A Landowner's Manual
Managing Agricultural Irrigation Drainage Water:

A guide for developing Integrated On-Farm Drainage Management systems

Developed for the
State Water Resources Control Board
by the
Westside Resource Conservation District
in conjunction with the
Center for Irrigation Technology,
California State University, Fresno

"Funding for this project has been provided in part by the U.S. Environmental Protection Agency (USEPA) pursuant to Assistance Agreement No. C998998901-0 and any amendments thereto which has been awarded to the State Water Resources Control Board (SWRCB) for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the USEPA or the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use."

Dedication

This drainage management manual is dedicated to the memory of Frank Menezes, who passed away in 2001.

Frank was a valuable asset to the San Joaquin Valley's Westside agricultural community, focusing on salinity and drainage management – in particular, development of the Integrated On-Farm Drainage Management system.

Frank's technical knowledge, practical understanding of farmers' and ranchers' needs, and warm and engaging manner made him one of the Westside's most respected and beloved individuals. Because of his tireless efforts in helping develop and implement IFDM systems on Red Rock Ranch and at other sites, this publication is dedicated to Frank Menezes.

Acknowledgements

This manual would not be possible were it not for the help, support and guidance of the following people and their affiliations:

Center for Irrigation Technology
Tim Jacobsen
Lisa Basinal
Marilyn Creel

California State University, Fresno
Sharon Benes
Florence Cassel-Sharmasarkar
Derek Dormedy
Dave Goorahoo

California Department of Water Resources
Kathleen Buchnoff
Vashek Cervinka
Jose Faria
Gerald Hatler
Charyce Taylor
Julie Vance
John Shelton
Manucher Alemi
Ray Hoagland
Holly Jo Ferrin
Tony Lam
Donald Woodson
Charles Blalock

MFG, Inc.
Mike Tietze
Nettie Drake, B&N Enterprises
Bill Bazlen

Westside Resource Conservation District
Morris “Red” Martin
Sarge Green

U.S. Department of Agriculture-Natural Resources Conservation Service
Clarence Finch (retired)
Kerry Arroues
Dave Krietemeyer
Raul Ramirez USDA

Hudson•Orth Communications
Liz Hudson
Shelley Orth

U.S.Department of Agriculture-Agriculture Research Station
Jim Ayers
Catherine Grieve
James Poss

California Department of Food and Agriculture
Matt Reeve

California Department of Fish and Game
Andy Gordus

University of California, Davis
Steve Grattan
Bryan Jenkins
Kenneth Tanji (retired)

University of California, Riverside
John Letey

Although many people contributed to the production of this drainage manual, two people must be recognized for their longtime commitment to the development of Integrated On-Farm Drainage Management systems.

Since 1985, Dr. Vashek Cervinka, of the Department of Water Resources, and Morris A. “Red” Martin, of the Westside Resources Conservation District, have been major forces in the development of agroforestry and on-farm drainage reuse to help manage salinity and shallow groundwater levels. Their early efforts and institutional knowledge of salinity and drainage on Westside soils — much of it documented in this manual — provides farmers with a viable option to ensure continued production of high quality food and fiber crops.

Acknowledgements

Red Rock Ranch
John Diener

State Water Resources Control Board
Wayne Verrill
Khoban Kochai

Central Valley Regional Water Quality Control Board
Anthony Toto
Lonnie Wass

AndrewsAg, Inc.
Michael Andrews

U.S. Bureau of Reclamation
Mike Delamore

Westlands Water District
Jerry Robb

Broadview Water District
David Cone

Provost and Pritchard
Eric Abrahamsen

Boyle Engineering
Ken Swanson

Tulare Lake Drainage District
Doug Davis

The authors of Chapter 6 wish to acknowledge the hard work of Cynthia Eroh and James Bartram who conducted fieldwork that provided information for this chapter. Also, the authors express appreciation to Dr. Vashek Cervinka, Clarence Finch, and the late-Frank Menezes, who were involved in the initial plant selection for drainage water reuse projects. Gratitude also is extended to the funding agencies, California State University (CSU) Agricultural Research Initiative (ARI) and the Proposition 204 Agricultural Drainage Reuse Program administered by the California Department of Water Resources. Earlier support was provided by a grant from the USDA National Research InitiativeWater Resources Assessment and Protection program.

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Chapter 1. General Information

I. Introduction

Chronic problems of salt, selenium, boron and other naturally occurring elements in surface and groundwater supplies plague agricultural regions throughout the Westside of the San Joaquin Valley and the western U.S. Compounding the problem is the build-up of salty subsurface groundwater resulting from dense clay layers and inadequate natural drainage.

The Integrated On-Farm Drainage Management (IFDM) system was developed to manage these problems. A state-of-the-art, yet practical irrigation management system, the IFDM provides for drainage water reuse to improve water availability for crop production and to minimize salt and selenium risks to water quality and the environment.

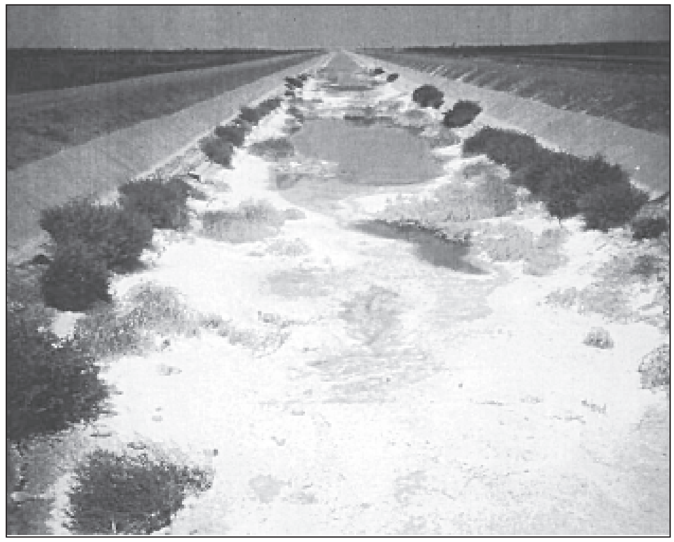
IFDM manages irrigation water on salt-sensitive, high value crops and reuses drainage water to irrigate salt-tolerant crops, trees and halophyte plants. Salt and selenium are removed from the farming system and can be marketed. This system views the subsurface drainage water containing salts and selenium as resources, rather than considering them as wastes and environmental problems.

Simply stated, the grower sequentially reuses drainage water to produce crops with varying degrees of salt tolerance. A solar evaporator receives the final volume of drainage water; this water evaporates and salt crystallizes. Plants absorb selenium, which may be volatilized; or accumulate in the plant tissue. Of the remaining selenium some will remain in the soil and some will be contained in the final effluent to become a component of harvested salt. There is no discharge of salts and selenium into rivers or evaporation ponds. Drainage water, salts and selenium are managed on the farm.

The use of an IFDM system for salt and water management on drainage-impacted farmland has two primary objectives:

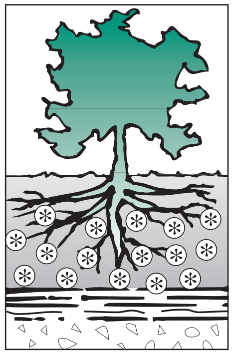
1. To use drainage water as a resource to produce marketable crops; and
2. To manage the salt and selenium in drainage water directly on-farm.

An IFDM system can serve as a viable alternative for landowners who may not choose to participate in a voluntary land retirement program for drainage-impacted lands. Once the irrigation systems have been optimized to maximize water use efficiency and to minimize the production of subsurface drainage water, an IFDM system can be designed to enable the landowner to process the resulting drainage water on-farm.



Drainage canals have been used to capture subsurface saline drainage water. The IFDM system manages the saline drainage effluent on-farm.

II. This manual



This manual is part of an educational and outreach program to educate landowners on the advantages, disadvantages, costs, environmental regulations and other issues involving an IFDM system. A companion manual is being produced to provide technical consultants and support personnel with the tools they need to assist growers with developing and implementing an effective IFDM program.

The seven-year IFDM pilot system at Red Rock Ranch has demonstrated that the use of IFDM on a larger scale is possible and practical. Several farms and water districts, likewise, have developed IFDM systems in their areas.

The merits of IFDM have been recognized by the U.S. Environmental Protection Agency and the State Water Resources Control Board through the award of a Clean Water Act Section 319(h) Grant to educate farmers and to train professionals about IFDM implementation. This manual is funded by the grant, and it targets the needs of the landowners, water/drainage district managers, engineers and technical professionals.

III. History

The Westside of the San Joaquin Valley is plagued with a build-up of salts, selenium, boron and other naturally occurring elements. Fine-textured soil and dense, shallow clay layers allow the build-up of these salts and trace elements by preventing unused irrigation water from percolating into the deep aquifer. Growers in the region are faced with severe problems of high water tables and soil salinization.

Prior to 1986, drainage water collected from fields in western Fresno County was discharged into the San Luis Drain with the ultimate objective of disposal into saline Bay-Delta waters. However, the Drain was closed in 1986 due to public concern over the environmental degradation of the Bay-Delta, and waterfowl poisonings, which resulted from selenium contamination at Kesterson Reservoir. Without a viable way to drain the land, growers' options to purge their land of salts become severely limited. As the salts and boron encroach into the crop root zone, yields are reduced, crop choices are limited, and over time, crop production can become unprofitable. Likewise, water quality in the Sacramento-San Joaquin Bay-Delta estuary ecosystem is being impacted by the addition of salts, selenium and other elements from storm run-off and subsurface drainage that ultimately reaches the San Joaquin River. A total maximum daily load (TMDL) for selenium is being implemented for the upper San Joaquin River and TMDLs for salt and boron currently are under development for the river. It is clear that alternative methods for managing salinity are needed to ensure the long-term agricultural productivity of the region.

Since 1985, several water and resource management agencies have responded to the need, developing the IFDM system. IFDM evolved from the agroforestry concept and was developed by the Westside Resource Conservation District, California Department of Water Resources, California Department of Food and Agriculture and the USDA-Natural Resources Conservation Service. Valuable research information has been contributed by the University of California, Davis and Riverside, California State University, Fresno and the USDA Salinity Lab in Riverside and Water Management Research Lab in Parlier, and staff from the Denver office of the U.S. Bureau of Reclamation. The Center for Irrigation Technology at California State University, Fresno is overseeing the preparation of these manuals and follow-up workshops on IFDM implementation. The Central Valley Regional Water Quality Control Board and U.S. Fish and Wildlife Service also have participated.

The pilot IFDM system was developed at Red Rock Ranch, owned by John Diener, in western Fresno County. Professional staff from several government agencies, universities, and consultants provide the required technical assistance.

The IFDM system has created conditions for economically viable and sustainable farming on the land that previously had severe salinity problems and consequently, reduced yields and productivity. Using the experiences from the Red Rock Ranch IFDM project, many growers are interested in developing IFDM systems on their farms.

To date, IFDM projects are being considered for drainage-impacted areas on the Westside and in Kern County. Likewise, farmers and water districts in the Grasslands Drainage Basin have expressed interest in IFDM to help reduce drainage flows, selenium load levels and drainage effluent in their discharge outlets. The IFDM system offers benefits to water managers, farmers and political leaders by providing a practical example of integrated farming and engineering methods to protect the quality of rivers, groundwater resources, soils and the environment.

Moreover, the concepts within IFDM are consistent with local and regional water and drainage management plans. The Federal-State Interagency San Joaquin Valley Drainage Program's final report, *A Management Plan For Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*, September 1990, recommends several measures for managing subsurface agricultural drainage, which are employed by IFDM systems. The major components include source control (water conservation practices), sequential reuse of drainage water and the treatment and/or disposal of drainage water.

Chapter 2. Salt Management Using IFDM

I. Introduction

Farming in high saline areas limits farmers' options on how they manage the accumulation of salt on productive farmland. The options are variable and depend on the physical conditions within the farm boundaries and the farm economics.

The key to any drainage management program is improved irrigation efficiency. The more efficient the irrigation, the less volume of drainage water to manage.

Land retirement, drainage water reuse and the sequential use of drainage water are a few of the major options available.

Efficient irrigation is the first step in establishing a successful IFDM system.

II. Land Retirement

As a result of decisions on recent litigation and for lands that are severely impacted by a high water table, land retirement is a land management option. Land retirement is the permanent removal of farmland from crop production.

However, there are some concerns about retiring historically productive agricultural land. These concerns include: reduced tax funds to the local government; the cost of managing previously privately owned land will become the responsibility of the Federal, State, and local governments; reduced land management may negatively affect selenium levels, and the economic impact on small communities.

Research funded by the U. S. Bureau of Reclamation is underway to evaluate whether or not land retirement will benefit wildlife.

III. Drainage Water Reuse

A. Single Reuse

Subsurface drainage water is used a single time to irrigate salt-tolerant crops and forages.

B. Cyclic Use

Cyclic use is applying irrigation water of appropriate quality according to plant growth stage. Salt-tolerance varies throughout the growing season in most crops.

For example, use of higher quality irrigation water is necessary during germination and stand establishment. Then, as the crop matures, lower quality irrigation water can be used.

C. Blending

Blending is a method of drainage water reuse. With this technique, crops are irrigated with a mixture of irrigation water and drainage water. More salt-sensitive crops can be grown using this technique than with single reuse.

D. Sequential Reuse

In sequential reuse, the drainage water is collected and applied to crops with an increasing degree of salt tolerance. The sequential use of drainage water is, in fact, an incomplete or partial IFDM system.

While IFDM embraces the same practice, the final stage of an IFDM system uses a solar evaporator to "process" the final stage of the drainage water, producing potentially marketable salts.

The development of the solar evaporator for the final step in the salt management system is the difference between sequential reuse and a complete IFDM system, as described in the Solar Evaporator Regulations under Draft Title 27 §22910:

"Integrated on-farm drainage management system" means a facility for the on-farm management of drainage water that does all of the following:

1. *Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.*
2. *Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual drainage water is substantially decreased and its salt content significantly increased.*
3. *Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.*
4. *Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated on-farm drainage management system and the solar evaporator.*

See Chapter 5 for more information on single reuse, cyclic use, blending and sequential reuse, including IFDM.

IV. What is an IFDM System and How Does It Work?

An IFDM system uses high quality irrigation water on salt-sensitive, high-value crops (Stage 1). Then subsurface drainage water is sequentially reused to irrigate plants of increasing salt tolerance (Stages 2, 3, and 4). After irrigation with fresh water in Stage 1, the subsurface drainage water is collected from the field and it is blended with fresh water and/or tailwater, for use in Stage 2. In Stage 3, forage grasses and/or halophytes are irrigated solely with subsurface drainage water coming from Stage 2. In a three–stage system, drain water from Stage 3 is concentrated and evaporated in a solar evaporator, leaving dry salt as a product, which may be marketed, stored, or disposed. In a four–stage system, halophytes are irrigated with water from Stage 3, then the drain water from Stage 4 is concentrated and evaporated in a solar evaporator, leaving dry salt as a product, which may be marketed, stored, or disposed. Figure 1 is a schematic of three–stage and four–stage sequential water reuse.

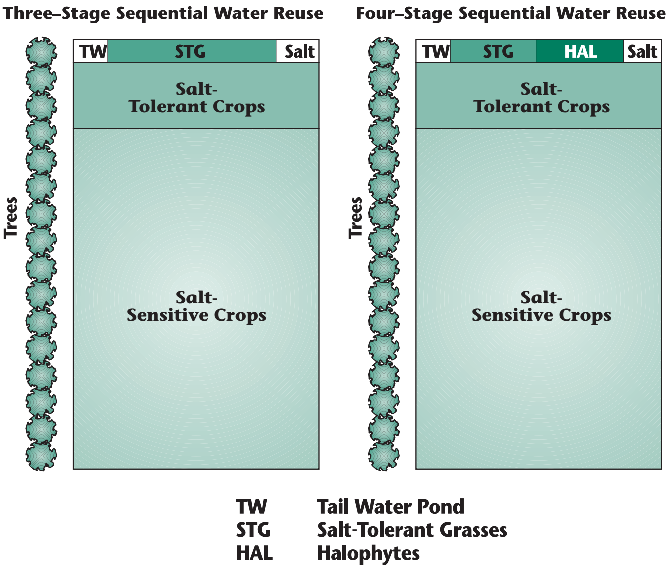


Figure 1. Multiple stage sequential water reuse.

Figure 2 shows the IFDM system at AndrewsAg (southern Kern County), which began in 1999 and consists of three–stages (drainage water reused twice). Figure 3 shows the IFDM system at Red Rock Ranch (Five Points, CA) which began in 1995 and consists of four–stages (drainage water reused three times).

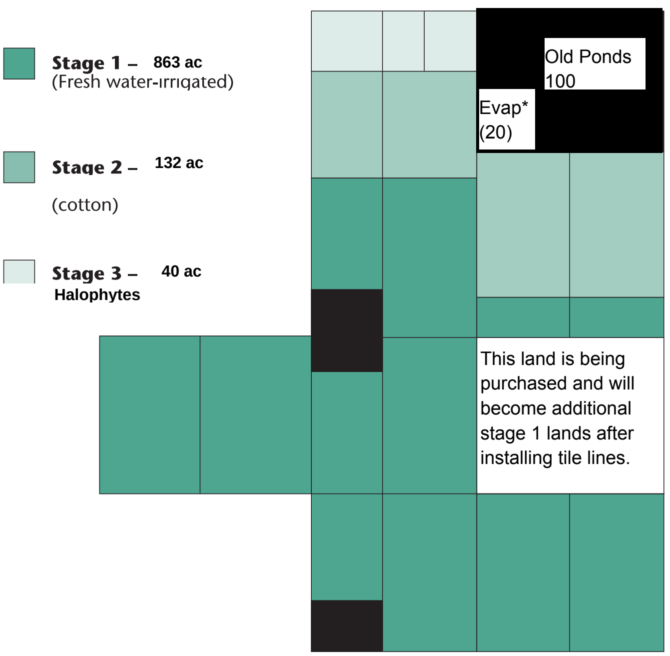


Figure 2. AndrewsAg IFDM. Sequential reuse, 3 stages (1035 acres).

*Evap = solar evaporator (20 A), 10 may have been sufficient

V. Components of an IFDM System

The system may consist of border strips of trees to intercept regional groundwater flow, three distinct crop production areas, each with its own subsurface drainage system and sump, sump pumps and piping to move the collected subsurface drainage water to each of the cropping areas, and a solar evaporator.

A. Border Strips of Trees

Border strips of trees are useful when subsurface lateral flow is a problem within ten feet of the surface. Benefits the tree strips offer include:

- Serve as a windbreak;
- Use large amounts of shallow groundwater, acting as biological pumps; and
- Lower water table.

Rows of trees are located upstream hydrologically of the IFDM system. Trees also are useful along crop areas where shallow groundwater problems arise. Eucalyptus, Athel and Casuarina trees are selected for their ability to use large volumes of water, and for their frost and salt tolerance (survive with water with TDS of 8,000-10,000 ppm).

B. Crop Production Areas

The crop production area begins with Stage 1 where irrigation water is used for the production of salt-sensitive, high-value crops. Stages 2, 3 and 4 use different ratios of tail, drainage and fresh water to produce increasingly salt-tolerant crops.

Stage 1 is the largest portion of the IFDM system. A well-designed subsurface drainage system provides the drainage necessary for the rapid leaching of salts brought in with the irrigation water. After one to three years, Stage 1 should be suitable for producing high-value salt-sensitive crops, which provide maximum economic return. Crop examples in rotation include a variety of vegetables.

Stage 2 is the second largest portion of the IFDM system and is the first step in using drainage water. Salt-tolerant crops are irrigated with the

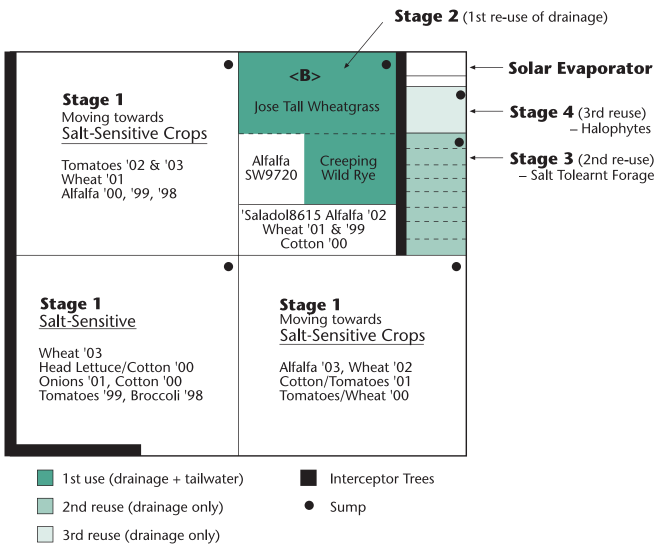


Figure 3. Red Rock Ranch IFDM. Sequential reuse, 4 stages (640 acres).

subsurface drainage water from Stage 1 that is blended with tail or irrigation water. Crop examples include cotton, tomatoes, sugar beets, canola and alfalfa.

Stage 3 is the smallest crop production area of the IFDM system and is the second step in reducing the volume of drainage water. Salt-tolerant crops are irrigated with the subsurface drainage water from Stage 2. Crops are limited to salt-tolerant forage grasses or halophytes. If the salinity of the drainage water to be applied is less than 15 dS/m, the forage grasses would be recommended.

Stage 4 could be included to further reduce the volume of drainage water and would be irrigated with subsurface drainage water from Stage 3. Stage 4 would only be planted with halophytes, plants that tolerate extreme salinity (applied water above 15 dS/m).

C. Subsurface Drainage System

The purpose of a subsurface drainage system is to:

- Provide control of water table for farmer;
- Improve salt leaching.

The spacing, depth and number of drains in the IFDM system are influenced by soil type and economics.

Eucalyptus trees are useful for border strips where subsurface lateral flow is a problem.

VI. Solar Evaporator

The purpose of the solar evaporator is to evaporate water in an acceptable manner.

Draft Title 27 §22920 of the Solar Evaporator Regulations states:

Solar evaporators shall be designed by a registered civil or agricultural engineer, or a registered geologist or certified engineering geologist.

The following definitions are from the Solar Evaporator Regulations under Draft Title 27:

(Draft Title 27 §22910 of the Solar Evaporator Regulations)

"Solar evaporator" means an on-farm area of land and its associated equipment that meets all of the following conditions:

1. *It is designed and operated to manage agricultural drainage water discharged from the IFDM system.*
2. *The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the IFDM system.*
3. *Agricultural drainage water from the IFDM system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.*
4. *The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface drainage under the solar evaporator provides adequate assurance that constituents in the agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.*

"Standing water" means water occurring under all of the following conditions:

1. *to a depth greater than one centimeter,*
2. *for a continuous duration in excess of 48 hours,*
3. *as a body of any areal extent, not an average depth, and*
4. *under reasonably foreseeable operating conditions.*

"Water catchment basin" means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin. A water catchment basin may include an enclosed solar still, greenhouse or other fully contained drainage storage unit. For the purposes of this definition, the term "within the boundaries of a solar evaporator" shall include a solar still, greenhouse, or other fully contained drainage storage unit adjacent to or near the portion of the solar evaporator that is outside the catchment basin.

The definition of water catchment basin includes an "enclosed solar still, greenhouse or other fully contained drainage storage unit."

Solar stills and greenhouses are enclosed structures that increase ambient temperature through solar radiation, causing an increase in evaporation.

One difference between them is that a solar still is a modified greenhouse that is used not only to increase evaporation, but also to separate salt and generate distilled water.

Research has been done with a solar still as a component of an IFDM system. It determined that a large area is required, and that it would be most appropriate for a large-scale operation. It is not commercially feasible on a small farm.

Red Rock Ranch solar evaporation drainage water system.

(Draft Title 27 §22910(l) of the Solar Evaporator Regulations)

"Reasonably foreseeable operating conditions" means:

1. *Within the range of the design discharge capacity of the IFDM system and the authorized solar evaporator system as specified in the Notice of Plan Compliance and Notice of Authority to Operate (§25209.13 of Article 9.7 of the Health and Safety Code);*
2. *Precipitation up to and including the local 25-year, 24-hour storm; and*
3. *Floods with a 100-year return period.*

Operation of a solar evaporator in exceedance of design specifications is not covered by "reasonably foreseeable operating conditions," and therefore would constitute a violation of the Notice of Authority to Operate.

(Draft Title 27 §22920 of the Solar Evaporator Regulations)

A water catchment basin may be required:

1. *As a component of a solar evaporator if standing water would otherwise occur within the solar evaporator under reasonably foreseeable operating conditions, or*
2. *If a solar evaporator is constructed with a liner. In this case, a water catchment basin shall be designed with the capacity to contain the maximum volume of water that the solar evaporator would collect under reasonably foreseeable operating conditions. A water catchment basin is not required for a solar evaporator that does not have a liner, if it is demonstrated that standing water will not occur under reasonably foreseeable operating conditions.*

A. Salt Management

(Draft Title 27 §22940 of the Solar Evaporator Regulations)

Salt Management — For solar evaporators in continuous operation under a Notice of Authority to Operate issued by a Regional Water Quality Control Board, evaporite salt accumulated in the solar evaporator shall be collected and removed from the solar evaporator if and when the accumulation is sufficient to interfere with the effectiveness of the operation standards of the solar evaporator as specified in this section. One of the following three requirements shall be selected and implemented by the owner or operator:

1. *Evaporite salt accumulated in the solar evaporator may be harvested and removed from the solar evaporator and sold or utilized for commercial, industrial, or other beneficial purposes.*
2. *Evaporite salt accumulated in the solar evaporator may be stored for a period of one-year, renewable subject to an annual inspection, in a fully contained storage unit inaccessible to wind, water, and wildlife, until sold, utilized in a beneficial manner, or disposed in accordance with (3).*
3. *Evaporite salt accumulated in the solar evaporator may be collected and removed from the solar evaporator, and disposed permanently as a waste in a facility authorized to accept such waste in compliance with the requirements of Titles 22, 23, 27 and future amendments of the CCR, or Division 30 (commencing with Section 40000) of the Public Resources Code.*

VII. Site Evaluation & Considerations

Once a farmer has been informed on what an IFDM system is, he can move forward to the project design and implementation. During the design phase, it is important to understand that a consultation with a qualified professional, such as a civil engineer, is neccessary for the individual site evaluation. A site evaluation should include climatology, groundwater, soil, farm area and subsurface drainage system.

Table 1. An example of monthly weather data available from CIMIS

Date	ETo in.	PRECIP in.
MAR 00	4.34	1.18
APR 00	6.34	0.87
MAY 00	8.56	0.00
JUN 00	8.75	0.04
JUL 00	8.62	0.00
AUG 00	7.95	0.04
SEP 00	6.04	0.00
OCT 00	3.87	1.81
NOV 00	1.72	--
DEC 00	1.15	0.00
JAN 01	1.59	0.33
FEB 01	2.08	0.95
----TOTAL AND AVERAGES	61.02	5.22

VIII. Climatology

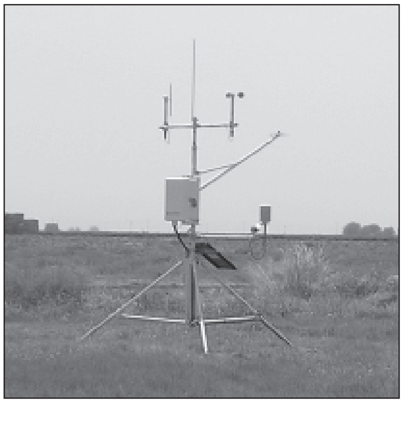
Review the historical and the most recent rainfall and other climatic data. An example of climatic data is presented in Table 1.

In areas with known flood potential, the designer will need to obtain data on flood occurrence from government agencies.

IX. Groundwater

In working with groundwater, there are four main issues that must be studied:

- Groundwater quality;
- Groundwater quantity;
- Regional groundwater flow; and
- Water table depth.



A typical CIMIS-type weather station is necessary to monitor conditions that may impact IFDM systems.

There is some seasonal fluctuation in each of these, so it is important to make sure that the evaluation period covers all seasons.

Groundwater Quality: Constituents generally tested include:

- Salinity measured in (EC) or (TDS)
- Calcium
- Boron
- Molybdenum
- Sodium
- Magnesium
- Chloride
- Arsenic
- Sulfate
- Selenium
- Nitrate
- pH

It is important to use the correct sampling procedures and to send samples and control samples to qualified (ELAP certified) labs (see Chapter 3). The Regional Water Quality Control Board will specify the protocol for sampling.

The information collected from this initial water sampling is baseline data. This information will be compared with future data in order to monitor the IFDM system performance and management. (See Chapter 3 for more details on water quality monitoring information.)

X. Regional Groundwater Flow

Shallow groundwater is made up of regional groundwater and deep percolation from inefficient irrigation. In general, the direction of the natural regional flow of groundwater is down-slope from the Coastal Range on the Westside of the Valley, and flows northeast to the trough of the Valley.

The USDA's Natural Resources Conservation Service has used observation wells (piezometers) and/or backhoe pits placed throughout fields, for charting water tables and assessing the magnitude of regional flow over time. The evaluation time varies with the complexity of the hydrology of the area.

A grid must first be established to determine the placement of monitoring wells (observing points). This grid is determined after evaluating available soils data and the agronomic experience of the farmer. Grower input is important in identifying problem areas on the site. Monthly observations should be recorded for a full year to account for seasonal groundwater fluctuations.

The collected data are used to locate drains at an optimum depth in order to minimize the volume of drainage water. Drain depth is important because if it is too shallow, it is not effective and if it is too deep, the drain would collect larger volumes of regional groundwater.

Some regional groundwater flow data is available from water districts, including Westlands, (groundwater observation well logs) and the Department of Water Resources.

- **EM-31 and EM-38** may be useful for the initial site evaluation (to gather baseline data) and later as a tool to evaluate changes.
- **EM-31** is an electromagnetic probe that logs information on the presence of water down to 10′ as well as the location by GPS coordinates, so that accurate maps of groundwater may be created.
- **EM-38** is an electromagnetic probe that logs information (in varying increments) on salinity down to 4′ as well as the location by GPS coordinates, so that accurate maps of salinity may be created.

XI. Soil

Soil survey: There are several soil resources that are available to landowners. The USDA Natural Resources Conservation Service (NRCS) has done extensive work on the characterization of the soils in the San Joaquin Valley, but it is essential that a site-specific soil survey be performed.
The steps are:

1. Create a grid: select, identify and map sampling sites, paying particular attention to intercept high EC areas.
2. Determine appropriate depth for sampling, based on the size of crop root zone (generally 5′).
3. Collect soil samples from selected sites. Send the samples to a certified laboratory that will analyze the soil and test for various constituents.

Clay soils pictured here are found at AndrewsAg in southern Kern County.

Backhoe pits may be utilized to study and characterize the soil profile.

Salinity survey: Salinity is usually one of the constituents evaluated in the soil survey report. Salinity data is useful in determining initial crop selection and leaching requirements.

Aerial photographs: 24,000 scale or 8″ to mile are helpful in identifying buried stream channels, high salt areas, and portions of the field that will require more intensive management. Infrared aerial photos are useful in identifying chronic salinity hot spots.

The data collected from the soil and salinity surveys will be used to design the IFDM system. It is to a farmer's benefit to collect as much background data as possible. A current on-site investigation including traditional soil analysis and salinity analysis will help assess the current conditions, and may be helpful for future reference and comparison. Historical and current background data is available from the NRCS and aerial photographs (both new and historical) are available at CSU, Fresno, NRCS or DWR.

XII. Farm Area

A detailed evaluation of the initial conditions of the site is the first step required for planning an IFDM design. Each of the following items has some impact on the design of the IFDM system:

A. Acreage

Determine how many acres will be devoted to each of the sections of the IFDM system based on your cropping system, the subsurface drainage volume and quality of subsurface drainage water. The subsurface drainage volume will be directly affected by irrigation water management.

B. Geography

Surveys and maps provide good information on location of stream beds (conduct underground water), and alluvial fans (slope and gradient vary and affect surface and subsurface flow which normally flows from southwest to northeast).

- Study historical cropping data from the past 5-7 (or more) years.
- Study the rainfall and climatic conditions (determine 24-hour rainfall) as well as flood occurrence (history of overland flow from flood occurrence). This information is available at local NRCS field offices.

C. Slope

Slope and ground elevation are evaluated in the initial site survey. The information collected from the survey is utilized to prepare a topographic map of the site, which is helpful in the design of the irrigation and subsurface drainage systems, the placement of trees, and location of solar evaporator.

D. Existing Systems and Infrastructure

Identify the location of farm water conveyance systems (canals, ditches, ponds, basins and collector sumps) as well as those located upslope of the site. Surface water conveyance systems have the potential to dilute the concentration of salt in the drainage water. Map out the site boundaries and locate field roads. Contact Underground Service Alert (USA) www.usanorth.org or (800) 227-2600, at least 2 working days before performing underground improvements, to find out the locations of underground utilities.

E. Information for Siting the Salt Harvest Area

Evaluate elevation and slope, hydraulic conductivity of the soil, and measure groundwater and water table levels over a period of one year (especially during the rainfall period) to record fluctuation. This data is essential in determining what area will be most suitable for the salt harvest facility. It is very important that the solar evaporator be sited away from tail water reservoirs, ditches, and areas with a potential flood hazard. Berms and levees should be used where necessary in order to avoid potential problems with flooding and storm water.

XIII. Subsurface Drainage System

The purpose of a subsurface drainage system is to provide control of the water table for farmers and to improve salt leaching. The drainage system should be designed by a qualified individual. The regulations state the solar evaporator must be designed by a registered civil or agricultural engineer or a registered geologist or certified engineering geologist.

Each of the crop areas requires an independent subsurface drainage system, sump and sump pump, as does the solar evaporator.

When designing the drainage water surface transport system, the qualified professional should account for the irrigation system efficiency and management, incoming water quality and leaching requirement.

XIV. Water Management & Monitoring

A. Water Pumping and Distribution in Crop Areas

Each pump must have a flow meter to monitor the amount of irrigation water applied. Each field must also have a sump into which the subsurface drainage system drains, a sump pump, and flow meter in order to keep track of the volume of water produced by the subsurface drainage system.

The quality of the subsurface drainage water and tail water collected from the sumps of Stage 1's salt-sensitive crops is monitored and mixed with fresh or tail water to make irrigation water of a specific EC to be applied to salt-tolerant crops in Stage 2. Thus, the salinity of Stage 2 is maintained within very close tolerances. Monitoring of water quality and measurement of the volume of water pumped allows for adjustments if there is a change in operation or water availability. This information can be used to improve water management.

B. Flow Control in the Subsurface Drainage System

Flow control is desirable in a subsurface drainage system because it allows groundwater levels to be managed throughout the growing season to allow crops to utilize higher EC water.

In addition, it allows the grower to store drainage water in the soil during low evapotranspiration months. Flow control structures may be installed into an existing subsurface drainage system. Existing systems will require modification to deliver drainage water to the solar evaporator.

The agricultural engineer who designs the system should discuss with the farmer where to place the flow controls in the IFDM system for maximum benefit.

C. Solar Evaporator

The objective of the solar evaporator is to evaporate water in an acceptable manner.

1. Location

Do not locate a solar evaporator:

1. Near tail water ponds;
2. Near irrigation or tail water ditches; and
3. In lowest topographic area of farm (danger of flooding).

(Draft Title 27 §22920 of the Solar Evaporator Regulations)

Flooding—A solar evaporator shall be located outside the 100-year floodplain, or shall be constructed with protective berms/levees sufficient to protect the solar evaporator from overflow and inundation by 100-year floodwaters, or shall be elevated above the maximum elevation of a 100-year flood.

This drainage sump at Red Rock Ranch will be used to collect monitoring data.

2. Surface preparation for solar evaporator and/ or salt concentrator

The prevention of the migration of salts from the solar evaporator into groundwater is done by proper surface preparation, and is addressed in the regulations (Draft Title 27 §22920 of the Solar Evaporator Regulations):

Protection of Groundwater Quality — Solar evaporators shall be immediately underlain by at least 1 meter of soil with a hydraulic conductivity of not more than 1 x 10^{-6} cm/sec above the zone of shallow groundwater at any time during the year. The surface of the solar evaporator shall be a minimum of five-feet (5 ft.) above the highest anticipated elevation of underlying groundwater. A solar evaporator may be constructed on a site with soils that do not meet the above requirement, with subsurface drainage under or directly adjacent to the solar evaporator, a liner, or other engineered alternative, sufficient to provide assurance of the equivalent level of groundwater quality protection of the above soil requirement.

3. Water Pumping and Distribution in Solar Evaporator

a. Flood, Spray, and Sprinkler Systems may be used, but there are risks associated with each of them.

- Flood systems must be intensively managed in order to avoid ponded water and potentially harming wildlife.

- The advantage of utilizing spray or sprinkler systems is that they allow water to be more equally distributed in the area of the solar evaporator.
- A risk of utilizing spray or sprinklers systems is drift.

Regardless of the system, it is critical **that there be a person designated and trained as the operator of the solar evaporator**. This person must be dedicated to supervising and managing the solar evaporator and avoiding conditions that could create wildlife hazards.

b. Automatic System for Flood, Spray, or Sprinkler Systems

- It is possible to have an automatic system for the solar evaporator that monitors the water level in the catchment areas and turns the pump on and off.
- Programming of the system must incorporate real time monitoring and CIMIS station data.
- By utilizing CIMIS data (from the station of closest proximity or from an on-site weather station), it is possible to program the system so the proper volume of water is pumped each day of the season.
- One method for decreasing the potential for water ponding is to limit the application rate to 70 percent of the ETo for the day or week.

c. Monitoring Wells

Monitoring wells will be required around the IFDM site, as prescribed by Draft Title 27 §22940 of the Solar Evaporator Regulations.

- The RWQCB sets the requirements for the number of wells to monitor the solar evaporator as well as what constituents water must be tested for.
- The RWQCB also sets the schedule for how often monitoring must be performed and the schedule for data and report submission.
- Monitoring is performed in order to show whether groundwater quality is affected by the use of the solar evaporator.

See Chapter 3 for more details on monitoring requirements.

d. Design Options for Solar Evaporator

The following are conceptual solar evaporation design options that are currently in the development stage.

It is essential that the qualified individual designing your solar evaporator determine what design option is most appropriate and effective for your individual farming operation.

One design option is a solar evaporator sloped toward the catchment basin, surrounded by levees (Figure 4).

The concentrated drainage water is applied by sprinklers to the surface of the solar evaporator. Some of the water evaporates and the remaining water becomes more concentrated and runs into the water catchment basin. The water catchment basin is a ditch that is covered by netting to prevent any access of wildlife to the water in the basin. This basin collects excess water during the rainy season and can be used for the temporary storage of drainage water. The water catchment basin must be designed to contain water generated from a 25-year/24-hour storm event. Both rain water and drainage water are pumped from this basin and applied to the surface of the solar evaporator.

It is possible that this type of solar evaporator could be subdivided into 2 or 3 sections or cells, and alternate use of sections or cells in order to allow complete evaporation and reduce insect

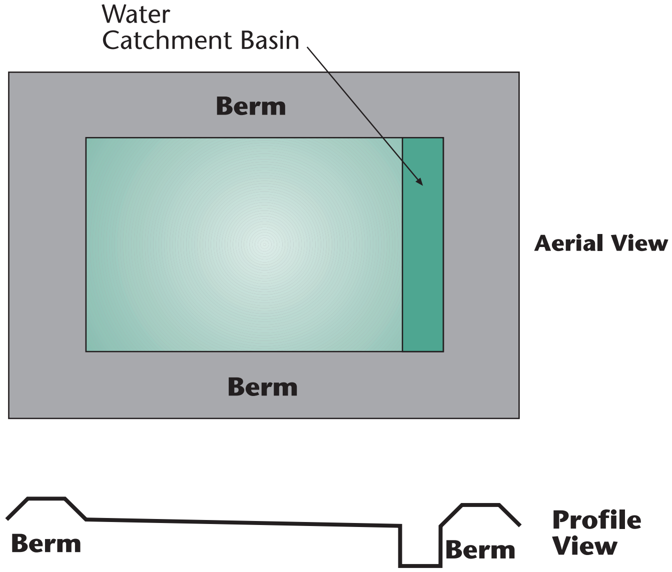


Figure 4. Solar evaporator and water catchment basin.

inhabitation. It is important to note that berms used to subdivide the solar evaporator into cells make the solar evaporator more attractive to nesting water birds. Avoiding the use of internal berms is a USFWS and CDFG best management practice recommendation to avoid impacts to nesting water birds.

Another design option is the combination of a solar evaporator with a salt concentrator, which would increase evaporation rates (Figure 5). Drainage water is applied to the sloped solar concentrator through specialized spray nozzles and recycled until the water reaches a specified concentration of salts. Then, the highly concentrated water is applied to the sloped solar evaporator to convert the salt to a dry crystallized form. The salt concentrator section would be covered with 2-1/2 to 3-inches of rock to increase evaporation time, as described above. This method could also be a multiple stage process of salt crystallization. A smaller salt harvest area would be the main advantage of this system that could also be used for the processing of marketable salt.

e. Design Considerations

Typical average evaporation rates in the San Joaquin Valley area are about 82 inches per year. Evaporation rates are reduced as the salt concentration in the drainage water increases.

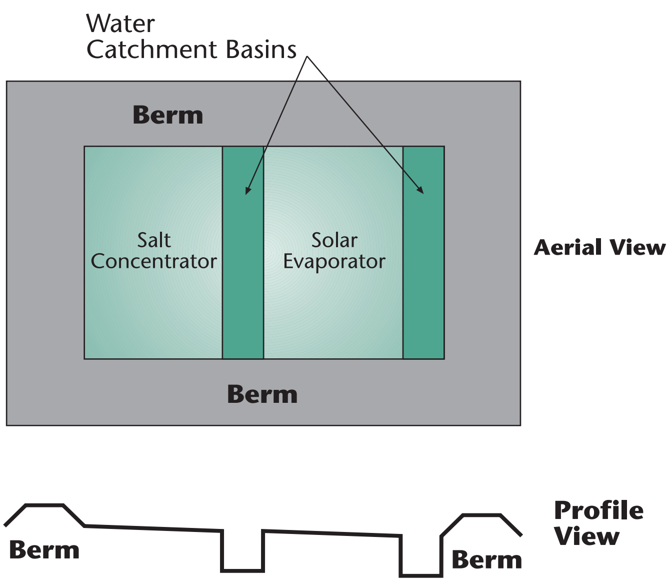


Figure 5. Solar evaporator with salt concentrator and water catchment basins.

Generally, the evaporation rate in a solar evap–orator is 70 percent of the typical evaporation rates (with an 82-inch evaporation rate, this would be about 58 inches). The estimated size of the solar evaporator for a given amount of processed drainage water is presented in Table 2.

Table 2. Estimated size of the solar evaporator.

Volume of Drainage Water to be Processed (acre-feet)	**Size of Solar Evaporator** calculated acres x 1.25=	recommended acres
6	1.3	1.6
8	1.7	2.1
10	2.1	2.6
12	2.5	3.2
14	2.9	3.7
16	3.4	4.2
18	3.8	4.7
20	4.2	5.3
22	4.6	5.8
24	5.1	6.3
26	5.5	6.8
28	5.9	7.4
30	6.3	7.9

Evaporation rates fluctuate during a year. The minimum levels are in the late fall, winter and early spring, and the maximum values are from late April to early October (Figure 6). The production of drainage water is greatest during the winter months, when evaporation rates are lowest. Since this pattern of water volume does not match the pattern of evaporation, consideration and planning of management options are necessary.

