Alternatives Analysis for the Rio Grande Salinity Management Program

Prepared for

U.S. Army Corps of Engineers

September 2011

CH2MHILL

Executive Summary

The U.S. Army Corps of Engineers (USACE) along with the New Mexico Interstate Stream Commission (ISC) under Section 729 of the Water Resources Development Act WRDA of 2007 has entered into an agreement to implement projects associated with the Rio Grande Salinity Management Program (Program). The purpose of the Program is to study, account, and ultimately intercept sources of salinity in the Upper Rio Grande Basin—focusing from San Acacia, New Mexico, to Fort Quitman, Texas—that adversely affect water quality and limit full utilization of the water resources in the basin.

In June 2010, USACE contracted with CH2M HILL to conduct an Alternative Analysis for the Program. The CH2M HILL team is augmented by guidance and information from eminent subject matter experts on the geology and hydrogeology of the Rio Grande: James Hogan, John Hawley, Fred Phillips, Jim Witcher, and Barry Hibbs.

This project developed and screened salinity management alternatives to refine six elevated salinity areas plus one river site and associated treatment options, previously identified by the Rio Grande Salinity Management Coalition (Coalition), to three prioritized areas. A formal decision support process was used to evaluate alternatives, which involved the following steps: (1) develop and gain agreement on non-monetary criteria to evaluate alternatives; (2) identify management alternatives; (3) quantify each criterion for each site/alternative combination to get a total non-monetary attribute score; and (4) develop cost estimates for each alternative, calculate overall attribute-cost scores, and select "best alternatives."

Evaluation criteria were selected and weights were assigned collaboratively with the Coalition during a workshop conducted in September 2010 in El Paso, Texas. Five evaluation criteria were selected: (1) salinity source contribution, (2) economic benefit of source reduction, (3) operational complexity of each management alternative, (4) environmental effects, and (5) availability of project infrastructure. For the economic benefits criterion, downstream concentrations were estimated using an existing model of the river salt balance developed by the State of New Mexico, supplemented with new models developed for specific reaches. Economic benefits were then evaluated based on salinity model results and potential economic benefits as defined in the Phase 1 economic report.

Three management alternatives were developed to intercept and treat or remove salt from saline sources: reverse osmosis treatment, electrodialysis treatment, and evaporative disposal by ponds or wetlands. For each candidate site, management alternatives were selected based on their technical feasibility. The volume of water that could be captured was estimated with assistance from the team's experts.

Non-monetary attributes were estimated for each site using the selected evaluation criteria, and sites were ranked accordingly. Preliminary results were presented at a Coalition workshop in February 2011 in Las Cruces, New Mexico. Costs were then estimated for each alternative and site combination, and attribute-to-cost ratios were calculated. The final ranking of sites, based on the attribute-to-cost ratios and further screened according to anticipated non-monetary attributes, yielded **Distal Mesilla Basin**, **Truth or Consequences,** and **Fabens** as the preferred sites for additional investigations. Preliminary hydrogeologic concept models were developed for these three sites, and preliminary recommendations for additional investigations were developed.

Contents

Section **Page**

Executive Summary ..... **iii**

Acronyms and Abbreviations ..... **xi**

1. Introduction and Purpose **1-1**
1.1 Report Outline 1-1
1.2 Background 1-2
1.3 Approach 1-3
1.4 Screening Criteria and Weights 1-4
1.4.1 Criterion A: Source Salinity Contribution 1-5
1.4.2 Criterion B: Potential Economic Benefit 1-6
1.4.3 Criterion C: Management Alternative Operational Complexity 1-6
1.4.4 Criterion D: Environmental Effects 1-6
1.4.5 Criterion E: Availability of Infrastructure 1-6
1.4.6 Determination of Criteria Weights 1-7

2. Management Alternatives **2-1**
2.1 Introduction 2-1
2.1.1 Definition 2-1
2.1.2 Purpose and Outline 2-1
2.1.3 Model Overview 2-1
2.2 Overview of Management Alternatives 2-2
2.2.1 Management Alternative 1: Interception, Treatment with Reverse Osmosis, and Release to River 2-3
2.2.2 Management Alternative 2: Interception, Treatment with Electrodialysis, and Release to River 2-3
2.2.3 Management Alternative 3: Interception and Disposal 2-4
2.2.4 Management Alternative 4: Dilution 2-4
2.3 Concentrate Disposal Alternatives 2-4
2.4 Reduction in Groundwater Flux 2-6
2.5 Projected Flows and Loads by Site 2-7
2.5.1 San Acacia 2-7
2.5.2 Truth or Consequences 2-9
2.5.3 Eastern Mesilla Basin 2-11
2.5.4 Distal Mesilla Basin 2-12
2.5.5 El Paso Wastewater Treatment Plants 2-14
2.5.6 Fabens 2-15
2.5.7 Rio Grande near Las Cruces New Mexico Below Mesilla Dam 2-17

3. Alternatives Analysis **3-1**
3.1 Introduction and Methods of Quantification 3-1
3.2 Raw Attribute Scores 3-1

3.2.1 Source Salinity Contribution 3-2
3.2.2 Potential Economic Benefit 3-2
3.2.3 Management Alternative Operational Complexity 3-5
3.2.4 Environmental Effects 3-6
3.2.5 Availability of Infrastructure 3-6
3.3 Normalized Attribute Scores 3-7
3.3.1 Normalization Methodology 3-7
3.3.2 Source Salinity Contribution 3-8
3.3.3 Potential Economic Benefit 3-9
3.3.4 Management Alternative Operational Complexity 3-9
3.3.5 Environmental Effects 3-10
3.3.6 Availability of Infrastructure 3-10
3.3.7 No Action Alternative 3-11
3.4 Attribute Score Development 3-11
3.4.1 Management Alternative 1: Interception, Treatment with Reverse Osmosis, and Release to River 3-11
3.4.2 Management Alternative 2: Interception, Treatment with Electrodialysis, and Release to River 3-12
3.4.3 Management Alternative 3: Interception and Disposal 3-12
3.5 Comparative Costs of Alternative Sites 3-15
3.5.1 Cost Estimates 3-15
3.5.2 Parameters Not Included in Cost Analysis 3-16
3.5.3 Cost Evaluation Results 3-16
3.6 Attribute-Cost Analysis 3-20
3.7 Sensitivity Analysis 3-21
3.7.1 Sensitivity: Approach 3-21
3.7.2 Sensitivity: Attributes 3-23
3.7.3 Sensitivity: Costs 3-23
3.7.4 Sensitivity: Cost-Attribute Analysis 3-24
3.7.5 Sensitivity: Summary 3-25
3.8 Summary of Conclusions by Site 3-25
3.8.1 San Acacia 3-25
3.8.2 Truth or Consequences 3-26
3.8.3 Eastern Mesilla Basin 3-28
3.8.4 Distal Mesilla Basin 3-29
3.8.5 El Paso WWTPs 3-31
3.8.6 Fabens 3-33
3.8.7 Rio Grande Near Las Cruces 3-34
3.9 Summary 3-36

4. Recommendations 4-1
4.1 Introduction 4-1
4.2 Conceptual Models 4-1
4.2.1 Distal Mesilla Basin 4-2
4.2.2 Truth or Consequences 4-3
4.2.3 Fabens 4-6
4.3 Additional Site Investigations 4-8

4.3.1 Distal Mesilla Basin 4-8
4.3.2 Truth or Consequences 4-10
4.3.3 Fabens 4-11
4.4 Future Pilot Studies 4-13
Disposal Methods 4-14
4.5 Assess Other Considerations 4-14
4.5.1 Socio-political 4-14
4.5.2 Other 4-14
4.6 Cost-Benefit Analysis 4-15
4.6.1 Cost Analysis 4-15
4.6.2 Benefit Analysis 4-15
4.7 Ongoing Monitoring Plan 4-16

5. References 5-1

Appendixes

A Background Information
B Salinity Modeling and Economic Benefit Analysis

Tables

1-1 Initial Criteria Presented at Workshop 1
1-2 Final Criteria and Weightings
1-3 Criteria Rankings and Weighting Data

2-1 Salinity Management Alternatives Considered
2-2 Concentrate Disposal Alternatives
2-3 Estimated Captured and Return Flow and Chloride Load at San Acacia
2-4 Estimated Captured and Return Flow and Chloride Load at Truth or Consequences
2-5 Estimated Captured and Return Flow and Chloride Load at Eastern Mesilla
2-6 Estimated Captured and Return Flow and Chloride Load at Distal Mesilla
2-7 Estimated Captured and Return Flow and Chloride Load at El Paso Wastewater Treatment Plants
2-8 Estimated Captured and Return Flow and Chloride Load at Rio Grande near Fabens
2-9 Estimated Captured and Return Flow and Chloride Load at Rio Grande near Las Cruces, New Mexico

3-1 Raw Values for Source Salinity Contribution
3-2 Summary of Model Results: Salinity and Economic Benefits
3-3 Management Alternative Operational Complexity Raw Scores
3-4 Raw Values for Environmental Effects
3-5 Raw Values for Availability of Infrastructure
3-6 Site Selection Criteria Definitions, Weights and Scoring Methodologies
3-7 Normalized Values for Source Salinity Contribution
3-8 Potential Economic Benefit Normalized Scores
3-9 Management Alternative Operational Complexity Normalized Scores

Tables, cont.

3-10 Normalized Scores for Environmental Effects
3-11 Normalized Values for Availability of Infrastructure
3-12 No Action Alternative Raw and Normalized Values
3-13 Weighted Attribute Results, Management Alternative 1: RO Treatment
3-14 Weighted Attribute Results, Management Alternative 2: ED Treatment
3-15 Weighted Attribute Results, Management Alternative 3: Evaporative Disposal
3-16 Summary of Additional Project Cost Allowances
3-17 Summary of Markup Assumptions
3-18 Cost Analysis Summary for Management Alternative 1: RO Treatment
3-19 Cost Analysis Summary for Management Alternative 2: ED Treatment
3-20 Cost Analysis Summary for Management Alternative 3: Evaporative Disposal
3-21 Attribute-Cost Summary by Management Alternative
3-22 Costs, Sensitivity Case 1
3-23 Costs, Sensitivity Case 2
3-24 Summary of Criterion Values for San Acacia
3-25 Summary of Costs for San Acacia
3-26 Attribute-Cost Summary for San Acacia
3-27 Summary of Criterion Values for Truth or Consequences
3-28 Summary of Costs for Truth or Consequences
3-29 Attribute-Cost Summary for Truth or Consequences
3-30 Summary of Criterion Values for Eastern Mesilla Basin
3-31 Summary of Costs for Eastern Mesilla Basin
3-32 Attribute-Cost Summary for Eastern Mesilla Basin
3-33 Summary of Criterion Values for Distal Mesilla Basin
3-34 Summary of Costs for Distal Mesilla Basin
3-35 Attribute-Cost Summary for Distal Mesilla Basin
3-36 Summary of Criterion Values for El Paso WWTPs
3-37 Summary of Costs for El Paso WWTPs
3-38 Attribute-Cost Summary for El Paso WWTPs
3-39 Summary of Criterion Values for Fabens
3-40 Summary of Costs for Fabens
3-41 Attribute-Cost Summary for Fabens
3-42 Summary of Criterion Values for Rio Grande Near Las Cruces
3-43 Summary of Costs for Rio Grande Near Las Cruces
3-44 Attribute-Cost Summary for Rio Grande Near Las Cruces
3-45 Summary of Management Alternatives Attribute-to-Cost Ratios, Attributes and Recommended Ranking

4-1 Hydrostratigraphic Units Shown on Schematic Hydrogeologic Cross Section of the Truth or Consequences Geothermal Area, Sierra County, New Mexico

Figures

1-1 Areas of Elevated Salinity Identified for Study
1-2 Decision Support Process Flow Path
1-3 Example Criteria Weighting Form

2-1 Management Alternatives 1 and 2: Interception, Membrane Treatment (RO or ED), and Disposal
2-2 RO Membrane Treatment System Process Schematic (top) and Typical Cartridge Configuration (bottom)
2-3 Electrodialysis Membrane Treatment
2-4 Management Alternative 3: Interception, Treatment with Natural Treatment Systems, and Disposal
2-5 Evaporation Ponds and Natural Treatment Systems Typical View
2-6 Deep Injection Well Typical (top) and Location of El Paso Deep Injection Wells (bottom)
2-7 River Treatment Management Alternative Criteria
2-8 River Treatment Management Alternative Flow Treatment

3-1 Site Selection Decision Process
3-2 Results: TDS Reduction
3-3 Results: Economic Benefits
3-4 Attribute Score Summary, Management Alternative No. 1: RO Treatment
3-5 Attribute Score Summary, Management Alternative No. 2: ED Treatment
3-6 Attribute Score Summary, Management Alternative No. 3: Evaporative Disposal
3-7 Attribute-Cost Summary by Management Alternative
3-8 Attribute-to-Cost Summary, Management Alternative 1: RO Treatment
3-9 Attribute-to-Cost Summary, Management Alternative 2: ED Treatment
3-10 Attribute-to-Cost Summary, Management Alternative 3: Evaporative Disposal
3-11 Attribute-to-Cost Summary, Management Alternative 3: Evaporative Disposal – Fabens Bypass Alternate
3-12 Cost Curve: Treatment
3-13 Cost Curve: Disposal
3-14 Attribute Scores, Sensitivity Case 1a
3-15 Attribute Scores, Sensitivity Case 1b
3-16 Attribute Scores, Sensitivity Case 2a
3-17 Attribute Scores, Sensitivity Case 2b
3-18 Sensitivity Result: Attribute Scores
3-19 Sensitivity Result: Attributes and Cost
3-20 Sensitivity Result: Attributes and Attribute-Cost

4-1 Structure-Contour Map of the Base of Santa Fe Group Basin Fill in the Lower Mesilla Valley and Paso del Norte Area
4-2 Schematic Down-Valley Hydrogeologic Cross Section of the Lower Mesilla
4-3 Images Showing Comparison of Gridded Total Dissolved Solids (TDS) Measured from Groundwater Wells and Gridded Conductivity Values Measured from Helicopter Electromagnetic (HEM) Data
4-4 Draft Hydrogeologic Cross-section for the Truth or Consequences Area

Figures, cont.

4-5 Conceptual Model for Salinization at Fabens
4-6 Schematic Hydrogeologic Section HH'; from Sierra del Presidio (Chihuahua) to Hueco uplift (TX) Across Fabens Area of the Lower El Paso/Juárez Valley
4-7 Water Chemistry Data from a Series of Monitoring Wells Drilled into a Saline Water at Fabens
4-8 TDS in the Rio Grande Alluvial Aquifer

Acronyms and Abbreviations

µg/L	micrograms per liter
µS/cm	micro Siemens per centimeter
2009 Study	2009 Rio Grande Salinity Assessment
AACE	Association for the Advancement of Cost Engineering
bgs	below ground surface
cfs	cubic feet per second
Coalition	Rio Grande Project Salinity Management Coalition
CPES	CH2M HILL's parametric Cost Estimating System
ED	electrodialysis
EDR	electrodialysis reversal
EPWU	El Paso Water Utilities
gpm	gallons per minute
ISC	Interstate Stream Commission
mg/L	milligrams per liter
mgd	million gallons per day
O&M	operation and maintenance
Program	Rio Grande Salinity Management Program
RO	reverse-osmosis
SC	specific conductance
TDS	total dissolved solids
USACE	U.S. Army Corps of Engineers
WWTP	wastewater treatment plant

SECTION 1

Introduction and Purpose

The U.S. Army Corps of Engineers (USACE) along with the New Mexico Interstate Stream Commission (ISC) under Section 729 of the Water Resources Development Act WRDA of 2007 has entered into an agreement to implement projects associated with the Rio Grande Salinity Management Program (Program). The purpose of the Program is to study, account, and ultimately intercept sources of salinity in the Upper Rio Grande Basin—focusing from San Acacia, New Mexico, to Fort Quitman, Texas—that adversely affect water quality and limit full utilization of the water resources in the basin.

In June 2010, USACE contracted with CH2M HILL to conduct an Alternative Analysis for the Program. The CH2M HILL team is augmented by the expertise of Dr. Fred Phillips, New Mexico Institute of Mining and Technology; Dr. James Hogan, University of Arizona; and Dr. John Hawley, Hawley Geomatters. Jim Witcher of Witcher Associates provided information during an initial site visit. Dr. Barry Hibbs, California State University, was invited to participate. All are widely recognized as subject matter experts on the geology and hydrogeology of the Rio Grande, and all have reviewed and contributed to this report, either directly or through their published research.

The overall study area for this report extends from San Acacia, New Mexico, to Fort Quitman, Texas, as shown in Figure 1-1. This purpose of this project is to evaluate potential salinity management alternatives for the Rio Grande using existing data. This evaluation considered a combination of three potential treatment options at six locations of elevated salinity inputs and one river site, as previously identified by the Rio Grande Salinity Management Coalition. This report also provides a path forward that identifies additional investigations and other considerations that will need further development for each of the refined areas and treatment options, in order to recommend the best site and method(s) for salinity control.

1.1 Report Outline

Section 1 of this report includes information on the study area, the specific sites evaluated, the decision support process followed, and the criteria and quantification method for site selection. Section 2 describes the management alternatives, how they are applied, and the analysis of each of these alternatives. Section 3 develops criteria attribute scores for each alternate site and management alternative, and then ranks sites by an attribute-cost score. Section 4 of the report outlines the recommendations of sites for further research, as well as the conceptual site model for each site.

Appendix A provides background information from the team's subject matter experts. Appendix B documents the basis for and preparation of the salinity model and the economic benefit model.

1.2 Background

The Rio Grande extends from southwestern Colorado to the Gulf of Mexico, making it the fourth longest river system in the United States. Stream flow for the river is highest during the irrigation season and lowest during non-irrigation season below Elephant Butte Reservoir.

The Upper Rio Grande system is a system composed of eight linked reservoirs operated by USACE and the U.S. Bureau of Reclamation. These reservoirs are used for water supply, irrigation supply, hydropower production, sediment management, flood damage reduction, and recreation. The reservoirs are managed with a seasonal release schedule to balance competing demands, while maximizing water storage for irrigation.

Water quality is a significant factor limiting the usability of the water within the Lower Rio Grande Basin (Moyer et al., 2009). Increasing salinity with distance downstream has been documented for over 100 years (Stabler, 1911) and appears to be largely derived from natural, localized sources. Salinity increases dramatically from 40 milligrams per liter (mg/L) to 2,000 mg/L in a series of steps along the river, with steps occurring at locations at the southern ends of sedimentary subbasins (Phillips et al., 2003; Hogan et al., 2007). Because the influence of natural sources are more evident at lower flows, the operational schedule of the river results in higher salinity concentrations during times of reduced releases of fresh water in the winter non-irrigation season (Doremus and Lewis, 2008).

The Rio Grande Compact, an agreement between the states of Colorado, New Mexico and Texas, determines the apportionment of Rio Grande water in the Upper Rio Grande Basin. The availability of this water has been a concern of water resource managers as they attempt to meet the current agricultural, municipal, and industrial water demands of the system and plan for future demands.

In 2007, the Rio Grande Compact Commission in partnership with local water managers partnered to create the Rio Grande Salinity Management Coalition (Doremus and Lewis, 2008). Part 1 of the Coalition's Salinity Management Program was completed in December 2009, resulting in a Rio Grande Salinity Assessment, an Economic Impact Assessment, and a geospatial salinity database.

As an outcome of the 2009 Rio Grande Salinity Assessment (2009 Study), the Rio Grande Project Salinity Management Coalition conducted a qualitative, initial screening of areas with elevated salinity to help identify those sites with the greatest potential for mitigation projects.

Three primary types of alternatives were recommended for evaluation: (1) targeted salinity management project(s) in areas of concentrated salinity, (2) treating Rio Grande flows at a single upstream location (below the reservoirs), and (3) No Action Alternative.

Six areas of elevated salinity were identified by the Coalition for further evaluation as potential targeted salinity control projects, and are shown in Figure 1-1. These include:

- **San Acacia**, located along the Rio Grande at the southern, distal end of the Albuquerque Basin, an alluvial fill aquifer in Central New Mexico.
- **Truth or Consequences,** a hydrothermal area, located along the Rio Grande just south of Elephant Butte Reservoir in Central New Mexico.

- **Eastern Mesilla Basin**, a hydrothermal area stretching from several miles north of Las Cruces, New Mexico, to El Paso, Texas.
- **Distal end of the Mesilla Basin**, a localized upwelling of saline groundwater just north of the El Paso Narrows, Texas.
- **Wastewater Treatment Plants** (WWTPs), owned and operated by El Paso Water Utilities (EPWU). Three WWTPs discharge to the Rio Grande or "sidestream" conveyance channels (e.g., American Canal and Riverside Canal). The treatment plants are as follows:
  - Northwest WWTP. The Northwest WWTP is the northernmost of the three, and discharges to the Rio Grande between Courchesne Bridge and the American Diversion Dam.
  - Haskell Street WWTP. The Haskell Street WWTP discharges to the American Canal south of the American Diversion Dam.
  - Roberto Bustamante WWTP. The Bustamante WWTP discharges to the Riverside Canal and Riverside Drain.
- **Fabens area**, a localized saline discharge resulting from artesian groundwater located in the Hueco Bolson, near Fabens, Texas.

A seventh site on the **Rio Grande near Las Cruces, New Mexico**, was studied to address an alternative to treat Rio Grande flows directly. A site was selected just south of the Mesilla diversion dam near Las Cruces, based on the location below the reservoirs; the need for power, people, and access; and to be upstream of primary economic benefits to the City El Paso.

1.3 Approach

In order to narrow the field of six sites plus one candidate river treatment site location, a decision support process was used. Figure 1-2 shows the steps taken by the project team to help narrow the options to two to four sites recommended for further study and research.

The decision support process for the screening of Rio Grande salinity management alternatives included the following steps:

1. **Develop and gain agreement on non-monetary criteria to evaluate alternatives**. Preliminary criteria were developed and presented in Workshop No. 1, held in El Paso, Texas, on September 21, 2010. During Workshop 1, criteria were modified and weights selected based on input from the group. Methods for quantifying criteria were subsequently developed, and final criteria and quantification methods were sent back out to the group for a final "vote" on weights. The revised criteria included: (1) source salinity contribution, (2) potential economic benefit, (3) management alternative operational complexity, (4) environmental effects, (5) availability of infrastructure, and (6) public acceptance. These criteria are described in greater detail below.
2. **Identify management alternatives**. Management alternatives were identified to include multiple conceptual treatment options appropriate to each of the sites, plus treating the

river at single location (downstream of reservoirs) and a No Action Alternative. Approximately three alternatives were identified per site, plus the river treatment option, and a No Action Alternative, yielding a total of twenty alternative-site combinations.

3. **Application of non-monetary attribute scores.** Criteria quantified by attributes of each site and management alternative were applied to rank and compare the alternatives. This involved development and use of a salinity model of the Rio Grande to evaluate the impact of treatment by each alternative. A detailed economic model was developed from the existing economic analyses (Michelsen et al., 2009). Results were normalized to a standard scale and weighted to obtain an attribute score for each management alternative.

4. **Develop cost estimates for each management alternative, calculate overall attribute - cost scores, and select the best performing sites.** Planning-level, order-of-magnitude costs were developed for capital, annual operation and maintenance (O&M), and 25-year present worth for all management alternatives. Normalized attribute -cost scores were developed by taking the non-monetary attribute scores from above and dividing by the "normalized" present worth cost of each alternative. Based on the relative attributes and cost of management alternatives, two to four sites were selected for further evaluation in a subsequent phase of work.

1.4 Screening Criteria and Weights

Screening criteria are used to evaluate the feasibility of management alternatives. There are two components of a management alternative, the location (site) and the treatment technology. Some criteria may be specific to sites only (the same for all technologies at a site), technologies only (the same for all sites using a given technology), or a combination of site and technology. Accordingly, the project team initially developed separate lists of potential selection criteria based on sites and based on treatment technology.

The following guidelines were used in final selection of screening criteria:

- Cost is best considered as a standalone factor in an attribute/cost analysis as opposed to treating cost like a non-monetary attribute, to prevent bias in evaluation of attributes.
- Evaluation criteria must be mutually exclusive to prevent double-counting attributes or biasing toward certain traits.
- Evaluation criteria must offer differentiation among alternatives.
- Evaluation criteria must be quantifiable to minimize subjectivity of evaluation and to maximize defensibility.
- Typically between five and eight evaluation criteria are selected.

From the above guidelines, the list of potential screening criteria was reduced to ten criteria. For each criterion, a method of quantification was proposed. Preliminary criteria and rationale for inclusion are presented in Table 1-1.

TABLE 1-1
Initial Criteria Presented at Workshop 1
Alternatives Analysis for the Rio Grande Salinity Management Program

Criteria	Definition
Source contribution	Mass loading
Infrastructure availability	Ability to leverage existing infrastructure
Economic benefit	Downstream economic benefit based on Preliminary Economic Impact Assessment
Mass removal	Net amount of salt mass removed from system
Extent of economic benefit/mass removal	Effect of mass removal on downstream users becomes more uncertain with distance
Complexity of treatment technology	Complexity of treatment • Design • O&M
Treatment technology risk	Risk factor associated with using a given technology at these concentrations and flow rates
Environmental effects	Environmental effect of the project
Regulatory complexity	Effort required for regulatory acceptance of the project
Public acceptance	Effort to gain public acceptance of project

The draft list of ten criteria was presented to the project team in the first workshop on September 21, 2010. Based on input in the workshop and a subsequent conference call held on October 15, 2010, the candidate list was reduced to a set of five final criteria to be used in the analysis, described below. Table 1-2 summarizes the criteria and their attributes.

1.4.1 Criterion A: Source Salinity Contribution

Source Salinity Contribution is defined as the contribution of salinity from a site to the Rio Grande, which denotes the potential for salinity reduction at the site. Depending on the site being evaluated, the source salinity contribution may be an estimate of either surface flows to or groundwater discharge to the Rio Grande. This criterion was quantified as a percentage of chloride flux in the Rio Grande at a baseline location, for the purposes of this study selected to be El Paso, Texas. Estimates of source salinity contribution were made based on literature references and data included in the compendium (Burley, 2010).

This location was selected for two primary reasons: (1) it is the most downstream location with sufficient stream flow and chloride/TDS data with which a reasonable annual average could be estimated, and (2) the salinity flux at this location is directly related to the greatest economic impact. The southernmost end of the study area, Ft. Quitman, has stream gage data; however, salinity data is more limited and the greater hydrologic variability (high flow and low flow where water and salts are stored in the shallow groundwater) make determining a salinity flux at this location more uncertain.

1.4.2 Criterion B: Potential Economic Benefit

Potential Economic Benefit is defined as the potential downstream benefit in dollars from a specific salinity reduction at one of the sites. This criterion was quantified using the Salinity and Economic Benefit Models. Salinity in the Rio Grande at the project site was estimated using a mass balance approach based on the management alternative being considered, which in turn was used as input in determining downstream salinity reduction. Downstream propagation of salinity reduction was based on the Salinity model. This value was input to the economic model to determine the potential economic benefit. The economic benefits at downstream locations were estimated based on equations in the 2009 Economic Impact Assessment completed in Part 1 of the program (Michelsen et al., 2009a). Detailed documentation on the models and a user guide for them can be found in Appendix B of this report.

1.4.3 Criterion C: Management Alternative Operational Complexity

The Management Alternative Operational Complexity criterion is defined as the relative operational complexity of the treatment scenario. This value was calculated as a function of complexity factors for each of the treatment scenario components for a given management alternative at a specific site. This value varies by management alternative and from site to site. Detailed descriptions of this value for each alternative at each site can be found in the Management Alternative Analysis section of the report.

1.4.4 Criterion D: Environmental Effects

The Environmental Effects criterion is defined as the environmental effect of a project at each location, measured as complexity of mitigation and regulatory requirements. The quantification of this criterion was determined to be the number of endangered species because it was a known quantifiable measurement compared to the imprecise nature of other quantification measures such as number of permits. The values for this criterion vary by site but not by management alternative. While intended to serve as a proxy for the complexity of project implementation posed by environmentally sensitive lands, this criterion ultimately was found to provide little differentiating power between alternatives and sites.

1.4.5 Criterion E: Availability of Infrastructure

Availability of Infrastructure is defined as the ability to leverage existing infrastructure for the salinity management project. The criterion is quantified as the distance in miles to an available 3-phase power source. This was selected as a proxy for other infrastructure elements such as roads, availability of trained personnel, etc. This criterion will vary by site but not by management alternative.

TABLE 1-2
Final Criteria and Weightings
Alternatives Analysis for the Rio Grande Salinity Management Program

Criteria	Definition	Quantification	Low or High Value Preferred	Final Weighting
A. Source salinity contribution	Contribution of salinity from site, which denotes potential for salinity reduction at site	Chloride flux at site, as percentage of chloride flux in Rio Grande at a baseline location, such as El Paso	High	23%
B. Potential economic benefit	Downstream economic benefit	Function with three factors: 1. Reduction of concentration in river at site 2. Estimated downstream propagation of salinity reduction 3. Economic benefit at downstream locations based on Preliminary Economic Impact Assessment	High	27%
C. Management alternative operational complexity	Relative operational complexity of treatment	Sum of "complexity factor" for each treatment scenario component	Low	19%
D. Environmental effects	Environmental effect of a project at each location, measured as complexity of mitigation and regulatory requirements	Environmental compliance complexity quantified by likely presence and number of endangered species	Low	16%
E. Availability of infrastructure	Ability to leverage existing infrastructure	Distance (miles) to power source	Low	15%

1.4.6 Determination of Criteria Weights

Following the October 15, 2010 conference call, members of the Coalition provided their criteria weightings via email to the project team. The example weighting form filled out by members of the Coalition is included as Figure 1-3.

Table 1-3 shows the results received from Coalition members and how they were tallied to compute the relative criteria weightings for the decision support process.

TABLE 1-3
Criteria Rankings and Weighting Data
Alternatives Analysis for the Rio Grande Salinity Management Program

	Coalition Workshop Attendee												
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**	**Rounded Average**
A	5	2	4	2	4	4	3	4	4	1	4	37	23%
B	3	4	5	1	3	5	4	5	5	5	5	45	27%
C	4	3	2	4	1	3	4	2	2	4	2	31	19%
D	1	1	3	5	5	1	1	3	3	2	2	27	16%
E	2	5	1	3	2	2	3	1	1	3	2	25	15%
												165	**100%**

Criteria A and B received the greatest weighting, reflecting the interest of the Coalition in addressing those sites with the greatest salinity contribution and, in so doing, achieving the greatest economic benefit. Criteria C, D, and E were scored between 15 to 19 percent.

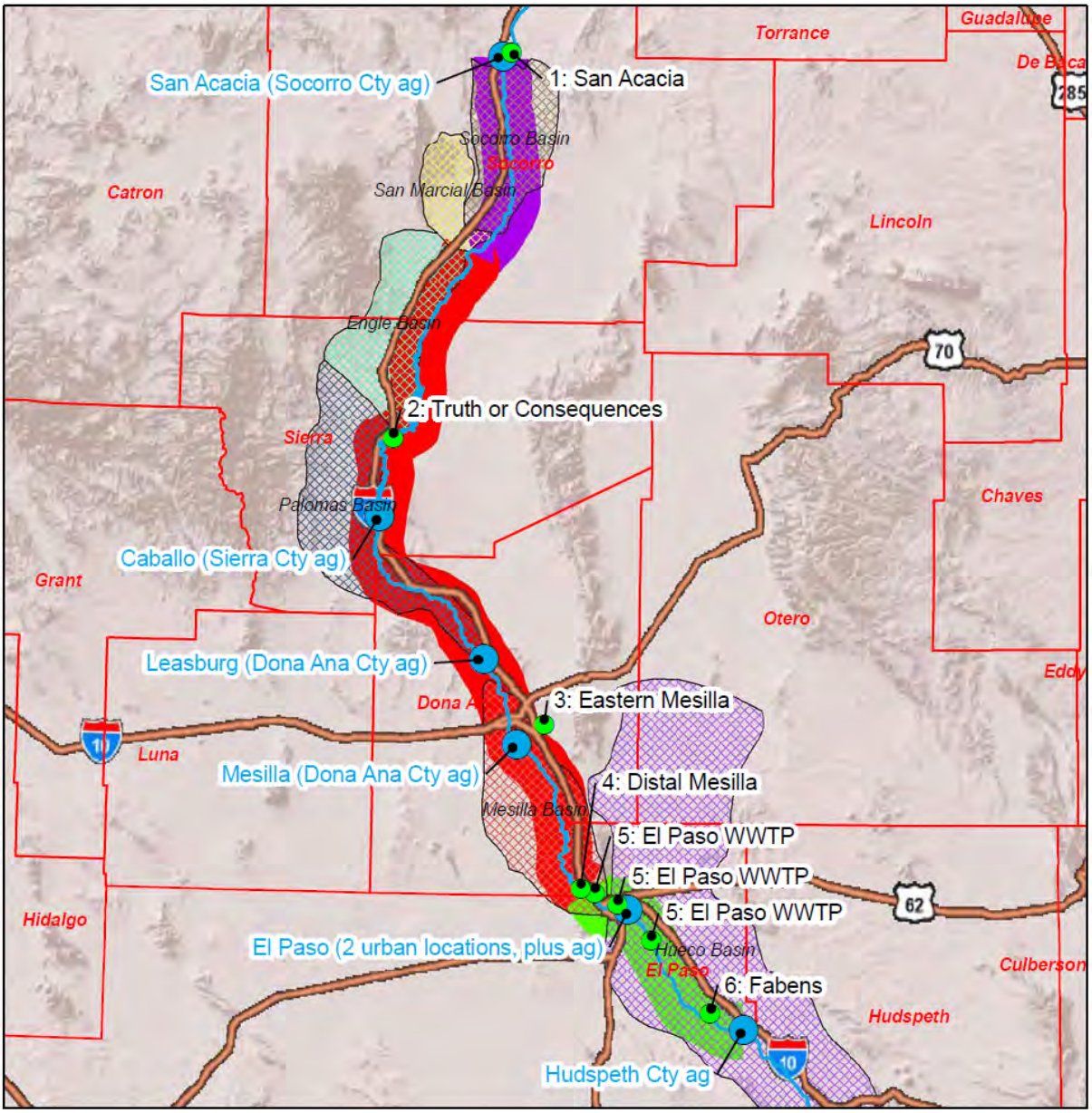
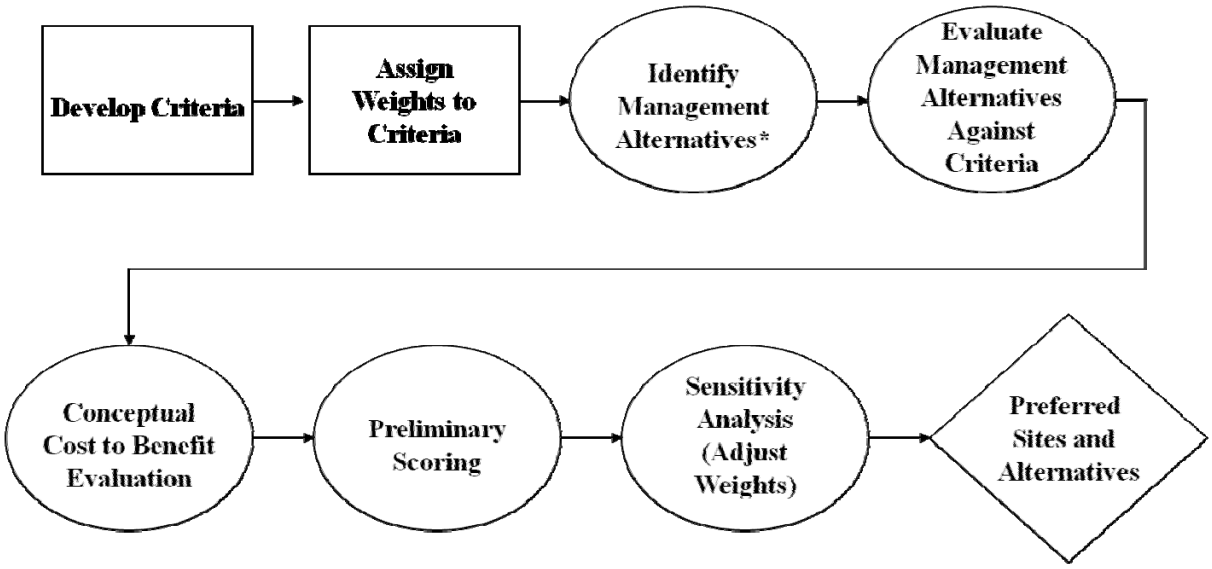


FIGURE 1-1
Areas of Elevated Salinity Identified for Study
Alternatives Analysis for the Rio Grande Salinity Management Program



* Alternative is defined as one treatment technology at one site.
Some sites will have multiple alternatives.

FIGURE 1-2
Decision Support Process Flow Path
Alternatives Analysis for the Rio Grande Salinity Management Program

ID		A	B	C	D	E
	Criteria	Source Salinity Contribution	Potential Economic Benefit	Management Alternative Operational Complexity	Environmental Effects	Availability of Infrastructure
A	Source Salinity Contribution					
B	Potential Economic Benefit					
C	Management Alternative Operational Complexity					
D	Environmental Effects					
E	Availability of Infrastructure					

Coalition members ranked the relative importance of a criterion in each row with the criterion in each column.

