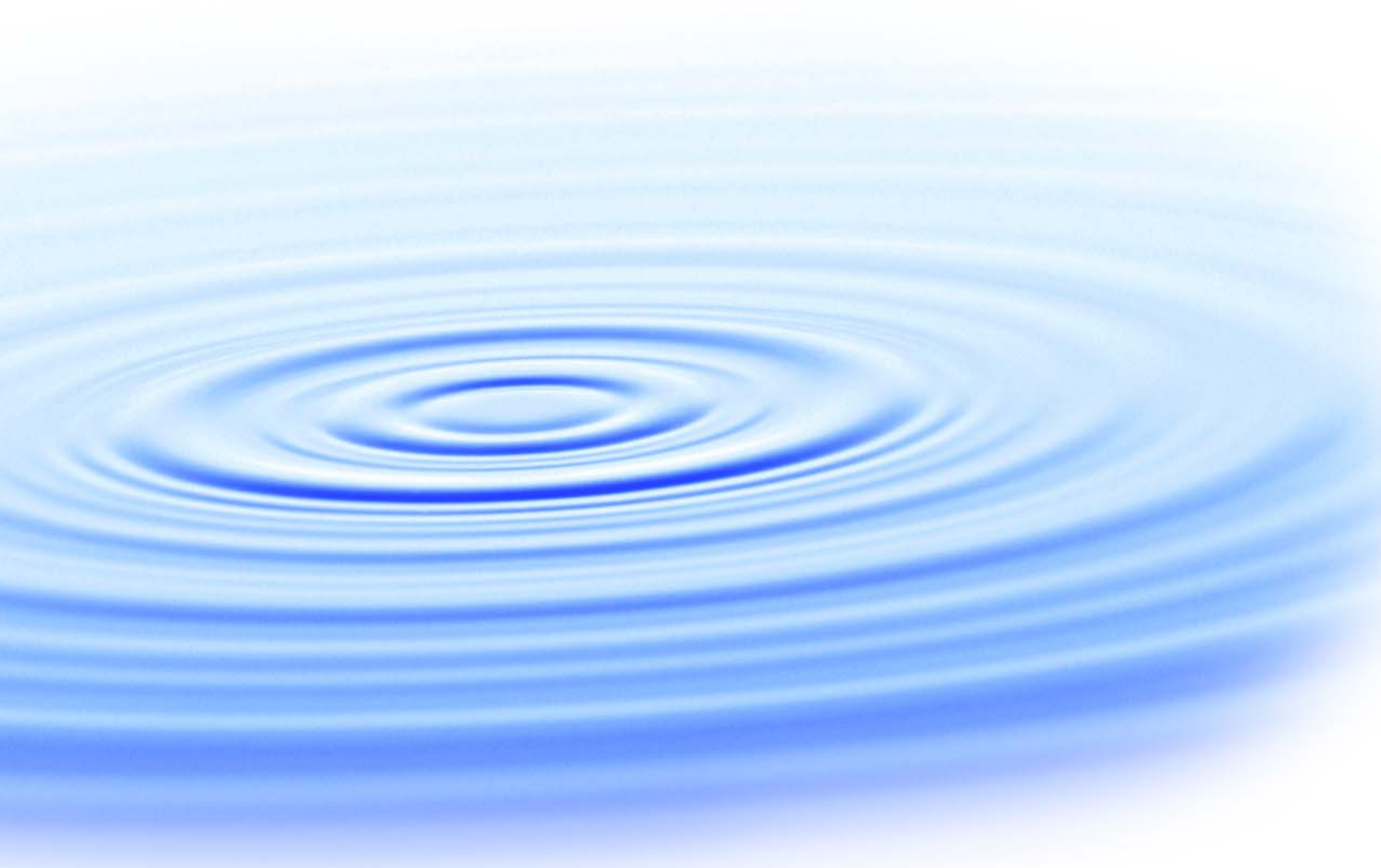
WateReuse Foundation

Regional Solutions for Concentrate Management



WateReuse Foundation

Regional Solutions for Concentrate Management

About the WateReuse Foundation

The mission of the WateReuse Foundation is to conduct and promote applied research on the reclamation, recycling, reuse, and desalination of water. The Foundation's research advances the science of water reuse and supports communities across the United States and abroad in their efforts to create new sources of high quality water through reclamation, recycling, reuse, and desalination while protecting public health and the environment.

The Foundation sponsors research on all aspects of water reuse, including emerging chemical contaminants, microbiological agents, treatment technologies, salinity management and desalination, public perception and acceptance, economics, and marketing. The Foundation's research informs the public of the safety of reclaimed water and provides water professionals with the tools and knowledge to meet their commitment of increasing reliability and quality.

The Foundation's funding partners include the U.S. Bureau of Reclamation, the California State Water Resources Control Board, the Southwest Florida Water Management District, and the California Department of Water Resources. Funding is also provided by the Foundation's Subscribers, water and wastewater agencies, and other interested organizations. The Foundation also conducts research in cooperation with the Global Water Research Coalition.

Regional Solutions for Concentrate Management

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Disclaimer

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TABLES

ACRONYMS

gpm	gallons per minute
HMTA	Hazardous Materials Transportation Act
mgd	million gallons per day
NEPA	National Environmental Policy Act
NF	nanofiltration
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance (costs)
PAC	Project Advisory Committee (WRF)
RAC	Research Advisory Committee (WRF)
RCRA	Resource Conservation and Recovery Act
RHA	Rivers and Harbors Act
RID	Roosevelt Irrigation District (AZ)
RO	reverse osmosis
ROW	right of way
SAR	sodium adsorption ratio
SDWA	Safe Drinking Water Act
SROG	Sub-Regional Operating Group
TCLP	toxic characteristic leachate potential (test)
TDS	total dissolved solids
TSCA	Toxic Substances Control Act
UIC	Underground Injection Control
WRF	WateReuse Foundation
WSMPU	Water System Master Planning Update (City of Phoenix, AZ)
WTF	water treatment facility
WWTP	wastewater treatment plant
ZLD	zero liquid discharge

FOREWORD

The WateReuse Foundation, a nonprofit corporation, sponsors research that advances the science of water reclamation, recycling, reuse, and desalination. The Foundation funds projects that meet the water reuse and desalination research needs of water and wastewater agencies and the public. The goal of the Foundation's research is to ensure that water reuse and desalination projects provide high-quality water, protect public health, and improve the environment.

A Research Plan guides the Foundation's research program. Under this plan, a research agenda of high-priority topics is maintained. The agenda is developed in cooperation with the water reuse and desalination communities, including water professionals, academics, and Foundation Subscribers. The Foundation's research focuses on a broad range of water reuse research topics, including the following:

- Defining and addressing emerging contaminants
- Public perceptions of the benefits and risks of water reuse
- Management practices related to indirect potable water reuse
- Groundwater recharge and aquifer storage and recovery
- Evaluating methods for managing salinity and desalination
- Economics and marketing of water reuse

The Research Plan outlines the role of the Foundation's Research Advisory Committee (RAC), Project Advisory Committees (PACs), and Foundation staff. The RAC sets priorities, recommends projects for funding, and provides advice and recommendations on the Foundation's research agenda and other related efforts. PACs are convened for each project and provide technical review and oversight. The Foundation's RAC and PACs consist of experts in their fields and provide the Foundation with an independent review, which ensures the credibility of the Foundation's research results. The Foundation's Project Managers facilitate the efforts of the RAC and PACs and provide overall management of projects.

The Foundation's primary funding partner is the U.S. Bureau of Reclamation. Other funding partners include the California State Water Resources Control Board, the California Department of Water Resources, the Southwest Florida Water Management District, Foundation Subscribers, water and wastewater agencies, and other interested organizations. The Foundation leverages its financial and intellectual capital through these partnerships and funding relationships. The Foundation is also a member of the Global Water Research Coalition.

This publication is the result of a study sponsored by the Foundation and is intended to communicate the results of this research project. The goals of this project were to survey concentrate disposal and management practices and to develop a decision methodology for managers, regulators, and other stakeholders to assess the viability of concentrate disposal options on regional and local bases.

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WateReuse Foundation

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Executive Director
WateReuse Foundation

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This project and its underlying research were funded by the WateReuse Foundation in conjunction with the U.S. Bureau of Reclamation, the California State Water Resources Control Board, the Awwa Research Foundation, the Water Environment Research Federation, and the City of Phoenix.

This study would not have been possible without the dedication of the following individuals and organizations: Brandy Kelso (City of Phoenix Water Services Department, AZ) and Dave Cash and Theresa Connor (Sarasota County, FL). The project team would like to thank the WateReuse Foundation for funding this applied research project, the City of Phoenix Water Services Department for their cash contribution, and Sarasota County, FL, and the Irvine Ranch Water District, CA, for their in-kind contributions.

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EXECUTIVE SUMMARY

PROJECT BACKGROUND AND OBJECTIVES

The WateReuse Foundation identified a need for research to investigate the impact of a geographical region on the potential solutions for desalination concentrate disposal and management in an effort to help managers, regulators, and stakeholders assess the viability of concentrate disposal options on a regional and local basis.

Funded by the WateReuse Foundation, Carollo Engineers, P.C., managed a 1.5-year applied research project to survey concentrate disposal and management practices and develop a decision methodology for managers, regulators, and stakeholders to assess the viability of concentrate disposal options on a regional and local basis. Co-Principal Investigators were Dr. Erin Mackey and Mr. Tom Seacord. The project team also included Laura Baumberger, Tracy Clinton, John Kadvany, and Ash Varharkar (also of Carollo Engineers).

The project objectives were as follows:

- To survey concentrate disposal and management practices
- To develop a decision methodology for managers, regulators, and stakeholders to assess the viability of concentrate disposal options on a regional and local basis

Specifically, the research was organized into four key tasks:

Task 1: Develop a literature survey to summarize what options may or may not be available for different regions across the country

Task 2: Develop a decision methodology that can be used across the country to assess not only what concentrate disposal options are technically feasible but also what options are viable and meet the goals set forth in the U.S. Bureau of Reclamation and Sandia National Laboratories report, *2003 Desalination and Water Purification Technology Roadmap*.

Task 3: Outreach: Conduct a Stakeholders Workshop in conjunction with the 2005 Annual WateReuse Association Symposium to solicit feedback on the draft methodology from Task 2 and develop recommendations for improvements that would enhance the utility of the decision model. Pursue publications and presentations at WateReuse Foundation, American Membrane Technology Association, American Water Works Association, and local conferences.

Task 4: Project reporting

CHAPTER 1

INTRODUCTION

Increasing numbers of municipal water suppliers are facing escalating demands for limited fresh water resources. Civil engineers face the challenge of implementing technologies that both provide additional fresh water and meet increasingly stringent environmental, regulatory, and financial constraints. Desalination offers the opportunity to meet increasing freshwater demands by converting brackish water and seawater into new high-quality potable supplies. In 2003, the U.S. Department of the Interior, Bureau of Reclamation, and Sandia National Laboratories collaborated on the *2003 Desalination and Water Purification Technology Roadmap* (the "*Roadmap*"; USBR and SNL, 2003). The *Roadmap* identified a vision for the implementation of desalination technologies to meet our nation's future drinking water supply needs. This vision encompassed three main challenges:

- Provide safe water
- Ensure sustainability and adequacy of the nation's water supply
- Keep water affordable

The disposal and management of desalination process by-product water (i.e., concentrate) is often a major issue in desalting operations. It can affect the safety of water supplies, jeopardize the sustainability of existing water supplies, and contribute significantly to desalination project costs. Furthermore, a complex regulatory environment and questionable public acceptability make planning-level decisions uncertain. This uncertainty makes it very difficult to complete the desalination implementation planning process with a single option for concentrate disposal that has a clear cost, acceptability, and timeline for implementation. Regional solutions for desalination concentrate disposal and management provide a venue for solving some of the uncertainties inherent in the regulatory and planning process and can help to achieve the goals set forth in the *Roadmap.*

1.1 PROJECT OBJECTIVES

The objectives of this study were to survey concentrate disposal and management practices and to develop a decision methodology for managers, regulators, and other stakeholders to assess the viability of concentrate disposal options on a regional and local basis.

While it is important to have a clear understanding of what concentrate disposal options are technically feasible, these options cannot always be implemented. Desalination projects often fail to become reality because concentrate disposal and management (1) may adversely affect the environment (e.g., sustainability, safety of other water sources, salinity balance) and/or (2) may not adequately address stakeholder values (e.g., water rates, water quality specifications, ecological issues).

This decision methodology can be used to integrate local and regional planning, growth forecasts, and water resources availability to develop a regional water supply portfolio that may include desalination. Using this decision process, options for concentrate disposal can be further assessed for viability based upon environmental impacts (e.g., regional salinity balance, safety of other local water supplies), sustainability, costs, and regulatory and public acceptability.

1.2 PROJECT APPROACH

Linking the relationship between technical feasibility and viability from the beginning of the thought process is critical. The focus of this study was to answer two central questions:

- What concentrate disposal and management options are technically feasible for various regions across the country?
- What makes these options not only technically feasible but also logistically and socially viable?

The decision methodology (see the WRFCMDT.mdb tool, included on the attached CD-ROM) and concentrate management survey presented here can help the user determine not only what options are technically feasible but also if and when these options are viable by considering the following:

1. Sustainability and reliability of a water supply portfolio on a local and regional basis
2. Salinity balance and other environmental impacts
3. Stakeholder values (e.g., environmental issues, aesthetics, water rates)
4. The potential need for additional studies to assess environmental impacts and/or to satisfy public interests

The approach used in this report combines a survey of the feasible concentrate disposal options and the associated laws and environmental concerns with an automated decision methodology that walks a user through the process of selecting among the technically feasible treatment options to achieve the following:

1. Understanding the advantages, disadvantages, and limitations of the various options available
2. Determining which alternative(s) would be a sound, defensible choice(s) for the user's desalting concentrate management needs

CHAPTER 2

CONTROLLING PARAMETERS IN CONCENTRATE MANAGEMENT

The effects of desalination concentrate disposal and management on water supply safety, sustainability, and cost often determine whether or not a project can proceed. Intangible stakeholder values also strongly influence the viability of desalination concentrate disposal options. In developing a desalting concentrate disposal plan, it is essential to fully understand and appreciate both what is technically possible for one's region and what decision process must be followed to determine whether an option is logistically and socially viable. (For example, if you are in the desert, you might consider evaporation ponds, but where will you put them? What are the environmental issues? How will the public feel about the cost?)

For decision makers looking to implement desalination, concentrate management is often a new challenge. Managing desalination concentrate is complex; there are many disparate, interrelated issues (Figure 2.1). The decision methodology presented in this report, with its associated materials and referenced supporting information, aims to unravel the decision-making complexities into a clear, well-defined path.

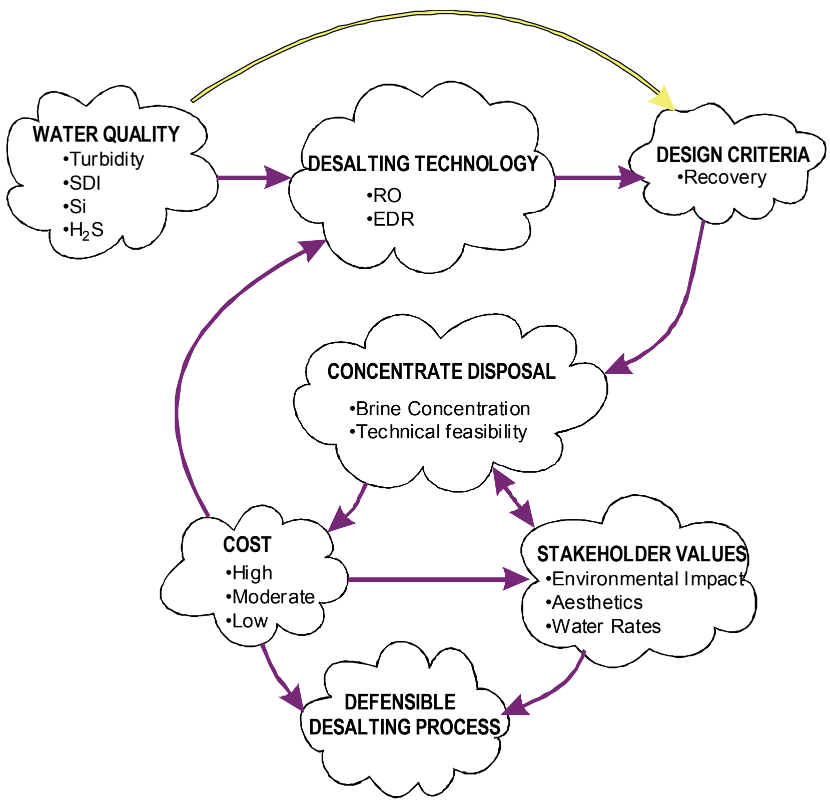

Figure 2.1. The controlling elements of concentrate management planning and implementation influence one another at multiple points in the decision-making process.

2.1 CRITICAL ELEMENTS OF DECISION METHODOLOGY DEVELOPMENT

The first step in developing a decision methodology is to identify and incorporate the key factors that control the decision-making process. This chapter defines the assumptions and controlling parameters used to develop the Concentrate Management Decision Methodology (CMDM) on the attached CD-ROM (WRFCMDM.mdb) and described in Chapters 3–6 by answering the following questions and then summarizing how all these pieces fit together.

- What should the user know about their desalting treatment plan before examining the issue of concentrate management?
- What defines a "region"?
- What issues control the decision-making process?

2.2 DEFINING A DESALTING TREATMENT SCENARIO

The key to a successful concentrate management planning process is to start with a complete treatment scenario. (Note: Each desalting strategy the user develops for concentrate management assessment is referred to here as a "treatment scenario.") In this decision methodology, it is assumed that the desalting (primary) treatment scenario has been defined in advance and the quality and quantity of concentrate to be produced are known. If this is not the case, the user can refer to Appendix A of this report for guidance on developing the broad details of such a scenario. The elements of this desalting treatment scenario are listed in Table 2.1.

Table 2.1. Elements of a Defined Desalting Treatment Scenario

Concentrate Management Site[1] Description	Water Needs	Desalting Process
• Urbanity • Land access • Partnering • Local water source • Salinity issues	• Volume • Water quality - Primary goals[2] - Secondary goals[3] • Long-term issues - Sustainability - Growth - Neighborhood changes	• Primary treatment - EDR - RO - High recovery - Low recovery • Concentrate characteristics - Flow rate - Production pattern(s) - Water quality

Abbreviations: EDR, electrodialysis reversal; RO, reverse osmosis.

[1] The same location as the primary desalting process, an alternate site, or a combination of the two.
[2] Primary Safe Drinking Water Act standards (i.e., health-related maximum contaminant levels).
[3] Secondary Safe Drinking Water Act standards (i.e., aesthetic goals).

2.2.1 Defining "Regions"

One of the cornerstones of this project is the fact that the local environment in which a desalting plan is implemented or considered for implementation greatly controls if and how a concentrate management technology will be selected and implemented. Any decision-making process must go forward within its local technical, geographical, and social spheres. For example, an ocean outfall will not work in the desert Southwest, a 90-ft-tall brine concentrator cannot easily be located in the middle of a neighborhood, and no technology can be installed if the majority of the public is fiscally or philosophically opposed to it. Therefore, the first step in constructing a concentrate management decision-making tool is to define the environment in which you will make your decision. This begins with defining the "region" in which the installation will reside. Simply by identifying the type of geographic region the plant will reside in allows a quick narrowing of the list of technically feasible options. Then, implementation can be considered within the context of the logistical, social, and economic atmospheres involved.

An obvious way to define "regions" would be to divide the continental United States into a grid of boxes by state and subregion (e.g., Northern and Southern California, inland Florida, coastal Florida); additionally, the "regional" choices open to two different utilities located close to each other can be different. This method would produce an exceedingly complex matrix of hundreds of options. A simple "U.S. grid" approach was not considered to be the best answer to this question. Instead, each user defines his or her scenario's "region" using two basic parameters:

- Population density
- Geography

This classification system results in nine regions, shown in Table 2.2. The definitions for each parameter in Table 2.2 are provided in Table 2.3.

Table 2.2. Classification of the Nine Concentrate Management Regions

By Region	By Population		
	High Density	Medium Density	Low Density
Inland, Arid	X	X	X
Inland, Not Arid	X	X	X
Coastal	X	X	X

Table 2.3. Definitions of Geographic and Demographic Regional Descriptors

Descriptor	Definition
Inland, Arid	Physical location of desalting plant allows no access to the ocean, and the climate is dry (annual evaporation rate of ≥60 in./year and annual precipitation rate of ≤10 in./year), e.g., desert Southwest
Inland, Not Arid	Physical location of desalting plant allows no access to the ocean, and the climate is relatively wet (annual evaporation rate of ≤60 in./year and/or annual precipitation rate of ≥10 in./year), e.g., inland Florida
Coastal	Physical location of desalting plant allows access to the ocean (note: connection to a "brine line" is considered coastal disposal), e.g., the Pacific or Atlantic coasts or the coast of the Gulf of Mexico
High Density	Characterized by high real estate prices and/or limited to no access to land in close proximity to the intended desalting site; typically precludes land-intensive options, e.g., Orange County, CA
Medium Density	Characterized by high to moderate real estate prices (depending upon location within the region), with moderate access to land within the region, although some locations in the region will often be prohibitively expensive, e.g., the Phoenix, AZ, valley or Boise, ID
Low Density	Characterized by low real estate prices and easy access to large tracts of land, e.g., rural areas

2.2.2 Controlling Factors in Regional Concentrate Management Decision-Making

Regardless of the region in which a utility resides, the parameters that control the decision-making process in concentrate management planning can be divided into two general classes: technology-specific issues and general issues. The questions identified for concentrate management are summarized in Tables 2.4 and 2.5 for technology-specific parameters and general design parameters, respectively.

Table 2.4. Concentrate Management Technology-Specific Controlling Parameters

Issue	Related Question(s)
Technical Feasibility	• Can the technical requirements be met (e.g., power, footprint)?
Cost	• How much would the technology cost?
Land Availability	• How much land is available to install the management system? • Where is it?
Public Acceptance	• What is the public's attitude about the technology? • Does the technology have significant socially undesirable aspects (e.g., environmental degradation, negative visual aesthetics)? • What interest groups will want or need to be involved in the planning process? • What steps need to be taken to achieve public acceptance of a desalting plan, particularly with respect to concentrate management? • Are there any issues (e.g., economic, aesthetic) that could introduce a "fatal flaw"?
Regulatory Requirements	• Can the necessary permits be obtained (e.g., NPDES)?
Colocation Potential	• Is there a potential for colocating the management system so as to improve the technical, cost, or aesthetic concerns (e.g., existing outfalls, proximity to power generation, existing waste treatment sites)?

Abbreviation: NPDES, National Pollutant Discharge Elimination System.

Table 2.5. General Installation Design-Controlling Parameters

Issue	Related Questions
Neighborhood Impacts	• How will the finished installation impact the neighborhood? What are the neighbors' concerns? • How will construction be negotiated? What is the communication plan?
Environmental Issues	• What are the environmental impacts of: - Constructing the site, and how can they be mitigated? - Operating the site, and how can they be mitigated?
Schedule	• What is the likely permitting timetable? • What is the construction timetable?
Risks	• What are the risks associated with implementing the technology of interest at the specified location? - Technical (e.g., probability that a new evaporation enhancement device will perform to specifications) - Economic (e.g., likelihood that water demand will proceed as projected) - Social (e.g., possibility the local community will perceive a significant environmental justice issue if the process is located at the site)
Partnering	• Are there partnership opportunities with other entities (power, water, wastewater, or reuse water purveyors or buyers) that could make desalting more viable from an economic, technical, and/or social perspective?

2.2.3 Integrating the Controlling Parameters into a Cohesive Decision-Making Process

While the controlling parameters can be individually listed and the issues related to them stated, solving the problem and answering the questions they raise cannot be easily teased apart. The decision-making process used to create a concentrate management plan can be described as a complex flowchart of facts and options that feed back and forth into the central development process. These controlling issues and descriptors, and their interrelated natures, were used to guide the development of the CMDM tool on the attached CD-ROM. The global structure of this methodology is described in Chapter 3.

The important information to take from this discussion for using the methodology is the following:

1. *Completely define your treatment scenario,* including the desalting process and the situation or atmosphere in which it will take place. This will define the environment in which decisions will need to be made.
2. *Define the "region" in which your desalting scenario will take place.* This will define the treatment technologies and regulations you will need to consider.
3. These terms and ideas will be referenced throughout the CMDM.

CHAPTER 3

CONCENTRATE MANAGEMENT DECISION METHODOLOGY STRUCTURE

This chapter describes the structure of the CMDM tool developed for this project. The global outline of the tool is illustrated in Figure 3.1. The methodology is designed to be used in a stepwise fashion, starting with characterization of the treatment and residuals scenario, then assessing the feasibility of proven (and, if desired, new) technologies, and finishing with an evaluation of the feasible options and selection of the next step in the desalting and concentrate management process. For many scenarios, it may become clear early in the analysis that the concentrate management schemes of a particular scenario identified in the decision-making process will all be untenable. At that point, the user has the option of either redefining a portion of the scenario and starting over or of jumping ahead, to Step 5, to plan the next action(s).

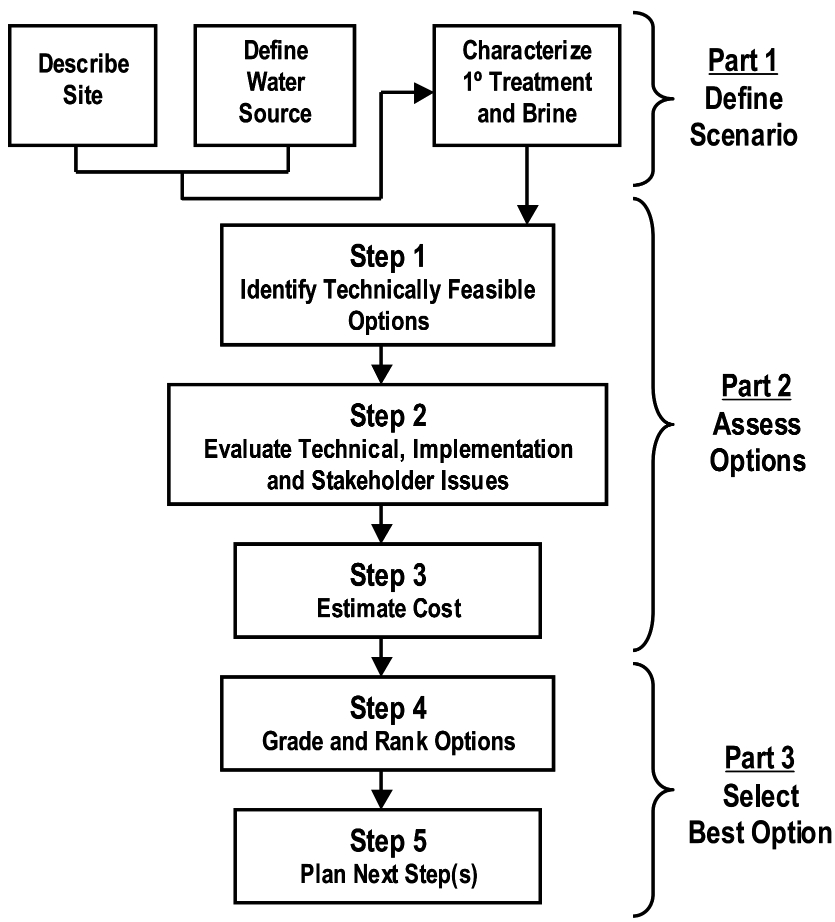

Figure 3.1. Global CMDM structure.

Note: This tool is intended to *facilitate* the planning process, but it is not intended to *replace* a detailed predesign and/or master plan. It is assumed that if a desalting plan were to be implemented following the use of this tool, a detailed process design would be completed before any firm, detailed decisions or assumptions about implementation of desalting, amount of brine produced, location of the desalting site, etc., were made.

A Microsoft Access software version of the decision methodology described here is included on the attached CD-ROM (WRFCMDM.mdb). It allows the user to develop as many different desalination treatment and management scenarios as desired. The following four chapters describe how to navigate the methodology and describe all the information that a user will need to use the tool. Chapters 8, 9, and 10 present three case studies to illustrate what information is typically gathered, how it is used, and how some of the key drivers for process selection come into play. Chapter 11 presents an overview of the current concentrate management technology options available, environmental and regulatory issues, and the role of stakeholders in the planning process. This, along with other texts referred to in the report, is intended to serve as a reference for the user as he or she works through the report. Chapter 12 comprises a list of the references used in developing this document.

CHAPTER 4

USING THE METHODOLOGY, PART 1: DEFINING THE DESALTING SCENARIO

The first step in developing a concentrate management plan is to define the primary treatment scenario that the strategy will accommodate. As the decision tool is targeted at concentrate management, it is assumed that the primary desalting process scenario is already developed. However, if this is not the case, Appendix A can be used to develop this information at a simple planning level. The CMDM tool (WRFCMDM.mdb on the attached CD-ROM), developed in Microsoft Access, can be used to organize this information and ensure it is complete.

The following flowchart (Figure 4.1) and accompanying text describe the organization of the treatment scenario characterization in the CMDM tool (which includes the tabs Overview, Raw Water Source, Primary Treatment, Location, and Decision-Making Climate). The tool first solicits answers to the following six questions and organizes the information in a summary report and detailed reports:

1. What is the treatment goal(s)?
2. In defining the water source, what is the life span of the project? What is the water source(s) intended for desalting? What is the raw water quality?
3. Where are the potential locations for the treatment site?
4. In what geographic and demographic regions could or would the facility be located?
5. What is the primary treatment process?
6. What are the potential stakeholder groups and issues (environmental, economic, and/or social)?

Guidance on the data required to answer each question is provided in the following sections.

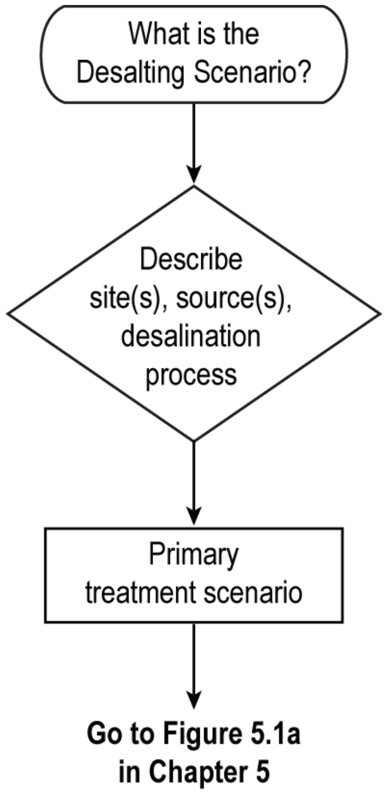

Figure 4.1. Flowchart 1: Defining the desalting scenario.

4.1 STEP 1: DEFINE THE REGIONAL WATER NEEDS

Table 4.1 summarizes the pertinent information that should be developed on the water treatment goals and cost assumptions. This corresponds to the first tab, Overview, of the CMDM tool (WRFCMDT.mdb) on the attached CD-ROM.