Options for addressing this problem include:

- Planning water application to decrease/minimize the volume of water to be managed;
- A surface water storage facility (storage tanks); and
- If growing shallow rooted plants, storage of excess water in the soil profile below the root zone for later use (i.e., Dosier valves and/or sumps).

The water application rates to the solar evaporator must correlate with evaporation rates. A simple electronic timer can control these application rates. The daily application rates will fluctuate from 0.04 to 0.5 inches during the year.

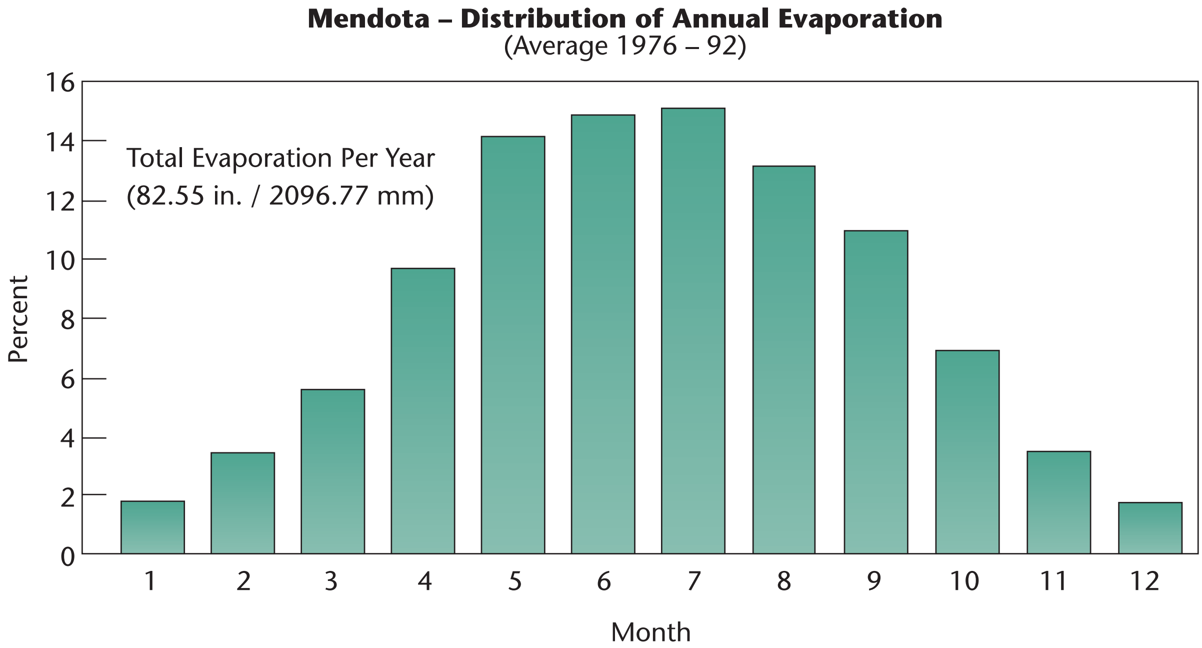


Figure 6. Evaporation rates throughout the year.

Table 3 gives the estimated time required to apply drainage water to the solar evaporator of a one-acre area, using a 250 gallons per minute pump.

The water catchment basin must be sized to accommodate the precipitation resulting from a local 25-year/24-hour storm. (See §22910(l), page 2-5).

Table 3. Water applied to solar evaporator (time required per day @ 250 gpm/acre).

Water Evaporated Per Day (inch/day)	Water Volume Per Acre (gal/day)	Time of Pumping (minutes/day)
0.04	1073.7	4.3
0.06	1610.6	6.4
0.8	2147.4	8.6
0.1	2684.3	10.7
0.15	4026.4	16.1
0.2	5368.6	21.5
0.25	6710.7	26.8
0.3	8052.8	32.2
0.35	9395.0	37.6
0.4	10,737.1	42.9
0.45	12,079.3	48.3
0.5	13,421.4	53.7

Example of annual salt accumulation in solar evaporator

One acre of solar evaporator can process nearly five acre-feet of water. At a salt concentration of 30,000 ppm (30 g/l), each acre-foot of water contains about 40 tons of salt. This would make about 200 tons of salt per one-acre area per year. This would create a layer of salt about 1.3 inches per year.

XV. Crop & Tree Areas

A. Water Reuse

Determine how many stages of water reuse are most appropriate for your farm.

- Three stage (Stage 1: salt sensitive, Stage 2: salt tolerant, Stage 3: very salt tolerant halophytes)
- Four stage (Stage 1: salt sensitive, Stage 2: salt tolerant, Stage 3: very salt tolerant, Stage 4: halophytes)

Considerations include cropping system, irrigation method, amount of subsurface drainage water produced and availability of irrigation water, tail water and fresh water.

B. Irrigation Methods

Irrigation of each area of the farm varies:

- Stage 1: Drip, sprinklers, or furrow may be used. Determine what is most appropriate for crop and adequate leaching.
- Stage 2: Furrow or sprinklers. Sprinklers are better for optimal leaching and the prevention of ponding. Some salt-tolerant field crops or vegetables may be sensitive to sprinkling with saline water (due to foliar absorption). In this case, furrow may be necessary.
- Stage 3 and/or Stage 4: Sprinklers for halophytes. For salt-tolerant forages sprinklers may be used with lower salinity water and they allow quicker drying of the soil for forage cutting. If the salinity of the drainage water is near the limit for the forage, then surface irrigation would reduce the potential for damage from saline sprinkling.

C. Establishment of Crops and Trees

The planting and establishment of trees and other perennials should be the first step in the implementation of an IFDM system. Trees should be irrigated with fresh water for at least the first year, in order to become established. Most crops, with the exception of halophytes, will also require fresh water irrigation for establishment. For perennial forages, this may also be a one-year period of time.

Location of Crops and Trees

- Location of trees depends upon direction and magnitude of regional flow.
- As mentioned before, trees are generally located along the appropriate boundaries in order to intercept regional subsurface groundwater flow.
- Avoid planting trees under power lines.
- Salt-sensitive crops are generally located on the IFDM fields with high elevations (keep in mind that there are pumping costs associated with elevation).

See Chapter 6 and the Appendix for more information on plant selection, culture, and management.

XVI. System Operation & Maintenance

A. Solar Evaporator

1. Monitoring

- Water table
- Groundwater quality
- Quantity of water pumped
- Maintain and monitor sprinkler distribution system
- Monitor application rate of water in solar evaporator

2. Wildlife

Avoid ponding water greater than 1 cm in depth for more than 48 hours to minimize impacts to avian wildlife (as required by Draft Title 27 §22940 regulations). If ponded water is avoided, many of the items listed below would not be an issue.

(Draft Title 27 §22940 of the Solar Evaporator Regulations)

Avian Wildlife Protection — The solar evaporator shall be operated to ensure that avian wildlife is adequately protected as set forth in §22910 (a) and (v). The following Best Management Practices are required:

1. *Solar evaporators (excluding water catchment basins) shall be kept free of all vegetation.*
2. *Grit-sized gravel (<5 mm in diameter) shall not be used as a surface substrate within the solar evaporator.*
3. *Netting or other physical barriers for excluding avian wildlife from water catchment basins shall not be allowed to sag into any standing water within the catchment basin.*
4. *The emergence and dispersal of aquatic and semi-aquatic macro invertebrates or aquatic plants outside of the boundary of the water catchment basin shall be prevented.*
5. *The emergence of the pupae of aquatic and semi-aquatic macro invertebrates from the water catchment basin onto the netting, for use as a pupation substrate, shall be prevented.*

To decrease the attractiveness of the area as a breeding site for birds, vegetation control around the solar evaporator is needed. Vegetation control

An example of tomatoes being grown on the Red Rock Ranch within the IFDM system.

should not be performed during the nesting season from February 1 through August 31 unless a qualified wildlife biologist has found the area to be nest-free.

Earthen berms or levees inside the perimeter of the solar evaporator are attractive to wildlife. (See the technical manual for information about alternatives to earthen levees.)

Hazing with propane canons, cracker shells and colored tape are some avoidance measures that may be effective in reducing migratory birds foraging and nesting in or around the solar evaporator during the early spring and summer months.

There should be a person designated and trained as the operator of the solar evaporator. This person must be dedicated to supervising and managing the solar evaporator and avoiding conditions that could create wildlife issues.

XVII. Future Investigations

Research is underway to discover new uses and applications for salt as well as to refine IFDM processes. The research focuses on the following areas.

A. Salt harvest Utilization and Marketing

Salt marketing is the preferred option for salt removal. Sodium sulfate is the main component of the salt produced by the salt harvest system in the San Joaquin Valley and is suitable for a variety of markets. Ninety-nine percent pure sodium sulfate has a market value of ~$50/ton. Commercial uses include the textile industry, ceramic and glass production and detergents. Salt consists of various combinations of sodium, calcium, sulfate, chloride, boron, magnesium, selenium and other elements, which are commercial commodities.

The Department of Water Resources has been working with the University of California, Davis, and several salt companies on the development of salt products and markets. The salt harvested from the farms in the San Joaquin Valley may have some economic value. Salt companies could benefit from a free source of salt and farmers could benefit from moving the salt out of the Valley. Salt production in the San Joaquin Valley also would be in relative proximity to main salt markets (Los Angeles Basin, Bakersfield, Fresno and the Bay Area) and to major ports (Stockton and Los Angeles Basin).

1. Recovery Purification and Utilization of Salts from Drainage Water

The key to producing a marketable salt product is a high degree of purity. Research is continuing on methods to produce and recover salts (of the necessary purity) in an economical manner.

B. Crops

1. New Salt-Tolerant Crops and Forage Crops

Possible crops being evaluated for salt tolerance include forage grasses, shrubs and flowers, such as statice and rose.

2. Halophytes with Commercial Value

Pickle weed has been grown successfully in some saline conditions. It is used as a food in several countries when irrigated with seawater (NaCl).

3. Flow-through System

The flow-through system that promotes biological activity with a hay bale carbon source has been used to reduce selenium levels in drainage water. Research into these systems is continuing with the goal of learning enough to make these systems more universally applicable.

4. Affect of Waterlogging on Soil Profile

Waterlogged soil is usually something to be avoided since, in waterlogged soil, water occupies all of the pore space in the soil, excluding air required for root respiration. Shallow groundwater can be an asset if it is deep enough in the soil profile. Some crops can use the water from shallow saline water tables to satisfy a portion of the crop's consumptive use. Storing drain water in the soil profile can mimic a naturally occurring, saline, shallow groundwater table. The ability to store water in the soil profile can provide additional flexibility in water management.

C. Energy Alternatives

1. Solar Ponds

Solar ponds are deep bodies of saline water that develop a temperature gradient from top to bottom. This difference in temperature from top to bottom can be used to generate electricity. Successful installations existed in Texas and research ponds are planned for the Central Valley.

2. Saline Biomass Production for Energy Use

Biomass production is a proven technology. Growing plant material (both plants and trees) for energy production can be economically beneficial.

Chapter 3. Monitoring, Recordkeeping and Reporting

I. Introduction

Water quality monitoring and the subsequent recordkeeping practices are important components of a successful IFDM program. Water monitoring is performed for four main reasons:

1. Characterize water to identify changes or trends;
   - Adequate groundwater monitoring data is a required component of the Notice of Intent application that is to be filed with the Regional Water Quality Control Board (RWQCB) prior to installing the solar evaporator. The groundwater monitoring data will be used to establish the baseline information to compare subsequent data submitted by the operator.
   - Monitoring not only is required by the Notice of Intent filed with the RWQCB, it is also necessary to evaluate the IFDM system. Monitoring reports show how well the system is working, and also to help identify specific water quality problems. In addition, it will be useful to determine California Environmental Quality Act (CEQA) baseline data.
   - Initially, monitoring is useful to describe the condition of the land prior to implementing IFDM. This information can help develop a baseline against which future evaluations can be compared. The baseline analysis will be used by engineers in the design of the IFDM system.
   - Lastly, the information is used to determine whether project goals are being met and if the system is in compliance with the RWQCB regulations.

2. Identify specific water quality problems;
3. Gather information to aid in system design and securing permits; and
4. Determine whether project compliance and implementation goals are being met, and gather information for establishing baseline conditions (e.g. affected environment) under CEQA.

II. Data Quality

The quality of environmental data collected is described by its accuracy, precision, completeness, representation and comparability. Multiple factors can influence the data quality, including sampling methods, the way samples are handled and analyzed, and the way data are handled.

Quality assurance (QA) includes measures that are performed to ensure that there is minimal error and that data are valid and reliable. The two measures of QA are quality control (QC) and quality assessment.

The RWQCB may require a Quality Assurance Program Plan (QAPP) for each IFDM project. A QAPP is an important planning document for environmental data collection because it details the project management, standard operating procedures (SOPs), QA (QC and quality assessment measures), and data assessment measures that will be implemented throughout the project.

The California Environmental Protection Agency SWRCB Water Quality website, www.swrcb.ca.gov/swamp/qapp.html, outlines the sections and appendices of a Surface Water Ambient Monitoring Program (SWAMP) QAPP. The table of contents from the website can be found in the Appendix.

The California Department of Water Resources (1998) *Guidelines for Preparing Quality Assurance Project Plans* is a helpful reference for QAPP development and preparation.

III. Monitoring & Reporting Program

IFDM systems are to be designed and operated to prevent threats to water quality, fish and wildlife, and public health. Monitoring and record keeping requirements, including a groundwater monitoring schedule, data, and any other information or reporting, will be specified by the RWQCB.

A properly designed monitoring program will aid in assessing any impact of the agricultural drainage water disposal on surface and groundwater quality, fish and wildlife, and public health. State and federal laws regulate agricultural drainage water surface discharges, which may impact surface waters.

Water monitoring samples are taken from a sump at the Red Rock Ranch near Five Points.

A. Groundwater Monitoring

A person operating a solar evaporator will be required to collect adequate groundwater data. All indicator parameters and constituents of concern need to be collected from monitoring wells installed by the operator. Groundwater monitoring includes measurements for water-level depth, specific electrical conductivity, standard minerals and trace elements as specified by the RWQCB.

B. Subsurface Agricultural Drainage Water Applied to the Solar Evaporator

A station will need to be established for measurement and collection of representative samples to measure the subsurface agricultural drainage water applied to the solar evaporator. Applied water monitoring will include mean daily flow measurements, specific electrical conductivity, standard minerals and trace elements as specified by the RWQCB.

C. Solar Evaporator Subsurface Drainage System Monitoring

Solar evaporator subsurface drainage systems (tile drains) are monitored for mean daily flow and specific electrical conductivity as specified by the RWQCB.

D. Sampling Plan

Sampling plans are written procedures that provide details on how sampling is conducted (SOPs) and are incorporated as part of the QAPP. A typical sampling plan may include details on the following:

- Sample locations (map or diagram)
- Sample type
- Sample frequency
- Number of samples
- Duration of sampling
- Sample volume
- Sample collection methods and holding times
- Equipment to be used for sample collection
- Sample containers
- Pretreatment of containers
- Type and amount of preservative to be used
- Blanks, duplicates/triplicates, spiked samples, replicates
- Chain of custody procedures
- Any other pertinent matter which will have a bearing on the quality assurance in collecting and handling samples (DWR, 1994)

E. Who will Perform the Monitoring and How?

A person knowledgeable and trained in monitoring protocols should be selected to collect representative water samples, perform specific field measurements, and prepare samples for laboratory analyses using accepted methodology.

F. What Parameters will be Measured?

All indicator parameters and constituents of concern must be identified in the sampling plan by the operator and submitted to the RWQCB for approval. The baseline sampling data will provide information to determine the constituents of concern and constituents of importance. A typical sampling plan may measure the following constituents:

1. **Trace Elements**
   a. Selenium
   b. Boron
   c. Arsenic
   d. Molybdenum
2. **Standard Minerals**
   a. Calcium
   b. Magnesium
   c. Sodium
   d. Potassium
   e. Alkalinity
   f. Sulfate
3. **Specific Electrical Conductivity and pH**
   Water quality parameters must be measured prior to collecting samples for laboratory analysis. Field measurements are recorded for specific conductance, pH, air and water temperatures, and weather observations. Agricultural observations, such as, the type of crop and crop height are noted and submitted with the water samples to the analytical laboratory. Weather data can be found at the nearest station of DWR's California Irrigation Management Information System, CIMIS, at: www.cimis.water.ca.gov
4. **Other**
   In addition, other elements of concern may be identified from the baseline monitoring data or as required by the RWQCB. Some elements are site-specific or found in elevated concentrations in designated areas of the San Joaquin Valley.

G. Approved Laboratories

The California Environmental Laboratory Improvement Act requires that an environmental laboratory producing analytical data for California regulatory agencies (including RWQCB) must be accredited through a Department of Health Services accreditation program for environmental health laboratories. The accredited labs also are known as certified through the Environmental Laboratory Accreditation Program (ELAP).

To select an ELAP certified laboratory in your area that can perform analyses on all required constituents, you must first identify the required Field of Testing (FOT)/ Field of Accreditation (FOA) numbers. The RWQCB will determine what constituents will be required and identify the corresponding FOT/FOA numbers.

Measuring groundwater depth

- The following website shows a table of FOT/ FOA numbers, brief descriptions and levels of complexity. www.dhs.cahwnet.gov/ps/ls/elap/pdf/FOT_Desc.pdf
- The following website shows a list of ELAP certified labs by county and name. To select a lab, look through the list of labs in your county and make sure that the lab that you select is accredited to perform analyses on all required FOT/FOA numbers. www.dhs.cahwnet.gov/ps/ls/elap/htm/LablistStart.htm

H. Where are the Monitoring Sites?

Monitoring sites that are accessible, easy to find and reachable in bad weather, will allow for measurements to be taken at the desired time. Assign a name and provide a description of each of the sampling locations. Develop a diagram with reference points on how to find the monitoring site.

I. When will the Monitoring Occur?

Sampling frequency will be determined by the RWQCB. In general, sampling should be frequent enough to describe all important water quality changes or trends. Initially, more frequent monitoring may be needed to establish the baseline conditions. Once established, the frequency of monitoring may be reduced by the RWQCB according to the laboratory test results.

IV. Reporting Requirements

It is important to summarize the data to clearly illustrate compliance with all applicable regulatory requirements. Arrange the data in tabular form so the required information is readily discernible. Certain technical information needs to be submitted with the monitoring report. Daily evapotranspiration values of the nearest weather station from which information is available and copies of the laboratory analyses are to be submitted as part of the report. Weather data can be found at DWR's California Irrigation Management Information System, CIMIS, at: www.cimis.water.ca.gov

Any person operating a solar evaporator should submit annual groundwater monitoring data and information at the earliest possible time, according to a schedule established by the RWQCB. The regional board shall notify the operator of each solar evaporator of the applicable submission schedule.

A. Examples of Water Monitoring Plans

The following three sections are examples of water monitoring plans listing some of the possible constituents that may need to be monitored. The RWQCB will determine the constituents that you will need to be monitored on your farm.

1. Applied Water Monitoring[1]

A station shall be established for measurement and collection of representative samples to measure the subsurface agricultural drainage water applied to the solar evaporator. Applied water monitoring may include the following:

Constituents	Units Measurement	Type of Monitoring	Monitoring Frequency
Mean Daily Flow	gpd	Meter	Continuous
Specific Electrical Conductivity	µmhos/cm or dS/m	Grab	Weekly
Standard Minerals[2]	mg/L	Grab	Quarterly
Trace Elements			
Selenium	µg/L	Grab	Monthly
Boron	µg/L	Grab	Quarterly
Arsenic	µg/L	Grab	Quarterly
Chromium	mg/L	Grab	Quarterly
Molybdenum	µg/L	Grab	Quarterly
Vanadium	µg/L	Grab	Quarterly

1 Analysis of certain constituents may require specialized field procedures (e.g. filtration and preservation) and are recommended to be performed by a qualified technician.

2 Standard minerals may include calcium, magnesium, sodium, potassium, alkalinity and sulfate.

µg/L = micrograms per liter
mg/l = milligrams per liter
µmhos/cm = micromhos per centimeter

2. Groundwater Monitoring[1]

Shallow groundwater should be monitored for all indicator parameters and constituents of concern. Samples should be collected from the installed wells and analyzed for the following:

Constituents	Units Measurement	Type of Monitoring	Monitoring Frequency
Depth	feet (tenths)	Measured	Quarterly
Specific Electrical Conductivity	µmhos/cm or dS/m @ 25°C	Grab	Quarterly
Standard Minerals[2]	mg/L	Grab	Quarterly
Trace Elements			
Selenium	µg/L	Grab	Quarterly
Boron	µg/L	Grab	Quarterly
Arsenic	µg/L	Grab	Quarterly
Chromium	µg/L	Grab	Quarterly
Molybdenum	µg/L	Grab	Quarterly
Vanadium	µg/L	Grab	Quarterly

1 Analysis of certain constituents may require specialized field procedures (e.g. filtration and preservation) and are recommended to be performed by a qualified technician.

2 Standard minerals may include calcium, magnesium, sodium, potassium, alkalinity and sulfate.

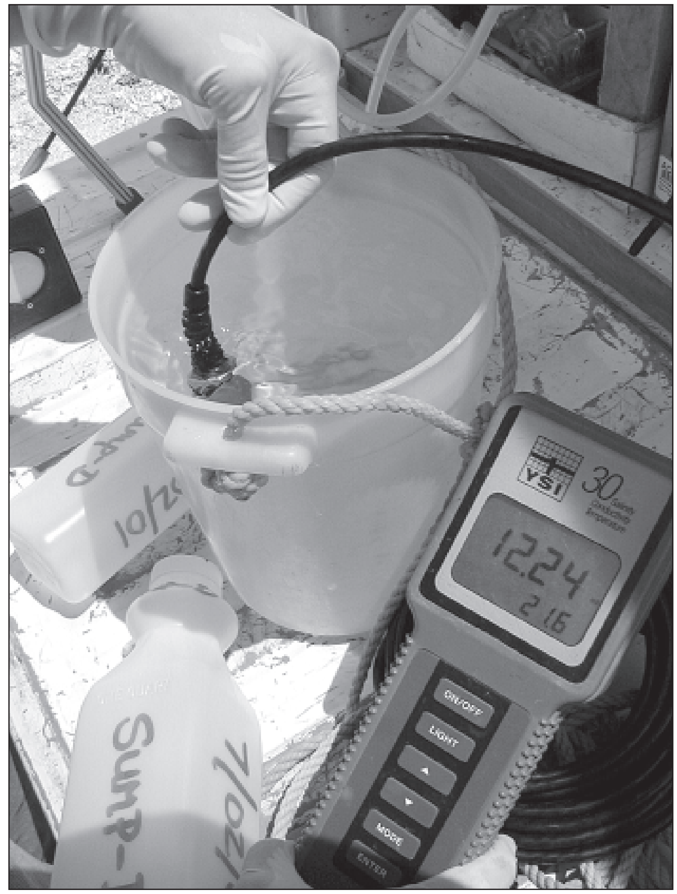
3. Solar Evaporator Subsurface Drainage System (Tile Drain) Monitoring

If the solar evaporator is equiped with a subsurface drainage system, the drain should be monitored for the following:

Constituent	Units	Type of Measurement	Monitoring Frequency
Mean Daily Flow	gpd	Meter	Continuous
Specific Electrical Conductivity	µmhos/cm or dS/m @ 25°C	Grab	Quarterly

B. Biological Monitoring

If standing water or other factors known to result in potential impacts to breeding and/or feeding birds are anticipated or have been demonstrated at a given IFDM site, the RWQCB, CDFG, and/or USFWS may determine that avian monitoring is required. Adequate avian monitoring at sites typically consists of the following:



Measuring conductivity

1. Timing

Biological surveys should be conducted weekly during the predicted avian breeding season, which is approximately from February 1 through August 31. During the non-breeding season, from September 1 through January 31, surveys will be conducted monthly. Monitoring should be conducted in a way that does not keep birds actively incubating eggs off of the nest during the heat of the day, since this can result in clutch failure. All wildlife monitoring will be conducted by, or under the direct supervision of, a qualified wildlife biologist with, or able to obtain, permits from the USFWS and the CDFG to collect the eggs.

2. Survey Components

Biological surveys will consist of:

1. Bird usage in the drainage management area, which includes the solar evaporator, halophyte plots, agroforestry plot or interceptor trees, sumps (including tail water), salt-tolerant grasses and adjacent crops will be documented by a qualified wildlife biologist. Data collected will at least include, but not be limited to, bird species present, approximate numbers of each bird species present, and any mating behaviors.
2. During the nesting season (approximately February 1 through August 31), a thorough search for nests and nesting activities should be conducted by a qualified wildlife biologist in and around the solar evaporator, halophyte plots, interceptor trees, sumps, and salt-tolerant grasses. Nests will be flagged, and nest fate monitoring will include counting nests, eggs and young. If shorebird nesting occurs on-site, one recurvirostrid (avian family which includes the Black-necked Stilt and the American Avocet) egg will be randomly collected from each detected nest, with no more than a total of five random eggs from five separate nests being collected from a given IFDM site during a given nesting season, unless directed to do otherwise by USFWS and CDFG. The collected egg contents will be chemically analyzed for moisture content, total recoverable selenium, and, if necessary, the concentration of other trace elements by a USFWS-approved laboratory. The egg contents also will be assessed for embryonic deformities by a USFWS-approved laboratory. Eggs will be collected according to USFWS egg collection protocol.
3. Presence of any ponded water in or around the solar evaporator, halophyte plots, interceptor trees, salt-tolerant grasses and/or adjacent crops will be documented. An estimate of percent coverage and approximate depth of the ponded water will be noted.

4. Presence of any aquatic invertebrate species in or around the solar evaporator, halophyte plots, agroforestry plot, salt-tolerant grasses and/or adjacent crops should be documented. The type of invertebrates present should be identified to the family level, and abundance (dense, scattered, few) in each location should be noted. Presence of live algal mats in any of these designated areas should also be reported.
5. The presence or evidence of other wildlife species in or around the solar evaporator, halophyte plots, interceptor trees, salt tolerant grasses and/or adjacent crops should be documented.

3. Reporting Requirements

The results of each survey component will be submitted to the Central Valley Regional Water Quality Control Board. Results will be submitted within a week of the survey date. The weekly reports will not include results of egg analyses, since obtaining complete results usually requires several months. Survey results should be summarized in four quarterly reports. The quarterly reports should be submitted to the Board as follows:

Reporting Period	Due Date
January-March	1 May
April-June	1 August
July-September	1 November
October-December	1 February

The USFWS Sacramento Office Contaminants Division and CDFG Southern Sierra Region Office in Fresno should also receive copies of all monitoring reports.

Figure 1. EM-38 survey equipment

C. Soil Monitoring

Soil monitoring is not required, but is recommended because it enables the tracking of the progress of the IFDM system (evaluate whether soil conditions are improving or declining) and provides information for fertilizer and nutrient applications. Generally, soil testing is performed once per year to measure EC, pH, and required anions and cations. Things to consider before sampling include:

- Field area (acres/sample)
- Sampling procedure
- Sampling depth
- Timing of sampling
- Sampling tools
- Sample handling
- Information forms
- Labs

There are numerous references for soil monitoring.

D. Salinity Monitoring

EM-38 surveys are not required, but may be helpful to evaluate salinity conditions in soil over time. See Figures 1 and 2.

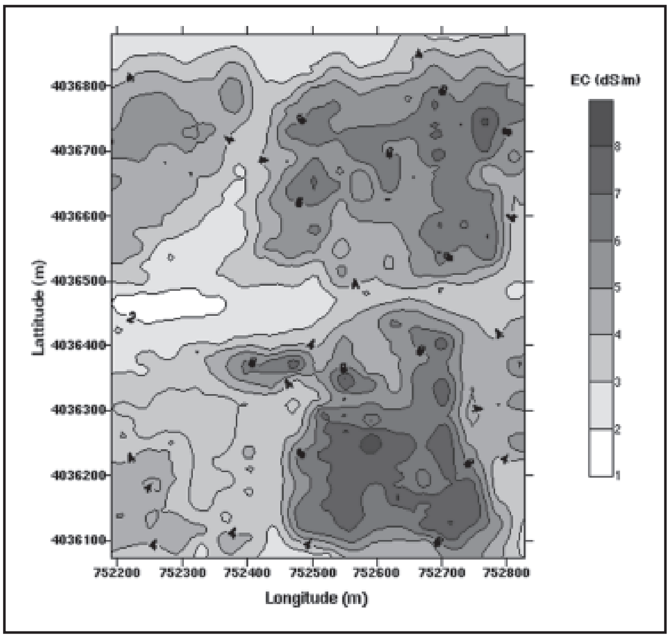


Figure 2. Salinity map created from EM-38 survey data (Values represented in this map are ECe (dS/m).

Chapter 4. The Impact of Geology and Soils in Salt Management

I. Introduction

Special farm management is needed on the Westside of the San Joaquin Valley because of its unique soil, climate and geological conditions. The soils are of marine origin and contain naturally occurring salts and trace elements that can be mobilized through cultural practices, such as irrigation. Accumulation and concentration of salts and trace elements can harm wildlife and reduce crop yields.

Valley land must be irrigated for crop production because of the arid climate (annual rainfall is less than 10 inches). Irrigation water is either imported or pumped from the ground and contains dissolved salts. When water is applied to crops, evaporation and transpiration remove the water from the soil, leaving behind the salts previously dissolved in the water. The salts become concentrated in the soil over time.

The unique geology of the Westside of the San Joaquin Valley results in a shallow groundwater table. The addition of irrigation water to leach salts further exacerbates the groundwater problem. The shallow water table saturates the root zone resulting in plant death and soil degradation. To solve this problem, subsurface drainage systems are installed 6 to 8 feet below the ground surface to collect the deep percolation (water that has moved beyond the root zone).

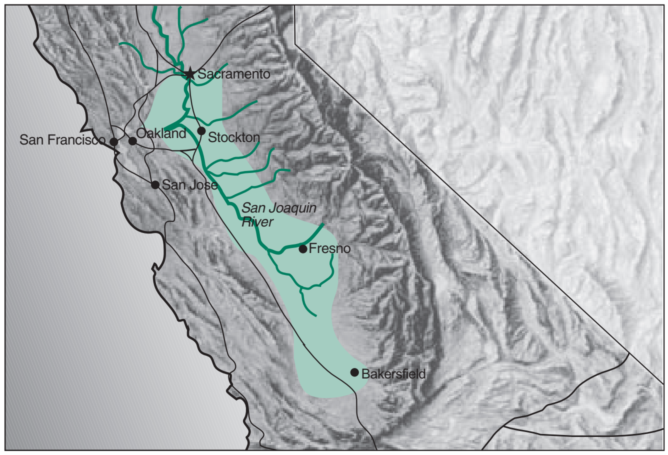


Figure 1. The San Joaquin Valley.

II. Soils of the Westside

A. Geography and Geology

The following information is taken from *Groundwater in the Central Valley of California - A Summary Report A2-A5*; Bertoldi, G.L., R.H. Johnson, et al. 1987. U.S. Geological Survey.

The Central Valley of California stands out as a notable topographic basin. It is about 400 miles long and averages about 50 miles in width. Surrounded on all sides by mountain ranges, the Valley has only one natural outlet through which surface water drains. That outlet, the Carquinez Strait, cuts through the central Coast Range on the Valley's west boundary. This work is focused around the San Joaquin and Tulare Basins, which make up most of the southern two-thirds of the Central Valley. The San Joaquin Basin is at the north end and drains into the San Joaquin River. At the southern end is a hydrologically closed basin (no drainage) called the Tulare Lake Hydrologic Basin.

Climate in the San Joaquin Basin and the Tulare Lake Hydrologic Basin is Mediterranean with an annual precipitation ranging between 5 and 16 inches. About 85 percent of the annual precipitation occurs from November to April. Summers are hot while winters are mild resulting in a long growing season. In contrast to the Valley's low precipitation, mean annual precipitation in the adjacent Sierra Nevada increases with altitude and ranges from 40 to more than 90 inches annually. Much of the precip–itation in the mountains is snow, especially in the higher southern Sierra Nevada. Peak runoff in the San Joaquin Valley generally lags peak precipitation by 5 to 6 months.

The southern San Joaquin Valley, made up of the San Joaquin and the Tulare Lake Hydrologic basins, contains 4 of the top 10 agricultural counties in the U.S., including Tulare, Fresno, Kern and Kings. To support this level of agricultural activity in an area that is deficient in precipitation requires a substantial amount of irrigation water. About half of the additional requirement comes from groundwater and half from surface water sources. The proportions of groundwater and surface water vary with annual precipitation.

B. Geologic Setting

From: *Groundwater in the Central Valley of California – A Summary Report*, A8-A9.

Learning about the formation of the Sierra Nevada and the Coast Range is important for understanding the deposition of aquifer material in the Central Valley and the distribution and movement of groundwater.

The Sierra Nevada is the largest single mountain range in the contiguous 48 states and is about 350 miles long and 55 to 80 miles wide. The Sierra Nevada is composed primarily of granite and related rocks. These rocks were tilted up toward the east by tectonic forces, and are evident by the much steeper slopes on the east side of the range. Wells drilled in the San Joaquin Valley penetrated granitic rocks at increasing depths toward the west, indicating that the granite exposed in the Sierra Nevada is only a small part of the whole mass.

The Coast Range is a result of overland thrusting of marine sediments that impact the San Joaquin and Tulare Lake Hydrologic basins in two ways. First, the emergence of the Coast Range thrust and its subsequent development established an orographic barrier for moisture-laden on-shore oceanic winds. As a result the San Joaquin Valley effectively was put into a rain shadow since the formation of its western boundary.

Secondly, the parent material of the Coast Range is marine sediment that remained inundated by the Pacific Ocean until fairly recently. The inundated areas were continuously changing in size and shape as the Coast Range emerged. Consequently both marine and continental shelf sediments were deposited.

Marine deposition was dominant in the initial developmental stages of the Coast Range and continental shelf deposits were prevalent during the latter stages of development. The marine deposits differ greatly in sediment type, sorting, and thickness because of the continually changing depositional environment. That is why the alluvial fans of the Westside of the San Joaquin

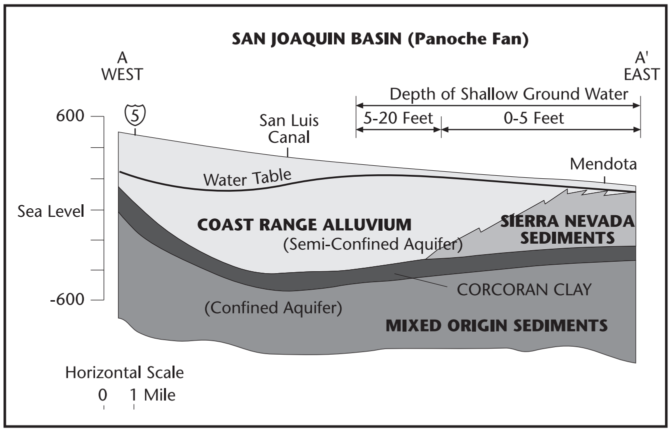


Figure 2: Cross-section diagram of the San Joaquin Valley showing Corcoran Clay layer in the San Joaquin Basin. Adapted from: *A Management Plan for Agricultural Subsurface Drainage and related Problems on the Westside San Joaquin Valley*: September 1990.

and Tulare Lake Hydrologic basins differ considerably in their chemical constituents.

C. Cultural Practices

For years, farmers in the San Joaquin and Tulare Lake Hydrologic basins have been pre-irrigating to provide proper seed bed moisture and to leach salts below the crop root zone; providing enough seasonal irrigation water to satisfy crop water requirements using an irrigation schedule; fertilizing; and realizing an acceptable yield.

Many Valley farmers have modified their cultural practices to manage drainage problems and to maintain acceptable yields. Cropping patterns have shifted in favor of increasing salt tolerance. Modifications of cultural practices have taken two forms: source control and the use of the shallow groundwater to satisfy some crop water needs.

The Valley's Westside slopes from the base of the Coast Range down to the Valley's center. The source of some shallow groundwater that impacts land in the Valley's center is the irrigated, upslope land on the Westside. The leaching faction, along with any over irrigation of this upslope land contributes to the shallow groundwater table as the water travels down the hydrologic slope to the Valley's center. The groundwater dissolves marine salts and minerals as it passes through the soil strata, adding to the salinity at the Valley's center.

D. Salinity

All soil has some level of salinity, which is a result of the dissociation of soil salts. These soil salts produce negative and positive ions upon dissociation.

Salts are necessary for plant growth and to maintain soil physical properties. The application of irrigation water with very low or very high concentrations of salt may cause infiltration problems, depending on the soil structure, compaction, organic matter content, and chemical make-up of the soil.

To determine whether infiltration problems may be a factor, it is important to determine the EC, or electrical conductivity, of the soil, as well as the concentration of calcium, magnesium, sodium, and SAR (sodium absorbtion ration) or ESP (exchangeable sodium percentage) (Oster and Jayawardane, 1998; Oster et al., 1996; Shainberg and Letey, 1984; and Hanson et al., 1999). Infiltration rates, hydraulic conductivity and soil tilth are affected by the balance between salinity and exchangeable sodium, especially as salinity decreases and exchangeable sodium increases.

Soil salinity is expressed as "ECe," the electrical conductivity of a saturated soil paste extract expressed in dS/m, but may be converted to TDS (ppm). The conversion factor varies with the degree of salinity. Soils that have ECs higher than 4 dS/m ECe (~2560 ppm TDS) are considered to be "saline;" however this designation certainly depends on the salt tolerance of the particular crop and management practices. Consequently, it is preferable to consult salinity tolerance tables and choose your crop accordingly. See Chapter 6 and Appendix for salinity tolerance tables.

E. Sodicity

Soils that have a SAR of 13 or an ESP of 15 are considered to be "sodic" and are likely to have low permeability to water. This tendency will be greater when irrigating with water that is very low in salinity.

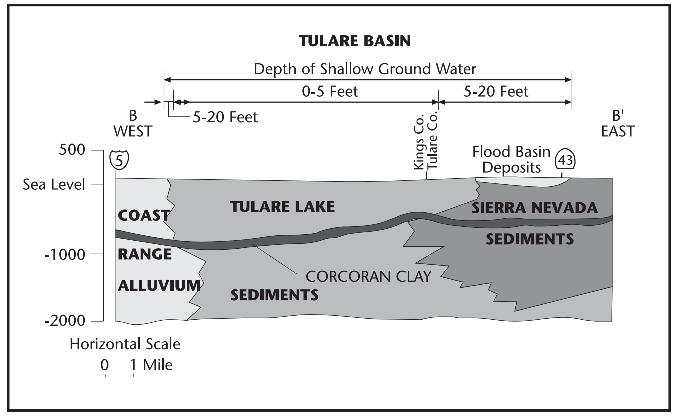


Figure 3: Cross-section diagram of the San Joaquin Valley showing the Corcoran Clay layer in the Tulare Basin. Adapted from: *A Management Plan for Agricultural Subsurface Drainage and related Problems on the Westside San Joaquin Valley*: September 1990.

F. Soil Reclamation

Reclamation of sodic soils is possible through chemical and physical management of the soils.

Reclamation techniques include the addition of soil or water amendments, fertilizer, organic residues, blending water supplies, cultivation and deep tillage, and irrigation management.

Amendments supply the calcium required to improve the chemical and physical properties (poor infiltration, compaction, high sodium levels) of the soil.

Addition of gypsum supplies calcium directly to the soil while adding acid to the soil or water can supply calcium indirectly. Acid liberates calcium from the lime that is commonly present in Westside soils and irrigation waters.

Gypsum or other amendments will not cause any significant improvement in soil physical properties if the soil problems result from restrictive layers or high water tables and no provision for subsurface drainage is made.

Chapter 5: Drainage Water Characteristics

I. Introduction

Water quality determines if, how and where the water can be used. Constituents in drainage water may include salts, toxic trace elements and nutrients. Water quality also can limit potential uses, as well as increase the costs of operation and maintenance of equipment and facilities. As salinity, measured either as total dissolved solids (TDS) or electrical conductivity (EC) increases, water quality decreases.

II. Units of Measurement

Water quality is assessed by evaluating the concentrations of, and relationships amongst, its constituents. This may include measuring the concentrations of salt ions such as sodium and chloride and trace elements such as boron and selenium, the sum of the dissolved salts which is salinity, or the ratio of sodium to calcium and magnesium which is sodicity. Water quality regulations establish standards for these constituents by which all must abide. Units of water quality are typically expressed as parts per million (ppm), parts per billion (ppb), or parts per trillion (ppt).

For dissolved salts and trace elements in water, volume-based units are most commonly employed. The measurement will be given as either milligrams per liter (mg/L) or milli-equivalents per liter (meq/L). The SI unit is millimoles of charge per liter (mmolc/L) which is primarily used in research. The following will help to explain these units, their equivalents, and conversions amongst them.

III. Characteristics of Agricultural Drainage Waters

A. "Tail Water" and Subsurface Drainage Water ("tile water")

There are two types of water that farmers routinely deal with on the Westside, "tail water" and subsurface drainage water.

- "Tail water" is surface water that was applied to irrigate crops but does not infiltrate into the soil and is collected as runoff.
- Subsurface drainage water as used in this manual refers to the water collected by the subsurface drainage system. The drains may collect or intercept irrigation and rain water that has moved through the soil profile as well as subsurface flows of groundwater. Hence, it is difficult to predict the composition, or trace the origin, of water collected by a subsurface drainage system.

1 ppm = 1 mg/L, the measurement most commonly used to characterize agricultural water on the Westside of the San Joaquin Valley.
1 ppb = μg/L, commonly used for trace elements
1 ppm = 1,000 ppb = 1,000,000 ppt
%C = 10,000 ppm

*Constituent	ppm → meq/L	meq/L → ppm
	multiply by	
Na (sodium)	0.043	23
Ca (calcium)	0.050	20
Mg (magnesium)	0.083	12
Cl (chloride)	0.029	35
SO_4 (sulfate)	0.021	48
HCO_3 (bicarbonate)	0.016	61
CO_3 (carbonate)	0.033	30

*from Hanson, Grattan, & Fulton, 1999, Agricultural Salinity & Drainage)

> Subsurface drainage water usually empties into a sump or some other type of collector from which it can be used to sequentially irrigate salt-tolerant crops.

Subsurface drainage water is usually of lower quality than the irrigation water applied to the soil surface. The drainage water has traveled through the soil profile and has picked up various compounds and substances, such as salts, soil particles, inorganic trace elements, and organic compounds. Subsurface drainage water from different locations has different compositions and characteristics. For example, in the Westside San Joaquin Valley, sodium sulfate is generally the predominant salt as compared to other salt-affected regions in the world where sodium chloride tends to predominate. Similarly, within the Valley, trace element composition in drainage water can differ greatly. At Red Rock (Five Points area) selenium concentrations in drainage water are much higher than at AndrewsAg (southern Kern Co.) or at Westlake Farms (near Stratford). However, at Westlake Farms, molybdenum concentrations are much higher than at the other two locations. These trace element compositions have implications, especially for forage production using drainage water.

B. Salts

The three primary sources of salts are irrigation water, soils and groundwater.

The primary source of imported irrigation water for the Westside is surface water from the Sacramento-San Joaquin Delta. Although it is extremely low in salts, each year an average of 800,000 tons of salt are imported to the northern San Joaquin Valley by surface water deliveries; 335,000 tons leave by way of the San Joaquin River. Another 2 million tons of salt are imported into the southern San Joaquin Valley by way of the water delivery system, where it remains because Tulare Basin is a hydrologically closed system (DWR, 2001). Moreover, in one hour alone, the salt accumulation in the San Joaquin Valley totals about 11 semi-truck trailers, at about 25 tons of salt per truck, according to the DWR (See Figure 1)

Because Westside soils are of a marine origin, they and the groundwater naturally contain salts. Irrigation adds more salts to the soil and groundwater. Additional sources of salt include local precipitation and runoff, pesticides, fertilizers, manure and other soil amendments, such as gypsum and lime.