FIGURE 1-3
Example Criteria Weighting Form
Alternatives Analysis for the Rio Grande Salinity Management Program

SECTION 2

Management Alternatives

2.1 Introduction

This section describes the development and screening of alternatives for the management of salinity at specific areas along the Rio Grande previously identified by the Coalition. Through this evaluation, the candidate list of six locations, plus the river, is reduced to the locations deemed most suitable for implementation of pilot projects designed to demonstrate the feasibility and benefits of salinity reduction in the river. General descriptions of each management alternative are provided, followed by detailed analyses of the conceptual performance of each alternative for each site and a summary of anticipated benefits.

2.1.1 Definition

A management alternative is defined as an application of a technology for the purpose of reducing an identified contribution of salinity at specific locations along the Rio Grande.

2.1.2 Purpose and Outline

This section provides conceptual descriptions of the hydrogeologic and geochemical characteristics of each site, and potential salinity reduction benefits, costs, and constraints for each management alternative. By comparing these attributes, a relative ranking of the sites is made for the purpose of evaluating site suitability for future projects.

This section also describes the management alternatives and provides a summary of the sites and their respective salinity loads, the attributes and costs associated with each alternative, and a preliminary ranking of site by attribute and cost.

2.1.3 Model Overview

The salinity model developed by the ISC was used as a basis for salinity modeling described in this report. The ISC model simulates chloride concentrations in the Rio Grande from San Marcial, New Mexico, to El Paso, Texas (Courchesne Bridge). Chloride was used because it behaves "conservatively," that is, it does not react with other constituents in groundwater or surface water.

Of the six management alternative sites under evaluation, one is upstream of the ISC model domain (San Acacia), three are within the model domain (Truth or Consequences, Eastern Mesilla Basin, Distal Mesilla Basin), and two are downstream of the model domain (El Paso WWTPs, Fabens). Additionally, in the context of evaluating economic benefits, the ISC model domain does not include all locations where economic benefits would be attained. Accordingly, CH2M HILL developed extensions of the salinity model both upstream and downstream of the existing ISC model. Detailed descriptions of the model segments (upstream extension, ISC model, and downstream extension) are included in Appendix B.

Economic benefits were calculated based on the Phase 1 economic model report (Michelsen et al., 2009a) and the associated addendum (Michelsen et al., 2009b). The main report presents reduction in damages in response to a hypothetical decrease in salinity. The addendum presents benefits associated with improvements to water quality, such as change in cropping patterns to less salt-tolerant (and higher yield) crops. Economic benefit used for the site selection criteria were calculated based on the sum of reduction of damages (main body) and economic benefits (addendum).

Section 3.2 of Appendix B includes a summary of methodology used to calculate both reduction in damages and economic benefits attributable to modeled salinity reductions.

2.2 Overview of Management Alternatives

The substances that contribute to the elevated salinity in the Rio Grande are geochemically conservative (that is, with low reactivity) and occur in excess of the requirements of biological systems. As a consequence, management approaches must be based primarily upon physical and chemical methods of removal. The salinity management alternatives considered are summarized in Table 2-1 and described in more detail in the following subsections. The treatment or disposal options are referred to as "management alternatives" in this report.

TABLE 2-1
Salinity Management Alternatives Considered
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Description	Technology	Selected for Analysis	Basis
1. Interception, Treatment with Reverse Osmosis, and Release to River	Withdraw from surface drain or groundwater and treat. Return permeate to river.	Reverse osmosis Concentrate disposal by evaporation pond or deep well injection	Yes	Standard technology application Removes salt Returns water to river
2. Interception, Treatment with Electrodialysis, and Release to River	Withdraw from surface drain or groundwater and treat. Return permeate from the river.	Electrodialysis Concentrate disposal by evaporation pond or deep well injection	Yes	Standard technology application Removes salt Returns water to river
3. Interception and Disposal	Withdraw from surface drain or groundwater and treated. Remove permanently from the river.	Evaporation and/or natural treatment systems Deep well injection	Yes	Standard technology application Removes salt
4. Dilution	Reduce source of river salinity by dilution with waters with less salinity.	Seasonal storage Capture agricultural drain water, treat, store and return to river when salinity is greater	No	Requires high sustained volume of low salinity water

2.2.1 Management Alternative 1: Interception, Treatment with Reverse Osmosis, and Release to River

Management Alternative 1 involves the interception of the saline sources, followed by treatment by a reverse osmosis (RO) membrane-based salt separation process, and return of desalinized permeate to the river. The interception process could include a diversion or pumped withdrawal from a surface drain, or installation of well(s) to extract the saline flow before entering the river. The desalting process would yield two streams of water: a relatively fresh permeate with a 85 to 90 percent reduction in salinity and a brine concentrate approximately six times more salty than the feedwater. For this concept, the treated permeate would be returned to the river with a 10 to 15 percent reduction in flow, and the concentrate would be disposed of separately. Figure 2-1 illustrates the key concept.

RO is a filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution to a selective membrane. The result is that the constituents larger than the membrane pores are retained on the pressurized side of the membrane and relatively pure water is allowed to pass to the other side.

RO membranes selectively limit the passage of large molecules or ions through the pores, but do allow smaller components of the solution (such as the water molecules) to pass freely. RO uses thin, semi-permeable membranes to separate saline water into low salinity product water (permeate) and a high salinity concentrate stream. Typical RO rejection rates for hardness, chloride, disinfection byproducts and precursors, total organic carbon, and color are at least 90 percent. RO treatment systems are generally configured to include modular racks of mounted cartridges designed for periodic replacement (Figure 2-2).

In addition to the membrane treatment components, pre-treatment of the raw water is required to remove sediments and particles that contribute to membrane fouling. Periodic maintenance is required to manage the potential for scaling or precipitation of super-saturated salts on the membrane surface to maintain membrane permeability.

A local and pertinent example of this technology within the study area is the largest inland RO treatment plant in the United States, operated by the City of El Paso (Hutchison, 2008). With a capacity of 27.5 million gallons per day (mgd), the plant treats brackish groundwater pumped from 32 wells in the Hueco Bolson to potable quality.

2.2.2 Management Alternative 2: Interception, Treatment with Electrodialysis, and Release to River

Similar to Management Alternative 1, Management Alternative 2 involves the interception of the saline sources, followed by treatment by a membrane-based salt separation process, and return of desalinized permeate to the river.

Management Alternative 2 would utilize electrodialysis (ED) treatment to separate the feedwater into a relatively fresh dilute and a brine concentrate. ED is a membrane treatment technology using electrical current to remove ions from solution and control membrane fouling using polarity reversal (Figure 2-3). The process produces an ion-reduced finished water and a brine concentrate, but with no net increase in overall ion content. ED technology is becoming economically competitive with current more widely applied technologies such as RO. Compared to RO, ED can achieve substantially higher brine

concentration. Through the use of membranes that selectively transport monovalent cations or anions, the ED concentrate can have reduced levels of calcium and sulfate, which would precipitate if they were to be transported into the concentrate at the same rates as monovalent ions. With the high brine concentrations achievable by ED, the acreage of evaporation ponds can be reduced substantially.

Compared to RO, ED technology has lower pressure requirements, lower fouling potential, and longer membrane life. However, ED has a generally lower product quality. ED membranes can be fouled by surfactants (primarily soaps and detergents) in feed water such as secondary sewage effluent. Fouling can be alleviated by periodic reversal of current, which is employed in the electrodialysis reversal (EDR) process. Current reversal causes a dilution of salts in the concentrate, so the high concentrations achievable with straight ED are more difficult with EDR.

2.2.3 Management Alternative 3: Interception and Disposal

Management Alternative 3 involves intercepting the high concentration salinity flow, as for the other alternatives, followed by disposal via an evaporation system, without membrane treatment (Figure 2-4). This management alternative would be capturing and treating a highly saline flow (greater than 10,000 TDS), which would not be potable water. By removing the salt, this process would be intended to ultimately increase potable or irrigable water supply.

2.2.4 Management Alternative 4: Dilution

The dilution alternative requires dilution of the saline sources with a relatively fresher water source to achieve lower salinities. This alternative was removed from consideration as impractical for the proposed sites because a dilution source of sufficient magnitude and seasonality is not available.

2.3 Concentrate Disposal Alternatives

Once the saline flow is separated from the river the concentrate generated by the management alternatives will require disposal. Table 2-2 provides a summary of the various alternatives considered for concentrate disposal. The two disposal systems selected for further analysis include evaporation ponds and related natural treatment systems, and deep injection wells, which are discussed in more detail below.

TABLE 2-2
Concentrate Disposal Alternatives
Alternatives Analysis for the Rio Grande Salinity Management Program

Category	Description	Technology	Selected for Analysis	Basis
Evaporation	Reduce concentrate volume through evaporation	Evaporation ponds	Yes	Accepted technology; regional examples
		Land application	No	Limited by vegetation tolerance and salt accumulation in soil
		Natural treatment system	Yes	Developing technology; regional examples; multiple benefits
Well injection	Disposal via injection to deep mineralized aquifers	Deep well injection	Yes	Accepted technology where geologically feasible; regional examples
Transportation	Physical transport of concentrate to existing disposal methods	Discharge to WWTP collection system, direct discharge to surface water	No	WWTP systems discharge to river therefore inappropriate Possible disposal to regional deep well
Zero discharge	Successive separation and thermal evaporation	Brine concentrators and crystallizers	No	Not practical for small flows;
Volume reduction	Successive separation and thermal evaporation	Proprietary: VSEP, HERO, Dew vaporation, sal proc	No	Limited known large-scale applications. Not practical for small flows.

Evaporation/Natural Treatment Systems

Evaporation ponds are lined, open water bodies constructed to utilize solar energy to evaporate water leaving behind precipitated salts (Figure 2-5). Accumulated salts are ultimately landfilled. Evaporation ponds are most feasible for concentrate disposal in arid climates with high evaporation rates, such as Texas and New Mexico, which can minimize the pond area required. Multiple ponds can be constructed to allow continual receipt of membrane concentrate while some ponds are taken offline for periodic maintenance. Periodic maintenance includes allowing the evaporation pond to set idle to firm the consistency of the residual salts. Once the salts have reached a satisfactory consistency, the ponds are cleaned by removing and transporting the precipitated salts to a landfill for ultimate disposal.

Evaporation ponds work well for small quantities of concentrate in areas with available land. For this analysis, evaporation ponds are suggested as an appropriate system for disposal of concentrate as well as separated saline source waters.

Recent pilot projects have demonstrated the feasibility of using constructed marshes planted with brackish marsh species to treat and evaporate concentrate from membrane systems (WRF, 2006). The presence of vegetation increases the rate of water loss through natural evapotranspiration, which can exceed the rate of evaporation (Bays et al., 2007). Membrane concentrate or saline sources separated from the river by one of the management

alternatives could be used as a water source for wetlands as a final or intermediate water volume reduction process before final disposal in an evaporation pond.

Deep Injection Well

Deep well injection uses injection wells to place treated or untreated liquid waste into geologic formations that have no potential to allow migration of contaminants into potential potable water aquifers. A typical injection well consists of concentric pipes, which extend several thousand feet down from the surface level into highly saline, permeable injection zones that are confined vertically by impermeable strata (Figure 2-6). The outermost pipe or surface casing extends below the base of any underground sources of drinking water and is cemented back to the surface to prevent contamination of drinking water aquifers.

Three deep injection wells are used by the City of El Paso to dispose of 3 mgd of membrane concentrate generated by the Kay Bailey Hutchinson Desalination Plant. An alternatives analysis found deep well injection to be economically favorable compared to evaporation ponds or enhanced evaporation systems (Hutchison, 2008). Detailed hydrogeologic studies and regulatory reviews required for this disposal process make this approach more useful for larger flows, where geologically feasible.

2.4 Reduction in Groundwater Flux

The treatment alternatives described in this report would contribute to salinity reduction in the Rio Grande by reducing groundwater flux (rate of flow) reaching the river. For the San Acacia, Eastern Mesilla Basin, Distal Mesilla Basin, and Fabens sites where groundwater pumping would be used to manage salinity, the groundwater pumping could further reduce the volume of saline flow reaching the Rio Grande in addition to that extracted directly by reducing the hydraulic head of the upwelling.

The extent of the flow reduction would depend on the hydrogeologic characteristics of each groundwater system at each site. Site-specific groundwater modeling would be necessary to estimate the reduced flow to the Rio Grande and any associated benefits.

However, source contributions provided in this report are estimates, and broad assumptions are attached to the extraction percentage estimate. These limitations argue against developing a quantitative estimate of the hypothesized benefit of reduction in groundwater flux.

Other aspects warrant considering this benefit qualitatively. For example, from a mass balance perspective, there are only three discharge pathways for saline groundwater sources: capture wells, discharge to river, or ET. The ET should not increase with the decrease in hydraulic heads. Because the decreased rate of groundwater discharge to the river should be accounted for solely by the “increase” (from zero currently) in capture well pumping rate, the fate of the additional salt would require explanation. Accumulating in storage is unlikely given that the relatively shallow extraction wells would remove water from storage, and also theoretically increase the upward gradient from the brine source. Also, the placement of the well could influence hydraulic head reduction. Too close to the river and river flow might be induced into the capture zone instead of a completely

groundwater source; too far, and there might not be any direct and measureable benefit to the river at all. Possible extraction solutions will need to balance these factors.

For the purpose of this analysis, the contribution of this benefit to salinity source reduction will be addressed qualitatively for the groundwater interception alternatives.

2.5 Projected Flows and Loads by Site

The salinity sources, flux, and physical settings vary significantly among the studied sites. The approach used to estimating treatable flows and loads at each used the following steps:

1. Review available pertinent literature on the sources at each location. Key references and understanding were derived from Moyer et al. (2009), Hawley and Kennedy (2004), and Hogan (2010).
2. Estimate the source contribution and volume that could be captured. This estimate was developed through consultation among project subject matter experts James Hogan, Fred Phillips, and John Hawley. This is calculated using (1) the estimated concentration of the source, which may be based on groundwater values, effluent values, or the river concentration depending on the site; (2) the volume of the salinity flux, which may be based on estimates from geochemical mixing models, effluent discharge volume, or stream gage data; and (3) the percentage of the flux that can be captured for treatment. The amount of information for each of these factors varies by site (given the amount of existing information) and the nature of the source (for example, WWTP effluent vs. diffuse saline groundwater discharge). As such, the uncertainty of these estimates will also vary; this is summarized below and discussed in more detail in Hogan (2010).
3. Estimate the amount of chloride to be removed by the management alternative. Based on professional experience in the design and operation of membrane treatment technologies, it was assumed that RO would reject 15 percent of the incoming flow and 90 percent of the chloride, and ED would reject 20 percent of incoming flow and 80 percent of the chloride. Treatment system permeates were assumed to return to the river. Alternatively, flows diverted completely from the river were assumed to equal a 100 percent reduction in load for the volume captured.

For all alternative sites, with the exception of the River alternative, the water would be extracted and treated continuously throughout the year. For the River alternative, water capture and treatment would be performed seasonally during the non-irrigation season. A brief description of the hydrogeology, salinity source, concentration, and load of the captured and treated streams for each of the evaluated areas is further discussed in the following sections.

2.5.1 San Acacia

Site Description

San Acacia is located along the Rio Grande at the southern end of the Albuquerque Basin, an alluvial fill aquifer in Central New Mexico. Groundwater in the Albuquerque Basin generally flows from north to south. The southern end of the Albuquerque Basin, near San Acacia, is defined by a convergence of the east and west bedrock basin boundaries, resulting

in the alluvial basin being shallower and narrower than areas to the north, and is referred to in Plummer et al. (2004) as the "San Acacia constriction." With the decrease in cross-sectional area, groundwater is assumed to "upwell" in this area, and groundwater discharge to the Rio Grande is assumed to be more pronounced (Moyer et al., 2009).

Hydrogeologic Understanding and Salinity Source Type

The salinity source appears to be a significant but relatively localized flux. This area has been recognized as a discharge zone for saline groundwater originating from depth within the basin (Plummer et al., 2004; Sanford et al., 2004). The source concentration is a mixture of a true deep brine source and more dilute groundwater from shallow flow paths (Williams, 2009). The salinity source is a relatively localized input of saline groundwater upwelling from deep sources of significant flux. Based on technical review and input from the project subject matter experts, the flow is less diffuse compared to Eastern Mesilla geothermal flow, and more diffuse than Distal Mesilla flow. Surface observations of saline pools have been made in the area near San Acacia; however, groundwater chemistry indicates that the discharge zone may extend northward toward La Joya/Bernardo (Plummer et al., 2004) and southward into the Socorro Basin to Polvadera (Anderholm, 1987).

Source Salinity Concentration

There are no known salinity data for groundwater at San Acacia. Nearby data from the southern end of the Albuquerque Basin indicate values up to 700 mg/L chloride and 2,000 mg/L TDS (Plummer et al., 2004). It is likely, given the shallow nature of these groundwater wells, that these values represent a mixture of the true deep brine source and more dilute groundwater from shallow flowpaths. Moyer et al. (2009) cite chloride concentrations up to 4,024 mg/L in the northern portion of the Socorro Basin portion near this site, which are likely from upward-flowing groundwater brines derived from the distal end of the Albuquerque Basin. Accordingly, the average of these two sources (2,400 mg/L chloride) is assumed, but it is recognized that there is significant uncertainty in the potential concentration that may be realized at the site.

Relative Load Contribution to Total Salinity Load

Based on the mass balance modeling of Mills (2003) and an isotopic mixing model (Hogan et al., 2007), this site appears to contribute up to 10 percent of the chloride load observed at El Paso (approximately 6,500 tons/year). Mills (2003) estimated a brine input of 54 to 780 tons of chloride per month (648 to 9,360 tons chloride/year) whereas Lacey's model (Lacey, 2006) estimated 112 to 202 tons of chloride per month (1,344 to 2,424 tons chloride/year). For planning purposes, the total saline inflow to Rio Grande was estimated to be about 750 gallons per minute (gpm) (1.7 cubic feet per second [cfs]), with chloride concentration of 2,400 mg/L, resulting in mass flux of about 4,000 tons of chloride per year or 6.2 percent of the annual chloride load at El Paso (Hogan, 2010).

Capture Assumption

Based on professional judgment of this diffuse flow system, wells can be installed to capture about 20 percent of total inflow to Rio Grande (150 gpm).

Flow and Load Projections

Table 2-3 summarizes the performance data for the management alternatives at San Acacia. Treatment by RO, ED, or diversion to evaporation ponds would remove 92, 84, and 100 percent of the captured salt load, respectively, for a 17, 18, and 20 percent reduction in total annual salt loads.

TABLE 2-3
Estimated Captured and Return Flow and Chloride Load at San Acacia
Alternatives Analysis for the Rio Grande Salinity Management Program

Estimate	Flow (gpm)	Chloride (mg/L)	Chloride Load (tons/year)
Source Contribution	750	2,400	4,000
Capture **(20 percent)**	150	2,400	800
Alternatives 1 and 2: Interception, Treatment, and Release to River			
Post-RO	129	240	68
Post-ERD	122	480	128
Alternative 3: Interception and Disposal	152	2,400	800

2.5.2 Truth or Consequences

Site Description

Truth or Consequences is located along the Rio Grande just south of Elephant Butte Reservoir in east-central New Mexico. Cox and Reeder (1962) characterized groundwater occurrence in the area under three general conditions:

> "1) as thermal water in the Magdalena Group of Pennsylvanian and Permian age and overlying alluvium of Quaternary age, 2) as nonthermal artesian water in the Santa Fe group of middle (?) (sic) Miocene to Pleistocene (?) (sic) age and alluvium of Quaternary age, and 3) as unconfined ground water in alluvium of Quaternary age under the flood plain of the Rio Grande."

Thermal waters are characterized by high salinity. The thermal waters discharge to the Rio Grande through the alluvium and at least one drainage ditch (also known as the "hot ditch") (Cox and Reeder, 1962). Accordingly, these thermal waters were identified previously by the Coalition as a source of water to be evaluated further during this current work effort.

Hydrogeologic Understanding and Salinity Source Type

This site is a localized geothermal upwelling between Truth or Consequences and Williamsburg (Hogan, 2010). According to Cox and Reeder (1962), "*the source of thermal water is inferred to be steam and hot gases rising from a deep-seated igneous intrusive body mixing with circulating ground water of meteoric origin*." Although there are additional geothermal inflows to the Rio Grande in the area, for the purposes of this evaluation the source was defined as the "hot ditch," which has quantified flows and concentrations, and could be captured and treated practically.

Source Salinity Concentration

Cox and Reeder (1962) and Moyer et al. (2009) reported values for these geothermal waters as 1,300 mg/L chloride and a specific conductivity of 4,450 micro Siemens per centimeter (µS/cm), which is approximately 2,600 mg/L TDS. Recent data (per D.B. Stephens as cited in Hogan, 2010), suggest a flow of less than 225 gpm [0.5 cfs] to 500 gpm [1.1 cfs] and salinity characteristics including 4,300 µS/cm specific conductivity, 2,600 mg/L TDS, and 1,400 mg/L chloride. Increases in chloride concentrations are observed for the Rio Grande in this area during winter when no reservoir releases occur.

Relative Load Contribution to Total Salinity Load

Surface flows through man-made channels (ditches) were estimated to be as much as 500 gpm with chloride concentration of about 1,400 mg/L, resulting in mass flux of as much as 1,500 tons of chloride per year. However, total hydrothermal inflow, according to ISC models (see Attachment 1 of Appendix B) was estimated to be about 2,600 gpm (including smaller surface and subsurface flows), with a mass flux of nearly 8,000 tons of chloride per year. The difference between these two estimates (1,500 tons per year and 8,000 tons per year) is likely an additional diffuse geothermal discharge along this reach that may increase the overall load from this location/source. For planning purposes, the source was defined as the surface ditch only, with flow of as much as 500 gpm, chloride concentration of 1,400 mg/L, and saline load of 1,400 tons of chloride per year (2.3% of annual chloride load at El Paso). It should also be noted that, while this maximum estimate of 1,500 tons per year was used for the analysis, assumption of half of this mass flux was assessed during sensitivity analysis (see Section 3). Similarly, an assumption of double the load, which would include some of the other diffuse flows, was also assessed during sensitivity analysis.

Capture Assumption

Because the source, at least for the “hot ditch” component, is readily accessible, it was assumed for the purpose of this project that 100 percent of water from primary existing ditches (as much as 500 gpm) could be diverted.

Flow and Load Projections

Table 2-4 summarizes the performance data for the management alternatives at Truth or Consequences. Treatment by RO, ED, or diversion to evaporation ponds would remove 91, 84, and 100 percent of the captured salt load, respectively, for a 91, 84, and 100 percent reduction in total annual salt loads.

TABLE 2-4
Estimated Captured and Return Flow and Chloride Load at Truth or Consequences
Alternatives Analysis for the Rio Grande Salinity Management Program

Estimate	Flow (gpm)	Chloride (mg/L)	Chloride Load (tons/year)
Source Contribution	500	1,400	1,500
Capture **(100 percent)**	500	1,400	1,500
Alternatives 1 and 2: Interception, Treatment, and Release to River			
Post-RO	415	140	128
Post-ERD	391	280	240
Alternative 3: Interception and Disposal	500	1,400	1,500

2.5.3 Eastern Mesilla Basin

Site Description

The Mesilla Basin runs from several miles north of Las Cruces, New Mexico, to El Paso, Texas, and the Mexican border. The hydrogeology of the basin has been well characterized (see, for example, Hawley and Kennedy, 2004). Groundwater generally flows from north to south, and toward the Rio Grande. A relatively extensive geothermal zone (the Las Cruces East Mesa Geothermal System), characterized by hot, saline waters, exists along the eastern portion of the Mesilla Basin, and extends from the southern end of the Doña Ana Mountains to the Texas border near Anthony, Texas (Witcher et al., 2004). This geothermal zone has several "probably upflow zones," although there is no documented connection to the surface flow system (Hogan, 2010). The "Eastern Mesilla" site consists of one of these upflow zones, the Tortugas Mountain area, located approximately 7 miles east of the Rio Grande. The Tortugas Mountain area is one of the better characterized portions of the geothermal zone, and "probably represents one of the larger heat and mass geothermal discharges," (Witcher, et al., 2004) and accordingly has a relatively large component of saline flow.

Hydrogeologic Understanding and Salinity Source Type

The salinity source is diffuse groundwater flow. The hydraulic connectivity to the Rio Grande is not well understood. Witcher et al. (2004) identified a geothermal zone in the eastern Mesilla Basin. This upwelling is fault controlled and occurs over a wide area. While these discharges are observed in the groundwater system, there is no documented connection to the surface water system. There is potential for these waters to contribute to the salinity in the Rio Grande, however, concentrations and loads have not been observed to increase in the river near this source. It is possible that these waters may contribute to the saline discharge observed at the distal end of the Mesilla Basin (Hogan, 2010).

Salinity Source Concentration

Witcher et al. (2004) reported chloride values ranging from 485 to 578 mg/L. Witcher et al. (2004) suggest this is at least 760 gpm with a chloride concentration of 500 mg/L.

Relative Contribution to Total Salinity Load

Witcher et al. (2004), using thermal modeling, calculated a geothermal chloride flux into the groundwater aquifer of 834 tons/year for a portion of the geothermal zone. Assuming the quantified flux is the total and that all of this reaches the Rio Grande, the Eastern Mesilla source would equate to 1.3 percent of the chloride load at El Paso (Hogan, 2010). Uncertainty associated with the estimate of chloride load and the connection to the Rio Grande is assessed in the sensitivity analysis (see Section 3).

Capture Assumption

Based on professional judgment of this diffuse flow system, for planning purposes, it was assumed that the wells could be installed to capture 10 percent of the total mass flux to Rio Grande (about 80 tons/year chloride).

Flow and Load Projections

Table 2-5 summarizes the performance data for the management alternatives at the Eastern Mesilla site. Treatment by RO, ED, or diversion to evaporation ponds would remove 91, 84, and 100 percent of the captured salt load, respectively, for an 8.8, 8.0, and 10 percent reduction in total annual salt loads.

TABLE 2-5
Estimated Captured and Return Flow and Chloride Load at Eastern Mesilla
Alternatives Analysis for the Rio Grande Salinity Management Program

Estimate	Flow (gpm)	Chloride (mg/L)	Chloride Load (tons/year)
Source Contribution	760	500	834
Capture **(10 percent)**	76	500	80
Alternatives 1 and 2: Interception, Treatment, and Release to River			
Post-RO	65	50	7
Post-ERD	61	100	13
Alternative 3: Interception and Disposal	76	500	80

2.5.4 Distal Mesilla Basin

Site Description

The Mesilla Basin extends from several miles north of Las Cruces, New Mexico, to El Paso, Texas. The basin has been well characterized (e.g., Hawley and Kennedy, 2004). Groundwater generally flows from north to south toward the Rio Grande. The southern/distal end of the Mesilla Basin at the north end of El Paso is defined by a convergence of the east and west bedrock basin boundaries (Franklin Mountains and Sierra Juarez-Cerro de Cristo Rey uplift). The Rio Grande flows through an erosional/structural gap between these highlands, called "El Paso del Norte" or "El Paso Narrows" (Hawley, 2010). This bedrock constriction is recognized to be an effective barrier to underflow discharge of groundwater from the Mesilla Basin to the Hueco Bolson aquifer to the south (Hawley, 2010). Accordingly, deep groundwater brines are forced up to the surface in this location and discharge to the Rio

Grande (Moyer et al., 2009). The "Distal Mesilla" site is defined as this relatively localized upwelling of saline waters just north of the El Paso Narrows.

Hydrogeologic Understanding and Salinity Source Type

The source is diffuse groundwater flow. The flow is the least diffuse of the three groundwater sites due to the bedrock constriction at El Paso Narrows. This site has been well studied and characterized. Similar to the San Acacia site, the Distal Mesilla Basin site is believed to be relatively significant but a localized discharge of saline groundwater upwelling from deep sources within the Mesilla Basin.

Salinity Source Concentration

Generally, groundwater salinity increases toward the El Paso Narrows with maximum observed chloride values of 14,500 mg/L and TDS of 31,000 mg/L. However, it is assumed that the concentration of waters that could be practically captured would be lower than these observed concentrations. For the purposes of this evaluation, average concentration of saline waters that could be captured was assumed to be 2,400 mg/L, which is based on the ISC salinity model (see Attachment 1 of Appendix B).

Relative Contribution to Total Salinity Load

Based on the mass balance modeling of Mills (2003) and an isotopic mixing model (Hogan et al., 2007), this site appears to contribute 10 to 15 percent of the chloride load observed at El Paso (6,500 to 9,750 tons of chloride per year). Mills (2003) estimated a brine input of 540 to 900 tons of chloride per month (6,480 to 10,800 tons of chloride per year) whereas Lacey (2006) estimated 163 to 819 tons of chloride per month (1,956 to 8,828 tons of chloride per year). For planning purposes based on the estimates above, a recommended value of 7,500 tons of chloride per year or 11.5 percent of the annual chloride load at El Paso was used (Hogan, 2010) as the source salinity assumption.

Capture Assumption

Based on professional judgment of this diffuse flow system, it was assumed that wells could be installed to capture about 30 percent of flow to the Rio Grande. For purposes of salinity and economic benefit modeling, the 30 percent capture assumption was applied to the 7,800 tons per year mass flux simulated in the ISC salinity model (1,500 gpm with 2,400 mg/L concentration).

Flow and Load Projections

Table 2-6 summarizes the performance data for the management alternatives at the Distal Mesilla site. Treatment by RO, ED, or diversion to evaporation ponds would remove 91, 84, and 100 percent of the captured salt load, respectively, for a 29.1, 26.7, and 31.8 percent reduction in total annual salt loads.

TABLE 2-6
Estimated Captured and Return Flow and Chloride Load at Distal Mesilla
Alternatives Analysis for the Rio Grande Salinity Management Program

Estimate	Flow (gpm)	Chloride (mg/L)	Chloride Load (tons/year)
Source Contribution	1,500	2,400	7,500
Capture **(30 percent)**	452	2,400	2,383
Alternatives 1 and 2: Interception, Treatment, and Release to River			
Post-RO	385	240	203
Post-ERD	362	480	381
Alternative 3: Interception and Disposal	452	2,400	2,383

2.5.5 El Paso Wastewater Treatment Plants

Site Description

Three WWTPs owned and operated by EPWU discharge to the Rio Grande or "sidestream" conveyance channels (e.g., American Canal and Riverside Canal):

- **Northwest WWTP**. The Northwest WWTP is the northernmost of the three, and discharges to the Rio Grande between Courchesne Bridge and the American Diversion Dam. Average discharge to the Rio Grande is about 5.8 mgd (4.8 mgd during irrigation season), with chloride concentration about 290 mg/L.
- **Haskell Street WWTP**. The Haskell Street WWTP discharges to the American Canal south of the American Diversion Dam. Average discharge to the American Canal is about 15.4 mgd (16.6 mgd during irrigation season), with chloride concentration about 230 mg/L (220 mg/L during irrigation season).
- **Roberto Bustamante WWTP**. The Bustamante WWTP discharges to the Riverside Canal and Riverside Drain. Average discharge is about 27 mgd, with chloride concentration about 290 mg/L (270 mg/L during irrigation season).

Hydrogeologic Understanding and Salinity Source Type

The source of water to the wastewater treatment plants is municipal water from El Paso. Water supply for El Paso consists of two sources: local groundwater from the Hueco Bolson and diversions from the Rio Grande. Rio Grande water is only used during the irrigation season (roughly March through September), during which time it accounts for about 45 percent of the total water supply. During the non-irrigation season, the municipal water supply is 100 percent local groundwater from the Hueco Bolson.

Salinity Source Concentration

El Paso effluent averages 230 to 290 mg/L of chloride.

Relative Contribution to Total Salinity Load

The annual chloride load from El Paso wastewater treatment plants is 20,800 tons per year (Hogan, 2010). It should be noted that the majority of this load is contributed downstream of El Paso and that, because El Paso takes a significant amount of its water supply from the Rio Grande, this, in part, represents "recycled" salts. In recent years surface water has supplied between 40 and 60 percent of El Paso's water supply (EPWU, 2007). Therefore, using 50 percent surface water as an average current estimate, only 10,400 tons per year should be considered "salt addition" while the other 10,400 tons are "recycled salts."

Thus, while the total salt flux represents 32 percent of the chloride load at El Paso, the new salt addition represents 16 percent of the chloride load at El Paso.

Capture Assumption

Because the salinity source at this site is a contained flow channel, it was assumed that 100 percent of this flow could be diverted for additional treatment.

Flow and Load Projections

Table 2-8 summarizes the performance data for the management alternatives at the WWTP sites. Treatment by RO and ED, or diversion to evaporation ponds would remove 91, 84, and 100 percent of the captured salt load, respectively, for a 91, 84, and 100 percent reduction in total annual salt loads.

TABLE 2-7
Estimated Captured and Return Flow and Chloride Load at El Paso Wastewater Treatment Plants
Alternatives Analysis for the Rio Grande Salinity Management Program

Estimate	Flow (gpm)	Chloride (mg/L)	Chloride Load (tons/year)
Source Contribution	34,416	256	19,336
Capture **(100 percent)**	34,416	256	19,336
Alternatives 1 and 2: Interception, Treatment, and Release to River			
Post-RO	29,254	26	1,664
Post-ERD	27,553	51	3,094
Alternative 3: Interception and Disposal	34,416	256	19,336

2.5.6 Fabens

Site Description

The Fabens site is located in the Hueco Bolson, near Fabens, Texas. Groundwater flow in the Hueco Bolson, north and east of the Rio Grande, is generally from north to south, with the Rio Grande (and local wells, including El Paso municipal wells) serving as the ultimate discharge sink.

Hydrogeologic Understanding and Salinity Source Type

This site has been well characterized by the work of Hibbs and Merino (2007) and Hawley et al. (2009). It is summarized in Hawley (2010), Hogan (2010), and Moyer et al. (2009), which in turn are summarized here. This site consists of upwelling groundwater under artesian conditions. The water is relatively low in chloride and TDS. During upwelling it passes through a sedimentary unit which likely contains evaporite deposits—possibly a paleo-playa deposit associated with the Ft. Hancock formation. This formation was found to be the significant source of salinity within the Hueco Bolson groundwater system (Druhan et al., 2007). These, now saline, groundwaters discharge to drains in the area, and are subsequently transported to the Rio Grande or used for agricultural purposes.

Salinity Source Concentration

Hibbs and Merino (2007) measured concentrations up to 14,650 mg/L chloride and 26,130 mg/L TDS for groundwater at this site.

Relative Contribution to Salinity Load

Based on model calibration (see Appendix B), the estimate of mass flux to the drain was about 7,000 tons per year. In the model this was simulated as flow of about 225 gpm, with a concentration of 14,650 mg/L. Because groundwater is the source of water to the drain, and no water quality data were available for the drain, it was assumed that the drain has the same concentration as observed in groundwater. The isotopic mixing model work of Hogan et al. (2007) suggests the percentage of "brine chloride" load doubles in this region compared to El Paso. That is to say the flux of chloride in this area could potentially be as high as 100 percent of the annual chloride flux at El Paso. The Rio Grande, particularly the vadose zone and shallow aquifer, could be a significant sink for chloride, thus the chloride flux in the Rio Grande at Fabens could be significantly less than observed at El Paso during the time of the geochemical analysis (Hogan, 2010). For the purposes of analysis, the model value of 7,000 tons per year, or 11.2 percent of load at El Paso was used.

Capture Assumption

While there is additional groundwater upwelling at this site, it was assumed that only water from the existing drain could be diverted. For this study, it was assumed that 100 percent of flow in the existing drain could be diverted for treatment.

In addition, an alternate capture method (Fabens Bypass Alternate) is described in Sections 3 and 4 that would include multiple extraction wells distributed over a wide area to capture lower salinity upwelling flow before transit through the evaporitic layer. Capture estimates for this flow are assumed to be the same. Water would be conveyed to existing drains.

Flow and Load Projections

Table 2-8 summarizes the flow, chloride concentration and loads to the river from Fabens captured and returned to the river under the management alternatives.

TABLE 2-8
Estimated Captured and Return Flow and Chloride Load at Rio Grande near Fabens
Alternatives Analysis for the Rio Grande Salinity Management Program

Estimate	Flow (gpm)	Chloride (mg/L)	Chloride Load (tons/year)
Source Contribution	223	14,650	7,171
Capture **(100 percent)**	223	14650	7171
Alternatives 1 and 2: Interception, Treatment, and Release to River			
Post-RO	190	1465	610
Post-ERD	178	2930	1,147
Alternative 3: Interception and Disposal	223	14,650	7,171

2.5.7 Rio Grande near Las Cruces New Mexico Below Mesilla Dam

Site Description

A river location was selected near Las Cruces based on infrastructure availability consistent with the requirements of a large-scale desalination facility (e.g., availability of power, people, and access) and to be upstream of El Paso in order to provide a quantifiable benefit consistent with other location selections. A site location was assumed just south of the Mesilla diversion dam.

Hydrogeologic Understanding and Salinity Source Type

The salinity of the river at this location has been described by Hogan (2010). The management alternatives at this site would treat the river only during the non-irrigation season (November to March), when chloride levels are elevated. Flow in the river at this location during the non-irrigation season is approximately 50 cfs.

