	226.4	23.4	6.3	18.2	1547	3248	6149	16.9	1144	1000	857	8.4	7.0	7.5	29.0	28.8	21.0	0.027
07/02/93	11:00	228.4	22.7	5.7	17.0	1538	3158	5939	16.9	1129	985	840	8.5	7.0	7.3	29.2	29.5	28.0	0.026

Filmtec BW-30 Element Test Data - Continued

Date	Time	Elapsed Time (hours)	Flowrate Feed (L/min)	Flowrate Reject (L/min)	Permeate (L/min)	Conductivity Feed (uS/cm)	Conductivity Interstage (uS/cm)	Conductivity Reject (uS/cm)	Conductivity Permeate (uS/cm)	Pressure Feed (kPa)	Pressure Interstage (kPa)	Pressure Reject (kPa)	pH Raw Feed	pH RO Feed	pH Reject	Temperature Raw Feed (deg C)	Temperature RO Feed (deg C)	Temperature Ambient (deg C)	Turbidity Filter Eff. (ntu)
07/02/93	13.30	230.9	22.7	5.7	17.0	1537	3198	6029	17.0	1108	965	822	8.5	7.0	7.3	29.7	30.3	32.0	0.026
07/02/93	16.00	233.4	22.7	5.7	17.0	1540	3168	5949	17.3	1095	954	812	8.5	7.0	7.3	30.2	30.8	32.0	0.029
07/06/93	10.00	238.4	22.7	5.7	17.0	1524	3178	6059	12.9	1179	1036	896	8.7	7.0	7.4	26.9	26.9	23.0	0.034
07/06/93	11.30	239.9	22.7	5.7	17.0	1524	3188	6099	15.2	1147	1007	868	8.7	6.9	7.3	27.4	27.7	28.0	0.031
07/06/93	15.00	243.4	22.8	5.7	17.0	1524	3218	6019	16.7	1100	962	825	8.7	7.0	7.2	28.9	29.6	34.0	0.029
07/06/93	16.00	244.4	22.7	5.7	17.0	1528	3198	6039	16.3	1090	950	811	8.8	7.0	7.2	30.9	31.1	34.0	0.028
07/07/93	09.00	245.4	22.7	5.7	17.0	1532	3198	6009	16.2	1171	1025	882	8.6	7.0	7.6	25.0	26.2	21.0	0.030
07/07/93	11.00	247.4	22.7	5.7	17.0	1529	3178	5969	15.8	1165	1019	877	8.6	7.0	7.6	27.7	27.7	23.0	0.029
07/07/93	13.30	249.9	22.7	5.7	17.0	1517	3088	5819	15.6	1122	979	834	8.6	7.0	7.4	28.3	28.9	32.0	0.028
07/07/93	16.30	252.9	22.7	5.7	17.0	1521	3128	5899	15.7	1102	960	817	8.6	7.0	7.4	29.1	29.9	34.5	0.026
07/08/93	09.00	256.6	22.7	5.7	17.0	1537	3128	5749	16.5	1150	1005	860	8.6	7.0	7.4	28.2	28.1	22.0	0.028
07/08/93	10.30	258.1	22.7	5.7	17.0	1531	3178	5979	16.0	1135	991	847	8.6	7.0	7.5	28.4	28.5	25.0	0.028
07/08/93	15.00	262.6	22.7	5.7	17.0	1523	3128	5889	15.9	1089	948	805	8.6	7.0	7.4	30.4	30.4	33.0	0.027
07/08/93	16.30	264.1	22.7	5.7	17.0	1521	3148	5959	15.9	1068	927	785	8.6	7.0	7.4	30.4	31.1	33.0	0.027
07/09/93	09.30	271.5	22.7	5.7	17.0	1540	3188	5969	15.9	1147	1000	855	8.6	7.1	7.6	28.5	28.2	20.0	0.027
07/09/93	11.30	273.5	22.7	5.7	16.9	1525	3148	5939	15.8	1118	974	831	8.6	7.0	7.5	28.7	28.0	28.0	0.026
07/09/93	13.30	275.5	22.8	5.7	17.0	1525	3138	5969	15.8	1100	957	815	8.6	7.0	7.4	29.2	29.8	33.5	0.026
07/09/93	15.00	277.0	22.5	5.6	17.0	1522	3178	6029	16.1	1064	926	788	8.6	7.1	7.4	30.2	31.0	35.0	0.026
07/12/93	15.00	288.5	22.7	5.7	17.0	1531	2668	5619	10.8	1206	1065	924	8.7	7.1	7.3	29.3	29.8	32.0	0.042
07/12/93	16.00	289.5	22.7	5.7	17.0	1537	3178	5839	10.9	1181	1044	908	8.7	7.0	7.3	29.7	30.2	32.0	0.045
07/13/93	09.30	298.7	22.7	5.7	17.0	1538	3199	5150	18.4	1283	1139	999	8.7	7.0	7.4	27.6	27.3	17.0	0.032
07/13/93	11.00	300.2	22.7	5.7	17.0	1515	3195	5910	20.6	1282	1138	999	8.7	7.0	7.4	27.6	27.5	21.0	0.031
07/13/93	15.00	304.2	22.7	5.7	17.0	1500	3153	5970	20.9	1236	1094	952	8.7	7.0	7.2	28.3	28.7	30.0	0.029
07/13/93	16.00	305.2	23.2	5.7	17.0	1506	3153	5980	21.1	1236	1094	950	8.7	7.0	7.3	28.4	28.8	30.1	0.030
07/14/93	09.00	307.2	22.7	5.7	17.0	1525	2988	5390	20.0	1382	1234	1087	8.7	7.0	7.4	26.8	25.4	17.0	0.028
07/14/93	10.30	308.7	22.7	5.7	17.0	1515	3181	6040	20.9	1291	1146	1002	8.7	6.9	7.4	26.9	26.8	21.0	0.027
07/14/93	11.30	309.7	22.7	5.7	17.0	1509	3178	6040	20.8	1290	1144	1000	8.7	7.0	7.4	27.1	27.1	23.0	0.027
07/15/93	09.30	321.9	22.7	5.7	17.0	1507	3183	5980	21.0	1288	1144	1001	8.8	7.0	7.5	27.1	26.9	20.0	0.027
07/15/93	11.30	323.9	23.1	5.7	17.3	1498	3179	6010	20.7	1284	1139	995	8.8	7.0	7.4	27.4	27.6	26.0	0.027
07/15/93	13.30	325.9	22.8	5.6	17.0	1496	3256	6020	20.6	1243	1102	963	8.8	7.0	7.4	27.6	28.2	29.5	0.027
07/15/93	15.30	327.9	22.6	5.6	17.0	1498	3178	6020	21.0	1223	1083	946	8.8	7.0	7.2	28.3	28.9	31.0	0.027
07/16/93	08.30	332.7	22.9	5.7	17.0	1503	3174	5950	21.4	1282	1137	993	8.7	7.0	7.5	27.3	27.3	16.0	0.027
07/16/93	10.30	334.7	22.8	5.6	17.0	1501	3170	5930	21.1	1282	1137	993	8.7	7.0	7.4	27.1	26.9	18.0	0.027
07/16/93	13.30	337.7	22.8	5.6	17.0	1490	3156	5940	20.6	1267	1123	981	8.8	7.0	7.3	27.4	27.4	25.0	0.026
07/16/93	15.30	339.7	23.1	5.7	17.2	1480	3135	5820	20.6	1252	1108	962	8.8	7.0	7.2	27.7	28.1	29.0	0.026
07/19/93	11.30	343.7	22.5	5.7	17.0	1454	3093	5200	13.2	1311	1166	1022	8.2	7.0	7.4	24.3	24.5	24.5	0.046
07/19/93	13.30	345.7	22.6	5.7	17.0	1466	3139	6060	16.7	1281	1139	1000	8.2	6.9	7.4	25.1	25.6	30.0	0.035
07/19/93	16.00	348.2	22.7	5.7	17.0	1470	3156	5970	17.8	1259	1118	978	8.1	6.9	7.3	25.7	26.4	31.0	0.033
07/20/73	09.00	354.6	23.0	5.7	17.3	1515	3209	6000	18.9	1318	1168	1022	8.0	6.9	7.5	27.9	26.1	18.0	0.032
07/20/73	11.30	357.1	22.7	5.7	17.0	1486	3173	5900	19.9	1209	1065	923	8.1	6.9	7.5	28.0	28.0	23.0	0.032
07/20/73	13.30	359.1	22.7	5.7	17.0	1479	3157	5920	19.5	1188	1046	905	8.1	6.9	7.4	28.3	28.7	28.5	0.030
07/20/73	16.00	361.6	22.7	5.7	17.0	1494	3197	6080	20.0	1146	1007	867	8.1	6.9	7.3	29.5	30.0	31.0	0.029
07/21/93	11.30	370.3	22.8	5.7	17.0	1477	3144	5910	18.0	1324	1176	1028	8.0	6.9	7.5	24.5	24.8	22.0	0.028
07/21/93	14.00	372.8	23.0	5.7	17.2	1472	3148	6000	17.9	1320	1172	1024	8.2	6.9	7.4	25.0	25.3	26.0	0.028
07/21/93	15.30	374.3	23.0	5.7	17.0	1472	3145	5990	18.1	1294	1149	1004	8.2	6.9	7.3	25.3	25.7	28.0	0.028
07/21/93	16.30	375.3	22.9	5.7	17.0	1478	3139	5960	18.5	1277	1132	987	8.2	6.9	7.2	25.5	26.0	28.0	0.028
07/22/93	09.30	381.6	22.8	5.7	17.0	1475	3155	6030	18.0	1398	1249	1101	8.3	6.9	7.5	23.0	23.1	19.0	0.028
07/22/93	11.00	383.1	22.7	5.7	17.0	1473	3155	6050	18.0	1387	1238	1090	8.3	6.9	7.4	23.0	23.2	21.5	0.028
07/23/93	11.00	389.8	23.0	5.7	17.0	1501	3193	6010	19.6	1242	1097	952	8.1	7.0	7.5	27.4	27.3	22.5	0.029
07/23/93	13.00	391.8	23.2	5.7	17.2	1495	3194	6030	19.4	1240	1094	949	8.1	6.9	7.5	27.6	27.7	26.0	0.029
07/23/93	15.30	394.3	22.7	5.7	17.0	1495	3167	5970	19.4	1202	1060	917	8.1	6.9	7.3	28.0	28.5	30.5	0.029
07/23/93	16.30	395.3	22.7	5.7	17.0	1499	3180	6000	19.5	1198	1057	913	8.1	6.9	7.3	28.2	28.6	30.5	0.028
07/26/93	11.30	398.7	22.7	5.7	17.0	1340	2629	5240	13.3	1258	1107	957	8.2	7.0	7.4	25.3	25.4	24.0	0.049
07/26/93	16.00	401.2	22.5	5.7	17.0	1350	2950	5660	16.0	1221	1082	945	8.2	6.9	7.3	26.3	26.7	30.0	0.041
07/27/93	11.00	410.0	22.8	5.7	17.0	1332	2900	5420	17.1	1308	1160	1013	8.3	6.9	7.4	24.4	24.5	23.0	0.033
07/27/93	13.00	412.0	22.7	5.7	17.0	1330	2908	5510	17.1	1273	1127	984	8.3	6.9	7.4	25.3	25.6	27.0	0.033
07/27/93	16.00	415.0	22.6	5.7	17.0	1330	2898	5500	17.6	1238	1096	953	8.3	6.9	7.3	26.1	26.6	28.5	0.034
07/28/93	14.00	417.8	22.9	5.7	17.0	1446	3173	6010	19.0	1179	1037	896	8.1	7.0	7.5	28.4	28.6	28.0	0.031
07/28/93	15.30	419.3	22.9	5.7	17.0	1443	3105	5740	19.7	1179	1036	895	8.2	6.9	7.3	28.4	28.9	30.0	0.030
07/28/93	16.30	420.3	22.8	5.7	17.0	1448	3111	5770	19.5	1170	1027	890	8.2	7.0	7.3	28.6	29.1	31.0	0.030
07/29/93	11.00	429.4	22.8	5.7	17.0	1437	3111	5870	18.5	1253	1109	967	8.2	7.0	7.4	26.4	26.8	24.5	0.033
07/29/93	13.00	431.4	22.7	5.7	17.0	1437	3108	5890	18.4	1226	1085	946	8.3	6.9	7.4	26.9	27.2	29.5	0.030
07/29/93	15.30	433.9	22.8	5.7	17.0	1434	3108	5880	18.3	1204	1063	975	8.3	6.9	7.3	27.5	28.1	33.0	0.029
07/29/93	17.00	435.4	22.7	5.7	17.0	1441	3102	5850	18.8	1187	1045	906	8.3	6.9	7.3	27.7	28.5	33.0	0.029
07/30/93	11.30	444.8	22.8	5.7	16.9	1470	3151	5860	18.9	1187	1046	905	8.2	7.0	7.4	27.9	28.4	30.0	0.035
07/30/93	13.00	446.3	22.7	5.7	17.0	1475	3073	5840	18.8	1178	1037	854	8.2	7.0	7.4	28.3	29.0	35.0	0.030
07/30/93	15.00	448.3	22.7	5.7	17.0	1472	3145	5840	18.9	1150	1012	872	8.2	7.0	7.3	28.9	29.9	37.0	0.030
07/30/93	16.30	449.8	22.7	5.7	17.0	1482	3158	5850	19.1	1144	1005	865	8.2	7.0	7.3	29.3	30.3	37.0	0.030
08/02/93	10.30	454.9	22.4	5.7	17.0	1009	2324	3949	9.7	1138	998	856	8.1	7.0	7.5	29.2	29.7	32.0	0.049

Filmtec BW-30 Element Test Data - Continued

Date	Time	Elapsed Time (hours)	Flowrate Feed (L/min)	Flowrate Reject (L/min)	Flowrate Permeate (L/min)	Conductivity Feed (uS/cm)	Conductivity Interstage (uS/cm)	Conductivity Reject (uS/cm)	Conductivity Permeate (uS/cm)	Pressure Feed (kPa)	Pressure Interstage (kPa)	Pressure Reject (kPa)	pH Raw Feed	pH RO Feed	pH Reject	Temperature Raw Feed (deg C)	Temperature RO Feed (deg C)	Temperature Ambient (deg C)	Turbidity Filter Effl. (ntu)
08/02/93	11:30	455.9	22.2	5.7	17.0	1020	2345	3742	11.2	1106	971	837	8.1	7.0	7.3	29.5	30.2	38.0	0.035
08/02/93	13:30	457.9	22.7	5.7	17.0	1025	2350	4520	11.5	1083	948	813	8.1	7.0	7.4	30.1	31.1	38.0	0.035
08/02/93	16:00	460.4	22.8	5.7	17.0	1030	2366	4160	13.5	1083	946	810	8.1	7.0	7.3	30.7	31.6	36.0	0.036
08/03/93	14:00	465.9	22.9	5.7	17.0	993	2000	4260	13.9	1125	981	833	8.2	7.1	7.4	29.2	30.0	37.0	0.033
08/03/93	16:00	467.9	22.9	5.7	17.0	996	2270	4340	15.3	1106	964	820	8.2	6.9	7.3	30.0	30.8	36.0	0.032
08/04/93	11:00	473.6	22.9	5.7	17.0	1375	2930	4790	18.2	1142	1002	860	8.1	7.1	7.4	29.9	30.6	32.0	0.040
08/04/93	13:30	476.1	22.8	5.7	17.0	1378	2969	4670	18.0	1124	986	846	8.1	7.0	7.4	30.3	31.3	37.5	0.033
08/04/93	15:00	477.6	22.9	5.7	17.0	1380	2971	4490	18.5	1111	974	835	8.1	7.0	7.4	30.8	31.8	38.0	0.033
08/04/93	16:00	478.6	22.9	5.7	17.0	1386	2980	4610	19.1	1111	974	835	8.1	7.0	7.4	31.0	37.9	36.5	0.033
08/05/93	14:30	484.1	22.9	5.7	17.0	1347	2913	4560	17.6	1110	972	832	8.1	7.1	7.4	30.4	31.5	38.0	0.035
08/05/93	15:30	485.1	22.9	5.7	17.0	1359	2921	4800	19.4	1110	972	833	8.1	7.0	7.3	30.8	31.6	39.0	0.032
08/06/92	08:30	494.8	22.7	5.8	17.0	1453	3135	5230	19.6	1185	1044	900	8.0	7.0	7.5	29.6	29.7	24.0	0.033
08/06/92	10:30	496.8	22.9	5.7	17.0	1455	3124	5260	20.0	1175	1034	892	8.1	7.0	7.4	29.7	30.1	31.0	0.036
08/06/92	14:00	500.3	22.8	5.7	17.0	1467	3109	4770	19.2	1127	988	848	8.1	7.0	7.4	30.7	31.6	39.0	0.031
08/06/92	16.00	502.3	22.9	5.7	17.0	1468	3129	5720	19.7	1112	975	836	8.1	7.0	7.0	31.5	32.1	38.0	0.031
08/09/93	09:30	508.9	22.7	5.7	17.0	1429	3078	5780	17.7	1242	1097	952	8.1	7.0	7.4	27.1	27.3	25.0	0.035
08/09/93	11:30	510.9	22.6	5.7	17.0	1429	3074	5820	18.6	1231	1088	944	8.2	7.0	7.4	27.2	27.7	29.5	0.030
08/09/93	14:30	513.9	22.7	5.7	17.0	1438	3085	5860	17.8	1203	1062	920	8.3	7.1	7.5	27.8	28.6	34.0	0.030
08/09/93	16:00	515.4	22.4	5.7	17.0	1443	3075	5810	18.1	1191	1051	908	8.2	7.1	7.4	28.3	29.1	34.5	0.030
08/10/93	14:30	520.0	22.3	5.7	17.0	1500	3211	5810	14.3	1219	1084	947	8.0	7.0	7.5	30.1	30.8	35.0	0.044
08/10/93	15:30	521.0	22.2	5.7	17.0	1515	3190	5640	14.9	1211	1037	940	8.0	7.1	7.5	30.3	30.7	35.0	0.047
08/11/93	09:14	530.0	22.0	5.7	17.0	1470	3169	5340	15.2	1350	1210	1072	8.1	7.0	7.5	27.7	26.3	22.0	0.037
08/11/93	14:00	534.8	22.6	5.7	17.0	1479	3147	5910	17.6	1227	1089	950	8.1	7.1	7.6	28.8	29.6	35.5	0.033
08/11/93	15:00	535.8	22.7	5.7	17.0	1481	3148	5810	18.7	1221	1084	949	8.2	7.0	7.5	29.0	29.7	35.0	0.032
08/11/93	16:00	536.8	22.6	5.7	17.0	1488	3170	5960	18.7	1214	1078	942	8.2	7.1	7.5	30.0	30.0	35.0	0.031
08/12/93	12:00	548.5	22.7	5.7	17.0	1493	3188	5820	19.5	1237	1096	956	8.0	7.0	7.6	28.8	29.2	29.0	0.044
08/12/93	13:30	550.0	22.7	5.7	17.0	1493	3181	5800	19.4	1230	1089	947	8.0	7.1	7.5	28.9	29.4	31.0	0.036
08/12/93	15:00	551.5	22.6	5.7	17.0	1490	3167	5690	19.2	1210	1069	930	8.1	7.0	7.5	29.3	29.9	32.0	0.033
08/12/93	16:00	552.5	22.7	5.7	17.0	1496	3175	5630	20.0	1208	1068	928	8.1	7.1	7.5	29.6	30.0	30.5	0.033
08/13/93	09:30	559.1	22.9	5.7	17.0	1464	3155	5830	17.4	1371	1224	1077	8.0	7.0	7.5	25.4	25.3	21.0	0.037
08/13/93	11:30	561.1	22.7	5.7	17.0	1463	3139	5820	17.9	1349	1204	1057	8.1	7.0	7.5	25.6	25.6	22.0	0.036
08/13/93	14:00	563.6	22.7	5.7	17.0	1468	3147	5860	17.7	1319	1175	1029	8.1	7.0	7.5	26.1	26.3	28.0	0.032
08/13/93	16:00	565.6	22.7	5.7	17.0	1471	3124	5730	17.8	1300	1158	1013	8.1	7.0	7.5	26.5	26.9	29.0	0.031
08/16/93	14:00	569.7	22.6	5.7	17.0	1458	3102	5720	11.9	1340	1200	1058	8.2	7.0	7.6	23.6	24.1	29.0	0.073
08/16/93	15:00	570.7	22.4	5.7	17.0	1470	3152	5850	12.5	1341	1201	1061	8.2	7.0	7.5	23.8	24.4	28.0	0.042
08/16/93	16:00	571.7	22.5	5.7	17.0	1479	3150	5940	16.6	1328	1189	1050	8.2	7.0	7.2	24.0	24.6	29.0	0.040
08/17/93	11:30	582.2	22.7	5.7	17.0	1468	3171	6090	16.1	1361	1218	1073	8.2	7.1	7.6	23.7	24.0	27.0	0.032
08/17/93	13:00	583.7	22.5	5.7	17.0	1477	3148	5960	17.6	1315	1172	1025	8.2	7.0	7.5	24.2	25.0	33.0	0.031
08/17/93	16.43	587.5	22.9	5.7	17.0	1484	3159	5920	18.0	1298	1156	1012	8.3	7.0	7.4	25.1	26.0	33.0	0.033
08/18/93	13:00	591.8	22.9	5.7	17.0	1409	3031	5610	19.7	1180	1040	898	8.0	7.0	7.4	29.2	29.2	26.0	0.036
08/18/93	14.00	592.8	22.6	5.7	17.0	1394	3005	5630	19.9	1156	1017	876	8.0	7.0	7.4	29.4	29.9	25.5	0.036
08/18/93	15:00	593.8	22.6	5.7	17.0	1404	3006	5460	20.1	1154	1016	874	8.0	6.9	7.4	29.7	30.3	27.0	0.036
08/18/93	16:00	594.8	22.7	5.7	17.0	1397	2999	5370	17.8	1150	1011	872	8.0	7.1	7.6	29.8	30.5	31.0	0.035
08/19/93	09:00	605.2	22.4	5.7	16.9	1457	3175	6080	20.2	1239	1096	955	8.0	7.0	7.6	27.7	27.6	19.0	0.046
08/19/93	14:00	610.2	22.6	5.7	17.0	1461	3112	5750	19.7	1173	1033	891	8.0	7.0	7.4	29.0	29.7	34.0	0.034
08/19/93	16:00	612.2	22.7	5.7	17.0	1464	3125	5810	19.7	1159	1020	879	8.0	7.0	7.5	29.7	30.4	34.0	0.035
08/20/93	10:12	622.5	22.7	5.7	17.0	1424	3072	5780	19.6	1293	1149	1003	8.0	7.2	7.5	26.5	26.1	25.5	0.046
08/20/93	11:28	623.7	22.9	5.7	17.1	1427	3062	5630	22.8	1250	1107	962	8.0	6.7	7.2	26.7	27.3	31.0	0.035
08/20/93	13:04	625.3	22.9	5.7	17.0	1418	3045	5440	19.5	1231	1090	946	8.1	8.9	7.3	27.0	27.7	33.0	0.033
08/20/93	15:16	627.5	22.6	5.7	17.0	1423	3048	4980	19.5	1211	1071	927	8.1	6.9	7.4	27.5	28.3	33.5	0.032
08/23/93	08:30	633.8	22.5	5.7	17.0	1257	2787	5190	14.6	1296	1153	1009	8.0	6.9	7.5	25.6	25.5	18.0	0.119
08/23/93	10:30	635.8	22.5	5.7	17.0	1257	2791	5410	14.5	1266	1128	989	8.0	6.8	7.5	26.0	26.2	27.0	0.048
08/23/93	12:30	637.8	22.5	5.7	17.0	1258	2778	5370	14.8	1228	1090	953	8.1	6.8	7.6	26.6	27.4	34.0	0.036
08/24/93	07:00	656.6	22.5	5.7	17.0	1369	2983	5630	25.7	1237	1096	955	8.1	7.0	7.3	28.0	27.6	13.5	0.029
08/24/93	09.00	658.6	22.9	5.7	17.0	1460	3155	5750	22.1	1241	1101	959	8.1	6.9	7.3	28.1	28.0	21.0	0.041
08/24/93	11.00	660.6	22.6	5.7	17.0	1452	3133	5850	20.7	1208	1071	933	8.1	6.9	7.5	28.4	28.8	32.5	0.034
08/24/93	13.30	663.1	22.6	5.7	17.0	1453	3134	5910	20.1	1176	1041	906	8.1	6.9	7.5	28.9	29.7	36.0	0.045
08/25/93	11.00	671.0	22.7	5.7	17.0	1504	3162	5830	22.5	1209	1068	923	8.0	7.0	7.3	27.8	28.3	30.0	0.037
08/25/93	12:00	672.0	22.7	5.7	17.0	1506	3190	5840	22.7	1196	1055	908	8.1	7.0	7.3	28.1	28.7	33.0	0.040
08/25/93	13:30	673.5	22.7	5.7	17.0	1509	3182	5820	22.7	1181	1039	893	8.1	7.0	7.3	28.6	29.4	35.0	0.045
08/25/93	15.50	675.5	22.7	5.7	17.0	1512	3189	5780	23.4	1165	1025	880	8.1	7.0	7.3	29.4	30.2	35.0	0.044
08/26/93	15.30	680.6	23.0	5.7	17.0	1519	3181	5880	24.3	1189	1046	900	8.1	7.0	7.3	28.4	28.9	27.0	0.045
08/27/93	11.00	683.2	22.9	5.7	17.0	1446	3068	5650	17.1	1180	1037	888	8.1	7.0	7.0	29.3	29.5	27.0	0.036
08/27/93	12:00	684.2	22.8	5.7	17.0	1450	3091	5680	17.3	1166	1025	878	8.1	7.0	7.0	29.4	29.9	20.7	0.036
08/27/93	13:30	685.7	22.9	5.7	17.0	1451	3091	5640	17.6	1153	1012	865	8.0	7.0	7.0	29.6	30.4	29.0	0.037
08/27/93	16:00	688.2	22.6	5.7	17.0	1477	3118	5720	25.0	1136	998	858	8.0	6.9	7.0	30.2	30.8	33.0	0.038
08/30/93	10:00	695.0	22.5	5.7	17.0	1165	2561	4710	15.5	1263	1120	973	8.1	6.9	7.0	25.5	25.6	23.0	0.058
08/30/93	11.30	696.5	22.6	5.7	17.0	1168	2604	4490	16.2	1244	1102	957	8.1	6.9	7.0	25.9	26.2	27.0	0.050
08/30/93	13:00	698.0	22.7	5.7	17.0	1169	2606	4420	16.1	1226	1086	943	8.1	6.9	7.0	26.3	26.8	31.5	0.054