Table 4.1. Information Needed To Define the Regional Water Needs and Economic Criteria for the Concentrate Management Scenario of Interest

Topic	Description
Water Needs	The needed finished water quality and quantity
Purpose	The reason for implementing desalting
Project Life Span	How long is the facility expected to operate (in years)?
Finished Water Max	Maximum finished water design flow rate (in mgd)
Finished Water Avg.	Average annual finished water design flow rate (in mgd)
Finished Water TDS	Target (design) TDS concentration in the finished water (in mg/L)
Prepared by	The agency and/or persons preparing the assessment
Availability of Capital	Existing, planned, and potential sources of funding
Tax Base	The local tax base that will support the project, including its current size and projected growth
Need for Bond Issues	Will a bond(s) need to be raised to support development of the program? (Note: The exact amount of the bond does not need to be identified at this time, but it is useful for the user to identify at what level of capital expense a bond would be needed.)
Public Interest in Growth	Characterize the general mood of the public in terms of growth. Is it growth-supportive overall? Are there significant segments of dissent? What are the bases for any sources of dissatisfaction (e.g., crowding, environmental impacts, costs)?
Economic Concerns	Any cost or funding concerns associated with implementing desalting
Cost Assumptions	The cost factors to be used in the capital, O&M, and life cycle cost estimates
Capital Repay Years	Number of years over which the capital expenditure is to be repaid
Interest Rate	Interest rate of the loan used to finance the capital for the project
Current ENR-CCI	The current Engineering News Record Construction Cost Index estimate, available at http://enr.construction.com/
Location Factor	Root square means (or equivalent) location factor to adjust the nationwide ENR-CCI value for local economic conditions (default value is 1)

Abbreviations: mgd, million gallons per day; TDS, total dissolved solids; O&M, operation and maintenance (costs).

4.2 STEP 2: DEFINE THE WATER SOURCE

Table 4.2 summarizes the pertinent information that should be developed on the raw water source(s) to be desalinated. This corresponds to the second tab of the CMDM tool, Raw Water Source.

Table 4.2. Information Needed To Define the Raw Water Source To Be Desalinated for the Concentrate Management Scenario of Interest

Parameter	Description
Description	The type of water source
Capacity	The design capacity of the primary treatment process
Flow Rate Max	Maximum finished water design flow rate (in mgd)
Flow Rate Avg	Average annual finished water design flow rate (in mgd)
Raw Water Quality	
TDS	Raw water TDS concentration (in mg/L)
Heavy metals, other contaminants	Concentrations of heavy metals, organic chemicals, radionuclides, etc., in the raw water (select appropriate units from menu)

Abbreviations: mgd, million gallons per day; TDS, total dissolved solids.

4.3 STEP 3: DESCRIBE THE PRIMARY TREATMENT SCENARIO AND RESULTANT CONCENTRATE

Table 4.3 summarizes the pertinent information that should be developed regarding the primary treatment process and the resultant concentrate. This corresponds to the third tab, Primary Treatment, of the CMDM tool.

Table 4.3. Information Needed To Define the Primary Treatment Scenario and Resultant Concentrate Characteristics for the Concentrate Management Scenario of Interest

Topic	Description
Treatment	Describe the primary treatment process
Process Type	Select primary treatment process type (NF, RO, EDR, thermal, or other) from menu
Overall Recovery	Percent permeate produced per unit feed water

Topic	Description
Blended TDS Goal	The desired TDS concentration in the finished water that is to be delivered to the customer
Permeate TDS	Filtered water TDS. Unless otherwise defined by user, for NF assume 50–75% rejection, for RO and thermal processes assume 90% rejection, for EDR assume 50–95% rejection (rejection is species dependent) If this value is expected to change significantly over time, this should be considered in the calculation so that proper size estimates can be made.
Design Product Flow Rate	Describe the design permeate flow rates.
Max Flow Rate	Maximum permeate design flow rate (in mgd): $Q_{finished\ water\ max} \times \left[1 - \frac{C_{finished\ water\ TDS\ goal} - C_{permeate}}{C_{feed\ water\ TDS} - C_{permeate}}\right]$. This value is automatically calculated.
Avg Flow Rate	Average annual permeate design flow rate (in mgd): $Q_{finished\ water\ avg} \times \left[1 - \frac{C_{finished\ water\ TDS\ goal} - C_{permeate}}{C_{feed\ water\ TDS} - C_{permeate}}\right]$. This value is automatically calculated.
Bypass Qty	Amount of water bypassed around the desalting system and blended with the permeate to achieve the blended TDS goal concentration in the finished water. $Q_{finished\ water\ avg} \times \left[\frac{C_{finished\ water\ TDS\ goal} - C_{permeate}}{C_{feed\ water\ TDS} - C_{permeate}}\right]$ "Max" is based on the maximum flow rate; "avg" is based on the average flow rate.
Total Finished Water Qty.	The final finished water flow rate equals $(Q_{by-pass} + Q_{permeate})$. This value is equal to the "Finished Water Max/Avg" in the Overview tab. "Max" is based on the maximum flow rate; "avg" is based on the average flow rate.
Characterize Concentrate	Characterize the concentrate based on the raw water quality
Concentrate TDS	The TDS concentration in the concentrate (in mg/L): $\frac{Q_{RO\ feed}C_{raw\ water} - Q_{RO\ permeate}C_{permeate}}{Q_{RO\ feed}(1-R)}$. This value is automatically calculated in the spreadsheet.

Topic	Description
Max Flow Rate	The concentrate flow rate based on the maximum design flow rate (in mgd) and the recovery: $\left(Q_{\max RO\ feed}(1-R)\right)$. This value is automatically calculated in the spreadsheet.
Avg Flow Rate	The concentrate flow rate based on the average design flow rate (in mgd) and the recovery: $\left(Q_{avg\ RO\ feed}(1-R)\right)$. This value is automatically calculated in the spreadsheet.
Heavy Metals and Organic Contaminants	The concentration of metals and/or organic compounds of concern: $\frac{Q_{RO\ feed}C_{raw\ water} - Q_{RO\ permeate} \times 0.05C_{raw\, water}}{Q_{avg\ RO\ feed}(1-R)}$. This value is automatically calculated in the spreadsheet; 95% retention is assumed. The validity of this assumption for a given application should be independently checked for that application.
Solids Loading Rate	The rate at which waste salts are produced from the primary process.
Maximum	The mass of TDS sequestered into the concentrate stream on a daily basis based on the maximum concentrate flow rate: $\left(Q_{conc\ max} \times C_{conc}\right)$. This value is automatically calculated in the spreadsheet.
Average	The mass of TDS sequestered into the concentrate stream on a daily basis based on the average concentrate flow rate: $\left(Q_{conc\ avg} \times C_{conc}\right)$. This value is automatically calculated in the spreadsheet.
Solids annual	The mass of TDS sequestered into the concentrate stream on an annual basis: $\left(Q_{conc\ avg} * C_{conc} \times 365\ \text{days}\right)$. This value is automatically calculated in the spreadsheet.

Abbreviations: NF, nanofiltration; RO, reverse osmosis; EDR, electrodialysis reversal; TDS, total dissolved solids; mgd, million gallons per day.

4.4 STEP 4: CHARACTERIZE THE CONCENTRATE MANAGEMENT REGIONAL LOCATION

Table 4.4 summarizes the pertinent information that should be developed regarding the potential treatment site(s) identified for both the primary treatment facility and for the concentrate management facility. This corresponds to the fourth tab, Locations, of the CMDM tool.

The final task in this step is to define the regional classification of the desalting scenario (Table 4.5) (defined under the tab Location), and the user first evaluates the technically feasible options based on the scenario's region (see Figure 5.1a, below, for guidance). This corresponds to the tab Viable Options in the CMDM tool. This "first cut" eliminates those technologies that could not, under any realistic scenario, be used in this type of region (defined in Table 4.6).

Table 4.4. Information Needed To Define (Potential) Concentrate Management Sites for the Concentrate Management Scenario of Interest

Topic	Description
Location	Name of location, designated use (primary treatment, concentrate management, or both)
Footprint	Parcel size; drawings and aerial photographs are very helpful
Access to Power	How much power can be accessed from existing power lines adjacent to or connecting to the property?
Ownership	Who owns the parcel(s)? Is the land owned by the utility, city, or county, or would it need to be acquired?
Environment	Characterize the surrounding neighborhood (wilderness, commercial, or residential). Is the neighborhood expected to change significantly within the lifetime of the facility? (For example, are the adjacent properties currently undeveloped farmlands but with residential areas that are expected to expand into the vicinity?) Are there any environmentally sensitive or endangered plants or wildlife in the area that could pose an issue?
Right-of-Way	Are there right-of-way issues associated with gaining access to the site (particularly if primary treatment and concentrate management are to be at separate locations)?
Region Designation	Region type based on the demographic–geographic matrix defined in Table 4.5

Table 4.5. The Nine Concentrate Management Regions

By Geography	By Population Density		
	High	Medium	Low
Inland, Arid	Region 1	Region 2	Region 3
Inland, Not Arid	Region 4	Region 5	Region 6
Coastal	Region 7	Region 8	Region 9

Table 4.6. Potential Technologies in Terms of Technical Feasibility

Concentrate Management Technology	Feasible for Region No.:								
	1	2	3	4	5	6	7	8	9
(Fresh) Surface Water and Wastewater Discharge	√	√	√	√	√	√	√	√	√
Ocean Discharge							√	√	√
Deep-Well Injection	√	√	√	√	√	√	√	√	√
Evaporation Pond[1]		√	√						
Land Application		√	√		√	√		√	√
Reuse and/or Blending	√	√	√	√	√	√	√	√	√
ZLD[1]	√	√	√	√	√	√	√	√	√

[1]Zero liquid discharge (ZLD) can be used as a brine reduction step with evaporation ponds to reduce their size.

4.5 STEP 5: CHARACTERIZE THE DECISION-MAKING CLIMATE

Table 4.7 summarizes pertinent information regarding the economic, social, and climatic conditions in which the desalination plan will be developed. This corresponds to the fifth tab, Decision-Making Climate, of the CMDM tool.

Table 4.7. Information Needed To Define the Decision-Making Climate for the Concentrate Management Scenario of Interest

Topic	Description
Group Type	Type of stakeholder group; social, civic, or activist organizations that would be concerned with the development of a concentrate management facility on this site (e.g., civic groups, environmental groups, sporting associations, business groups, neighbors, land owners)
Issue	Issue(s) in which stakeholders might have an interest
Stakeholder	Stakeholder name
Notes	The specific concerns corresponding to each group

The following two chapters, "Assessing Concentrate Management Options" and "Grading and Ranking the Concentrate Management Options," outline the details of working through the concentrate management decision-making methodology (steps 1 through 4 in Figure 3.1).

CHAPTER 5

USING THE METHODOLOGY, PART 2: ASSESSING THE CONCENTRATE MANAGEMENT OPTIONS

The second step in developing a concentrate management plan involves assessing the available concentrate management options on technical, economic, and practical levels with regard to the desalting scenario defined in Chapter 4 (the Overview, Raw Water Source, Primary Treatment, Location, and Decision-Making Climate tabs) of the CMDM tool (WRFCMDM.mdb) on the attached CD-ROM. Part 2 of the concentrate management planning process, described in this chapter, corresponds to the tabs Viable Options and Cost Estimates in the CMDM tool.

The following flowcharts (Figures 5.1a to c and 5.2) and the accompanying text and tables describe the thought process underpinning this assessment.

5.1 STEPS 1 AND 2: IDENTIFY AND EVALUATE THE TECHNICAL AND IMPLEMENTATION ISSUES

Based on the regional classification of the desalting scenario from Table 5.1 (defined under the tab Location), the user first evaluates the technically feasible options for the scenario's region (see Figure 5.1a for guidance). This corresponds to the tab Viable Options in the CMDM tool.

The next step is to evaluate (at a planning level) the technical and implementation issues that could occur for each concentrate management option identified in Step 1 (which appear as subtabs under the primary tab Viable Options), eliminating those that do not meet minimum requirements for viability (e.g., the footprint is too large for the available space). The applicable technology-specific controlling parameters and the general controlling parameters identified in Section 2.1.2 should be considered in this evaluation. Guidance to assist with this evaluation is provided in Figures 5.1a to c, Tables 5.1 and 5.2, and Chapter 11. This is also located under the tab Viable Options in the CMDM tool.

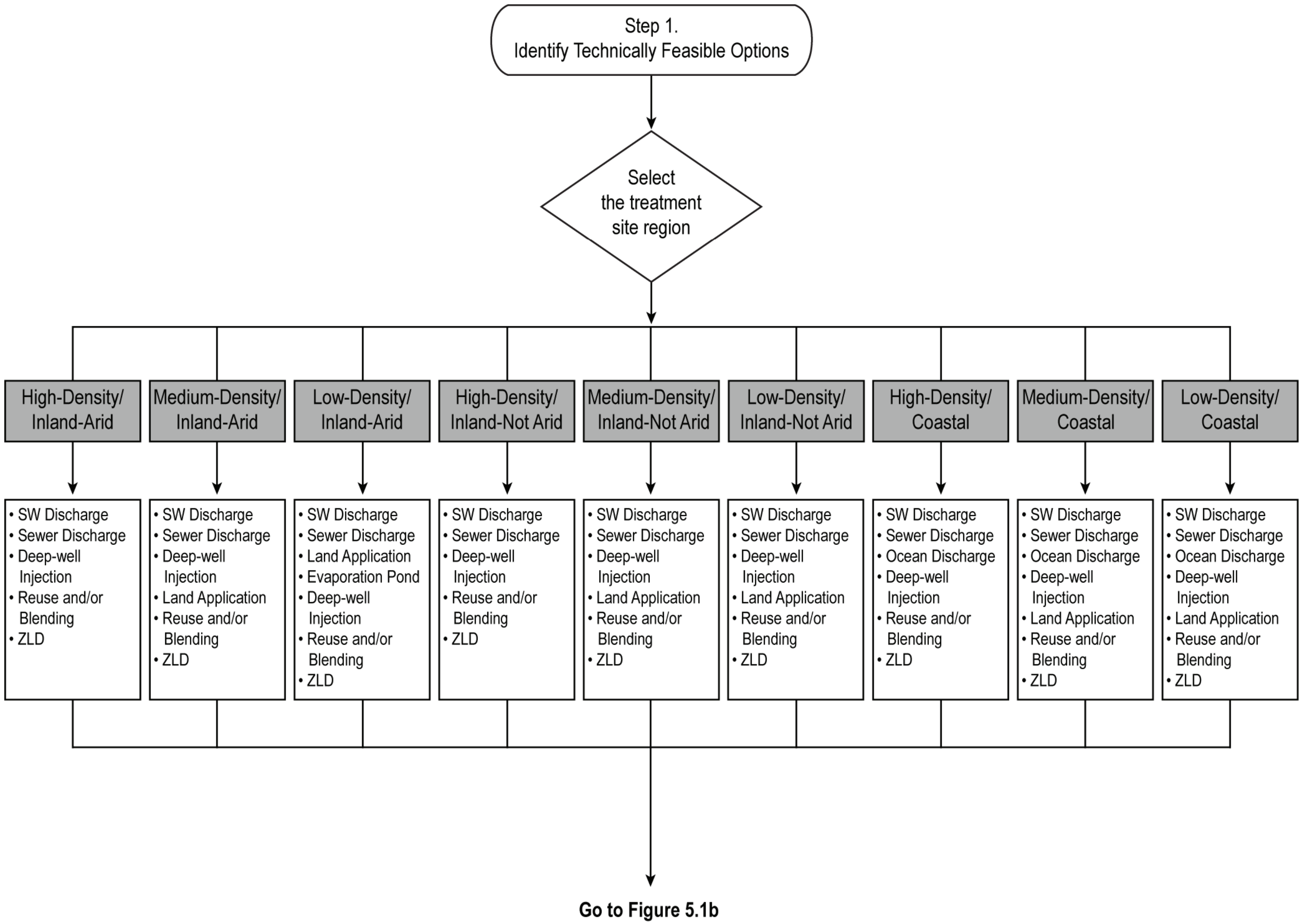

Figure 5.1a. Flowchart 2: Assess the concentrate management options, Step 1. Identify the technically feasible options.

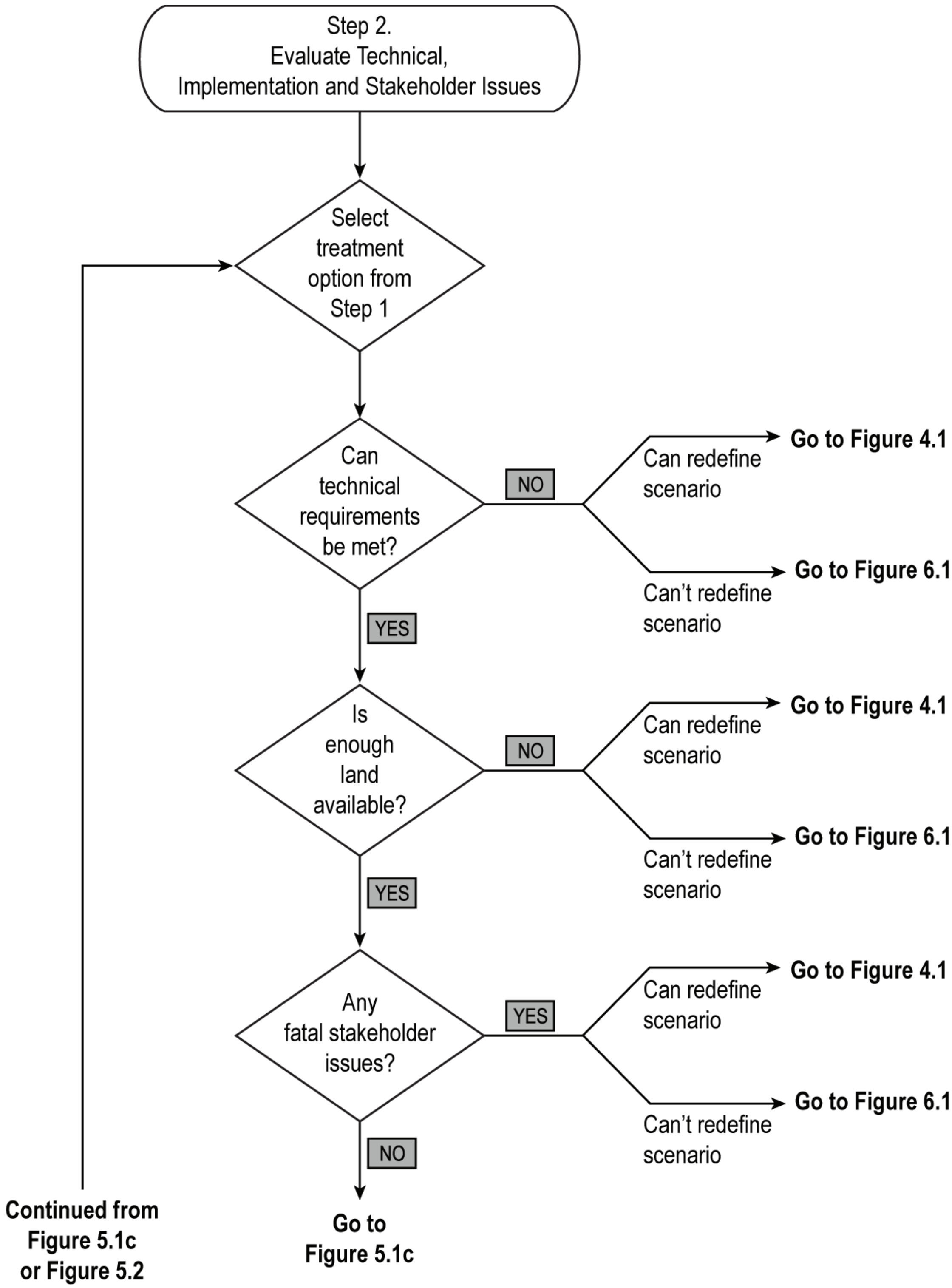

Figure 5.1b. Flowchart 2: Assess the concentrate management options, Step 2. Evaluate the technical, implementation, and stakeholder issues (part 1).

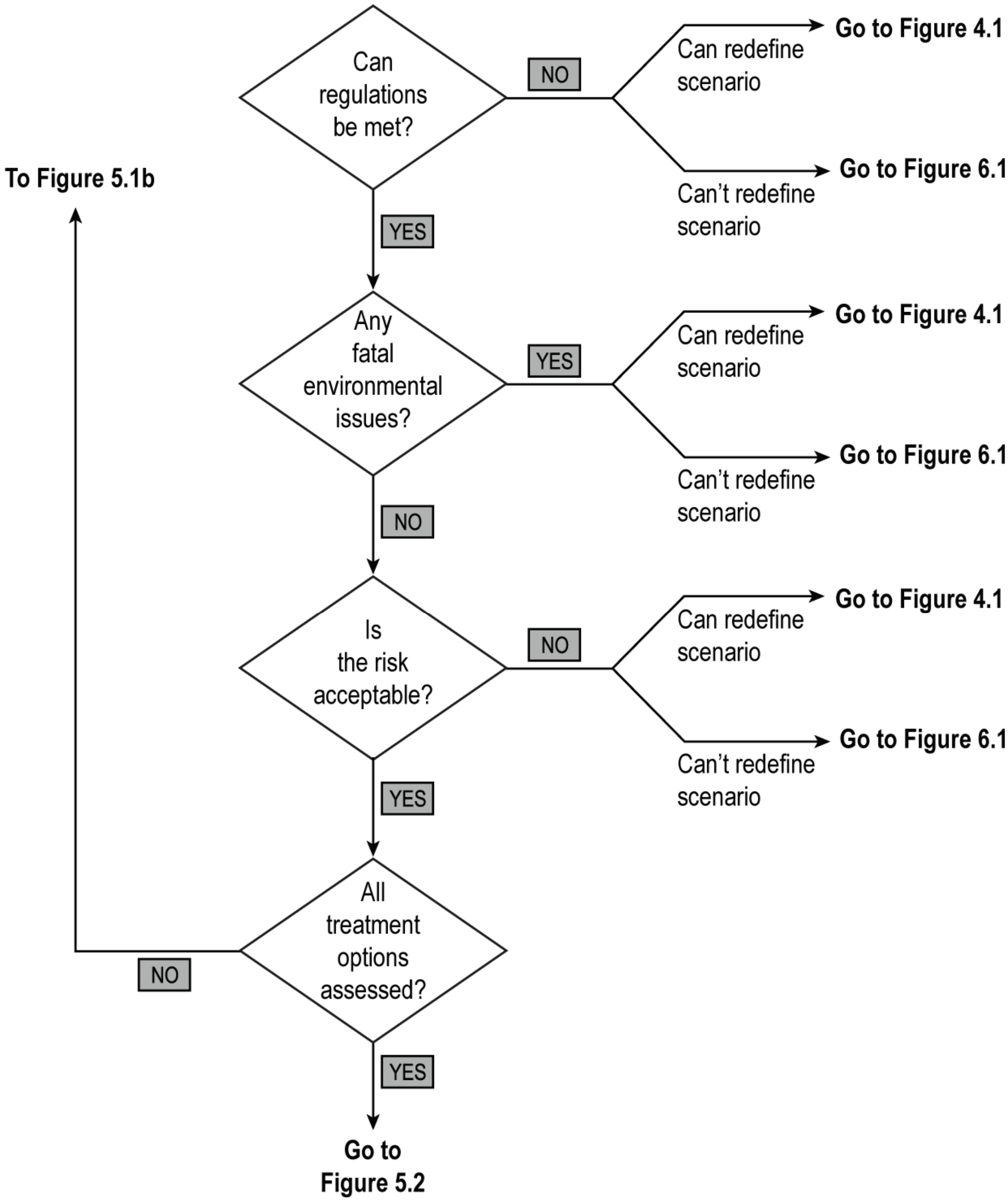

Figure 5.1c. Flowchart 2: Assess the concentrate management options, Step 2. Evaluate the technical, implementation, and stakeholder issues (part 2).

Table 5.1. Information Needed To Assess Feasibility of Implementation of a Particular Treatment Technology for the Concentrate Management Scenario of Interest

Viability Criterion[1]	Pertinent Question(s)
Technical Feasibility	Can the technical requirements be met (e.g., power, footprint)?
Regulatory Requirements	Can the necessary permits be obtained (e.g., NPDES)? Refer to Table 5.2 for further guidance on this issue. The specific requirements for various federal regulations are provided in Chapter 11.
Cost Magnitude	Can the order of magnitude of the cost be paid? Guidance on cost issues is provided in the next section and in Chapter 11.
Land Availability	Is enough land available to install this system? Refer to Table 5.4 for further guidance on this issue.
Public Acceptance	Is installation of the technology in question acceptable to the public, particularly the neighbors? *Issues to consider:* What is the public's attitude about the technology? Does it have significant socially undesirable aspects (e.g., environmental degradation, visual aesthetics)? What interest groups will want to be involved in the planning process? What steps will have to be taken to achieve public acceptance of a desalting plan, particularly with respect to concentrate management? Are there any issues that could become a "fatal flaw" (e.g., economic, aesthetic)? *Note*: It is recommended that the user begin the stakeholder involvement process at this point. The first steps are to identify who the stakeholders are and begin to determine their issues and concerns.
Neighborhood Impact	If relevant, the effects on surrounding neighborhoods should be considered. This evaluation could consider noise pollution, power requirements, and proximity to other public and/or private areas. Questions to consider include the following: - How will the finished installation affect the neighborhood? - How will construction be navigated? What are the neighbors' concerns? - How will construction be negotiated? What is the neighborhood communication plan?
Environmental Issues	Environmental effects, permitting requirements, and sustainability of the technology should be addressed and evaluated. What are the environmental impacts of: - Constructing the site? (and how can they be mitigated?) - Operating the site? (and how can they be mitigated?)

Viability Criterion[1]	Pertinent Question(s)
Risk	The risks associated with each option should be identified. Risks could include the likelihood of the concentrate management technology being publicly accepted, affordable, permittable, flexible, reliable, and expandable, if required for future growth. What are the risks associated with implementing the technology of interest at the specified location? - Technical (e.g., probability that the new evaporation enhancement device will perform to specifications) - Economic (e.g., likelihood that the water demand will grow as projected) - Social (e.g., might the local community perceive a significant environmental justice issue at the treatment site?)
Overall Feasibility	If all criteria are rated "yes" or "maybe," the option will be rated "feasible." If any criterion is rated "no," the option will be automatically eliminated. This field is calculated automatically.

Abbreviation: NPDES, National Pollutant Discharge Elimination System.
[1]Rate each criterion as Yes, No, or Maybe until you reach a "No" response. One "No" automatically eliminates the concentration management option being evaluated.

Table 5.2. Applicable Federal Regulations for the Various Concentrate Management Technologies of Interest

Disposal Option	CWA	SDWA	HMTA	RHA	NEPA	ESA	RCRA, CERCLA, TSCA
Surface Water Discharge	√			√	√	√	
Ocean Discharge	√			√	√	√	
Deep-Well Injection		√					√
Evaporation Ponds			√		√		√
Land Application	√		√		√	√	√
Reuse and Blending	√	√					

Abbreviations: CWA, Clean Water Act; SDWA, Safe Drinking Water Act; HMTA, Hazardous Materials Transportation Act; RHA, Rivers and Harbors Act; NEPA, National Environmental Policy Act; ESA, Endangered Species Act; RCRA, Resource Conservation and Recovery Act; CERCLA, Comprehensive Environmental Response, Compensation, and Liability Act; TSCA, Toxic Substances Control Act.

5.2 STEP 3: ESTIMATE PLANNING-LEVEL COSTS FOR EACH TECHNOLOGY

For each concentrate management option remaining from Step 2, the user can now estimate the capital, operations and maintenance (O&M), and life cycle costs for the viable options. These correspond to the tab Cost Estimates in the CMDM tool. As with the Viable Options tab, each feasible technology will have its own subtab. All white boxes prompt the user for information. Yellow boxes denote automatic calculations. Assumptions can be reviewed by clicking on the Assumptions box under each technology cost-estimating subtab. The equations used are summarized in Appendix A.

This step is intended to help the user develop comparative, order-of-magnitude costs for implementing each technology option of interest based on the defined scenario. The CMDM tool (WRFCMDM.mdb on the enclosed CD-ROM) can be used to estimate planning-level costs for each technology. Variances in the costs of labor, materials, equipment, services provided by others, the contractor's methods of determining prices, competitive bidding or market conditions, practices, or bidding strategies will have a significant impact on site-specific costs. It should be assumed that proposals, bids, and actual construction costs will vary.

As stated in Chapter 11, there are concentrate management cost models available that are well-suited to estimate the capital and operating costs of various disposal options. One of them, developed by Mickley and associates in conjunction with the U.S. Bureau of Reclamation (Mickley, 2001, 2006), has been adapted for use here. Equipment-specific cost calculations for deep-well injection, evaporation ponds, land application, and zero liquid discharge (ZLD) are based in large part on Mickley's 2001 cost values.[2] Present day costs can be more accurately approximated if cost-scaling factors for location and the fiscal year are incorporated into the estimate (e.g., the ENR-CCI). The assumptions for ocean discharge, blending and reuse, surface water discharge, and wastewater discharge are described in the concentrate management tool and can be accessed through each technology tab.

If a Pump Station Is Needed

If the concentrate will have to be pumped from the primary treatment site to a separate concentrate management site, the data in Tables 5.3 and 5.4 can be used to estimate the capital cost of a concentrate pump station.

Assessing Viability Based on Cost

At this point, the user can eliminate any options that are judged economically nonviable by simply returning to the Viable Options tab and changing the Cost Magnitude from "Yes/Maybe" to "No," and this option will be eliminated. If no concentrate management options remain, the user can skip to Step 5 (Chapter 7) or redefine the scenario (Chapter 4) and reassess his or her options.

5.2.1 General Guidelines on Estimating Concentrate Management Costs

If the user desires, calculations can be done independently with more recent cost data. Guidance to assist with this evaluation is provided in Figure 5.2, Tables 5.4 and 5.5, and Chapter 11, as well as in the following discussion.

It is recommended that the capital cost factors listed in Table 5.3 and the O&M cost factors listed in Table 5.8 be considered in estimating the O&M costs associated with the respective concentrate management technologies, whether the cost pages provided here or independent cost assessments are used.

[2] Some costs for standard equipment, like steel tanks, piping, and brine concentrators, have been estimated using more current values.

Table 5.3. Estimated Equipment Capital Costs for a Concentrate Pump Station as a Function of Size (0.1–50 mgd)

Pump Station Capacity, mgd	Pump Station Building Costs, ft^3	Pump Station Size, ft^3	Equipment Costs, $	Capital Cost, $
0.1	275	400	16,000	194,300
0.5	275	900	36,000	437,175
1	275	1200	40,000	565,500
5	250	1600	80,000	754,000
10	250	2000	120,000	986,000
20	250	2500	180,000	1,297,750
40	200	3000	510,000	1,979,250
50	200	3000	630,000	2,240,250

Pump Installation Factor: 1.5
Piping Costs Associated (% of total): 15%
Site Work (% of total): 5%
Electrical and I&C (% of total): 25%

Design Criteria and Assumptions

1. Costs are developed assuming normal discharge head (<100 ft).
2. Costs do not include contingency, engineering, owner inspection, contractor overhead, or profits.
3. Costs include an enclosed pump station building, centrifugal pumps, motors, controls, piping, etc.
4. Costs assume power is available and do not include a dedicated substation.
5. These costs do not include ROW or land acquisition or permitting costs.
6. Assume no groundwater, rock, hazardous material, or archaeological finds.
7. Assume all built during one construction phase.
8. Assume pump station pumps from plant site to evaporation ponds or application site.
9. Assumes 100-ft discharge head. User should be cautioned if the discharge head is too high. Extra costs should be added by the user.
10. Costs do not include the contractor's overhead profit, contingency, or engineering fee.
11. Pumps costs are based on split case pump, Fairbanks Moorse. Quotes obtained August 8, 2007, in Arizona (HMS, Paul Terry).
12. Pump costs include pump, motor, base, and stainless steel impeller (corrosive resistant) but exclude variable frequency drives.