Salinity Source Concentration

Chloride concentrations during the irrigation season average approximately 80 mg/L and up to 200 mg/L during the winter (non-irrigation season). Figure 2-7 shows the general trend in chloride concentrations in the river by season, with a highlight on the area in the vicinity of Las Cruces.

Relative Contribution to Salinity Load

Based on output of the project model (described in Appendix B), the contribution of the River at this location to the salinity load at El Paso was assumed to be 70 percent during the non-irrigation season. The contribution to the salinity load over an annual cycle is approximately 30 percent. A target chloride concentration reduction of 60 percent was estimated to be necessary to yield non-irrigation season river concentrations comparable to irrigation season values (Figure 2-7).

Capture Assumption

The volume of water assumed to be captured at this location was estimated to be 70 percent of the river flow, based upon the volume needed to be treated to yield a return flow of sufficient volume to dilute the river to the target concentration (Figure 2-8). River treatment would only be performed during the non-irrigation (winter) season.

Flow and Load Projections

Table 2-9 summarizes the flow, chloride concentration, and loads to the river from the river treatment site captured and returned to the river under the management alternatives.

TABLE 2-9
Estimated Captured and Return Flow and Chloride Load at Rio Grande near Las Cruces, New Mexico
Alternatives Analysis for the Rio Grande Salinity Management Program

Estimate	Flow (gpm)	Chloride (mg/L)	Chloride Load (tons/year)
Source Contribution	22,440	200	7,000
Capture	15,709	200	2,830[a]
Alternatives 1 and 2: Interception, Treatment, and Release to River			
Post-RO	13,353	20	240[a]
Post-ERD	12,567	40	465[a]
Alternative 3: Interception and Disposal[b]	15,709	200	2,830[a]

[a] Non-irrigation season only without the “shoulder months” (mid-October–mid-February)
[b] Using deep injection wells

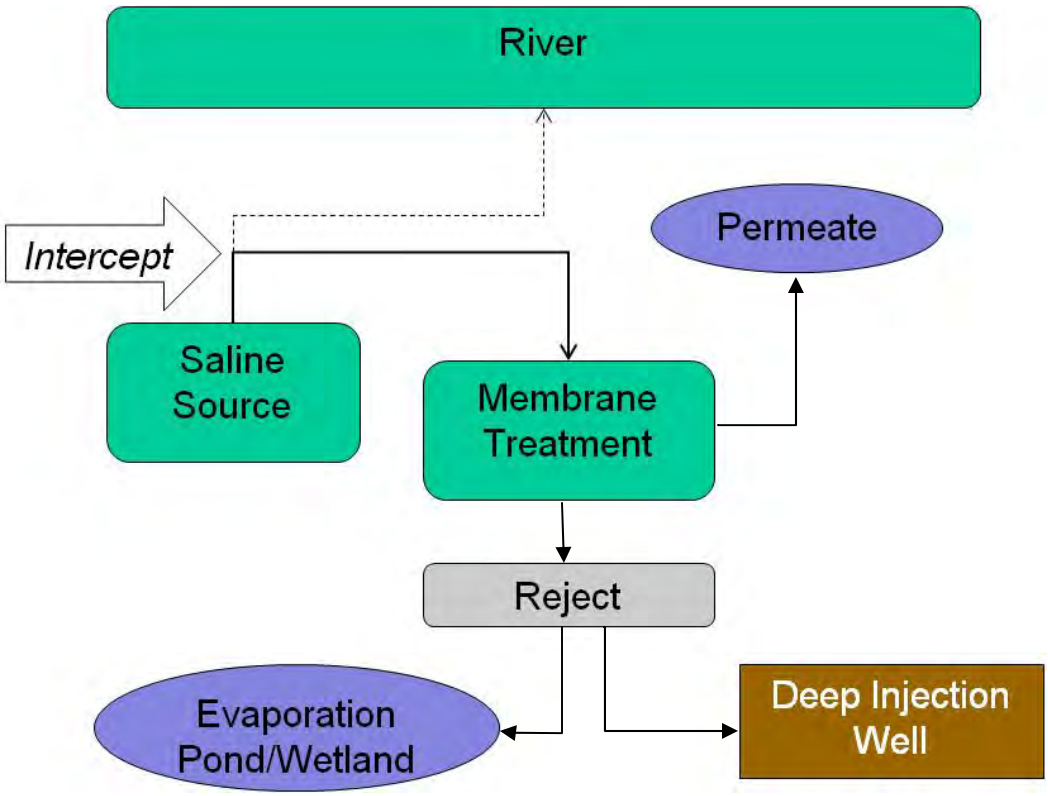


FIGURE 2-1
Management Alternatives 1 and 2: Interception, Treatment (RO or ED), and Disposal
Alternatives Analysis for the Rio Grande Salinity Management Program

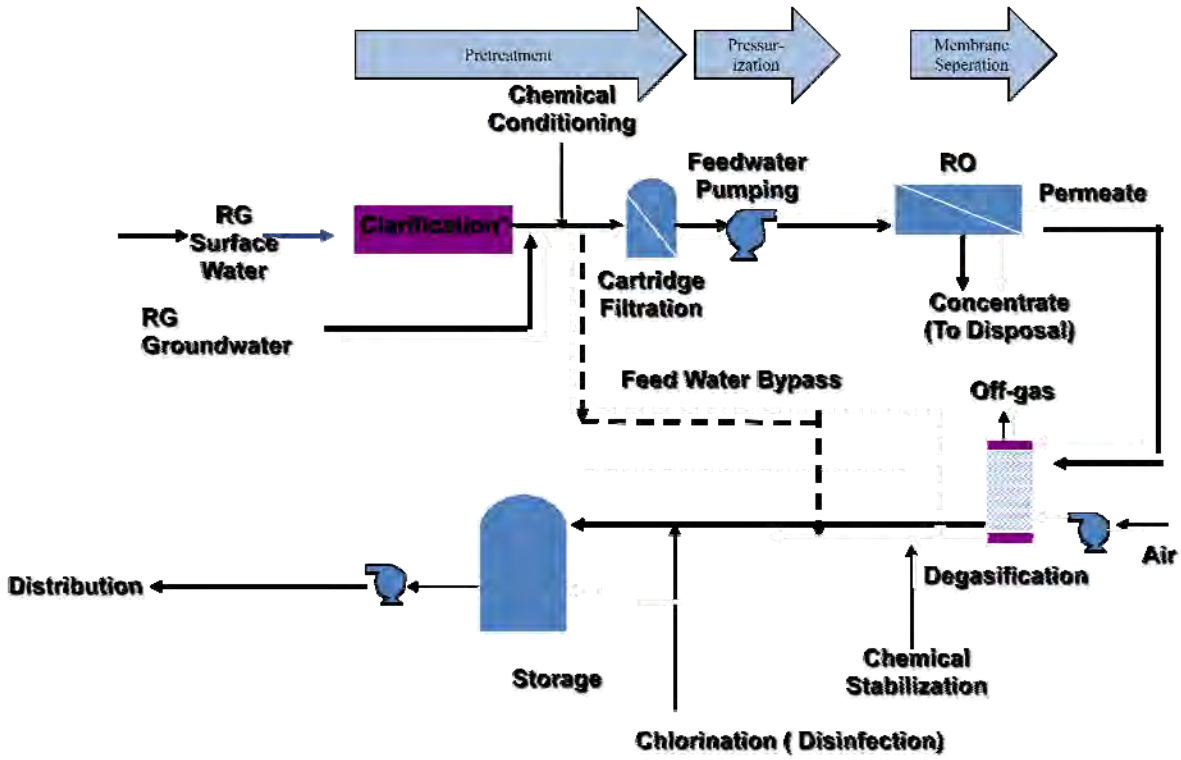


FIGURE 2-2
RO Membrane Treatment System Process Schematic (top) and Typical Cartridge Configuration (bottom)
Alternatives Analysis for the Rio Grande Salinity Management Program

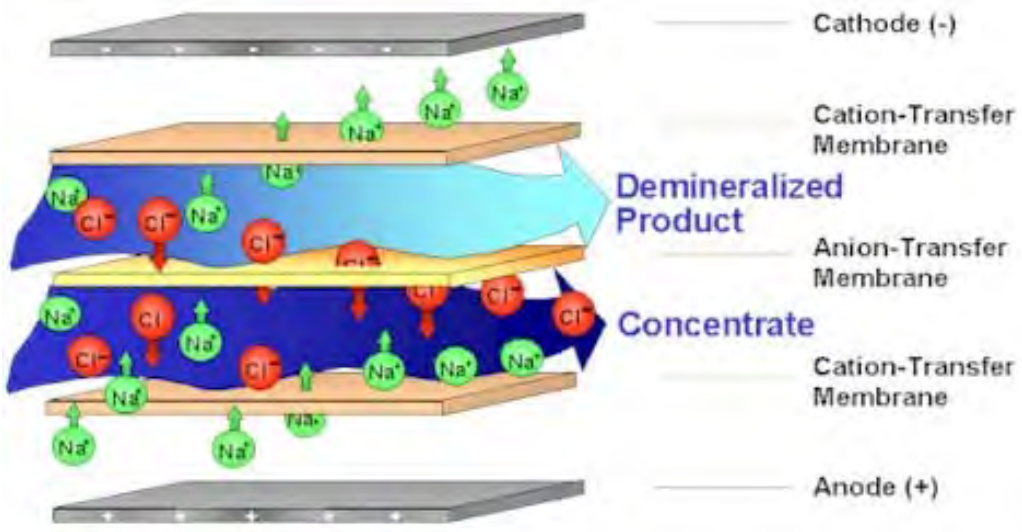


FIGURE 2-3
Electrodialysis Membrane Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

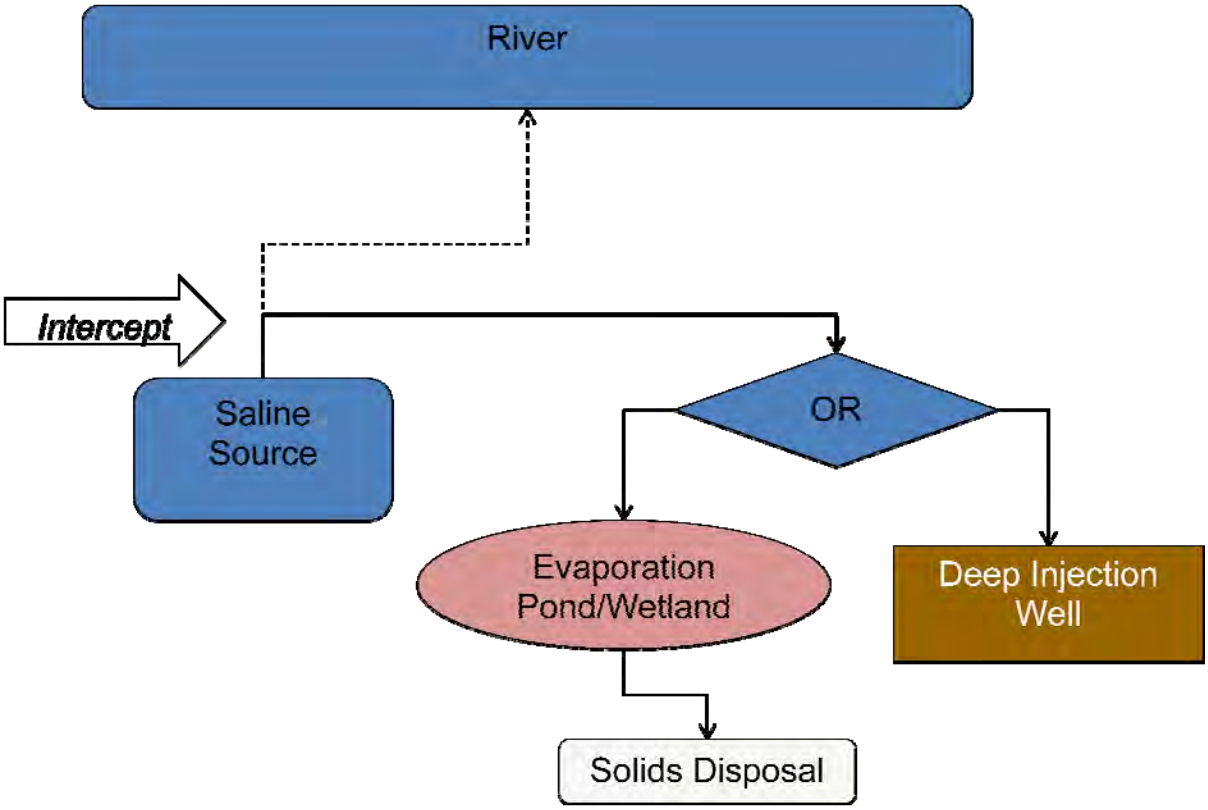


FIGURE 2-4
Management Alternative 3: Interception and Disposal
Alternatives Analysis for the Rio Grande Salinity Management Program

FIGURE 2-5
Evaporation Ponds and Natural Treatment Systems Typical View
Alternatives Analysis for the Rio Grande Salinity Management Program

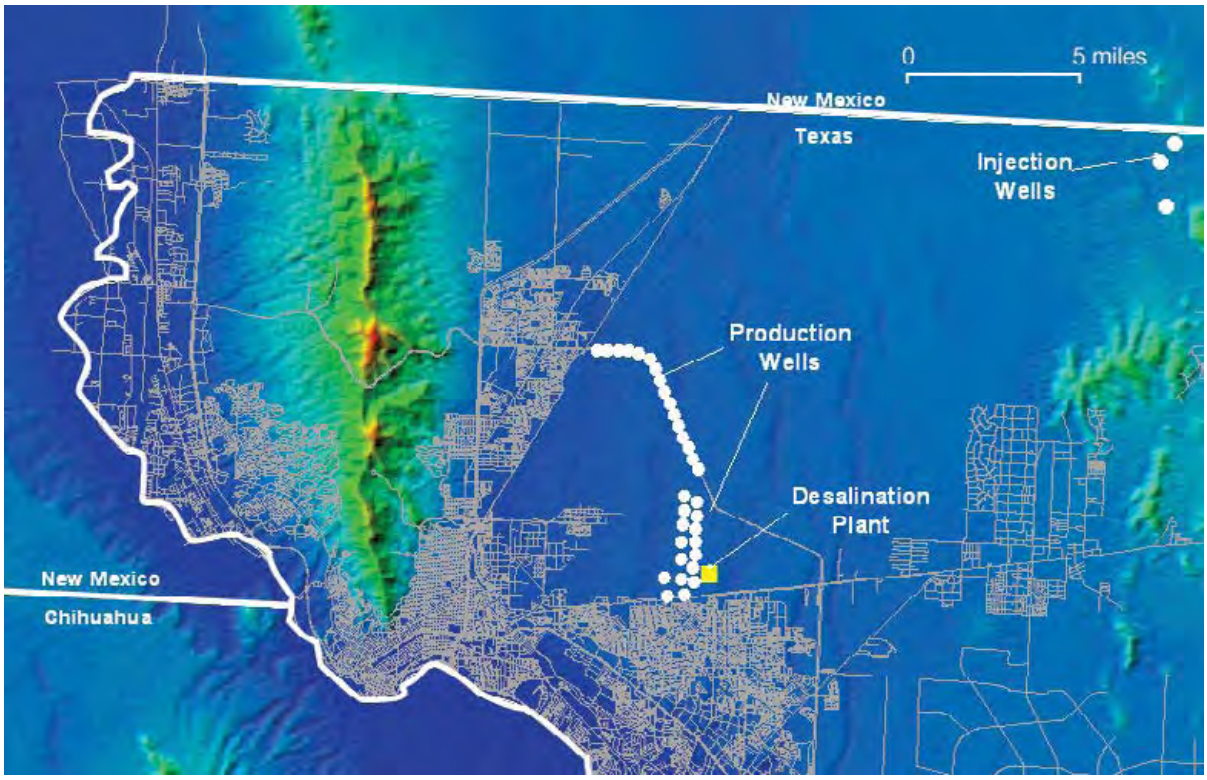


FIGURE 2-6
Deep Injection Well Typical (top) and Location of El Paso Deep Injection Wells (bottom)
Alternatives Analysis for the Rio Grande Salinity Management Program

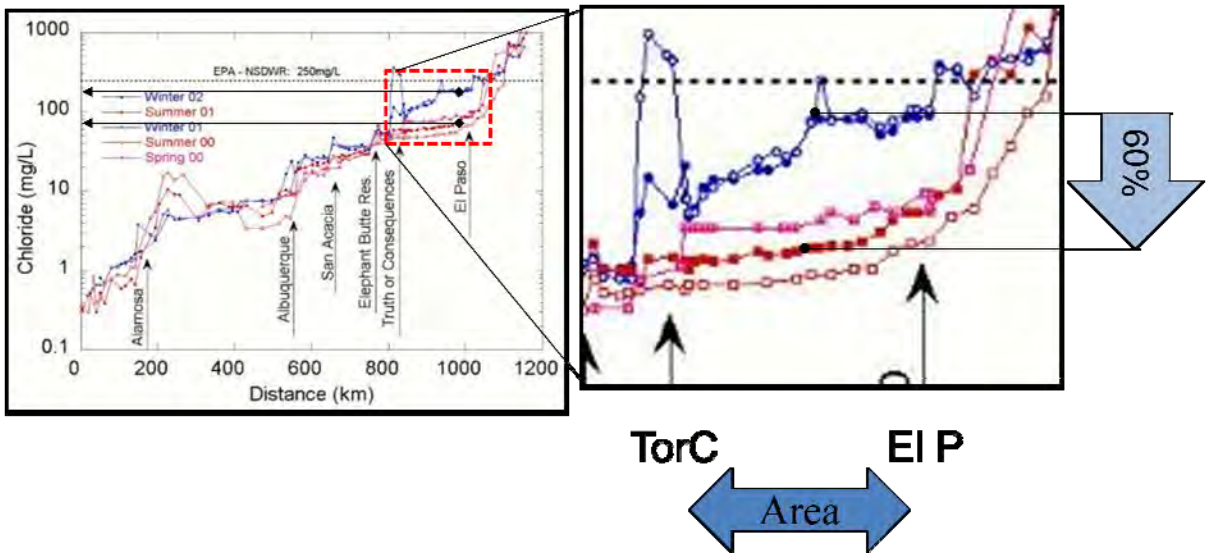
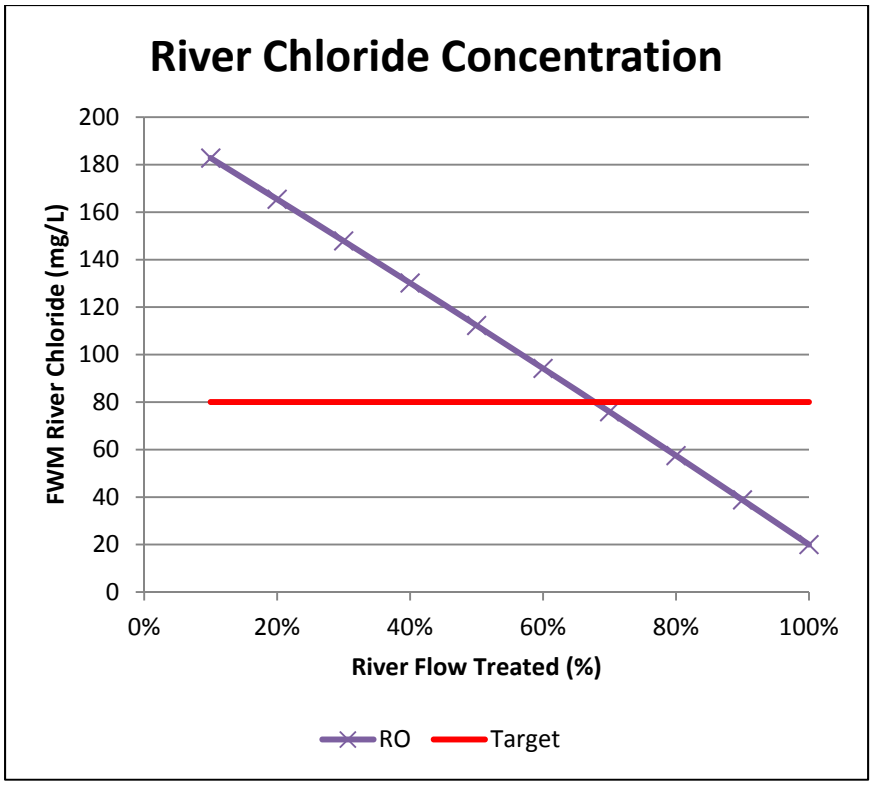


FIGURE 2-7
River Treatment Management Alternative Criteria
Alternatives Analysis for the Rio Grande Salinity Management Program

Source: Hogan, 2010



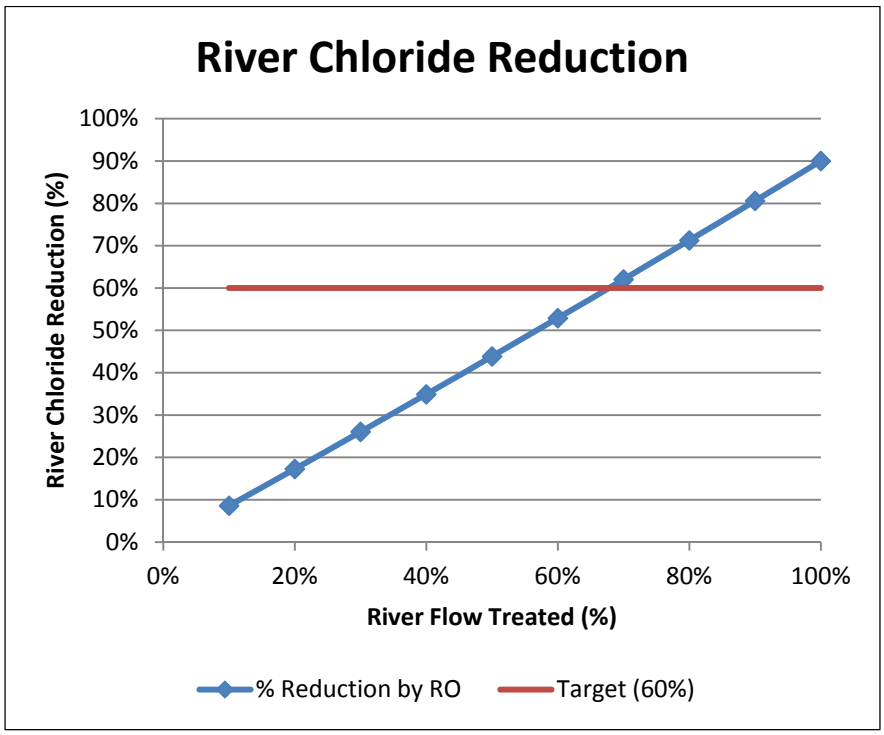


FIGURE 2-8
River Treatment Management Alternative Flow Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program
Flow weighted mean concentration vs. percentage of river flow treated (top) and reduction in river chloride vs. percentage of river flow (bottom)

SECTION 3

Alternatives Analysis

3.1 Introduction and Methods of Quantification

As discussed in Section 1, to narrow the field of six sites plus one candidate river treatment site location, the decision support process included the following steps:

1. Develop and gain agreement on non-monetary criteria to evaluate alternatives.
2. Identify management alternatives.
3. Application of non-monetary attribute scores.
4. Develop cost estimates for each management alternative, calculate overall attribute -cost scores, and select the best performing sites.

This section screens the site alternatives developed in Sections 1 and 2 using criteria established with Coalition participation and describes the approach used for site alternative analysis. Figure 3-1 illustrates the decision-making process.

As described in Section 1, site selection criteria were identified and confirmed at a workshop conducted in El Paso in September 2010. Decision criteria were selected to represent important site attributes that are independent, provide differentiation, and are measurable quantitatively. Weights were assigned by the workshop participants to indicate the relative importance of each criterion to achieving the project goals. The weighting consisted of distributing a total of 100 points over the primary criteria.

For all criteria, the project team developed a quantitative measurement and scoring methodology to define the performance of each alternative. Section 3.2 presents the raw attribute scores for each criterion. Section 3.3 discusses the process to normalize the raw scores for each criterion which leads to calculation of the total attribute score. Section 3.4 outlines the application of the weighting to the normalized scores to obtain the attribute. Section 3.5 describes the development of the various costs for each alternative at each site. In section 3.6 the report outlines the methodology by which the cost-attribute scores were calculated. Section 3.7 discusses the Sensitivity Analysis conducted. Section 3.8 summarizes the various values for each site. Lastly, Section 3.9 outlines the preferred sites that were determined based on the attribute-cost analysis.

3.2 Raw Attribute Scores

As described in Section 1, five final screening criteria were used to evaluate the relative non-monetary attributes of the management alternatives based on defined guidelines. A method of quantification was proposed for each of the five criteria:

- Source salinity contribution
- Potential economic benefit
- Management alternative operational complexity
- Environmental effects
- Availability of infrastructure

The results of the criteria analysis is provided in the following subsections.

3.2.1 Source Salinity Contribution

Source Salinity Contribution was defined as the chloride flux at site, as percentage of chloride flux in Rio Grande at El Paso. The values used for this were obtained through consultation with Dr. James Hogan and can be found in Section 2 and Appendix A of this document. These are summarized in Table 3-1.

TABLE 3-1
Raw Values for Source Salinity Contribution
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Source Type	Estimated Source Flow (gpm)	Estimated Source Chloride Concentration (mg/L)	Estimated Source Mass Flux (tons/yr)	Data Sources*	Raw Source Salinity Contribution Value
San Acacia	Groundwater	750	2,400	4,000	Moyer et al. (2009), Plummer et al. (2004), Mills (2003), Lacey (2006)	6.20%
Truth or Consequences	Surface Drain	up to 500	1,400	1,400	Cox and Reeder (1962), Moyer et al. (2009), D.B. Stephens as cited in Hogan (2010)	2.30%
Eastern Mesilla Basin	Groundwater	760	500	834	Witcher et al. (2004)	1.30%
Distal Mesilla Basin	Groundwater	1,500	2,400	7,500	Moyer et al. (2009), Mills (2003), Hogan et al. (2007), Lacey (2006)	11.50%
El Paso WWTPs	Effluent	35,000	250	19,300	EPWU, personal communication (2011)	30.20%
Fabens	Surface Drain	223	14,650	7,200	Surface drain concentration assumed to be equal to groundwater as measured by Hibbs and Merino (2007); flow based on mass balance model calibration in this current work (Appendix B)	11.20%
Rio Grande near Las Cruces New Mexico	Surface Water	22,400	200	4,000	ISC salinity model	8.60%

* See Section 2 for details on the sources used for each site. In most cases, multiple sources were used, and professional judgment was used to select a single value of concentration and flow based on the range of measured and reported data.

3.2.2 Potential Economic Benefit

The salinity models and economic benefit models were run for each management alternative–site combination, except the Rio Grande at Las Cruces option. A detailed summary of the models, including a discussion of how the salinity model simulates propagation of salinity reduction to downstream sites, is provided in Appendix B. Table 3-2 presents a summary of the model results for salinity and economic benefits for each alternative. Results of simulated TDS reduction, along with simulated economic benefits, are presented in Figures 3-2 and 3-3.

TABLE 3-2
Summary of Model Results: Salinity and Economic Benefits
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative		Cl Mass Reduction (tons/yr)	Result	San Acacia (Socorro County Ag)	Caballo (Sierra County Ag)	Leasburg (Doña Ana County Ag)	Mesilla (Doña Ana County Ag)	Courchesne (reference value only)	El Paso Water Treatment Plants	El Paso Agriculture	Hudspeth County Agriculture	Net Economic Benefit
Baseline/No Action Alternative		0	Irrigation season TDS (mg/L)	353	458	485	491	617	650	715	1,151	
			Net Economic Benefit (reduction in damage + benefit)	$0	$0	$0	$0	$0	$0	$0	$0	$0
San Acacia	RO	732	Irrigation season TDS (mg/L): simulated (change from baseline)	347 (6)	453 (5)	480 (5)	486 (5)	612 (5)	646 (4)	711 (4)	1149 (2)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$29**	**$157**	**$1,625**		**n/a**	**$111,250**	**$116,505**	**$3,029**	**$232,595**
	ED	672	Irrigation season TDS (mg/L): simulated (change from baseline)	348 (5)	453 (4)	481 (5)	487 (5)	613 (4)	646 (4)	712 (3)	1149 (2)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$27**	**$144**	**$1,492**		**n/a**	**$102,173**	**$107,002**	**$2,782**	**$213,621**
	Evap Ponds	800	Irrigation season TDS (mg/L): simulated (change from baseline)	347 (6)	452 (5)	480 (5)	486 (6)	612 (5)	645 (5)	711 (4)	1149 (2)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$31**	**$171**	**$1,775**		**n/a**	**$121,524**	**$127,258**	**$3,308**	**$254,067**
Truth or Consequences	RO	1,373	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	449 (9)	476 (9)	482 (9)	608 (9)	642 (8)	708 (7)	1148 (3)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$279**	**$2,854**		**n/a**	**$202,538**	**$212,027**	**$5,507**	**$423,206**
	ED	1,260	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	450 (8)	477 (8)	483 (8)	609 (8)	643 (7)	709 (6)	1148 (3)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$256**	**$2,619**		**n/a**	**$185,884**	**$194,606**	**$5,056**	**$388,421**
	Evap Ponds	1,500	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	448 (9)	476 (10)	482 (10)	608 (9)	642 (9)	708 (8)	1147 (4)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$305**	**$3,121**		**n/a**	**$221,423**	**$231,780**	**$6,020**	**$462,649**
Eastern Mesilla Basin	RO	73	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	650 (0)	715 (0)	1151 (0)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$5,217**	**$5,466**	**$142**	**$10,825**
	ED	67	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	650 (0)	715 (0)	1151 (0)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$4,789**	**$5,018**	**$131**	**$9,938**
	Evap Ponds	80	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	650 (0)	715 (0)	1151 (0)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$5,702**	**$5,974**	**$155**	**$11,831**
Distal Mesilla Basin	RO	2,180	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	603 (14)	637 (13)	703 (12)	1146 (5)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$339,182**	**$354,883**	**$9,206**	**$703,272**
	ED	2,002	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	604 (13)	638 (12)	704 (11)	1146 (5)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$311,231**	**$325,674**	**$8,451**	**$645,355**
	Evap Ponds	2,383	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	601 (16)	636 (15)	702 (13)	1145 (6)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$370,893**	**$388,014**	**$10,063**	**$768,970**
El Paso WWTPs	RO	17,692	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	603 (47)	580 (135)	1061 (90)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$1,204,070**	**$4,112,161**	**$151,515**	**$5,467,747**
	ED	16,242	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	607 (43)	592 (123)	1068 (83)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$1,101,861**	**$3,751,290**	**$138,633**	**$4,991,783**
	Evap Ponds	967	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	648 (3)	708 (7)	1146 (5)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$64,605**	**$213,826**	**$8,119**	**$286,550**
Fabens	RO	6,561	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	650 (0)	715 (0)	899 (252)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$0**	**$0**	**$402,489**	**$402,489**
	ED	6,024	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	650 (0)	715 (0)	921 (230)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$0**	**$0**	**$368,953**	**$368,953**
	Evap Ponds	7,171	Irrigation season TDS (mg/L): simulated (change from baseline)	353 (0)	458 (0)	485 (0)	491 (0)	617 (0)	650 (0)	715 (0)	877 (274)	
			Net Economic Benefit (reduction in damage + benefit) ($/yr)	**$0**	**$0**	**$0**		**n/a**	**$0**	**$0**	**$436,607**	**$436,607**

Although simulated reductions of TDS concentration at downstream sites are similar for a given alternative, mass reduction is simulated to decrease moving downstream. The combination of decreased mass reduction and decreased streamflow results in similar reduction of concentration. It is also worth noting that the reservoirs serve to "hold" salinity reductions during the non-irrigation season, thus resulting in greater mass reductions during the irrigation season. Accordingly, even though reduction of mass load decreases moving downstream, the model suggests that a similar mass removal at San Acacia would result in similar mass load reductions during the irrigation season at Courchesne Bridge (see Appendix B for more details).

In general, the model results suggest that the majority of economic benefits are realized at El Paso WWTPs (both irrigation and municipal). Although the greatest TDS reduction (230 to 275 mg/L reduction) is simulated at Hudspeth County irrigation in response to the Fabens management alternatives, the economic benefit associated with this TDS reduction is still less than the benefit attained at El Paso WWTPs for lesser TDS reductions. The greatest total economic benefit (about $5M/yr to $5.5M/yr) is attained under the El Paso WWTPs alternative, which is consistent with this alternative having the greatest mass removal. This economic benefit is nearly an order of magnitude greater than the next greatest economic benefit—about $650,000/yr to $770,000/yr—attained at the Distal Mesilla Basin site.

While the salinity and economic models evaluate potential economic benefits during the irrigation season, the concept of the Rio Grande at Las Cruces alternative is to treat water during the non-irrigation season. It was assumed that the economic benefit of the Rio Grande at Las Cruces option would primarily be to El Paso municipal water use, the only potential major non-irrigation season water use. Accordingly, economic benefit was assumed to be equal to $1.04M/yr, following work on that subject by Michelsen et al (2009b).

3.2.3 Management Alternative Operational Complexity

Management alternative operational complexity was defined as the sum of a "complexity factor" for each treatment component. The development of management alternatives for each site was outlined in Section 2. The raw scores for this criterion are listed in Table 3-3.

TABLE 3-3
Management Alternative Operational Complexity Raw Scores
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Management Alternative: RO	Management Alternative: ED	Management Alternative: Evap Ponds + NTS
San Acacia	3.5	2.5	1.5
Truth or Consequences	3.5	2.5	1.5
Eastern Mesilla Basin	3.5	2.5	1.5
Distal Mesilla Basin	3.5	2.5	1.5
El Paso WWTPs	4	3	5
Fabens	3.5	2.5	4*
Rio Grande near Las Cruces, New Mexico	4	3	5

*At Fabens, the second Treatment Option was Intercept not Evaporation Ponds and Natural Treatment.
Note: The values for determining the complexity of the treatment system for each Management Alternative at each site is to value the RO system as a 3, ERD as a 2, NTS + Evap. Ponds as 0.5, and the Disposal (natural treatment systems, deep injection well, evaporation ponds, etc. – up to 4) as 1.

3.2.4 Environmental Effects

Environmental effects were quantified as the number of endangered species found at the site. The raw scores can be found in Table 3-4, and as shown, this did not differentiate at any site with the exception of San Acacia, where the presence of southwestern willow flycatcher and silvery minnow is likely.

TABLE 3-4
Raw Values for Environmental Effects
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Raw Environmental Effects Value
San Acacia	2
Truth or Consequences	0
Eastern Mesilla Basin	0
Distal Mesilla Basin	0
El Paso WWTPs	0
Fabens	0
Rio Grande near Las Cruces New Mexico	0

3.2.5 Availability of Infrastructure

The availability of infrastructure criteria was determined to be the distance in miles to the nearest power source (3-phase 250 kVA). The raw values are listed in Table 3-5.

TABLE 3-5
Raw Values for Availability of Infrastructure
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Raw Availability of Infrastructure Value
San Acacia	5
Truth or Consequences	3
Eastern Mesilla Basin	3
Distal Mesilla Basin	1
El Paso WWTPs	1
Fabens	5
Rio Grande near Las Cruces New Mexico	1

3.3 Normalized Attribute Scores

This section outlines how the scores were normalized and the results of this process. The reason for normalization of the raw values is to account for the variability of the range of values for each criterion.

3.3.1 Normalization Methodology

Table 3-6 provides details on the definition, weights, and normalization scoring methodology for each criterion. A score between 0 and 5 was assigned to each criterion scaled proportionally to the range between the highest and lowest values.

TABLE 3-6
Site Selection Criteria Definitions, Weights and Scoring Methodologies
Alternatives Analysis for the Rio Grande Salinity Management Program

Criterion	Weight (%)	Quantification for Raw Score	Normalization Scoring Methodology and Range (0–5)
Source Salinity Contribution	23	Chloride flux at site, as percentage of chloride flux in Rio Grande at El Paso	Sites with greatest chloride flux assigned “5” and lowest assigned “0”
Potential Economic Benefit	27	Function with three factors: 1. Reduction of concentration in river at site 2. "Condition" by distance downstream 3. Economic benefit at downstream locations based on reports by Texas A&M University and New Mexico Water Resources Research Institute (TAMU/ NMWRRI) reports	Sites with the greatest annual chloride mass removal (tons per year) and modeled economic benefit to downstream sites assigned “5,” and the lowest assigned “0”
Management Alternative Operational Complexity	19	Sum of "complexity factor" for each treatment component: • RO: 3 • ERD: 2 • NTS + Evap. Ponds: 0.5 Disposal (natural treatment systems, deep injection well, evaporation ponds, etc – up to 4): 1	Site with greatest complexity factor sum assigned “0” and lowest assigned “5” Disposal added to treatment score for total score (e.g., RO treatment + Evap ponds = 3 +0.5 = 3.5)
Environmental Effects	16	Number of endangered species	Sites with greatest number tallied of federally listed endangered species was assigned “0,” and lowest was assigned “5”
Availability of Infrastructure	15	Distance (miles) to power source (3-phase 250 kVA)	Sites with commercial/residential land uses with existing facilities or easements in place would have a short distance. Shortest distance assigned a “5”, longest distance assigned “0” Sites located on undeveloped areas, with greater distance to power sources, would have a longer distance

TABLE 3-6
Site Selection Criteria Definitions, Weights and Scoring Methodologies
Alternatives Analysis for the Rio Grande Salinity Management Program

Criterion	Weight (%)	Quantification for Raw Score	Normalization Scoring Methodology and Range (0–5)
Source Salinity Contribution	23	Chloride flux at site, as percentage of chloride flux in Rio Grande at El Paso	Sites with greatest chloride flux assigned “5” and lowest assigned “0”
Potential Economic Benefit	27	Function with three factors: 1. Reduction of concentration in river at site 2. "Condition" by distance downstream 3. Economic benefit at downstream locations based on reports by Texas A&M University and New Mexico Water Resources Research Institute (TAMU/ NMWRRI) reports	Sites with the greatest annual chloride mass removal (tons per year) and modeled economic benefit to downstream sites assigned “5,” and the lowest assigned “0”
Management Alternative Operational Complexity	19	Sum of "complexity factor" for each treatment component: • RO: 3 • ERD: 2 • NTS + Evap. Ponds: 0.5 Disposal (natural treatment systems, deep injection well, evaporation ponds, etc – up to 4): 1	Site with greatest complexity factor sum assigned “0” and lowest assigned “5” Disposal added to treatment score for total score (e.g., RO treatment + Evap ponds = 3 +0.5 = 3.5)

3.3.2 Source Salinity Contribution

Source salinity contribution values were normalized by assigning the sites with greatest chloride flux a value of “5” and the lowest a value of “0”. These are summarized in Table 3-7.