Filmtec BW-30 Element Test Data - Continued

			Flowrate			Conductivity				Pressure			pH			Temperature			Turbidity
Date	Time	Elapsed Time (hours)	Feed (L/min)	Reject (L/min)	Permeate (L/min)	Feed (uS/cm)	Interstage (uS/cm)	Reject (uS/cm)	Permeate (uS/cm)	Feed (kPa)	Interstage (kPa)	Reject (kPa)	Raw Feed	RO Feed	Reject	Raw Feed (deg C)	RO Feed (deg C)	Ambient (deg C)	Filter Effl. (ntu)
09/01/93	09 00	722 0	22.9	5 8	17 0	1500	3206	5920	23.3	1210	1066	921	-	-	-	28 2	29 3	21.0	0 033
09/01/93	10 30	723 5	22.7	5 7	17 0	1500	3197	5820	23 3	1193	1052	910	-	7 2	-	28 3	28 6	26 0	0 039
09/01/93	13 00	726 0	22 9	5 7	17 0	1500	3158	5570	23 3	1175	1035	892	-	-	-	28 7	28 3	33 0	0 038
09/02/93	10 00	733 3	22 7	5 7	17 0	1502	3254	6150	21.4	1210	1068	926	-	-	-	27 9	28 2	27 0	0 035
09/02/93	12 00	735 3	22.5	5 7	17 0	1505	3204	5960	22.5	1196	1054	911	-	-	-	28 1	28 7	32 0	0 038
09/02/93	14 30	737 8	22.7	5 7	17.0	1503	3217	5970	20.9	1161	1019	877	-	6 8	-	28 9	29.9	35 0	0 042
09/07/93	11.30	738 4	22 8	5 8	17 0	1428	3067	4970	14.4	1178	1037	830	-	7 0	-	29 1	29.4	26 0	0 116
09/07/93	14 00	740 9	22 6	5 7	17.0	1452	3121	5400	17 2	1119	982	834	-	6.9	-	30 5	31 2	36 0	0 083
09/07/93	15.00	741 9	22 8	5 7	17.0	1458	3115	5740	19.8	1105	970	842	-	7.1	-	30 9	31.6	36.0	0 081
09/07/93	16 30	743 4	22.7	5.7	17.0	1463	3136	5770	20.1	1102	966	891	-	7.1	-	31 4	32.1	36.1	0.079
09/08/93	11 30	749 6	22.5	5.7	17.0	1461	3075	5622	19.6	1194	1052	908	-	7.0	-	28 8	29.1	33.0	0 034
09/08/93	13 27	751.5	22 7	5 7	17.0	1463	3133	5700	19.8	1170	1032	892	-	7.0	-	29 0	29 8	38.0	0.033
09/08/93	14 52	752 9	22.6	5.7	17.0	1465	3130	5230	19.9	1142	1006	867	-	7 0	-	29 4	30.5	39.0	0.033
09/08/93	15 40	753.7	22 8	5 7	17.0	1466	3131	4880	20.2	1140	1003	866	-	7.0	-	29 7	30.8	39.0	0.034
09/09/93	11 00	761 8	22 6	5.7	17.0	1468	3145	5880	20.6	1186	1045	903	-	7.0	-	28 3	29 0	34.2	0 034
09/09/93	13 00	763 8	22.9	5.7	17.0	1477	3134	5890	19.7	1145	1003	859	-	7.0	-	29.2	30 6	40.0	0 034
09/09/93	15 30	766 3	22.7	5 7	17.0	1482	3143	5770	19.9	1117	982	840	-	7.0	-	29.9	31.2	40.5	0 035
09/09/93	16 30	767.3	22 9	5 7	17.0	1486	3148	5730	20.7	1116	979	838	-	7.0	-	30.2	31 4	39.0	0.035
09/10/93	11 30	774.2	22.9	5 7	17.0	1459	3086	5660	20.7	1165	1024	880	-	7.0	-	28 9	29 6	33.5	0 034
09/10/93	13 29	776.2	23.0	5 8	17.1	1463	3101	5680	20.0	1139	999	852	-	7.0	-	29.5	30 6	39.0	0.034
09/10/93	14 28	777.2	22.8	5 7	17.1	1465	3113	5650	21.7	1126	986	842	-	6.9	-	29.8	31 0	39.0	0.034
09/10/93	15 30	778.2	22 9	5 7	17.0	1472	3124	5770	21.9	1113	975	833	-	7.0	-	30.3	31.5	39.0	0.035
09/13/93	11 00	785.2	22.6	5 7	17.0	1456	3137	5940	18.9	1410	1267	1121	-	7.0	-	24.7	24 7	19.0	0.048
09/13/93	12 00	786.2	22 5	5.7	17.0	1464	3139	5820	17.9	1414	1269	1124	-	7.0	-	24.8	24 7	22.0	0.048
09/13/93	13 03	787.3	22.6	5 7	17 1	1458	3143	5750	17 8	1402	1257	1110	-	6 9	-	25.0	25 1	25.0	0.050
09/13/93	16 14	790 4	22.8	5.7	17 0	1458	3127	4650	18 7	1348	1205	1057	-	6.9	-	25.7	26 1	26.0	0 048
09/14/93	15 00	796.3	23.1	5 7	17.0	1446	3063	5740	17.0	1386	1239	1082	-	7.0	-	23 9	24 1	28.0	0.052
09/14/93	16 00	797.3	22.8	5.7	17.0	1455	3088	5750	17.8	1350	1203	1051	-	7.0	-	24.6	25 1	29.0	0.051
09/14/93	17 00	798 3	22.9	5.7	17.0	1458	3104	5780	18 5	1356	1208	1056	-	7.0	-	24.7	25 2	30.0	0.051
09/15/93	11 00	807.1	23.0	5.7	17 0	1383	2988	5600	19.0	1296	1146	996	-	7.0	-	26 7	26.5	18 5	0.033
09/15/93	11 30	807.6	23.2	5.7	17.0	1376	3152	5550	18.9	1292	1145	992	-	6.9	-	26.8	26 6	19.5	0.034
09/15/93	13 54	810.0	22 9	5 7	17.0	1371	3138	5510	18.9	1274	1126	972	-	7 0	-	27.0	27.1	25 0	0.031
09/15/93	16 19	812.4	22.9	5 7	17.0	1373	3129	5410	19.3	1257	1109	956	-	7.0	-	27.4	27.5	26.0	0 031
09/16/93	14 00	818.1	22.8	5.7	17 0	1547	3210	5840	18.2	1342	1194	1042	-	7.0	-	25.0	25.0	19 5	0.034
09/16/93	14 30	818.6	22.6	5 7	17.0	1544	3210	5760	18.7	1343	1196	1044	-	7.0	-	25.0	24.9	19.5	0.033
09/16/93	15 30	819.6	23.0	5 7	17.0	1546	3210	5890	19.2	1346	1198	1046	-	7.0	-	25.0	24 9	19.5	0.035
09/16/93	17 00	821 1	22.8	5.7	17.0	1547	3210	5810	19.1	1354	1206	1052	-	7.0	-	25.0	24.8	19 0	0.035
09/17/93	10 26	830.1	23.0	5.7	17.0	1363	2855	4750	16.2	1428	1275	1118	-	6.9	-	22 5	22 4	17.0	0.031
09/17/93	11 30	831.2	23.0	5.7	17.0	1363	2846	3520	16.6	1421	1270	1115	-	6.9	-	22.5	22 6	20 0	0.033
09/17/93	16.00	835.7	22.8	5.7	17.0	1361	2858	5340	16.8	1391	1244	1090	-	7.0	-	23.1	23.2	21.0	0.034
09/17/93	17.00	836 7	23.0	5.7	17.0	1360	2858	5260	16.9	1392	1244	1090	-	6.9	-	23.2	23 2	21.0	0.034
09/20/93	10.00	840.2	22 5	5.7	17.0	1241	2606	4420	11.9	1443	1293	1138	-	7.0	-	21 5	21 5	20.0	0.077
09/20/93	11.00	841 2	22 7	5 7	17.0	1260	2672	5000	12.5	1434	1286	1137	-	7.0	-	21 6	21.7	21.0	0 073
09/20/93	12 00	842.2	22.3	5.7	17.0	1256	2672	4940	13.6	1400	1253	1108	-	7.0	-	22.0	22 3	24.0	0.071
09/21/93	11 30	849.1	22.8	5 7	17.0	1450	3010	5430	18.2	1295	1146	991	8.4	7.0	7 7	25 5	25.3	21.0	0 036
09/21/93	13 30	851.1	22.9	5 7	17.0	1449	3010	5410	18.9	1275	1127	975	8.4	6.9	7 6	25.7	25 8	24.0	0.034
09/21/93	14 30	852.1	22.6	5.7	17.0	1458	2986	5420	20.0	1271	1127	974	8.4	7.0	7 5	25.9	25 7	25.5	0.035
09/21/93	16 30	854.1	22.9	5.7	17.0	1452	3000	5440	19.3	1252	1105	955	8.5	6.9	7 6	26.2	26 4	26.0	0.035
09/22/93	10 00	861.6	22.4	5.7	17.0	1537	3220	5870	15.6	1290	1148	1006	8.3	6.9	7 6	25 5	25 1	15.0	0.059
09/22/93	11 00	862.6	22.3	5.7	17.0	1532	3220	5890	16.2	1284	1148	1005	8.3	6 9	7 6	25.5	25 2	18.5	0.062
09/22/93	12 00	863.6	22 6	5.7	17.0	1530	3220	5820	17.2	1280	1139	990	8.4	6.9	7 6	25 6	25 4	21.0	0.064
09/23/93	14.30	871.4	22 6	5.7	17 0	1505	3100	5270	12.9	1311	1163	1005	8.4	7.1	7.7	24.0	24.6	30.5	0.124
09/23/93	16.00	872.9	22.3	5 7	17.0	1517	3120	5240	14.9	1269	1127	985	8.5	7.0	7 7	24.6	25 4	31.0	0.066
09/23/93	16.30	873.4	22.6	5 7	17.0	1520	3150	5340	13.9	1266	1126	984	8.5	7.0	7 6	24.7	25.5	31.0	0.062
09/24/93	09 20	882 3	23.4	5 7	17.7	1481	3160	3690	18.2	1395	1243	1093	8.5	7.0	7 8	24 1	24.0	28.0	0.040
09/24/93	14:35	887.6	22.6	5 7	17.0	1481	3090	5690	19.3	1244	1104	961	8.5	7.0	7 6	25.8	26 4	35.0	0.040
09/24/93	15.21	888.3	22 5	5 7	17.0	1485	3100	5290	19.9	1223	1083	940	8.5	7.0	7 6	26 2	27 1	35.0	0.040
09/24/93	16.11	889.2	22.7	5 7	17.1	1489	3110	4290	20.9	1216	1076	934	8.5	6.9	7 6	26 9	27 4	34.0	0.040
09/27/93	11 00	890.7	22 4	5 7	17.0	1501	3120	5550	14.8	1292	1149	1004	8.6	7.0	7 7	25 7	26 1	31.0	0.054
09/27/93	12.00	891.7	22 4	5 7	17.0	1516	3150	5880	16.0	1272	1130	987	8.6	7.0	7 7	26 0	26 6	35.0	0.054
09/27/93	12.30	892 2	22.6	5 7	17.0	1522	3160	5850	17.1	1249	1107	967	8.6	7.0	7 7	26 3	27 0	36.0	0.051
09/27/93	15.12	894.9	22 8	5 7	17.0	1534	3120	5690	18.7	1200	1058	907	8.5	7.1	7 7	27 8	28.8	39.0	0.055
09/29/93	11.00	904.7	22 8	5 7	17.0	1523	3150	5600	15.5	1217	1073	926	8.3	7.0	7 8	27 9	28 3	29.0	0.069
09/29/93	12 00	905.7	22.5	5 9	17.0	1526	3160	5670	16.6	1190	1051	909	8.3	7 0	7 7	28.1	28.6	32.5	0.076
09/29/93	13.00	906 7	22.4	5 7	17.0	1530	3180	5810	14.5	1169	1034	896	8.3	7 0	7 7	28 3	29.1	34.5	0.070
09/29/93	15.00	908.7	22 7	5 7	17.0	1536	3180	4200	17.1	1150	1013	874	8.4	7 0	7 6	27.1	29 9	36.0	0.050
09/30/93	14.00	915.3	22.4	5 7	17.0	1151	3220	5690	19.0	1161	1025	884	8 3	7.0	7 6	28 6	29 2	34 5	0.037
09/30/93	15.00	916.3	22 5	5 7	17 0	1560	3230	5950	18.9	1152	1015	876	8 4	7.0	7 7	28.9	29 7	35.5	0.039
09/30/93	[illegible]	[illegible]	[illegible]	5 7	17 0	1562	3240	5970	19.7	1139	1004	866	8.4	7.0	7 7	28 3	30 0	35.0	0 041

Filmtec BW-30 Element Test Data - Continued

Date	Time	Elapsed Time (hours)	Flowrate Feed (L/min)	Flowrate Reject (L/min)	Flowrate Permeate (L/min)	Conductivity Feed (uS/cm)	Conductivity Interstage (uS/cm)	Conductivity Reject (uS/cm)	Conductivity Permeate (uS/cm)	Pressure Feed (kPa)	Pressure Interstage (kPa)	Pressure Reject (kPa)	pH Raw Feed	pH RO Feed	pH Reject	Temperature Raw Feed (deg C)	Temperature RO Feed (deg C)	Temperature Ambient (deg C)	Turbidity Filter Effl. (ntu)
10/01/93	09:00	926.2	22.5	5.7	17.0	1516	3170	5810	20.3	1244	1001	958	8.4	7.0	7.6	27.0	27.0	28.0	0.031
10/01/93	16:15	933.4	22.5	5.7	17.0	1529	3160	5830	22.1	1151	1014	874	8.5	7.0	7.7	29.2	29.9	39.0	0.044
10/01/93	16:45	933.9	22.6	5.7	17.0	1530	3160	5710	22.1	1151	1014	875	8.5	7.0	7.7	29.3	30.0	37.0	0.043
10/01/93	17:15	934.4	22.8	5.7	17.0	1533	3180	5540	23.0	1150	1012	874	8.5	7.0	7.7	29.5	30.1	36.1	0.043
10/05/93	13:30	941.4	22.4	5.7	17.0	1527	3180	5780	16.0	1257	1117	973	8.6	6.9	7.7	26.2	26.4	26.0	0.053
10/05/93	14:30	942.4	22.6	5.7	17.0	1531	3170	5790	18.5	1246	1105	962	8.6	6.9	7.6	26.5	26.7	27.0	0.053
10/05/93	15:30	943.4	22.5	5.7	17.0	1552	3180	5890	15.8	1231	1093	950	8.7	6.9	7.6	26.8	27.1	27.5	0.064
10/05/93	17:00	944.9	22.4	5.7	17.0	1539	3190	5850	17.3	1227	1087	945	8.7	7.0	7.6	27.0	27.2	28.0	0.044
10/06/93	10:00	946.7	23.2	5.7	17.0	1547	3200	5690	18.9	1355	1207	1050	8.5	7.0	7.6	23.8	23.7	24.5	0.054
10/06/93	16:00	952.7	23.0	5.7	17.0	1528	3180	5030	14.8	1324	1177	1026	8.6	8.2	-	24.8	24.9	25.0	0.049
10/07/93	10:30	957.5	22.5	5.7	17.1	1541	3220	5970	17.1	1367	1223	1074	8.5	7.0	7.6	23.6	23.3	17.5	0.098
10/07/93	11:30	958.5	23.1	5.7	17.0	1538	3210	5920	20.4	1358	1213	1066	8.5	6.8	7.6	23.7	23.6	20.0	0.044
10/07/93	17:00	964.0	23.2	5.7	17.0	1546	3140	5620	21.8	1312	1167	1018	8.5	6.9	7.6	24.9	24.9	24.0	0.059
10/07/93	17:30	964.5	23.4	5.7	17.0	1540	3200	5810	22.7	1312	1167	1016	8.5	6.8	7.6	25.0	25.0	23.0	0.057
10/08/93	09:55	966.1	22.9	5.7	17.1	1526	3170	5760	21.0	1390	1241	1085	8.5	6.9	7.6	23.4	23.0	17.0	0.026
10/08/93	10:48	967.0	23.0	5.7	17.0	1524	3170	5810	21.6	1379	1227	1072	8.5	6.9	7.6	23.4	23.2	18.0	0.025
10/08/93	15:00	971.2	23.2	5.7	17.0	1527	3150	5800	21.4	1345	1198	1045	8.5	6.8	7.6	23.9	23.9	23.5	0.024
10/08/93	16:30	972.7	22.6	5.7	17.0	1524	3160	5770	21.8	1330	1184	1033	8.5	6.8	7.6	24.6	24.2	25.5	0.024
10/11/93	12:00	977.4	22.2	5.7	17.0	1473	3070	5330	16.9	1400	1255	1105	8.6	6.9	7.5	21.8	22.2	21.0	0.062
10/11/93	12:30	977.9	22.3	5.7	17.0	1498	3110	5710	16.2	1425	1279	1130	8.6	6.9	7.5	21.9	22.0	19.5	0.044
10/12/93	10:00	987.4	22.9	5.7	17.0	1539	3140	5420	15.4	1400	1247	1087	8.5	6.9	7.7	23.2	22.4	21.0	0.042
10/12/93	11:00	988.4	22.7	5.7	17.0	1531	3150	5600	17.3	1325	1180	1032	8.5	6.9	7.7	23.3	23.4	22.0	0.041
10/12/93	14:00	991.4	22.6	5.7	17.0	1526	3180	5670	19.1	1294	1151	1006	8.6	6.9	7.6	24.1	24.4	26.0	0.048
10/12/93	16:00	993.4	22.6	5.7	17.0	1533	3190	5930	21.0	1270	1128	985	8.6	6.9	7.6	24.8	25.1	28.0	0.051
10/13/93	11:00	996.7	22.9	5.7	17.0	1567	3240	5980	23.8	1241	1094	945	8.4	6.9	7.6	26.0	26.1	24.0	0.042
10/13/93	12:00	997.7	22.9	5.7	17.0	1567	3230	5820	23.9	1240	1094	944	8.4	6.9	7.6	26.1	26.2	26.0	0.045
10/14/93	11:30	1007.4	23.0	5.7	17.0	1577	3250	6060	21.2	1352	1202	1046	8.5	6.9	7.7	24.1	23.4	19.5	0.033
10/14/93	13:30	1009.4	22.9	5.7	17.0	1559	3250	6060	22.2	1285	1137	986	8.5	6.9	7.7	24.6	24.7	25.5	0.026
10/14/93	16:00	1011.9	22.9	5.7	17.0	1563	3230	5930	22.9	1269	1124	976	8.5	6.9	7.7	24.9	25.2	26.0	0.026
10/15/93	10:00	1022.1	22.9	5.7	17.0	1495	3070	5650	21.5	1340	1189	1037	8.5	6.9	7.7	23.1	23.1	17.5	0.027
10/15/93	11:30	1023.6	22.8	5.7	17.0	1476	3060	5600	21.4	1338	1189	1036	8.5	6.9	7.7	23.2	23.2	20.5	0.027
10/15/93	13:30	1025.6	22.9	5.7	17.0	1475	3070	5640	21.4	1324	1176	1024	8.5	6.8	7.7	23.4	23.5	22.0	0.026
10/15/93	15:00	1027.1	22.8	5.7	17.0	1481	3080	5640	22.5	1308	1160	1009	8.5	6.9	7.7	23.8	23.9	22.0	0.026
10/18/93	11:00	1032.6	22.3	5.7	17.0	1497	3130	5710	18.5	1501	1349	1195	8.7	6.8	7.6	19.0	19.0	17.0	0.045
10/18/93	12:00	1033.6	22.5	5.7	17.0	1504	3130	5720	19.8	1492	1341	1186	8.7	6.9	7.6	19.0	19.0	18.0	0.041
10/19/93	12:00	1044.7	22.7	5.7	17.0	1535	3180	5750	22.8	1318	1168	1015	8.5	6.8	7.6	23.2	23.3	22.5	0.030
10/19/93	13:30	1046.2	22.9	5.7	17.0	1539	3160	5720	22.6	1295	1147	993	8.5	6.8	7.6	23.6	23.8	29.0	0.028
10/19/93	14:30	1047.2	23.0	5.7	17.0	1543	3150	5780	23.1	1281	1136	983	8.5	6.8	7.6	23.9	24.1	27.0	0.028
10/19/93	17:30	1050.2	22.9	5.7	17.0	1550	3190	5820	24.2	1268	1120	970	8.5	6.9	7.6	24.5	24.7	25.5	0.026
10/20/93	12:00	1053.9	23.0	5.7	17.0	1531	3140	5690	22.2	1297	1147	992	8.5	7.0	7.6	23.4	23.7	28.0	0.033
10/20/93	12:30	1054.4	23.0	5.7	17.0	1532	3140	5650	22.3	1292	1144	988	8.5	7.0	7.6	23.3	23.7	28.0	0.030
10/21/93	13:30	1067.5	23.0	5.7	17.0	1530	3140	5760	11.0	1310	1163	1009	8.5	6.9	7.6	22.7	23.2	30.0	0.027
10/21/93	16:00	1070.0	22.8	5.7	17.0	1538	3170	5800	22.9	1278	1133	981	8.5	6.9	7.6	23.5	24.2	26.0	0.026
10/21/93	17:00	1071.0	23.0	5.7	17.0	1542	3170	5780	23.5	1287	1140	988	8.5	6.9	7.6	23.6	24.0	25.0	0.025
10/22/93	10:00	1079.2	22.7	5.7	17.0	1512	3140	5700	25.0	1207	1062	914	8.4	6.9	7.6	26.9	26.4	21.0	0.027
10/22/93	12:45	1081.9	22.8	5.7	17.0	1518	3140	5680	25.5	1169	1026	879	8.4	6.9	7.7	27.1	27.4	26.5	0.029
10/22/93	15:00	1084.2	22.9	5.7	17.0	1520	3140	5570	25.9	1168	1025	876	8.4	6.9	7.7	27.4	27.7	29.0	0.030
10/22/93	16:00	1085.2	22.8	5.7	17.0	1522	3150	5520	26.1	1162	1018	871	8.4	6.9	7.6	27.5	27.9	29.0	0.030
10/25/93	11:00	1090.9	22.4	5.7	17.0	1515	3150	5500	17.4	1410	1265	1116	8.6	6.9	7.6	20.9	21.2	21.5	0.056
10/25/93	11:30	1091.4	22.5	5.7	17.0	1520	3170	5680	19.4	1409	1261	1112	8.6	6.9	7.6	21.1	21.3	25.5	0.054
10/25/93	12:00	1091.9	22.5	5.7	17.0	1520	3160	5810	19.7	1405	1256	1103	8.6	6.9	7.6	21.1	21.4	26.5	0.053
10/25/93	12:30	1092.4	22.9	5.7	17.0	1519	3150	5750	19.8	1390	1242	1089	8.6	6.9	7.6	21.2	21.6	27.5	0.052
10/26/93	10:30	1100.4	22.9	5.7	17.0	1557	3210	5680	24.0	1246	1100	948	8.5	6.9	7.7	24.9	25.0	22.5	0.032
10/26/93	11:30	1101.4	22.7	5.7	17.0	1555	3200	5670	24.3	1242	1095	943	8.5	6.9	7.6	25.0	25.2	23.5	0.030
10/26/93	16:00	1105.9	22.7	5.7	17.0	1561	3200	5410	25.3	1189	1045	895	8.5	6.9	7.6	26.2	26.9	31.0	0.027
10/26/93	17:30	1107.4	22.7	5.7	17.0	1565	3220	5630	26.2	1188	1045	896	8.5	6.9	7.6	26.6	26.9	28.0	0.026
10/27/93	11:00	1111.5	22.5	5.7	17.0	1558	3210	5720	25.0	1240	1094	942	8.5	6.9	7.6	25.1	25.2	24.5	0.030
10/27/93	11:30	1112.0	22.6	5.7	17.0	1562	3210	5720	25.1	1237	1090	939	8.5	6.9	7.6	25.2	25.4	25.0	0.031
10/27/93	12:00	1112.5	22.6	5.7	17.0	1561	3210	5710	24.8	1237	1090	938	8.5	6.9	7.6	25.3	25.4	25.0	0.031
10/27/93	12:30	1113.0	22.7	5.7	17.0	1561	3210	5680	25.1	1231	1085	933	8.5	6.9	7.6	25.3	25.5	25.0	0.031
10/28/93	13:30	1123.3	22.7	5.7	17.0	1537	3160	5800	23.0	1271	1122	970	8.5	6.9	7.7	23.7	24.2	27.5	0.030
10/28/93	14:00	1123.8	22.7	5.7	17.0	1539	3160	5780	23.1	1263	1116	963	8.5	6.9	7.7	24.0	24.4	27.5	0.029
10/28/93	17:30	1127.3	22.7	5.7	17.0	1548	3190	5820	24.9	1253	1105	956	8.5	7.0	7.7	24.7	24.9	23.0	0.026
10/29/93	11:30	1136.1	22.6	5.7	17.0	1493	3110	5650	25.4	1206	1030	910	8.5	6.9	7.8	26.1	26.0	20.5	0.028
10/29/93	14:00	1138.6	22.7	5.7	17.0	1495	3090	5660	25.7	1181	1038	892	8.4	6.9	7.6	26.4	26.6	26.5	0.028
10/29/93	15:00	1139.6	22.8	5.7	17.1	1495	3080	5590	25.4	1180	1035	885	8.5	6.9	7.6	26.6	26.9	28.0	0.028
10/29/93	16:00	1140.6	22.8	5.7	17.0	1497	3080	5600	25.8	1170	1027	878	8.5	6.9	7.6	26.8	27.1	28.5	0.028
11/01/93	12:00	1145.6	22.7	5.7	17.0	1539	3160	5660	21.2	1402	1251	1095	8.5	6.9	7.6	20.7	20.9	18.5	0.033
11/01/93	12:30	1146.1	22.6	5.7	17.0	1534	3150	5750	21.3	1396	1247	1088	8.5	6.9	7.6	20.8	20.9	19.0	0.032