NOTE: This cost estimate is intended to be an order-of-magnitude, planning-level estimate for comparison with other technologies and is not for design or final planning purposes. The cost estimate herein is based on the design parameters, assumptions, and cost elements detailed on this page. These costs do not include ROW or land acquisition or permitting costs.

Variances in the cost of labor, materials, equipment, services provided by others, or contractor's methods of determining prices, competitive bidding or market conditions, practices, or bidding strategies will have a significant impact on site-specific costs. It should be assumed that proposals, bids, or actual construction costs will vary in some, if not all, elements from the costs presented herein.

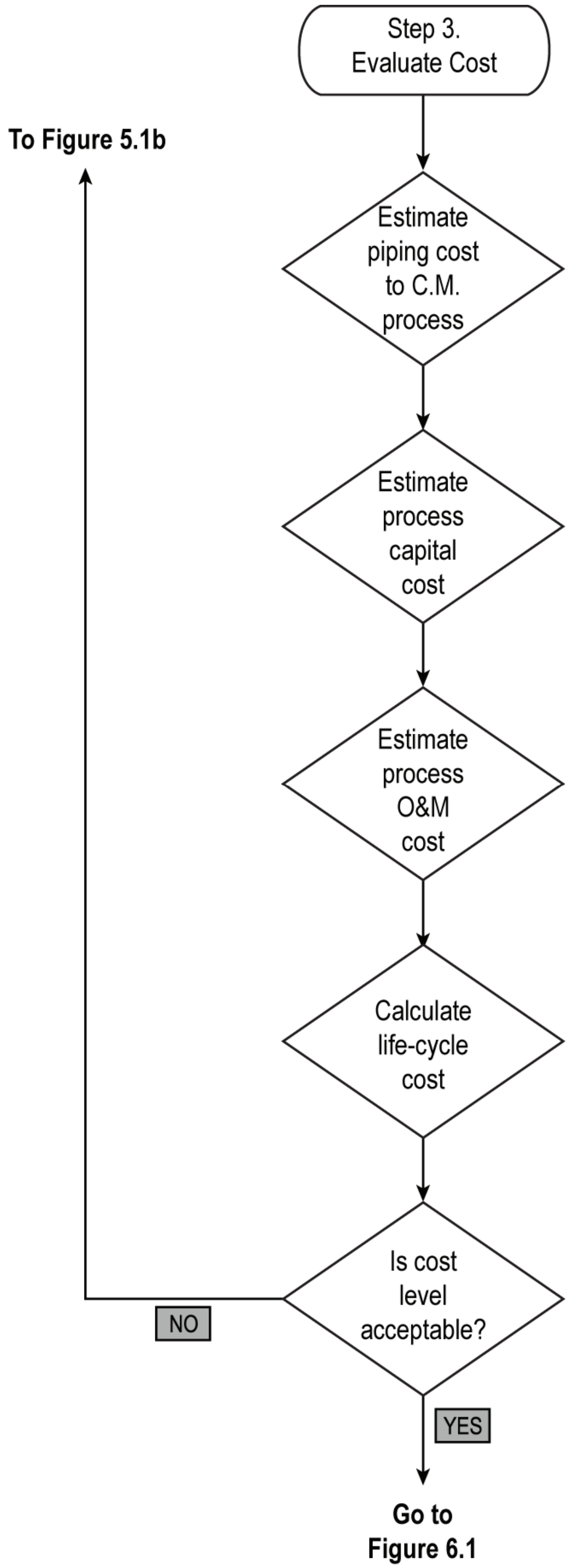

Figure 5.2. Flowchart 2: Assess the concentrate management options, Step 3. Estimate costs.

Table 5.4. Information Needed To Estimate Planning-Level Capital Costs for Each Potential Treatment Technology Identified in Step 1 for the Concentrate Management Scenario of Interest

Capital Cost Parameter	Cost Factors to Consider		
For All Technology Types			
Construction Permitting	Standard construction permits (e.g., right-of-way, building permits, dredge-and-fill permit) and construction drawings approvals Environmental Impact Statements (which may be required based on the geographic location of the technology and/or the characteristics of the technology to be employed) Endangered Species Act evaluation (if federal funds are involved)		
Piping from Desalting Operation to Discharge Point	The cost of pipe installation is highly site specific and so must be calculated based on the particular characteristics of the site following standard pipeline design methods (this is outside the scope of this project). To estimate this cost on a planning level, it is recommended that a cost per unit length be estimated using standard cost-estimating references, such as current-year means construction cost data manuals (Reed Construction Data, published by Construction Publishers and Consultants, Kingston, MA).		
Technology-Specific Costs			
Surface Water and Ocean Discharge	Conveyance of concentrate to shoreline; this includes pumps, the pipeline structure itself (materials and fabrication), and any needed trenching Pipe from shore to outfall; pipeline materials and construction (possible underwater fabrication and dredging or trenching) Outfall structure; diffuser pipe, risers, ports, and associated construction costs (fabrication and trenching) Note: The outfall structures for freshwater and ocean discharges are significantly different, as well as site specific. The costs for these two options should not be considered interchangeable.		
Wastewater Discharge	Conveyance of concentrate to wastewater treatment lines; this includes pumps, the pipeline structure itself (materials and fabrication), and any needed trenching		
Deep-Well Injection	Well siting	Logging, testing, and surveying	
	Well installation	Drilling and reaming	
	Casing (materials and installation)	Grouting (materials and installation)	
	Packer (materials and installation)	Monitoring wells installation	
	Supporting equipment & labor	Mobilization–demobilization	
	Injection tube (materials and installation)		
Evaporation Ponds	Land costs	Earthwork	Land clearing, perimeter dikes
	Baffle dikes (optional)	Dike covers	Site management, fencing
	Maintenance roadways	Leachate monitoring	Solids dredging and disposal
Land Application	Loading rate	Land type	Storage time
	Land unit cost (ponds, ROW)	Land costs	Needed land area
	Land clearing unit	Land clearing	Piping to and on-site

Capital Cost Parameter	Cost Factors to Consider		
	Underdrains	Storage tanks	Distribution system material
	Installed distribution system	Pumps	Sprinkler, valves, control system
Reuse or Blending	Conveyance of concentrate to blending point	Pumps	
	Outfall structure	Pipe (diffuser)	
	Risers	Ports	
	Fabrication (and possible trenching)		
	Pipeline to the discharge point (materials and fabrication, including trenching)		
ZLD	Reject level of concentrator (this affects sizing)		
	Capital cost of installed concentrator	Capital cost of installed crystallizer	

Abbreviation: ROW, right of way.

Table 5.5. Information Needed To Estimate Planning-Level O&M Costs for Each Potential Treatment Technology Identified in Step 1 for the Concentrate Management Scenario of Interest

Capital Cost Parameter	Cost Factor(s) To Consider
Surface Water, Ocean, and Wastewater Discharge	Dominant cost element is electric power to pump the concentrate to the outfall
Deep-Well Injection	Dominant cost element is electric power to pump the concentrate into the disposal well(s)
Evaporation Ponds	Dominant costs include dredging and disposal of the solids and leachate monitoring
Land Application	Dominant cost element is electric power to pump the concentrate to the application site
Reuse or Blending	Dominant cost element is electric power to pump the concentrate to the blending and reuse point
ZLD	Dominant cost element is electric power to pump the concentrate to the outfall. Other significant costs include calcium sulfate (to seed the slurry and facilitate precipitation) and solids disposal

5.2.2 Life Cycle Costs

The easiest way to compare the total costs of various concentrate management scenarios is on a life cycle basis, either in terms of total cost or annual cost. The cost factors that are typically considered in estimating the life cycle cost associated with technology implementation include:

- Total project life
- Capital cost
- Capital cost payment plan (principal to be borrowed or bonded, interest rate, payment life)
- Annual O&M costs

This information corresponds to the third section of the Cost Estimates tab in the CMDM tool.

Life cycle cost (LCC_T) can be calculated using the following three equations:

$$LCC_T = C_{C,T} + C_{O\&M,T} \qquad \text{eq 5.1}$$

$$C_{AC} = P\frac{(1+i)^n - 1}{i(1+i)^n} \qquad \text{eq 5.2}$$

and

$$C_{O\&M,T} = C_{O\&M}\frac{(1+i_{infl})^{n_{project}} - 1}{i_{infl}(1+i_{infl})^{n_{project}}} \qquad \text{eq 5.3}$$

where:

$C_{AC,T}$	=	Total capital cost
$C_{O\&M,T}$	=	Total O&M cost
i	=	Annual interest rate
P	=	Capital cost
n	=	Repayment schedule
$C_{O\&M}$	=	Annual O&M cost
i_{infl}	=	Estimated rate of inflation (typically based on the long-term Consumer Price Index)
$n_{project}$	=	Project lifetime

The annualized LCC in present dollars can be calculated using the following two equations:

$$LCC = C_{AC} + C_{O\&M} \quad \text{eq 5.4}$$

$$C_{AC} = i \frac{P(1+i)^n}{(1+i)^n - 1} \quad \text{eq 5.5}$$

where:

C_{AC} = Annualized capital cost

The following chapter, "Grading and Ranking the Concentration Management Options," outlines a procedure for evaluating the relative merits of the desalting scenario–concentrate management options identified in Steps 1 through 3 of the CMDM methodology.

CHAPTER 6

USING THE METHODOLOGY, PART 3: GRADING AND RANKING THE CONCENTRATE MANAGEMENT OPTIONS

The third segment of the decision methodology involves identifying the best option(s) for the (potential) project in question and determining the next steps in proceeding with a desalting technology for the user's water supply.

6.1 STEP 4: GRADE AND RANK THE FEASIBLE TREATMENT OPTIONS

The fourth step in developing a concentrate management plan involves grading the concentrate management options on technical, economic, and practical implementation bases and ranking them. Alternatively, a number of desalting scenario–concentrate management plans could be compared.

If only one desalting scenario–concentrate management plan option has been identified in the evaluation process, the user may want to consider grading and ranking that scenario against alternative treatment and water management plans (e.g., limiting growth, developing a new potable water source, employing enhanced conservation and/or reuse plans to reduce water needs), if such options are possible.

It should be noted that, based on this evaluation, it is not unlikely that some or all of the alternatives will be eliminated from further consideration for the scenario defined.

6.1.1 Developing a Grading and Ranking Plan

As with Parts 1 and 2, the tabs Grading Criteria and Ranking Options are provided in the CMDM tool (WRFCMDM.mdb) on the attached CD-ROM. The following flowchart (Figure 6.1) and accompanying text can be used to develop a grading and ranking plan. Guidance on the data required to answer each question is provided in the following sections.

The particular evaluation criteria and ranking scheme the user develops will depend upon their particular situation and needs. The technical aspects in Part 2, Step 3, should be considered, as should relatively intangible factors, such as environmental impacts and neighborhood concerns.

To complete Step 4, the following actions could be taken, or a different methodology that better addresses your specific needs can be developed.

1. Choose the evaluation criteria that are important considerations for your situation. The suggested evaluation criteria provided under the tab Grading Criteria are defined in Table 6.1. If desired, you can add other criteria in the Other Name boxes under the Grading Criteria tab. The default value for any grading criterion provided that is not desired should be set as 0.

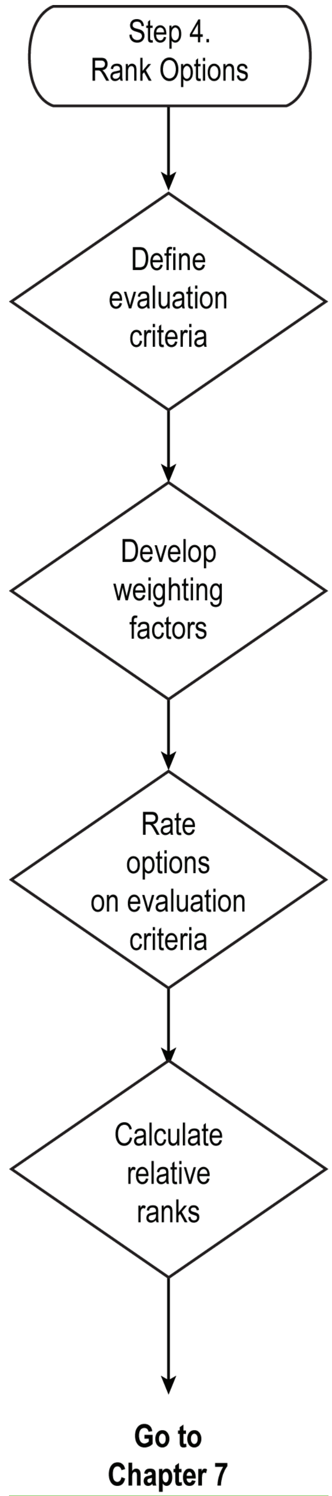

Figure 6.1. Flowchart 3: Grade and rank the feasible treatment options.

Table 6.1. Suggested Evaluation Criteria for Grading and Ranking Different Concentrate Management Alternatives for the Desalting Scenario of Interest

Grading Criterion	Consideration(s)
Complexity	• How much operator training will be required? • Is the project anticipated to need frequent maintenance?
Ease to Implement	• How easy will the project be to implement if selected? • Are there roadblocks that could inflate the timeline? • How quickly could it be implemented, even if no significant difficulties were encountered? • Are their schedule restrictions?
Footprint	• How big is it? • Does its size limit flexibility in siting? • If one site is preferred over another, where different options preclude one site or another, they may be viewed less favorably.
Environmental Impact	• What is the relative negative effect on the local environment?
Life Cycle Cost	• How much does it cost (total, capital, and O&M)? • Is one of these cost components driving feasibility, schedule, or ease of implementation?
Power Requirements	• What is the power demand relative to the other options? • Is power anticipated to greatly rise in the near future due to increasing demands, falling supplies, or other economic forces?
Public Acceptance	• How acceptable is this option to the public? • Acceptability can be defined in terms of aesthetics, neighborhood impacts, economic costs, etc.
Regulatory Acceptance	• Are any regulatory challenges anticipated? • What is the projected timeline for permitting?
Risk	• How reliable or risky is this option in the short term? • How reliable or risky is this option in the long term?
Other	• Any other factors the user wishes to add to the grading criteria

2. Develop weighting factors (from 1 to 5, entered in the Value field under the Grading Criteria tab) for each individual evaluation criterion. The user can do this individually, or members of a planning group can complete an exercise to determine the overall agreement of the group. One common methodology for determining weighting factors in a group setting is described below:

   Members of the decision-making group individually assess the importance of each criterion. Each group member assigns a weighting factor to each individual criterion based on his or her belief of its relative merit within the context of all criteria. After each member assigns a weighting factor to each criterion, the individual values are averaged to determine the weighting factors to be used in the ranking process.

3. Under the Ranking tab, grade each potential concentrate management option based on its ability to achieve each individual evaluation criterion on a scale from 1 to 5. For example, Table 6.2 illustrates a situation in which three concentrate management options and three evaluation criteria are being considered. The table also includes a location for each weighting factor criterion determined in Part 2 of this evaluation process.

Table 6.2. Example Base Ranking Spreadsheet for Comparing Options

Evaluation Criterion	Rank, Based on Concentrate Management Option			Weighting Factor
	Option 1	Option 2	Option 3	
A	2	3	0	x
B	4	5	2	y
C	1	4	2	z

4. For each concentrate management option, the CMDM tool calculates the relative rankings of each option by multiplying the grade of each evaluation criterion by its weighting factor. These values can be termed the "weighted ranks." This example is further illustrated in Table 6.3.

Table 6.3. Example Weighted Ranking Spreadsheet for Comparing Options

Evaluation Criterion	Weighted Risk Factor for Concentration Management Option		
	Option 1	Option 2	Option 3
A	$2 \times x$	$3 \times x$	$0 \times x$
B	$4 \times y$	$5 \times y$	$2 \times y$
C	$1 \times z$	$4 \times z$	$2 \times z$

5. Sum the weighted ranks for each concentrate management option to determine the total score using eq 6.1, below (and as illustrated in Table 6.4).

$$Weighted\ Score = \frac{\sum Criterion\ i\ Score \times WF_i}{\sum WF_i} \qquad \text{eq 6.1}$$

where:

Criterion *i* score = Grade assigned to a given concentrate management option for criterion *i*

WF_i = Weighting factor for criterion *i*

Table 6.4. Example Ranking and Total Score Spreadsheet for Comparing Options

Evaluation Criterion	Concentrate Management Option 1	Concentrate Management Option 2	Concentrate Management Option 3
A	2 × x	3 × x	0 × x
B	4 × y	5 × y	2 × y
C	1 × z	4 × z	2 × z
Total Score	∑Option 1	∑Option 2	∑Option 3

The total scores for each option can then be compared and considered in association with any other particular topics the user wishes to consider (e.g., costs).

The following Chapter, "Planning the Next Steps in Desalination Project Development," outlines some options the user can take once he or she has conducted the concentrate management assessment.

CHAPTER 7

USING THE METHODOLOGY, PART 4: PLANNING THE NEXT STEPS IN DESALINATION PROJECT DEVELOPMENT

The fourth segment of the decision methodology involves planning the next steps in the desalination planning and implementation process, including deciding "where do we go from here?" (now that an option or list of options, or no viable options, have been identified). It is important to remember that if a desalting plan will be carried forward following the use of this tool, *a detailed process design should be completed before any final decisions or assumptions about implementing a specific concentrate management plan are made*.

Section 7.1 suggests possible next steps in the planning process for cases where viable alternatives have been identified and for cases where no viable alternatives have been established.

7.1 STEP 5: NEXT STEPS

1. *If a viable alternative(s) has been identified,* plan the next steps in moving forward with the desalting process. These steps could include, in no particular order:
   - Investigate other source and/or treatment scenarios to see if a better alternative can be developed prior to any further action
   - Initiate a detailed predesign study or preliminary design to evaluate the details of implementing the option(s) selected and to briefly revisit the options that were discounted to provide a second opinion, or "reality check"
   - Define the stakeholder process needed for creating a successful treatment plan and begin involving stakeholders in the decision-making process, if that has not already been done
   - Explore funding issues and options

2. *If no viable alternative(s) has been identified,* the next steps could include any combination of the following actions:
   - Revise the scenario and repeat the decision methodology with the new parameters
   - Investigate the potential for partnering with other utilities
   - Investigate the potential for colocation with a new or existing power plant
   - Consider an alternative site
   - Explore new technologies further in terms of improving recovery (reducing the rate of brine production) or using new concentrate management methods
   - Wait for concentrate management technologies to improve
   - Look for other avenues to meet water supply needs (e.g., alternative freshwater sources for potable use, trading discharge credits with local industries for wastewater plants, improving efficiency of water use to minimize the need for reuse water)

3. *Plan the involvement of stakeholders in the evaluation process*. Stakeholder involvement is now an important piece of many water and wastewater master planning decisions. The movement of environmental regulation away from technology-based standards to water-based outcomes, such as the development of local total maximum daily load standards, often entails requirements for responsible agencies or districts to consult or otherwise involve stakeholders in water management decisions.

   The goal of stakeholder involvement is to negotiate a mutually agreeable desalination plan that balances stakeholder values (e.g., ecological quality, costs, drinking water quality, urban versus agricultural use) *with the technical engineering reality* (e.g., availability of alternative water sources, regulatory constraints, technology costs).

   What's needed, therefore, are ways to integrate technical assessments and stakeholder values into the decision-making process. If stakeholders have not already been engaged in the decision-making process in the feasibility evaluations (Steps 3 and 4), Step 5 offers a very valuable and important opportunity to begin this process. The technical issues and options associated with the desalting scenario–concentrate management plans identified (and those that were discarded) could be presented to key stakeholder parties with the aim of:

   - Educating the public about what is technically feasible with the associated costs and benefits and what is not feasible
   - Getting input as to how they would value the different aspects of each option (e.g., cost, land requirements, risk)
   - Gaining stakeholder buy-in to the final decision through involvement in this process

   Chapter 11 provides more background information on involving stakeholders in the decision-making process.

CHAPTER 8

CASE STUDY 1: SARASOTA COUNTY UTILITIES (UNIVERSITY WELLFIELD WATER TREATMENT FACILITY)

The following case study is presented as the first example in the CMDM software (WRFCMDM.mdb) on the attached CD-ROM. This case study presents an example of how the tool can be used to navigate and organize the data related to the concentrate management decision-making process. The following presents an introduction to the case study and the report output from the tool.

8.1 INTRODUCTION

Located in southwestern Florida, Sarasota County (the County) is home to approximately 350,000 residents. Sarasota County Utilities provides service to just over 470 square miles of the County and serves approximately 65,000 potable water supply customers. The County currently operates three water treatment facilities (WTFs): the Carlton WTF, the University WTF, and the Venice Gardens WTF. The County also receives and distributes potable water from Manatee County (blended with groundwater from the County-owned University Wellfield at the University WTF) and the Peace River/Manasota Regional Water Supply Authority.

The County's water supply source is a combination of ground and surface waters that includes the Peace River and the Manatee County Reservoir, as well as a mix of several brackish water wellfields. The University Wellfield is located in the north-central portion of the County and is comprised of seven active wells with an average annual daily permitted pumping capacity of 2.0 million gal/day (mgd). The University Wellfield is used as a supplemental water supply to blend with water purchased from Manatee County.

The University Wells are located within the Floridan Aquifer System and range in depth from 580 to 640 ft. The wells were constructed from 1981–1989 to increase the supply in the northern portions of the County. Typically, only three wells are operated at one time to allow the others "rest" and to equalize production from each well. The University Wellfield is an established source for the County, and rotational pumping of the aquifer prevents environmental degradation.

The existing water use permit at the University WTF allows for 2.0 and 2.4 mgd of pumping under annual average day and peak month conditions, respectively. The University WTF treatment currently includes only degasification and disinfection. Like all County WTFs, the University WTF uses free chlorine for primary disinfection and adds ammonia to produce chloramines for residual disinfection.

The University Wellfield is limited in its production due to water quality constraints. Because the groundwater contains high concentrations of total dissolved solids (TDS), the County blends water from the University Wellfield with lower-TDS water purchased from Manatee County. The County maintains a blend ratio of 5:1 (Manatee purchase/University Wellfield volumes) to keep TDS levels below 500 mg/L, which is a regulated secondary maximum contaminant level in Florida. Purchase from Manatee County is scheduled to decline gradually until 2025, at which time the contract to purchase water expires. At that time, the County will no longer be able to use this water source unless another treatment method is employed to decrease TDS concentrations.

The current population projections for the County and surrounding areas show that water demand will exceed water supply within the next 15 years unless alternate water supply sources are developed. Implementation of reverse osmosis (RO) at the University WTF has been recommended to meet this treatment need. The Sarasota County Water Supply Master Plan recommends an RO treatment upgrade to be on-line at the University WTF by the year 2015 to meet these future water needs. In addition to providing the County with additional flexibility, reliability, and diversity in water supply options, this source will provide water in the northern areas of the county, where it currently is the only source aside from the Manatee County purchase.

Therefore, the County is planning an RO expansion project at the University WTF, which will by necessity include a concentrate disposal plan. This Sarasota County case study illustrates the use of the CMDM tool and its associated MS Excel files on the attached CD-ROM, focusing on RO treatment and concentrate disposal in a coastal community.

8.2 WRFCMT.MDB OUTPUT FOR SCENARIO 1

Concentrate Management Planning Tool

Project Name: University Wellfield Reverse Osmosis WTF, Scenario 1

Prepared by: Sarasota County and Carollo Engineers

Overview

The Overview page summarizes the County's water treatment goals based on the discussion provided in the introduction to this chapter. It should be noted that the County requires the University WTF RO upgrade for its own water needs, rather than the needs of the entire region. However, the use of the CMDM tool can be used in the same manner. This section corresponds to the first tab of the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM.

Purpose: Potable water supply for Sarasota County, FL. Upgrade in treatment to remove TDS

Project Life Span: 20 years; needs to be online by ~2015 to meet water demands and water quality standards

Flow Rate Max: 2.4 mgd, existing water use permit allocation

Flow Rate Avg: 2.0 mgd, existing water use permit allocation

Finished Water TDS: 400 mg/L; must meet Florida secondary maximum contaminant level of 500 mg/L

Local Economic Climate

Available Capital: Available; RO expansion at University WTF is in the County capital improvement program (CIP)

Tax Base: Sarasota County

Need Bonds: Likely

Pubic Interest in Growth: Support of population; rapidly growing area with a relatively strong economy; economic growth is important to the County

Economic Concerns: Continue to provide for and support economic growth

Cost Assumptions:

Capital Repay Years:	0 years	***Interest Rate:***	6.00%
Current ENR-CCI:	0	***Location Factor:***	1.000

Raw Water Source

The Raw Water page summarizes the characteristics of the University Wellfield raw groundwater source. This section corresponds to the second tab on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM.

Capacity:

Flow Rate Max: 2.4 mgd

Flow Rate Avg: 2.0 mgd

Raw Water Quality:

TDS: 1160 mg/L avg conc (range, 1000–1400 mg/L)

Heavy metals and other contaminants

Arsenic: 2.8 µg/L avg conc (range, 2–3 µg/L)

Selenium: 3.1 µg/L avg conc (range, 3.0–3.5 µg/L)

Primary Treatment

The Primary Treatment page summarizes the primary treatment process selected and the resulting concentrate. This section corresponds to the third tab on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM.

Treatment:

Process Type: RO

Overall Recovery: 85%

Blended TDS Goal: 400 mg/L

Permeate TDS: 40 mg/L

Design Product Flow Rate:

Max Flow Rate:	1.63 mgd (bypass qty, 0.77)
Avg Flow Rate:	1.36 mgd (bypass qty, 0.64)

Characterize Concentrate:

Concentrate TDS:	7455 mg/L
Max Flow Rate:	0.29 mgd
Avg Flow Rate:	0.24 mgd

Solids Loading Rate:

Max Per Day:	18,046 lbs/day
Avg Per Day:	14,935 lbs/day
Annual:	2726 tons

Location

The Location page summarizes information regarding the treatment site identified for the treatment facilities and the concentrate management facility. For this case study, the primary treatment and concentration management facility will be at the existing University WTF site, adjacent to the primary treatment process. This section corresponds to the fourth tab on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM.

Location:	Existing WTP site
Footprint:	Existing site, must provide necessary footprint
Access to Power:	Good, existing power feeds will be used
Ownership:	Sarasota County
Environment:	Surrounded by businesses and some residential
Right of Way:	Piping off-site would require right of way (ROW); concentrate disposal options requiring off-site piping could be time-consuming acquisitions through the surrounding areas and expensive due to ROW issues
Region No.:	8, Coastal, Medium Density

Decision-Making Climate

The Decision-Making Climate page summarizes information regarding the economic, social, and climatic conditions in which the University WTF RO expansion will be developed. This section corresponds to the fifth tab on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM.

Group Type	***Stakeholder***	***Issue Notes***
Environmental	State and Federal regulatory agencies	No environmental issues identified
Neighbors	Local businesses and neighbors	No issues with the existing site

Viable Options

The Viable Options page assesses the potential options on a technical, economic, and practical implementation level. The first part of this process is to assess the feasibility of all the theoretically possible treatment options (based on the local climate and population density and defined by the Region selected on the Location page). Sarasota County has been classified as a coastal region with medium population density. The concentrate management technologies available to the County are (fresh) surface water discharge, wastewater discharge, ocean discharge, deep-injection well, land application, reuse or blending with other wastewater sources, and ZLD.

One of the central intents of this exercise is to eliminate the options that can easily be eliminated based on simple, global considerations (e.g., "I know I can't put anything in the sewer... sewer discharge." The applicable technology-specific parameters and other general controlling parameters identified in Section 2.1.2 and discussed in section 5.1 are considered in this evaluation. The results of the Sarasota County case study are summarized here. This section corresponds to the sixth tab (and has multiple subtabs) on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM.

Viable Options: Surface Water Discharge

Treatment Details:	Piping outfall to the Gulf of Mexico
Technically Feasible:	
Regulatory Requirements:	No; no local freshwater source that is acceptable for discharge
Cost Magnitude:	
Land Availability:	
Public Acceptance:	
Neighborhood Impact:	
Environmental Issues:	
Risk:	
Overall Feasibility:	No

Viable Options: Wastewater Discharge

Treatment Details:	Connect to the sanitary wastewater treatment system
Technically Feasible:	Yes; connection to the sanitary wastewater treatment system is very close to existing WTF site; discharge into the wastewater treatment system would be technically feasible
Regulatory Requirements:	Maybe; must meet reuse requirements at the wastewater treatment plant; initial evaluation indicates that the concentrations of dissolved solids will be acceptable
Cost Magnitude:	Yes; low-cost alternative requiring only minimal piping
Land Availability:	Yes; existing site has room available for this low-footprint option

Public Acceptance:	Yes; will contribute to the reuse system without creating overly high TDS reuse water; will not disturb surrounding areas, as the option would not be seen or heard
Neighborhood Impact:	Yes, negligible aesthetic impact
Environmental Issues:	Yes; none anticipated; the quantity of brine in relation to the quantity of wastewater allows blending to within environmental and permits regulations.
Risk:	Yes; little risk, as meets all other feasibility criteria
Overall Feasibility:	Maybe

Viable Options: Ocean Discharge

Treatment Details:	Piping to an outfall in the Gulf of Mexico.
Technically Feasible:	Yes
Regulatory Requirements:	No; outfalls in the Gulf of Mexico are not generally acceptable to regulatory agencies or permitted
Cost Magnitude:	
Land Availability:	
Public Acceptance:	No, not acceptable to the public
Neighborhood Impact:	
Environmental Issues:	
Risk:	No, unpermittable and unacceptable to the public
Overall Feasibility:	No

Viable Options: Deep-Well Injection

Treatment Details:	Inject into the confined subsurface on-site
Technically Feasible:	Yes; local geology is favorable for deep-well injection
Regulatory Requirements:	Yes, requires a permit, but few obstacles are anticipated
Cost Magnitude:	Yes; significantly more expensive than wastewater treatment discharge option but could be constructed if necessary
Land Availability:	Maybe, moderate space available, could be a tight fit, but room for a deep-injection well may be available; additional land acquisition might be necessary depending on the footprint needed
Public Acceptance:	Yes, injection wells are commonly used in southwest Florida; the County has other deep-injection wells
Neighborhood Impact:	Yes, negligible aesthetic issues
Environmental Issues:	Yes, none anticipated; deep-injection well permitting considers environmental issues
Risk:	Yes, expensive, but meets regulatory and technical requirements
Overall Feasibility:	Maybe

Viable Options: Land Application

Treatment Details:	Irrigate salt-tolerant crops
Technically Feasible:	
Regulatory Requirements:	
Cost Magnitude:	
Land Availability:	No, the County does not have land available for this option; they would need to purchase additional land
Public Acceptance:	
Neighborhood Impact:	
Environmental Issues:	No; it is expected that land application would require extensive environmental analysis
Risk:	No; due to unknown regulatory requirements, expensive land prices, and potential environmental issues, this option is considered high risk
Overall Feasibility:	No

Viable Options: Reuse and Blending

Treatment Details:	Blend with another wastewater discharge
Technically Feasible:	No; there is not a reuse site for blending; however, this option is similar to the wastewater discharge option, as the concentrate will ultimately be blended for reuse
Regulatory Requirements:	
Cost Magnitude:	
Land Availability:	
Public Acceptance:	
Neighborhood Impact:	
Environmental Issues:	
Risk:	
Overall Feasibility:	No

Viable Options: ZLD

Treatment Details:	Install on-site or off-site brine concentrator and spray drier and crystallizer or similar equipment
Technically Feasible:	Yes
Regulatory Requirements:	
Cost Magnitude:	No, due to the other less expensive and simpler concentrate management options, ZLD is not being considered at this time
Land Availability:	
Public Acceptance:	

Neighborhood Impact:

Environmental Issues:

Risk:

Overall Feasibility: No

The County eliminated fresh surface and ocean discharge options due to stringent regulatory and permitting requirements. Environmental issues associated with these technologies also precluded these two options. Cost of land and land availability played an important role in elimination of concentrate management technologies such as land application and spray irrigation. High capital and O&M costs involved with ZLD acted as a deterrent for its selection amongst the list of concentrate management technologies. The County does not have facilities for reuse and blending the concentrate with other wastewater sources, and hence this technology was also eliminated at this stage.

