5 Results

5.1 Brackish water analysis

The source water used for this study was the concentrate stream from a brackish water RO desalination plant. For much of the initial experimentation, a synthetic approximation of this water was made in the laboratory based on the reported raw water ion concentrations, assuming 75% recovery. The synthetic water was used in an effort to obtain approximate and reproducible results before direct analysis of the natural water. The natural water taken as concentrate from the North Cameron Regional Water Supply Corporation (NCRWSC) RO plant was analyzed in the laboratory, and the calcium and total carbonate concentrations were compared to the synthetic water. For both species, the natural concentrate water was measured to be within 5% of the calculated synthetic water recipe.

Using the software Visual MINTEQ (version 2.61, 2009), an aqueous equilibrium modeling software which accounts for ion-pair (complex) formation, the synthetic and natural waters were determined to be supersaturated with respect to three salts: calcium carbonate, dolomite, and celestite. The degree of supersaturation as indicated by the saturation ratio (*S*) for each salt was calculated using the initial concentrations from Table 4-1, a pH of 7.8, and total carbonate concentration of 22.2 mM. These results are shown in Table 5-1.

Table 5-1 Saturation ratios of select salts for synthetic NCRWSC RO concentrate (pH = 7.8).

Salt	*S*
Calcite ($CaCO_3$)	5.6
Dolomite, ordered ($CaMg(CO_3)_2$)	5.9
Gypsum ($CaSO_4*2H_2O$)	0.9
Magnesite ($MgCO_3$)	1.7
Strontianite ($SrCO_3$)	2.1
Celestite ($SrSO_4$)	1.4

Calcite and dolomite have the greatest driving force to precipitate, while celestite is only slightly supersaturated. Immediate precipitation of all three salts is being prevented (or at least delayed) by the presence of antiscalant. Increasing the recovery of the system would increase the saturation ratios and would risk causing scale formation on the membrane surface.

Precipitation processes focused on the removal of calcium and carbonate would effectively lower the saturation ratio of calcium carbonate and dolomite, the two most supersaturated salts in the NCRWSC RO concentrate, allowing for further treatment without the risk of scale formation. To accomplish this goal, the antiscalant must be either inactivated or overcome to achieve chemical precipitation and solid/liquid separation. With this objective in view, antiscalant oxidation was investigated.

6.4 Economic feasibility

With the simplified analysis presented in Chapter 5, the high cost of concentrate disposal provides an opportunity to reduce the overall cost of inland brackish groundwater desalination by minimizing the volume of concentrate disposed through improved recovery.

7 Acknowledgements

The authors gratefully acknowledge the primary financial support from the Texas Water Development Board for this project. Additional financial support was obtained from several environmental engineering consulting firms: Black & Veatch, Carollo, CDM, HDR, and Malcolm Pirnie.

Several people were instrumental in our work with the North Cameron Regional Water Supply Corporation Plant. Bill Norris of NRS Engineers was responsible for making the initial contact and obtaining permission for us to be involved with their plant. Additional help from NRS Engineers was provided by Jesus Leal, Jake White, and Paula Galvan. The North Cameron plant is jointly owned by two water supply companies, and the assistance of managers Chuck Browning of the North Alamo Water Supply Corp. and Brian McManus of the East Rio Hondo Water Supply Corp. is gratefully acknowledged. Jessie Roblis and Stephen Sanchez are involved with the operation of the plant, and their assistance throughout our visits to the plant enabled us to accomplish our goals there; their welcoming attitude and willingness to answer all types of questions is certainly appreciated.

The authors are also very grateful for the review of the draft version of this report provided by TWDB staff. Their comments were detailed and insightful and helped improve the value and readability of this report.

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Appendix - TWDB Comments on the Draft Report and Responses to Comments

The following plain text is a record of comments on the draft version of this report, and the *italics text is a record of responses to those comments*.