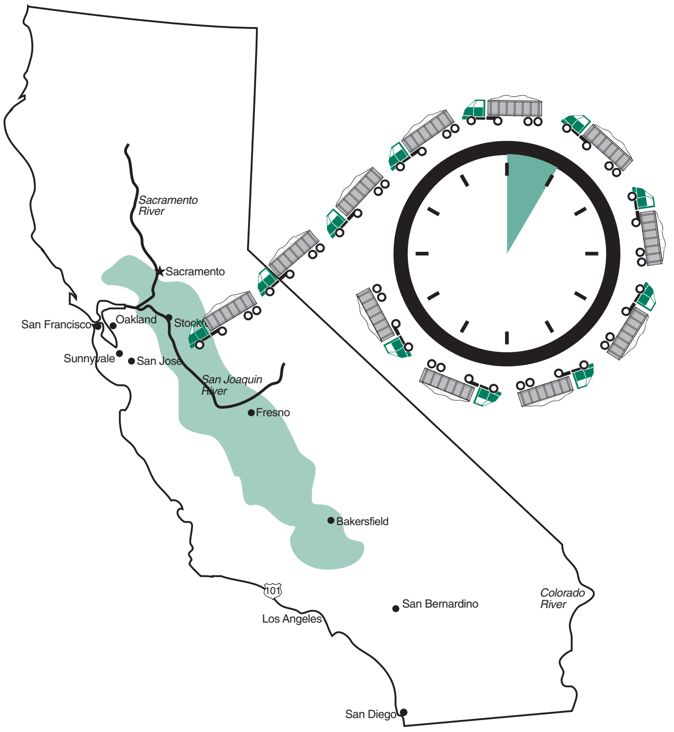


Figure 1. Salt accumulation in the San Joaquin Valley totals about 11 semi-trailers an hour at 25 tons per truck. From Salt balance in the San Joaquin Valley. 2001. *Water Facts*, Department of Water Resources.

Due to the variation in salts that are found in soils and irrigation waters, it is therefore logical that salt composition and concentrations in drainage water would also vary greatly. Salts that are commonly found in subsurface drainage water include sulfates, chlorides, carbonates, and bicarbonates of sodium, calcium, and magnesium. Tail water also may contain these salts, but generally in much lower concentrations than in drainage water. To summarize:

- Subsurface drainage water generally contains high levels of salts.
- Tail water contains slightly more salts than the applied water, but much less than drainage water.
- The salts present in subsurface drainage water may make the water unsuitable for domestic or industrial uses.

C. Water Salinity

Common units for water salinity are **EC** (electrical conductivity) expressed in deciSiemens per meter (dS/m), or in **TDS** (total dissolved solids) expressed in parts per million (**ppm**), or its equivalent mg/L. The conversion factors for these units are slightly different for San Joaquin Valley drainage waters than for other waters, and they increase as salinity of the water increases (Table 1).

Table 1. Conversion Factors for drainage waters in the San Joaquin Valley (from Agricultural Salinity and Drainage by Hanson, Grattan and Fulton, 1999).

TDS (ppm) = 740 x EC (dS/m); when EC is less than 5 dS/m
TDS (ppm) = 840 x EC (dS/m); when EC is between 5 and 10 dS/m
TDS (ppm) = 920 x EC (dS/m); when EC is greater than 10 dS/m
TDS (meq/l) = 10 x EC (dS/m)

An older unit for EC is millimhos per centimeter (mmhos/cm) which equals ds/m.

D. Water Sodicity (sodium in the water)

Sodicity refers to the amount of sodium (Na) present in the water. This can be expressed as the exchangeable sodium percentage (ESP). More often, however, the sodium level is expressed in relation to calcium and magnesium levels in the water. The measurement is called the sodium adsorption ratio or SAR. The equation is as follows:

$$\text{SAR in (meq/L)} = \frac{\text{Na}}{\div\ (\text{Ca} + \text{Mg}) / 2}$$

High SAR waters pose special problems for soil management. This is because sodium breaks down (disperses) the clays in soil, which leads to a loss of soil structure, and reduced infiltration.

Irrigation water having a SAR > 10 or an ESP of 13 may infiltrate poorly when applied to a medium or fine-textured soil, particularly if the salinity of the water is low. However, it is actually the combination of both SAR and EC that determines how well a water will infiltrate into soil. This is sometimes called the "permeability hazard."

Many of the Westside drainage waters are saline-sodic, therefore proper soil management will be essential in the drainage water-irrigated areas of the IFDM system to offset soil degradation caused by sodium in the water.

E. Toxic Trace Elements

Westside soils originated from marine sediments and contain salts and potentially toxic trace elements (selenium, molybdenum, arsenic, uranium and boron). The presence and concentration of these trace elements can vary greatly within the Valley. These trace elements can be concentrated by agricultural practices as the crop uses water and leaves behind the salt and trace elements. As irrigation water dissolves existing soil salts, the trace elements can potentially leach into groundwater.

Major trace elements include:

- **Selenium –** an essential trace element for animals and humans than can cause repro–ductive failure and teratogenic effects in birds. The water and wildlife water quality limit for selenium is 2 mg/L (ppb) (Table 2).
- **Molybdenum** – an essential trace element for plants and some animals, but can be toxic to ruminant animals. The CVRWQCB's recommended limit and irrigation guideline limits for molybdenum in water for agricultural use is 10 mg/L (ppb) (Table 2).
- **Arsenic** – a mammalian toxin.
- **Uranium** – radioactive element found in specific locations throughout the Valley.
- **Boron** – an element that may cause a reduction in the growth rate of chicks. Many agronomic crops are sensitive to boron.

Most of the elements originate naturally from the soils, but imported irrigation water may also contain some trace elements. These elements are classified as "substances of concern" because of their potential to negatively impact water quality, public health, agricultural productivity, and/or fish and wildlife (San Joaquin Valley Drainage Program, 1990). For crop production, boron is generally of greatest concern. For wildlife, selenium poses the greatest hazard. Table 2 lists irrigation water guidelines and target water quality concentrations for wildlife.

Table 2. Irrigation guideline limits for various constituents and water quality targets for wildlife. Irrigation guidelines taken from Ayers and Westcot (1985). For wildlife targets, a more complete table and reference are given in Chapter 7.

Constituent	Irrigation guideline limits (mg/l)	Targeted Wildlife and Water Quality (mg/l)
Arsenic (As)	100	<5
Boron (B)	—	<0.3
Cadmium (Cd)	10	—
Chromium (Cr)	100	—
Copper (Cu)	200	—
Iron (Fe)	500	—
Lead (Pb)	5,000	—
Manganese (Mn)	200	—
Mercury (Hg)	—	—
Molybdenum(Mo)	10	<10
Nickel (Ni)	10	—
Selenium (Se)	20	<2
Uranium (U)	—	—
Vanadium (V)	100	—
Zinc (Zn)	2,000	—

F. Nutrients

If too much water is added to leach salts from the soil, nutrients may also be leached, potentially resulting in reduced growth and yields. The leached nutrients could be considered an asset if the subsurface drainage water containing the nutrients is collected and applied to other crops in the IFDM system.

For example, most Westside San Joaquin Valley drainage waters are high in nitrate. Drainage water from Red Rock Ranch and AndrewsAg may contain more than 80 ppm NO_3-N (Table 3). In most cases, forages or halophytes produced with this water do Not need nitrogen fertilizer applications. For salt tolerant field crops, the rate of applied nitrogen fertilizer could be greatly reduced.

G. Methods for Using Saline Drainage Water for Irrigation

Several methods exist for utilizing a saline water source, such as subsurface drainage water, in an irrigation program. These methods differ regarding where, when or how the saline water is applied to the grower's field, and whether non-saline water is included in the cropping system. The IFDM system described in this manual is primarily a sequential reuse system

1. Sequential Reuse

In this practice, part of the farm or sub-region is designated as the reuse area. The area consists of a sequence of fields within the boundaries of a farm, or an irrigation district, that are irrigated with saline water of increasingly higher concentrations (Grattan and Rhoades, 1990). That is, the drainage collected under one field – which is more saline than the irrigation water – is used to irrigate the next field in the sequence and so on. The main purpose is to obtain an additional economic benefit from the available water resources, to minimize the area affected by shallow water tables, and to reduce the volume of drainage water that requires disposal.

An IFDM system implements sequential reuse, as described above, with a solar evaporator at the terminal end.

The existing sequential reuse systems are the 4-stage system at Red Rock Ranch and 3-stage system at AndrewsAg. The number of stages includes the area irrigated with fresh water, hence the 4-stage system at Red Rock Ranch involves

Table 3. Composition of drainage water used to irrigate salt-tolerant forages and halophytes in drainage water reuse projects on the Westside of the San Joaquin Valley.

Location & Year	Plants irrigated	EC (dS/m)	SAR	Boron (ppm) (mg/L)	Selenium (ppb) (ug/L)	Molybdenum (ppb) (ug/L)	Sodium (meq/L)	Calcium (meq/L)	Magnesium (meq/L)	Chloride (meq/L)	Sulfate (meq/L)	Bicarbonate (meq/L)	Nitrate-N (ppm) (mg/L)	pH
Red Rock Ranch														
(5/22/03)	**Forages†**	13.7	26.8	24	980	< 50	122	26.9	14.2	61.5	102	3.9	84.6	7.2
(1/29/03)	(2nd reuse)	13	41.7	23	990	.	134	26.8	13.2	57.1	101	4	83	7.8
(5/22/03)	**Halophytes††**	12.7	25.1	21.8	720	< 50	116.5	29.2	13.9	62.6	83.6	5.74	75.6	7.5
(1/29/03)	(3rd reuse)	17.8	37	33	1380	.	171	27.3	17.8	94.5	121	6.7	98.9	7.8
Andrews Ag														
(1/02/03)	**Halophytes** (2nd reuse)	10.6	26.8	14.1	260	.	126	21.3	24.5	24.9	142	3.6	83.3	8.3
Panoche/ SJRWQIP	**Forages** (only 1 reuse)	5 - 8	.	6 - 8	60 - 120	.	.	.	.	.	.	.	.	.
Mendota (1997)	**Halophytes** (3rd reuse)	29	44	48	700	.	323	31	82.7	106	225	.	64	8
Mendota (San Luis Drain†††)														
(1990)		10.7	19.2	14.4	325	88	95.9	27.7	22.4	.	.	48	.	

† Water from Sump B at Red Rock Ranch
†† Water from Sump C at Red Rock Ranch
††† Water sampled from the San Luis Drain near Mendota, CA (ASCE, 1990)

three reuses of the drainage water and in the 3-stage system at AndrewsAg, the drainage water is reused twice. The term "stage" is only applied to the cropping areas; the terminal solar evaporation area is not included.

2. Single Reuse

A few examples exist, such as the San Joaquin River Water Quality Improvement Project (SJRIP) operated by Panoche Drainage District, where subsurface drainage water is used once for the irrigation of salt-tolerant crops and forages. When this project started, only a small portion of the 4,000-acre reuse area had subsurface drainage and the main objective was to displace some of the subsurface drainage water being discharged to the San Joaquin River under a special agreement (Grasslands Bypass Project) so as to meet water quality objectives.

Although not the preferred system for long-term sustainability, single use can be used in the initial stages of a subsurface drainage water reuse project, for example, when a means of drainage water disposal is needed and a long-term commitment and funds for installing a complete drainage system have not been secured.

However, in order to control soil salinization and maintain both soil permeability to water and maintain plant productivity in the reuse area, it is likely that a subsurface drainage system would be needed in the reuse area. This would result in the conversion of a single reuse system to a multiple stage, sequential reuse system, similar to IFDM.

3. Blending

Blending involves mixing saline water and good quality water together to achieve an irrigation water of suitable quality based on the salt tolerance of the chosen crop. The blended water is used for irrigation. The AndrewsAg IFDM system blends fresh water and drainage water for its "Stage 2" cotton, as described below. Blending is not attractive if saline water does not supply at least 25 percent of the total irrigation water requirement. That is, the costs and risks of the increased management associated with adding salts to the irrigation supply will likely outweigh the benefits from increasing the total water supply by only a slight to modest amount.

4. Cyclic Use

The "cyclic" method was first introduced and tested by Rhoades (1984). Saline drainage water is used solely for certain crops and only during certain portions of their growing season. The objective of the cyclic strategy is to minimize soil salinity during salt-sensitive growth stages, or when salt-sensitive crops are grown. With a cyclic strategy, the soil salinity profile is purposefully reduced by irrigation with good quality water, thereby facilitating germination and permitting crops with lesser tolerances to be included in the rotation. The cyclic strategy keeps the average soil salinity lower than that under the blending method, especially in the upper portion of the profile, which is critical for emergence and plant establishment (Grattan and Rhoades, 1990).

5. Combining Strategies

These strategies are not mutually exclusive. In fact, a combination may be most practical in some cases. For example, within a sequential reuse scheme such as IFDM, blending and/or cyclic methods may be used occasionally to germinate and establish the salt-tolerant crops. This is also true for the establishment of salt-tolerant perennial forages, some of which require at least a full year of fresh water irrigation prior to applying the saline subsurface drainage water.

Another example would be the AndrewsAg IFDM which is a sequential reuse, but for the Stage 2 cotton, fresh water and drainage water are often blended. The ratio ranges from 1/3 fresh water and 2/3 drainage water to 2/3 fresh water and 1/3 drainage water, depending on subsurface drainage water supply.

In general, the blending and cyclic strategies are suitable for subsurface drainage water that is relatively low in salinity (< 8 dS/m= 6700 ppm TDS). Both require an ample supply of both good quality and saline water to be available for irrigation throughout the season. These methods have been successful in field tests (Rhoades et al., 1988; Grattan & Oster, 2003).

Chapter 6: Plant Selection for IFDM

I. Introduction

The use of saline drainage water for irrigation requires several changes from standard management practices including:

- Selection of appropriate crops — or perennial forages and halophytes for more saline waters.
- Improvements in water and soil management.
- More frequent water and soil sampling.
- Adoption of advanced irrigation technology.

Management is focused on:

- Salinity control within the root zone (maintaining a net downward flow of water and salt).
- Avoiding deterioration of soil physical conditions.
- Avoiding the accumulation of certain trace elements (e.g. B, Se, Mo) that may be problematic to plant production, or to wildlife, should they be present.

Selecting plants and the intensity of management required for an IFDM system depends on the salinity and composition of the drainage water, and whether good quality water also is available for irrigation.

Drainage water can be a resource and a constraint. Various drainage water constituents can have negative or positive impacts on plants, soil, water and different kinds of animals influenced by the system. A summary of these impacts with increases in various drainage water parameters are illustrated in Table 1. In the case of nitrate, there is a benefit for plants.

II. Considerations for Proper Plant Selection

When choosing plants, one should keep in mind the areas of the IFDM system where the plants will be grown, as well as the soil conditions and the purpose of that area. In Stage 1, which is irrigated only with fresh water, salts are leached out of the root zone and the soil is improved. This allows salt-sensitive plants to be grown. The larger the area within Stage 1, the greater is the profit potential. In subsequent stages, saline drainage water is applied to the plants and criteria such as salt and boron tolerance are paramount.

Prior to any plant selection, a representative water sample should be taken from a groundwater monitoring well; or preferably from a drain-

Table 1. Drainage water constituents having potential impacts on plants, soil structure, migratory waterfowl and wildlife, ruminant animals, and groundwater or surface water.

Drainage Water Parameter	Potential Negative (X) or Positive (+) Impacts On...†				
	Plants	Soil Structure	Migratory Waterfowl & Wildlife	Ruminant Animals	Groundwater or Surface Water
Salinity	X	+	X	+/X	X
Boron	X		X		X
SAR (sodicity)		X			
Selenium			X	+/X††	X
Molybdenum				X	
Nitrate	+			X	X

†Only significant & direct impacts are listed.
††Positive impact up to a given concentration, above which a mixed ration may be needed to avoid toxicity.

Table 2. Comparison of salinity tolerance and profit potential for various plants in an IFDM system.

Plants	Irrigation water salinity (EC) (fresh, mixed, or drainage)	Profit Potential
Salt-sensitive vegetables	below 2 dS/m †	high
Salt-tolerant vegetables & flowers	below 6 dS/m	medium
Field crops (cotton, wheat, canola)	below 8 dS/m	low
Salt-tolerant forages	8-15 dS/m††	low
Halophytes	Above 15 dS/m	none - low
Salt-tolerant trees	5-10 dS/m	none - low

†Most require irrigation water less than 2 dS/m. Optimal soil and water management is required to use waters from 2 to 4 dS/m.
††Over the short term, Jose Tall Wheatgrass, Paspalum, creeping wild rye and bermuda grass can be irrigated with water up to 20 dS/m.

age sump, if the drainage system has already been installed. The water analysis is the basis for plant selection.

Ideally, the water should be taken from several feet below the surface, rather than sampling immediately at the water surface.

The required characteristics for selected salt-tolerant plants (Stage 2 and higher) include:

- Salinity and boron tolerance;
- High water use (ET);
- Tolerance to frequent flooding-*if using flood irrigation;*
- Marketability of harvested biomass;
- Perennials or long–season annuals are preferred because they use water almost year-round;
- Frost tolerance;
- Are NOT an invasive plant; and
- Are NOT a host plant for insect vectors of plant viruses.

A. Determining Salt and Boron Tolerance

Salinity and boron tolerance are the main factors influencing plant selection in IFDM systems.

1. Salt

The Maas Hoffman tables (Maas & Grattan, 1999) provide salt tolerance rankings for many fiber, grain, forage, vegetable and woody crops. The tables are primarily for agronomic crops: halophytes are not listed, and only limited information is available for salt-tolerant forages. These tables can be found in the Appendix or at the USDA George E. Brown Salinity lab website, http://www.ussl.ars.usda.gov. They also are included in a very useful and reader friendly manual entitled "*Agricultural Salinity and Drainage*" by Hanson, Grattan, and Fulton, which after reprinting will be available for on-line purchase at http://anrcatalog.ucdavis.edu.

For each plant species listed, the Maas Hoffman tables give a threshold soil salinity (ECe in dS/m) above which a yield decrease is likely. The tables also list a "slope" value which is the expected yield reduction in percent for every unit (1 dS/m) increase above the threshold. The threshold values are based on the average root zone salinity. The slope value indicates how rapidly yield decreases once the threshold soil salinity has been passed. It is the combination of threshold and slope that determines the final tolerance ranking. Crops that are more tolerant to salinity have high threshold and low slope values.

Some crops may perform differently than predicted by the Maas Hoffman salinity tolerance ranking if certain management practices to minimize salinity impacts are implemented, such as:

- A high leaching fraction or end-of-season reclamation;
- Planting position (shoulders of bed for furrow irrigated, and along the drip line for drip irrigated crops);
- Proper timing of the application of saline water ("cyclic" strategy).

Threshold soil salinities for individual crops are listed in the Maas Hoffman tables found in the Appendix. For most crops belonging to each

Pistachio

of the four tolerance categories, the thresholds are as listed in Table 3.

Table 3. Soil Salinity Threshold (Ece)

"S" (sensitive):	1.0 to 1.8 dS/m ECe.
"MS" (moderately sensitive):	1.5 to 2.8 dS/m ECe.
"MT" (moderately tolerant):	4.0 to 6.3 dS/m ECe.
"T" (tolerant):	6.8 to 10 dS/m ECe.

In systems such as IFDM that utilize "wastewaters," the starting point for plant selection is actually the applied water salinity (drainage or drainage blend), rather than the soil salinity. Unfortunately, comprehensive salt tolerance tables similar to the Maas Hoffman tables, but based on irrigation water salinity, are not available. The soil salinity (ECe) resulting from irrigation with water of a given salinity (ECi.w.) is difficult to predict because of the influences of texture, drainage, duration of saline irrigation, and leaching fraction. However, a reasonable but rough estimate is that:

Soil salinity (ECe) = 1.5 x irrigation water salinity (ECi.w.)

provided that a leaching fraction of 15-20 percent is achieved over the long term (Ayers and Westcot, 1985). Therefore based on this relationship, irrigation with drainage waters over 6.5 dS/m (i.e. ECe=9.8 dS/m) would exceed the limit (Maas Hoffman thresholds) for most salt-tolerant agronomic crops.

2. Boron

Maas and Hoffman also compiled boron tolerance tables that list threshold values for numerous agronomic crops based on the boron concentrations in the "soil water" (saturated paste extract). These tables were recently revised by Maas and Grattan (1999). Some salt-tolerant crops are also tolerant ("T") or moderately tolerant ("MT") to boron; for example, cotton, sugarbeets, asparagus, and red beet. Alfalfa is boron tolerant (T) and but is listed as moderately sensitive ("MS") to salinity. Nevertheless, there are new cultivars available that have higher salt tolerance. Tomato and garlic are also boron tolerant; but they are, respectively, moderately sensitive ("MS") and sensitive ("S") to salinity. These boron-tolerance tables do not contain listings for salt-tolerant forages or halophytes.

With soil boron concentrations of 4-8 ppm (mg/L) in the saturated paste extract or drainage waters of similar concentration, only boron-tolerant agronomic plants should be planted. For drainage waters of 10-15 ppm boron, blending could be utilized, as is done at AndrewsAg in southern Kern County. Boron toxicity was not observed in trials in the San Joaquin Valley in which annual crops were irrigated with saline-sodic drainage water containing 7 to 10 ppm (mg/L) boron. These included cotton, melon, sugarbeet, tomato and wheat (summarized in Grattan & Oster, 2003).

Pistachio trees were irrigated with drainage water containing 10 dS/m salinity for more than 8 years with no reported yield reductions (B. Sanden, UC Cooperative Extension, personal communication). However, in this study boron concentrations were low in the simulated drainage water. At Red Rock Ranch where young pistachio trees were irrigated with drainage water containing 18-24 ppm boron, severe foliar injury attributable to boron toxicity occured. The symptoms generally appeared in July and August when ET was highest, and the trees recovered each year following leaf fall. The impact of this foliar injury on nut yield was not determined, but it would not be advisable to irrigate pistachio with drainage water having boron concentrations greater than 3-4 ppm until more research is done with drainage water containing both high salinity and boron.

Table 4. Example of Maas Hoffman salinity tolerance coefficients and slopes for field crops and vegetables (Maas & Grattan, 1999).

	Maas Hoffman Salinity Tolerance Values		
	Threshold soil salinity (ECe) in dS/m	Maximum water salinity (ECiw in dS/m) that can be used without yield reduction*	Slope (% yield reduction per unit dS/m increase)
Salt-Tolerant Field Crops			
Cotton	7.7	5.1	5.2
Wheat	6.0	4.0	7.1
Barley	8.0	5.3	5.0
Sugarbeet	7.0	4.7	5.9
Canola (*B. napus*)	11.0	7.3	13
Canola (*B. campestris*)	9.7	6.5	14
Salt-Tolerant Vegetables			
Artichoke	6.1	4.1	11.5
Asparagus	4.1	2.7	2.0
Red beet	4.0	2.7	9.0
Zucchini squash	4.9	3.3	10.5
Purslane	6.3	4.2	9.6
Moderately Salt-Sensitive Vegetables			
Garlic	3.9	2.6	14.3
Pea	3.4	2.3	10.6
Broccoli	2.8	1.9	9.2
Tomato	2.5	1.7	9.9
Salt-Sensitive Vegetables			
Carrot	1.0	0.7	14.0
Onion	1.2	0.8	16.0
Bean	1.0	0.7	19.0

* assumes 15-20% leaching fraction

III. Field Crops & Vegetables

Factors to consider when irrigating agronomic plants with drainage water:

- Species and varieties may have different salinity tolerances;
- Vegetables tend to be more sensitive to salinity than field crops;
- Plants may be more sensitive to saline water at different growth stage; and
- Establishment of crops must usually be done under non-saline conditions.

A. Field Crops

Cotton, barley and canola are among the most tolerant field crops. For example, because the soil salinity (ECe) threshold for cotton is 7.7 dS/m, the estimated limit for irrigation water salinity that could be applied to cotton over the long term without yield loss would be 5.1 dS/m (Table 4). If the average soil salinity in the root zone reached

Table 5. The maximum percent of saline water (4 to 10 dS/m) that can be mixed with non-saline irrigation water (0.8 dS/m) to achieve a yield potential of 100% and 80% for selected crops that vary in salt tolerance. Estimates assume a leaching fraction of 25% (Dinar and Letey, 1986).

EC of the Saline Irrigation Water (dS/m)					
		4	6	8	10
Crop	**Salt tolerance[1]**	**100 % yield**			
Lettuce	MS (1.3, 13)	2	2	1	1
Alfalfa	MS (2.0, 7.3)	14	9	6	5
Tomato	MS (2.5, 9.9	25	15	11	9
Zucchini	MT (4.7, 9.4)	62	38	28	22
Cotton	T (7.7, 5.2)	100	62	44	35
		80 % yield			
Lettuce	MS (1.3, 13)	37	23	17	13
Alfalfa	MS (2.0, 7.3)	80	52	39	31
Tomato	MS (2.5, 9.9	78	48	35	27
Zucchini	MT (4.7, 9.4)	100	84	68	58
Cotton	T (7.7, 5.2)	100	100	100	100

[1] The first number in parenthesis is the average root zone threshold salinity (A) in dS/m, and the second is the percent yield decline per unit increase in average root zone salinity (slope) (B). MS, MT and T refer to moderately sensitive, moderately tolerant and tolerant, respectively.

8.7 dS/m under saline irrigation, there would be about a 5.2% reduction in crop yield. See Appendix for a complete listing of Maas Hoffman salinity tolerance rankings and a simple equation to calculate the relative yield predicted for a given crop and soil salinity (ECe).

Canola is even more salt tolerant than cotton, having a threshold salinity (ECe) of 11.0 dS/m (Table 4). Canola shows promise both as a selenium accumulator and as a biodiesel crop (G. Banuelos, USDA-WMRL, Parlier, CA, personal communication).

In an IFDM system where crops like cotton are being grown to "consume" drainage water, some yield loss due to salinity may be acceptable. Table 5 lists agronomic crops and compares the percentage of drainage water of different salinities that could be utilized if the yield goal was 80% rather than 100%. As shown in the lower half of the table, much higher percentages of drainage water can be used when the yield goal is lowered from 100% to 80% (Dinar & Letey, 1986).


Vegetables growing under IFDM Stage 2 conditions.

Blending, however, requires additional management and irrigation equipment, e.g. to blend the drainage and fresh waters, and to monitor the salinity of the final blend. As proposed by Grattan and Oster (2003) and discussed in Chapter 5, with a blend of less than 25 percent drainage water one should consider whether or not blending is time and cost-effective.

B. Vegetables

Asparagus, artichokes, red beets and zucchini squash are among the most salt-tolerant vegetables; however, most drainage waters would need to be blended with fresh water to keep the salinity of the irrigation water low enough for these vegetables. Soil salinities in the root zone should ideally be kept at or below the threshold salinities listed in Table 5.

Swiss chard (*Beta* vulagaris var. flavescens), mustard greens (*Brassica juncea*), and kale (*Brassica oleracea* var (*Acephala* group) can be grown under irrigation with saline water (3-15 dS/m; 2220–10,120 ppm TDS) although at the higher irrigation water salinities, soil drainage must be very good and yield may be reduced as much as 50% (Shannon et al, 2000).

With leafy vegetables, plant size will be reduced by salinity. The potential yield reduction can be offset by denser plantings. If the greens are destined for packaged salad mixes, the smaller plant size may not be a detriment.

For non-leafy vegetables, saline water may reduce yield, but it may also improve quality; for example, it can increase soluble solids in tomato and sugar content in cantaloupe (Grattan & Oster, 2003).

Two kind of statice (*Limonium spp*.) that can be sold as cut flowers thrive on saline waters. These flowers are being tested at the USDA Salinity Lab in Riverside (C. Grieve, personal communication). Early results indicate that salinity reduces stem length and that *L. sinuatum* is more tolerant than *L. perezii*.

IV. Salt-Tolerant Forages

Some salt-tolerant grass and legume forages are listed below, ranked in order of promise. For IFDM, the highest priority is given to salt and boron tolerance, productivity and water use (ET). Also considered are forage quality and the remaining factors previously discussed.

A. Tall Grasses

1. *'Jose'* Tall Wheatgrass (*Agropyron elongatum* or *Elytrigia elongata*)
2. Creeping Wild Rye var. '*Rio*' (also called Beardless Wild Rye) (*Leymus triticoides* or *Elymus triticoides*)
3. Tall Fescue (*Festuca arundinacea* vars. *'Alta'* and '*Goars'*)
4. Alkali sacaton (*Sporobolus airoides* var. '*solado'*)
5. Koleagrass, Perlagrass (*Phalaris tuberosa* var. '*Hirtiglumis'*)
6. Puccinellia (*Puccinellia ciliata*)

B. Turf Grasses

1. Paspalum (*Paspalum vaginatum* vars. *"Polo'*, '*PI 299042*', and *'Sealsle 1'*)
2. Bermuda grass (*Cynodon dactylum*, vars. '*Common*', *'Giant'* and *'Tifton'*)

C. Legumes

1. Salt-tolerant alfalfa (*Medicago sativum*)
   — cvs. '*Salado*' and '*Ameristand 801S*'.
   — cvs. '*SW9720*'
2. Narrowleaf trefoil (*Lotus glaber*)
3. Strawberry clover (*Trifolium fragiferum*)

The following forage characteristics should be considered:

- Salt and boron tolerance
- Biomass production

Jose Tall Wheatgrass

- Water use (ET)*
- Ion accumulation*; Se, S, NO_3, Mo, Cu, Mg, in particular. Also Na, Cl, K, Si
- Forage quality*
- Length of growing season
- Warm season vs. cool season
- Competitive ability (in the presence of invasive weeds)*
- Availability of seed or transplants
- Ease of establishment and maintenance
- Suitability for hay ("cut-and-carry") vs. grazing
- Grower and market acceptability

**under saline conditions*

Table 6 compares the salt-tolerant forages using the criteria stated above.

Ideally, a forage production system should include both warm and cool season types and legumes along with the grasses. With the exception of adding in legumes, such as trefoil or clover, it is generally recommended that species be planted separately rather than inter-planting. The challenge is to manage the stand (i.e., cutting frequency and height) so as to maximize both the productivity (biomass accumulation) and the forage quality. Generally, as biomass accumulates (more time allowed between cuttings), forage quality decreases (Robinson, 2003).

Research thus far suggests that in general, salinity does not reduce forage quality (Robinson, 2003), but it can increase ash and nitrate, both of which are undesirable. Also, more frequent monitoring of elemental composition is required because if they should occur, excessive concentra-

Table 6. Comparison of salt-tolerant forages.

	Maximum Recommended[1] ECi.w. (dS/m)	Forage Quality[2]	Growing Season	Length of Growing Season	Suitability Hay vs. Grazing[4]	Seed or Transplant Availability[5]	Competitive Ability
Tall Grass forages							
'Jose' Tall Wheatgrass	8-15	High	Weakly cool[3]	Long	Grazing/ hay	Good (seed)	Good
Creeping Wild Rye var. *'Rio'*	8-13	Medium low	Weakly cool	Long grazing	Hay (plugs better)	Fair (seed)	Very Good
Tall fescue var. *'Alta'*	8-13	Medium high	Weakly cool	Medium long	Grazing/ hay	Good (seed)	Good
Alkali sacaton, var. *'Solado*	8-15	Low	Warm	Medium long	Grazing/ hay	Fair (seed; plugs better)	Good
Perlagrass	8-13	Medium	Cool	Medium	Grazing/ hay	Fair (seed; plugs better)	Poor
Puccinellia	8-13	Medium	Strictly cool	Short	Grazing/ hay	Fair (seed)	Average
Turf Grass or forages							
Bermuda grass	8-15	Medium high	Warm	Medium	Grazing/ hay	Good (seed)	Average to good
Paspalum	8-15	Medium high	Warm	Medium long	Grazing/ hay	Good (sod or stolons)	Average to good
Leguminous forages							
Salt-tolerant alfalfas (varieties listed on 6-6)	4-5	High	Warm	Long	Hay	Good (seed)	Average to good
Trefoil—narrow leaf	4-6	High	Weakly cool	Short	Grazing/ hay	Fair (seed)	Average

1 Can be irrigated with water of lower salinities, but then a forage or crop of lower salt tolerance and higher profitability, may be better. At the high end of the salinity range, productivity may be significantly reduced. Estimates are based on available scientific data and personal observation.
2 Rankings of forage quality are on a relative scale, which only compares the forages listed and only under conditions of saline irrigation.
3 "Weakly cool": forage grows best in the spring and fall. Does not go dormant in the summer, but growth is greatly reduced.
4 Listing before slash mark is the best use. Listing after slash mark is second in preference. Listings are best, current estimates: response to grazing has not been thoroughly tested for most of these forages.
5 "Good": commercial sources readily available and can supply large amounts. "Fair": commercial sources may not be available, but small amounts can be procured from the USDA Plant Materials Center (PMC) in Lockeford, CA, or from special purveyors. See Appendix.

tions of nitrate, molybdenum and sulfur could result in nutritional problems for animals that were fed forages irrigated with Westside drainage water (Grattan et al., 200X). In the case of selenium, modest enrichment could increase the value of the forage.

'Jose' tall wheatgrass is considered to be a top candidate because it has good productivity and forage quality under saline irrigation, a long growing season, and seed is readily available. It is sold locally in the San Joaquin Valley as "Westside wheatgrass." Under irrigation with saline drainage water from 10 to 14 dS/m and growing in very saline soils at Red Rock Ranch (17 and 20 dS/m ECe in the top 12 inches) produced approximately 9,000 kg/ha/yr in one field and only 4,700 kg DM/ha/yr of dry material in the other field. In addition to higher salinity and boron in the less productive field, the forage was irrigated less frequently; it had been cut shorter than the recommended level; and the physical soil conditions were more degraded. In both fields productivity has declined as the soil salinity has increased, but stable stands have been maintained. Forage quality of the tall wheatgrass was the highest of the grass forages growing at Red Rock Ranch for the two fields described in Table 7.

Table 7. Forage quality for Jose Tall Wheatgrass growing at Red Rock Ranch

	Field 1 17dS/m ECe	Field 2 20 dS/m ECe
Metabolizable energy (ME) (MJ/kg)	9.3	8.7 MJ/kg
Crude Protein (CP) (%)	8.5	12.2 %
Neutral detergent fiber (NDF) 52.2 (%)	64.0 %	
Acid detergent fiber (ADF) (%)	32.6	30.6%
Ash (%)	9.6	7.2 %

Creeping Wild Rye, irrigated with the same drainage water at Red Rock Ranch, but growing in less saline soil (11 to 13 dS/m ECe) accumulated much more biomass (11,500 to 13,000 kg DM/ha/yr), but forage quality was lower than for *'Jose'* Tall Wheatgrass. This grass has a more upright growth habit, which along with the lower soil salinity of the field, explains its higher

Creeping Wild Rye

productivity. The erect growth also makes Creeping Wild Rye suitable for haying, if forage quality is deemed acceptable.

Paspalum is also a top contender. It has good productivity and forage quality under saline irrigation and being a warm season grass, it complements the production of cool season grasses such as tall wheatgrass and Creeping Wild Rye. Paspalum has not been extensively tested in the field under irrigation with drainage water, but it was a top performer in sand tank studies where synthetic drainage water was applied (Robinson et al., 2003). Sod and chopped stolons are available commercially.

Bermuda grass has performed well in a beef cattle grazing study at Westlake Farms (S. Kaffka, UC Davis, personal communication) where it is growing under irrigation with saline drainage water with soil salinities averaging 13 dS/m ECe for the top 12 inches. Two seeded varieties, '*Common*' and '*Giant,*' were grown: '*Common*' is exclusively for grazing, and *'Giant'* is suitable for grazing or hay. Forage quality was considered to be acceptable for beef cattle: averages were CP = 16%, ADF = 29.4%, and ash = 13.1%. Forage productivity and quality also were good based on sand tank studies at the U.S. Salinity Laboratory (Robinson, et al., 2003). Some scientists do not consider Bermuda grass to be an invasive species, but there are different opinions on this issue.

Although most of the candidate forages are suitable for grazing, great caution will need to be taken if IFDM forage plantings are grazed. Rotational grazing will be essential to allow forage fields to dry out adequately prior to grazing. Grazing should not be done when soils are wet, as compaction will reduce water infiltration. This would further exacerbate the tendency toward reduced infiltration in soils irrigated with saline-sodic waters. Mixed forage plantings are generally not recommended for IFDM, optimizing the management for each species. However, in a grazing system there would be a nutritional benefit for the animals from mixed pastures. More research is needed to develop appropriate forage mixtures for IFDM grazing systems.

D. Establishment and Maintenance

Soil sampling and water analysis should be conducted prior to forage planting to determine if pre-plant leaching is required and/or soil amendments such as gypsum, sulfur or sulfuric acid should be applied to increase the soluble calcium fraction in the soil, which in turn will reduce sodicity and improve infiltration and drainage.

As indicated in Table 6, many of the salt-tolerant forages can be seeded. Seeding is generally more successful for large-seeded forages such as tall wheatgrass. For small-seeded forages like alkali sacaton, a good firm moist seedbed is essential. Good land preparation may be difficult, however, on heavy clay soils that have poor structure due to sodium-induced clay dispersion. Using plugs or other container-grown material is more expensive, but they generally have a higher success rate. Fall is the best time to establish the cool season grasses. Warm season grasses should be established in the spring. It is best to establish the salt-tolerant forages with fresh water, ideally for the entire first year.

Proper cutting heights vary from forage to forage, but should not be too low for the perennial bunch grasses. In particular, tall wheatgrass should not be cut below a 6-inch height. Once the stand is established, cutting should be frequent enough to maintain vigorous growth (maximum ET) and provide acceptable forage quality.

More details on forage establishment and maintenance can be found in the Appendix.

V. Halophytes

Halophytes are largely undomesticated plants that are native to saline coastal marshes or inland salt flats. "Halo" means "salt" in Latin. These plants are truly salt-requiring; in fact, most do not grow well under non-saline conditions. Some halophytes can be irrigated with water as saline as seawater. Halophytes are suitable for irrigation with highly saline water (> 15 dS/m; 12,000 ppm TDS) and/or for highly saline soils (ECe ≥ 20 dS/m; 16,000 ppm TDS). Salicornia and Allenrolfea are the most salt-tolerant plants, thriving in soils with ECe of 50-60 dS/m in the top 12 inches. All of the halophytes are warm season plants. They include:

- Saltgrass (*Distichlis spicata* var. '*stricta'*)
- Iodine bush (*Allenrolfea occidentalis*)
- Pickleweed Samphire (*Salicornia bigelovii*)
- Saltbush (*Atriplex lentiformis* and *A. numularia*)
- Cordgrass (*Spartina gracilis, S. alterniflor,* and *S. patens*)

Allenrolfea (Iodine Bush)

At present these halophytes have limited economic value, but for Salicornia and saltgrass, breeding and selection is underway to improve their agronomic traits and develop new agricultural uses and products. Even if no revenue is generated from halophyte cultivation, the value of these plants in an IFDM system is their suitability for irrigation with concentrated drainage water, thereby allowing further volume reduction prior to discharge of the final effluent into a solar evaporation system. Profit is instead gained by an increase in the fresh water irrigated area of the IFDM with high value crops. Therefore, halophytes may serve the purpose as sacrificial

Table 8. Comparison of halophytes

	Suitable ECi.w. [1] (dS/m)	Establishment (ease/time)[2]	Maintenance[3]	Competitive ability	Availability seeds or transplants[4]	Water use (ET)	Economic potential	Selenium uptake	Comments
Annual									
Salicornia bigelovii	≥15	More difficult*/ few months	Medium	Fair	Low (seed, by agreement)	High	Medium	Very High	*not well-adapted to hard surface crust, best sown onto wet soils in late fall/winter.
Perennials									
Saltgrass	≥15	Average/ one year*	None*	Very Good	Good (rhizomes or clumps from native stands, or commercial)	Lower	Low	Medium	*new shoots must form on rhizome. Plugs from seed faster. "Nypa" does not produce seed
Allenrolfea	≥15	Average/ one year*	Low	Good	Fair (sprigs from native stands and seeds)	(No data)	Very Low	High	*new shoots must form on sprig. Seeding not tested.
Atriplex spp.	≥15	Average/ few months	Medium*	Very Good	Good (seed, or rooted cuttings — native stands or commercial)	Medium	Very Low	Low	*Shrubs get very large, best to cut every year or two.
Cordgrass	≥15	Average/ few months if plugs are used	Low*	Good	Good (clumps rooted in containers— native stands or commercial	No data	Low	Medium	*Cutting not required but may increase ET.

[1] ECi.w = electrical conductivity of the irrigation water in dS/m.
[2] Establishment details can be found in the Appendix. Scale is relative. The success rate for establishing vegetation in saline areas is generally lower than for standard argronomic plantings on non-saline sites.
[3] Maintenance scale: Low = little care; Medium = may require re-seeding (Salicornia) or trimming (Atriplex); High = frequent trimming or re-seeding required.
[4] Availability: Good = commercial sources readily available and can supply large amounts; Fair = commercial sources may not be available, but plant material can be collected from native stands or small amounts requested from the USDA Plant Materials Center (PMC) in Lockeford, CA. Low = special purveyors and/or formal agreements may be required (Salicornia and "Nypa Forage" saltgrass).

to reduce the volume of drainage water and thereby expand the area that is not affected by high saline water tables.

For IFDM, the following halophyte characteristics should be considered.

- Water use (ET)
- Tolerance to water-logging and to soils with poor aeration and hard surface crusts
- Length of growing season
- Perennial vs. annual
- Ease of establishment and maintenance
- Availability of seed or transplants
- Competitive ability (in the presence of invasive weeds)
- Biomass production and amount of vegetative cover over soil surface
- Economic potential (as forage, animal feed supplement, seed oil, biomass, other)
- Ion accumulation; in particular Se, B, NO_3, S, Mo, Cu
- Grower and market acceptability

Salt and boron tolerance is not included because all are highly tolerant.

Table 8 compares the halophytes using many of the criteria listed above.

Thus far, saltgrass, Allenrolfea and Salicornia are the most promising halophytes. Saltgrass ranks high because once established, maintenance is minimal, and it provides a very dense vegetative cover which reduces evaporation and excess salt accumulation at the soil surface. The fibrous root system of the grass may also improve infiltration and drainage (Oster, et al., 1996). This is critical because the loss of soil permeability to water is a major problem in IFDM halophyte fields.

Allenrolfea has performed exceptionally well in the IFDM system at AndrewsAg. A 20-acre stand was established using cuttings taken from native stands surrounding the farm and after one year, a nearly full stand of 2-to-3-foot tall bushes was established. Allenrolfea stands at both AndrewsAg and Red Rock Ranch have competed well with invading halophytes and selenium accumulation is high.

Salicornia is the halophyte with the greatest potential for economic return. The "green tips" can be sold profitably as a gourmet addition to salad; however, when irrigated with drainage water, it is unlikely that a fresh market product could be sold. Salicornia also has promise as a cooking oil crop and as a selenium supplement for animals. It has very high selenium accumulation (>10ppm (mg/kg). Salicornia establishment can be difficult in fine-textured soils that form a tough surface crust. It grew exceptionally well at the Mendota agroforestry site, but it has not grown as well at Red Rock Ranch. Surface applications of gypsum at 3-tons/acre appear to be improving stand establishment in the spring.