Having evaluated the options and the controlling and governing parameters, the County identified the following option:

1. Wastewater treatment discharge
2. Deep-well injection

Cost Estimates

The Cost Estimates pages can be used to develop the capital, O&M, and life cycle costs for each alternative. (It should be noted that the intent of establishing planning-level costs is to develop order-of-magnitude comparisons of the various technologies based on the user's scenario.)

This evaluation follows the discussions in Chapter 11, Figure 5.2, and Tables 5.7 through 5.9. This section would typically correspond to the fifth tab on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM; however, these costs were developed independently and so are summarized in the Additional Notes section.

Grading Criteria

The Grading Criteria page is used to weight various aspects of each potentially feasible option. The criteria were given weighting factors based on their relative importance to the County in selecting their concentrate management option. This section corresponds to the seventh tab on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM.

Grading Criterion	***Factor (1-10)***	***Comments regarding factor score***
Complexity:	0	
Ease To Implement:	5	Factors include time required for design and construction of the disposal alternative and level of difficulty in implementing the alternative.
Footprint:	0	
Environmental:	7	Factors include disturbance of the natural environment, effects on fish and habitats, disturbance of recreational activities, impacts on aesthetic and scenic resources, and impacts associated with traffic, land transportation, and other long-term impacts.
Life Cycle Cost:	8	Factors include capital costs and O&M costs over the lifetime of the project.
Power Requirements:	0	
Public Acceptance:	7	Factors include the aesthetic impacts to the neighborhood, disruption of other neighborhood activities, and acceptance by the public and other stakeholders for the disposal options.
Regulatory Acceptance:	10	Factors include the number of permits required for the disposal alternative, the time required for the permitting process, feasibility of obtaining and renewing the permit, monitoring, reporting, and recordkeeping requirements.
Risk:	0	
Reliability:	8	Factors include mechanical reliability, process dependency on natural temperature or climate, and long-term process reliability.
Operability:	6	Factors include the ease of the process for the operational staff, maintenance requirements, and system variable residual loads.

Ranking

The Ranking page is used to rate each technology on the weighting factors listed in the previous section. This was completed by assigning scores from 1 (lowest) to 5 (highest) on the favorability of each option. This section corresponds to the eighth tab on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM. Guidance on the data required for this step is provided in Chapter 6.

Grading Criterion	Factor	SWD	WWTD	OD	DWI	EP	LA	R/B	ZLD
Complexity	0	0	0	0	0	0	0	0	0
Ease To Implement	5	0	5	0	4	0	0	0	0
Footprint	0	0	0	0	0	0	0	0	0
Environmental Impact	7	0	4	0	4	0	0	0	0
Life Cycle Cost	8	0	4.5	0	2	0	0	0	0
Power Requirements	0	0	0	0	0	0	0	0	0
Public Acceptance	7	0	3.5	0	4	0	0	0	0
Regulatory Requirements	10	0	4	0	4	0	0	0	0
Risk	0	0	0	0	0	0	0	0	0
Reliability	8	0	5	0	4	0	0	0	0
Operability	6	0	4.5	0	4	0	0	0	0
Weighted Score		0	220.5	0	188	0	0	0	0
Perfect Score: 255									

Abbreviations: SWD, surface water discharge; WWTD, wastewater treatment discharge; OD, ocean discharge; DWI, deep-well injection; EP, evaporation ponds; LA, land application; R/B, reuse and blending.

Additional Notes

The Additional Notes page can be used to make any additional project notes not input under the previously described tabs. This section corresponds to the ninth tab on the WRFCMDM.mdb program (Scenario 1) on the attached CD-ROM.

Continued use of this source is needed to provide supply in the northern areas of the County, as well as to maintain the use of the existing water use permit.

For costs, after the potential feasible options are identified, the user should develop the capital, O&M, and life cycle costs for each alternative. This evaluation follows the discussions in Chapter 11, Figure 5.2, and Tables 5.7 through 5.9. This step corresponds to the tab Cost Estimates in the CMDM tool (although the methodology used was site specific).

It should be noted that the intent of establishing planning-level costs is to develop order-of-magnitude comparisons of the various technologies based on the user's scenario. The results of the cost estimates for the Sarasota County case study are summarized below.

Technology Type: Wastewater Treatment Discharge

1. ***Capital Cost***
   Piping to C.M. facility: $75/ft, based on recent pipeline costs
   Length needed: 500 ft, approx. distance to nearest wastewater treatment line
   Total cost: $37,500

   C.M. facility cost: $10,000, minimal mechanical parts and labor
   Total cost: $90,741/gpd capacity

2. ***O&M Cost***
   Volumetric cost: $0.02/1000 gal; estimate for line maintenance (no pump needed; use head from RO process)
   Annual cost: $3184, based on average concentrate flow rate

3. ***Annual Life Cycle Cost***
   Design life of facility: 20 years
   Interest rate: 7%
   Annual life cycle cost: $5000

Technology Type: Deep-Well Injection

1. ***Capital Cost***
   Piping to C.M. facility: $75/ft, based on recent pipeline costs
   Length needed: 100 ft, approx. distance to nearest wastewater treatment line
   Total cost: $7500

   C.M. facility cost: $5,000,000, minimal mechanical parts and labor
   Total cost: $9,565,984/gpd capacity

2. ***O&M Cost***
   Volumetric cost: $0.04/1000 gal, estimate for line maintenance (no pump needed; use head from RO process)
   Annual cost: $6369, based on average concentrate flow rate

3. ***Annual Life Cycle Cost***
   Design life of facility: 20 years
   Interest rate: 7%
   Annual life cycle cost: $240,000

The following sections expand upon some of the issues pertaining to each disposal option.

Deep-Well Injection

1. *Technical feasibility*: Deep-well injection is a widely used concentrate management technology in Florida, which has a geology suited to this type of application.

2. *Permittability*: Deep-well injection must meet the regulatory requirements set by the Underground Injection Control rules. The County has implemented deep-well injection in the past at other facilities and has met all the regulatory requirements related to use of this technology. Thus, deep-well injection seems to be a feasible option with regard to regulatory requirements.
3. *Environmental issues*: One of the environmental issues associated with deep injection wells is the potential failure of the wells which could lead to groundwater contamination. However, Sarasota County lies in Florida, where the geology is suited to deep injection well applications.
4. *Neighborhood impacts*: Deep injection wells have relatively low energy requirements and are usually located away from public and private areas. Noise levels from well operations are low, and overall neighborhood impacts due to deep-well injection are minimal.
5. *Ease of implementation*: Permitting and construction of a deep injection well typically requires 1 year, which meets the County's time constraints.

Wastewater Treatment Discharge

1. *Technical feasibility*: Many small RO plants (less than 6 mgd) discharge concentrate to an existing wastewater treatment system. The impact of adding RO concentrate to the wastewater treatment line is minimal. Mass balance calculations performed on TDS suggest a small increase in wastewater TDS concentrations of approximately 300 mg/L. The Bee Ridge Water Reclamation Facility is capable of handling this concentration, and as a result the impact of RO concentrate discharge to the wastewater treatment lines is minimal.
2. *Permittability*: The discharge of RO concentrate to wastewater treatment lines does not have specific requirements as far as governing bodies are concerned. However, the local sanitary agency might impose limitations to protect wastewater treatment systems and plant infrastructure. The Sarasota County plans to collaborate with the Bee Ridge Water Reclamation Facility for disposal of RO concentrate.
3. *Environmental issues*: Aside from the high brine concentration, which may limit the volume of concentrate discharged to the wastewater treatment lines, there exist hardly any environmental issues for implementation of this technology for the County.
4. *Neighborhood impacts*: A discharge of RO concentrate to the wastewater treatment line will have minimal impacts with respect to noise pollution and proximity to public and private areas.
5. *Ease of implementation*: This option only requires piping to the nearest sanitary wastewater line, which can be accomplished in the timeframe required.

8.3 NEXT STEPS

The last segment of the decision methodology is to plan the next steps in the desalination project implementation process. The user must decide how to next proceed based on the options that have been identified (or, in some cases, if no viable options have been identified). The next steps for the Sarasota County case study are described below.

The Sarasota County Water Supply Master Plan was completed in early 2006. This document developed demand projections based on data from 2005 and recommends various projects to meet its residents' needs through the year 2050. One of the projects recommended in the Master Plan is the addition of the RO treatment process at the University WTF. This project will assist in meeting demands in the northern areas of the County and will allow the County to continue to use the existing water use permit at the University Wellfield. Although the project will only provide a small percentage of the County's total water supply, continued use of this facility is vital in the County's long-range water supply plan.

The preferred concentrate management option for the University WTF is wastewater disposal. Preliminary evaluations indicate that the small quantity of concentrate will not adversely affect the wastewater collection system or treatment plant. It is anticipated that the County will be able to use this preferred, low-cost option. Construction of a deep injection well remains the backup disposal method, should wastewater disposal become unfeasible for any reason.

The schedule for the University Wellfield RO upgrades was developed based on the projected water needs in the County and to match the gradual step-down of contracted water purchases from Manatee County. It is likely that the Master Plan will be updated on a regular basis, which could slightly modify demand projections and the anticipated project schedule.

The County's Master Plan includes the following timeline for RO upgrades at the University WTF:

- 2013: Facility permitting and begin design process
- 2014: Complete design and start construction
- 2015: Complete construction and process start-up

CHAPTER 9

CASE STUDY 2: IMPLEMENTING A NEW REUSE SUPPLY IN AN INLAND ARID CLIMATE

The following case study is presented as the second and third examples in the CMDM software (WRFCMDM.mdb) on the attached CD-ROM. This case study illustrates how the tool can be used to navigate and organize the data related to the concentrate management decision-making process. The following presents an introduction to the case study and the report output from the tool.

9.1 INTRODUCTION

In this example, a metropolitan area in an inland arid region is planning to develop a new reuse water supply at an existing WWTP within the city limits. The reuse supply is planned to have an 8.0-mgd capacity and to produce an annual average of 4.0 mgd of reclaimed wastewater. This new supply will be used for irrigation of city parks and to recharge groundwater. Salt accumulation in the area is a concern that the City must address.

In this example, the City considered two scenarios. In Scenario 1 (record 2 in the CMDM.mdb), the City considered either on-site or off-site treatment. In Scenario 2 (record 3 in the CMDM.mdb), the City considered a combination of on- and off-site treatments.

9.2 WRFCMDM.MDB OUTPUT FOR SCENARIO 2

Concentrate Management Planning Tool

Project Name: Reuse example: on-site or off-site treatment, Scenario 2
Prepared by: Carollo Engineers

Overview

The Overview page summarizes the City's water treatment goals based on the discussion provided in the introduction to this chapter. This section corresponds to the first tab of the WRFCMDM.mdb program (Scenario 2) on the attached CD-ROM.

Purpose: New reuse supply; turf irrigation, groundwater recharge
Project Life Span: 30 years; expansion up to 22 mgd in the year 2015
Flow Rate Max: 8.0 mgd
Flow Rate Avg: 4.0 mgd
Finished Water TDS: 650 mg/L, want to match source water TDS

Local Economic Climate

Available Capital: Need bonds; in CIP

Tax Base:

Need Bonds: Yes

Pub Interest Growth:

Economic Concerns:

Cost Assumptions:

Capital Repay Years:	20 years	***Interest Rate:***	6.00%
Current ENR-CCI:	8008	***Location Factor:***	0.931

Raw Water Source

> The Raw Water page summarizes the characteristics of the WWTP reclaimed (wastewater) source. This section corresponds to the second tab on the WRFCMDM.mdb program (Scenario 2) on the attached CD-ROM.

Description: New reuse supply; reclaimed wastewater

Capacity:

Flow Rate Max: 8.0 mgd

Flow Rate Avg: 4.0 mgd

Raw Water Quality

TDS: 1170 mg/L

Heavy metals and other contaminants

Selenium, 4.0 µg/L

Primary Treatment

> The Primary Treatment page summarizes the primary treatment process selected and the resulting concentrate. This section corresponds to the third tab on the WRFCMDM.mdb program (Scenario 2) on the attached CD-ROM.

Treatment

Process Type: RO, two-stage RO planned

Overall Recovery: 80%

Blended TDS Goal: 650 mg/L

Permeate TDS: 40 mg/L (estimate; pilot plant data not available)

Design Product Flow Rate:

Max Flow Rate: 3.68 mgd (bypass qty, 4.32)

Avg Flow Rate: 1.84 mgd (bypass qty, 2.16)

Characterize Concentrate:

Concentrate TDS:	5690 mg/L
Max Flow Rate:	0.92 mgd
Avg Flow Rate:	0.46 mgd

Solids Loading Rate:

Max Per Day:	43,695 lb/day
Avg Per Day:	21,847 lb/day
Annual:	3987 tons

Location

The Location page summarizes information regarding the treatment site identified for the treatment facilities and the concentrate management facility. For this case study, the primary treatment and concentration management facility will be either at the existing WWTP site, adjacent to the primary treatment process or off-site in the desert. This section corresponds to the fourth tab on the WRFCMDM.mdb program (Scenario 2) on the attached CD-ROM.

Location Desc:	WWTP site or out of metro area
Footprint:	20 acres, includes space for future treatment; expansion, limited room for CMT
Access to Power:	Good; substation nearby
Ownership:	City land plus private/public land off-site would require land acquisition
Environment:	Residential, cemetery, park, and greenbelt, plus rural
Right of Way:	Would need to negotiate with residents and businesses to build a pipeline; off-site could be considered, but logistical issues could well preclude its practicality
Region No:	3, Inland, Arid; Low Density

Decision-Making Climate

The Decision-Making Climate page summarizes information regarding the economic, social, and climatic conditions in which the reclaimed water RO system will be developed. This section corresponds to the fifth tab on the WRFCMDM.mdb program (Scenario 2) on the attached CD-ROM.

Group Type	*Stakeholder*	*Issue Notes*
Civic	Various	Impact of salinity on the water supply
Environmental	Various	Effects of salt disposal and effects of recharge
Neighbors	WWTP area residents	Noise, sight lines, odor, ROW issues
Others	Reuse customers	Salinity levels, particularly sodium adsorption ratio (SAR; affects primary treatment which, in turn, affects concentrate quality and quantity)
Others	Wastewater Department	Controls WWTP and sewer system, separate from water treatment
Regulators	Dept. of Env. Quality	Permitting, environmental impact Dept. of Fish & Wildlife assessments
Sporting	Groups using the park	Effects of salt on playing fields (affects primary treatment which, in turn, affects concentrate quality and quantity)

Viable Options

The Viable Options page assesses the potential options on technical, economic, and practical implementation levels. The first part of this process is an assessment of the feasibility of all the theoretically possible treatment options (based on the local climate and population density and defined by the Region selected on the Location page). The WWTP or off-site options have been classified as an inland arid, low-density location. The concentrate management technologies available to the City are (fresh) surface water discharge, wastewater discharge, deep-well injection, evaporation ponds, land application, reuse or blending with other wastewater sources, and ZLD.

One of the central intents of this exercise is to identify the options that can easily be eliminated based on simple, global considerations (e.g., "I know I can't put anything in the sewer"). The applicable technology-specific parameters and other general controlling parameters identified in Section 2.1.2 and discussed in Section 5.1 are considered in this evaluation. The results of the new reuse supply Scenario 1 are summarized here. This section corresponds to the sixth tab (and has multiple subtabs) on the WRFCMDM.mdb program (Scenario 2) on the attached CD-ROM.

Viable Options: Surface Water Discharge

Treatment Details:	Dispose of concentrate with WWTP effluent
Technically Feasible:	Yes, connect concentrate line to the plant's tertiary effluent line
Regulatory Requirements:	Maybe; high-salinity concentrate could not quality for an National Pollutant Discharge Elimination System (NPDES) permit; salinity accumulation is a significant issue in the area; the State has adopted a 1250 mg/L TDS limit
Cost Magnitude:	Yes; relatively low-cost option
Land Availability:	Yes; very small footprint
Public Acceptance:	Maybe; see Environmental Issues
Neighborhood Impact:	Yes; minimal aesthetic issues
Environmental Issues:	Maybe; impact on salt accumulation in the valley may preclude this option
Risk:	Yes; permitting is in question, but cost and logistics make it very attractive
Overall Feasibility:	Maybe

Viable Options: Wastewater Discharge

Treatment Details:	Dispose of the concentrate in the sewer
Technically Feasible:	Maybe; would result in increasing salt accumulation; impact on the sludge system is not expected to be problematic, but further study would be needed to confirm this assumption
Regulatory Requirements:	No; high-saline water would not qualify for an NPDES permit
Cost Magnitude:	
Land Availability:	
Public Acceptance:	
Neighborhood Impact:	
Environmental Issues:	
Risk:	
Overall Feasibility:	No

Viable Options: Deep-Well Injection

Treatment Details:	On-site injection well
Technically Feasible:	Maybe; local geology likely not amenable to deep-well injection; need to have both the right geology and sufficient capacity
Regulatory Requirements:	No; Dept. Env. Quality regulations preclude this option
Cost Magnitude:	
Land Availability:	
Public Acceptance:	

Neighborhood Impact:
Environmental Issues:
Risk:
Overall Feasibility: No

Viable Options: Evaporation Ponds

Treatment Details: Pipe effluent off-site to evaporation ponds
Technically Feasible: Yes
Regulatory Requirements: Maybe
Cost Magnitude: Maybe
Land Availability: Maybe
Public Acceptance: Maybe
Neighborhood Impact: Yes
Environmental Issues: Maybe
Risk: Maybe; treatment of unconcentrated effluent likely impractical, too much land needed.

Overall Feasibility: Maybe

Viable Options: Land Application

Treatment Details: Too much concentrate for irrigation based on existing opportunities
Technically Feasible: Maybe; would need to find crops that could tolerate the high salt load; research is ongoing in this area
Regulatory Requirements:
Cost Magnitude:
Land Availability: No
Public Acceptance:
Neighborhood Impact:
Environmental Issues:
Risk:
Overall Feasibility: No

Viable Options: Reuse or Blending

Treatment Details: Blend with another, low-salinity treated wastewater source
Technically Feasible: No; no low-salinity blending sources available
Regulatory Requirements:
Cost Magnitude:
Land Availability:
Public Acceptance:
Neighborhood Impact:
Environmental Issues:

Risk:

Overall Feasibility: No

Viable Options: ZLD

Treatment Details:	Install a brine concentrator on-site with off-site evaporation ponds
Technically Feasible:	Yes; uses a brine concentrator to produce low-TDS product water and a concentrated waste (~200,000 mg/L); final solidification step consists of spray drying for producing dry solids that can be disposed of in a landfill
Regulatory Requirements:	Yes; no significant permitting issues anticipated
Cost Magnitude:	Maybe; very expensive
Land Availability:	Yes; small footprint, will fit on-site
Public Acceptance:	Maybe; expensive and unsightly
Neighborhood Impact:	Maybe; sight lines and sound quality issues
Environmental Issues:	Maybe; see Public Acceptance
Risk:	Yes; technically feasible, stakeholder issues to negotiate
Overall Feasibility:	Maybe

The City eliminated the wastewater discharge option due to stringent regulatory and permitting requirements. Environmental issues also precluded this option. The local geology and state regulations preclude deep-well injection. Cost of land and land availability played an important role in the elimination of the land application option. The City does not have facilities for reuse and blending the concentrate with other wastewater sources and, hence, this technology was also eliminated at this stage.

Having evaluated the options and the controlling and governing parameters, the City identified three feasible options:

1. Surface Water Discharge: dispose of concentrate with WWTP effluent
2. Evaporation Ponds: off-site disposal
3. ZLD: install a brine concentrator on-site with off-site evaporation ponds

Cost Estimates

The Cost Estimates pages can be used to develop the capital, O&M, and life cycle costs for each alternative. (It should be noted that the intent of establishing planning-level costs is to develop order-of-magnitude comparisons of the various technologies based on the user's scenario.)

This evaluation follows the discussions in Chapter 11, Figure 5.2, and Tables 5.7 through 5.9. This section corresponds to the fifth tab on the WRFCMDM.mdb program (Scenario 2) on the attached CD-ROM.

Concentrate Management Decision Methodology: Cost Report

Project reuse example: on-site or off-site treatment, Scenario 2
Prepared by: Carollo Engineers

Surface Water Discharge Cost Report

Flow Rate Max: 0.92 mgd

Flow Rate Avg: 0.46 mgd

(Total costs are rounded to the nearest thousand)

Total Pipeline Cost: 6 in; 1000 ft; unit cost $68.60; total cost $65,950

Outfall Structure: $25,000

Pump Station: $565,500

Permits: $15,000

Engineering: 10.0%; total cost $67,145

Contingency: 10.0%; total cost $67,145

Total Capital Cost: $806,000

Pumping Energy Cost: desired PSI, 44; 26.8 HP pump; energy cost, 0.0800; total cost, $19,478

Misc Maintenance: 1.00%, $8060

Monitoring Lab Cost: $15,000

Total Annual O&M: $43,000

Annualized Capital Cost: $70,000

Total Annual Cost: $113,000

Evaporative Ponds Cost Report

Flow Rate Max: 0.92 mgd

Flow Rate Avg: 0.46 mgd

Parameters	
Pond Life in Years:	30 years
Mean Rainfall:	10 in.
Pan Evaporation Rate:	20
Est Evaporation Rate:	14
Salt precipitation:	0.0028
Evaporative Loss Rate:	4.0028
Depth of Pond:	8
Precipitation Freeboard:	1
Wind Velocity:	5
Fetch:	1
Evaporative Surface:	1854.333
Wave Freeboard:	0.235
Runup Freeboard:	0.3525
Calculated Dike Height:	1.3445

Capital Costs		
Total Land Cost:	$200.00	$370,867
Land Clearing per Acre:	$1000.00	$1,854,333
Dike per Acre:	$1285.09	$2,382,982
Nominal Liner:	$314.03	$314
Fence per Acre:	$1831.01	$3,395,302
Road per Acre:	$314.99	$584,099
Pump Station:		$0
Excavation Cost:		$0
Subtotal:		$8,587,897
Engineering:		$919,489
Contingency:		$919,489
Permits:		$25,000
Total Capital Cost:		$11,034,000

Operation and Maintenance Costs	
Dike Height for Costing:	4
Land Cost per Acre:	$200
Land Clearing per Acre:	Brush
Land Ratio:	1
Total Acreage Needed:	1854.333
Desired PSI:	144
Energy Cost:	0.0800
Pump HP:	26.8
Annual Solids Load:	3987
Dredging Cost:	$50.00
Solids Disposal Fee:	$200.00

Pumping Energy Cost:	$19,478
Misc Maintenance:	$110,340
Monitoring Lab Cost:	$15,000
Total Dredging:	$199,350
Solid Waste Landfill Cost:	$797,400
Total Annual O&&M	$1,142,000

Total Capital Costs*:*	$11,034,000
Total Annual O&M*:*	$1,142,000
Annualized Capital Cost:	$962,000
Total Annual Cost:	$2,104,000

Zero Liquid Discharge Cost Report

Flow Rate Max: 0.92 mgd

Pumping Energy Cost:

Flow Rate Avg: 0.46 mgd; 144 desired; pump HP 26.8; energy, 0.0800; total $19,478

Flow Rate Avg: 638.8 gal

	Energy Costs:	***Energy, kWh:***	***Energy Cost:***
Reject Level (2–10%):	*2.00*		
Concentrator:	3,800	$2,663,040	
Concentrate Reject (gpm):	13		
Crystallizer:	80	$56,064	
Spray Drier:	0	$0	
Concentrator Cost:	$11,749,384		
	0	$0	
Crystallizer Cost:	$3,082,281		
Spray Drier Cost: $0		***Annual Solids***	***Landfill Costs/Ton:***
Other: $0		3987	$200
Pump Station: $0		***Solids Disposal Cost:*** $797,400	
Permits:	$15,000		
	1.00%	***Misc Maintenance:***	$178,158
Engineering:	$1,484,667	***Monitoring Lab Cost:***	$15,000
Contingency:	$1,484,667		
Total Annual O&M:	$3,729,000		
Total Capital Cost:	$17,816,000		
Annualized Capital Cost:	$1,553,000		
Total Annual Cost:	$5,282,000		

Grading Criteria

Grading Criterion	*Factor (1–10)*	*Comments regarding factor score*
Complexity:	6	Ease of process for the operational staff, maintenance requirements, system variable residual loads
Ease To Implement:	6	Time required for design and construction of the disposal alternative, level of difficulty in operating and implementing the alternative, approval of government agencies, and public perception
Footprint:	6	Land required to construct the disposal facility, site constraints, impacts on other facilities at the WWTP, and ROW and easement requirements
Environmental:	6	Disturbance of the natural environment, effects on fish and habitats, disturbance of recreational activities, impacts on aesthetic and scenic resources, impacts associated with traffic, land transportation, and other long-term impacts
Life Cycle Cost:	10	
Power Requirements:	8	Fuel and electricity, availability of alternate energy sources, on-site power
Public Acceptance:	8	Public support of the project in both technical and economic terms
Regulatory Acceptance:	8	Number of permits required; time requirement for the permitting process; effluent limitations; Best Manufacturing Practices; feasibility in obtaining and renewing the permit; monitoring, reporting, and recordkeeping requirements
Risk:	0	
Reliability:	8	Mechanical reliability, process dependency on natural temperature, wind intensity, humidity, precipitation, geohydrologic impacts on outside resources, and long-term process reliability

Ranking

Grading Criterion	Factor	Surface Water Discharge	Wastewater Discharge	Ocean Discharge	Deep-Well Injection	Evaporative Ponds	Land Application	Reuse or Blending	ZLD
Complexity	6	5	0	0	0	3	0	0	2
Ease To Implement	6	5	0	0	0	2	0	0	3
Footprint	6	5	0	0	0	1	0	0	5
Environmental Impact	6	2	0	0	0	4	0	0	4
Life Cycle Cost	10	5	0	0	0	1	0	0	1
Power Requirements	8	5	0	0	0	4	0	0	1
Public Acceptance	8	3	0	0	0	2	0	0	3
Regulatory Requirements	8	2	0	0	0	3	0	0	5
Risk	0	0	0	0	0	0	0	0	0
Reliability	8	5	0	0	0	4	0	0	4
Weighted Score		272	0	0	0	174	0	0	198

Perfect Score: **330**

Additional Notes

> The Additional Notes page can be used to make any additional project notes not input under the previous tabs. This section corresponds to the ninth tab on the WRFCMDM.mdb program (Scenario 2) on the attached CD-ROM.

For Location, part of the area is for setbacks and future plant expansions; there is not much existing area available at the plant for salinity control treatment and management.

The inlet pressure to the brine concentrator assumes lifting the water 90 ft (39 psi) + 5 psi + 100 psi to boost it to the evaporation pond off-site.

Salt disposal costs are fixed; there is no evaporation pond advantage there.

9.3 WRFCMDM.MDB OUTPUT FOR SCENARIO 3

Concentrate Management Planning Tool
Project Name: Reuse example, on-site or off-site treatment, Scenario 3
Prepared by: Carollo Engineers

Overview

> The Overview page summarizes the City's water treatment goals based on the discussion provided in the introduction to this chapter. This section corresponds to the first tab of the WRFCMDM.mdb program (Scenario 3) on the attached CD-ROM.

Purpose: New reuse supply; turf irrigation, groundwater recharge

Project Life Span: 30 years; expansion up to 22 mgd in the year 2015

Flow Rate Max: 8.0 mgd

Flow Rate Avg: 4.0 mgd

Finished Water TDS: 650 mg/L; want to match source water TDS

Local Economic Climate
Available Capital: Need bonds; in CIP
Tax Base:
Need Bonds: Yes
Pub Interest Growth:
Economic Concerns:
Cost Assumptions:

Capital Repay Years:	20 years	***Interest Rate:***	6.00%
Current ENR-CCI:	8008	***Location Factor:***	0.931

Raw Water Source

The Raw Water page summarizes the characteristics of the WWTP reclaimed (wastewater) source. This section corresponds to the second tab on the WRFCMDM.mdb program (Scenario 3) on the attached CD-ROM.

Description: New reuse supply, reclaimed wastewater
Capacity:

Flow Rate Max: 8.0 mgd

Flow Rate Avg: 4.0 mgd

Raw Water Quality

TDS: 1170 mg/L

Heavy Metals and other Contaminants

Selenium, 4.0 µg/L

Primary Treatment

The Primary Treatment page summarizes the primary treatment process selected and the resulting concentrate. This section corresponds to the third tab on the WRFCMDM.mdb program (Scenario 3) on the attached CD-ROM.

Treatment

Process Type: RO, two-stage RO planned

Overall Recovery: 80%

Blended TDS Goal: 650 mg/L

Permeate TDS: 40 mg/L, estimate, pilot plant data not available

Design Product Flow Rate

Max Flow Rate: 3.68 mgd, bypass qty 4.32

Avg Flow Rate: 1.84 mgd, bypass qty 2.16

Characterize Concentrate

Concentrate TDS: 5690 mg/L

Max Flow Rate: 0.92 mgd

Avg Flow Rate: 0.46 mgd

Solids Loading Rate

Max Per Day: 43,695 lbs/day

Avg Per Day: 21,847 lbs/day

Annual: 3987 tons

Location

> The Location page summarizes information regarding the treatment site identified for the treatment facilities and the concentrate management facility. For this case study, the primary treatment and concentration management facility will be either at the existing WWTP site, adjacent to the primary treatment process, or off-site in the desert. This section corresponds to the fourth tab on the WRFCMDM.mdb program (Scenario 3) on the attached CD-ROM.

Location Desc:	WWTP site + out of metro area
Footprint:	20 acres; includes space for future treatment; expansion, limited room for CMT
Access to Power:	Good; substation nearby
Ownership:	City land + private/public land; off-site would require land acquisition
Environment:	Residential, cemetery, park, greenbelt + rural
Right of Way:	Would need to negotiate with residents and businesses to build a pipeline; off-site could be considered, but logistical issues could well preclude its practicality
Region No.:	2, Inland Arid; Medium Density

Decision-Making Climate

> The Decision-Making Climate page summarizes information regarding the economic, social, and climatic conditions in which the reclaimed water reverse osmosis system will be developed. This section corresponds to the fifth tab on the WRFCMDM.mdb program (Scenario 3) on the attached CD-ROM.