Filmtec BW-30 Element Test Data - Continued

Date	Time	Elapsed Time (hours)	Flowrate Feed (L/min)	Flowrate Reject (L/min)	Permeate (L/min)	Conductivity Feed (uS/cm)	Conductivity Interstage (uS/cm)	Conductivity Reject (uS/cm)	Conductivity Permeate (uS/cm)	Pressure Feed (kPa)	Pressure Interstage (kPa)	Pressure Reject (kPa)	pH Raw Feed	pH RO Feed	pH Reject	Temperature Raw Feed (deg C)	Temperature RO Feed (deg C)	Temperature Ambient (deg C)	Turbidity Filter Effl. (ntu)
11/01/93	13.00	1146.6	22.7	5.7	17.0	1534	3140	5730	21.4	1397	1245	1087	8.5	6.9	7.6	20.8	21.0	20.0	0.031
11/02/93	10.30	1161.4	22.2	5.7	17.0	1538	3170	5510	21.6	1127	987	843	8.4	6.9	7.7	28.2	27.8	24.5	0.086
11/02/93	11.30	1162.4	22.5	5.7	17.0	1560	3260	5730	26.2	1121	981	841	8.4	6.9	7.6	26.3	28.4	25.0	0.064
11/03/93	12.00	1173.5	22.7	5.7	17.0	1562	3230	5670	25.0	1225	1078	930	8.5	6.7	7.6	24.7	25.1	27.0	0.046
11/03/93	12.30	1174.0	22.7	5.7	17.0	1564	3230	5800	25.4	1224	1079	929	8.5	6.7	7.6	24.7	25.1	27.1	0.048
11/04/93	14.30	1184.9	22.5	5.7	17.0	1518	3140	5690	25.6	1204	1058	906	8.5	7.0	7.6	25.5	25.8	25.0	0.032
11/04/93	16.00	1186.4	22.9	5.7	17.0	1523	3150	5680	26.0	1204	1059	908	8.5	7.0	7.6	25.5	25.5	22.5	0.031
11/04/93	16.30	1186.9	22.8	5.7	17.0	1522	3140	5650	26.0	1222	1075	925	8.5	6.9	7.6	25.4	25.4	21.0	0.031
11/04/93	17.00	1187.4	22.6	5.7	17.0	1523	3160	5720	26.3	1223	1075	925	8.5	6.9	7.6	25.4	25.2	19.0	0.031
11/05/93	09.00	1196.6	22.7	5.7	17.0	1504	3130	5750	23.0	1329	1177	1021	8.5	6.9	6.1	22.3	22.1	17.0	0.030
11/05/93	13.00	1199.6	22.7	5.7	17.0	1501	3100	5760	23.4	1291	1142	990	8.6	6.8	7.7	22.8	23.1	25.0	0.026
11/05/93	16.00	1202.6	22.6	5.7	17.0	1510	3130	5800	24.7	1267	1119	968	8.6	6.9	7.6	23.6	23.8	23.5	0.025
11/05/93	17.30	1204.1	22.5	5.7	17.0	1507	3130	5720	25.1	1268	1119	968	8.6	6.9	7.6	23.7	23.6	22.0	0.025
11/08/93	11.00	1210.0	22.4	5.7	17.0	1444	3010	5460	18.2	1500	1348	1192	8.7	6.9	7.7	17.7	18.0	20.0	0.057
11/08/93	11.30	1210.5	22.6	5.7	17.0	1445	3030	5630	18.6	1493	1344	1192	8.7	6.9	7.7	17.7	18.0	21.0	0.059
11/08/93	12.30	1211.5	22.5	5.7	17.0	1447	3020	5620	19.4	1490	1340	1186	8.7	6.9	7.7	17.9	18.2	21.0	0.058
11/08/93	13.00	1212.0	22.0	5.7	17.0	1449	3020	5650	19.8	1471	1320	1165	8.7	6.9	7.7	18.1	18.5	23.0	0.058
11/09/93	10.30	1221.2	22.7	5.7	17.0	1520	3140	5600	26.0	1221	1074	920	8.4	6.9	7.7	24.7	24.8	23.5	0.047
11/09/93	13.30	1224.2	22.8	5.7	17.0	1519	3120	5620	26.1	1200	1053	900	8.5	6.9	7.7	25.3	25.6	26.5	0.056
11/09/93	16.00	1226.7	22.7	5.7	17.0	1533	3160	5630	27.8	1180	1035	886	8.5	6.9	7.7	25.9	26.1	26.0	0.056
11/11/93	10.00	1232.1	22.7	5.7	17.0	1566	3230	5740	27.2	1222	1072	918	8.4	6.9	7.7	25.0	25.0	20.0	0.030
11/11/93	11.00	1233.1	22.7	5.7	17.0	1565	3240	5740	27.1	1215	1065	913	8.5	6.9	7.7	25.0	25.0	21.0	0.030
11/11/93	12.00	1234.1	22.7	5.7	17.0	1562	3230	5720	27.3	1214	1064	913	8.5	6.9	7.7	25.1	25.2	22.5	0.030
11/11/93	12.30	1234.6	22.7	5.7	17.0	1561	3230	5730	27.2	1208	1061	909	8.5	6.9	7.7	25.1	25.2	23.0	0.031
11/12/93	08.47	1243.5	22.6	5.7	17.0	1543	3200	5960	21.0	1571	1412	1249	8.6	6.9	7.7	16.6	16.3	13.0	0.033
11/12/93	10.14	1245.0	22.8	5.7	17.0	1539	3200	5980	21.0	1559	1401	1239	8.6	6.9	7.7	16.7	16.5	13.5	0.028
11/12/93	13.00	1247.8	22.8	5.7	17.0	1543	3200	5980	21.5	1544	1388	1227	8.6	6.9	7.7	16.8	16.7	13.5	0.027
11/12/93	15.30	1250.3	22.7	5.7	17.0	1544	3210	5980	21.6	1544	1388	1227	8.6	6.9	7.7	17.1	16.9	12.5	0.026
11/15/93	11.00	1256.1	22.5	5.7	17.0	1482	3090	5650	19.7	1494	1340	1183	8.7	6.9	7.7	17.4	17.4	15.5	0.052
11/15/93	11.30	1256.6	22.5	5.7	17.0	1492	3090	5600	21.1	1485	1332	1176	8.6	6.9	7.7	17.4	17.5	16.7	0.050
11/16/93	10.30	1266.9	22.7	5.7	17.0	1544	3190	5770	23.5	1399	1244	1085	8.7	6.9	7.7	20.0	19.6	11.6	0.035
11/16/93	11.30	1267.9	22.7	5.7	17.0	1530	3170	5690	23.9	1383	1228	1067	8.7	6.9	7.7	20.0	20.0	14.0	0.031
11/16/93	13.30	1269.9	22.6	5.7	17.0	1523	3140	5620	24.0	1366	1213	1055	8.5	6.9	7.7	20.1	20.2	18.1	0.030
11/16/93	14.40	1270.9	22.9	5.7	17.0	1527	3150	5730	24.3	1366	1213	1054	8.6	6.8	7.7	20.3	20.3	18.8	0.030
11/17/93	11.30	1279.3	22.5	5.7	17.0	1537	3150	5620	23.9	1379	1225	1067	8.5	6.9	7.7	20.6	20.6	18.3	0.030
11/17/93	12.00	1279.8	22.8	5.7	17.0	1528	3140	5620	23.6	1376	1221	1062	8.5	6.9	7.7	20.6	20.7	19.1	0.030
11/17/93	12.30	1280.3	22.8	5.7	17.0	1526	3140	5630	23.8	1374	1220	1062	8.5	6.9	7.7	20.6	20.7	19.6	0.030
11/18/93	11.00	1289.9	22.9	5.7	17.0	1523	3140	5690	21.7	1465	1309	1148	8.6	6.9	7.7	18.5	18.4	16.7	0.032
11/18/93	14.00	1292.9	22.8	5.7	17.0	1522	3130	5640	22.9	1420	1268	1108	8.5	6.9	7.7	19.2	19.3	19.3	0.031
11/18/93	15.30	1294.4	22.9	5.7	17.0	1524	3140	5670	23.1	1417	1261	1101	8.5	6.9	7.9	19.5	19.6	17.8	0.031
11/18/93	16.30	1295.4	22.7	5.7	17.0	1529	3150	5630	23.6	1411	1258	1102	8.5	6.9	7.7	19.6	19.6	16.8	0.029
11/19/93	14.44	1308.0	22.8	5.7	17.0	1466	3050	5540	26.9	1159	1011	860	8.5	6.9	7.7	27.1	26.6	22.5	0.028
11/19/93	16.40	1309.9	22.7	5.7	17.0	1473	3060	5440	29.4	1155	1009	858	8.5	6.9	7.7	26.8	26.6	18.8	0.029
11/22/93	12.00	1315.6	22.7	5.7	17.0	1499	3040	5230	21.0	1153	1005	850	8.5	6.8	7.7	28.0	26.7	20.4	0.061
11/22/93	12.30	1316.1	22.1	5.7	17.0	1500	3140	5500	23.2	1109	968	826	8.5	6.9	7.7	28.0	27.8	22.0	0.071
11/23/93	11.00	1328.4	22.4	5.7	17.0	1538	3200	5650	24.4	1231	1083	937	8.5	6.9	7.7	24.1	23.8	16.1	0.067
11/23/93	11.30	1328.9	22.2	5.7	17.0	1534	3190	5740	23.2	1224	1081	936	8.5	6.9	7.7	24.0	23.9	16.9	0.070
11/23/93	14.30	1331.9	22.5	5.7	17.0	1534	3200	5840	28.7	1226	1083	936	8.5	6.8	7.7	24.2	24.0	17.7	0.067
11/23/93	15.19	1332.7	22.2	5.7	17.0	1530	3200	5820	28.8	1227	1082	937	8.5	6.8	7.7	24.3	24.1	18.0	0.055
11/24/93	10.30	1340.0	22.7	5.7	17.0	1538	3160	5620	27.0	1324	1171	1015	8.5	6.9	7.7	21.7	21.5	15.5	0.043
11/24/93	11.00	1340.5	22.5	5.7	17.0	1540	3180	5720	27.1	1321	1170	1013	8.5	6.8	7.7	21.7	21.5	15.4	0.044
11/24/93	12.00	1341.5	22.8	5.7	17.0	1536	3170	5730	26.8	1321	1170	1013	8.5	6.8	7.7	21.7	21.6	16.5	0.050
11/24/93	12.30	1342.0	22.8	5.7	17.0	1535	3170	5710	26.7	1320	1168	1012	8.5	6.8	7.7	21.8	21.6	16.9	0.052
11/29/93	11.30	1352.7	22.8	5.7	17.0	1513	3100	5640	21.8	1472	1315	1154	8.5	6.9	7.7	17.6	17.7	19.2	0.025
11/29/93	12.00	1353.2	22.8	5.7	17.0	1514	3100	5580	22.1	1464	1309	1148	8.5	6.9	7.7	17.7	17.8	19.4	0.025
11/30/93	10.30	1362.1	22.8	5.7	17.0	1536	3160	5650	25.3	1421	1265	1105	8.5	6.9	7.7	18.8	18.7	14.0	0.024
11/30/93	11.00	1362.8	22.7	5.7	17.0	1530	3150	5700	25.5	1417	1262	1102	8.5	6.8	7.7	18.8	18.8	15.0	0.024
11/30/93	15.00	1366.6	22.7	5.7	17.0	1539	3170	5810	25.3	1404	1251	1093	8.5	6.8	7.7	19.2	19.1	17.0	0.024
11/30/93	16.00	1367.6	22.8	5.7	17.0	1540	3160	5740	26.2	1386	1233	1078	8.5	6.9	7.7	19.3	19.3	17.1	0.024
12/01/93	11.30	1372.9	22.2	5.7	17.0	1526	3150	5660	21.5	1319	1172	1022	8.5	6.8	7.7	20.5	20.5	17.1	0.051
12/01/93	12.00	1373.4	22.3	5.7	17.0	1530	3160	5780	22.4	1328	1179	1032	8.5	6.9	7.7	20.5	20.5	17.0	0.050
12/01/93	12.30	1373.9	22.3	5.7	17.0	1534	3170	5670	23.5	1327	1178	1028	8.5	6.9	7.7	20.5	20.6	18.0	0.053
12/02/93	14.30	1384.7	22.7	5.7	17.0	1506	3060	5630	25.1	1354	1202	1043	8.5	6.9	7.7	19.7	20.1	21.2	0.042
12/02/93	16.00	1386.2	22.7	5.7	17.0	1516	3110	5630	26.7	1346	1195	1039	8.5	6.9	7.7	20.2	20.3	19.6	0.043
12/03/93	10.31	1395.7	22.8	5.7	17.0	1496	2906	5380	25.6	1360	1206	1046	8.5	6.9	7.7	19.8	19.9	18.0	0.031
12/03/93	13.53	1399.0	22.8	5.7	17.0	1489	3070	5590	25.5	1327	1127	1020	8.5	6.8	7.7	20.6	20.8	23.1	0.025
12/03/93	15.02	1400.2	22.7	5.7	17.0	1495	3080	5660	26.1	1326	1173	1020	8.5	6.8	7.7	20.7	20.8	20.1	0.024
12/03/93	15.46	1400.9	22.7	5.7	17.0	1502	3090	5670	26.9	1326	1173	1020	8.5	6.9	7.7	20.7	20.8	21.1	0.024
12/07/93	11.00	1417.5	22.2	5.7	17.0	1465	2748	5570	18.0	1570	1414	1254	8.6	6.9	-	14.9	15.0	14.7	0.055