IFDM Stage 3 halophytes at AndrewsAg.

Atriplex also grows very well under irrigation with saline drainage water and in the tough soil conditions normally encountered in IFDM halophyte plots. At present, however, Atriplex plantings are not allowed by the California Department of Food and Agriculture (CDFA) and the county agricultural commissioners due to concerns that it may harbor the Sugarbeet Yellows virus. It has been suggested that Atriplex is no more likely to harbor the virus than would other native vegetation, but the restriction is being maintained.

A. Soil Management

With long-term application of saline-sodic drainage water to IFDM halophyte plots, infiltration and soil permeability to water will decline appreciably. All of the halophytes listed above have demonstrated tolerance to water-logged soil conditions. Surface applications of gypsum, soil sulfur, or sulfuric acid are likely to be required and at rates higher than those used in conventional agriculture. Organic amendments also may have potential to mediate the negative effects of sodic irrigation waters; however, this has not been demonstrated.

B. Establishment and Maintenance

Halophytes can be established with fresh or saline water. The best time for seeding or transplanting is generally in the fall. The application of gypsum or soil sulfur prior to planting is advisable. Salicornia is generally more difficult to establish due to its inability to emerge through a tough surface crust. Atriplex does not appear to have this problem. Saltgrass and Allenrolfea are usually slower to establish, taking about one year because new shoots must form from the transplanted material. In the case of Allenrolfea, some seedlings may arise from seed dropped from transplanted sprigs. Other than soil amendment application, halophyte fields generally do not require much maintenance, especially if the plants are not being harvested for agricultural products. Saltgrass does not require cutting so it is maintenance free. Larger shrubs such as Allenrolfea may require cutting to restrict plant size and to reduce woody growth and maximize ET. Salicornia generally re-seeds itself and new plants emerge through last year's skeletons; however, weak stands will require over-seeding.

More details on halophyte establishment and maintenance can be found in the Appendix.

VI. Trees

Trees tend to be more sensitive to salinity and boron than field crops or forages. Therefore, drainage water is applied to salt-tolerant crops, forages and halophytes, and only occasionally to selected trees that show some tolerance to salinity and boron. Exceptions may be when drainage flows are very high or when drainage water salinities are low (5-8 dS/m). For example, drainage water could be used to irrigate Pistachio or Eucalyptus, though ideally with blending and with a subsurface drain line under the tree block. In the San Joaquin River Water Quality Improvement Project (SJRIP) that is managed by Panoche Drainage District, 10 acres of Pistachio have been established under irrigation with fresh water (300 ppm TDS = 0.5 dS/m) from the Delta Mendota Canal. The district may begin blending with sump water in Spring 2004 when the trees will be in their third year. Once the trees are mature the salinity of the blended water will range from 600 to 4000 ppm TDS (= 0.81 to 5.4 dS/m) with boron concentrations between 0.75 and 5 ppm. The orchard has subsurface drainage lines (Chase Hurley, Panoche Drainage District, personal communication).

Three methods of planting trees to reduce water-logging and ameliorate saline conditions on cropland are as follows:

- Interceptors are planted across regional subsurface flows to lower water tables (e.g. from 1 to 6 feet) in the immediate vicinity of the planting;
- Trees can also be used in a manner similar to a relief tile system by planting at a designed spacing to lower the water table; and
- Tree plantations for the reuse of low salinity drainage water (5 - 10 dSm). A subsurface drain line under the trees collects the concentrated drainage which can then be applied to salt-tolerant forages or halophytes.

Trees that are most promising for IFDM systems include:

- Athel (*Tamarisk aphylla*)
- Eucalyptus (*Eucalyptus camaldulensis*, "River Red Gum," clones 4573, 4543, 4544)
- Pistachio (*Pistacia vera*), e.g. var. "*Kerman*" on rootstock "*Pioneer gold*"
- Casuarina (*Casuarina cumminghamiana*)

Among this group, Athel is the most tolerant to salinity and boron, while Pistachio is less tolerant. Eucalyptus appears to be intermediate between the two. Pistachio has shown foliar injury when exposed to saline-sodic water containing high levels of boron, but no tolerance thresholds have been established. Casuarina has not been adequately tested under irrigation with saline drainage water.

Important considerations for using trees in IFDM systems include:

- Soil type, climate and salinity of the water will affect the water use (ET) of the trees. ET is reduced at higher salinities.
- Concerns include insufficient tolerance to water-logging, frost and high boron concentrations in the drainage water.
- Without drainage and adequate leaching in the tree blocks, the trees may also be injured by excess salt accumulation in the root zone.

A. Soil and Irrigation Water Quality Conditions

Soil conditions and the quality of irrigation water are the most important elements to consider when establishing trees. Soil sampling should be done to determine levels of salinity, boron and SAR before an area is planted. Soil salinity should not exceed 12 dS/m, boron should not exceed 12 ppm (3-4 ppm for pistachio and perhaps higher), and SAR should not be greater than 25. If these limits are exceeded, a drainage system is needed to leach out the elements before planting. Soil amendments such as gypsum, sulfur or sulfuric acid can be added to replace sodium which then must be leached below the root zone. Both the irrigation water and the shallow groundwater have to be tested for water quality: water salinity should be less than 8 dS/m, boron less than 10 ppm, and SAR less than 20 ppm. Pistachio, being the least boron tolerant, may require water of lower boron concentrations. As the most salt tolerant, Athel may withstand irrigation water or soil salinities higher than those listed.

B. Planting and Irrigation

The best time to plant trees in the San Joaquin Valley is the beginning of April to the end of June. Planting from July to the end of September is not recommended because of high summer temperatures.

Water must be available for irrigation immediately after planting. Water with a salinity of less then EC 3 dS/m is preferred for the first year of establishment on all plantings. Once established, eucalyptus trees and salt-tolerant grasses can be successfully irrigated with drainage water of about EC 8 to 12 dS/m. A sufficient volume of this saline water is required for salt leaching and a drainage system is required. Otherwise the salt load in the soil would increase to levels above ECe 20 dS/m, which is fatal to the trees.

Irrigation scheduling must provide for periods of soil drying and aeration. Gypsum applications have been shown to improve aeration and thus eucalyptus performance in soils with high clay content, according to studies at the Tulare Lake Drainage District (Oster, et al., 1999).

Over-irrigation and water ponding will damage the trees. The interceptor and relief plantings should be irrigated at least twice after the first year, once in May and then in September. These water applications will leach down some of the salts near the feeder roots. A good irrigation schedule for drainage water reuse plantations depends upon the soil and climatic conditions. The soil needs to dry out sufficiently between irrigations to reduce water-logging problems and anaerobic soil conditions.

C. Weed Control

Weed control is necessary to reduce competition with trees and habitat for rodents that damage trees. Weeds may also create environmental problems if they increase visitation or nesting by shore birds.

Undesirable weeds can be controlled by hoeing, disking and mowing or by applying a pre-emergent herbicide before planting and during the first two years of establishment. The first herbicide application should be made in March or April for summer annuals and September or October for winter annuals.

D. Grazing

Grazing can also be used once the trees are established and are over 10 feet tall. Good times for grazing are around April, and then again in July and October. Do not graze when soils are wet, as compaction will increase bulk density and reduce aeration and water infiltration. Mineral blocks can be set out to reduce damage by livestock girdling the base of trees. Blocks should be set out every two to five acres being grazed.

A cropping system that includes a combination of wider belts of salt-tolerant crops/grasses and rows of trees can also be considered. In this case, the irrigation water is mainly applied to crops/grasses but the trees also use it. This system is easy to manage as separate management can be employed for the crops/forages.

VII. Conclusion

Over the past decade, research and informal testing by university, government and resource agency personnel have identified a large number of salt-tolerant agronomic crops, forages, halophytes and trees that can be used in IFDM plantings. The final choice of species used within each of these groupings will depend on local soil and irrigation water salinities and boron concentrations, design of the particular IFDM system and intensity of management, and on grower preferences.

Chapter 7: Drainage Water and Its Effect on Wildlife Resources

I. Introduction

A goal of IFDM is to dispose of highly saline agricultural subsurface drainage water in an environmentally sound way that does not impact wildlife. Draft Title 27 Solar Evaporator Regulation states, *"The solar evaporator shall be operated to ensure that avian wildlife is adequately protected."*

Depending on the design and management of the solar evaporator, wildlife, such as shorebirds and waterfowl, may be attracted to the solar evaporator if standing water or scattered puddles are allowed to form. The saline subsurface drainage water may contain elevated selenium, which is the primary constituent of concern, and the hyper-saline water itself may impact wildlife.

II. Laws that Address Wildlife Issues

- California Code of Regulations (CCR) Draft Title 27 Solar Evaporator Regulations established minimum requirements for the design, construction, operation and closure of solar evaporators as components of IFDM systems with the intent of protecting wildlife from exposure to salt and selenium.
- California Environmental Quality Act (CEQA): environmental impact analysis is a component of CEQA, and delineates mitigation and monitoring requirements that may have to be incorporated into an IFDM system in order to ensure adequate CEQA compliance.
- Migratory Bird Treaty Act (MBTA) is enforced by both the USFWS and the CDFG.
- Federal Endangered Species Act (FESA) and the California Endangered Species Act (CESA) were created to protect species from extinction and are enforced by the USFWS and the CDFG, respectively.

See Chapter 9 for more details on laws and regulations.

The Central Valley Regional Water Quality Control Board currently is developing regulations regarding monitoring. The following is from Draft Title 27 Solar Evaporator Regulations, §22940:

Inspection – The CVRWQCB issuing a Notice of Authority to Operate a solar evaporator shall conduct authorized inspections in accord with §25209.15 of Article 9.7 of the Health and Safety Code to ensure continued compliance with the requirements of this article. The CVRWQCB shall request an avian wildlife biologist to assist it in its inspection of each authorized solar evaporator at least once every May. If an avian wildlife biologist is not available, the CVRWQCB shall nevertheless conduct the inspection. During the inspection, observations shall be made for compliance with §22910 (a) and (v), and the following conditions that indicate an unreasonable threat to avian wildlife:

(1) Presence of vegetation within the boundaries of the solar evaporator;

(2) Standing water or other mediums within the solar evaporator that support the growth and dispersal of aquatic or semi-aquatic macro invertebrates or aquatic plants;

(3) Abundant sustained avian presence within the solar evaporator that could result in nesting activity;

(4) An apparent avian die-off or disabling event within the solar evaporator;

(5) Presence of active avian nests with eggs within the boundaries of the solar evaporator.

A qualified wildlife biologist or agent identified by the Central Valley Regional Water Quality Control Board, may conduct the following biological surveys:

- Monitor for aquatic invertebrate activity if standing water is present for greater than 48 hours;
- Monitor bird activity (bird census, year round, monthly to twice per month);
- If nesting is detected, monitor nesting activity and nest fate (every 1-2 weeks from mid-March through July);
- If nesting is detected, collect egg selenium concentration data;

- Collecting and research take permits from the CDFG and USFWS are required for the collection of mammals, birds and their nests and eggs, reptiles, amphibians, fish and invertebrates.
- According to Draft Title 27 Solar Evaporator Regulations, §22940:

If active avian nests with eggs are found within the boundaries of the solar evaporator, the RWQCB shall report the occurrence to the USFWS and DFG within 24 hours, and seek guidance with respect to applicable wildlife laws and implementing regulations. Upon observation of active avian nests with eggs within the boundaries of the solar evaporator, all discharge of agricultural drainage water to the solar evaporator shall cease until (a) the nests are no longer active, or (b) written notification is received by the owner or operator, from the RWQCB, waiving the prohibition of discharge in compliance with all applicable state and federal wildlife laws and implementing regulations (i.e., as per applicable exemptions and allowable take provisions of such laws and implementing regulations.)

III. Constituents of Concern

A. Selenium

Selenium originates from the natural weathering of cretaceous shale (rocks that have the highest selenium concentration 500-28,000 ppb); however, there are two human-related activities that have resulted in the mobilization and introduction of selenium into aquatic systems. The first activity is the irrigation of selenium-containing soils for crop production in arid to semiarid areas of the country. The other source is from the procurement, processing (i.e. oil refineries), and combustion of fossil fuels (Lemly and Smith, 1987).

Selenium is a double-edge sword. Animals needs trace levels of the mineral in their diet for survival, but at levels slightly above trace amounts it can be very toxic. In addition, clinical signs for selenium deficiency are similar to selenium toxicity. Many veterinarians have misdiagnosed selenium toxicity as a selenium deficiency, resulting in adding selenium supplements to a patient's diet, which increased the toxicity response to a higher level.

The signs of acute selenium poisoning in laboratory animals include garlic breath, vomiting, dyspnea (difficulty or shortness of breath), tetanic spasms of the muscles, and respiratory failure (Koller and Exon, 1986). Acute poisoning of livestock is associated with plant material containing 400-800 ppm selenium (Eisler, 1985). "Alkali disease" is a livestock disease resulting from chronic selenium exposure; it is characterized by a lack of vitality, anemia, stiffness of joints, deformed and sloughed hooves, roughened hair coat, and lameness (Koller and Exon, 1986).

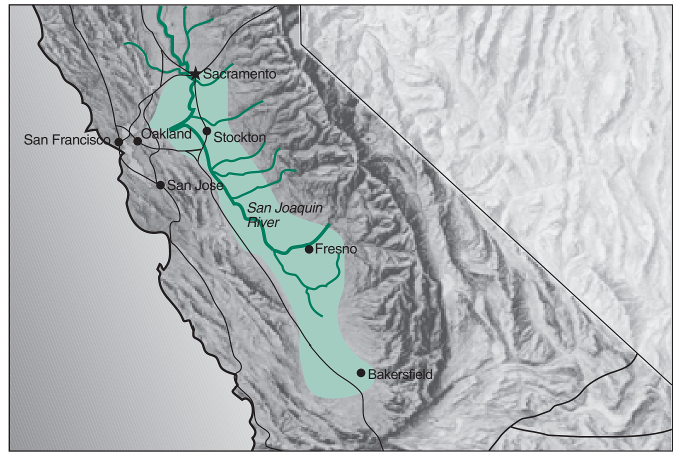


Figure 1. Land area with aquatic systems that maintain various levels of constituents of concern for wildlife.

The most common signs of selenium poisoning in wild birds are emaciated adults, poor reproduction rates, embryonic deaths and deformities (missing or abnormal body parts, such as wings, legs, eyes, and beaks, and fluid accumulation in the skull), and adult mortality (Friend and Franson, 1999). In order to diagnose selenium poisoning, factors such as a history of potential exposure, gross developmental defects, microscopic lesions (evidence of chronic liver damage), and selenium concentrations in tissues, food, water and sediment must be examined.

Plants and invertebrates in contaminated aquatic systems can accumulate selenium, which can sometimes reach levels that are toxic to birds and other organisms that eat them (Friend and Franson, 1999) as shown in Figure 1.

B. Boron

Boron is an essential trace nutrient necessary for plants and animals, as well as for some species of fungi, bacteria and algae. Boron is naturally

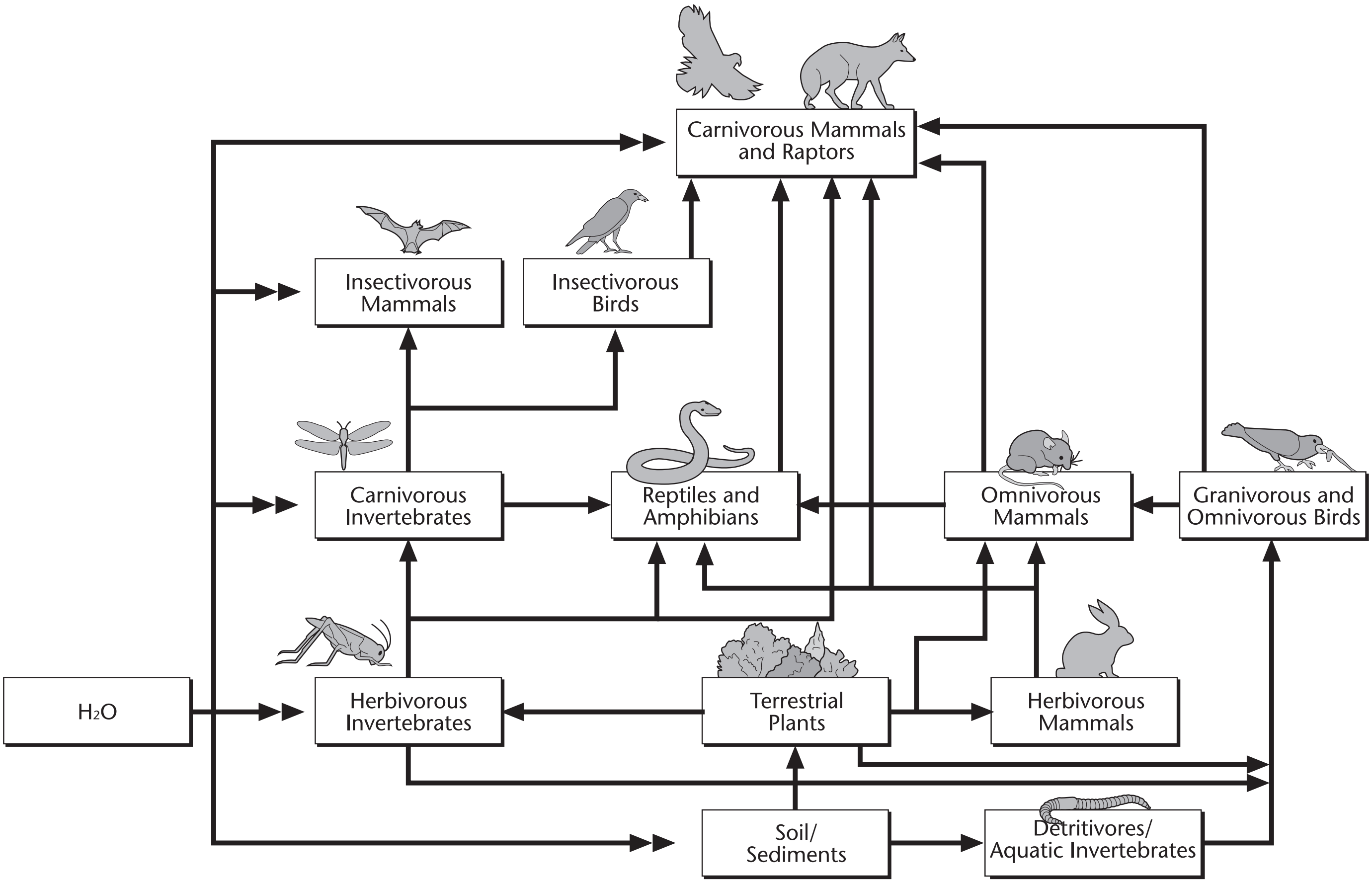


Figure 2. Bio-accumulation of selenium flow-chart for wildlife.

occurring and is found in varying concentrations in San Joaquin Valley soils and water. There is some evidence that elevated boron may decrease the growth rate of chicks. Also different plant species, including agricultural crops, have different tolerances to boron concentrations in soil and water.

C. Molybdenum

Molybdenum is an essential micronutrient. Evaporation ponds in the southern San Joaquin Valley often contain high concentrations of molybdenum (Ohlendorf and Skorupa, 1993). There is little information about the negative effects of molybdenum on avian and mammalian wildlife.

D. Arsenic

Arsenic is a teratogen (causes deformities) and carcinogen (causes cancer), which can cause fetal death and malformation in many mammal species but may be an essential nutrient in small amounts. High levels of arsenic have been found in the water and sediments of some agricultural subsurface drainage evaporation basins, in the soil, and in underground water tables in the San Joaquin Valley. However, to date, elevated concentrations of arsenic have not been found in wild bird eggs. In addition, some aquatic invertebrate species have been negatively affected by arsenic in the evaporation basins (Ohlendorf and Skorupa, 1993).

E. Salinity and Salt Toxicosis

Evaporation basins are used to collect and dispose of highly saline subsurface drainage water produced in the Tulare Basin, and to a limited extent, on the Westside of the San Joaquin Valley. Aquatic invertebrates, such as brine shrimp, thrive in the hyper-saline water and attract many birds. Waterfowl, particularly the ruddy duck, have been affected by salt encrustation of feathers and salt toxicosis by loafing and feeding in deep hyper-saline water evaporation basins. Salt toxicosis (sodium poisoning) generally occurs in times of drought or cool winter temperatures when there is no access to fresh water. The symptoms of salt toxicosis include conjunctivitis (swelling of the eyelids), lens opacity, cataract formation, and vascular congestion in various organs such as the oropharynx (throat), lungs, kidney, and spleen, and most prominently in the meninges of the brain, and myocardial and skeletal muscle degeneration (Gordus et al., 2002). Gordus et al. (2002) found that ambient temperatures below 4°C and hyper-saline water >70,000 µmhos/cm resulted in salt encrustation and salt toxicosis in ruddy ducks.

IV. Water Quality Objectives

Table 1. Water quality objectives for the protection of wildlife. Please note that the following threshold values may change based on future State and Federal regulatory water quality objective requirements. Note: µg/L equals microgram per liter and mg/L equals milligrams per liter.

	Target Water Quality	Water Quality Needs Further Study	Unacceptable
	No Effect	Level of Concern	Toxicity
Selenium (µg/L)[a]	<2	2-5	>5
Arsenic (µg/L)	<5	5-10	>10[b]
Boron (mg/L)	<0.3	0.3-0.6	>0.6[c]
Molybdenum (µg/L)	<10	10-19	>19[b]

a Draft Environmental Impact Statement (EIS)/Environmental Impact Report (EIR), Grassland Bypass Project, 2001-2009 (URS 2000).

b Preliminary Draft Water Quality Criteria for Refuge Water Supplies Title 34 PL 102-575 Section 3406 (d) 1995. The California Regional Water Quality Board Agriculture Water Quality Objectives for molybdenum is 10 µg/L (A Compilation of Water Quality Goals, Marshack 1998).

c Proposed California Regional Water Quality Board Boron and Salinity Objectives for Full Protection of Beneficial Uses in the Lower San Joaquin River at Vernalis. The California Regional Water Quality Board agriculture water quality objective for boron is 0.70 to 0.75 mg/L (A Compilation of Water Quality Goals, Marshack 1998).

V. Biological Sampling

A. Aquatic Invertebrates

Many studies have shown that aquatic invertebrates (insects, snails, worms, etc.), can accumulate high levels of selenium from water and sediment. Sampling and measuring the selenium concentrations of aquatic invertebrates is one of the best indicators for monitoring predator exposures in cases where information is difficult to obtain directly from predator species (Luoma and Presser, 2000). Sampling of aquatic invertebrates may need to be performed if there is standing water that has elevated selenium concentrations, has an established population of invertebrates, and a significant number of birds are observed feeding and using the flooded area.

B. Bird Eggs

Many cases have shown that aquatic birds that feed and nest at subsurface drainage water disposal sites have above normal rates of embryo mortality and teratogenesis and adult mortality, as seen at Kesterson Reservoir (Ohlendorf & Skorupa, 1989).

Collecting bird eggs is the most efficient method for determining selenium impacts to birds that feed and nest at a solar evaporation basin. This is because bird eggs are easy to find and collect, the loss of one egg collected from a nest is not enough to negatively impact a population, embryos are the most sensitive life stage to selenium poisoning, and egg selenium concentrations represent a direct selenium exposure relationship to the adult female over time (Lemly, 1996).

VI. Maintaining a Bird-Free Solar Evaporator

Factors that make solar evaporators attractive or unattractive to birds are:

- Size of the solar evaporator – Larger solar evaporators are more attractive than smaller solar evaporators.
- Location – Is the site within or near a local flyway corridor or wildlife area or refuge? The Valley historically supported extensive wetlands that provided important stop-over foraging and resting habitat for migratory birds. As a result, any artificial "wetlands" that currently occur within the Valley are very attractive to water birds due to the limited wetland acreage remaining.
- Depth of water – Shallow water attracts shore birds and dabbling ducks, and deep water attracts ruddy ducks and eared grebes.

- Standing water – Aquatic invertebrates can become established, which is a food base for water birds.
- Design and management – Certain designs and management techniques enhance the attractiveness of a pond to birds.

Avoidance measures to greatly reduce the negative impacts on waterbirds were developed by several researchers in cooperation with DFG and USFWS, (San Joaquin Valley Drainage Program, 1999), (Bradford et al. 1991), (CH2M Hill et al. 1993), (Salmon and March, 1991), (California Department of Water Resources and San Joaquin Valley Drainage Program, 1998). These measures include:

- Design – Steep banks, flat or level bottoms, no uneven bottoms or high spots, no windbreaks, islands or internal berms present.
- Management – An effective program may reduce the likelihood of a solar evaporator attracting waterbirds to a site.
    - Hazing (propane cannons and cracker shells) is one avoidance measure that may be effective in reducing migratory birds foraging and nesting in or around the solar evaporator during the early spring and summer months. Note: Shorebirds and dabbling ducks, such as northern shovelers, mallards and pintails, are easier to haze compared to eared grebes and diving ducks, such as ruddy ducks. Hazing should be discontinued after a nest has become established and eggs have been laid so the nest is not abandoned.
- To prevent aquatic invertebrates from becoming established, do not allow water greater than 1 cm in depth to stand for more than 48 hours.
- Keep dikes, banks and pond bottoms weed free. Manual weed control should not take place during the nesting season unless a qualified wildlife biologist has determined the area to be nest free.
- Appropriate monitoring program should be in place that support an Adaptive Management Program.

Chapter 8: IFDM Economics

I. Introduction

Although the cost of planning and implementing an IFDM system may be high, the potential for economic gain and to continue farming may be higher. The benefits from an IFDM strategy include the ability to produce higher value crops and manage salinity and groundwater levels, while complying with regulations.

The potential costs for the planning and implementation of an IFDM system may include:

1) Fees and professional assistance for environmental permitting;
2) Design;
3) Fee for filing a Notice of Intent with the Regional Water Quality Control Board;
4) Land preparation;
5) Surface and subsurface drainage system installation;
6) Installation and maintenance of the solar evaporator;
7) Water distribution/irrigation system;
8) Time to establish the system in whole (2-3 years);
9) Management of system operation;
10) Waste management;
11) Cropping changes; and
12) Development of the salt-tolerant vegetation section.

II. Cost Breakdown

Additional annual costs, not commonly considered, may include the opportunity cost; taxes; assessments on land used for the solar evaporator and salt-tolerant crops; interest and the amortized rate; and length of time to amortize the initial costs of the surface and subsurface drainage system and solar evaporator.

Furthermore, as soil salinity is reduced with an IFDM system and the production of higher value crops becomes possible, an increase in the revenue and value of the farm may be realized. Input costs, such as water, fertilizer and pesticides, may be reduced depending on past cultural practices.

Additional costs to be considered are plant selection, economies of scale, operation and maintenance, and initial and fixed costs.

A. Plant Selection

Plant selections for Stages 3 and 4, which include salt-tolerant crops, forages, trees and halophytes, can affect the crop revenue and land value. The costs associated with plant selection include establishment cost, cultural cost and the value or marketability of the crop.

Some salt-tolerant agronomic crops may be produced in Stage 3 with the higher salinity drainage water, but reduced yields must be considered. In addition, consideration and value must be given to the IFDM system benefits offered by the selected salt-tolerant plants, specifically water use and salt tolerance. The function of these stages is to concentrate salts by using drainage water in a productive way, thus minimizing the amount of water to be processed in the solar evaporator.

B. Economies of Scale

The cost of a complete system could range from $800 to $1,000 per acre depending on the size of the project. A large portion of the budget will be the subsurface drains, the drainage water distribution system, irrigation for salt-tolerant forage crops, and the salt harvest area. The cost of the engineering and CEQA compliance also are significant and should be considered. Any annual costs associated with the Stage 3 and 4 crop areas, the solar evaporator, and regulatory compliance become a cost of doing business (overhead) to be applied to the total IFDM project. The larger the project area, the lower the annual per-acre charge for these expenses.

The average cost of an IFDM system increases as the size of the solar evaporator increases and/or rental rate or opportunity cost of land increases. Improving irrigation management and efficiency will be the key to minimizing the size of the solar evaporator.

Moreover, minimizing the size of the solar evaporator maximizes the land available for production. The size of the solar evaporator is a function of the irrigation management practices and the volume of drainage water collected.

C. Operations & Maintenance Costs

The operations and maintenance costs of the farming operation may increase due to the enhanced level of management and the additional equipment required to transport subsurface drainage water between field stages. Monitoring and reporting should be included in the operations and maintenance budget. The annual operations and maintenance cost for an IFDM system will range from $100 to $120 per acre, depending on the level of monitoring required.

D. Initial, Fixed & Variable Costs

Table 1 shows the estimated costs of installing, operating and maintaining the solar evaporator and the estimated annual costs of land used for the evaporator, salt-tolerant crops, forages and halophytes. It includes the fixed costs, initial costs for a subsurface drainage system, initial costs for a solar evaporator and operations and maintenance costs.

The initial cost for the simplest solar evaporator is approximately $1,000 per acre, which may include a sprinkler system, engineering analysis, construction costs and materials (pipe, pumps and sprinklers for water distribution).

The initial cost for the design and construction of the subsurface drainage system is approx-

Table 1: The estimated costs of installing, operating and maintaining the solar evaporator and the estimated annual costs of land used for the evaporator, salt-tolerant crops, forages and halophytes. Assume costs to be amortized over 10 years and an interest rate of six percent.

Item	**Initial Cost ($/acre)**	**Annual Cost ($/acre)**
The Subsurface Drainage System		
Estimated installation cost	400.00	
Amortized installation cost		35.58
Operations & Maintenance		5.00
Sum of estimated annual costs for the drainage system		40.58
The Solar Evaporator		
Estimated installation cost	1,000.00	
Amortized installation cost		137.48
Operations & Maintenance		120.00
Taxes and assessments		25.00
Rental or opportunity cost		150.00
Sum of estimated annual costs for the evaporator		432.48
Land Used for Salt-Tolerant Crops and Forages		
Taxes and assessments		25.00
Rental or opportunity cost		150.00
Annual production costs		339.00
Sum of estimated annual costs for salt-tolerant crops		514.00
Land Used for Halophytes		
Taxes and assessments		25.00
Rental or opportunity cost		150.00
Annual production costs		200.00
Sum of estimated annual costs for halophytes		375.00

imately $400 per acre, including engineering analysis, construction costs and materials.

The fixed costs include annual amortized costs of the subsurface drainage system, solar evaporator and rental or opportunity cost of the land for the solar evaporator.

After determining the fixed cost to include an IFDM system into the farming operation, it is important to determine the variable cost for the system. Variable cost items may include the operations and maintenance, IFDM manager, installation and production cost for the salt-tolerant crops and forages and compliance with environmental and wildlife regulations.

However, the fulltime IFDM system manager can greatly offset the costs associated with regulatory compliance. This manager's responsibilities should include a complete understanding of the significance of the environmental and wildlife regulations, (i.e., draft Title 27 draft regulations). If the regulations are not met, operations and maintenance costs for the system can dramatically increase.

III. Funding Sources

The three main funding sources to plan, design and implement an IFDM system are private financing, bank loans and grants. Grant programs may be from a public source (federal, state, regional and/or local), or from a private source. If the public grant source is used, it is important to remember that any financial records become public documents and are open for public review, and automatically require the implementation of CEQA and/or NEPA.

Current public grant programs may include:

- A state revolving fund available to growers in Westlands Water District for capital improvements to implement source reduction (subsurface drainage and irrigation equipment).
- The Federal USDA-NRCS EQIP grant program with funds available to growers for installing subsurface drains.

There are many funding resources available for possible grants and/or loan programs. Contact the local office of the following agencies or look on the Web for more information:

Federal

- U.S. Department of Agriculture – Natural Resources Conservation Service
- U.S. Department of Agriculture – Agricultural Research Service
- U.S. Department of the Interior – Bureau of Reclamation
- U.S. Fish and Wildlife Service
- U.S. Environmental Protection Agency

State

- Bay- Delta Authority (formerly CALFED Bay-Delta Program)
- California Department of Water Resources
- State Water Resources Control Board
- Central Valley Regional Water Quality Control Board
- California Department of Fish and Game
- California Department of Food and Agriculture
- University of California Cooperative Extension Service
- California State University, Fresno – Center for Irrigation Technology

Regional/ Local

- Resource Conservation districts
- Water and Irrigation districts

Chapter 9: Laws and Regulations

I. Introduction

An Integrated On-Farm Drainage Management system strives to provide an economically feasible and environmentally sound program for managing salts on irrigated farmland. Farmers who wish to develop an IFDM system must be aware of the myriad rules and regulations that govern water quality, wildlife protections and hazardous material.

Although the list of questions and considerations may seem daunting and overwhelming, there are technical and regulatory experts who can consult and work with growers to achieve a successful IFDM system. The key to this success is to develop a cooperative working relationship with the regulatory agencies and a willingness to maintain open dialogue and communications throughout the regulatory review and necessary environmental permitting process.

The assistance of a qualified biologist and/or planner is essential to navigating the environmental permit process. Consideration of the following questions and being prepared to provide a thorough and accurate description of all project activities should make the environmental compliance process easier and assist in successfully navigating any regulatory hurdles.

Please note, this chapter is merely a guideline to the complex process of environmental law and permitting. A more detailed account of the laws and regulations will appear in the technical manual for developing an IFDM system.

II. Questions That Should be Answered Before Proceeding with a Project

The following questions are intended to highlight features of the project that are often concerns for regulatory agencies.

Has an Initial Study (IS) or Environmental Assessment (EA) been completed or is one being done by a local or state permitting agency in accordance with the California Environmental Quality Act (CEQA) or the National Environmental Policy Act (NEPA)?

Will the project require certification, authorization or issuance of a permit by any local, state or federal agency?

Have all adjacent landowners been contacted and notified before conducting any activity?

Will the project require the issuance of a variance or conditional use permit by a city or county?

Is the project currently operating under an existing use permit issued by a local agency?

What types of vegetation are currently present at the project site, including trees, brush, grass, etc.?

What types of wildlife or fish may use the project site or adjoining areas for habitat (food source, nesting, migration, water, etc.)?

Has the California Department of Fish and Game (CDFG) or the U.S. Fish and Wildlife Service (USFWS) been consulted relative to the existence of, or impacts to, threatened or endangered species on or near the project site?

Will the project result in changes to scenic views from existing residential areas, public lands, and public roads or present a visual distraction?

Will the project impact existing recreational opportunities?

Will the project result in changes or effects upon historical, or archeological and cultural resources?

Will the project result in changes or effects upon geological or paleontological resources?

Will the project include excavation?

Will the project change existing features of any hills or result in substantial alteration of ground contours?

Will the project occur on filled land or on a slope of 10 percent or more?

Will the project discharge silt or other material into a designated body of water for California or the U.S.?

Will the project involve the application, use, or disposal of hazardous material?

Will activities or the completed project result in significant amounts of noise or vibration levels?

Will activities or the completed project result in significant amounts of dust, ash, smoke, fumes or odors?

Will the project involve the burning of brush, grass, trees or materials?

Will the project substantially increase fossil fuel or energy resource consumption?

Have any other similar projects been planned or completed in the same general area?

Will the project have the potential to encourage, facilitate or allow additional new growth or development or impact local services?

Will the project result in a change to the pattern, scale or character of the general project area?

Will the project affect existing agricultural uses or result in the loss of existing agricultural lands?

Will the project be funded by private or public funds?

III. Regulatory Requirements

Both state and federal agencies have the regulatory authority over projects like IFDM. The affected regulations that could impact an IFDM project include:

California Environmental Quality Act (CEQA): CEQA was passed by the California Legislature in 1970. Generally, CEQA requires state and local agencies to identify the significant and potentially significant environmental impacts of their actions and to implement measures to avoid or mitigate for those impacts. If a significant effect is anticipated, an Environmental Impact Report (EIR) is written; otherwise; a Negative Declaration is prepared.

National Environmental Policy Act (NEPA): NEPA requires incorporating environmental considerations into the planning process for all federal projects and for projects requiring federal funding or permits. If a significant effect is anticipated, an Environmental Impact Statement (EIS) is written; otherwise, a Finding of No Significant Impact (FONSI) is prepared.

Note: *Projects that are developed by state or federal agencies, and/or funded or permitted by state or federal agencies must address CEQA and NEPA. Projects that involve state participation must conform with CEQA, while projects with federal participation must conform to NEPA guidelines. Projects with both state and federal interests are subject to environmental analyses under both acts.*

Federal Clean Water Act: The Federal Clean Water Act established the basic structure for regulating discharges of pollutants into the waters of the United States. The act sets water quality standards for all toxic and non-toxic contaminants in surface waters, implements wetland protection programs, and charges the states to adopt standards and to establish treatments and controls to protect water quality within its borders.

Section 404, Clean Water Act: Section 404 of the Clean Water Act regulates the location of a structure, excavation and discharge into "waters of the United States," which can include wetlands, perennial or ephemeral streams and lakes. The U.S. Environmental Protection Agency and U.S. Army Corps of Engineers have primary jurisdiction and issue permits under Section 404.

Section 402, Clean Water Act: Section 402 requires that all point sources discharging pollutants into waters of the United States obtain a National Pollutant Discharge Elimination System Program (NPDES) permit. Point source pollutants are defined as those that come from a concentrated point of origin such as a pipe, factory, feedlot or those coming from a readily determined source, as opposed to non-point pollutants, which come from diffuse sources. The Regional Water Quality Control Board regulates the Section 402 permits.

Resource Conservation and Recovery Act (RCRA): RCRA is the federal statute governing management and disposal of waste. In the case of salt residue from an IFDM system, the material is not a listed hazardous waste. However, it could be a characteristic hazardous waste if the leachable selenium concentration in the solid residue (or the dissolved selenium in disposed liquid) exceeds the allowable level of 1.0 milligrams per liter (mg/L) using the Toxicity Characteristic Leaching Procedure (TCLP).

Note: *The California State Water Resources Control Board is currently developing a resolution under SB 1372 (Title 27 Draft Regulations) that would simplify some of the regulatory requirements for management of salt residue from an IFDM system. The proposed resolution would allow for on-site storage of salt residue for periods of up to one year under certain conditions. It is not clear whether the resolution would exempt the salt residue from RCRA storage and management requirements for this duration if selenium levels in the residue exceed hazardous levels.*

Hazardous Waste Control Law (HWCL): HWCL is the California statute governing management and disposal of hazardous waste. California requirements are generally similar to requirements under RCRA, except that additional requirements may apply to salt waste from an IFDM system.

Land Disposal Restrictions (LDR): Certain hazardous wastes are banned from land disposal unless they are treated to meet certain standards. This treatment is generally performed by the disposal facility. Selenium waste waters must be treated to a standard of 1.0 mg/L prior to disposal and non-wastewater wastes must be treated to a leachable concentration of 5.7 mg/L as determined by TCLP.

Toxic Pits Cleanup Act (TPCA): TPCA was enacted in 1984 to regulate the cleanup of pits historically used for the disposal of liquid hazardous waste in California. Because drainage discharged to solar evaporators sometimes contains naturally occurring selenium in excess of hazardous waste levels, certain requirements of TPCA were automatically triggered. This issue has been addressed by SB 1372 (Title 27 Draft Regulations), which recognizes that TPCA was not intended to address the unique circumstances and conditions pertinent to solar evaporators, and therefore exempts IFDM systems from this regulation.

Porter-Cologne Water Quality Control Act: The Porter-Cologne Water Quality Control Act of California requires that nine Regional Water Quality Control Boards (RWQCBs) be created to regulate water quality through the establishment and enforcement of Basin Plans that define beneficial use quality objectives for water resources in their respective areas. Any waste disposal activities or releases that impact or threaten to impact the quality of "waters of the state" (either surface water or groundwater) may be regulated. Waste disposal is regulated by issuing Waste Discharge Requirements (WDRs) that specify measures that must be taken and monitoring requirements that must be followed to assure that water quality is not impacted.

NOTE: *Under SB 1372 (Title 27 Draft Regulations), the State Water Resources Control Board (SWRCB) will adopt a resolution that waives WDRs for IFDM systems. The resolution will require that operators of IFDM systems follow a series of simplified requirements that are essentially generic WDRs for these operations and are intended, among other things, to prevent potential impacts to water quality. If these requirements are not followed and a discharge from an IFDM system impacts or threatens groundwater or surface water quality, a RWQCB could order that the release be investigated or could issue a cease and desist order requiring cleanup.*

CCR Title 27 Landfill Regulations: The disposal of non-hazardous, non-inert waste is regulated under Title 27 of the California Code of Regulations. Under these regulations, non-hazardous waste that has the potential to degrade water quality is defined as "Designated Waste," and must be disposed of in properly designed and classified surface impoundments with liners that are licensed to accept such waste.

RCRA Subtitle D Landfill Requirements: Design, monitoring and closure requirements for hazardous waste landfills are outlined in Subtitle D of RCRA and in Titles 22 and 23 of the California Code of Regulations. The requirements now being considered in the resolution drafted by the SWRCB pursuant to SB 1732 are not consistent with these requirements. It is not clear whether salt residue containing selenium above TCLP, STLC and/or TTLC concentrations will be permitted to be disposed in place without these requirements being triggered.

Section 401, Clean Water Act, Water Quality Certification: Under CWA Section 401, a landowner that applies for a federal permit or license for an activity that could result in a discharge to "waters of the United States" must also obtain a State Water Quality Certification that the discharge meets state water quality objectives. Most Water Quality Certifications are associated with CWA Section 404 permits.

Basin Plans or Water Quality Control Plans: The development of basin plans was required by the state Porter-Cologne Water Quality Act (sections 13240-13247) and the federal Clean Water Act (section 303). The basin plans consist of designated beneficial uses to be protected, water quality objectives for groundwater and surface water and an implementation program for meeting the objectives. Basin plans are administered by the RWQCBs and are used by other agencies in permitting and resource management activities.

Federal Endangered Species Act (FESA): This act affords regulatory protection to plant and animal species federally listed as endangered, threatened, or proposed for listing. The act includes a provision (Section 9) that prohibits parties from the import, export, possession, transport, sale, or the unauthorized "take" of any listed species, which includes harassing, harming (which includes significantly modifying or degrading habitat), pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting wildlife or any attempt to engage in such conduct.

California Endangered Species Act (CESA): This act establishes a state policy to conserve, protect, restore, and enhance threatened or endangered species and their habitats. CESA mandates that a state agency cannot approve a project that potentially jeopardizes the continued existence of a listed species when reasonable and prudent alternatives exist. A state lead agency must consult with CDFG during the CEQA process. CDFG will issue comments addressing their concerns and will offer reasonable and prudent alternatives for a project.

Stream Bed Alteration Agreement – Fish and Game Code, section 1600: CDFG requires notification from agencies and/or individuals prior to taking any action that would divert, obstruct, or change the material, flow, bed, channel, or bank of any river, stream, lake or any other waterway that may provide aquatic habitat. CDFG will propose reasonable project changes if the project has the potential to negatively affect resources. CDFG will seek to protect fish and wildlife resources and may stipulate conditions to protect these resources.

Fully Protected Animals: The state attempted to identify and provide protection to those animals that were rare or faced possible extinction prior to CESA under various legislative bills. This resulted in a list of 37 mammals, birds, reptiles and amphibians that were given Fully Protected status, (see Appendix). Under the more recent endangered species laws and regulations, most Fully Protected species also have been listed as threatened or endangered species. However, Fully Protected species may not be taken or possessed at any time and no licenses or permits (including a 2081) may be issued for their take except in rare circumstances.