TABLE 3-7
Normalized Values for Source Salinity Contribution
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Normalized Source Salinity Contribution Value
San Acacia	1
Truth or Consequences	0.4
Eastern Mesilla Basin	0.2
Distal Mesilla Basin	1.9
El Paso WWTPs	5
Fabens	1.9
Rio Grande near Las Cruces New Mexico	1.4

3.3.3 Potential Economic Benefit

Table 3-8 presents a summary of normalized values for the potential economic benefit criterion. The values were normalized by assigning a "5" to the sites with the greatest chloride mass removal and modeled economic benefit to downstream sites, and a score of "0" to those with the lowest.

TABLE 3-8
Potential Economic Benefit Normalized Scores
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Management Alternative: RO	Management Alternative: ED	Management Alternative: Evap Ponds + NTS
San Acacia	0.2	0.2	1.2
Truth or Consequences	0.4	0.4	2.2
Eastern Mesilla Basin	0.0	0.0	0.1
Distal Mesilla Basin	0.6	0.7	3.7
El Paso WWTPs	5.0	5.0	1.4
Fabens	0.4	0.4	1.8
Rio Grande near Las Cruces New Mexico	1.0	1.0	5.0

3.3.4 Management Alternative Operational Complexity

Management alternative operational complexity was normalized assigning the site with greatest complexity factor sum assigned "0" and lowest assigned "5". The normalized scores for this criterion are listed in Table 3-9.

TABLE 3-9
Management Alternative Operational Complexity Normalized Scores
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Management Alternative: RO	Management Alternative: ED	Management Alternative: Evap Ponds + NTS
San Acacia	0.6	0.8	3.5
Truth or Consequences	0.6	0.8	3.5
Eastern Mesilla Basin	0.6	0.8	3.5
Distal Mesilla Basin	0.6	0.8	3.5
El Paso WWTPs	0	0	0
Fabens	0.6	0.8	3.5
Rio Grande near Las Cruces New Mexico	0	0	0

3.3.5 Environmental Effects

The environmental effects criteria were normalized with sites with greatest number tallied of federally listed endangered species assigned a "0," and the lowest was assigned "5". The normalized scores are listed in Table 3-10

TABLE 3-10
Normalized Scores for Environmental Effects
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Normalized Environmental Effects Value
San Acacia	0
Truth or Consequences	5
Eastern Mesilla Basin	5
Distal Mesilla Basin	5
El Paso WWTPs	5
Fabens	5
Rio Grande near Las Cruces New Mexico	5

3.3.6 Availability of Infrastructure

The availability of infrastructure criteria were normalized with the shortest distance assigned a "5", longest distance assigned "0". These normalized values are listed in Table 3-11.

TABLE 3-11
Normalized Values for Availability of Infrastructure
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Normalized Availability of Infrastructure Value
San Acacia	0
Truth or Consequences	2
Eastern Mesilla Basin	2
Distal Mesilla Basin	4
El Paso WWTPs	4
Fabens	0
Rio Grande near Las Cruces New Mexico	4

3.3.7 No Action Alternative

The No Action Alternative was addressed separately from previous sites. The raw and normalized values for the No Action Alternative are listed in Table 3-12.

TABLE 3-12
No Action Alternative Raw and Normalized Values
Alternatives Analysis for the Rio Grande Salinity Management Program

Criterion	Raw Value	Normalized Score
Source Salinity Contribution	0	0
Potential Economic Benefit	0	0
Management Alternative Operational Complexity	0	5
Environmental Effects	0	5
Availability of Infrastructure	0	5

As stated in Section 1.3, Approach, the management alternatives include a No Action Alternative. As part of this initial screening, the No Action Alternative is presented as a separate alternative but may be best considered a management alternative with respect to each of the sites analyzed along with the other management alternatives considered. By comparing with the model results summarized n Table 3-2, the No Action Alternative can be compared against the salinity and economic benefits gained at the various sites by the other applicable management alternatives. The raw and normalized values for the No Action Alternative found in Table 3-12 are influenced by definitions that are more applicable to the other management alternatives.

As defined, the criteria for Operational Complexity, Environmental Effects and Availability of Infrastructure imply actions specific to the other alternatives that have little or no practicability in measuring no action. Therefore, the use of the No Action Alternative should not be used as a direct comparison at this time but provides a reference between the other management alternatives and the No Action Alternative.

3.4 Attribute Score Development

The following sections describe the application of the weighting to the normalized scores to obtain attributes.

3.4.1 Management Alternative 1: Interception, Treatment with Reverse Osmosis, and Release to River

The weighted criteria scores for RO treatment of the saline water sources are summarized in Table 3-13 and Figure 3-4. A comparison of scores shows the descending rank order of sites to be: El Paso WWTPs (3.90) > Distal Mesilla Basin (2.13) > Rio Grande near Las Cruces (1.98) > Fabens (1.44) > Truth or Consequences (1.41) > Eastern Mesilla Basin (1.27) > San Acacia (0.41). These values can be compared against a “perfect” score of 5.0. For the top four, this distribution is attributable primarily to Criteria A and B, the source salinity contribution and

a varying influence by economic benefit. The remaining sites are influenced to small but varying amounts by the other factors.

The No Action Alternative received a normalized score of 2.5. This outcome is caused by the influence of low scores for Criteria C, D, and E without the balancing provided by any scores for Criteria A and B.

3.4.2 Management Alternative 2: Interception, Treatment with Electrodialysis, and Release to River

The weighted scores for ED treatment of the saline water sources are summarized in Table 3-14 and Figure 3-5. The descending rank order of sites is: El Paso WWTPs (3.9) > Distal Mesilla Basin (2.17) > Rio Grande near Las Cruces (2.01) > Fabens (1.48) > Truth or Consequences (1.45) > Eastern Mesilla Basin (1.31) > San Acacia (0.65). The score values matched the ranking for Management Alternative 1. As before, this distribution is attributable primarily to Criteria A and B, the source salinity contribution and a varying influence by economic benefit.

3.4.3 Management Alternative 3: Interception and Disposal

The weighted scores for evaporative disposal of the saline water sources at all sites and are summarized in Table 3-15 and Figure 3-6. The descending rank order of sites is: Distal Mesilla Basin (3.50) > Rio Grande near Las Cruces (3.08) > El Paso WWTPs (2.93) > Truth or Consequences (2.45) > Fabens (2.37) > Eastern Mesilla Basin (1.83) > San Acacia (1.23). As with the other management alternatives, the general order reflects the anticipated salinity source contribution and economic benefit, but in this case the ranking for Distal Mesilla Basin is adjusted upward by the reduced management complexity. In general, these scores are slightly greater than the other management alternatives reflecting reduced management complexity.

TABLE 3-13
Weighted Attribute Results, Management Alternative 1: RO Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

Criterion	San Acacia	Truth or Consequences	Eastern Mesilla Basin	Distal Mesilla Basin	El Paso WWTPs	Fabens	Rio Grande near Las Cruces	No Action Alternative
A. Source Salinity Contribution	0.24	0.09	0.05	0.44	1.15	0.43	0.33	0.00
B. Potential Economic Benefit	0.06	0.10	0.00	0.17	1.35	0.10	0.26	0.00
C. Management Alternative Operational Complexity	0.12	0.12	0.12	0.12	0.00	0.12	0.00	0.95
D. Environmental Effects	0.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80
E. Availability of Infrastructure	0.00	0.30	0.30	0.60	0.60	0.00	0.60	0.75
Total	**0.41**	**1.41**	**1.27**	**2.13**	**3.90**	**1.44**	**1.98**	**2.50**

TABLE 3-14
Weighted Attribute Results, Management Alternative 2: ED Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

Criterion	San Acacia	Truth or Consequences	Eastern Mesilla Basin	Distal Mesilla Basin	El Paso WWTPs	Fabens	Rio Grande near Las Cruces	No Action Alternative
A. Source Salinity Contribution	0.24	0.09	0.05	0.44	1.15	0.43	0.33	0.00
B. Potential Economic Benefit	0.06	0.11	0.00	0.18	1.35	0.10	0.28	0.00
C. Management Alternative Operational Complexity	0.16	0.16	0.16	0.16	0.00	0.16	0.00	0.95
D. Environmental Effects	0.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80
E. Availability of Infrastructure	0.00	0.30	0.30	0.60	0.60	0.00	0.60	0.75
Total	**0.45**	**1.45**	**1.31**	**2.17**	**3.90**	**1.48**	**2.01**	**2.50**

TABLE 3-15
Weighted Attribute Results, Management Alternative 3: Evaporative Disposal
Alternatives Analysis for the Rio Grande Salinity Management Program

Criterion	San Acacia	Truth or Consequences	Eastern Mesilla Basin	Distal Mesilla Basin	El Paso WWTPs	Fabens	Rio Grande near Las Cruces	No Action Alternative
A. Source Salinity Contribution	0.24	0.09	0.05	0.44	1.15	0.43	0.33	0.00
B. Potential Economic Benefit	0.32	0.60	0.02	1.00	0.38	0.48	1.35	0.00
C. Management Alternative Operational Complexity	0.67	0.67	0.67	0.67	0.00	0.67	0.00	0.95
D. Environmental Effects	0.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80
E. Availability of Infrastructure	0.00	0.30	0.30	0.30	0.60	0.00	0.60	0.75
Total	**1.23**	**2.45**	**1.83**	**3.50**	**3.08**	**2.37**	**3.08**	**2.50**

3.5 Comparative Costs of Alternative Sites

With the relative attributes of the different alternatives summarized, the analysis focuses on determining an attribute-to-cost ratio, with the goal of establishing a preference for final site ranking. This section describes the cost estimation procedure, key assumptions, and final attribute-to-cost ratios for the different management alternatives.

3.5.1 Cost Estimates

Planning-level cost estimates were prepared for each site alternative, consistent with the limitations for Class 4 estimates as defined by the Association for the Advancement of Cost Engineering (AACE). This level of estimate is prepared based on preliminary engineering information, which is from 1 to 5 percent complete. The typical expected accuracy range for this estimate is –15 to –30 percent on the low side and +20 to +50 percent on the high side. While efforts have been made to base all costs on actual experience, these costs are included to facilitate a comparison of alternatives, and are not intended for budgetary planning purposes.

All costs for RO, ED, and evaporation ponds for all sites, with the exception of the Rio Grande near Las Cruces and El Paso WWTPs sites, were based on available CH2M HILL cost data from project estimations and equipment cost quotes compiled using CH2M HILL's parametric Cost Estimating System (CPES). CPES is a proprietary conceptual design and cost-estimating tool that generates accurate and detailed cost estimates during the conceptual stage of a project.

For the Rio Grande near Las Cruces and El Paso WWTPs alternatives, treatment and disposal costs were scaled to the costs of the existing Kay Bailey Hutchinson plant based on the ratio of the alternative flow rates (Rio Grande near Las Cruces = 23 mgd; El Paso WWTPs = 50 mgd) to the existing plant (27.5 mgd).

The size of the evaporation ponds for concentrate disposal depends on the reject flow rate from the treatment process. The influent to the evaporation pond was based on an assumption that a fraction of the feed flow (RO 15%, ED 20%) will be rejected and sent to the ponds. Costs for evaporation ponds for disposal of river flows depended upon the total flow rate diverted, and were consequently greater in area. Evaporation rates were developed from pan evaporation data measured and compiled by the National Climate Data Center for Leasburg, New Mexico. A salinity correction factor of 0.7 was used to account for decreased evaporation rates with increasing salinity content. The evaporation rate averaged 2.2 gpm per acre. This resulted in evaporation pond sizes more than 40 percent larger than determined assuming pan evaporation rates, and is a conservative approach allowing long-term storage of accumulated salts in the ponds.

For sites assuming extraction of saline groundwater, a conceptual well field, pump, and conveyance system was estimated, as described in detail below. Sites assuming a surface water withdrawal were assigned an allowance for intake, pump station, and conveyance.

Tables 3-16 and 3-17 summarize the additional project costs and markups applied to the facilities in the cost estimate. These additional project costs were common for Management

Alternatives 1 and 2. No site location adjustment factors were included as part of the cost estimates. A contingency percentage was not added.

TABLE 3-16
Summary of Additional Project Cost Allowances
Alternatives Analysis for the Rio Grande Salinity Management Program

Cost Allowance	Value
Installation and Finishes	20%
Instrumentation and Control	15%
Mechanical	15%
Overall Site Work	10%
Electrical	5%

TABLE 3-17
Summary of Markup Assumptions
Alternatives Analysis for the Rio Grande Salinity Management Program

Markup	Value
Overhead	10%
Profit	5%
Mobilization/Bonds/Insurance	5%
Contingency	30%

3.5.2 Parameters Not Included in Cost Analysis

Costs for the following were not included in the cost analysis:

- Escalation – all costs are presented in July 2010 dollars.
- Market adjustment factor(s)
- Common facilities to all alternatives such as process units
- Non-construction costs, including permitting, engineering, services during construction, commissioning and startup, rights-of-way, land costs, and legal/administration costs.

3.5.3 Cost Evaluation Results

As a basis for developing conceptual costs for evaluating the different sites and management alternatives, a conceptual description of the infrastructure was developed to describe the facilities necessary to capture, convey, treat and dispose of saline groundwater or surface water sources. This section summarizes the AACE Class 4 cost estimates prepared for the site alternatives as follows:

- **San Acacia –** Extraction wells + 150 gpm package RO or ED system for treatment + evaporation ponds for concentrate disposal.

- **Truth or Consequences –** Extraction facilities + 500 gpm package RO or ED system for treatment + evaporation ponds for concentrate disposal.
- **Eastern Mesilla Basin –** Extraction wells + 100 gpm package RO or ED system for treatment + evaporation ponds for concentrate disposal.
- **Distal Mesilla Basin –** Extraction wells + 500 gpm package RO or ED system for treatment + evaporation ponds for concentrate disposal.
- **El Paso WWTPs –** Extraction facilities + new 35,000 gpm constructed RO or ED desalination plant for treatment + deep well injection for concentrate disposal.
- **Fabens –**For the Fabens Bypass Alternate method of disposal, this site would consist of a well system to extract lower salinity groundwater at depth and then discharge these waters to the surface without treatment.
- **Rio Grande near Las Cruces –** Extraction facilities + a new 16,00**0** gpm constructed RO or ED desalination plant for treatment + deep well injection for concentrate disposal.

Tables 3-18, 3-19, and 3-20 summarize the capital and O&M costs for each of the RO, ED, and evaporation pond management alternatives. Each cost represents an estimated construction and equipment cost, in July 2010 dollars. Total present worth cost is represented with O&M costs estimated over a 25-year period at a 5 percent annual rate.

TABLE 3-18
Cost Analysis Summary for Management Alternative 1: RO Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Capture and Conveyance[a]	Treatment[a]	Disposal[a]	O&M[a]	Total Present Worth Cost (5%, 25 years) [a,b]
San Acacia	$539,000	$956,000	$619,000	$164,000	$4,425,000
Truth or Consequences	$15,000	$1,670,000	$1,965,000	$477,000	$10,371,000
Eastern Mesilla Basin	$3,004,000	$666,000	$424,000	$120,000	$5,785,000
Distal Mesilla Basin	$871,000	$1,670,000	$1,965,000	$477,000	$11,227,000
El Paso WWTPs	[c]	$150,304,000	$81,540,000	$7,328,000	$325,472,000
Fabens	$1,101,200	$740,000	$1,006,000	$253,000	$6,410,000
Rio Grande near Las Cruces	[c]	$94,325,000	$75,540,000	$3,343,000	$218,194,000

[a]All costs are presented in July 2010 dollars.
[b]Rounded to the nearest thousand.
[c]Included in treatment cost.

TABLE 3-19
Cost Analysis Summary for Management Alternative 2: ED Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Capture and Conveyance[a]	Treatment[a]	Disposal[a]	O&M[a]	Total Present Worth Cost (5%, 25 yrs) [a,b]
San Acacia	$539,000	$956,000	$619,000	$125,000	$3,875,250
Truth or Consequences	$15,000	$1,670,000	$1,965,000	$346,000	$8,525,140
Eastern Mesilla Basin	$3,004,000	$666,000	$424,000	$94,000	$6,129,460
Distal Mesilla Basin	$871,000	$1,670,000	$1,965,000	$346,000	$9,381,140
El Paso WWTPs	[c]	$150,304,000	$81,540,000	$7,238,000	$333,827,420
Fabens	$1,101,160	$740,000	$1,006,000	$187,000	$5,481,000
Rio Grande near Las Cruces	[c]	$94,325,000	$75,540,000	$3,343,000	$216,967,870

[a]All costs are presented in July 2010 dollars.
[b]Rounded to the nearest thousand.
[c]Included in treatment cost.

TABLE 3-20
Cost Analysis Summary for Management Alternative 3: Evaporative Disposal
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Capture and Conveyance[a]	Treatment[a]	Disposal[a]	O&M[a]	Total Present Worth Cost (5%, 25 yrs) [a,b]
San Acacia	$539,000	NA	$11,440,000	$ 46,000	$12,627,140
Truth or Consequences	$ 15,000	NA	$37,752,000	$113,000	$39,359,170
Eastern Mesilla Basin	$3,004,000	NA	$7,659,000	$41,000	$11,240,690
Distal Mesilla Basin	$871,000	NA	$37,752,000	$113,000	$40,215,170
El Paso WWTPs	[c]	NA	[e]	[e]	[e]
Fabens	$1,106,000	NA	$18,962,000	$86,000	$21,273,900
Fabens – Bypass	$1,106,000	NA	[d]	$41,000	$1,638,690
Rio Grande near Las Cruces	[c]	NA	[e]	[e]	[e]

[a]All costs are presented in July 2010 dollars.
[b]Rounded to the nearest thousand.
[c]Included in treatment cost.
[d]Included in conveyance cost.
[e]Technically infeasible, not included.

NA = not applicable

Costs associated with the Rio Grande near Las Cruces and El Paso WWTPs sites were estimated by scaling the related costs at the Kay Bailey Hutchinson Desalination Plant by

flow ratio. Capture and treatment costs were aggregated, given the costing approach taken. Disposal costs were developed for deep well injection, and were based on the City of El Paso's concentrate disposal program. Given the concentrate volume that would be generated at these two sites, an evaporation pond system was not considered feasible, a conclusion drawn by others for similar large-scale concentrate disposal assessments (e.g., Bucher Willis & Ratliff Corp., 2009).

Sites for the RO management alternative were ranked in the following order of decreasing cost: El Paso WWTPs > Rio Grande near Las Cruces >Distal Mesilla Basin>Truth or Consequences> Eastern Mesilla Basin> Fabens> San Acacia. Costs ranged widely from a maximum of approximately $333 million for the El Paso WWTPs site to approximately $3.9 million for San Acacia. Predictably, the large conveyance and treatment requirements associated with the El Paso WWTPs and Rio Grande near Las Cruces sites far exceed the costs of the other sites, but all have significant associated costs. The high costs of the El Paso WWTPs and Rio Grande near Las Cruces sites make them appear financially infeasible; however, they are included here for attribute-cost analysis evaluation.

The treatment costs for the ED alternative are estimated using the same assumptions of size of systems and appurtenant features as the RO treatment alternatives. Lower O&M costs were presumed for the ED alternative ($1.00/1,000 gallons) compared to the RO alternative ($1.50/1,000 gallons). The ED management alternative shows the same relative ranking of cost as the RO alternative.

By definition, treatment costs were not estimated for the evaporative disposal alternative, and the volume of flow to the evaporative disposal system was increased to account for the flow captured. Costs for evaporative disposal were not calculated for the Rio Grande near Las Cruces and El Paso WWTPs sites because the areas estimated for evaporation ponds were greater than 7,000 acres and greater than 15,000 acres, respectively, and are clearly technically infeasible. The remaining sites for the evaporative disposal management alternative were ranked in the following order of decreasing cost: Distal Mesilla Basin > Truth or Consequences > Fabens>San Acacia > Eastern Mesilla Basin. Costs ranged from $40 million for the Distal Mesilla Basin site to $11 million for Eastern Mesilla Basin. Disposal costs are significant for all alternatives, given the need for an evaporation pond or deep injection well solution to keep the captured salts from re-entering the river system. Evaporation pond area is a projection based on the flow to be evaporated, and offers little economy of scale.

The Fabens Bypass Alternate yielded a lower cost of $1.6 million, and is included in this suite of comparisons because it does not require an assumption of treatment. This concept assumed that wells would be placed within approximately 0.5 mile of existing canals to provide a bypass of upward migrating flow and convey the lower salinity water to surface drainage canals. The total cost for this alternative is composed of well capture and conveyance costs.

3.6 Attribute-Cost Analysis

The attribute scores and estimated costs for each management alternative were used to develop an attribute-to-cost ratio for the site alternatives by dividing the weighted scores by costs normalized to the least-cost management alternative. It should be reiterated that the attribute is a non-monetary attribute based on evaluation criteria, not an economic benefit.

The normalized costs, the attribute sums, and the calculated attribute-to-cost ratio for the management alternatives are summarized in Table 3-21 and Figure 3-7.

TABLE 3-21
Attribute-Cost Summary by Management Alternative
Alternatives Analysis for the Rio Grande Salinity Management Program

	San Acacia	Truth or Consequences	Eastern Mesilla Basin	Distal Mesilla Basin	El Paso WWTPs	Fabens	Rio Grande near Las Cruces
Management Alternative 1: RO Treatment							
Normalized Cost	1.0	2.3	1.3	2.5	49	1.5	74
Attributes	0.41	1.41	1.3	2.13	3.90	1.44	1.98
Attribute: Cost	0.4	0.6	1.0	0.8	0.1	1.0	0.0
Management Alternative 2: ED Treatment							
Normalized Cost	1.0	2.2	1.6	2.4	86	1.4	56
Attributes	0.45	1.45	1.31	2.17	3.90	1.48	2.01
Attribute: Cost	0.5	0.7	0.8	0.9	0.0	1.0	0.0
Management Alternative 3: Evaporative Disposal							
Normalized Cost	1.1	3.5	1.0	3.6	NA	1.3	NA
Attributes	1.2	2.45	1.83	3.5	2.93	2.37	3.08
Attribute: Cost	1.1	0.7	1.8	1.0	NA	1.3	NA
Management Alternative 3 Extension: Evaporative Disposal – Fabens Bypass							
Normalized Cost	1.0	3.12	0.89	3.2	NA	0.15	NA
Attributes	1.23	2.45	1.83	3.5	2.93	2.37	3.08
Attribute: Cost	1.2	0.8	2.1	1.1	NA	15.4	NA

NA = Not applicable; alternatives not technically feasible.

The best treatment alternative identified by the decision model should consist of the alternatives with the greatest attribute-to-cost ratio. Figures 3-8 through 3-11 provide summary graphics comparing the attribute -to-cost scores for each site for the different management alternatives.

Management Alternatives 1 and 2 were ranked consistently. The Distal Mesilla Basin had the greatest attribute-to-cost ratio (0.8-0.9), followed by Fabens (0.7-1.3), Truth or Consequences (0.6-0.7), Eastern Mesilla Basin (0.5–0.8), San Acacia (0.4–0.5), and finally Rio

Grande near Las Cruces and El Paso WWTPs (0). Of this ranking, the position of the Eastern Mesilla Basin is influenced strongly by the low cost of treatment and the low volume of water captured, although it has the highest projected cost for capture of the groundwater capture and treatment alternatives. Conversely, the high ranking of Distal Mesilla Basin is influenced by the high attribute scores.

For Management Alternative 3, the scores changed for each alternative, with Eastern Mesilla Basin gaining in position (2.1) followed by Fabens (1.3), San Acacia (1.2), Distal Mesilla Basin (1.1), then 0.8 for Truth or Consequences. The Rio Grande near Las Cruces and El Paso WWTPs sites were not ranked because of the technical infeasibility of evaporation pond area requirements. The relative position of the Mesilla Basin sites is influenced by the low volume to be treated (Eastern Mesilla Basin) and the greatest attribute score (Distal Mesilla Basin).

The extension of Management Alternative 3, the Fabens Bypass, was found to yield the greatest score (15.4) of all alternatives, given the assumption that no additional treatment is required and no disposal is required. Conceptually, this alternative warrants further consideration, given this distinctly greater attribute-to-cost ratio.

3.7 Sensitivity Analysis

A sensitivity analysis was undertaken to evaluate uncertainty in values assigned to criteria. Because the first two criteria, source salinity contribution and potential economic benefit, are associated with the most uncertainty, the sensitivity analysis focused on these two criteria. The remaining three criteria were not evaluated in the sensitivity analysis for two reasons. Environmental effect (number of species) and availability of infrastructure (miles to nearest 500 kV source) were easily quantifiable, and have low uncertainty associated with them. Management alternative complexity, within each management alternative (e.g., RO), is generally the same for most sites except the treatment plants and the treat the river option, and so was not a significant differentiator between the sites.

3.7.1 Sensitivity: Approach

Criteria A and B were re-evaluated for each site using several different assumptions. Costs were then estimated for these alternate assumptions, and the cost-attribute analysis rerun. Results are compared to the "baseline" analysis and a qualitative assessment is provided of how the site rankings could differ if our assumptions related to Criteria A and B were changed within reasonable bounds.

The sensitivity approach was performed on the RO management alternative. It was assumed that the effect that uncertainty has on final site selection would be similar in the RO alternative as compared with the other alternatives.

Alternate Assumptions Evaluated

Two alternate assumptions were evaluated for each site. These are herein referred to as "cases," and are described below.

Case 1: Assume that twice the saline mass flux could be captured at each site, as compared with the baseline analysis, for sites in which this assumption makes sense (i.e., not El Paso

WWTPs or the Rio Grande near Las Cruces options). This assumption is evaluated two different ways:

- **Case 1a**: Case 1a assumes that the source salinity contribution is two times the value assumed for the baseline analysis, and that the same percent of that mass flux would be captured. For example, the base case assumes San Acacia contributes 4,000 tons chloride per year, and that 20 percent of that flux (800 tons/yr) could be captured. Case 1a assumes the source is actually 8,000 tons per year, and 20 percent of that flux (1600 tons/yr) could be captured. In Case 1a, both Criterion A (source salinity contribution) and Criterion B (economic benefit) change.

This sensitivity case was applied to sites for which the source contribution is uncertain: San Acacia, Truth or Consequences, Eastern Mesilla Basin, and Distal Mesilla Basin, and Fabens. The Rio Grande at Las Cruces option and El Paso WWTPs are well–quantified sources, so it is unreasonable to assume the source could be double.

For Criterion A, all sites included in the sensitivity analysis use a value equal to two times the value used in the baseline analysis.

For Criterion B, all sites except Fabens were evaluated using the salinity and economic models. It should be noted, however, that by assuming double the mass influx, the salinity models may no longer be in calibration, so results should be interpreted with caution. For Fabens, testing the hypothesis of double the mass flux would require recalibrating the El Paso salinity model. However, the other sites showed that economic benefit doubles if the amount of mass flux captured is doubled. Accordingly, for the purposes of this sensitivity analysis it was assumed that the economic benefit at Fabens would also double if the source salinity contribution doubled.

- **Case 1b**: Case 1b assumes that the source has the same mass flux as was assumed in the baseline analysis, but that the salinity control measure would capture and treat twice the percentage of that flux that was assumed in the baseline analysis. In this case, there is no change to Criterion A for any of the sites, since the assumption of source salinity contribution does not change. Similarly, because the baseline case already assumed nearly full capture of the mass flux at the Rio Grande at Las Cruces, El Paso WWTPs, and Fabens, this sensitivity case was not evaluated for these sites. For the remaining sites (San Acacia, Truth or Consequences, Eastern Mesilla Basin, and Distal Mesilla Basin), the change to economic benefits is the same as in Case A, because mass removal is the same (double baseline estimate).

Case 2: Assume that half the saline mass flux is captured at each site, as compared with the baseline analysis. Similar to Case 1, this assumption was evaluated two different ways:

- **Case 2a**: Case 2a assumes that the source salinity contribution is half the value that was assumed for the baseline analysis, and that the same percent of that mass flux would be captured. This sensitivity case was not evaluated for the sites with more certain mass flux: Rio Grande at Las Cruces and El Paso WWTPs. Accordingly, source salinity contribution was reduced by 50% for all sites with uncertainty associated with them: San Acacia, Truth or Consequences, Eastern Mesilla Basin, Distal Mesilla Basin, and Fabens. Economic benefit for these sites was simulated using the salinity and economic models, assuming 50% reduction in mass captured and treated. It should be noted, however, that

by assuming half of the mass influx, the salinity models may no longer be in calibration, so results should be used with caution.

- **Case 2b**: Case 2b assumes that the source has the same mass flux as was assumed in the baseline analysis, but that the salinity control measure would capture and treat half the percentage of the flux that was assumed in the baseline analysis. This sensitivity case was applied to all sites.

It should be noted that for consistency in comparison, the normalization scale for this scenario was not changed. If the scale were changed, the results would be identical to those of the baseline scenario, because all economic benefits were reduced by half, and therefore there is no change to *relative* benefits between the sites.

Cost Estimates

Because the amount of flow that would be treated in each sensitivity case differs from the baseline analysis, it is necessary to develop cost estimates for the new flow rates. Cost estimates for capture and conveyance were re-evaluated using the same methodology as the baseline analysis. For treatment costs and disposal costs, cost curves were developed that relate the size of the plant to the cost, based on the cost estimates used in the baseline analysis.

Cost curves for treatment costs are presented in Figure 3-12. A power curve was assumed, using a power of 0.6, which is a "middle of the road" standard power used in this type of analysis. A typical range is 0.5 to 0.7 (AWARE (1974).

Cost assumptions for disposal are based on a linear trendline fit to the more detailed cost estimates in the baseline analysis (see Figure 3-13).

3.7.2 Sensitivity: Attributes

Total attribute scores are presented in Figures 3-14 through 3-17, broken out by criteria. Figure 3-18 presents total attribute results for the baseline case and all sensitivity cases. A general conclusion from Figure 3-18 is that the relative ranking of sites based on total attributes would not change even if different assumptions were made about the source salinity contribution and percent of the saline source that would be captured. Distal Mesilla Basin has the greatest range of attributes based on the sensitivity analysis, mainly because Criteria A and B make up a large percentage of the overall attribute score at this site. Eastern Mesilla Basin, on the other hand, scores very low on these two criteria, so changes in these assumptions do little to change the overall attribute score at Eastern Mesilla Basin.

3.7.3 Sensitivity: Costs

Cost estimates for each sensitivity analysis case are presented in Tables 3-22 and 3-23. Total present worth cost is also presented graphically in Figure 3-19.

TABLE 3-22
Costs, Sensitivity Case 1
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Capture and Conveyance	Treatment	Disposal	O&M	Total Present Worth Cost (5%, 25 years)
San Acacia	$1,204,000	$1,287,000	$1,194,000	$329,000	$8,321,003
Truth or Consequences	$30,000	$2,650,000	$3,892,000	$953,000	$19,999,991
Eastern Mesilla Basin	$3,474,000	$1,009,000	$809,000	$239,000	$8,659,855
Distal Mesilla Basin	$2,186,000	$2,650,000	$3,892,000	$953,000	$22,156,391
Rio Grande at Las Cruces	$0	$94,325,000	$75,540,000	$3,343,000	$216,967,870
El Paso WWTPs	$0	$150,304,000	$81,540,000	$7,238,000	$333,827,420
Fabens	$2,200,000	$1,748,000	$1,965,000	$507,000	$13,057,512

TABLE 3-23
Costs, Sensitivity Case 2
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Capture and Conveyance	Treatment	Disposal	O&M	Total Present Worth Cost (5%, 25 years)
San Acacia	$475,000	$666,000	$424,000	$105,000	$3,044,065
Truth or Consequences	$8,000	$1,153,000	$1,002,7000	$238,000	$5,516,109
Eastern Mesilla Basin	$1,737,000	$560,000	$327,000	$82,000	$3,779,956
Distal Mesilla Basin	$539,000	$1,009,000	$809,000	$194,000	$5,090,125
Rio Grande at Las Cruces	$0	$0	$0	$2,584,000	$138,197,265
El Paso WWTPs	$0	$0	$0	$4,117,000	$196,943,897
Fabens	$550,000	$666,000	$424,000	$105,000	$3,118,785

3.7.4 Sensitivity: Cost-Attribute Analysis

Attribute-cost ratios, using the same methodology used for the baseline analysis, are presented in Figure 3-20. In general, the relative attribute-cost ratios amongst the sites did not change during the sensitivity analysis. In some cases, the relative ranking of Eastern Mesilla Basin and Distal Mesilla Basin get reversed. In addition, it is possible that if the source contribution is double what was assumed, then San Acacia could have a similar attribute-cost ratio as Truth or Consequences. The remaining relative rankings would remain the same.

3.7.5 Sensitivity: Summary

The sensitivity analysis suggests that the uncertainty associated with the source salinity contribution and percent of the source that could be captured and treated is not sufficient to alter the relative rankings of the sites based on attributes. When costs are applied, there are only two cases where relative attribute-cost ratios would change. The relative rankings of Eastern Mesilla Basin and Distal Mesilla Basin could potentially be reversed. In addition, if source salinity contribution at San Acacia is double what was assumed in the baseline analysis, it could be put on par with Truth or Consequences. Despite these two potential changes, the sensitivity analysis suggests that the sites recommended in this report would remain the preferred sites even if assumptions of source salinity are incorrect by a factor of two.

3.8 Summary of Conclusions by Site

3.8.1 San Acacia

San Acacia is the lowest-ranked site based on attributes for all management alternatives. Compared with the other sites, San Acacia has a modest source salinity contribution. However, because it is a diffuse groundwater source and only a portion of the salinity source could be captured, the potential economic benefit is relatively low. Additionally, there are potential environmental effects at San Acacia, and limited available infrastructure.

Costs for San Acacia, however, are the lowest of any of the alternatives. The relatively low costs, however, are not low enough to overcome the low attributes for RO and ED treatment. Accordingly, the attribute-cost ratio ranks near the bottom of all sites. Only El Paso WWTPs and Rio Grande have lower attribute-cost ratios for RO and ED.

TABLE 3-24
Summary of Criterion Values for San Acacia
Alternatives Analysis for the Rio Grande Salinity Management Program

	Raw			Normalized			Weighted Attribute		
Criterion	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**
Source Salinity Contribution	6.2%	6.2%	6.2%	1	1	1	0.24	0.24	0.24
Potential Economic Benefit	$230	$210	$250	0.2	0.2	1.2	0.06	0.06	0.32
Management Alternative Operational Complexity	3.5	2.5	1.5	0.6	0.8	3.5	0.12	0.16	0.6
Environmental Effects	2	2	2	0	0	0	0	0	0
Availability of Infrastructure	5	5	5	0	0	0	0	0	0

TABLE 3-25
Summary of Costs for San Acacia
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Capture & Conveyance	Treatment	Disposal	O&M	Net Present Worth Cost
Management Alternative: RO	$539,000	$956,000	$619,000	$164,000	$4,424,760
Management Alternative: ED	$539,000	$956,000	$619,000	$125,000	$3,875,250
Management Alternative: Evap Ponds + NTS	$539,000	NA	$11,440,000	$46,000	$12,627,140

TABLE 3-26
Attribute-Cost Summary for San Acacia
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Normalized Cost	Attribute	Attribute:Cost
Management Alternative: RO	1.0	0.41	0.4
Management Alternative: ED	1.0	0.45	0.5
Management Alternative: Evap Ponds + NTS	1.12	1.23	1.1

3.8.2 Truth or Consequences

Truth or Consequences ranks in the lower-middle in attribute scores. Attribute scores are similar to Fabens, and are higher than San Acacia and Eastern Mesilla Basin. Although the source salinity contribution is amongst the lowest of the sites (only Eastern Mesilla Basin scores lower), because it is a surface source and 100 percent of the source could be captured and treated, it ranks among the middle for potential economic benefit. It scores similar to other sites in operational complexity, has no known environmental issues, and ranks in the middle on availability of infrastructure.

Cost estimates for Truth or Consequences also generally rank in the middle. The combination of attributes and cost result in an attribute-cost ratio that ranks fourth, behind Fabens, Distal Mesilla Basin, and Eastern Mesilla Basin.