Filmtec BW-30 Element Test Data - Continued

Date	Time	Elapsed Time (hours)	Flowrate			Conductivity				Pressure			pH			Temperature			Turbidity
			Feed (L/min)	Reject (L/min)	Permeate (L/min)	Feed (uS/cm)	Interstage (uS/cm)	Reject (uS/cm)	Permeate (uS/cm)	Feed (kPa)	Interstage (kPa)	Reject (kPa)	Raw Feed	RO Feed	Reject	Raw Feed (deg C)	RO Feed (deg C)	Ambient (deg C)	Filter Eff. (ntu)
12/07/93	13:30	1420.0	22.8	5.7	17.0	1464	3030	5640	21.6	1551	1393	1230	8.6	6.8	-	15.3	15.5	19.6	0.044
12/07/93	15:00	1421.5	22.6	5.7	17.0	1483	3060	5670	23.1	1531	1375	1214	8.8	6.9	7.7	15.8	16.0	17.7	0.041
12/07/93	17:00	1423.5	22.4	5.7	17.0	1495	3090	5760	24.2	1529	1372	1212	8.6	6.9	7.7	16.3	16.2	13.8	0.037
12/09/93	15:00	1440.6	22.6	5.7	17.0	1545	3190	5800	28.7	1289	1139	985	8.5	6.9	7.8	21.6	21.3	19.4	0.040
12/09/93	16:30	1442.1	22.8	5.7	17.0	1553	3210	5690	30.7	1257	1106	956	8.5	6.9	7.8	22.5	22.4	16.4	0.039
12/09/93	17:00	1442.6	22.7	5.7	17.0	1550	3210	5630	30.8	1257	1107	956	8.5	6.8	7.8	22.4	22.2	14.9	0.039
12/10/93	13:34	1453.3	23.0	5.7	17.0	1496	3080	5750	24.4	1356	1202	1043	8.5	6.9	7.8	20.2	19.8	23.7	0.027
12/10/93	14:53	1454.6	23.0	5.7	17.0	1511	3120	5820	26.9	1295	1143	986	8.5	6.9	7.8	20.8	21.2	24.1	0.026
12/10/93	15:22	1455.1	22.8	5.7	17.0	1522	3120	5720	28.0	1295	1143	988	8.5	6.9	7.8	20.9	21.2	25.6	0.023
12/13/93	10:30	1465.5	22.7	5.7	17.0	1458	3000	5300	18.8	1420	1264	1100	8.5	7.0	7.8	18.0	17.6	13.6	0.069
12/13/93	11:00	1466.0	22.9	5.7	17.0	1467	3010	5370	20.6	1392	1239	1079	8.5	6.9	7.8	18.4	18.1	14.5	0.073
12/13/93	12:00	1467.0	22.8	5.7	17.0	1471	3030	5480	20.5	1381	1229	1076	8.5	6.9	7.8	18.7	18.6	16.3	0.070
12/13/93	12:30	1467.5	22.7	5.7	17.0	1472	3040	5520	20.1	1374	1220	1063	8.5	6.9	7.8	19.0	18.9	15.9	0.071
12/14/93	11:00	1476.6	22.4	5.7	17.0	1539	3170	5720	23.9	1592	1432	1266	8.5	6.9	7.8	14.6	14.5	9.8	0.039
12/14/93	14:00	1479.6	22.7	5.7	17.0	1535	3170	5900	23.6	1589	1429	1265	8.5	6.9	7.8	14.8	14.7	12.1	0.037
12/14/93	15:00	1480.6	22.6	5.7	17.0	1534	3180	5940	23.8	1584	1425	1262	8.5	6.9	7.8	14.8	14.7	12.0	0.037
12/15/93	11:00	1487.3	22.5	5.7	17.0	1440	3090	6160	24.1	1449	1293	1134	8.5	6.9	7.8	17.3	17.1	10.6	0.030
12/15/93	11:30	1487.8	22.5	5.7	17.0	1435	2990	5600	24.9	1448	1292	1131	8.5	6.9	7.8	17.4	17.0	11.4	0.029
12/15/93	12:00	1488.3	22.5	5.7	17.0	1435	2987	5570	25.0	1447	1291	1131	8.5	6.9	7.8	17.4	17.1	11.3	0.029
12/16/93	11:00	1499.2	22.7	5.7	17.0	1475	3050	5670	25.5	1476	1319	1155	-	7.0	-	16.7	16.4	10.4	0.029
12/16/93	14:30	1502.7	22.8	5.7	17.0	1474	3040	5700	25.3	1448	1293	1133	-	6.9	-	17.0	16.9	13.3	0.028
12/17/93	17:00	1510.5	22.8	5.7	17.0	1482	3060	5700	26.5	1667	1504	1335	-	6.9	-	12.4	12.6	13.9	0.028
12/17/93	10:24	1510.9	22.8	5.7	17.0	1482	3010	5670	22.2	1667	1505	1336	-	6.9	-	12.5	12.6	15.0	0.029
12/17/93	12:52	1513.4	22.7	5.7	17.0	1462	3020	5710	22.4	1648	1487	1321	-	6.8	-	12.9	13.0	15.8	0.028
12/20/93	11:00	1517.8	22.5	5.7	17.0	1568	3260	5860	34.7	1144	997	850	8.5	6.9	-	26.1	25.6	12.3	0.047
12/20/93	13:30	1520.3	22.7	5.7	17.0	1568	3240	5690	35.4	1128	982	836	8.5	6.9	-	26.4	26.0	15.6	0.045
12/20/93	16:00	1522.8	22.7	5.7	17.0	1581	3270	5710	37.2	1141	995	848	8.5	6.9	-	26.6	25.8	13.8	0.044
12/20/93	17:00	1523.8	22.5	5.7	17.0	1580	3270	3800	37.6	1140	992	846	8.5	6.9	-	26.6	25.9	12.0	0.047
12/21/93	14:30	1528.3	22.7	5.7	17.0	1560	3210	5730	29.1	1317	1163	1009	-	6.9	-	20.4	20.2	16.2	0.030
12/21/93	15:00	1528.8	22.7	5.7	17.0	1560	3210	5670	29.6	1314	1161	1007	-	6.9	-	20.5	20.3	17.7	0.030
12/21/93	16:00	1529.8	22.7	5.7	17.0	1568	3200	5750	30.5	1305	1152	996	-	6.9	-	20.6	20.5	17.2	0.027
12/21/93	16:30	1530.3	22.7	5.7	17.0	1571	3220	5810	30.9	1306	1153	998	-	6.9	-	20.7	20.5	14.6	0.027
12/22/93	11:30	1540.3	22.7	5.7	17.0	1522	3150	5550	34.9	1152	1004	854	-	6.9	-	25.3	25.0	14.2	0.027
12/22/93	13:00	1541.8	22.8	5.7	17.0	1523	3150	5570	34.3	1152	1004	853	-	6.9	-	25.4	25.1	17.1	0.027
12/22/93	14:00	1542.8	22.9	5.7	17.0	1517	3130	5540	34.5	1141	996	848	-	6.9	-	25.5	25.4	19.1	0.027
12/22/93	15:00	1543.8	22.7	5.7	17.0	1529	3160	5610	35.7	1141	995	849	-	6.9	-	25.6	25.3	18.6	0.028
12/23/93	14:00	1551.8	22.7	5.7	16.9	1541	3160	5980	26.0	1464	1309	1151	-	6.9	-	16.3	16.5	18.1	0.029
12/23/93	15:00	1552.8	22.6	5.7	17.0	1541	3160	5980	26.0	1459	1302	1143	-	6.9	-	16.5	16.7	18.3	0.029
12/23/93	17:00	1554.8	22.9	5.7	17.0	1558	3210	5990	27.2	1472	1314	1154	-	6.8	-	16.9	16.6	12.6	0.026
12/27/93	14:50	1558.0	22.7	5.7	17.0	1488	3070	5540	17.4	1561	1402	1240	-	7.0	-	14.6	15.0	18.1	0.061
12/27/93	15:13	1558.4	22.2	5.7	17.0	1495	3080	5530	17.6	1548	1392	1231	-	6.9	-	14.6	14.8	19.2	0.067
12/27/93	17:00	1560.2	22.4	5.7	17.0	1503	3090	5630	19.9	1555	1396	1236	-	6.9	-	14.6	14.9	19.5	0.068
12/28/93	12:59	1568.2	22.7	5.7	17.0	1558	3220	5730	35.9	1134	984	837	-	6.9	-	25.9	25.6	19.6	0.043
12/28/93	13:42	1568.9	22.7	5.7	17.0	1554	3210	5120	36.6	1124	975	827	-	6.8	-	26.1	25.9	20.6	0.041
12/28/93	15:00	1570.2	22.7	5.7	17.0	1568	3230	5740	37.7	1122	976	829	-	6.9	-	26.3	25.9	20.3	0.043
12/29/93	13:06	1579.1	22.7	5.7	17.0	1528	3160	5790	26.4	1407	1242	1095	-	6.9	-	19.5	18.0	19.4	0.026
12/29/93	15:31	1581.5	22.9	5.7	17.1	1543	3190	5810	30.7	1306	1153	997	-	6.9	-	20.3	20.4	21.9	0.025
12/30/93	09:30	1592.2	22.8	5.7	17.0	1545	3190	6040	27.5	1495	1335	1173	-	6.9	-	16.2	15.9	10.1	0.025
12/30/93	10:00	1592.7	22.6	5.7	17.0	1537	3190	6020	27.4	1494	1335	1172	-	6.9	-	16.2	16.0	11.5	0.025
12/30/93	11:00	1593.7	22.7	5.7	17.0	1532	3160	5990	27.1	1460	1303	1143	-	6.9	-	16.4	16.4	15.5	0.025
01/03/94	09:30	1605.6	23.3	5.7	17.0	1522	3180	5770	23.2	1371	1217	1061	-	6.9	-	19.2	19.0	17.5	0.050
01/03/94	11:30	1607.6	22.8	5.7	17.0	1526	3190	5840	27.4	1307	1156	1002	-	6.9	-	20.4	20.6	24.2	0.058
01/03/94	13:30	1609.6	22.4	5.7	17.0	1526	3150	5710	29.5	1260	1109	956	-	6.9	-	21.3	21.7	16.7	0.055
01/03/94	15:00	1611.1	22.6	5.7	17.0	1538	3180	5740	31.5	1238	1088	936	-	6.9	-	22.1	22.5	25.4	0.057
01/04/94	12:00	1616.4	22.6	5.7	17.0	1536	3120	5300	30.4	1330	1174	1017	-	6.9	-	19.5	19.8	19.7	0.030
01/04/94	13:30	1617.9	22.8	5.7	17.0	1531	3150	5670	29.7	1306	1152	997	-	6.9	-	19.8	20.2	23.5	0.028
01/04/94	15:00	1619.4	22.6	5.7	17.0	1550	3190	5480	32.5	1293	1141	986	-	6.9	-	20.1	20.6	24.9	0.025
01/04/94	17:00	1621.4	22.6	5.7	17.0	1550	3190	5480	32.5	1293	1141	987	-	6.9	-	20.5	20.5	19.1	0.025
01/05/94	14:30	1629.7	22.7	5.7	17.0	1532	3160	5550	30.5	1317	1164	1007	-	6.9	-	19.5	19.7	20.4	0.026
01/05/94	15:30	1630.7	22.7	5.7	17.0	1538	3170	5610	31.2	1317	1163	1007	-	6.9	-	19.7	19.8	19.7	0.026
01/05/94	16:00	1631.2	22.8	5.7	17.0	1541	3170	5690	31.3	1331	1176	1019	-	6.9	-	19.7	19.7	17.4	0.026
01/05/94	16:30	1631.7	22.6	5.7	17.0	1542	3180	5520	30.9	1333	1177	1019	-	6.9	-	19.7	19.5	16.0	0.026
01/07/94	13:30	1645.1	22.8	5.7	17.0	1570	3250	5800	41.9	1078	933	785	7.7	6.9	7.3	27.5	27.2	16.5	0.025
01/06/94	16:00	1647.6	22.6	5.7	17.0	1570	3250	5800	41.9	1092	946	798	7.7	6.9	7.3	27.6	26.9	17.0	0.025
01/06/94	17:00	1648.6	22.7	5.7	17.0	1586	3280	5790	43.4	1092	944	799	7.6	6.9	7.3	27.5	26.9	14.0	0.026
01/07/94	11:00	1654.7	22.9	5.7	17.0	1555	3200	5940	30.6	1347	1193	1035	-	6.9	-	19.8	19.7	14.6	0.024
01/07/94	13:31	1657.2	22.6	5.7	17.1	1550	3180	5940	31.1	1329	1176	1021	-	6.8	-	20.1	20.1	18.1	0.024
01/07/94	14:33	1658.2	22.8	5.7	17.0	1559	3200	5990	32.4	1323	1171	1015	-	6.9	-	20.3	20.2	18.4	0.025
01/07/94	16:00	1659.7	22.8	5.7	17.0	1565	3220	6000	32.6	1322	1170	1015	-	6.9	-	20.6	20.2	16.3	0.024

Filmtec BW-30 Element Test Data - Continued

			Flowrate			Conductivity				Pressure			pH			Temperature			Turbidity
Date	Time	Elapsed Time (hours)	Feed (L/min)	Reject (L/min)	Permeate (L/min)	Feed (uS/cm)	Interstage (uS/cm)	Reject (uS/cm)	Permeate (uS/cm)	Feed (kPa)	Interstage (kPa)	Reject (kPa)	Raw Feed	RO Feed	Reject	Raw Feed (deg C)	RO Feed (deg C)	Ambient (deg C)	Filter Eff. (ntu)
01/10/94	09 30	1660 9	22 5	5 7	17 0	1525	3130	5740	23 8	1422	1266	1111	-	6 9	-	19 1	18.8	9 7	0 055
01/10/94	10 30	1661 9	22 6	5 7	17 0	1517	3120	5220	24 8	1420	1264	1108	-	6 9	-	19 1	18 9	12 7	0 050
01/10/94	13 30	1664 9	22 6	5 7	17 0	1510	3100	5710	26 9	1366	1211	1058	-	6 9	-	20 4	20 1	16 8	0 049
01/11/94	11 30	1672 6	22 9	5 7	17 0	1540	3150	5760	29.8	1358	1200	1043	-	6.9	-	19 8	19.8	15 6	0 043
01/11/94	14 00	1675 1	22 9	5 7	17 0	1537	3130	5530	29 7	1344	1188	1032	-	6.9	-	20 2	20 2	19 0	0 043
01/11/94	16 30	1677 6	22 6	5 7	17 0	1551	3180	5800	31 7	1332	1175	1023	-	6 9	-	20 8	20 6	16 6	0.042
01/12/94	13 30	1684 7	22 8	5 7	17 0	1521	3090	5750	27 9	1410	1251	1093	-	6 9	-	17 7	18 3	21 1	0 028
01/12/94	14 30	1685 7	22 7	5 7	17 0	1523	3120	5880	28 1	1409	1252	1093	-	6 9	-	18 0	18 4	21 1	0 028
01/12/94	16 00	1687 2	22 7	5 7	17 0	1533	3150	5940	28 9	1401	1242	1086	-	6.9	-	18 6	18 7	18 3	0 028
01/12/94	16 30	1687 7	22 6	5 7	17 0	1535	3150	5930	29 5	1398	1240	1085	-	6.9	-	18 7	18 7	17 3	0 027
01/13/94	09 30	1698 3	22 7	5 7	17 0	1551	3190	5850	37 6	1145	995	848	-	7.0	-	26 2	25 1	12 2	0 031
01/13/94	10 30	1699 3	22 5	5 7	17 0	1551	3190	5850	37 4	1132	982	834	-	7 0	-	26 3	26.1	16 5	0 031
01/13/94	11 30	1700 3	22 9	5 7	17 0	1543	3180	5840	38 5	1132	981	833	-	6 9	-	26 3	26 2	17 6	0 026
01/13/94	14 00	1702 8	22 9	5 7	17 0	1545	3170	5830	39 1	1117	967	822	-	6 9	-	26 7	26 7	23 2	0 027
01/14/94	11 00	1709 1	22 7	5 7	17 0	1547	3170	5920	33 4	1261	1105	951	-	6 9	-	21 8	21.9	19 8	0 032
01/14/94	11 30	1709 6	22 7	5 7	17 0	1547	3170	5880	33.4	1256	1101	948	-	6 9	-	21 8	22.0	20.9	0 027
01/14/94	13 30	1711 6	22.7	5 7	17 1	1552	3170	5890	33.5	1254	1098	947	-	6 9	-	21 9	22.1	23 0	0.027
01/14/94	15 30	1713 6	22.8	5 7	17 0	1557	3170	5920	33.8	1245	1091	940	-	6 9	-	22 1	23.3	23.4	0 027
01/17/94	10 30	1715 0	22 4	5 7	17 0	1536	3160	5760	20.4	1303	1151	999	-	7 0	-	21 4	21 2	19 0	0.076
01/17/94	11 30	1716 0	22 3	5 7	17 0	1536	3170	5840	26.4	1282	1130	979	-	6.9	-	21 5	21.6	21 4	0.073
01/17/94	15 30	1720 0	22 7	5 7	17 0	1545	3160	5820	32.8	1237	1086	937	-	6 9	-	22 7	22.9	26 7	0.068
01/17/94	17 00	1721 5	22 4	5 7	17.0	1550	3180	5740	33.7	1242	1090	941	-	6 9	-	22.9	22 9	21 5	0 064
01/18/94	11 00	1727 1	22 9	5 7	17.0	1551	3160	5750	32.9	1255	1099	946	-	6 9	-	22 0	22 1	20 8	0.052
01/18/94	11 30	1727.6	22.9	5 7	17.0	1551	3160	5750	32.9	1255	1099	946	-	6 9	-	22 0	22 1	20 8	0 052
01/18/94	11 30	1728 6	22.9	5 7	17.0	1552	3160	5740	32.7	1255	1099	945	-	6 8	-	22 0	22.2	21.6	0 054
01/18/94	14 00	1730 1	22 8	5 7	17 0	1541	3150	5770	32.8	1230	1077	922	-	6 8	-	22 7	22.9	25.1	0.057
01/18/94	16 00	1732 1	22 2	5 7	17.0	1563	3180	5710	35.0	1213	1060	908	-	6 9	-	23.3	23.5	25 8	0.053
01/19/94	16 30	1738 3	22 9	5 7	17.0	1551	3160	5640	32.8	1272	1117	966	-	7.0	-	21.6	21.7	21.8	0.026
01/20/94	14 30	1756 5	23 1	5 7	17.0	1554	3240	6030	38.9	1099	950	803	-	7 0	-	27.3	27.3	23.4	0 026
01/20/24	15 00	1757 0	22.7	5 7	17.0	1559	3210	5880	39.3	1097	949	804	-	7.0	-	27.5	27.5	23.6	0 026
01/21/94	13 00	1765.9	22.7	5 7	17.0	1548	3170	5890	34.4	1206	1053	901	-	7.0	-	23 0	23.3	21 5	0.024
01/21/94	15 30	1768.4	22.9	5 7	17.0	1557	3200	5950	34.8	1195	1043	892	-	7.0	-	23.5	23.8	24.9	0 024
01/21/94	16 30	1769.4	22.7	5 7	17.0	1561	3200	5930	35.5	1196	1043	894	-	7.0	-	23.7	23.7	21.7	0 024
01/24/94	14 00	1773.0	22 5	5 7	17.0	1564	3240	5930	33.5	1098	952	809	-	7.0	-	27 3	26 8	17 6	0 066
01/24/94	15 00	1774.0	22.2	5 7	17 0	1566	3250	5570	34.0	1101	954	812	-	7.1	-	27.3	26.7	17.5	0.068
01/24/94	16 00	1775.0	22 6	5 7	17.1	1569	3250	5560	34.7	1119	969	824	-	7.1	-	27.3	26.5	17.6	0.068
01/25/94	14 30	1783.6	22 7	5 7	17.0	1550	3160	5830	25.4	1602	1436	1272	-	7.1	-	16.5	14.3	10.0	0.029
01/25/94	15 30	1784.6	22 7	5 7	17.0	1544	3160	5750	27.4	1476	1311	1147	-	7.0	-	17.0	16.6	10.9	0 029
01/25/94	16.00	1785.1	22.8	5 7	17.0	1531	3140	5850	26.9	1517	1354	1191	-	7.1	-	15.4	15 3	15 8	0 027
01/27/94	10 00	1806.7	22 5	5 7	17.0	1594	3230	5960	32.3	1302	1143	990	-	7.0	-	23.1	21.3	6 6	0.027
01/27/94	11 00	1807.7	22.8	5.7	17.0	1557	3190	5810	35.4	1249	1091	938	-	7.0	-	22 9	22 1	6 7	0 026
01/27/94	12 00	1808.7	22.9	5 7	17.0	1556	3180	5810	35.5	1250	1092	939	-	7.0	-	22 4	21 9	10 7	0.025
01/28/94	14.00	1820.4	22 8	5 7	17.0	1532	3140	5880	29.1	1408	1248	1089	-	7.0	-	18.1	17 8	14.3	0.025
01/28/94	15 00	1821.4	22.8	5.7	17.0	1540	3160	5930	29.8	1398	1240	1082	-	7.0	-	18.2	17.9	14.4	0 026
01/31/94	14.00	1824.2	22.8	5 8	17.0	1522	3130	5800	24.8	1551	1388	1224	-	7.0	-	15.6	15.4	14 1	0 048
01/31/94	16:00	1826.2	22.9	5 7	17.0	1525	3120	5850	25.7	1528	1365	1204	-	7.0	-	16.0	15.8	15 8	0.048
02/01/94	15:00	1832.4	22.8	5.7	17.0	1528	3130	5780	28.7	1434	1273	1111	-	7.0	-	17.6	17.3	14.5	0 042
02/01/94	15.30	1832.9	22.8	5 7	17.0	1530	3120	5680	28.9	1435	1273	1116	-	7.1	-	17.6	17.4	13 8	0 040
02/01/94	16 00	1833 4	22.5	5 7	17.0	1530	3140	5660	29.2	1432	1273	1116	-	7.0	-	17.6	17.3	13.2	0 039
02/02/94	10 30	1842.3	22.4	5 7	17.0	1513	3090	5690	21.7	1412	1253	1095	-	7.0	-	17.5	17.4	13.9	0 067
02/02/94	11.00	1842.8	22.7	5.7	17.1	1510	3110	5510	22.2	1412	1255	1100	-	7.0	-	17.5	17 5	15 3	0.068
02/02/94	13:00	1844.8	22.9	5.7	17.0	1509	3080	5830	26.5	1395	1236	1080	-	7.0	-	17.9	17.9	18.0	0.066
02/02/94	15.00	1846.8	22.9	5 7	17.0	1517	3120	5810	29.4	1387	1228	1072	-	7.0	-	18 7	18.4	15.7	0.064
02/03/94	10:00	1853.4	22.9	5 7	17.1	1513	2789	5700	26.8	1494	1330	1166	-	7.0	-	16 0	15.7	9.6	0 052
02/03/94	11:00	1854.4	22 6	5 7	17.0	1508	3090	5730	27.2	1483	1319	1157	-	7.0	-	16.1	15.9	12.8	0.051
02/03/94	15 30	1858.9	22.9	5 7	17.0	1511	3080	5820	27.7	1461	1299	1139	-	7.0	-	16 4	16 5	15 1	0.046
02/03/94	16 00	1859.4	23.0	5 7	17.0	1512	3080	5840	27.8	1459	1298	1138	-	7.0	-	16 4	16 5	15 1	0 045

APPENDIX C

Analytical Data for the FilmTec BW-30 Element Testing

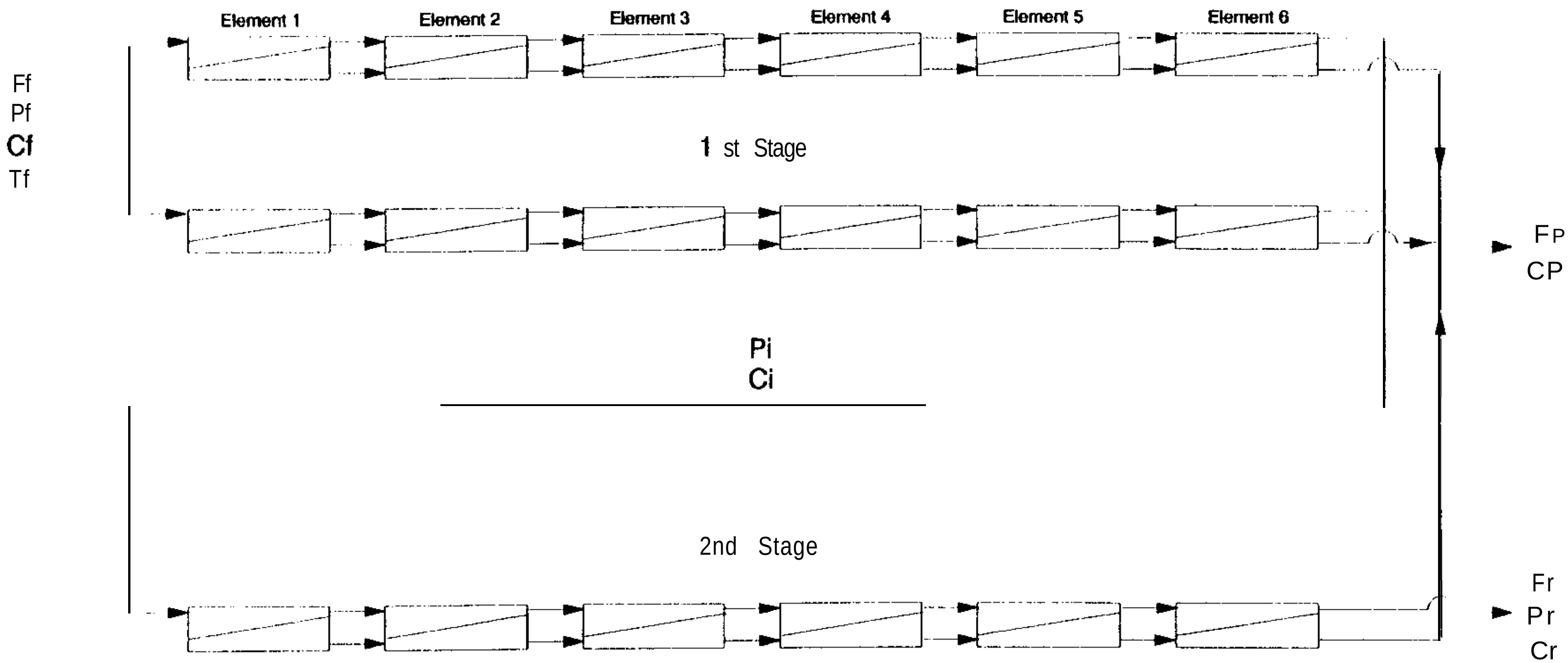
Analytical Data for the FilmTec BW30 Element Testing

			561-Hour Data 8/13/93		
			RO Feed	Permeate	Reject
CATIONS					
Calcium	Ca	mg/L	29	<0.1	111
Magnesium	Mg	mg/L	4.1	<0.1	8.1
Sodium	Na	mg/L	285	4.0	1150
Potassium	K	mg/L	I.4	co. 1	5.4
Aluminum	Al	mg/L	0.17	co.04	<0.04
Barium	Ba	mg/L	0.06	<0.002	0.22
Strontium	Sr	mg/L			
Iron (total)	Fe	mg/L	0.90	co.02	0.03
Iron (soluble)	Fe	mg/L	0.03	co.02	0.03
Manganese	Mn	mg/L	0.05	<0.005	0.05
Phosphorus (total)	P	mg/L			
Boron	B	mg/L	0.39	0.1	1.17
copper	Cu	ug/L	20	<3	IO
Selenium	Se	ug/L	2	<2	7
Mercury	Hg	ug/L	<0.4	co.4	<0.4
ANIONS					
Bicarbonate	HC03	mg/L	271	6.1	923
Carbonate	co3	mg/L	0	0	0
Chloride	Cl	mg/L	231	I.5	959
Sulfate	so4	mg/L	141	0.5	736
Flouride	F	mg/L	1.8	0.03	29
Nitrate	NO3	mg/L	7.5	0.4	30
Nitrite	NO2	mg/L	0.06	co.01	0.06
Ammonium	NH4+	mg/L			
Inorganic N (total)		mg/L	1.8	0.1	7.1
Silica (total)	SiO2	mg/L	22.9	<1	85.8
Silica (dissolved)		mg/L	22.3	<1	83.2
Total Organic Carbon		mg/L	CI.0	<1.0	3.9
Heterotrophic Plate Count	HPC	CFU/mL	>5700	381	>5700
Alkalinity	as CaCO3	mg/L			
Hardness	as CaC03	mg/L	90	1.0	352
Specific Conductance	Reported	µS/cm	1450	13	7200
Total Dissolved Solids	Reported	mg/L	665	25	3620
Total Dissolved Solids	Summation	mg/L	996	I4	4036
pH			8.2	5.6	7.7
Turbidity		ntu			
cations		meq/L	14.38	0.20	56.70
Anions		meq/L	14.11	0.16	59.51
Ratio Cations:Anions			1.02	I.26	0.95

APPENDIX D

Generalized RO Process Diagram for Checking Data Reduction

Generalized RO Process Diagram for Checking Data Reduction



Ff Flow, feed
Fr Flow, reject
Fp - Flow, permeate

Cf Conductivity. feed
Ci Conductivity, interstage
Cr - Conductivity, reject
Cp - Conductivity, permeate

Pf - Pressure, feed
Pi Pressure. interstage
Pr - Pressure. reject

Tf - Temperature, feed

APPENDIX E

RO Element Serial Numbers as Loaded in Pressure Vesselsy

RO Element Serial Numbers as Loaded in Pressure Vessels

Manufacturer FilmTec ; Model BW30-2540 ; Date 6/4/93

Stage 2, Vessel 1B, Elements 4-6

A1690876	A1690405	A1690750

Stage 2, Vessel 1 A, Elements 1-3

A1690854	A1690669	A1690416

Stage 1, Vessel 2B, Elements 4-6

A1690812	A1690760	A1690800

Stage 1, Vessel 2A, Elements l-3

Al 690770	A1690790	A1690796

Stags 1, Vessel 1B, Elements 4-6

A1690779	A1690814	A1690421

Stage 1, Vessel 1 A, Elements 13

A1690782	A1690409	A1690819

Note: Facing east from back of skid.