Migratory Bird Treaty Act: This act is the result of a series of conventions with Canada, Japan, Mexico and Russia establishing a federal statute that prohibits the pursuit, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage or export at any time or in any manner, any migratory bird, unless permitted by regulations. This includes feathers, nests, eggs, other parts, or products of a migratory bird. Most birds are protected under this act.

Bald Eagle Protection Act: This law provides for the protection of the bald eagle (the national emblem) and was later amended to include the golden eagle by prohibiting the take, possession, sale, purchase, barter, offer to sell or purchase or barter, transport, export or import at any time or in any manner a bald or golden eagle, alive or dead; or any part, nest or egg of these eagles. By definition, take includes: pursuing, shooting, poisoning, wounding, killing, capturing, trapping, collecting, molesting, or disturbing.

California Reclamation Board: The California Reclamation Board was established to control flooding along the Sacramento and San Joaquin rivers and their tributaries, to assist in establishing and maintaining flood control works and the integrity of the existing flood control systems, and is required to enforce standards that will best protect the public from floods. The Board's jurisdiction extends over the entire Central Valley and includes the Tulare and Buena Vista basins. An encroachment permit application must be submitted to the Board for review if a project falls within the Board's jurisdictional area.

IV. Environmental Evaluation Resources

Many useful resources are available to make the environmental evaluation and permit process easier, but nothing can substitute for the assistance provided by qualified professionals. Below are just some of the resources available. Many are available online.

Note: *An attempt has been made to provide the parent website for resources rather than the actual link as websites continually change and direct links often expire within a short period of time. You may be required to navigate and search a website to find the listed resource.*

Biological Data

The Wildlife and Habitat Data and Analysis Branch of CDFG provides useful tools and resources to consultants and agency personnel to evaluate impacts to biological resources. Some of the information is available to the general public and some is provided through a subscription-based service.

Species Lists

The following species lists are available from CDFG:

Complete List of Amphibians, Reptiles, Birds and Mammals in California

State and Federally Listed Endangered and Threatened Animals of California

Special Animals

State and Federally Listed Endangered, Threatened, and Rare Plants of California

Special Vascular Plants, Bryophytes, and Lichens List

California Technology, Trade and Commerce Agency – California Permit Handbook

http://commerce.ca.gov

The California Technology, Trade and Commerce Agency provides an online guide (and print version) to the state's environmental permit process. The Handbook contains useful summaries, tips and contacts to help you understand the permit process.

CERES – CEQA Website

www.ceres.ca.gov

The California Environmental Resources Evaluation System (CERES), under the California Resources Agency, maintains a CEQA website that provides the CEQA guidelines, forms, and numerous CEQA resources.

Governor's Office of Planning and Research

www.opr.ca.gov

The State Clearinghouse, under the Governor's Office of Planning and Research, is the point of contact for the distribution of environmental documents prepared under CEQA. The State Clearinghouse Handbook provides information about CEQA and the environmental document review process.

California Department of Fish and Game

www.dfg.cal.gov

Reclamation Board

www.recbd.water.ca.gov

State Water Resources Control Board

www.swrcb.ca.gov

US Army Corps of Engineers, Regulatory Program

www.usace.army.mil/inet/functins/cw/cecwo/reg

US Fish and Wildlife Service, Permits

http://permits.fws.gov

V. Answers to the Most Common Questions Concerning the Solar Evaporator Regulations

Definition:

What is the regulatory definition of a solar evaporator?

Linked regulatory definitions have been established by the State Legislature for "solar evaporator, integrated on-farm drainage management system, and on-farm."

A solar evaporator is designed and operated to manage agricultural drainage water discharged from an integrated on-farm drainage management system. The integrated on-farm drainage management system (1) collects drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural water is substantially decreased and its salt content is significantly increased; (2) reduces the level of salt and selenium in the soil; (3) discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management; (4) eliminates discharge of agricultural drainage water outside the boundaries of the property that produces the agricultural drainage water managed by the system.

*Finally, "on-farm" means within the boundaries of a geographically contiguous property, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an IFDM system and a solar evaporator. These linked definitions constitute a permitable solar evaporator under the new regulations. For the complete text of the definitions, see the California Code of Regulations (**CCR**) **§22910.***

How can a solar evaporator be integrated into my existing farming operation?

An IFDM system, including a solar evaporator, can be established in the entirety or a portion of your contiguous property that is currently used or will be used for commercial agricultural production, depending on your need to manage saline shallow groundwater.

Application Process:

What is the procedure for applying for and obtaining a permit to construct and operate a solar evaporator?

At present, any person who intends to construct and operate a solar evaporator shall first file a Notice of Intent (NOI) with the Regional Water Quality Control Board (RWQCB). The NOI (see Appendix) consists of a one-page form, plus supporting documentation, including the design of the solar evaporator, calculation of the maximum rate of drainage discharge to the solar evaporator, baseline groundwater monitoring data, and a local water balance analysis (annual evapotranspiration, ET, and precipitation). The solar evaporator design must be certified by a registered professional who is a civil or agricultural engineer, or a geologist or engineering geologist.

The RWQCB shall, within 30 days of receiving the NOI, review the NOI and inspect the proposed location, and if the NOI is found to be in compliance with the regulations, issue a written Notice of Plan Compliance (NPC). If the NOI is found to not be in compliance, the RWQCB shall issue a written response to the applicant identifying the reasons for non-compliance. The applicant can then take steps to revise the NOI in order to bring it into compliance.

After receiving an NPC, an applicant may proceed with construction of the solar evaporator in conjunction with an IFDM system. Before operating the solar evaporator, the applicant must request the RWQCB to conduct a compliance inspection. The RWQCB will conduct the inspection within 30 days of receiving the request, and if the solar evaporator is in compliance with the NOI and NPC, will issue a Notice of Authority to Operate (NAO). If upon inspection, the solar evaporator is found to not be in compliance, the RWQCB will issue a written response identifying the reasons for non-compliance. The applicant can then take steps to modify the solar evaporator in order to bring it into compliance with the NOI and NPC.

For the actual text of the procedures, see the Health and Safety Code (**HSC**) **§25209.13.**

Please note that these regulations may be subject to change.

Who can submit an application?

The permitable applicant of a solar evaporator facility has been defined by the State Legislature as a single owner or operator of a geographically contiguous property that is used for the commercial production of agricultural commodities with an IFDM system.

When can an application be submitted?

An application can be submitted at any time, but an NAO cannot be issued on or after January 1, 2008.

Will an Environmental Impact Report be required?

A CEQA checklist and initial study need to be completed to determine any additional environmental regulations that might apply.

Solar Evaporator Design Requirements:

What are the requirements for choosing a site for a solar evaporator?

The solar evaporator may be located anywhere on your agricultural property within the boundary of and contiguous with your IFDM system. The solar evaporator should NOT be located on the low point of the farm, and should be placed above the 100-year floodplain, and where the criteria for groundwater protection may be met.

The criteria include a one-meter depth of soil with permeability of 1 x 10-6 cm/sec or less, and a distance of five-feet or more between the bottom surface of the solar evaporator and the highest anticipated level of underlying shallow groundwater. Sites not meeting these conditions may be engineered to achieve the same level of flood and groundwater quality protection.

What types of solar evaporator designs will be permitted?

Any solar evaporator design can be permitted if it meets the basic design requirements of the new regulations. In addition to flood and groundwater quality protection, the design must include no discharge of agricultural drainage outside of the solar evaporator; discharge to the solar evaporator must be by sprinklers or another adjustable mechanism that will prevent the occurrence of standing water; wind drift of sprinkler spray shall be prevented; and avian wildlife shall be adequately protected.

A water catchment basin may be constructed as part of the solar evaporator in order to contain standing water that might otherwise occur in the solar evaporator. The maximum size of the solar evaporator cannot exceed 2 percent of the total area of the complete IFDM system.

What is a water catchment basin?

A water catchment basin is an area within the boundaries of a solar evaporator designed to receive and hold any water that might otherwise become standing water within the solar evaporator under reasonably foreseeable operating conditions. The entire area of the water catchment basin needs to be permanently covered with netting or otherwise constructed to ensure protection of avian wildlife.

What is meant by "reasonably foreseeable operating conditions?"

"Reasonably foreseeable operating conditions" were stated by the State Legislature as defining the regulatory limits for the design of a solar evaporator, but were not quantified. The SWRCB has quantified these conditions as follows:

- the local 25-year, 24-hour maximum precipitation event,
- floods with a 100-year return period.

This means that the solar evaporator must be designed to not have standing water in the event of a 25-year, 24-hour precipitation amount, or that the water catchment basin must have sufficient volume to hold that amount of water accumulating in the solar evaporator. If a storm event occurs exceeding that amount, any associated occurrence of standing water within the solar evaporator will not be considered a violation of the regulations. In an analogous manner, inundation of the solar evaporator by a flood event exceeding the 100-year return period will also not be considered a violation of the regulations.

Is the use of a liner required?

Use of a liner is not required. Although, a liner may be used to meet the requirements for groundwater quality protection if existing soil conditions are unfavorable, and other engineered solutions are infeasible. In this case, the liner must meet the stated specifications, including a thickness of 40-millimeters.

If the groundwater quality protection requirement is met without use of a liner, an owner/operator may use a liner at his discretion, as a functional component of the solar evaporator design. In this latter case, the 40-millimeter thickness specification does not apply.

Is the installation of a subsurface drainage system required?

Subsurface drainage systems under or adjacent to a solar evaporator are not required. Subsurface drainage systems may be installed where it is deemed necessary to provide adequate insurance that groundwater quality will be protected.

Solar Evaporator Operation Requirements:

What are the operational requirements for solar evaporators?

The solar evaporator must be operated so that:

- There is **no standing water** within the evaporator, except for the water catchment basin. Application of drainage water with a timed sprinkler system should be used to set the application at rate that will not result in standing water.
- A nuisance condition such as wind-blown salt spray is not created.
- There is **no discharge of drainage water** outside the boundaries of the solar evaporator.
- Avian wildlife is adequately protected.

What steps are necessary to ensure the adequate protection of avian wildlife?

In addition to no standing water, the following Best Management Practices are required to ensure adequate protection of avian wildlife:

- Keep the solar evaporator free of all vegetation.
- Do not use grit-size gravel as a surface substrate in the solar evaporator.
- Prevent access to standing water in a water catchment basin with netting and do not allow the netting to sag into standing water in the catchment basin.

- Prevent the growth of insects in the solar evaporator, the growth and dispersal of insects from the water catchment basin, and use of the netting as a site for insect pupation.

What are the monitoring requirements?

Monitoring requirements will be established by the Regional Board at the time of the issuance of a Notice of Plan Compliance within 30 days of the submittal of a Notice of Intent to construct a solar evaporator. Groundwater and avian wildlife protection monitoring shall be required, as well as any information necessary to ensure compliance with the requirements of the regulations. Monitoring reports shall be submitted annually.

What options are available for the storage of salt accumulated in the solar evaporator?

Salt may continue to accumulate in an authorized solar evaporator as long as the accumulation does not interfere with the required operation of the evaporator. Salt may be harvested at any appropriate time and utilized or sold for beneficial of commercial purposes. Otherwise, salt can be temporarily stored in an enclosed storage unit inaccessible to wind, water and wildlife, and subject to annual inspection.

Are inspections separate from monitoring?

Yes. Monitoring and other recordkeeping is the responsibility of the operator.

Inspections are the responsibility of the Regional Board and shall be conducted at least once annually during the month of May. Inspection shall be made for observations indicating a threat to avian wildlife including:

- presence of vegetation within the perimeter of the solar evaporator;
- standing water and the growth of insects;
- presence of birds or nests with eggs within the perimeter of the solar evaporator;
- an avian die-off or disabling event associated with the solar evaporator.

Solar Evaporator Closure Requirements:

How long can I continue to operate a solar evaporator?

The Notice of Authority to Operate must be renewed every five years. Renewal can be achieved as long as the solar evaporator continues to meet the State and Regional Board requirements. As long as the Notice of Authority is renewed and is in effect, closure is not required.

If closure is necessary or desired, what requirements have to be met?

Three options are available for closure: (1) harvest of salt followed by clean closure; (2) closure in place; (3) removal of salt and disposal in an authorized waste facility. The operator will select the closure option, and submit a plan to the regional board for approval.

- **Clean closure**: The salt from the solar evaporator may be harvested and utilized following the guidelines under salt management. After the removal of the salt, the solar evaporator and surrounding area need to be restored to a condition that does not threaten wildlife, does not threaten to pollute water, and does not cause a nuisance condition.
- **Closure in place:** A cover can be constructed over the solar evaporator retaining salt inplace and making use of the existing foundation.
- **Waste Facility Disposal:** Salt may be removed and disposed permanently in an authorized waste facility. After salt removal, the solar evaporator site is clean closed as above.

For complete requirements, see **CCR §22950**.

Senate Bill No. 1372

CHAPTER 597

An act to amend Section 25208.3 of, and to add Article 9.7 (commencing with Section 25209.10) to Chapter 6.5 of Division 20 of, the Health and Safety Code, relating to water.

[Approved by Governor September 15, 2002. Filed with Secretary of State September 16, 2002.]

LEGISLATIVE COUNSEL'S DIGEST

SB 1372, Machado. State Water Resources Control Board: agricultural drainage: solar evaporators.

(1) Under the Agricultural Water Conservation and Management Act, water suppliers, as defined, individually, or in cooperation with other public agencies or persons, may institute a water conservation or efficient water management program consisting of farm and agricultural related components. Existing law, the Toxic Pits Cleanup Act of 1984, prohibits a person from discharging liquid hazardous wastes into a surface impoundment if the surface impoundment, or the land immediately beneath the impoundment, contains hazardous wastes and is within $^{1}/_{2}$ mile upgradient from a potential source of drinking water.

This bill would require the State Water Resources Control Board to adopt, on or before April 1, 2003, emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators, as defined. The bill would require any person who intends to operate a solar evaporator to file a notice of intent with the regional water quality control board. The bill would specify a procedure for the issuance of a notice of authority by the regional board to operate a solar evaporator, including requiring the regional board to inspect the solar evaporator prior to authorizing the operation of the solar evaporator. The bill would prohibit a regional board from issuing a notice of authority to operate a solar evaporator on and after January 1, 2008.

The bill would require any person operating a solar evaporator to submit annually, according to a schedule established by the regional board, groundwater monitoring data and other information deemed necessary by the regional board. The bill would require the regional board to inspect any solar evaporator at least once every 5 years to ensure continued compliance with the provisions of the bill.

The bill would exempt any solar evaporator operating under a valid written notice of authority to operate issued by the regional board, including any facility that the regional board determines is in compliance with the requirements of the bill, from the provisions of the toxic pits act and other specified waste discharge requirements imposed under the Porter-Cologne Water Quality Control Act.

Because the provisions added by the bill would be located within the hazardous waste control laws and a violation of those laws is a crime, the bill would impose a state-mandated local program by creating new crimes regarding the operation of solar evaporators.

(2) Existing law, the toxic pits act, requires the state board to impose a fee upon any person discharging any liquid hazardous waste or hazardous waste containing free liquids into a surface impoundment. The state board is required to collect and deposit the fees in the Surface Impoundment Assessment Account in the General Fund. The money within that account is available, upon appropriation, to the state board and the regional boards for purposes of administering the toxic pits act.

This bill would additionally authorize the board to expend the fees deposited in the account for the purpose of administering the surface impoundments that would be exempted from the toxic pits act by the bill, thereby imposing a tax for purposes of Article XIII A of the California Constitution.

(3) The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement.

This bill would provide that no reimbursement is required by this act for a specified reason.

The people of the State of California do enact as follows:

SECTION 1. Section 25208.3 of the Health and Safety Code is amended to read:

25208.3. (a) The state board shall, by emergency regulation, adopt a fee schedule that assesses a fee upon any person discharging any liquid hazardous wastes or hazardous wastes containing free liquids into a surface impoundment, except as provided in Section 25208.17. The state board shall include in this fee schedule the fees charged for applications for, and renewals of, an exemption from Section 25208.5, as specified in subdivision (h) of Section 25208.5, from subdivision (a) of Section 25208.4, as specified in subdivision (b) of Section 25208.4, from subdivision (c) of Section 25208.4, as specified in Section 25208.16, and from Sections 25208.4 and 25208.5, as specified in subdivision (e) of Section 25208.13. The state board shall also include provisions in the fee schedule for assessing a penalty pursuant to subdivision (c). The state board shall set these fees at an amount equal to the state board's and regional board's reasonable and anticipated costs of administering this article.

(b) The emergency regulations that set the fee schedule shall be adopted by the state board in accordance with Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, and for the purposes of that chapter, including Section 11349.6 of the Government Code, the adoption of these regulations is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health and safety, and general welfare. Notwithstanding Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, any emergency regulations adopted by the state board pursuant to this section shall be filed with, but not be repealed by, the Office of Administrative Law and shall remain in effect until revised by the state board.

(c) The state board shall send a notice to each person subject to the fee specified in subdivision (a). If a person fails to pay the fee within 60 days after receipt of this notice, the state board shall require the person to pay an additional penalty fee. The state board shall set the penalty fee at not more than 100 percent of the assessed fee, but in an amount sufficient to deter future noncompliance, as based upon that person's past history of compliance and ability to pay, and upon additional expenses incurred by this noncompliance.

(d) The state board shall collect and deposit the fees collected pursuant to this article in the Surface Impoundment Assessment Account, which is hereby created in the General Fund. The money within the Surface Impoundment Assessment Account is available, upon appropriation by the Legislature, to the state board and the regional boards for purposes of administering this article and Article 9.7 (commencing with Section 25209.10).

SEC. 2. Article 9.7 (commencing with Section 25209.10) is added to Chapter 6.5 of Division 20 of the Health and Safety Code, to read:

Article 9.7. Integrated On-Farm Drainage Management

25209.10. The Legislature finds and declares all of the following:

(a) The long-term economic and environmental sustainability of agriculture is critical to the future of the state, and it is in the interest of the state to enact policies that enhance that sustainability.

(b) High levels of salt and selenium are present in many soils in the state as a result of both natural occurrences and irrigation practices that concentrate their presence in soils.

(c) The buildup of salt and selenium in agricultural soil is an unsustainable practice that degrades soil, harms an irreplaceable natural resource, reduces crop yields and farm income, and poses threats to wildlife.

(d) Salt and selenium buildup can degrade groundwater, especially in areas with perched groundwater aquifers.

(e) Off-farm drainage of irrigation water with high levels of salt and selenium degrades rivers and waterways, particularly the San Joaquin River and its tributaries. This environmental damage presents a clear and imminent danger that warrants immediate action to prevent or mitigate harm to public health and the environment.

(f) Discharge of agricultural drainage water to manmade drains and ponds has resulted in environmental damage, including damage to wildlife. Proposals to discharge agricultural drainage to natural water bodies, including the San Francisco Bay, are extremely expensive and pose threats to the environmental quality of those water bodies.

(g) Water supplies for agricultural irrigation have been reduced significantly in recent years, necessitating increased efforts to use water more efficiently.

(h) Although salt can be collected and managed as a commercial farm commodity, California currently imports salt from other countries.

(i) Integrated on-farm drainage management is a sustainable system of managing salt-laden farm drainage water. Integrated on-farm drainage management is designed to eliminate the need for off-farm drainage of irrigation water, prevent the on-farm movement of irrigation and drainage water to groundwater, restore and enhance the productive value of degraded farmland by removing salt and selenium from the soil, conserve water by reducing the demand for irrigation water, and create the potential to convert salt from a waste product and pollutant to a commercial farm commodity.

(j) Although integrated on-farm drainage management facilities are designed and operated expressly to prevent threats to groundwater and wildlife, these facilities currently may be classified as surface impoundments pursuant to the Toxic Pits Act of 1984, which discourages farmers from using them as an environmentally preferable means of managing agricultural drainage water.

(k) It is the policy of the state to conserve water and to minimize the environmental impacts of agricultural drainage. It is therefore in the interest of the state to encourage the voluntary implementation of sustainable farming and irrigation practices, including, but not limited to, integrated on-farm drainage management, as a means of improving environmental protection, conserving water, restoring degraded soils, and enhancing the economic productivity of farms.

25209.11. For purposes of this article, the following terms have the following meanings:

(a) "Agricultural drainage water" means surface drainage water or percolated irrigation water that is collected by subsurface drainage tiles placed beneath an agricultural field.

(b) "On-farm" means within the boundaries of a property, geographically contiguous properties, or a portion of the property or properties, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an integrated on-farm drainage management system and a solar evaporator.

(c) "Integrated on-farm drainage management system" means a facility for the on-farm management of agricultural drainage water that does all of the following:

(1) Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.

(2) Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural drainage water is substantially decreased and its salt content significantly increased.

(3) Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.

(4) Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated on-farm drainage management system and the solar evaporator.

(d) "Regional board" means a California regional water quality control board.

(e) "Solar evaporator" means an on-farm area of land and its associated equipment that meets all of the following conditions:

(1) It is designed and operated to manage agricultural drainage water discharged from the integrated on-farm drainage management system.

(2) The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the integrated on-farm drainage management system.

(3) Agricultural drainage water from the integrated on-farm drainage management system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.

(4) The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface tile drainage under the solar

evaporator provides adequate assurance that constituents in the agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(f) ‘‘State board’’ means the State Water Resources Control Board.

(g) ‘‘Water catchment basin’’ means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin.

25209.12. On or before April 1, 2003, the state board, in consultation, as necessary, with other appropriate state agencies, shall adopt emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators. The regulations shall include, but are not limited to, requirements to ensure all of the following:

(a) The operation of a solar evaporator does not result in any discharge of on-farm agricultural drainage water outside the boundaries of the area of land that makes up the solar evaporator.

(b) (1) The solar evaporator is designed, constructed, and operated so that, under reasonably forseeable operating conditions, the discharge of agricultural water to the solar evaporator does not result in standing water.

(2) Notwithstanding paragraph (1), a solar evaporator may be designed, constructed, and operated to accommodate standing water, if it includes a water catchment basin.

(3) The board may specify those conditions under which a solar evaporator is required to include a water catchment basin to prevent standing water that would otherwise occur within the solar evaporator.

(c) Avian wildlife is adequately protected. In adopting regulations pursuant to this subdivision, the state board shall do the following:

(1) Consider and, to the extent feasible, incorporate best management practices recommended or adopted by the United States Fish and Wildlife Service.

(2) Establish guidelines for the authorized inspection of a solar evaporator by the regional board pursuant to Section 25209.15. The guidelines shall include technical advice developed in consultation with the Department of Fish and Game and the United States Fish and Wildlife Service that may be used by regional board personnel to identify observed conditions relating to the operation of a solar evaporator that indicate an unreasonable threat to avian wildlife.

(d) Constituents in agricultural drainage water discharged to the solar evaporator will not migrate from the solar evaporator into the vadose zone or the waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(e) Adequate groundwater monitoring and recordkeeping is performed to ensure compliance with the requirements of this article.

(f) Salt isolated in a solar evaporator shall be managed in accordance with all applicable laws and shall eventually be harvested and sold for commercial purposes, used for beneficial purposes, or stored or disposed in a facility authorized to accept that waste pursuant to this chapter or Division 30 (commencing with Section 40000) of the Public Resources Code.

25209.13. (a) Any person who intends to operate a solar evaporator shall, before installing the solar evaporator, file a notice of intent with the regional board, using a form prepared by the regional board. The form shall require the person to provide information including, but not limited to, all of the following:

(1) The location of the solar evaporator.

(2) The design of the solar evaporator and the equipment that will be used to operate it.

(3) The maximum anticipated rate at which agricultural drainage water will be discharged to the solar evaporator.

(4) Plans for operating the solar evaporator in compliance with the requirements of this article.

(5) Groundwater monitoring data that are adequate to establish baseline data for use in comparing subsequent data submitted by the operator pursuant to this article.

(6) Weather data and a water balance analysis sufficient to assess the likelihood of standing water occurring within the solar evaporator.

(b) The regional board shall, within 30 calendar days after receiving the notice submitted pursuant to subdivision (a), review its contents, inspect, if necessary, the site where the proposed solar evaporator will be located, and notify the operator of the proposed solar evaporator whether it will comply with the requirements of this article. If the regional board determines that the proposed solar evaporator will not comply with this article, the regional board shall issue a written response to the applicant identifying the reasons for noncompliance. If the regional board determines the solar evaporator will comply with the requirements of this article, the regional board shall issue a written notice of plan compliance to the operator of the proposed solar evaporator.

(c) Any person who receives a written notice of plan compliance pursuant to subdivision (b) shall, before operating the installed solar evaporator, request the regional board to conduct a compliance inspection of the solar evaporator. Within 30 calendar days after receiving a request, the regional board shall inspect the solar evaporator and notify the operator whether it complies with the requirements of this article. If the regional board finds that the solar evaporator does not comply with the requirements of this article, the regional board shall issue a written response to the applicant identifying the reasons for noncompliance. Except as provided in subdivision (e), if the regional board determines that the solar evaporator complies with the requirements of this article, the regional board shall issue a written notice of authority to operate to the operator of the solar evaporator. The regional board may include in the authority to operate any associated condition that the regional board deems necessary to ensure compliance with the purposes and requirements of this article.

(d) No person may commence the operation of a solar evaporator unless the person receives a written notice of authority to operate the solar evaporator pursuant to this section.

(e) (1) On and after January 1, 2008, a regional board may not issue a written notice of authority to operate a solar evaporator pursuant to this section.

(2) The requirements of paragraph (1) do not affect the validity of any written notice of authority to operate a solar evaporator issued by the regional board before January 1, 2008.

(f) The regional board shall review any authority to operate issued by the regional board pursuant to this section every five years. The regional board shall renew the authority to operate, unless the regional board finds that the operator of the solar evaporator has not demonstrated compliance with the requirements of this article.

25209.14. (a) Any person operating a solar evaporator shall annually, according to a schedule established by the regional board pursuant to subdivision (b), submit groundwater monitoring data and any other information that is deemed necessary by the regional board to ensure compliance with the requirements of this article.

(b) Each regional board shall adopt a schedule for the submission of the data and information described in subdivision (a) at the earliest possible time. The regional board shall notify the operator of each solar evaporator of the applicable submission schedule.

25209.15. (a) The regional board, consistent with its existing statutory authority, shall inspect any solar evaporator that is authorized to operate pursuant to Section 25209.13 at least once every five years to ensure continued compliance with the requirements of this article. In conducting any inspection, the regional board may request the participation of a qualified state or federal avian biologist in a technical advisory capacity. The regional board shall include in the inspection report conducted pursuant to this section any evidence of adverse impacts on avian wildlife and shall forward the report to the appropriate state and federal agencies.

(b) If the regional board, as a result of an inspection or review conducted pursuant to this article, determines that a solar evaporator is not in compliance with the requirements of this article, the regional board shall provide written notice to the operator of the solar evaporator of that failure, and shall include in that written notice the reasons for that determination.

(c) Chapter 5 (commencing with Section 13300) of, and Chapter 5.8 (commencing with Section 13399) of, Division 7 of the Water Code apply to any failure to comply with the requirements of this article and to any action, or failure to act, by the state board or a regional board. The regional board may, consistent with Section 13223 of the Water Code, revoke or modify an authorization to operate issued pursuant to this article.

25209.16. (a) For the purposes of Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, including Section 11349.6 of the Government Code, the adoption of the regulations required to be adopted pursuant to Section 25209.12 is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health and safety, and general welfare.

(b) Notwithstanding Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, any emergency regulations adopted by the state board pursuant to Section 25209.12 shall be filed with, but not be repealed by, the Office of Administrative Law and shall remain in effect until revised by the state board.

25209.17. Any solar evaporator operating under a valid written notice of authority to operate issued by the regional board pursuant to this article, including any facility operating pursuant to Article 9.5 (commencing with Section 25208) prior to January 1, 2003, that the regional board determines is in compliance with the requirements of this article, is not subject to Article 9.5 (commencing with Section 25208) or Sections 13260 or 13263 of the Water Code. Upon determining pursuant to this section that a facility is a solar evaporator in compliance with this article, the regional board shall, as appropriate, revise or rescind any waste discharge requirements or other requirements imposed on the operator of the facility pursuant to Article 9.5 (commencing with Section 25208) or Section 13260 or 13263 of the Water Code.

SEC. 3. No reimbursement is required by this act pursuant to Section 6 of Article XIII B of the California Constitution because the only costs that may be incurred by a local agency or school district will be incurred because this act creates a new crime or infraction, eliminates a crime or infraction, or changes the penalty for a crime or infraction, within the meaning of Section 17556 of the Government Code, or changes the definition of a crime within the meaning of Section 6 of Article XIII B of the California Constitution.

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Chapter 9: Laws and Regulations

See Chapter 9 text and Appendix for contact information.

Appendix

Maas Hoffman Tables are from:
Agricultural Drainage, ASA Monograph 38. 1999. J. van Schilfgaarde and R.W. Skaggs (eds.) American Society of Agronomy. Madison, WI, pp. 71-81, 83-85, and 92-94.

Glossary

Amendment. See ***Soil amendment***; see ***Water amendment***

Anion. Negatively charged constituent or *ion* in the water. Chloride, sulfate, and bicarbonate are anions.

Application uniformity. See ***Distribution uniformity***.

Attainable leaching fraction. The smallest average leaching fraction required under a given set of conditions to satisfy crop needs and control salinity in the least-watered parts of the field.

Cation. Positively charged constituent or *ion* in the water. Sodium, calcium, magnesium, and potassium are cations.

Cation exchange capacity. Relative capacity of positively charged ions (cations) attached to clay particles in a given soil to be exchanged for other types of cations in the soil solution. Too much sodium on the clay particles relative to calcium and magnesium can cause the clay to swell, making the soil less permeable to water.

Chlorosis. Yellowing or bleaching of leaves, often induced by a nutrient deficiency, specific-ion toxicity, or disease.

Continuous ponding. The process of reclaiming saline soils by ponding water on the soil surface until enough salt has been removed from the crop root zone.

Crop water use. The amount of water used by a specific crop in a given period of time. *See also* ***Evapotranspiration***.

Deep percolation. The phenomenon of irrigation water flowing through the soil past the root zone where it is lost to crop production.

Distribution uniformity (DU). A measure of how uniformly water is applied over a field, calculated as the minimum depth of applied water, divided by the average depth of applied water, multiplied by 100.

Electrical conductivity. The extent to which water conducts electricity, which is proportional to the concentration of dissolved salts present and is therefore used as an estimate of the total dissolved salts in soil water. Electrical conductivity is expressed in millimhos per centimeter (mmhos/cm) or decisiemens per meter (dS/m):

EC_i, ECiw, or ECw = electrical conductivity of the irrigation water
ECsw = electrical conductivity of the soil water
ECe = electrical conductivity of the saturated soil extract

Evapotranspiration. The amount of water used by a specific crop in a given period of time, comprised of water evaporating from the soil and water transpiring from the plants. Crop evapotranspiration estimates are available from the California Department of Water Resources CIMIS program and from University of California Cooperative Extension offices as either historical averages or real-time estimates.

Exchangeable Sodium Percentage (ESP). The percentage of exchangeable sodium that occupies the total cation exchange capacity of the soil. ESP can be calculated from the following formula:

$$ESP = \frac{\text{Exchangeable (meq/100g)}}{\text{Cation exchange capacity (meq/100g)}} \times 100$$

Foliar absorption rate. Rate at which constituents in water are absorbed by plant leaves.

Glycophytes. A group of plants adversely affected by salinity. Most crop plants are glycophytes.

Halophytes. Plant group capable of tolerating relatively high levels of salinity.

Hydraulic conductivity. The ease with which water flows through the soil, determined by the physical properties and water content of the soil.

Infiltration rate. The rate at which water infiltrates the soil, usually expressed in inches or centimeters per hour.

Interceptor drain. Usually a single drain line installed perpendicular to the direction of groundwater flow, used to remove shallow groundwater flowing from upper-lying areas or to intercept seepage from waterways.

Intermittent ponding. A method of reclaiming saline soil by ponding small amounts of water on the soil surface in a wetting and drying cycle.

Ion. A positively or negatively charged constituent in water. Cations are positively charged ions and anions are negatively charged ions. Sodium, calcium, magnesium, and potassium are cations, and chloride, sulfate, and bicarbonate are anions.

Irrigation efficiency. A measure of the portion of total applied irrigation water beneficially used – as for crop water needs, frost protection, salt leaching, and chemical application – over the course of a season. Calculated as beneficially used water divided by total water applied, multiplied by 100.

Leaching. Applying irrigation water in excess of the soil moisture depletion level to remove salts from the root zone.

Leaching fraction. The fraction of infiltrated water applied beyond the soil moisture depletion level, which percolates below the root zone as excess water.

Leaching requirement. The leaching fraction needed to keep the root zone salinity level at or below the threshold tolerated by the crop. The leaching fraction is determined by the crop's tolerance to salinity and by the salinity of the irrigation water.

Necrosis. Plant condition indicated by the presence of dead tissue, often induced by an extreme nutrient deficiency, disease, or specific-ion toxicity.

Parallel drainage system. Drainage system consisting of buried perforated pipe placed at equal intervals throughout a field for draining away subsurface water caused by deep percolation through the overlying land. Also called a *relief drainage system.*

Piezometer. Device for monitoring groundwater depth and movement by measuring the hydraulic head at a point below the water table or water level.

Polymers. Soil amendments reputed by manufacturers to react with lime in the soil to supply free calcium.

Pre-irrigation reclamation method. A method of estimating the amount of irrigation water needed for leaching to reduce soil salinity to acceptable levels during preirrigations.

Relief drainage system. See ***Parallel drainage system.***

Saline/sodic soil. Soil affected by both excess salt and excess sodium.

Salinity. Soil condition in which the salt concentration in the crop root zone is too high for optimum plant growth and yield.

Sodicity. Condition in which the salt composition of the soil within the crop root zone is dominated by sodium, which affects soil structure and water infiltration.

Sodium adsorption ratio (SAR). Relationship between the concentration of sodium (Na) in the irrigation water relative to the concentrations of calcium (Ca) and magnesium (Mg), expressed in meq/l as follows:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Soil amendment. A substance added to the soil primarily to improve its physical condition.

Specific-ion toxicity. Injury to the plant caused by a specific constituent, usually chloride, boron, or sodium, that has accumulated in a particular part of the plant, such as leaves and stems.

Glossary

Total dissolved solids (TDS). A measure of the dissolved solids in soil water, expressed in either parts per million or milligrams per liter, used to estimate the relative salinity hazard of the water.

Uniformity. See ***Distribution uniformity***.

Water amendment. Chemicals added to water to improve soil-water properties, such as water infiltration.

This glossary is from Agricultural Salinity and Drainage, Water Management Series Publication Number 3375, 1999, Division of Agriculture and Natural Resources.

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Appendix

California Environmental Protection Agency

State Water Resources Control Board Water Quality Website

The California Environmental Protection Agency SWRCB Water Quality website www.swrcb.ca.gov/swamp/qapp.html outlines the sections and appendices of a Surface Water Ambient Monitoring Program (SWAMP) QAPP. The following table of contents is from the website:

Table of Contents

A helpful reference for QAPP development and preparation is DWR's "Guidelines for preparing a QAPP."

Table 1: Salt Tolerance of Herbaceous Crops[1]

Crop		Salt tolerance parameters				References
Common name	Botanical name[‡]	Tolerance based on:	Threshold[¶] (Ec_e)	Slope dS/m	Rating[#] % per dS/m	
Fiber, grain, and special crops						
Artichoke, Jerusalem	*Helianthus tuberosus* L.	Tuber yield	0.4	9.6	MS	Newton et al., 1991
Barley[††]	*Hordeum vulgare* L.	Grain yield	8.0	5.0	T	Ayers et al., 1952 Hassan et al., 1970a
Canola or rapeseed	*Brassica campestris* L. [syn. B. *rapa L.*]	Seed yield	9.7	14	T	Francois, 1994a
Canola or rapeseed	*B. napus* L.	Seed yield	11.0	13	T	Francois, 1994a
Chick pea	*Cicer arietinum* L.	Seed yield	—	—	MS	Manchanda & Sharma, 1989; Ram et al., 1989
Corn[§§]	*Zea mays* L.	Ear FW	1.7	12	MS	Bernstein & Ayers, 1949b (p. 41-42); Kaddah & Ghowail, 1964
Cotton	*Gossypium hirsutum* L.	Seed cotton yield	7.7	5.2	T	Bernstein, 1955 (p. 37-41), 1956 (p. 33-34); Berntein & Ford, 1959a (p. 34-35).
Crambe	*Crambe abyssinica*	Seed yield	2.0	6.5	MS	Francois & Kleiman, 1990 Hochst. Ex R. E. Fries
Flax	*Linium usitatissimum* L.	Seed yield	1.7	12	MS	Hayward & Spurr, 1944
Guar	*Cyamopsis tetragonoloba* (L.) Taub.	Seed yield	8.8	17	T	Francois et al., 1990
Kenaf	*Hibiscus cannabinus* L.	Stem DW	8.1	11.6	T	Francois et al., 1992
Millet, channel	*Echinochloa turnerana*	Grain yield	—	—	T	Shannon et al., 1981 (Domin) J.M. Black
Oat	*Avena sativa* L.	Grain yield	—	—	T	Mishra & Shitole, 1986; USSL[‡‡]
Peanut	*Arachis hypogaea* L.	Seed yield	3.2	29	MS	Shalhevet et al., 1969
Rice, paddy	*Oryza sativa* L.	Grain yield	3.0[¶¶]	12[¶¶]	S	Ehrler, 1960; Narale et al., 1969; Pearson, 1959; Venkateswarlu et al., 1972
Roselle	*Hibiscus sabdariffa* L.	Stem DW	—	—	MT	El-Saidi & Hawash, 1971
Rye	*Secale cereale* L.	Grain yield	11.4	10.8	T	Francois et al., 1989
Safflower	*Carthamus tinctorius* L.	Seed yield	—	—	MT	Francois & Bernstein, 1964b
Sesame[##]	*Sesamum indicum* L.	Pod DW	—	—	S	Yousif et al., 1972
Sorghum	*Sorghum bicolor* (L.)	Grain yield	6.8	16	MT	Francois et al., 1984 , Moench
Soybean	*Glycine max* (L.) Merrill	Seed yield	5.0	20	MT	Abel & McKenzie, 1964; Bernstein et al., 1955b (p. 35-36); Bernstein & Ogata, 1966
Sugarbeet[†††]	*Beta vulgaris* L.	Storage root	7.0	5.9	T	Bower et al., 1954
Sugarcane	*Saccharum officinarum* L.	Shoot DW	1.7	5.9	MS	Bernstein et al., 1966; Dev & Bajwa, 1972; Syed & El-Swaify, 1972
Sunflower	*Helianthus annuus* L.	Seed yield	4.8	5.0	MT	Cheng, 1983; Francois, 1996
Triticale	*X Triticosecale* Wittmack	Grain yield	6.1	2.5	T	Francois et al., 1988
Wheat	*Triticum aestivum* L.	Grain yield	6.0	7.1	MT	Asana & Kale, 1965; Ayers et al., 1952; Hayward & Uhvits, 1944 (p. 41-43)
Wheat (semidwarf)[‡‡‡]	*T. Aestivum* L	Grain yield	8.6	3.0	T	Francois et al., 1986
Wheat, Durum	*T. Turgidum* L. var. *durum* Desf.	Grain yield	5.9	3.8	T	Francois et al., 1986

Table 1: Salt Tolerance of Herbaceous Crops[1] (continued)

Crop		Salt tolerance parameters				References
Common name	Botanical name[‡]	Tolerance based on:	Threshold[¶] (Ec_e)	Slope dS/m	Rating[#] % per dS/m	
Grasses and forage crops						
Alfalfa	*Medicago sativa* L.	Shoot DW	2.0	7.3	MS	Bernstein & Francois, 1973a; Bernstein & Ogata, 1966; Bower et al., 1969; Brown & Hayward, 1956; Gauch & Magistad, 1943; Hoffman et al., 1975
Alkaligrass, Nuttall	*Puccinellia airoideS*	Shoot DW	—	—	T*	USSL staff, 1954 (Nutt.) Wats. & Coult.
Alkali sacaton	*Sporobolus airoides* Torr.	Shoot DW	—	—	T*	USSL staff, 1954
Barley (forage)[††]	*Hordeum vulgare* L.	Shoot DW	6.0	7.1	MT	Dregne, 1962; Hassan et al., 1970a
Bentgrass, creeping	*Agrostis stolonifera* L.	Shoot DW	—	—	MS	Younger et al., 1967
Bermudagrass[§§§]	*Cynodon dactylon* L. Pers.	Shoot DW	6.9	6.4	T	Bernstein & Ford, 1959b (p. 39-44); Bernstein & Francois, 1962 (p. 37- 38); Langdale & Thomas, 1971
Bluestem, Angleton	*Dichanthium aristatum* (Poir.) C.E. Hubb. [syn. *Andropogon nodosus* (Willem.) Nash]	Shoot DW	—	—	MS*	Gausman et al., 1954
Broadbean	*Vicia faba* L.	Shoot DW	1.6	9.6	MS	Ayers & Eberhard, 1960
Brome, mountain	*Bromus marginatus* Nees ex Steud.	Shoot DW	—	—	MT*	USSL staff, 1954
Brome, smooth	*B. inermis* Leyss	Shoot DW	—	—	MT	McElgunn & Lawrence, 1973
Buffellgrass	*Pennisetum ciliare* (L.) Link. [syn. *Cenchrus ciliaris*]	Shoot DW	—	—	MS*	Gausman et al., 1954
Burnet	*Poterium sanguisorba* L.	Shoot DW	—	—	MS*	USSL staff, 1954
Canarygrass, reed	*Phalaris arundinacea* L	Shoot DW	—	—	MT	McElgunn & Lawrence 1973
Clover, alsike	*Trifolium hybridium* L.	Shoot DW	1.5	12	MS	Ayers, 1948a
Clover, Berseem	*T. alexandrinum* L.	Shoot DW	1.5	5.7	MS	Asghar et al., 1962; Ayers & Eberhard, 1958 (p. 36-37); Ravikovitch & Porath, 1967; Ravikovitch & Yoles, 1971
Clover, Hubam	*Melilotus alba* Dest. var. *annua* H. S. Coe	Shoot DW	—	—	MT*	USSL staff, 1954
Clover, ladino	*Trifolium repens* L	Shoot DW	1.5	12	MS	Ayers, 1948a; Gauch & Magistad, 1943
Clover, Persian	*T. resupinatum* L	Shoot DW	—	—	MS*	de Forges, 1970
Clover, red	*T. pratense* L.	Shoot DW	1.5	12	MS	Ayers, 1948a; Saini, 1972
Clover, strawberry	*T. fragiferum* L.	Shoot DW	1.5	12	MS	Ayers, 1948a; Bernstein & Ford, 1959b (p. 39-44); Gauch & Magistad, 1943
Clover, sweet	*Melilotus sp.* Mill.	Shoot DW	—	—	MT*	USSL staff, 1954
Clover, white Dutch	*Trifolium repens* L	Shoot DW	—	—	MS*	USSL staff, 1954
Corn (forage)[§§]	*Zea mays* L.	Shoot DW	1.8	7.4	MS	Hassan et al., 1970b; Ravikovitch, 1973; Ravikovitch & Porath, 1967
Cowpea (forage)	*Vigna unguiculata* (L.) Walp.	Shoot DW	2.5	11	MS	West & Francois, 1982
Dallisgrass	*Paspalum dilatatum* Poir.	Shoot DW	—	—	MS*	Russell, 1976
Dhaincha	*Sesbania bispinosa* (Linn.) W.F. Wright [syn.	Shoot DW	—	—	MT	Girdhar, 1987; Karadge

