DISPOSAL OF CONCENTRATES FROM BRACKISH WATER DESALTING PLANTS

Proceedings of a Seminar
Held at MacArthur's Holiday Inn

November 18, 1988

Palm Beach Gardens, Florida

EDITOR
O.K. Buros

Sponsored by the

NATIONAL WATER SUPPLY IMPROVEMENT ASSOCIATION
(NWSIA)

and the

South Florida Water Management District
(SFWMD)

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PREFACE

The use of membrane processes, especially reverse osmosis, has become an extremely popular and economical water treatment technology in Florida over the past decade. Currently, Florida has more membrane capacity than any other state in the country. This capacity will soon exceed 100 million gallons a day (MGD) and many large plants of 5 and 10 MGD are being designed for future construction. Membrane plants can play an important role in providing potable water for many of the fast growing coastal areas of the state. Now that membrane technology has proven to be successful, it is important to consider some of the other things that are crucial to the use of membrane processes in Florida.

The most important of these is the disposal of the concentrate (also called reject or brine) stream from the plants. This stream can amount to 50 to 100 percent of the volume of the potable water produced. To allow membrane processes to continue to increase in use, it is crucial to be able to dispose of this waste in an environmentally safe and cost effective manner.

This problem has attracted considerable attention in the state and it was an appropriate topic for a day long seminar that was held on November 18, 1988 at MacArthur's Holiday Inn in Palm Beach Gardens, Florida. This was the second seminar on desalting in Florida that was co-sponsored by the National Water Supply Improvement Association (NWSIA) and the South Florida Water Management District (SFWMD). The first seminar, held in August 1987, addressed the subject of desalination in south Florida. These seminars were the direct result of the interest and initiative of one of SFWMD's staff, Mr. Nagendra Khanal.

These proceedings contain, for the most part, papers that were presented by the various participants on their respective topics. However, the introductory remarks, the question-and-answer periods, the roundtable discussions, and the summary remarks contained in this proceedings were derived from the video tapes which were made of the sessions. All of these sections were first transcribed and then edited to bridge the gap between the spoken and written word. The NWSIA would like to acknowledge the help of Carol Springer of Gainesville who carefully transcribed and helped to edit the tapes and papers of the seminar so as to produce the text for this proceedings.

The NWSIA has a history of interest in desalting technology in Florida. It has held two national conferences in the state: one in Sarasota in 1978 and the other in Orlando in 1984 as well as sponsoring a number of other desalting seminars in Florida. In 1990, it will again hold its national conference in Orlando.

The NWSIA was formed in 1973 to promote the appropriate use of desalination, water reuse, and other water sciences. Members include water utilities, manufacturers and suppliers of related equipment, consultants, academicians, and other interested individuals.

Through its publications, conferences, and technology transfer seminars, the NWSIA provides a forum for discussing a wide variety of water supply improvement topics. The Association works closely with other water industry-oriented organizations, giving members access to the entire water supply community. The NWSIA is affiliated at the international level with the International Desalination Association (IDA) and in the United States with the California Association of Reclamation Entities of Water (CAREW).

The Board of Directors and staff of the NWSIA were pleased to work with our co-sponsor, the South Florida Water Management District, in organizing this seminar and we hope we can work together on additional seminars in the future.

O. K. Buros
Gainesville, Florida
Proceedings Editor

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Gainesville, Florida

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Executive Director
National Water Supply Improvement Association
St. Leonard, Maryland

Bill Harlow
Consultant
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INTRODUCTION AND WELCOME
by the
South Florida Water Management District
and the
National Water Supply Improvement Association

O. K. BUROS (Moderator)

Today the National Water Supply Improvement Association and the South Florida Water Management District have joined together to present a second seminar. Last August we presented a seminar at this same location on an introduction to desalination and membrane processes.

Today, we are going to talk about a topic which I think is of extreme value, not only here in the state of Florida but all over the United States and, in fact, all over the world. That subject is the disposal of concentrates from brackish water desalting plants. We are going to start the seminar off with a word of welcome from a number of people who represent both the National Water Supply Improvement Association and the South Florida Water Management District.

I would like to start by introducing you to Jack Jorgensen. He is the Executive Director of the National Water Supply Improvement Association.

JACK JORGENSEN

I know that there are many of you who are not members of the National Water Supply Improvement Association and, of course, we are always looking for members. The NWSIA is not a big organization but we have been around about 25 years now. We do have seminars such as this around the country and we have national conferences every two years. The latest one being this summer in San Diego, California. In 1990, it will be in Orlando, Florida, and we hope that by then that all of you who are not members will join and will start making contributions to

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This paper was prepared by the editor based on a recording of the presentation. Where deemed appropriate, the presentation has been edited for clarity.

these efforts on workshops and seminars. We have room for a lot of people so come around and talk to me.

Today is our second joint effort with the South Florida Water Management District. We are very happy with this relationship with the District and hope that it will continue with the cooperative spirit it has had in the past.

The National Water Supply Improvement Association's plans are to hold more seminars in the future and we are also getting involved with some training programs on reverse osmosis. Today we all have the opportunity to talk, to make new friends, and have one-on-one conversations. These are a few of the many benefits that this seminar will provide us today.

O. K. BUROS

Someone asked me before the seminar started what the difference was between the American Water Works Association (the AWWA) and the National Water Supply Improvement Association (the NWSIA). I would like to emphasize that there is a difference. The difference is that the National Water Supply Improvement Association might better be called the American Desalination Association. We are interested, and put most of our program work, into desalination. Although we also work on water reuse and other water sciences we have, for the last ten years, been working on promoting desalination, its appropriate application, and trying to make people comfortable with it.

As Jack said, NWSIA is a small organization of a few hundred people rather than like AWWA who has about 45,000 people. We can give you a lot of individual attention, both at the utility, consultant and manufacturers level. So, it is a good group and I think that it behooves anybody who is interested in desalting to join the organization. I am now going to turn this over to the president of NWSIA, Bill Harlow.

A few words about Bill. Bill claims to have recently retired from the Englewood Water District and now he says he's too busy to do anything. He was the administrator for the district for the past 11 years. The Englewood Water District was one of the first utilities along the west coast that started to experience some serious saltwater intrusion. This created a problem and they solved that problem by building a reverse osmosis plant. That plant was built so that it can be enlarged which is one of the advantages of desalting in that desalting plants can be economically increased in capacity so that they can continually serve the needs of a community while it grows. The Englewood plant is currently producing about 1.5 MGD and it is one of the best designed plants on Florida's west coast.

BILL HARLOW

I too would like to welcome everybody here. One of the things that a operator of a desalting plant has to deal with is that after he has produced the product water, he's got something left over that he has to dispose of. I hope that by the end of the day that you will have a clearer picture of what we can do with this concentrate stream which is left over from our operations.

There has been a lot said here about the National Water Supply Improvement Association and we have forgotten one very important individual in the workings of the NWSIA. He is the chairman of our Technology Transfer Committee, Mr. Walter Barnes. Walter and his committee has worked very diligently recruiting the people who are speaking today.

I hope that we answer some of your questions for you and at the same time, we may raise some questions which some of the regulatory agencies and the State of Florida need to face up to. If we do, we will have accomplished something for the utilities.

NWSIA is divided into three parts. We have the utilities, or the users of the equipment, as Division One. We have the manufacturers of the equipment, the engineers who put it together, and the sales representatives who sell the equipment in what we call Division Two. Those of us who retire, when we can't do anything else, we go over to Division Three. Those are the individual members and well wishers of the association. We rely heavily on the Division Three membership to provide the leadership and many of the speakers that are talking today.

O. K. BUROS

As a final part of our introductory remarks, we would like to have a word of welcome from the South Florida Water Management District. That word is going to be given by Tilford Creel who is the Deputy Executive Director for the District. We, in the National Water Supply Improvement Association, are very grateful with the cooperation we have gotten from the South Florida Water Management District and their intense interest in this subject.

TILFORD CREEL

Thanks very much Kris. Nagendra Khanal, who has been very instrumental at the District in supporting this conference, provided me some excellent notes; some of which have been covered already. But what I will do is relate to you a few things about what is happening in south Florida and then maybe launch into why we think that RO is particularly helpful and why desalination, specifically, can solve some of south Florida's problems.

First, let me clarify the area that our District covers. Most of you are from south, southeast, or southwest Florida, but let me tell you a little bit about our territory and why we are pleased to be able to co-sponsor this seminar. We go from Orlando in the north all the way to the Keys in the south and from Fort Pierce on the Atlantic to Fort Myers on the Gulf. Those who know south Florida know the difference in climatic problems that we have. We often get too much water when we get a hurricane off our coast and other times we don't have enough water. Right now we don't have enough on the west coast of Florida. We have already issued a Phase One water shortage warning for Lee and Collier and parts of Hendry counties. This is two months early. We wouldn't expect to have this kind of problem until maybe January or February, and here we are in November. That is rather disturbing to us because I believe we have done an awfully good job as a community in trying to resolve some of our water problems.

We believe that xeriscape, from the point of landscaping, is the wave of the future in south Florida and we have provided a strong leadership role in ensuring that landscaping does, in fact, use xeriscape principles. We are rather pleased about xeriscape, and if you want more information, please let us know and we'll be glad to send it.

As most of you already know, Florida is the country's fourth largest state in terms of population and we expect to be the third largest by the year 2000. What we are finding is that with this growth come the problems that any place could expect, and Florida is no different. What we have are people coming from the midwest and northeast parts of the country and expecting to have Florida green at all times of the year--that's difficult to do unless you have a steady source of water. But how do you get that? That's part of the problem today. RO is one way to do it, wastewater reuse is another, and another is to look at different ways of using the water that we have.

We are also concerned that the quality of life which we are experiencing today in south Florida will be there for our children and our grandchildren. What we are trying to do is to clean up the whole ecosystem from Lake Kissimmee in the north, down the Kissimmee River, through the Lake Okeechobee conservation areas, and into the Everglades National Park. It is all tied together and, unfortunately or fortunately, depending upon your point of view, we have 4.5 to 5 million people (and by the next century 6 to 6.5 million people) in that area. And that is kind of difficult to do, to put all of those things together and have the same quality of life. Matter of fact, lawsuits have been filed in attempts to make us do better in that regard. We believe we are taking a lot of positive steps. Time will tell how people will view these positive steps.

Public pressures--I think that if you have learned anything in following the politics of south Florida, you know that the previous governor, now U.S. Senator Graham, during his administration took a view that the environment was important. As he went further into his administration he found it to be extremely important and he embraced it very strongly. I believe that Senator Graham became a very effective Governor and a U.S. Senator primarily because he understood the ecological values of south Florida. Governor Martinez, I believe, has embraced the same approach, and what I think you'll see is all politicians understanding that if you're going to balance the growth that is coming to south Florida, then you'd better understand exactly how it is going to be done and do it well; otherwise, you will probably be doing some other project other than being governor or senator or representative.

One other point I would make is that on the RO side we have just recently had lots of discussions between Osceola and Brevard County. That gets back into the issue of whether you should, in fact, investigate RO and whether it can effectively provide you with additional sources of water or whether you should immediately tap the ground water of an adjacent county. The Legislature gave us the mandate to go ahead and get into the business of transferring the water but they specifically said, "look at the ground water sources first, and then look at any other alternative." What we found out after about a year and a half of arguing, bickering, and court cases is that we didn't do as good a job in looking at the other alternatives, including RO, as we should have. That is now going to be the focus for the next year or so and we are possibly also going to get a well in place and make sure it works.

In Lee County, they have the same kind of problem. I would say that probably in south Palm Beach and Broward you are going to get some of those same pressures as well. More people, more use of the ground water, and further saltwater intrusion, so how do you effectively use the water that you have.

People say, "Are you frustrated by the amount of pressure that is constantly on the Water Management Districts or the DER or the other public agencies?" Not a bit. I think it is absolutely marvelous that we have an opportunity to solve some problems, and if we don't solve them then they aren't going to get solved.

I thank you very much for inviting me here today. We are very pleased to be able to co-sponsor this seminar. It is absolutely essential that the professionals in this business also understand the public policy sides of these issues. If you have concerns about the public policy side, please feel free to contact us at any time. We are on the verge, in my view, of solving a lot of very difficult situations with technology, and these seminars will allow us to use technology to do that problem solving.

INTRODUCTION TO THE PROBLEM OF THE DISPOSAL OF DESALTING CONCENTRATES IN FLORIDA

by

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by

O. K. Buros, Ph.D.

CH2M HILL

Gainesville, Florida

Florida is a leader in the field of desalination in the United States. Within a short time, Florida will probably have in the order of 100 million gallons per day (MGD) of installed desalting capacity. With 100 MGD of installed capacity of RO and electrodialysis plants, it means that we are going to have a discharge of concentrate in the order of 50 to 100 MGD. This has become a concern to many regulators, consultants, and operators and is the subject of today's seminar.

There has been a lot of promotion of membrane applications within the State of Florida. These applications include not only the reduction of total dissolved solids, but also in the removal of precursors for THMs, reduction of color, and the removal or reduction of a number of other things.

One of the big advantages of membrane processes is that many of the substances discussed in the Safe Drinking Water Act can be taken care of by the membrane process at no extra cost. Therefore, we expect the use of membrane processes to gain in popularity. If you look at the amount of plants to be designed in Florida just during this past year, it is in the order of 50 to 60 MGD installed capacity. However, with all the success in membrane applications, there comes a nagging problem. That problem is the disposal of the concentrate, reject, brine, whatever you want to call it, that comes from the desalting plant.

In the early days, the desalination plants in Florida were located along the coastal areas and it is my contention that, first of all, regulators probably didn't realize that there was a second stream aside from the product water stream. When they did realize it, it was allowed to be put into the adjacent gulf or the sea and it wasn't considered a problem. However, what is happening now is not only a recognition of the existence and nature of this concentrate discharge but also the fact that some of the plants are being located far away from the coast. In this case, it is becoming prohibitively expensive to extend the pipelines down to the sea so as to dispose of the concentrate. Therefore, other rational methods of concentrate disposal which will both permit the use of membrane processes and at the same time safeguard the environment must be found.

At this seminar, we are bringing together a mixed group -- manufacturers, consultants, users, and regulatory people. Not to solve the problem, because I doubt that we will arrive at the ultimate solution but to discuss the problem. The idea is to exchange ideas on technologies, regulations, etc., so as to bring out the various aspects of some of the technologies that are available and some of the regulatory problems that exist. Hopefully, within that context, we will all obtain a better understanding which will enable us to continue to work at solving this problem. This is important to the water resource development in the State of Florida. At this stage in the state's development, we don't want to give up on using membrane processes; therefore, we will have to find a viable way to dispose of these concentrates.

As you look through the program, you will see that we are going to start by talking about the character of concentrates in desalting plants. We are then going to move on to Bill Conlon, who is going to review the historical development of the regulations. Dr. DeHan from the Florida Department of Environmental Regulation will discuss some of the current regulatory concerns and then we are going to move into some of the disposal techniques that are available. These are disposal techniques that are used here in Florida, around the United States, or around the world. We are going to discuss the use of surface water discharge, deep injection wells, irrigation, solar ponds, thermal evaporators, electrodialysis and high recovery reverse osmosis. The latter four processes are concentration technologies which reduce the volume of concentrate but makes it a lot more concentrated.

We are then going to have a roundtable discussion which will be a good opportunity for everybody to ask their questions and voice their opinions. The roundtable is entitled "Where do we go from here?" and we are going to have a variety of consultants and regulatory people take part. We will conclude the seminar with David Furukawa who will summarize the day's discussions.

CHARACTERIZATION OF DESALTING CONCENTRATES

by

Ian C. Watson, P.E.
Rostek Services, Inc.
Fort Myers, Florida

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INTRODUCTION

With the recent rapid growth of desalting applications in Florida, and the current backlog of planned work of some 60 MGD, the whole subject of desalting concentrate disposal has assumed a most significant role. For the regulatory agencies in the State of Florida to make informed, intelligent decisions concerning the ultimate disposal of these waters, the designer must provide to them the proper information. The purpose of this presentation is to provide some insight into the methodology and techniques that can be used to predict concentrate characteristics at an early stage in the study or design process.

DISCUSSION OF PROCESSES

In order that the designer may realistically project expected concentrate characteristics, it is necessary to examine the various membrane processes that produce the concentrate. There are four types worthy of consideration, but only three that normally would be encountered in the State of Florida. These are:

- Membrane Softening
- Brackish Water Reverse Osmosis
- Brackish Water Electrodialysis

Some consideration should also be given to seawater desalination by reverse osmosis, but the potential applications in the foreseeable future are so limited that only a brief discussion is indicated.

BRACKISH WATER REVERSE OSMOSIS (RO)

By far, the most common desalting application in Florida, brackish water reverse osmosis has been used in the state for almost two decades. During this time frame, there have been two significant advances that directly affect concentrate characteristics. One is the increasing efficiency of the membranes' salt rejection mechanism, and the other is the current use of synthetic scale inhibitors. The latter allows higher levels of supersaturation of scale forming potential, thus allowing an increased overall water recovery. (Figure 1 demonstrates these effects for a typical southwest Florida well water.) While both of these advances have direct impact on the projected operating costs, the concentrate disposal problem may, in some cases, be made more difficult.

Figure 1
EFFECT OF RECOVERY AND SALT REJECTION

COMPONENT	RAW[1]	CASE 1[2]	CASE 2[3]	CASE 3[4]	CASE 4[5]
Calcium	60.00	237.30	393.20	238.60	396.50
Magnesium	76.00	300.60	498.10	302.20	502.20
Sodium	314.00	1112.60	1755.50	1181.60	1916.30
Potassium	11.00	37.60	58.40	40.70	65.40
Strontium	10.00	39.50	65.50	39.80	66.10
Barium	.02	.08	.11	.08	.11
Bicarbonate	109.90	421.20	688.60	430.20	709.90
Sulphate	338.20	1348.60	2243.40	1350.30	2248.30
Chloride	543.00	1945.40	3086.00	2055.00	3340.40
Fluoride	2.00	6.70	10.20	7.30	11.70
Silica	19.00	60.40	90.70	67.70	107.20
TDS	1483.10	5509.80	8889.70	5713.60	9364.20

[1]Raw is acidified
[2]Y = 75%, S.R. = 96%
[3]Y = 85%, S.R. = 96%
[4]Y = 75%, S.R. = 98%
[5]Y = 85%, S.R. = 98%

MEMBRANE SOFTENING

After an early start, membrane softening applications languished until about three years ago, when a combination of events precipitated the boom that can be seen today. Membrane softening is routinely evaluated as a viable alternative to "conventional" water treatment technology, and major plants are either in design or in planning, totalling about 52 MGD. Since the concentrate generated by these plants will be significantly different from that generated by RO, characterization will require a different approach. Probably the most significant differences are the makeup and concentration of the concentrate, and the volume. Without exception, these large municipal facilities will operate at recoveries in excess of 85%, and will produce a concentrate whose predominant ion species are calcium, bicarbonate, and sulphate. Typically, sodium chloride concentration is low, because (a) there is not much in the feed water, and (b) sodium chloride rejection is very low. (Figure 2 compares Fort Myers feed and concentrate.)

Figure 2

FORT MYERS FEED/CONCENTRATE

COMPONENT	RAW[1]	FEED[2]	CONCENTRATE[3]
Calcium	80.00	80.00	618.00
Magnesium	12.00	12.00	93.00
Sodium	50.00	50.00	153.00
Potassium	4.00	4.00	10.00
Strontium	.50	.50	3.90
Barium	.05	.05	.40
Bicarbonate	244.00	111.00	548.00
Sulphate	20.00	125.00	1092.00
Chloride	70.00	70.00	211.00
Fluoride	.00	.00	.00
Silica	5.00	5.00	10.00
TDS	364.00	402.00	2466.00
Color	60-80	60-80	> 300

[1]Unacidified

[2]Acidified

[3]Concentrate at 90% Y

ELECTRODIALYSIS REVERSAL (EDR)

Although not a common desalting technology in Florida, there are several hundred plants of this type around the world, with several multi-million gallon systems. There appears, from recent activity, to be a renewed interest in the Florida market by the sole U.S. practitioner, Ionics. Therefore, it is appropriate that the process be included in this seminar.

The EDR process is somewhat different from RO in that the permeate quality can be tailored to a specific requirement by adjustment of stack power. Recoveries, particularly with water of high scaling potential, tend to be somewhat higher than RO, although this is normally more of an economic rather than technical decision. It is also a characteristic that monovalent ions are separated more efficiently than divalent, so that the concentrate from an EDR system will tend to be somewhat higher proportionally in sodium chloride than that from an equivalent RO system. (Figure 3 compares concentrate quality from RO and EDR, for plants with similar operating characteristics.)

Figure 3

COMPARISON OF RO AND EDR CONCENTRATE

COMPONENT	RAW[1]	CASE 1[2]	CASE 2[3]	CASE 3[4]
Calcium	60.00	389.00	430.00	1406.00
Magnesium	76.00	493.00	526.00	1704.00
Sodium	314.00	1868.00	2014.00	6399.00
Potassium	11.00	64.00	75.00	244.00
Strontium	10.00	64.90	68.00	223.00
Barium	.02	.13	.12	4.00
Bicarbonate	227.00	729.00	1227.00	3707.00
Sulphate	246.00	2180.00	1735.00	5647.00
Chloride	543.00	3258.00	3767.00	12220.00
Fluoride	2.00	13.00	10.20	27.00
Silica	19.00	91.00	19.00	19.00
TDS	1508.00	8785.00	9851.00	31570.00

[1] Unacidified

[2] RO at 85% Y, acidified feed

[3] EDR at 85% Y, no chemical addition

[4] EDR at max. Y, scale inhibitor added

SEAWATER REVERSE OSMOSIS

Although seawater RO is rare in Florida, there may, in the future, be an upswing in interest. Since by definition, seawater plants would be constructed close to the sea, concentrate disposal would be back into the sea. The high rejection requirement of seawater membranes (in excess of 99%) and the high osmotic pressures involved, limit the practical recovery of seawater systems to 30 to 50%. Pretreatment for water from sea wells is similar to brackish water RO but surface intakes require extensive pretreatment, thus adding to the problems already associated with concentrate disposal.

PREDICTION OF CONCENTRATE CHARACTERISTICS

In the absence of field data, such as that generated by pilot tests, the designer must be able to predict concentrate quality from examination of the feed water characteristics. While software developed by the membrane manufacturers will predict, with reasonable accuracy, the major ionic species, most of those components examined by the Department of Environmental Regulation (DER) will not be thus predictable, and will have to be derived in theory.

Some rules of thumb may be utilized:

1. Heavy metals (silver, mercury, etc.) will be re-rejected in the approximate similar ratio as calcium and magnesium, as will iron.

2. Organics by and large are well-rejected, in excess of 95%. This rule does not apply to low molecular weight organics, and while limited data is available from manufacturers, organic rejection data as a whole are sparse. EDR will not reject nonpolar organics, but will separate some organic materials.

3. Since 99% of the groundwater used as feed to membrane plants in Florida is anaerobic, and contains hydrogen sulphide, the concentrate will be anaerobic and contain hydrogen sulphide. DER regulations require 5 mg/l of DO in the discharge, which means aeration. Aeration also

oxidizes hydrogen sulphide and iron, which may present a turbidity problem. EDR systems typically are designed for the removal (and coincidental introduction of DO) of hydrogen sulphide prior to the process.

4. Concentrate pH is typically higher than feed water pH, due to the concentration of alkalinity. In most cases, pH limits for discharge do not require pH adjustment. However, if the pH must be raised, it is well to remember that some components are supersaturated, and pH adjustment may result in precipitation of these sparingly soluble salts.

5. Periodically (2 to 4 times per hour per train), EDR discharges an off-spec product which tends to dilute the concentrate blowdown.

6. For brackish water RO, the concentration factor based on 100% salt rejection can be calculated from the recovery, using

   CF = 1/(1-Y) where Y = recovery expressed as a decimal

   Since no membrane has 100% salt rejection, and there is a variation in rejection, ion to ion, this provides a very conservative result.

7. Using the CF formula, at 90% recovery the CF is 10. Therefore, for the typical feed to a membrane softening system of about 400 ppm, the concentrate might be assumed to be about 4,000 ppm. For this membrane type, however, the concentrate is typically 2,000 to 2,500 ppm TDS, with the CF for sodium chloride about 3.

SUMMARY

Desalting plant concentrate characteristics may be predicted with reasonable accuracy, in the absence of actual test data. In most cases, discussion of the problem statement with the manufacturers is advisable. If not, certain rules of thumb can be used to approximate the probable concentrate characteristics.

HISTORIC DEVELOPMENT
OF THE CONCENTRATE REGULATIONS

by

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MEMBRANE CONCENTRATE DISCHARGE REGULATIONS IN FLORIDA

The State of Florida has, by far, the highest percentage of membrane process plants in the United States. Regulatory agencies, consultants, utility owners, and other interested groups are cooperating to establish pragmatic and environmentally sound regulations for concentrate (brine) discharges. This paper addresses the historical development of these regulations.

THE NEED FOR CONCENTRATE DISPOSAL REGULATIONS

Florida is not the only state faced with the concentrate disposal issue. At least seven or more other states have established regulations to protect water resources from further degradation from brine or concentrate disposal. In fact, Section 305(b) of the Clean Water Act requires states to report to the U.S. Environmental Protection Agency (EPA) on the extent to which their waters are meeting the goal of the Act and recommend how compliance may be accomplished. According to the National Water Quality Inventory, 1986 Report to Congress, 36 states reported brine/salinity as a major groundwater contaminant. These 36 states represented 69% of the states based on a total of 52 states and territories reporting. It would appear from these data that the proper disposal of concentrate should be a concern to all professionals engaged in the use of membrane processes.

EARLY DISPOSAL REGULATIONS

The first concentrate disposal stream in the State of Florida was associated with the Florida Keys Aqueduct Authority's Stock Island Distillation Plant over three decades ago. This concentrate was discharged directly into the Atlantic Ocean. Later, circa 1969, several small membrane process plants (reverse osmosis and electrodialysis) were installed in the Sarasota area. These plants discharged directly to brackish surface water bodies. Up until this point, no permits were required for desalting plant concentrate discharge. Initially, the Florida Department of Health and Rehabilitative Services (FHRS), was responsible for regulating water treatment facilities. It was their contention that the concentrate streams from membrane process plants were less brackish than seawater or the brackish water bodies receiving the discharge. Therefore, the FHRS chose a simplistic approach and deduced, like rainwater, the dilution of the brackish water bodies with a less brackish concentrate would have little or no effect.

Later, in the early 1970's, the Florida Department of Pollution Control (FDPC), who had authority to regulate domestic and industrial waste decided they should regulate the growing number of concentrate discharges. But, FDPC did not have a discharge category for concentrate discharges. FDPC had only two discharge permit categories, one for domestic and another for industrial wastes. Because membrane process concentrates more closely fit the characteristics of an industrial, rather than a domestic waste, FDPC elected to permit concentrate streams as an industrial waste. Those presently working in the industry feel a separate permit category should have been created for concentrate disposal. One of the primary difficulties in permitting the disposal of concentrate today stems from the failure of FDPC to establish a separate permitting category for concentrate disposal at the onset. This failure complicates an otherwise "water permitting" problem/issue. Maybe then, concentrate would not have been labeled an industrial waste by the United States Environmental Protection Agency (USEPA).

Shortly after FDPC began permitting concentrate discharge as an industrial waste, EPA established a National Pollution Discharge

Elimination System (NPDES) program which required discharges of concentrate to surface waters to obtain a permit. At this point in the history of concentrate regulations, two permits were required to discharge concentrate to a surface water body, FDPC industrial waste permit and an EPA NPDES permit. In the mid 1970's, the FHRS and FDPC regulatory control of water and wastewater treatment plants was turned over to a newly created agency called the Florida Department of Environmental Regulation (FDER).

CURRENT REGULATIONS AND TRENDS IN REGULATORY CONTROL

Until the mid 1980's, permitting of concentrate discharges had posed no major problems for FDER. A number of developments caused the agency to more closely scrutinize the application of existing disposal regulations. A few examples are: siting of brackish water reverse osmosis (RO) plants further inland; establishing certain Outstanding Florida Waters (OFWs); applying the membrane process to water softening; and increasing growth and activity of environmental groups. Permit applications, for even the most traditional method of concentrate disposal, were being reviewed more closely for:

- Radionuclides
- Odors (hydrogen sulfide)
- Low dissolved oxygen levels
- Sulfide toxicity
- Low pH

As a result, several existing concentrate discharges were required to pretreat. These new developments caused more frequent proposal of other disposal methods such as spray irrigation and deep well injection. Permitting of deep well injection involved approval from the local area Technical Advisory Committee (TAC) where the membrane process plant was sited. Permitting of the deep well injection method is more complex than permitting a surface water discharge because dealing with multi-agency TAC's was now required. A typical TAC consists of members from FDER, EPA, local water management agency and others, all of whom are concerned with groundwater contamination. There are now at least a dozen membrane facilities testing or using deep wells permitted in Florida for the disposal of concentrate from membrane process plants.

It was fast becoming apparent to design professionals in the membrane processes field that a trend was occurring which could eventually lead to extreme difficulty in permitting concentrate disposal and, therefore, limiting the use of membrane technology. Membrane technology is probably one of the best available water treatment technologies for meeting the water quality standards imposed on the water industry by the 1986 Amendments to the Safe Drinking Water Act (SDWA) and other drinking water regulations.

On March 13, 1987, the writer requested by letter to the Assistant Secretary of FDER, that a workshop be established to address the problem. As a result, the Assistant Secretary to FDER agreed to a workshop on concentrate disposal to be held on June 26, 1987. At this meeting, an informal Fact-Finding Group on Concentrate Disposal was established. The Director of the Division of Environmental Programs for FDER was appointed by the Assistant Secretary to chair the group. Two additional meetings of the Fact-Finding Group on Concentrate Disposal were held, culminating in a public workshop and proposed rule change on July 28, 1988. On October 20, 1988, the Florida Environmental Regulation Commission approved amendments to Chapter 17-28.700. The rule change was a direct result of a cooperative spirit on the part of FDER to work with consultants, utility owners, and other interested parties to provide a more pragmatic approach to the application of FDER rules and regulations while protecting our natural resources.

The rule change to 17-28, Florida Administrative Code (FAC), governs those membrane process plants discharging into Class G-III or Class G-IV groundwater and allows them to discharge non-hazardous concentrate through land application to aquifers containing greater than 1,500 mg/l TDS. The membrane process discharges to such aquifers cannot cause a violation of the primary or secondary drinking water standards at any private or public water supply well outside of the installation's property boundary. Although this one rule change does not solve the regulatory constraints, it could be the beginning of an era of cooperation between FDER, consultants, utility owners, and other interested parties.

Further changes in the FAC would redefine membrane process concentrate injection wells as municipal rather than industrial, thus relieving them from the tubing and packer requirements associated with industrial wells. Still other changes in the FAC would introduce membrane process concentrate injection wells as a "Group 7" category under the Underground Injection Control Class V wells. In so doing, the membrane process concentrate injection wells will once again be relieved from the Class I well requirements of tubing and packers. At present, these changes represent only FDER staff proposals and have not received approval of FDER's Rule Committee, or of EPA. The rule changes have been proposed to EPA by FDER. EPA has not closed the door on these changes but have asked for further information concerning the characterization of concentrate which could prove concentrate is neither corrosive nor an industrial waste. In addition, EPA requires proof that the present tubing and packer requirements for deep wells do, in fact, present an economic hardship for utility owners.

REGULATIONS, CONCERNS, AND REQUIREMENTS BY DISPOSAL METHOD

Table 1 shows the general applicable regulations, regulatory concerns, necessary permits, and other requirements for each of the concentrate disposal methods used to date in Florida.

SUMMARY AND RECOMMENDATIONS

Membrane processes will play an important role as a treatment technology which will assist the water treatment industry in meeting present and future drinking water regulations. Perhaps membrane technology will be the best available technology in terms of the most organic and inorganic contaminant removal for the amount of capital invested. However, safe methods of concentrate disposal will be necessary, as well as fair and pragmatic regulations concerning disposal for the application of membrane processes to continue.

Table 1

REGULATIONS, CONCERNS, AND REQUIREMENTS BY DISPOSAL METHOD

DISPOSAL METHOD	APPLICABLE REGULATIONS	REGULATORY CONCERNS	PERMITS REQUIRED	OTHER REQUIREMENTS
Surface Water	Rule 17-3, FAC Rule 17-4, FAC	o Receiving stream limitations o Radionuclides o Odors (hydrogen sulfide) o Low dissolved oxygen levels o Sulfide toxicity o Low pH o "Free from" restrictions	o Industrial Operating (IO) o NPDES	o Mixing zone o Possible pretreatment
Deep Well Injection	Rule 17-3, FAC Rule 17-4, FAC Rule 17-22, FAC Rule 17-28, FAC 40 CFR 144 40 CFR 146 40 CFR 147	o Confining layer o Upconing to USDWs o Injection well integrity o Corrosivity	o Injection Well Operating Permit	o Well liner o Monitoring well o 5-year integrity test
Spray Irrigation	Rule 17-3, FAC	o Groundwater protection (GI, II, and III Rules)	o Monitoring Plan	o Monitoring wells o Possible pretreatment o Backup disposal method o Need for irrigation water
Drainfield or Borehole	Rule 17-3, FAC	o Groundwater protection	o Monitoring Plan	o Monitoring wells o Proper soil conditions and/or rock permeability
Sanitary Sewer Collection System	None: Approval by Local Agencies	o Effect on local wastewater treatment plant performance (biomass effluent quality)	o None	o None

CURRENT REGULATORY CONCERNS
RELATED TO THE DISPOSAL
OF RO CONCENTRATES IN FLORIDA

by

Dr. Rodney S. DeHan
Florida Department of Environmental Regulation
Tallahassee, Florida

DISPOSAL OF CONCENTRATES
FROM BRACKISH WATER DESALTING PLANTS

November 18, 1988

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Tallahassee, Florida

INTRODUCTION

DER's position on the whole issue of RO and desalination which was expressed during the October adoption of the latest amendments on the groundwater regulations affecting the concentrate discharge is that the Department does encourage the use of RO. It is a good groundwater treatment and management technique. That is our sentiment, and FDER will do what it can to facilitate the operation and, ultimately, the discharge of the RO concentrate. FDER wants to have a happy position of having RO plants operate as efficiently as possible with minimum impact on the environment and it is doable. This sentiment finds support in Chapter 187, Florida Statutes, which is the State Comprehensive Plan. The document's goal is stated as follows:

> "Florida shall ensure the availability of an adequate supply of water for all competing uses deemed reasonable and beneficial and shall maintain the functions of the natural systems and the overall level of present surface and groundwater quality. Florida shall improve and restore the quality of waters not presently meeting water quality standards."

This paper was prepared by the editor based on a recording of the presentation. Where deemed appropriate, the presentation has been edited for clarity.

The plan goes on to list some 14 policies by which that goal is to be achieved and the very first policy reads "to ensure the safety and quality of drinking water supplies and promote the development of reverse osmosis and desalination technologies for developing water supplies." This policy is supported wholeheartedly by the DER,, and we are actively striving to implement it.

The groundwater regulation codes were developed in 1983 and prominent among these codes was the groundwater classification scheme. We classify the groundwater into four classes, G-I through G-IV, on the basis of water quality as measured by total dissolved solids (TDS) and geological confinement. The G-I classification is yet to be implemented. As many of you know, the G-I classification is languishing in the Court of Appeals due to a challenge by the development industries and others. So until the court resolves the issue, G-I will be left, at least for the time being, in limbo.

GROUNDWATER CLASSIFICATIONS

CLASS G-I — Potable water use, single source aquifers with TDS of less than 3,000 mg/l. This is the existing definition which will be replaced (when resolved by the court) by the new definition making G-I class aquifers the wellhead protection areas.

CLASS G-II — Potable water use, aquifers with less than 10,000 mg/l TDS.

CLASS G-III — Non-potable water use, unconfined aquifers with 10,000 mg/l TDS or greater, or TDS of 3,000-10,000 mg/l and reclassified by the Environmental Regulation Commission (ERC) as having no potential as a source of drinking water.

CLASS G-IV — Non-potable water use, confined aquifers with 10,000 mg/l TDS or greater

The G-II class represents the majority of Florida's aquifers with good water quality measuring--a TDS of 200 to 500 mg/l.

The G-III and G-IV are the non-potable groundwaters containing water of 10,000 TDS and higher. The difference between G-III and G-IV is that G-III is unconfined or semi-confined while G-IV is confined. I think G-IV and G-III are probably the two aquifer classifications that are of most concern to you as operators and owners of RO or desalination systems. The following summarizes the groundwater quality standards enforced by the Department.

WATER QUALITY STANDARDS FOR GROUNDWATER

The water quality standards includes three suites of parameters that must be adhered to and those are:

- o Minimum Criteria or "Free-Froms"
- o Primary Drinking Water Standards
- o Secondary Drinking Water Standards

THE MINIMUM CRITERIA

Those are also referred to commonly as "free-froms." This is the terminology used in the statute which states that groundwater in all places at all times shall be "free-from" and it lists a variety of chemicals that do not have maximum contaminant levels, and it dictates that those must not be present in the water at levels that may be carcinogenic, mutagenic, teratogenic or toxic or cause nuisance.

PRIMARY DRINKING WATER STANDARDS

These standards are:

- o Health based,

- o Established by EPA (except sodium and volatile organics),

- Accepted under the authority of the Florida Safe Drinking Water Act,

- Included in Chapter 17-22, Florida Administrative Code (FAC), and applicable to community and some non-community drinking water systems.

<u>SECONDARY DRINKING WATER STANDARDS</u>

These standards are:

- Generally based on aesthetics rather than public health effects,

- Established by EPA as "guidelines,"

- Accepted under the authority of Florida Safe Drinking Water Act,

- Included in Chapter 17-22, FAC, and are applicable to community drinking water systems,

- Included in Chapter 17-3, FAC, as groundwater standards.

The primary drinking water standards are the health standards and they, with the exception of radionuclides, are of little concern to RO concentrate discharge.

The secondary standards are the aesthetic standards and are the standards that are usually exceeded in the RO concentrate. The minimum criteria, as I mentioned, are the carcinogenic, mutagenic, and so forth. Once again, those are of little concern to the issue of RO concentrate discharge.

The primary drinking water standards are health based. They are adopted under the authority of the Federal and State Safe Drinking Water Acts. Currently, they are spelled out in Chapter 17-22, FAC, (the

Drinking Water Rule). They are also adopted in Chapter 17-3, FAC, and 17-4, FAC, Groundwater. So, in Florida, the drinking water and groundwater criteria are identical and whenever we adopt a drinking water standard in 17-22, FAC, we automatically adopt it in 17-3, FAC, and 17-4, FAC, as a groundwater standard. Incidentally, these numbers--17-22, 17-3, and 17-4 and so forth--are all being changed in an attempt to streamline the nomenclature system.

The primary drinking water standards are listed in Table 1 and include organics, inorganics, pesticides, bacteria and radionuclides, all of which must be monitored in any discharge to groundwater if the waste stream contains any of these parameters.

The secondary standards are of concern to industry. They are generally based on aesthetics but, if violated, they still make the water undrinkable unless they are removed to the applicable MCL. They are once again listed in Chapter 17-22 and adopted as groundwater standards.

Last year FDER amended the secondary standards as they relate to groundwater and exempted existing facilities from compliance with the secondary standards but they are still applicable to new facilities. Table 2 lists the secondary standards and they are self-explanatory. They are originally proposed to protect the segment of the population that drink water without any treatment. They constitute about 20% of the state's population or 2 million people currently residing in Florida.

The effect of the secondary drinking water standards are generally related to taste, odor, or color. Some may have some health affects as sulfates, at very high levels, but generally they must be complied with for aesthetic purposes only.

The permitting requirements for groundwater discharge are in 17-3, FAC, and 17-4, FAC, and they deal with installations discharging to Class G-II groundwater which is the main discharge to groundwater that we need to be concerned with. Existing sources and new sources are dealt with in different ways in the rules. The existing sources are those that were discharging before January 1983, and new sources are those that are discharging after 1983. The most critical concept in groundwater discharge is the so called zone of discharge (ZOD). It is equivalent to

Table 1

PRIMARY DRINKING WATER STANDARDS

INORGANICS

Contaminant	MCL (mg/l)
Arsenic	0.05
Barium	1.0
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate	10.0
Selenium	0.01
Silver	0.05
Sodium	160.0
Fluoride	4.0

ORGANICS

Contaminant	MCL (mg/l)
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP, Silvex	0.01

Table 1 - Continued

PRIMARY DRINKING WATER STANDARDS

VOLATILE ORGANICS

Contaminant	MCL (mg/l)
Trichloroethylene	3.0
Tetrachloroethylene	3.0
Carbon tetrachloride	3.0
Vinyl chloride	1.0
1,1,1-Trichloroethane	200.0
1,2-Dichloroethane	3.0
Benzene	1.0
Ethylene dibromide	0.02

RADIONUCLIDES

Contaminant	MCL (mg/l)
Radium-226	
Radium-228	5 pCi/l
Gross Alpha	15 pCi/l

Table 2

SECONDARY DRINKING WATER STANDARDS

MAXIMUM CONTAMINANT LEVELS

Parameter	Level
Chloride	250 mg/l
Color	15 color units
Copper	1 mg/l
Corrosivity	Non-corrosive
Foaming agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 TON
pH	6.5
Sulfate	250 mg/l
Total dissolved solids	500 mg/l

the mixing zone in surface water discharge regulation. Basically, the zone of discharge is a three-dimensional segment of the aquifer whose dimensions differ between existing and new sources. Any facility discharging indirectly to groundwater must obtain a DER permit which must include a monitoring plan that describes, among other things, the dimensions of a zone of discharge, the location of monitoring wells and the parameters to be monitored. A minimum of three monitoring wells is required. One well is the background monitor well that will determine the quality of the natural, unaffected background; the second is a compliance monitoring well which may be located either at the property boundary in the existing sources or a hundred feet from the waste edge, whatever that may be, in new sources. If the discharge contains "free froms," or minimum criteria, then it does not receive a zone of discharge, and a third well must be placed as close as possible to the waste edge to ensure that the minimum criteria are adhered to and that the groundwater is not used as a step for dilution or treatment of minimum criteria.

