USE OF A BENCH SCALE SYSTEM TO SIMULATE PROTOTYPE SCALING IN A FULL-SCALE SYSTEM.

RICHARD JOHN BOYER

University of Texas at El Paso

Department of Civil Engineering

APPROVED:

Dr. Charles D. Turner, Chair

Dr. John C. Walton

Dr. Larry P. Jones

Associate Vice President for
Graduate Studies

It is with great pride and enthusiasm that I dedicate this small effort to my parents,
Dick and Sue Boyer,
without whom absolutely none of this would have been possible.
Thanks mom and dad, for never losing faith in me,
even when I thought I had sometimes.

Also, big thanks to my sisters, Kathleen and Stefani, who have always been there for me if not in body, in spirit, and thanks to the entire Lehmkuhl and Boyer clans for their love and support.

Finally, to my friends who kept me going throughout the past few years....

Brenda and Sal Anchondo
David C. Doran
Kimberly A. Fincher
Troy Gonzalez
Gregg B. Haan
Rebecca S. Moore
Heather O'Connell
Richard C. Robins
Tina and Jerry Shaffer
Luis "The King" Silva
Charles C. Siros
Monte and Soozi Walker

USE OF A BENCH SCALE SYSTEM TO SIMULATE PROTOTYPE SCALING

IN A FULL-SCALE SYSTEM.

by

RICHARD JOHN BOYER, B.S.C.E., E.I.T.

THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING

Department of Civil Engienering

THE UNIVERSITY OF TEXAS AT EL PASO

December 1998

ACKNOWLEDGEMENTS

I would like to thank Dr. Charles Turner, for being my advisor and mentor for the past few years. He was always ready to give me an encouraging word, or to push me harder than I thought I could. I would also like to thank him for his unending enthusiasm for the title of being an engineer and for those who pursue it.

Thanks to Dr. John Walton for the help he has given me, and whose San Diego Chargers jokes always made me laugh. Thanks to Dr. Larry Jones for sitting on my committee.

Very large thanks to Jesus Moncada, for always answering my questions with patience, even though I asked a lot of them more than once. His help is greatly appreciated.

Thanks to the Center for Environmental Resource Management here at UTEP for their help and financial assistance in making this thesis possible.

As colleagues, Mayela Quezada, Sandra Moreno, and Ofelia Garbalena have provided me with no end of data and knowledge. This thesis could not have been done without their help.

Finally, thanks to everyone in the ASCE office past and present, for their help and contributions.

This thesis submitted to the committee on July 17, 1998.

ABSTRACT

Membrane processes are becoming more cost effective for the desalination of brackish groundwater. The main operational problem is flux loss through the membrane. Scaling of membranes is inevitable when desalinating saline water, however, now membrane scaling can be simulated in the laboratory. Using the rapid bench scale membrane test system, membranes can be tested in the laboratory at a lower cost and without possible damage to the main system. Actual data recorded from using the RBSMT was then compared to field data recorded from the Homestead dual membrane facility at the Homestead colonia, in East El Paso, Texas. Both sets of data had similar trends, mainly the increase in pH and saturation index of the feed waters passed through the two systems.

The main purpose of this experiment was to see if the rapid bench scale membrane test system can be used to simulate conditions in a full-scale facility, and ultimately predict these conditions. Increasing the saturation index of different feed waters into the RBSMT will do this. By using the concentrates obtained from the different feed waters passed through the RBSMT as the next feed water, the saturation index of each feed water is increased.

For the RBSMT, the saturation index of the feed water increased from –0.31 to 0.88, indicating that each successive feed water had a higher potential of precipitating salts onto the membrane. The flux loss through the system was reduced by 10% over a 140-hour period due to this increase in saturation index. This data was compared to an

11% flux loss in the stage two membranes at the Homestead facility over a 1,824-hour period. The data from Homestead showed a similar increase in saturation index over time, from –0.50 to 0.17. While this does not prove that bench scale system can predict scaling in a full-scale facility, it does suggest that the bench scale system can be used to simulate those conditions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

1.1 Introduction

Since the late 1800's, the Hueco Bolson, an unconfined, alluvial aquifer, has been the major source of water for the cities of El Paso, Texas, and Ciudad Juarez, Mexico. It currently supplies nearly 40% of El Paso's water needs, and all of the water needs of Ciudad Juarez. However, the volume of potable water remaining in the aquifer is quickly diminishing.

According to the 1990 census, El Paso currently has a population of 580,000 people, with a growth rate of 2.1 % per year. Ciudad Juarez has 1.5 million people, with a growth rate of 5% per year (http://www.nmsu.edu/~frontera/may96/9may1096.html, 2/10/98). The average El Paso resident uses 175 gallons per day of water, equaling 100 million gallons per day for the city (http://www.nmsu.edu/~frontera/may96/9may1096.html, 2/10/98). Ciudad Juarez residents only use 88 gallons per day, but that equals nearly 132 million gallons per day for the (http://www.nmsu.edu/~frontera/may96/9may1096.html, 2/10/98). With the combined populations of both cities estimated to be nearly 4 million by the year 2030, the stress on the Hueco Bolson can only increase. An estimation of the population growth is listed in table 1.1, and a graph can be seen in figure 1.1 on the following page (http://www.cerm.edu, 1997).