Group Type	***Stakeholder***	***Issue Notes***
Civic	Various	Impact of salinity on the water supply
Environmental	Various	Effects of salt disposal & effects of recharge
Neighbors	WWTP area residents	Noise, sight lines, odor, ROW issues
Others	Reuse customers	Salinity levels, particularly SAR (affects primary treatment which, in turn, affects concentrate quality and quantity)
Others	Wastewater Dept.	Controls WWTP and sewer system, separate from water treatment.
	Regulators	Dept. Env. Quality, Permitting, environmental impact Dept. Fish & Wildlife assessments.
Sporting	Groups using the park	Effects of salt on the playing fields (affects primary treatment which, in turn, affects concentrate quality and quantity)

Viable Options

The Viable Options page assesses the potential options on a technical, economic, and practical implementation level. The first part of this process is to assess the feasibility of all the theoretically possible (based on the local climate and population density and defined by the Region selected on the Location page) treatment options. The WWTP + off-site options have been classified as an inland arid, medium-density location. The concentrate management technologies available to the City are (fresh) surface water discharge, wastewater discharge, deep-well injection, land application, reuse or blending with other wastewater sources, and ZLD.

One of the central intents of this exercise is to eliminate the options that can easily be eliminated based on simple, global considerations (e.g., "I know I can't put anything in the sewer"). The applicable technology-specific parameters and other general controlling parameters identified in Section 2.1.2 and discussed in section 5.1 are considered in this evaluation. The results of the new reuse supply Scenario 1 are summarized here. This section corresponds to the sixth tab (and has multiple subtabs) on the WRFCMDM.mdb program (Scenario 3) on the attached CD-ROM.

Viable Options: Surface Water Discharge

Treatment Details: Dispose of concentrate with WWTP effluent

Technically Feasible: Yes, connect concentrate line to the plant's tertiary effluent line

Regulatory Requirements: Maybe; high-salinity concentrate could not quality for an NPDES permit; salinity accumulation is a significant issue in the area; State has adopted a 1250 mg/L TDS limit

Cost Magnitude: Yes, relatively low-cost option

Land Availability: Yes, very small footprint

Public Acceptance: Maybe, see Environmental Issues

Neighborhood Impact: Yes, minimal aesthetic issues

Environmental Issues: Maybe, impact on salt accumulation in the valley may preclude this option

Risk: Yes, permitting is in question, but cost and logistics make it very attractive

Overall Feasibility: Maybe

Viable Options: Wastewater Discharge

Treatment Details: Dispose of the concentrate in the wastewater treatment system

Technically Feasible: Maybe, would result in increasing salt accumulation; impact on the sludge system is not expected to be problematic, but further study would be needed to confirm this assumption

Regulatory Requirements: No, high-saline water would not qualify for a NPDES permit

Cost Magnitude:

Land Availability:

Public Acceptance:

Neighborhood Impact:

Environmental Issues:

Risk:

Overall Feasibility: No

Viable Options: Deep-Well Injection

Treatment Details: On-site injection well

Technically Feasible: Maybe, local geology likely not amenable to deep-well injection; need to have both the right geology and sufficient capacity

Regulatory Requirements: No, DEQ regulations preclude this option

Cost Magnitude:

Land Availability:

Public Acceptance:

Neighborhood Impact:

Environmental Issues:

Risk:

Overall Feasibility: No

Viable Options: Land Application

Treatment Details: Too much concentrate for irrigation based on existing opportunities

Technically Feasible: Maybe, would need to find crops that could tolerate the high salt load; research is ongoing in this area

Regulatory Requirements:

Cost Magnitude:

Land Availability: No

Public Acceptance:

Neighborhood Impact:

Environmental Issues:

Risk:

Overall Feasibility: No

Viable Options: Reuse or Blending

Treatment Details: Blend with another, low-salinity treated wastewater source

Technically Feasible: No, no low-salinity blending sources available

Regulatory Requirements:

Cost Magnitude:

Land Availability:

Public Acceptance:

Neighborhood Impact:

Environmental Issues:

Risk:

Overall Feasibility: No

Viable Options: Zero Liquid Discharge

Treatment Details: Install a brine concentrator on-site with off-site evaporation ponds

Technically Feasible: Yes, uses a brine concentrator to produce low-TDS product water and a concentrated waste (~200,000 mg/L); final solidification step consists of spray drying for producing dry solids that can be disposed of in a landfill

Regulatory Requirements: Yes, no significant permitting issues anticipated

Cost Magnitude: Maybe; very expensive

Land Availability: Yes, small footprint, will fit on-site

Public Acceptance: Maybe, expensive and unsightly

Neighborhood Impact: Maybe, sight lines and sound quality issues

Environmental Issues: Maybe; see Public Acceptance

Risk: Yes, technically feasible, stakeholder issues to negotiate

Overall Feasibility: Maybe

The City eliminated the wastewater discharge option due to stringent regulatory and permitting requirements. Environmental issues also precluded this option. The local geology and state regulations preclude deep-well injection. Cost of land and land availability played an important role in the elimination of the land application option. The City does not have facilities for reuse and blending the concentrate with other wastewater sources and hence this technology was also eliminated at this stage.

Having evaluated the options and the controlling and governing parameters, the City identified two feasible options:

1. Surface Water Discharge: dispose of concentrate with WWTP effluent
2. ZLD with evaporation ponds: install a brine concentrator on-site with off-site evaporation ponds.

Cost Estimates

The Cost Estimates pages can be used to develop the capital, O&M, and life cycle costs for each alternative. (It should be noted that the intent of establishing planning-level costs is to develop order-of-magnitude comparisons of the various technologies based on the user's scenario.)

This evaluation follows the discussions in Chapter 11, Figure 5.2, and Tables 5.7 through 5.9. This section corresponds to the fifth tab on the WRFCMDM.mdb program (Scenario 3) on the attached CD-ROM.

Concentrate Management Decision Methodology - Cost Report

Project Reuse Example: On-site or off-site treatment, Scenario 3
Prepared by: Carollo Engineers

Surface Water Discharge Cost Report

(totals are rounded to nearest thousand)

Flow Rate Max: 0.92 mgd

Flow Rate Avg: 0.46 mgd	
Total Pipeline Cost: pipe size, 6 in.; length, 1000 ft; unit cost, 68.60	$65,950
Outfall Structure:	$25,000
Pump Station:	$565,500
Permits:	$15,000
Engineering: 10.0%	$67,095
Contingency: 10.0%	$67,095
Total Capital Cost:	$805,000
Pumping Energy Cost: desired psi, 144; 26.8 HP; energy cost, 0.0800	$19,478
Misc Maintenance: 1.00%	$8,050
Monitoring Lab Cost:	$15,000
Total Annual O&M:	$43,000
Annualized Capital Cost:	$70,000
Total Annual Cost:	$113,000

Zero Liquid Discharge Cost Report

Flow Rate Max: 0.92 mgd

Energy Cost:

Flow Rate Avg: 0.46 mgd; 144 desired psi, 26.8 HP, energy cost, 0.0800 $19,478

Flow Rate Avg: 638.8 gal

		Energy Costs	***Energy kWh***	***Energy Cost:***
Reject Level (2– 10%):	2.00			
Concentrator:			3800	$2,663,040
Concentrate Reject (gpm):	13			
Crystallizer:			0	$0
Spray Drier:			0	$0
Other: Evaporation pond				$1,700,000
Concentrator Cost: $11,749,384				
			0	$0

Crystallizer Cost:	$0			
Spray Drier Cost:	$0	***Annual Solids Landfill Costs/ton:***		
Other: Evaporation pond	$1,700,000	3987	$200	
Pump Station:	$200,000		***Solids Disposal Cost:***	$797,400
Permits:	$15,000			
	1.00%		***Misc Maintenance:***	$163,973
Engineering:	$1,366,438		***Monitoring Lab Cost:***	$15,000
Contingency:	$1,366,438			
Total Annual O&M:	$3,659,000			
Total Capital Cost:	$16,397,000			
Annualized Capital Cost:	$1,430,000			
Total Annual Cost:	$5,089,000			

Grading Criteria

Grading Criterion	***Factor (1–10)***	***Comments regarding factor score***
Complexity:	6	Ease of process, the operational staff, maintenance requirements, system variable residual loads
Ease To Implement:	6	Time required for design and construction of the disposal alternative, level of difficulty in operating and implementing the alternative, approval of government agencies, and public perception
Footprint:	6	Land required to construct the disposal facility, site constraints, impacts on other facilities at the WWTP, and ROW and easement requirements
Environmental:	6	Disturbance of natural environment, effects on fish and habitats, disturbance of recreational activities, impacts on aesthetic and scenic resources, impacts associated with traffic, land transportation, and other long-term impacts
Life Cycle Cost:	10	
Power Requirements:	8	Fuel and electricity, availability of alternate energy sources, on-site power

Public Acceptance:	8	Public support of the project in both technical and economic terms
Regulatory Acceptance:	8	Number of permits required, time requirement for permitting process, effluent limitations, Best Manufacturing Practices, feasibility in obtaining and renewing the permit, and monitoring, reporting, and recordkeeping requirements
Risk:	0	
Reliability:	8	Mechanical reliability, process dependency on natural temperature, wind intensity, humidity, precipitation, geohydrologic impacts on outside resources, and long-term process reliability

Additional Notes

The Additional Notes page can be used to make any additional project notes not input under the previous tabs. This section corresponds to the ninth tab on the WRFCMDM.mdb program (Scenario 3) on the attached CD-ROM.

For the Location, part of the area is for setbacks and future plant expansions; there is not much existing area available at the plant for salinity control treatment and management.

The inlet pressure to the brine concentrator assumes lifting the water 90 ft (39 psi) + 5 psi + 100 psi to boost it to the evaporation pond off-site.

Salt disposal costs are fixed; no evaporation pond advantage there.

Ranking

Grading Criteria	Factor	Surface Water Discharge	Wastewater Discharge	Ocean Discharge	Deep-Well Injection	Evaporative Ponds	Land Application	Reuse or Blending	ZLD
Complexity	6	5	0	0	0	0	0	0	2
Ease To Implement	6	5	0	0	0	0	0	0	2
Footprint	6	5	0	0	0	0	0	0	4
Environmental Impact	6	2	0	0	0	0	0	0	4
Life Cycle Cost	10	5	0	0	0	0	0	0	1
Power Requirements	8	5	0	0	0	0	0	0	1
Public Acceptance	8	3	0	0	0	0	0	0	3
Regulatory Requirements	8	2	0	0	0	0	0	0	5
Risk	0	0	0	0	0	0	0	0	0
Reliability	8	5	0	0	0	0	0	0	4
Weighted Score		272	0	0	0	0	0	0	186

Perfect Score: ***330***

CHAPTER 10

CASE STUDY 3: CITY OF PHOENIX

IMPLEMENTING A NEW POTABLE WATER SUPPLY IN AN INLAND ARID CLIMATE

The following case study is presented as the fourth example in the CMDM software (WRFCMDM.mdb) on the attached CD-ROM. This case study presents an example of how the tool can be used to navigate and organize the data related to the concentrate management decision-making process. The following presents an introduction to the case study and the report output from the tool.

10.1 INTRODUCTION

The City of Phoenix Water Services Department is planning to develop a new WTP near the end of the Salt River Project's Western Canal at Dobbins Road and 19th Avenue. Pending the Water System Master Plan Update (WSMPU; 2005–2006), the Western Canal WTP is planned to initially produce 40 mgd of potable water by the year 2014 and ultimately up to 120 mgd of potable water (by 2055), based on the WSMPU 1998 recommendations. It is expected that adding the Western Canal WTP will:

- Enhance the reliability and redundancy of the City's potable water supply
- Improve service to Pressure Zone 1 and the Low West pressure zone (hereinafter referred to as Zone 0) to meet the increase in demand of these areas
- Improve the water quality in the above-mentioned areas by reducing water age and disinfection by-products formation

In the first step of meeting these goals, the City of Phoenix undertook development of a Master Plan to facilitate the successful development of the Western Canal WTP site. The City and their consultants knew that the available water sources were brackish and would require either NF or RO as the primary treatment process. Figure 10.1 details the methodology used to achieve the following master plan objectives:

- Identify and evaluate the quantity and quality of the primary and alternative surface and groundwater supplies for the Western Canal WTP
- Establish finished quality water goals based on current, pending, and future drinking water regulations as well as unregulated aesthetic requirements
- Evaluate surface and groundwater treatment processes that can achieve these goals
- Evaluate the associated management and disposal options to deal with the residuals and concentrate generated from the water treatment processes
- Evaluate the synergism between the surface and groundwater treatment processes.
- Develop strategies that help to improve the City's water system reliability and flexibility
- Determine whether the proposed treatment processes as well as the residuals and concentrate management and disposal can be fit on the Western Canal site; identify the off-site facility requirements

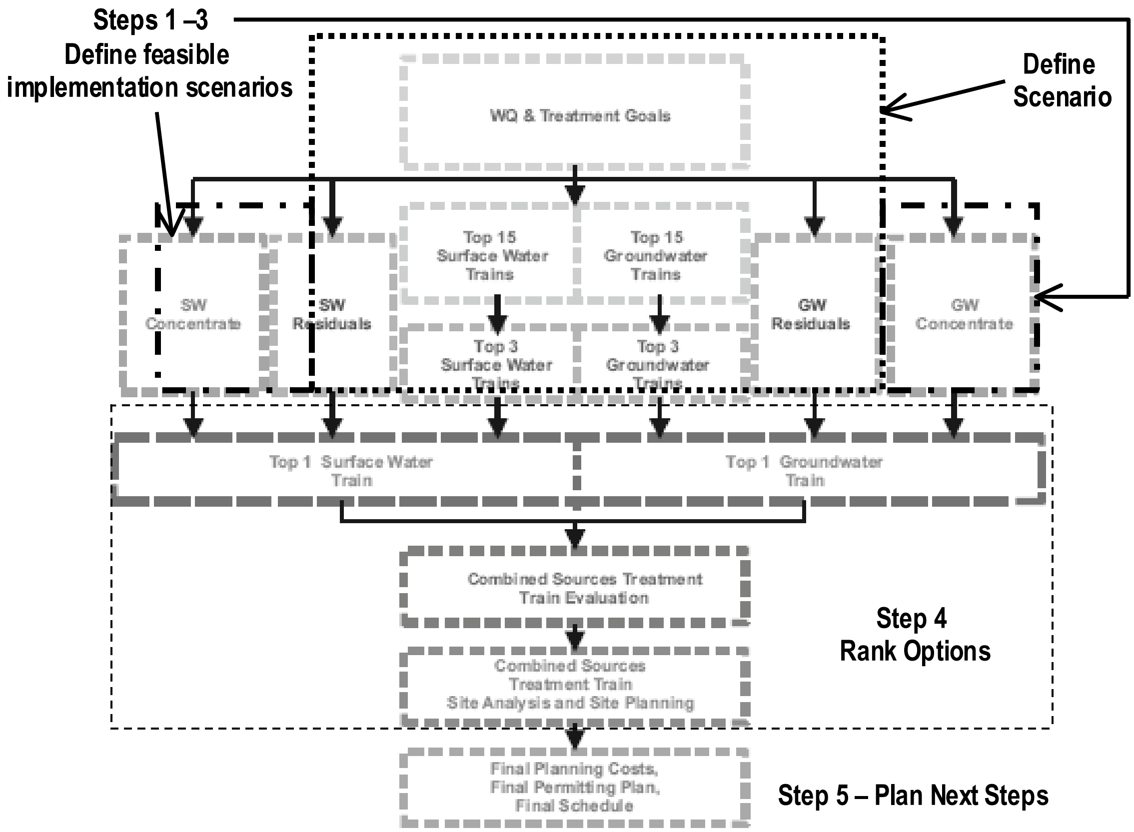

Figure 10.1. City of Phoenix Western Canal water treatment plant master plan approach.

In assessing the primary treatment concentrate disposal options, Phoenix and its consultants worked through more than 30 different primary treatment scenario–concentrate management plan concepts. The options considered included the following components:

- Raw Water Source
    - Surface water (SW) source (as a primary supply)
    - Groundwater (GW) source (as a supplemental supply)
    - Combined SW and GW use (using SW as a primary supply and developing a supplemental wellfield supply)
- Primary Treatment
    - Pretreatment–granular activated carbon–NF
    - Pretreatment–RO
- Treatment Location
    - Primary treatment: Western Canal site
    - Concentrate management:
        - On-site
        - Off-site

- Concentrate Management Technologies
    - Wastewater discharge
    - Irrigation
    - Reuse
    - ZLD

10.2 WRFCMDM.MDB OUTPUT FOR SCENARIO 4

Concentrate Management Planning Tool

Project Name: Western Canal WTP; Scenario 4

Prepared by: The City of Phoenix and Carollo Engineers

Overview

The Overview page summarizes the City's water treatment goals based on the discussion provided in the introduction to this chapter. This section corresponds to the first tab of the WRFCMDM.mdb program (Scenario 4) on the attached CD-ROM.

Purpose:	New potable water supply for the City of Phoenix
Project Life Span:	20 years
Flow Rate Max:	20.0 mgd
Flow Rate Avg:	14.5 mgd; designed for 75% capacity average flow rate
Finished Water TDS:	700 mg/L, to match the existing water supply

Local Economic Climate:

Available Capital:	Bonds; RO expansion at Western Canal in CIP
Tax Base:	
Need Bonds:	Yes
Pub Interest Growth:	Support of growth is important to the City; rapidly growing area with a relatively strong economy
Economic Concerns:	Continue to provide for and support economic growth; have the infrastructure to support the desired expansion

Cost Assumptions

Capital Repay Years:	20 years	***Interest Rate:***	7.00%
Current ENR-CCI:	7939	***Location Factor:***	0.895

Raw Water Source

> The Raw Water page summarizes the characteristics of the Western Canal WTP groundwater source. This section corresponds to the second tab on the WRFCMDM.mdb program (Scenario 4) on the attached CD-ROM.

Description: Groundwater wells; brackish groundwater; drill wells in surrounding area to create supplemental supply

Capacity:

Flow Rate Max: 20.0 mgd

Flow Rate Avg: 14.5 mgd; designed for 75% capacity operation average flow rate

Raw Water Quality

TDS: 1486 mg/L average concentration (range, 1200–1600 mg/L)

Heavy Metals and Other Contaminants

1,1-Dichloroethene (2), 6.1 µg/L

Dibromochloromethane, 0.2 µg/L

Primary Treatment

> The Primary Treatment page summarizes the primary treatment process selected and the resulting concentrate. This section corresponds to the third tab on the WRFCMDM.mdb program (Scenario 4) on the attached CD-ROM.

Treatment

Process Type: RO

Overall Recovery: 85%

Blended TDS Goal: 700 mg/L

Permeate TDS: 40 mg/L

Max Flow Rate: 10.87 mgd, bypass quantity 9.13

Avg Flow Rate: 7.88 mgd, bypass quantity 6.62

Characterize Concentrate

Concentrate TDS: 9672 mg/L

Max Flow Rate: 1.92 mgd

Avg Flow Rate: 1.39 mgd

Solids Loading Rate

Max per Day:	155,013 lb/day
Avg per Day:	112,223 lb/day
Annual:	20,481 tons

Location

> The Location page summarizes information regarding the treatment site identified for the treatment facilities and the concentrate management facility. For this case study, the primary treatment and concentration management facility will be at the existing Western Canal WTP site, adjacent to the primary treatment process. This section corresponds to the fourth tab on the WRFCMDM.mdb program (Scenario 4) on the attached CD-ROM.

Location Desc:	Western Canal WTP site
Footprint:	120 acres, existing site must provide the necessary footprint
Access to Power:	Good; two existing power feeds will be used, power station to be built on-site
Ownership:	City of Phoenix, long-term owner
Environment:	Within residential and farm area; expected to be all residential in the next 10–15 years
Right of Way:	Would be needed for off-site treatment
Region No.:	2, Inland Arid, Medium Density

Decision-Making Climate

> The Decision-Making Climate page summarizes information regarding the economic, social, and climatic conditions in which the Western Canal WTP reverse osmosis system will be developed. This section corresponds to the fifth tab on the WRFCMDM.mdb program (Scenario 4) on the attached CD.

Group Type	***Stakeholder***	***Issue Notes***
Civic	Business community	Strong support for growth
Environmental	Ariz. Dept. Env. Qual. (AZDEQ) and environmental groups	Salt accumulation in the valley is a serious long-term problem
Neighbors	Local residents and farmers	No issues with the existing site; aesthetics are of concern
Others	Southwest Regional Operating Group (SROG)	Controls WWTP and wastewater system

Viable Options

> The Viable Options page assesses the potential options on technical, economic, and practical implementation levels. The first part of this process is to assess the feasibility of all the theoretically possible treatment options (based on the local climate and population density and defined by the Region selected on the Location page). The Western Canal WTP has been classified as an inland arid, medium-density location. The concentrate management technologies available to the City are (fresh) surface water discharge, wastewater discharge, deep-well injection, land application, reuse or blending with other wastewater sources, and ZLD.
>
> One of the central intents of this exercise is to eliminate the options that can easily be eliminated based on simple, global considerations (e.g., "I know I can't put anything in the sewer"). The applicable technology-specific parameters and other general controlling parameters identified in Section 2.1.2 and discussed in section 5.1 are considered in this evaluation. The results of the Western Canal evaluation are summarized here. This section corresponds to the sixth tab (and has multiple subtabs) on the WRFCMDM.mdb program (Scenario 4) on the attached CD-ROM.

Viable Options: Surface Water Discharge

Treatment Details:	Blend with either 23rd Ave. or 91st Ave. WWTP effluent	
Technically Feasible:	Yes	Discharge into adjacent Western Canal would be technically simple but would require significant off-site piping to connect to either WWTP
Regulatory Requirements:	No	Can't get NPDES permit for high-TDS water
Cost Magnitude:	Yes	Low-cost alternative
Land Availability:	Yes	Low-footprint option, site has plenty of room for piping; ROW would be needed
Public Acceptance:	Maybe	Potentially problematic; disposal of "wastes" into surface water is not environmentally friendly
Neighborhood Impact:	Yes	No aesthetic issues on-site
Environmental Issues:	No	Salt accumulation in the valley is a long-term problem
Risk:	No	Permitting is highly unlikely, especially as SROG and AZDEQ would have to be in agreement with plan
Overall Feasibility:	No	

Viable Options: Wastewater Discharge

Treatment Details:	Connect directly to the wastewater treatment system	
Technically Feasible:	Yes	Connection to the wastewater system exists on-site; discharge into the wastewater system would be technically feasible
Regulatory Requirements:	No	Likely can't get NPDES permit, SROG agreements
Cost Magnitude:	Yes	Low-cost alternative requiring only minimal piping

Land Availability:	Yes	Existing site has room available for this low-footprint option
Public Acceptance:	Maybe	Potentially problematic; disposal of "wastes" into surface water is not environmentally friendly
Neighborhood Impact:	Yes	Negligible aesthetic impact
Environmental Issues:	No	Salt accumulation is a long-term problem in the valley
Risk:	No	Permitting is highly unlikely, especially as SROG and AZDEQ would have to be in agreement with plan
Overall Feasibility:	No	

Viable Options: Deep-Well Injection

Treatment Details:	On-site deep-well injection; single wellhead	
Technically Feasible:	No	Local geology is not adequate for high-volume, long-term waste injection
Regulatory Requirements:		
Cost Magnitude:		
Land Availability:		
Public Acceptance:		
Neighborhood Impact:		
Environmental Issues:		
Risk:		
Overall Feasibility:	No	

Viable Options: Land Application

Treatment Details:		Land application, blend with Roosevelt Irrigation District (RID) canal water
Technically Feasible:	Yes	Variation of the 23rd Avenue blending option; requires a 12-in. pipeline to WWTP; RID uses the 23rd Avenue WWTP effluent for irrigating its land; elevated metals levels may be a problem
Regulatory Requirements:	Maybe	Modify existing reuse permit, sign cooperative agreements with RID
Cost Magnitude:	Yes	A relatively low-cost alternative
Land Availability:	Yes	Small footprint, site has plenty of room for piping; ROW permits would be needed
Public Acceptance:	Yes	Land application is environmentally friendly; heavy metals issue must be addressed (show negligible human impact); aerial sprinkling of unsuitable reclaimed water may produce unsightly salt deposits, which degrade public confidence (consider in design)
Neighborhood Impact:	Yes	Negligible aesthetic impact

Environmental Issues:	Maybe	Heavy metals poisoning of crops could be at issue at high flow rates
Risk:	Yes	Moderate risk; consensus and permitting not assured, right-of-way permits needed
Overall Feasibility:	Maybe	

Viable Options: Reuse or Blending

Treatment Details:		Reuse at Palo Verde Nuclear Generating Station by blending concentrate with 91st Ave. WWTP effluent in the pipeline
Technically Feasible:	Yes	Requires 12-in. pipeline from Western Canal WTP to Palo Verde pipeline; may be diluted with 91st Ave. effluent; capacity must be evaluated before final decision-making
Regulatory Requirements:	Maybe	Requires extensive permitting (6–12 month timeline); requirements for effluent quality, monitoring, and record keeping, etc.; requires SROG approval, reuse permit modifications, and AZ Public Service coordination to confirm TDS increases are acceptable
Cost Magnitude:	Yes	Relatively low-cost option
Land Availability:	Yes	Small footprint, site has plenty of room for piping; ROW permits would be needed
Public Acceptance:	Yes	Reuse is environmentally friendly; heavy metals are not an issue in this application
Neighborhood Impact:	Yes	Negligible aesthetic impact
Environmental Issues:	Maybe	Consider ultimate salt disposal; salt accumulation in the valley is a problem
Risk:	Maybe	Moderate risk; extensive permitting, ROW, and cooperative agreements needed
Overall Feasibility:	Maybe	

Viable Options: Zero Liquid Discharge

Treatment Details:		Install a precipitation step and a brine concentrator and crystallizer on-site
Technically Feasible:	Yes	Lime and soda ash addition, and/or caustic soda, which removes salts and reduces concentration of membrane foulants (SO_4^-, CO_3^-); MVRE process produces low-TDS product water and concentrated brine (~200,000 mg/L), dried solids are landfilled
Regulatory Requirements:	Yes	
Cost Magnitude:	No	High cost negates further consideration of this option unless more attractive alternatives do not pan out
Land Availability:	Yes	Moderate footprint will fit on-site

Public Acceptance:	Maybe	Expensive for the general public; aesthetically unattractive to the neighbors
Neighborhood Impact:	Maybe	90-ft-tall tower, obvious, and has noise issues (never popular in a neighborhood)
Environmental Issues:	Yes	ZLD does not have significant environmental issues outside those associated with power generation to supply the electricity needed
Risk:	Yes	If other options are ultimately not viable, this will be the only technically workable option unless off-site options prove tenable
Overall Feasibility:	No	

The City eliminated fresh surface and wastewater discharge options due to stringent regulatory and permitting requirements. Environmental issues associated with these technologies also precluded these two options. High capital and O&M costs involved with ZLD acted as a deterrent for its selection among the list of concentrate management technologies.

Having evaluated the options and the controlling and governing parameters, the City identified two feasible options:

1. Land Application: blend with RID canal water
2. Blending or Reuse: reuse at Palo Verde Nuclear Generating Station by blending concentrate with 91st Ave. WWTP effluent in the pipeline

Cost Estimates

The Cost Estimates pages can be used to develop the capital, O&M, and life cycle costs for each alternative. (It should be noted that the intent of establishing planning-level costs is to develop order-of-magnitude comparisons of the various technologies based on the user's scenario.)

This evaluation follows the discussions in Chapter 11, Figure 5.2, and Tables 5.7 through 5.9. This section would typically correspond to the fifth tab on the WRFCMDM.mdb program (Scenario 4) on the attached CD-ROM; however, these costs were developed independently and so are summarized in the Additional Notes section.

Grading Criteria

Grading Criterion	***Factor (1–10)***	***Comments regarding factor score***
Complexity:	6	Ease of the process for the operational staff, maintenance requirements, and system variable residual loads (score of 1 = relatively difficult operational needs, 10 = relatively easy operation)
Ease To Implement:	5	Time required for design and construction of the disposal alternative, level of difficulty in operating and implementing the alternative, approval of government agencies, and public perception

Footprint:	10	Land required to construct the disposal facility, site constraints, impacts on other facilities at the Western Canal WTP, and ROW and easement requirements
Environmental:	5	Disturbance of natural environment, effects on fish and habitats, disturbance of recreational activities, impacts on aesthetic and scenic resources, impacts associated with traffic, land transportation, and other long-term impacts
Life Cycle Cost:	10	Capital costs (site development, process equipment, electricity requirements, instrumentation, piping, contingency, and taxes and bonding), and O&M costs (disposal fees, equipment maintenance cost, power, fuel costs, and labor costs)
Power Requirements:	8	Fuel and electricity availability of alternate energy sources, on-site power
Public Acceptance:	7	Aesthetic impacts and disruption to the neighborhood, acceptance by the public and other stakeholders
Regulatory Acceptance:	5	Number of permits required for operating the unit process, time requirement for permitting process, effluent limitations, Best Management Practices, feasibility in obtaining and renewing the permit, monitoring, reporting, and recordkeeping
Risk:	0	
Reliability:	8	Mechanical reliability, process dependency on natural temperature, wind intensity, humidity, precipitation, hydrogeologic impacts on outside resources, and long-term process reliability
Operability:	5	Ease of process for the operational staff, maintenance requirements, and system variable residual loads

Ranking

Grading Criterion	Factor	Surface Water Discharge	Wastewater Discharge	Ocean Discharge	Deep-Well Injection	Evaporation Ponds	Land Application	Reuse or Blending	ZLD
Complexity	6	0	0	0	0	0	3.5	3.5	0
Ease To Implement	5	0	0	0	0	0	3.5	3.5	0
Footprint	10	0	0	0	0	0	3	4	0
Environmental Impact	5	0	0	0	0	0	3.5	4	0
Life-Cycle Cost	10	0	0	0	0	0	3.5	3.5	0
Power Requirements	8	0	0	0	0	0	0	3.5	0
Public Acceptance	7	0	0	0	0	0	2.5	2.5	0
Regulatory Requirements	5	0	0	0	0	0	0	2.5	0
Risk	0	0	0	0	0	0	0	0	0
Operability	5	0	0	0	0	0	2.5	3.5	0
Weighted Score		0	0	0	0	0	179	237	0

Perfect Score: 345

Additional Notes

The Additional Notes page can be used to make any additional project notes not input under the previous tabs. This section corresponds to the ninth tab on the WRFCMDM.mdb program (Scenario 4) on the attached CD-ROM.

The City of Phoenix Water Services Department is planning to develop a new WTP near the end of the Salt River Project's Western Canal at Dobbins Road and 19th Avenue. Pending the WSMPU (2005–2006), the Western Canal WTP is master planned to initially produce 40 mgd of potable water in year 2014 and ultimately up to 120 mgd of potable water (by 2055) based on the WSMPU 1998 recommendations. It is expected that adding the Western Canal WTP will:

- Enhance the reliability and redundancy of the City's potable water supply
- Improve service to Pressure Zone 1 and the Low West pressure zone (Zone 0) to meet the increase in demand for these areas
- Improve the water quality in the above-mentioned areas by reducing water age and disinfection by-product formation

In the first step of meeting these goals, the City of Phoenix undertook development of a Master Plan to facilitate the successful development of the Western Canal WTP site. The City and their consultants knew that the available water sources were brackish and would require either NF or RO as the primary treatment process.