The vertical extension of the zone of discharge is assumed to be to the first surficial confining bed. But the rule is silent on the vertical extent of the zone of discharge and the districts must specify that extent on a case-by-case basis. As mentioned earlier, the concept of the zone of discharge is to allow some degree of dilution and treatment (via biological or chemical degradation) of primary and secondary drinking water parameters. The minimum criteria on the other hand are considered too harmful to risk introducing into the groundwater, thus are not allowed a zone of discharge.

The above discussion was a brief introduction to the regulations governing general discharge to the groundwater. The remainder of the paper will discuss the regulations specifically dealing with discharge of RO concentrate.

In October of 1988, the Department introduced an amendment to the rules governing the discharge of RO concentrate. The amendment, adopted by the ERC allowed an unlimited zone of discharge to facilities discharging RO concentrates on land or into impoundments underlain by aquifers containing 1,500 mg/l or higher of TDS.

Other attempts to relax some of the regulations governing deep well injection of RO concentrate were unsuccessful. The deep well injection program or rather the underground injection control (UIC) program is a federal program that was authorized under the Safe Drinking Water Act and delegated to the DER and adopted as Chapter 17-28, FAC, which regulates underground injection. In delegating that program to the State, the federal government or the EPA, does not wash its hands of the program. FDER basically has to abide by their guidelines, and if FDER is to change or to relax or modify these regulations in 17-28, then those regulations must be changed nationally as well if they are to meet the EPA guidelines.

The UIC program deals with the construction and operation of underground injection wells. Its purpose is to ensure that wastewater injected underground does not contaminate underground sources of drinking water. Permits issued to users of such wells must be evaluated prior to approval by a Technical Advisory Committee (TAC). The TAC membership has representatives of the DER, EPA, the USGS, and the water management districts. Its purpose is to provide the DER with technical assistance and to insure that the permittee is not subjected to overlapping or conflicting regulations administered by the state and regional agencies.

The injection wells that are under the U.S. regulations are listed under five classes--Class I through V. Class I, which are the deep well injections, number about 107, either operating or under construction. The majority of those are discharging domestic effluents, and there are only about 6 or 7 that are receiving industrial effluents. Class II deals with the discharge of brine resulting from oil and gas exploration. This is under the jurisdiction of the Department of Natural Resources (DNR). Class III is the mining type well. Several years ago the phosphate industry had three experimental wells that have since been discontinued, so we do not have any mining wells now. Class IV is hazardous waste discharge wells which are banned in Florida. Class V are the drainage wells, and we have about 10,000 of those. The majority of them, some 80%, are air conditioning return flow wells. They are closed circuit air conditioning return flow wells and heat exchange wells. There are a few hundred drainage wells that do receive stormwater discharge and, in a few cases, receive treated domestic effluent. Those are mostly located in the Orlando and Miami area.

Figure 1 illustrates some of the requirements in Class I wells. Chapter 17-28, FAC, requires at least one confining zone separating the zone of injection, from any underground source of drinking water (USDW). In Figure 1, there are at least two impermeable zones separating the injection zone which is saltwater with more than 10,000 TDS. In all of these Class I wells, the injection zone must, therefore, be a Class IV aquifer. It must have more than 10,000 TDS, and it must be confined. The idea is that under no circumstances migration, either lateral or vertical, of the injected fluid is allowed to reach a USDW.

Figure 2 illustrates the difference in the construction of a municipal and an industrial injection well. The basic difference is the requirement of tubing and packer in wells constructed to receive industrial effluents. This is a requirement specified in federal regulations. Any changes, therefore, contemplated in state regulations must be approved by EPA. In Florida, large diameter wells are commonly used which require especially designed packers which in turn increases the cost of well construction. Our estimates for the cost of manufacturing, installation, and testing of tubing and packer may range between $80,000 to $100,000 per well.

Because of these costs, the RO plant owners, operators, and their consultants approached the Department with the request to change the regulation by reclassifying RO concentrate injection wells as municipal rather than industrial. If successful, this reclassification would relieve the RO concentrate wells of the tubing and packer requirement. FDER approached the EPA with a multi-pronged argument:

a. RO concentrate is less harmful to public health and the environment than domestic effluents since the latter contains many man-made toxic constituents while the concentrate contain only naturally occurring elements. EPA countered with the argument that the RO process concentrates these natural constituents in a small area of the receiving aquifer to levels that are not encountered in natural settings. They also

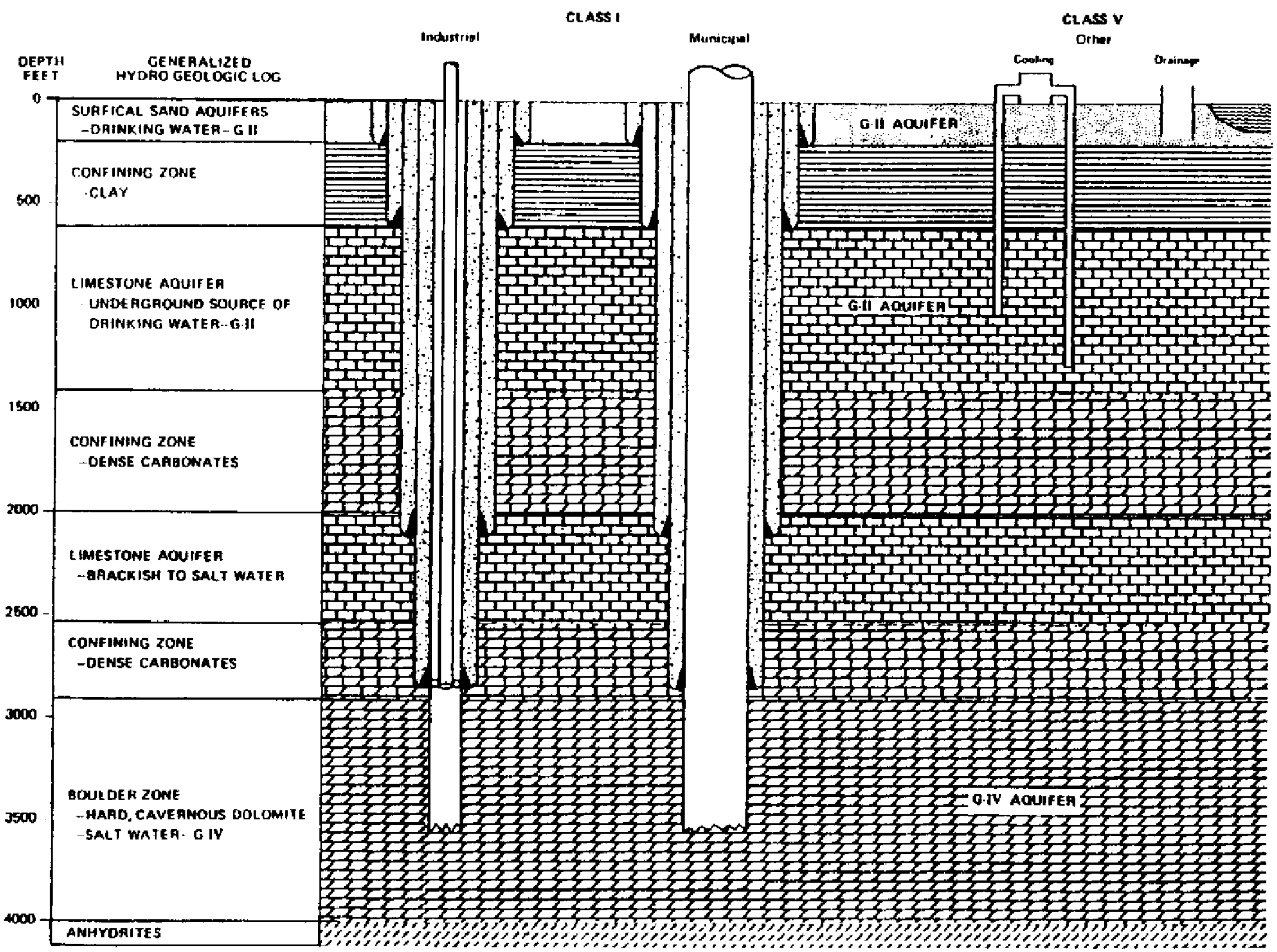
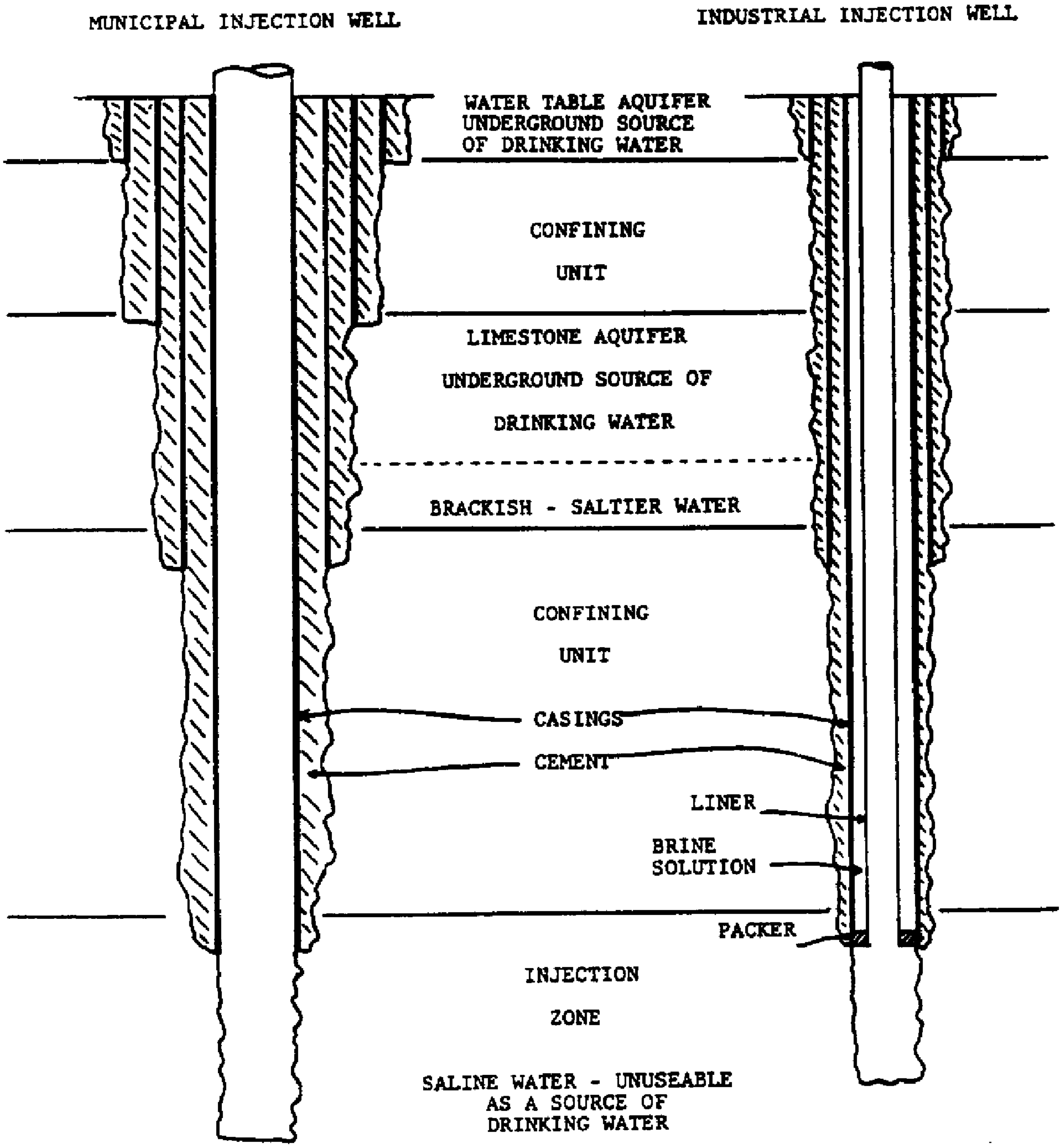


Figure 1 CLASS I AND CLASS V INJECTION WELLS

From: Florida Underground Injection Control Program Handbook, FDER, 1983.



From: Florida Underground Injection Control Program Handbook, FDER, 1983.

Figure 2 TYPICAL CLASS I INJECTION WELL CONSTRUCTION pointed out that the exemption of municipal wells from the tubing and packer requirement was originally in response to pressure from Florida.

b. FDER suggested that the costs of tubing and packer are an unnecessary burden on municipalities interested in utilizing highly mineralized aquifers. EPA suggested that the costs are in fact minimal and represent only ten percent of the cost of well construction.

c. FDER suggested that one way of addressing the industrial definition issue would be by blending RO concentrate with domestic effluent and keeping such wells classified as municipal. Our suggestion of using 35% to 50% ratio instead of the 5% limit to industrial contribution practiced by EPA was rejected by the agency without clear justification.

d. FDER proposed to create a Group VII drainage wells under the Class V category of wells and allowing such wells to receive RO concentrate. This suggestion was also rejected on the basis that the Act language clearly specify that any discharge through Class V wells into USDW must be of drinking water quality while injection into non-potable aquifers is through Class I wells.

e. To address the EPA's concern for high corrosivity of the RO concentrate, FDER suggested that a requirement could be introduced prohibiting metallic casings in RO concentrate discharge wells. The EPA countered by the argument that plastic or fiberglass casings could cause mechanical integrity problems.

FDER has not given up on convincing EPA of our position on this issue. However, if we are to attempt a second set of negotiations, the help of the RO users/operators and their consultants is critically needed. Such help would be in the shape of site-specific documented data dealing with:

- Cost of tubing and packers,
- Corrosivity of the various RO concentrates,
- Comparison between the concentrate and secondary treated domestic effluents quality and corrosivity,
- Documentation of reliable mechanical integrity exhibited by non-metallic casings.

Table 3 shows some of the changes in rule numbering which may be of some use to you. Chapter 17-3 and 17-4 are now 17-520. Ground Water Permitting and Monitoring Requirements which used to be Chapter 17-4 will be 17-522. Underground Injection Control which was 17-28 will now be 17-528. Other related rules, 17-20 will be 17-531, that is the Water Well Contractors Rule. The Water Well Construction, 17-22 will be 17-532, and we have a brand new rule that will hopefully be on the books in March of this year. It is designed to identify the contaminated aquifer areas in the state and develop well construction and location criteria for wells to be located within these areas to prevent interconnection of contaminates from one aquifer to the other and to relieve some of the liability that the state may be saddled with for people drilling wells in contaminated areas.

Table 3

CHANGES IN RULE DESIGNATIONS

RULE TITLE	OLD CHAPTER	NEW CHAPTER
Groundwater Standards and Exemptions	17-3 17-4	17-520
Groundwater Permitting and Monitoring Requirements	17-4	17-522
Underground Injection Control	17-28	17-522
Water Well Contractors	17-20	17-531
Water Well Construction	17-21	17-532
Prevention of New Potable Water Well Contamination		17-524

SURFACE WATER DISCHARGE OF REVERSE OSMOSIS CONCENTRATES

by

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and
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Post, Buckley, Schuh & Jernigan, Inc.
Orlando, Florida

DISPOSAL OF CONCENTRATES
FROM BRACKISH WATER DESALTING PLANTS

November 18, 1988

SURFACE WATER DISCHARGE OF REVERSE OSMOSIS CONCENTRATES

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INTRODUCTION

On the most recent list available from the Florida Department of Environmental Regulation (FDER), there are 96 membrane plants in the State of Florida treating water for potable consumption. Most of these plants are located in coastal areas and utilize brackish groundwater as their raw water source. Table 1 shows the location and size of each plant. Recently, questions have been raised as to the environmental impacts of these discharges to the surface waters; and, as a result, some of these plants may have had problems receiving and/or renewing their operating permits. The distribution of potable water membrane plants in the State of Florida, by size of plant, is shown in Figure 1. From this figure, it can be seen that the majority of plants in the state (85%) have a design capacity of less than 0.5 MGD, and most of these (66%) are sized for less than 0.1 MGD. Also, 85% of the total capacity of membrane plants is produced at just 14 of the plants. One of these 14 larger plants is an electrodialysis type plant, the remainder are reverse osmosis (RO) plants.

Because most of these plants are located in coastal areas, they are normally adjacent to highly saline surface waters. Therefore, they will normally discharge the concentrate to these surface waters.

Table 2 is a list of the concentrate disposal methods used by these 13 RO plants in Florida, as well as their location and capacity. As can be seen from this list, the majority of the large RO plants in the state

Table 1

MEMBRANE PLANTS IN FLORIDA

COUNTY	NAME OF PLANT	CAPACITY (MGD)
Brevard	Aquarina	0.040
	Cove of Casseekee	0.020
	Cove of South Beaches	0.010
	Chuck's Steak House	0.005
	South Shores	0.100
Charlotte	Alligator Utilities	0.040
	Burnt Store Colony	0.080
	Burnt Store Utilities	0.360
	Charlotte Harbor Water Association	0.450
	Eagle Point Nest NHP	0.040
	Gasparilla Pines	0.200
	Hunter Creek MHP	0.040
	Knight Island Utilities	0.030
	Pines at Punta Gorda	0.024
	Rotunda West Utilities	0.500
	Seaside Service System	0.010
Dade	Elliot Key	0.001
Flagler	Marineland	0.100
	Picknicker Rest & Travel Park	0.006
Hendry	Citrus Belle	0.001
	South Florida United Methodist	0.010
Indian River	Indian River Co. South	2.120
	Indian River Shores	0.012
	Marsh Island	0.040
	North Beach Water Company	0.500
	Pelican Point	0.040
	Village Green	0.100
	Village Green West	0.133
Lake	Wekiva Falls Park	0.015
Lee	Cape Coral	13.800
	Greater Pine Island	0.825
	Gulf Coast Resort	0.028
	Imperial Harbor Mobile Home Est.	0.096
	Sanibel Island Water Association (ED)	1.700
	Sanibel Island Water Association	2.400
	Useppa Island Association	0.027
Martin	Indian River Plantation	0.200
	Joe's Point	0.120
	River Club	0.057
	Sailfish Point	0.225
Monroe	Ocean Reef Club	1.040
	Card South Gulf Club	0.300
	FKAA	3.000
Orange	KOA Christmas	0.014
	Sea World	0.008

Table 1 -- Continued

MEMBRANE PLANTS IN FLORIDA

COUNTY	NAME OF PLANT	CAPACITY (MGD)
Palm Beach	Acme Improvement District	1.800
	Loxahatchee Grover Elementary School	0.003
	Palm Beach Park of Commerce	0.180
Sarasota	Arbors MHP	0.030
	Bay Lakes Estates MHP	0.043
	Bee Ridge Landfill	0.001
	Cocilla	0.040
	Camelot Lakes MHP	0.100
	Courtside Tennis Club	0.003
	Fairwinds Condominiums	0.018
	Heron Bay Club	0.010
	Kings Gate Club	0.030
	Kings Gate RV	0.030
	Lake Tippecanoe	0.038
	Lake Village MHP	0.075
	Lyons Cover Condo	0.072
	Myakka River Stat Park	0.050
	Nokomis School	0.008
	North Creek Utilities	0.030
	Palm and Pines MHP	0.010
	Peterson Manufacturing	0.008
	Plantation Utilities	0.250
	City of Sarasota	4.500
	Sorrento Utilities	0.250
	South Bay Utilities	0.250
	Spanish Lakes MHP	0.100
	Sun-N-Fun	0.127
	Tri-State	0.015
	Venice	2.000
	Venice Ranch MHP	0.020
	Windward Islands	0.029
	Workman Electronic	0.001
	Venice Garden Utilities	0.750
St. Johns	Parker Hannifin Corporation	0.014
St. Lucie	Bryn Mawr Camp Resort	0.150
	Ft. Pierce Jai Alai	0.039
	Harbor Foundation	0.019
	Miramar	0.040
	Ocean Harbor South	0.100
	Ocean Towers	0.120
	Queen's Cove	0.010
	Sand Dollar	0.100
Volusia	Golden Bay Colony	0.040
	Hawaiian Tropic	0.043
	Indian Harbor Estates	0.035
	Kingston Shores	0.150
	Lake Villa Estates (CYRS)	0.010
	Riverwood Park	0.003
	South Water Front Park	0.015
	Terra Mar Village	0.043

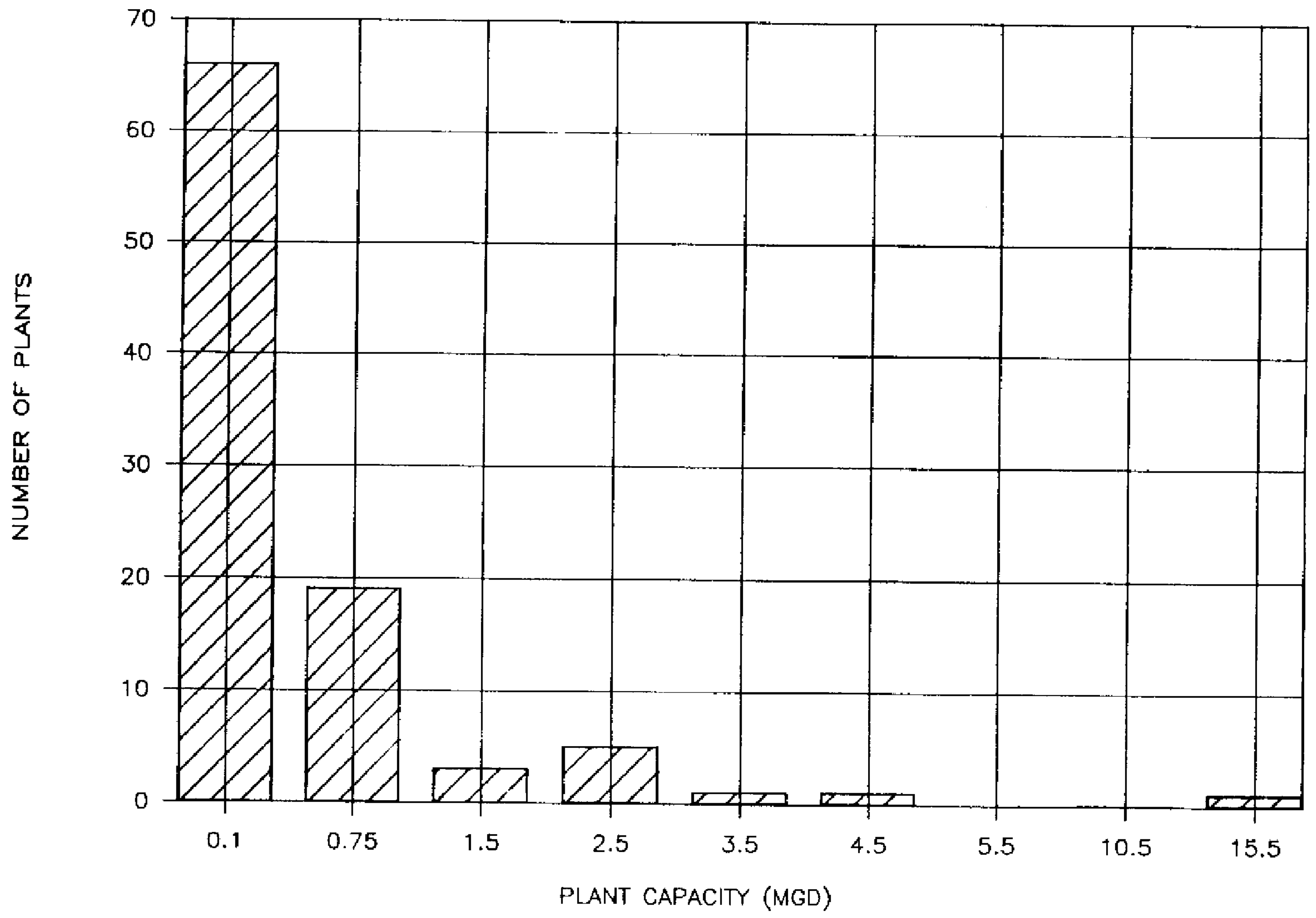

Figure 1 DISTRIBUTION OF RO PLANTS IN FLORIDA

Table 2
CONCENTRATE DISPOSAL METHODS FOR THE LARGE
(0.5 MGD OR GREATER)
REVERSE OSMOSIS PLANTS IN FLORIDA

NAME OF PLANT	COUNTY	CAPACITY (MGD)	CONCENTRATE[1] DISPOSAL METHOD
Rotunda West Utilities	Charlotte	0.500	SWD
Indian River County South	Indian River	2.120	SWD
North Beach Water Company	Indian River	0.500	SWD
Cape Coral	Lee	13.800	SWD
Greater Pine Island	Lee	0.825	SWD
Sanibel Island Water Association	Lee	2.400	SWD
Ocean Reef Club/ Card Sound Gulf Club	Monroe	1.340 (total)	SWD
Florida Keys Aqueduct Authority	Monroe	3.000	SWD
Acme Improvement District	Palm Beach	1.800	DWI
Englewood Water District	Sarasota	1.500	DWI
City of Sarasota	Sarasota	4.500	SWD
Venice	Sarasota	2.000	SWD
Venice Gardens Utilities	Sarasota	0.750	DWI

[1]SWD = Surface Water Discharge
DWI = Deep Well Injection

(10 out of 13) use surface water discharge to dispose of their concentrate. The remaining three utilize deep well injection. These ten plants will be examined in greater detail in order to describe a typical system; the types of receiving water bodies, environmental concerns, and economic considerations related to this form of concentrate discharge.

ENVIRONMENTAL CONSIDERATIONS

The body of water chosen and the necessity of post-treatment required by RO concentrate disposal is dictated by the Florida Department of Environmental Regulation (FDER) and the U.S. Environmental Protection Agency (EPA) maximum contaminant levels (MCL) for surface water discharge. Concentrate discharge to surface waters in Florida must meet the criteria of Class III waters. Class III waters are those classified for use for recreation and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The specific requirements to be met for this class of water are contained in the Appendix. Table 3 contains the water quality criteria for the most important constituents. Any discharges that exceed these prescribed limits constitutes pollution of these waters.

In order to more fully understand RO concentrate discharge, in 1987 the FDER performed a survey of 25 RO plants discharging to both fresh and marine waters in the State of Florida. Their results were then compared with the Class III standards assuming no dilution flow was available for mixing prior to discharge. The parameters surveyed, and the results obtained, are given in Table 4. Inspection of the data contained in this table indicates that the majority of all plants exceeded the criteria considerations in dissolved oxygen, mercury, and radionuclides. Chromium, lead, silver, arsenic and selenium did not exceed either Class III marine or freshwater criteria at any of the plants surveyed. Fluoride, copper, iron and zinc exceeded the criteria at only a small fraction of the plants surveyed. The results of this survey would indicate that to bring all plants within the criteria or Class III waters may require further treatment. However, Section 17.4.244, Florida Administrative Code (F.A.C.), states:

Table 3

CLASS III WATER STANDARDS FOR CONSTITUENTS SURVEYED

CONSTITUENT	WATER QUALITY CRITERIA	
	FRESH	MARINE
Dissolved Oxygen	>5 mg/l	>4 mg/l
Combined Radium 226 & 228	≤5 pCi/l	≤5 pCi/l
Gross Alpha (including Radium 226 only)	≤15 pCi/l	≤15 pCi/l
Mercury	≤0.2 µg/l	≤0.1 µg/l
Copper	≤0.03 mg/l	≤0.016 mg/l
Fluoride	≤10.0 mg/l	≤5.0 mg/l
Iron	≤1.0 mg/l	≤0.3 mg/l
Zinc	≤0.03 mg/l	≤1.0 mg/l
Chloride		Not Incr. >10%
Cadmium	0.8 - 1.2 µg/l	≤ 5.0 µg/l
Chromium	≤0.05 mg/l	≤0.05 mg/l
Lead	≤0.03 mg/l	≤0.05 mg/l
Silver	≤0.07 µg/l	≤0.05 µg/l
Arsenic	≤0.05 mg/l	≤0.05 mg/l
Selenium	≤0.025 mg/l	≤0.025 mg/l

Table 4

CLASS III WATER STANDARDS SURVEY RESULTS

CONSTITUENT	FRACTION EXCEEDING STANDARDS
Dissolved Oxygen	21/25
Combined Radium 226 & 228	9/10
Gross Alpha	9/12
Mercury	7/11
Copper	3/11
Fluoride	3/25
Iron	2/25
Zinc	2/25
Chloride	Data Not Available
Cadmium	Below Detection Limits
Chromium	0/11
Lead	0/11
Silver	0/11
Arsenic	0/11
Selenium	0/11

The Department may allow the water quality adjacent to a point of discharge to be degraded to the extent that only the minimum conditions described in Section 17-3.051 (1) apply within a limited, defined region known as a mixing zone. Under the circumstances defined elsewhere in this section, a mixing zone may be allowed so as to provide an opportunity for mixing and thus to reduce the costs of treatment.

Methods to determine the required mixing zones have been proposed for nontidal canals, rivers, and other similar water bodies.

As part of the work done during the survey, more detailed testing was carried out at the City of Venice and the Indian River County plants. This work included testing of the receiving body of water, both upstream and downstream of the discharge point. The results of this work are discussed in the next section.

CASE HISTORIES

Some of the information included in this paper was gathered in the Spring of 1988 in conjunction with a Masters Degree project being completed for the Department of Civil Engineering at the University of South Florida. As part of this project, a questionnaire was sent out to the operators of the 13 known RO plants in Florida with a design size of 0.5 MGD, or greater, which discharged to a surface water body. (A copy of this questionnaire is included in the Appendix.) Ten of the 13 plants responded by completing and returning this form. Follow-up phone calls were made to obtain additional information not included in the original questionnaire, such as what post-treatment was done on the concentrate. Some of the questions asked in the questionnaire were concerned with history and general operating data, such as how long the plant had been operational and what the average daily flows of raw water, product and concentrate were. More specific information was requested regarding the water quality testing done, including a matrix for the operator to fill out on the types of water quality tests performed and on what streams (i.e., raw, product, concentrate, and/or receiving water). The operators were also asked to describe the receiving surface water body and the type of discharge structure used. The results of this survey are given in Table 5.

Reviewing this survey information on Table 5 indicates that only two of the ten plants responding provided any post-treatment of the concentrate. These were at the North Beach Water Company in Vero Beach where aeration and odor removal systems are provided, and at the Cape Coral Plant where hydrogen sulfide removal is practiced with chlorine and aeration. This information also indicates that special discharge structures are not normally used. The receiving water bodies were, in the majority of the cases, of marine quality saline waters. Almost all discharges were in close proximity to bays or the open ocean.

As part of this survey, the questionnaire addressed the monitoring being carried out for constituents in the raw water, product, concentrate, and receiving body. Specifically, testing for the following parameters were requested:

- o Total Dissolved Solids
- o Dissolved Oxygen
- o Chlorine
- o Copper
- o Mercury
- o Iron
- o Zinc
- o Radionuclides
  - Gross Alpha
  - Gross Beta
  - Radium 226
  - Radium 228

The results of this portion of the survey are contained in Tables 6 and 7, for the RO plant concentrate and receiving stream, respectively. Of the ten plants requested information, seven responded. Of these seven, six installations are testing some constituents in the concentrate stream and four are testing some receiving water parameters.

Table 5

RO PLANTS USING SURFACE WATER DISCHARGE FOR CONCENTRATE DISPOSAL

PLANT	CONCENTRATE POST-TREATMENT	DISCHARGE STRUCTURE	RECEIVING WATER BODY
Rotunda West Utilities	None as originally designed	8-inch PVC pipe, discharge is located under the mean low water line	Discharge flows through 3,300 ft. of 8-inch PVC pipe to a point downstream of an existing salinity dam on a tidal creek that empties into Charlotte Harbor
Indian River County South	None	Open pipe	Canal to tidal lagoon at the Indian River 1.5 miles downstream of outfall
North Beach Water Co.	Aeration at WTP and "Pep-Con" odor removal system	Unknown	Direct discharge to the Indian River
Cape Coral (Dow and Hydranautics Plants)	Dow*: No treatment	Dow*: Perforated pipe	Dow: Tidal flushed canal flows into Matiache Pass
	Hydra: H_2S removal with chlorine and aerators in lake	Hydra: In-line diffusers	Hydra: Tidal flushed lake with tidal flow into Caloosahatchee River
Greater Pine Island	None as originally designed		Discharge into a man-made canal approximately 2 miles to open water at Matlacha Pass
Sanibel Island Water Assoc.	None	12-inch pipe with screen over the end	Discharge via outfall pipe 150 yards into the Gulf of Mexico
Ocean Reef Club/Card Sound Gulf Club	None as originally designed	Open pipe outfall	Discharge into Angel Fish Creek which connects Biscayne Bay to Hawk Channel (Atlantic Ocean)
Florida Keys Aqueduct Authority	None	Open pipe in a seawall	Discharge into ship channel which leads to the Gulf of Mexico
City of Sarasota	Gravity aerator	Storm sewer	Blended with ion exchange concentrate and rinse water and discharged via storm sewer to Sarasota Bay
Venice	None as originally designed	Storm sewer	Discharge to Hatchett Creek leads to the Intracoastal Waterway

*By March 1989, both plants will have H_2S treatment and aerators. Receiving body will be tidal flushed lake.

Table 6

LABORATORY TESTING DONE ON CONCENTRATE STREAM

Plant	TDS		D.O.		Cl		Cu		Hg		Fe		Zn		Gross Alpha		Gross Beta		Ra 226		Ra 228	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
*Rotunda West Utilities																						
Indian River County South	X		X		X			X		X		X		X	X		X			X		X
*North Beach Water Co.																						
Cape Coral (Dow and Hydraunautics plants)	X		X		X		X		X		X		X		X		X		X		X	
Greater Pine Island		X		X		X		X		X		X		X		X		X		X		X
Sanibel Island Water Assoc.	X			X	X		X		X		X		X		X			X		X		X
*Ocean Reef Club/ Card Sound Gulf Club																						
Florida Keys Aqueduct Authority		X	X			X		X		X		X		X		X		X		X		X
City of Sarasota	X				X			X		X		X		X		X		X		X		X
Venice	X			X	X			X		X	X			X	X				X			

* data not available.

Table 7

LABORATORY TESTING DONE ON RECEIVING STREAM

Plant	TDS		D.O.		Cl		Cu		Hg		Fe		Zn		Gross Alpha		Gross Beta		Ra 226		Ra 228	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
*Rotunda West Utilities																						
Indian River County South	X		X		X			X		X		X		X		X		X		X		X
*North Beach Water Co.																						
Cape Coral (Dow and Hydraunautics plants)	X		X		X		X		X		X		X		X		X		X		X	
Greater Pine Island		X		X		X		X		X		X		X		X		X		X		X
Sanibel Island Water Assoc.		X		X		X		X		X		X		X		X		X		X		X
*Ocean Reef Club/ Card Sound Gulf Club																						
Florida Keys Aqueduct Authority	X		X		X			X		X		X		X		X		X		X		X
City of Sarasota		X		X		X		X		X		X		X		X		X		X		X
Venice	X			X	X			X		X		X		X	X				X			

* data not available.

- o City of Venice
- o Indian River County

Partial results of this testing is given in Tables 8 and 9. No specific conclusions can be drawn from this information.

Table 8
CITY OF VENICE
TEST RESULTS - 1987

Sample Location	pH	DO (mg/l)	Cond. (umho/cm)	H_2S (ppm)
	CONSTITUTENT CONCENTRATIONS			
o 200 feet upstream	7.3	4.1	675	0.53
o RO concentrate	6.0	4.0	6,900	5.53
o Stormwater pipe	6.1	4.0	6,800	5.91
o 40 feet downstream nearside	6.9	4.0	1,650	0.86
o 40 feet downstream farside	6.7	4.1	3,150	1.3
o 100 feet downstream	6.8	4.0	1,950	0.95
o 175 feet downstream	6.9	4.0	1,700	0.86

Table 9
INDIAN RIVER COUNTY
TEST RESULTS - 1987

Sample Location	pH	DO (mg/l)	Cond. (umho/cm)	H_2S (ppm)
	CONSTITUTENT CONCENTRATIONS			
o 50 feet upstream	6.9	4.2	476	0.88
o RO concentrate	6.5	2.8	5,450	4.96
o 8 feet downstream	6.8	4.3	690	0.72
O 75 feet downstream	6.7	4.2	550	0.68

The City of Venice has been reporting the following to the FDER from 1983 through the present, as part of their permitting requirements:

- o Chlorides
- o Fluorides
- o Turbidity
- o pH

Values for these constituents are taken upstream and downstream from the discharge point, as well as from the RO concentrate. The results over the period have been averaged and are present in Table 10. These results also must be considered inconclusive due to the fact that downstream concentration is greater than upstream, even though the RO concentrations would seem to support the reverse.

Table 10
CITY OF VENICE
AVERAGED TEST RESULTS -- 1983-1987

		CONCENTRATION	
Constituent	Upstream	RO Concentration	Downstream
o Chlorides (mg/l)	1,227	880	1,267
o Fluorides (mg/l	1.05	0.79	1.13
o Turbidity (NTU)	2.86	1.17	3.18
o pH	7.30	6.03	7.23

Notes:
Upstream location is 100 feet from outfall.
RO location is at the plant.
Downstream location is 100 feet from outfall.

ECONOMIC CONSIDERATIONS

The cost of surface discharge systems will, of course, depend upon what is required to meet the Class III water quality standards. For example, to meet dissolved oxygen requirements, aerators with associated concentrate transfer pumps can be employed. If mixing is required, diffusers or venturies with inline static mixers or other similar methods can be employed. These methods can be employed quite easily and economically. However, if further reduction of the concentrate levels is required prior to discharge, cost can be expected to be quite high. Further reduction of contaminants would require some sort of additional concentration and disposal steps to be carried out. This presentation will not address concentration of the reject; others will report on this.

The costs evaluated in this presentation assume the following concentrate treatment steps would normally be required to meet the criteria of Class III waters:

- Aeration
- Transfer pumps
- Mixing

Actual costs for such a system will depend upon:

- Distance of discharge point from plant
- Concentrate flow
- Piping material
- Buried or aboveground piping installation

For the purposes of this presentation, Table 11 gives the basis assumed for costing. Costs were developed for plant sizes between 1 and 12 MGD, and are presented in Table 12. These costs are also presented graphically in Figure 2.

Table 11

COST BASIS

CONCENTRATE DISPOSAL

- o Discharge point 1-1/2 miles from plant site
- o RO plant recovery at 85 percent
- o Piping material PVC
- o Mixer
- o Installed costs
- o Mid-1988 cost basis

Table 12

POST-TREATMENT COSTS

COMPONENT	INSTALLED COSTS ($) 1.0 (MGD)	3.0 (MGD)	6.0 (MGD)	12.0 (MGD)
Concentrator Piping	105,000	174,400	244,100	348,800
Aerator	5,900	9,800	14,600	21,600
Transfer Pump	14,400	24,400	29,700	34,300
Mixer	2,700	4,500	6,600	9,900
TOTAL	128,000	213,100	295,000	414,600
% of Total Plant Cost	10%	9%	7%	5.5%

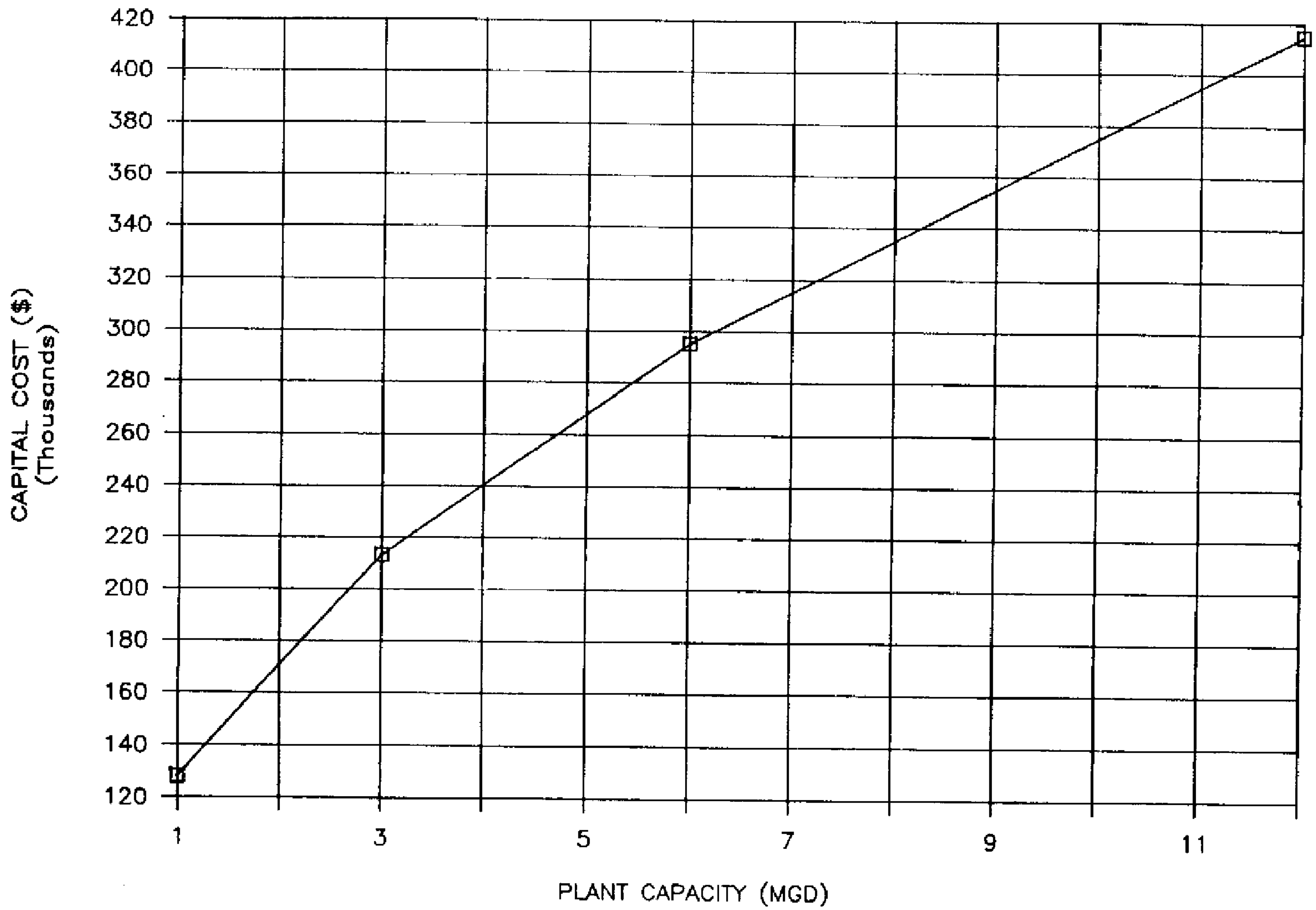

Figure 2 RO CONCENTRATE DISPOSAL

CONCLUSIONS

From the cursory studies and surveys conducted to date, some concern has been generated regarding some constituents normally present in RO concentrates. Specifically, the following:

- Dissolved Oxygen
- Gross Alpha Radioactivity
- Fluorides
- Sulfides

None of these were produced by the RO process itself and it would appear that post-treatment methods can be developed to eliminate any adverse effect on the environment. However, compliance with the radioactivity standards is a difficult problem not easily resolved.