RO Element Serial Numbers as Loaded in Pressure Vessels

Manufacturer Desalination Systems ; Model Desal-3LP ; Date 7/21/94

Stage 2, Vessel 1B, Elements 4-6

63505	63508	63504

Stage 2, Vessel 1A, Elements 1-3

63487	63489	63497

Stage 1, Vessel 2B, Elements 4-6

63496	63488	63491

Stage 1, Vessel 2A, Elements 1-3

63517	63516	63515

Stage 1, Vessel 1B, Elements 4-6

63493	63494	63495

Stage 1, Vessel 1 A, Elements l-3

63514	63512	63513

Note: Facing east from back of skid.

APPENDIX F

Desal-3LP Element Test Data

Desal-3LP Element Test Data

Date	Time	Elapsed Time (hours)	Flowrates: Feed (L/min)	Flowrates: Reject (L/min)	Flowrates: Permeate (L/min)	Conductivities: Feed (uS/cm)	Conductivities: Interstage (uS/cm)	Conductivities: Reject (uS/cm)	Conductivities: Permeate (uS/cm)	Pressure: Feed (kPa)	Pressure: Interstage (kPa)	Pressure: Reject (kPa)	pH: Raw Feed	pH: RO Feed	pH: Reject	Temperature: Raw Feed (deg C)	Temperature: RO Feed (deg C)	Temperature: Ambient (deg C)	Turbidity Filter Effl. (ntu)
07/22/94	10.15	2.7	23.0	5.7	17.0	1604	2591	5480	29.6	1495	1322	1127	-	7.3	-	26.1	26.3	24.6	0.025
07/22/94	11.15	3.7	23.3	5.7	17.0	1602	3000	5430	29.2	1471	1298	1101	-	7.6	-	26.2	26.6	27.3	0.024
07/22/94	13.51	6.1	23.4	5.7	17.0	1603	2995	5600	30.3	1402	1231	1039	-	7.4	-	27.0	27.7	34.1	0.027
07/22/94	16.25	8.9	23.2	5.7	17.0	1618	3020	5550	33.7	1315	1146	955	-	7.4	-	28.9	29.6	30.3	0.024
07/25/94	11.15	12.9	23.3	5.7	16.9	1599	2400	5550	29.9	1316	1144	944	-	7.4	-	27.6	28.2	30.5	0.036
07/25/94	13.30	15.1	23.2	5.8	17.3	1610	2988	5680	34.5	1310	1135	934	-	7.2	-	28.1	28.9	34.6	0.051
07/25/94	15.00	16.6	23.2	5.7	17.0	1606	2978	5680	35.5	1276	1104	908	-	7.5	-	28.6	29.5	38.1	0.056
07/25/94	16.30	18.2	22.9	5.7	17.0	1615	2997	5680	37.6	1244	1075	883	-	7.5	-	29.1	30.3	37.0	0.056
07/26/94	14.00	23.4	22.5	5.7	16.9	1617	3000	5630	37.6	1248	1080	887	-	7.4	-	28.6	29.6	35.7	0.033
07/26/94	15.00	24.4	22.9	5.7	17.1	1618	3020	5740	40.5	1234	1050	872	-	7.2	-	29.1	30.3	38.2	0.035
07/26/94	16.00	25.4	22.9	5.7	17.1	1621	3030	5760	39.8	1231	1049	870	-	7.2	-	29.4	30.6	37.7	0.039
07/27/94	14.45	34.6	22.8	5.7	17.1	1654	3050	5550	35.0	1224	1054	857	-	7.2	-	29.2	30.5	36.9	0.048
07/27/94	15.35	35.5	22.8	5.7	17.0	1657	3090	5700	33.1	1218	1050	858	-	7.3	-	29.5	30.3	33.5	0.067
07/27/94	16.45	36.6	22.9	5.7	16.9	1658	3100	5570	35.8	1218	1049	858	-	7.3	-	29.8	30.4	31.9	0.069
07/28/94	13.20	46.7	22.8	5.7	17.1	1669	3130	5750	41.0	1216	1049	859	-	7.3	-	29.5	30.6	37.5	0.049
07/28/94	14.20	47.6	22.8	5.7	17.0	1670	3110	5810	41.9	1203	1033	841	-	7.4	-	29.8	30.9	37.6	0.046
07/28/94	16.00	49.3	23.0	5.7	17.0	1677	3130	5740	42.9	1201	1032	840	-	7.4	-	30.3	31.2	37.2	0.040
07/29/94	12.00	55.8	22.7	5.7	17.0	1706	3210	5960	38.6	1298	1126	931	-	7.5	-	27.3	28.0	32.9	0.023
07/29/94	13.35	57.3	23.0	5.7	17.1	1708	3190	5910	39.9	1270	1097	900	-	7.4	-	27.7	28.9	35.6	0.047
07/29/94	14.41	58.4	22.7	5.6	17.0	1712	3200	5910	39.7	1250	1079	885	-	7.4	-	28.1	29.1	34.1	0.051
08/01/94	11.10	67.7	22.7	5.7	16.9	1709	3190	5900	36.2	1303	1128	928	-	7.4	-	26.9	27.3	27.5	0.055
08/01/94	14.30	71.0	23.1	5.7	17.1	1718	3200	5920	40.0	1276	1100	904	-	7.3	-	27.7	28.6	36.1	0.051
08/01/94	15.20	71.9	22.9	5.7	17.0	1717	3190	5990	40.9	1256	1084	887	-	7.3	-	27.9	29.0	36.7	0.053
08/02/94	13.30	79.5	22.8	5.7	17.0	1711	3210	5910	41.2	1260	1088	894	-	7.5	-	27.8	28.7	32.4	0.037
08/02/94	14.56	80.2	23.0	5.7	17.0	1715	3200	6000	42.4	1244	1069	872	-	7.3	-	28.4	28.4	36.1	0.038
08/02/94	15.49	81.6	23.0	5.7	17.0	1719	3200	5870	43.1	1234	1060	865	-	7.4	-	29.7	29.7	36.5	0.038
08/02/94	16.48	82.6	22.8	5.7	17.0	1722	3210	5780	43.5	1226	1055	860	-	7.4	-	30.0	30.0	36.3	0.038
08/03/94	12.50	89.6	22.9	5.7	17.0	1683	3170	5680	40.3	1259	1087	891	-	7.5	-	27.7	28.6	34.9	0.041
08/03/94	15.00	91.7	22.9	5.7	17.1	1682	3170	5890	41.9	1237	1064	870	-	7.4	-	28.2	29.4	37.0	0.040
08/03/94	15.50	92.6	23.0	5.7	17.1	1689	3150	5830	42.6	1230	1058	863	-	7.4	-	28.4	27.6	36.8	0.039
08/04/94	11.55	101.4	22.6	5.7	17.0	1698	3200	5930	38.9	1290	1117	922	-	7.6	-	27.2	27.7	31.3	0.043
08/04/94	13.10	102.7	22.8	5.7	17.0	1698	3200	6030	41.8	1257	1086	894	-	7.4	-	27.5	28.5	36.2	0.042
08/04/94	14.50	104.2	23.0	5.7	17.0	1697	3170	5810	42.8	1235	1064	865	-	7.4	-	28.0	29.3	38.0	0.039
08/04/94	16.00	105.4	23.0	5.7	17.0	1701	3170	5890	42.8	1230	1059	862	-	7.4	-	28.3	29.6	38.3	0.039
08/05/94	14.25	113.2	22.6	5.7	17.0	1699	3180	5840	43.5	1200	1029	835	-	7.7	-	29.0	30.3	42.0	0.036
08/05/94	15.00	113.8	22.8	5.7	17.0	1711	3180	5940	44.6	1196	1026	830	-	7.6	-	29.2	30.5	42.5	0.037
08/05/94	16.30	115.2	23.2	5.7	17.0	1720	3190	5940	46.2	1183	1012	820	-	7.5	-	29.7	31.1	42.2	0.037
08/08/94	14.00	127.0	22.9	5.7	17.0	1701	3190	5850	43.0	1190	1017	819	-	7.3	-	30.0	31.0	35.6	0.093
08/08/94	15.30	129.5	22.9	5.7	17.0	1700	3180	5830	43.9	1172	1002	808	-	7.3	-	30.2	31.2	37.2	0.089
08/08/94	16.30	130.5	22.9	5.7	17.1	1703	3200	5910	45.2	1169	998	799	-	7.4	-	30.5	31.5	36.6	0.090
08/09/94	11.30	138.1	22.8	5.7	17.0	1702	3210	5930	44.6	1204	1033	845	-	7.3	-	29.5	30.1	30.6	0.065
08/09/94	14.09	140.8	22.8	5.7	17.0	1702	3200	5880	47.4	1170	1000	806	-	7.3	-	30.2	31.3	31.4	0.060
08/09/94	16.33	143.1	22.8	5.7	17.1	1709	3230	5870	44.5	1161	990	798	-	7.5	-	33.8	38.0	35.5	0.057
08/10/94	15.30	161.1	22.9	5.7	16.9	1712	3180	5520	43.8	1162	992	795	-	7.5	-	30.8	31.7	38.2	0.079
08/10/94	16.44	162.4	22.8	5.7	17.0	1717	3210	5840	37.3	1148	978	784	-	7.5	-	31.1	32.1	37.8	0.098
08/11/94	15.13	171.2	22.7	5.7	17.0	1713	2607	5820	46.1	1100	933	740	-	7.3	-	32.2	33.4	39.7	0.058
08/11/94	15.47	172.7	22.8	5.7	17.1	1721	3221	5790	44.4	1104	936	743	-	7.3	-	32.2	33.4	39.8	0.069
08/12/94	16.25	189.5	22.9	5.7	17.0	1695	3210	5610	41.4	1181	1006	812	-	7.2	-	31.2	31.5	29.7	0.043
08/15/94	15.00	201.4	22.9	5.7	17.0	1726	3310	6040	45.9	1147	975	782	-	7.2	-	31.2	32.0	33.6	0.048
08/15/94	16.30	202.9	22.9	5.7	17.1	1730	3280	6000	47.1	1147	974	780	-	7.3	-	31.5	32.1	32.6	0.051
08/16/94	14.30	211.7	22.0	5.0	17.1	1659	3240	6160	46.7	1136	975	806	-	7.3	-	30.6	31.6	35.9	0.035
08/16/94	16.00	213.1	22.2	5.0	17.1	1665	3240	6190	46.8	1132	973	805	-	7.3	-	31.6	31.8	35.1	0.059
08/16/94	17:00	214.0	22.3	5.0	17.1	1670	3260	6150	45.2	1132	972	804	-	7.3	-	35.9	30.2	33.8	0.061
08/17/94	14.10	224.5	22.8	5.7	17.0	1686	3210	5730	46.4	1193	1020	827	-	7.3	-	29.6	30.3	35.3	0.028
08/17/94	15:40	225.9	23.0	5.7	17.1	1686	3190	5810	47.3	1187	1012	813	-	7.3	-	30.0	30.8	33.8	0.045
08/17/94	16:50	227.1	23.0	5.7	17.0	1685	3200	5870	47.8	1176	1003	808	-	7.3	-	30.2	31.0	33.8	0.053
08/18/94	14.06	242.9	22.8	5.7	17.0	1683	3120	5430	37.0	1200	1023	814	-	7.3	-	29.4	30.1	35.0	0.041
08/18/94	14:50	243.6	23.2	5.7	17.0	1687	3150	5460	37.9	1213	1032	824	-	7.3	-	29.6	30.4	32.3	0.054
08/18/94	16.00	244.7	22.5	5.7	17.0	1692	3190	5590	41.6	1184	1010	812	-	7.3	-	29.9	30.7	34.0	0.062
08/19/94	11.30	254.5	22.4	5.7	17.0	1626	3090	5660	38.5	1231	1055	856	-	7.3	-	28.6	29.9	29.9	0.038
08/19/94	12.50	255.9	22.9	5.7	17.1	1627	3080	5300	39.6	1208	1032	835	-	7.3	-	28.9	33.1	33.1	0.041
08/19/94	14.49	257.8	22.7	5.7	17.0	1630	3080	5090	41.1	1179	1007	814	-	7.3	-	29.4	35.3	35.3	0.039
08/19/94	15.50	258.9	22.8	5.7	17.0	1633	3080	5390	37.5	1171	997	804	-	7.3	-	29.7	35.6	35.6	0.030
08/22/94	14:50	279.7	23.0	5.7	17.0	1626	3050	5440	35.5	1294	1113	899	-	7.3	-	26.9	27.7	31.9	0.122
08/22/94	15:30	280.4	22.8	5.7	16.9	1628	3080	5320	37.5	1280	1101	895	-	7.3	-	27.1	27.8	32.4	0.100
08/23/94	15:21	291.8	22.5	5.7	17.0	1524	2888	5340	33.7	1268	1093	889	-	7.3	-	26.0	27.0	35.4	0.044
08/23/94	16:26	292.9	22.9	5.8	17.0	1527	2898	5360	34.3	1263	1086	881	-	7.3	-	26.3	27.4	35.2	0.047
08/23/94	17.13	293.7	22.6	5.6	17.0	1531	2913	5390	36.0	1258	1082	881	-	7.3	-	26.5	27.5	34.4	0.041
08/24/94	14.50	303.7	23.0	5.7	17.0	1625	3060	5580	37.9	1245	1068	866	-	7.3	-	26.9	28.0	36.8	0.036

Desal-3LP Element Test Data - Continued

Date	Time	Elapsed Time (hours)	Flowrates Feed (L/min)	Flowrates Reject (L/min)	Flowrates Permeate (L/min)	Conductivities Feed (uS/cm)	Conductivities Interstage (uS/cm)	Conductivities Reject (uS/cm)	Conductivities Permeate (uS/cm)	Pressure Feed (kPa)	Pressure Interstage (kPa)	Pressure Reject (kPa)	pH Raw Feed	pH RO Feed	pH Reject	Temperature Raw Feed (deg C)	Temperature RO Feed (deg C)	Temperature Ambient (deg C)	Turbidity Filter Effl. (ntu)
08/24/94	15 58	304.8	22.7	5.7	17.0	1627	3050	5660	39.5	1237	1062	861	-	7.3	-	27.2	28.2	37.4	0.029
08/24/94	16 55	305.7	23.0	5.7	17.1	1635	3080	5610	39.5	1237	1060	860	-	7.3	-	27.5	28.6	37.1	0.030
08/25/94	14 59	323.0	23.1	5.7	17.0	1608	2698	5100	34.5	1214	1037	826	-	7.3	-	28.9	29.9	38.7	0.075
08/25/94	15 38	323.2	23.1	5.7	17.0	1608	3000	5300	36.7	1213	1034	824	-	7.3	-	28.9	30.1	38.3	0.061
08/25/94	16 52	324.0	23.4	5.7	17.0	1606	3010	5370	38.2	1210	1032	823	-	7.3	-	28.9	30.1	38.2	0.058
08/29/94	13 56	343.6	22.9	5.7	17.0	1597	3040	5350	43.0	1155	982	789	-	7.0	-	29.9	30.6	35.4	0.058
08/29/94	15 39	345.3	22.7	5.7	16.8	1600	3020	5450	42.1	1133	963	769	-	7.3	-	30.6	31.4	35.4	0.043
08/30/94	15 00	352.0	23.4	5.7	17.0	1565	2382	5280	32.2	1292	1108	895	-	7.4	-	26.3	27.3	34.3	0.025
08/30/94	16 00	353.0	22.9	5.7	16.9	1564	2966	5390	35.4	1261	1083	878	-	7.3	-	26.8	27.7	33.4	0.022
08/31/94	14 00	365.4	22.8	5.7	17.0	1557	2972	5260	36.6	1300	1121	922	-	7.3	-	25.7	26.3	29.0	0.020
08/31/94	15 30	366.9	23.0	5.7	17.0	1558	2967	5460	37.2	1279	1100	895	-	7.3	-	26.1	26.9	32.1	0.018
08/31/94	16 00	367.3	22.8	5.7	17.0	1557	2960	5380	37.2	1280	1100	899	-	7.3	-	26.2	27.0	32.3	0.019
09/01/94	15 00	376.0	23.1	5.7	17.0	1597	3020	5600	35.3	1293	1117	912	-	7.3	-	25.5	26.3	31.9	0.022
09/01/94	15 41	376.6	22.7	5.7	17.1	1597	3020	5610	35.8	1294	1114	911	-	7.4	-	25.7	26.5	30.8	0.025
09/02/94	14 54	387.8	23.2	5.7	17.1	1601	3030	5590	36.8	1297	1117	912	-	7.4	-	25.9	26.6	33.1	0.022
09/02/94	15 36	388.5	22.9	5.7	17.0	1602	3030	5620	36.4	1281	1103	899	-	7.4	-	26.1	26.9	33.7	0.027
09/02/94	16 00	388.8	22.5	5.7	17.0	1601	3030	5530	37.3	1275	1099	897	-	7.5	-	26.1	26.9	33.9	0.026
09/06/94	14 35	405.6	23.0	5.7	17.0	1647	3110	5730	40.8	1241	1063	862	-	7.5	-	27.4	28.5	37.0	0.055
09/06/94	15 00	406.1	23.2	5.7	17.0	1651	3120	5710	40.8	1230	1055	852	-	7.4	-	27.6	28.7	37.2	0.060
09/06/94	15 51	406.9	22.9	5.7	17.2	1654	3120	5780	42.4	1231	1052	853	-	7.4	-	27.9	28.8	37.2	0.061
09/08/94	10 34	415.1	23.3	5.7	17.0	1628	2920	5600	40.7	1297	1114	903	-	7.3	-	26.9	27.2	27.9	0.051
09/08/94	14 54	418.7	23.0	5.7	17.0	1616	3040	5480	39.8	1235	1058	858	-	7.3	-	27.6	28.4	35.8	0.041
09/09/94	14 55	427.5	22.8	5.7	17.0	1638	3090	5290	42.5	1225	1049	847	-	7.3	-	27.4	28.2	37.3	0.024
09/09/94	15 16	427.9	22.8	5.7	17.0	1640	3090	5620	41.6	1213	1038	837	-	7.2	-	27.6	28.6	37.9	0.021
09/09/94	15 51	428.5	22.9	5.7	17.0	1642	3090	5650	41.4	1211	1038	835	-	7.4	-	27.7	28.8	37.8	0.027
09/12/94	17 09	440.5	23.0	5.7	17.0	1609	3070	5580	32.7	1384	1200	993	-	7.2	-	24.2	24.3	25.6	0.061
09/14/94	09 02	452.0	23.0	5.7	17.0	1603	3070	5250	30.9	1514	1323	1108	-	7.5	-	21.4	21.2	15.6	0.028
09/14/94	11 51	454.5	22.6	5.7	17.0	1597	3050	5650	32.1	1413	1231	1022	-	7.3	-	22.3	22.6	25.2	0.033
09/14/94	14 29	457.1	22.9	5.7	17.0	1600	3040	5720	34.3	1377	1196	987	-	7.2	-	23.2	23.8	31.3	0.036
09/14/94	15 57	458.6	22.8	5.7	17.0	1608	3030	5500	35.5	1360	1179	974	-	7.3	-	23.8	24.6	32.2	0.021
09/15/94	15 27	463.7	22.8	5.7	17.0	1596	2978	5500	35.9	1320	1140	931	-	7.3	-	24.5	25.3	34.6	0.024
09/15/94	16 01	464.3	23.0	5.7	17.0	1590	2986	5540	37.1	1320	1140	934	-	7.3	-	24.7	25.4	34.7	0.022
09/16/94	15 12	475.2	23.1	5.7	17.0	1570	2996	5510	37.7	1266	1090	891	-	7.3	-	24.9	26.7	35.8	0.022
09/16/94	15 51	475.9	22.8	5.7	17.1	1571	2963	5440	37.0	1272	1094	891	-	7.4	-	25.2	26.4	34.7	0.020
09/21/94	12 47	488.3	22.7	5.7	17.0	1585	3010	5390	38.2	1301	1121	915	-	7.3	-	25.4	26.0	31.0	0.032
09/21/94	14 23	489.9	22.9	5.7	17.0	1584	3000	5540	39.0	1261	1083	881	-	7.2	-	26.0	26.9	33.0	0.030
09/23/94	14 49	500.8	22.8	5.7	17.0	1571	3000	5400	39.3	1261	1082	880	-	7.3	-	26.4	27.1	32.8	0.029
09/23/94	15 55	501.9	22.9	5.7	17.1	1576	3010	5530	40.4	1259	1079	877	-	7.4	-	26.8	27.4	31.8	0.029
09/26/94	15 28	510.2	23.2	5.7	17.0	1587	3030	5450	38.5	1330	1142	929	-	7.4	-	25.3	26.0	31.1	0.048
09/26/94	15 50	510.7	23.0	5.7	17.0	1586	3030	5480	39.1	1310	1128	924	-	7.4	-	25.4	26.1	31.5	0.046
09/27/94	15 52	523.9	22.7	5.7	17.0	1604	3040	5600	39.0	1264	1084	882	-	7.3	-	26.3	27.0	34.9	0.038
10/03/94	10 43	534.3	22.7	5.7	17.0	1589	3080	5630	38.5	1373	1183	972	-	7.4	-	24.7	24.5	16.8	0.035
10/03/94	14 00	537.6	22.9	5.7	17.0	1586	3070	5590	37.8	1346	1160	952	-	7.3	-	25.1	25.1	21.2	0.032
10/03/94	15 00	538.6	22.7	5.7	17.0	1589	3070	5600	38.0	1345	1159	952	-	7.3	-	25.2	25.2	21.7	0.028
10/03/94	16 00	539.6	22.9	5.7	17.0	1592	3070	5600	38.9	1340	1154	947	-	7.3	-	25.3	25.3	21.8	0.026
10/04/94	14 32	546.6	22.9	5.7	17.0	1573	3030	5640	31.1	1556	1362	1141	7.7	7.3	7.2	20.5	20.4	16.2	0.084
10/04/94	15 58	547.7	22.9	5.7	17.0	1571	3030	5710	30.4	1542	1351	1135	7.7	7.2	7.2	20.6	20.4	16.3	0.050
10/04/94	16 08	548.2	22.5	5.7	17.0	1570	3030	5670	30.6	1533	1343	1129	7.7	7.3	7.3	20.6	20.5	16.5	0.049
10/10/94	15 00	589.8	23.2	5.7	17.0	1526	2888	5280	29.2	1434	1239	1016	7.7	7.2	7.2	22.5	23.1	31.6	0.075
10/10/94	15 45	590.6	23.1	5.7	17.0	1535	2916	5340	30.0	1401	1209	998	7.7	7.2	7.2	22.5	22.8	31.4	0.090
10/11/94	15 20	601.4	22.9	5.7	17.0	1511	2889	4760	32.8	1394	1202	988	7.7	7.2	7.2	22.9	23.4	29.3	0.153
10/11/94	16 00	602.0	22.9	5.7	17.0	1515	2904	5490	32.9	1387	1195	983	7.7	7.2	7.2	23.2	23.7	29.3	0.116
10/12/94	15 00	613.2	23.0	5.7	17.0	1514	2912	5370	33.4	1393	1199	988	7.8	7.2	7.2	23.2	23.7	28.1	0.058
10/12/94	15 37	613.8	23.2	5.7	17.0	1515	2920	5430	35.4	1391	1196	983	7.8	7.2	7.1	23.4	23.9	27.7	0.056
10/14/94	14 34	636.7	23.0	5.7	17.0	1452	2816	5170	32.6	1446	1244	1028	7.8	7.4	7.4	22.3	22.3	20.8	0.061
10/14/94	15 40	637.3	23.0	5.7	17.0	1452	2815	5280	32.8	1436	1235	1020	7.8	7.3	7.3	22.5	22.5	20.4	0.055
10/14/94	16 01	637.7	23.0	5.7	17.0	1452	2820	5230	32.9	1439	1237	1022	7.8	7.2	7.3	22.6	22.5	19.8	0.056
10/17/94	15 12	649.0	22.6	5.7	17.0	1456	2800	5120	26.7	1657	1450	1224	7.8	7.3	7.2	16.8	17.2	23.5	0.054
10/17/94	15 40	649.4	22.9	5.7	17.0	1455	2808	5230	27.1	1656	1448	1221	7.8	7.3	7.2	17.0	17.3	23.6	0.051
10/18/94	15 19	660.6	22.9	5.7	17.0	1458	2805	5130	27.5	1606	1400	1176	7.8	7.2	7.2	17.7	18.2	25.4	0.044
10/18/94	15 41	660.9	23.0	5.7	17.0	1461	2818	5370	28.0	1604	1397	1173	7.9	7.2	7.2	17.8	18.3	25.1	0.043
10/19/94	15 07	672.6	23.0	5.7	17.0	1456	2803	5300	29.0	1541	1337	1118	7.8	7.3	7.2	19.0	19.5	25.8	0.042
10/19/94	15 53	673.4	22.8	5.7	17.0	1458	2817	5350	29.6	1541	1336	1117	7.8	7.2	7.2	19.1	19.6	25.9	0.041
10/19/94	16 15	673.7	23.1	5.7	17.0	1460	2817	4900	29.7	1539	1334	1113	7.8	7.2	7.2	19.3	19.7	26.0	0.041
10/21/94	14 06	687.4	23.2	5.7	17.1	1442	2797	5340	31.4	1508	1300	1080	8.0	7.1	7.2	20.0	20.4	26.1	0.030
10/21/94	14 54	688.2	23.0	5.7	17.0	1444	2793	5300	30.8	1485	1283	1065	8.0	7.2	7.2	20.3	20.9	27.0	0.030
10/21/94	15 56	689.2	23.1	5.7	17.0	1445	2809	5370	32.2	1472	1267	1050	8.0	7.2	7.1	20.7	21.2	27.1	0.030
10/24/94	16 00	695.6	22.6	5.7	17.0	1442	2793	5370	24.0	1535	1330	1111	7.7	7.2	7.2	18.9	19.3	16.7	0.130
10/25/94	13 53	707.3	22.8	5.7	17.0	1448	2822	5130	29.4	1545	1338	1118	7.7	7.3	7.4	19.0	19.4	23.0	0.077