In assessing the primary treatment–concentrate disposal options, Phoenix and its consultants worked through more than 30 different primary treatment scenario–concentrate management plan concepts. The viable options for the Primary Treatment and Region (location type) final selection have been summarized in this case study.

Cost Estimates

The cost estimates were not done using the Cost Estimation tool. Site-specific calculations were done instead. The intent of this initial cost estimate was to develop comparative, order-of-magnitude (planning-level) costs for implementing each technology option of interest based on the defined scenario. For the wastewater option, pumping pressure will be supplied by the RO system (i.e., permeate will come out at sufficient pressure to negate the need for additional pumping). The results of these initial cost estimates are summarized below:

Concentrate Management Option	**Est. Annualized Life Cycle Cost**
91st Ave. WWTP effluent/PVNGS pipeline	$ 2,000,000
Blend with RID canal water	$ 2,000,000
Chemical precipitation/HPRO/MVRE/spray drying	$20,000,000
Chemical precipitation/HPRO/MVRE/crystallizers	$12,000,000
SAL-PROC/MVRE/crystallizers	$18,000,000

Ranking

Blending with 91st Ave. WWTP effluent for reuse at the Palo Verde Nuclear Generating Station was the preferred non-ZLD option, and chemical precipitation, HPRO, MVRE, and crystallizers was the preferred ZLD option. The City and its engineer then moved forward with a number of other primary treatment–concentrate management scenarios. Ultimately, the selected treatment scenario included the following elements:

- *Source water*: The primary water supply will be the Salt River Project's Western Canal, and the local groundwater will be tapped to serve as an alternative or backup supply.
- *Primary treatment process*: Partial stream RO with pretreatment (presedimentation basin, conventional coagulation, flocculation, and sedimentation, microfiltration or conventional dual-media filters, and granular activated carbon contactors.
- *Concentrate Management Plan*: The membrane concentrate management and disposal facility will include selenium adsorption and a concentrate transfer pump station on the Western Canal site. A pipeline to the 91st Avenue WWTP would be built. Ultimately, concentrate volume reduction (via RO) and on-site or off-site ZLD facilities would be added (for the phase II expansion to 80 mgd).

10.3 NEXT STEPS

The last segment of the decision methodology involves planning the next steps in the desalination planning and implementation process, deciding, "where do we go from here," now that an option or list of options has been identified (or, in some cases, no viable options have been identified).

The Western Canal WTP master plan was completed based on WSMPU 1998 recommendations, i.e., a WTP in two phases with the first being 40 mgd and the second taking the plant to 120 mgd, along with the tentative schedule provided by the City. The now-complete WSMPU (2005–2006) results have shown reduced ultimate demands for the City's planning area and consequently suggest that the Western Canal WTP should produce 40 mgd in the year 2015 and ultimately up to 80 mgd in 2030. The schedule and ultimate capacity of the Western Canal WTP have tentatively been reduced in accordance with these recommendations. As the WSMP will be updated on a periodic basis, it is reasonable to anticipate that the ultimate (phase II) capacity of the Western Canal WTP may be more than or less than the current projections.

The current version of the City's Master Plan includes the following timeline for phase 1 implementation of the Western Canal WTP:

- ~2007–2009: ~18-month pilot study for low-pressure RO
- 2009–2012: Design
- 2012–2015: Construction
- 2015: Phase I startup

The City also plans, or is considering, the following actions:

1. Data Collection. Data gaps indicate that the City's Water Services Department should consider conducting a supplemental data gathering and sampling program to strengthen the baseline of water quality data for the tail end of the Western Canal and further evaluate other potential auxiliary sources for the City's water supply.

2. Design. A 1-year bench and pilot study will be run in conjunction with the predesign effort and/or prior to the design. The objective of the study would be to investigate the low-pressure RO membrane performance of all applicable membrane suppliers and the associated antiscalant dosage and limitations in treating both the local groundwater and the surface water. A pilot study may also be run prior to design and implementation of the ZLD concentrate management and disposal options to assess the ability of high-pressure RO to reduce the concentrate volume. Additional groundwater data may be collected from the Salt River Project's wells to determine if there are other constituents of concern that may challenge the preferred Western Canal WTP process train.

3. Stakeholder Involvement. The City is planning to start public involvement activities for the Western Canal WTP site early in the decision process for the proposed non-ZLD concentrate management and disposal strategy to help select the optimal regional concentrate.

CHAPTER 11

SURVEY OF CONCENTRATE MANAGEMENT OPTIONS AND ISSUES

In this study, “concentrate” refers to the by-product produced in desalting processes. It is characterized by high TDS concentrations, typically in the 1000 to >10,000 mg/L range. The concentrations of TDS and other constituents and the volume of concentrate produced depend directly upon the feed water quality and the achieved product water recovery, and so selection of the primary treatment process is an integral component to the concentrate disposal issue.

Concentrate disposal methods need to be evaluated with respect to both technical and nontechnical issues. (Will it fit in the available space? Will right-of-way easements be needed? How much would it cost to implement the technology? What are the regulatory hurdles? What are the environmental constraints?) The three parameters that most influence the feasibility of concentrate disposal options are (1) concentrate volume, (2) TDS concentration, and (3) geographical region.

The concentrate management technologies considered in the CMDM tool, emerging technologies for improving concentrate management, applicable regulations, environmental issues (salinity balance), and stakeholder partnering are highlighted in this concentrate management overview.

11.1 AVAILABLE TREATMENT OPTIONS

The technically feasible treatment options identified for this project and their associated relative costs are summarized in Table 11.1. When looking at different disposal options, the first, most desirable option is surface water or wastewater discharge (~50% of all plants nationwide [Mickley, 2006]), but there is often no access to these options for geographical and/or regulatory reasons. Larger plants may also consider using deep-well injection where the geology is feasible (primarily Florida and Texas). Other concentrate disposal options (evaporation ponds, reuse, and land application) are used in a few locations, but to date costs and regulatory and environmental issues have precluded their widespread adoption.

Within the United States, the majority of desalination systems in operation today are located in Florida, California, and Texas. Surveys by Kenna and Zander (2000) and by Mickley (2006) confirmed that the main methods of concentrate disposal in Florida are deep-well injection and surface water or ocean discharge. In contrast to Florida, desalination plants located in California primarily use ocean (one-third) or wastewater discharge (a little over one-half). In Texas, surface water discharge is the predominant choice.

Table 11.1. Available Treatment Technologies and Associated Relative Costs

Treatment Technology	Relative Cost		
	Low	Moderate	High
(Nonocean) Surface Water Discharge	√		
Discharge to Ocean	√	√	
Discharge to Wastewater	√		
Deep-Well Injection	√		
Evaporation Ponds	√	√	
Land Application	√	√	
ZLD Technologies			
Brine Concentrators			√
Crystallizers			√
New Technologies for Enhanced Evaporation			
WAIV	√		
Slim-Line™	√		
Solar-Bee™	√		
Long-Term Storage			
Disposal in Salt Caverns in the Southwest Region	√		
Salt Solidification and Disposal in Inactive Salt Mines	√		

11.2 CONVENTIONAL CONCENTRATE MANAGEMENT OPTIONS

11.2.1 (Fresh) Surface Water Discharge

The most common disposal practice in the United States, surface water discharge, involves the transport and discharge of the concentrate stream through a pipe from the treatment plant to a flowing stream or a nonmarine surface water body, such as a lagoon or pond. (For the purposes of this study, ocean discharge is discussed separately.) An outfall structure and mixing zone are used to dilute the concentrate to avoid acute toxicity[1] at the discharge point. This outfall structure can be either buried or located above ground on a lake or streambed. Dilution of the concentrate stream can be accomplished with surface water, groundwater, WWTP effluent, or cooling water. Disposal costs depend primarily on the length of the discharge pipeline, which conveys the concentrate to the receiving water.

While some water treatment professionals initially assumed that desalination concentrate would be well-suited for surface water discharge because it contains only constituents from the raw feed water in higher concentrations (Kenna and Zander, 2000),[2] its high salinity (and in some cases high heavy metal concentration) can harm aquatic life. This often precludes it as an option, but where it is logistically feasible, economic considerations usually make it the most attractive option.

[1] Acute toxicity is defined as the presence of any substance that results in a mortality rate of >50% of test organisms.
[2] An exception would be antiscalants, which are fed to RO and electrodialysis reversal (EDR) systems to improve performance.

11.2.1.1 Geographic Limits to Feasibility

Disposal requires an NPDES permit. The requirements for NPDES permits vary by state.[3] Regional U.S. Environmental Protection Agency (EPA) offices set the limits. In general, discharge of desalination concentrate to low-salinity surface waters (e.g., rivers, lagoons) is not permitted if it would increase the TDS of the receiving water body by more than 10%. Therefore, a mixing zone has to be sized properly to meet the discharge requirements. A regional salinity imbalance can also be a limitation to surface water discharge.

Advantages:

- An established, well-accepted disposal practice
- Low capital and operating costs
- Low energy requirements
- Significant economies of scale can be realized with increasing treatment volumes

Constraints:

- An NPDES permit is required, and limits may include total suspended solids, TDS, and/or specific contaminants and nutrients. This may be most critical during low seasonal flows in local surface waters.
- The presence of arsenic, radionuclides, dissolved gases, and/or low dissolved oxygen can limit the viability of surface water disposal.
- Whole effluent toxicity tests might be required for permitting.
- EDR reject containing free chlorine would have to be neutralized with a reducing agent before it could be discharged.

11.2.2 Ocean Discharge

Ocean discharge involves the transport of the concentrate via pipeline to the ocean, where it is disposed of through an ocean outfall structure, which can be either buried under or constructed on the ocean floor. As with surface water discharge, ocean discharge requires the construction of an outfall structure with diffusers to create mixing zones. The purpose of the ocean outfall structure is to assure that adequate mixing is introduced to ensure that the discharged effluent will not damage the water quality in the receiving water body, its life forms, wildlife, or the surrounding area. Desalination plants colocated with power plants may dilute the concentrate with power plant cooling water.

11.2.2.1 Geographic Limits to Feasibility

Desalination plants need to be close to the ocean or have access to a “brine line” to convey the concentrate to an ocean outfall. Most arid inland regions’ sanitary wastewater systems do not have access to such an ocean piping system; however, desalination plants in the Santa Ana Watershed could discharge to the Santa Ana Regional Interceptor, although capacity constraints limit access.

[3] See Section 11.1.6 for details on the NPDES permitting system.

Advantages:

- An established, well-accepted disposal practice
- If outfall structures can be kept relatively simple, it has moderate to low capital costs.
- Low energy requirements
- Significant economies of scale can be realized with increasing treatment volumes.

Constraints:

- Sophisticated outfall structures are needed to create mixing zones and to minimize acute toxicity. Gaining a regulatory permit can be very difficult.
- Aeration of the concentrate prior to discharge is required, which increases costs.
- The permitting process is lengthy. For example, in California, the major permit requirements needed for an ocean brine discharge line are (1) an NPDES discharge permit under the Clean Water Act for the brine disposal, (2) a Coastal Development permit from the California Coastal Commission, (3) Section 10 Rivers and Harbors Act approval for the discharge pipe, and (4) a Section 404 permit under the Clean Water Act for the discharge pipe. Each of these permits involves review and approval by multiple state and/or federal agencies.
- Whole effluent toxicity tests may be required for permitting.

11.2.3 Wastewater Discharge

Wastewater discharge involves the transport of the concentrate via a pipeline to the wastewater line. The technology applied for wastewater discharge includes piping to the treatment line but not usually a complex outfall structure. Wastewater discharge permits often limit the volume of concentrate that can be discharged, which could restrict future expansion. Discharge costs depend upon an initial connection fee, and the operating costs vary based on volume and pollutant load.

Prior to discharge to a WWTP, a desalination facility needs to receive permission to discharge to an existing wastewater line. The agency might impose limitations to protect wastewater treatment systems and plant infrastructure and to assure that there are no negative impacts on the treatment process performance and on the quality of the final effluent and biosolids. The high TDS and calcium precipitation potential of the concentrate stream will, in many cases, require pH adjustment to prevent scaling of the wastewater system pipelines. In addition, the impact of TDS on the wastewater treatment process has to be evaluated prior to discharge.

The most current data available (Mickley, 2006) suggest that about 30% of desalination plants discharge the membrane concentrate they produce to wastewater systems.

11.2.3.1 Limits to Feasibility

The desalination plants need to be in close proximity to a wastewater system that can accept high-TDS water.

Advantages:

- Established, well-accepted disposal practice
- Very simple technology
- Low-cost alternative
- Low energy requirements

Constraints:

- High salt loads may limit the options for the reuse of treated wastewater (e.g., irrigation of crops with a high TDS tolerance).
- Although the desalting plant that discharges to the wastewater line that flows to a wastewater treatment plant does not itself need an NPDES permit, it will need a discharge permit from the WWTP, which will have to evaluate the impact of the brine stream on its ability to comply with its NPDES permit. High salt loads sometimes cause compliance problems and so preclude discharge through this avenue.
- For discharge to a wastewater line that flows directly to a receiving body, an NPDES permit is required and, again, high salt loads may limit the ability to obtain this permit.
- Whole effluent toxicity tests may be required for permitting.
- The actual biotoxicity caused by the concentrate would need to be determined.

11.2.4 Deep-Well Injection

In deep-well injection, desalination concentrates are injected into porous subsurface geologic formations that can contain and isolate the waste (Figure 11.1). Injection wells must keep the wastes isolated from local aquifers, particularly those that are potable. This requires that the wells be drilled and maintained properly (to prevent facilitation of waste migration), and the geologic formation into which they are injected must be suitably confined.

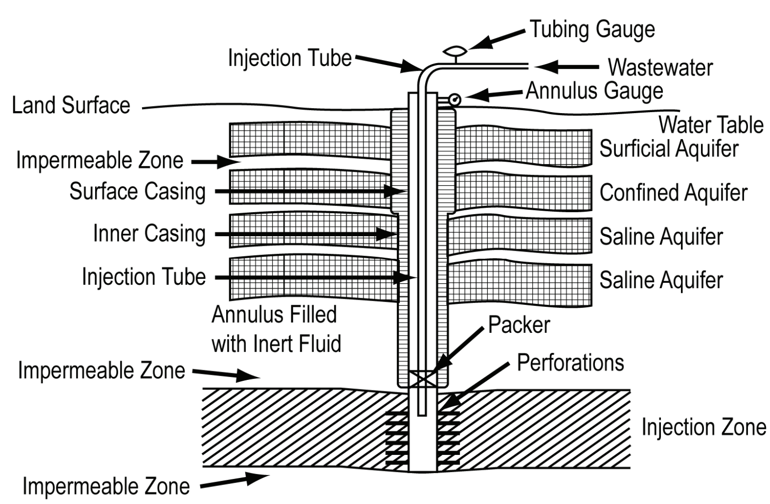

Figure 11.1. Typical construction of an injection well.

Well depths typically range from 1000 to 10,000 ft. The technology used in deep-well injection includes pumping, well casings, cement, packing, and pressure gauges. Since desalting concentrate is technically an "industrial waste," the wells must include more expensive tubing and packers than those used for municipal disposal wells. In addition, some concentrates may require pretreatment to remove solids that may plug the injection site.

Approximately 17% of all RO concentrates in the United States are injected into deep wells (Mickley, 2006), primarily in Florida, which has geology well-suited to this application.

11.2.4.1 Limits to Feasibility

Deep-well injection is not feasible in seismic zones (e.g., much of the West Coast) or in regions containing recoverable mineral resources (e.g., oil fields in Texas). The geologic formation used must be able to keep the wastes isolated from local groundwaters, particularly those that are potable. Required characteristics include low permeability, no cracks that would facilitate waste movement, and no hydraulic connections to current or potential future potable sources.

Advantages:

- An established disposal practice for desalination and hazardous wastes
- Relatively low energy requirements
- Cost-effective for moderate to large plant capacities
- Significant economies of scale can be realized with increasing treatment volumes.

Constraints:

- Only possible in regions with special geological conditions
- Not viable in seismic zones or in regions containing recoverable mineral resources
- Usually not a sustainable long-term solution
- Injection well failure can lead to groundwater contamination.
- Monitoring wells are required to verify that vertical fluid movement does not occur.
- A backup disposal or storage method must be available during maintenance periods.

11.2.5 Evaporation Ponds

In evaporation ponds, the concentrate is piped into a large, shallow lagoon, and the water is allowed to evaporate through solar heating. Periodically (typically every 5 years or so) the dried salt cake is dredged out of the lagoon and landfilled. The permitting and construction of the evaporation ponds are similar to those for landfills. The technology used in evaporation ponds includes piping to the ponds, pond liners, access roads and fences, and excavation equipment for dredging out salts. Most states require monitoring wells and impervious clay or synthetic liners, which substantially increase the construction costs. Evaporation ponds require large tracts of land, and so practicality considerations have historically limited its use to low flow rates (<0.2 mgd).

Evaporation ponds are a viable disposal option for regions where land costs are low and water evaporation rates significantly exceed the amount of rainfall, e.g., the arid Southwest. The evaporation rate is affected by humidity, wind velocity, air and water temperature, and concentrate salinity. A significant aspect of evaporation pond operation is that the rate of evaporation slows over time as the salinity increases. For water saturated with sodium chloride, the solar evaporation rate is ~70% that of fresh water (Office of Saline Water, 1971). The U.S. Bureau of Reclamation reported that solutions of 2, 5, 10, and 20% sodium chloride have evaporation rates of ~97, 98, 93, and 73% of fresh water, respectively (USBR, 1969). This phenomenon must be considered when sizing an evaporation pond system.

11.2.5.1 Salt Gradient Solar Pond

A special case of evaporation ponds is the salt gradient solar pond. A solar pond is a body of water that collects and stores solar energy. In uncontrolled evaporation ponds, water is warmed by the sun, expands, and rises to the surface. Once it reaches the surface, the water cools through convection or evaporation. The now colder and heavier water sinks, replacing the warmer water below, creating natural convective circulation that mixes the water and dissipates the heat efficiently. The design of solar ponds reduces either convection or evaporation in order to store the heat collected by the pond. The useful thermal energy is then withdrawn from the solar pond in the form of hot brine. A common method to speed heat removal is to extract heat with a heat transfer fluid, which is pumped through a heat exchanger placed on the bottom of the pond. (Note: As of the publication of this report, solar gradient ponds are not considered economically viable for desalting waste management in the United States.) It is not recommended that this option be seriously considered unless further research is conducted. It is included in the discussion here to provide a point of information for the reader, in case such an option is proposed from another source.

11.2.5.2 Limits to Feasibility

Evaporation ponds are a viable disposal option for geographic regions with low land costs and a warm, arid climate (e.g., an annual evaporation rate of >60 in./year and an annual precipitation rate of <10 in./year).

Advantages:

- Established disposal practice
- Can be an inexpensive option for small plants in a warm, arid region
- Low energy requirements
- Low maintenance requirements

Constraints:

- Precipitated salts have to be disposed of as hazardous waste if they do not pass a toxic characteristic leachate potential (TCLP) test.
- Poorly constructed or damaged evaporation ponds can contaminate groundwater.
- Future permitting regulations could be more restrictive.
- Typically limited to small footprints and flow rates

11.2.6 Land Application

Land application involves the use of concentrate for irrigation. The technology used includes piping to the application site, sprinklers and valves, monitoring wells, and in some cases underdrains and catch basins. Land application can be classified as “beneficial reuse” if the concentrate is used for soil conditioning or irrigation. Crops with low economic value but high nutrient uptake capacity, such as salt-tolerant grasses, are well-suited for irrigation with membrane concentrates.

Historically, spray irrigation has been the method of choice for applying concentrates. This requires dilution to prevent the pollution of groundwater sources. For example, if irrigation water had a TDS of 2000 mg/L and was applied with 80% irrigation efficiency, the remaining water leaching through the root zone would have a TDS of 8000 mg/L, a concentration that would make the water unusable for sensitive crops. Other irrigation methods include fixed sprinkling systems, which can be fixed on the ground surface or buried, and moving sprinkler systems, including center pivot, side roll, and wheel-moved apparatuses.

Land application permitting is subject to federal standards for use or disposal of wastewater treatment plant residuals (40 CFR 503). Prior to land application, it is necessary to assess the SAR, pH, trace metals uptake, and percolation factors of the vegetation and soil and the potential impact on public health. If the concentrate is not used immediately, pretreatment (e.g., aeration) might be necessary. Monitoring wells are also required.

11.2.6.1 Limits to Feasibility

Land application may be an option if the desalination plant is in the vicinity of an agricultural region with the need for irrigation water for saline-tolerant crops. Desalination concentrate is typically not appropriate for irrigating lawns, golf courses, or parks due to the high sodium levels. In these cases, blending with reclaimed wastewater could make it feasible.

Advantages:

- An inexpensive option for small plants
- Low energy requirements

Constraints:

- Runoff to surface water and percolation to groundwater are of concern and may require additional permits. Generally, berms can be built to prevent overland runoff.
- Spray irrigation may be prohibited for high TDS levels and for large flow rates.
- Land application and infiltration could cause degradation of groundwater quality.
- Not suited for irrigation if vegetation is sensitive to salinity; limited to crops or grasses with low economic value and high nutrient uptake.
- A backup disposal or storage method must be available during periods of heavy rainfall.

11.2.7 Mechanical ZLD

By definition, a ZLD technology will reduce the concentrate waste stream to a dry salt. This is typically done in two steps, starting with brine concentration through an initial evaporative process to concentrate the waste and then through a secondary system (either an evaporation pond or another mechanical process) to reduce it to a dry salt.

11.2.7.1 Brine Concentrators

A brine concentrator uses vapor compression and thermal evaporation in a tall (typically ~90-ft) packed tower to reduce the concentrate to a slurry that can be solidified in an evaporation pond or crystallization or spray drier process and landfilled (Figure 11.2). Recovery varies as a function of the feed water quality. Typically, ~95% of the wastewater feed will be converted to distillate (<10 mg/L TDS) for reuse (RCC Ionics, 2005). At the time this report was prepared, brine concentrators ranged in size from ~150 gpm (0.2 mgd) to ~800 gpm (1.1 mgd).

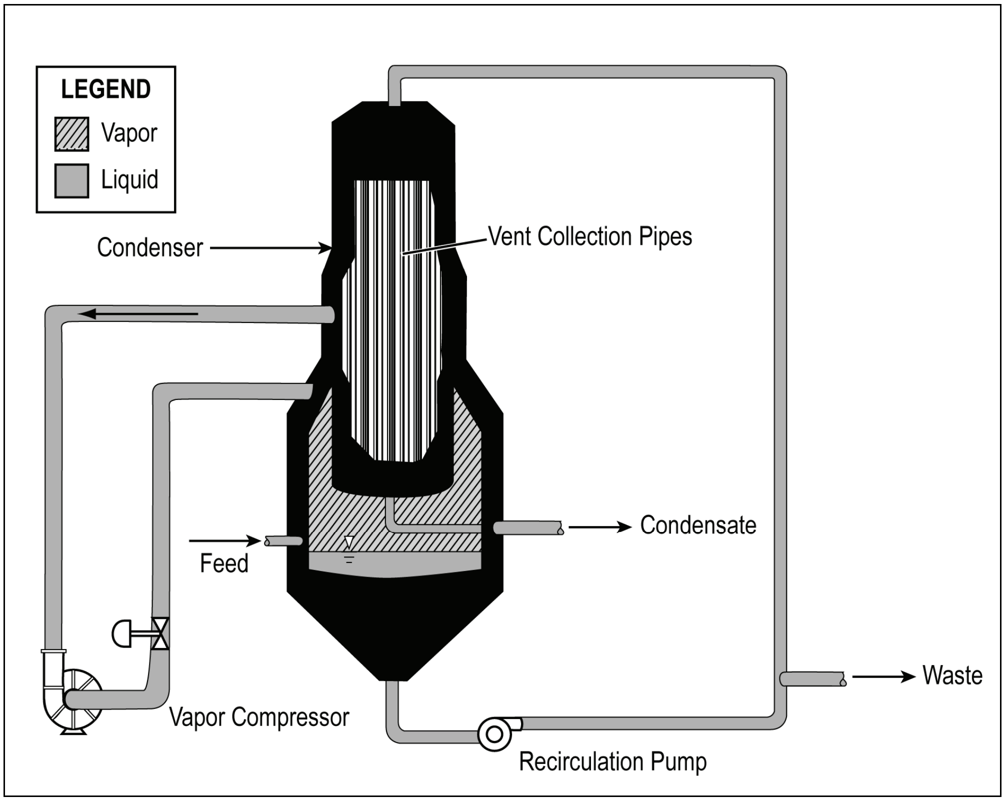

Figure 11.2. Flow schematic of a brine concentrator.

The technology used with brine concentrators includes conveyance pipe to and from the concentrator, the brine concentrator tower, a heat exchanger, a deaerator, a seed slurry storage and delivery system, and a vapor compressor.

The capital and operating costs of brine concentrators are extremely high. Because of the corrosive nature of many concentrates, brine concentrators are usually built with expensive materials, including titanium, molybdenum, and stainless steel. With energy requirements in the range of 60–90 kW-h/1000 gal (RCC Ionics, 2005), historically this technology has only been considered economical for use in power plants and other industrial settings.

Advantages of brine concentrators:

- Feasible in areas where other, lower-cost options are not
- Product recoveries can range from 90–98%
- Can simplify the permitting process (by replacing more permit-intensive technologies)
- Small footprint

Constraints for brine concentrators:

- Very high costs
- Very energy-intensive (~60–90 kWh/1000 gal)
- The tall (~90-ft) tower and noise associated with its operation could make siting in residential areas untenable.

11.2.7.2 Crystallizers

In crystallization, forced circulation vapor compression in a tall, cylindrical vessel reduces the salt slurry of a concentration process to dry salt and distilled water (Figure 11.3). The technology used for crystallizers includes conveyance pipe to the crystallizer, the vapor compression chamber, a heat exchanger, a seed slurry storage and delivery system, a recirculation pump, and a vapor compressor.

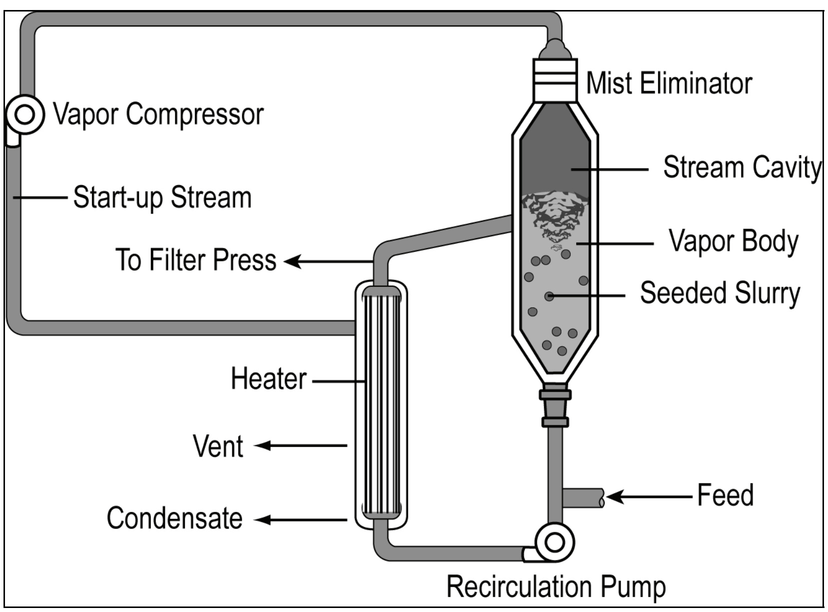

Figure 11.3. Flow schematic of a crystallizer.

Currently, only industrial water treatment plants are using this technology to handle the reject from desalination processes. The energy requirements of crystallizers are even higher than for brine concentrators, requiring approximately 200–250 kWh/1000 gal. Crystallizer sizes range from 2 to ~50 gpm.

Advantages of crystallizers:

- Concentration of slurries to solid waste
- Recovered product water can be used elsewhere
- Feasible in areas where other, lower-cost options are not
- Small footprint

Constraints for crystallizers:

- Very high costs
- Very energy-intensive (~200–250 kWh/1000 gal)

11.2.7.3 Spray Driers

In spray driers, the concentrate slurry is sprayed in a vertical drying chamber through a centrifugal atomizer. The dry solids are blown by hot air through a bag filter, where they are collected. The moist air is exhausted out the top of the bag. The solids are collected in a hopper below. The technology used with spray driers includes a conveyance pipe to the drier, an atomizer, spray drying chamber, a bag filter, and a solids storage chamber. Spray driers are typically cheaper to operate than crystallizers at flow rates below 10 gpm (Mickley, 2006).

Advantages of spray driers:

- Concentration of slurries to solid waste
- Recovered product water can be used elsewhere
- Feasible in areas where other, lower-cost options are not
- Small footprint

Constraints for spray driers:

- Very high capital costs
- Very energy-intensive (>200 kWh/1000 gal)

11.3 EMERGING TECHNOLOGIES FOR IMPROVING CONCENTRATE MANAGEMENT

Technology options are constantly changing and growing. Inland brine disposal in arid regions, where the standard disposal methods of ocean, surface water, and wastewater discharge are not available, has helped drive the development of innovative new processes to minimize or eliminate membrane desalting concentrates. Some of the new and emerging concentrate treatment and disposal technologies are briefly discussed in this section.

- Improving recovery
    - HERO™
    - Chemical precipitation with secondary RO
    - Dual NF
    - Two-pass NF
    - Hybrid technologies

- Vibratory sheer enhancement process (VSEP)-enhanced membrane filtration
- Seeded slurry precipitation and recycle RO (SPARRO)
- Dual RO with intermediate chemical precipitation
- Dual RO with intermediate biological reduction
- Hybrid RO–ED and RO–EDR

- Enhanced evaporation
  - Wind-aided intensified evaporation
  - Spray evaporators
  - Solar-Bee™
- Long-term storage
  - Disposal in salt caverns
  - Salt solidification and disposal in inactive salt mines
- Mineral recovery
  - SALPROC™

Though not standard desalination concentrate management tools at the time of publication, these technologies, depending upon the options available for a given location, may warrant further investigation, particularly as their viability is substantiated by new installations.

11.3.1 Improving Recovery

11.3.1.1 HERO™

The high-efficiency RO system (HERO™) is a high-efficiency desalination system consisting of a two-pass RO system with chemical treatment and ion exchange. The reject stream of the primary RO process is treated in weakly acidic cationic exchange resins. The carbon dioxide from the RO reject has to be removed, and the pH is raised above 10 to allow operation of the secondary RO at high silica concentrations and to ultimately achieve high recoveries (Figure 11.4).