Presently, there is a wide disparity in post-treatment methods being carried out at each facility. This is most probably due to the differences in permitting requirements (i.e., some plants are given potable water permits, some are given industrial waste permits).

Finally, there are apparent differences in the types of testing and reporting being carried out.

REFERENCES

DER, "Water Quality Standards," December 15, 1987.

McClelland, S. "Methods for the Consideration of Mixing Zones and Effluent Limits for Conservative Pollutants," Water Quality Technical Series, Vol. 3, No. 5, Bureau of Water Analysis, May 1980.

Communications, City of Venice to FDER.

Minutes of Meeting, "RO Concentrate Disposal Fact Finding Committee Meeting," December 16, 1987.

Minutes of Meeting, "FDER Concentrate Disposal Workshop, June 26, 1987.

APPENDIX

Reverse Osmosis Plant - Operators Questionnaire

Water Quality Standards

Permits - Mixing Zones

REVERSE OSMOSIS PLANT
OPERATOR'S QUESTIONNAIRE

1. When did your plant first begin operation? (month/year)

____

2. Has it been in continuous operation since then?
____ yes ____ no (If not, please elaborate)

____

____

3. What is your average daily flow of:

raw water ______________ (MGD)
product water ______________ (MGD)
concentrate ______________ (MGD)

4. Do you have data on the following, and if so, on what date do your records begin? ______________ (date)

	Raw Water	Product	Concentrate	Receiving Stream
TDS	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
D.O.	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Chloride	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Copper	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Mercury	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Iron	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Zinc	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Radionuclides:				
Gross	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Gross	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Ra 226	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no
Ra 228	__ yes __ no	__ yes __ no	__ yes __ no	__ yes __ no

5. Please describe the receiving surface water and sketch the discharge structure on the back of this page, if possible:

____

____

____

6. Would you be willing to cooperate in this study by sending copies of your water quality data for the above listed parameters which I am most interested in? ___ yes ___ no

Thank you very much for your help. I will be in touch with all participants very shortly.

109/F110988

(ii) Recapitulation of temperature limitations prescribed above:

ZONE	STREAMS	LAKES	COASTAL		OPEN
			SUMMER	REMAINDER	
NORTH.	90°F Max.	90°F Max.	92°F Max.	90°F Max.	97°F Max.
	AM. +5°F	AM. +3°F	AM. +2°F	AM. +4°F	AM. +17°
PENIN.	92°F Max.	92°F Max.	92°F Max.	90°F Max.	97°F Max.
	AM. +5°F	AM. +3°F	AM. +2°F	AM. +4°F	AM. +17°

(f) Upon application on a case by case basis, the Department may establish a zone of mixing beyond the POD to afford a reasonable opportunity for dilution and mixture of heated water discharges with the RBW, in the following manner:

(i) Zones of mixing for thermal discharges from non-recirculated cooling water systems and process water systems of new sources shall be allowed if supported by a demonstration, as provided in Section 316(a), Public Law 92-500 and regulations promulgated thereunder, including 40 C.F.R. Part 122, by an applicant that the proposed mixing zone will assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is to be made and such demonstration has not been rebutted. It is the intent of the Commission that to the extent practicable, proceedings under this provision should be conducted jointly with proceedings before the federal government under Section 316(a), Public Law 92-500.

(ii) Zones of mixing for blowdown discharges from recirculated cooling water systems, and for discharges from non-recirculated cooling water systems of existing sources, shall be established on the basis of the physical and biological characteristics of the RBW.

(iii) When a zone of mixing is established pursuant to this Subsection 17-3.050(1)(f), F.A.C., any otherwise applicable temperature limitations contained in Section 17-3.050(1), F.A.C., shall be met at its boundary; however, the Department may also establish maximum numerical temperature limits to be measured at the POD and to be used in lieu of the general temperature limits in section 17-3.050(1), F.A.C., to determine compliance by the discharge with the established mixing zone and the temperature limits in Section 17-3.050(1), F.A.C.

Specific Authority: 403.061, 403.062, 403.087, 403.504, 403.704, 403.804, F.S.

Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.702, 403.708, F.S.

History: Formerly 28-5.02, 17-3.02, Amended 10-28-70, Amended and Renumbered 3-1-79.

17-3.051 Minimum Criteria for Surface Waters. All surface waters of the State shall at all places and at all times be free from:

(1) Domestic, industrial, agricultural, or other man-induced non-thermal components of discharges which, alone or in combination with other substances or in combination with other components of discharges (whether thermal or non-thermal):

(a) Settle to form putrescent deposits or otherwise create a nuisance; or

(b) Float as debris, scum, oil, or other matter in such amounts as to form nuisances; or

(c) Produce color, odor, taste, turbidity, or other conditions in such degree as to create a nuisance; or

(d) Are acutely toxic; or

(e) Are present in concentrations which are carcinogenic, mutagenic, or teratogenic to human beings or to significant, locally occurring, wildlife or aquatic species; or

(f) Pose a serious danger to the public health, safety, or welfare.

(2) Thermal components of discharges which, alone, or in combination with other discharges or components of discharges (whether thermal or non-thermal):

(a) Produce conditions so as to create a nuisance; or

(b) Do not comply with applicable provisions of Subsection 17-3.050(1), F.A.C.

Specific Authority: 403.061, 403.062, 403.087, 403.504, 403.704, 403.804, F.S.

Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.702, 403.708, F.S.

History: Formerly 28-5.02, 17-3.02, Amended 10-28-78, Amended and Renumbered 3-1-79, Amended 1-1-83.

17-3.06 Classification of Waters, Usage.

Specific Authority: 403.061. F.S.

Law Implemented: 403.021, 403.031, 403.061, 403.101(1), F.S.

History: Formerly 28.506, Amended and Renumbered as 17-3.081, 3-1-79.

17-3.061 Surface Waters: General Criteria.

(1) The criteria of surface water quality hereinafter provided shall be applied to all surface waters except within zones of mixing.

(2) Effluent limits may be established for pollutants for which analytical detection limits are higher than the established water quality criteria based upon computation of concentrations in the receiving waters. Monitoring reports shall specify the detection limits and indicate non-detectable results in such cases. Unless otherwise specified, for enforcement purposes such non-detectable results shall be accepted in monitoring reports as demonstrating compliance for that pollutant as long as specified effluent limits are met.

(3) A violation of any of the following surface water quality criteria constitutes pollution. Additional, more stringent or alternative criteria than indicated in this paragraph may, however, be specified for individual classes of water under Sections 17-3.091, 17-3.111, 17-3.121, 17-3.131, and 17-3.141 of this Chapter.

(a) Arsenic - shall not exceed 0.05 milligrams per liter.

(b) BOD - shall not be increased to exceed values which would cause dissolved oxygen to be depressed below the limit established for each class and, in no case shall it be great enough to produce nuisance conditions.

(c) Chlorides - in predominantly marine waters, the chloride content shall not be increased more than ten percent (10%) above normal background chloride content. Normal daily and seasonal fluctuations in chloride levels shall be maintained.

(d) Chromium - shall not exceed 0.50 milligrams per liter hexavalent or 1.0 milligrams per liter total chromium in effluent discharge and shall not exceed 0.05 milligrams per liter total chromium after reasonable mixing in the receiving water.

(e) Copper - shall not exceed 0.5 milligrams per liter.

(f) Detergents - shall not exceed 0.5 milligrams per liter.

(g) Dissolved Oxygen -

1. Notwithstanding the specific numerical criteria applicable to individual classes of water, dissolved oxygen levels that are attributable to natural background conditions or man-induced conditions which cannot be controlled or abated may be established as alternative dissolved oxygen criteria for a water body or portion of a water body.

2. Alternative dissolved oxygen criteria may be established by the Secretary or a District Manager in conjunction with the issuance of a permit or other Department action only after public notice and opportunity for public hearing. The determination of alternative criteria shall be based on consideration of the factors described in Section 17-3.031(2)(a)-(d), F.A.C.

3. Alternative criteria shall not result in a lowering of dissolved oxygen levels in the water body, water body segment or any adjacent waters, and shall not violate the minimum criteria specified in Section 17-3.051, F.A.C. Daily and seasonal fluctuations in dissolved oxygen levels shall be maintained.

(h) Fluorides - shall not exceed 10.0 milligrams per liter as fluoride ion.

(i) Lead - shall not exceed 0.05 milligrams per liter.

(j) Nutrients - The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this Chapter. Man-induced nutrient enrichment (total nitrogen or total phosphorus) shall be considered degradation in relation to the provisions of Section 17-3.041 and Section 17-4.242, F.A.C.

(k) Oils and Greases:

1. Dissolved or emulsified oils and greases shall not exceed 5.0 milligrams per liter.

2. No undissolved oil, or visible oil defined as iridescence, shall be present so as to cause taste or odor, or otherwise interfere with the beneficial use of waters.

(l) pH - shall not vary more than one unit above or below natural background provided that the pH is not lowered to less than 6 units or raised above 8.5 units. If natural background is less than 6 units, the pH shall not vary below natural background or vary more than one unit above natural background. If natural background is higher than 8.5 units, the pH shall not vary above natural background or vary more than one unit below background.

(m) Phenolic compounds as listed - Chlorinated phenols including trichlorophenols; chlorinated creosols; 2-chlorophenol; 2, 4 dichlorophenol and pentachlorophenol; 2, 4-dinitrophenol; phenol - shall not exceed 1.0 micrograms per liter unless higher values are shown not to be chronically toxic. Such higher values shall be approved in writing by the Secretary. Phenolic compounds other than those produced by the natural decay of plant material, listed or unlisted, shall not taint the flesh of edible, fish or shellfish or produce objectionable taste or odor in a drinking water supply.

(n) Radioactive Substances:

1. Combined radium 226 and 228 - shall not exceed five picocuries per liter.

2. Gross alpha particle activity including radium 226, but excluding radon and uranium - shall not exceed fifteen picocuries per liter.

(o) Specific Conductance - shall not be increased more than 50% above background or to 1275 micromhos per centimeter, whichever is greater, in predominantly fresh waters.

(p) Substances in concentrations which injure, are chronically toxic to, or produce adverse physiological or behavioral response in humans, animals, or plants - none shall be present.

(q) Substances in concentrations which result in the dominance of nuisance species - none shall be present.

(r) Turbidity - shall not exceed 29 Nephelometric Turbidity Units (NTU's) above natural background.

(s) Zinc - shall not exceed 1.0 milligrams per liter.

Specific Authority: 403.061, 403.062, 403.087, 403.504, 403.704, 403.804, F.S.
Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.141, 403.161, 403.181, 403.502, 403.702, 403.708, F.S.
History: Formerly 17-3.05(1) and (2), Amended 2-12-75, 8-26-75, 6-10-76, Amended and Renumbered 3-1-79, Amended 10-2-80, 2-1-83, 4-26-87.

17-3.07 Criteria: Class I Waters - Public Water Supply.
Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.031, 403.061, 403.101, F.S.
History: Formerly 28-5.07, Amended 7-3-73, Amended and Renumbered as 17-3.091, 3-1-79.

17-3.071 Groundwaters: General Criteria.
Specific Authority: 403.061, 403.062, 403.087, 403.504, 403.704, 403.804, F.S.
Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.702, 403.708, F.S.
History: New 3-1-79, Amended 12-27-79, 1-12-81, 1-19-82, Amended and Renumbered as 17-3.401, 1-1-83.

17-3.08 Criteria: Class II Waters - Shellfish Propagation and Harvesting.
Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.031, 403.061, 403.101, F.S.
History: Formerly 28-5.08, Amended 6-10-72, 8-30-72, 7-3-73, Amended and Renumbered as 17-3.111, 3-1-79.

17-3.081 Classification of Surface Waters, Usage, Reclassification.

(1) All surface waters of the State have been classified according to designated uses as follows:

CLASS I	Potable Water Supplies
CLASS II	Shellfish Propagation or Harvesting
CLASS III	Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife
CLASS IV	Agricultural Water Supplies
CLASS V	Navigation, Utility and Industrial Use

(2) Classification of a water body according to a particular designated use or uses does not preclude use of the water for other purposes.

(3) The specific water quality criteria corresponding to each surface water classification are listed in Sections 17-3.091 to 17-3.141, F.A.C., inclusive.

(4) Water quality classifications are arranged in order of the degree of protection required, with Class I water having generally the most stringent water quality criteria and Class V the least. However, Class I, II, and III surface waters share water quality criteria established to protect recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

(5) Criteria applicable to a classification are designed to maintain the minimum conditions necessary to assure the suitability of water for the designated use of the classification. In addition, applicable criteria are generally adequate to maintain minimum conditions required for the designated uses of less stringently regulated classifications. Therefore, unless clearly inconsistent with the criteria applicable, the designated uses of less stringently regulated classifications shall be deemed to be included within the designated uses of more stringently regulated classifications.

(6) Any person regulated by the Department or having a substantial interest in this Chapter may seek reclassification of waters of the State by filing a petition with the Secretary in the form required by Section 17-1.24, F.A.C.

(7) A petition for reclassification shall reference and be accompanied by the information necessary to support the affirmative finding required in this Section to support the proposed reclassification.

(8) All reclassifications of waters of the State shall be adopted, after public notice and public hearing, only upon an affirmative finding by the Environmental Regulation Commission that:

(a) The proposed reclassification will establish the present and future most beneficial use of the waters; and

(b) Such a reclassification is clearly in the public interest.

(9) Reclassification of waters of the State which establishes more stringent criteria than presently established by this Chapter shall be adopted, only upon additional affirmative finding by the Environmental Regulation Commission that the proposed designated use is attainable, upon consideration of environmental, technological, social, economic, and institutional factors.
Specific Authority: 403.061, 403.087, 403.088, 403.804, F.S.
Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.504, 403.702, 403.708, F.S.
History: Formerly 28-5.06, 17-3.06, Amended and Renumbered 3-1-79, Amended 1-1-83, 2-1-83.

17-3.09 Criteria: Class III Waters - Recreation - Propagation and Management of Fish and Wildlife.
Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.031, 403.061, 403.101, F.S.
History: Formerly 28-5.09, Amended 6-10-72, 8-30-72, 7-3-73, Amended and Renumbered as 17-3.121, 3-1-79.

17-3.091 Criteria: Class I Waters - Potable Water Supplies. The criteria listed below are for surface waters designated for use as a potable supply. The standards contained in Sections 17-3.051 and 17-3.061, F.A.C., shall apply to all waters of this class, unless more stringent levels are specified below. The following criteria are to be applied except within zones of mixing:

(1) Alkalinity - shall not be depressed below 20 milligrams per liter as $CaCO_3$.

(2) Ammonia (un-ionized) - shall not exceed 0.02 milligrams per liter.

(3) Bacteriological Quality - Coliform group shall not exceed 1,000 per 100 milliliters as a monthly average, using either most probable number (MPN) or membrane filter (MF) counts; nor exceed 1,000 per 100 milliliters in more than 20% of the samples examined during any month; nor exceed 2,400 per 100 milliliters (MPN or MF count) at any time. Based on a minimum of five samples taken over a 30-day period, the fecal coliform bacterial level shall not exceed 200 per 100 milliliters as computed by the log mean, nor shall more than 10% of the total samples taken during any 30-day period exceed 400 per 100 milliliters.

(4) Barium - shall not exceed 1 milligram per liter.

(5) Beryllium - shall not exceed 0.011 milligrams per liter in waters with a hardness equal to or less than 150 (in milligrams per liter of $CaCO_3$), and shall not exceed 1.10 milligrams per liter in harder waters.

(6) Biological Integrity - the Shannon-Weaver diversity index of benthic macroinvertebrates shall not be reduced to less than 75% of background levels as measured using organisms retained by a U.S. Standard No. 30 sieve and collected and composited from a minimum of three Hester-Dendy type artificial substrate samplers of 0.10 to 0.15 square meters area each, incubated for a period of four weeks.

(7) Cadmium - shall not exceed 0.8 micrograms per liter in a water with a hardness (in milligrams per liter of $CaCO_3$) equal to or less than 150, and shall not exceed 1.2 micrograms per liter in harder waters.

(20) Phosphorus (elemental) - shall not exceed 0.1 micrograms per liter.

(21) Polychlorinated Biphenyls - shall not exceed 0.001 micrograms per liter.

(22) Selenium - shall not exceed 0.025 milligrams per liter.

(23) Silver - shall not exceed 0.05 micrograms per liter.

(24) Total Dissolved Gases - shall not exceed 110% of the saturation value for gases at the existing atmospheric and hydrostatic pressures.

(25) Transparency - the depth of the compensation point for photosynthetic activity shall not be reduced by more than 10% as compared to the natural background value.

Specific Authority: 403.061, 403.062, 403.087, 403.504, 403.704, 403.804, F.S.
Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.702, 403.708, F.S.
History: Formerly 28-5.08, 17-3.08, Amended 6-10-72, 8-30-72, 7-3-73, Amended and Renumbered 3-1-79, Amended 2-1-83.

17-3.12 Definitions.
Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.031, 403.061, 403.101, F.S.
History: Formerly 28-5.12, Amended and Renumbered as 17-3.021, 3-1-79.

17-3.121 Criteria: Class III Waters - Recreation - Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife. The criteria listed below are for surface waters classified as Class III. The standards contained in Sections 17-3.051 and 17-3.061, F.A.C., also apply to all waters of this classification unless additional or more stringent criteria are specified below. The following criteria are to be applied except within zones of mixing.

(1) Alkalinity - shall not be depressed below 20 milligrams per liter as $CaCO_3$ in predominantly fresh waters.

(2) Aluminum - shall not exceed 1.5 milligrams per liter in predominantly marine waters.

(3) Ammonia (un-ionized) - shall not exceed 0.02 milligrams per liter in predominantly fresh waters.

(4) Antimony - shall not exceed 0.2 milligrams per liter in predominantly marine waters.

(5) Bacteriological Quality - fecal coliform bacteria shall not exceed a monthly average of 200 per 100 ml of sample, nor exceed 400 per 100 ml of sample in 10 percent of the samples, nor exceed 800 per 100 ml on any one day, nor exceed a total coliform bacteria count of 1,000 per 100 ml as a monthly average, nor exceed 1,000 per 100 ml in more than 20 percent of the samples examined during any month, nor exceed 2,400 per 100 ml at any time. Monthly averages shall be expressed as geometric means based on a minimum of 10 samples taken over a 30 day period. Either MPN or MF counts may be utilized.

(6) Beryllium - in predominantly fresh waters shall not exceed 0.011 milligrams per liter in waters with a hardness equal to or less than 150 (in milligrams per liter of $CaCO_3$) and shall not exceed 1.10 milligrams per liter in harder waters.

(7) Biological Integrity - the Shannon-Weaver diversity index of benthic macroinvertebrates shall not be reduced to less than 75 percent of established background levels as measured using organisms retained by a U.S. Standard No. 30 sieve and, in predominantly fresh waters, collected and composited from a minimum of three Hester-Dendy type artificial substrate samplers of 0.10 to 0.15 m^2 area each, incubated for a period of four weeks; and, in predominantly marine waters, collected and composited from a minimum of three natural substrate samples, taken with Ponar type samplers with minimum sampling area of 225 square centimeters.

(8) Bromine and Bromates - free (molecular) bromine shall not exceed 0.1 milligrams per liter in predominantly marine waters, and bromates shall not exceed 100 milligrams per liter in predominantly marine waters.

(9) Cadmium - shall not exceed 5.0 micrograms per liter in predominantly marine waters; shall not exceed 0.8 micrograms per liter in predominantly fresh waters in water with a hardness (in milligrams per liter of $CaCO_3$) of less than 150, and shall not exceed 1.2 micrograms per liter in harder waters.

(10) Chlorine (total residual) - shall not exceed 0.01 milligrams per liter.

(11) Copper - shall not exceed .015 milligrams per liter in predominantly marine waters; shall not exceed .03 milligrams per liter in predominantly fresh waters.

(12) Cyanide - shall not exceed 5.0 micrograms per liter.

(13) Dissolved Oxygen - in predominantly fresh waters, the concentration shall not be less than 5 milligrams per liter. In predominantly marine waters, the concentration shall not average less than 5 milligrams per liter in a 24-hour period and shall never be less than 4 milligrams per liter. Normal daily and seasonal fluctuations above these levels shall be maintained in both predominantly fresh waters and predominantly marine waters.

(14) Fluorides - shall not exceed 5.0 milligrams per liter in predominantly marine waters.

(15) Iron - shall not exceed 1.0 milligrams per liter in predominantly fresh waters; 0.3 milligrams per liter in predominantly marine waters.

(16) Lead - shall not exceed .03 milligrams per liter in predominantly fresh waters.

(17) Mercury - shall not exceed 0.1 micrograms per liter in predominantly marine waters; shall not exceed 0.2 micrograms per liter in predominantly fresh waters.

(18) Nickel - shall not exceed 0.1 milligrams per liter.

(19) Nutrients - In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.

(20) Pesticides and Herbicides:

(a) Aldrin plus Dieldrin - shall not exceed 0.003 micrograms per liter.

(b) Chlordane - shall not exceed 0.01 micrograms per liter in predominantly fresh waters and shall not exceed 0.004 micrograms per liter in predominantly marine waters.

(c) DDT - shall not exceed 0.001 micrograms per liter.

(d) Demeton - shall not exceed 0.1 micrograms per liter.

(e) Endosulfan - shall not exceed 0.003 micrograms per liter in predominantly fresh waters and shall not exceed 0.001 micrograms per liter in predominantly marine waters.

(f) Endrin - shall not exceed 0.004 micrograms per liter.

(g) Guthion - shall not exceed 0.01 micrograms per liter.

(h) Heptachlor - shall not exceed 0.001 micrograms per liter.

(i) Lindane - shall not exceed 0.01 micrograms per liter in predominantly fresh waters and shall not exceed 0.004 micrograms per liter in predominantly marine waters.

(j) Malathion - shall not exceed 0.1 micrograms per liter.

(k) Methoxychlor - shall not exceed 0.03 micrograms per liter.

(l) Myrex - shall not exceed 0.001 micrograms per liter.

(m) Parathion - shall not exceed 0.04 micrograms per liter.

(n) Toxaphene - shall not exceed 0.005 micrograms per liter.

(21) pH - shall not vary more than one unit above or below natural background of predominantly fresh waters and coastal waters as defined in 17-3.050(1)(c), F.A.C., or more than two-tenths unit above or below natural background of open waters as defined in 17-3.050(1)(c), F.A.C., provided that the pH is not lowered to less than 6 units in predominately fresh waters, or less than 6.5 units in predominately marine waters, or raised above 8.5 units. If natural background is less than 6 units, in predominately fresh waters or 6.5 units in predominately marine waters, the pH shall not vary below natural background or vary more than one unit above natural background of predominately fresh waters and coastal waters, or more than two-tenths unit above natural background of open waters. If natural background is higher than 8.5 units, the pH shall not vary above natural background or vary more than one unit below natural background of predominately fresh waters and coastal waters, or more than two-tenths unit below natural background of open waters.

(22) Phosphorus (elemental) - shall not exceed 0.1 micrograms per liter in predominantly marine waters.

(23) Phthalate Esters - shall not exceed 3.0 micrograms per liter in predominantly fresh waters.

(24) Polychlorinated Biphenyls - shall not exceed 0.001 micrograms per liter.

(25) Selenium - shall not exceed 0.025 milligrams per liter.

(26) Silver - shall not exceed 0.07 micrograms per liter in predominantly fresh waters and 0.05 micrograms per liter in predominantly marine waters.

(27) Total Dissolved Gases - shall not exceed 110% of the saturation value for gases at the existing atmospheric and hydrostatic pressures.

(28) Transparency - the depth of the compensation point for photosynthetic activity shall not be reduced by more than 10% compared to the natural background value.

(29) Zinc - shall not exceed .03 milligrams per liter in predominantly fresh waters.
Specific Authority: 403.061, 403.062, 403.087, 403.504, 403.704, 403.804, F.S.
Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.702, 403.708, F.S.
History: Formerly 28-5.09, 17-3.09, Amended 6-10-72, 8-30-72, 7-3-73, Amended and Renumbered 3-1-79, Amended 2-1-83.

17-3.13 Drainage Wells, Permits.
Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.031, 403.061, 403.182, F.S.
History: Formerly 28-5.13, Repealed 3-1-79.

17-3.131 Criteria: Class IV Waters - Agricultural Water Supplies. The criteria listed below are for surface waters classified as Class IV. The standards established in Sections 17-3.051 and 17-3.061, F.A.C., also apply to all waters of this classification, unless additional or more stringent criteria are specified below. The following criteria are to be applied except within zones of mixing.

(1) Alkalinity - shall not exceed 600 milligrams per liter as $CaCO_3$.

(2) Beryllium - shall not exceed 0.1 milligrams per liter in waters with a hardness in milligrams per liter of $CaCO_3$ of less than 250 and shall not exceed 0.5 milligrams per liter in harder waters.

(3) Boron - shall not exceed 0.75 milligrams per liter.

(4) Color, odor, and taste producing substances and other deleterious substances, including other chemical compounds, attributable to domestic wastes, industrial wastes, and other wastes - only such amounts as will not render the waters unsuitable for agricultural irrigation, livestock watering, industrial cooling, industrial process water supply purposes or fish survival.

(5) Cyanide - shall not exceed 5.0 micrograms per liter.

(6) Dissolved Oxygen - shall not average less than 4.0 milligrams per liter in a 24-hour period and shall never be less than 3.0 milligrams per liter.

(7) Iron - shall not exceed 1.0 milligrams per liter.

(8) Mercury - shall not exceed 0.2 micrograms per liter.

(9) Nickel - shall not exceed 0.1 milligrams per liter.

Specific Authority: 403.061, 403.062, 403.807, 403.504, 403.704, 403.804, F.S.
Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.702, 403.708, F.S.
History: Formerly 28-5.10, 17-3.10, Amended 6-10-72, 8-30-72, Amended and Renumbered 3-1-79, Amended 2-1-83.

17-3.14 Drainage Wells, Applications.
Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.061, 403.101, 403.182, F.S.
History: Formerly 28-5.14, Repealed 3-1-79.

2. the ditch contains flowing water only when there is a discharge or immediately after rainfall;

3. the petitioner has legal control of the ditch and abutting land sufficient to restrict public access;

4. migration of indigenous aquatic organisms into the ditch will be prevented; and

5. the ditch is not used for recreation and contains no significant population of fish or wildlife. "Significant population of fish or wildlife" shall mean the presence of commercially or recreationally important species or significant quantities of organisms which provide food for such species.

(b) The Department shall modify the Petitioner's permit, consistent with the Secretary's or District Manager's Order.

Specific Authority: 403.061, 403.062, 403.087, 403.504, 403.704, 403.804, 403.805, F.S.

Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.101, 403.121, 403.141, 403.161, 403.182, 403.201, 403.502, 403.702, 403.708, F.S.

History: New 3-1-79, Amended 1-1-83, 2-1-83.

17-4.244 Mixing Zones: Surface Waters.

(1) Zones of mixing for non-thermal components of discharges.

(a) The Department may allow the water quality adjacent to a point of discharge to be degraded to the extent that only the minimum conditions described in Section 17-3.051(1), Florida Administrative Code, apply within a limited, defined region known as the mixing zone. Under the circumstances defined elsewhere in this section, a mixing zone may be allowed so as to provide an opportunity for mixing and thus to reduce the costs of treatment. However, no mixing zone or combination of mixing zones shall be allowed to significantly impair any of the designated uses of the receiving body of water.

(b) A zone of mixing shall be determined based on consideration of the following:

1. The condition of the receiving body of water including present and future flow conditions and present and future sources of pollutants.

2. The nature, volume and frequency of the proposed discharge of waste including any possible synergistic effects with other pollutants or substances which may be present in the receiving body of water.

3. The cumulative effect of the proposed mixing zone and other mixing zones in the vicinity.

(c) Except for the thermal component of discharges and nitrogen and phosphorus acting as nutrients, to which this paragraph is inapplicable, mixing zones which do not adhere to all of provisions (1)(d) through (1)(i) below shall be presumed to constitute a significant impairment of the designated uses of surface waters of Classes I, II and III. However, an applicant for a specified mixing zone who affirmatively demonstrates after public notice in the Florida Administrative Weekly and in a newspaper of general circulation in the area where the mixing zone is proposed, and after a public hearing, if one is requested, that a proposed mixing zone which does not comply with one or more of the provisions of paragraphs (1)(d) through (1)(i) will not produce a significant adverse effect on the established community of organisms in the receiving body of water or otherwise significantly impair any of the designated uses of the receiving body of water, shall be exempt from those requirements. The Secretary shall authorize that mixing zone for which the applicant makes an affirmative demonstration by the preponderance of competent substantial evidence that the applicable requirements of this section have been met.

(d) A mixing zone shall not include an existing drinking water supply intake nor include any other existing water supply intake if such mixing zone would significantly impair the purposes for which the supply is utilized.

(e) A mixing zone shall not include a nursery area of indigenous aquatic life nor include any area approved by the Department of Natural Resources for shellfish harvesting.

(f) In canals, rivers, streams, and other similar water bodies, the maximum length of a zone of mixing shall be 800 meters unless a shorter length is necessary to prevent significant impairment of a designated use. In no case, shall a mixing zone be larger than is necessary for the discharge to completely mix with the receiving water to meet water quality standards.

(g) In lakes, estuaries, bays, lagoons, bayous, sounds, and coastal waters, the area of a mixing zone shall be 125,600 square meters unless a lesser area is necessary to prevent significant impairment of a designated use. In no case shall a mixing zone be larger than is necessary to meet water quality standards.

(h) open ocean waters, the area of a mixing zone shall be 502,655 square meters unless a lesser area is necessary to prevent significant impairment of a designated use. In no case shall a mixing zone be larger than is necessary to meet water quality standards.

(i) The mixing zones in a given water body shall not cumulatively exceed the limits described below:

1. In rivers, canals, and other similar water bodies: 10% of the total length;

2. In lakes, estuaries, bays, lagoons, bayous and sounds: 10% of the total area.

(j) Additional standards which apply within mixing zones in Class I, II and Class III waters are as follows:

1. The dissolved oxygen within a mixing zone shall not average less than 4.0 milligrams per liter in the mixing zone volume; and,

2. The turbidity within the mixing zone shall not average greater than 41 Nephelometric Turbidity Units in the mixing zone volume above natural background.

(k) Mixing zones in Class IV and V waters are subject only to the provisions of (d) above and of Section 17-3.051, F.A.C., and shall not significantly impair the designated uses of the receiving body of water.

(2) Until such time as a permit is issued, modified, or renewed, discharges in existence prior to the effective date of this rule shall continue to meet such mixing zone restrictions (for each component or characteristic of a discharge):

(a) As are specified by permit; or,

(b) Which were applied to the discharge in the Department's permitting process prior to the effective date of this rule.

(3) Except for discharges covered by (2) above, after the adoption of this rule there shall be no zone of mixing for any component of any discharge unless a Department permit containing a description of its boundaries has been issued for that component of the discharge.

(4)(a) Waters within mixing zones shall not be degraded below the applicable minimum standards prescribed for all waters at all times in Section 17-3.051, F.A.C. In determining compliance with the provisions of 17-3.051(1), F.A.C., the average concentration of the wastes in the mixing zone shall be measured or computed using scientific techniques approved by the Department; provided that, the maximum concentration of wastes in the mixing zone shall not exceed the amount lethal to 50% of the test organisms in 96 hours (96 hr LC_{50}) for a species significant to the indigenous aquatic community, except as provided in subsection (b) or (c) below. The dissolved oxygen value within any mixing zone shall not be less than 1.5 milligrams per liter at any time or place.

(b) The maximum concentration of wastes in the mixing zone (except for open ocean discharges) may exceed the 96 hr. LC_{50} only when all of the following conditions are satisfied.

1. Dilution ratio of the effluent exceeds 100:1 under critical conditions. That is, flow in the receiving waters exceeds 100 units for every unit of effluent flow under critical conditions. Critical conditions are defined as those under which least dilution of the effluent is expected, e.g., maximum effluent flow and minimum receiving stream flow.

2. High rate diffusers or other similar means are used to induce rapid initial mixing of the effluent with the receiving waters such that exposure of organisms to lethal concentrations is minimized.

3. Toxicity must be less than acute (as defined in Rule 17-3.021(1), F.A.C.) no more than a distance of 50 times the discharge length scale in any spatial direction. The discharge length scale is defined as the square-root of the cross-sectional area of any discharge outlet. In the case of a multiport diffuser, this requirement must be met for each port using the appropriate discharge length scale of that port. This restriction will ensure a dilution factor of at least 10 within this distance under all possible circumstances, including situations of severe bottom interaction, surface interaction, or lateral merging.

4. The effluent when diluted to 30% of full strength, shall not cause more than 50% mortality in 96 hours (95 hr. LC_{50}) in a species significant to the indigenous aquatic community.

5. If the following pollutants are present in the effluent, their concentrations (in the effluent) shall not exceed the values listed:

Acrylonitrile	65 ug/l
Aldrin	7.5 ng/l
Dieldrin	7.5 ng/l
Benzene	4 mg/l
Benzidine	53 ng/l
Beryllium	6.4 ug/l
Cadmium	100 ug/l
Carbon Tetrachloride	694 ug/l
Chlordane	48 ng/l
Hexachlorobenzene	74 ng/l

Chlorinated ethanes:	
1,2-dichloroethane	24.3 mg/l
1,1,2-trichloroethane	4.2 mg/l
1,1,2,2-tetrachloroethane	1 mg/l
Hexachloroethane	874 ug/l
Chloroalkyl Ethers:	
bis(chloromethyl) ether	184 ng/l
bis(2-chloroethyl) ether	136 ug/l
Chloroform	1.57 mg/l
Chromium (hexavalent)	0.5 mg/l
DDT	2.4 ug/l
Dichlorobenzidine	2 ug/l
1,1-Dichloroethylene	185 ug/l
Dinitrotoluene	11 ug/l
Diphenqlhydrazine	56 ug/l
Ethylbenzene	33 mg/l
Fluoranthene	540 ug/l
Halomethanes	1.6 mg/l
Heptachlor	29 ng/l
Hexachlorocyclohexane	
a Hexachlorocyclohexane	310 ng/l
B Hexachlorocyclohexane	547 ng/l
Y Hexachlorocyclohexane	625 ng/l
Lead	0.5 mg/l
Mercury	1.5 ug/l
Nickel	1 mg/l
Nitrosamines	124 ug/l
Polynuclear aromatic hydrocarbons	3 ug/l
Polychlorinated biphenyls (PCBs)	8 ng/l
Selenium	100 ug/l
Tetrachloroethylene	885 ug/l
Thallium	480 ug/l
Toxaphene	73 ng/l
Trichloroethylene	8 mg/l
Vinyl Chloride	52 mg/l

(c) For open ocean discharges, the effluent when diluted to 30% full strength, shall not cause more than 50% mortality in 96 hours (96 hr. LC_{50}) in a species significant to the indigenous aquatic community. Rapid dilution shall be ensured by the use of multiport diffusers. The discharge shall otherwise comply with federal law.

(5) Except for the minimum conditions of waters as specified in Section 17-3.051, F.A.C., and the provisions of Section 17-4.244, F.A.C., no other water quality criteria apply within a mixing zone.

(6) Mixing zones for dredge and fill permits shall not be subject to provisions (1)(c) through (1)(j), (2), (3), (4), or (5) of this section, provided that applicable water quality standards are met at the boundary and outside the mixing zone.

(a) The dimensions of dredge and fill mixing zones shall be proposed by the applicant and approved, modified or denied by the Department.

(b) Criteria for departmental evaluation of a proposed mixing zone shall include site-specific biological and hydrographic considerations.

(c) In no case, however, shall the boundary of a dredge and fill mixing zone be more than 150 meters downstream in flowing streams or 150 meters in radius in other bodies of water, where these distances are measured from the cutterhead, return flow discharge, or other points of generation of turbidity or other pollutants.

(7) Where a receiving body of water fails to meet a water quality standard for pollutants set forth in department rules, a steam electric generating plant discharge of pollutants that is existing or licensed on July 1, 1984, may be granted a mixing zone, provided that:

(a) The standard would not be met in the water body in the absence of the discharge; and

(b) The discharge is in compliance with all applicable technology-based effluent limitations; and

(c) The discharge does not cause a measurable increase in the degree of noncompliance with the standard at the boundary of the mixing zone; and

(d) The discharge otherwise complies with the mixing zone provisions specified in this section.

(8) Additional relief from mixing zone restrictions necessary to prevent significant impairment of a designated use is through:

(a) Reclassification of the water body pursuant to Section 17-3.081, Florida Administrative Code;

(b) Variance granted for any one of the following reasons:

1. There is no practicable means known or available for the adequate control of the pollution involved.

2. Compliance with the particular requirement or requirements from which a variance is sought will necessitate the taking of measures, which, because of their extent or cost, must be spread over a considerable period of time. A variance granted for this reason shall prescribe a timetable for the taking of measures required.

3. To relieve or prevent hardship of a kind other than those provided for in paragraphs 1. or 2. Variances and renewals thereof granted upon authority of this sub-paragraph shall each be limited to a period of 24 months except that variances granted pursuant to the Florida Electrical Power Plant Siting Act may extend for the life of the permit or certification.

(c) Modification of the requirements of this section for specific criteria by the Secretary upon compliance with the notice and hearing requirements for mixing zones set forth in (1)(c) above and upon affirmative demonstration by an applicant by the preponderance of competent substantial evidence that:

1. The applicant's discharge from a source existing on the effective date of this rule complies with best technology economically achievable, best management practices, or other requirements set forth in Chapter 17-6, F.A.C., and there is no reasonable relationship between the economic, social, and environmental costs and the economic, social and environmental benefits to be obtained by imposing more stringent discharge limitations necessary to comply with mixing zone requirements of Subsection 17-4.244(1), F.A.C., and the provisions relating to dissolved oxygen in Subsection 17-4.244(4), F.A.C.

2. No discharger may be issued more than one permit or permit modification or renewal which allows a modification pursuant to this subsection unless the applicant affirmatively demonstrates that it has undertaken a continuing program, approved by the Department, designed to consider water quality conditions and review or develop any reasonable means of achieving compliance with the water quality criteria from which relief has been granted pursuant to this subsection.

3. With respect to paragraphs 17-4.244(1)(c), F.A.C., and 17-4.244(7)(c), F.A.C., the applicant must affirmatively demonstrate the minimum area of the water body necessary to achieve compliance with either subsection. Within a minimum area determined by the Secretary to be necessary to achieve compliance, the discharger shall be exempt from the criterion for which a demonstration has been made.

(d) Whenever site specific alternative criteria are established pursuant to Section 17-3.031, Florida Administrative Code, a mixing zone may be issued for dissolved oxygen if all provisions of Section 17-4.244, Florida Administrative Code are met with the exception of Subparagraph 17-4.244(1)(i)1., Florida Administrative Code.

Specific Authority: 403.061, 403.062, 403.087, 403.504, 403.704, 403.804, 403.805, F.S.

Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.101, 403.121, 403.141, 403.161, 403.182, 403.201, 403.502, 403.702, 403.708, F.S.

History: Formerly part of 17-3.05, Revised and Renumbered 3-1-79, Amended 10-2-80, 1-1-83, 2-1-83, 12-19-84, 4-26-87.

17-4.245 Installations Discharging to Ground Water; Permitting and Monitoring Requirements.

(1) Statement of Intent and Definitions.

(a) It is the intent of the Department whenever possible to incorporate ground water discharge considerations into other appropriate Department permits, and not to require a separate permit for ground water discharges; provided, however, that any published notice of proposed agency action shall contain notice that ground water considerations are being incorporated into such other permits.

(b) It is also the intent of the Department, in implementing the ground water provisions of this Chapter, to coordinate, cooperate, and, where feasible, enter into interagency agreements with the various water management districts that are vitally concerned with maintaining ground water quality.

DISPOSAL OF CONCENTRATE FROM BRACKISH WATER DESALTING PLANTS BY USE OF DEEP INJECTION WELLS

by

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Manager, Water Resources Department
and
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Hydrogeologist
CH2M HILL
Deerfield Beach, Florida

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INTRODUCTION

Disposing of the concentrate from reverse osmosis plants presents a challenging dilemma to the engineering profession. The conventional method of disposal in Florida has been discharge to a brackish surface water body. In Florida, however, the distance to saline water bodies and regulatory constraints can restrict this type of disposal. One technically feasible and cost-effective alternative to surface water discharge is underground disposal using deep injection wells. An estimated 70 deep injection well systems are working in Florida at this time. Although most of these are for the disposal of treated municipal wastewater effluents, there have been some constructed to dispose of desalting concentrate.