Truth or Consequences has the advantage of being a relatively well-quantified source that, as defined here, is a surface flow that would be easy to capture. The economic benefits and cost associated with Truth or Consequences are both modest, resulting in it being a reasonable site to pursue further.

TABLE 3-27
Summary of Criterion Values for Truth or Consequences
Alternatives Analysis for the Rio Grande Salinity Management Program

	Raw			Normalized			Attribute		
Criterion	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**
Source Salinity Contribution	2.3%	2.3%	2.35	0.4	0.4	0.4	0.09	0.09	0.09
Potential Economic Benefit	$420	$390	$460	0.4	0.4	2.2	0.10	0.11	0.60
Management Alternative Operational Complexity	3.5	2.5	1.5	1	0.6	3.5	0.12	0.16	0.67
Environmental Effects	0	0	0	5	5	5	0.80	0.80	0.80
Availability of Infrastructure	3	3	3	2	2	2	0.30	0.30	0.30

TABLE 3-28
Summary of Costs for Truth or Consequences
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Capture & Conveyance	Treatment	Disposal	O&M	Net Present Worth Cost
Management Alternative: RO	$15,000	$1,670,000	$1,965,000	$477,000	$10,370,930
Management Alternative: ED	$15,000	$1,670,000	$1,965,000	$346,000	$8,525,140
Management Alternative: Evap Ponds + NTS	$15,000	NA	$37,752,000	$113,000	$39,359,170

TABLE 3-29
Attribute-Cost Summary for Truth or Consequences
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Normalized Cost	Attribute	Attribute:Cost
Management Alternative: RO	2.3	1.41	0.6
Management Alternative: ED	2.2	1.45	0.7
Management Alternative: Evap Ponds + NTS	3.5	2.45	0.7

3.8.3 Eastern Mesilla Basin

Eastern Mesilla Basin ranks near the bottom in attribute scores, only above San Acacia. It has the lowest source salinity contribution and the lowest potential economic benefit. It should be noted that the low economic benefit is due in part to low source salinity and low percent capture of that salinity, but the salinity model also suggest that only about half of the mass removal at the site would be observed as reduced mass load in the Rio Grande (see Appendix B). This is consistent with the uncertain connection between the site and the Rio Grande. The bulk of Eastern Mesilla Basin's attribute scores come from the lack of environmental effect and the availability of infrastructure.

Despite Eastern Mesilla Basin's low attribute score, the cost is relatively low, primarily because the treatment system would be small so treatment capital and O&M costs are the lowest of any site. This results in a attribute-cost ratio that ranks among near the top; only Distal Mesilla Basin and Fabens have higher attribute-cost ratios. However, because the source salinity contribution and economic benefit are so low, and the connection to the Rio Grande is uncertain, this site is not recommended despite the relatively high attribute-cost ratio.

TABLE 3-30
Summary of Criterion Values for Eastern Mesilla Basin
Alternatives Analysis for the Rio Grande Salinity Management Program

	Raw			Normalized			Attribute		
Criterion	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**
Source Salinity Contribution	1.3%	1.3%	1.3%	0.2	0.2	0.2	0.05	0.05	0.05
Potential Economic Benefit	$10	$10	$10	0	0.0	0.1	0.00	0.0	0.02
Management Alternative Operational Complexity	3.5	2.5	1.5	0.6	0.8	3.5	0.12	0.16	0.67
Environmental Effects	0	0	0	5	5	5	0.80	0.80	0.80
Availability of Infrastructure	3	3	3	2	4	4	0.30	0.30	0.30

TABLE 3-31
Summary of Costs for Eastern Mesilla Basin
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Capture & Conveyance	Treatment	Disposal	O&M	Net Present Worth Cost
Management Alternative: RO	$3,004,000	$666,000	$424,000	$120,000	$5,785,000
Management Alternative: ED	$3,004,000	$665,655	$424,000	$94,000	$6,129,460
Management Alternative: Evap Ponds + NTS	$3,004,000	NA	$7,659,000	$41,000	$11,240,690

TABLE 3-32
Attribute-Cost Summary for Eastern Mesilla Basin
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Normalized Cost	Attribute	Attribute:Cost
Management Alternative: RO	1.3	1.27	1.0
Management Alternative: ED	1.58	1.31	0.8
Management Alternative: Evap Ponds + NTS	1.0	1.83	1.8

3.8.4 Distal Mesilla Basin

Distal Mesilla Basin ranks near the highest of all sites in attribute scores, generally ranking second only to El Paso WWTPs. Distal Mesilla Basin scores high on attributes in large part because the source salinity is the second highest behind El Paso WWTPs. Economic benefit is also significant, even though it is a diffuse source; it was assumed that 30 percent of the source could be captured and treated. Infrastructure is readily available, and there are no known potential endangered species.

Cost estimates for Distal Mesilla Basin are the highest aside from the large treatment options at the Rio Grande at Las Cruces and El Paso WWTPs, but are not appreciably higher than other sites such as Truth or Consequences. Accordingly, the attribute-cost ratio ranks amongst the highest of all the sites, only behind Fabens. It should be noted that cost estimates were conservative with respect to treatment plant size. While mass flux is relatively well quantified, how that flux is apportioned into flow rates and concentration is not as well quantified. Relatively high flow and low concentration were assumed for salinity capture, resulting in a conservative cost estimate. If salinity could be captured with lower flows and higher concentrations, the attribute-cost ratio would improve further.

Distal Mesilla Basin ranks near the highest of all sites in attribute scores, generally ranking second only to El Paso WWTPs. Distal Mesilla Basin scores high on attributes in large part because the source salinity is the second highest behind El Paso WWTPs. Economic benefit

is also significant, even though it is a diffuse source; it was assumed that 30 percent of the source could be captured and treated. Infrastructure is readily available, and there are no known potential endangered species.

Cost estimates for Distal Mesilla Basin are the highest aside from the large treatment options at the Rio Grande at Las Cruces and El Paso WWTPs, but are not appreciably higher than other sites such as Truth or Consequences. Accordingly, the attribute-cost ratio ranks amongst the highest of all the sites (generally third, behind Eastern Mesilla Basin and Fabens). It should be noted that cost estimates were conservative with respect to treatment plant size. While mass flux is relatively well quantified, how that flux is apportioned into flow rates and concentration is not as well quantified. Relatively high flow and low concentration were assumed for salinity capture, resulting in a conservative cost estimate. If salinity could be captured with lower flows and higher concentrations, the attribute-cost ratio would improve further.

While Distal Mesilla Basin appears to be a favorable site, additional work should be performed to quantify the mass flux and potential source salinity capture. Additionally, the site is in a highly developed area, and feasibility of siting a capture and treatment system needs to be evaluated further.

TABLE 3-33
Summary of Criterion Values for Distal Mesilla Basin
Alternatives Analysis for the Rio Grande Salinity Management Program

	Raw			Normalized			Attribute		
Criterion	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**
Source Salinity Contribution	11.5%	11.5%	11.5%	1.9	1.9	1.9	0.44	0.44	0.44
Potential Economic Benefit	$700	$650	$770	0.6	0.7	3.7	0.17	0.18	1.0
Management Alternative Operational Complexity	3.5	2.5	1.5	1	0.8	3.5	0.12	0.16	0.67
Environmental Effects	0	0	0	5	5	5	0.80	0.80	0.80
Availability of Infrastructure	1	1	1	4	4	4	0.60	0.60	0.60

TABLE 3-34
Summary of Costs for Distal Mesilla Basin
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Capture & Conveyance	Treatment	Disposal	O&M	Net Present Worth Cost
Management Alternative: RO	$871,000	$1,670,000	$1,965,000	$477,000	$11,226,930
Management Alternative: ED	$871,000	$1,670,000	$1,965,000	$346,000	$9,381,140
Management Alternative: Evap Ponds + NTS	$871,000	NA	$37,752,000	$113,000	$40,215,170

TABLE 3-35
Attribute-Cost Summary for Distal Mesilla Basin
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Normalized Cost	Attribute	Attribute:Cost
Management Alternative: RO	2.5	2.13	0.8
Management Alternative: ED	2.4	2.17	0.9
Management Alternative: Evap Ponds + NTS	3.6	3.5	1.0

3.8.5 El Paso WWTPs

El Paso WWTPs rank the highest in attribute scores, primarily because source salinity contribution and potential economic benefit are the highest. However, the amount of water that would need to be treated is very large, and treatment costs are the highest of any of the sites. Due to the high costs, which are nearly two orders of magnitude greater than at the lowest-cost sites, the attribute-cost ratio ranks second lowest only to the Rio Grande at Las Cruces option. Accordingly, this site is not recommended for further investigation.

TABLE 3-36
Summary of Criterion Values for El Paso WWTPs
Alternatives Analysis for the Rio Grande Salinity Management Program

	Raw			Normalized			Attribute		
Criterion	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**
Source Salinity Contribution	30.2%	30.2%	30.2%	5.0	5.0	5.0	1.15	1.15	1.15
Potential Economic Benefit	$5,470	$5,000	$290	5.0	5.0	1.4	1.35	1.35	0.38
Management Alternative Operational Complexity	4.0	3.0	5.0	0	0	0.0	0	0.0	0.0
Environmental Effects	0	0	0	5	5	5	0.8	0.8	0.8
Availability of Infrastructure	1	1	1	4	4	4	0.6	0.6	0.6

TABLE 3-37
Summary of Costs for El Paso WWTPs
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Capture & Conveyance	Treatment	Disposal	O&M	Net Present Worth Cost
Management Alternative: RO	NA	$150,304,000	$81,540,000	$6,645,000	$325,472,000
Management Alternative: ED	NA	$150,304,000	$81,540,000	$7,238,000	$333,827,420
Management Alternative: Evap Ponds + NTS	NA	NA	NA	NA	NA

TABLE 3-38
Attribute-Cost Summary for El Paso WWTPs
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Normalized Cost	Attribute	Attribute:Cost
Management Alternative: RO	74.3	3.9	0.1
Management Alternative: ED	86	3.9	0.0
Management Alternative: Evap Ponds + NTS	NA	NA	NA

3.8.6 Fabens

Fabens generally ranks in the middle with respect to attribute scores. It is similar to Truth or Consequences, and lower than El Paso WWTPs, the Rio Grande at Las Cruces, and Distal Mesilla Basin. Fabens scores relatively high on source salinity contribution, and near the middle for potential economic benefit. It should be noted, however, that quantification of both of these criteria is much more uncertain than at other sites. Fabens scores poorly for availability of infrastructure, and is comparable to other sites in complexity and environmental effects.

The cost estimates for Fabens is relatively low, and is only higher than San Acacia and Eastern Mesilla Basin. The combination of cost and attribute, however, results in an attribute-cost score that is the highest of any of the sites.

The high attribute-cost ratio suggests that this site should be carried forward for further analysis. The attributes of the site are relatively clear in that it is a localized potentially significant salinity source, and the bypass alternative potentially involves no treatment costs. However, there is uncertainty associated with the source salinity contribution and the potential economic benefits would be restricted to Hudspeth County irrigation. These factors should be further evaluated to better define the potential benefit of salinity control at this site.

TABLE 3-39
Summary of Criterion Values for Fabens
Alternatives Analysis for the Rio Grande Salinity Management Program

	Raw			Normalized			Attribute		
Criterion	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**
Source Salinity Contribution	11.2%	11.2%	11.2%	1.9	1.9	1.9	0.43	0.43	0.43
Potential Economic Benefit	$400	$370	$370	0.4	0.4	1.8	0.1	0.1	0.48
Management Alternative Operational Complexity	3.5	2.5	1.5	0.6	0.8	3.5	0.12	0.16	0.67
Environmental Effects	0	0	0	5	5	5	0.8	0.8	0.8
Availability of Infrastructure	5	5	5	0	0	0	0	0	0

TABLE 3-40
Summary of Costs for Fabens
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Capture & Conveyance	Treatment	Disposal	O&M	Net Present Worth Cost
Management Alternative: RO	$1,106,160	$740,000	$1,006,000	$253,000	$6,410,930
Management Alternative: ED	$15,000	$740,000	$1,006,000	$187,000	$5,480,990
Management Alternative: Evap Ponds + NTS	$1,100,160	$0	$18,962,000	$86,000	$21,273,090
Management Alternative: Fabens Bypass	$1,100,160	$0	$0	$60,000	$1.945.560

TABLE 3-41
Attribute-Cost Summary for Fabens
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Normalized Cost	Attribute	Attribute:Cost
Management Alternative: RO	1.5	1.44	1.0
Management Alternative: ED	1.4	1.48	1.0
Management Alternative: Evap Ponds + NTS	1.9	2.4	1.3
Management Alternative: Fabens Bypass	0.15	2.4	15

3.8.7 Rio Grande Near Las Cruces

The Rio Grande near Las Cruces site has attribute scores that rank behind El Paso WWTPs and Distal Mesilla Basin for RO and ED. An evaporative disposal alternative was not estimated for this site, given the infeasibly large area requirements. One of the key criteria that cause this site to rank highly is the potential economic benefit, which is second only to El Paso WWTPs. The source salinity contribution is also relatively high, while other criteria are comparable to other sites. Because this site would be treated during the non-irrigation season, the economic benefit was evaluated differently than the rest of the sites, although it still relied on work done by Michelsen, et al (2009a, 2009b).

The cost of treatment at this site is the second highest cost (El Paso WWTPs is first), and is over an order of magnitude greater than the next highest cost. The result is a low attribute-cost ratio. Accordingly, this site is not recommended for further evaluation moving forward.

TABLE 3-42
Summary of Criterion Values for Rio Grande Near Las Cruces
Alternatives Analysis for the Rio Grande Salinity Management Program

	Raw			Normalized			Attribute		
Criterion	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**	**RO**	**ED**	**Evap + NTS**
Source Salinity Contribution	8.6%	8.6%	8.6%	1.4	1.4	1.4	0.33	0.33	0.33
Potential Economic Benefit	$1,040	$1,040	$1,040	1.0	1.0	5.0	0.26	0.28	1.35
Management Alternative Operational Complexity	4	3	5	0	0	0	0	0	0.0
Environmental Effects	0	0	0	5	5	5	0.80	0.80	0.80
Availability of Infrastructure	1	1	1	4	4	4	0.60	0.60	0.60

TABLE 3-43
Summary of Costs for Rio Grande Near Las Cruces
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Capture & Conveyance	Treatment	Disposal	O&M	Net Present Worth Cost
Management Alternative: RO	NA	$94,325,000	$75,540,000	$3,430,000	$218,194,700
Management Alternative: ED		$94,325,000	$75,540,000	$3,343,000	$216,967,870
Management Alternative: Evap Ponds + NTS	NA	NA	NA	NA	NA

TABLE 3-44
Attribute-Cost Summary for Rio Grande Near Las Cruces
Alternatives Analysis for the Rio Grande Salinity Management Program

Management Alternative	Normalized Cost	Attribute	Attribute:Cost
Management Alternative: RO	49.3	1.98	0.0
Management Alternative: ED	59	2.0	0.0
Management Alternative: Evap Ponds + NTS	NA	NA	NA

3.9 Summary

The analysis of attribute scores of the different site alternatives yielded distinct groups ranked in descending order of ranges: El Paso WWTPs (2.9-3.9) > Distal Mesilla Basin (2.1-3.5) and Rio Grande near Las Cruces (2.0-3.1) > Truth or Consequences, Fabens and Eastern Mesilla Basin (1.4-2.4) > San Acacia (0.4-1.2). This ranking is weighted by the relatively greater importance of salinity source contribution and potential economic benefit (Table 3-45).

From these results, the four sites with the highest attribute-to-cost ratios are Distal Mesilla Basin, Eastern Mesilla Basin, Fabens, and Truth or Consequences. Results of sensitivity analysis indicated a ranking of Distal Mesilla Basin, Fabens, and Truth or Consequences, in a descending order of attributes. Considering attribute-to-cost ratios and non-monetary attributes together, it is recommended that three sites be considered for further investigation are: Distal Mesilla Basin, Truth or Consequences, and Fabens.

TABLE 3-45
Summary of Management Alternatives Attribute-to-Cost Ratios, Attributes and Recommended Ranking
Alternatives Analysis for the Rio Grande Salinity Management Program

Site	Management Alternative 1	Management Alternative 2	Management Alternative 3	(A) Average Treatment Attribute-to-Cost Ratio	(B) Average Treatment Attribute	Recommended Rank*		
						A	B	Final
Distal Mesilla Basin	0.8	0.9	1.0	0.85	2.25	2	1	1
Fabens	1.0	1.0	1.3	1.0	1.56	3	2	2
Truth or Consequences	0.6	0.7	0.7	0.65	1.53	3	3	3
Eastern Mesilla Basin	1.0	0.8	1.8	0.9	1.39	1	4	e
San Acacia	0.4	0.5	1.1	0.45	0.53	4	5	e
Rio Grande near Las Cruces	0.1	0.0	NA	0.0	2.0	e	e	e
El Paso WWTPs	0.0	0.0	NA	0.0	3.9	e	e	e

* “A” is the ranking of each site in descending order by Average Treatment Attribute-to-Cost Ratio under Column A. “B” is the ranking of each site in descending order by Average Treatment Attribute under Column B. “Final” is the recommended rank. “e” excluded from final screening;

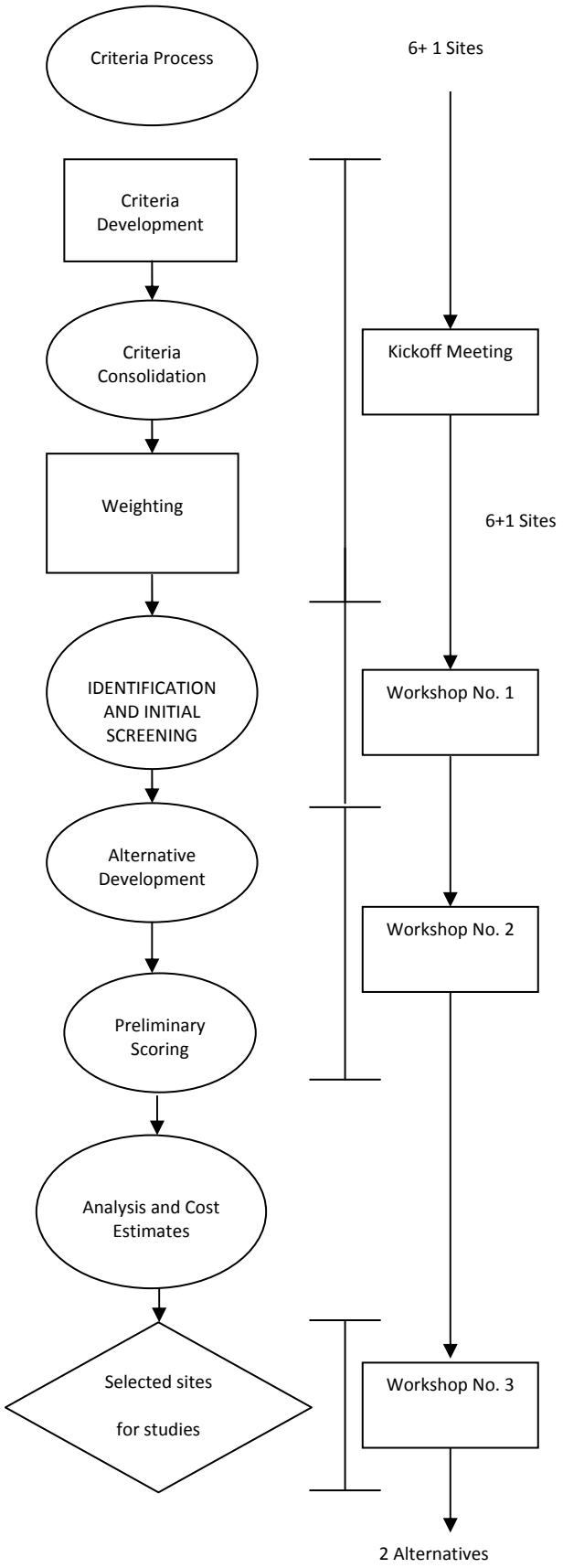


FIGURE 3-1
Site Selection Decision Process
Alternatives Analysis for the Rio Grande Salinity Management Program

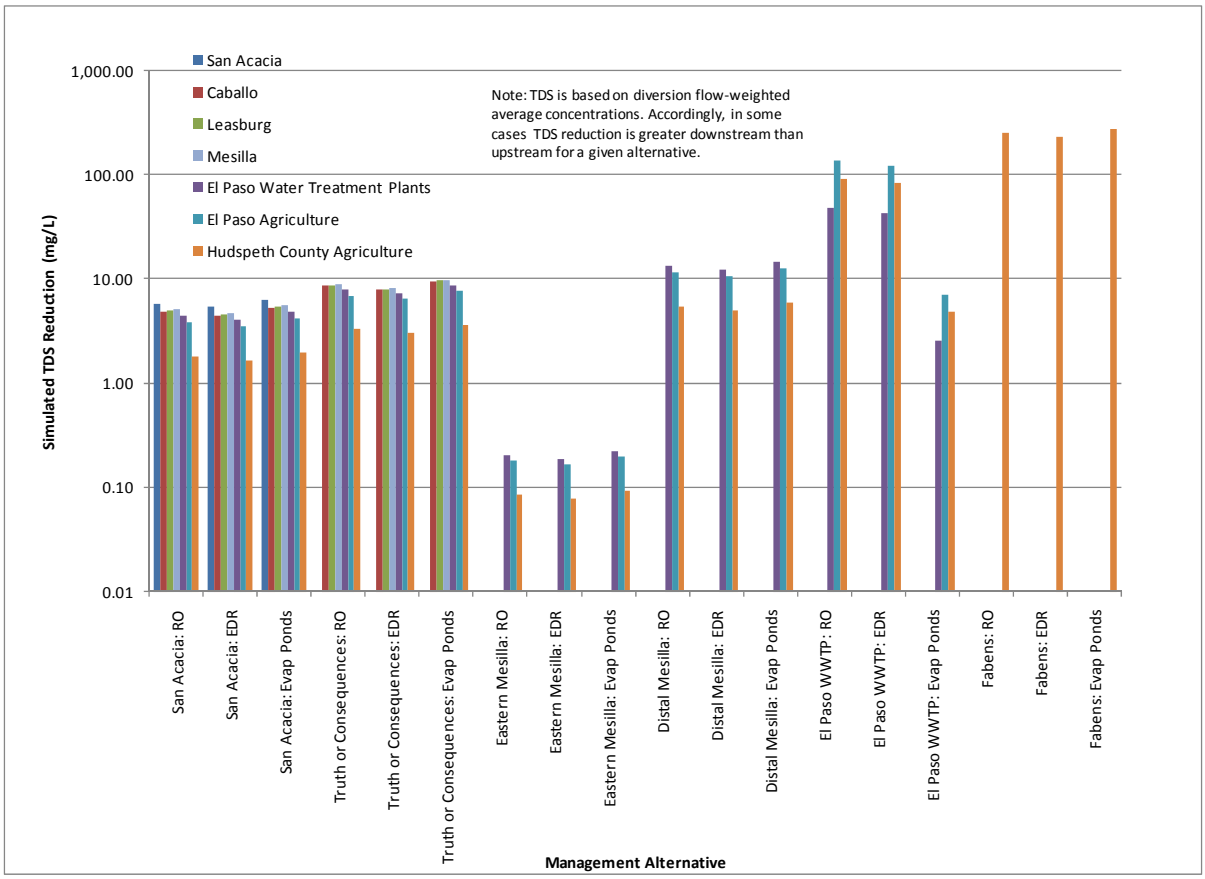


FIGURE 3-2
Results: TDS Reduction
Alternatives Analysis for the Rio Grande Salinity Management Program

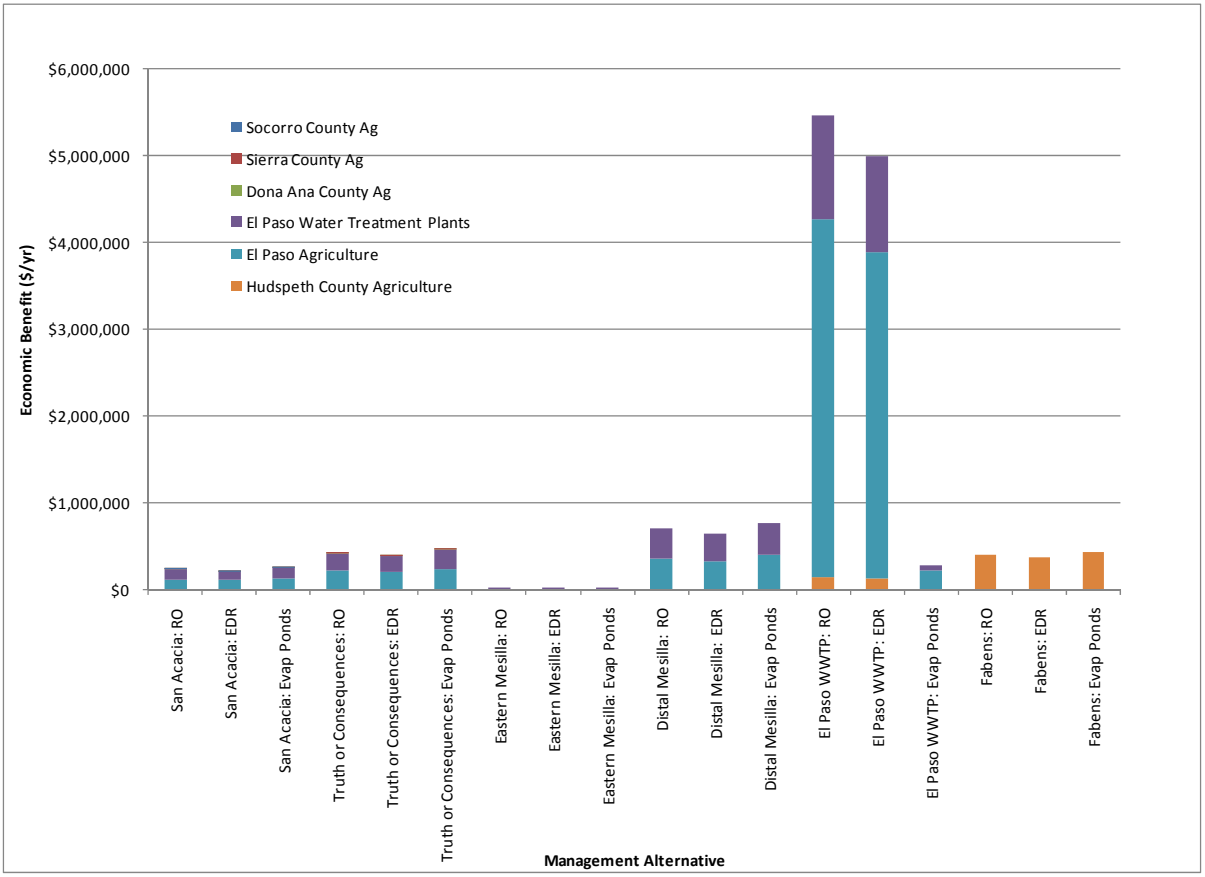


FIGURE 3-3
Results: Economic Benefits
Alternatives Analysis for the Rio Grande Salinity Management Program

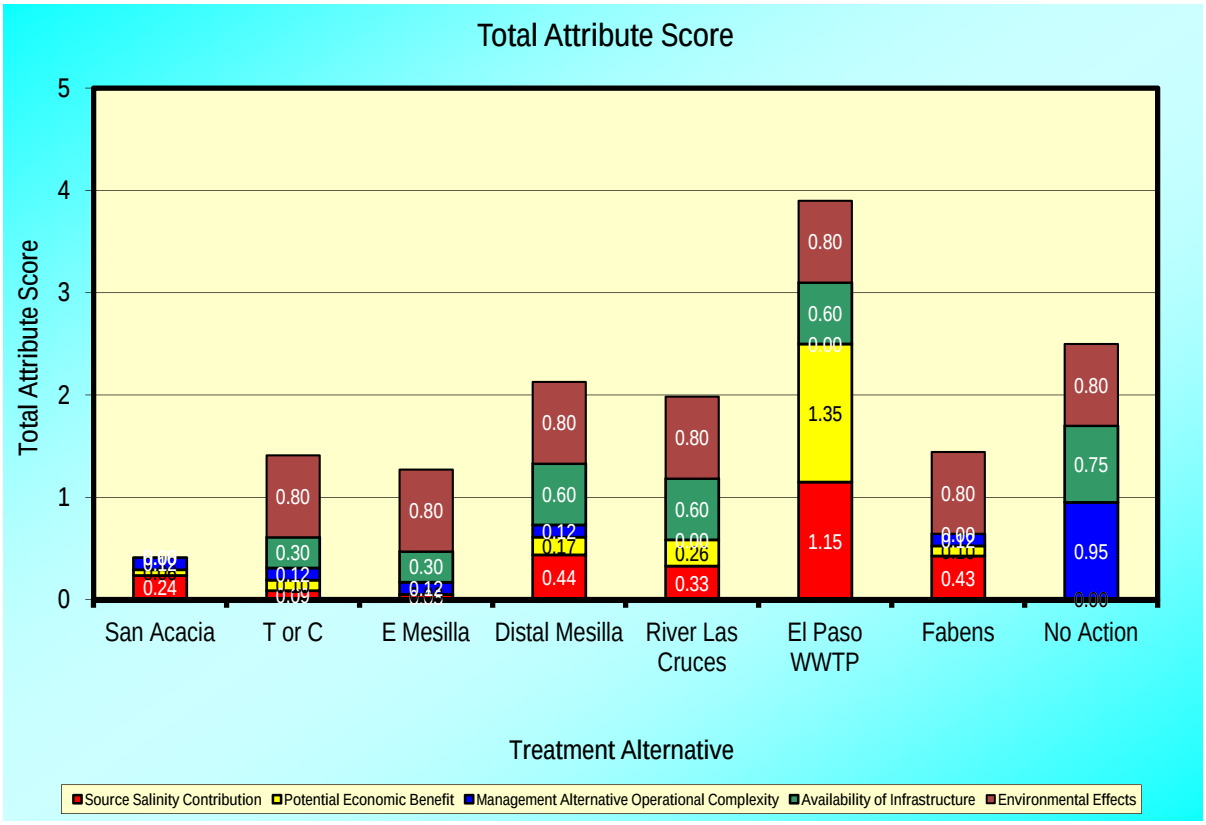


FIGURE 3-4
Attribute Score Summary, Management Alternative No. 1: RO Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

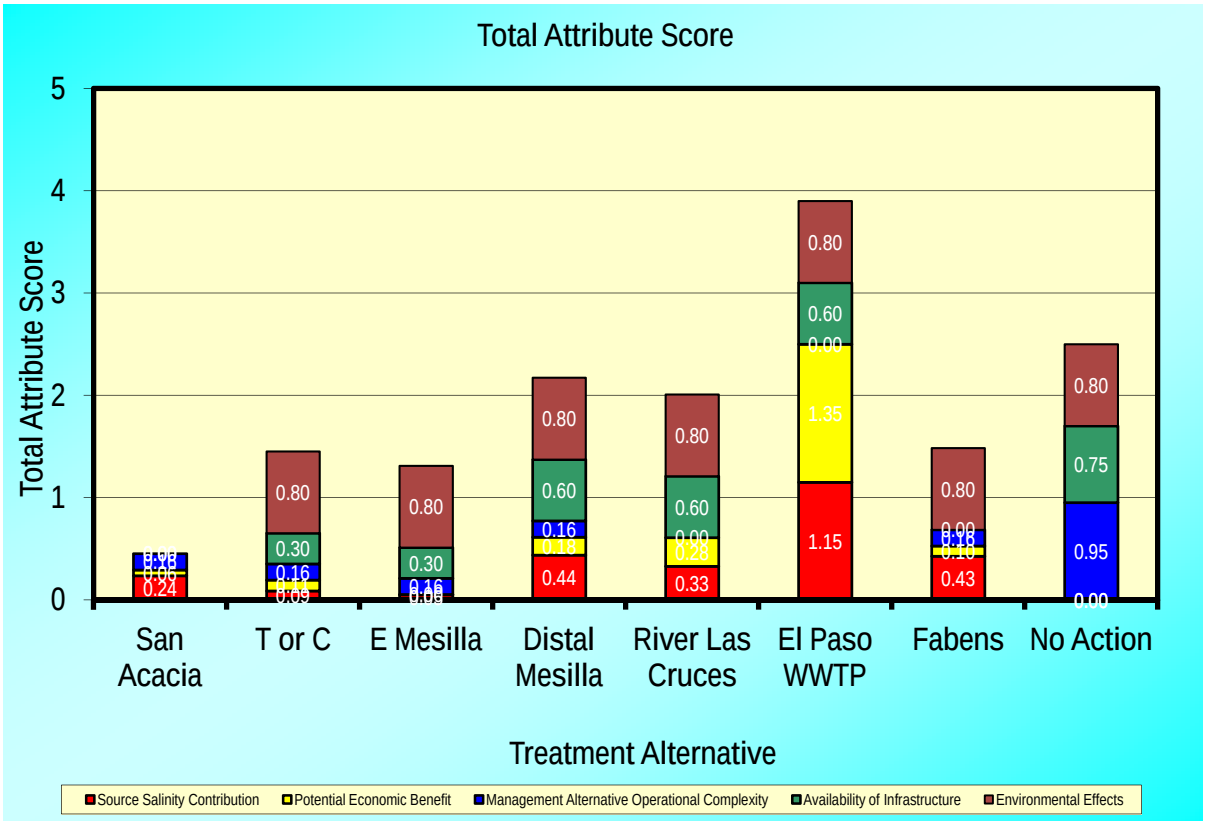


FIGURE 3-5
Attribute Score Summary, Management Alternative No. 2: ED Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

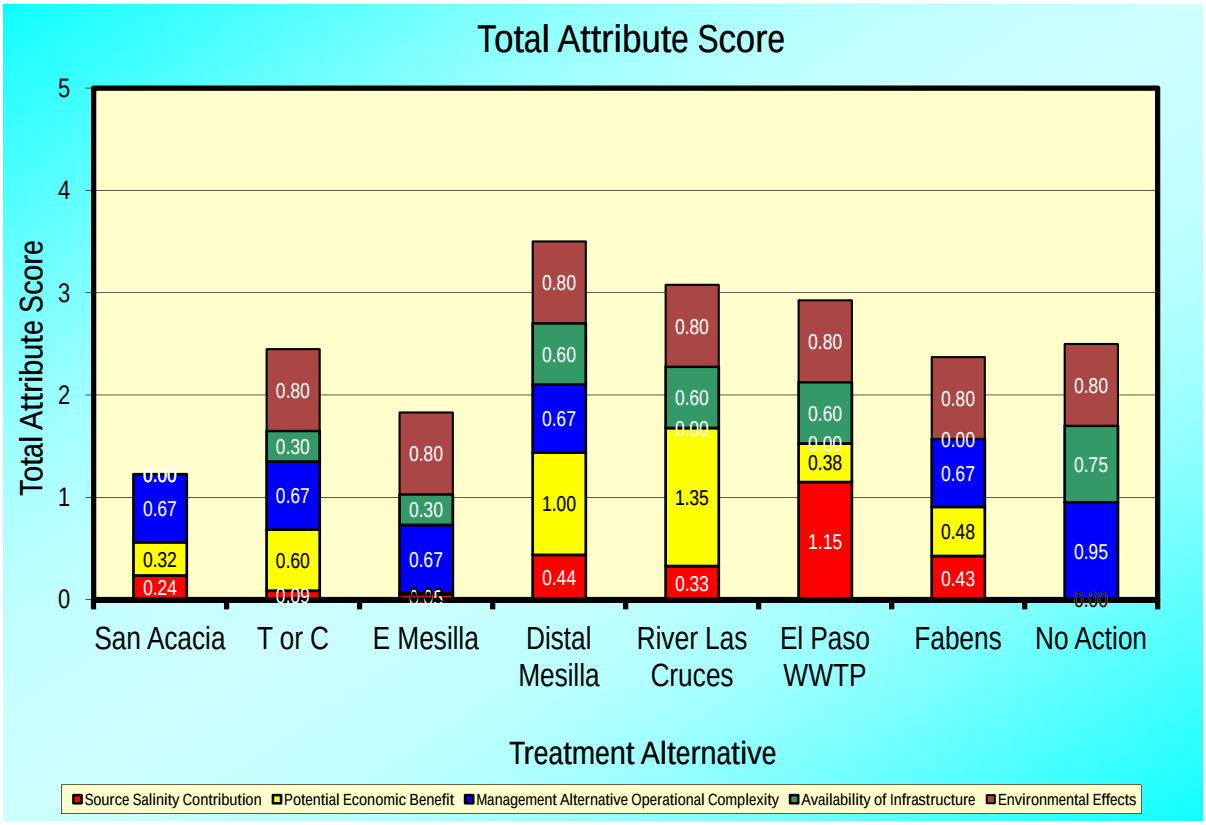


FIGURE 3-6
Attribute Score Summary, Management Alternative No. 3: Evaporative Disposal
Alternatives Analysis for the Rio Grande Salinity Management Program