Desal-3LP Element Test Data - Continued

Date	Time	Elapsed Time (hours)	Flowrates Feed (L/min)	Flowrates Reject (L/min)	Flowrates Permeate (L/min)	Conductivities Feed (uS/cm)	Conductivities Interstage (uS/cm)	Conductivities Reject (uS/cm)	Conductivities Permeate (uS/cm)	Pressure Feed (kPa)	Pressure Interstage (kPa)	Pressure Reject (kPa)	pH Raw Feed	pH RO Feed	pH Reject	Temperature Raw Feed (deg C)	Temperature RO Feed (deg C)	Temperature Ambient (deg C)	Turbidity Filter Eff. (ntu)
10/25/94	15.00	708.4	22.8	5.7	17.0	1448	2812	5370	30.1	1534	1329	1110	7.8	7.3	7.3	19.3	19.6	23.7	0.069
10/25/94	16.10	709.6	22.8	5.7	17.1	1450	2823	5370	30.7	1532	1326	1109	7.8	7.2	7.3	19.6	19.9	23.0	0.067
10/25/94	16.51	710.2	22.9	5.7	17.0	1450	2831	5430	30.8	1525	1319	1100	7.8	7.2	7.2	19.8	20.0	22.4	0.064
10/26/94	15.54	719.5	23.0	5.7	17.0	1444	2824	5360	30.2	1451	1249	1038	7.7	7.2	7.2	20.8	21.2	26.1	0.068
10/26/94	16.23	720.0	23.1	5.7	17.0	1444	2822	5240	31.0	1450	1248	1030	7.8	7.2	7.2	21.0	21.3	27.6	0.066
10/27/94	15.43	731.9	22.7	5.7	17.0	1442	2786	5060	34.5	1406	1206	993	7.8	7.3	7.2	21.5	22.2	29.0	0.056
10/27/94	16.41	732.8	22.9	5.7	17.0	1450	2802	5270	35.6	1404	1203	991	7.8	7.2	7.1	21.9	22.5	29.5	0.055
10/28/94	15.00	743.3	22.7	5.7	17.0	1442	2791	4990	33.7	1395	1195	982	7.8	7.2	7.3	22.1	22.6	28.2	0.065
10/28/94	15.45	744.1	22.9	5.7	17.0	1447	2797	4750	34.8	1403	1198	980	7.7	7.2	7.2	22.3	22.8	28.0	0.063
10/31/94	15.23	755.5	22.9	5.7	17.0	1434	2759	5170	31.1	1544	1338	1117	7.7	7.1	7.0	18.5	19.1	25.7	0.064
10/31/94	15.51	756.0	22.8	5.7	17.0	1437	2765	4710	31.2	1530	1325	1106	7.7	7.2	7.0	18.7	19.3	24.9	0.061
11/01/94	16.04	766.5	22.9	5.7	17.0	1430	2771	4870	30.3	1509	1305	1089	7.8	7.2	7.2	19.3	19.8	25.7	0.055
11/01/94	16.27	766.9	22.8	5.7	17.0	1431	2777	5210	30.6	1516	1310	1093	7.8	7.2	7.2	19.4	19.8	25.4	0.056
11/03/94	15.08	778.0	22.6	5.7	17.0	1433	2807	5180	27.3	1704	1493	1268	7.9	7.3	7.1	16.4	16.2	12.3	0.044
11/03/94	16.09	779.0	22.7	5.7	17.0	1433	2808	5140	27.2	1706	1496	1272	7.9	7.3	7.1	16.4	16.1	12.4	0.041
11/04/94	15.49	789.7	22.6	5.7	17.0	1407	2744	5010	25.1	1743	1530	1303	7.8	7.2	7.0	15.4	15.5	15.9	0.057
11/07/94	15.21	802.0	22.6	5.7	17.0	1402	2729	5110	28.6	1795	1581	1353	7.8	7.1	6.8	13.8	14.0	16.7	0.038
11/07/94	16.28	803.1	22.7	5.7	17.0	1418	2773	5210	28.0	1808	1593	1364	7.8	7.1	6.8	14.0	14.0	14.5	0.036
11/09/94	14.04	813.4	22.7	5.7	17.0	1398	2725	5070	28.5	1724	1511	1284	7.9	7.2	6.9	14.5	15.0	20.4	0.030
11/09/94	14.48	814.1	22.9	5.7	17.0	1407	2744	5100	29.2	1722	1509	1283	7.9	7.4	6.8	14.7	15.1	20.3	0.030
11/09/94	15.50	815.2	22.7	5.7	17.0	1417	2755	5160	29.1	1722	1507	1281	7.9	7.1	6.8	14.9	15.3	19.3	0.030
11/14/94	15.07	829.0	23.1	5.7	17.0	1421	2746	5200	27.5	1717	1502	1272	8.1	6.6	6.7	15.2	15.3	19.2	0.125
11/14/94	16.03	829.9	22.7	5.7	16.9	1415	2737	5180	28.8	1700	1487	1258	8.1	7.0	6.6	15.6	15.6	16.8	0.082
11/15/94	14.52	836.8	22.7	5.7	17.0	1393	2697	5000	24.9	1900	1682	1448	7.8	7.2	6.6	11.6	12.2	19.3	0.053
11/15/94	16.00	838.0	22.6	5.7	16.9	1408	2721	5130	24.7	1903	1685	1443	7.8	7.4	6.8	11.9	12.2	17.6	0.054
11/15/94	16.31	838.5	22.7	5.7	16.9	1406	2720	5160	24.5	1901	1685	1453	7.8	7.4	6.8	12.1	12.3	16.1	0.056
11/16/94	14.29	848.7	22.8	5.7	17.0	1412	2747	5250	23.2	1920	1703	1473	7.8	7.2	7.0	11.9	12.1	14.0	0.053
11/16/94	14.56	849.1	22.6	5.7	17.0	1410	2748	5316	23.8	1913	1695	1463	7.8	7.4	7.0	11.9	12.1	14.2	0.053
11/16/94	15.58	850.1	22.4	5.7	17.0	1410	2754	5220	24.5	1930	1714	1482	7.8	7.3	7.0	12.0	12.1	13.2	0.053
11/21/94	15.27	872.7	22.8	5.7	17.0	1441	2250	4370	17.7	1981	1759	1526	7.8	7.2	7.0	10.5	10.9	17.8	0.056
11/21/94	16.02	873.2	22.7	5.7	17.0	1143	2259	4380	19.0	1991	1770	1535	7.8	7.1	6.9	10.6	10.9	16.2	0.054
11/22/94	14.54	884.0	22.6	5.7	17.0	1130	2286	4630	13.7	1780	1564	1336	7.9	7.3	7.3	14.2	14.3	18.9	0.063
11/22/94	15.39	884.8	22.7	5.7	17.0	1137	2249	4370	17.3	1739	1525	1300	7.9	7.4	7.1	14.7	14.8	18.7	0.067
11/22/94	16.37	885.7	22.7	5.7	17.0	1140	2263	4370	18.7	1729	1516	1293	7.9	7.3	7.0	15.0	15.0	16.1	0.067
11/24/94	15.12	896.0	22.8	5.7	17.0	1122	2214	4300	20.1	1723	1511	1284	7.9	7.2	7.0	14.6	15.0	21.0	0.079
12/24/94	15.51	896.7	22.8	5.7	17.1	1130	2226	4310	21.8	1726	1512	1284	7.9	7.3	6.9	14.8	15.0	19.2	0.078
11/28/94	15.42	908.1	22.5	5.7	17.0	1106	2172	4170	18.5	1997	1778	1545	7.9	7.2	7.0	10.3	10.7	16.9	0.169
11/28/94	16.06	908.5	22.5	5.7	17.0	1108	2185	4290	17.0	1999	1780	1547	7.8	7.2	7.0	10.4	10.7	15.9	0.158
11/29/94	15.55	920.2	22.8	5.7	17.1	1109	2188	4190	18.9	1883	1666	1430	7.9	7.1	6.7	11.3	11.9	18.1	0.129
11/29/94	16.12	920.5	22.8	5.7	17.0	1114	2193	4180	19.2	1884	1669	1438	7.9	7.3	6.8	11.4	11.9	17.3	0.128
11/30/94	14.56	932.0	22.8	5.7	17.0	1128	2234	4240	27.4	1401	1198	980	7.8	7.4	6.9	21.3	21.5	22.4	0.200
11/30/94	15.55	933.0	23.1	5.7	17.0	1125	2218	4090	28.0	1388	1187	973	7.9	7.0	6.9	21.5	21.6	21.9	0.198
12/01/94	15.47	941.2	22.8	5.7	16.9	1122	2178	3790	21.4	1554	1346	1121	7.9	7.2	7.0	17.6	17.9	20.6	0.174
12/01/94	16.23	941.8	22.9	5.7	17.0	1129	2246	4170	24.2	1560	1351	1125	7.9	7.1	6.8	17.6	17.7	18.0	0.172
12/05/94	15.46	953.2	23.0	5.7	17.0	1139	2266	4230	15.9	1632	1422	1195	8.0	7.2	7.2	16.5	16.3	15.5	0.248
12/05/94	16.15	953.7	22.8	5.7	17.0	1148	2301	4370	18.1	1611	1403	1179	8.0	7.1	7.1	16.7	16.5	14.7	0.252
12/06/94	14.54	965.2	23.0	5.7	17.0	1152	2302	4200	19.4	1689	1478	1251	7.7	7.1	7.0	14.7	14.7	14.9	0.169
12/07/94	13.33	974.1	22.9	5.7	17.0	1118	2216	4260	23.4	1593	1365	1141	7.9	7.1	7.1	17.3	17.1	14.5	0.210
12/07/94	15.06	975.0	23.0	5.7	17.0	1120	2231	4190	22.8	1576	1366	1142	7.9	7.3	7.0	17.3	17.1	16.0	0.500
12/07/94	16.11	976.0	22.9	5.7	17.0	1122	2227	4170	24.5	1569	1360	1137	7.9	7.0	7.0	17.4	17.2	14.5	-
12/08/94	15.35	982.9	23.5	5.7	17.0	1161	2289	4250	23.8	1648	1438	1212	7.9	7.1	6.8	15.9	15.6	14.3	0.500
12/08/94	16.28	983.8	23.1	5.7	17.0	1158	2291	4310	24.1	1665	1453	1226	7.9	7.1	6.8	16.0	15.5	11.8	0.498
12/12/94	16.05	992.7	22.5	5.7	17.0	1152	2247	4300	22.0	1841	1626	1390	8.1	7.6	6.8	12.1	12.1	14.1	0.496
12/14/94	14.01	995.6	22.6	5.7	17.0	1140	2241	4310	19.7	1812	1597	1366	8.2	7.4	7.2	12.9	12.8	13.5	-
12/14/94	14.58	996.6	24.1	5.7	17.0	1143	2096	3980	18.4	1803	1587	1354	8.2	7.4	7.1	13.3	13.2	14.5	-
12/14/94	16.29	998.1	22.9	5.7	17.0	1148	2263	4210	21.2	1780	1565	1336	8.2	7.1	7.0	13.8	13.6	12.2	0.106
12/19/94	15.53	1004.6	22.7	5.7	17.0	1179	2315	4230	32.1	1323	1104	912	7.9	6.9	6.9	22.9	23.0	12.5	0.276

APPENDIX G

Analytical Data for the Desal-3LP Element Testing

Analytical Data for the Desal-3LP Element Testing

			5-Hour Data 7/22/94				523-Hour Data 9/27/94				996-Hour Data 12/19/94			
			RO Feed	Interstage	Permeate	Reject	RO Feed	Interstage	Permeate	Reject	RO Feed	Interstage	Permeate	Reject
CATIONS														
Calcium	Ca	mg/L	95	190	<1	408	83	169	<1	308	59	107	<1	198
Magnesium	Mg	mg/L	17	32	<1	68	17	34	<1	62	11	21	<1	40
Sodium	Na	mg/L	210	395	4	810	210	360	6	780	168	305	2	540
Potassium	K	mg/L	7	13	<1	29	8	14	<1	28	6	12	<1	19
Aluminum	Al	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Barium	Ba	mg/L	<0.1	0.2	<0.1	0.3	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1
Strontium	Sr	mg/L	0.6	1.1	<0.1	2.5	0.5	1.1	<0.1	2.0	0.5	0.9	<0.1	1.6
Iron	Fe	mg/L	0.21	<0.02	<0.02	<0.02	0.73	0.02	<0.02	0.03	0.24	<0.02	<0.02	<0.02
Manganese	Mn	mg/L	0.15	0.03	<0.01	0.06	0.08	0.03	<0.01	0.04	0.02	0.01	<0.01	0.02
Phosphorus (total)	P	mg/L	0.15	0.6	<0.05	1.3	0.35	0.55	<0.05	0.9	<0.05	0.4	<0.05	0.75
Boron	B	mg/L	1.0	1.6	0.6	2.3	1.1	1.6	0.7	2.0	1.0	1.7	0.6	2.5
Copper	Cu	µg/L	-	-	-	-	3.3	2.3	3.8	3.1	1.3	1.0	<0.4	2.4
Selenium	Se	µg/L	-	-	-	-	1.0	2.6	<0.5	4.8	2.2	3.1	<0.4	6.4
Mercury	Hg	µg/L	-	-	-	-	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2
ANIONS														
Bicarbonate	HCO3	mg/L	88	186	9	113	101	159	6	317	110	171	3	296
Carbonate	CO3	mg/L	9	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Chloride	Cl	mg/L	270	500	5	1100	260	500	7	1000	190	330	3	580
Sulfate	SO4	mg/L	290	560	2	1200	290	540	<1	1100	220	450	0.6	770
Flouride	F	mg/L	0.8	0.9	<0.1	2.3	0.5	0.8	<0.1	1.9	0.7	0.6	<0.1	2.1
Nitrate	NO3	mg/L	1.3	2.6	<0.1	4.9	1.8	3.5	<0.1	6.2	3.5	5.8	0.7	11.1
Nitrite	NO2	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ammonium	NH4+	mg/L	<0.1	0.3	<0.1	0.9	<0.1	0.1	<0.1	0.4	<0.1	<0.1	<0.1	<0.1
Inorganic N (total)	N	mg/L	0.3	0.6	0.0	1.8	0.4	0.9	<0.1	1.7				
Silica (total)	SiO2	mg/L	24	45	<1	95	18	36	<1	70	18	34	<1	65
Silica (dissolved)		mg/L	24	38	<1	84	18	32	<1	70	18	33	<1	56
Total Organic Carbon	TOC	mg/L	<1.0	1.7	<1.0	2.9	<1.0	1.3	<1.0	2.3	<1.0	1.3	<1.0	1.8
Heterotrophic Plate Count	HPC	cfu/mL	>5700	3021	76	>5700	2380	1468	197	2452	2380	208	14	741
Alkalinity	as CaCO3	mg/L	88	153	8	93	83	130	5	260	90	140	<3	243
Hardness	as CaCO3	mg/L	309	609	<3	1300	279	564	<3	1030	194	355	<3	662
Specific Conductance	Reported	µS/cm	1430	2900	33	5600	1490	3000	40	4600	1100	1880	18	4100
Total Dissolved Solids	Reported	mg/L	940	1900	15	3770	990	1760	30	3780	720	1330	15	2270
Total Dissolved Solids	Summation	mg/L	990	1883	21	3742	978	1789	24	3616	774	1410	10	2470
pH		-	8.3	7.7	6.4	7.8	8.2	8.0	6.8	7.9	8.2	7.9	6.5	8.0
Turbidity		ntu	1.4	0.3	0.1	0.5	6.8	0.3	0.2	0.2	3.0	0.15	0.1	0.1
Cations		meq/L	15.79	30.20	0.34	62.84	15.30	27.81	0.46	55.87	11.61	21.20	0.25	38.00
Anions		meq/L	15.46	28.90	0.33	58.07	15.08	28.05	0.30	56.51	11.84	21.61	0.16	37.53
Ratio Cations Anions		-	1.02	1.04	1.03	1.08	1.01	0.99	1.54	0.99	0.98	0.98	1.61	1.01

APPENDIX H

Proposed Saline Marsh Monitoring Program

Proposed
Saline Marsh Monitoring Program

(July 5, 1994)

STUDY I. Bioproductivity: Sustaining Habitat With A Reverse osmosis Reject Stream

1. NBS' botanist will monitor plant growth quarterly

2. District personnel will monitor plant growth weekly in both the control *and* experimental saline marshes. Written observations are to placed in both an Observation Bound Notebook and Observation Form. Copies of the Observation Forms are to be submitted monthly to the Wetland's Project Manager. If possible, the different species plant growth are to be measured weekly. Observation from plant growth by species will be ranked as follows:

<u>Plant Health Rating Scale</u>
from USBR

0 = No effect

1, 2, 3 = Leaf injury, epinasty, elongation abnormalities, discoloration, and/or chlorosis, minor to moderate

4, 5, 6 = Severe symptoms of conditions 1, 2, 3 and Possibility of some upper stem injury

7 = *Severe 1, 2, 3* symptoms plus 50 percent (%) stem injury

8 = *Severe 1, 2,* 3 symptoms plus rhizome and *stem* injury; stem usually 75 percent (%) dead

9 = Upper leaves and stem dead except for remaining 4 to 5 cm above soil; strong possibility of severe rhizome damage

10 = Plant dead

Also, weekly Polaroid photographic records will be taken at eight (8) locations, and the photographs are permanently placed in a Photo-Logbook. In Figure 1, letters mark the photographic locations. On the photographs will be written the date and photographic location. In addition, monthly photographs on slide film will be taken at the same eight (8) locations as mentioned previously. Significant changes in plant health will also be photographed on slide film.

3. Annually, benthic invertebrates are to be collected, counted and identified, by USBR, District personnel and/or outside benthic invertebrate specialist (if funds are available). In both the control and experimental saline marshes, ten (10) random subsamplings will be collected into a large flat pan to form a composite sample. The random subsamplings will use either a core sampler or Petersen grab sampler. From the composite Sample, grids are placed and all benthic organisms within a grid are removed for counting and identification. This is done either by sifting through the sediments or utilizing a series of seives. Grids will be randomly selected until at least one hundred (100) organisms have been obtained from the composite sample. The benthic organisms are to be preserved in formalin, Lugol's solution or some other preservation media for later identification. These organisms are to be classified by family and/or genus. A diversity index will be used to quantify the biological information in both the control and experimental saline marshes.

4. Wildlife and other general observations, such as weather, are to be written daily in the Observation Bound Notebook and summarized weekly on the Observation Form. Again, the Wetland's Project Manager will receive monthly copies of the Observation Forms.

STUDY II. General Rater Quality And Accumulation of Toxics In Saline Marshes Sustained With A Reverse Osmosis Reject Stream

1. Semi-annually, water quality parameters will be measured by analyzing five (5) grab samples in the Saline Marshes. The five (5) sample locations are shown in figure 1, location #1, 4, 5 & 8 and the reject stream. Parameters to be measured will include:

   General Minerals - Ammonium (NH_4), Ammonia-N (NH,-N, Calcium (Ca), Magnesium (Mg), Potassium (X), Sodium (Na), Bicarbonate (HCO,), Carbonate (CO,), Hydroxide (OH), Chloride (Cl), Fluoride (F), Nitrate (NO,), Nitrate-N (NO,-N), Sulfate (SO,), Hardness (Hard), Total Dissolved Solids (TDS), Conductivity (EC), Boron (B) and pH

   Miscellaneous - ortho-Phosphate (o-PO,), Total Phosphate-P (Total PO,-P), Suspended Solids (TSS), % Sodium, and Sodium Adsorption Ratio (SAR)

Metals -- Aluminum (Al), Antimony (Sb), Arsenic (As), Barium (Ba), Beryllium (Be), Cadmium (Cd), Total Chromium (Total Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se), Silver (Ag), Thallium (Tl), Zinc (Zn), and Boron (B)

If funding is available, Mercury (Hg), Selenium (Se), Copper (cu) and Boron (B) will be monitored more frequently (preferably, monthly) at the five (5) sampling sites mentioned above.

2. Conductivity (EC) and Temperature (and TDS by estimation) are to be monitored weekly at nine (9) sampling sites, locations #1 thru 8 in Figure 1 and the Reverse Osmosis (R.O.) reject line.

3. Monthly, Total Dissolved Solids (TDS @ 180°C) is to be monitored at nine (9) sampling sites , locations #1 thru 8 in Figure 1 and the Reverse Osmosis (R.O.) reject line.

4. Annually, composite soil samples of the inlet and outlet of the Control and Experimental Saline Marshes (location #1, 4, 5, & 8 of Figure 1) are to be analyzed for metals (see above STUDY II Paragraph 1 "Metals"). At each sample location, a minimum of three (3) soil grab samples, O-3 inches *in* depth using a core sampler or a Petersen grab sampler, are to be taken across *the* width of the *marsh.* These samples are then composited, in a large glass beaker, as one sample for each site. In addition to the "Metals" analyses, the following constituents will be tested for the soil samples.

   Particle-size analysis (PSA), pH, Conductivity (EC), Sodium Adsorption Ratio (SAR), Cation Exchange Capacity (CEC), and Organic Matter Content

5. Annually, the primary species of plants (stems, tubers and leaves) are to be collected, marked and analyzed by an outside contract laboratory for toxic accumulation, specifically Metals (see above STUDY II Paragraph 1 "Metals"). A minimum of two (2) grams (dry weight) of plants are needed for analysis, however, five (5) grams (dry weight) will be optimal. Estimated wet weight needed will be approximately one hundred (100) grams.

6. Annually, the benthic invertebrates in the saline marshes are to be collected randomly (see above STUDY I Paragraph 3) and sent to an outside contract laboratory for analysis of Metal accumulation (see above STUDY II Paragraph 1 "Metals") . In addition to the collection of the benthic organisms, rinsing and purging are required for sample

preservation. Again, a minimum of two (2) grams (dry weight) of benthic invertebrates are needed for analysis, however, five (5) grams (dry weight) will be optimal. Estimated wet weight needed will be approximately one hundred (100) grams. Once this is collected, the live benthic organisms are rinsed with filtered ambient water and held in a beaker with the filtered ambient water for four (4) to six (6) hours. This time period allows for ingested materials to be purged from the benthic organisms. After the purging period, the ambient water is drained. Again, a final rinse is done with filtered ambient water and drained.