One deep injection well system successfully operating to dispose of the concentrate from a reverse osmosis plant is located at Englewood, Florida. This system is capable of injecting up to 1,700 gpm of reverse osmosis concentrate at a pressure of about 15 psi. The injection zone at this site extends from 1,040 feet to 1,800 feet below land surface.

This paper was prepared by the editor based on a recording of the presentation. Where deemed appropriate, the presentation has been edited for clarity.

BACKGROUND ON INJECTION WELLS

Chapter 17-28 of the Florida Administrative Code (FAC) defines an injection well as a well designed to receive fluids injected by gravity flow or under pressure. Using deep injection wells to dispose of treated wastewater has been successfully practiced in Florida for more than 20 years. Deep injection well systems can be used to dispose of brine, treated effluent, and hazardous and industrial wastes. In Florida, however, injection wells to dispose of hazardous waste are not permitted.

Disposal by deep injection well offers several advantages over conventional methods, which usually involve discharge to a surface water body. An injection well system is a simple and effective means of disposing of large volumes of fluids under varying weather conditions. This is particularly important in Florida, where the high water table and heavy rainfall are important factors in the feasibility of a disposal alternative.

Florida's unique underground environment also favors the use of deep injection wells. Underlying southeastern Florida is the "Boulder Zone," a highly transmissive interval of fractured dolomite and limestone. Water quality of this zone is similar to seawater. The Boulder Zone is isolated from overlying aquifers by thick, dense layers of dolomite and limestone. The low transmissivity of these layers act as a barrier to fluid exchange, thus protecting the water quality of the overlying aquifers.

A successful deep injection well system must meet several criteria and the receiving aquifer must have a relatively high transmissivity in order to accept the injected waste at economical pressures. The injection well system has to be designed not to plug or to degrade transmissivity of the aquifer.

REGULATIONS

In Florida, the Department of Environmental Regulation (DER) regulates deep injection well systems. DER approves the final design of the system and issues the appropriate construction and operating permits.

The Technical Advisory Committee (TAC) on deep injection wells unites the expertise of representatives from DER's district and Tallahassee offices; the Environmental Protection Agency; the local water management district, and the U.S. Geological Survey. Other regulatory agencies also may be involved. The purpose of the TAC is to offer technical advice to the permitting arm of DER; however, DER is not required to abide by the position of the TAC.

Chapter 17-28, FAC, governs the design, permitting, and operation of deep injection well disposal systems in Florida. It defines five types of injection wells:

- Class I - Municipal/industrial wells
- Class II - Oil/gas wells
- Class III - Mining of mineral wells
- Class IV - Hazardous/radioactive waste wells (not permitted in Florida)
- Class V - All other (grouped by water quality)

Chapter 17-28, FAC, is generally divided into three parts. Part I discusses the general requirements of injection well construction, primarily mechanical integrity. This section specifies that no leaks will be allowed in the casing and that no fluid may infiltrate an underground source of drinking water (defined as an aquifer having concentrations of less than 10,000 mg/l of total dissolved solids). To evaluate mechanical integrity, pressure tests are run to detect leaks in the casing and radioactive tracer surveys are run to detect fluid movement from within the casing upward to overlying aquifers.

Part II of Chapter 17-28, FAC, addresses general criteria and standards for injection wells. It defines general feasibility, demonstration of confinement, testing of the injection zone, construction standards, operating requirements, and monitoring requirements.

Part III of Chapter 17-28, FAC, discusses permitting procedures. Permits require about 90 days to process, usually in a two- phase approach. Phase I is the submission of a test construction permit, which lasts from 6 to 12 months. Phase II is the submission of the required operations testing data and engineering report to obtain an operating permit. Operating permits require renewal every 5 years.

TYPICAL DESIGN OF DEEP INJECTION WELLS

In southeast Florida, deep injection wells are multi-cased, with the final casing set to the top of the selected injection zone. Figure 1 illustrates the construction of a typical deep injection well in Florida. Three to four casings are generally used and staged in the construction process. The final depths for each of the casings depends on the surrounding lithology. The staged casings isolate upper zones from deeper, brackish zones and minimize fluid exchange between aquifers. They also provide safe drilling conditions by limiting the amount of borehole that is open during construction.

The diameter of the final inner casing depends on the expected flow velocity, which is limited by DER to 8 feet per second based on the inside diameter of the casing. The inner casing of injection wells in Florida typically range from 12 to 30 inches in diameter, with outer casings being progressively larger. Casings are typically 1/2-inch-thick steel. All casings are generally cemented from bottom up to land surface. In southeast Florida, the final casing depth settings are around 2,700 feet with most wells drilled to a total depth of 3,300 feet.

Materials used for injection wells depend on the characteristics of fluids being injected and the surrounding environment. Injection wells

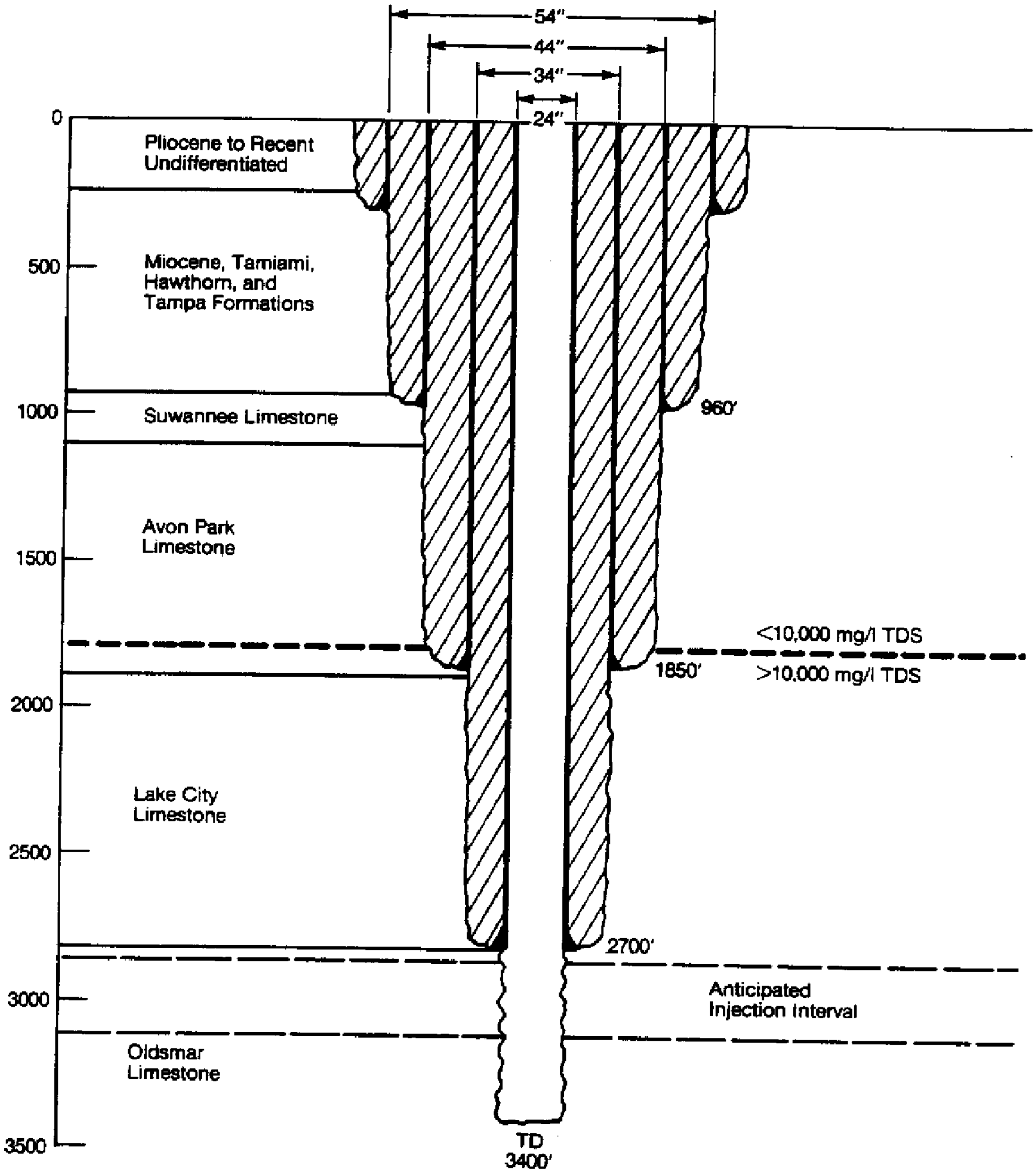

Figure 1 TYPICAL INJECTION WELL IN SOUTH FLORIDA

used to dispose of concentrate from reverse osmosis plants require additional corrosion protection. Various types of materials such as fiberglass, plastic (ABS), stainless steel, or extra thick steel pipe have been used, or considered, for the construction of the inner liner of this type of injection well.

Deep injection wells used for injecting treated wastewater effluent in southeast Florida cost approximately $2 to $3 million to construct and test. Single zone monitor wells, required to detect any upward migration of injected fluids from injection wells, cost about $0.5 million. Both cost estimates can vary depending on the location, design, and type of construction material used.

A considerable amount of testing occurs during the construction of a deep injection well. Water samples are collected during drilling to correlate water quality with depth and to identify underground sources of drinking water. Drill cuttings are collected to establish site-specific lithology, and pumping tests may be performed to locate production zones. Geophysical logs are run to help identify aquifer characteristics and interpret other field data.

Field testing is used for determining preliminary water quality parameters, such as chlorides, conductivity, temperature, and pH. Water samples are also sent to laboratories for more detailed analyses.

ENGLEWOOD WATER DISTRICT DEEP INJECTION WELL

Englewood, Florida, is approximately 30 miles south of Sarasota and 1 mile from the Gulf of Mexico. The Englewood Water District (EWD) operates a reverse osmosis plant that discharges concentrate to a deep injection well system. The disposal facilities are comprised of a deep injection well and a monitor well. Emergency discharge has been provided through a tidal channel connected to the Gulf.

Drilling and testing of the EWD deep injection well was performed in steps to ensure identification of the hydrogeologic characteristics. Pumping tests, geophysical logging, water sampling, coring, and packer tests were used to identify production and confinement zones and underground sources of drinking water.

As a reverse osmosis disposal well, unique problems are presented by the corrosive nature of the injected fluid. EWD chose fiberglass reinforced (FRP) casing to protect against possible corrosion. Piping from the reverse osmosis plant to the deep injection well is stainless steel.

The EWD injection well was completed using three casing strings. A 30-inch-diameter outer casing was first set to isolate the surficial sediments. A second, 20-inch-diameter casing was set to 450 feet to prevent swelling of a clayey formation. The final, 10-3/4-inch-diameter inner casing was placed to a depth of 1,040 feet, which is the top of the injection zone. Completion of the well consisted of drilling an open hole from 1,040 feet to 1,800 feet. When tested, this well was capable of accepting 1,700 gpm at injection pressures of only 15.5 psi.

Instrumentation for this injection well disposal system includes continuous flow and pressure recorders plus sampling of the monitor well on a weekly, monthly, and quarterly basis.

SUMMARY

Under the appropriate site-specific conditions, deep injection wells can offer a feasible solution to disposing of concentrates from reverse osmosis plants. Deep injection well systems can be reliable, environmentally safe, and cost-effective. There has been considerable experience with deep injection wells for the disposal of treated wastewater effluents in the state so that deep injection wells are a proven technology for South Florida.

QUESTION

Orren Hillman, Martin County. You talked earlier about treatment at depth and I don't understand what treatment at depth means.

ANSWER

With the wells to dispose of RO concentrate, it doesn't really apply as there is just some mixing. With wastewater plants effluents you may have some denitrification with depth.

QUESTION

Joe Walter with Williams, Hatfield & Stoner. You mentioned an estimate of about $2 to $2.2 million for an injection well. Does that include all engineering services, testing, permitting, or so forth or was that just the construction cost?

ANSWER

That was just the construction cost and that was for a treated wastewater effluent well down here in southeast Florida and you have to look at each well specifically. The Englewood well construction costs was in the range of $500,000 to $600,000. The engineering costs depend on the area and the total scope of work. It can be in the range of $100,000 to $400,000.

QUESTION

Tom Leahy, City of Virginia Beach. If I understood you, it was about $2 million for the well, about $500,000 for the monitor well, and $400,000 of indirect costs for a total of about $3 million for that well. Would that be a total cost?

ANSWER

That was not the Englewood well. That was for a typical municipal effluent disposal well here in southeast Florida.

QUESTION

J. R. Slone from Briley, Wild & Associates. I think I heard you say that there was a well in Gainesville that went into the potable aquifer zone. Could you explain a little bit about that well and, particularly, how it was permitted?

ANSWER

I don't have the total background on that well. That is a well that is in an aquifer that can be used for potable water. It is downgradient from water supply sources in Gainesville. As far as permitting, that was before my time. I was still in school when that was being permitted.

IRRIGATION WITH MEMBRANE PLANT CONCENTRATE: FORT MYERS CASE STUDY

by

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and
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Fort Myers, Florida

DISPOSAL OF CONCENTRATES
FROM BRACKISH WATER DESALTING PLANTS

November 18, 1988

IRRIGATION WITH
MEMBRANE PLANT CONCENTRATE
FORT MYERS CASE STUDY

by
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INTRODUCTION

The safe disposal of membrane plant concentrate can be a very difficult engineering task. The difficulty of the disposal problem varies with the multi-farious membrane treatment levels currently available and in use in Florida and across the country. Utilizing the concentrate as an irrigation supply poses several concerns, including the salinity levels of the concentrate and the tolerance of the plants or crops to those levels. Other concerns are the concentrated levels of other constituents and their potential impacts on the plants, surface water, and groundwater eventually receiving the irrigation waters.

The following sections present water quality standards suggested for irrigation. Regulatory standards for receiving surface and groundwaters are also reviewed. A case study utilizing the proposed Fort Myers Membrane Softening Plant, illustrates the application of these standards to a membrane plant concentrate.

IRRIGATION SUITABILITY

The first major concern in using membrane plant concentrate for irrigation is its suitability as a water source for the plants or crops to be irrigated. An initial irrigation suitability analysis has been recommended by R.S. Ayers and D.W. Westcot (1976). They developed guidelines for evaluating the acceptability of a given water source for irrigation relative to the general problems of salinity, permeability, and specific ion toxicity.

Salinity is discussed from the standpoint of a reduction in soil water available to the crop. Most of the salts added with the irrigation water are left behind in the soil as water is removed by the crop. These salts may accumulate and reduce the availability of soil water in the root zone of the crop in proportion to the salinity of the water. This is called the osmotic effect and can be measured as a force the plant must overcome (osmotic potential) to obtain the water.

Table 1 presents guidelines for evaluating the potential salinity problem. The electrical conductivity of a water is usually an adequate measure of the potential salinity problem. According to Ayers and Westcot, waters relatively high in lime (calcium carbonate and bicarbonate) or gypsum (calcium sulphate) may not contribute as greatly to a soil salinity problem as would waters of equal salinity but low in gypsum or lime. In waters high in dissolved gypsum or lime, the potential salinity problem in Table 1 may be discounted by 10 to 30% at leaching fractions (percent of irrigation water going beyond the root zone) in the 10 to 20% range. A discounting of the potential salinity problem by as much as 20% is reported reasonable for waters which are high in calcium (400 mg/l to 600 mg/l) and magnesium (240 mg/l to 365 mg/l) and are also accompanied by high bicarbonate and sulphate levels. It should be noted that this salinity concern is generally limited to arid regions.

Soil permeability problems occur when the rate of water infiltration into and through the soil is reduced by the effects of specific salts, or the lack of salts, in the water. The infiltration rate can be reduced to such an extent that the crop is not properly supplied with water. Ayers and Westcot identify three factors which can determine a waters' long-term influence on soil permeability. These include: (1) sodium content relative to calcium and magnesium; (2) bicarbonate and carbonate content; and (3) the total salt concentration of the water. A simultaneous analysis of these factors is accomplished through the Adjusted Sodium Adsorption Ratio (SAR) concept presented in their report.

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November 18, 1988

Table 1

GUIDELINES FOR INTERPRETATION OF WATER QUALITY FOR IRRIGATION

IRRIGATION PROBLEM	DEGREE OF PROBLEM		
	No Problem	Increasing Problem	Severe Problem
Salinity			
EC (mmhos/cm)	< 0.75	0.75 - 3.0	> 3.0
Permeability			
EC (mmhos/cm)	> 0.5	0.5 - 0.2	< 0.2
adj. SAR			
EC < .4	< 6	6 - 9	> 9
EC = .4 - 1.6	< 8	8 - 16	> 16
EC > 1.6	< 16	16 - 24	> 24
Specific Ion Toxicity			
Sodium (adj. SAR)	< 3	3 - 9	> 9
Chloride (mg/l)	< 142	142 - 355	> 355
Boron (mg/l)	< 0.75	0.75 - 2.0	> 2.0

Source: Ayers & Westcot, 1976.

Specific ion toxicity refers to the effects of boron, sodium, chlorides, and other trace elements which may be detrimental to the irrigated plants. Ayers and Westcot address many of these problems and present guidelines as shown on Table 1. Table 2 presents a summary of several tables compiled by the Environmental Protection Agency (EPA, 1981) relative to suggested irrigation standards for trace elements.

OTHER WATER QUALITY CONSIDERATIONS

Assuming that the membrane plant concentrate has been determined to be a suitable irrigation water, other considerations should be raised regarding the surface water and groundwater quality that may be impacted

Table 2

RECOMMENDED MAXIMUM TRACE ELEMENT LEVELS IN IRRIGATION WATERS

(Assumes Application Rates of 3 to 8 feet per Year)

ELEMENT	SUGGESTED MAXIMUM IRRIGATION WATER LEVEL (mg/l)	DRINKING WATER STANDARD (mg/l)
Aluminum (Al)	10	--
Arsenic (As)	0.1 - 2.0	.05
Beryllium (Be)	0.1 - .05	--
Boron (B)	0.5 - 2.0	--
Cadmium (Cd)	.01 - .05	.01
Chromium ($Cr^{+}6$)	.05 - 1.0	.05
Cobalt (Co)	0.1 - 5.0	--
Copper (Cu)	0.2 - 5.0	1.0
Fluoride (Fl)	1.8	--
Iron (Fe)	5 - 20	.3
Lead (pb)	5 - 10	.05
Lithium (Li)	2.5	--
Manganese (Mn)	.02 - 10	.002
Molybdenum (Mo)	.01 - .05	--
Nickel (Ni)	.2 - 2	.01
Selenium (Se)	.02	.01 - .05
Silver (Ag)	4 - 8	.004 - .05
Vanadium (V)	.1 - 1	5
Zinc (Zn)	2 - 10	--

Source: Process Design Manual for Land Treatment of Municipal Wastewater, U.S. EPA, Cincinnati, 1981.

by this irrigation. Consideration must be given to the groundwater underlying the irrigation site. Irrigation water eventually percolating to the aquifer must not be detrimental to the background water quality of the aquifer. The same is true for surface waters directly receiving excess concentrate beyond that used for irrigation or surface water bodies which receive and store the concentrate for eventual irrigation.

Florida Administrative Code (FAC), Chapter 17-3, addresses Water Quality Standards which are to be maintained for various classifications of both the groundwaters and surface waters of the state. Ambient water quality levels which may exceed the established standards for a given classification cannot be degraded. Additionally, compliance with these standards is generally only required beyond the permitted zones of mixing for surface waters or the zone of discharge for groundwaters.

The effects of a concentrate water found suitable for irrigation can typically be minimized through reasonable irrigation practices. Blending of particularly problematic concentrates with other more suitable irrigation supplies will assist in minimizing any degradation. The interrelated actions of soil filtering, plant uptake, soil biochemical and physiochemical reactions and soil particle adsorption must all be considered in evaluating the potential groundwater impacts of irrigating with concentrate.

CASE STUDY
FORT MYERS MEMBRANE SOFTENING PLANT

BACKGROUND

Table 3 presents the water quality data obtained for the feed and reject water (concentrate) from the Fort Myers pilot scale testing plant on June 22, 1988. These data confirmed data previously obtained from a year-long pilot scale study performed on Fort Myers water in 1986 and 1987. Based on the earlier water quality data, several disposal options for the concentrate were discussed with local Florida Department of Environmental Regulation staff in 1987. At that time the staff recommended consideration of utilizing the concentrate as a supplemental irrigation supply for the golf course located adjacent to the City's proposed water plant site.

Table 3

FORT MYERS MEMBRANE SOFTENING PLANT
PROJECTED WATER QUALITY DATA

ELEMENT	FEED WATER	REJECT WATER	POND WATER
Alkalinity ($CaCO_3$)	170	267	161
Aluminum (AL)	ND	ND	–
Arsenic (As)	ND	.005	.008
Barium (Ba)	.05	ND	ND
Benzene	ND	ND	ND
Beryllium (Be)	ND	ND	ND
Bicarbonate ($CaCO_3$)	170	267	161
Bicarbonates (HCO_3)	207	326	196
Boron (B)	.05	.07	–
Cadmium (Cd)	ND	ND	ND
Calcium (Ca)	63	244	56
Carbonate ($CaCO_3$)	ND	ND	ND
Carbon Dioxide (CO_2)	10	ND	2.2
Carbon Tetrachloride	ND	ND	ND
Chloride (Cl)	86	170	72
Chromium (Cr)	ND	.005	ND
Copper (Cu)	ND	.005	ND
Endrin	ND	ND	ND
Ethylene Dibromide (EDB)	ND	ND	.07
Fluoride (Fl)	.21	.59	.19
Hydrogen Sulfide (H_2S)	.48	1.8	.11
Hydroxide ($CaCO_3$)	ND	ND	ND
Iron (Fe)	.33	1.4	1.0
Lead (Pb)	ND	ND	ND
Lindane	ND	ND	ND
Magnesium (Mg)	11	47	8.8
Manganese (Mn)	.006	.018	.009
Mercury (Hg)	ND	ND	ND
Methoxychlor	ND	ND	ND
N.C.H. ($CaCO_3$)	32	536	15
Nickel (Ni)	ND	.006	ND
Nitrate Nitrogen (N)	.04	ND	.03
Selenium (Se)	ND	ND	ND
Silica (SiO_2)	6.9	9.7	6.4
Silver (Ag)	ND	ND	ND
Sodium (Na)	50	101	46
Strontium (Sr)	.06	2.6	.05
Sulfate (SO_4)	32	560	15
Surfactants	ND	.03	.02
Tetrachloroethylene	ND	ND	ND
Total Hardness ($CaCO_3$)	202	803	176
Total Organic Carbon (TOC)	17.2	152.3	–
Toxaphene	ND	ND	ND
Trichlorolthylene	ND	ND	ND
Turbidity (NTU)	.48	3.5	10
Vinyl Chloride	ND	ND	ND
Zinc (Zn)	.023	ND	.02
1, 1, 1 - Trichloroethane	ND	ND	ND
1, 2 - Dichloroethane	ND	ND	ND
2, 4 - D	ND	ND	ND
2, 4, 5 - TP	ND	ND	ND
Gross Alpha at 95% Confidence Limit (pCi/l)	5.2+/-3.4	11.9+/-8.4	5.1+/-2.5
Color (PCU)	60	500	50
Odor (TU)	1	3	3
Total Dissolved Solids	330	1500	390
pH Value	7.5	6.8	8.1
pH_s Value	7.3	6.6	7.4
Stability Index 2 pHs - pH	7.1	6.8	6.7
Saturation Index pH-pHs	0.2	-0.2	7
Interpretation	Stable	Stable	Scale Forming

Notes:

- * All units in mg/l unless otherwise noted.
- * Sampled June 22, 1988
- * N.D.: None Detected
- * –: Not measured

The new water plant is currently under design. It is anticipated to have an initial start-up demand of 8 to 10 MGD of finished water with an ultimate capacity of 20 MGD. With a design recovery rate of 90%, approximately 2.2 MGD of concentrate will ultimately require disposal (0.9 to 1.1 MGD initially).

Review of the golf course drainage and irrigation plans reveals about 150 acres are under irrigation. Suggested irrigation rates for southwest Florida of 1 inch per week in the wet season and 1.5 inches per week in the dry season were assumed. On this basis, about 0.8 MGD of irrigation water is used on an annual average daily basis. The current irrigation supply for the course is the estimated 54 million gallons of available water stored onsite in the existing lakes and canals within the golf course area's stormwater management system. Table 3 also presents water quality data for the golf course drainage system obtained in June, 1988.

Under the projected plan, concentrate will be introduced to the golf course drainage system at a remote pond, approximately 1.5 miles upstream of the irrigation system intake and pumping facilities. Ultimately, a blend of onsite water and concentrate will be utilized for irrigation.

Additional irrigation sites and disposal methods were identified, since the projected concentrate flows will exceed the estimated irrigation demand of the golf course. The new water treatment plant will be located on a site almost 9 acres in size. This site is located within a proposed 150 acre public works complex that is planned for development over the next few years. This entire complex site could eventually provide additional irrigation demand for the concentrate.

Excess concentrate not utilized for irrigation will be discharged off of the golf course site in accordance with the drainage plan of the course. The excess concentrate in combination with stormwater runoff and intercepted groundwater will enter the City's overall stormwater drainage system.

An evaluation of the proposed concentrate from the proposed Fort Myers Membrane Softening Plant must encompass a wide variety of considerations due to the multiple irrigation and ultimate disposal methods being proposed. This evaluation must include:

1. A determination of the irrigation suitability of the concentrate without blending. If it is found to be suitable, then it appears reasonable to assume that the concentrate blended with the current golf course irrigation supply would be suitable.

2. A study of the potential impacts of introducing the concentrate to the existing surface water pond, lake, and canal system on the golf course relative to degrading the water quality of the overall system and impacts on the fish and other aquatic organisms contained in the drainage system.

3. A study of the potential impacts on the groundwaters beyond projected zones of discharge (assumed to be downgradient boundaries of City properties).

4. A study of the potential impacts from the discharge of the excess blended waters from the golf course boundaries to the City's overall stormwater drainage system.

Each of these items is reviewed below.

IRRIGATION SUITABILITY

Irrigation suitability is determined by comparing the data contained in Table 3 for the projected concentrate quality against those criteria listed in Tables 1 and 2. Table 4 presents the results of this comparison.

The conclusion from the analysis is that the raw concentrate is suitable for irrigation in accordance with the criteria defined in the tables. Although the salinity, sodium, and chloride levels indicate mild increasing problems, experiences in other areas of Florida have shown much higher tolerances of ornamental shrubs and turf grasses to these constituents than recommended in Table 1 (personal communications with St. Petersburg reuse system staff, 1986).

Table 4
FORT MYERS CASE STUDY
IRRIGATION SUITABILITY ANALYSIS

CONSTITUENT	CONCENTRATE LEVEL[1]	COMPARISON/CONCLUSION
Salinity		
EC (mmhos/cm)	1.84	Increasing problem (offset by SO_4, Ca and HCO_3)
Permeability		
EC (mmhos/cm)	1.84	No Problem
adj. SAR	3.81	No Problem
Specific Iron Toxicity		
Sodium adj. (SAR)	3.81	Mild Increasing Problem
Chloride	170	Mild Increasing Problem
Boron	.07	No Problem
Trace Elements	--	Below Suggested Levels/ Suitable

[1]Expressed in mg/l unless otherwise noted.

ONSITE SURFACE WATER IMPACTS

A comparison was made of the projected concentrate water quality in Table 3 with the criteria for Class III surface waters in FAC 17-3.121. The criteria cited in this section were established for recreation water and for the protection of a healthy, well-balanced population of fish and wildlife. It was felt that if the concentrate was within general compliance of these criteria and adjusted for existing background levels, it can be assumed that there will be minimal potential degradation to the receiving waters' biological and physiochemical make-up.

The comparison showed three criteria with which the projected concentrate quality will not be in full compliance.

Iron concentrations of 1.4 mg/l in the concentrate will exceed the regulated and background limits of 1.0 mg/l and concentrate pH will be about 1.3 units below the background limits. It is felt that a moderate zone of mixing will eliminate these concerns.

Of more concern is the maintenance of dissolved oxygen levels in the receiving waters. Significant levels of Total Organic Carbons and other chemical oxygen demanding constituents will be introduced to the receiving waters, potentially degrading the available DO in those waters. To eliminate this concern, the concentrate water will be aerated prior to leaving the water treatment plant site producing DO levels ranging from 4 to 5 ppm. A cascading outfall structure to the receiving pond will also aid in developing sufficient DO levels prior to assimilation with the pond water. This cascading effect will also allow release of H_2S and CO_2 contained in the concentrate having a positive effect on the pH.

RECEIVING GROUNDWATERS

Irrigated water not consumed by evapotranspiration processes or stored within the soil matrix will percolate to the underlying groundwaters. In accordance with FAC 17-3.403 and 17-3.404, Class G-1 and G-II groundwaters beyond the allowed zone of discharge shall be maintained at levels compatible with the primary and secondary drinking water standards or within background concentration levels which exceed the listed standards.

Under special permits, the groundwaters underlying the golf course are intercepted by a boundary canal system included in the overall drainage system discussed earlier. This appears to adequately protect the adjacent City well field from any negative impacts of herbicide, fertilizer, and insecticide applications on the golf course.

Groundwaters underlying the City's proposed public works complex generally flow in a northwesterly direction, away from the City's existing well field site. These groundwaters are also partially intercepted by roadway swales and canals along the perimeter of the site. Comparison of the concentrate water quality data to the primary and secondary drinking standards shows five non-conforming constituents.

The only primary standard being exceeded is turbidity. Turbidity is an indication of suspended matter in the water. EPA (1981) studies have shown that irrigation systems for wastewater treatment provide 98 to 99% removal of suspended solids. Therefore, turbidity levels in the groundwater should remain relatively unaffected.

The concentrate levels of iron, color, sulfates, and TDS potentially exceed the desired levels for the secondary drinking water standards. Iron is effectively removed from the water as it passes through the soil matrix by adsorption and crop uptake. Experience with the City's river water recharge system in the existing well field shows that color is also significantly reduced through land application systems.

The TDS levels are likely to be highly impacted by the sulfate ion and associated ion pairs (in addition to the calcium and magnesium bicarbonates) which are considered chemically stable (Hem, 1975). These constituents are likely to leach through the soil matrix and assimilate in the underlying groundwaters. As these groundwaters generally flow away from the only community water supply in the area, no detrimental impacts would be anticipated beyond the assumed zone of discharge (City property lines).

EXCESS FLOWS OFFSITE OF GOLF COURSE

The water discharged from the golf course site, consisting of a blend of existing onsite stormwater, intercepted groundwater and concentrate, is anticipated to be required to meet the criteria cited in FAC 17-3.121 for Class III surface waters. As was discussed earlier, relative to onsite surface water impacts, aeration is included in the post-treatment of the new plant's reject water to assist in complying with these criteria prior to discharging the concentrate into the golf course system. The golf course drainage system's outfall weir is located approximately two miles downstream of the proposed point where concentrate will be introduced to the system. It is anticipated that the non-complying iron and pH levels of the concentrate will be assimilated into the background levels of the onsite drainage system as it flows through a series of lakes and canals prior to discharging over the weir.

CONCLUSION

The use of irrigation as the primary disposal method becomes more difficult as the salinity and TDS of the feedwaters increase beyond the freshwater levels. Crop tolerances to specific ions become of greater concern. Blending with suitable irrigation water supplies is a means of decreasing the applied salinity and TDS concentrations.

The use of membrane softening concentrate as an irrigation supply appears feasible for the City of Fort Myers, based on generalized irrigation guidelines and applicable state water quality criteria.

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THE USE OF SOLAR PONDS IN THE DISPOSAL OF DESALTING CONCENTRATE

by

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Chief, Special Investigations Branch
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The major problem in the San Joaquin Valley is in the disposal of agricultural drainage water. The San Joaquin Valley, illustrated in Figure 1, is about 100 to 200 miles long. It has no outlet to the ocean and the area with drainage problems cross-hatched in the figure can potentially generate up to a half-million acre feet of drainage water in the next 50 years or so.

This paper will discuss one aspect of a feasibility study that the Department of Water Resources has for reclaiming this drainage water and storing, for the next 40 or 50 years, the concentrates left over from the reclaiming of that water. The principal features of the study is a 25 million gallon per day (MGD) reverse osmosis plant and the disposal of the concentrates produced by this plant.

Table 1 is a typical composition of the water from the San Luis drain which is no longer in operation. With a TDS of about 9,000 ppm, this is pretty typical of the agricultural drainage water in California. The element of real concern in California is selenium which, in this water, was about 0.3 milligram per liter. In California, a concentration of selenium of 1 milligram per liter is considered a hazardous waste. So, if this water is concentrated by evaporation two or three times, as occurred in the Kesterson Reservoir, it got beyond hazardous waste limits and created all sorts of problems.

This paper was prepared by the editor based on a recording of the presentation. Where deemed appropriate, the presentation has been edited for clarity.

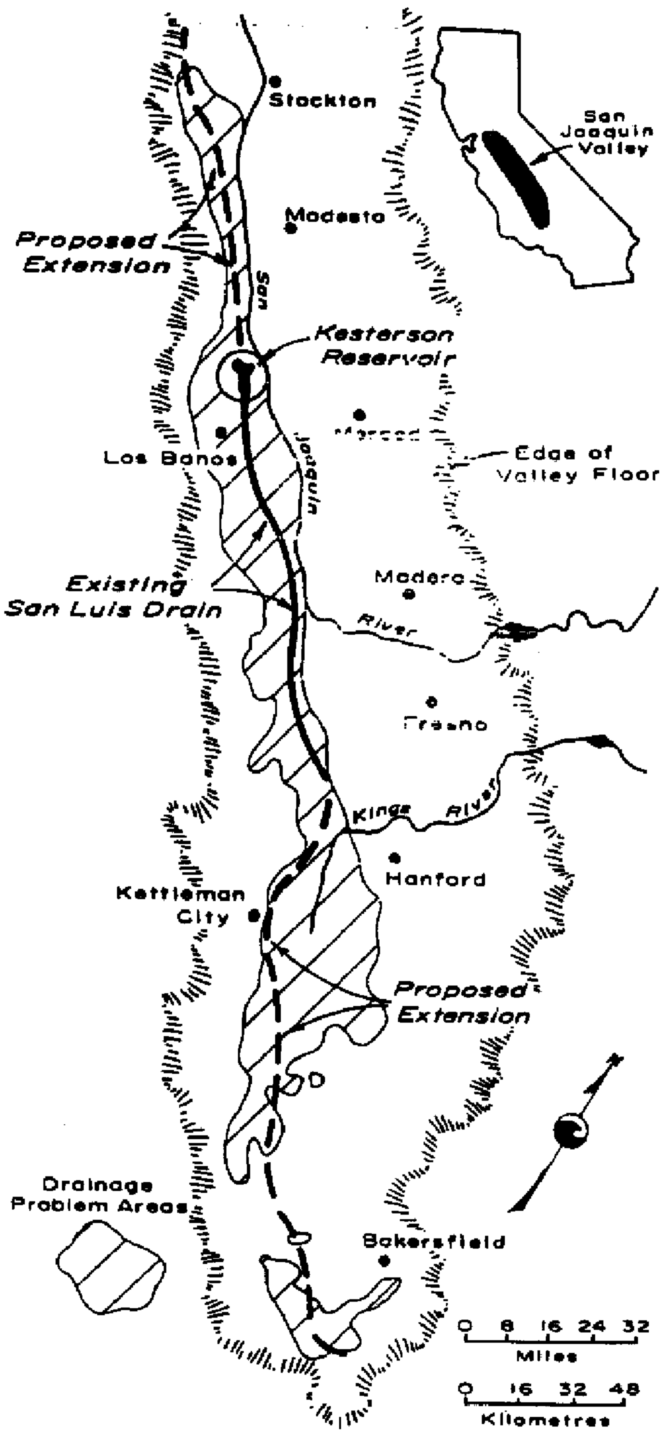

Figure 1 AGRICULTURAL DRAINAGE AND THE SAN JOAQUIN VALLEY

Table 1

SAN LUIS DRAIN WATER COMPOSITION

PARAMETER	VALUE
Temperature, °F	60
Total dissolved solids, ppm	8,930
Total hardness, as ppm $CaCO_3$	2,390
Alkalinity, as ppm $CaCO_3$	168
Calcium (Ca), ppm	552
Magnesium (Mg), ppm	268
Sodium (Na), ppm	1,990
Potassium (K), ppm	5.6
Chromium (Cr), ppm	0.01
Iron (Fe), ppm	0.02
Manganese (Mn), ppm	0.25
Strontium (Sr), ppm	6.6
Silica (Si), ppm	8.8
Sulfate (SO_4), ppm	3,800
Chloride (Cl), ppm	1,360
Boron (B), ppm	15
Selenium (Se), ppm	0.312
Nitrate (NO_3), ppm	190
Chemical oxygen demand (COD), ppm	16
Biochemical oxygen demand (BOD), ppm	2
Total organic carbon (TOC), ppm	7.8
pH	8.2

In the study we are using a salt-gradient solar pond. This is not an evaporation pond or concentration technology per se, as much as it is a way to use concentrated brines produced by the desalting processes, particularly from evaporators.

Figure 2 illustrates the process flowsheet of the original concept for the Los Banos facility that was to be constructed in the Valley for reclaiming the drainage water. It consisted of several pretreatment and desalting processes followed by evaporation ponds and a salt-gradient solar pond. The purpose of a salt-gradient solar pond was to provide heat to generate power. The idea being to store the brine for 30 or 40 years and use it to generate power, by use of a Rankine cycle turbine, to provide energy for the desalting plant. After a number of years there would be enough solar ponds to make the facility self-sufficient in energy.

Figure 3 shows the system that finally evolved after a number of years of effort. This system is being used partly because the selenium had become such an issue and the concept that the desalting plants and drainage disposal, in general, will become almost a zero-discharge type of operation. There were a few changes here, the principal of which is the addition of a vapor compressor, or some other terminal evaporator, onto the tail-end of the facility. The reverse osmosis system is a 3-stage reverse osmosis unit. The first stage operates at low pressure while the third stage is designed for seawater.

At first it was thought that concentrating the water 10 times through the reverse osmosis units was going to be sufficient. However, with the selenium and zero discharge situation, that wasn't enough. It was necessary to achieve a concentration factor of about 25 before ultimate disposal which is why the vapor compression evaporator was added.

Figure 4 illustrates the half-acre salt-gradient solar pond at Los Banos. There are only two ponds of this size in actual test operations in the United States. One is in El Paso and is sponsored by the U.S. Bureau of Reclamation and the other is the pond that is in operation at the Los Banos test facility. There are a couple of other very small research ponds in the United States of about a tenth of an acre in size.