Table 1: Salt Tolerance of Herbaceous Crops[1] (continued)

Crop		Salt tolerance parameters				References
Common name	Botanical name[‡]	Tolerance based on:	Threshold[¶] (Ec_e)	Slope dS/m	Rating[#] % per dS/m	
Grasses and forage crops (con't)						
Fescue, tall	*Festuca elatior* L.	Shoot DW	3.9	5.3	MT	Bower et al., 1970; Brown & Bernstein, 1953 (p. 44-46)
Fescue, meadow	*Festuca pratensis* Huds.	Shoot DW	—	—	MT*	USSL staff, 1954
Foxtail, meadow	*Alopecurus pratensis* L.	Shoot DW	1.5	9.6	MS	Brown and Bernstein, 1953 (p. 44-46)
Glycine	*Neonotonia wightii* [syn. *Glycine wightii* or *javanica*	Shoot DW	—	—	MS	Russell, 1976; Wilson, 1985
Gram, black or Urd bean	*Vigna mungo* (L.) Hepper [syn. *Phaseolus mungo* L.]	Shoot DW	—	—	S	Keating & Fisher, 1985
Grama, blue	*Bouteloua gracilis* (HBK) Lag. Ex Steud.	Shoot DW	—	—	MS*	USSL staff, 1954
Guinea grass	*Panicum maximum* Jacq.	Shoot DW	—	—	MT	Russell, 1976
Hardinggrass	*Phalaris tuberosa* L. var. *stenoptera* (Hack) A.S.	Shoot DW	4.6	7.6	MT	Brown & Bernstein, 1953 (p. 44-46) Hitchc.
Kallargrass	*Leptochloa fusca* (L. Kunth [syn. *Diplachne fusca* Beauv.]	Shoot DW	—	—	T	Sandhu et al., 1981
Lablab bean	*Lablab purpureus* (L.) Sweet [syn. *Dolichos lablab* L.]	Shoot DW	—	—	MS	Russell, 1976
Lovegrass[¶¶¶]	*Eragrostis sp*. N. M. Wolf	Shoot DW	2.0	8.4	MS	Bernstein & Ford, 1959b (p. 39-44)
Milkvetch, Cicer	*Astragalus cicer* L.	Shoot DW	—	—	MS*	USSL staff, 1954
Millet, Foxtail	*Setaria italica* (L.) Beauvois	Dry Matter	—	—	MS	Ravikovitch & Porath, 1967
Oatgrass, tall	*Arrhenatherum elatius* (L.) Beauvois ex J. Presl & K. Presl	Shoot DW	—	—	MS*	USSL staff, 1954
Oat (forage)	*Avena sativa* L.	Straw DW	—	—	T	Mishra & Shitole, 1986; USSL[‡‡]
Orchardgrass	*Dactylis glomerata* L.	Shoot DW	1.5	6.2	MS	Brown & Bernstein, 1953 (p. 44-46); Wadleigh et al., 1951
Panicgrass, blue	*Panicum antidotale* Retz.	Shoot DW	—	—	MS*	Abd El-Rahman et al., 1972; Gausman et al., 1954
Pigeon pea	*Cajanus cajus* (L.) Huth [syn. *C. indicus* (K.) Spreng.]	Shoot DW	—	—	S	Subbaro et al., 1991; Keating & Fisher, 1985
Rape (forage)	*Brassica napus* L.		—	—	MT*	USSL staff, 1954
Rescuegrass	*Bromus unioloides* HBK	Shoot DW	—	—	MT*	USSL staff, 1954
Rhodesgrass	*Chloris Gayana* Kunth.	Shoot DW	—	—	MT	Abd El-Rahman et al., 1972; Gausman et al., 1954
Rye (forage)	*Secale cereale* L.	Shoot DW	7.6	4.9	T	Francois et al., 1989
Ryegrass, Italian	*Lolium multiforum* Lam.	Shoot DW	—	—	MT*	Shimose, 1973
Ryegrass, perennial	*Lolium perenne* L.	Shoot DW	5.6	7.6	MT	Brown & Bernstein, 1953 (p. 44-46)
Ryegrass, Wimmera	*L. Rigidum* Gaud.		—	—	MT*	Malcolm & Smith, 1971
Saltgrass, desert	*Distichlis spicta* L. var. *stricta* (Torr.) Bettle	Shoot DW	—	—	T*	USSL staff, 1954
Sesbania	*Sesbania exaltata* (Raf. V.L. Cory	Shoot DW	2.3	7.0	MS	Bernstein, 1956 (p. 33-34)
Sirato	*Macroptilium atropurpureum* (D.C.) Urb.	Shoot DW	—	—	MS	Russell, 1976

Table 1: Salt Tolerance of Herbaceous Crops[1] (continued)

Crop		Salt tolerance parameters				References
Common name	**Botanical name**‡	**Tolerance based on:**	**Threshold**¶ **(Ec_e)**	**Slope dS/m**	**Rating**# **% per dS/m**	
Grasses and forage crops (con't)						
Sphaerophysa	*Sphaerophysa salsula* (Pall.) DC	Shoot DW	2.2	7.0	MS	Francois & Bernstein, 1964a (p. 52-53)
Sudangrass	*Sorghum sudanense* (Piper) Stapf	Shoot DW	2.8	4.3	MT	Bower et al., 1970
Timothy	*Phleum pratense* L.	Shoot DW	—	—	MS*	Saini, 1972
Trefoil, big	*Lotus pedunculatus* Cav.	Shoot DW	2.3	19	MS	Ayers, 1948a,b (p. 23-25)
Trefoil, narrowleaf birdsfoot	*L. corniculatus* var *tenuifolium* L.	Shoot DW	5.0	10	MT	Ayers, 1948a, b (p. 23-25)
Trefoil, broadleaf birdsfoot	*L. corniculatus* L. var *arvenis* (Schkuhr) Ser. ex DC	Shoot DW	—	—	MS	Ayers, 1950b (p. 44-45)
Vetch, common	*Vicia angustifolia* L.	Shoot DW	3.0	11	MS	Ravikovitch & Porath, 1967
Wheat (forage)‡‡‡	*Triticum aestivum* L.	Shoot DW	4.5	2.6	MT	Francois et al., 1986
Wheat, Durum (forage)	*T. turgidum* L. var. durum Desf.	Shoot DW	2.1	2.5	MT	Francois et al., 1986
Wheatgrass, standard crested	*Agropyron sibiricum*	Shoot DW	3.5	4.0	MT	Bernstein & Ford, 1958 (p. 32-36)
Wheatgrass, fairway crested	*A. cristatum* (L.) Gaertn. (Willd.) Beauvois	Shoot DW	7.5	6.9	T	Bernstein & Ford, 1958 (p. 32-36)
Wheatgrass, intermediate	*A. intermedium* (Host)	Shoot DW	—	—	MT*	Dewey, 1960 Beauvois
Wheatgrass, slender	*A. trachycaulum* (Link) Malte	Shoot DW	—	—	MT	McElgunn & Lawrence, 1973
Wheatgrass, tall	*A. elongatum* (Hort) Beauvois	Shoot DW	7.5	4.2	T	Bernstein & Ford, 1958 (p. 32-36)
Wheatgrass, western	*A. Smithii* Rydb.	Shoot DW	—	—	MT*	USSL staff, 1954
Wildrye, Altai	*Elymus angustus* Trin.	Shoot DW	—	—	T	McElgunn & Lawrence, 1973
Wildrye, beardless	*E. triticoides* Buckl.	Shoot DW	2.7	6.0	MT	Brown & Bernstein, 1953
Wildrye, Canadian	*E. canadensis* L.	Shoot DW	—	—	MT*	USSL staff, 1954
Wildrye, Russian	*E. junceus* Fisch.	Shoot DW	—	—	T	McElgunn & Lawrence, 1973

Table 1: Salt Tolerance of Herbaceous Crops[1] (continued)

Crop		Salt tolerance parameters				References
Common name	Botanical name‡	Tolerance based on:	Threshold¶ (Ec_e)	Slope dS/m	Rating# % per dS/m	
Vegetables and fruit crops						
Artichoke	*Cynara scolymus* L.	Bud yield	6.1	11.5	MT	Francois, 1995
Asparagus	*Asparagus officinalis* L.	Spear yield	4.1	2.0	T	Francois, 1987
Bean, common	*Phaseolus vulgaris* L.	Seed yield	1.0	19	S	Bernstein & Ayers, 1951; Hoffman & Rawlins, 1970; Magistad et al., 1943; Nieman &, 1959; Osawa, 1965
Bean, lima	*P. lunatus* L.	Seed yield	—	—	MT*	Mahmoud et al., 1988
Bean, mung	*Vigna radiate* (L.) R. Wilcz.	Seed yield	1.8	20.7	S	Minhas et al., 1990
Cassava	*Manihot esculenta* Crantz	Tuber yield	—	—	MS	Anonymous, 1976;Hawker & Smith, 1982
Beet, red†††	*Beta vulgaris* L.	Storage root	4.0	9.0	MT	Bernstein et al., 1974; Hoffman & Rawlins, 1971; Magistad et al., 1943
Broccoli	*Brassica oleracea* L. (Botrytis group)	Shoot FW	2.8	9.2	MS	Bernstein & Ayers, 1949a (p. 39); Bernstein et al., 1974
Brussel Sprout	*B. oleracea* L. (Gemmifera Group)		—	—	MS*	
Cabbage	*B. oleracea* L. (Capitata Group)	Head FW	1.8	9.7	MS	Bernstein & Ayers, 1949a (p. 39); Bernstein et al., 1974; Osawa, 1965
Carrot	*Daucus carota* L.	Storage root	1.0	14	S	Bernstein & Ayers, 1953a; Bernstein et al., 1974; Lagerwerff & Holland, 1960; Magistad et al., 1943; Osawa, 1965
Cauliflower	*Brassica oleracea* L. (Botrytis Group)		—	—	MS*	
Celery	*Apium graveolens* L. var Dulce (Mill.) Pers.	Petiole FW	1.8	6.2	MS	Francois & West, 1982
Corn, sweet	*Zea mays* L.	Ear FW	1.7	12	MS	Bernstein & Ayers, 1949b (p. 41-42)
Cowpea	*Vigna unguiculata* (L.) Walp.	Seed yield	4.9	12	MT	West & Francois, 1982
Cucumber	*Cucumis sativus* L	Fruit yield	2.5	13	MS	Osawa, 1965; Ploegman & Bierhuizen, 1970
Eggplant	*Solanum melongena* L. var *esculentum* Nees.	Fruit yield	1.1	6.9	MS	Heuer et al., 1986
Garlic	*Allium sativum* L.	Bulb yield	3.9	14.3	MS	Francois, 1994b
Gram, black Or Urd bean	*Vigna mungo* (L.) Hepper [syn. *Phaseolus mungo* L.]	Shoot DW	—	—	S	Keating & Fisher, 1985
Kale	*Brassica oleracea* L. (Acephala Group)		—	—	MS*	Malcolm & Smith, 1971
Kohlrabi	*Brassica oleracea* L (Gongylodes Group)		—	—	MS*	
Lettuce	*Lactuca sativa* L.	Top FW	1.3	13	MS	Ayers et al., 1951; Bernstein et al., 1974; Osawa, 1965
Muskmelon	*Cucumis melo* L. (Reticulatus Group)	Fruit Yield	1.0	8.4	MS	Mangal et al., 1988 Shannon & Francois, 1978
Okra	*Abelmoschus esculentus* (L.) Moench	Pod yield	—	—	MS	Masih et al., 1978; Paliwal & Maliwal, 1972
Onion (bulb)	*Allium cepa* L.	Bulb yield	1.2	16	S	Bernstein & Ayers, 1953b; Bernstein et al., 1974; Hoffman & Rawlins, 1971; Osawa, 1965

Table 1: Salt Tolerance of Herbaceous Crops[1] (continued)

Crop		Salt tolerance parameters				
Common name	**Botanical name**[‡]	**Tolerance based on:**	**Threshold**[¶] **(Ec_e)**	**Slope dS/m**	**Rating**[#] **% per dS/m**	**References**
Vegetables and fruit crops						
Onion (seed)	*Allium cepa* L	Seed yield	1.0	8.0	MS	Mangal et al., 1989
Parsnip	*Pastinaca sativa* L.		—	—	S*	Malcolm & Smith, 1971
Pea	*Pisium sativum* L.	Seed FW	3.4	10.6	MS	Cerda et al., 1982
Pepper	*Capsicum annuum* L.	Fruit yield	1.5	14	MS	Bernstein, 1954 (p. 36-37); Osawa, 1965, USSL[‡‡]
Pigeon pea	*Cajanus cajan* (L.) Huth [syn. *C. indicus* (K.) Spreng.]	Shoot DW	—	—	S	Keating & Fisher, 1985; Subbarao et al., 1991
Potato	*Solanum tuberosum* L.	Tuber yield	1.7	12	MS	Bernstein et al., 1951
Pumpkin	*Cucurbita pepo* L var. *Pepo*		—	—	MS*	
Purslane	*Portulaca oleracea* L.	Shoot FW	6.3	9.6	MT	Kumamoto et al., 1992
Radish	*Raphanus sativus* L.	Storage root	1.2	13	MS	Hoffman & Rawlins, 1971; Osawa, 1965
Spinach	*Spinacia oleracea* L.	Top FW	2.0	7.6	MS	Langdale et al., 1971; Osawa, 1965
Squash, scallop	*Cucurbita pepo* L. var *melopepo* L. Alef.	Fruit yield	3.2	16	MS	Francois, 1985
Squash, zucchini	*C. pepo* L. var *melopepo* (L.) Alef.	Fruit yield	4.9	10.5	MT	Francois, 1985; Graifenberg et al., 1996
Strawberry	*Fragaria x ananassa* Duch.	Fruit yield	1.0	33	S	Ehlig & Bernstein, 1958; Osawa, 1965
Sweet potato	*Ipomoea batatas* (L.) Lam.	Fleshy root	1.5	11	MS	Greig & Smith, 1962; USSL[‡‡]
Tepary bean	*Phaseolus acutifolius* Gray		—	—	MS*	Goertz & Coons, 1991; Hendry, 1918; Perez & Minguez, 1985
Tomato	*Lycopersicon lycopersicum* (L.) Karst. Ex Farw. [syn. *Lycopersicon esculentum* Mill.]]	Fruit yield	2.5	9.9	MS	Bierhuizen & Ploegman, 1967; Hayward & Long, 1943; Lyon, 1941; Shalhevet & Yaron, 1973
Tomato, cherry	*L. lycopersicum* var. *Cerasiforme* (Dunal) Alef.	Fruit yield	1.7	9.1	MS	Caro et al., 1991
Turnip	*Brassica rapa* L. (Rapifera Group)	Storage root	0.9	9.0	MS	Francois, 1984a
Turnip (greens)		Top FW	3.3	4.3	MT	Francois, 1984a
Watermelon	*Citrullus lanatus* (Thunb. Matsum. & Nakai	Fruit yield	—	—	MS*	de Forges, 1970
Winged bean	*Psophocarpus tetragonolobus* L. DC	Shoot DW	—	—	MT	Weil & Khalil, 1986

[†] These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices.
[‡] Botanical and common names follow the convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) where possible.
[§] FW = fresh weight, DW = dry weight.
[¶] In gypsiferous soils, plants will tolerate EC_e's about 2dS/m higher than indicated.
[#] Ratings are defined by the boundaries in Fig. 3-3. (Ratings with an * are estimates.)
[††] Less tolerant during seedling stage, EC_e at this stage should not exceed 4 or 5 dS/m.
[‡‡] Unpublished U.S. Salinity Laboratory data.
[§§] Grain and forage yields of DeKalb XL-75 grown on an organic muck soil decreased about 26% per deciSiemen/meter above athreshold of 1.9 dS/m (Hoffman et al., 1983).
[¶¶] Because paddy rice is grown under flooded conditions, values refer to the electrical conductivity of the soil water while the pants are submerged. Less tolerant during seedling stage.
[##] Sesame cultivars, Sesaco 7 and 8, may be more salt tolerant than indicated by the S rating.
[†††] Sensitive during germination and emergence, EC_e should not exceed 3 dS/m.
[‡‡‡] Data from one cultivar, Probred.
[§§§] Average of several varities. Suwannee and Coastal are about 20% more tolerant, and common and Greenfield are about 20% less tolerant than the average.
[¶¶¶] Average for Boer, Wilman, Sand, and Weeping cultivars (Lehman seems about 50% more tolerant).

Table 2: Salt Tolerance of Woody Crops†

Crop		Salt tolerance parameters				References
Common name	Botanical name‡	Tolerance based on:	Threshold¶ (Ec_e)	Slope dS/m	Rating# % per dS/m	
Almond	*Prunus duclis* (Mill.) D.A. Webb	Shoot growth	1.5	19	S	Bernstein et al., 1956; Brown et al., 1953
Apple	*Malus sylvestris* Mill.		—	—	S	Ivanov, 1970
Apricot	*Prunus armeniaca* L.	Shoot growth	1.6	24	S	Bernstein et al., 1956
Avocado	*Persea americana* Mill.	Shoot growth	—	—	S	Ayers, 1950a; Haas, 1950
Banana	*Musa acuminata* Colla	Fruit yield	—	—	S	Israeli et al., 1986
Blackberry	*Rubus macropetalus* Doug. ex Hook	Fruit yield	1.5	22	S	Ehlig, 1964
Boysenberry	*Rubrus ursinus* Cham. and Schlechtend	Fruit yield	1.5	22	S	Ehlig, 1964
Castorbean	*Ricinus communis* L.		—	—	MS*	USSL staff, 1954
Cherimoya	*Annona cherimola* Mill.	Foliar injury	—	—	S	Cooper et al., 1952
Cherry, sweet	*Prunus avium* L.	Foliar injury	—	—	S*	Beeftink, 1955
Cherry, sand	*Prunus besseyi* L., H. Baley	Foliar injury, stem growth	—	—	S*	Zhemchuzhnikov, 1946
Coconut	*Cocos nucifera* L.		—	—	MT*	Kulkarni et al., 1973
Currant	*Ribes sp.* L	Foliar injury, stem growth	—	—	S*	Beeftink, 1955; Zhemchuzhnikov, 1946
Date palm	*Phoenix dactylifera* L.	Fruit yield	4.0	3.6	T	Furr & Armstrong, 1962; (p. 11-13); Furr & Ream, 1968; Furr et al., 1966
Fig	*Ficus carica* L.	Plant DW	—	—	MT*	Patil & Patil, 1983a; USSL staff, 1954
Gooseberry	*Ribes sp.* L.		—	—	S*	Beeftink, 1955
Grape	*Vitis vinifera* L.	Shoot growth	1.5	9.6	MS	Groot Obbink & Alexander, 1973; Nauriyal & Gupta, 1967; Taha et al., 1972
Grapefruit	*Citrus x paradisi* Macfady.	Fruit yield	1.2	13.5	S	Bielorai et al., 1978
Guava	*Psidium guajava* L.	Shoot and root growth	4.7	9.8	MT	Patil et al., 1984
Guayule	*Parthenium argentatum* A. Gray	Shoot DW rubber yield	8.7 7.8	11.6 10.8	T T	Maas et al., 1988
Jambolan plum	*Syzgium cumini* L.	Shoot growth	—	—	MT	Patil & Patil, 1983b
Jojoba	*Simmondsia chinensis* (Link) C.K. Schneid	Shoot growth	—	—	T	Tal et al., 1979; Yermanos et al., 1967
Jujube, Indian	*Ziziphus mauritiana* Lam.	Fruit yield	—	—	MT	Hooda et al., 1990
Lemon	*Citrus limon* (L.) Burm. F.	Fruit yield	1.5	12.8	S	Cerda et al., 1990
Lime	*Citrus aurantiifolia* (Christm.) Swingle		—	—	S*	
Loquat	*Eriobotrya japonica* (Thunb.) Lindl.	Foliar injury	—	—	S*	Cooper & Link, 1953; Malcolm & Smith, 1971
Macadamia	*Macadamia integrifolia* Maiden & Betche	Seedling growth	—	—	MS*	Hue & McCall, 1989
Mandarin orange; tangerine	*Citrus reticulata* Blanco	Shoot growth	—	—	S*	Minessy et al., 1974
Mango	*Mangifera indica* L.	Foliar injur	—	—	S	Cooper et al., 1952

Table 2: Salt Tolerance of Woody Crops[†] (continued)

Crop		Salt tolerance parameters				References
Common name	Botanical name[‡]	Tolerance based on:	Threshold[¶] (Ec_e)	Slope dS/m	Rating[#] % per dS/m	
Natal plum	*Carissa grandiflora* (E.H. Mey.) A. DC.	Shoot growth	—	—	T	Bernstein et al., 1972
Olive	*Olea europaea* L. fruit yield	Seedling growth,	—	—	MT	Bidner-Barhava & Ramati, 1967; Taha et al., 1972
Orange	*Citrus sinensis* (L.) Osbeck	Fruit yield	1.3	13.1	S	Bielorai et al., 1988; Bingham et al., 1974; Dasberg et al., 1991; Harding et al., 1958
Papaya	*Carica papaya* L.	Seedling growth, foliar injury	—	—	MS	Kottenmeier et al., 1983; Makhija & Jindal, 1983
Passion fruit	*Passiflora edulis* Sims.		—	—	S*	Malcolm & Smith, 1971
Peach	*Prunus persica* (L.) Batsch	Shoot growth, fruit yield	1.7	21	S	Bernstein et al., 1956 Brown et al., 1953; Hayward et al., 1946
Pear	*Pyrus communis* L.		—	—	S*	USSL staff, 1954
Pecan	*Carya illinoinensis* (Wangeth) C. Koch	Nut yield trunk growth	—	—	MS	Miyamoto et al., 1986
Persimmon	*Diospyros virginiana* L.		—	—	S*	Malcolm & Smith, 1971
Pineapple	*Ananas comosus* (L.) Merrill	Shoot DW	—	—	MT	Wambiji & El-Swaify, 1974
Pistachio	*Pistachia vera* L.	Shoot growth	—	—	MS	Sepaskhah & Maftoun, 1988; Picchioni et al., 1990
Plum; prune	*Prunus domestica* L.	Fruit yield	2.6	31	MS	Hoffman et al., 1989
Pomegranate	*Punica granatum* L.	Shoot growth	—	—	MS	Patil & Patil, 1982
Popinac, white	*Leucaena leucocephala* (Lam.) De Wit [syn. *Leucaena glauca* Benth.]	Shoot DW	—	—	MS	Gorham et al., 1988; Hansen & Munns, 1988
Pummelo	*Citrus maxima* (Burm.)	Foliar injury	—	—	S*	Furr & Ream, 1969
Raspberry	*Rubus idaeus* L.	Fruit yield	—	—	S	Ehlig, 1964
Rose apple	*Syzgium jambos* (L.) Alston	Foliar injur	—	—	S*	Cooper & Gorton, 1951 (p. 32-38)
Sapote, white	*Casimiroa edulis* Llave	Foliar injur	—	—	S*	Cooper et al., 1952
Scarlet wisteria	*Sesbania grandiflora*	Shoot DW	—	—	MT	Chavan & Karadge, 1986
Tamarugo	*Prosopis tamarugo* Phil.	Observation	—	—	T	Natl. Acad. Sci., 1975
Walnut	*Juglans* spp.	Foliar injury	—	—	S*	Beeftink, 1955

[†] These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices. The data are applicable when rootstocks are used that do not accumulate Na^+ or Cl^- rapidly or when these ions do not predominate in the soil.
[‡] Botanical and common names follow the convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) where possible.
[§] In gypsiferous soils, plants will tolerate EC_e's about 2 dS/m higher than indicated.
[¶] Ratings are defined by the boundaries in Fig. 3-3. Ratings with an * are estimates.

Table 3: Boron tolerance limits for agricultural crops.

Crop		Boron tolerance parameters				References
Common name	Botanical name	Tolerance† based on:	Threshold‡ g m-3	Slope % per g m-3	Rating§	
Alfalfa	*Medicago sativa* L.	Shoot DW	4.0-6.0		T	Eaton, 1944
Apricot	*Prunus armeniaca* L.	Leaf & stem injury	0.5-0.75		S	Woodbridge, 1955
Artichoke, globe	*Cynara scolymus* L.	Laminae DW	2.0-4.0		MT	Eaton, 1944
Artichoke, Jerusalem	*Helianthus tuberosus* L.	Whole plant DW	0.75-1.0		S	Eaton, 1944
Asparagus	*Asparagus officinalis* L.	Shoot DW	10.0-15.0		VT	Eaton, 1944
Avocado	*Persea americana* Mill.	Foliar injury	0.5-0.75		S	Haas, 1929
Barley	*Hordeum vulgare* L.	Grain yield	3.4	4.4	MT	Bingham et al., 1985
Bean, kidney	*Phaseolus vulgaris* L.	Whole plant DW	0.75-1.0		S	Eaton, 1944
Bean, lima	*Phaseolus lunatus* L.	Whole plant DW	0.75-1.0		S	Eaton, 1944
Bean, mung	*Vigna radiata* L. R. Wilcz.	Shoot length	0.75-1.0		S	Khundairi, 1961
Bean, snap	*Phaseolus vulgaris* L.	Pod yield	1.0	12	S	Francois, 1989
Beet, red	*Beta vulgaris* L.	Root DW	4.0-6.0		T	Eaton, 1944
Blackberry	*Rubus sp*. L	Whole plant DW	<0.5		VS	Eaton, 1944
Bluegrass, Kentucky	*Poa pratensis* L.	Leaf DW	2.0-4.0		MT	Eaton, 1944
Broccoli	*Brassica oleracea* L. (Botrytis group)	Head FW	1.0	1.8	MS	Francois, 1986
Cabbage	*Brassica oleracea* L. (Capitata group)	Whole plant DW	2.0-4.0		MT	Eaton, 1944
Carrot	*Daucus carota* L.	Root DW	1.0-2.0		MS	Eaton, 1944
Cauliflower	*Brassica oleracea* L. (Botrytis group)	Curd FW	4.0	1.9	MT	Francois, 1986
Celery	*Apium graveolens* L. var. dulce (Mill.) Pers.	Petiole FW	9.8	3.2	VT	Francios, 1988
Cherry	*Prunus avium* L.	Whole plant DW	0.5-0.75		S	Eaton, 1944
Clover, sweet	*Melilotus indica* All.	Whole plant DW	2.0-4.0		MT	Eaton, 1944
Corn	*Zea mays* L.	Shoot DW	2.0-4.0		MT	El-Sheikh et al., 1971
Cotton	*Gossypium hirsutum* L.	Boll DW	6.0-10.0		VT	Eaton, 1944
Cowpea	*Vigna unguiculata* (L.) Walp.	Seed yield	2.5	12	MT	Francois, 1989
Cucumber	*Cucumis sativus* L.	Shoot DW	1.0-2.0		MS	El-Sheikh et al., 1971
Fig, kadota	*Ficus carica* L.	Whole plant DW	0.5-0.75		S	Eaton, 1944
Garlic	*Allium sativum* L.	Bulb yield	4.3	2.7	T	Francois, 1991
Grape	*Vitis vinifera* L.	Whole plant DW	0.5-0.75		S	Eaton, 1944
Grapefruit	*Citrus x paradisi* Macfady.	Foliar injury	0.5-0.75		S	Haas, 1929
Lemon	*Citrus limon* (L.) Burm. f.	Foliar injury, plant DW	<0.5		VS	Eaton, 1944; Haas, 1929
Lettuce	*Lactuca sativa* L.	Head FW	1.3	1.7	MS	Francois, 1988
Lupine	*Lupinus hartwegii* Lindl.	Whole plant DW	0.75-1.0	S		Eaton, 1944
Muskmelon	*Cucumis melo* L. (Reticulatus group)	Shoot DW	2.0-4.0		MT	Eaton, 1944; El- Sheikh et al.,1971
Mustard	*Brassica juncea* Coss.	Whole plant DW	2.0-4.0		MT	Eaton, 1944
Oat	*Avena sativa* L.	Grain (immature) DW	2.0-4.0		MT	Eaton, 1944
Onion	*Allium cepa* L.	Bulb yield	8.9	1.9	VT	Francois, 1991
Orange	*Citrus sinensis* (L.) Osbeck	Foliar injury	0.5-0.75		S	Haas, 1929
Parsley	*Petroselinum crispum* Nym.	Whole plant DW	4.0-6.0		T	Eaton, 1944
Pea	*Pisum sativa* L.	Whole plant DW	1.0-2.0		MS	Eaton, 1944
Peach	*Prunus persica* (L.) Batsch.	Whole plant DW	0.5-0.75		S	Eaton, 1944; Haas, 1929

Table 3: Boron tolerance limits for agricultural crops. (Continued)

Crop		Boron tolerance parameters				References
Common name	**Botanical name**	**Tolerance† based on:**	**Threshold‡ g m-3**	**Slope % per g m-3**	**Rating§**	
Peanut	*Arachis hypogaea* L.	Seed yield	0.75-1.0		S	Gopal, 1971
Pecan	*Carya illinoinensis* (Wangenh.) C. Koch	Foliar injury	0.5-0.75		S	Haas, 1929
Pepper, red	*Capsicum annuum* L.	Fruit yield	1.0-2.		MS	Eaton, 1944
Persimmon	*Diospyros kaki* L.f.	Whole plant DW	0.5-0.75		S	Eaton, 1944
Plum	*Prunus domestica* L.	Leaf & stem injury	0.5-0.75		S	Woodbridge, 1955
Potato	*Solanum tuberosum* L.	Tuber DW	1.0-2.0		MS	Eaton, 1944
Radish	*Raphanus sativus* L.	Root FW	1.0	1.4	MS	Francois, 1986
Sesame	*Sesamum indicum* L.	Foliar injury	0.75-1.0		S	Khundairi, 1961
Sorghum	*Sorghum bicolor* (L.)	Grain yield	7.4	4.7	VT	Bingham et al., Moench 1985
Squash, scallop	*Curcurbita pepo* L. *var melopepo* (L.) Alef.	Fruit yield	4.9	9.	T	Francois, 1992
Squash, winter	*Curcurbita moschata Poir*	Fruit yield	1.0	4.3	MS	Francois, 1992
Squash, zucchini	*Curcurbita pepo* L. *var melopepo* L. Alef.	Fruit yield	2.7	5.2	MT	Francois, 1992
Strawberry	*Fragaria sp*. L.	Whole plant DW	0.75-1.0		S	Eaton, 1944
Sugar beet	*Beta vulgaris* L.	Storage root FW	4.9	4.1	T	Vlamis & Ulrich, 1973
Sunflower	*Helianthus annuus* L.	Seed yield	0.75-1.0		S	Pathak et al., 1975
Sweet potato	*Ipomoea batatas* (L.) Lam.	Root DW	0.75-1.0		S	Eaton, 1944
Tobacco	*Nicotiana tobacum* L.	Laminae DW	2.0-4.0		MT	Eaton, 1944
Tomato	*Lycopersicon lycopersicum* (L.) Karst. ex Farw.	Fruit yield	5.7	3.4	T	Francois, 1984b
Turnip	*Brassica rapa* L. (Rapifera	Root DW group)	2.0-4.0		MT	Eaton, 1944
Vetch, purple	*Vicia benghalensis* L.	Whole plant DW	4.0-6.0		T	Eaton, 1944
Walnut	*Juglans regia* L.	Foliar injury	0.5-0.75		S	Haas, 1929
Wheat	*Triticum aestivum* L.	Grain yield	0.75-1.0	3.3	S	Bingham et al., 1985; Khundairi, 1961

† FW = fresh weight, DW = dry weight.

‡ Maximum permissible concentration in soil water without yield reduction. Boron tolerances vary, depending upon climate, soil conditions, and crop varieties.

§ The B tolerance ratings are based on the following threshold concentration ranges: <0.5 g m^{-3} very sensitive (VS), 0.5 to 1.0 g m^{-3} sensitive (S), 1.0 to 2.0 g m^{-3} moderately sensitive (MS), 2.0 to 4.0 g m^{-3} moderately tolerant (MT), 4.0 to 6.0 g m^{-3} tolerant (T), and >6.0 g m^{-3} very tolerant (VT).

Sources for Plant Materials

Government-Forages or Halophytes

1. USDA Plant Materials Center (PMC), Lockeford California. (209) 727-5319.
2. Westside Resource Conservation District (WSRCD). (559) 227-2489.

Commercial*— Salt Tolerant Forages

1. America's Alfalfa. Tel: (800) 873-2532.

Material: 'Salado' and 'Ameristand 801S' salt tolerant alfalfa.

2. K-F Seeds. 4307 Fifield Road. Brawley, CA 92227. Tel: (760) 344-6391, FAX: (760) 344-6394. Material: Bermudagrass seed. Varieties 'Giant' and 'Common'.

'Tifton' is also recommended, but may not be available from this company.

3. S&W Seed Co. P.O. Box 235, Five Points, CA 93624. Tel: (559) 884-2535 swseedco@pacbell.net. Web: www.swseedco.com

Materials: "Westside Wheatgrass", a commercialized variety of 'Jose' Tall Wheatgrass and "SW 9720' Salt tolerant alfalfa.

4. West Coast Turf. PO Box 4563, Palm Desert, CA 92261. Tel: (800) 447-1840, (760) 346-TURF, and FAX: (760) 360.5616. Material: Seashore Paspalum ('SeasIsle 1') sod or chopped stolons.

Commercial*— Halophytes

1. NyPa International. Dr. Nick Yensen. 727 N. Ninth Ave., Tucson, Arizona 85705. Tel: 520 624-7245, FAX: 520-908-0819, email: nypa@aol.com web: http://expage.com/nypa.

Materials: "NyPa forage", a commercialized saltgrass (Distichlis spicata).

Tulare Lake Drainage District, Corcoran, CA (tel. 559-992-3145) may also be contacted to obtain NyPa forage.

2. Saline Seed, Inc. Contact: Mr. Daniel Murphy, 1900 Mountain Valley Lane Escondido, California 92029. Tel: 760-294-3079, Fax: 760-294-3081, e-mail danielmurphyusa@yahoo.com. Web: http://salicornia.com/

Materials: Salicornia and other halophytes and salt tolerant forages.

*List is not inclusive and does not represent an endorsement of these companies.

IFDM Plant Management Guide

Clarence Finch & Frank Menezes
With revisions by Sharon Benes and Vashek Cervinka (12-2003)

Salt-tolerant Grasses and Halophytes

This guide uses the term "salt-tolerant grasses" for plants tolerating drainage water of EC from 8 to 15 dS/m, and the term "halophytes" for plants tolerating drainage water above EC 15 dS/m. Using water salinity of EC 15 as a separating limit is rather artificial, but it can be said that halophytes tolerate higher salinity than salt-tolerant grasses.

This selection of forages, halophytes, and trees for saline drainage management for the Westside San Joaquin Valley was based on literature review from the USA, Australia, Israel, and other countries, field evaluation trials, and a survey of salt-tolerant plants in semi-arid world regions. The set of plants used in both areas is the result of a multiple-year selection process. These plants are being selected not only for salt management purposes, but also for their biological interaction with conventional farm crops to avoid introducing species that could be potential weeds or host plants for insect vectors of plant viruses.

Salt-tolerant grasses and halophytes should preferably be perennial plants to manage higher flows of drainage water during the winter/spring period. The other required characteristics include high water demand, tolerance to frequent flooding, frost tolerance, and marketability of harvested biomass. Salt-tolerant grasses and halophytes are mainly used for the re-use of drainage water so as to reduce its volume. They are grown on a relatively small area of the farm (2%-8%). Trees are most commonly used in strips to intercept subsurface lateral flows of groundwater and/or to locally drop the water table. Commercial value is of primary importance for the areas under irrigation with freshwater or low salinity water where vegetables and salt-tolerant field crops (cotton, wheat, canola, sugar beets, and possibly, alfalfa) are grown. However, economic value can be a secondary consideration in the selection of salt-tolerant grasses, halophytes, and trees.

Recommended plant management

Prepare soil by leveling the planting area to achieve uniform water distribution in the fields of salt-tolerant grasses and halophytes. This is essential for plant growth and salt leaching, as well as for minimizing water ponding that could potentially attract wildlife. When establishing the plants in an area with slope, divide this the area into blocks by throwing up borders (ridges of soil) to confine the water and level each block for uniform water distribution. If an area is too steep to level to a uniform grade for irrigation and leaching, use sprinklers to irrigate. Good stands require weed-free soil conditions.

Establish plants by seeding or by planting rooted plants (plugs). Use a drill on a "vegetable type" seedbed or on a seedbed prepared with a corrugated roller. Broadcast seed on a leveled, disked corrugated surface of shallow furrow (such as tomato beds). It is recommended to plant plugs in the bottom of the rills (furrows). This reduces the salt load around the base of the plants and allows water to reach the plants more quickly. Alternatively, in a raised bed system, the seed or cuttings should be placed on the edges of the bed, avoiding the center of the bed which is the zone of maximum salt accumulation.

There are a number of methods for planting rooted plants such as by shovel, dibble, or by a mechanical vegetable planter. The most successful method is either the tree planter or the vegetable planter because they open up the soil, and the plant is placed deeper in the soil. Timing of planting is very important. Cool season grasses should be planted in the fall. Warm season plants in the spring.

When planting rooted plants, irrigation should follow as soon as possible after planting. Fresh water (less than 3 dS/m) should be used to irrigate until salt-tolerant plants are well established. Some perennials have to be planted and established for about a year before applying water over 10 dS/m. Salicornia and other halophytes may require saline water to be established. Once plants are established, border (flood) irrigation is recommended to effectively leach salts. Sprinklers are also effective for leaching salts below the root zone and/or on land that is too steep to flood. Irrigation frequency depends on plant, soil, and climatological conditions. Cycles of watering and drying are important. Yellowing of plants may be caused by over-watering or salt build-up.

Mowing helps to control weeds. Mowing height can be critical to plant survival. The following are the recommended mowing heights for plants:

Bermudagrass and Saltgrass
10 cm (4 inches)

Tall Wheatgrass, Alkali Sacaton, Beardless wildrye, 20 to 25 cm (8 to 10 inches) and Cordgrass

Atriplex and Allenrolfea 25 to 50 cm (10 to 20 inches)

Harvest salt-tolerant grasses and halophytes for hay or seeds. Grazing can be a preferable method of management. Do not graze when soils are wet, as compaction will reduce water infiltration.

Salt Tolerant Grasses and Halophytes
(Brief Description)

Jose Tall Wheatgrass (Elytrigia elongata) (Agropyron elongatum)

Tall wheatgrass is a tall growing, erect, late maturing, perennial bunch grass. Plants range from 60 to 150 cm (2 to 5 feet) tall and the grass produces large erect seed heads that develop a good crop of seed. Growth starts in the spring and continues into late summer. The plant can be established in the fall by broadcast or drill, on a weed-free firm seedbed. Good stands can be established on saline-alkali sites by planting in bottoms of furrows and irrigating every 4 to 5 days until the seedlings have emerged to a height of 10 to 15 cm (4 to 6 inches). Established plants have been growing in soils with up to ECe of about 25 dS/m. It can be irrigated with drainage water of EC ranging from 8 to 13 dS/m. Tall wheatgrass is utilized by all kinds of livestock as pasture, hay

Jose Tall Wheatgrass

or silage. It is important to maintain a stubble height of 20 cm (8 inches) when cutting for hay, silage or mowing down old seed head growth. This plant is excellent habitat for wildlife providing safe escape and excellent nesting cover, especially for pheasants.

Creeping wildrye ('Rio'), also called Beardless wildrye (Leymus triticoides or Elymus triticoides).

Creeping wildrye is a native perennial grass 60 to 150 cm (2 to 5 feet) tall growing singly or in small clumps. Due to its scaly underground rhizomes, it often spreads over large areas. While most native stands do not produce viable seed, the 'Rio' selection consistently produces viable seed. The plant can be established by seed in the fall, also by the underground rhizomes or by container grown plants. Established plants of creeping wildrye have been growing with EC 10 to 12 dS/m drain water. This forage is eaten by cattle and sheep and is excellent escape and nesting cover for wildlife.

Alkali Sacaton ('Salado') (Sporobolus airoides)

Alkali sacaton is a warm season native perennial bunchgrass. Plants range from 60 to 75 cm (2 to 2.5 feet) tall with curving leaves. Seed heads form a widely spreading panicle nearly one-half the entire height of the plant. Plants may be 20 to 30 cm (8 to 12 inches) in diameter at ground level. The plant is established in the spring by seed or container-grown plants. Due to small seed, a good firm moist seedbed is required. Established plants have been growing with EC of 10 to 14 dS/m

Creeping wildrye

Alkali Sacaton

drain water. Alkali sacaton is good forage for cattle and horses and fair for sheep. This forage is sometimes called "salado," which should not be confused with a new salt tolerant variety of alfalfa, also called "salado".

Koleagrass ('Perla') (Phalaris tuberosa var. hirtiglumis)

Koleagrass is a tall, robust, rapid developing perennial bunchgrass. Plants range from 60 to 150 cm (2 to 5 feet) tall with short stout rhizomes originating from the base. Perla is established in the fall by seeding on a firm, weed free seedbed, or by container-grown plants. Established plants have been growing with EC of 10 to 12 dS/m drain water. Perlagrass is a very palatable grass relished by all kinds of livestock. It starts growth in the fall with moisture and continues to grow into the winter months. Due to this growth habit the plant supplies fall and winter feed for livestock and excellent cover for wildlife, especially pheasants.

Tall Fescue ('Alta' and 'Goar') (Festuca arundinacea)

Tall Fescue is an aggressive, erect, deeply rooted perennial bunch grass. The plant is from 60 to 100 cm (2 to 3 feet) tall and produces heavy sod and fibrous root material. Growth starts in the spring and continues into late winter. The plant is established in the fall from seeds by broadcast or drill on a weed-free firm seedbed. Once established, it can be irrigated with drainage water of EC 8 to 12 dS/m. Tall fescue is utilized by all kinds of livestock as pasture or hay. It is an excellent shade and nesting cover for wildlife.

Bermuda grass

Bermuda grass is a perennial crop that is moderately salt tolerant, and drought resistant. It is established by seed and spreads by rhizomes. Bermuda grass forms dense turf and can be grazed or cut for hay harvesting.

Halophytes

Pickleweed ('Samphire') (Salicornia bigelovii)

Pickleweed is a low growing very succulent annual plant that is 15 to 38 cm (6 to 15 inches) tall with green scale-like leaves. The plant is established from seed by broadcast or drilling on a well- prepared firm seedbed, similar to establishing alfalfa stands. In fact, the seed is similar in size to alfalfa. Seeding is recommended after the frost period in the spring; however in the SJV, seed can be applied in the late fall / early winter: it will lie dormant and germinate in about March. The stand can be flood or sprinkler irrigated. The plant requires salty water of EC 20 to 30 dS/m. Surface soil in this stand may have an ECe as high as 50 dS/m. Salicornia can be irrigated with lower EC water, provided that the soil salinity is considerably higher than 20 dS/m; however, its growth and seed production will be less. Pickleweed may have multiple uses. One of its main uses is for seed production. When processed it produces oil which contains polyunsaturated fat close to the level of safflower oil and better than soybean oil. The meal from

Iodine Bush

Saltbush

the oil processing can be used as a feed source for poultry and livestock. The young top portions of the plant are used as a salad green and a tasty vegetable in areas of the world where it is irrigated with brackish water or with seawater.