7. Flows will be monitored daily for the control and experimental saline marshes. Flow data will be recorded in the Observation Bound Notebook, and weekly summarized on the Observation Form. Monthly, the Wetland's Project Manager will receive copies of the Observation Forms.

STUDY III. controlling Wildlife Use of Evaporation Ponds.

1. Observations are to be made daily of wildlife use in the marshes or evaporation cellss and recorded in the Observation Bound Notebook. Weekly, the daily observations are to be summarized on the Observation Form. Also, a detailed weekly observation shall include signs of wildlife use such as tracks and droppings and be written down in both the Observation Bound Notebook and Observation Form. Again, the Wetland's Project Manager will receive monthly copies of the Observation Forms. Photographic records are to be kept of any significant findings, and the photographs will then be kept in the Photo-Logbook. On the photographs, the date, time and description of the photographs will be written down.

STUDY IV. The Presence Of Toxics In Evaporation Pond Concentrate.

1. Semi-annually, the water in the evaporation cells is to be sampled for metals (see above STUDY II Paragraph 1 "Metals") . A grab sample shall be taken at location I and II in Figure 1.

2. In addition, weather characteristics such as rainfall and evaporation (from the evaporation pan) are to be observed daily and written down in the Observation Bound Notebook. Weekly, the weather characteristics are to be summarized in the Observation Form, and monthly, copies sent to the wetlands Project Manager.

Proposed
Saline Marsh Monitoring Program
Summary

Daily

1. Wildlife and other observations such as weather, flow data, and pan evaporation rate are to be observed and written in the Observation Bound Notebook.

Weekly

1. Wildlife and other observations such as daily flow data, weather, pan evaporation rate, are to summarized on the Observation Form.

2. Photographic records are to be taken of the Saline Marshes from eight (8) locations (see figure 1, A thru H), and the photographs are to be permanently placed in a photo-logbook.

3. Detailed wildlife use observations of the Saline Marshes and Evaporation Ponds and are to be written in the Observation Bound Notebook and Observation Form.

4. EC and Temperature (and TDS by summation) are to be monitored at locations #1 thru 8 in Figure 1 and at the R.O. Reject line.

Monthly

1. Copies of the Observation Forms are to be submitted to Wetland's Project Manager.

2. TDS @ 180°C are to be monitored at location #1 thru 8 in Figure 1 and at the R.O. Reject line.

3. Slide photographes are to be taken of the Saline Marshes from eight (8) location (see figure 1, A thru H), and the slides are to be stored in the photo-logbook.

4. Five (5) grab samples (see Figure #1, 4, 5 & 8 and reject stream) will be monitored for Selenium (Se), Mercury (Hg), copper (Cu) and Boron (B) -- optional.

Quarterly

1. NBS' botanist will monitor plant growth. Dates: unknown

Semi-Annually

1. Five (5) grab samples (water) from the Saline Marshes (see Figure 1, $1, 4, 5 & 8 and reject stream for sample locations) will be sampled for General Minerals, Metals and other constituents.

Dates: June 30th and January 30th

2. Two (2) grab samples (water) from the Evaporation Ponds (see Figure 1, I & II for sample locations) are to be sampled and analyzed for Metals. Dates: June 30th and January 30th

Annually

1. From ten (10) random subsamples collected to form a composite sample, benthic invertebrates are to be collected and split. One hundred (100) random specimens are to be preserved in preservation media and identified -- optional. For the other split, approximately one hundred (100) grams (wet weight) of specimens will be sent to an outside laboratory for Metals analyses. Dates: June 30th

2. Four (4) composited sediment sample are to be analyzed for Metals (see figure 1, #1, 4, 5 & a for sample location. In addition to Metals analyses, Particle-Size Analysis (PSA), pH, Conductivity (EC), Sodium Adsorption Ratio (SAR), Cation Exchange capacity (CEC) and Organic Matter Content will be analyzed. Dates: June 30th

3. A minimum of two (2) grams (dry weight) for each plant species are to be collected and sent to an outside laboratory for Metals analyses. Dates: June 30th

Notes

1. If samples are to be held overnight, samples are to be preserved according to either the contract laboratory's preservation procedure or 18th Edition of Standard Methods.
2. Dates are approximate days to sample.

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APPENDIX I

Pictorial Illustration of the Vegetation Establishment in the Saline Vegetated Wetlands through the Study Period

The following series of pictures show an abridged progression of the plant growth and establishment from May 1993 through August 1995. Photographs were taken by Ms. Stella Denison, EMWD biologist, and Ms. Joanna Crombie, EMWD Water Quality Specialist.

North Wetland - May 25, 1993
One month after planting. Four salinity tolerant species were planted in horizontal bands across the cell repeated three times to expose the plants to different positions along the salinity gradient.

South Wetland - May 25, 1993
One month after planting. Four salinity tolerant species were planted in horizontal bands across the cell repeated three times to expose the plants to different positions along the salinity gradient.

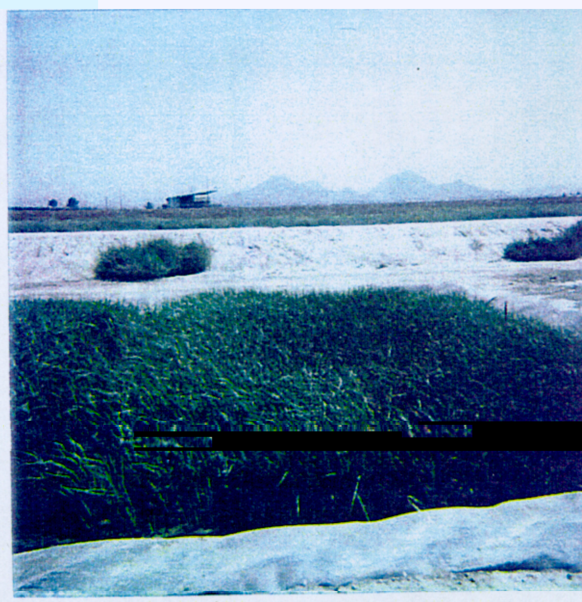
North Wetland - May 25, 1993
Same as above. Picture taken from west end.

South Wetland - May 25, 1993
Same as above. Picture taken from east end.

North Wetland August 5, 1993
Fourteen weeks after planting, alkali bulrush (*Bolboshoenus robustus)* had spread to every available area except the bands planted with creeping spikerush (*Eleocharis palustris*). Spike-rush is visible in the lower left corner of photo.

South Wetland August 5, 1993
Fourteen weeks after planting, alkali bulrush (*Bolboshoenus robustus*) had spread to every available area except the bands planted with creeping spikerush (*Eleocharis palustris*). Spikerush is the band in the center of the photo

North Wetland - August 5, 1993
Same as above. Picture taken from west end. Only alkali bulrush is visible.



South Wetland August 5, 1993
Same as above. Picture taken of west end. Spikerush is visible in band along left side of photo.

North Wetland - October 4, 1993
Over five months after planting, older alkali bulrush is browning due to cooler temperatures.

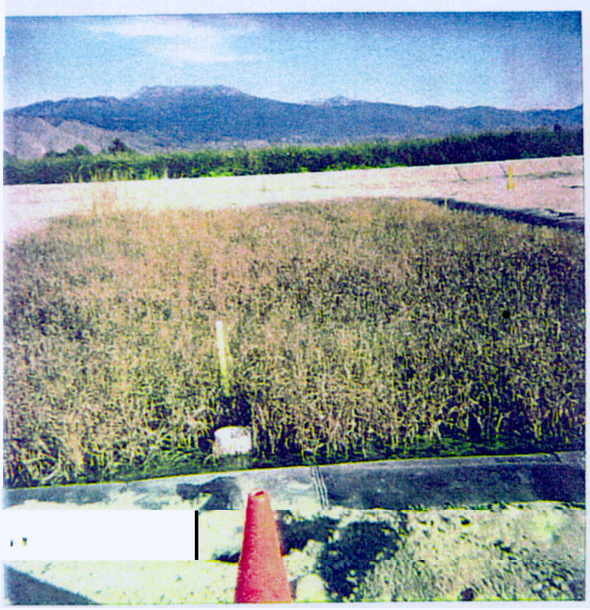
South Wetland - October 4, 1993
Over five months after planting, older alkali bulrush and spiketush are browning due to cooler temperatures and saline conditions.

North Wetland - October 4, 1993
Same as above, Picture taken from west end. Cattail (*Typha spp.*) recruits are visible in the left background.

South Wetland - October 4, 1993
Same as above.. Picture taken of east end. Spiketush is visible in left foreground, cattails are visible in left background, and younger, greener alkali bulrush is visible in left middle-ground.

North Wetland January 10, 1994
Eight months after planting, the majority of vegetation has senesced due to the colder temperatures. Picture taken from east end.

South Wetland January 10, 1994
Eight months after planting, the majority of vegetation has senesced due to the colder temperatures. Picture taken of east end, looking south.



North Wetland - January 10, 1994
Same as above. Picture taken from west end.

South Wetland January 10, 1994
Same as above. Picture iaken of east end, looking north.

North Wetland - May 27, 1994

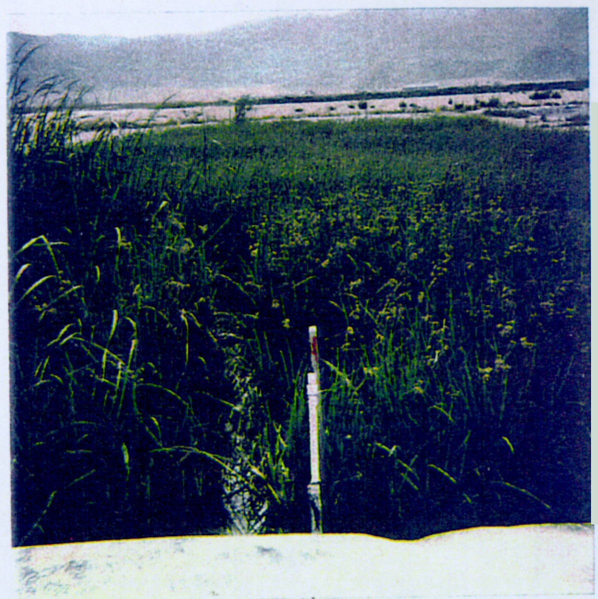
Thirteen months after planting, the vegetation is lush and green after the spring rains. More cattail plants are visible on right side. A band of lush spikerush is visible on the left.

South Wetland - May 27, 1994

Thirteen months after planting, the vegetation is lush and green after the spring rains and no reject brine flow since February 9, 1994

North Wetland - May 27, 1994

Same as above. Picture taken from east end. Lush spikerush visible in foreground, cattail visible on the right, and alkali bulrush in background.

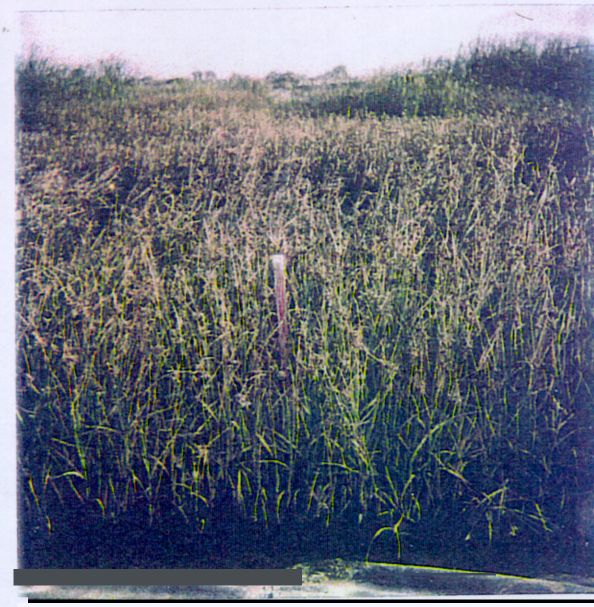


South Wetland - May 27, 1994

Same as above. Picture taken from east end, looking west. Cattail visible on left side. Lush alkali bulrush dominates rest of wetland.

North Wetland - August 26, 1994

Sixteen months after planting, cattail continues to spread. Alkali bulrush is still dominant, while a small spikerush stand is visible in the left foreground.



South Wetland - August 26, 1994

Sixteen months after planting, and five weeks of receiving reject brine flow, the older alkali bulrush plants are browning due to the higher water salinities.

North Wetland - August 26, 1994

Same as above. Picture taken from east end., Lush cattail and alkali bulrush are visible in the foreground.

South Wetland - August 26, 1994

Same as above. Picture taken from east end, looking west. Lush cattail visible on left side. Older alkali bulrush is browning.

North Wetland - January 13, 1995
Twenty and one half months after planting, the vegetation has mostly senesced due to the colder temperatures.

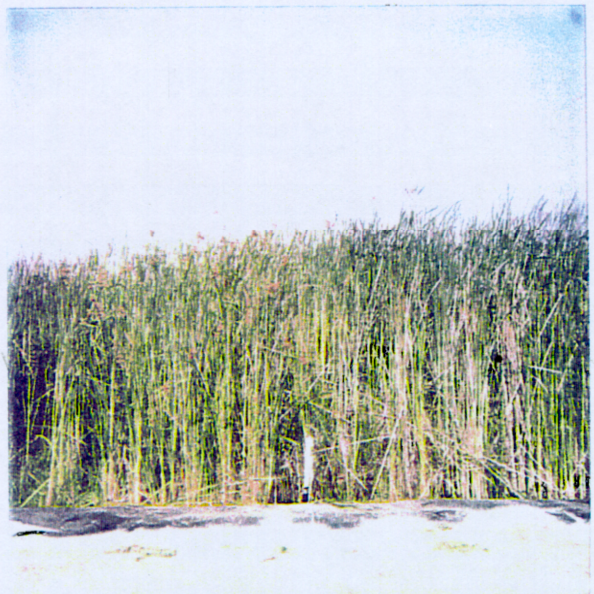
South Wetland - January 13, 1995
Twenty and one half months after planting, and almost six months of receiving reject brine flow, the vegetation has senesced due to the colder temperatures.

North Wetland January 13, 1995
Same as above. Picture taken from east end.

South Wetland - January 13, 1995
Same as above. Picture taken from east end, looking west

North Wetland - May 26, 1995
Twenty-five months after planting, the vegetation was lush and green after the spring rains and warm temperatures. Although the three main plant species were still present, cattails were becoming the dominant species.

South Wetland - May 26, 1995
Twenty-five months after planting, and nine months of receiving reject brine flow, the alkali bulrush and cattail came back at densities similar to the previous year. In contrast to the previous year, the plants were browner probably due to the higher water salinities.



North Wetland - May 26, 1995
Same as above. Picture taken from east end. Cattail was becoming the dominant species. A few hardstem bulrush recruits are visible in the left foreground.

South Wetland - May 26, 1995
Same as above. Picture taken from east end. looking west. More cattail are visible. Vegetation was browning due to water salinities.

North Wetland - August 28, 1995
Twenty-eight months after planting, cattail became the dominant species in the cell. High evaporation and low water flow stressed vegetation in the wetland.

South Wetland - August 28, 1995
Twenty-eight months after planting, twelve months of receiving reject brine flow, and high evaporation rates caused browning of the vegetation.

North Wetland - August 28, 1995
Same as above. Picture taken from east end.

South Wetland - August 28, 1995
Same as above. Picture taken from east end, looking west.

APPENDIX J

Electrical Conductivity (EC) and Total Dissolved Solids (TDS)
Readings in the North and South Vegetated Wetlands

Electrical **Conductivity** (EC) and Total **Dissolved Solids** (TDS) Readings In the North and South Vegetated Wetlands[5]

Date	North Cell								
	Station 5		Station 6		Station 7		Station 8		
	EC	TDS	EC	TDS	EC	TDS	EC	TDS	AVG EC
07/13/93	6360	4134	6680	4342	6580	4277	6550	4258	6543
07/14/93	6470	4206	6710	4362	6570	4271	6930	4505	6670
07/21/93	6250	4063	6550	4258	7140	4641	7640	4966	6895
07/23/93	2120	1378	2190	1424	3530	2295	4490	2919	3083
07/29/93	5200	3380	5100	3315	5200	3380	5310	3452	5203
08/02/93	5400	3510	5640	3666	5520	3588	5350	3478	5478
08/04/93	5280	3432	5490	3569	5630	3660	5490	3569	5473
08/09/93	6860	4459	7000	4550	7220	4693	7320	4758	7100
08/12/93	6270	4076	8710	5662	7070	4596	7880	5122	7483
08/18/93	4860	3159	4870	3166	4790	3114	4710	3062	4808
09/01/93	5570	3621	7420	4823	7990	5194	6890	4479	6968
01/18/94	3500	2275	3800	2470	3950	2568	4250	2763	3875
01/21/94	4050	2633	4190	2724	4360	2834	4500	2925	4275
01/28/94									
02/24/94	1400	910	1350	878	1300	845	1350	878	1350
03/03/94	1550	1008	1600	1040	1650	1073	1700	1105	1625
03/11/94	1650	1073	1850	1203	1800	1170	1950	1268	1813
03/18/94	2300	1495	2400	1560	2400	1560	2400	1560	2375
03/28/94	1450	943	1800	1170	1700	1105	1750	1138	1675
04/04/94	1900	1235	2200	1430	2100	1365	2300	1495	2125
04/19/94	950	618	1800	1170	2500	1625	2400	1560	1913
04/27/94	550	358	1050	683	2100	1365	2600	1690	1575
05/06/94	1550	1008	3200	2080	2900	1885	2900	1885	2638
05/13/94	1600	1040	2100	1365	2600	1690	2500	1625	2200
05/20/94	900	585	1050	683	1850	1203	1650	1073	1363
06/03/94	800	520	1450	943	2700	1755	2900	1885	1963
06/10/94	1100	715	1500	975	2900	1885	2000	1300	1875
06/17/94	1800	1170	2000	1300	2200	1430	2200	1430	2050
06/24/94	1850	1203	2000	1300	2400	1560	2400	1560	2163
07/01/94	1700	1105	2100	1365	2500	1625	2800	1820	2275
07/08/94	950	618	1150	748	1400	910	1200	780	1175
07/15/94	1950	1268	2200	1430	2300	1495	2600	1690	2263
08/16/94	450	293	850	553	1950	1268	2000	1300	1313
08/22/94	550	358	1250	813	1850	1203	1900	1235	1388
08/30/94	350	228	650	423	1450	943	1450	943	975
09/06/94	650	423	1000	650	1450	943	1250	813	1088
09/13/94	400	260	850	553	1250	813	1200	780	925
09/20/94	400	260	900	585	1100	715	1450	943	963
09/27/94	550	358	1100	715	1400	910	1350	878	1100
10/04/94	500	325	1200	780	1250	813	1400	910	1088
10/11/94	450	293	1000	650	1100	715	1250	813	950
10/18/94	600	390	1100	715	1200	780	1200	780	1025
11/01/94	350	228	450	293	700	455	750	488	563
11/08/94	1200	780	850	553	950	618	1000	650	1000
11/15/94	500	325	350	228	450	293	450	293	438
11/22/94	800	520	700	455	800	520	900	585	800
11/29/94	900	585	700	455	800	520	800	520	800
12/06/94	1000	650	800	520	900	585	900	585	900
12/13/94	950	618	850	553	1000	650	1000	650	950
12/20/94	800	520	850	553	1000	650	1000	650	913
12/27/94	1000	650	1000	650	900	585	975	634	969
01/03/95	450	293	450	293	450	293	400	260	438
01/10/95	600	390	700	455	700	455	650	423	663
01/17/95	700	455	750	488	750	488	750	488	738
01/24/95	700	455	800	520	850	553	800	520	788
02/03/95	815	530	971	631	945	614	888	577	905
02/10/95	269	175	523	340	833	541	558	363	548
02/17/95	319	207	537	349	540	351	540	351	484
02/24/95	65	42	390	254	709	461	748	486	478

Date	South Cell								
	Station 1		Station 2		Station 3		Station 4		
	EC	TDS	EC	TDS	EC	TDS	EC	TDS	AVG EC
07/13/93	6520	4238	7220	4693	7330	4765	7420	4823	7123
07/14/93	6820	4433	6810	4427	7360	4784	7510	4882	7125
07/21/93	7200	4680	7220	4693	8080	5252	8330	5415	7708
07/23/93	3220	2093	2780	1807	2390	1554	3550	2308	2985
07/29/93	5510	3582	5470	3556	6520	4238	6560	4264	6015
08/02/93	6600	4290	6450	4193	6510	4232	6440	4186	6500
08/04/93	6870	4466	6730	4375	7040	4576	7210	4687	6963
08/09/93	7580	4927	8840	5746	8630	5610	9460	6149	8628
08/12/93	7500	4875	7260	4719	9090	5909	9050	5883	8225
08/18/93	6040	3926	6180	4017	6220	4043	6250	4063	6173
09/01/93	7680	4992	7640	4966	9990	6494	10021	6514	8833
01/18/94	5200	3380	6250	4063	6500	4225	6500	4225	6113
01/21/94	5800	3770	6400	4160	6700	4355	6850	4453	6438
01/28/94	5400	3510	5500	3575	5700	3705	5500	3575	5525
02/24/94	2600	1690	2500	1690	2500	1625	2500	1625	2525
03/03/94	2900	1885	2900	1885	3000	1950	2800	1820	2900
03/11/94	3200	2080	3100	2015	3100	2015	3200	2080	3150
03/18/94	4100	2665	4200	2730	4000	2600	4000	2600	4075
03/28/94	2300	1495	2300	1495	2300	1495	2200	1430	2275
04/04/94	2800	1820	3000	1950	2900	1885	2900	1885	2900
04/19/94	2600	1625	2700	1755	2900	1885	2800	1820	2725
04/27/94	750	488	1600	1040	2800	1820	2800	1820	1988
05/06/94	3400	2210	4000	2600	3800	2470	3800	2470	3750
05/13/94	1650	1073	1750	1138	2200	1430	2400	1560	2000
05/20/94	1800	1170	1650	1073	1900	1235	1850	1203	1800
06/03/94	1750	1138	2200	1430	3200	2080	3300	2145	2613
06/10/94	1800	1170	2100	1365	3300	2145	3500	2275	2675
06/17/94	3000	1950	3100	2015	3000	1950	3050	1983	3038
06/24/94	2400	1560	2500	1625	2400	1560	2500	1625	2450
07/01/94	2300	1495	2600	1690	2600	1690	2600	1690	2525
07/08/94	1250	813	1350	878	1700	1105	1650	1073	1488
07/15/94	2700	1755	2800	1820	2700	1755	3100	2015	2825
08/16/94	5900	3835	5900	3835	6200	4030	6400	4160	6100
08/22/94	6400	4160	5900	3835	6200	4030	6400	4160	6225
08/30/94	4600	2990	5900	3835	6000	3900	6100	3965	5650
09/06/94	4500	2925	6600	4290	6700	4355	6800	4420	6150
09/13/94	6500	4225	6200	4030	6500	4225	6400	4160	6400
09/20/94	5400	3510	6000	3900	5500	3575	5600	3640	5625
09/27/94	6100	3965	6300	4095	6800	4420	6700	4355	6475
10/04/94	6200	4030	6500	4225	6400	4160	6800	4420	6475
10/11/94	6300	4095	6400	4160	6600	4290	6900	4485	6550
10/18/94	6000	3900	6200	4030	6700	4355	6700	4355	6400
11/01/94	4900	3185	4800	3120	4900	3185	5300	3445	4975
11/08/94	4000	2600	4900	3185	5000	3250	5000	3250	4725
11/15/94	3500	2275	3700	2405	3800	2470	3900	2535	3725
11/22/94	3600	2340	3800	2470	3900	2535	3700	2405	3750
11/29/94	3500	2275	3700	2405	3800	2470	3800	2470	3700
12/06/94	3600	2340	3800	2470	3700	2405	3900	2535	3750
12/13/94	3500	2275	3700	2405	3900	2535	3900	2535	3750
12/20/94	~~3600~~	~~2340~~	~~3800~~	~~2470~~	~~3800~~	~~2470~~	~~4000~~	~~2600~~	~~3800~~
12/27/94	3800	2470	3900	2535	3900	2535	4100	2665	3925
01/03/95	1000	650	900	585	750	488	800	520	863
01/10/95	1150	748	1200	780	1200	780	1250	813	1200
01/17/95	1300	845	1550	1008	1400	910	1400	910	1413
01/24/95	1500	975	1750	1138	1350	878	1250	813	1463
02/03/95	~~1778~~	~~1168~~	~~1803~~	~~1172~~	~~1848~~	~~1200~~	~~1766~~	~~1148~~	~~1798~~
02/10/95	3400	2210	2280	1482	2340	1521	2210	1437	2558
02/17/95	1717	1116	2210	1437	1930	1255	1910	1242	1942
02/24/95	3150	2048	3830	2490	2320	1508	2400	1560	2925

Note: Shaded numbers indicate periods when the RO system was not operating, and therefore reject flow was unavailable.