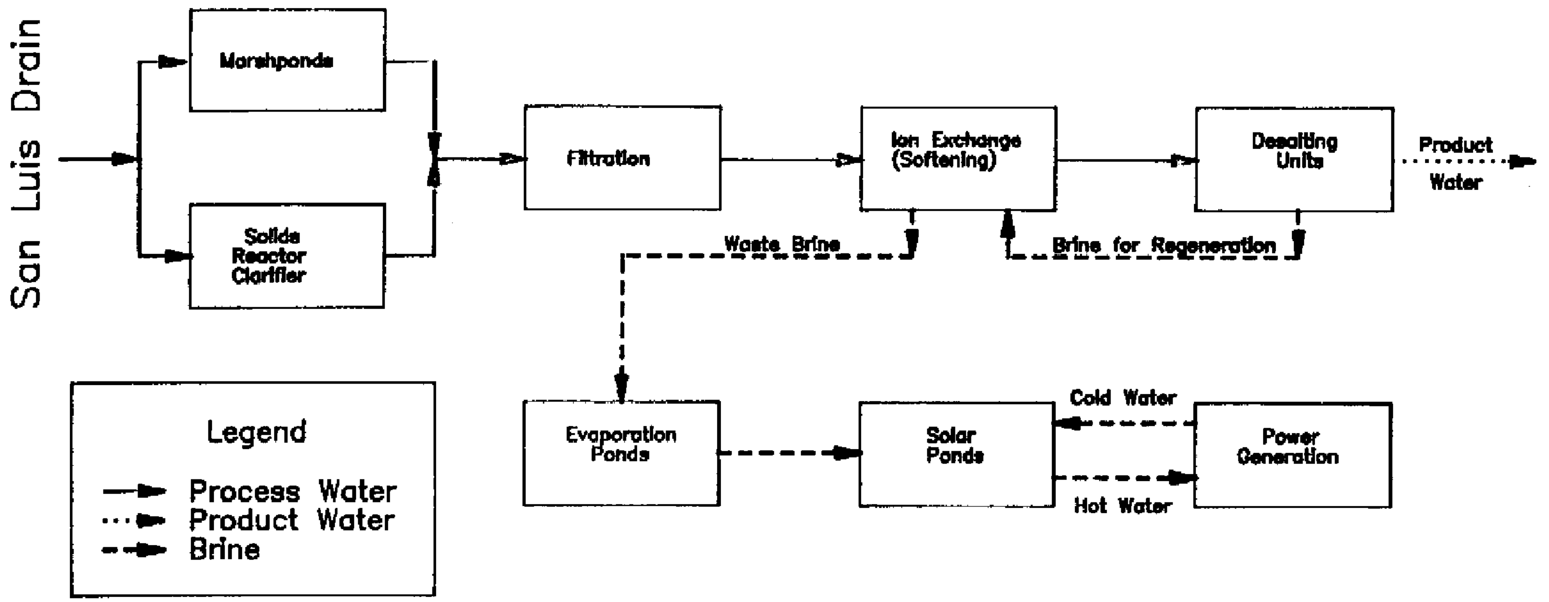

Figure 2 ORIGINAL CONCEPTUAL PROCESS FLOWSHEET FOR THE LOS BANOS DEMONSTRATION DESALTING FACILITY

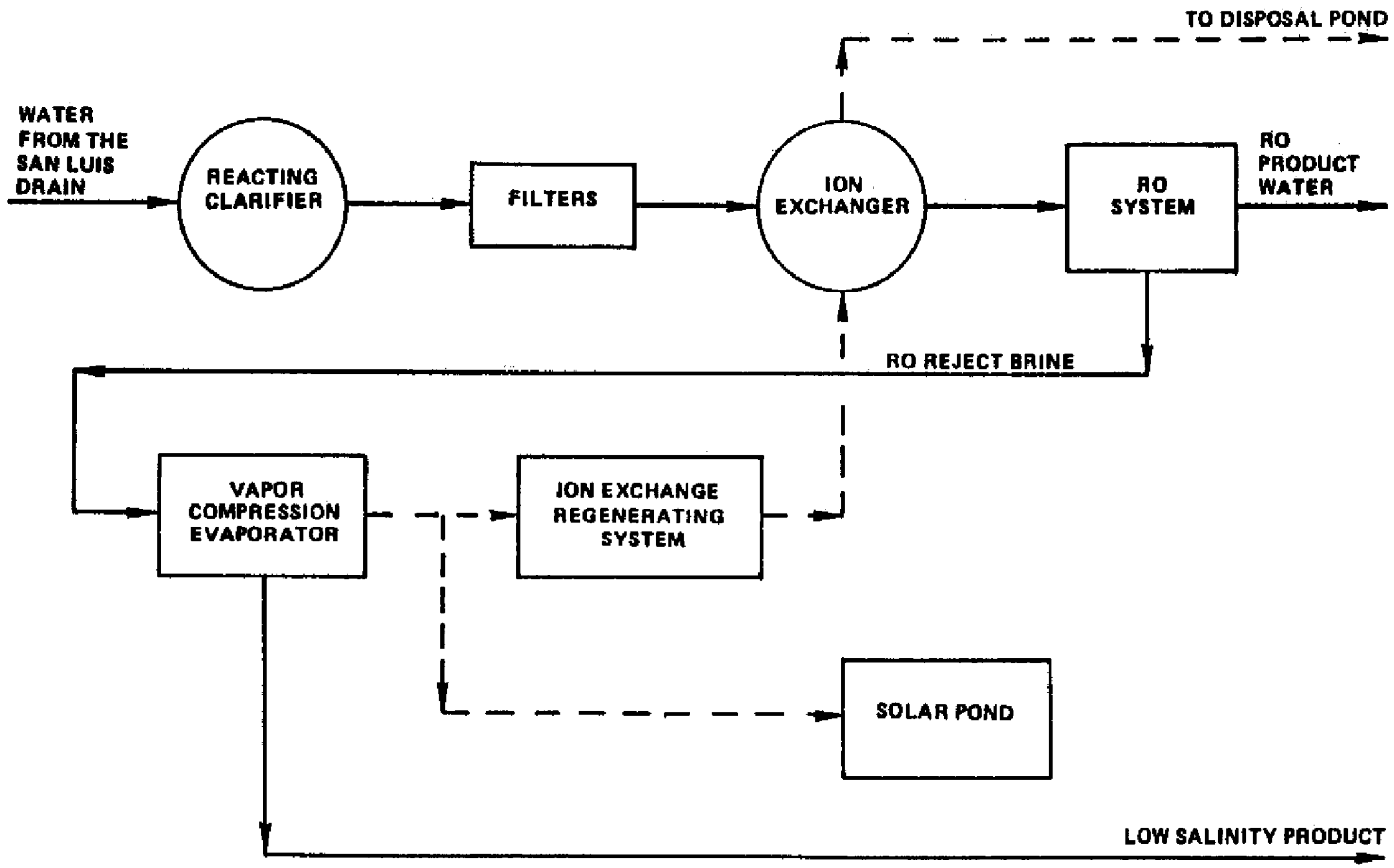

Figure 3 REVISED CONCEPTUAL PROCESS FLOWSHEET FOR THE LOS BANOS DEMONSTRATION DESALTING FACILITY

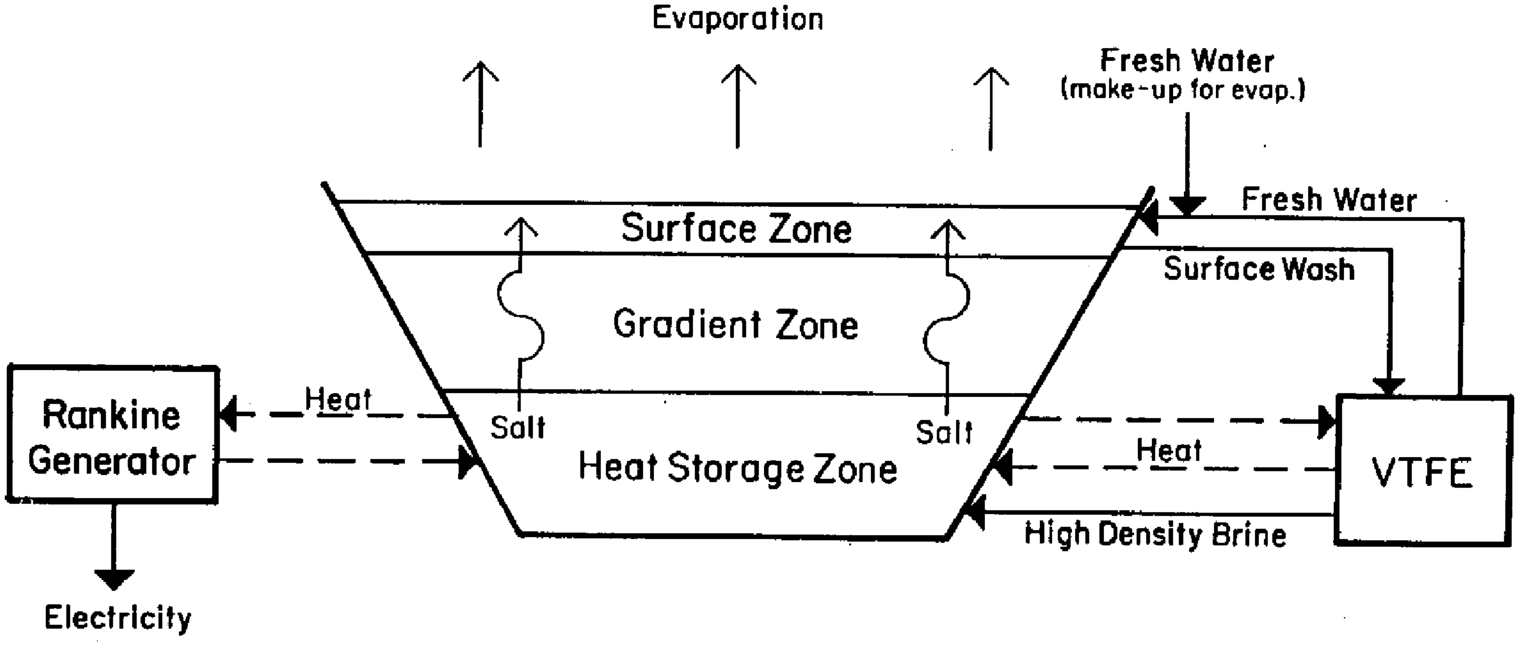

Figure 4 LOS BANOS SALT-GRADIENT POND SCHEMATIC

Basically, this solar pond is a 12-foot deep lined pit in the ground with the bottom 3 to 4 feet being filled with brine having a salt concentration of about ten times that of seawater. Above that is a 3 to 4-foot thick zone called a gradient zone. It is a zone of changing concentration. In this gradient zone, each inch of fluid is more dense than the inch above it, hence, the term gradient. The bottom, or the heat storage zone, is a convective zone that mixes as it is heated while the gradient zone is a non-convective zone that does not mix because of the density gradient. The surface zone, which is about 12 inches deep, is a small convective zone on top which results from the evaporation of water. Freshwater is run across it to make up for evaporation and the salts migrating from below.

The salt-gradient pond is heated by the ultraviolet radiation which reaches the bottom heat storage zone and warms the water. The water in that zone cannot circulate back to the surface due to the gradient, non-convective zone above. Therefore, it cannot give up its heat back up to the atmosphere. The end result is that the heat storage zone of this type of pond can reach temperatures of 200°F at the bottom. With temperatures like that you can extract the water, run it through a Rankine cycle turbine and generator to produce electrical power. You could also take the heat and use it directly in a thermal evaporator or for process heat.

Research on the Los Banos system is at the energy production stage right now and is focused on using the Rankine generator. We are now in the process of installing an evaporator to run directly from the heat from the solar pond. An electric vapor compression evaporator has been run to get experience in using that kind of evaporator and producing the brines for the pond.

Figure 5 is a different drawing of the system which describes the power generation cycle. The hot water from the pond goes into an evaporator which boils R-113 freon, producing a vapor that passes through and drives the turbine which in turn drives the generator. The freon vapor then goes to the condenser where it is liquified and recycled to the evaporator.

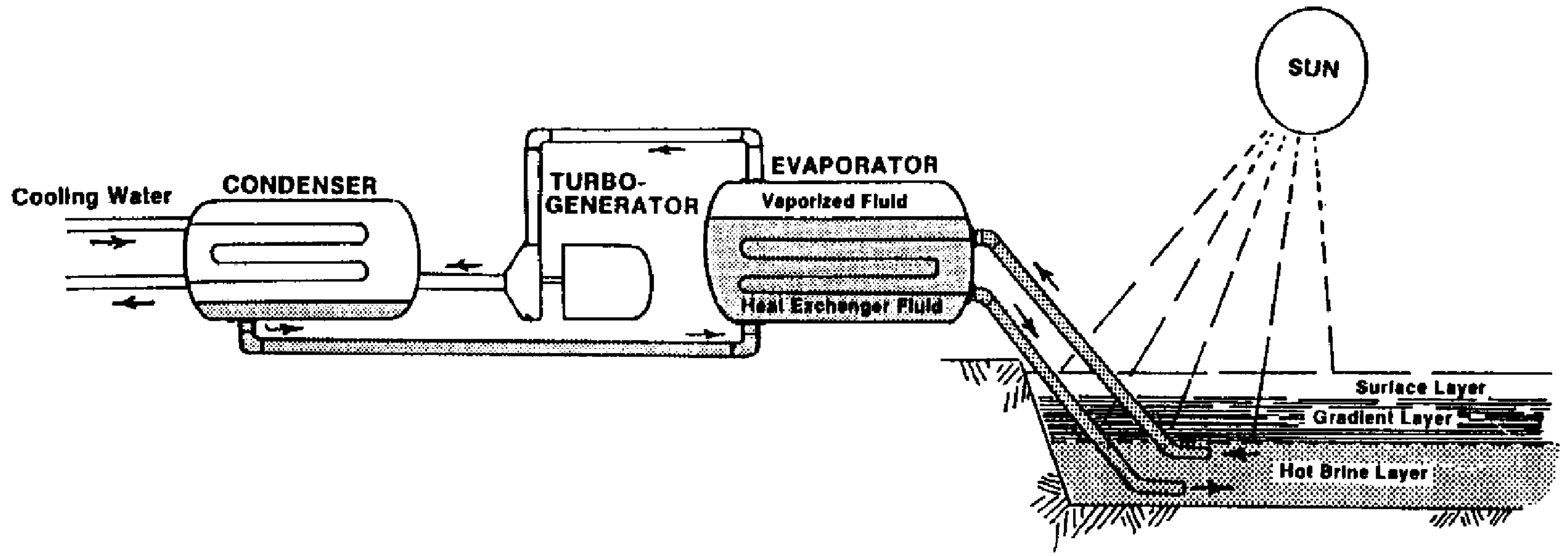

Figure 5   LOS BANOS SOLAR POND ELECTRIC GENERATION SYSTEM

Figure 6 is an aerial photograph taken of the test facility. Each of the two ponds are a half-acre in size, only the one on the right is actually used as a solar pond. The grid you see on the top, in 20 foot squares, is to prevent any mixing due to wind from breaking up the gradient zone. It is made from PVC pipe with some iron in it to make it float just below the surface. That grid breaks up the surface waves and prevents any mixing. The generator building and miscellaneous equipment are just to the left of the pond.

Figure 7 shows the average temperature history in the heat storage zone from the day we started the stratification of the salt layers, which was in September of 1985, until July 1987. Almost as soon as the pond was stratified, its temperature increased until about October, 1985, when it started dropping as winter approached. In the San Joaquin Valley, there are a couple months of fog during the year which cuts the amount of solar insolation but it doesn't cut it quite as much as some people would think. The lowest temperature in this cycle was only 108°F in January, 1986. This was despite the fact that the pond really had never reached operational temperature during the previous months. In 1986, it reached a maximum temperature of 186°F in July when unfortunately an operational error caused the gradient to be lost almost entirely and it had to be reestablished. But even after all of that, during the following winter it only dropped to 123°F.

Figure 8 shows the condition of the Los Banos pond during 1988. What is illustrated here is some of the characteristics of the pond. We have been running experiments on the clarity of the pond water and have found that by taking extra caution and time to keep the brines as clear as possible, we can increase the solar efficiency of the pond. The theoretical maximum for using solar energy in a situation like this is about 30 percent. We are getting close to that by taking some measures to clean the brine. This is done by occasionally adding powdered activated carbon to sweep it clean. The carbon spreads out over the whole pond turning it inky-black and then the carbon settles. It does an amazing job of cleaning.

On February 17, 1988, we had a carbon application. The temperature initially dropped but it soon resumed its rise. In about April, we

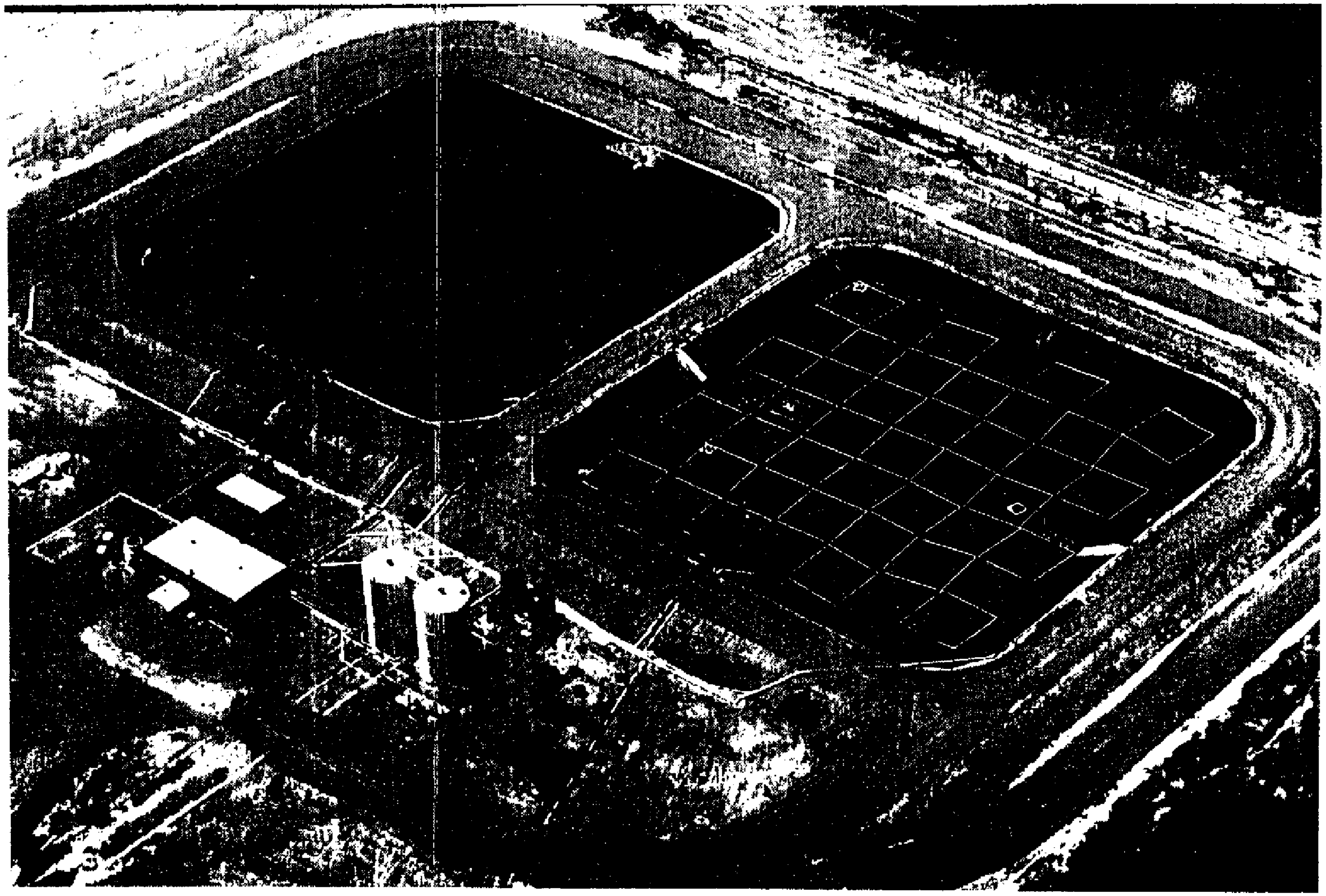

Figure 6   AERIAL VIEW OF THE LOS BANOS SOLAR POND SYSTEM

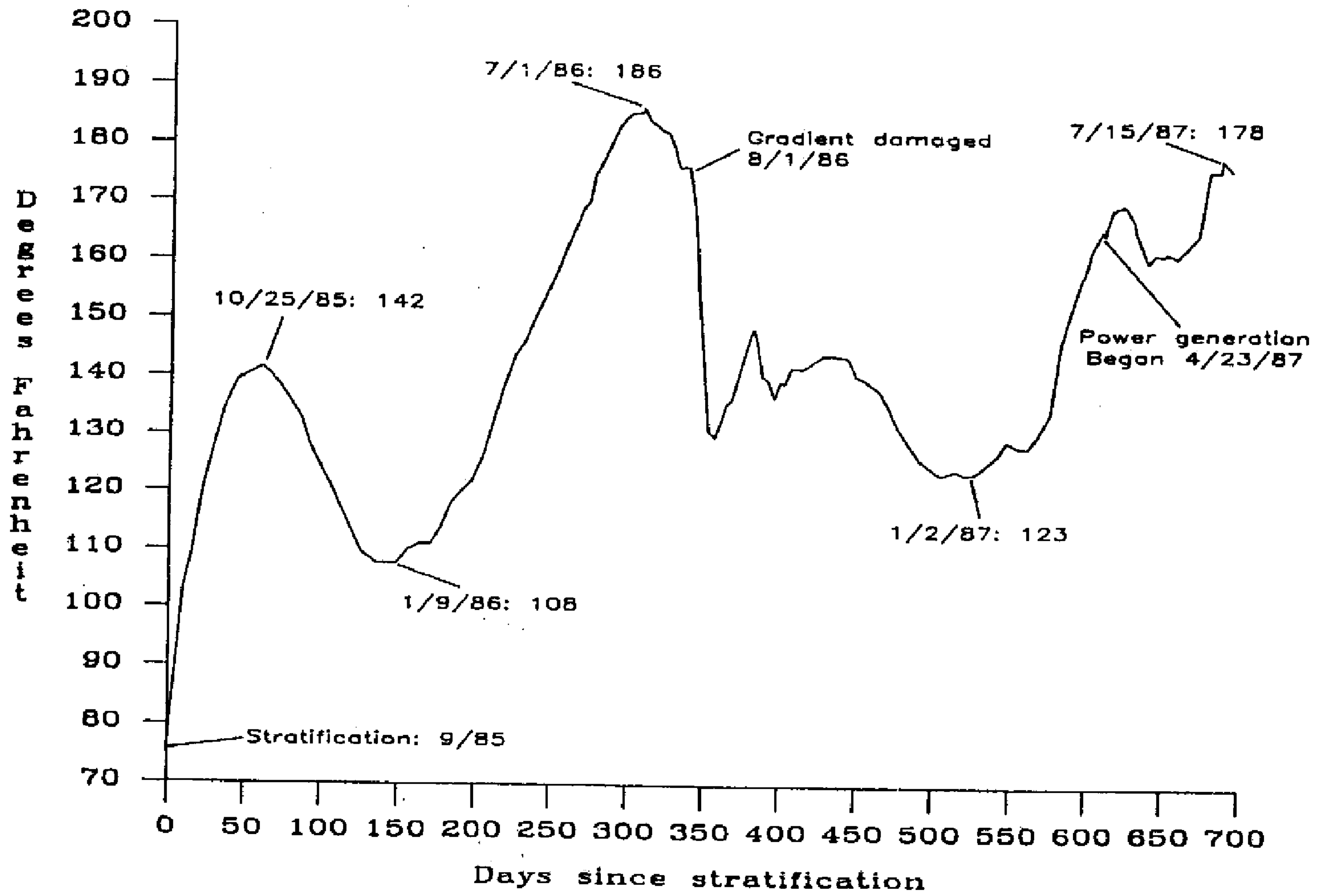

Figure 7 TEMPERATURE VARIATIONS IN THE HEAT STORAGE ZONE, 1985 - 1987

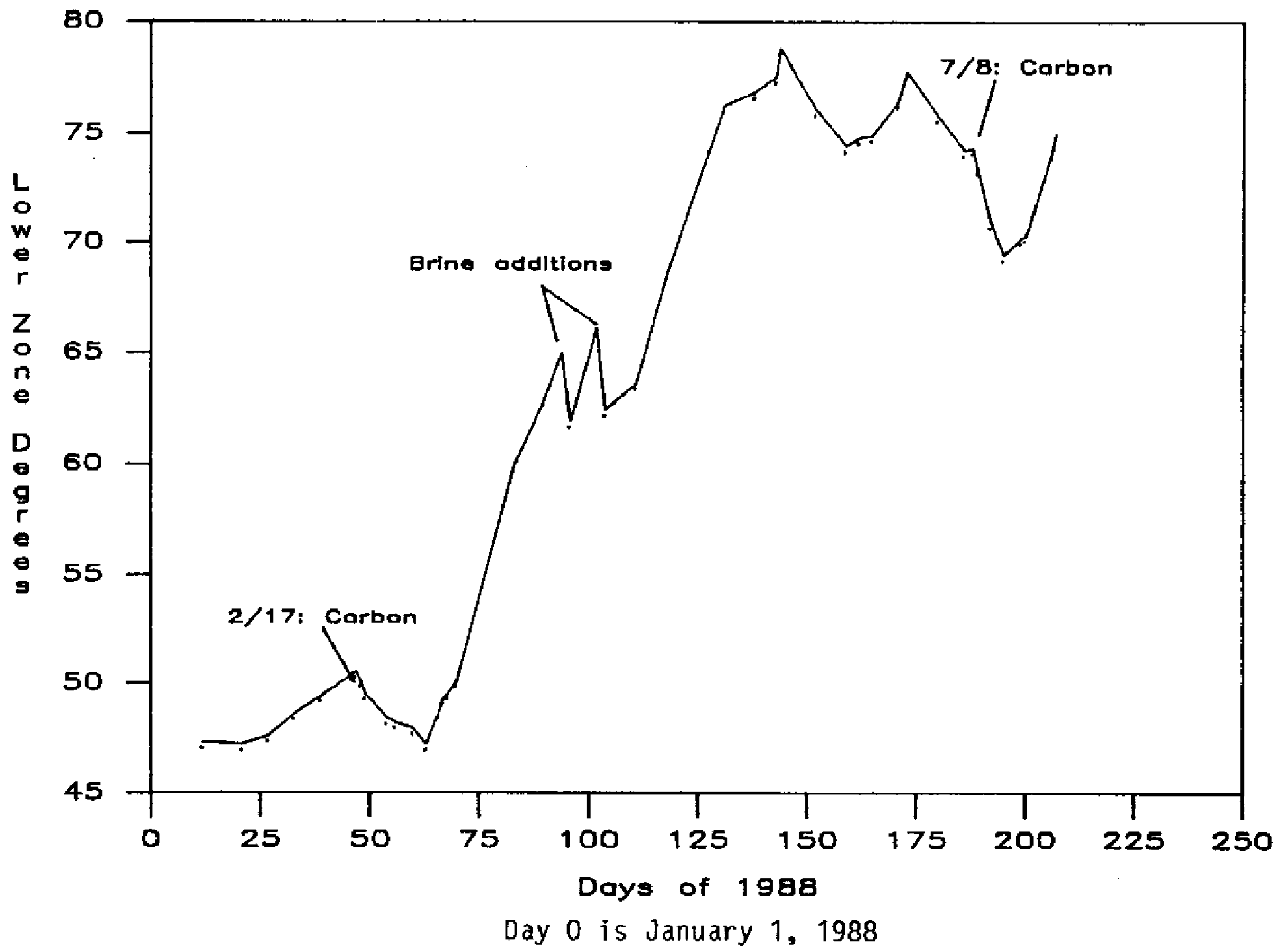

Figure 8 TEMPERATURE VARIATIONS IN THE HEAT STORAGE ZONE IN 1988

added more brine which also temporarily reduced the temperature. When the pond reached about 75°C (about 167°F) we started running the generator periodically, adding more carbon and brine to it. It should be remembered that this is a research pond, not a full operating pond.

Figure 9 shows the conditions in the pond on July 26, 1988. The temperature profile of the pond shows that there is an unusually deep surface zone. This is for a variety of reasons, but from a depth of about 130 centimeters (cm) from the bottom, a fairly typical temperature profile has been established with the gradient zone. At a depth of about 45 to 50 cm, we start to see the indications of the heat storage zone. The density profile curve had an odd quirk to it that day. It was stratified even in the lower conductive zone from a density standpoint. Brine was being added at that point and the changes there were probably caused by that and some movement of heat in the ground.

With regards to economic and environmental considerations, we have not done all the studies we would like to do in that area so we don't really have much that we can state about economics at the present time. However, based on some paper studies we have done using the 25 MGD RO plant and developing solar ponds as we produce the brine, we came up with the curves shown in Figure 10.

In the high-salt pond case, the brine is not stratified and the pond is not placed into operation until we have 350,000 ppm brine. So because of that it takes a long time, even after the evaporators, to evaporate the water. It takes a while to generate enough pond area to be developing power and what that shows is that in that situation it would take about 15 years before we would be developing more power than we actually need in the plant. In the low-salt pond case, we would start out with a little lower density in the pond. In that case, we can start to generate more power than can be used in the plant in about 7 years. If you double each of those numbers, that would be about the time that you would be paid in accumulated energy debt. These numbers are very tentative but they give you some idea of what is possible.

These ponds and other facilities do take area. Figure 11, and the paper study which it is from, was based on our use of a biological pretreatment system which we abandoned because of the selenium problem.

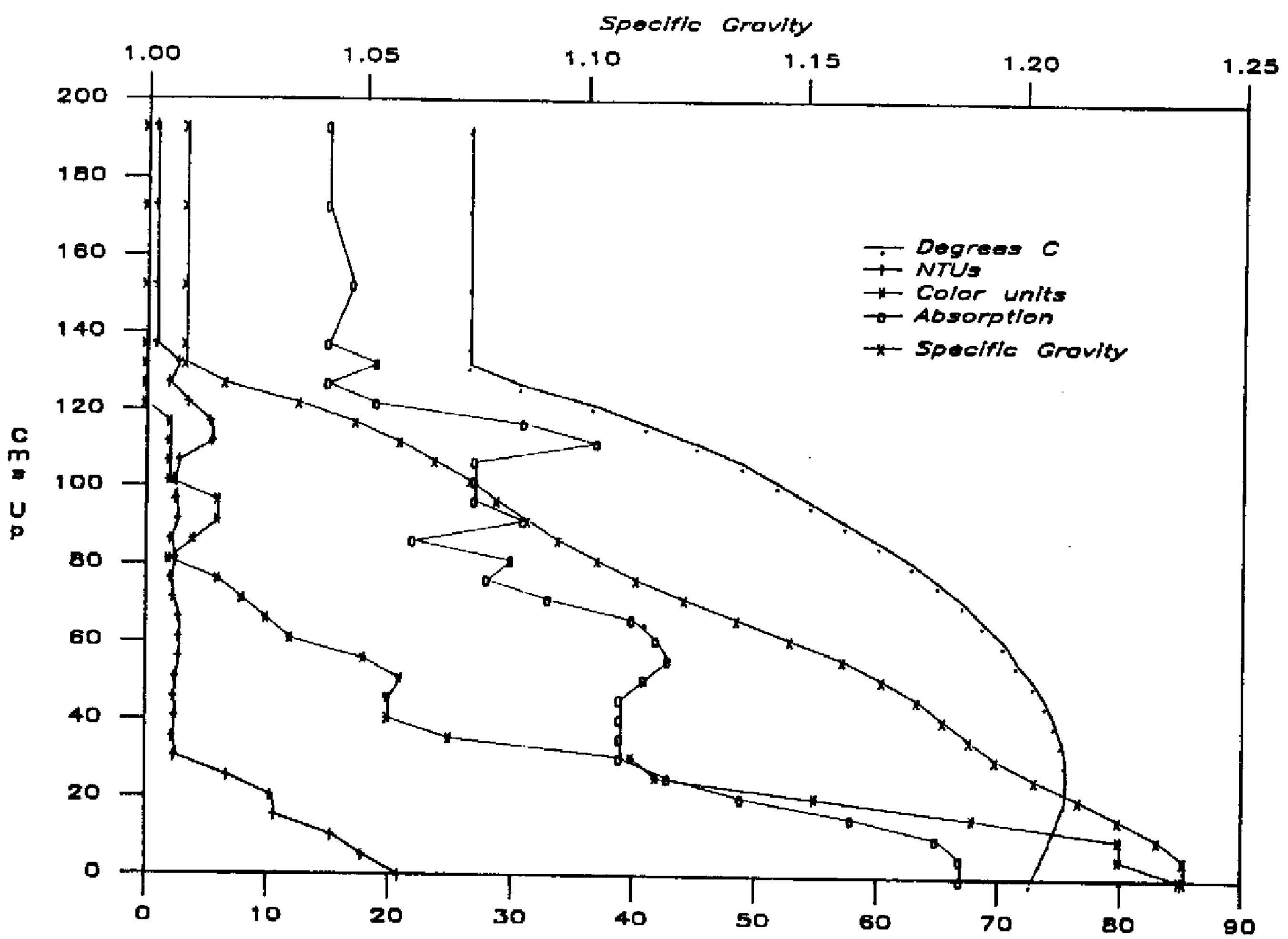

Figure 9 PARAMETER PROFILE OF THE LOS BANOS SOLAR POND ON JULY 26, 1988

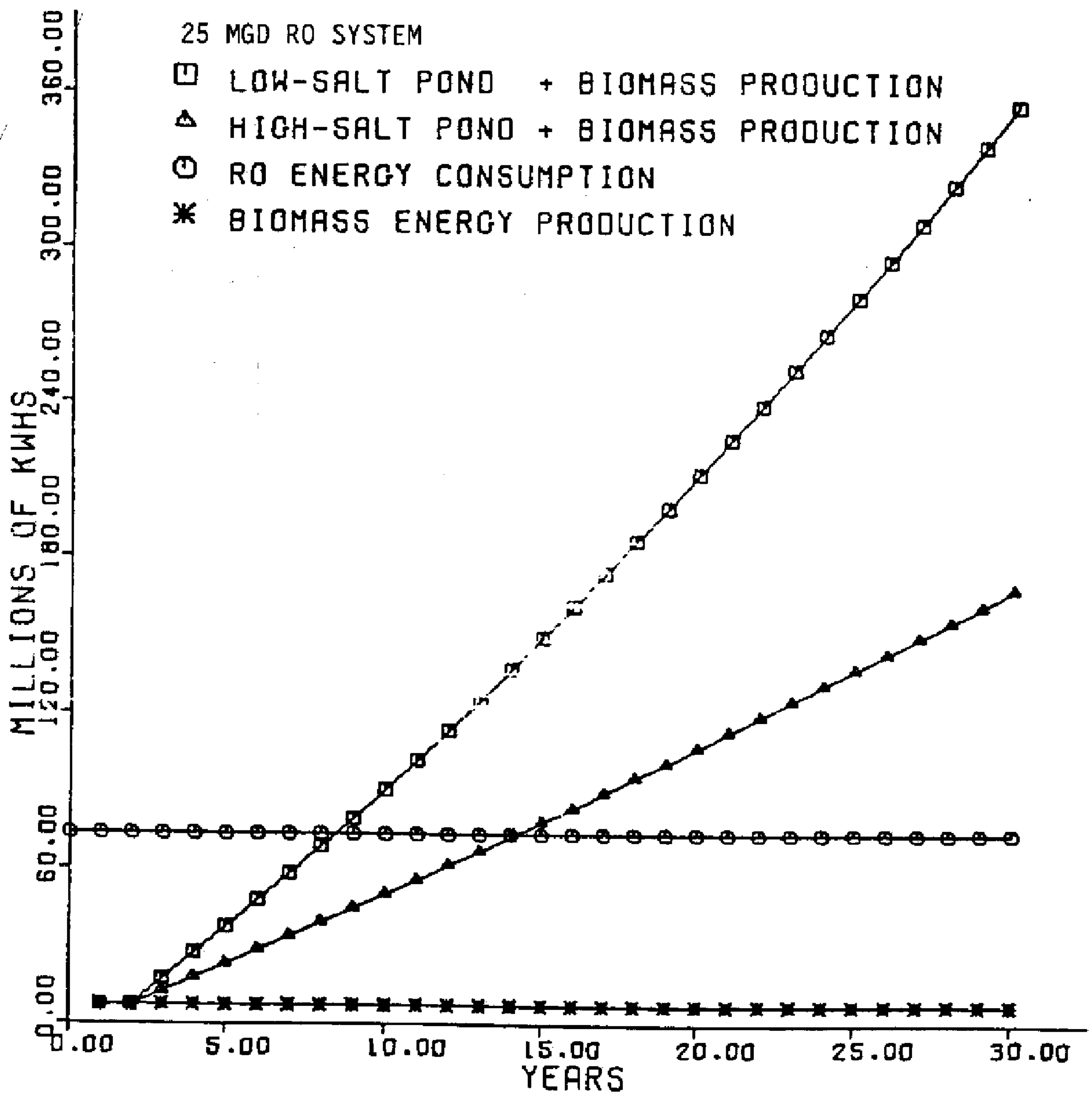

Figure 10 PROJECTED ELECTRICAL USE AND PRODUCTION AT LOS BANOS

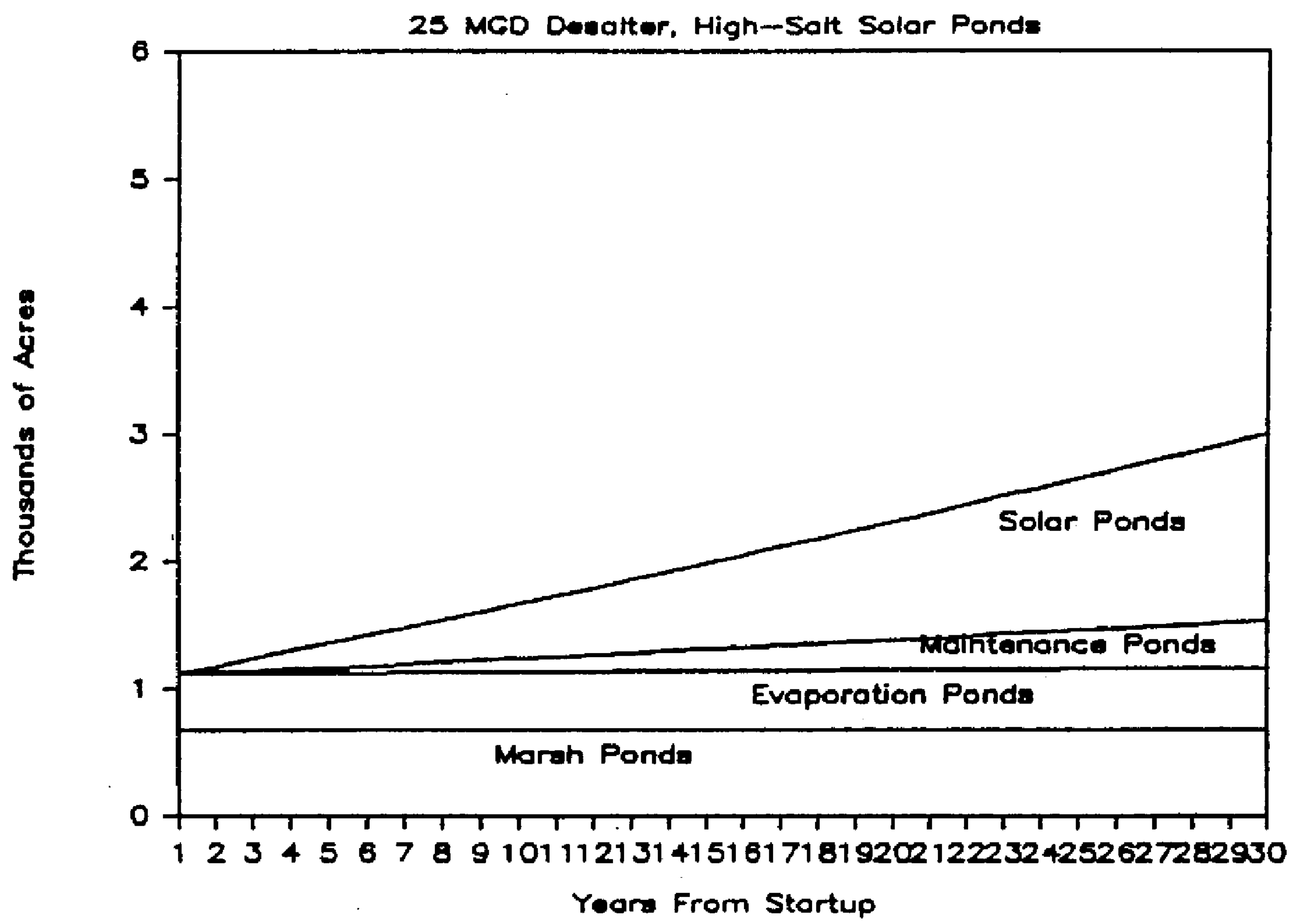

Figure 11 PROJECTED MAXIMUM LAND REQUIREMENTS AT LOS BANOS

But if you disregard the marsh and evaporation ponds then after say 30 years, it would take about 1,700 to 1,800 acres of these solar ponds, depending on the type of solar pond used. This figure happens to be for the high-salt pond, it would be different for the low-salt pond.

The cost of this operation has to run close to a cost of a Class I hazardous waste disposal site, depending upon where you are. These things are highly site-specific. You might be able to get away with one liner, you might get away with one liner and a drainage system. It is very, very site-specific. It is not for everybody. It is expensive, somewhere between $50,000 to $250,000 an acre. Typical electrical production costs, if you were just going to try to market the power, would be about 7¢ to 10¢ per kWhr.

In terms of environmental considerations, the big one is to prevent leakage of brine from the pond itself. This is important anyway as you don't want to lose your heat so you don't want to lose your salt. Right now it is pretty research-oriented. In essence, this project would provide a temporary storage of water or brines. This gives one 30 or 40 years until you can work out other ways to dispose of brine.

DISPOSAL OF CONCENTRATES FROM BRACKISH WATER DESALTING PLANTS BY MEANS OF EVAPORATION TECHNOLOGY

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The use of reverse osmosis (RO) plants to desalt brackish water in South Florida has increased rapidly in the last decade. The concentration of scale forming species such as calcium sulfate and silica usually limits RO recovery in these plants to about 75% of the total feedwater flow. The remaining 25% of the flow is reject brine which presents a serious disposal problem for plants in inland locations. This paper describes the use of brine concentrators to reduce the RO reject brine to 2% of the overall flow and so significantly reduce the disposal problem. The hybrid concept of RO followed by evaporative brine concentration has been applied to similar problems (De Moel et al, 1985; Kohli (1985); Houle et al, (1979).

INTRODUCTION

Reverse osmosis plants discharge a permeate stream with low dissolved solids (TDS), and a reject stream with high TDS. In the reject stream, the concentration of scale forming species such as calcium sulfate and silica must be controlled to prevent damage to the RO membranes. As a result, in desalting brackish water, the permeate stream is usually limited to about 75% of the feed stream. The disposal of the remaining 25%, the brine stream, presents technical, regulatory, and financial problems for plants in inland locations.

Evaporative brine concentrators may be used to treat the RO reject to recover an additional 23% of the feedwater as a stream containing less than 20 ppm total dissolved solids. This reduces the volume of the stream requiring disposal to just 2% of the feedwater volume.

Evaporation is a commercially available process that has a successful track record in concentrating RO brines and waters of similar quality in power plants, water reclamation facilities, and industrial plants.

The hybrid brackish water desalting plant consisting of RO followed by evaporative brine concentration gives the following advantages:

- Recovers 98% of the feedwater as potable water
- Reduces the size of a new RO plant by 23%
- Reduces the RO pretreatment operating cost (chemicals, power, etc.)
- Reduces the size and cost of the pretreatment equipment
- Reduces the limits imposed on the RO plant because it can now produce less pure water which may be mixed with the distillate from the brine concentrator to produce potable water
- Reduces the quantity of brine requiring disposal from 25% of the raw water to 2%, resulting in a significant reduction in disposal costs

The concentrate stream from the evaporation process step may be placed in a holding pond for temporary storage pending final disposal to the ocean.

PROCESS DESCRIPTION

Figures 1 and 2 are process flowsheets of two versions of the evaporative brine concentration process known as vapor compression evaporation (VCE).