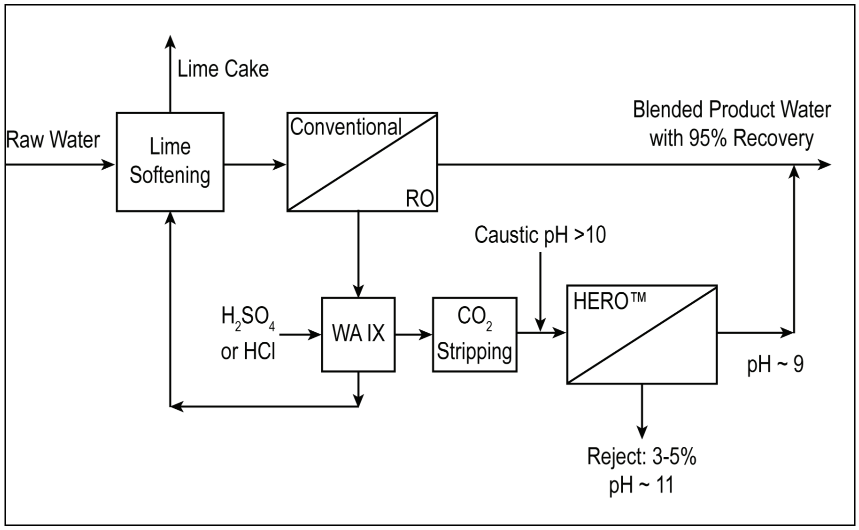

Figure 11.4. Flow schematic of a high-efficiency RO system. (Abbreviation: WA IX, weakly acidic cation exchange)

Advantage:

- Total product water recovery of >95%

Constraints:

- Patented technology
- Production of chemical pretreatment wastes, which must be landfilled

11.3.1.2 Chemical Precipitation with a Secondary RO Process

The approach of chemical precipitation with a secondary RO process is an RO concentrate treatment and minimization approach that is based on the combination of established technologies, such as lime soda softening and RO (Figure 11.5). The concentrate from the primary RO is high in TDS and hardness; sparingly soluble salts limit product water recovery. The goal is to reduce the scaling potential of the primary RO concentrate to allow further product recovery in a secondary RO process. Lime soda softening and media filtration are applied upstream of the secondary RO to remove constituents with high scaling potential, such as calcium, magnesium, sulfate, and silica.

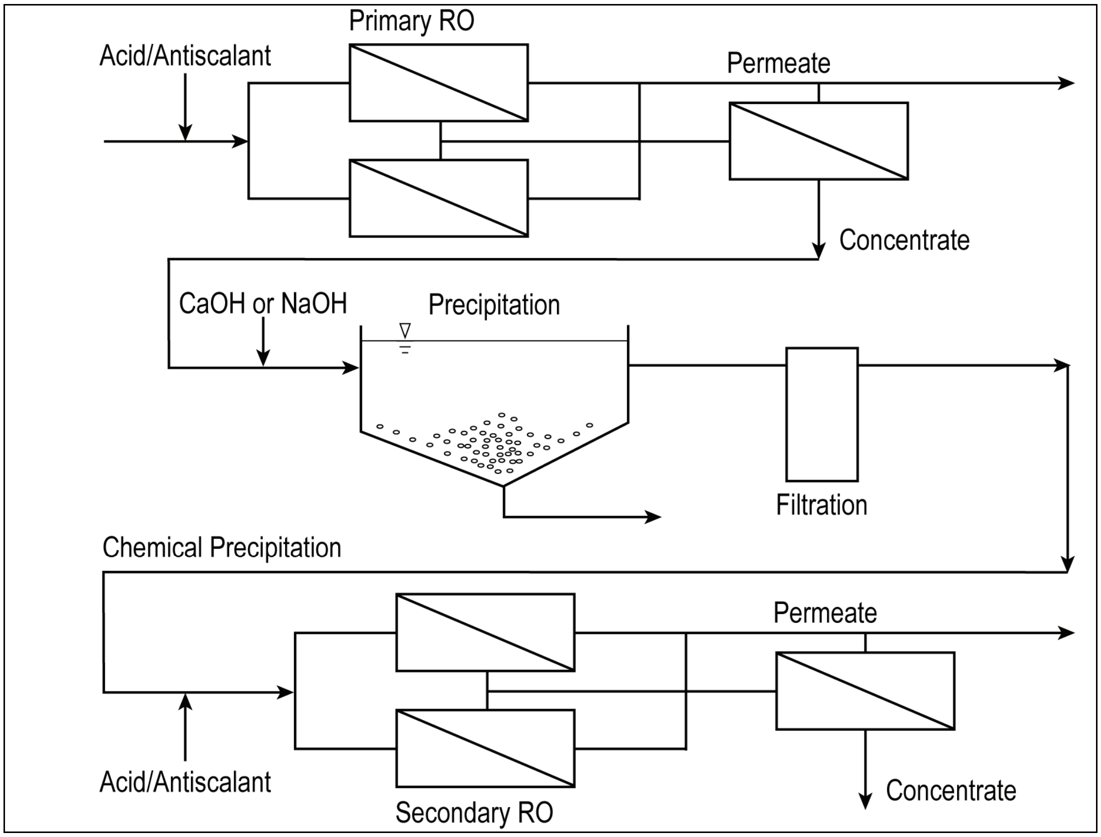

Figure 11.5. Flow schematic for chemical precipitation with a secondary RO process.

Advantages:

- Application of established unit processes
- Relatively low energy requirements
- Reduction of concentrate disposal volume

Constraints:

- Production of sludge, which must pass a TCLP test and be landfilled
- High amounts of chemicals are often needed

11.3.1.3 Dual NF

In a variation on dual-stage RO, the dual NF process, the concentrate from a primary NF step is further treated with a secondary NF step. In cases where inorganic constituents are high (typical for desalination applications), intermediate chemical precipitation is needed.

Advantages:

- Application of established unit processes
- Relatively low energy requirements
- Reduction of concentrate disposal volume

Constraints:

- Production of sludge, which must pass a TCLP test and be landfilled
- No full-scale installations
- Large amounts of chemicals are often needed

11.3.1.4 VSEP Enhanced Membrane Filtration

VSEP is a fouling reduction technology developed by New Logic (Emeryville, CA) and is used in conjunction with a proprietary polymeric membrane.

VSEP uses vibration of the membrane surface to minimize binding. Specifically, the high-frequency vibration of the membrane surface produces a shear wave that propagates sinusoidally from the surface of the membrane. The high shear energy allows the membrane to operate at filtration rates 5–15 times higher than in conventional cross-flow membrane systems.

Industrial applications of this technology include the treatment of wash water from crude oil desalting, dewatering of oily wastewater, recycling of used crankcase oil and oil-based coolants, glycol recovery, tank bottom treatment, and treatment of tank wash-down water and truck and bus wash water. In water purification, there are now two VSEP systems that have been installed: one in Japan for the production of ultrapure water for electronic disk manufacturing (for removal of humics, color, turbidity, permanganate consumption, and total iron), and a 1-mgd facility for municipal water purification.

At this time, there are no extensive studies testing the efficiency and cost-effectiveness of this technology for the handling of RO concentrate.

Advantages:

- Low energy costs
- Can treat high-salinity wastewaters
- High recovery

Constraints:

- Footprint of additional process unit
- Proprietary technology
- Untested for RO concentrate treatment in drinking water plants

11.3.1.5 SPARRO

Seeded RO, which was first developed in the late 1970s by Resources Conservation Company (Seattle, WA), involves circulating a slurry of seed crystals within an RO system to promote salt precipitation. The crystals serve as preferential growth sites for calcium sulfate and other calcium salts and silicates. As their solubility limits are exceeded, the salts begin to precipitate and concentrate within the membrane tubes (Juby and Schutte, 2000). The preferential growth of scale on the seed crystals and subsequent precipitation reduces scaling of the membrane surface. The need to circulate a slurry restricts this process to membrane configurations that will not plug, such as tubular membrane systems, and this has posed challenges to its successful implementation.

The SPARRO process (Figure 11.6) takes seeded RO a step further by solving some of the issues described above.

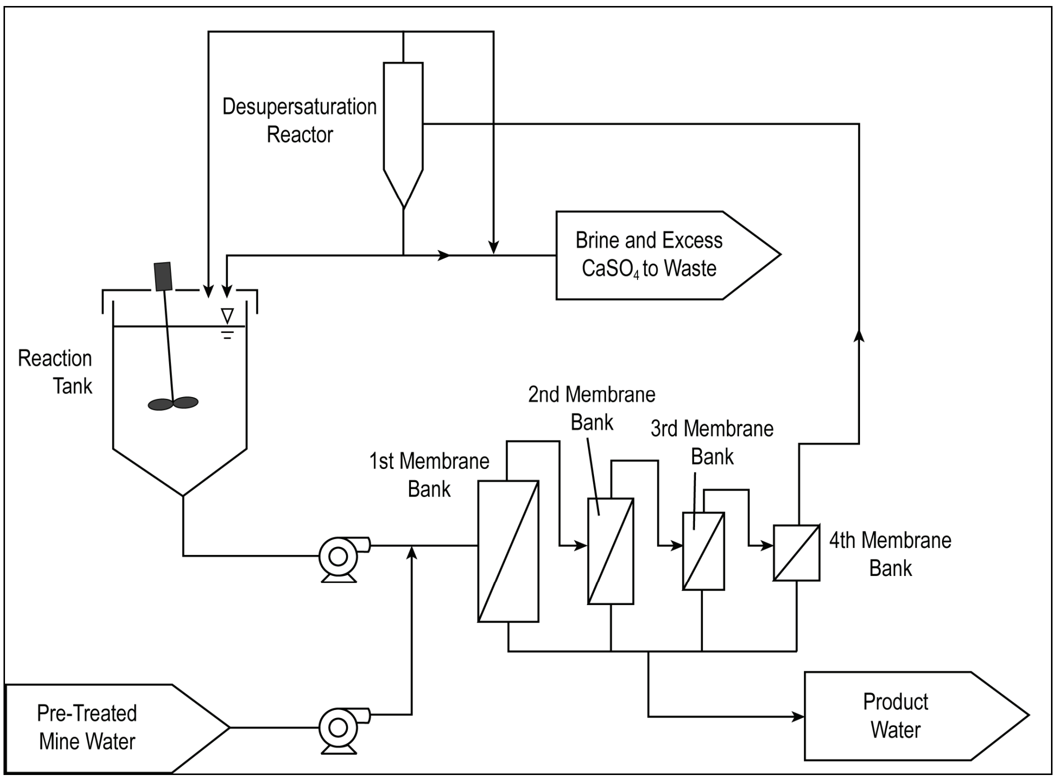

Figure 11.6. Schematic of the SPARRO process.

Significant components of the SPARRO process include:

- Separate pumps for influent feed water and seed slurry that allow conventional RO pumps to be used for the influent feedstream
- A tapered membrane stack configuration
- A smaller desupersaturation reactor
- Separate seed crystal and brine blowdown systems to allow the independent control of the mass of suspended and dissolved solids in the system

Advantages:

- Low energy costs
- Can treat high-salinity wastewaters
- No scale formation
- High recovery

Constraints:

- Large footprint
- Confined to membrane configurations that are not subject to plugging, such as tubular membranes
- Required addition and disposal of seed chemicals

11.3.1.6 Dual RO with Intermediate Chemical Precipitation

Dual RO with intermediate chemical precipitation is a physical–chemical method for improving RO recovery. First, the concentrate for the primary RO process is treated using a physical–chemical process, and then the effluent from the physical–chemical process is passed through another filtration step. The first step focuses on removing sparingly soluble salt components (e.g., calcium and magnesium) from the concentrate through precipitation, reducing the scaling potential of the concentrate. The second filtration step, medium filtration or membrane filtration, removes the solids that carry over from the precipitation process.

When a secondary RO system is used for the secondary filtration step, the feed water has a higher TDS, requiring higher pressures than the primary RO system. The overall recovery of the process has been reported to be around 95% or greater for brackish water (Williams et al., 2002).

Advantages:

- Application of established unit processes
- High recovery

Constraints:

- Production of sludge from the chemical precipitation process
- Footprint and costs of chemical feed and storage facilities and the secondary RO system

11.3.1.7 Dual RO with Intermediate Biological Reduction

In the process using dual RO with intermediate biological reduction, the concentrate from a primary RO step is first treated in a biological reactor, followed by air stripping for the removal of anions (e.g., sulfates and carbonates) to reduce the scaling potential of the concentrate. The effluent of the biological reactor is then filtered through a medium or membrane filter to remove carryover solids from the biological process. Finally, the filtered water is sent to a secondary RO unit or recycled to the primary RO. It has been estimated that this system may reach recovery rates over 95% (Williams and Pirbazari, 2003).

Advantages:

- Application of established unit processes
- High recovery

Constraints:

- Additional process units
- Production of sludge from the biological process
- Footprint and costs for the additional process units

11.3.1.8 Hybrid RO–ED and EDR

Hybrid RO–ED and RO–EDR are being considered for RO concentrate minimization. ED is a process in which ion species are driven through a membrane from one compartment of low concentration to another of high concentration under the influence of an electrical potential. Combining ED with RO or NF can increase the overall recovery of the membrane process. The osmotic pressure at the RO membrane is lowered, and so the concentration polarization at the membrane interface is also lowered. The energy expenditure for the electrodialysis is kept low, because the high salt concentration within the RO unit lowers the cell pair resistance.

Studies using serial RO–ED have been conducted to investigate the production of fresh water and salts from seawater and have confirmed the potential of this technology for desalination (Davis et al., 2002; Tanaka et al., 2003). Tanaka et al. (2003) showed that the energy consumption to recover salt from RO reject from a desalination plant was 80% of the energy consumption used by the plant to achieve the same result. In 1986, Ionics used a six-stage EDR system to reclaim 70 gpm from a 4500-mg/L TDS RO concentrate (Rehal, 1992). The reclaimed product had 550 mg/L of TDS. An additional clarification process using lime and magnesium carbonate was added after the EDR unit to remove silica and accept ultrafiltration concentrate. The recovery rate of the EDR system was 83–87%, resulting in an overall recovery of 97% for the EDR–RO system.

Advantages:

- Use of proven technologies
- High recovery

Constraint:

- More pilot-scale studies are needed to confirm the benefits of this technology under the conditions of and materials used in drinking water plants.

11.3.2 Enhanced Evaporation

Due to their large area requirements, evaporation ponds can be an environmental and financial burden. Technologies that enhance the rate of evaporation can help address these issues.

11.3.2.1 Wind-Aided Intensified Evaporation

In wind-aided intensified evaporation (WAIV) systems, wind energy is used to enhance evaporation on wetted surfaces (Figure 11.7). The brine is sprayed over vertical transport surfaces to reduce the pond footprint. The hydrophilized evaporation surfaces typically consist of woven nettings.

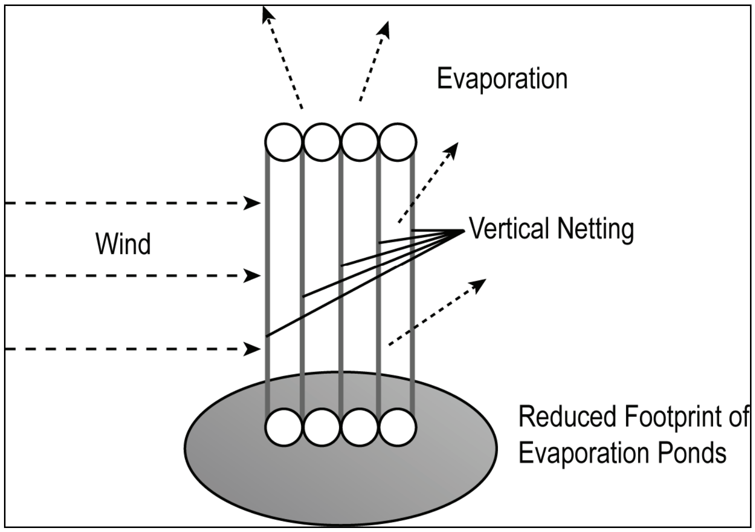

Figure 11.7. Schematic for WAIV.

Advantages:

- Reduces the footprint of evaporation ponds
- Very low energy requirements

Constraints:

- Only feasible for climates with high evaporation rates
- Precipitative fouling of feed lines
- Scattering of concentrate flow due to wind

11.3.2.2 Spray Evaporators

Two mechanical spray evaporators, the TurboMist (Slimline Manufacturing Ltd., BC, Canada) and the Super Polecat (Snow Machines Inc., Midland, MI), have been tested in recent desalination projects (Jorgensen, 2006). They use snow cannon or agricultural spraying technology customized with corrosion-resistant materials for evaporation of salt solutions. Essentially, these machines spray a fine mist of concentrate into the air to volatilize water, further concentrating salts and contaminants. These evaporators were found to be vulnerable to biological clogging and scaling of the nozzles when the water sprayed was near salt saturation. In El Paso, TX, a TurboMist™ cannon was successfully operated over a period of 1 year, but the project was eventually terminated due to the high energy requirements.

The evaporation rate can be affected by a number of environmental and design factors, including flow rate, temperature, humidity, wind, and the spray's spatial distribution, residence time, and droplet sizes.

Advantage:

- Reduces the footprint of evaporation ponds

Constraints:

- Only feasible for climates with high evaporation rates
- High energy requirement
- Biological clogging
- Nozzle scaling with high salt concentrations

11.3.2.3 Solar-Bee™

The solar-powered mixing apparatus Solar-Bee™ is a floating solar-powered circulator. Solar-Bee™ draws up to 10,000 gpm from below the apparatus and spreads it across the top of the reservoir in a near-laminar flow manner for long distance coverage and continuous surface renewal. As for spray evaporation, evaporation rates strongly affect this process. Jorgensen (2006) reported that tests conducted at the Salton Sea comparing evaporation rates in a pond with Solar-Bee™ and one without (both filled with 45,000 mg/L TDS water) showed the following:

- The overall evaporation rate was increased by 30%.
- Daytime evaporation rates were lower (14% less) in the pond with the Solar-Bee™.
- Nighttime evaporation rates in the pond with the Solar-Bee™ were 50% higher than in the control pond.

Advantages:

- Reduces the footprint of evaporation ponds
- Solar powered
- Low maintenance and operation costs

Constraints:

- Needs further research to substantiate its long-term performance
- Proprietary technology

11.3.3 Long-Term Storage

11.3.3.1 Disposal in Salt Caverns

Another potential future disposal option is the storage of highly concentrated salt solutions (e.g., reject from brine concentrators) in existing salt storage caverns, like those found in Texas (Figure 11.8), Utah, and New Mexico. Salt has a very low permeability, making it an ideal medium for containment of stored materials. The salt caverns, already used for storage of hazardous waste, could be used to store brine solutions as well.

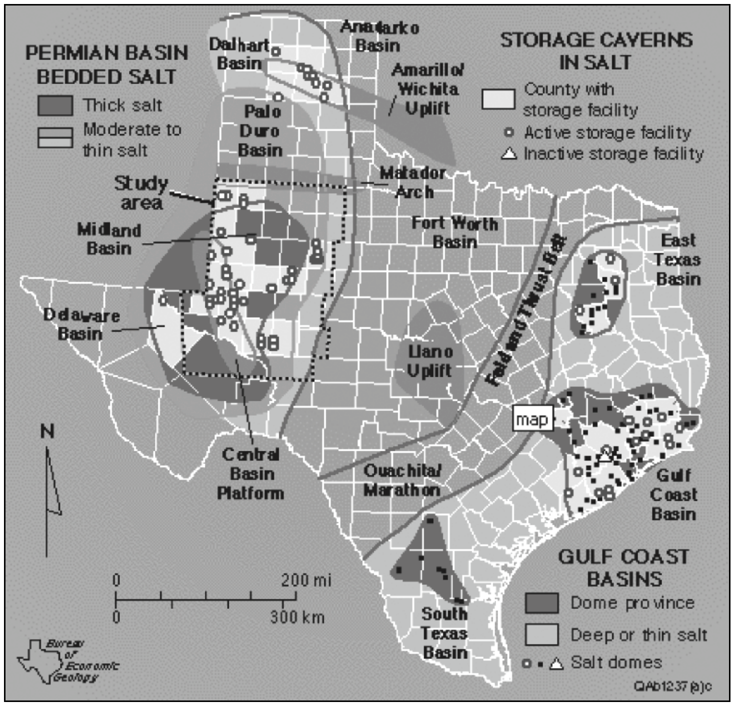

Figure 11.8. Map of existing salt storage caverns in Texas. (Source: Bureau of Economic Geology)

In the current disposal process, the caverns are initially filled with clean brine. Wastes are introduced as a slurry of waste and carrier fluid (brine or fresh water). To avoid excessive leaching of the cavern roof by the subsaturated solution, operators may introduce a lower-density hydrocarbon pad that floats at the top of the cavern, keeping the unsaturated carrier fluid from coming in contact with the cavern roof. The clean brine displaced by the incoming slurry is removed from the cavern and is sold or deep-well injected. When the cavern is filled, the hydrocarbon pad is removed and the cavern is sealed.

Advantage:

- Potential low-cost option for concentrate disposal

Constraint:

- Applicability restricted to specific geologies

11.3.3.2 Salt Solidification and Disposal in Inactive Salt Mines

There is a need to refill unstable inactive salt mines; the collapse of caverns may lead to earthquakes and structural damage to buildings on the surface. Solidified salts could be used to refill underground salt mines and provide structural stability. For sodium chloride brine solidification, a specific approach has been developed in which $MgCl_2$ ($MgSO_4$), CaO, and MgO are added, resulting in a gel of $NaCl–MgCl_2–H_2O$ with $Ca(OH)_2$ as a cement (Figure 11.9).

Figure 11.9. Solidified brine solution. (Source: KUTEC)

Inactive salt mines are located in the western region of the United States (Texas, New Mexico, and Utah). These are warm and arid regions, where water shortages are pressing the development of desalination plants. Examples of inactive salt mines are listed below.

- Utah: Redmond Clay and Salt, Morton (in Grantsville), GSL (in Ogden), Cargill (in Timpie)
- New Mexico: United (in Carlsbad), New Mexico Salt and Minerals (in Loving)
- Kansas: Cargill (in Hutchinson)
- Arizona: Morton (in Glendale)

Before the successful integration of solidified salt into caverns, the following structural and environmental issues must be considered:

- Fire and corrosion resistance of structural components
- Structural characteristics of the gel-type materials used for backfilling, especially regarding creep and brittleness
- Solubility of the salt material
- Hydrological investigations of the surrounding area to ensure there will be no threat to local groundwater

Advantage:

- Potential low-cost option for concentrate disposal

Constraint:

- Applicability restricted to specific geologies

11.3.4 Mineral Recovery

11.3.4.1 SALPROC™

The SALPROC™ process by GEO-Processors (Sydney, Australia) is based on chemical precipitation, with the objective to recover salt for commercial use. The unit processes applied might vary for groundwater and seawater desalination plants, but the process typically includes chemical precipitation to sequentially recover valuable salt products, such as magnesium carbonate, calcium carbonate, and gypsum.

Advantages:

- Greater water recovery with the objective to achieve ZLD
- Fully consumes saline streams
- Potential cost offset through sales of salt products

Constraints:

- Sale of salt products would depend on local markets
- Unknown market potential for desalination "products"
- A patented technology

11.4 ESTIMATING COST

11.4.1 Capital Cost Elements

Table 11.2 summarizes the major capital cost elements for the most common concentrate management technologies. In general terms, where surface water discharge and wastewater disposal are available, these are the least costly disposal methods, depending only on transport system costs, possible posttreatment costs, an outfall structure for surface water disposal, and the disposal fee for disposal to the wastewater or brine line. The disposal methods of percolation, spray irrigation, and evaporation ponds are dependent on climate, soil conditions, and land availability and are all land-intensive operations. Assuming that suitable conditions exist for each of these options, land costs will be significant, and assuming that transport costs are similar, irrigation costs would be less expensive than evaporation ponds. Mechanical ZLD processes are usually the most costly option.

Table 11.2. Capital Cost Items That Should Be Included for Various Concentrate Disposal Options

Capitol Cost Item	SWD	WWTP	DWI	SI	EP	ZLD
Transport System (pipe, pump)	X	X	X	X	X	X
Treatment System (includes blending)	X*	X*		X*		
Outfall Structure	X					
Injection Well (depth, pump, materials)			X			
Monitoring Wells			X	X	X	
Land, Land Preparation				X	X	
Distribution System (pipe, pump)				X		
Wet Weather Storage				X		
Alternate Disposal System			X			
Subsurface Drainage System				X		
Disposal Fee		X				
Skid-Mounted System						X

Abbreviations: SWD, surface water discharge; SI, spray irrigation; WWTP, wastewater treatment plant; EP, evaporation pond; DWI, deep-well injection; ZLD, zero liquid discharge.
*, case dependent.

11.4.2 Operations and Maintenance Cost Elements

11.4.2.1 Surface Water Disposal

Operating costs for surface water disposal are limited to conveying the concentrate to the shoreline or deeper into the water, as required. In some cases, pumping may be required.

11.4.2.2 Deep-Well Injection

Operating costs for deep-well injection are limited to the pumping power for deep-well injection. Maintenance tasks involve the monitoring of the well casing integrity and any repairs of the well casing.

11.4.2.3 Evaporation Pond

The evaporation pond has the lowest operational costs compared to other disposal options. Maintenance costs are limited to repair of dikes, liners, pipes, and flow control devices.

11.4.2.4 Spray Irrigation

The operation of spray irrigation systems is very labor-intensive compared to other disposal methods, especially in the maintenance and repair of the sprinkler systems and of the vegetative surface.

11.4.2.5 Zero Liquid Discharge

The large energy costs for the brine concentrators used in ZLD contribute largely to it being the most expensive system to operate.

11.4.3 Cost Models

Cost models cannot deliver highly accurate cost estimates due to the large number of site-specific cost factors (e.g., different regulatory requirements or variations in climate, soil characteristics, and receiving water quality). Cost models can, however, help in the decision-making process and in the preliminary assessment of disposal options, when very little cost data are available. Based on the capacity of the desalination plant and on the concentrate flow rate, the cost models make it possible to rule out some of the concentrate management options and to focus on a few for further evaluation.

There are different cost models available which are suited to estimate the capital and operating costs of various disposal options. One of them has been developed by Mickley and Associates and is now available through the U.S. Bureau of Reclamation (Mickley, 2006) and has been adapted for use in the Microsoft Access-based CMDM tool on the attached CD-ROM. The Mickley models assist in estimating the relative capital cost and operating costs for the following disposal options:

- Deep-well injection
- Evaporation ponds
- Land application (spray irrigation)
- ZLD

11.5 SALINITY BALANCE

Increased evaporation rates and reduced inflows are greatly accelerating the concentrations of salts and nutrients in some areas. A regional salinity imbalance can be a limitation to disposal options for desalination concentrates, especially for surface water discharge, and so should be considered during the concentrate management planning process. A salt management plan is increasingly becoming an integral part of long-term water management plans in arid regions of the United States (e.g., the Zone 7 Alameda County Flood Control and Water Conservation District's Livermore–Amador Valley Main Groundwater Basin salt management plan).

For example, the TDS content of the groundwater aquifer that serves the Phoenix metropolitan area increases every year (as of mid-2005 the total increase was in the 300–500 mg/L TDS range). There is a significant volume of surface flow (i.e., Colorado River surface water via the Central Arizona Project canal) into the Phoenix area and insignificant surface flow out of the area. Municipal and agricultural uses of the local water resources subject these waters to evaporation and evapotranspiration, which further increase the TDS concentration. The resulting high-TDS wastewaters percolate to the water table or are discharged to local surface waters that are hydraulically connected to the groundwater (USBR, 2000). As a result, the Sub-Regional Operating Group recommended that the local WWTPs' effluent TDS concentrations not exceed 1200 mg/L. Local long-term planning includes the construction of several advanced WTPs in the next 20 years to remove excess TDS (>1200 mg/L) from wastewater flows. These advanced WTPs will likely use membrane filtration, generating significant volumes of high-TDS concentrate that will require disposal. The Sub-Regional Operating Group predicts that over 20 advanced WTPs will be constructed and generating concentrate flows by 2025.

Salinity balance modeling is also used to simulate water volume and the dissolved solids concentration throughout a region. The University of San Diego developed a salinity model for the restoration of the Salton Sea to evaluate the success of the restoration project (Ponce and Shetty, 2001). Another example is the Salinity Management Study for Southern California, completed by the Metropolitan Water District of Southern California. In that study, the Metropolitan Water District investigated the salinity imbalance and the impacts of TDS or salinity to the coastal plain of southern California (Figure 11.10). It was found that by reducing the salinity levels of imported water, the region could benefit from both improved use of local groundwater and recycled water and reduced costs to water consumers and utilities.

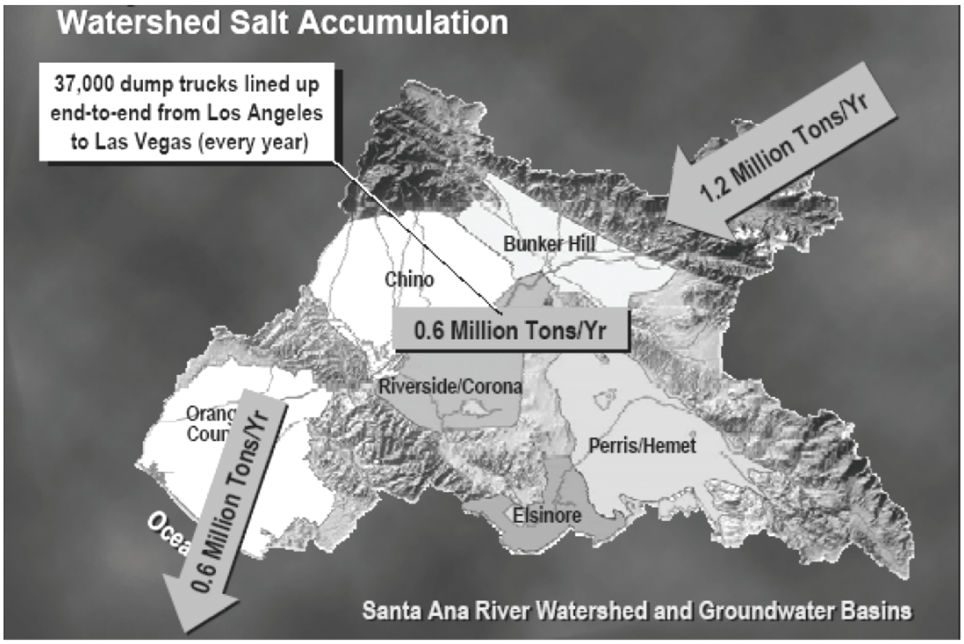

Figure 11.10. Salt balance and accumulation in a watershed source (Santa Ana Watershed Project Authority, SARI System Enhancements Project)

11.5.1 Impacts of Elevated Salinity in Urban Areas

The impacts of high TDS levels on the municipal water supply and on consumer confidence are described here.

- *Consumer confidence.* High-TDS waters generate taste and odor problems. Although not directly harmful to health, poor palatability of high-TDS water will create distrust among the public regarding the overall safety of the municipal water supply (Mackey, 2003).
- *Corrosion*. Especially when switching to higher-TDS water, the corrosion of pipes is accelerated and can lead to reddish and turbid tap water.
- *Treatment costs.* The use of RO treatment or lime softening to reduce elevated levels of TDS increases the cost of water treatment. In the United States, 1030 municipal

water treatment plants, providing 3055 mgd of water (a service population of roughly 20 million), soften their water.

- *Irrigation.* In the arid Southwest, a large fraction of municipal water is used for external irrigation. Salinity effects on crops include osmotic stress, reduced permeability of soils, and direct toxicity from specific ions. Many landscape plants are very sensitive to salinity damage, particularly at levels greater than 1000 mg/L TDS. Wastewater with a SAR $\{[Na]/([Ca] + [Mg])^{1/2}\}$ greater than 6 can limit the use of wastewater for irrigation.