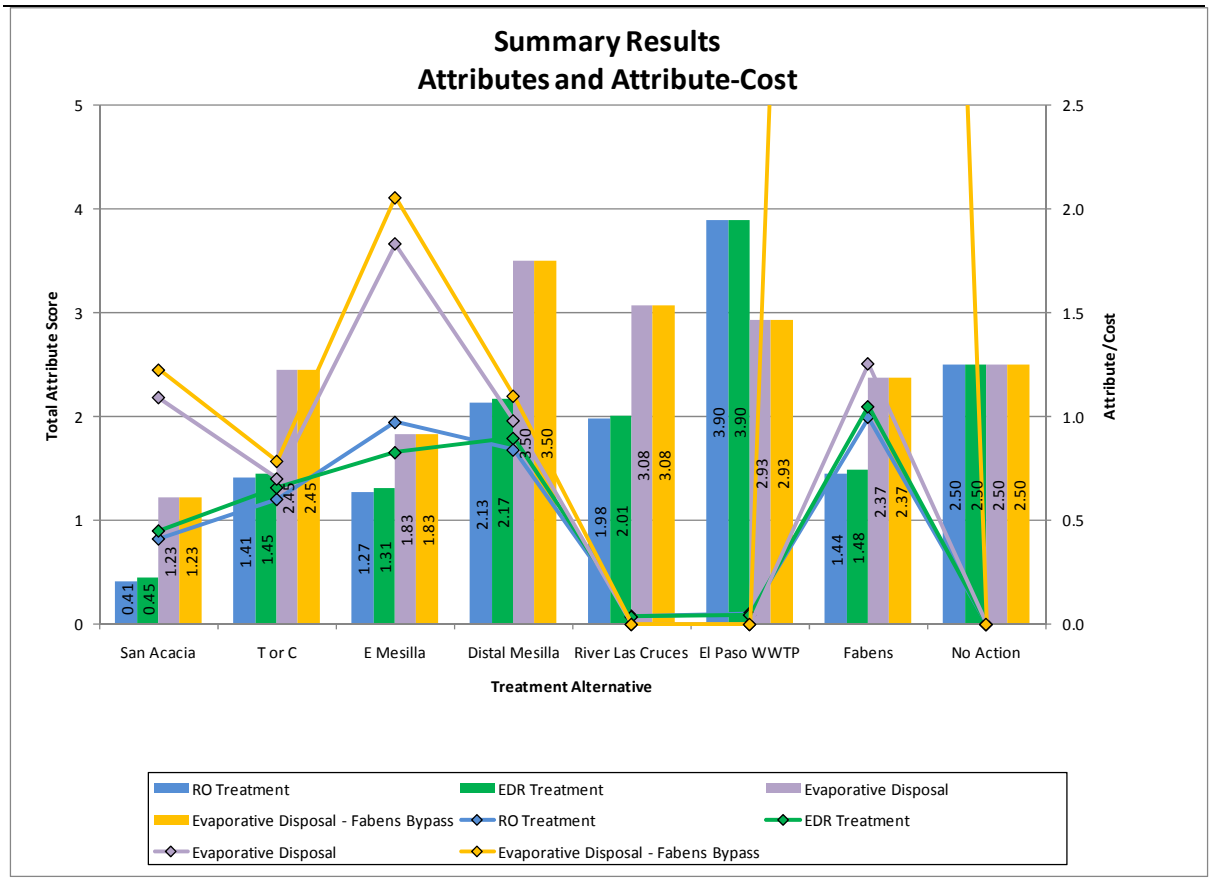


FIGURE3-7
Attribute-Cost Summary by Management Alternative
Alternatives Analysis for the Rio Grande Salinity Management Program

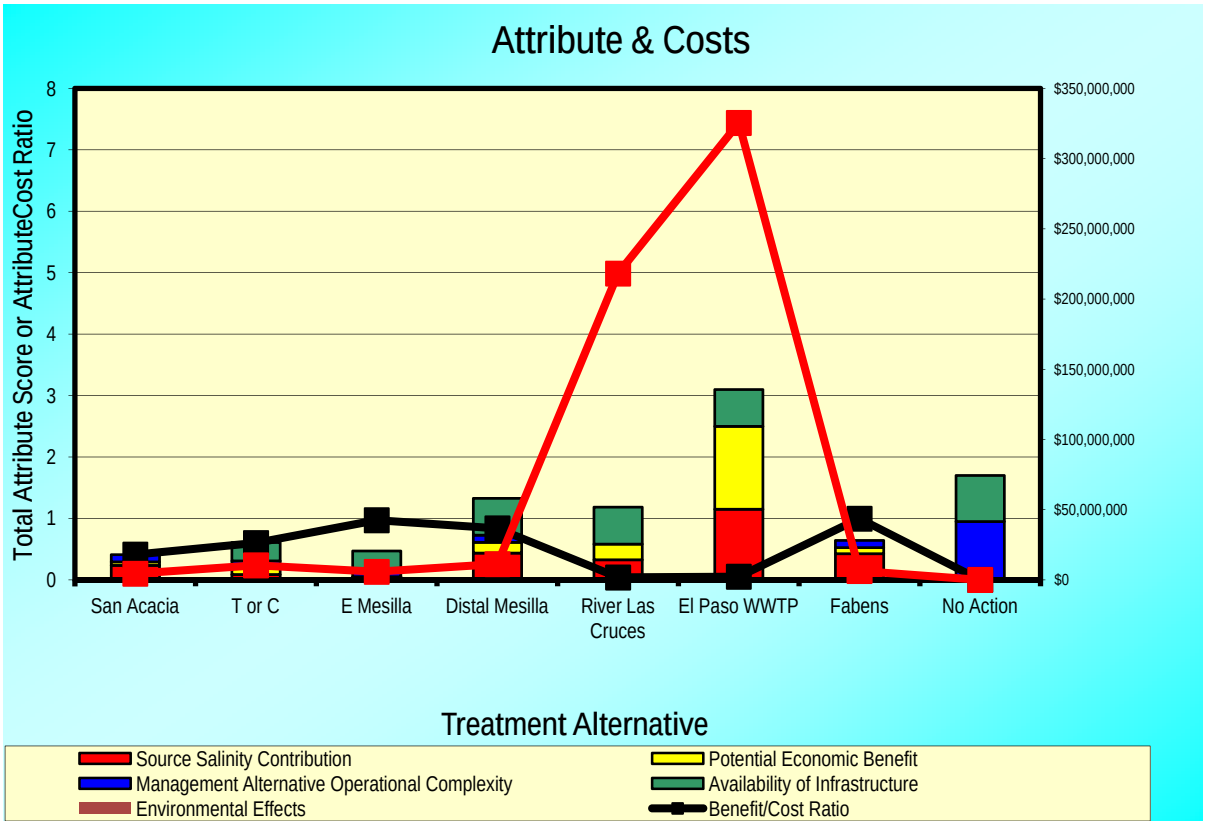


FIGURE 3-8
Attribute-to-Cost Summary, Management Alternative 1: RO Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

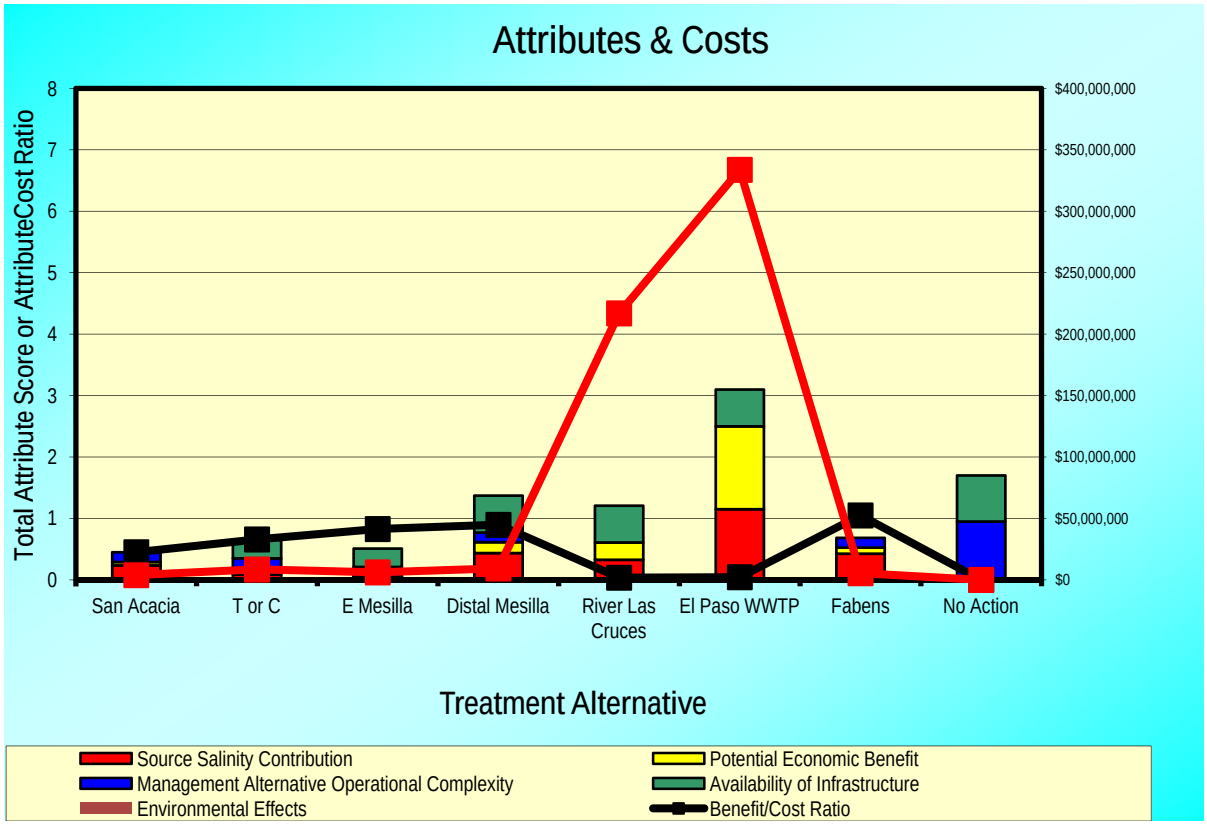


FIGURE 3-9

Attribute-to-Cost Summary, Management Alternative 2: ED Treatment

Alternatives Analysis for the Rio Grande Salinity Management Program

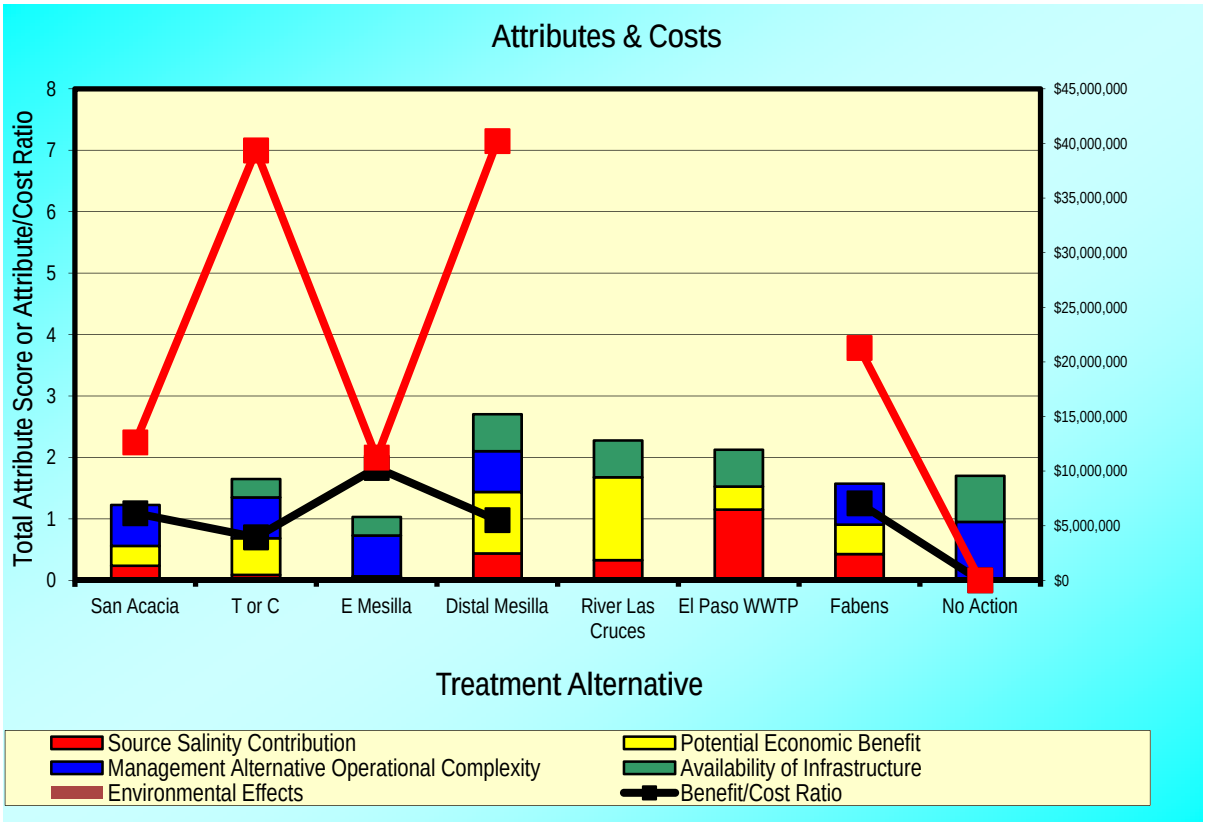


FIGURE 3-10
Attribute-to-Cost Summary, Management Alternative 3: Evaporative Disposal
Alternatives Analysis for the Rio Grande Salinity Management Program

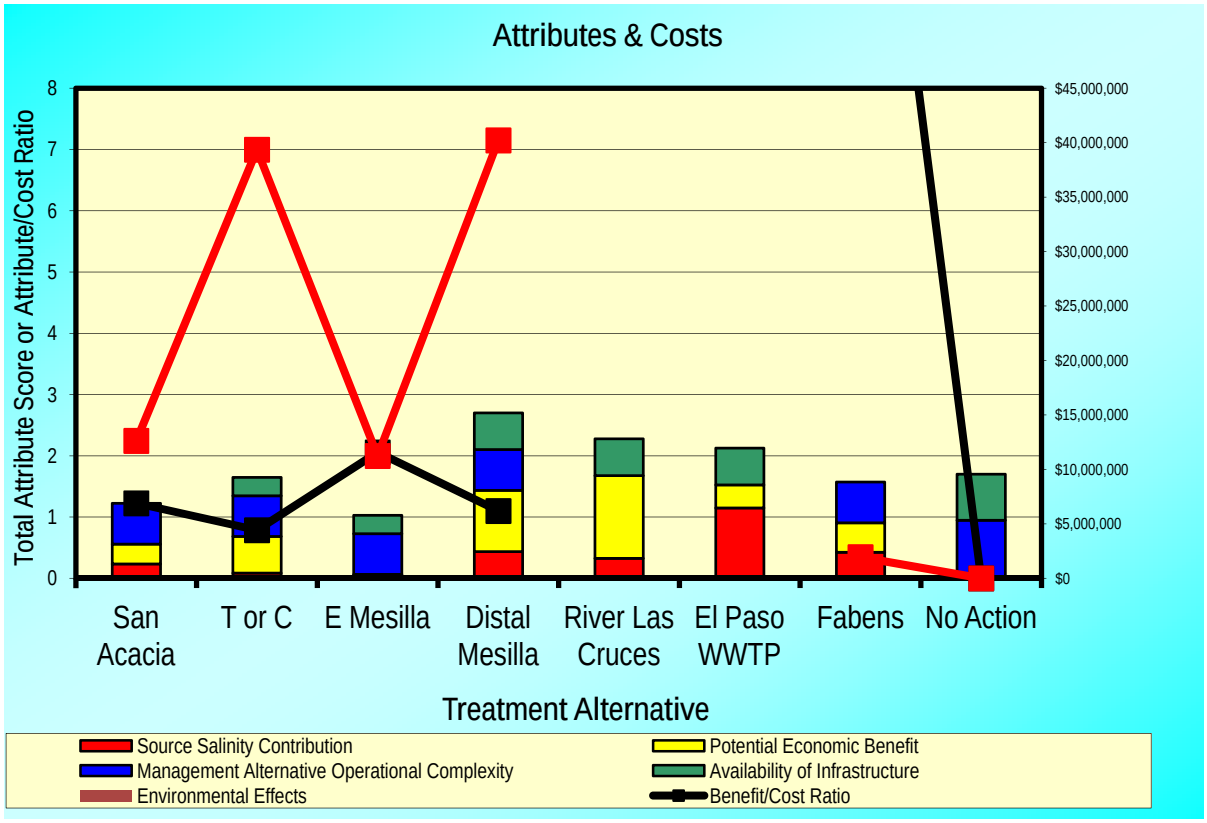


FIGURE 3-11
Attribute-to-Cost Summary, Management Alternative 3: Evaporative Disposal – Fabens Bypass Alternate
Alternatives Analysis for the Rio Grande Salinity Management Program

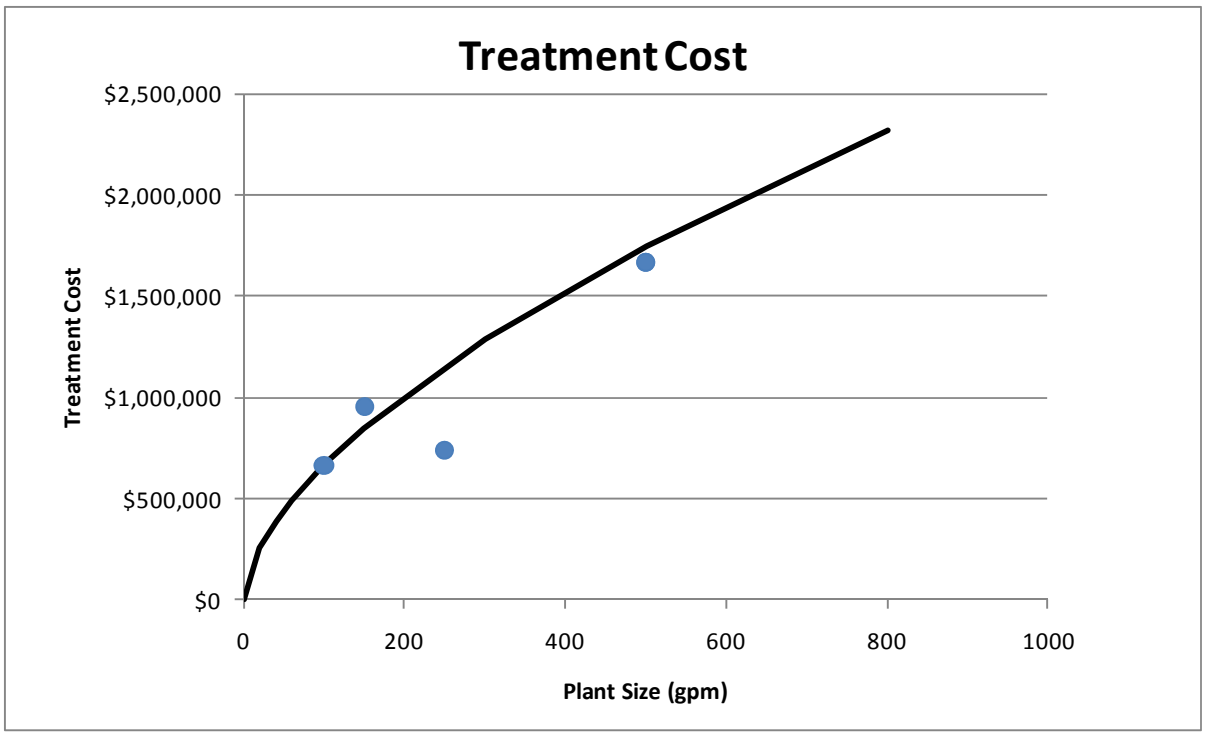


FIGURE 3-12
Cost Curve: Treatment
Alternatives Analysis for the Rio Grande Salinity Management Program

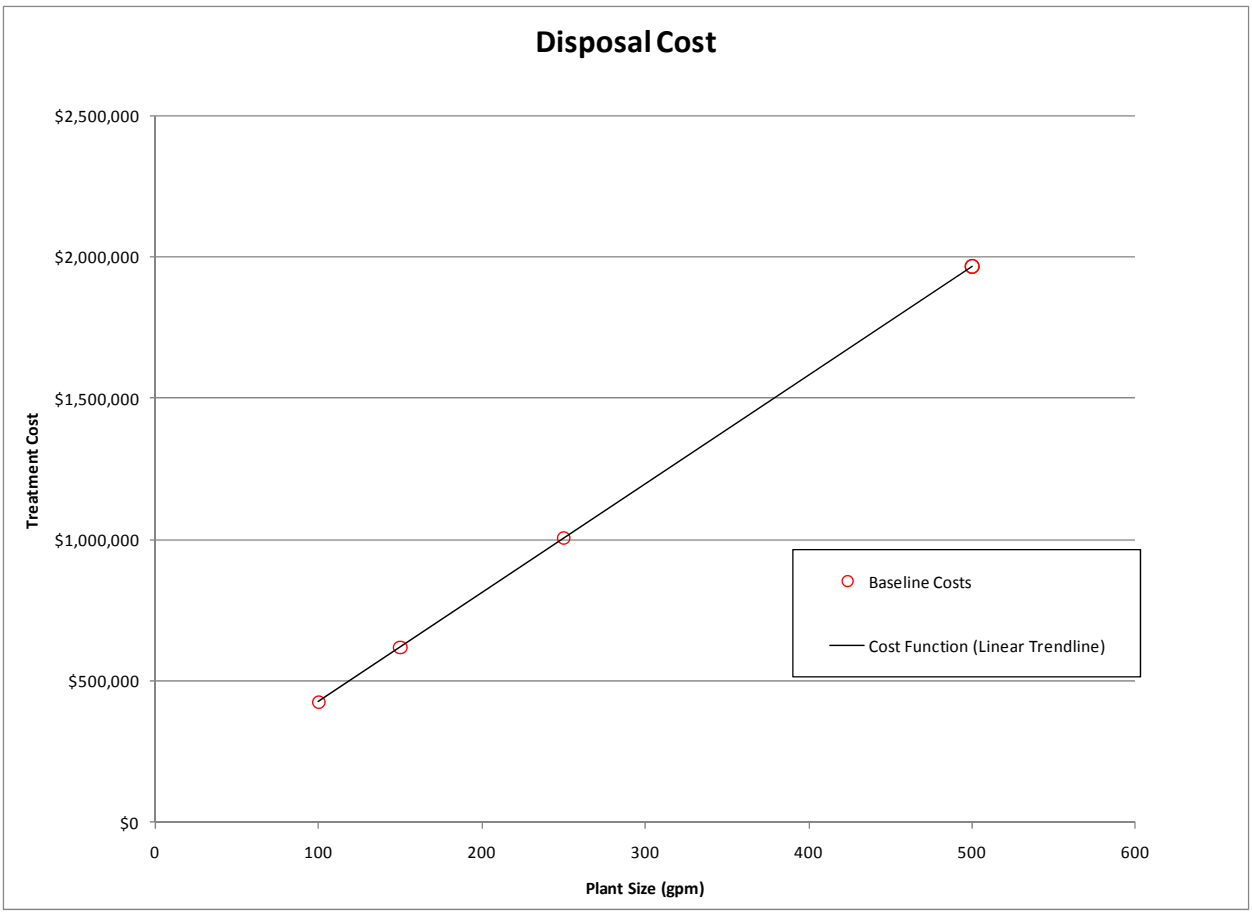


FIGURE 3-13
Cost Curve: Disposal
Alternatives Analysis for the Rio Grande Salinity Management Program

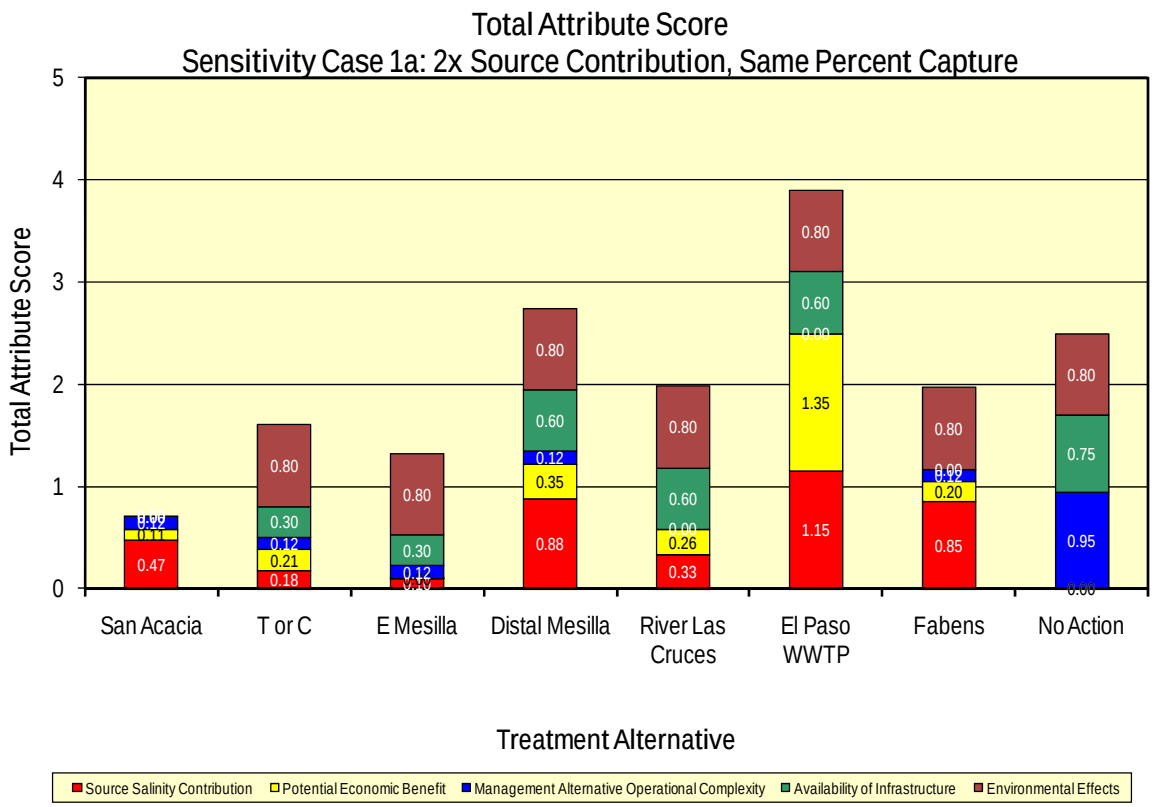


FIGURE 3-14
Attribute Scores, Sensitivity Case 1a
Alternatives Analysis for the Rio Grande Salinity Management Program

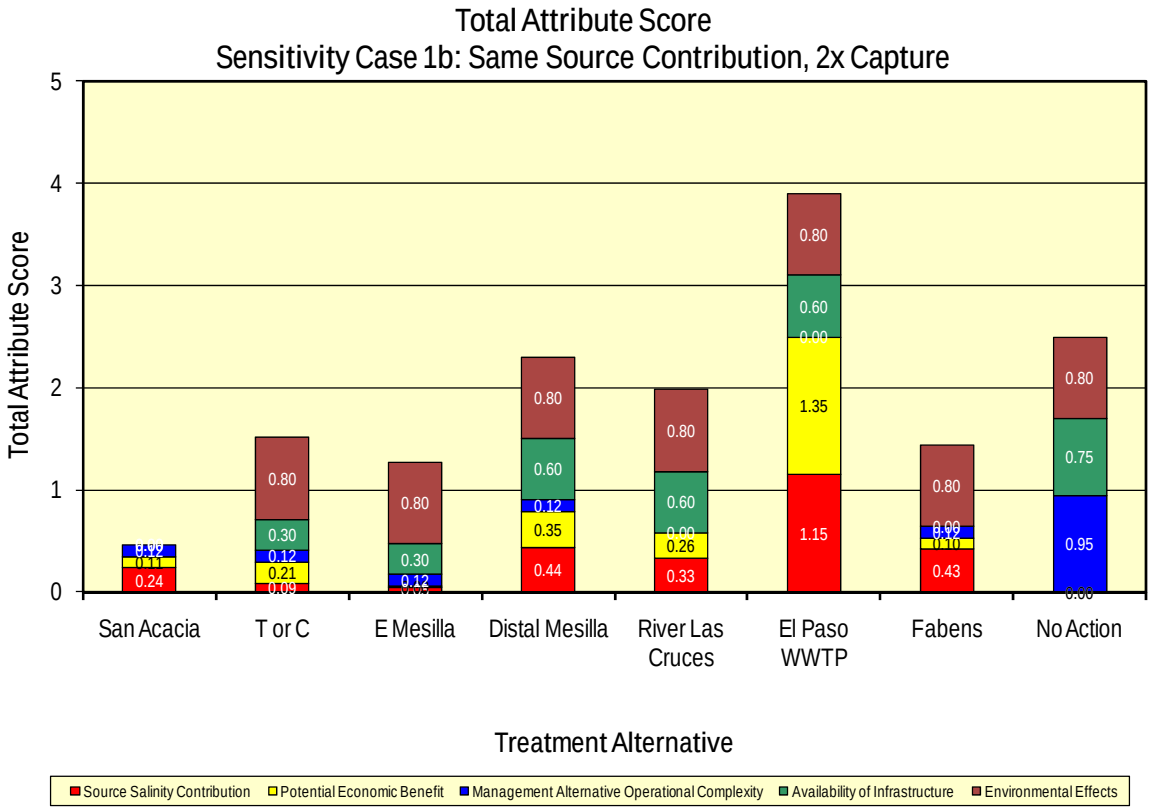


FIGURE 3-15
Attribute Scores, Sensitivity Case 1b
Alternatives Analysis for the Rio Grande Salinity Management Program

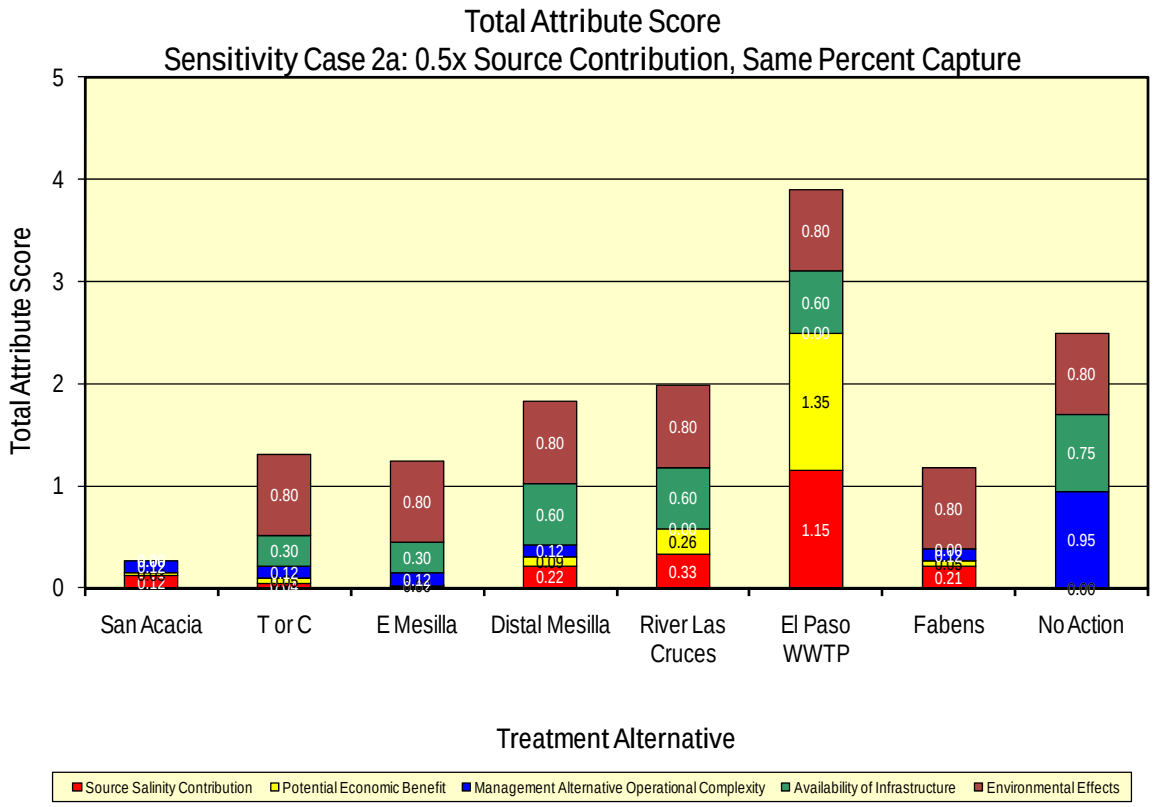


FIGURE 3-16
Attribute Scores, Sensitivity Case 2a
Alternatives Analysis for the Rio Grande Salinity Management Program

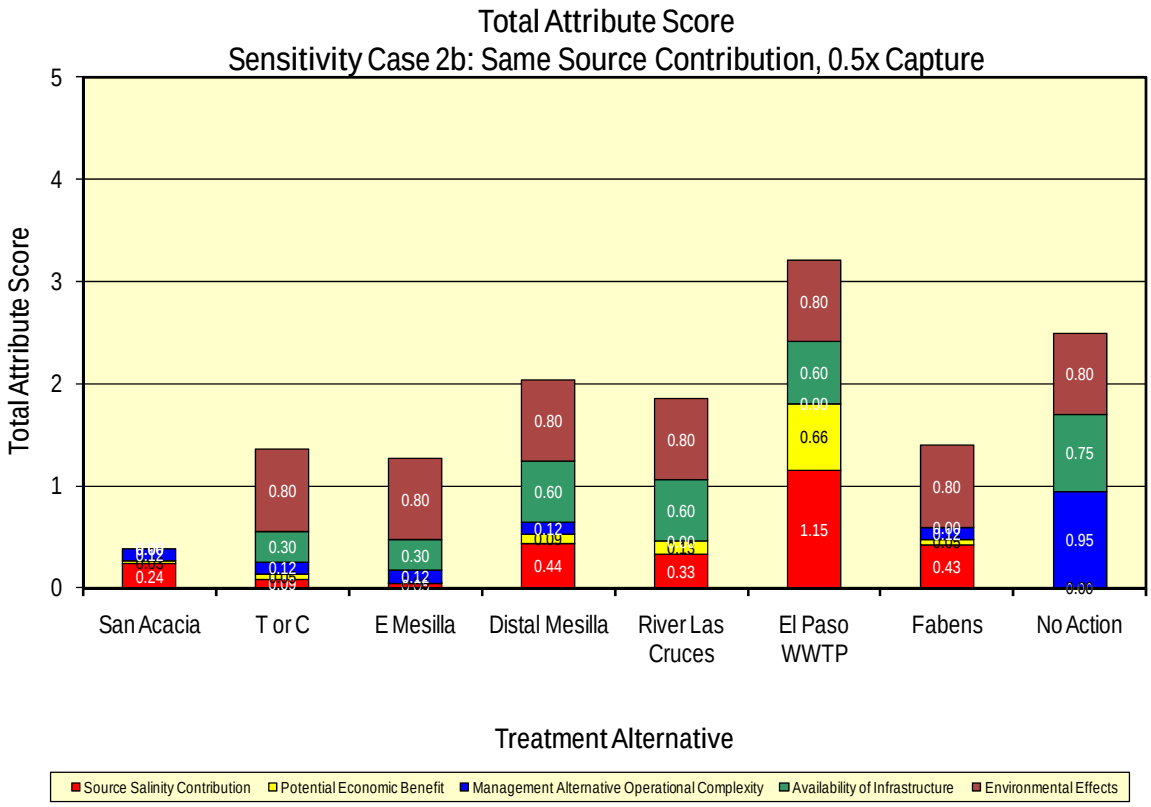


FIGURE 3-17
Attribute Scores, Sensitivity Case 2b
Alternatives Analysis for the Rio Grande Salinity Management Program