Figure 1 represents the process developed by Resources Conservation Company (RCC) of Bellevue, Washington. The feed to the concentrator is pumped from a holding tank and treated, if necessary, with a small dose of

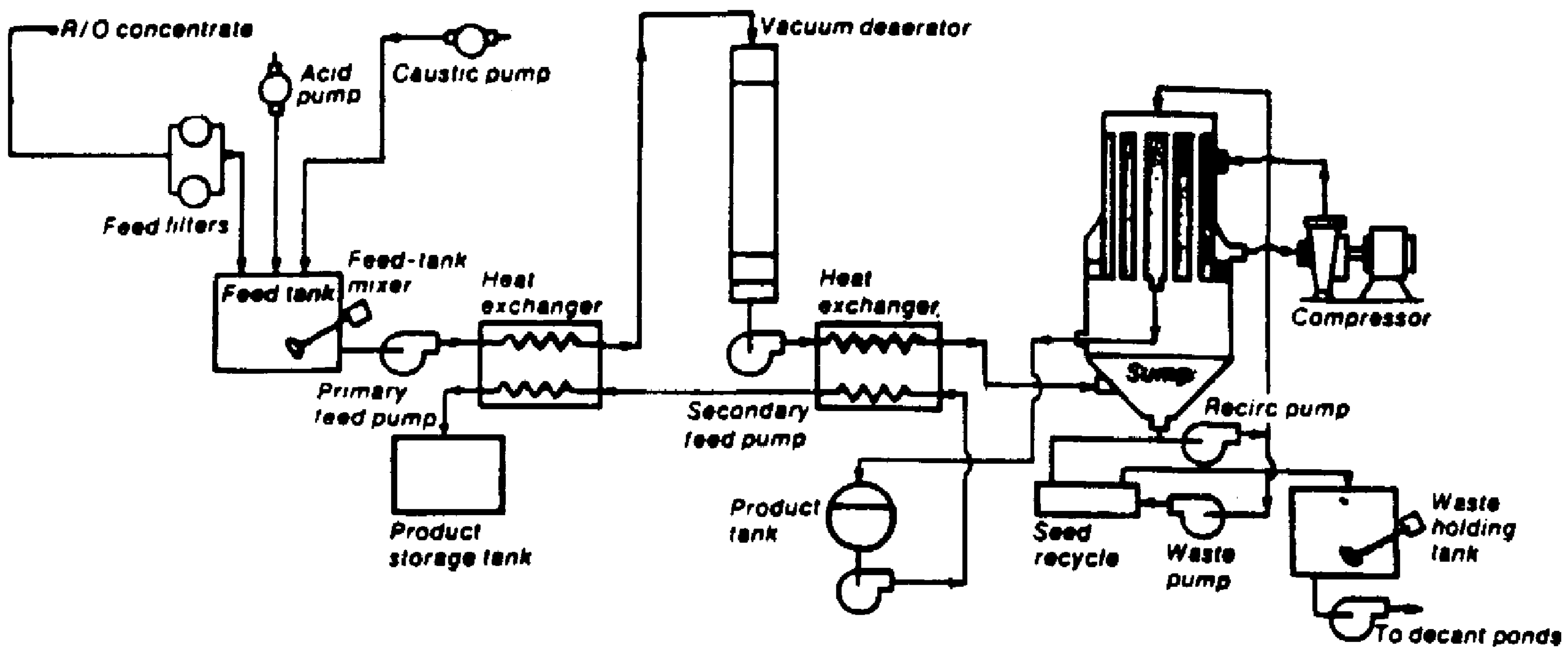

Figure 1 THE RCC VAPOR COMPRESSION EVAPORATION PROCESS FLOW DIAGRAM

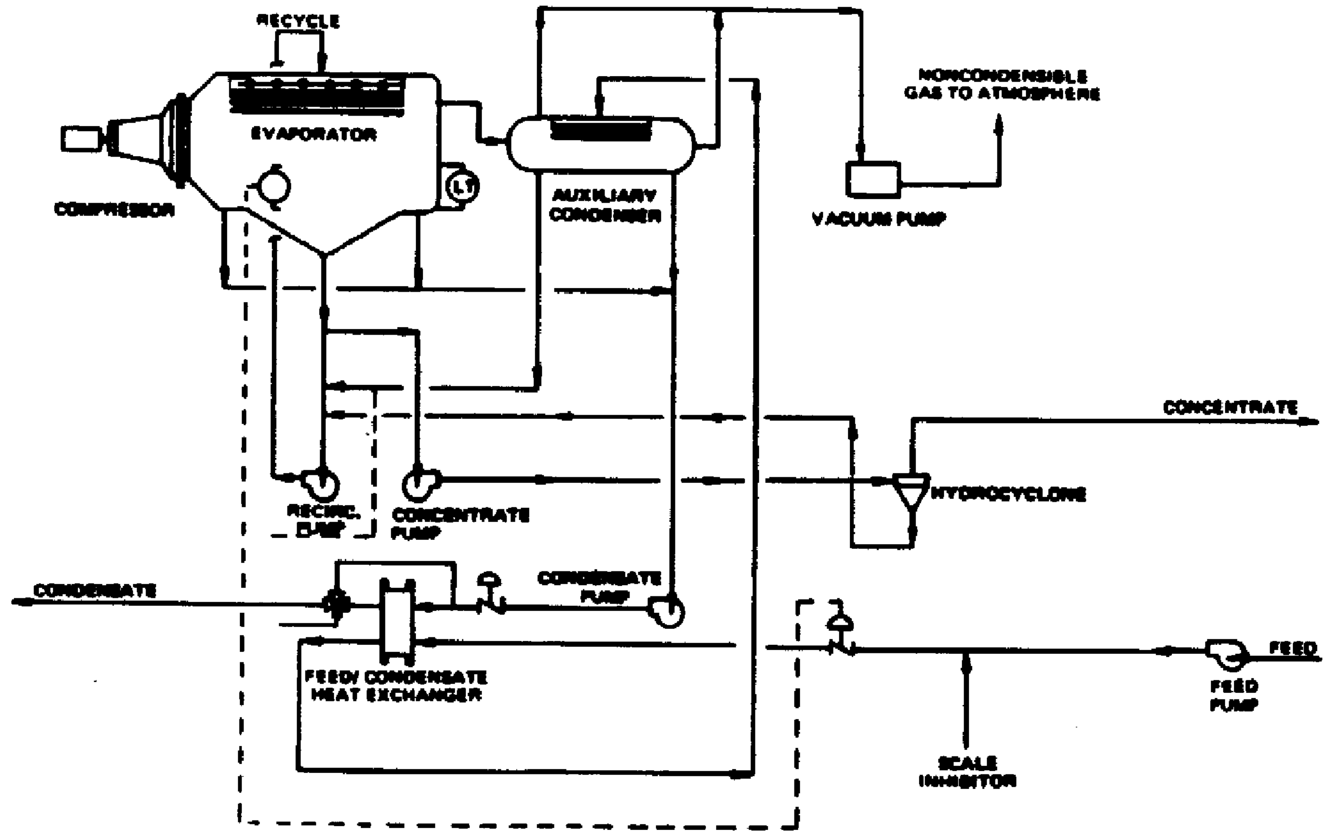

Figure 2 PROCESS FLOW DIAGRAM OF THE VAPOR COMPRESSION EVAPORATOR SUPPLIED BY AMBIENT TECHNOLOGIES

scale inhibitor. The feed then passes through a heat exchanger where it recovers heat from the condensate stream as that stream leaves the concentrator. The preheated feed next passes through a deaerator where non-condensible gases are removed and vented to the atmosphere. After leaving the deaerator, the feed, at its boiling temperature, enters the evaporator sump. The feed mixes with concentrate slurry and is continuously recirculated to the flood box of a vertical tube evaporator.

From the flood box, the slurry is distributed to the inside walls of the heat transfer tubes as a thin film. As the thin film runs down the inside of the tubes, water is evaporated and the resulting steam passes through a mist eliminator before entering the suction line of an electrically driven compressor. Compression raises the condensation temperature of the steam above the boiling point of the recirculating brine. As this steam releases its heat of condensation, it condenses on the shell side of the tubes and is collected in the product tank. With the release of the heat of condensation, more water is evaporated from the brine film on the inside of the tubes. Consequently, the compressor supplies the energy which drives the system. To provide the initial charge of vapor to the compressor, a small auxiliary boiler supplies steam to the evaporator for a short time at start-up (Anderson, 1976).

Figure 2 represents the process supplied by Ambient Technologies of New York. As in the RCC process, the feed is treated with scale inhibitor, if required, then preheated and deaerated. The feed then goes to a condenser where a vacuum pump connected to the condenser continuously removes non-condensable gases. This vacuum pump is also used to reduce the pressure in the evaporator at start-up. The feed then mixes with recirculating brine, enters the evaporation chamber in the main vessel and is sprayed on the external surface of a nest of horizontal heat transfer tubes at a rate just sufficient to create a thin continuous film. Through its suction, a radial blade centrifugal compressor provides a pressure lower than the equilibrium pressure of the water sprayed on the tubes. As a result, part of the water flashes into vapor.

After passing through a separator to remove droplet carryover, the vapor is compressed and discharged to the inside of the tubes. There it condenses, giving up its latent heat which evaporates a portion of the brine on the outside of the tubes. The condensate is pumped out by the product pumps. The unflashed brine accumulates as concentrate at the bottom of the evaporation chamber.

Unlike reverse osmosis, the vapor compression evaporation process can tolerate the presence of scale formers. Deposition on the plant components is prevented by maintaining a comparatively high concentration of calcium sulfate crystals in the recycled brine. These crystals provide nuclei on which the scale deposits, in preference to the equipment and piping. Any scale deposited on the evaporator surfaces is scoured off by the recirculating slurry.

The VCE process supplied by Ambient Technologies was tested at the California Department of Water Resources' Demonstration Desalting Facility at Los Banos. The average operating conditions obtained during this test are summarized below:

Feed flow, gpd	56,680
Product flow, gpd	53,980
Feed TDS, ppm	9,084
Product TDS, ppm	10
Concentrate TDS, ppm	206,676
Recycled brine temperature, °C	48.9
Product temperature, °C	48.6

Several commercial VCE's of the type supplied by Ambient Technologies are in successful operation worldwide.

The RCC process is operating successfully at 40 locations throughout the world. Typical operating conditions for an RCC unit are shown below:

Feed flow, gpd	504,000
Product flow, gpd	478,800
Feed TDS, ppm	12,000
Product TDS, ppm	<10
Recycled brine TDS, ppm	210,000
Operating temperature, °C	105.6

The equipment supplied by RCC uses titanium tubes, while the equipment supplied by Ambient Technologies uses aluminum alloy tubes. In addition to the two equipment suppliers mentioned in this paper, there are several other vendors of vapor compression evaporators worldwide.

PROJECTED HYBRID PLANT PERFORMANCE

For the purpose of this presentation, it is assumed that the feed to the VCE has a TDS concentration of 10,000 ppm and is saturated with calcium sulfate. Vapor compression evaporation will recover an additional 23% of the feedwater, for a combined RO and VCE recovery of 98%. This leaves only 2% of the volume of the feed stream for final disposal.

Plant sizes of 1 million gallons per day (MGD), 5 MGD and 10 MGD of product water, were considered for this evaluation. The projected performance of these plants is given below:

CASE	RO PRODUCT (gpd)	RO REJECT (gpd)	VCE PRODUCT (gpd)	BRINE TO ULTIMATE DISPOSAL (gpd)
1 MGD	765,300	255,100	234,700	20,400
5 MGD	3,826,500	1,275,500	1,173,500	102,000
10 MGD	7,653,000	2,551,000	2,347,000	204,100

COSTS

There are several features inherent to the VCE that affect its economics. All other things being equal, the smaller the temperature rise and, hence, the compression ratio, the higher the overall efficiency of the process. On the other hand, a small temperature rise requires a large heat transfer area. Consequently, the choice of operating conditions is a trade-off between the cost of energy and plant investment. A second consideration concerns the operating temperature of the VCE. The choice of low operating temperature will greatly decrease corrosion but will provide vapor of high specific volume, thereby increasing the size of the compressor and vapor lines.

The price of the VCE system depends on the application. Small sizes may be installed for about $7.50 per gpd. As the sizes increase, the installed price may be reduced to approximately $6.00 per gpd.

The vapor compression cycle is very attractive because of its high energy effectiveness under commercially attainable operating conditions. For dual effect systems, the energy consumption can be reduced to the range of 60 to 70 kWhr/1000 gal of condensate produced by the evaporator.

The energy consumption for a typical brackish water RO plant is approximately 6 kWhr/1000 gal.

If waste heat is available as the energy source for evaporation, multi-effect distillation may be substituted for VCE as the evaporative portion of the hybrid desalting plant. The use of waste heat would cut the energy cost significantly. Bechtel is currently evaluating the optimization of the components of a hybrid desalting plant to reclaim agricultural subsurface drainage water in the San Joaquin Valley of California. This project is being funded by the California Department of Water Resources. The selection of the pretreatment, RO, and evaporation components of this system is being made so as to minimize the overall cost of the facility. The final report for this project will be available in early 1989.

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RECLAIMING REVERSE OSMOSIS BLOWDOWN WITH ELECTRODIALYSIS REVERSAL

by

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INTRODUCTION

The electrodialysis reversal (EDR) process is now being used to reclaim concentrated wastewaters from RO systems for reuse as RO feedwater. This dramatically reduces both RO feed volume requirements, and the volume of RO blowdown normally sent to waste. Use of EDR for reclaiming RO blowdown yields overall RO water recovery in excess of 97 percent.

Presently, the largest operating EDR-RO reclaim unit is located at a major aerospace and electronics facility in the southwestern United States. In 1985, this plant undertook a significant manufacturing expansion. This required installation of a complex Industrial Wastewater Reclamation System (IWRS) to limit additional consumption of municipal supply water through reuse of 400 to 500 gpm of 800 to 1,600 ppm TDS general plant and process wastewater. An overall system comprising heavy metals removal, pond storage, multi-media filtration, chlorination followed by UF with dechlorination and RO, was to provide low TDS reuse water for plant demineralizer and process systems. However, capacity of existing evaporative ponds used for all waste collection could not be expanded. A water balance calculation showed that 100+ gpm design flow of RO waste would quickly exceed pond capabilities.

Use of EDR or vapor compression was intensively explored for physical reduction of final waste volumes. Based on a combination of proven performance with 8,000 ppm TDS feed and highly saturated levels of $CaSO_4$, up-front capital costs, total O&M costs, system reliability, and the actual water balance requirements of the facility; EDR was selected as the best method to use.

Combined UF-RO-EDR has been online, at this plant, for over 2-1/2 years. The EDR unit has met or surpassed all initial design projections for both system performance and total O&M costs. EDR is reclaiming the present 70 gpm, 5,300 ppm TDS RO waste to 550 ppm TDS. Total O&M costs are less than $1.00/1,000 gallons of RO blowdown fed to the EDR unit.

There are now three individual EDR installations for RO brine reclamation in the United States. Another EDR unit is designed to concentrate a 23 gpm, 40,000 ppm TDS RO brine to 5 gpm, 130,000 ppm TDS for initiation of solar ponding. Reclaimed water goes to RO feed sources. The third EDR application is installed at a gallium-arsenide chip manufacturing plant for reclaim of both RO and lab and fab wastewater. Reclaim is sent to cooling tower makeup, while final high TDS EDR waste goes to truck-away disposal.

EDR technology is a highly cost-effective process for reducing both the feedwater required and the wastewater generated with RO systems. This has significant implications for major RO units operating in areas that have limited or restricted use of municipal water supply. For areas that have inadequate waste disposal, whether sewage treatment or evaporative ponding, the use of EDR reclamation of RO waste will allow RO systems to continue operation. EDR can even allow for expansion of RO systems in areas that have supply water and waste disposal infrastructure limitations.

BASICS OF ED/EDR

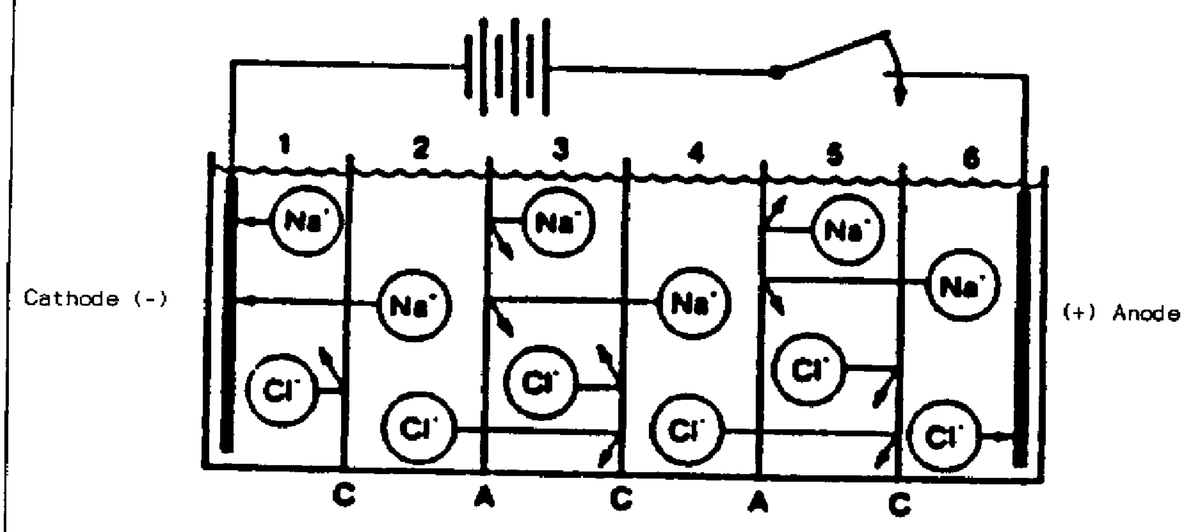
EDR is the first commercially available membrane desalination process which is symmetrically reversible. The "reversal" technology yields, to a high degree, a self-cleaning membrane system. This has eliminated many of the operational problems long associated with unidirectional desalting (i.e, ED and RO). EDR has, to the greatest extent, eliminated permanent/nonremovable membrane scaling, premature replacement of membranes, intensive use of chemicals, and extensive operator and maintenance labor. These positive advantages have resulted in EDR's application to waste reclamation, such as the desalination of highly concentrated RO blowdowns.

EDR is a technical advancement over the classical unidirectional electrodialysis (ED) process. This technology has been described many times before but will be briefly reviewed for a better understanding of EDR.

Figure 1 illustrates the basics of ED, where a DC electric field is applied across a series of alternating cation and anion selective membranes. The ionizable salts in aqueous solution are affected by the DC field in that they are dissociated into their individual ions/elements. The positive ions (cations) are attracted to the negative cathode, the negative ions (anions) are attracted to the positive anode.

Figure 1

BASICS OF ELECTRODIALYSIS



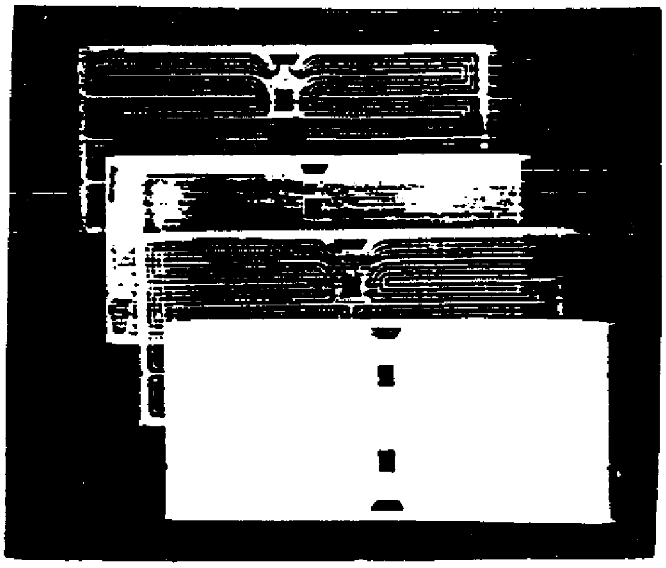
The charged (and attracted) ions are transferred through the membranes as shown. Alternating compartments remove ions while adjacent compartments concentrate the same salts to higher levels of salinity. Cation membranes allow cations to "pass" because they have mobile and exchangeable cation exchange sites; anions are rejected. The anion membranes have mobile and exchangeable anion exchange sites which allow anions to "pass" while cations are rejected.

Membranes are made of synthetic ion exchange resins in sheet form reinforced with a woven synthetic fiber cloth. Typical ion-selective membranes are composed of a polystyrene matrix crosslinked with divinylbenzene which are post-treated to yield aromatic substituted pendant polyions. Anion selective membranes bear chemically bonded positively charged quaternary ammonium groups. The negatively charged mobile counterions are the principal carriers of the electric current. The cation-selective membranes are characterized by phenol substituted sulfonate anions with mobile countercations. Low electrical resistance of membranes is attributable to the high concentration of counterions.

Turbulence of flow (for maximized DC field effect on charged ions), turbulence of flow for membrane surface cleaning and proper spacing of cation and anion membranes is essential with ED. A flat sheet spacer (made from polyethylene) is placed between each cation and anion membrane to accomplish the three above requirements. The series of cation membrane-spacer-anion membrane-spacer is referred to as a "cell pair," which is shown in Figure 2.

Figure 2

CELL PAIR



As described, this process depicts classical or unidirectional ED. The polarity of the DC field remains the same throughout the demineralization process. As a consequence, the ions always move in the same direction and are concentrated in the same brine compartments.

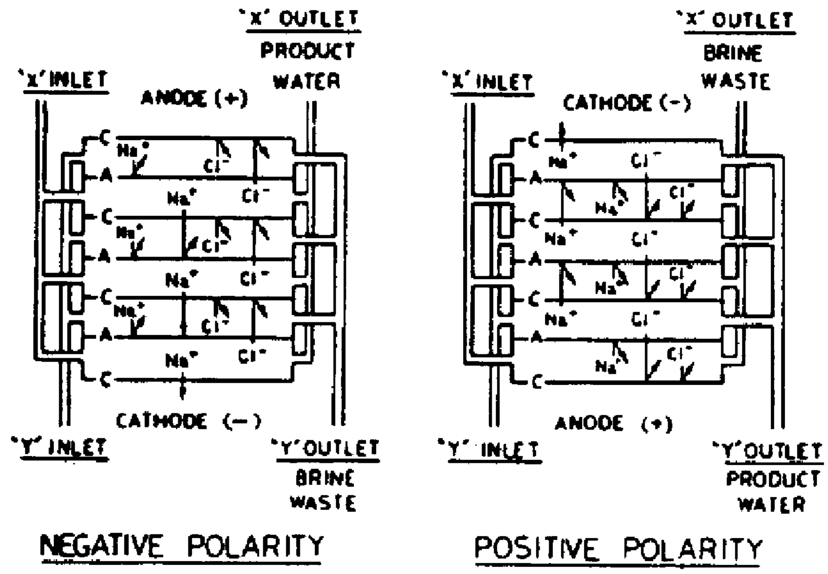
The chemistry of the concentrate stream imposes operational limitations on unidirectional membrane processes such as ED and RO. These limitations are related to membrane fouling and scaling tendencies and are of critical importance for long-term, stable system performance. Small, soluble amounts of $CaCO_3$, $CaSO_4$, $SrSO_4$, $BaSO_4$, and iron in the feedwater are quickly concentrated to precipitation levels in the brine. These precipitates, or scales, seriously degrade performance. It is often necessary to presoften or treat the feedwater with acid and/or complexing agents such as sodium hexametaphosphate (SHMP). Even with constant addition of complexing agents to the concentrate stream, unidirectional ED processes show marked deterioration of performance with time. Also, non-mineral substances such as colloids, bacteria, molds, and polymeric materials tend to deposit on unidirectional membrane surfaces. The subsequent decline in system performance necessitates process shutdown for cleaning.

EDR is simply an ED process in which the polarity of the applied DC field is automatically reversed at 15 to 20 minute intervals (Figure 3). This reverses the direction of ion movement within the membrane stack. Concentrate stream scale and foulants tend to be removed from membrane surfaces and carried away. As a consequence of the current reversal, former brine compartments become demineralizing compartments and vice versa. Special three-way valving allows automatic switching of the feed and the recycled concentrate and product streams. The product water quality at the time of reversal becomes "off-spec" due to the compartment interchange. This off-spec water is purged for 0.5 to 1.5 minutes until the demineralized stream returns to making specified product.

The advantages of EDR demineralization are outstanding. EDR is capable of controlled demineralization of feedwaters of any salinity. The extent of demineralization can be controlled from 50% to 99% by the number of EDR stages used, the temperature of the water, and other design variables. For waters where the concentrate stream has a

Figure 3

ELECTRODIALYSIS REVERSAL PROCESS



Langelier Index of +2.2 or less, a calcium sulfate saturation of 150% or less, EDR units can operate without continuous chemical addition. For most water supplies, these criteria usually allow zero chemical feed operation of EDR units with recoveries in the range of 75% to 90%+.

For waters where the concentrate stream would have a Langelier Index of greater than +2.2 and/or calcium sulfate saturation in excess of 175% to 200% and up to 400% saturation, high recovery operation of EDR units (up to 90% to 95%) can be achieved with the addition of very small amounts of acid and/or complexing agent to the concentrate stream. The recovery ratio in an EDR unit is controlled simply by the makeup volume into the concentrate recirculation loop. EDR is capable of concentrating salts and minerals to levels over 100,000 mg/l. Naturally occurring concentrations of barium or strontium sulfates are readily controlled without scaling. Silica is not removed by either the ED or EDR processes. Silica is not ionized under normal conditions. However, even high naturally-occurring silica concentrations (i.e., 150 mg/l) do not cause silica scaling in EDR units.

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EDR is capable of stable operation on feedwaters with 5 minute silt density indices (SDIs) as high as 15. Such waters are typical of most untreated surface waters and can occur in treated surface waters with less than optimal pretreatment. Since a high percentage of industrial and power station feedwaters are from surface supplies, this capability of EDR is important to its use for these applications.

With the use of a new chlorine-resistant anion membrane, EDR is now capable of sustaining long-term continuous exposure to 0.5 ppm residual chlorine, as well as weekly cleanings with up to 20 ppm free chlorine. This chemical resistance enhances EDR operation on biologically contaminated waters. Average membrane life in most EDR applications is in the 5 to 15 year range. In common with older ED equipment, EDR units are capable of long-term operation at temperatures up to 45 degrees C, pH range of 1 to 10, and a cleaning pH range of 0 to 11, thus enabling use of wide varieties of cleaning agents.

Modern EDR stacks require little manual disassembly for cleaning. If because of some major overload, the stacks do get filled with mud, carbon, sand, or gross dirt, they may be disassembled and fully manually cleaned by maintenance personnel. Reassembly of membrane stacks provides as-new performance.

DESIGN REQUIREMENTS FOR EDR UNIT FOR RO BRINE RECLAMATION

Expansion of a southwestern United States located aerospace facility was limited by availability of municipal water supply, and limitations on existing evaporative waste ponds. An older technology method of waste reuse at the facility provided 72% water recovery of waste generated within the plant. This level of performance was totally inadequate for the magnitude of the plant's new production capacity.

Accordingly, a new Industrial Wastewater Reclamation System (IWRS) was designed, using clarification for heavy metals removal, settling ponds, multi-media filtration, followed by chlorination, UF, dechlorination and RO.

An initial engineering study called for 500+ gpm of plant wastewater at 800 to 1,600 ppm TDS to be fed to the new IWRS. Reclaimed product from the final treatment RO, at 50 ppm TDS, would be returned to the plant as demineralizer and process feedwater. Depending on actual operating conditions, RO water recovery was estimated to be 75% to 80%. RO wastewater would go directly to existing onsite evaporative ponding. However, with actual pond feed capacity limited at 40 gpm to 50 gpm, it was apparent that an 80 gpm to 100 gpm RO blowdown would quickly overflow the system. To eliminate this problem, two process solutions for reducing waste volume were investigated.

First, conventional vapor compression (VC) was analyzed, where all RO and UF brines would be sent to VC. Reclaimed product quality would be 5 ppm TDS and VC water recovery would be 93% to 95% with final wastes going to ponds.

A second potential solution involved the use of EDR to reclaim 85% of the RO blowdown to a quality equal to RO feedwater. EDR was considered because of its proven ability to operate efficiently under super saturated conditions. Figure 4 depicts a simplified version of the study model used.

Because EDR does not remove SiO_2, a reactor clarifier using both lime and magnesium carbonate was included to post-treat the EDR product water. At the same time, UF wastes could be settled out in this clarifier, thereby eliminating any UF waste flow to the ponds. Clarifier effluent would be sent directly to settling ponds before multi-media filtration for inclusion with the heavy metals clarification effluent.

Early on, to show that EDR would work on RO brines high in TDS, high in SiO_2, and high in levels of Flocon* sequestering agent (10 to 15 ppm), a pilot study was run with EDR. The older technology IWRS, at the plant, included an RO system using cellulose acetate membranes. A small test EDR unit was set up to take a small portion of this RO waste as feedwater. Over a 2 month period, both salt removal and EDR membrane compatibility was successfully demonstrated.

Proceeding with the engineering study a synergism was developed for the total IWRS study, including EDR. The model showed that 521 gpm of

*Flocon is a registered trademark of Phizer, Inc.

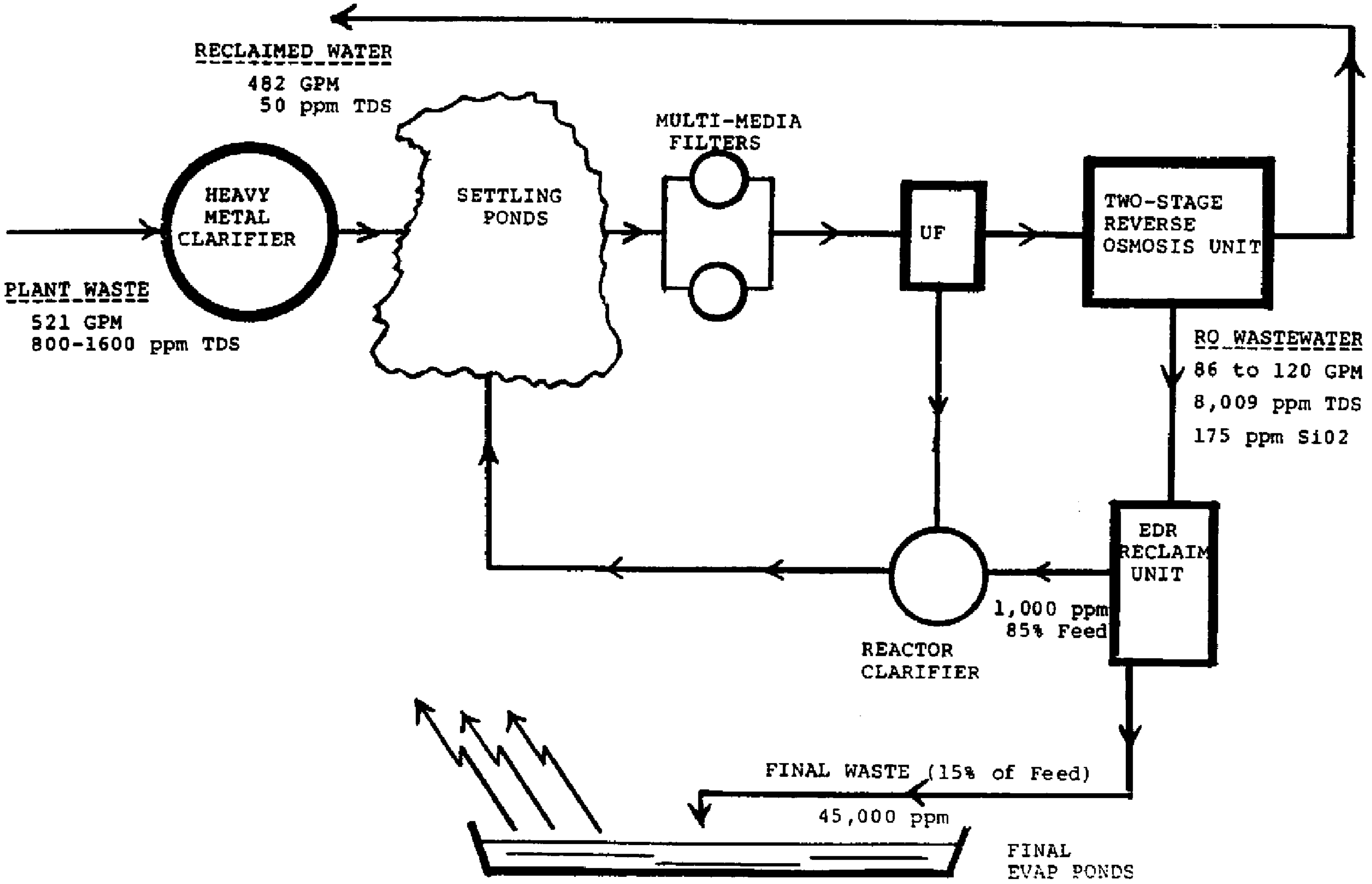

Figure 4 INDUSTRIAL WASTEWATER RECLAIM SYSTEM

plant wastewater fed to the IWRS would yield 482 gpm back to the facility as reclaimed water. The "design RO blowdown" was based on worst case conditions. Actual plant operation predicted an RO waste quality ranging from 3,000 ppm TDS to 8,009 ppm TDS. The data on Table 1 illustrates the worst case design feedwater to EDR. Table 2 shows the predicted performance of EDR based on the high TDS feedwater.

Table 1

DESIGN FEED ANALYSIS

	ppm
Na	2821
Ca	133
Mg	15
K	24
Cl	1942
HCO3	937
SO4	1933
NO3	29
Total TDS	8009
SiO2	175
pH	8.5

Table 2

DESIGN EDR PERFORMANCE SUMMARY

1.	RO Waste to EDR	85 - 120 gpm
	EDR Product	85% of feed
	EDR Waste	15% of feed
2.	EDR Product	1,000 ppm
	Feed Quality	8,009 ppm
	Waste to Ponds	45,000 ppm
3.	EDR Energy	15 kWhr/1,000 gal
4.	Chemical Feed	25 gal/day HCl

Comparing EDR and VC anticipated performances produced the results indicated in Table 3.

Table 3

PERFORMANCE COMPARISON

	EDR System	VC System
Up-Front Capital	$450,000 - EDR $300,000 - Clarifier	$1.5 M - $4.0 M
Cost of Reclaim	$1.25/1,000 gal	$8.00/1,000 gal
Reclaimed Water Quality	Less than 1,000 ppm	5 ppm
Wasteflow to Evaporation Ponds	13 gpm (from RO waste)	15 gpm (from RO and UF waste)
System Feed	RO waste only	RO and UF waste
Energy Consumption	15 kWhr/1,000 gal	100 kWhr/1,000 gal

Based on the above cost-effectiveness evaluation, the EDR process was selected for use in the new IWRS system.

Specifically, Figure 5 shows the overall design of the EDR system, as a simplified flow schematic diagram using the worst-case feedwater condition.

EDR system function is to reclaim RO blowdown. A six stage EDR system with one line of EDR membrane stacks (stages) was employed to provide a reclaim water with less than 1,000 ppm TDS. High water recovery was essential. Pond influence capacity was estimated at 40 to 50 gpm. Wastes to ponding included multi-media filter backwash (10 gpm averaged), RO cleaning chemical blowdown, EDR cleaning chemical blowdown, and a variety of other smaller possible flows. EDR water recovery was therefore to be maximized at 83% to 86% to allow a maximized availability for these "other" waste flows.

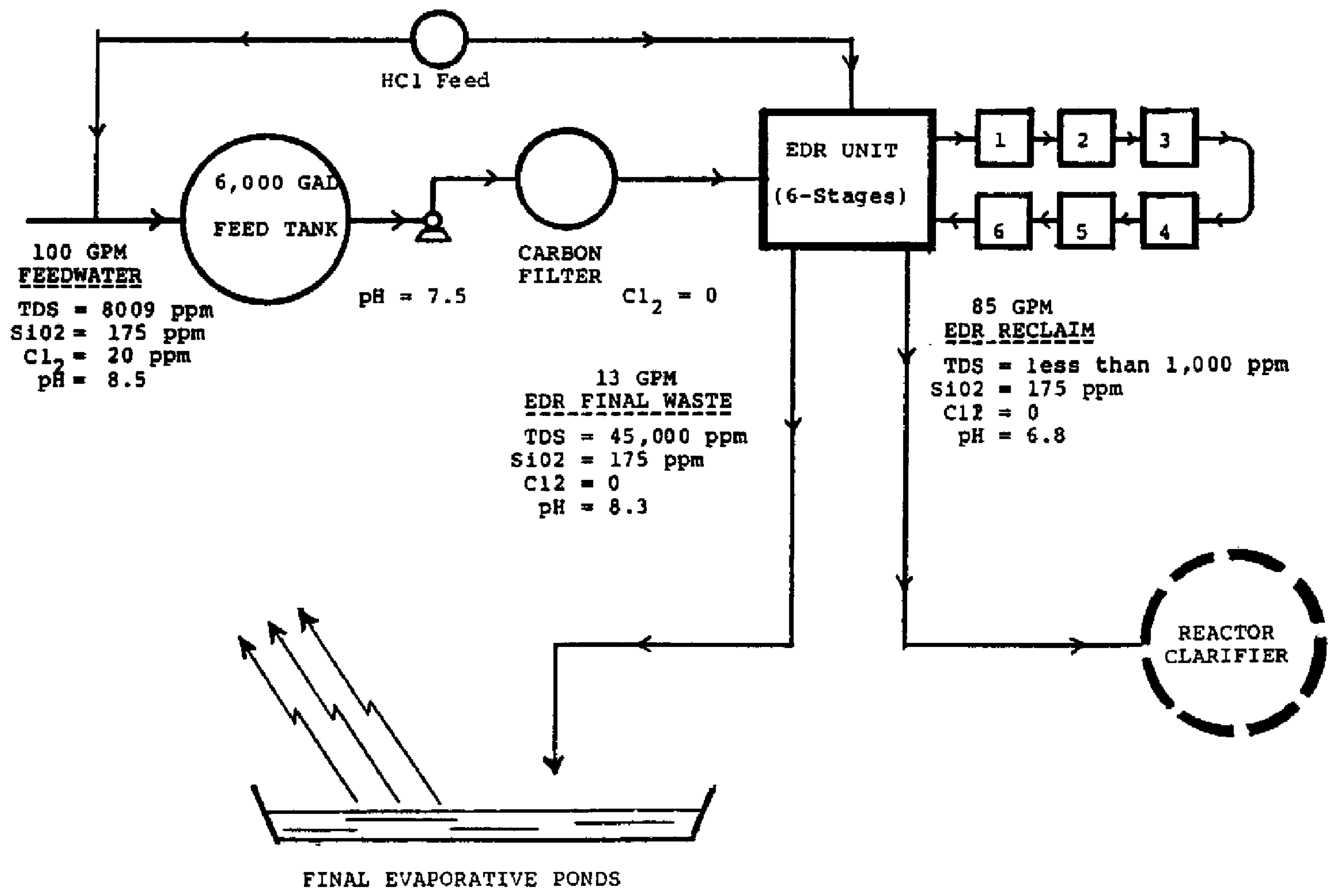

Figure 5 EDR BRINE RECLAIM UNIT

Figure 5 shows a 6,000 gallon EDR feed tank. This was incorporated to average out anticipated salinity swings from the RO blowdown. An activated carbon filter was incorporated to remove possibly as much as 20 ppm free residual chlorine. As called out in the BASICS OF ED/EDR, the upper limits for Langelier Index in EDR recirculating brine are +2.2 with no chemical feeds and +3.0 with chemical feed to brine. Using 83% to 86% water recovery, the 8,009 ppm TDS feedwater, and the 1,000 ppm, or better reclaimed product water, the equivalent Langelier Index was estimated at +3.6 in EDR brine.

To control Langelier Index a dosing of 15 gal/day of HCl into the EDR feedwater, before the averaging tank, effectively lowered the feed pH to a point where the Langelier Index of +3.0 in EDR brine was met. An additional dosing of 10 gal/day into the EDR brine loop effectively reduced the Langelier Index to +2.2. The final EDR waste brine at 13 gpm and 45,000 ppm TDS would flow by gravity to the existing evaporative ponds with no further treatment.

The EDR unit was specifically designed for maximum reliability and for the extreme variability anticipated with this application. To insure reliability of operation components like feed and brine pressurization pumps, cartridge filter housings, etc., were installed as duplex systems. To insure proper operation over the possibly wide swings in feedwater salinity, 3,000 ppm to 8,009 ppm TDS, a microprocessor master controller (MPC) was designed into the unit. Set points, based on feedwater conductivity were programmed into the MPC at which point individual EDR stacks, or stages, would be electrically shut down, starting with the last stage first. As feedwater conductivity continued to drop, additional stages would be shut down. This design provision insured that lower TDS feedwaters would not cause polarization in the later EDR stages.

Another condition required of this EDR unit was that an absolute minimum of operator attention and maintenance labor be required. Several special features were incorporated into the system. For example, the MPC unit was programmed to control the full clean-in-place (CIP) EDR membrane flushing/cleaning procedure, normally performanced once a month. A single push-button actuation by the maintenance staff personnel produced fully automatic chemicals feeding, chemicals recirculation, dumping to drain, membrane flushing/ rinsing, system checkout and bringing the EDR unit back on line. This feature would prove to be very successful.

The EDR unit was installed in late 1985 and initial system operation commenced in early 1986.

ACTUAL OPERATION OF EDR SYSTEM

To the present time, the IWRS has not seen wastewaters as high in TDS as anticipated. The RO unit has not produced the "worst case" level of salinity in brine blowdown to the EDR unit. While EDR was designed for an 8,009 ppm TDS feedwater, actual feed salinity has ranged from 3,000 ppm to 5,000+ ppm TDS. Table 4 illustrates a recent feedwater analysis and Table 5 shows EDR product.

Table 4
FEEDWATER ANALYSIS
March 30, 1988

	ppm
Na	1430
Ca	147
mg	9
K	0
Cl	878
HCO3	62
SO4	2040
NO3	0
TDS (ion)	4,579
SiO2	90
pH	6.1
TOC	11.6

Table 5
EDR PRODUCT
March 30, 1988

	ppm
Na	184
Ca	6
mg	1
K	0
Cl	16
HCO3	0
SO4	345
NO3	0
TDS (ion)	553
SiO2	90
pH	4.4
TOC	5.5

Since initiation of RO brine reclamation, the EDR unit has operated in excess of 12,000 hours. Based on actual operating conditions several items, or design elements, originally incorporated into the system have been modified/deleted.