11.5.2 Salinity and Concentrate Management on an Ecosystem Level

Salinity and concentrate disposal are problems that are best addressed on an ecosystem (watershed) level. A regional concentrate management approach would integrate source water management, drinking water treatment, wastewater treatment and disposal, and irrigation management. Furthermore, since the salinity problem has an impact on agriculture, farming activities have to be included in the approach.

11.6 REGULATIONS AND PERMITTING

There are many layers to membrane concentrate disposal regulations. The process of complying with these regulations is complex and requires a detailed review in the planning phase when considering the implementation of a membrane desalting process.

The three characteristics of concentrate management that dictate the regulatory environment in which a water utility will have to operate are (1) concentrate water quality, (2) geography, and (3) disposal method. The permitting cycle can also be quite lengthy and must be factored into the planning timeline. The applicable laws can range from permitting the construction and operation of a discharge pipe to the toxicity tests required for landfilling dewatered solids.

The following discussion provides a roadmap for understanding the regulation of membrane by-product disposal and reuse and how to identify and implement viable concentrate management options (from a regulatory standpoint).

11.6.1 Federal Regulations

In federal regulations, wastes are classified as either industrial or municipal. “Municipal waste” is, by definition, wastewater treatment plant effluent that may contain microorganisms. Consequently, membrane concentrate streams are, by definition, “industrial wastes.” The regulatory requirements for management of this industrial waste will vary as a function of the disposal method. The disposal options and applicable regulations are summarized in Table 11.3. The following subsections summarize the federal regulations that govern waste disposal.

Table 11.3. Federal Regulatory Requirements

Disposal Option	CWA	SDWA	HMTA	RHA	NEPA	ESA	RCRA, CERCLA, TSCA
Fresh Surface Water Discharge	√			√	√	√	
Ocean Discharge	√			√	√	√	
Wastewater Discharge	√	√		√	√	√	
Deep-Well Injection		√					√
Evaporation Ponds			√		√		√
Spray Irrigation, Land Application	√		√		√	√	√
Reuse and Blending	√	√					

Abbreviations: CWA, Clean Water Act; SDWA, Safe Drinking Water Act; HMTA, Hazardous Materials Transportation Act; RHA, Rivers and Harbors Act; NEPA, National Environmental Policy Act; ESA, Endangered Species Act; RCRA, Resource Conservation and Recovery Act; CERCLA, Comprehensive Environmental Response, Compensation and Liability Act; TSCA, Toxic Substances Control Act.

11.6.1.1 CERCLA

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) is applicable to water and wastewater treatment residuals only if the water plant has stored, treated, or disposed of a "hazardous waste" as defined under the Resource Conservation and Recovery Act (RCRA). If the water plant releases quantities of a hazardous waste in excess of a CERCLA-defined reportable quantity, the water plant must notify the National Response Center.

While CERCLA places no specific design or permitting requirements on disposal of membrane concentrate, the disposal practices plan to be implemented should be in compliance with all RCRA requirements to minimize any potential liability exposure under CERCLA. Most membrane concentrate streams would not qualify as "hazardous."

11.6.1.2 CWA

The Clean Water Act (CWA) regulates the discharge of industrial waste, domestic wastewater plant effluent, and membrane process concentrates to any surface water. All states are required to establish ambient water quality standards for their water bodies. The CWA requires all point source dischargers to have an NPDES permit. Point sources are discrete conveyances, such as pipes or human-made ditches. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. While the U.S. EPA administers the NPDES program, the states have been delegated the responsibility of issuing permits and establishing water quality-based discharge limits for receiving waters. Table 11.4 lists the states authorized to regulate NPDES-related programs.

Table 11.4. States Authorized To Regulate NPDES-Related Programs (as of March 2006)

State	Approved State NPDES Permit Program	Approved to Regulate Federal Facilities	Approved State Pretreatment Program	Approved General Permits Program
Alabama	✔	✔	✔	✔
Alaska				
Arizona	✔	✔	✔	✔
Arkansas	✔	✔	✔	✔
California	✔	✔	✔	✔
Colorado	✔			✔
Connecticut	✔	✔	✔	✔
Delaware	✔			✔
Florida	✔	✔	✔	✔
Georgia	✔	✔	✔	✔
Guam				
Hawaii	✔	✔	✔	✔
Idaho				
Illinois	✔	✔		✔
Indiana	✔	✔		✔
Iowa	✔	✔	✔	✔
Kansas	✔	✔		✔
Kentucky	✔	✔	✔	✔
Louisiana	✔	✔	✔	✔
Maine	✔	✔	✔	✔
Maryland	✔	✔	✔	✔
Massachusetts				
Michigan	✔	✔	✔	✔
Minnesota	✔	✔	✔	✔
Mississippi	✔	✔	✔	✔
Missouri	✔	✔	✔	✔
Montana	✔	✔		✔
Nebraska	✔	✔	✔	✔
Nevada	✔	✔		✔
New Hampshire				
New Jersey	✔	✔	✔	✔
New Mexico				
New York	✔	✔		✔
North Carolina	✔	✔	✔	✔
North Dakota	✔	✔		✔
Ohio	✔	✔	✔	✔
Oklahoma	✔	✔	✔	✔
Oregon	✔	✔	✔	✔

State	Approved State NPDES Permit Program	Approved to Regulate Federal Facilities	Approved State Pretreatment Program	Approved General Permits Program
Pennsylvania	✔	✔		✔
Rhode Island	✔	✔	✔	✔
South Carolina	✔	✔	✔	✔
South Dakota	✔	✔	✔	✔
Tennessee	✔	✔	✔	✔
Texas	✔	✔	✔	✔
Utah	✔	✔	✔	✔
Vermont	✔		✔	✔
Virginia	✔	✔	✔	✔
Washington	✔		✔	✔
West Virginia	✔	✔	✔	✔
Wisconsin	✔	✔	✔	✔
Wyoming	✔	✔		✔

If construction of a concentrate discharge pipe is planned, a 404 permit (referring to requirements under Section 404 of the CWA) will be required. While the original CWA wording was interpreted to apply only to dredging activities, the U.S. Army Corps of Engineers has applied it to most construction activities as well.

Discharge of waste to wetlands, wastewater treatment plants, and wastewater sludge is also regulated by the CWA. The U.S. Army Corps of Engineers has been charged with issuing permits for the disposal of fill material to wetlands. Siting and construction of membrane concentrate disposal lines through a wetland are also subject to the CWA requirements for wetlands protection.

While indirect discharge (e.g., to WWTPs) of membrane concentrate does not require an NPDES permit, membrane plants may be required to comply with the U.S. EPA Pretreatment Control Program standards. Pretreatment requirements focus on maintaining the operation and performance of wastewater treatment facilities. Corrosive and toxic contaminants that would inhibit the biological processes at a wastewater plant must be removed before discharge.

In the case of wastewater sludge from wastewater treatment facilities, it is unlikely that membrane-desalting concentrate will contribute significantly to the concentration of solids from a wastewater treatment facility. However, this issue should be considered.

- NPDES permitting is typically part of the mandate of a state's environmental department and can be found by searching the state's environmental department website using the keyword "NPDES." For example, the following states' regulatory agencies and NPDES contacts are as follows:

    - Arizona: Arizona Pollutant Discharge Elimination System, http://www.azdeq.gov/environ/water/permits/azpdes.html

- California: California State Water Conservation Board, http://www.swrcb.ca.gov/rwqcb7/permit-assistance-NPDES.html
- Florida: Florida Department of Environmental Protection, http://www.dep.state.fl.us/water/nonpoint/index.htm
- Nevada: Nevada Bureau of Water Pollution Control, http://ndep.nv.gov/bwpc/bwpc01.htm
- New Mexico: New Mexico Environment Department, http://www.nmenv.state.nm.us/swqb/NPDES/index.html
- Texas: Texas Natural Resource Conservation Commission's Texas Pollutant Discharge Elimination System, http://www.tnrcc.state.tx.us/permitting/waterperm/wwperm/tpdes.html

- CWA-related questions to answer about your desalination scenario:
    - Can my projected waste flow be discharged into the wastewater line or local receiving body?
    - Under what conditions might this be feasible with the treatment technology under consideration?
    - Is this a "deal breaker"?

11.6.1.3 ESA

The Endangered Species Act (ESA) provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The Fish and Wildlife Service (U.S. Department of the Interior) and the National Marine Fisheries Service (U.S. Department of Commerce) are the main administering agencies for the Endangered Species Act.

- ESA-related question(s) to answer about your desalination scenario:
    - If the user knows that endangered species are present (which would likely be determined in an environmental impact assessment), steps will need to be taken to mitigate any adverse impacts on their well-being. If such steps cannot be reasonably taken the project may have to be abandoned.

11.6.1.4 HMTA

Residuals from water or wastewater treatment processes that are transported off-site are regulated by the Hazardous Materials Transportation Act (HMTA). Classification, packaging, labeling, and transporting hazardous materials are also regulated by the HMTA. Compliance with this regulation is technically the responsibility of the hauler. Execution of the HMTA is delegated to the U.S. Department of Transportation.

- HMTA-related question(s) to answer about your desalination scenario:
    - Is the selected trucking company in compliance with state HMTA regulations?

11.6.1.5 NEPA

The National Environmental Policy Act (NEPA) requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. To meet this requirement, federal agencies prepare a detailed Environmental Impact Statement (EIS).[4] EPA reviews and comments on EISs prepared by other federal agencies, maintains a national filing system for all EISs, and assures that its own actions comply with NEPA.

- NEPA-related question(s) to answer about your desalination scenario:
    - Is an EIS required for the treatment and/or disposal site?

11.6.1.6 RCRA

RCRA establishes the "cradle-to-grave" concept that applies to generation, treatment, storage, transportation, and disposal of hazardous waste materials. A "hazardous waste" is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. EPA defines four hazardous waste characteristics:

- Ignitability: can readily catch fire and sustain combustion
- Corrosivity: acidic or alkaline and can readily corrode or dissolve flesh, metal, or other materials
- Reactivity: can readily explode or undergo violent reactions
- Toxicity: contains toxic chemicals that could leach into the local aquifer(s) and expose users to hazardous chemicals.

Membrane concentrate streams are typically not considered RCRA wastes. However, there is language in Subtitle C of RCRA that applies specifically to water and wastewater treatment plant residuals management: all wastes must pass the "hazardous waste identification process" to allow disposal in a municipal landfill. Therefore, it is the responsibility of a water utility to determine if the membrane concentrate produced meets the definition of a hazardous waste under RCRA.

Membrane desalting by-products may possess the characteristics of corrosivity or toxicity. If it is determined that the by-product meets these definitions, a U.S. EPA generator identification number must be obtained. Treatment of a RCRA hazardous waste requires specific operational and design requirements. Evaluation of the anticipated contaminants and, ultimately, testing of the membrane concentrate stream are required to determine if it meets any of the definitions of a RCRA hazardous waste.

If a sludge is to be disposed of in a municipal landfill, it would have to pass the TCLP (Method 1310). The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes. If a total analysis of the waste demonstrates that individual analytes are not present in the waste, or that they are present but at such low concentrations that the appropriate regulatory levels will not be exceeded, the TCLP need not be run. Details on this procedure can be found at:

http://www.epa.gov/epaoswer/hazwaste/test/pdfs/1310/pdf and
http://www.epa.gov/epaoswer/hazwaste/test/faqs_tclp.htm.

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[4] Instructions on submitting an EIS can be found at
http://www.epa.gov/compliance/nepa/submiteis/index.html.

- RCRA-related questions to answer about your desalination scenario:
    - Are there any contaminants present in the desalination waste stream that would preclude municipal landfill disposal?
    - If hazardous waste disposal is required, is there a nearby location available to take your volume of sludge over the lifetime of the installation? How much would it cost?

11.6.1.7 RHA

Section 10 of the Rivers and Harbors Act (RHA) states that:

> "the creation of any obstruction not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited… and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or enclosure within the limits of any breakwater, or of the channel of any navigable water of the United States…"

Shoreline areas are protected under the State Shoreline Management Act and local shoreline master programs. In areas under federal jurisdiction, such as harbors and coastal zones, federal Coastal Zone Management Act regulations apply. For most local jurisdictions, a Joint Aquatic Resources Application form and/or a state EPA checklist provide the basis for identifying shoreline and coastal zone issues and sources of information.

- A Section 10 permit is required for a structure or work outside the limits defined for navigable waters if it affects the course, location, condition, or capacity of the water body. This includes freshwater and coastal discharge structures, such as those used for brine disposal into navigable water bodies.
- For information on Section 10 permits, see Section 520.03. Section 9 of the Act requires U.S. Coast Guard approval for any bridge over navigable waters (see Section 520.04).

11.6.1.8 SDWA

The Safe Drinking Water Act (SDWA) specifies the Underground Injection Control (UIC) program regulations that were developed by the U.S. EPA. The SDWA UIC program regulates the disposal of membrane by-products via an underground injection well. States are delegated by the U.S. EPA to permit underground injection of wastewater. Regulatory standards are very stringent and encompass everything from well construction to operation and monitoring.

The Wellhead Protection Program is also administered as part of the SDWA. These regulations are intended to protect potable groundwater supplies from contamination due to underground injection of wastewater or land application of wastewater from a reuse system.

- Determine which state agency you will need to contact for this information. This is typically part of the mandate of the state's Environmental Department and can be found by searching the state's Environmental Department website using the keyword "UIC." For example, the following states' regulatory agencies and UIC contacts are as follows:

- Arizona: Arizona Pollutant Discharge Elimination System, http://www.azdeq.gov/environ/water/permits/app.html
    - Florida: Florida Department of Environmental Protection, http://www.dep.state.fl.us/water/uic/
    - Nevada: Nevada Bureau of Water Pollution Control, http://ndep.nv.gov/bwpc/uic01.htm
    - New Mexico: New Mexico Environment Department, http://www.nmenv.state.nm.us/gwb/New%20Pages/UIC.htm
    - Texas: Texas Natural Resource Conservation Commission's Underground Injection Control program, http://www.tnrcc.state.tx.us/permitting/wasteperm/uicrw/uic/

- SDWA-related question(s) to answer about your desalination scenario:
    - Does my state allow underground injection?

11.6.1.9 TSCA

The Toxic Substances Control Act (TSCA) regulates the sale of toxic substances. TSCA requirements would only apply if the membrane concentrates were to be sold for reuse (i.e., blended with treated wastewater for land application).

EPA classifies chemical substances as either "existing" chemicals or "new" chemicals. One can determine if the substance in question is a new chemical by consulting the EPA's TSCA Chemical Substance Inventory. There are approximately 75,000 chemical substances, as defined in Section 3 of TSCA, on the Inventory at this time. Any substance that is not on the Inventory is classified as a new chemical.

If a substance is "new," it can be manufactured for a commercial purpose only if it is subject to an exemption from premanufacturing notification reporting or a TSCA reporting exclusion (for example, a low volume exemption or exclusion as a naturally occurring material). For "existing" substances, the Inventory can be used to determine if there are restrictions on manufacture or use under TSCA.

The TSCA Inventory is available in paper form as well as on computer tape, diskettes, or CD-ROM. The TSCA Inventory in paper form was updated in 1990 and does not reflect additions to the Inventory since then. The electronic Inventories are updated every 6 months. EPA does not provide searches of the nonconfidential TSCA Inventory, but there are a number of ways you can research whether a chemical is listed on the nonconfidential portion of the TSCA Inventory:

- Many public libraries and company libraries have copies of the TSCA Inventory. In addition, the Inventory is available at federal depository libraries. To find the closest federal depository library, call your local library or look in the Directory of U.S. Government Depository Libraries (http://www.access.gpo.gov/su_docs/locators/findlibs/index.html).
- Assistance in determining whether a chemical substance is on the TSCA Inventory is available on a fee basis from at least two organizations: the Chemical Abstracts Service and Dialog. To request assistance, phone the Chemical Abstracts Service at (800) 848-6538 or Dialog at (800) 334-2564. Other companies may offer similar

services in the future; contact the TSCA Hotline at (202) 554-1404 (voice) or (202) 554-5603 (fax) for an up-to-date list.

- A copy of the TSCA Inventory can be purchased from the Government Printing Office, (202) 512-1800, or the National Technical Information Service, (703) 487-4650.
- For compliance with this rule, the applicant should include a plan for complying with Title I (Control of Toxic Substances) requirements (http://www.access.gpo.gov/nara/cfr/waisidx_01/40cfrv27_01.html). This title includes provisions for testing of existing chemical substances and mixtures, regulation of hazardous chemical substances and mixtures, and manufacture and processing notices, in addition to managing imminent hazards and reporting and recordkeeping requirements.
- It is likely that the utility and/or engineer(s) would need assistance from a specialist in TSCA compliance and related manufacturing regulatory issues.

11.6.2 State Regulations

Regulatory agencies that will provide comment on the disposal and/or reuse of membrane by-products should be identified so as to address any potential issues that may limit project execution. Identifying these agencies early may help to curtail any delays associated with the permitting of a waste discharge. A similar procedure should be followed for the construction and operation of the water treatment plant itself.

In general, each State has a designated agency responsible for enforcing federal environmental legislation. For example:

- In California, water issues are managed by the California Environmental Protection Agency's Water Control Board (www.swrcb.ca.gov).
- In Florida, water issues are managed by the Florida Department of Environmental Protection Division of Water Facilities (www.dep.state.fl.us).
- In Texas, water issues are managed by the Texas Commission on Environmental Quality Water Utilities Water Quality Division (www.tceq.state.tx.us/nav/util_water).

A discussion of the specific regulations and implementation provisions for each U.S. state is outside the scope of this work. However, a great deal of this information can be obtained from the regulatory surveys published by Kenna and Zander (2000) and Mickley (2006) on state-specific regulatory agencies and requirements with respect to concentrate management.

11.7 HANDLING STAKEHOLDER ISSUES

11.7.1 Stakeholders Are Intrinsic to the Decision-Making Process

Stakeholder involvement is now an important piece of many water and wastewater decisions. The movement of environmental regulation away from technology-based standards to water-based outcomes, such as the development of local total maximum daily load standards, is often accompanied by requirements that responsible agencies or districts consult or otherwise involve stakeholders in water management decisions.

Ever-increasing water demands plus declining supplies imply difficult trade-offs among agricultural, urban, ecological, industrial, and recreational water uses. Trade-offs depend both on what the technologies can achieve for local or regional water quality and the relative importance of competing stakeholder interests. Some of the key trade-offs managers need to address that are related to the "what and how" of stakeholder involvement include:

- Integrating technical and policy or value discussions in open forums
- Respecting formal regulatory processes (e.g., Environmental Impact Statements) while using a stakeholder process to overcome their limitations
- Providing meaningful stakeholder roles and responding to stakeholder needs while maintaining technical rigor and defensibility
- Using good science and engineering while balancing effort versus accuracy in sampling, modeling, and assessment
- Directing stakeholders toward consideration of water quality, environmental, and financial outcomes rather than the means used to achieve them

These trade-offs combine policy issues or stakeholder values (e.g., ecological quality, costs, drinking water quality, urban versus agricultural use) with technical problems (e.g., effectiveness of chemical treatment, availability of land needed for construction, feasibility of reuse options). They also combine formal decision-making actions with a more-open-ended process of a water or wastewater district working with regulators and decision makers. What's needed, therefore, are ways to organize what a decision is about (values and technical assessment) to integrate stakeholder views into the process for how a decision is made.

So, what is important for plant and district managers to know about working with stakeholders? How are values identified and related to technical analyses? What are the main components of a strategic approach to stakeholder involvement? How are complex decisions made, with their many layers and dependencies across technologies, environmental outcomes, and financial limitations?

Many approaches to stakeholder involvement exist. Their usefulness depends as much on the water treatment or water quality problem as on the importance of public input. The selection process should depend on available resources, political challenges, technical issues, amount of dollars at stake, whether environmental and health outcomes are relevant, the timeframe for decision-making, legal requirements, and so on.

The principal message is that analytic tools help organize complex choices, while public participation methods are essential for interacting effectively with stakeholders about these choices. Using both sets of "tools" will lead to successful integration of stakeholders into the decision-making process.

11.7.2 Public Participation: Communication Exchange and Decision-Making Roles

Controversy arises when the legitimacy of the decision-making process is questioned. Stakeholder involvement does not mean public relations or even risk communication, which typically are one-way processes in which information is provided to the public. True involvement means getting useful information from interested groups and individuals and using that information in the decision-making process. Stakeholder involvement can take many forms, such as a preferred project recommendation or ranking of project alternatives. Typically, stakeholders do not make the final project choices themselves but have the opportunity to inform or influence decision makers.

If a single axiom is to be selected for stakeholder involvement, it is to *involve stakeholders early on in the decision process and give them a meaningful role*. Allowing stakeholders to have a role in how a decision is defined or framed is just as important as any final choices made. Controversy arises when the legitimacy of the decision-making process is questioned, and a means of precluding that is to assure adequate roles for stakeholders from the start. No process can guarantee better outcomes, but some role for public participation is often essential for many public works decisions. Figure 11.11 provides an example of meetings that can be used in a master planning stakeholder process.

Figure 11.11. A stakeholder process designed to lead to a recommendation in the form of a group "opinion statement."

Techniques used in this type of approach include open-ended whole-group discussions, small work groups focusing on different technology choices, and presentations from specialists on engineering, regulatory, legal, scientific, political, and financial issues. By identifying questions or issues as part of the opinion statement with "majority" and "minority" views, even when stakeholder consensus is not perfect, an informative range of inputs is delivered to district boards, city councils, or regulators who are the final decision makers.

11.7.2.1 Eight Practices for Successful Stakeholder Involvement

1. *Use decision analysis concepts to understand and organize stakeholder values.* Aim for measurable consequences and clear trade-offs, but not unrealistic precision.
2. *Keep close attention to how issues interact and change.* Engineering, regulatory, legal, scientific, political, and financial concerns can shift over time in relative importance.
3. *Define clear and meaningful stakeholder roles and goals.* Make these roles and goals consistent with your decision-making responsibilities and the level of input appropriate for the decision.
4. *Begin stakeholder involvement early.* Organize the stakeholder process into manageable steps which define progress and lead to a completed stakeholder product.
5. *Keep the process focused on "values," not on "alternatives."* Focus participants on the goals rather than how they may want to get there.
6. *Do your homework.* Know your stakeholders and their issues well.
7. *Maintain trust and credibility.* Once lost, trust and credibility are almost impossible to regain.
8. *Think "win-win."* Your aim should be to get everyone as much of what they need or want as you reasonably can. This will often build stakeholder buy-in more than anything else.

APPENDIX A

DEFINING A SCENARIO

The following procedure walks the user through a process of defining water treatment capacity needs in preparation for using the concentrate management decision methodology matrix. The information needed to define the treatment scenario encompasses the following:

1. Defining the water source

2. Defining the treatment site characteristics

3. Selecting the primary treatment option, product water recovery, and concentrate volumes for discharge

A1 DEFINE THE WATER SOURCE

The following steps will assist in the quantitative and qualitative characterizations of the raw water source:

1. *Define the water volume and quality needed.* Keep in mind that properly defining the life span of the intended project is an issue critical to the ultimate design and success of the project.

2. *Identify the water source(s) intended for desalting.* Keep in mind long-term viability when assessing the source(s); will it be reliable over the lifetime of the project? If not, consider another source, or include that disadvantage in the planning process. It may be beneficial to identify another source, either as a primary source or as a backup supplement and/or replacement.

3. *Characterize the raw water source to be used in terms of volume and water quality.* The raw water quality will dictate pretreatment requirements and desalting process recovery rates. Generally, the following water quality parameters are of primary interest and should be characterized:

    - Total dissolved solids (TDS)
    - Heavy metals, such as iron and arsenic
    - Organic toxins, such as pesticides

A1.1 Define the Treatment Site and Finished Water Quality Goals

The following steps will assist in the quantitative and qualitative characterizations of the finished water[1]:

1. *Define the finished water quality goals.*

- Define minimum and/or maximum levels for the following:
  - Alkalinity
  - Hardness (as $CaCO_3$)
  - TDS
  - pH
  - Other constituents of concern (e.g., Ar, B, Se, NO_3, pesticides)

- Is the primary goal TDS reduction, or are there other requirements to remove specific constituents to meet specific maximum contaminant levels, such as for arsenic, boron, selenium, and/or nitrate?

2. *Define the volume of product water needed* during peak and average periods.

3. *Define the region* using the following matrix:

By Geography	By Population		
	High Density	**Medium Density**	**Low Density**
Inland, Arid	X	X	X
Inland, Not Arid	X	X	X
Coastal	X	X	X

4. *Characterize the possible treatment site location(s)* in broad terms:

- Approximate square footage
- Access to power
- Potential stakeholder groups
- Known potential environmental issues (both environmental impact and environmental justice)

A1.2 Select the Primary Treatment Process

Based on the water quality data established in Section A1.1, the descriptions listed below can be used to determine potential desalting treatment schemes. The concentrations of the recovery-limiting salts are the most critical data for consideration and will determine the treatment options and recoveries possible. Reverse osmosis (RO) and electrodialysis reversal

[1] If long-term build-out is planned, include this consideration in the planning scenario, i.e., be sure to leave room on-site for future expansions and evaluate disposal issues with future needs in mind.

(EDR) are the two available desalting options currently available for full-scale plants, with RO generally being the preferred method in terms of cost and ease of operation. These technologies have different limitations with regards to TDS, silica, hardness, turbidity, chlorine, and heavy metals. Table A.1 provides guidance on the typical allowable water quality ranges for RO and EDR treatment technologies.

Table A.1. Impacts of Key Water Quality Parameters on RO and EDR Recoveries

Water Quality Parameter	Allowable Range for RO	Allowable Range for EDR	Notes
TDS (in mg/L) • Brackish Water • Seawater	• 1000–12,000 mg/L at 60–85% recovery • >12,000 mg/L at 30–60% recovery	• 1000–8000 mg/L at 60–93% recovery • 1000–8000 mg/L at 60–93% recovery	For primary desalination of brackish waters, a three-stage process should be used as the default, unless a site-specific analysis is performed
Turbidity (in NTU)	<0.5	<2	Defines pretreatment needs beyond cartridge filtration
Hardness	Can impact recovery	Can impact recovery	Use RO–EDR projection software to assess impact
Alkalinity	Can impact chemical pretreatment	Can impact chemical pretreatment	
Reactive Si (in mg/L)	≤33 for ~85% recovery, <55 for ~70% recovery	No limitations	
Heavy metals/organic toxins (Ar, Fe, B, pesticides)	Can impact recovery and can affect concentrate disposal options	Can impact recovery and can affect concentrate disposal options	Use RO–EDR projection software to assess impact
Chlorine (in mg/L)	0	<0.5 mg/L	

Abbreviations: NTU, nephelometric turbidity units.

Depending on the raw water quality parameters and treatment limitations defined in Table A.1, the following desalination options can be considered (thermal desalination is not considered here due to its very high energy demands).

- High-recovery RO
- Low-recovery RO
- EDR
- A combination of the above (e.g., low-recovery and high-recovery RO units in series)

A1.2.1 Impact of Silica on Selection of Primary Process

For RO, feed water silica concentrations above 55 mg/L will, in most cases, result in irreversible fouling problems that substantially lower product water recovery and consequently result in excessive concentrate streams and high RO disposal costs. In such cases, it is recommended that only EDR be selected for this exercise.

A1.2.2 Impact of Suspended Solids on Selection of Primary Process

RO and EDR vary in their abilities to desalt water containing particulate matter (e.g., turbidity and suspended solids). It is reasonable to assume that groundwater wells will produce water of adequate quality for direct feed into the desalting process without advanced pretreatment (other than cartridge filtration). For wastewater effluent, water reuse, or brackish surface water applications, it is reasonable to assume that additional suspended solids removal would be required in order to avoid irreversible plugging of feed channels within the RO membrane elements and EDR stacks. This would be required regardless of effluent treatment level.

A1.2.3 Suggested Criteria for Selecting a Desalination Primary Process Scenario

The following descriptions further define the requirements for each potential treatment technology. Selection of the most appropriate technology and recovery level should be based on the operational limitations listed below, information provided in Table A.1, and the water quality data established in Section A1.

1. *High-recovery RO:* RO can achieve recoveries of up to 85% with ~100% retention of minerals if the following conditions can be met:
    - Si < 33 mg/L
    - Turbidity < 5 NTU (or else pretreatment is required)
    - Silt density index (SDI) < 5
    - Fe < 0.1 mg/L
    - Total chlorine ~0 mg/L

2. *Low-recovery RO:* RO can achieve recoveries of up to 70% with ~100% retention of minerals if the following conditions can be met:
    - Si concentration between 33 and 55 mg/L
    - Turbidity < 5 NTU (or else pretreatment is required)
    - SDI < 5
    - Fe < 0.1 mg/L
    - Total chlorine ~0 mg/L

3. *EDR:* EDR can achieve recoveries of up to 93% with ~100% retention of minerals if the following conditions can be met:
    - Turbidity < 2 NTU (or else pretreatment is required)
    - Fe < 0.3 mg/L
    - Hydrogen sulfide < 0.1 mg/L
    - SDI < 5
    - Fe < 0.1 mg/L
    - Total chlorine ~0 mg/L

A1.3 CHARACTERIZE THE CONCENTRATE PRODUCED

The final step in defining the treatment scenario is to determine the required desalting capacity and quantity of concentrate produced. The desalting capacity will typically be based on the blended water quality TDS goal (i.e., a blend of the desalted and bypassed groundwater or effluent flow rate). With a TDS concentration of less than ~600 mg/L, a significant portion of groundwater or effluent can go untreated and be blended with desalted water to meet a TDS goal.

The following steps will assist in characterizations of the concentrate quality and quantity:

1. *Define the recovery (R) based on the desalting process*, selected in step A1.2:
   - For high-recovery RO, $R = 0.85$ (85%)
   - For low-recovery RO, $R = 0.70$
   - For EDR, $R = 0.90$

2. *Calculate the flow rate of bypass water* to be blended with the primary process permeate to produce the finished water quality, based on the desired finished water flow rate (Q_{FW}), the target finished water TDS (C_{FW}), the influent TDS (C_{feed}), and the permeate TDS (C_P):

$$Q_{bypass} = \left[\frac{C_{FW} - C_P}{C_{feed} - C_P}\right] \times Q_{FW} \qquad \text{eq A.1}$$

3. Calculate the flow rate of permeate and RO or EDR system feed and the concentrate, (Q_C) based on the bypass flow rate and the recovery:

$$Q_{permeate} = Q_{FW} - Q_{by-pass} \qquad \text{eq A.2}$$

$$Q_{feed} = \frac{Q_{permeate}}{R} \qquad \text{eq A.3}$$

$$Q_C = Q_{feed} - Q_{permeate} \qquad \text{eq A.4}$$

4. Define the concentrate water quality (C_{Conc}) based on product water recovery and feed water rate:

$$C_{Conc} = \frac{(Q_{feed} C_{Feed} - Q_p C_p)}{Q_C} \qquad \text{eq A.5}$$

5. Calculate the solids loading rate ($\dot{C}_{Conc}$) based on product water recovery and feed water rate:

$$\dot{C}_{conc} = Q_{conc} C_{conc} \times {10^6\,gal}/{Mgal} \times {1\,L}/{0.26417\,gal} \times {2.21\,lbs}/{10^6\,mg}$$

eq A.6

Advancing the Science of Water Reuse and Desalination



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