Saltgrass (Distichlis spicata)

Saltgrass is a gray green to blue green, perennial grass with strong extensively creeping rhizomes. The mature plant can grow to 45 cm (18 inches) tall. The plant can be established by seed. The most common method of establishment is from rhizomes. Rhizomes can be single or chunks of sod. Plants establish much faster from sod. Spring establishment is the most desirable. Established plants have been growing in soils with an ECe of 30 dS/m. In its natural state plants are commonly found on roadsides, ditch banks and along salt marshes adjacent to coastal tidal marsh areas. The plant is grazed by livestock.

Cordgrass (Spartina species)

A perennial bunch-like, coarse-textured grass 30 to 100 cm (1 to 3 feet) tall and up to 30 to 75 cm (1 to 2.5 feet) thick at the base. Some plants have extensive creeping rhizomes. The plant can be established from rooted cuttings that were grown in plastic cone containers. Planting stock is taken from a clump of a mature plant and the small base of the plant is rooted in cone containers. Rooted plants can be established at any time of the year, but the best time is during the fall and spring. Cordgrass has been grown with drainage water with an EC of up to 35 dS/m. In its natural state, plants are growing in salt marshes and tidal flats. On the Atlantic coast, marsh hay consisting of mostly cordgrass is used for packing or bedding. The species of cordgrass grown are (Spartina alternaflora and Spartina gracilia) and 2 accessions of (Spartina patens) named 'Flageo' and 'Avalon' that has rhizomes.

Iodine bush (Allenrolfea occidentalis)

Iodine bush is an erect bush 30 to 180 cm (1 to 6 feet) tall, multiple branched. The green foliage is somewhat fleshy, with scale-like leaves. Establishment can be from seed or container-grown plants. Seed can be planted by broadcast or drill in late winter. Plantings in the fall can be made by seed, but weed competition at this time makes stand establishment difficult. Due to very small seed, the plants have very weak seedling vigor and a firm, weed-free condition must prevail during establishment. Container-grown plants can be established in the fall or spring. Seed can be easily harvested from native stands in the early winter. Established plants have been growing in soils with up ECe of 60 dS/m and with water of EC 30 dS/m. In its natural state, livestock have grazed the plant and have eliminated stands in dryland pastures when other vegetation has been used up. Its use in feed supplements has not been investigated extensively.

Saltbush (Atriplex species)

Atriplex is an erect spreading perennial shrub with dense foliage. It ranges from 2 to 6 feet in height and in width. Seed maturity is from October to December. The plant can be established from seed, bare-root or container-grown plants. Seed can be planted by broadcast or drill in late winter, January through March. A good firm seedbed is required. Broadcast seeding may appear inadequate the first year, but small plants at the end of the first year produce strong plants the second year. The best way to establish this shrub is from container-grown plants. Transplanting can be done in fall or spring. Established plants tolerate drainage water EC ranging from 28 to 30 dS/m. Livestock use Atriplex as browse or as a feed supplement, especially when fed in selenium deficient areas. In its natural state it provides excellent cover for upland game and rabbits. Atriplex can be a host for the sugar beet leafhopper, which may carry a virus that causes a curly top disease in sugar beets, and in vegetable crops like tomatoes, beans, and cantaloupe. Some of the Atriplex species used are A. lentiformis and A. nummularia.

Trees

Trees use and evaporate drainage water. This is achieved through the sequential reuse, by intercepting the flow of drainage water from upslope, or through the uptake of shallow groundwater. Trees can be viewed as biological pumps.

The role of Eucalyptus trees is to lower water tables and to occasionally receive reused drainage water, and thus, to assist in reducing the volume of drainage water to be managed.

Eucalyptus camaldulensis, River Red Gum, has been the superior tree selected and is now propagated as clones by a nursery in Southern California. The best Eucalyptus clones are 4573, 4543, and 4544. These are identification numbers assigned to selected trees by the Eucalyptus Improvement Association.

Both salt-tolerant plants and trees use drainage water and reduce its volume. The trees take up saline groundwater to lower water tables, intercept sub-surface water flows, sequentially reuse drainage water, and create a biological barrier between low-saline and high-saline areas. Drainage water is mainly applied to salt-tolerant plants and only occasionally to the trees (e.g., during high flows of drainage water).

Planting and care of trees

Three methods of planting trees to reduce saline conditions on cropland are used. The trees intercept subsurface water flow, consume groundwater to lower water tables, and sequentially reuse drainage water. The tree blocks also serve as windbreaks, buffer strips, filter strips, and reduce dust problems.

Eucalyptus

The planting area should be leveled to avoid water ponding. Standing water can damage the trees and could become a potential environmental concern by attracting shore birds. If standing water can infiltrate or be drained off the area in three days or less, dead leveling may be an option. If dead leveling is not used, the recommended slope is .025/100 feet. If standing water is a problem at the end of the irrigation run, a tailwater return system is recommended to reduce tree loss from waterlogging. As with most trees or crops, eucalyptus trees perform best under optimum soil and water conditions with deep, well-drained soil.

Timing of plantation establishment is important for a complete drainage water reuse system. If fresh water or water less then EC 3 dS/m is available, then trees can be planted at the same time as halophytes.

Before planting trees, soils should be ripped or chiseled if the water table is not near the surface. Disk the area to control weeds and prepare soil for planting. Trees are planted in the bottom of furrows or on the leveled land. Planting the trees in the bottom of the furrows reduces salt load around the tree base as the sale accumulates on the top of the furrows. Planting the trees on the leveled land provides for the efficient salt leaching. Both methods can provide for the uniform distribution of water. Tree spacing within the row should be a minimum of eight feet. Tree row spacing will be determined by the width of equipment that will be used in the planting area. Allow two feet on each side of equipment (disk, mowers, spray rigs, etc.). For example, a 10-foot wide disk would require a row spacing of 14 feet. A wider spacing of 5 x 3 m (15 x 10 feet) is preferable. Trees can be planted using a mechanical tree planter. The ripper shank on the planter breaks up the soil and provides better root development for the new tree. If a tree planter is not available, hand planting can be done in a ripped or chiseled furrow. Proper spacing of trees is an advantage of hand planting.

Pistachio

Background information

In countries such as Australia, Egypt, Israel, and other arid regions, salt-tolerant trees have been irrigated with saline water. In 1985 the California Department of Food and Agriculture, the USDA-Soil Conservation Service, and the International Tree Crops Institute decided to try this concept in California. Eucalyptus seed was imported from the Province of Lake Albacutya in Victoria, Australia. The California Department of Forestry and private nurseries propagated seedlings.

Seedlings were first planted in Fresno and Kings Counties, primarily on farmland areas with high saline conditions that could not produce a crop. Survival was low on soils with high sodium levels. Sodium Absorption Ratios (SAR) exceeding 50 were primarily in Kings County.

In 1986 seedlings were propagated from seeds imported from Central Australia, Alice Springs, and surrounding areas. Some of these seedlings were interplanted in areas where the Lake Albacutya ones had died. They survived and selected trees were planted in areas with high saline and sodium conditions to determine their tolerance. Many other varieties of trees were planted in the same conditions. These included Eucalyptus from many provinces in Australia, Cottonwoods, Hybrid Cottonwoods, Athel, Salt cedar, Mesquite, Acacia, and Casurina obesa, cunninghamiana, glauca, and equisetifolia. Some of the varieties were irrigated with saline water of 6 to 20 dS/m and others with fresh water.

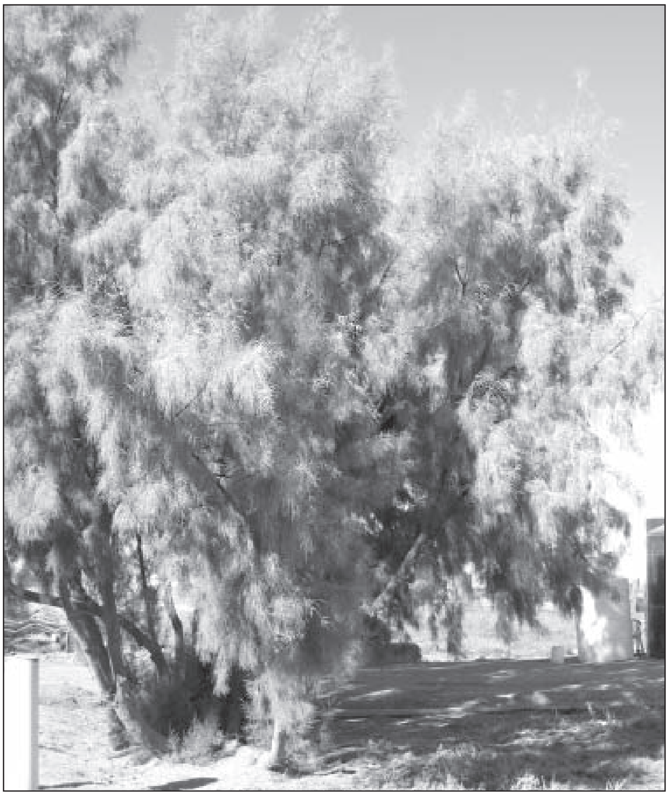
Other trees were also tried, including hybrid Willows and several varieties of Eucalyptus camaldulensis, rudis, robusta, occidentalis, grandis, viminalis, and tereticornis. Seedlings from old, established trees in Fresno and Kings Counties were also tried.

When the IFDM (Agroforestry) project started in the WRCD area (spring 1985), eucalyptus seeds were imported from Australia, Israel or Egypt, and the quality of propagated trees was inconsistent. To improve the quality of eucalyptus trees for IFDM/Agroforestry sites in the San Joaquin Valley, a selective breeding program was initiated in 1987. The IFDM/Agroforestry project team has worked closely with the California Eucalyptus Improvement Association (EIA) in its effort to coordinate the selection and propagation of superior trees. Trees are selected for salt tolerance, rate of growth, vigor, and frost tolerance. This selection effort has been successful, and most eucalyptus trees planted on irrigated farms since 1990 have been propagated from plant tissues and seeds developed in California. Selected trees have been systematically evaluated each year since 1989, and 22 trees have been chosen for tissue culture propagation. Two orchards have also been planted in experimental designs that facilitate the evaluation of growth characteristics of selected trees. Seed orchards have been established at several farms in the San Joaquin Valley, and at the USDA-NRCS Plant Material Center in Lockeford, California.

The IFDM program is oriented toward higher diversification of salt-tolerant trees and crops planted for salt management. Casuarina trees have been planted since 1985, but their performance has not always been satisfactory. Casuarina glauca is not frost tolerant; it was damaged by frost in 1990, and did not recover. Casuarina cumminghamiana has been frost damaged on several farms, and its recovery rate was lower than that of eucalyptus trees. Several individual trees performed very well under extremely difficult conditions (frost, salt, and drought). Athel (Tamarix aphylla) trees are well established in the valley, being mainly used as windbreaks. They are salt-tolerant and recover well from frost damage. They may be beneficial on farms where salinity levels are above EC 20. Eucalyptus seeds collected in 1994 from highly saline seeps in Australia and nearby surrounding areas are now being tested alongside the best clones.

Eucalyptus has been the most common salt-tolerant tree used for the management of salt and drainage. Positive results have been obtained from the management of trees over a 12-year period. Trees initially propagated on various sites in the Valley from seeds imported from Australia did not have uniform characteristics, as the growth rate and salt and frost tolerance varied significantly. The selection of superior trees through the valuable guidance of the Eucalyptus Improvement Association started in 1987/88. The best trees (4543, 4544, 4573, and 4590) were selected and are now propagated as clones by a nursery in Southern California. The selection and testing process continues with additional eucalyptus varieties.

Since 1985, more than 700,000 trees have been planted for the management of salt on irrigated farmland in the San Joaquin Valley. Eucalyptus camaldulensis is mainly planted at this time because of its salt tolerance, high water requirements, and relatively easy care.



Tamarisk (Athel)

The difference between Tamarisk Athel and Tamarisk Salt Cedar

Tamarisk Athel is an upright tree reaching up to 60 feet tall, with a dense spreading crown and several heavy large limbs. It is a fast-growing, evergreen tree. Its diameter is about 2.5 feet. The propagation method is vegetative. It commonly occurs on salt flats, springs, and other saline habitats. It is drought resistant and is tolerant of alkaline and saline soils. It uses large volume of water; a large tree can absorb about 200 gallons of groundwater per day. It does not colonize sites by seed.

Tamarisk Salt Cedar is a shrub growing up to 20 feet tall. It is considered a weed that produces a large amount of seeds and spreads in a wide area. It commonly occurs on salt flats, springs, and other saline habitats. It is drought resistant and is tolerant of alkaline and saline soils. It uses a large volume of water.

California Regional Water Quality Control Board
Central Valley Region
Robert Schneider, Chair

Winston H. Hickox
Secretary for Environmental Protection

Gray Davis
Governor

Fresno Branch Office
Internet Address: http://www.swrcb.ca.gov/~rwqcb5
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Mr. Gerald Stoltenberg
Westside Resource Conservation District
P.O. Box 205
Five Points, CA 93624

18 April 2002

DRAINAGE WATER BLENDING, WESTSIDE RESOURCE CONSERVATION DISTRICT, FRESNO COUNTY

Thank you for your letter of 18 March 2002, which asks for clarification on the regulatory requirements for the blending of drainage water used for the irrigation of salt tolerant crops.

Drainage water is a waste that can create nuisance conditions and/or affect the beneficial uses of waters of the state. The Regional Water Quality Control Board, Central Valley Region, (Regional Board) regulates discharges of wastewater that can affect waters of the state, including waste used for irrigation by agriculture. Examples include: packing house wastewater, food processing wastewater, biosolids, municipal wastewater reclamation, etc. While the Regional Board has the authority to regulate this waste using Waste Discharge Requirements (WDRs), drainage water is generally reused for irrigation without formal regulatory controls. In fact, the beneficial reuse of the drainage water can often result in water quality benefits by reducing the discharge of pollutants to surface waters.

The Regional Board generally considers drainage water applied on-farm a Non Point Source (NPS) of pollutants. However, compliance with the Clean Water Act, the Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code), and the Water Quality Control Plan for the Tulare Lake Basin, Second Edition, 1995 (Basin Plan) is not a voluntary choice. It is the Regional Board's responsibility to ensure compliance with these laws and regulations. The NPS strategy calls for three tiers of regulatory control. Tier 1: Self-Determined Implementation of Management Practices; Tier 2: Regulatory Based Encouragement of Management Practices; and Tier 3: Effluent Limitations and Enforcement Actions. Under Tier 1, the Westside Resource Conservation District could develop and implement workable solutions to NPS pollution control, which affords the opportunity to solve problems before more formal regulatory controls are taken. Potential problems can often be addressed through modifications in management measures that make formal regulatory control unnecessary. However, the reuse of drainage water must comply with the Basin Plan and State Water Resources Control Board Resolution No. 68-16, the State's "antidegradation" policy. The on-farm reuse of drainage water, if done properly and for beneficial use, should pose minimal threat to waters of the state. It may be possible to regulate the blending of drainage water for the irrigation of salt tolerant crops under the first tier if a demonstration can be made that the blended water is beneficially used for agricultural production. Examples of agricultural production would include the sale of a marketable crop or a crop grown for grazing. If the reuse of drainage water causes a nuisance, threatens to impair the beneficial uses of ground or surface waters, or is not beneficially used, then additional control and possibly enforcement actions may be needed.

The Regional Board considers the blending of drainage water to extend the water supply for agricultural production, a reasonable use of water. The blending of high quality water with poorer quality drainage water for its reuse on crops is generally accepted and encouraged. However, any operation that adds unusable drainage water to usable water and results in an unusable blend would probably be considered an unreasonable use of water.

In some cases, other regulations may apply. For example, the waste may be hazardous and subject to hazardous waste regulations contained in Title 22, California Code of Regulations, hazardous waste restrictions in the Basin Plan, and possibly the Resource Conservation and Recovery Act.

The Regional Board believes that a mechanism needs to be developed to ensure drainage water is used for agronomic benefit, protects water quality, and prevents nuisance conditions so that the discharge is not disposed of improperly. The challenge is to identify the potential problems that may develop with any reuse project and to develop practices that address the situation. Recently, you were awarded a Clean Water Act section 319(h) grant to develop an education and outreach program concerning Integrated On-Farm Drainage Management. The handbooks developed from that grant are required to outline the environmental and regulatory requirements, which should clarify what is necessary. The 319(h) grant should be used to identify management measures to achieve compliance with all applicable regulations.

If you have further questions please email or telephone Anthony Toto at totoa@rb5f.swrcb.ca.gov or (559) 445-6278.

LONNIE M. WASS
Supervising Engineer
RCE No. 38917

cc: Dr. Steve Schwarzbach, U.S. Fish and Wildlife Service, Sacramento
Ms. Frances McChesney, Office of Chief Counsel, State Water Resources Control Board, Sacramento
Mr. Walt Shannon, Division of Water Quality, State Water Resources Control Board, Sacramento
Mr. Dennis Westcot, Regional Water Quality Control Board, Sacramento
Mr. Bill Loudermilk, Department of Fish and Game, Fresno
Dr. Andy Gordus, Department of Fish and Game, Fresno
Ms. Paula Landis, Department of Water Resources, Fresno
Mr. John Shelton, Department of Water Resources, Fresno
Mr. Manucher Alemi, Department of Water Resources, Sacramento

California Regional Water Quality Control Board
Central Valley Region

NOTICE OF INTENT

TO COMPLY WITH THE CONDITIONS OF ARTICLE 9.7.
Commencing with Section 25209.10 of the Health and Safety Code
Integrated On-Farm Drainage Management

FACILITY

A. NAME OF FACILITY OR BUSINESS OPERATING THE FACILITY:_______________________________

ADDRESS OF FACILITY:_______________________________
Number and Street City Zip Code

COUNTY:_______________________________

CONTACT PERSON:_______________________ TELEPHONE NO._______________________

B. NAME OF LEGAL OWNER OF FACILITY:_______________________________

ADDRESS OF LEGAL OWNER OF FACILITY:_______________________________
Number and Street City Zip Code

CONTACT PERSON:_______________________ TELEPHONE NO._______________________

C. NAME OF CONTACT PERSON TO RECEIVE REGIONAL BOARD CORRESPONDENCE:_______________________

ADDRESS OF CONTACT PERSON:_______________________________
Number and Street City Zip Code

TELEPHONE NO. OF CONTACT PERSON: _______________________

LOCATION OF SOLAR EVAPORATOR

NUMBER OF ACRES ________ SECTION ____ TOWNSHIP ____, RANGE ____. APN _________ COUNTY __________

Provide a map of the area of the complete IFDM system (including irrigated fields for reuse) and indicate location of solar evaporator, tile lines, and monitoring wells.

DESIGN OF SOLAR EVAPORATOR

Provide a technical report prepared by an appropriately-registered California professional for the design of the solar evaporator. The report should describe of the capacity and the equipment to operate the solar evaporator. Explain features to prevent inundation from a 100-year flood. Include the tile drain design and the soil properties such as permeability, grain size distribution, percent clay, etc.

MAXIMUM ANTICIPATED RATE OF DISCHARGE TO THE SOLAR EVAPORATOR _________

OPERATIONAL PLANS FOR COMPLIANCE

Provide a plan for compliance with the requirements of article 9.7. Plans must include measures to prevent standing water, mitigate wildlife impacts, and prevent migration of constituents from the solar evaporator into the vadose zone. Include weather data and a water balance sufficient to assess the likelihood of standing water, and supporting the design of the solar evaporator.

CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA) COMPLIANCE

HAS ANY CEQA DOCUMENT BEEN ADOPTED/CERTIFIED BY A LEAD AGENCY FOR THIS PROJECT?
______YES ______NO (IF YES, PLEASE ENCLOSE A COPY OF THE ADOPTION/CERTIFICATION)

IF NO, WILL ANY CEQA DOCUMENT BE PREPARED? ______YES ______NO

IF YES, WHO WILL PREPARE THE CEQA DOCUMENT? _______________________________

APPROXIMATE DATE OF COMPLETION__________________

CERTIFICATION

I HEREBY CERTIFY UNDER PENALTY OF PERJURY THAT THE INFORMATION PROVIDED IN THIS NOTICE OF INTENT AND IN ANY ATTACHMENTS IS TRUE AND ACCURATE TO THE BEST OF MY KNOWLEDGE. IN ADDITION, I CERTIFY THAT THE CONDITIONS OF ARTICLE 9.7 OF THE HEALTH AND SAFETY CODE WILL BE COMPLIED WITH.

SIGNATURE OF OWNER OF FACILITY	SIGNATURE OF OPERATOR OF FACILITY
PRINT OR TYPE NAME	PRINT OR TYPE NAME
TITLE AND DATE	TITLE AND DATE

Laws and Regulations referred to in Chapter 9

Chapter 9 briefly outlines the various laws and regulations that may apply to development of an IFDM system. Additional details for each law is discussed here:

California Environmental Quality Act (CEQA): The California Public Resource Code §21000-21006 establishes the legislative intent and policy supporting the CEQA environmental disclosure and review process for projects conducted in the State of California. Public Resource Code §21065 defines a project as:

"an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment, and which is any of the following:

(a) An activity directly undertaken by any public agency.

(b) An activity undertaken by a person which is supported, in whole or in part, through contracts, grants, subsidies, loans, or other forms of assistance from one or more public agencies.

(c) An activity that involves the issuance to a person of a lease, permit, license, certificate, or other entitlement for use by one or more public agencies."

Any project that fits the above definition, whether undertaken by a private or public entity, is subject to the CEQA process. An overview of the CEQA process is illustrated in Figure 1. Early in the process, a lead agency is designated. Generally, the lead agency is the California government agency principally responsible for approving or carrying out a project. The lead agency is responsible for preparing all necessary environmental disclosure documentation, for assuring that the documentation is legally adequate, and for encouraging public participation. Other agencies, known as responsible agencies, also may be directly involved with the CEQA process. These agencies are legally responsible for some aspect of the project or resource in the project area and will provide input to the lead agency as the project is planned and CEQA documentation is prepared. It is common for public agencies with permitting authority over a project to serve as responsible agencies. Once a lead agency is designated, an IS is prepared to help determine whether the project could have any significant effect on the environment. If a significant effect is anticipated, an Environmental Impact Report (EIR) is written, otherwise a Negative Declaration is prepared.

CEQA documentation is prepared not only to fully inform decision makers about the details and any possible impacts of a project before deciding whether to proceed, but it's also prepared to fully inform the general public about a proposed project and any potential impacts. The public disclosure aspect of CEQA is stressed in the CEQA statute, and protocols that facilitate public disclosure and interaction are provided in the CEQA guidelines (http://www.ceres.ca.gov/).

Although the CEQA process is outlined and discussed in the guidelines, it is best to let someone with a strong CEQA background determine which level of environmental analysis is appropriate for the proposed project, and to then complete the necessary actions to ensure CEQA compliance.

National Environmental Policy Act (NEPA): NEPA requires incorporating environmental considerations into the planning process for all federal projects, and for projects requiring federal funding or permits.

The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality [CEQ]. *Sec. 2 [42 USC § 4321], Federal Code.*

Unlike CEQA, NEPA allows each federal agency to develop their own NEPA guidelines; however, the CEQA requires that each agency's NEPA policy integrate environmental impact analysis into project planning and environmental disclosure documents including:

EA's and Environmental Impact Statements (EIS). Like CEQA, public disclosure and interaction are mandated by NEPA.

Federal Clean Water Act: The act specifies that federal agencies identify reasonable alternatives to a proposed project along with the preferred alternative (the proposed project), as well as describing any anticipated impacts.

Typical activities that affect water quality may include but are not limited to:

- Discharge of process wastewater and commercial activities not discharged into a sewer (factory wastewater, cooling water, etc.)
- Confined animal facilities (e.g., dairies)
- Waste containments (landfills, waste ponds, etc.)
- Construction sites
- Boatyards
- Discharges of pumped groundwater and cleanup (underground tank cleanup, dewatering, spills)
- Material handling areas draining to storm drains
- Sewage treatment facilities
- Filling of wetlands
- Dredging, filling, and disposal of dredge wastes
- Waste to land

Various agencies have been granted regulatory authority over different aspects of the Clean Water Act. Sections of the Clean Water Act most relevant to Integrated Farm Drainage Management (IFDM) projects may include:

Section 404, Clean Water Act: *Waters of the United States are divided into "wetlands" and "other waters of the United States." Wetlands are defined as "areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions"* (33 Code of Federal Regulations [CFR] 328.3[b], 40 CFR 230.3). Jurisdictional wetlands must support positive indicators for hydrophytic vegetation, hydric soil, and wetland hydrology. Other waters of the United States are defined as those that lack positive indicators for one or more of the three wetland parameters identified above and include seasonal or perennial water bodies, including lakes, stream channels, drainages, ponds, and other surface water features, that exhibit an ordinary high-water mark (33 CFR 328.4).

Section 402, Clean Water Act:

Common pollutants that are subject to NPDES permit limitations are biological waste, toxic chemicals, oil and grease, metals, and pesticides. NPDES permitting is administered by the Regional Water Quality Control Board (RWQB) under the authority of the State Water Resources Control Board (SWRCB).

Resource Conservation and Recovery Act (RCRA): In California, RCRA is enforced by local Certified Unified Program Agencies (CUPAs) and the Department of Toxic Substances Control (DTSC). When it was enacted in 1976, it introduced the concept of "cradle to grave" management of hazardous waste as well as use of the Uniform Hazardous Waste Manifest. Under RCRA, in order for a substance to be considered a hazardous waste, it must first be a waste (i.e., you are done using it and/or it is inherently "waste-like"). Secondly, the waste must either (1) be on a list of wastes that are automatically considered to be hazardous; or (2) display characteristics that make it a hazardous waste (i.e., toxicity, ignitability, reactivity or corrosivity).

If the waste is hazardous under RCRA, the generator must file a notification with EPA and obtain a hazardous waste generator identification number, comply with requirements for appropriate storage of the material prior to shipment, ship the material under a Uniform Hazardous Waste Manifest using a hauler licensed to transport hazardous waste, and dispose of the material at a specially licensed treatment or disposal site. Selenium and selenium compounds are considered Acutely Hazardous Wastes under RCRA. If the amount of Acutely Hazardous Waste generated exceeds 1 kilogram (kg) in any given month, then the generator is responsible to comply with additional reporting, training, storage and waste minimization requirements.

Finally, the generator is responsible for the waste even after it is deposited in a disposal facility. This means that the generator could ultimately be responsible to contribute funds to clean up of the disposal facility, if that were to be required in the future. Of note is the fact that if a hazardous waste is recyclable, it is subject to RCRA storage and handling requirements, but there is no long-term liability. If the salt residue were a commercial product and not a waste, it would not be subject to RCRA requirements.

Hazardous Waste Control Law (HWCL) is codified in the Health & Safety Code Division 20, Chapter 6.5 and implementing regulations found in California Code of Regulations, Title 22, Division 4.5. The requirements of the HWCL are enforced by the local CUPA and/or DTSC.

Hazardous Waste Control Law (HWCL) California defines characteristic hazardous wastes based on either (or both) the soluble or total concentration of a hazardous constituent.

For selenium, this is defined as a Soluble Threshold Limit Concentration (STLC) of 1.0 mg/L as determined by the California Waste Extraction Test or a Total Threshold Limit Concentration of 100 mg/kg. Hazardous waste generated in California is subject to additional reporting requirements and a hazardous waste generator tax levied by the state Board of Equalization. Any treatment of hazardous waste at a site to change its characteristics or render it less toxic is subject to additional regulatory and permitting requirements.

Section 404, Clean Water Act: Certain ongoing, normal farming practices in wetlands are exempt and do not require a permit. This includes, among other things, maintenance (but not construction or alteration of) drainage ditches, construction and maintenance of irrigation ditches, and construction and maintenance of farm or stock ponds. In order to be exempt, the activities cannot be associated with converting an agricultural wetland into a non-wetland or bringing a wetland into agricultural production. Other requirements define and regulate "Prior Converted Cropland" and "Farmed Wetlands."

Federal Endangered Species Act (FESA): Actions that lead to take can result in civil or criminal penalties. Authorization for "take" must be received from the appropriate federal regulatory agency (USFWS, NOAA Fisheries, etc.), if compliance with standard avoidance measures are not feasible. Section 10 outlines the process by which entities may obtain a permit for the "incidental take" of a listed species.

Under Section 7 a federal lead agency must consult with relevant federal regulatory agencies to ensure that the actions of a project do not jeopardize the continued existence of listed species. If the project has the potential to affect listed species, a federal lead agency must prepare a Biological Assessment (BA) identifying the project effects and submit it to other federal agencies for review. The reviewing federal agencies would make a determination regarding effects and proposed mitigation measures and, after consultation, issues a Biological Opinion (BO) that may authorize "take" but could lead to changes in avoidance and mitigation measures and may require modification of the project design.

If the project affects species listed jointly under the federal and state Endangered Species Acts, DFG typically participates in Section 7 consultation to the greatest extent possible. The federal BO generally reflects both state and federal findings, and DFG is encouraged in the state Endangered Species Act to adopt, when possible, the USFWS biological opinion as its own formal written determination on whether jeopardy to endangered species exists. If, however, USFWS and DFG ultimately fail to agree, the agencies may issue independent biological opinions.

California Endangered Species Act (CESA): Section 2080 of the Fish and Game Code prohibits "take" of any species that the Fish and Game Commission determines to be an endangered species or threatened species. Take is defined in Section 86 of the Fish and Game Code as *"hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill."* CESA allows for take incidental to otherwise lawful development projects but emphasizes early consultation to avoid potential impacts to rare, endangered, and threatened species and to develop appropriate mitigation planning. Mitigation planning is intended to offset project caused losses of listed species populations and their essential habitats.

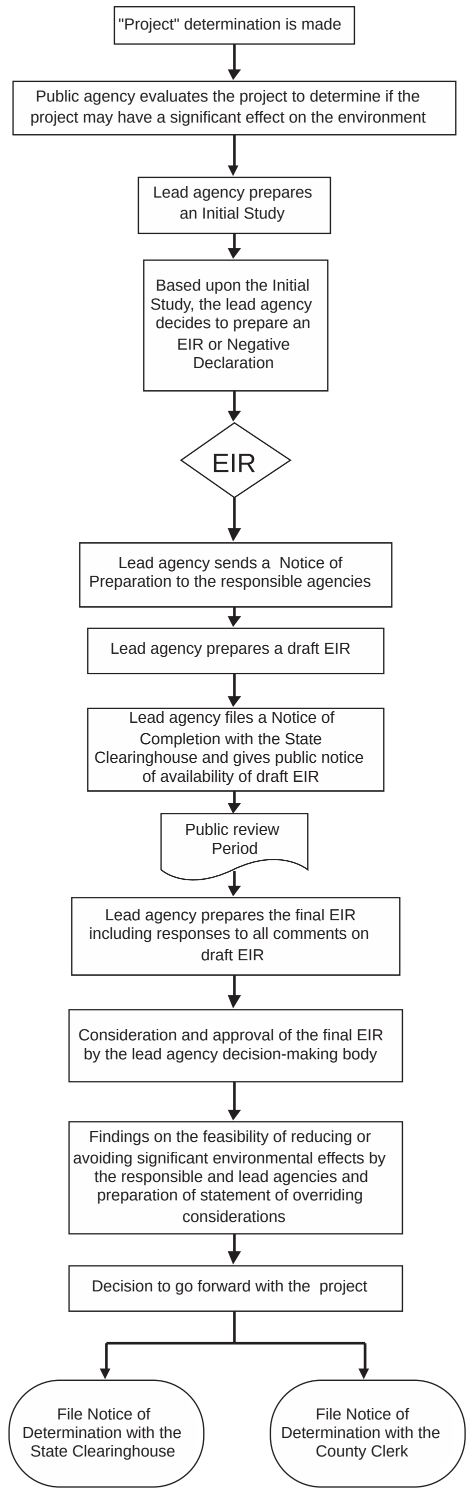
Sections 2081(b) and (c) of the California Endangered Species Act allow the Department to issue an incidental take permit for a State listed threatened and endangered species only if specific criteria are met. Title 14 California Code of Regulations (CCR), Sections 783.4(a) and (b) summarizes the criteria as: *"The authorized take* ***is*** *incidental to an otherwise lawful activity; The impacts of the authorized take are minimized and fully mitigated; The measures required to minimize and fully mitigate the impacts of the authorized take are roughly proportional in extent to the impact of the taking on the species, maintain the applicant's objectives to the greatest extent possible, and are capable of successful implementation; Adequate funding is provided to implement the required minimization and mitigation measures and to monitor compliance with and the effectiveness of the measures; and Issuance of the permit will not jeopardize the continued existence of a State-listed species."*

Fish and Game Code outlines the authority DFG has to protect and conserve natural resources within the state. The code has provisions for DFG authority under the CESA including regulatory authority for activities in channels, beds, and banks of lakes, rivers and streams.

Fully Protected Animals: Table 1 provides a complete list of animals with Fully Protected status.

Figure 1. CEQA Process.

Overview of the CEQA process



Adapted from CERES CEQA process flow chart

Appendix

Table 1. Fully Protected Animals.

COMMON NAME	SCIENTIFIC NAME
Fishes	
Colorado River squawfish (=Colorado pikeminnow)	*Ptychocheilus lucius*
thicktail chub	*Gila crassicauda*
Mohave chub (=Mohave tui chub)	*Gila mohavensis*
Lost River sucker	*Catostomus luxatus* (=*Deltistes luxatus*)
Modoc sucker	*Catostomus microps*
shortnose sucker	*Chasmistes brevirostris*
humpback sucker (=razorback sucker)	*Xyrauchen texanus*
Owens River pupfish (=Owens pupfish)	*Cyprinoden radiosus*
unarmored threespine stickleback	*Gasterosteus aculeatus williamsoni*
rough sculpin	*Cottus asperrimus*
Amphibians	
Santa Cruz long-toed salamander	*Ambystoma macrodactylum croceum*
limestone salamander	*Hydromantes brunus*
black toad	*Bufo exsul*
Reptiles	
blunt-nosed leopard lizard	*Gambelia sila* (=*Gambelia silus*)
San Francisco garter snake	*Thamnophis sirtalis tetrataenia*
Birds	
American peregrine falcon	*Falco peregrinus anatum*
brown pelican (=California brown pelican)	*Pelecanus occidentalis* (=*P. o. occidentalis*)
California black rail	*Laterallus jamaicensis coturniculus*
California clapper rail	*Rallus longirostris obsoletus*
California condor	*Gymnogyps califonianus*
California least tem	*Sterna albifrons browni* (=*Sterna antillarum browni*)
golden eagle	*Aquila chrysaetos*
greater sandhill crane	*Grus candadensis tabida*
light-footed clapper rail	*Rallus longirostris levipes*
southern bald eagle (=bald eagle)	*Haliaeetus leucocephalus leucocephalus* (=*Haliaeetus leucocephalus*)
trumpeter swan	*Cygnus buccinator*
white-tailed kite	*Elanus leucurus*
Yuma clapper rail	*Rallus longirostris yumanensis*
Mammals	
Morro Bay kangaroo rat	*Dipodomys heermanni morroensis*
bighorn sheep	*Ovis canadensis* - except Nelson bighorn sheep (*ssp. Ovis canadensis nelsoni*) in the area described in subdivision (b) of Section 4902 (Fish and Game Code)
northern elephant seal	*Mirounga angustirostris*
Guadalupe fur seal	*Arctocephalus townsendi*
ring-tailed cat	*Genus Bassariscus* (=*Bassariscus astutus*)
Pacific right whale	*Eubalanea sieboldi* (=*Balaena glacialis*)
salt-marsh harvest mouse	*Reithrodontomys raviventris*
southern sea otter	*Enhydra lutris nereis*
wolverine	*Gulo luscus* (=*Gulo gulo*)

Chapter Authors and Biographies

Chapter 1

Liz Hudson

Liz Hudson, APR, is a principal in Hudson•Orth Communications, a public relations firm specializing in agriculture and water communications. Hudson has more than 25 years experience in agricultural and water communications. She has a degree in agricultural journalism from California Polytechnic State University, San Luis Obispo, and holds a national accreditation in public relations from the Public Relations Society of America.

Chapter 2

Tim Jacobsen

Tim Jacobsen is an education specialist for the Center for Irrigation Technology at California State University, Fresno. He has worked in the area of agricultural irrigation for 20 years and now teaches on agricultural topics throughout California.

Lisa Basinal

Lisa Basinal is an Education Specialist for the Center for Irrigation Technology at California State University, Fresno. She has worked in the areas of plant genetics, post-harvest, and agricultural pumping and irrigation for the past six years and now teaches on agricultural topics throughout California.

Nettie R. Drake

Nettie R. Drake is a watershed specialist with MFG, Inc., an environmental engineering and scientific consulting firm. She has an extensive background in agricultural production and has been involved with watershed and resource management on the Westside of the San Joaquin Valley for the past eight years. As part of the watershed management, she has been very involved with the drainage issues and the evolution of the IFDM systems.

Vashek Cervinka, Ph.D.

Dr. Vashek Cervinka is an agricultural engineer specializing in agricultural drainage issues and renewable energy. He earned a doctorate from the University of California, Davis, and has 35 years of experience in agriculture with the California Department of Food and Agriculture, the California Department of Water Resources, and Westside Resource Conservation District. For the last 19 years he has worked extensively with IFDM.

Kathleen Buchnoff

Kathleen Buchnoff is an engineer in the California Department of Water Resources' Integrated Drainage Management Section, a part of the Agricultural Drainage Program. That program's goal is to control subsurface drainage water, salt, selenium, boron and other toxic elements to maintain agricultural productivity on irrigated farmland with salinity problems. Buchnoff also provides technical assistance in the areas of drainage management, concentration and removal of salts from drainage water through various technologies, utilization of drainage salts and related areas. She also assists in coordinating the monitoring activities for IDM projects.

Morris A. "Red" Martin

Morris A. "Red" Martin has been a Westside fixture for nearly 50 years. His career includes serving as a Soil Conservationist with the U.S. Department of Agriculture's Soil Conservation Service, now called Natural Resources Conservation Service. Martin is a recognized expert in soil and water conservation and a pioneer in the area of IFDM development and implementation. Martin also serves as a guest lecturer at California State University, Fresno, where he received a degree in agriculture. He also served as the Executive Director of the Westside Resource Conservation District.

Chapter 3

Kathleen Buchnoff

Kathleen Buchnoff is an engineer in the California Department of Water Resources' Integrated Drainage Management Section, a part of the Agricultural Drainage Program. That program's goal is to control subsurface drainage water, salt, selenium, boron and other toxic elements to maintain agricultural productivity on irrigated farmland with salinity problems.

Buchnoff also provides technical assistance in the areas of drainage management, concentration and removal of salts from drainage water through various technologies, utilization of drainage salts and related areas. She also assists in coordinating the monitoring activities for IDM projects.

Julie Vance

Julie Vance is an Environmental Scientist with the California Department of Water Resources, San Joaquin District. Vance has been involved with drainage issues for six years. Her areas of expertise include agricultural drainage-related impacts to avian species, aquatic ecology, aquatic invertebrates, amphibian ecology, special status species of the San Joaquin Valley and environmental permitting and compliance.

Lisa Basinal

Lisa Basinal is an Education Specialist for the Center for Irrigation Technology at California State University, Fresno. She has worked in the areas of plant genetics, post-harvest, and agricultural pumping and irrigation for the past six years and now teaches on agricultural topics throughout California.

Chapter 4

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Chapter 5

Sharon E. Benes, Ph.D.

Dr. Sharon E. Benes received her doctorate in plant physiology from the University of California, Davis. She now serves as an Assistant Professor in the Department of Plant Science at California State University, Fresno, where she teaches undergraduate and graduate courses in soils and plant nutrition. Benes' area of research specialty includes examining the response of plants to salinity and soil and water management under saline conditions. Since 1977 she has conducted long-term field evaluations of salt-tolerant forages and halophytes for drainage water reuse systems for the Westside of the San Joaquin Valley.

Tim Jacobsen

Tim Jacobsen is an education specialist for the Center for Irrigation Technology at California State University, Fresno. He has worked in the area of agricultural irrigation for 20 years and now teaches on agricultural topics throughout California.

Lisa Basinal

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Chapter 6

Sharon E. Benes, Ph.D.

Dr. Sharon E. Benes received her doctorate in plant physiology from the University of California, Davis. She now serves as an Assistant Professor in the Department of Plant Science at California State University, Fresno, where she teaches undergraduate and graduate courses in soils and plant nutrition. Benes' area of research specialty includes examining the response of plants to salinity and soil and water management under saline conditions. Since 1977 she has conducted long-term field evaluations of salt-tolerant forages and halophytes for drainage water reuse systems for the Westside of the San Joaquin Valley.

Stephen R. Grattan, Ph.D.

Dr. Stephen R. Grattan is a Plant-Water Relations Specialist for the University of California, Davis. Grattan has worked for more than 20 years on crop responses to saline conditions. Grattan's areas of expertise include irrigation management with saline water, plant response in saline environments; uptake of nutrients and trace elements by plants in saline environments; and crop water use.

Clarence Finch

Clarence Finch is retired from the U.S. Department of Agriculture's Natural Resources Conservation Service and currently works in a volunteer capacity for that agency. In his 35 years with the NRCS, he specialized in the area of vegetation establishment for the purpose of erosion control.

Lisa Basinal

Lisa Basinal is an Education Specialist for the Center for Irrigation Technology at California State University, Fresno. She has worked in the areas of plant genetics, post-harvest, and agricultural pumping and irrigation for the past six years and now teaches on agricultural topics throughout California.

Chapter 7

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Lisa Basinal is an Education Specialist for the Center for Irrigation Technology at California State University, Fresno. She has worked in the areas of plant genetics, post-harvest, and agricultural pumping and irrigation for the past six years and now teaches on agricultural topics throughout California.

Andrew G. Gordus, Ph.D.

Dr. Andrew G. Gordus is a Senior Environmental Scientist (Supervisor) with the California Department of Fish and Game and has been involved in irrigation and drainage management issues for more than 10 years. He received his doctorate in comparative pathology from the University of California, Davis. Dr. Gordus's areas of expertise include wildlife disease and toxicology; waterfowl and shorebird management; wetland and upland habitat management; and environmental regulations.

Chapter 8

Tim Jacobsen

Tim Jacobsen is an education specialist for the Center for Irrigation Technology at California State University, Fresno. He has worked in the area of agricultural irrigation for 20 years and now teaches on agricultural topics throughout California.

Nettie R. Drake

Nettie R. Drake is a watershed specialist with MFG, Inc., an environmental engineering and scientific consulting firm. She has an extensive background in agricultural production and has been involved with watershed and resource management on the Westside of the San Joaquin Valley for the past eight years. As part of the watershed management, she has been very involved with the drainage issues and the evolution of the IFDM systems.

Chapter 9

Gerald Hatler

Gerald Hatler is an Environmental Scientist with the California Department of Water Resources where he conducts fish and wildlife resource evaluation, environmental documentation and project review. He has been involved with natural resource evaluation, management and research for seven years. Prior to his current position, Hatler worked for the California Department of Fish and Game managing, developing and participating in research programs; evaluations of fish, wildlife and botanical resources with an emphasis on riparian habitat restoration; geomorphology; anadromous fisheries; big game population assessment; and telemetry studies.

Wayne Verrill

Wayne Verrill works as an Environmental Scientist with the State Water Resources Control Board. He is a soil scientist by training with previous experience in environmental consulting. Verrill has worked for the State of California for eight years primarily on utilization and disposal of agricultural drainage.

Mike Tietze, C.HG, C.E.G.

Michael Tietze is a Senior Consulting Hydrogeologist with MFG, Inc., a Tetra Tech company, and he currently manages the company's California operations. Tietze has 20 years experience working with industrial, agricultural, timber, commercial and municipal clients and law firms investigating the presence of and behavior of toxic substances in the environment. He has also worked on assessing compliance with environmental regulations and developing clean-up strategies.