1. EDR is not using any acid feed to either the feedwater or into the recirculating brine. At 85% water recovery the Langelier Index of EDR brine has been below the +2.2 upper limit cutoff for no chemicals addition described earlier.

2. The MPC control program and DC rectifier setting will be adjusted so that DC energy across each stack is "idealized," with each stack having the same energy setting. This will reduce both overall DC energy consumption and even out the eventual wear on stack electrode plates.

3. The EDR stacks have been reduced in size. Original "design" feed rate to EDR was 86 to 120 gpm. Actual feed rate has been 70 gpm. To optimize energy consumption and salinity reductions, EDR stacks have been reduced from 500 down to 400 cell pairs per stage.

4. The EDR unit has been intentionally shut down for long intervals of time by plant operator personnel. Since EDR reclaims a large, 85%, portion of RO waste, the 13 gpm going to evaporative ponds has been less than actual evaporation rates during summer months. To prevent the ponds from drying out, the EDR, during summer months, has been shut off and the actual RO brine has been sent to ponds to maintain a minimum liquid level.

Since system initiation, only one brief operational problem developed. EDR uses a small amount of HCl, 3 to 4 gpd, to keep the stack electrode chambers clean. Three to four times per day, a small amount of dilute HCl is injected into the electrode chambers for this purpose.

Plant personnel allowed the dilute acid day tank to run empty, acid feed stopped and some of the electrode plates became heavily scaled and the chambers plugged up. As a result, several electrode plates had to be replaced.

This situation was remedied by putting a level control system with alarm signal into the acid day tank unit. The failure to feed dilute acid to electrodes has not occurred again.

To date, the only significant spare parts replacement has been the early on electrode change-out as described above. In 12,000+ hours of operation, a total of $10,000 has been spent on spares. Based on the approximate 43 million gallons of reclaimed RO water provided by EDR, the total replacement parts cost is $0.26/1,000 gallons, including electrodes. Excluding this one-time upset condition, actual spares replacements are running at less than $0.10/1,000 gallons.

Per actual demand requirements EDR has been available for service approximately 95% of the time. This availability figure is in line with U.S. consulting engineering estimates for EDR reliability on the more usual brackish water to drinking water desalination applications of EDR.

OVERALL CONCLUSIONS

The installation of EDR for reclaiming RO blowdowns, to reduce feedwater supply requirements to RO in water short areas, and EDR's reduction of waste brine volumes to evaporative ponding has been an unconditional success. The data, and the successful performance from this installation, has already generated additional applications for EDR concentration of RO blowdowns, with further inquiries on even newer potential installations. The EDR process has shown itself to be highly reliable. EDR is easy to operate, particularly with modifications made to the system for brine concentration applications. The process has not developed any intrinsic weakness in over 12,000 hours of operation at this site.

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HIGH RECOVERY REVERSE OSMOSIS

by

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INTRODUCTION

The costs of transmission and disposal of RO plant concentrates per unit of water production are directly related to brine volumes, which affect size of pipe, stripping towers, sedimentation basins, outfalls and/or injection wells, and any repumping required en route. These costs may be markedly reduced by increasing product recovery.

For example, as illustrated in Figure 1, the volume of brine to be conveyed, treated, and discharged at 90% recovery is less than one-half of that at 80%, and at 95%, less than one-fifth.

CONSTRAINTS

There are technological constraints to such an adjustment. For most surface and groundwaters, without pretreatment such a concentration of dissolved substances in the feed (10 times at 90% recovery) would result in heavy scaling in both membranes and downstream brine system components. Without post-treatment, deep injection wells will be at risk of plugging.

This paper will address the pre- and post-treatment techniques applicable whereby brine disposal costs and constraints can be minimized via high recovery RO.

IMPACT OF RAW WATER COMPOSITION ON RECOVERY

The mechanisms of brine concentration by RO, i.e., separation of molecular species at ambient temperatures, are well known and need not be further addressed here. However, to highlight the reasons for treatment options, the following are the scale-forming cast of characters to be faced at high recoveries:

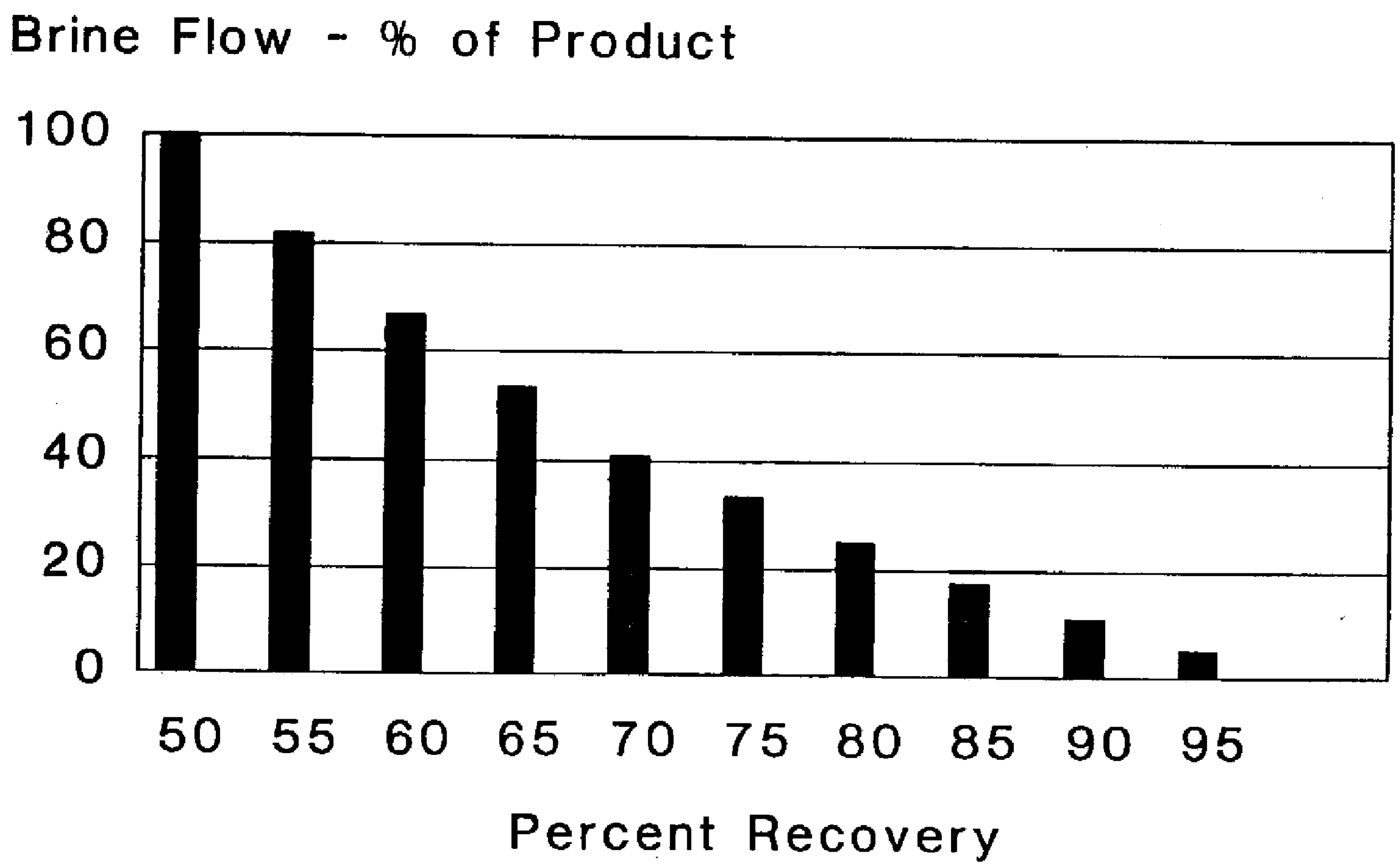


Figure 1 BRINE FLOW AS PERCENT OF PRODUCT FLOW VERSUS PERCENT RECOVERY

Calcium Sulfate (dihydrate)	$CaSO_4.2H_2O$
Strontium Sulfate	$SaSO_4$
Barium Sulfate	$BaSO_4$
Silica	SiO_2

Of course, calcium carbonate ($CaCO_3$) scale can be readily prevented at any concentration by acid pretreatment.

THE SULFATES

The three sulfates are listed in order of their theoretical solubility products (Ksp) at 25°C and similar solution strengths.

$CaSO_4$	3×10^{-4}	(most soluble)
$SrSO_4$	2×10^{-6}	(most soluble)
$BrSO_4$	1×10^{-9}	(least soluble)

Sr and Ba sulfate scales have seldom occurred alone, and industry practice has been to use K_{sp} multipliers of 8 and 40, respectively, for design limits when scale inhibitors are used.

$CaSO_4$ is the most prevalent non-carbonate scale species found in groundwaters and its solubility is far more predictable. Although some supersaturation can also be achieved with scale inhibitors ($1.2 \times K_{sp}$ is acceptable for most raw water supplies), high recovery RO will require pre- and/or post-treatment to inhibit $CaSO_4$ scaling in membranes, brine systems, and injection wells.

SILICA

Fortunately, some pretreatment methods discussed below can reduce silica to acceptable levels. Solubility of SiO_2 can be improved by raising water temperature or raising pH above 8; however, these measures may be costly or impractical in many cases.

PRE- AND POST-TREATMENT FOR HIGH RECOVERY

Figure 2 illustrates in graphical form the pronounced differences in ionic distribution from one regional groundwater to the next.

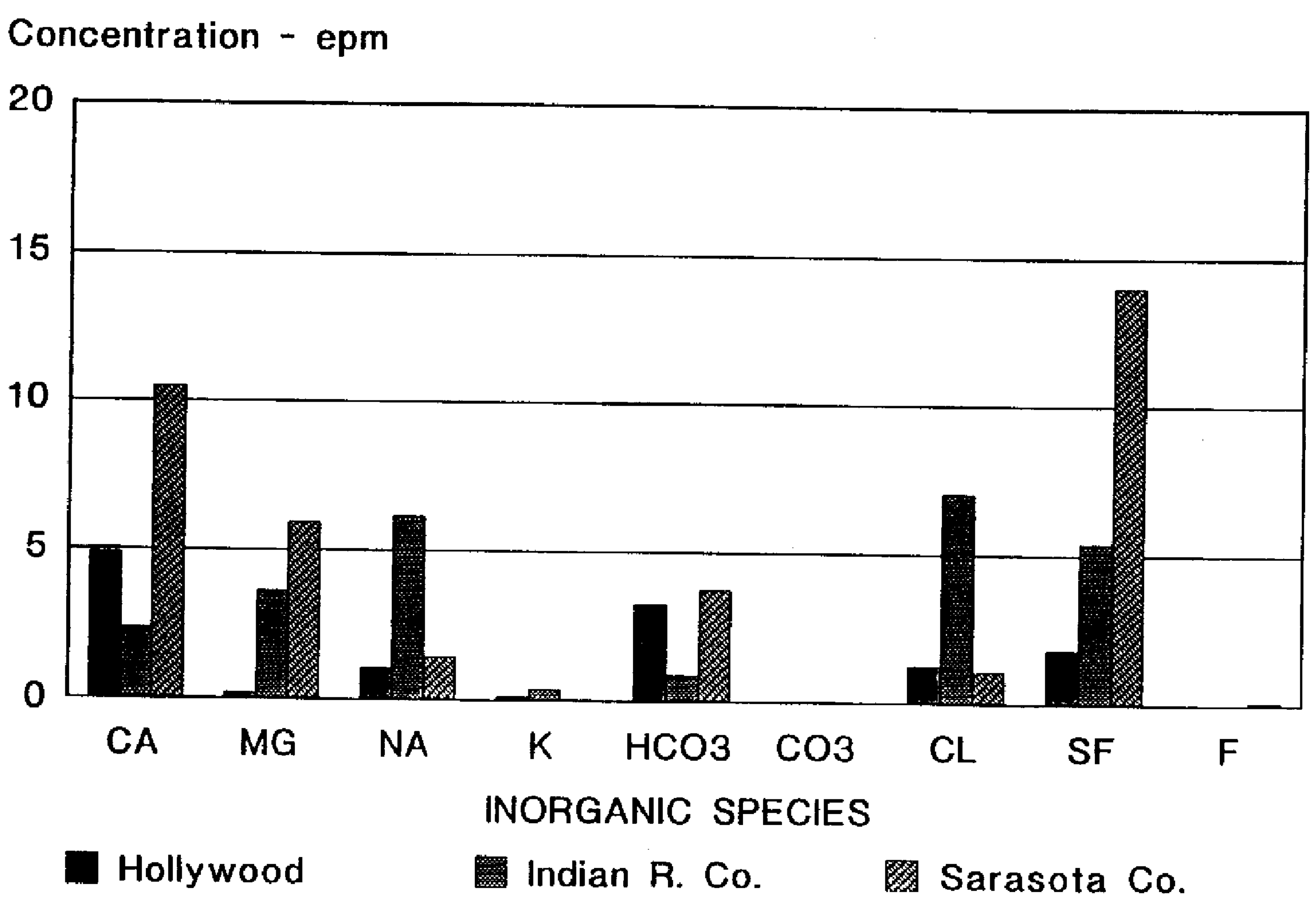


Figure 2 RAW WATER CHARACTERIZATION FOR HIGH RECOVERY RO

Predictive calculations of solubility of $CaSO_4$ vs. solution strength and temperature, will show the following for each raw water at 90% and 95% recoveries.

RECOVERY	HOLLYWOOD	INDIAN RIVER COUNTY	SARASOTA COUNTY
90%	Soluble	Soluble	Exceeds solubility
95%	Barely soluble	Exceeds solubility	Exceeds solubility

To achieve solubility requires removal of Ca or SO_4 ion from solution.

PRETREATMENT BY LIME-SODA SOFTENING

Ca removal from the raw feed has the advantages of reducting acid requirement to prevent $CaCO_3$ scale, especially if lime or lime soda softening is used as a pretreatment. However, it involves substantial solids handling and ultimate lime sludge disposal.

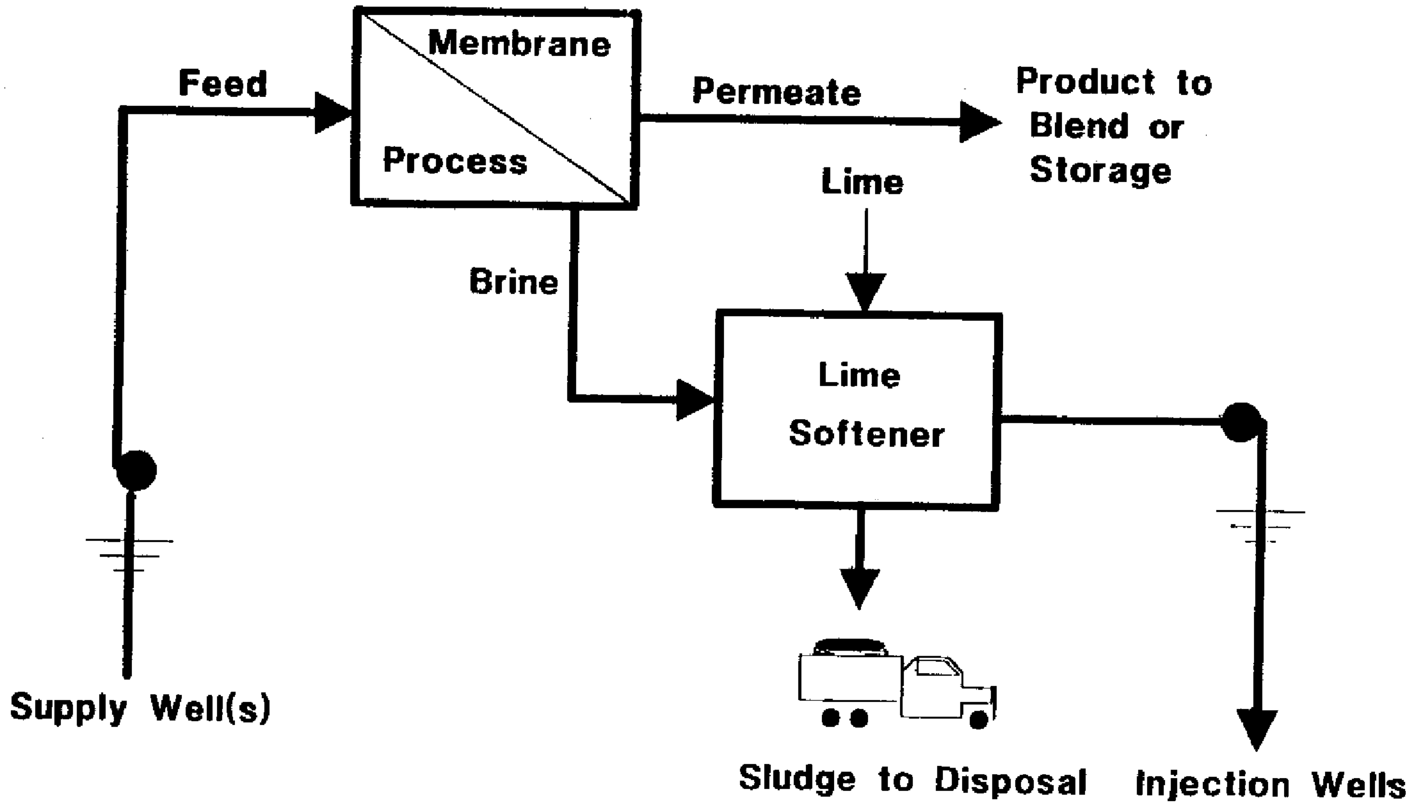
POST-TREATMENT BY LIME/LIME-SODA SOFTENING

Fouling of higher stage membranes by $CaSO_4$ can be detected early enough to be corrected; however, downhole precipitation in the expensive injection well may not at considerable hazard to the entire project. Post-treatment of the brine by lime or lime-soda softening (Figure 3) may be prudent in many cases.

PRETREATMENT BY DESULFATION

Sulfate removal by a weak base ion exchanger, regenerable by the NaCl in the brine reject, is a relatively new but attractive option to increase $CaSO_4$ solubility, as well as $BrSO_4$ and $SrSO_4$ (Figure 4). However, its major drawback is that the SO_4/Cl exchange may raise feed chlorides to such an extent that LP RO (rather than ULP softening) membranes will be necessary to achieve final water quality standards.

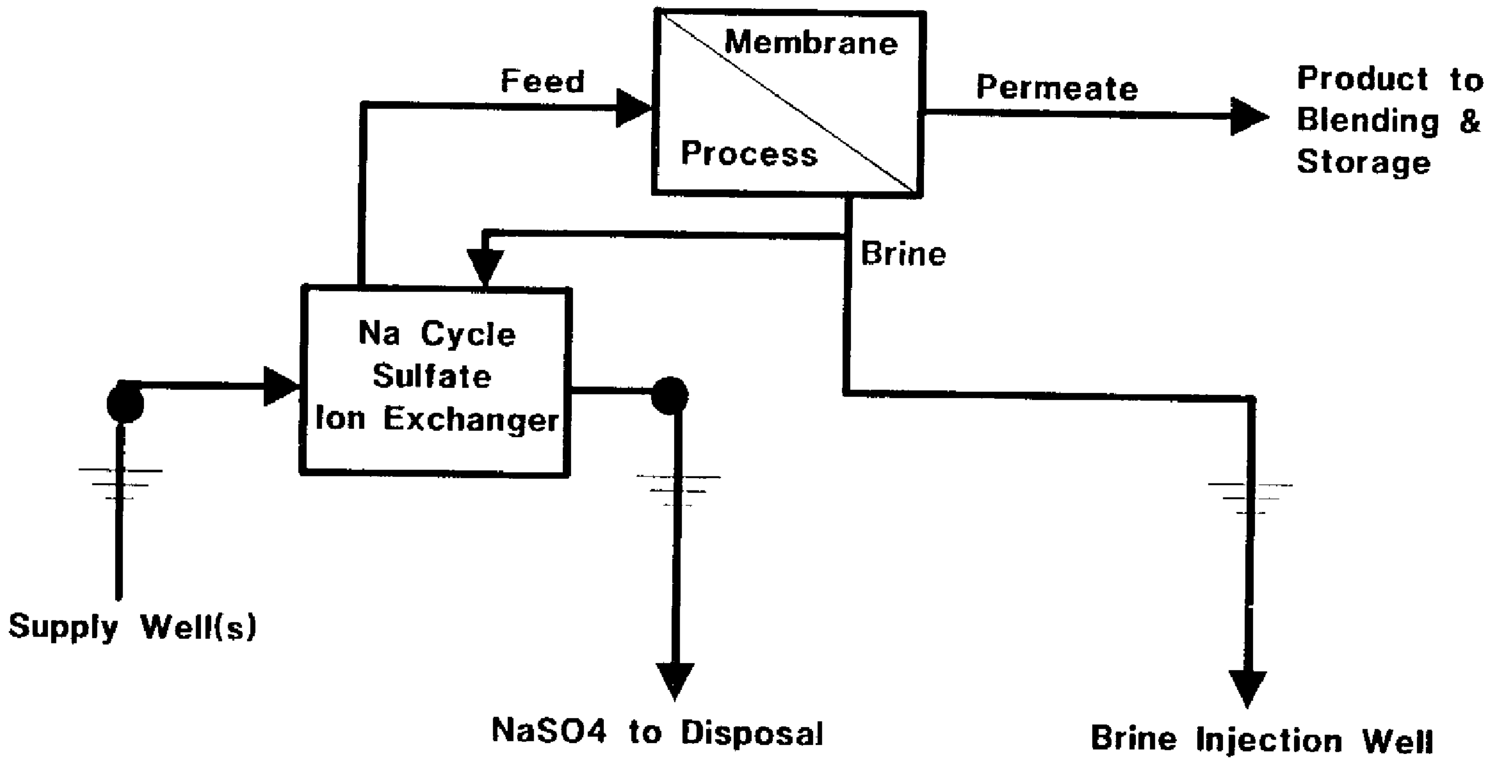
High Recovery Membrane Processes for Minimizing Disposal Volume



Benefits • Prevents $CaSO_4$ plugging of injection well

Figure 3 BRINE LIME SOFTENING SCHEME TO PROTECT INJECTION WELLS

High Recovery Membrane Processes for Minimizing Disposal Volume



Benefits
- Prevents membrane scaling by Ca, Ba & Sr sulfate
- Prevents SO4 plugging of injection well

Drawback
- Feed Cl increase by SO4/Cl exchange may require LP vs ULP membranes

Figure 4 Desulfation Pretreatment Scheme for High Non-Carbonate Feedwaters

BRINE CONCENTRATION, SOLIDS DRYING, AND DISTILLATE PRODUCTION

For many years, zero discharge requirements have been met by electric utilities using mechanical evaporative techniques in place of solar ponds. These devices are multi-effect evaporators powered by vapor recompression for maximum thermal efficiency, and feature internal recirculation of $CaCO_4$ seed material which acts as the receptor for further precipitation. The final slurry is demoisturized and/or transported to a disposal site.

The product water is a pure distillate which, as shown in Figure 5, can be used or sold separately.

Both capital and energy costs are fairly high but are proven economically justifiable in the utility industry by savings in ponding area.

Any RO facility faced with deep well injection, lengthly disposal pipeline pumping, or even zero discharge, may have a viable option by this technique. Additional economic benefit may even be realized by the sale of premium quality distillate.

IMPACT ON PRODUCT QUALITY AND COST

Operation at high recoveries is accompanied by reduction in salt rejection performance and product flow. To compensate, options are available such as:

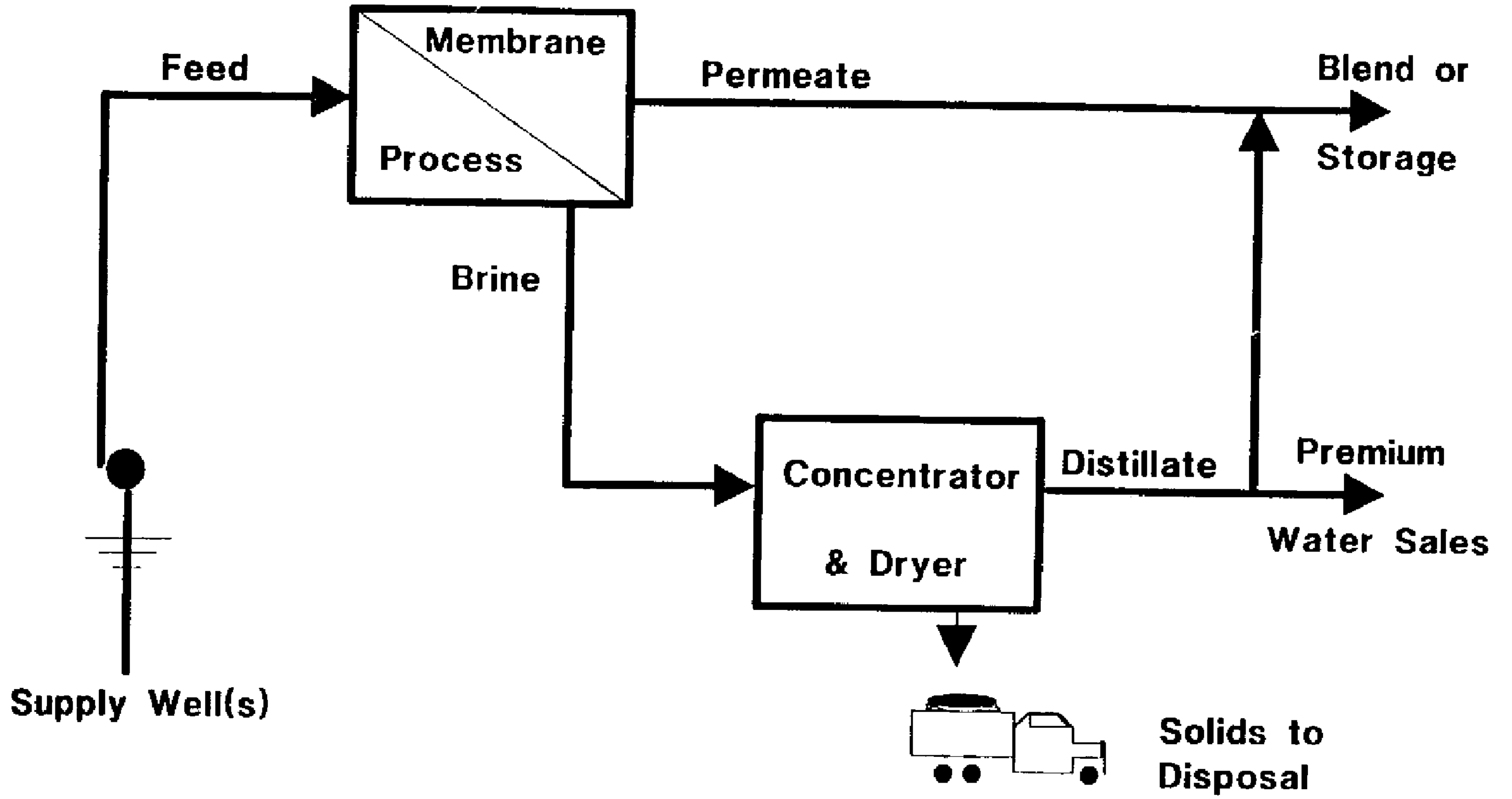
- o Increasing interstage driving pressure by booster pumps to improve quality and quantity

- o Increasing surface area to maintain productivity

CONCLUSIONS

As a means to minimize or eliminate brine disposal problems, high recovery RO must be accompanied by pre- or post-treatment to avoid scale precipitation, almost entirely by $CaSO_4$.

High Recovery Membrane Processes for Minimizing Disposal Volume



Benefits
- Eliminates need for injection well(s)
- Produces byproduct distilled water

Drawback
- Concentrator/dryer requires high energy

Figure 5 BRINE CONCENTRATION AND DRYING WITH PREMIUM WATER PRODUCTION

All such methods will add to water cost. However, rigorous comparison must be made with the costs and constraints of brine disposal at recoveries low enough not to require these treatments. Such examination is invariably and totally site-specific.

Prior to detailed design of any large RO facility, it is always prudent to invest in a pilot plant testing program, whereby membrane performance under varying recovery and flux may be evaluated on the raw feed to be used at full scale. Because of the even tighter design limits imposed at high recovery, pilot tests of combined membrane and treatment processes are absolutely essential.

WHERE DO WE GO FROM HERE?

A ROUNDTABLE DISCUSSION

Moderated by

Brian E. Smith, Chief
Special Investigations Branch
California Department of Water Resources
Fresno, California

With Panelists

David Paul, Consultant
Farmington, New Mexico

Bill Harlow. Consultant
Englewood, Florida

Howard L. Rhodes, Director
Division of Water Facilities
Florida Department of Environmental Regulation
Tallahassee, Florida

William Conlon, Principal Engineer
James M. Montgomery Engineers
Port Charlotte, Florida

Bruce Watson, Senior Consultant
Stone & Webster Engineering Corporation
Ft. Lauderdale, Florida

Thomas M. Leahy, III
Water Resource Engineer
Virginia Beach, Virginia

DISPOSAL OF CONCENTRATES
FROM BRACKISH WATER DESALTING PLANTS

November 18, 1988

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Water Resource Engineer
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This paper was prepared by the editor based on a recording of the presentation. Where deemed appropriate, the presentation has been edited for clarity.

O. K. BUROS

The roundtable discussion will be on "Where are we going to go from here?" We are going to talk about some of the things, that based on the knowledge and information that we have presented so far, might help us to come to a solution or an idea of where we are and what we need to do to go beyond this point in the subject of the disposal of desalting concentrates. The chairman of the roundtable will be Brian Smith.

BRIAN SMITH

Where do we go from here? The idea here is to have a roundtable discussion on a number of topics related to concentrate disposal. First I will introduce the members of the panel. Some you know as they have already spoken but some have not. Then to begin, we will ask each of them to say a few words on how they have felt about the conference and the issue of concentrate disposal.

On my far right is David Paul. He is an industrial water consultant, specializing in reverse osmosis training. He is now located in Farmington, New Mexico. He will be taking a few minutes to discuss with us concentrate disposal using a thermal brine concentrator and solar evaporation. David's experience in this area has been 8 years as manager of the San Juan generating station's $100 million water management system which includes 2,000 gpm of RO, 2,300 gpm of falling film evaporation, and 115 acres of solar evaporation ponds.

Next is Mr. Conlon who spoke earlier this morning and then Mr. Howard L. Rhodes who is the Director of Water Facilities Division of the Florida Department of Environmental Regulation located in Tallahassee. He will be discussing DER's position on reuse and regulatory constraints. Mr. Rhodes' experience in this area has been as chair of an adhoc group of professionals in the field of reverse osmosis seeking solutions to concentrate disposal problems. He is an environmental engineer with a bachelor's and master's degree from Auburn University. He has worked for 19 years with DER in many different areas. He was the Director of Environmental Programs five years prior to his present position.

Next is Mr. Watson who also spoke earlier and Mr. Harlow who is President of NWSIA who you have already met. Mr. Tom Leahy is a water resource engineer with the City of Virginia Beach, Virginia. He will be discussing costs and environmental processes associated with disposal. Mr. Leahy has 5 years experience in this area with Dow and IBM in desalting and ultrapurification and electronics processing. He has 8 years with the City of Virginia Beach working in water resources evaluation and permit processing. He has a bachelor's and master's degree in chemical engineering from the University of Florida. He is a licensed professional engineer and is project manager for a $220 million water supply project for the City of Virginia Beach and Chesapeake.

DAVID PAUL

I think that the biggest thing that strikes me is the cooperative nature that we see here with the National Water Supply Improvement Association, the South Florida Water Management District, and DER. I think that if the rest of the country could use Florida as an example, that we could stop some of the national issues that we have. It really is going to take industry, the government, and the public working together to solve these problems.

This week I was doing a training program at Cape Coral. Having come from the power industry in the southwest, I am going to briefly describe to you some of the equipment and how complicated it can get. I worked for 8 years at the San Juan generating station. It is a 1800 megawatt coal-fired plant which has spent $140 million on water treatment. This plant is one of the most technologically advanced and one of the cleanest in the world. It requires this advanced industrial water treatment because it is a zero discharge facility. About 13,000 gpm is discharged by the plant. It is used every minute of every day of the year. None of this discharged water can leave the facility except through evaporation. It all has to be processed or recycled to the plant so it is a zero discharge station.

The air pollution control system is unique in the United States in that it removes SO_2 (sulfur dioxide) from the stack gas using a sodium sulfide solution. That makes the wastewater really complicated and wastewater is the feedwater to RO here. So there is a lot of extensive pretreatment.

Leon Awerbuch previously talked about combining reverse osmosis with brine concentrators. San Juan has a brine concentrator which will take the reject or the concentrate from the reverse osmosis system, concentrate that even more so that every 100 gpm of feedwater becomes 3 gpm of concentrate. That concentrated concentrate is 30 to 40% solids and goes out to the solar evaporation ponds. So, the feedwater to the reverse osmosis system is all of the discharged water from the power station, whether it is a sewage, water from cooling tower blowdowns, or anything imaginable from the power plant.

I am just going to run through the pretreatment scheme. From the collection pond it goes through an extensive pretreatment system to get out all of the compounds in the water that would damage the reverse osmosis system. Because we are in New Mexico, it gets very cold in the winter time, so the feedwater has to be warmed in a plate and frame heat exchanger. It then goes to a lime soda-ash softener where most of the suspended solids are removed. As a finishing process for the suspended solids, the water goes through a dual media anthracite filter. This is followed by a 2,000 gpm RO unit. Before entering the RO membranes, it is dechlorinated, acidified, passed through micron cartridge filters, and then pressurized with the high pressure pumps.

The RO system produces a permeate, which is a good water, and a concentrate. This is a 80% recovery system, so 20% of feedwater becomes concentrate and goes to brine concentrate evaporators. The brine from the concentrator then goes out to 115 acres of solar evaporation ponds, which completes the job of concentrating the solids.

WILLIAM CONLON

I agree with Dave's comments on the conference so far. I have been asked to talk a little bit about economic considerations of concentrate disposal.

Up until now, the trends in membrane processes have been for costs to go down. The trend has been going downward. In fact, there is a curve in a recent publication which a lot of people here contributed to on using desalination technologies for water treatment. It is a background paper by the Office of Technology Assessment. There is a curve in there showing RO costs and ED costs going down in the future. However, I am a little concerned how all the treatment and so forth that may be needed due to concentrate disposal regulations will affect future costs. This could occur as RO plants are located further inland or because of other water concerns that these costs will now start to go back up. This is a concern that we all should have.

As far as what disposal method is best, I would have to agree with the other gentleman that spoke earlier, in that it really is site-specific. There is no one disposal method that works at one site that is exactly the same for another particular disposal situation and there is no concentrate water quality that is exactly the same either. The costs varies from location to location. Then there are other variables such as pretreatment required, the method of disposal, the O&M costs, how much staffing is required, permitting, and the distance from the water treatment plant site to the disposal point. If I had a preference, I would prefer to go to something easy like surface water, then a brackish groundwater in coastal zones, and then possibly deep well injection rather than get into the esoteric methods which seem to be very possible.

HOWARD RHODES

About a year ago, Bill Conlon mentioned that we had a task force that was set up to address some of the issues that were beginning to come to the forefront in the area of concentrate disposal. I think it was recognized at that time by professionals in the field that things were getting a little bit tight and difficult to deal with, especially compared to some of the earlier days. We had about three meetings and probably will have some more in the future.

Basically, what those meetings were to do was to address the issues here in the state in terms of regulatory issues where we might have problems in the area of concentrate disposal. It resulted in some fairly good ideas that came forth and probably a better understanding by all parties of some of the problems. That will not be the last type of meeting that we are going to have. I am totally of the opinion that RO is an salt derivative type treatment process that is going to become the wave of the future of the state and I certainly hope so. The reason I do is that we have several things at play here, some of which have not been brought up and I think that everything I can say about RO and the concentrate has already been mentioned for the most part but I would like to introduce two or three other items that have not been brought up.

One of them is that the population of the State in Florida is migrating. Whenever they come to the state, about 80 to 95% of the folks will want to live on the coastal areas. There are not too many who want to go to the central or northern part of the state. What that does is to generate need for water on the coastal areas. As a result of that, we have water that is being depleted along the coastal areas around the entire state. The subsequent result of the large populations is that the political power centers on the coastal areas and their need for water will generate whatever muscle is needed to get the water, wherever it is, or whatever is needed. One of the results has already occurred in the west central part of the state. That has to do with water wars and we are going to see more of that happening in other parts of the state.

Processes like RO tend to generate the water at the site and location where people are. It also tends to generate a problem called concentrate disposal. About 10 years ago, I started telling people that the biggest problem in wastewater treatment was not the treatment itself but the disposal of the wastewater when they got through. That pretty much proved to be true because that is where the costly item is today is in the disposal. The engineering, the technology, and wastewater treatment is not a problem in the treatment process. Everybody knows how to do that. Disposal is the big problem. I predict the same thing for desalting and I think that what I am seeing here today is that RO concentrate disposal is going to be the big problem in this industry in the future and I think that what we, as a regulatory agency in the state, are going to do and we are committed to do this, is to work with this industry and the professionals in the industry to make sure that the disposal of concentrate is a viable way to promote reuse in this state. It solves a number of problems.

Another problem it solves which may not be readily evident is when surface water or groundwater is drained to population centers, it lowers the water table and sets up an ecological destruction process. Whether it be from streams or whether it be from groundwater, it is ultimately some sort of outflow from streams and lakes and makes that water no longer available for your ecological system. So from an environmental viewpoint, it is a very good reason for us to be taking brackish water that cannot be used for other means.

Another item that may be of some interest is in some of these task forces that we have had in the past. They have been pretty much adhoc and we may continue those in adhoc, or maybe even in a more formalized way, in the future. One of the reasons being that we, in the agency, have just gone through a major reorganization and now we have what is called a Division of Water Facilities as opposed to some of the other organizational units we may have had in the past. This should give us a better opportunity to focus on some of problems that we have in the state.

BRUCE WATSON

Was the issue discussed of the potential of plugging of injection wells due to running close to the concentration boundary of some of these salts? I think it is a very interesting one and one that ought to be explored.

I personally am not necessarily so much in the membrane processes as certainly some of the others. As on occasion I have got up at 3:00 a.m. wanting to see how a test of one kind or another is going and have found operators asleep, or plants unattended, or setpoints are way off the mark. Might one think that if we are to get most of the squeal from the pig, that is to run right up to the maximum concentration possible or feasible with the water supply you have, and with the pre- and post-treatments. Is it conceivable that in the long term, that a very expensive injection well can be put out of action? Is that something that has been encountered or may be something that could be a real problem?

BILL HARLOW

Thanks Bruce, you really got me right into one of the reasons why I decided to retire. Howard has already touched on something that I really wanted to speak about because I got the prediction and I am looking just 11 years ahead. I am going to tell you this right now, that if you draw a line from the middle of Tampa Bay to Sebring, back to Melbourne, that the land area south of that is going to run out of water. The area south of the line that I described is the potable water, recharged by water that comes down from the skies above and soaks into the ground and replenishes the water table. At least that is my impression of what is happening because I have seen it happen in Englewood.

I will make the statement that there will not be a community within 25 to 50 miles of the coastline from that area all the way around, that will not be using reverse osmosis or some desalting technology to supply the hoards of people that locate there in the next 11 years. I hope you agree with me on that one, Howard.

The thing that really strikes me is that in my chemical engineering background, I know that what goes in has got to equal what comes out. So, therefore, if we use some sort of a desalting process, if we take water that we can put into the distribution mains to satisfy the needs of the community, we still have this thing that we today have been calling concentrate to dispose of.

In Englewood we have some of the most brackish, brackish water that is being used by any of the RO plants in the state. I won't say we have the most brackish but we are right near the top. I did a little figuring and for 1 million gallons of water produced, we are going to have something around 56,000 pounds per day of TDS that we are going to have to dispose of. Think about it for a little while and decide how you are going to do it.

Right now, Englewood is putting concentrate down a well. The thing that bothers me a great deal about all the sorts of things that we are doing is that the EPA is currently following the dictates of Congress and the Safe Drinking Water Act and they are asking the utilities and the water providers of the country to analyze their raw water and their distribution water for some 83 chemicals and items. They are going to add 25 more each year and one of these days, as Tom Leahy says, somebody is going to discover that they have got an abnormal amount of 2-4 tri-awful-awful in their water supply and they aren't going to be allowed to get rid of it.

What is going to happen? They won't let us put it back in the ground again. They won't let us do something to it that will throw it out in the air. We are going to have to discover some way of taking care of this horrible compound that might be there. It is something to think about.

As far as this business of plugging up the well goes. I have nightmares about what is going to happen to the day that the well at Englewood decides to get plugged. We started out operating that plant with what was known as a waste load allocation from the DER which allowed us to discharge 500,000 gallons of brine or concentrate into Godfrey Creek and it is going to be up for renewal in 1989. The board of supervisors, who is an elected board of lay people, decided that they didn't need that because we have the well. So they are not going to spend any money to renew that permit. The net result is that there is going to come the day that they have to renew the 5 year operating permit on that well. That is going to require that they shut everything down while they do an integrity test on the well. We are in for some fun.

TOM LEAHY

It's nice to be in front of a technically-oriented and friendly crowd. Lately I have been in front of a lot of crowds that are non-technical and very hostile because the project that I am putting in goes through a number of jurisdictions that would rather that we just didn't exist and a lot of times I have felt like a dragon addressing the knights of the roundtable.