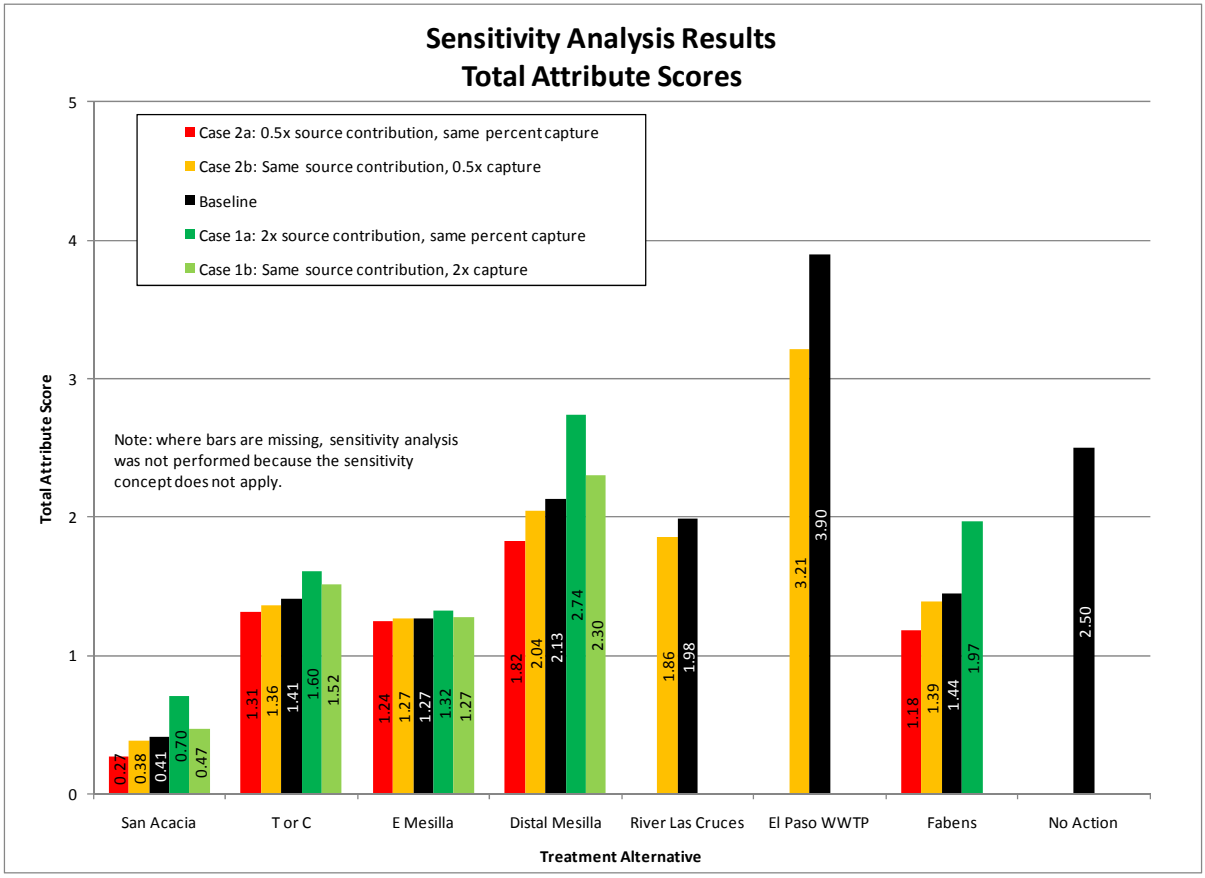


FIGURE 3-18
Sensitivity Result: Attribute Scores
Alternatives Analysis for the Rio Grande Salinity Management Program

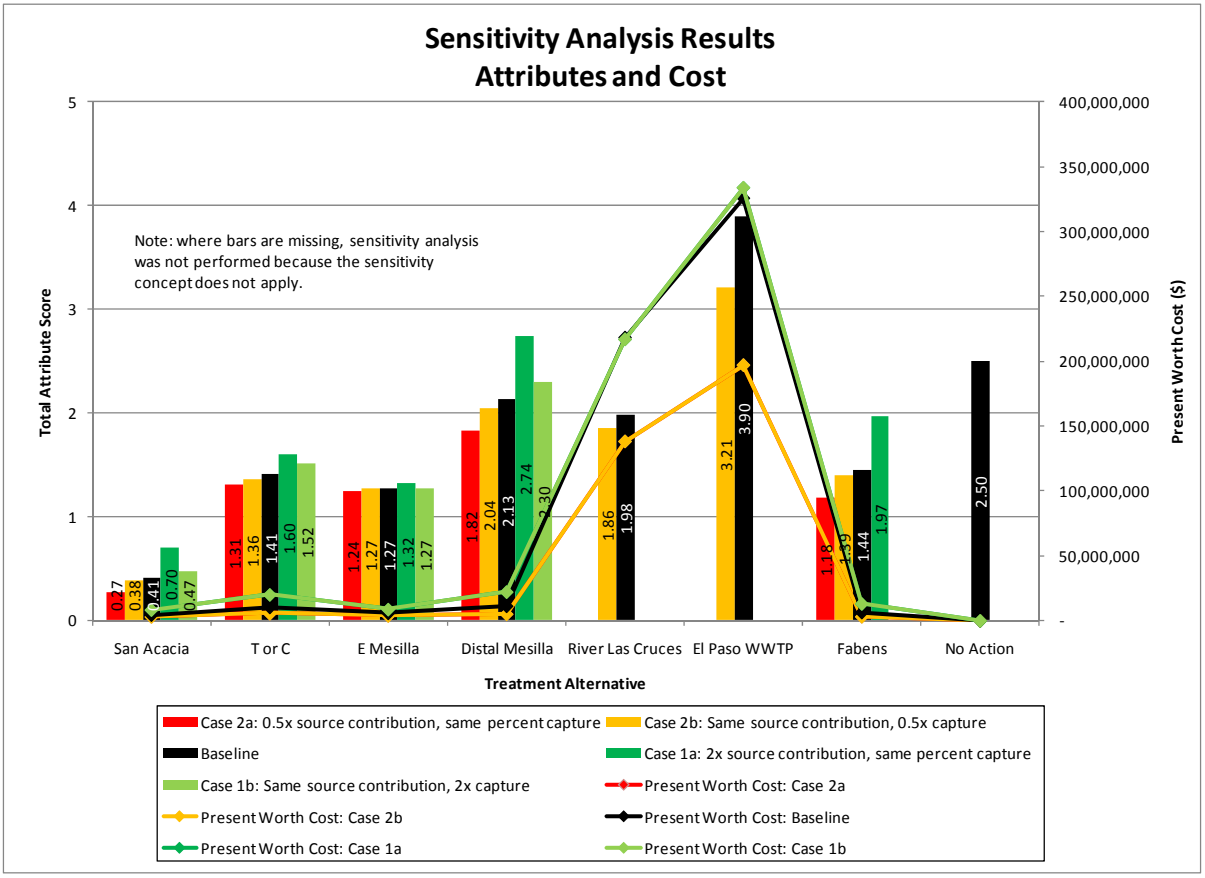


FIGURE 3-19
Sensitivity Result: Attributes and Cost
Alternatives Analysis for the Rio Grande Salinity Management Program

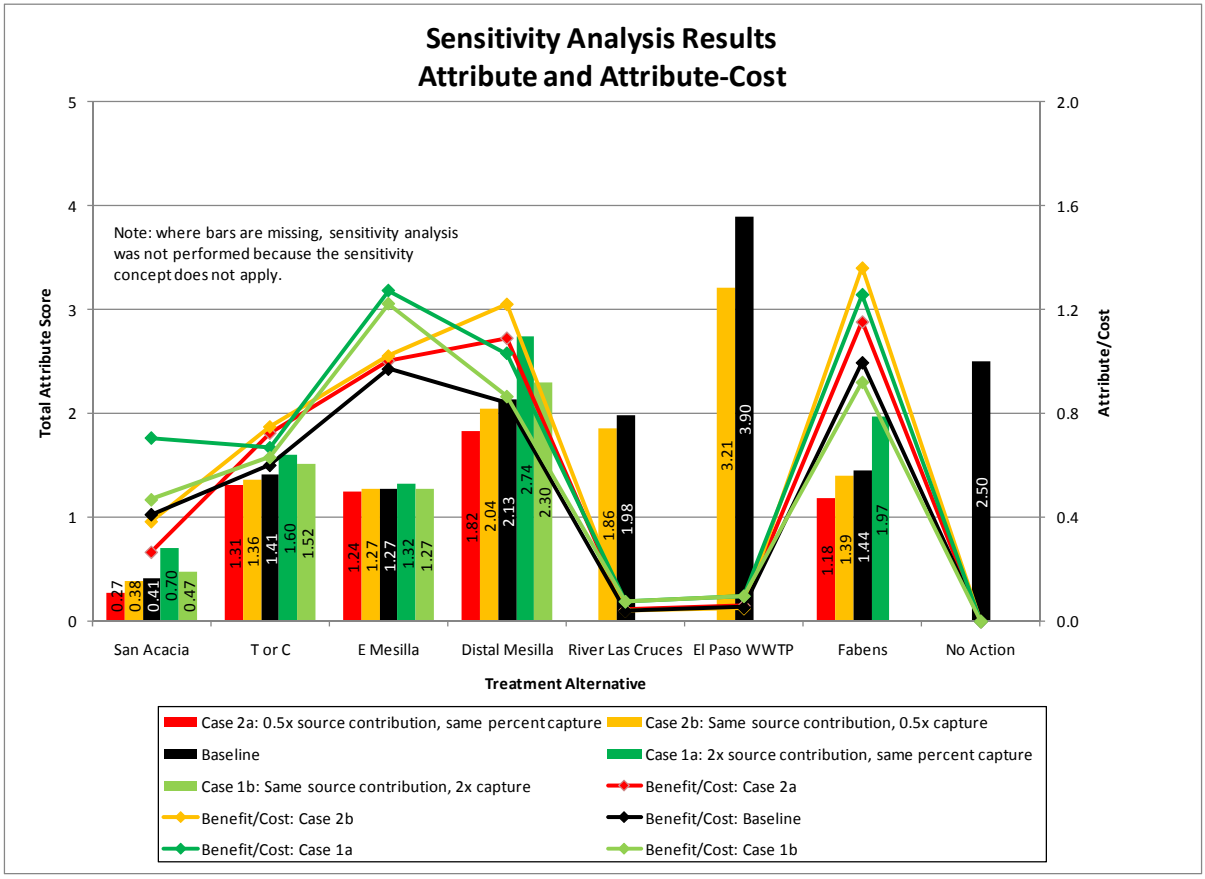


FIGURE 3-20
Sensitivity Result: Attributes and Attribute-Cost
Alternatives Analysis for the Rio Grande Salinity Management Program

SECTION 4

Recommendations

4.1 Introduction

The objective of this alternatives analysis is to select two to four sites for further investigation of the feasibility and approach to salinity source reduction to the Rio Grande. The results of the attribute-cost analysis of the seven candidate sites presented in Section 3 recommended the Distal Mesilla Basin, Truth or Consequences, and the Fabens sites, based on an initial ranking by attribute-to-cost ratios, and then further ranked by attributes (see Section 3.9).

Building from this final ranking, this section provides recommendations for additional investigations at the preferred areas. These recommendations are intended to refine the approach to and feasibility of salinity source reduction efforts and the understanding of anticipated attributes. The recommended sites encompass the range of site conditions, from surface water drains at Truth or Consequences to a dispersed network of groundwater extraction wells at Distal Mesilla Basin, to both surface drain and groundwater well concepts at a relatively remote location at Fabens. An integrated and coordinated program will be necessary to efficiently assess the saline source contribution and recovery potential at the different sites.

Additional site investigations are recommended for each of the three final preferred sites. Results of site investigations should indicate whether a feasible and cost-effective method of saline water extraction can be implemented. Following this initial analysis, preliminary engineering studies would be prepared to describe the method of extraction, conveyance, salt separation, concentrate management, permeate conveyance and return, and general site engineering. More detailed preliminary cost estimates for capture and treatment would be developed and compared with economic benefits associated with the alternatives. Based in part on the more detailed cost-attribute analysis, along with other considerations, a preferred area and treatment method could be recommended.

The following section presents conceptual hydrogeologic site models for the three preferred sites, and includes summaries of additional site investigations, development of conceptual designs, other considerations, and cost-attribute analyses.

4.2 Conceptual Models

Conceptual models were developed for each of the three recommended sites. These conceptual models incorporate current understanding of the causes of salinization including generalized hydrogeology and geochemistry. The three sites provide contrasting mechanisms ranging from deep basin salinity sources (Distal Mesilla Basin), hydrothermal (Truth or Consequences) and artesian flow through evaporite strata (Fabens) that taken together are representative of the diversity of potential sites throughout the study area.

4.2.1 Distal Mesilla Basin

Generalized Hydrogeology

The Mesilla Basin extends from several miles north of Las Cruces, New Mexico, to El Paso, Texas in the southeast, and well into Mexico in the southwest. The basin hydrogeology has been well characterized (e.g., Hawley and Kennedy, 2004). Groundwater generally flows from north to south toward the Rio Grande. The southern/distal end of the Mesilla Basin at the north end of El Paso is defined by a convergence of the east and west bedrock basin boundaries (Franklin Mountains and Sierra Juarez-Cerro de Cristo Rey uplift). The Rio Grande flows through an erosional/structural gap between these highlands, called "El Paso del Norte" or "El Paso Narrows" (see Appendix A). This bedrock constriction is recognized to be an effective barrier to underflow discharge of groundwater from the Mesilla Basin to the Hueco Bolson aquifer to the south (see Appendix A). Accordingly, deep groundwater brines are forced up to the surface in this location and discharge to the Rio Grande (Moyer et al., 2009). The Distal Mesilla Basin site is defined as this relatively localized upwelling of saline waters just north of the El Paso Narrows.

A geologic map and cross-section of the distal end of the Mesilla Basin are presented in Figures 4-1 and 4-2. The key structural features related to salinity management are the Mesilla Fault zone and the Juarez Uplift. The combined Santa Fe Group aquifer materials abruptly thin from about 2,500 feet west of the Mesilla Fault zone to less than 100 feet near the bedrock constriction (Juarez Uplift). This thinning reportedly occurs over a distance of about 9 miles (Hawley and Kennedy, 2004; Figure 4-2). This thinning of the alluvium causes the deep saline waters to flow upward toward the land surface. A distinct upward groundwater-flow gradient existed in the Texas part of the lower Mesilla Valley prior to development of municipal and industrial wells in the intermediate and deep aquifer zones (Leggat et al., 1962).

In the El Paso Narrows, saturated Rio Grande Valley fill is no more than 80 feet thick and it is restricted to an inner-valley area that has a maximum width of less than 1,000 feet (Figures 4-1 and 4-2). Based on subsurface data reported by Slichter (1905), hydraulic conductivity of these fluvial deposits appears to be relatively low (probably in the low to moderate range [K_h <3m/d]); and the hydraulic gradient of both surface and subsurface flow components is about 0.001. Therefore, Slichter's (1905) estimate of about 0.1 cfs (50 gpm, 81 ac-ft/yr) of underflow is probably near the upper limit of potential subsurface discharge from the Mesilla Basin to the Hueco Bolson. Accordingly, it is assumed that nearly all of the deep groundwater flow in the southern end of the Mesilla Basin discharges to the Rio Grande north of the El Paso Narrows.

In consideration of implementing a potential salinity control measure, it is assumed that wells would be installed to intercept the upwelling saline water before it discharges to the Rio Grande. Accordingly, it is important to have an understanding of the aquifer materials. In most places in the Mesilla Basin, major aquifers in the upper part of the Santa Fe Group and the late Quaternary valley alluvial fill are well integrated with the complex surface-flow regime of the inner Mesilla Valley. The saturated thickness of this sequence of ancestral and modern river deposits ranges from about 600 feet near Las Cruces, New Mexico, to more than 300 feet at Cañutillo, Texas (near the Mesilla Fault zone). Compared with middle and lower Santa Fe units, upper-zone river alluvium and upper Santa Fe hydraulic conductivities are high to moderate (Hawley and Kennedy, 2004).

Hydrogeochemistry

Based on the mass balance modeling of Mills (2003) and the isotopic mixing model (Hogan et al., 2007) this site appears to contribute 10–15% of the chloride load observed at El Paso (6,500–9,750 tons chloride/year). Mills (2003) estimated a brine input of 540–900 tons of chloride/month (6,480–10,800 tons chloride/year) whereas Lacey's model (2006) estimated 163–819 (1,956–8,828 tons chloride/year). For planning purposes based on the estimates above, a recommend value of 7,500 tons of chloride/year or 11.5% of the annual chloride load at El Paso is used.

The source of salinity is diffuse groundwater flow. The Distal Mesilla Basin site is believed to be a relatively significant but localized discharge of saline groundwater upwelling from deep sources within the Mesilla Basin. In general, groundwater salinity increases towards Paseo del Norte, with maximum values observed in the ISC-4 well which has chloride of 14,500 mg/L and TDS of 31,000 mg/L. Spatial distribution of TDS from Moyer et al. (2009) is presented in Figure 4-3. The saline discharge is likely the least diffuse of similar sites along the Rio Grande (e.g., San Acacia) due to the bedrock constriction at El Paso del Norte described above.

Challenges and Knowledge Gaps

This location appears to be a relatively significant and localized input. Due to the work of ISC/NMED (Daniel B. Stephens & Associates, 2010) and the USGS (Frenzel and Kaehler, 1992; Nickerson and Myers, 1993; Nickerson, 2006) the area has been reasonably well characterized.

Key knowledge gaps include determining the extent of the saline groundwater discharge zone in order to develop numerical groundwater models of well capture for this site. The following additional data are needed to evaluate the potential for salinity control:

1. Salinity extent. Work from Moyer et al. (2009) should be evaluated and additional locations selected for new monitoring wells to help constrain the extent of salinity.
2. Aquifer properties. Aquifer testing on new or existing wells would provide information that can be used to help estimate well pumping rates that would be required to reduce upward flow. Aquifer properties, including transmissivity and vertical hydraulic conductivity, would be used in a local groundwater model used to assess alternatives.
3. Numerical groundwater model. The model should be calibrated locally to observed hydraulic heads, and include observed aquifer properties. The model could then be used to assess various salinity control measures and their effect on reducing saline discharge to the Rio Grande.

4.2.2 Truth or Consequences

Generalized Hydrogeology

This site is a localized geothermal upwelling between Truth or Consequences and Williamsburg. According to Cox and Reeder (1962), "*the source of thermal water is inferred to be steam and hot gases rising from a deep-seated igneous intrusive body mixing with circulating ground water of meteoric origin*."

Although there are additional geothermal inflows to the Rio Grande in the Truth or Consequences area, for the purposes of this evaluation the source was defined as the "hot ditch," which has quantified flows and concentrations, and could be captured and treated practically. Because groundwater heads would not change, it is assumed that diversion of the surface flows to treatment for salinity control would not affect the water quality or discharge rate of groundwater flowing to the hot ditch.

Hydrogeochemistry

The commonly reported values for these geothermal waters (from Cox and Reeder, 1962, as found in Moyer et al., 2009) are 1,300 mg/L chloride and a specific conductivity (SC) of 4,450 µS/cm (roughly 2,600 mg/L TDS). More recent data collected by Daniel B. Stephens & Associates (2010) are generally in agreement indicating a consistent source:

May 2009 – 1.1 cfs; 4,300 µS /cm SC; 2,600 mg/L TDS; 1,400 mg/L chloride
May 2007 – <0.5 cfs; 4,700 µS /cm SC; 2,700 mg/L TDS; 1,300 mg/L chloride

Surface flows through man-made channels (ditches) were estimated to be about 500 gpm, with mass flux of about 1,500 tons of chloride per year. This translates to 2.3% of the chloride load at El Paso. Total inflow, according to ISC models was estimated to be about 2,600 gpm (including smaller surface and subsurface flows), with a mass flux of nearly 8,000 tons of chloride per year. It is possible that there is an additional diffuse geothermal discharge along this reach that may increase the overall load from this location/source.

Challenges and Knowledge Gaps

For a salinity management project solely focused on the "hot ditch," there are few challenges or knowledge gaps as this appears to be a consistent source readily accessible at the surface. If the scope of this project were expanded to incorporate the potentially greater salinity contribution from this area, then a detailed hydrogeologic investigation would be required to determine the location and quantify the contribution of these sources. The complex hydrogeology of this location (Figure 4-4) would make this a significant undertaking.

TABLE 4-1
Hydrostratigraphic Units Shown on Schematic Hydrogeologic Cross Section of the Truth or Consequences Geothermal Area, Sierra County, New Mexico
Alternatives Analysis for the Rio Grande Salinity Management Program

Post-Santa Fe Group Hydrostratigraphic Units (HSUs), and Major Lithofacies-Assemblage Components (*LFA*s)
RG—Fluvial deposits of the inner Rio Grande Valley (Historic-Holocene to uppermost Pleistocene. 2007)—Pinkish-gray to grayish-brown sand, sandy pebble to cobble gravel, and silty to sandy clay; contains paleo-channel, point-bar, and overbank floodplain deposits that underlie the floor of the inner Rio Grande Valley; gravel dominated by rounded volcanic, granite, metamorphic, and chert clasts; very weak to no soil development; commonly 60 to 80 feet thick in the Truth or Consequences area. Lithofacies Assemblages (***LFA*s**) ***a1-3***. Correlative with **Qv1** of Lozinsky (1986). *Major component of the shallow-aquifer system*
TAY—Younger fluvial-terrace (channel and floodplain) deposits of the ancestral Rio Grande (Upper Pleistocene)—Pale-brown to light-brown; texture and clast composition like **RG**; weakly developed soils with stage I and II carbonate morphology (Gile et al., 1966); depositional surface as much as 70 feet above river-floodplain base level, and less than 30 feet thick. Lithofacies Assemblages (***LFA*s**) ***a1-3***. Correlative with **Qt4** of Lozinsky (1986). *Entirely in the vadose zone*

TABLE 4-1
Hydrostratigraphic Units Shown on Schematic Hydrogeologic Cross Section of the Truth or Consequences Geothermal Area, Sierra County, New Mexico
Alternatives Analysis for the Rio Grande Salinity Management Program

TAO—Older fluvial-terrace (channel and floodplain) deposits of the ancestral Rio Grande (Middle Pleistocene)—Brown to light reddish-brown; texture and clast composition like **RG**; moderately developed soils with stage II and III carbonate morphology (Gile et al., 1966); depositional surface as much as 80 to 120 feet above river-floodplain base level, and less than 30 feet thick. Lithofacies Assemblages (***LFA*s**) ***a1-3.*** Correlative with **Qt2 and Qt3** of Lozinsky (1986). *Entirely in the vadose zone*
Santa Fe Group Hydrostratigraphic Units (HSUs) And Major Lithofacies-Assemblage Components (*LFA*s)
USF—Upper Santa Fe Gp HSUs-undivided intermontane-basin fill (Pliocene and Early Pleistocene). Unit includes intertonguing piedmont-slope (**USF1**) and basin-floor (**USF2**) alluvium deposited prior to incision of the present valley systems of the Rio Grande and its major tributaries (e.g., Cuchillo Creek). Primarily Lithofacies Assemblages (***LFA*s**) ***1-4 & 5-8***. Generally correlative to the Palomas Formation as defined by Lozinsky and Hawley (1986), and Seager and Mack (2003). *Locally significant basin-fill aquifer with saturated thickness exceeding 300 ft*
USF1—Upper Santa Fe HSU: Coarse- to medium-grained, piedmont-alluvial deposits; derived mainly from the northern Caballo and Mud Springs uplifts. Well-developed soils on constructional-surface remnants, with stage III and IV carbonate morphology (Gile et al., 1966); Primarily ***LFA*s *5-8***. *As much as 200 feet thick and partly in vadose zone*
USF2—Upper Santa Fe HSU: Fine- to coarse-grained fluvial deposits derived from the ancestral Upper Rio Grande watershed in central New Mexico; gravel dominated by rounded volcanic, granite, metamorphic, and chert clasts. Primarily ***LFA*s *1-3*** (Fig. 1, Table 2). *As much as 200 feet thick and mostly in vadose zone*
MSF—Middle and Lower(?) Santa Fe Gp HSUs-undivided; intermontane-basin fill (Miocene-Late Oligocene): Unit includes intertonguing piedmont-slope and basin-floor lithofacies assemblages. Primarily ***LFA*s *3-8***. Generally equivalent to the Rincon Valley Formation as defined and mapped by Seager et al. (1971), and Seager and Hawley (1973). *Partly-confined, deep Santa Fe Group aquifer in the northern Palomas Basin area (south of the Mud Springs fault, with saturated thickness locally exceeding 1,000 ft*
Pre-Santa Fe Group (Middle Tertiary) Lithostratigraphic Units
Tt—Thurman Formation (Oligocene): primarily volcaniclastic sandstone and mudstone, with some interbedded silicic (ash-fall) tuffs. Unit is transitional upward with basal Santa Fe deposits. Limited to moderate potential (<50gpm) for warm-brackish groundwater production in the Palomas Valley area, about 6 mile southwest of Truth or Consequences (Kelley and Silver, 1952, p. 189).
Paleozoic Sedimentary Rocks of the Southern Mud Springs Uplift Area
P—Abo Formation- redbed mudstones and sandstones (Permian). *Not an aquifer.*
Pzu—Magdalena Group (Pennsylvanian): mainly limestone, with shale and minor sandstone interbeds. Fault-associated zones with open-fracture to small-scale cavernous porosity are the primary component of the Truth or Consequences thermal-aquifer system (Theis et al., 1941; Conover et al. 1955)
Pzl—Carbonate-rock sequence (Ordovician Montoya/El Paso Groups/) capped by the Devonian Percha Shale, and conformably underlain by sandstone and interbedded limestone and siltstone of the Bliss Formation (Ordovician/Cambrian)
XY— Undivided Proterozoic (Precambrian) Crystalline Rocks of the Southern Mud Springs Uplift

Note: Hydrogeologic details for each lithofacies can be found in Appendix A.
Source: Developed by Hawley Geomatters for the project

4.2.3 Fabens

Generalized Hydrogeology

The Fabens site is located in the southwestern portion of the Hueco Bolson, near Fabens, Texas. Groundwater flow in the Hueco Bolson, north and east of the Rio Grande, is generally from north to south, with the Rio Grande (and local wells, including El Paso municipal wells) serving as the ultimate discharge sink. This site has been well characterized by the work of Hibbs and Merino (2006 and 2007) and Hawley et al. (2009). This site consists of upwelling groundwater under artesian conditions. The water at depth is relatively low in chloride and TDS. During upwelling it passes through a sedimentary unit that likely contains evaporite deposits—possibly a paleo-playa deposit described in more detail below (Figure 4-5). These, now saline, groundwaters discharge to drains in the area, and are subsequently transported to the Rio Grande or used for agricultural purposes.

As with other sites, the dominant aquifer units are part of the Santa Fe Group. In this location the aquifer is part of the upper Santa Fe Group (Figure 4-6), which in many places, including Fabens, have been influenced by a complex combination of active but episodic tectonism and cyclic shifts in a semiarid to arid climatic regime (Gile et al. 1981, Mack et al. 2006). At this location the upper Santa Fe Group consists of basin floor silt/clay with interbedded sand lithofacies know in the Hueco Bolson as the Ft. Hancock formation (Figure 4-6; see Appendix A for more detail). This formation was found to be the significant source of salinity within the larger Hueco Bolson groundwater system (Druhan et al., 2007).

As detailed in Appendix A, sometime in the earliest Pleistocene, probably between 1.5 and 2 Ma, the course of the ancestral Rio Grande shifted into parts of the southern Mesilla Basin, and possibly the Bolson de los Muertos depression to the south. This continued until the early Middle Pleistocene time (~0.7 Ma) when the ancestral Rio Grande was again flowing into the Hueco Bolson via the topographic saddle between the Franklin and Juárez uplifts. These well-documented shifts river course had profound impacts on both deposition environments, and groundwater-flow regimes and hydrochemistry throughout the Hueco Bolson. During this period, basin-floor aggradation would have essentially ceased and a *relict* fluvial plain with numerous playa-lake depressions, including the potential for evaporite deposits, would have quickly developed across much of the Bolson surface. Bolson-floor plains that were previously supplied with both freshwater surface flow and medium to coarse grained sediments were converted to internally-drained, ephemeral-lake plains. The work of Hibbs and Merino fits the above-described conceptual model of catastrophic, but geologically temporary basin abandonment by a major fluvial system.

Hydrogeochemistry

During monitoring well drilling in the Fabens area, Hibbs and Merino (2006) detected the saline paleo-playa unit at depths of 150 feet to 250 feet below ground surface (bgs) (Figure 4-7). Chloride concentrations were measured to be about 14,650 mg/L in a well screened 150 to 250 feet bgs, 239 mg/L in a well 350 to 450 feet bgs, and 176 mg/L in a well screened 650 to 750 feet bgs. The deeper wells were flowing artesian wells, suggesting upward flow across the paleo-playa unit. Examining the chemistry of numerous shallow wells in the Rio Grande alluvial aquifer suggests that this salinity source/upwelling zone is relatively localized in the Fabens area (Figure 4-8).

Most previous salinity studies on the Rio Grande (e.g., Mills, 2003; Lacey, 2006) did not extend past El Paso. As such the best estimate of salinity flux at this site is based on model calibration done for this study (see Appendix B) which estimated 7,000 tons per year or 11.2 percent of load at El Paso. In the model this was simulated as flow of about 225 gpm, with a concentration of 14,650 mg/L. The isotopic mixing model work of Hogan et al. (2007) suggests the percentage of "brine chloride" load doubles in this region compared to El Paso. That is to say the flux of chloride in this area could potentially be as high as 100 percent of the annual chloride flux at El Paso. This site could also be a sink for chloride, thus the chloride flux in the Rio Grande at Fabens could be significantly less than observed at El Paso during the time of the geochemical analysis (Hogan, 2010).

Challenges and Knowledge Gaps

There is uncertainty in this magnitude of the flux, although monitoring of the Island Drain could easily help to constrain this value.

For the purposes of salinity management at this site, one potential option is to pump relatively clean groundwater from depth. Groundwater wells would be relatively deep (about 750 feet, based on observed chloride concentrations) and would pump relatively clean groundwater from below the assumed evaporite deposits. These wells would serve two purposes: (1) provide hydraulic control by lowering groundwater heads, which would reduce the amount of water that flows upward through the evaporite beds, and (2) provide a source of cleaner water. For the purposes of analysis, it was assumed that wells would pump at a rate similar to the flow rate in the existing drain. However, additional pumping may be required to reduce upward artesian flow through the evaporite deposits.

This conceptual model relies heavily on data collected from a single set of nested wells. The following additional data are needed to evaluate the potential for salinity control by pumping of clean groundwater from depth:

1. Salinity Mass flux. Geochemical and flow data should be collected from the Rio Grande and drains in the region to determine the extent and quantify the amount of saline brine entering the surface water system.

2. Hydraulic head distribution with depth. The extent of the upward gradient should be addressed to help determine well pumping rates that would be required to overcome the upward gradient. Hydraulic head distribution would serve as a calibration target for a local groundwater model used to assess alternatives.

3. Aquifer properties. Aquifer testing on new or existing wells would provide information that can be used to help estimate well pumping rates that would be required to reduce upward flow. Aquifer properties, including transmissivity and vertical hydraulic conductivity, would be used in a local groundwater model used to assess alternatives.

4. Numerical groundwater model. The model should be calibrated locally to observed hydraulic heads, and include observed aquifer properties. The model could then be used to assess the reduction of upward mass flux to the intercepting drain (flow rate and lateral extent of reduced flow) under various pumping alternatives.

5. Additional exploratory wells. Additional wells would be helpful to assess the lateral extent of the saline paleo-playa unit, and to obtain additional groundwater level data for model calibration.

4.3 Additional Site Investigations

This section outlines the recommended approaches for additional site investigations.

4.3.1 Distal Mesilla Basin

The conceptual model of the Distal Mesilla site suggests that upwelling deep groundwater brines discharge to the Rio Grande between Anthony, New Mexico/Texas and the El Paso Narrows. Key data gaps from the current work effort include lack of control on the spatial extent of the saline groundwater discharge zone, limited understanding of the saline discharge rate and concentration (though there is a reasonable handle on the mass flux), hydraulic properties of the aquifer in this zone, and water quality parameters of the water to be treated. It is recommended that additional work be performed to fill these data gaps, and that a conceptual design for the saline capture and treatment systems be developed. The conceptual designs can then be used to compare the recommended sites, based on criteria such as mass removal and cost.

Compile Available Data and Develop Data Collection Plan

Available groundwater data, including groundwater levels, TDS and chloride concentrations, and aquifer test results, should be summarized graphically to illustrate distribution of the saline source both spatially and stratigraphically by depth. The results of the data compilation would be used to determine preferred locations for additional data collection to define the extent of the saline source and to bracket hydrogeologic properties near the site. A data collection plan should be developed to establish minimum standards and methods of data collection and quality assurance.

Collect Additional Data

For the purpose of this preliminary recommendation, as many as five monitoring wells are assumed to be needed at the site to help characterize the hydrogeology and delineate extent of source salinity. It is assumed that these wells would extend to the bedrock unit, estimated to be several hundred feet deep, and screened in the lowermost productive portion of the Santa Fe Group aquifer above the bedrock. The intent is to sample and characterize the portion of the aquifer that has the highest proportion of deep saline upwelling water (prior to mixing with shallower cleaner water in the upper zones).

At each well, groundwater levels and TDS and chloride in groundwater should be measured. In addition, groundwater levels at other wells in the area should be measured at the same time so a detailed assessment of hydraulic gradients, both horizontal and vertical, can be made.

Aquifer tests should also be performed at each monitoring well or at existing production wells, if available, using the new wells as monitoring wells. Test results would bracket the understanding of the site hydrogeologic properties necessary for the development of the conceptual design of the saline capture system.

Refine Conceptual Model

The conceptual model presented in this report should be refined based on the collection of additional data, as described above. The conceptual model would focus on the site itself, and consist of a localized water budget, extent of saline source, and hydrogeologic properties.

Develop Numerical Groundwater Model

It is recommended that a groundwater model (e.g., MODFLOW) with solute transport modeling capabilities (e.g., MT3D) be developed. The groundwater model would be used to select well locations for salinity capture and to help predict reduction of mass flux to the river as a result of the proposed salinity control.

The Mesilla Basin has been studied extensively. Existing numerical models should be investigated for application and potential limitations to their use in simulating salinity control scenarios. Following this review, either an existing groundwater model should be selected and modified as necessary, or a new local model should be developed and calibrated. In either case, it is recommended that local hydraulic properties be adjusted and the model be calibrated to aquifer tests performed as part of this work.

The contaminant transport functionality would allow salinity to be simulated under a number of capture scenarios. The purpose of the model is to assist in developing preferred salinity capture alternatives, as discussed below.

Capture of Saline Groundwater

The groundwater model developed in the previous tasks should be used to select a preferred hydraulic capture scenario for the selected the site. The groundwater model could be used to evaluate a number of different capture alternatives. The intent is to maximize capture by varying the following:

- Number of wells
- Well locations and spacing
- Pumping rates from wells
- Well depth and screen interval

Criteria used to evaluate potential capture scenarios should include number of wells and pumping rates required (fewer wells and lower pumping rates preferred to keep costs low), and simulated reduction in mass flux to the Rio Grande (greater reduction in mass flux preferred).

Disposal Methods

Disposal options at the site include evaporation ponds and wetlands/enhanced evaporation. Additional work is required to estimate land area required for disposal, and to determine the best method and cost of disposing of the concentrate.

Projected evaporation rates are necessary to estimate the land area required for evaporative disposal. Evaporation varies with a number of factors, including water chemistry.

Physical Layout and Conveyance

Based on the assumptions of salinity capture methods, treatment facilities, and layout, a conceptual physical layout for each potential salinity capture scenario should be developed. Conveyance routes from the capture site(s) to treatment plant, and from treatment plant to disposal, should be developed on a conceptual basis. It is assumed that land use maps and terrain maps would be sufficient for this level of conceptual design.

Estimated Reduction in Mass Flux Due to Salinity Control

Estimates of reduction in mass flux to the surface water system should be developed, based on groundwater modeling results, plus treatment and disposal effects.

4.3.2 Truth or Consequences

The targeted salinity source is surface flow in a ditch, and could be captured using a diversion. While some additional saline capture might be attainable through groundwater wells, due to the complex nature of the hydrogeology and potential negative effects on surface flows such as the hot ditch or commercial hot springs, it is recommended that further investigations be focused on the surface ditch only at this time. Additional site-specific investigations could include better quantification of the mass load at this source and siting of diversion facilities and pilot- and full-scale treatment facilities.

Collect Additional Data

It is recommended that continuous monitoring of flow rates in the surface ditches be performed for one year, and chloride and TDS be sampled monthly. While some data are available for this source, the flow rates appear to fluctuate. The intent of continuous monitoring is to gain a better assessment of the mass load that could be captured and treated. In addition, it is recommended that water quality parameters relevant to design of a treatment system be collected.

Capture of Saline Surface Water

A conceptual design should be developed for a diversion structure to capture the saline surface water source for treatment.

Disposal Methods

Disposal options at this site include evaporation ponds and wetlands/enhanced evaporation. Additional work is required to estimate land area required for disposal, and to determine the best method and cost of disposing of the concentrate.

Physical Layout and Conveyance

Based on the assumptions of salinity capture methods, treatment facilities, and layout, a conceptual physical layout for each potential salinity capture scenario should be developed. Conveyance routes from the capture site(s) to treatment plant, and from treatment plant to disposal, should be developed on a conceptual basis. It is assumed that land use maps and terrain maps would be sufficient for this level of conceptual design.

Estimated Reduction in Mass Flux Due to Salinity Control

Based on water quality data collected and the conceptual design of the treatment and disposal facilities, a revised estimate of reduction of mass flux to the Rio Grande should be developed.

4.3.3 Fabens

The conceptual model of the Fabens site suggests that relatively clean water at depth flows upward through an evaporite deposit, which causes it to become saline, prior to discharging to local drains (and likely discharging directly to the Rio Grande as well). Accordingly, there are two proposed salinity control methods. First, water in the drain could be captured and treated. Second, relatively deep (about 750 feet) wells could pump relatively clean groundwater from below the assumed evaporite deposits, providing hydraulic control and a source of clean water. The following recommendations are intended to develop a preferred salinity control method, and to develop a conceptual design of the preferred method.

Compile Available Data and Develop Data Collection Plan

Available groundwater data, including groundwater levels, TDS and chloride concentrations, and aquifer test results, should be summarized graphically to illustrate spatial distribution and stratigraphically by depth. It is assumed that the conceptualizations from Hibbs and Merino (2006 and 2007) would be used as a basis for this effort. The results of the data compilation would be used to determine preferred locations for additional data collection to define the extent of the evaporite deposit and to bracket hydrogeologic properties near the site. A data collection plan should be developed to establish minimum standards and methods of data collection and quality assurance.