Electrical Conductivity (EC) and Total Dissolved Solids (TDS) Readings in the North and South Vegetated Wetlands -Continued

	North Cell									South Cell								
	Station 5		Station 6		Station 7		Station 8			Station 1		Station 2		Station 3		Station 4		
Date	EC	TDS	EC	TDS	EC	TDS	EC	TDS	AVG EC	EC	TDS	EC	TDS	EC	TDS	EC	TDS	AVG EC
03/06/95	157	102	253	164	427	278	335	218	293	1707	1110	2990	1944	1790	1164	1980	1287	2117
03/24/95	135	88	221	144	354	230	398	259	277	2670	1738	3410	2217	3020	1963	3050	1983	3038
03/31/95	150	98	533	346	546	355	488	317	429	4160	2704	4260	2769	3850	2503	4030	2620	4075
04/14/95	84	55	120	78	410	287	475	309	272	4400	2860	5260	3419	5940	3861	6380	4147	5495
06/09/95	88	57	287	187	408	265	941	612	431	7310	4752	8130	5285	7490	4869	7230	4700	7540
06/16/95	92	60	575	374	458	298	1112	723	559	6050	3933	6600	4290	7850	5103	7070	4596	6893
06/30/95	83	54	252	164	267	174	922	599	381	11680	7592	10400	6760	9770	6351	10130	6585	10495
07/07/95	151	98			1030	670			295	5060	3289	8630	5610	13680	8892	12220	7943	9898
08/04/95	260	169	510	332	490	319	720	468	495	7650	4973	8590	5584	9670	6286	9300	6045	8803
08/10/95	240	156	420	273	570	371	1020	663	563	8320	5408	9500	6175	10050	6533	9190	5974	9265
09/11/95	327	213	393	255	373	242	550	358	411	9680	6292	12640	8216	12120	7878	12080	7852	11630
09/22/95	75	49	546	355	496	322	298	194	354	12010	7807	12770	8301	11670	7586	12610	8197	12265
09/29/95	130	85	419	272	690	449	1337	869	644	8010	5207	10780	7007	11380	7397	11410	7417	10395
10/06/95	142	92	704	458	585	380	1730	1125	790	9120	5928	9790	6364	10440	6786	2970	1931	8080

	North Cell		South Cell	
Average for the Study	From 01/18/94	1141.9	From 7/13/93	4923.6
Average for August 1994 through August 1995		715.2		4734.9
Average for August 1994 through October 1995		699.4		5292.8

APPENDIX K

Average Evaporation Pan and Precipitation Data Over Time Intervals Between Listed Dates

Average Evaporation and Precipitation Data over Time Intervals Between Listed Dates

Date	Time	Pan Level Reading	Water added to level	Difference	Average Evap. over Interval	Rainfall
05/21/93	09:00	1.604				
05/24/93	09:00	1.056	4.131	0.548	0.183	
05/29/93	09:00	2.677		1.454	0.291	
06/02/93	09:00	1.640		1.028	0.257	
06/04/93	09:00	1.036	4.046	0.613	0.307	
06/07/93	09:00	4.290		1.246	0.415	1.490
06/08/93	09:00	4.007		0.103	0.103	
06/09/93	09:00	3.882		0.215	0.215	
06/11/93	09:00	3.006		0.876	0.438	
06/14/93	09:00	1.980		1.026	0.342	
06/15/93	11:00	1.520		0.460	0.460	
06/16/93	11:00	1.146	3.970	0.374	0.374	
06/17/93	11:00	3.533		0.437	0.437	
06/21/93	09:00	2.000		1.533	0.383	
06/22/93	09:00	1.623		0.377	0.377	
06/24/93	09:00	0.970	3.533	0.653	0.327	
06/25/93	11:00	3.278		0.255	0.255	
06/28/93	09:00	2.026		1.252	0.417	
06/29/93	11:00	1.572		0.454	0.454	
06/30/93	10:00	1.124		0.448	0.448	
07/02/93	09:00	0.475	4.678	0.649	0.325	
07/06/93	11:00	2.786		1.892	0.473	
07/07/93	09:00	2.448		0.338	0.338	
07/09/93	09:00	1.683	4.521	0.765	0.383	
07/12/93	09:00	3.408		1.113	0.371	
07/13/93	09:00	3.046		0.362	0.362	
07/14/93	09:00	2.762		0.284	0.284	
07/15/93	10:00	2.434		0.328	0.328	
07/16/93	09:00	2.068	4.786	0.366	0.366	
07/19/93	09:00	3.673		1.113	0.371	
07/20/93	09:00	3.345		0.328	0.328	
07/23/93	09:00	2.594		0.751	0.250	
07/27/93	11:00	1.351		1.243	0.311	
07/29/93	17:00	0.735	3.410	0.616	0.308	
07/30/93	09:30	3.334	4.561	0.076	0.076	
08/02/93	09:30	3.346		1.215	0.405	
08/03/93	09:30	3.015		0.331	0.331	
08/04/93	09:30	2.618		0.397	0.397	
08/05/93	09:30	2.216		0.402	0.402	
08/06/93	09:30	1.834	4.592	0.382	0.382	
08/09/93	09:30	3.361		1.231	0.410	
08/10/93	09:30	3.032		0.329	0.329	
08/13/93	09:30	1.941	4.873	1.091	0.364	
08/16/93	09:30	3.823		1.050	0.350	
08/17/93	09:30	3.514		0.309	0.309	
08/18/93	09:30	3.178		0.336	0.336	
08/19/93	11:00	2.801		0.377	0.377	
08/20/93	10:30	2.578	4.522	0.223	0.223	
08/23/93	08:00	3.310		1.212	0.404	
08/24/93	07:00	2.937		0.373	0.373	
08/27/93	11:00	1.822	3.806	1.115	0.372	
08/30/93	08:00	2.857		0.949	0.316	
08/31/93	09:00	2.515		0.342	0.342	
09/01/93	09:00	2.240		0.275	0.275	
09/02/93	09:00	1.937		0.303	0.303	
09/03/93	09:00	1.518	4.521	0.419	0.419	
09/07/93	09:00	2.606		1.915	0.479	
09/09/93	09:00	1.855		0.751	0.376	
09/10/93	09:00	1.512	4.556	0.343	0.343	
09/13/93	09:00	3.396		1.160	0.387	
09/17/93	11:00	2.622		0.774	0.194	
09/20/93	08:00	1.958		0.664	0.221	
09/21/93	11:00	1.694		0.264	0.264	
09/22/93	10:00	1.521		0.173	0.173	
09/24/93	10:00	1.068	4.422	0.453	0.227	
09/28/93	10:00	2.989		1.433	0.358	
10/01/93	10:00	1.948	3.866	1.043	0.348	
10/06/93	10:00	2.284		1.582	0.318	
10/07/93	10:00	1.924	4.431	0.360	0.360	
10/11/93	10:00	3.866		0.565	0.141	
10/15/93	10:00	3.265		0.601	0.150	
10/19/93	10:00	3.073		0.192	0.048	
10/22/93	10:00	2.485	4.181	0.838	0.279	0.250
10/26/93	16:00	3.221		0.960	0.240	
10/29/93	10:00	2.180	4.540	1.781	0.594	0.740
11/02/93	10:00	3.693		0.847	0.212	
11/05/93	10:00	2.708	4.587	1.125	0.375	0.140
11/12/93	08:00	3.810		0.777	0.111	
11/15/93	11:00	3.657		0.153	0.051	
11/19/93	13:00	3.174		0.483	0.121	
11/29/93	09:00	2.016		1.158	0.116	
11/30/93	09:00	1.918		0.098	0.098	
12/02/93	15:00	1.740		0.178	0.089	
12/03/93	10:00	1.641		0.099	0.099	
12/07/93	10:00	4.073	4.577	0.078	0.020	2.510
12/10/93	15:00	3.775		0.802	0.267	
12/13/93	09:00	3.913		0.062	0.021	0.200
12/17/93	10:00	3.822		0.091	0.023	
12/20/93	10:00	3.713		0.109	0.036	
12/23/93	14:00	3.439		0.274	0.091	
12/27/93	14:00	2.869		0.570	0.143	
12/28/93	12:00	2.774		0.095	0.095	
12/29/93	13:00	2.637		0.137	0.137	
01/03/94	10:00	2.076		0.561	0.112	
01/07/94	10:00	1.460		0.616	0.154	
01/10/94	13:00	1.160	3.690	0.300	0.100	
01/11/94	10:00	3.770		0.120	0.120	
01/12/94	11:00	3.606		0.164	0.164	
01/13/94	11:00	3.464		0.142	0.142	
01/14/94	11:00	3.396		0.068	0.068	
01/17/94	09:00	2.976		0.420	0.140	
01/20/94	11:00	2.492		0.484	0.161	
01/25/94	11:00	2.608		0.084	0.017	0.200
01/26/94	11:00	2.569		0.039	0.039	
01/28/94	11:00	2.762		0.007	0.003	0.200
02/04/94	09:00	3.074		0.038	0.005	0.350
02/08/94	09:00	4.392		0.082	0.021	1.400
02/18/94	15:00	3.775		0.617	0.062	
02/22/94	13:00	4.242		0.033	0.008	0.500
02/25/94	15:00	3.812		0.430	0.143	
03/01/94	10:00	3.368		0.444	0.111	
03/08/94	14:00	2.788		0.580	0.083	
03/23/94	10:00	1.800		0.988	0.066	
03/24/94	10:00	1.672		0.128	0.128	
03/25/94	09:00	2.264		0.108	0.108	0.700
03/28/94	09:00	2.078		0.186	0.062	
03/31/94	09:00	1.739		0.339	0.113	
04/13/94	09:00	0.500	4.586	6.659	0.512	5.420
04/15/94	11:00	4.316		0.270	0.135	
04/19/94	16:00	3.715		0.601	0.150	

Note: Shaded numbers indicate periods when the RO system was not operating, and therefore reject flow was unavailable.

Average Evaporation and Precipitation Data over Time Intervals Between Listed Dates - Continued

Date	Time	Pan Level Reading	Water added to level	Difference	Average Evap. over interval	Rainfall
04/22/94	16:00	3.187		0.528	0.176	
05/04/94	11:00	2.472		0.715	0.060	
05/06/94	13:00	2.087		0.385	0.193	
05/09/94	12:30	1.792		0.595	0.198	0.300
05/12/94	15:45	0.900	3.996	0.892	0.297	
05/13/94	08:30	3.790		0.206	0.206	
05/24/94	07:30	1.091		2.699	0.245	
05/27/94	14:00	1.187	3.778	0.004	0.001	0.100
06/03/94	09:00	1.414		2.364	0.338	
06/07/94	09:00	0.500	4.120	0.914	0.229	
06/13/94	11:30	2.029		2.091	0.349	
06/17/94	15:00	0.750	4.282	1.279	0.320	
06/21/94	10:30	2.825		1.457	0.364	
06/24/94	16:00	1.372	4.346	1.453	0.484	
07/01/94	15:30	1.475	4.482	2.871	0.410	
07/08/94	08:00	2.065		2.417	0.345	
07/11/94	15:00	0.750	1.812	1.315	0.438	
07/13/94	13:30	0.500	4.431	1.312	0.656	
07/18/94	15:30	2.508		1.923	0.385	
07/25/94	08:00	0.500	4.144	2.008	0.287	
07/26/94	14:00	2.802		1.342	0.447	
07/27/94	This data is for the purpose of simulating actual			1.243	0.311	
07/28/94	conditions since the data for this period is lost.			0.616	0.308	
07/29/94				0.076	0.076	
08/02/94				1.215	0.405	
08/03/94				0.331	0.331	
08/04/94				0.397	0.397	
08/05/94				0.402	0.402	
08/08/94				0.382	0.382	
08/09/94				1.231	0.410	
08/10/94				0.329	0.329	
08/11/94				1.091	0.364	
08/12/94				1.050	0.350	
08/15/94				0.309	0.309	
08/16/94				0.336	0.336	
08/17/94				0.377	0.377	
08/18/94				0.223	0.223	
08/19/94				1.212	0.404	
08/22/94				0.373	0.373	
08/23/94				1.115	0.372	
08/24/94				0.949	0.316	
08/25/94				0.342	0.342	
08/26/94				0.275	0.275	
08/29/94				0.303	0.303	
08/30/94		3.161		0.303	0.303	
08/31/94		2.833		0.328	0.328	
09/01/94		2.540		0.293	0.293	
09/02/94		2.234		0.306	0.306	
09/06/94		0.750	4.655	1.484	0.371	
09/07/94		4.263		0.392	0.392	
09/09/94		3.454		0.809	0.405	
09/12/94		2.426		1.028	0.343	
09/13/94		2.161		0.265	0.265	
09/14/94		1.950		0.211	0.211	
09/15/94		1.689		0.261	0.261	
09/16/94		1.290	4.260	0.399	0.399	
09/20/94		2.960		1.300	0.325	
09/21/94		2.661		0.299	0.299	
09/22/94		2.400		0.261	0.261	
09/26/94		1.368		1.032	0.258	

Date	Time	Pan Level Reading	Water added to level	Difference	Average Evap. over interval	Rainfall
09/27/94		1.185	4.183	0.183	0.183	
09/28/94		3.800		0.283	0.283	
09/30/94		3.220		0.680	0.340	
10/03/94		2.689		0.531	0.177	
10/04/94		2.517		0.172	0.172	
10/05/94		2.688		0.031	0.031	0.200
10/10/94		1.704		0.982	0.196	
10/11/94		1.474		0.230	0.230	
10/12/94		1.242		0.232	0.232	
10/13/94		1.009	4.506	0.233	0.233	
10/14/94		4.235		0.273	0.273	
10/17/94		3.904		0.331	0.110	
10/18/94		3.700		0.204	0.204	
10/19/94		3.492		0.208	0.208	
10/21/94		3.157		0.335	0.168	
10/25/94		2.505		0.652	0.163	
10/26/94		2.385		0.120	0.120	
10/27/94		2.253		0.132	0.132	
10/28/94		2.089		0.164	0.164	
10/31/94		1.721		0.368	0.123	
11/01/94		1.561		0.160	0.160	
11/03/94		1.698		0.163	0.082	0.300
11/04/94		1.570		0.128	0.128	
11/07/94		1.257		0.313	0.104	
11/08/94		1.190		0.067	0.067	
11/10/94		0.988		0.202	0.101	
11/14/94		1.081		0.407	0.102	0.500
11/15/94		0.972	3.772	0.109	0.109	
11/16/94		3.576		0.246	0.246	0.050
11/17/94		3.595		0.000	0.000	0.019
11/18/94		3.352		0.293	0.293	0.050
11/21/94		3.141		0.211	0.070	
11/22/94		3.040		0.101	0.101	
11/23/94		2.914		0.126	0.126	
11/28/94		2.622		0.592	0.118	0.300
11/29/94		2.502		0.120	0.120	
11/30/94		2.493		0.009	0.009	
12/01/94		2.274		0.219	0.219	
12/05/94		1.960		0.314	0.079	
12/06/94		1.922		0.038	0.038	
12/07/94		1.857		0.065	0.065	
12/08/94		1.673		0.184	0.184	
12/13/94		1.496		0.377	0.075	0.200
12/14/94		1.351		0.145	0.145	
12/19/94		0.943		0.408	0.082	
12/20/94		0.750	4.488	0.193	0.193	
12/21/94		4.388		0.100	0.100	
12/22/94		4.274		0.164	0.164	0.050
12/23/94		4.310		0.164	0.164	0.200
12/29/94		4.310		0.500	0.083	0.500
12/30/94		4.348		0.062	0.062	0.100
01/09/95		3.638		1.710	0.171	1.000
01/10/95		3.592		0.046	0.046	
01/12/95		6.292		0.200	0.100	2.900
01/13/95		6.590	4.700	0.002	0.002	0.300
01/17/95		4.600		0.110	0.027	0.010
01/18/95		4.525		0.075	0.075	
01/19/95		4.447		0.078	0.078	
01/20/95		4.430	0.906	0.337	0.337	0.320
01/23/95		1.347		0.000	0.000	0.441

Average Evaporation and Preclpltation Data over Time Intervals Between Listed Dates • Continued

Date	Time	Pan Level Reading	Water added to level	Difference	Average Evap. over Interval	Rainfall
01/24/95		1.379		0.409	0.102	0.441
01/25/95		1.705		-0.000	-0.000	0.326
01/27/95		2.310		0.000	0.000	0.605
01/30/95		2.100		0.210	0.070	
01/31/95		1.960		0.140	0.140	
02/01/95		1.901		0.059	0.059	
02/02/95		1.793		0.108	0.108	
02/03/95		1.743		0.050	0.050	
02/08/95		1.142		0.601	0.120	
02/09/95		1.074		0.068	0.068	
02/10/95		1.001	4.946	0.073	0.073	
03/01/95		3.098		1.848	0.097	
03/02/95		3.104		0.094	0.094	0.100
03/03/95		3.247		0.057	0.057	0.200
03/06/95		4.967		-0.020	-0.007	1.700
03/07/95		4.730		0.237	0.237	
03/08/95		4.687		0.043	0.043	
03/09/95		4.555		0.132	0.132	
03/10/95		4.511		0.044	0.044	
03/13/95		4.471		2.140	0.713	2.100
03/14/95		4.401		0.070	0.070	
03/15/95		4.324		0.077	0.077	
03/16/95		4.265		0.059	0.059	
03/17/95		4.120		0.145	0.145	
03/20/95		3.822		0.298	0.099	
03/21/95		3.781		0.041	0.041	
03/22/95		4.139		0.042	0.042	0.400
03/23/95		4.714		-0.575	-0.575	
03/27/95		4.378		0.336	0.084	
03/29/95		3.946		0.432	0.216	
03/31/95		3.666		0.280	0.140	
04/03/95		3.194		0.472	0.157	
04/04/95		2.974		0.220	0.220	
04/06/95		2.689		0.285	0.142	
04/07/95		2.489	3.965	0.200	0.200	
04/10/95		3.315		0.650	0.217	
04/11/95		3.112		0.203	0.203	
04/12/95		2.856		0.256	0.256	
04/13/95		2.570		0.286	0.286	
04/14/95		2.284		0.286	0.286	
04/20/95		3.640		0.000	0.000	1.556
04/21/95		3.070		0.770	0.770	
04/24/95		2.241		0.829	0.276	
04/25/95		1.970		0.271	0.271	
04/26/95		1.734		0.236	0.236	
04/27/95		1.390		0.344	0.344	
05/01/95		0.750		0.640	0.160	
05/02/95		0.550	3.852	0.200	0.200	
05/03/95		3.634		0.218	0.218	
05/05/95		3.194		0.440	0.220	
05/08/95		3.130		0.264	0.088	0.200
05/09/95		3.020		0.110	0.110	
05/11/95		2.557		0.463	0.231	
05/15/95		2.104		0.653	0.163	0.200
05/19/95		1.415		0.689	0.172	
05/22/95		0.500	3.784	0.915	0.305	
05/26/95		3.513		0.271	0.068	
05/30/95		2.326		1.187	0.297	
~~05/31/95~~		~~1.975~~	~~3.239~~	~~0.351~~	~~0.351~~	
~~06/01/95~~		~~2.760~~		~~0.478~~	~~0.479~~	

Date	Time	Pan Level Reading	Water added to level	Difference	Average Evap. over Interval	Rainfall
06/02/95		2.596		0.164	0.164	
06/05/95		1.492		1.104	0.368	
06/06/95		1.084		0.408	0.408	
06/07/95		1.202	1.498	-0.118	-0.118	
06/08/95		1.224		0.274	0.274	
06/09/95		0.500	1.723	0.724	0.724	
06/12/95		0.500	3.700	1.223	0.408	
06/13/95		3.456		0.244	0.244	
06/14/95		2.838		0.618	0.618	
06/15/95		2.436		0.402	0.402	
06/16/95		2.240		0.296	0.296	0.100
06/19/95		1.836		0.654	0.218	0.250
06/20/95		1.436	4.349	0.400	0.400	
06/21/95		3.840		0.509	0.509	
06/22/95		3.598		0.242	0.242	
06/23/95		3.100		0.498	0.498	
06/26/95		1.894		1.206	0.402	
06/27/95		1.418		0.476	0.476	
06/28/95		1.032	4.175	0.386	0.386	
06/29/95		3.611		0.564	0.564	
06/30/95		3.200		0.411	0.411	
07/05/95		1.265		1.935	0.387	
07/06/95		0.610		0.655	0.655	
07/07/95		0.001	4.659	0.609	0.609	
07/10/95		3.212		1.447	0.482	
07/11/95		2.813		0.399	0.399	
07/12/95		2.490		0.323	0.323	
07/13/95		1.898		0.592	0.592	
07/14/95		1.431		0.467	0.467	
07/17/95		0.500		1.131	0.377	0.200
07/18/95		0.010		0.490	0.490	
07/19/95		-0.500	4.666	0.510	0.510	
07/20/95		4.079		0.587	0.587	
07/21/95		3.697		0.382	0.382	
07/24/95		2.186		1.511	0.504	
07/25/95		1.431		0.755	0.755	
07/26/95		1.454		-0.023	-0.023	
07/27/95		1.011	4.654	0.443	0.443	
07/28/95		4.086		0.568	0.568	
07/31/95		2.583		1.503	0.501	
08/02/95		1.809		0.774	0.387	
08/03/95		1.367		0.442	0.442	
08/04/95		0.026		1.341	1.341	
08/08/95		-0.750	4.351	0.776	0.194	
08/09/95		3.895		0.456	0.456	
08/15/95		3.253		0.642	0.107	
08/16/95		0.625	3.613	2.628	2.628	
08/17/95		3.286		0.327	0.327	
08/21/95		1.884		1.402	0.351	
08/22/95		1.526		0.358	0.358	
08/24/95		0.500	4.470	1.026	0.513	
08/25/95		4.182		0.288	0.288	
08/28/95		3.038		1.144	0.381	
08/31/95		1.847		1.191	0.397	
09/01/95		1.454		0.393	0.393	
09/05/95		0.000	4.039	1.454	0.364	
09/06/95		3.763		0.276	0.276	
09/07/95		3.329		0.434	0.434	
09/08/95		2.921		0.408	0.408	
09/11/95		1.866		1.035	0.345	

Average Evaporation and Precipitation Data over Time Intervals Between Listed Dates - Continued

Date	Time	Pan Level Reading	Water added to level	Difference	Average Evap. over interval	Rainfall
09/12/95		1.415	4.038	0.471	0.471	
09/13/95		3.757		0.281	0.281	
09/14/95		3.302		0.455	0.455	
09/15/95		2.844		0.458	0.458	
09/18/95		1.938		0.906	0.302	
09/19/95		1.588		0.350	0.350	
09/20/95		1.283		0.305	0.305	
09/21/95		*1.092*	*4.052*	*0.191*	*0.191*	
09/25/95		2.607		1.445	0.361	
09/27/95		2.038		0.569	0.285	
09/28/95		1.775		0.263	0.263	
09/29/95		1.628		0.147	0.147	
10/02/95		0.002	4.554	1.626	0.542	
10/03/95		4.099		0.455	0.455	
10/04/95		3.615		0.484	0.484	
10/05/95		3.301		0.314	0.314	
10/06/95		2.977		0.324	0.324	