I would like to tell you a little about our investigations into the costs of desalting and its pertinence here. The reason is that our idea of brine disposal for estimating these costs was a pipeline to a ditch. It really wasn't a ditch, it was a river but it was a small river. The headwaters of it drained suburban areas. You can imagine that the water quality wasn't very good. When it didn't rain we had a drought and basically it became a mud flat. The main body of this river opened into the Elizabeth and James Rivers which had very heavy ship building and drydock industries. That portion of the Elizabeth River had the distinction of being the most polluted water system in the country until Bush discovered Boston Harbor. Maybe it is the second most polluted. If it is one of the most polluted rivers in the world, who cares what we are going to put into this river. We planned to add some oxygen back by cascading the flow over some steps or rip-rap so that it won't be anaerobic and bring the pH up. This would prevent fish kills because that is bad for public relations as people don't want to see dead fish washing up but otherwise we are not going to worry about it too much. It never dawned on us that somebody would come up and try to clean that river up and then say, "Well, any discharges into this river have to be clean now."

So we figured out a cost of a 10 MGD plant and it came out to be about $25 million. Immediately a lot of people who supply equipment said "Nah, we can do it for less than that." We asked how much. They said they could do it for 40% less than that. We said, well, wait a minute; this $25 million isn't all desalting, only $10 million is the desalting plant. The groundwater collection system is $10 million and that broke out to about $5 million for some very expensive, very deep, wells that had to be separated by several thousand feet and then there was very expensive and extensive collection piping systems. So that accounted for the $20 million; the other $5 million was the indirect costs that everybody always forgets about like design, property, and remodification of our distribution system. The latter was necessary because we would now be putting water into a system at a new location.

I guess the point is that within the $25 million, we had next to no cost for brine discharge. Now if we were to build that project, it would be affected by the Chesapeake Bay initiative which is directed to cleaning up the Chesapeake Bay. We would now have to deal with the 2 milligram per liter of phosphorus and this is not from the sodium hexametaphosphate but the groundwater itself which had phosphorus in it.

So obviously when you concentrate the water, you get four times as much phosphorus as was there and that is very important when you go into an estuary because that tends to speed up degradation. The concentrate would also be saturated with iron and a couple of other salts. We said, "Hey, they will floc out and settle, we are in mud flats now." But that really wouldn't make the 30/30 discharge from a secondary sewage treatment plant. So I guess the point I want to make is that to do the project now would entail some substantial additional costs for brine disposal.

The other thing that I wanted to mention was in the environmental area. The last decade or so everybody said this is environmentally sound. We are going to desalt this water that nobody wanted. We're not going to build a reservoir, we're not going to build a pipe to a reservoir that nobody wants us to build. We'll just get rid of this brine and forget about it. Now we realize that it is a waste discharge. In Florida, I will tip my hat to you, your Corps takes strong control of it; you have strong state and jurisdictional governments, well organized to solve these problems. In Virginia, they don't. Basically I guess, your DER adopts all the federal regulations and the Clean Water Act. They probably add some of their own and that is the framework that you work with them.

In any case, you are going to have to get a permit and if your project involves dredging and filling in wetland areas, you are probably going to have to get a U.S. Army Corps of Engineers permit too and these permits are going to require you to do an environmental assessment. If that says there is going to be some impacts, you are going to have to do an environmental impact statement.

Well, all of a sudden everybody in the world gets to put their two cents in here--Fish and Wildlife, EPA, National Fisheries Service, all the special interest groups, the Sierra Club, etc. One person may think that what you are doing is great and another person may not like what you're doing and you may have environmental agencies with cross purposes. Up in Virginia we have one environmental agency pushing very hard for jurisdiction to go to desalting because they don't want to build a reservoir because it is going to flood some wetlands. Another environmental agency, charged with the protection of groundwater, doesn't want to put the wells in because the groundwater in the area is in a critical situation. They want you to build a surface water impoundment. You get this problem of cross purposes.

The fact of the matter is that if someone doesn't want you doing it, maybe a garden club in the area in which you're going to discharge this water to an estuary and they are growing daffodils along the side; and if that garden club president happens to have a spouse who is a lawyer, they are going to come in there and challenge your decisions. Then you have to do these environmental assessments, even though the impact may be minimal, you are going to look at the whole range of projects. So then someone is going to start saying, "We will evaluate the groundwater impacts and all this." It gets very complicated and the thought that RO plants might allow you to get away from all those problems doesn't work anymore. Now we are finding out that it is getting just as complicated as the other type of projects.

BRIAN SMITH

A number of the presentations today have concentrated on some of the regulations that exist here in Florida and their effects. A question that I would ask of our panel members is to propose or to suggest what kind of changes that Florida needs and what the panel members here would recommend. I don't know where to begin with in terms of specifics but I thought that I would let Mr. Conlon begin and then we will just go round the table and let Mr. Rhodes respond.

BILL CONLON

First I just wanted to comment on what Bruce Watson had commented on, what happens to the injection wells after they have been in operation for a while. I can only tell you from my personal experience of two wells that I have been involved with were RO. One in Plantation in Sarasota County, and one in Venice Gardens. One had been in operation for 3 years and one for about 5 years.

They are going through an integrity test right now and the initial pressures that were on the wells, one was 4-1/2 pounds and the other was about 7-1/2 pounds. Those pressures are still the same today. Both of those wells are about 1,400 feet deep. When the wells were TV'ed, they said that there was enough room down there that you could put in a couple of Metro buses, it was such a large hole. Tom Missimer, who is a hydrologist, has mentioned many times that he thinks that is a problem, especially with the formation of the Floridan aquifer which is like the enamel on your teeth which would plug up a well. He said you wouldn't be able to clean it, and so forth, and he got me real scared and I was like Howard, waking up in the middle of the night thinking about it.

There are some of the worst brackish waters in Sarasota County. They are high in calcium sulfate. We haven't seen a problem yet but we really don't know what is going to happen. I do know that USGS has a computer model that is available, I can't remember the name of it, but it predicts what will happen when you mix two waters in an injection well. I know that is available and maybe they will run the program for you and you'll sleep better at night. But that is a concern and I think that it has already been addressed. There are certain methods that concentrate to a greater degree so that you would probably have to have pretreatment before you put it down to prevent problems from happening.

As far as where do we go from here, I just hope that the spirit of cooperation that has already taken place, that has enabled us to get some changes in the regulations in a very short period of time continues between the regulatory agencies and those of us who work in the field. I don't know exactly, because of the complex nature of some of these regulations, what we ought to attack next. I think that should be left to Howard to answer.

BRIAN SMITH

Do any of you in the audience who are operators or owners of facilities have any ideas or any changes that might want to discuss relative to any specific changes in regulations or in the process of making regulations. You find in California that sometimes it is a matter of understanding the process. I know I have run into it personally. One of the things that Bill Harlow said struck a cord in me, is waking up at midnight and worrying about our operators. This is my first chance to sit down with a couple of people who have been managers of very complex water treatment plants. I thought that maybe I was the only one who had gone through these kinds of things, up at midnight worrying about if one of your operators is going to dump a whole clarifier full of lime down the San Luis drain which they managed to do at 3:00 a.m. one night. The result was the Fish & Game people knocking on the door the next morning. They wear guns in our state. When they knock on your door you take it seriously.

I was going to ask David Paul, what does the role of training play in preventing problems once you are under regulation and things of that nature? David is in the business now of training operators and has been a manager of a water treatment facility.

DAVID PAUL

The $100 million water management system at San Juan station takes about 120 people, working 24 hours a day, 365 days a year. The budget for that was somewhere in the neighborhood of $10 to $12 million a year. What I have found in the past 8 years of management experience I have there is that the single best thing that we could do was to train our people, so that they were not treated like mushrooms. Everyone knows about the alternative of keeping them in the dark and being careful what you feed them. That is basically what I have seen in the majority of the RO plants and overall in the desalination industry. People are grossly undertraining. It is tough enough to get a company or a municipality to spend the capital dollars on RO systems because it is a lot of money. However, once that is done it is necessary to go ahead and protect that investment with dollars in people and their training. Unfortunately, that is kind of unusual.

To give you an example, in my department where there were 36 water treatment operators, over a 4 year period we have reduced the operating costs from $5 million a year down to $2.5 million. We put $1 million in training and that is astronomical, isn't it, but that $1 million of training was to protect a $100 million investment and so it doesn't sound so big then. I just can't say enough about the value of the investment in management and technical training to protect your capital dollars. It will be repaid in availability, protection of NPDES permits, and not having operators making mistakes in the middle of the night that could cost your company $100,000 a day in fines or shut you down.

BILL HARLOW

Plant operations is one of the areas that I have been working in for 49 years and David just gave the answer to the operator problem. The training of your operators is, by and large, the most important thing that you can do as a manager of a plant. If you train your people so that they understand the ways we are regulated, the things we can't do, as well as the things we can do; they will be on top of it every time. If they know that they are going to be treated fairly, paid appropriately, and that you appreciate the work that they are doing for you, they will bust their butts off. If you neglect any one of those three items, they are going to be a problem to you, so my answer to it is, train them, pay them, praise them.

BRIAN SMITH

I would like to emphasize that a little bit. When you are not there during the night and graveyard shifts, the operators are in control of the plant and they can get you into a whole lot of trouble or they can save you tremendous amounts of money. I have had operators call me at 3:00 a.m. in the morning--this was a test plant with research going on, but they were good well-trained, well-motivated operators who take it seriously when we said call at 2:00 a.m., let us know, even if it isn't a real problem, we still want to know it anyway. They might see something that was extremely important and it can keep you out of trouble with the regulators. I have seen this in too many instances.

In California, you don't have that many desalting plants but I have seen it happen with conventional water treatment, and particularly wastewater treatment plants, on to a lot of our own water regulatory hearings and I have seen cities being threatened for non-compliance for what was probably an operations problem. Somebody went to sleep, was not well trained, or whatever.

I know that in California we use a water treatment plant certification program put on by our Department of Health Services but we don't have that many desalting plants so that aspect isn't really covered very much. Perhaps that is an area to explore, a special side certificate or something to your water treatment plant certification process or maybe a separate membrane plant certification process. It can save you quite a bit in the long run.

BRUCE WATSON

Just a short antidote that pertains exactly on this topic. About 25 years ago we were doing a test of a chemical in a plant in the Caribbean. I won't name the location. I got up at 3:00 a.m. to see what was going on and I arrived at the plant to find no sign of the operator. He wasn't doing his normal rounds so I went into the control room to find him and found this rather exotic looking lady sitting there and I asked, where is whatever his name was? She replied, "Oh, he's asleep tonight in the back." So I walked around to the back and there he was on a pile of rags on the floor, in a drunken slumber shall we say. I guess they had had a party, but she said, "We do this every night. I know how to handle this plant, no problem, no problem."

HOWARD RHODES

I think that operators of any type of plant are basically what makes them go, from our perspective, whether they are going a good job or a bad job. If they are not doing a good job it winds up being the owner's responsibility for better or for worse.

There are a couple of things that I did not mention earlier. One of them is that this industry is a growing industry. I think it is poised to take off. The problem with that is that now perhaps you are fixing to be discovered. There is a backside to that coin. In regard to that, I would say that for the most part very few people really are that cognizant of what RO is. Maybe in the industry a lot of technical people do, but if you go outside the board room walls that most of us work in, they don't really know what it is or what it is about.

I would challenge the people that are here today that when you have the opportunity to talk to public groups, that you talk to them. Take a chance to get on the program of these specific clubs. From time to time it would be worthwhile to even to talk to reporters, heaven forbid, and editorial boards so that they begin to have an understanding of what the industry is about, and that it is not going to produce dirty water that is fixing to kill everything that it comes into contact with.

I heard something at lunch today where one of our staff allegedly went to a plant and wanted to see the dirty water that came out of the RO reject. Those are types of things that the educational process will alleviate. I think that it is something that is really going to come to the forefront not too far down the road.

Another area of importance is that we have designated many areas of surface water bodies as Outstanding Florida Waters (OFW). For purposes of wastewater plants, domestic sewage plants if you will, and industrial plants, what that translates into is that you cannot discharge any new discharges into those waters. I think that you are going to find that the RO concentrate is not going to be allowed in those waters either. I think that this is one thing that is going make it somewhat difficult in trying to find real good solutions.

TOM LEAHY

There was a reference made to the public's reception. I'm not exactly sure since I have never worked for a private utility before, but working for a public utility, you are one step away from the board of directors in the city and they are in constant communication with the civic leagues. Two things that I have found in 8 years with the city--one is that people, at least in Virginia Beach, do not mind paying high water rates so we do have high water rates and high sewer rates too. We don't subsidize our system.

We have very low per capita water usage because we have had a lot of shortages and being in a very fixed cost business, the less people use, the higher the unit cost goes up. They don't like that much but generally they don't mind paying high water rates. But there are two things they don't want to hear. They don't want to hear that there is anything wrong with their water. They want to know that it is just one step away from being drinking water in heaven, or something. The other thing they don't want to hear is that the city is doing anything to pollute the environment. Now, they don't mind running the city down, complaining about this or that. But boy, let someone else outside complain about the city not being a good citizen and they go straight to the council, they go straight to the ballot box and they come down hard. So you do have a job to do to getting this brine disposal situation understood. This means making people understand that it is a waste but that you're going to treat it and dispose of it properly because they are not going to like it if they think that you are messing up the environment.

BRIAN SMITH

A lot of discussion this afternoon has been along the lines of some of the other concentration technologies and some of us have presented some of the kinds of development, demonstration and testing work that we are involved in. I would like to pose a question, particularly to those of you who are in the cities, various utilities, etc., that are operating RO plants--is there anything else we can be doing in the development and testing field or the basic research fields, to help in disposing of these kinds of concentrates or any thoughts anyone has along that line?

LEON AWERBUCH

I think there already are available technologies, pretty well demonstrated to dispose concentrate from RO and we have mentioned a few today. Some of them are more complicated than others. Distillation is one technique, a variety of them exist, some of them well proven and some of them under development.

To mention a few in distillation, we mentioned the evaporation technique by vapor compression. It is well proven and well demonstrated. There are techniques of evaporation using waste heat, that is waste heat from power plants. There are techniques combining waste heat from power plants and desalting which will minimize the energy costs. There are new technologies dealing with some techniques which never took place, like freezing. Walt Barnes asked me to mention freezing. It was a well known technique, particularly if you take the freezing part that will probably take some time to be developed. There are other things which are in development. I really shouldn't talk for Alber's new desalting process and others which are new and appropriate to conduct development and defusion techniques, evaporation, direct contact.

I can see that the end of the story is cost--the amount of money which it will take to dispose of the brine. Evaporation techniques, EDR or others are going to cost little enough, both in capital and energy to allow desalination to grow. If they become very expensive, we will have some halt in brackish water desalting. The problem I see is that at one point or another we will have a cross-over between seawater desalination which doesn't jeopardize the environment, particularly on the coastal line of Florida.

I see one in which I really hope that that would take place. We have a sample of a cogeneration scheme. The first one approved by the Federal Energy Regulatory Commission which allows use of waste heat from power plants in San Diego to send energy from a simple gas turbine power plant to distillation plants. This drastically reduces the cost of energy because it is basically waste heat. Is it possible in Florida to combine power plants, which will use the reject heat for concentrate or brine disposal and then use the electricity part of it for RO? I was curious of the reaction of people who are in Florida.

BRIAN SMITH

Leon just asked a question that I was going to express the same thing. I know that in the San Joaquin Valley there is a lot of discussion about the use of cogeneration plants and sites for the disposal of the drainage water. It would seem like this would be an opportunity here in Florida. Is there anyone here from Florida that would care to discuss this a little bit? The prospects of either working with these private or public utilities?

AUDIENCE

Maybe they do it different, but at the moment the utility companies and the power companies do not talk to each other. That is a basic problem.

BRIAN SMITH

That is a problem that I thought that I heard about, just not communicating.

HOWARD RHODES

With regard to the issue of water utilities. As I mentioned earlier, we have a problem with domestic wastewater plants. We are promoting this throughout the state, and then on the other side, probably compelling a lot of reuse of water throughout the state. When you get down to that point you wind up with people seeking out alliances that they didn't have in the past. As a result of that we are beginning to see wastewater utilities beginning to talk to power companies. They are beginning to encourage the power companies to use some of the wastewater as cooling water and I think it is not too far down the road after that occurs, that we will begin to see complete utilization and recycling of material from water supplies. We will no longer just have separate drinking water utilities and wastewater utilities.

We are going to have reuse and we are going to have the whole complete cycle of water so it is going to be used and reused again. This industry is going to be a major factor in that because one of the things about wastewater is that it picks up a lot of salts and that is one of the things that has not been affected by any treatment process, as most of them are biological and they don't take the salts out. Desalination does and I believe it is going to be a major factor. Whether it comes real soon or not, I don't know but I think that things are probably going to have to get more expensive for it to happen.

TOM LEAHY

One thing that years ago was never thought about was the source of energy for evaporating concentrate. I know in the past we have always used solid waste disposal sites for getting rid of waste. I think the future is coming where, as Howard talked about the population moving into Florida along the coast; where there will not be any more room for solid waste disposal sites and then we have a chance for resource and recovery facilities.

In resource and recovery systems there is energy produced by burning the solid waste so you have that energy which you could possibly use to run evaporation processes to get rid of the concentrate streams. We also have a problem with land disposal and solid waste because of leachate getting into the groundwater supplies so this would do away with that too. It is a twofold solution. The situation is that land costs are going so sky high that it may be that now is the time to start looking at resource recovery.

JACK JORGENSEN

My association in the business has been in the research and development area of materials. Over the years, particularly in the last 10 to 15 years, there has essentially been no real new breakthroughs in the business. Everything we have done has been either an upgrading or tinkering with this or that from the basic research of 15 years ago. As a result of that, the primary work of the programming by the Department of the Interior, that was sponsoring early research and development work, has gone down the drain and essentially now there is nothing going on in the way of grants or aid to researchers in the area of water treatment of this nature.

In the last year and a half, Senator Simon, a Democrat from Illinois, has become especially interested in the business to the extent that the Office of Technology Assessment (OTA) report, that Bill referred to, came as a result of his requesting that OTA prepare a study of this kind. Many of us in this room participated in that study. The follow-up of that is that he continues to be interested in developing some further ideas on what research and development programs should look like and who should be doing them. In a year of tight money in the federal budget, he was instrumental in having inserted, in one of the agency budgets, a call for a special study by the President's Office to come up with just that--What should be done in the area of research and development for desalting and water reuse. Also, what place should government be allowed to have in that sort thing.

That report is due back to him on December 1st and the wheels are turning. There will be a report and his staff is now anticipating that report and are going to put together a piece of legislation which he hopes to introduce to Congress early next year. I'm kind of surprised, but gratified, to see a Senator from Illinois advocating this when the basic users of this technology are, at least for the most part, in Florida or California.

What he is interested in now, and what his staff is interested in, is finding people that will start calling the Senator and his staff and calling their Senators and Congressmen and getting them on board. Getting co-sponsors of the legislation, getting staff from the other Senators and Congressmen to assist in putting together the proper words that will fit the needs of the area. Our NWSIA Legislative Committee is now trying to promote some of that and I would encourage anyone in the room, particularly from Florida and California, to start thinking about it. But just don't think about it, your Congressmen and Senators are home now, make a call to their office and start talking to them about new funding, with a new authorization for basic research, development, and demonstration of the technology.

LEON AWERBUCH

The Board of Directors of NWSIA met yesterday and passed a resolution addressed to Congress to create a Office of Desalting Technology. I don't know who has a text of the resolution but would you read it out?

BRIAN SMITH

> "That NWSIA champion creation of an Office of Desalting Technology within the U.S. Department of Commerce to promote the desalting industry for national and international business and commerce; that the Office of Desalting Technology will develop and demonstrate U.S. industry's capabilities to be able to compete in the national and international markets;

that the Office of Desalting Technology enhance and improve desalting, water reuse, and the new water sciences for the practical applications to meet domestic and industrial needs; that the goal of the program will be to reestablish the U.S. global leadership position."

I'm kind of an infant in the desalting field. I didn't come into it until about 1978 but at the time when I started, I was introduced to it by some people in the Department of Water Resources in California who have since retired. They took me around to the universities to people who were in research, getting money from the Office of Saline Water, I guess that at that time it was the Office of Water Research and Technology. I was very impressed with the work that they were doing. I could see their advances and as we got into the Los Banos demonstration project in the very early 1980's, that money started to dry up just at a time that I know I could have used a lot of help and assistance. Fortunately, I was able to come up with money out of my budgets to help a little bit but it was no where near enough and I saw a lot of expertise, at least among the California universities, lost. Some of the people have retired and we are not training new people, so hopefully in this time of tight budgets we can find some money somehow, and I think this is a good way to get started.

IAN WATSON

I have a few scribbled notes here that address points that each of the speakers have made here. First, Mr. Rhodes, you struck a chord when you mentioned that 80 or 90% of the people who have moved to the State of Florida want to live along the coastline or, for some peculiar reason, in Orlando. Those are the areas that the groundwater is most heavily stressed. Because of that, we in this industry as consultants and designers, must maximize the use of the water that is available there. In many cases this means that although you minimize the amount of concentrate, it is at much higher concentrations and is then directly in conflict with many of the standards that DER has, of necessity, adopted.

The three things that you have to remember is that you have to (1) maximize groundwater use; (2) minimize the cost because it is, after all, a public water supply in most cases; and (3) protect the environment. Those three things lead directly to what I feel, is perhaps one of the most important aspects and maybe one that is sort of overlooked in what is the true economic value of water in the State of Florida. I pay $1.25 per 1,000 gallons in the City of Fort Myers. My wife then spends some $10.00 a week on bottled water. When you add that up, that is about $4.00 per thousand and I would be more than happy to pay that to the City.

To continue to another point that Bill Harlow made. The question of the costs and what do you pay the operators. The operators are critical. Anybody in this room that has been involved in plant design and you do a good job but when push comes to shove everybody says "Boy, you designed a great plant but boy did you really screw up that one." It is the operators who ultimately make or break your reputation and it is important to pay them for the skills that are required--not minimum wage which is the case of many utilities, or close to it. You have to be up in the $8.00, $9.00, $10.00 an hour range for a B License operator; $6.00 or $7.00 range for a C License.

Coming in on licensing, several years ago, two or three of us were discussing with DER the possibility of having a special test which would lead to a rider to the various levels of licensing. There would be a C License rider, a B License rider, a A License rider which would certify that person as a licensed RO or membrane plant operator. We felt that was very important in light of what was happening in projections that were being made in capacity.

On the question of injection wells, I roughly calculated in my head, Bill, that at 56,000 pounds per day, you are looking at 8,000 tons a year and that is for a 1.5 MGD plant. That's for one. Where is all that salt going in the ground? And if it is a 50 MGD plant, which has been discussed for one Florida installation, it boggles the mind. How long can you operate injection wells under those circumstances?

Finally, Tom Leahy has come in about public relations. When we had a little upset in our plant at Cape Coral, we invited the local media to come over to the plant. We prepared three glasses--one of the feedwater, one permeate, and one reject, and they all appeared identical. In fact, the reject and the permeate looked a little better than the feedwater. We had just applied for the permit and it had been advertised. On that evenings news, the reporter referred to it as dirty wastewater. The next day we had an intervenor in the process.

The potential of desalting is there I believe. All of us who live here in Florida recognize that it is going to continue to grow. Southwest Florida is growing extremely rapidly and we probably have the least resource perhaps of anywhere in the state. There was an opportunity recently for a resource recovery project and, with typical 19th Century thinking, they decided to expand the landfill. That is ridiculous and, in the end, everybody is going to pay the price.

So I am particularly pleased to be here today in this joint session with DER, with the South Florida Water Management District, and with all the technical folks and the operators. I think together we have to push and together we can succeed.

DAVID PAUL

I would just like to add to what Ian just said. How many people in the room actually come from a facility, like an end-user? How many from the government? How many from industry? It is pretty outstanding the mix that we have and I would just like to say that we have 35 more minutes here and we have a Director of DER here, we have the South Florida Water Management District people here. This is just an outstanding opportunity. I just hope that everybody realizes that it's not like this around the nation. You don't get this type of group together. It is so unusual that I just hope that everyone takes advantage of this opportunity to use this roundtable to talk to industry if you are an end-user or if you are a vendor or representative to tell the government what it is you like or what it is you don't like. It is just a real rare opportunity.

BOB EVANS

I am Bob Evans with Acme Improvement District and I would like to make a comment and then ask a question. I am an operator, and our District just recently went through an RO design and I want you to know that I woke up in the middle of the night with nightmares about engineers. I do have a question though. There are not that many RO plants in the country so I was wondering if there are any formalized operator training available?

DAVID PAUL

Well, at the San Juan station I formed a four year training program for my operators. Four years where the operators had to take a test every week and we called it an apprenticeship. Now that I am out on my own I have developed some training programs. It is preliminary at this point but NWSIA and myself are working together and will be over the next month or two to get something formalized.

BOB EVANS

The problem is that, even with the California Manual, the RO section really tends to give just a cursory overview of our operations. It is not really in depth enough to train operators that are going to be operating an RO plant.

AUDIENCE

Once a year, at the TREEO Center in Gainesville, there is one day of at least an eight hour session on RO.

AUDIENCE

My name is Mark Seamans and I am with the City of Cape Coral and just to answer your question, there is an excellent training program available right now and David Paul is the one that puts it out. We were lucky enough to have him on a three day basic seminar. I have been at the Cape Coral plant now for three years and I have learned more technically in that three day seminar than I did in the whole three years on the job.

BRIAN SMITH

I know that in putting together the Los Banos plant, that we had a number of different technologies. We got the vendors to help us as a source of training. They spent what time they could with us but I wished that I had for our operations staff that kind of thing, about a 12 month program of formalized training. It would really pay us dividends, at least for my engineers and my staff, who I worry about too sometimes at midnight. We spend many hours going over data and looking at operation logs to try to figure out what the operators did and tracing strange occurrences. It is a real problem.

BILL HARLOW

Walt Barnes just suggested that I might share with you something that is happening in NWSIA right at the moment. The NWSIA Board is struggling right now with the possibility of putting on a training session for between 16 and 20 foreign plant operators. We have been approached by a foreign country who want to send their operators to the United States for training. We have a rough draft of a training program put together.

It is my opinion that that particular draft could be adopted to some sort of a training session that we could go around the country and provide to operators here in the United States. David Paul was in the Board meeting the other day when we were talking about this and we are in turn talking to David. So, I think that there is going to be some help for you people out there. I do not know if it is going to come soon enough for those of you who are in the design phase right now but we are going to try to make this one of those things that we can offer to the user of the processes.

This has been one of the criticisms that I think that NWSIA has had in the past, that we are pretty top heavy with membrane manufacturers, equipment manufacturers, engineers designing plants, and we really don't do very much for the utility that uses the process. Well, here is a chance for us to do it.

AUDIENCE

Bill Hendershaw of Hydropro. One of the things over the years that has amazed me in this business is how little use of videotaping is done. How many plants have we started up where there are absolutely no records, they change over operators, the owner is suddenly left with a piece of equipment that no one has had any initial training on. I don't know about the work that was done at Cape Coral but the original process engineering was done in 1977 or 1978, I am sure that none of those people that received the initial users training are anywhere around today and none of that was videotaped. I don't know if the recent work was.

If NWSIA is going to do something I can certainly see where it should be taped because I do not see how any training program is going to reach enough people, particularly the smaller utilities. Whereas a simple videotape, whether it is a half-hour or an hour long, at least gives them some exposure because most of these people are not going to sit down and read long manuals. The manual may be written great but they are not going to read it from cover-to-cover, no matter what they sign off on and certify that they did.

BRIAN SMITH

I would like to second that in the use of video tape. In the Los Banos project in California, we videotaped the training program for the Ambient Technologies vapor compression unit and we, in fact, had other operators come in and we used that and supplemented it with the manual.

It is one thing just to read the manual and something else if you can hear somebody pointing to a particular valve or a particular control and be able to see the unit. This is especially effective if you can do it on one of your own plants because not every plant is designed the same. I think that they are all a little bit different. You start with the basic process and membrane modules thinking it will be the same but when you put together a new system, it is different. I suspect that if you went around to every plant in Florida that there would be distinctive differences on how you should operate it. It would seem like there would be a need for a generic training program on tape perhaps that could be sent around what with the availability of the VCR cameras and recorders. You can do it in your own plants because the program that we did, we coerced one of own operators into bringing in his own camera and it served as a very valuable tool. So, I second that motion.

AUDIENCE

Along the lines of not calling treated wastewater, effluent; and not calling concentrate, brine; how would you consider here that EPA wouldn't let you reclassify concentrate as a domestic waste? Do you think it will ever get its own classification as not industrial waste but maybe repermitted as just concentrate?

HOWARD RHODES

I think the classification that started, at least in Florida, on types of discharges were very limited when they first came out. It started out as domestic and industrial wastewater and if it was a discharge, it had to be forced into one of those two cubby holes. Over the years there has been a wide variety of things placed in that cubby hole of industrial waste.

We were approached about two weeks ago by the agricultural industry here in Florida. They have stormwater runoff that is a water that has continued to cause problems and they asked almost identically the same question. We have told them that we will sit down with them and discuss with a fact finding group, if you will, the feasibility of setting up a permit for that type of operation. However, the way that EPA has its standards right now, we will probably have to investigate and see if it is feasible to do it. Now, at some point down the road, that is something that I think will be worthwhile to discuss as we begin to get more and more RO plants here in the state that concentrate might be a category deserving of a special classification but I can't say that right now.

BILL HARLOW

Ian Watson has struck a nerve with me again. He brought up the subject matter. I inserted that 56,000 pounds of salts from 1 million gallons of the Englewood concentrate to get you to thinking. During the break, I overheard a couple of guys say, "Well, why don't we just collect all this stuff and send it back up north and use it on the roads up there to take snow off the roads." They aren't so far from having a good idea.

All we have to do now is to work together to try and find a way that we can collect all of this concentrate that is being generated, take it into one large facility at which we reduce it to calcium chloride, or snow salt if you want to call it that. Leon is working on an idea for cogeneration that can get this done, get this evaporated and we have the germ of an idea but it is going to take somebody with enough power of imagination to put something together so that we can get something started. There is a lot of this concentrate available. There ought to be a lot of waste heat floating around in all these electric plants that we have around here and maybe we need to get this one to some level of feasibility.

BRIAN SMITH

This is a problem, salt disposal, that we are dealing with in the San Joaquin Valley on a mega level. We are talking about millions of tons per year so we have been looking into methods of collecting sodium sulfate which maybe you can come up with some ideas as to how we can do that. There is some value here and I didn't quite expect that. I have received a real education the last couple of days. I know that I for one didn't know that much about Florida's desalting industry and the problems that you face. I am terribly impressed. I think you have taken this whole business a long way, farther than I think most people realize and then having to deal with many questions that perhaps the desalting industry didn't quite realize might come.

You have a lot of plants, you have a lot of issues now coming up that in a big single plant like the Yuma Plant, or a single 25 million gallon a day plant that we have thought about in San Joaquin Valley. You are beginning to take this to where it is becoming an everyday thing and I for one compliment you. I am terribly impressed.

WALT BARNES

May I make a human interest observation. I don't know how many of you remember the Office of Saline Water in the Department of Interior. I just wanted to mention a couple of things. One, we had in the audience today, Mr. Joe Strobel, who was the first employee of the Office of Saline Water and that goes back into the 1950's sometime--where all of this reverse osmosis stuff started. So he was responsible for some of the early development activities in reverse osmosis and I think that it was a milestone that he was here with us today.

Another bit of human interest which many of you may remember but hasn't been mentioned today and that is that the first water was successfully squeezed through a membrane at the University of Florida by Professor Reid. He did not have a viable reverse osmosis process but he did do the first successful membrane work and I think it is worth remembering.

LEON AWERBUCH

Just to add to the congratulatory fashion of Florida and the seminar which we had today, I wanted to mention that the problem that Florida is facing today is a global problem. Starting with California, agricultural water reuse is one.

Now I am talking for the International Desalting Association which is the parent of NWSIA, we just got a letter from a state in the middle of India which had the same problem. They wrote "What do we do with the waste of our RO plants in the middle of India?" The problem is true to Saudi Arabia where they have to maximize the water recovery from inland brackish water desalting. The problem I can closely address is typical in Poland for different reasons. Their coal mine operation depends on removing salt in mine water and desalinating it with a combination of reverse osmosis and distillation.

So, what we are talking about here today is very significant, not only to Florida and to desalination technology, but really has a wide implication for the worldwide desalting business and desalting development. I think that what Bill said, that really we need to use innovative new ways of thinking, set the example. I really think that it is time. In Florida, there will be more discussions between the power utilities and water utilities. In California, in the days of Silicon Valley, we were talking about building a center for disposal of Silicon Valley effluents which would process all the waste in one centralized location. I am anxious for an opportunity to do that with a combination of power and concentrate disposal in this area.

Florida is unique in its technical development and setting of regulations. These ideas are really helping out not only Florida but could be applied to a lot of desalting communities.

SUMMARY AND CLOSING REMARKS

by

David H. Furukawa
Consultant
Poway, California

DISPOSAL OF CONCENTRATES
FROM BRACKISH WATER DESALTING PLANTS

November 18, 1988

SUMMARY AND CLOSING REMARKS

by

David H. Furukawa

Consultant

Poway, California

I am really pleased to see so many people here and you don't realize how important it is for people who participate in a meeting like this to have so many bright faces out there at the end of the day. I have been to many meetings where people would just slowly trickle out and, by the end of the day, the room is nearly empty. However, this crowd is very encouraging and I congratulate all of you that have stayed with us to the end.

Actually, various people have pretty well summarized the content of the meeting especially during the roundtable. It is really difficult to take all the material presented at a meeting like this and try to condense it into a very short summary on the program. It is hard to do without some individual editorializing but I will do what I can.

Like the last South Florida Water Management District desalination seminar, this one was opened by a very astute set of observations by Tilford Creel. He reminded us all that there is a water shortage today. Now that is something that we, Californian's, don't connect with Florida because we think that water is so abundant here and really when we look at the state, there is a great abundance of water but perhaps not in the right places. In California we have even a worse problem. We do have a lot of water. Unfortunately, most of it is up north and they don't want to give it up to us in the south. Mr. Creel apologized a bit later for introducing some politics into the situation. Well, I don't know of a water supply or water problem anywhere in the United States that is not

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This paper was prepared by the editor based on a recording of the presentation. Where deemed appropriate, the presentation has been edited for clarity.

intertwined with politics. It is a thing of the times and water is becoming a crucial issue in all parts of the United States and, in fact, the world.

He said some key words that I think envelop the gist of the program today. He talked about conservation. I think we all need to take heed to that word. We need to conserve the water that we do have. He talked a lot about desalting and the fact that we need to reuse the water more. He mentioned another word that is often heard in desalting types of discussions and that was xeriscape; that is, trying to grow plants, materials that use less water in order to conserve that water.

Above all, his interest was in maintaining the quality of life here in Florida for Floridians and for those that are moving into the state from other parts of the country. He also talked about solving these major water supply problems with technology. I think you heard today, a good number of technological solutions to this problem of disposing of the reverse osmosis concentrate. Concentrate is a word that is so familiar with those of us in the industry from many years back and we are trying to re-educate ourselves to use the proper language so that people will understand us.

Talking about language, I am finding out that this industry, particularly as a result of the regulatory requirements of concentrate discharge, is coming up with a new language. I just noted down here some of the acronyms that I have heard today. In addition to the standard desalting terms like RO, UF, and ED; we now have DER, NPDES, FDER, DPC, OFW, THMs, and the one I think is the best of all -- ZOD. Now that has some pizzazz that I haven't heard in this industry in a long time but it is really interesting that a whole new generation of language is developing out of this particular industry and its problems. We have to take things a little bit light hearted and can't always be serious about these things and I think that this group is going to find the right niche.

Well, today I hope that you got a good understanding of the problem and the technology. I think that Dr. Buros gave a good introduction to the problem. I was very surprised myself that desalting capacity here in Florida is soon going to be greater than 100 MGD.

That is a lot of capacity. We, Californians, believe that we are always far ahead of every place else. I want you to know that today I stand here very humble because the State of Florida has indeed exceeded California in desalting capacity and has done an awful lot in promoting the desalination processes and you are to be congratulated.

There is no question that desalination is a key solution to some of Florida's water problems. Ian Watson did a marvelous job of talking to you about the characteristics of desalting concentrates. As you found out, the nature of those concentrates depends on many things including: the raw water composition, what kind of membrane you are using, what the recovery is, etc. In his discussion, he used the word that I have heard at least a dozen times today -- SITE SPECIFIC. I think that you will find that the problems of concentrate discharge are site-specific and the solutions to those problems are also site-specific. So, you are not going to find one answer to all of them. I have heard words today about the fact that there is no panacea to concentrate disposal and it is true. I think that every one of these cases needs to be handled individually.

Bill Conlon took us through the history of how some of these regulations have developed over the years. He has been instrumental in helping with the regulations and trying to get this industry on track in that respect.

Dr. DeHan walked us through some of the regulations and I must admit that he was right, I did come away a bit confused. There are a lot of numbers and the fact is, they are all changing. I think that it does point out one thing though, that the regulations in this particular industry and affecting concentrate discharge in particular, are a moving target. I think the cooperation demonstrated here this afternoon between all of you shows that you are seeking an answer. You are looking for the answer that is going to be the most satisfactory for end users and the regulatory agencies in that part of the industry.

O. J. Morin pointed out a number of facts with regard to surface water discharge and the fact that approximately 10% of the plant cost is going to end up in the post-treatment of the discharge. This is very important as it means that in the planning stages of any desalting plant, everyone without question, is now going to have to include additional monies to cover the cost of concentrate disposal.

Albert Muniz talked to us about deep well injection and you heard the care needed in being successful with deep well injection. Like anything new that is done, you need experience and knowledge of what to expect will happen with it in the future. This is an area that must be explored and people are going to have to find out more about it in order to be comfortable with using deep well injection. There is a natural hesitancy and we, in the industry, have to learn more about it.

With regard to the disposal techniques, Eddie Edwards walked us through a really good case study of how discharge is handled in terms of irrigation and, again, he mentioned the word site-specific. So, that is a key word. Certainly I have picked up today that all of this wonderful technology out there can be utilized but it has to be utilized properly and with each site and its differences in mind.

Then we talked about the concentration technologies. I found the solar pond experience related to us by Brian Smith extremely interesting because it is a very innovative way of utilizing a brine pond. In this case, I can properly call it a brine pond--being a salt created pond. But, I think that he touched upon some technologies that are not really new but are finally being utilized in a practical fashion.

Leon Awerbuch talked about thermal evaporators and during the discussion period later, he mentioned that there are some new developments that are underway in thermal processes. I think that in that area of development you are going to find some other things. True, as Jack Jorgensen pointed out, there have not been any major breakthroughs in the industry in about 10 years. However, there have been some marvelous improvements. There have been some innovations that have caused our industry to progress and I think you will see more and more of those. Especially in the area of membranes. The thing that we look for are newer and better membranes. Nanofiltration is an example. How many of you three years ago had even heard of nanofiltration. Now it is here and being used. It can happen very quickly when an aggressive industry finds that there is a need, they will find a product to satisfy that need.

Gene Reahl touched on something that a lot of us probably had not thought about before, that electrodialysis reversal is very good at concentrating the reject from reverse osmosis. I think that is a really innovative bit of thinking. We also learned that it can be, depending on the site and the composition of the water that you are treating, a very efficient and cost-effective method of taking care of a concentrate disposal problem.

High recovery reverse osmosis has been something that we all have tried to achieve for some time and Bruce Watson took you through some of the particulars of a particular application. Again, it was a specific waste stream. I am sure that I am using the word specific far too often but I am trying to make a point--that every one of these situations is, indeed, unique and probably everyone has a slightly different solution. I am sure that every one of these problems is going to have a different combination of technologies to get you to a satisfactory solution.

In the roundtable discussion period, a number of topics were touched upon. It was very obvious from the amount of discussion on it, that training of RO operators ought to be a number one priority. I think that the industry itself needs to do a better job of preparing instructional manuals for the equipment that they supply to the end users. They need to prepare better materials to assure that the equipment is going to be operated properly.

There is no doubt that taking care of concentrate discharge does add to the cost of treatment. However, I might point out that from the discussions that you have heard today, that there are a great number of innovative and professional people in this room who can assist you in helping to solve particular concentrate problems. I urge you to cooperate, discuss, get some dialogue going that will allow you to assist each other in solving these problems. I think that one of the biggest pluses that I have observed here today is the tremendous cooperative spirit that end users, regulatory people, and industry are showing. It is a rare event, believe me. You are all to be congratulated. It has been a tremendous experience for me to be here.

I hope that all of you have enjoyed this workshop and hopefully will invite us back again. We, in NWSIA, enjoy putting these seminars on and taking seriously Mr. Rhodes, who has gently chided us, that perhaps we are not getting ourselves across to the public. I would like to close by taking a note from a commercial that I am sure you all have heard, I urge all of you to reach out and teach someone.

BIOGRAPHICAL INFORMATION

DISPOSAL OF CONCENTRATES
FROM BRACKISH WATER DESALTING PLANTS

November 18, 1988

BIOGRAPHICAL INFORMATION

LEON AWERBUCH is Business Development Manager and Principal Engineer for desalination programs for the Bechtel Corporation. He has 26 years of experience in desalination projects around the world.

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TILFORD CREEL is the Deputy Executive for the South Florida Water Management District. Formerly he was in charge of the Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi.

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BILL HARLOW recently retired as Manager of the Englewood Water District (EWD). The EWD has recently completed the expansion of their RO plant to 1.5 mgd. Mr. Harlow is the President of NWSIA.

JACK JORGENSEN is the Executive Director for the NWSIA. His previous work has included private consulting on water resources and 32 years with the U.S. Interior Department.

THOMAS M. LEAHY, III is the Water Resource Engineer for the City of Virginia Beach. For the past 8 years he has worked on the evaluation and planning of the future water supply for the city.

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BRIAN E. SMITH is Chief of the Special Investigations Branch of the California Department of Water Resources' San Joaquin District. He is investigating desalting of drainage waters.

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