Collect Additional Data

For evaluation of the surface capture alternative, it is recommended that continuous monitoring of flow rates of the surface drain be performed for one year, and chloride and TDS be sampled monthly. The intent of this monitoring is to gain a better understanding of the mass flux that would need to be treated. In addition, this information would be valuable for additional efforts supporting revisions to the salinity and economic benefit models of the area.

For the purpose of evaluating potential for the groundwater capture option, it is preliminarily recommended that as many as five monitoring wells be installed at the site to help characterize the hydrogeology and delineate extent of source salinity. It is recommended that nested wells be installed above and below the evaporite deposit to help characterize extent of salinity by depth, and to help characterize vertical hydraulic gradients and vertical flow rates across the evaporite deposit.

At each well, groundwater levels and TDS and chloride in groundwater should be measured. In addition, groundwater levels at other wells in the area should be measured at the same time so a detailed assessment of hydraulic gradients, both horizontal and vertical, can be made.

Aquifer tests should be performed at each monitoring well or at existing production wells, if available. Aquifer tests should be designed with a primary purpose of estimating the vertical conductance of the geologic materials. Test results would bracket the understanding of the site hydrogeologic properties necessary for the development of the conceptual design of the saline capture system, specifically how pumping at depth would affect current discharge to drains.

Refine Conceptual Model

The conceptual model presented in this report should be refined based on the collection of additional data, as described above. The conceptual model would focus on the site itself, and consist of a localized water budget, extent of saline source, extent of the evaporite deposit, and hydrogeologic properties (including horizontal and vertical conductivity, and storage coefficients).

Develop Numerical Groundwater Model

To develop conceptual designs of source salinity capture using groundwater wells, a groundwater model (e.g., MODFLOW) with contaminant transport functionality (e.g., MT3D) should be used. The contaminant transport functionality would allow salinity to be simulated. The purpose of the model is to assist in developing preferred salinity capture alternatives, as discussed below. Of key importance is to use the model to estimate pumping rates required to reduce or eliminate the upwelling of water through the evaporite deposit.

Capture of Saline Groundwater

The groundwater model developed in the previous tasks should be used to select a preferred hydraulic capture scenarios for the site. The groundwater model could be used to evaluate a number of different capture alternatives. The intent is to maximize capture by varying the following:

- Number of wells
- Well locations and spacing
- Pumping rates from wells
- Well depth and screen interval

Criteria used to evaluate potential capture scenarios include number of wells and pumping rates required (fewer wells and lower pumping rates preferred to minimize cost) and reduction of discharge to the surface drains.

The hydraulic control option should be compared with diversion and treatment of the existing drain to determine the preferred method of source salinity capture.

Capture of Saline Surface Water

A conceptual design should be developed for a diversion structure to capture the saline surface water source for treatment.

Disposal Methods

Disposal options at the selected sites include evaporation ponds and wetlands/enhanced evaporation. Additional work is required to estimate land area required for disposal, and to determine the best method and cost of disposing of the concentrate.

Physical Layout and Conveyance

Based on the assumptions of salinity capture methods, treatment facilities, and layout, a conceptual physical layout for each potential salinity capture scenario should be developed. Conveyance routes from the capture site(s) to treatment plant, and from treatment plant to disposal, should be developed on a conceptual basis. It is assumed that land use maps and terrain maps would be sufficient for this level of conceptual design.

Estimated Reduction in Mass Flux Due to Salinity Control

For each salinity-control scenario, estimates of reduction in mass flux to the surface water system should be developed. These should be based on data collected from the surface drain (surface capture scenario) or groundwater modeling results (groundwater capture scenario), plus treatment and disposal effects.

4.4 Future Pilot Studies

Treatment methods should be piloted at the site ultimately selected for further analysis to establish design parameters, equipment specifications, pre- and post-separation treatment processes, and to confirm the anticipated salinity reduction. Initial planning for siting, conveyance, and disposal facilities should be completed to provide a basis for final siting, design, and construction. A pilot study likely would require a minimum of 2 to 3 months.

Efforts should be made to co-locate or otherwise develop a collaborative approach to the pilot study with other ongoing analyses, such as the work being performed by El Paso Water Utilities and work being done in Alamogordo at the National Desalination Center. The latter facilities may be appropriate as a location for further investigations.

Pilot facilities would be located with access to the saline water source (whether as a surface water or piped groundwater) and a power supply for the unit. The need for a raw water storage tank will be assessed. The pilot facility would be located/housed inside a building (e.g., metal shed) to protect equipment components from the elements. If one is not available, it would be necessary to determine if one needs to be built or to install the pilot unit inside a container or trailer. Security and limited access to the site by the public would be important.

The skid-mounted pilot treatment requirements (e.g., 2- or 3-stage) would be determined and secured from a membrane supply and system integration company. The pilot system is assumed to run utilizing 8-inch membrane elements and would include pre-treatment (i.e., cartridge filters) and an RO feed pump. Bulk storage and chemical feed system requirements would be determined for any pre-treatment chemicals (i.e., acid for pH adjustment and scale inhibitor).

Given the intent of the pilot study, concentrate could be returned locally to the sewer or surface drain. However, the concentrate should be used as the primary water source for a

corresponding pilot study of evaporation rates and the use of wetlands for enhancing concentrate evaporation rates, described in following sections.

The pilot system would be staffed at a level consistent with the study objectives. A starting assumption is that a minimum of 20 hours per week of a junior-level engineer would meet most requirements for running the pilot system, with oversight by a senior-level engineer. Additional budget should be anticipated at the beginning for planning the pilot study, preparing a research plan and setting up the system, and at the conclusion of the pilot study to review and present the findings.

Disposal Methods

Disposal options at the selected sites include evaporation ponds and wetlands/enhanced evaporation. Additional work is required to estimate land area required for disposal, and to determine the best method and cost of disposing of the concentrate. As described above, a pilot study would provide a source of concentrate that could be used to confirm evaporation rates and suitability for management using brackish wetlands.

Evaporation rates should be measured and compared to measured reference evapotranspiration from the nearest available weather station. Based on this comparison, coefficients could be developed that relate reference evapotranspiration to actual evaporation of effluent water at the site. These coefficients can then be applied to the historical record of evaporation to obtain estimates of ranges of seasonal evaporation. It should be noted that the coefficient will vary as the evaporation ponds are heating and cooling (both short-term and seasonally). A range of coefficients should be used to assess required size and depth of the evaporation ponds and/or wetlands disposal system. In addition, typical engineering safety factors should be included to account for pond down-time, including maintenance and concentrate removal.

It is assumed that during facility operation, the concentrate would be periodically removed from the ponds and taken to a landfill. Concentrate accumulation rates should be estimated based on results of pilot evaporation system testing, and from an evaluation of the pilot treatment effluent water quality. Potential landfills for disposal should be evaluated. It is recommended that concentrate disposal cost be estimated based on information from local landfills, and from local trucking companies.

4.5 Assess Other Considerations

4.5.1 Socio-political

It is recommended that opportunities be explored for potential joint state, federal, or regional programs for the above feasibility studies as well as the long-term regional salinity control measures.

4.5.2 Other

Land ownership and land use maps should be evaluated to determine potential sites for the project, based on land area requirements developed above.

4.6 Cost-Benefit Analysis

A detailed economic cost-benefit analysis should be performed for the recommended salinity control scenarios. Preliminary costs and benefits presented in this report should be refined. Specifically, detailed costs estimates should be developed that are consistent with the conceptual designs developed above. Additional work would also be required to estimate potential economic benefits of the conceptual designs at each site.

4.6.1 Cost Analysis

Capital and O&M costs should be developed for each conceptual design. Costs should be developed for the following:

1. Source salinity capture: well installation and operation
2. Treatment: treatment plant installation and O&M cost
3. Conveyance: installation and O&M cost for conveyance from capture locations to treatment plant, and from treatment plant to disposal site
4. Disposal: installation and O&M for disposal method

4.6.2 Benefit Analysis

It is assumed that potential benefits would be based on the salinity and economic benefit modeling performed. To obtain more accurate estimates of economic benefit, the following work is recommended:

1. **Refine El Paso to Hudspeth County salinity model**. A high degree of uncertainty is associated with the downstream portion of the salinity model and further refinement is warranted. Specifically, the "plumbing" of the system in the reach downstream of the El Paso Narrows is highly uncertain. A detailed and current schematic of canal and drain flow between El Paso and Hudspeth County irrigation ponds should be developed. System operations personnel should be consulted to get a better idea of rule sets associated with flow routing, for example, when flows get diverted to the Rio Grande as opposed to being routed toward the Hudspeth County irrigation ponds. Based on the above, as well as additional data collection at the Fabens site, it will be necessary to update the salinity model to better predict salinity of Hudspeth County irrigation water currently and after the salinity control has been implemented.
2. **Refine economic model**. Two primary refinements required in salinity modeling are as follows:
    a. Account for variable salinity reductions. For some facets of the economic evaluation presented in this report, a linear change in economic benefits between two defined points was assumed. While this may be within the range of error associated with estimates of economic benefits, it is recommended that the model be refined to account for variable salinity reductions.
    b. Refine economic benefits associated with change in cropping patterns in Hudspeth County. Economic benefits to Hudspeth County were not included in the Phase 1

economic model. For this current alternatives analysis, benefits to Hudspeth County based on change in crop pattern were calculated using the same methodology used in the Phase 1 economic model for change in crop patterns in El Paso County. While this approach is reasonable for this current screening evaluation, it would need to be refined to allow for a more accurate cost-benefit analysis needed to support selection of the optimal site for salinity control.

In addition, the economic model should be revisited to ensure that all benefits are accounted for. Specifically, this includes a method for adding potential benefits to one another (the Phase 1 economic report suggests that benefits should not be added to reduction in damages), and incorporation of potential non-irrigation season benefits to the El Paso Water Utilities.

3. **Simulate salinity control scenarios**. Each salinity control scenario should be evaluated by running the revised salinity and economic models. Input to the salinity model should be based on the estimates of reduction in mass flux to the surface water system developed during conceptual design.

4.7 Ongoing Monitoring Plan

It is recommended that a groundwater and surface water quality monitoring program be implemented. The purpose of the monitoring program with respect to the salinity control measures is to evaluate performance of the proposed salinity control measure. It is important that water quality monitoring program be implemented well in advance of construction of the salinity-control measure in order to establish baseline or background/pre-project conditions. The monitoring program should be designed to fit within the larger-scale water quality monitoring proposed by Moyer et al. (2009).

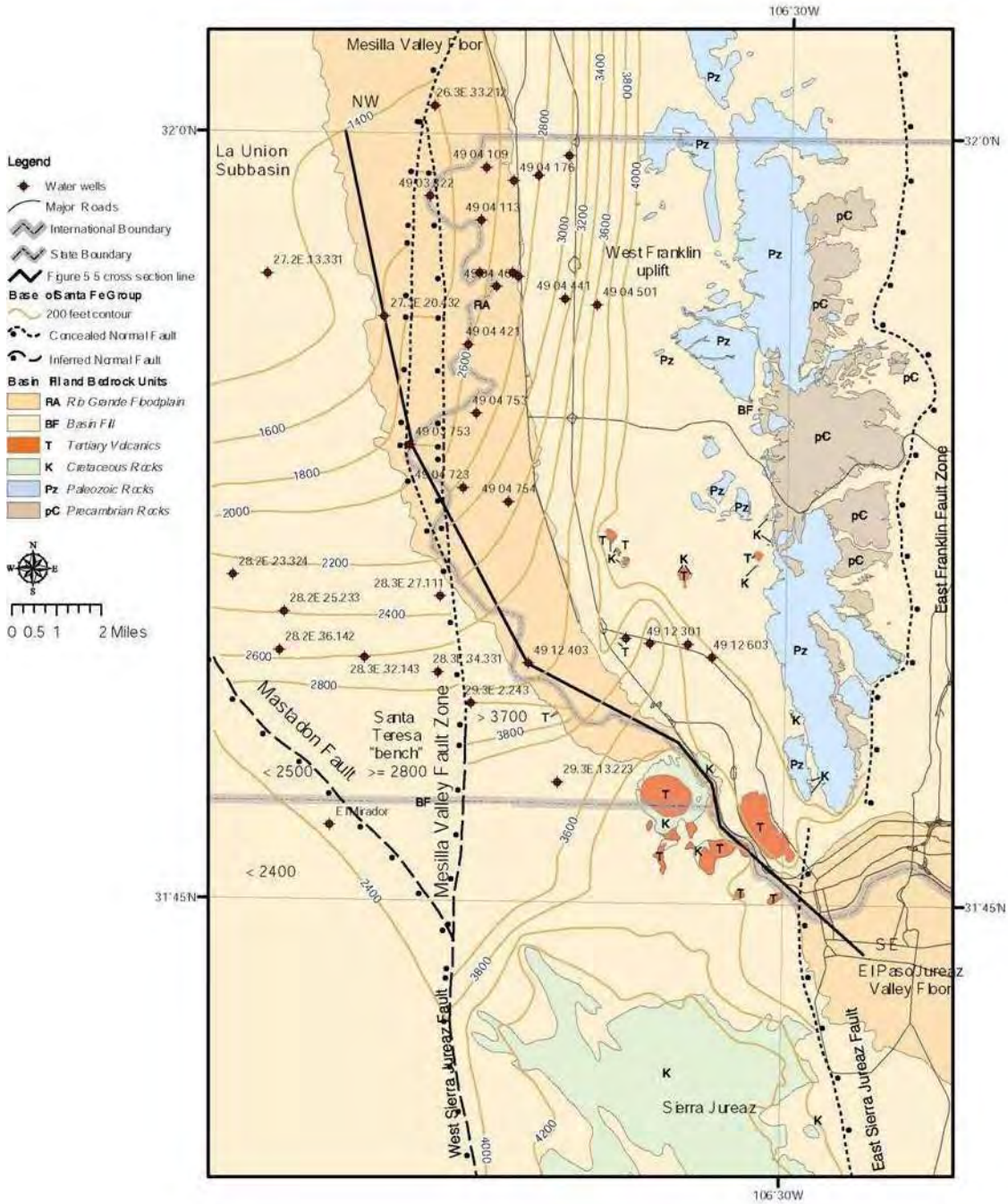


FIGURE 4-1
Structure-Contour Map of the Base of Santa Fe Group Basin Fill in the Lower Mesilla Valley and Paso del Norte Area showing location of Figure 4-2 (NW-SE down-valley cross-section).
Source: Hawley and Kennedy (2004, Fig. 5-2)

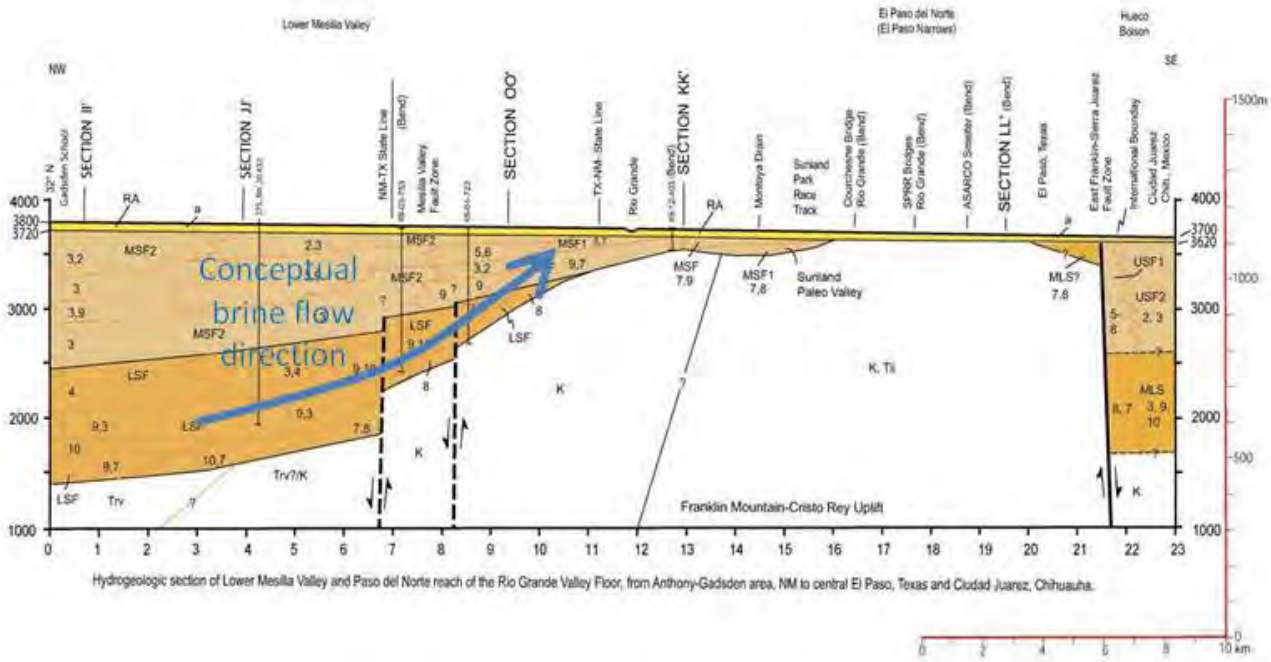


FIGURE 4-2
Schematic Down-Valley Hydrogeologic Cross Section of the Lower Mesilla
Valley-Paso del Norte-western Hueco Bolson segment of the Rio Grande Valley.
From near Anthony (NM-TX, 32° N Lat.) to El Paso-Cd. Juárez city centers. Line of section shown on Figure 4-1.
Source: Hawley and Kennedy, 2004 (Fig. 5-3, and Plate 6 on CD-ROM)

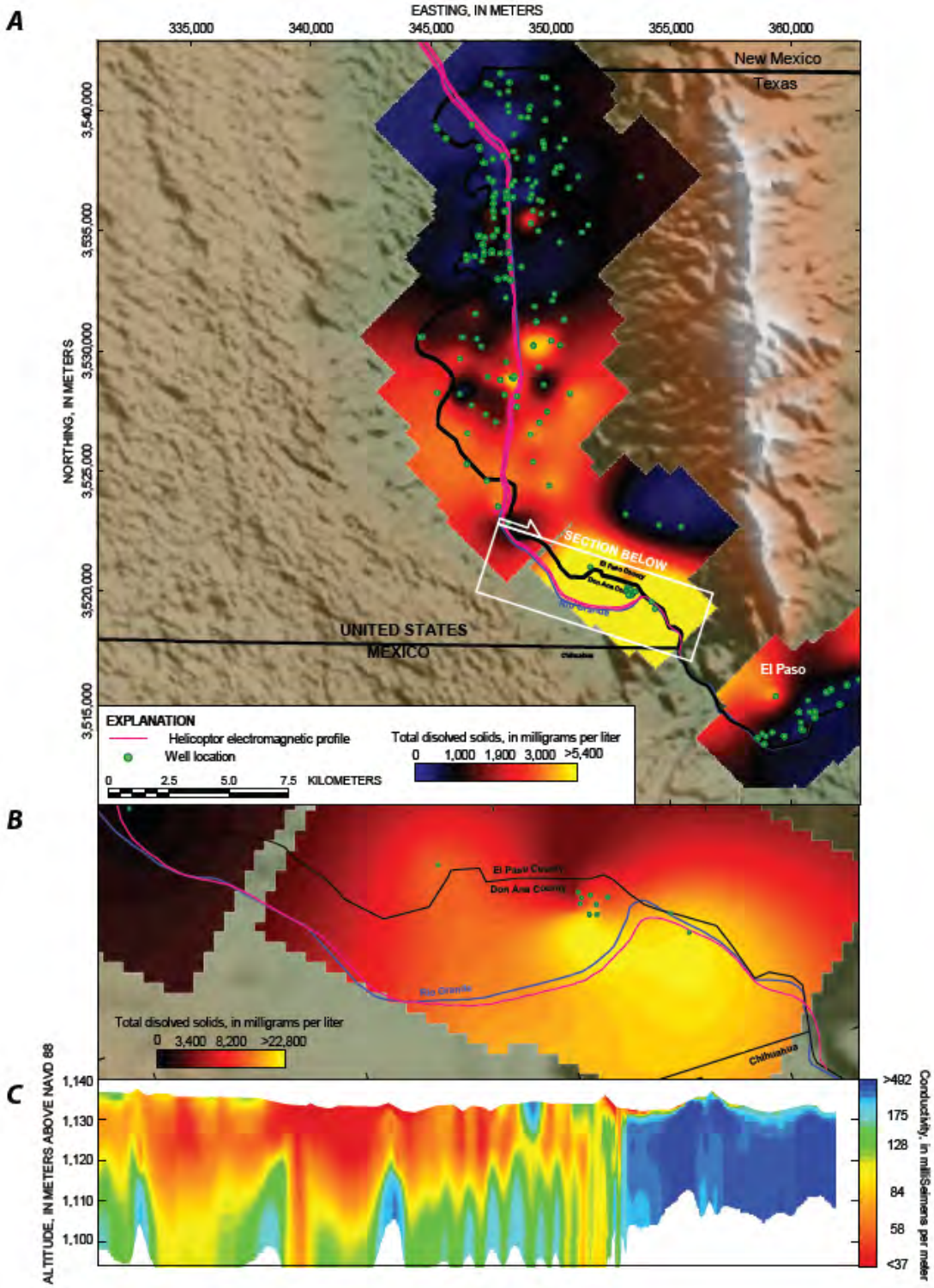


FIGURE 4-3

Images Showing Comparison of Gridded Total Dissolved Solids (TDS) Measured from Groundwater Wells and Gridded Conductivity Values Measured from Helicopter Electromagnetic (HEM) Data

(A) Map showing gridded TDS at the study area and location of the HEM profile, (B) map showing gridded TDS at the location of the HEM section, and (C) section showing gridded conductivity values from the HEM profile.

Source: Figure from Moyer, et al. (2009).

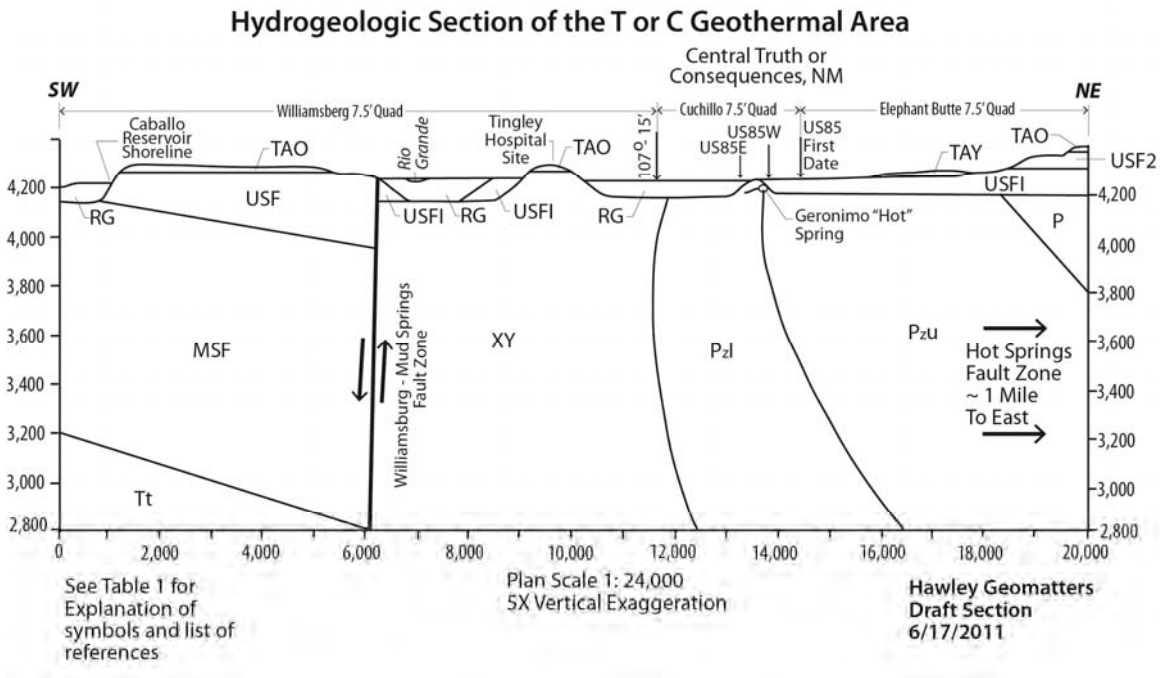


FIGURE 4-4

Draft Hydrogeologic Cross Section for the Truth or Consequences Area Developed by Hawley Geomatters for the Project

Units are described in detail in Table 4-2.

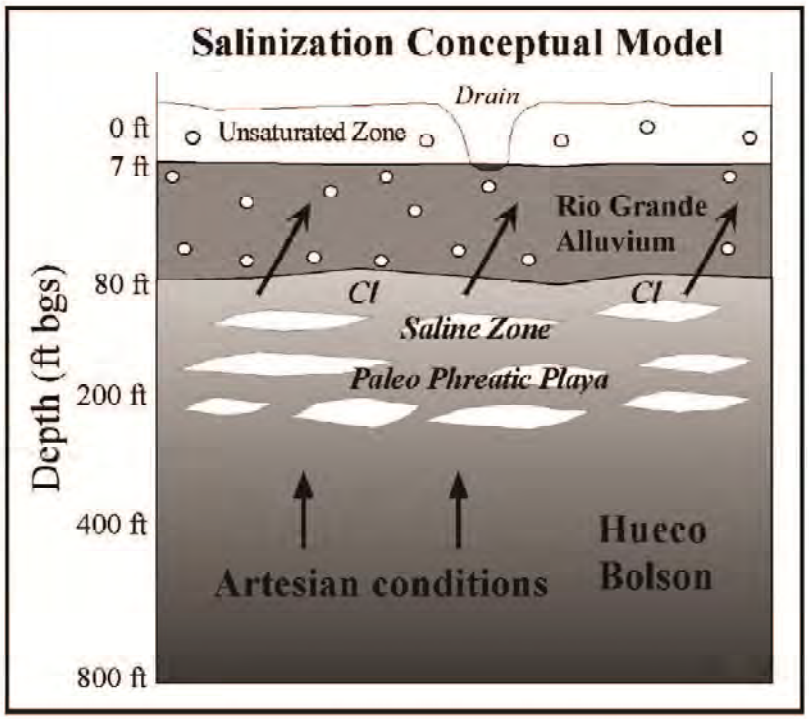


FIGURE 4-5
Conceptual Model for Salinization at Fabens
Upwelling groundwater passes through evaporite deposits resulting in salinization that is carried to the Rio Grande.
Source: Hibbs and Merino, 2006.

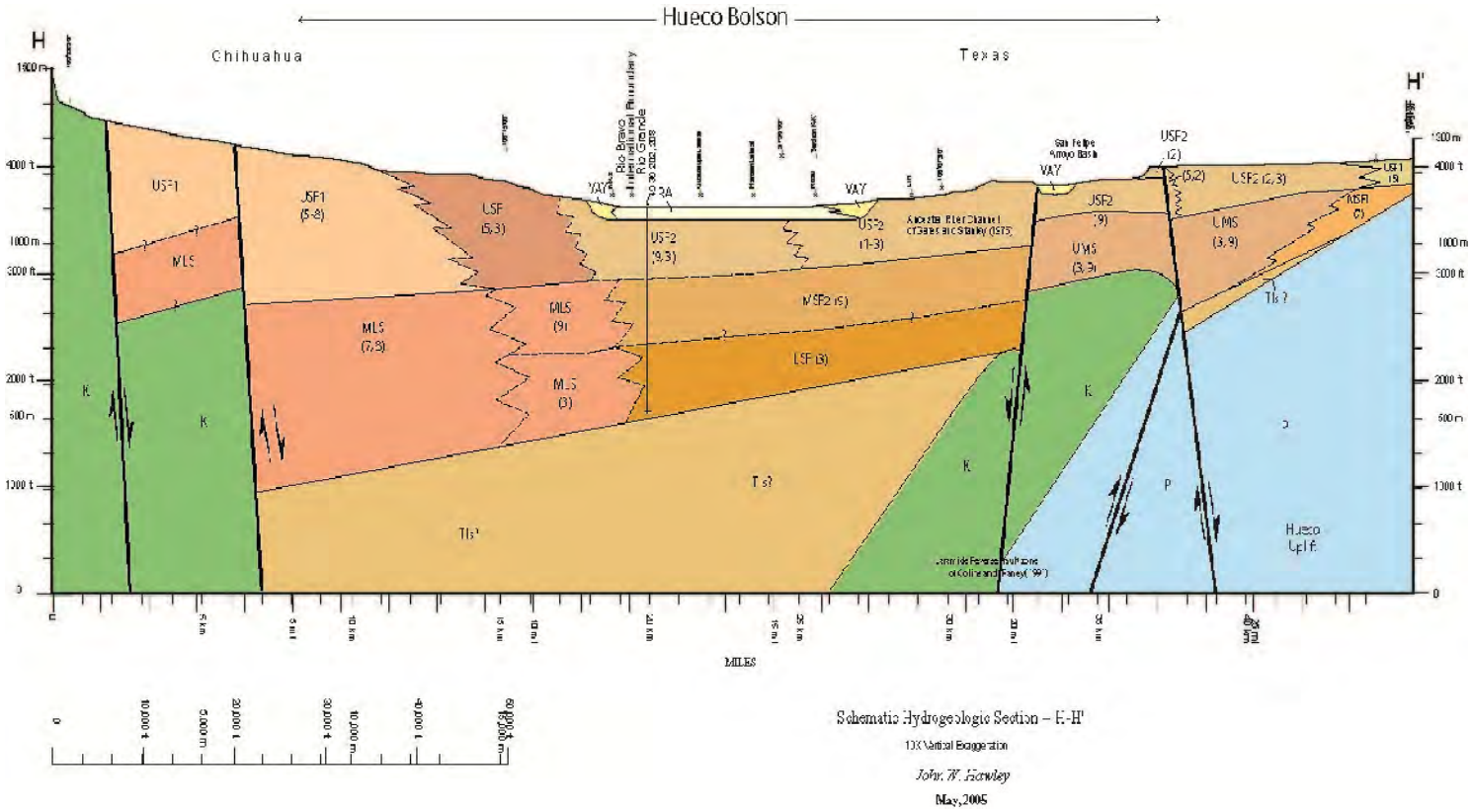
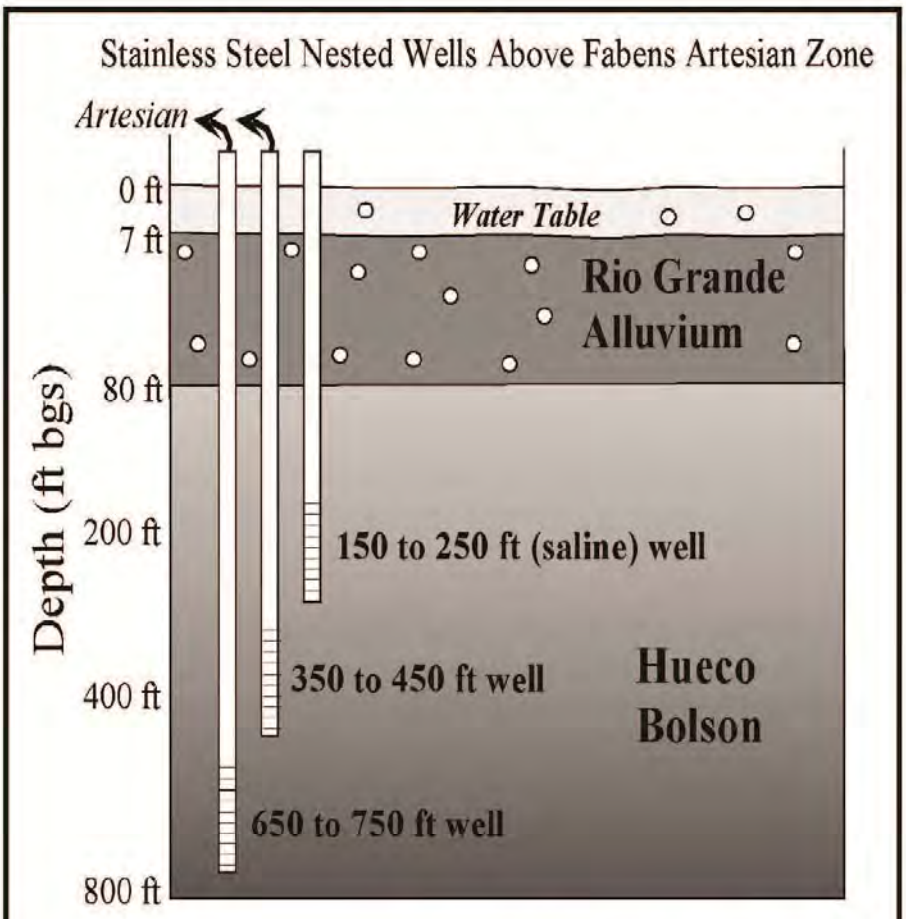


FIGURE 4-6
Schematic Hydrogeologic Section HH'; from Sierra del Presidio (Chihuahua) to Hueco uplift (TX)
Across Fabens Area of the Lower El Paso/Juárez Valley
Line of section runs through town of Fabens; shown on Figure 7 of Appendix A.
Source: Hawley and others, 2009 (Plate 2i on CD-ROM)



Well	TDS	Cl	Cl/Br	SO4
150 to 250 ft (saline)	26,130	14,657	5881	1123
350 to 450 ft	1809	239	293	878
650 to 750 ft	8100	176	568	5234

FIGURE 4-7
Water Chemistry Data from a Series of Monitoring Wells Drilled into a Saline Water at Fabens
Source: Hibbs and Merino, 2006.

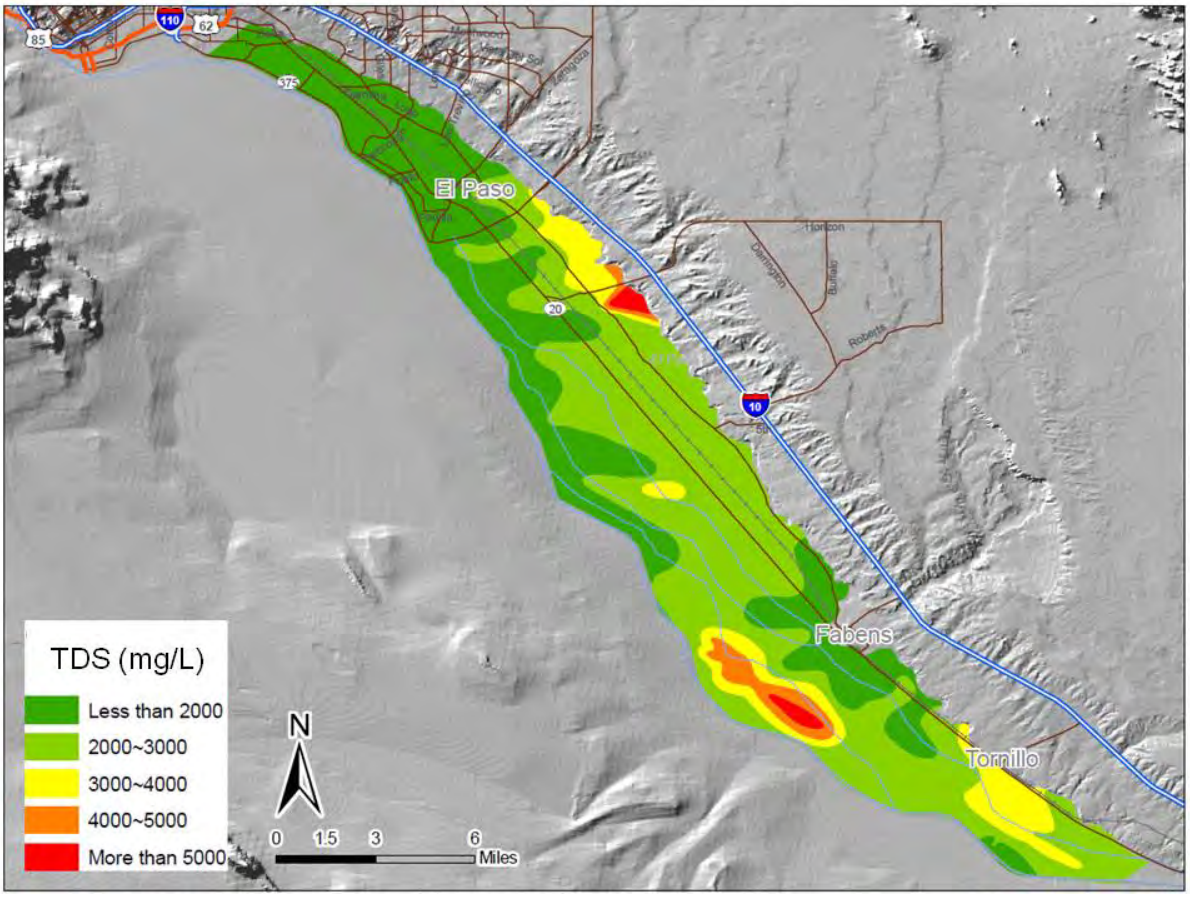


FIGURE 4-8
TDS in the Rio Grande Alluvial Aquifer (from Hibbs and Merino, 2006)
The Fabens area is a clear salinity "hot spot" in the Hueco Bolson resulting from a combination of upwelling water and evaporate-bearing units of the Ft. Hancock formation.

SECTION 5

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