REVISED
July 07, 2003

Appendix Item 7
STATE WATER RESOURCES CONTROL BOARD
BOARD MEETING SESSION--DIVISION OF WATER QUALITY
JULY 16, 2003

ITEM 9

SUBJECT

CONSIDERATION OF A RESOLUTION ADOPTING EMERGENCY REGULATIONS THAT ESTABLISH MINIMUM REQUIREMENTS FOR THE DESIGN, CONSTRUCTION, OPERATION, AND CLOSURE OF SOLAR EVAPORATORS AS COMPONENTS OF INTEGRATED ON-FARM DRAINAGE MANAGEMENT SYSTEMS

DISCUSSION

In 1990, the San Joaquin Valley Drainage Program recommended the implementation of sequential agricultural drainage reuse systems, now known as Integrated on-Farm Drainage Management (IFDM) systems, as one major component of a comprehensive agricultural drainage management plan to address the impact of poor quality shallow groundwater on now almost one million acres of agricultural land on the westside of the San Joaquin Valley. The plan recommended that 156,000 acres of tile-drained cropland be included in drainage reuse or IFDM systems by the year 2000 in the initial phase of the proposed 50-year plan to manage shallow groundwater and salinity in-valley and sustain productivity of agricultural lands. The recommendation was contained in *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*, popularly known as the Rainbow Report. In 1991, the State Water Resources Control Board (SWRCB) entered into a Memorandum of Understanding with seven other State and federal agencies to form the San Joaquin Valley Drainage Implementation Program (SJVDIP) for the purpose of implementing the recommendations of the Rainbow Report.

There are two types of evaporation systems currently used by farmers in the San Joaquin Valley to manage agricultural drainage water. The first are the large evaporation ponds in Tulare Lake Basin that receive and store drainage water directly from irrigated farmland without reuse. The second are the solar evaporators operated as part of an IFDM system. Agricultural drainage water is sequentially reused (one to three times) to irrigate salt-tolerant forage and other crops until the volume of drainage water is substantially decreased and its salt content significantly increased. The concentrated brine is then sprayed into an on-farm solar evaporator—a shallow basin that is the endpoint of the sequential reuse system. No off-farm discharge of drainage water occurs in this system. It has been proposed that crystallized salts from the solar evaporator be harvested as a commercial product; however, no markets have yet been established.

The first drainage reuse pilot project was initiated on a site near Mendota by the Westside Resource Conservation District in 1985, with the support of several State and federal government agencies. In 1994, work began on the development of a complete IFDM system for sequential drainage reuse at Red Rock Ranch in western Fresno County. Development of IFDM systems and solar evaporators has focused for the last nine years on Red Rock Ranch. The Red Rock Ranch prototype IFDM system has achieved significant improvements in root zone soil and water quality and crop productivity on about 76% of the farmed acreage, with substantial improvement in the productivity of high-value salt-sensitive crops. Productive reuse has been made of the drainage water collected on-farm for irrigating salt-tolerant forage, cotton, and other crops on another 23% of the IFDM system acreage.

A small solar evaporator was constructed as the salt end-point component of this IFDM system. Waste Discharge Requirements (WDR) for its operation were established by the Central Valley Regional Water Quality Control Board (CVRWQCB). However, naturally high selenium concentrations in the drainage discharged to the evaporator invoked regulatory provisions of the Toxic Pits Cleanup Act (TPCA 1984) and created difficulties in permitting the solar evaporator as the essential final component of the IFDM system. Red Rock Ranch experienced difficulty in efficiently operating the solar evaporator while meeting the WDR's and was served with Notices of Violation. Problems were associated with ponding sufficient to develop a growth of invertebrates (primarily brine flies) initiating a selenium-containing food chain that resulted in impacts to nesting shorebirds. The data for stilts nesting near the solar ~~pond~~ evaporator at Red Rock Ranch represent the highest percent incidence of selenium-induced birth defects reported from field studies to date. These and other problems resulted in the cessation of operation of the original solar evaporator at the Ranch. Attempted solutions to resolve the conflict with TPCA were found to be impractical and infeasible.

Meanwhile, rising water tables and increasing soil salinity threaten root zone soil and water quality and continued productivity on westside San Joaquin Valley agricultural lands. To date, complete IFDM systems have been developed on only about 1600 acres of agricultural land. At the present time, other alternatives for the management of subsurface agricultural drainage, such as out-of-valley disposal of drainage to the Bay-Delta or Pacific Ocean, or discharge to large, conventional evaporation ponds, is either generally unavailable or infeasible. A number of growers on the westside of the San Joaquin Valley would like to institute complete IFDM systems with solar evaporators and resulting improvements in soil and water quality, but are reluctant to do so until the existing regulatory issues with respect to the Red Rock Ranch solar evaporator are resolved. Further, other growers and districts are instituting partial IFDM systems with salt-tolerant crop reuse components but with no solar evaporators as a salt endpoint. Incomplete IFDM systems without salt endpoints risk future loss of soil and water quality improvements, and impacts to wildlife.

This situation has placed the entire operation of IFDM systems and the future implementation of the Rainbow Report recommendations in question and led to the passage of Senate Bill (SB) 1372 in September, 2002. By this act, solar evaporators are exempt from the provisions of TPCA. Solar evaporators did not exist at the time of enactment of TPCA, and the provisions of TPCA do not take account of the unique circumstances and conditions pertinent to solar evaporators. SB 1372 also exempts solar evaporators from WDRs under the California Water Code, and requires the development of new emergency regulations specifically designed to address the environmental and operational conditions associated with solar evaporators, thereby facilitating the full development and completion of IFDM systems.

The new regulations establish minimum requirements for the design, construction, operation, and closure of solar evaporators and have been developed through a review of existing information on the development and regulation of solar evaporators, and through informal consultation with other State agencies, primarily the Department of Water Resources, and the Department of Food and Agriculture. Technical advice and recommendations were requested of the Department of Fish and Game and the U.S. Fish and Wildlife Service, as required by SB 1372. A fact finding field tour of existing and proposed solar evaporators was made in December, 2002, with meetings held with existing operators and prospective applicants. The tour included an innovative new solar evaporator design currently being developed and tested at Red Rock Ranch.

The new regulations closely follow the language and intent of SB 1372, adding clarity and specificity where needed or useful. Existing regulations in the California Code of Regulations are cited or referenced where appropriate. The new regulations are primarily designed to account for the no standing water provision of SB 1372. A specific definition of “standing water” has been developed based on limiting the potential for growth of brine flies that could result in biomagnification of selenium in a food chain. The “standing water” definition is thereby designed to provide adequate wildlife protection. Another important definition is “reasonably foreseeable operating conditions” that has been specified for both the design capacity of solar evaporator operating systems and natural occurrence of floods and incident rainfall. The definition of “water catchment basin” has been expanded to include a solar still or greenhouse as a fully contained component for the final separation and desiccation of salt. The new design and operation standards are intended to facilitate the development and implementation of solar evaporators as components of IFDM systems, while protecting avian wildlife and existing groundwater quality.

Adoption by the SWRCB of new solar evaporator emergency regulations has been determined by the Office of the Chief Counsel to be subject to an emergency exemption from the California Environmental Quality Act.

POLICY ISSUE

Should the SWRCB adopt emergency regulations (see attachment) that establish minimum requirements for the design, construction, operation, and closure of solar evaporators as components of IFDM systems in compliance with SB 1372?

FISCAL IMPACT

Annual costs of approximately $181,000 are anticipated for the (CVRWQCB) in FY 2003-2004, and $161,000 annually thereafter, to carry out the provisions of the new solar evaporator regulations. SB 1372 requires any Regional Water Quality Control Boards (RWQCBs) receiving a Notice of Intent to construct and operate a solar evaporator to review the application, inspect the site, identify additional data requirements, conduct facility inspections after construction, determine facility compliance with the requirements of the regulations, review annual monitoring data reports, and other tasks. Although the bill prohibits RWQCBs from approving new facilities after January 1, 2008, operation of facilities approved prior to that date would be allowed to continue and, therefore, would require continued regulatory effort by the RWQCBs. Funds from the existing Surface Impoundment Assessment Account in the General Fund (approximately $1.2 million) may be used for this purpose.

RWQCB IMPACT

Yes, mainly Central Valley Regional Water Quality Control Board.

STAFF RECOMMENDATION

Staff recommends adoption of emergency regulations that establish minimum requirements (see attachment) for the design, construction, operation, and closure of solar evaporators as components of IFDM systems in compliance with SB 1372.

STATE WATER RESOURCES CONTROL BOARD
RESOLUTION NO. 2003-

AUTHORIZING A RESOLUTION ADOPTING EMERGENCY REGULATIONS THAT ESTABLISH MINIMUM REQUIREMENTS FOR THE DESIGN, CONSTRUCTION, OPERATION, AND CLOSURE OF SOLAR EVAPORATORS AS COMPONENTS OF INTEGRATED ON-FARM DRAINAGE MANAGEMENT (IFDM) SYSTEMS

WHEREAS:

1. The sustainability of approximately one million acres of productive agricultural land on the westside of the San Joaquin Valley is threatened by rising shallow groundwater of poor quality.

2. Recommended measures contained in *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*, to provide short-term agricultural drainage relief, include sequential drainage reuse or IFDM systems.

3. IFDM systems require an evaporation system as the final component for the separation and collection of salt.

4. The Legislature has found that IFDM is a sustainable system of managing salt-laden farm drainage water. IFDM is designed to eliminate the need for off-farm drainage of irrigation water, prevent the on-farm movement of irrigation and drainage water to groundwater, restore and enhance the productive value of degraded farmland by removing salt and selenium from the soil, conserve water by reducing the demand for irrigation water, and create the potential to convert salt from a waste product and pollutant to a commercial farm commodity.

5. The Legislature has found it is the policy of the state to conserve water and to minimize the environmental impacts of agricultural drainage. It is therefore in the interests of the state to encourage the voluntary implementation of sustainable farming and irrigation practices, including, but not limited to, IFDM as a means of improving environmental protection, conserving water, restoring degraded soils, and enhancing the economic productivity of farms.

6. The Legislature has directed the State Water Resources Control Board (SWRCB), on or before April 1, 2003, to adopt emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators. The SWRCB granted a delay in adoption as requested by other State agencies and stakeholders.

7. This action to adopt emergency solar evaporator regulations is exempt from the requirements of the California Environmental Quality Act pursuant to Public Resources Code section 21080(b)(4).

8. The SWRCB has developed new solar evaporator regulations in compliance with Senate Bill 1372 (SB 1372) to be located within California Code of Regulations Title 27, that facilitate the development and implementation of solar evaporators as components of IFDM systems, while protecting avian wildlife safety and groundwater quality.

THEREFORE BE IT RESOLVED THAT:

The State Water Resources Control Board adopts emergency regulations (see attachment) that establish minimum requirements for the design, construction, operation, and closure of solar evaporators as components of IFDM systems in compliance with SB 1372.

CERTIFICATION

The undersigned, Clerk to the Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on July 16, 2003.

____

Debbie Irvin
Clerk to the Board

Title 27. Environmental Protection

Division 2. Solid Waste

Subdivision 1. Consolidated Regulations for Treatment, Storage, Processing, or Disposal of Solid Waste

Chapter 7. Special Treatment, Storage, and Disposal Units

Subchapter 6. Solar Evaporators

Article 1. Solar Evaporator Regulations

[Note: regulations in this article were promulgated by the State Water Resources Control Board (SWRCB), are administered by the appropriate Regional Water Quality Control Board (RWQCB), and are applicable to the owner or operator of a solar evaporator for the management of agricultural drainage water discharges from an integrated on-farm drainage management system (IFDM).]

§22900. SWRCB – Applicability.

(a) General—This article applies to the discharge of agricultural drainage water from Integrated On-Farm Drainage Management (IFDM) systems to solar evaporators as defined in §22910. No SWRCB-promulgated parts of the Division 2 of Title 27 and Division 3, Chapter 15 of Title 23 of the California Code of Regulations (CCR) shall apply to the discharge of agricultural drainage water from IFDM systems to solar evaporators unless those sections are specifically referenced in this article. Any person who intends to operate a solar evaporator after ~~July 1, 2003~~ [effective date] shall comply with the requirements of this article before a Notice of Plan Compliance and Notice of Authority to Operate (§25209.13 of Article 9.7 of the Health and Safety Code) will be issued by a Regional Water Quality Control Board (RWQCB).

§22910. SWRCB – Definitions.

For purposes of this article, the following terms have the following meanings:

(a) "Adequately protected" means that:
(1) Avian wildlife have no access to standing water in a water catchment basin.
(2) Standing water does not occur in a solar evaporator outside of a water catchment basin, under reasonably forseeable operating conditions.

(3) The solar evaporator, including the water catchment basin, does not become a medium for the growth of ~~aerial~~ aquatic and semi-aquatic macro invertebrates that could become a harmful food source for avian wildlife, under reasonably forseeable operating conditions.

(b) "Agricultural drainage water" means surface drainage water or percolated irrigation water that is collected by subsurface drainage tiles placed beneath an agricultural field.

(c) “Avian Wildlife Biologist” means any State or federal agency biologist, ecologist, environmentalspecialist (or equivalent title) with relevant avian wildlife monitoring experience (as determined by the RWQCB), or any professional biologist, ecologist, environmental specialist (or equivalent title) possessing valid unexpired State and federal collecting permits for avian wildlife eggs.

(d) “Boundaries of the solar evaporator” or “boundaries of a solar evaporator” means the outer edge of the solar evaporator or any component of the solar evaporator, including, but not limited to, berms, liners, water catchment basins, windscreens, and deflectors.

(~~d~~e) “Certified Engineering Geologist” means a registered geologist, certified by the State of California, pursuant to section 7842 of the Business and Professions Code.

(~~e~~f) “Hydraulic conductivity” means the ability of natural and artificial materials to transmit water. The term is expressed as a measure of the rate of flow through a unit area cross-section of material. The unit of measure is cm/sec.

(~~f~~g) "Integrated on-farm drainage management system" means a facility for the on-farm management of agricultural drainage water that does all of the following:
(1) Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.
(2) Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural drainage water is substantially decreased and its salt content significantly increased.
(3) Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.
(4) Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated on-farm drainage management system and the solar evaporator.

(~~g~~h) “Liner” means:
(1) a continuous layer of natural or artificial material, or a continuous membrane of flexible and durable artificial material, or a continuous composite layer consisting of a membrane of flexible artificial material directly overlying a layer of engineered natural material, which is installed beneath a solar evaporator, and which acts as a barrier to vertical water movement, and
(2) a material that has appropriate chemical and physical properties to ensure that the liner does not fail to contain agricultural drainage water because of pressure gradients, physical contact with the agricultural drainage water, chemical reactions with soil, climatic conditions, ultraviolet radiation (if uncovered), the stress of installation, and the stress of daily operation, and

(3) a material that has a minimum thickness of 40 mils (0.040 inches) for flexible artificial membranes or synthetic liners.
(4) The requirements of this definition are applicable only if a liner is used to meet the requirements of §22920(c).

(~~h~~i) “Nuisance” means anything which meets all of the following requirements:
(1) Is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property.
(2) Affects at the same time an entire community or neighborhood, or a considerable number of persons, although the extent of the annoyance or damage inflicted on individuals may be unequal.
(3) Occurs during, or as a result of, the treatment or disposal of wastes.

(~~i~~j) "On-farm" means within the boundaries of a property, geographically contiguous properties, or a portion of the property or properties, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an IFDM system and a solar evaporator.

(~~j~~k).”Pollution” means an alteration of the quality of the waters of the state by waste to a degreewhich unreasonably affects either of the following:
(1) The waters for beneficial uses.
(2) Facilities which serve these beneficial uses.

(~~k~~l) “Reasonably foreseeable operating conditions” means:
(1) within the range of the design discharge capacity of the IFDM system and the authorized solar evaporator system as specified in the Notice of Plan Compliance and Notice of Authority to Operate (§25209.13 of Article 9.7 of the Health and Safety Code),
(2) precipitation up to and including the local 25-year, 24-hour storm, and
(3) floods with a 100-year return period.
Operation of a solar evaporator in exceedance of design specifications is not covered by “reasonably foreseeable operating conditions,” and therefore would constitute a violation of the Notice of Authority to Operate.

(~~l~~m) “Regional Board” and “RWQCB” means a California Regional Water Quality Control Board.

(~~m~~n) “Registered Agricultural Engineer” means an agricultural engineer registered by the State of | California, pursuant to section 6732 of the Business and Professions Code.

(~~n~~o) “Registered Civil Engineer” means a civil engineer registered by the State of California, pursuant to section 6762 of the Business and Professions Code.

(~~o~~p) “Registered Geologist” means a geologist registered by the State of California, pursuant to section 7842 of the Business and Professions Code.

(~~p~~q) "Solar evaporator" means an on-farm area of land and its associated equipment that meets all of the following conditions:

(1) It is designed and operated to manage agricultural drainage water discharged from the IFDM system.
(2) The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the IFDM system.
(3) Agricultural drainage water from the IFDM system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.
(4) The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface tile drainage under the solar evaporator provides adequate assurance that constituents in the agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(~~q~~r) "Standing water" means water occurring under all of the following conditions:
(1) to a depth greater than one centimeter,
(2) for a continuous duration in excess of 48 hours,
(3) as a body of any areal extent, not an average depth, and
(4) under reasonably forseeable operating conditions.

(~~r~~s) "Subsurface drainage tiles" or "subsurface tile drainage" means any system of subsurface drainage collection utilizing drainage tiles, perforated pipe, or comparable conveyance, placed below the surface of any IFDM system area including the solar evaporator.

(~~s~~t) "Unreasonable threat" to avian wildlife means that avian wildlife is not adequately protected.

(~~t~~u) "Vadose zone" means the unsaturated zone between the soil surface and the permanent groundwater table.

(~~u~~v) "Water catchment basin" means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin. A water catchment basin may include an enclosed solar still, greenhouse or other fully contained drainage storage unit. For the purposes of this definition, the term "within the boundaries of a solar evaporator" shall include a solar still, greenhouse, or other fully contained drainage storage unit adjacent to or near the portion of the solar evaporator that is outside the catchment basin.

(~~u~~w) "Waters of the state" means any surface water or groundwater, including saline water, within the boundaries of the state.

§22920. SWRCB – Solar Evaporator Design Requirements.

(a) Registered Professionals—Solar evaporators shall be designed by a registered civil or agricultural engineer, or a registered geologist or certified engineering geologist.

(b) Flooding--A solar evaporator shall be located outside the 100-year floodplain, or shall be constructed with protective berms/levees sufficient to protect the solar evaporator from overflow and inundation by 100-year floodwaters, or shall be elevated above the maximum elevation of a 100-year flood.

(c) Protection of Groundwater Quality -- Solar evaporators shall be immediately underlain by at least 1 meter of soil with a hydraulic conductivity of not more than 1×10^{-6} cm/sec above the zone of shallow groundwater at any time during the year. The surface of the solar evaporator shall be a minimum of five-feet (5 ft.) above the highest anticipated elevation of underlying groundwater. A solar evaporator may be constructed on a site with soils that do not meet the above requirement, with subsurface tile drainage under or directly adjacent to the solar evaporator, a liner, or other engineered alternative, sufficient to provide assurance of the equivalent level of groundwater quality protection of the above soil requirement.

(d) Discharge to the Facility -- All discharge to the solar evaporator shall be agricultural drainage water collected from the IFDM system or recirculated from the solar evaporator as a component of the IFDM system. No agricultural drainage water from the IFDM system or the solar evaporator may be discharged outside the boundaries of ~~the area of land that makes up~~ the solar | evaporator

(e) Facility Size -- The area of land that makes up the solar evaporator may not exceed 2 percent of the area of land that is managed by the IFDM system.

(f) Means of Discharge to the Facility – Discharge of agricultural drainage water from the IFDM system to the solar evaporator shall be by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water in the solar evaporator, outside a water catchment basin. The sprinklers shall be equipped with screens or shields or other devices as necessary to prevent the drift of agricultural drainage water spray outside the boundaries of the solar evaporator.

(g) Water Catchment Basin -- A water catchment basin may be required:
(1) As a component of a solar evaporator if standing water would otherwise occur within the solar evaporator under reasonably foreseeable operating conditions, or
(2) If a solar evaporator is constructed with a liner. In this case, a water catchment basin shall be designed with the capacity to contain the maximum volume of water that the solar evaporator would collect under reasonably forseeable operating conditions. A water catchment basin is not required for a solar evaporator that does not have a liner, if it is demonstrated that standing water will not occur under reasonably foreseeable operating conditions.

(h) Avian Wildlife Protection -- The solar evaporator shall be designed to ensure that avian wildlife is adequately protected as set forth in §22910 (a) and (~~u~~v). |

§22930. SWRCB – Solar Evaporator Construction Requirements.

(a) Registered Professionals—Construction of solar evaporators shall be supervised and certified, by a registered civil or agricultural engineer, or a registered geologist or certified engineering geologist, as built according to the design requirements and Notice of Plan Compliance (§25209.13 of Article 9.7 of the Health and Safety Code).

§22940. SWRCB – Solar Evaporator Operation Requirements.

(a) Limitation on Standing Water -- The solar evaporator shall be operated so that, under reasonably forseeable operating conditions, the discharge of agricultural drainage water to the solar evaporator will not result in standing water, outside of a water catchment basin. Agricultural drainage water from the IFDM system shall be discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water in the solar evaporator.

(b) Prevention of Nuisance -- The solar evaporator shall be operated so that, under reasonably forseeable operating conditions, the discharge of agricultural drainage water to the solar evaporator does not result in:
(1) The drift of salt spray, mist, or particles outside of the boundaries of the solar evaporator, or
(2) Any other nuisance condition.

(c) Prohibition of Outside Discharge -- The operation of a solar evaporator shall not result in any discharge of agricultural drainage water outside the boundaries of ~~the area of land that makes up~~ | the solar evaporator.

(d) Salt Management -- For solar evaporators in continuous operation under a Notice of Authority to Operate issued by a Regional Water Quality Control Board, evaporite salt accumulated in the solar evaporator shall be collected and removed from the solar evaporator if and when the accumulation is sufficient to interfere with the effectiveness of the operation standards of the solar evaporator as specified in this section. One of the following three requirements shall be selected and implemented by the owner or operator:
(1) Evaporite salt accumulated in the solar evaporator may be harvested and removed from the solar evaporator and sold or utilized for commercial, industrial, or other beneficial purposes.
(2) Evaporite salt accumulated in the solar evaporator may be stored for a period of one-year, renewable subject to an annual inspection, in a fully contained storage unit inaccessible to wind, water, and wildlife, until sold, utilized in a beneficial manner, or disposed in accordance with (3).
(3) Evaporite salt accumulated in the solar evaporator may be collected and removed from the solar evaporator, and disposed permanently as a waste in a facility authorized to accept such

waste in compliance with the requirements of Titles 22, 23, 27 and future amendments of the CCR, or Division 30 (commencing with Section 40000) of the Public Resources Code.

(e) Monitoring -- Monitoring and record keeping, including a groundwater monitoring schedule, data, and any other information or reporting necessary to ensure compliance with this article, shall be established by the RWQCB in accord with §25209.14 of Article 9.7 of the Health and Safety Code.

(f) Avian Wildlife Protection -- The solar evaporator shall be operated to ensure that avian wildlife is adequately protected as set forth in §22910 (a) and (~~u~~v). The following Best Management Practices are required:
(1) Solar evaporators (excluding water catchment basins) shall be kept free of all vegetation.
(2) Grit-sized gravel (<5 mm in diameter) shall not be used as a surface substrate within the solar evaporator.
(3) Netting or other physical barriers for excluding avian wildlife from water catchment basins shall not be allowed to sag into any standing water within the catchment basin.
(4) The emergence and dispersal of ~~aerial~~ aquatic and semi-aquatic macro invertebrates or aquatic plants outside of the boundary of the water catchment basin shall be prevented.
(5) The emergence of the pupae of ~~aerial~~ aquatic and semi-aquatic macro invertebrates from the water catchment basin onto the netting, for use as a pupation substrate, shall be prevented.

(g) Inspection – The RWQCB issuing a Notice of Authority to Operate a solar evaporator shall conduct authorized inspections in accord with §25209.15 of Article 9.7 of the Health and Safety Code to ensure continued compliance with the requirements of this article. The RWQCB shall request an avian wildlife biologist to assist the RWQCB in its inspection of each authorized solar evaporator at least once annually during the month of May. If an avian wildlife biologist is not available, the RWQCB shall nevertheless conduct the inspection. During the inspection, observations shall be made for compliance with §22910 (a) and (~~u~~v), and the following conditions that indicate an unreasonable threat to avian wildlife:
(1) Presence of vegetation within the ~~perimeter~~ boundaries of the solar evaporator;
(2) Standing water or other mediums within the solar evaporator that support the growth and dispersal of ~~aerial~~ aquatic or semi-aquatic macro invertebrates or aquatic plants;
(3) Abundant sustained avian presence within the solar evaporator that could result in nesting activity;
(4) An apparent avian die-off or disabling event within the solar evaporator;
(5) Presence of active avian nests with eggs within the ~~perimeter~~ boundaries of the solar evaporator.

If active avian nests with eggs are found within the ~~perimeter~~ boundaries of the solar evaporator, the RWQCB shall report the occurrence to the USFWS and DFG within 24 hours, and seek guidance with respect to applicable wildlife laws and implementing regulations. Upon observation of active avian nests with eggs within the ~~perimeter~~ boundaries of the solar evaporator, all discharge of agricultural drainage water to the solar evaporator shall cease until (a) the nests are no longer active, or (b) written notification is received by the owner or operator, from the RWQCB, waiving the prohibition of discharge in compliance with all applicable state and federal wildlife laws and implementing regulations (i.e., as per applicable exemptions and allowable take provisions of such laws and implementing regulations.)

§22950. SWRCB – Solar Evaporator Closure Requirements.

(a) For solar evaporators ceasing operation through discontinuance of operation or non-renewal of a Notice of Authority to Operate issued by a RWQCB, closure and post-closure plans shall be prepared and submitted to the RWQCB and approved by the RWQCB prior to closure. Closure plans shall conform to one of the following three requirements to be selected and implemented by the owner or operator:

(1) Evaporite salt accumulated in the solar evaporator may be harvested and removed from the solar evaporator and sold or utilized for commercial, industrial, or other beneficial purposes or stored for a period of one-year, renewable subject to an annual inspection, in a fully contained storage unit inaccessible to wind, water, and wildlife, until sold, utilized in a beneficial manner, or disposed in accordance with (3). After the removal of accumulated salt, the area within the boundaries of the solar evaporator shall be restored to a condition that does not pollute or threaten to pollute the waters of the state, that does not constitute an unreasonable threat to avian wildlife, and that does not constitute a nuisance condition. Clean closure may be accomplished in accord with §21090(f) and §21400 of CCR Title 27.

(2) The solar evaporator may be closed in-place, with installation of a final cover with foundation, low-hydraulic conductivity, and erosion-resistant layers, as specified in §21090 and §21400 of CCR Title 27. Closure in-place shall include a closure plan and post-closure cover maintenance plan in accord with §21090 and §21769 of CCR Title 27.

(3) Evaporite salt accumulated in the solar evaporator may be collected and removed from the solar evaporator, and disposed permanently as a waste in a facility authorized to accept such waste in compliance with the requirements of Titles 22, 23, 27 and future amendments of the CCR, or Division 30 (commencing with Section 40000) of the Public Resources Code. After the removal of accumulated salt, the area within the boundaries of the solar evaporator shall be restored to a condition that does not pollute or threaten to pollute the waters of the state, that does not constitute an unreasonable threat to avian wildlife, and that does not constitute a nuisance condition.

Senate Bill No. 1372

CHAPTER 597

An act to amend Section 25208.3 of, and to add Article 9.7 (commencing with Section 25209.10) to Chapter 6.5 of Division 20 of, the Health and Safety Code, relating to water.

[Approved by Governor September 15, 2002. Filed with Secretary of State September 16, 2002.]

LEGISLATIVE COUNSEL'S DIGEST

SB 1372, Machado. State Water Resources Control Board: agricultural drainage: solar evaporators.

(1) Under the Agricultural Water Conservation and Management Act, water suppliers, as defined, individually, or in cooperation with other public agencies or persons, may institute a water conservation or efficient water management program consisting of farm and agricultural related components. Existing law, the Toxic Pits Cleanup Act of 1984, prohibits a person from discharging liquid hazardous wastes into a surface impoundment if the surface impoundment, or the land immediately beneath the impoundment, contains hazardous wastes and is within $^{1}/_{2}$ mile upgradient from a potential source of drinking water.

This bill would require the State Water Resources Control Board to adopt, on or before April 1, 2003, emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators, as defined. The bill would require any person who intends to operate a solar evaporator to file a notice of intent with the regional water quality control board. The bill would specify a procedure for the issuance of a notice of authority by the regional board to operate a solar evaporator, including requiring the regional board to inspect the solar evaporator prior to authorizing the operation of the solar evaporator. The bill would prohibit a regional board from issuing a notice of authority to operate a solar evaporator on and after January 1, 2008.

The bill would require any person operating a solar evaporator to submit annually, according to a schedule established by the regional board, groundwater monitoring data and other information deemed necessary by the regional board. The bill would require the regional board to inspect any solar evaporator at least once every 5 years to ensure continued compliance with the provisions of the bill.

The bill would exempt any solar evaporator operating under a valid written notice of authority to operate issued by the regional board, including any facility that the regional board determines is in compliance with the requirements of the bill, from the provisions of the toxic pits act and other specified waste discharge requirements imposed under the Porter-Cologne Water Quality Control Act.

Because the provisions added by the bill would be located within the hazardous waste control laws and a violation of those laws is a crime, the bill would impose a state-mandated local program by creating new crimes regarding the operation of solar evaporators.

(2) Existing law, the toxic pits act, requires the state board to impose a fee upon any person discharging any liquid hazardous waste or hazardous waste containing free liquids into a surface impoundment. The state board is required to collect and deposit the fees in the Surface Impoundment Assessment Account in the General Fund. The money within that account is available, upon appropriation, to the state board and the regional boards for purposes of administering the toxic pits act.

This bill would additionally authorize the board to expend the fees deposited in the account for the purpose of administering the surface impoundments that would be exempted from the toxic pits act by the bill, thereby imposing a tax for purposes of Article XIII A of the California Constitution.

(3) The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement.

This bill would provide that no reimbursement is required by this act for a specified reason.

The people of the State of California do enact as follows:

SECTION 1. Section 25208.3 of the Health and Safety Code is amended to read:

25208.3. (a) The state board shall, by emergency regulation, adopt a fee schedule that assesses a fee upon any person discharging any liquid hazardous wastes or hazardous wastes containing free liquids into a surface impoundment, except as provided in Section 25208.17. The state board shall include in this fee schedule the fees charged for applications for, and renewals of, an exemption from Section 25208.5, as specified in subdivision (h) of Section 25208.5, from subdivision (a) of Section 25208.4, as specified in subdivision (b) of Section 25208.4, from subdivision (c) of Section 25208.4, as specified in Section 25208.16, and from Sections 25208.4 and 25208.5, as specified in subdivision (e) of Section 25208.13. The state board shall also include provisions in the fee schedule for assessing a penalty pursuant to subdivision (c). The state board shall set these fees at an amount equal to the state board's and regional board's reasonable and anticipated costs of administering this article.

(b) The emergency regulations that set the fee schedule shall be adopted by the state board in accordance with Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, and for the purposes of that chapter, including Section 11349.6 of the Government Code, the adoption of these regulations is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health and safety, and general welfare. Notwithstanding Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, any emergency regulations adopted by the state board pursuant to this section shall be filed with, but not be repealed by, the Office of Administrative Law and shall remain in effect until revised by the state board.

(c) The state board shall send a notice to each person subject to the fee specified in subdivision (a). If a person fails to pay the fee within 60 days after receipt of this notice, the state board shall require the person to pay an additional penalty fee. The state board shall set the penalty fee at not more than 100 percent of the assessed fee, but in an amount sufficient to deter future noncompliance, as based upon that person's past history of compliance and ability to pay, and upon additional expenses incurred by this noncompliance.

(d) The state board shall collect and deposit the fees collected pursuant to this article in the Surface Impoundment Assessment Account, which is hereby created in the General Fund. The money within the Surface Impoundment Assessment Account is available, upon appropriation by the Legislature, to the state board and the regional boards for purposes of administering this article and Article 9.7 (commencing with Section 25209.10).

SEC. 2. Article 9.7 (commencing with Section 25209.10) is added to Chapter 6.5 of Division 20 of the Health and Safety Code, to read:

Article 9.7. Integrated On-Farm Drainage Management

25209.10. The Legislature finds and declares all of the following:

(a) The long-term economic and environmental sustainability of agriculture is critical to the future of the state, and it is in the interest of the state to enact policies that enhance that sustainability.

(b) High levels of salt and selenium are present in many soils in the state as a result of both natural occurrences and irrigation practices that concentrate their presence in soils.

(c) The buildup of salt and selenium in agricultural soil is an unsustainable practice that degrades soil, harms an irreplaceable natural resource, reduces crop yields and farm income, and poses threats to wildlife.

(d) Salt and selenium buildup can degrade groundwater, especially in areas with perched groundwater aquifers.

(e) Off-farm drainage of irrigation water with high levels of salt and selenium degrades rivers and waterways, particularly the San Joaquin River and its tributaries. This environmental damage presents a clear and imminent danger that warrants immediate action to prevent or mitigate harm to public health and the environment.

(f) Discharge of agricultural drainage water to manmade drains and ponds has resulted in environmental damage, including damage to wildlife. Proposals to discharge agricultural drainage to natural water bodies, including the San Francisco Bay, are extremely expensive and pose threats to the environmental quality of those water bodies.

(g) Water supplies for agricultural irrigation have been reduced significantly in recent years, necessitating increased efforts to use water more efficiently.

(h) Although salt can be collected and managed as a commercial farm commodity, California currently imports salt from other countries.

(i) Integrated on-farm drainage management is a sustainable system of managing salt-laden farm drainage water. Integrated on-farm drainage management is designed to eliminate the need for off-farm drainage of irrigation water, prevent the on-farm movement of irrigation and drainage water to groundwater, restore and enhance the productive value of degraded farmland by removing salt and selenium from the soil, conserve water by reducing the demand for irrigation water, and create the potential to convert salt from a waste product and pollutant to a commercial farm commodity.

(j) Although integrated on-farm drainage management facilities are designed and operated expressly to prevent threats to groundwater and wildlife, these facilities currently may be classified as surface impoundments pursuant to the Toxic Pits Act of 1984, which discourages farmers from using them as an environmentally preferable means of managing agricultural drainage water.

(k) It is the policy of the state to conserve water and to minimize the environmental impacts of agricultural drainage. It is therefore in the interest of the state to encourage the voluntary implementation of sustainable farming and irrigation practices, including, but not limited to, integrated on-farm drainage management, as a means of improving environmental protection, conserving water, restoring degraded soils, and enhancing the economic productivity of farms.

25209.11. For purposes of this article, the following terms have the following meanings:

(a) ‘‘Agricultural drainage water’’ means surface drainage water or percolated irrigation water that is collected by subsurface drainage tiles placed beneath an agricultural field.

(b) ‘‘On-farm’’ means within the boundaries of a property, geographically contiguous properties, or a portion of the property or properties, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an integrated on-farm drainage management system and a solar evaporator.

(c) ‘‘Integrated on-farm drainage management system’’ means a facility for the on-farm management of agricultural drainage water that does all of the following:

(1) Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.

(2) Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural drainage water is substantially decreased and its salt content significantly increased.

(3) Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.

(4) Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated on-farm drainage management system and the solar evaporator.

(d) ‘‘Regional board’’ means a California regional water quality control board.

(e) ‘‘Solar evaporator’’ means an on-farm area of land and its associated equipment that meets all of the following conditions:

(1) It is designed and operated to manage agricultural drainage water discharged from the integrated on-farm drainage management system.

(2) The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the integrated on-farm drainage management system.

(3) Agricultural drainage water from the integrated on-farm drainage management system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.

(4) The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface tile drainage under the solar

evaporator provides adequate assurance that constituents in the agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(f) ‘‘State board’’ means the State Water Resources Control Board.

(g) ‘‘Water catchment basin’’ means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin.

25209.12. On or before April 1, 2003, the state board, in consultation, as necessary, with other appropriate state agencies, shall adopt emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators. The regulations shall include, but are not limited to, requirements to ensure all of the following:

(a) The operation of a solar evaporator does not result in any discharge of on-farm agricultural drainage water outside the boundaries of the area of land that makes up the solar evaporator.

(b) (1) The solar evaporator is designed, constructed, and operated so that, under reasonably forseeable operating conditions, the discharge of agricultural water to the solar evaporator does not result in standing water.

(2) Notwithstanding paragraph (1), a solar evaporator may be designed, constructed, and operated to accommodate standing water, if it includes a water catchment basin.

(3) The board may specify those conditions under which a solar evaporator is required to include a water catchment basin to prevent standing water that would otherwise occur within the solar evaporator.

(c) Avian wildlife is adequately protected. In adopting regulations pursuant to this subdivision, the state board shall do the following:

(1) Consider and, to the extent feasible, incorporate best management practices recommended or adopted by the United States Fish and Wildlife Service.

(2) Establish guidelines for the authorized inspection of a solar evaporator by the regional board pursuant to Section 25209.15. The guidelines shall include technical advice developed in consultation with the Department of Fish and Game and the United States Fish and Wildlife Service that may be used by regional board personnel to identify observed conditions relating to the operation of a solar evaporator that indicate an unreasonable threat to avian wildlife.

(d) Constituents in agricultural drainage water discharged to the solar evaporator will not migrate from the solar evaporator into the vadose zone or the waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(e) Adequate groundwater monitoring and recordkeeping is performed to ensure compliance with the requirements of this article.

(f) Salt isolated in a solar evaporator shall be managed in accordance with all applicable laws and shall eventually be harvested and sold for commercial purposes, used for beneficial purposes, or stored or disposed in a facility authorized to accept that waste pursuant to this chapter or Division 30 (commencing with Section 40000) of the Public Resources Code.

25209.13. (a) Any person who intends to operate a solar evaporator shall, before installing the solar evaporator, file a notice of intent with the regional board, using a form prepared by the regional board. The form shall require the person to provide information including, but not limited to, all of the following:

(1) The location of the solar evaporator.

(2) The design of the solar evaporator and the equipment that will be used to operate it.

(3) The maximum anticipated rate at which agricultural drainage water will be discharged to the solar evaporator.

(4) Plans for operating the solar evaporator in compliance with the requirements of this article.

(5) Groundwater monitoring data that are adequate to establish baseline data for use in comparing subsequent data submitted by the operator pursuant to this article.

(6) Weather data and a water balance analysis sufficient to assess the likelihood of standing water occurring within the solar evaporator.

(b) The regional board shall, within 30 calendar days after receiving the notice submitted pursuant to subdivision (a), review its contents, inspect, if necessary, the site where the proposed solar evaporator will be located, and notify the operator of the proposed solar evaporator whether it will comply with the requirements of this article. If the regional board determines that the proposed solar evaporator will not comply with this article, the regional board shall issue a written response to the applicant identifying the reasons for noncompliance. If the regional board determines the solar evaporator will comply with the requirements of this article, the regional board shall issue a written notice of plan compliance to the operator of the proposed solar evaporator.

(c) Any person who receives a written notice of plan compliance pursuant to subdivision (b) shall, before operating the installed solar evaporator, request the regional board to conduct a compliance inspection of the solar evaporator. Within 30 calendar days after receiving a request, the regional board shall inspect the solar evaporator and notify the operator whether it complies with the requirements of this article. If the regional board finds that the solar evaporator does not comply with the requirements of this article, the regional board shall issue a written response to the applicant identifying the reasons for noncompliance. Except as provided in subdivision (e), if the regional board determines that the solar evaporator complies with the requirements of this article, the regional board shall issue a written notice of authority to operate to the operator of the solar evaporator. The regional board may include in the authority to operate any associated condition that the regional board deems necessary to ensure compliance with the purposes and requirements of this article.

(d) No person may commence the operation of a solar evaporator unless the person receives a written notice of authority to operate the solar evaporator pursuant to this section.

(e) (1) On and after January 1, 2008, a regional board may not issue a written notice of authority to operate a solar evaporator pursuant to this section.

(2) The requirements of paragraph (1) do not affect the validity of any written notice of authority to operate a solar evaporator issued by the regional board before January 1, 2008.

(f) The regional board shall review any authority to operate issued by the regional board pursuant to this section every five years. The regional board shall renew the authority to operate, unless the regional board finds that the operator of the solar evaporator has not demonstrated compliance with the requirements of this article.

25209.14. (a) Any person operating a solar evaporator shall annually, according to a schedule established by the regional board pursuant to subdivision (b), submit groundwater monitoring data and any other information that is deemed necessary by the regional board to ensure compliance with the requirements of this article.

(b) Each regional board shall adopt a schedule for the submission of the data and information described in subdivision (a) at the earliest possible time. The regional board shall notify the operator of each solar evaporator of the applicable submission schedule.

25209.15. (a) The regional board, consistent with its existing statutory authority, shall inspect any solar evaporator that is authorized to operate pursuant to Section 25209.13 at least once every five years to ensure continued compliance with the requirements of this article. In conducting any inspection, the regional board may request the participation of a qualified state or federal avian biologist in a technical advisory capacity. The regional board shall include in the inspection report conducted pursuant to this section any evidence of adverse impacts on avian wildlife and shall forward the report to the appropriate state and federal agencies.

(b) If the regional board, as a result of an inspection or review conducted pursuant to this article, determines that a solar evaporator is not in compliance with the requirements of this article, the regional board shall provide written notice to the operator of the solar evaporator of that failure, and shall include in that written notice the reasons for that determination.

(c) Chapter 5 (commencing with Section 13300) of, and Chapter 5.8 (commencing with Section 13399) of, Division 7 of the Water Code apply to any failure to comply with the requirements of this article and to any action, or failure to act, by the state board or a regional board. The regional board may, consistent with Section 13223 of the Water Code, revoke or modify an authorization to operate issued pursuant to this article.

25209.16. (a) For the purposes of Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, including Section 11349.6 of the Government Code, the adoption of the regulations required to be adopted pursuant to Section 25209.12 is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health and safety, and general welfare.

(b) Notwithstanding Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, any emergency regulations adopted by the state board pursuant to Section 25209.12 shall be filed with, but not be repealed by, the Office of Administrative Law and shall remain in effect until revised by the state board.

25209.17. Any solar evaporator operating under a valid written notice of authority to operate issued by the regional board pursuant to this article, including any facility operating pursuant to Article 9.5 (commencing with Section 25208) prior to January 1, 2003, that the regional board determines is in compliance with the requirements of this article, is not subject to Article 9.5 (commencing with Section 25208) or Sections 13260 or 13263 of the Water Code. Upon determining pursuant to this section that a facility is a solar evaporator in compliance with this article, the regional board shall, as appropriate, revise or rescind any waste discharge requirements or other requirements imposed on the operator of the facility pursuant to Article 9.5 (commencing with Section 25208) or Section 13260 or 13263 of the Water Code.

SEC. 3. No reimbursement is required by this act pursuant to Section 6 of Article XIII B of the California Constitution because the only costs that may be incurred by a local agency or school district will be incurred because this act creates a new crime or infraction, eliminates a crime or infraction, or changes the penalty for a crime or infraction, within the meaning of Section 17556 of the Government Code, or changes the definition of a crime within the meaning of Section 6 of Article XIII B of the California Constitution.