DRAFT REPORT
IMPROVING RECOVERY: A CONCENTRATE MANAGEMENT STRATEGY FOR INLAND DESALINATION
TWDB Contract #0704830717

Dealing with concentrate and its disposal is an important factor for inland desalination. An important and helpful feature of this report is that it describes work in areas that were not successful as, for example, the work on peroxone.

The reviewers of the report provided the following comments:

General Comments

1. The following words have been used in two different forms in the report:
   - Seawater (page 2, first paragraph, line 5) and sea water (Page 2, second paragraph, line 2). Please use the word 'seawater' consistently in the report.
   - Saltwater (page 2, second paragraph, line 3) and salt water (Page 4, 3rd paragraph, lines 5 and 6). Please use one or the other word consistently in the report.

   Text was corrected.

2. The name 'North Cameron Regional Water' should be replaced with the full name of the agency, which is North Cameron Regional Water Supply Corporation (NCRWSC).

   Text was corrected.

Specific Comments

Page iii

Names and titles of TWDB's Board members are printed incorrectly. Please visit http://www.twdb.state.tx.us/about/board_members/Board_Members.asp to obtain current names and titles of TWDB's Board members.

Text was corrected.

Section 5.4 (Pages 60 to 63)

1. First paragraph of Section 5.4 in page 60: Please include in the discussion that in some cases the potential benefit of increased recovery is a combination of the increased efficiency in the use of the source water (less waste) as well as reduced volumes requiring disposal.

   This suggestion was accepted with an addition to the text.

2. Section 5.4.1 (Page 61, first paragraph): To estimate monthly capital cost payment, please consider using 20 year amortization with 6% interest rate to comply with TWDB's regional planning estimates.

   This new analysis was performed and the text and table revised.

3. Table 5-2 (Page 61): Please add the cost of disposing of the sludge in the Table. Additionally, please re-label the column 'Capital Cost' as 'Amortized Capital Cost'.

   The cost of chemical softening sludge was not included in this analysis, and has been noted in the text. The column title was corrected.

4. Last paragraph of Page 61: The cost used for construction of evaporation ponds, $6,000 per acre, appears to be very low. The report "Self-Sealing Evaporation Ponds for Desalination Facilities in Texas" prepared for TWDB by the Bureau of Economic Geology in 2007 suggests a cost of $50,000 to $70,000 per acre for a five-acre evaporative pond. This cost would be for a minimally equipped pond. Ponds for use with hazardous materials with double liners and leakdetect systems are much more expensive. Please consider revising the estimate.

   In the draft version of this report, the cost of $6000/acre was only the price of purchasing the land, and the cost estimation procedure in Mickley (2006) involves several parameters to estimate the total cost as a function of the purchase price of the land, as well as the costs of dike, liner, fence, and road. Depending on the estimation parameters, the total cost of an evaporation pond rangesfrom $20,000 to $80,000 per acre. However, in deference to the reviewers, the cost estimates for disposal by evaporation pond presented in the final version of this report were calculated based on a total price of $50,000/acre and a 20 year, 6% amortization.

5. First paragraph of Page 62: If the need is 1.5 MGD of pre-blending permeate, at 95% recovery, NCRWSC would require 1.58 MGD of source water or 0.42 mgd less than at 75% recovery. Please clarify if the benefit is accounted for in the analysis. Additionally, for completeness, the narrative should acknowledge the commonly used disposal by surface discharge (understanding that surface discharge would be a much unlikely option for high TDS concentrate streams).

   (See comment and response above regarding Section 5.2.) The analysis was performed assuming that the increase in recovery would increase the overall production of the plant (i.e., that the original BWRO facility would not be affected by the additional treatment

system), so the benefit of decreasing permeate was not considered. The infeasibility of surface discharge was noted in the text.

Section 6.3 (Page 65)

If electro-osmosis is a problem, it can be reduced somewhat by use of tighter, *i.e.*, lower water content, membranes. Please address this issue in the report.

Text was corrected to include this idea.