Adding to the problem is a lack of natural recharge into the aquifer. With a regional annual rainfall amount of only 8 inches per year, the Rio Grande and natural precipitation do not recharge the aquifer as quickly as the water is pumped out. As the

Year	El Paso	Cd. Juarez	Total
1950	194,968	131,308	326,276
1960	314,070	276,995	591,065
1970	359,291	424,135	783,426
1980	479,899	567,365	1,047,264
1990	591,610	798,499	1,390,109
2000	713,904	1,203,794	1,917,698
2010	876,560	1,641,282	2,517,842
2020	1,034,560	2,020,822	3,055,382
2030	**1,205,676**	**2,565,766**	**3,771,442**

Table 1.1: Population projection for the El Paso/Ciudad Juarez area

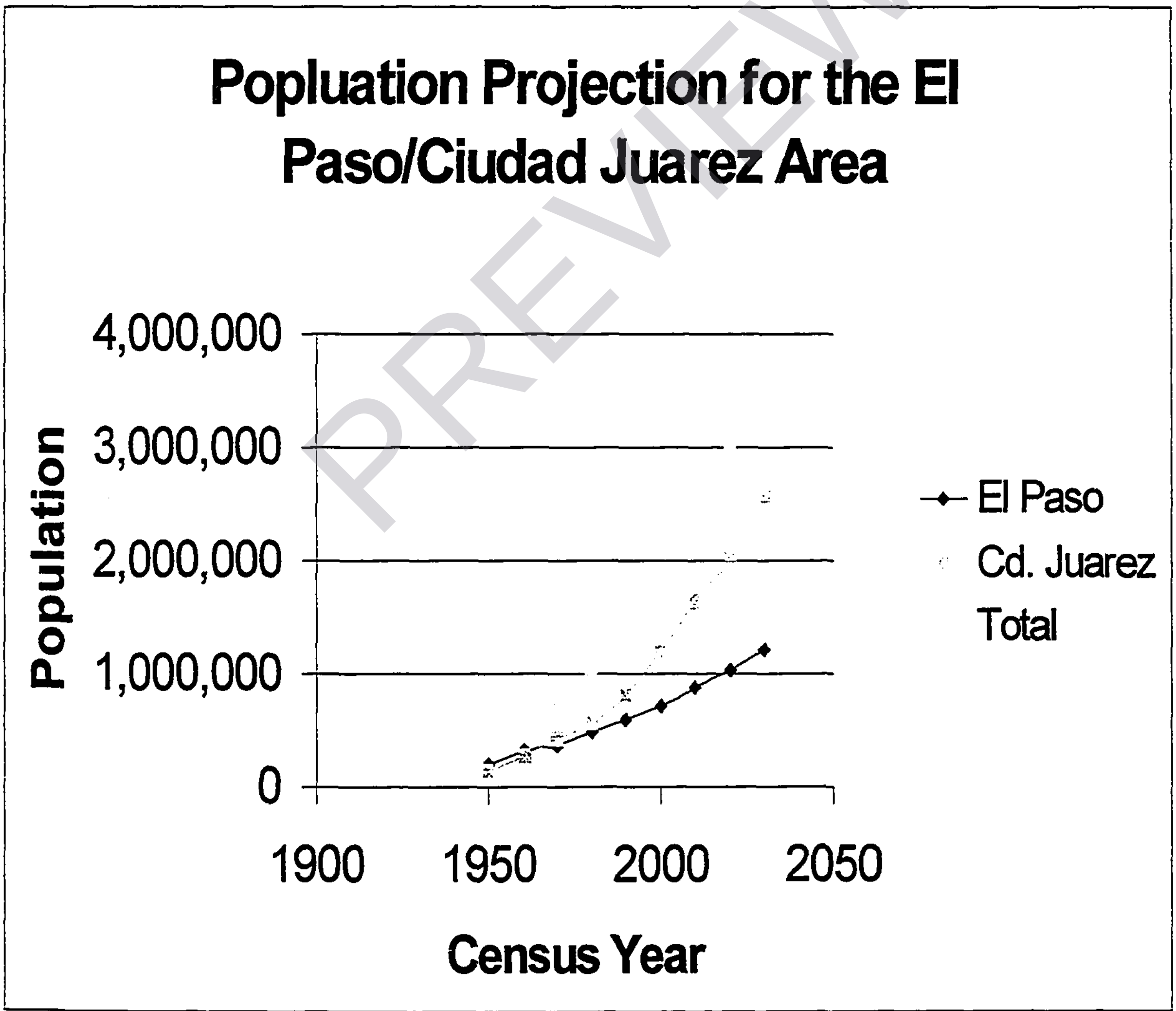

Figure 1.1: El Paso/Ciudad Juarez Population Projection

fresh water is removed, brackish water intrudes into the fresh water portion of the aquifer, making it non-potable. The problem is especially magnified in the eastern subdivisions of El Paso, the Colonias (Moncada, 1996). A Colonia is, by definition "a rural and unincorporated subdivision of a US city located along the Texas-Mexico international boundary. Substandard housing, inadequate plumbing and sewage disposal systems, and inadequate access to clean water characterize Colonias. Twenty four percent of households are not connected to treated water" (Salinas, Bensenberg, Amazeen, 1988). Many residents use their own wells for water, and this water can be very saline, with a total dissolved solids concentration (TDS) content of 1100 – 1400 (Moncada, 1996). Total dissolved solids (TDS) is a measure of the total amount of materials dissolved in a sample of water. The Texas State limit for TDS is 1000 for drinking water, and the Environmental Protection Agency's (EPA) secondary limit is 500. Seawater, for example, has a TDS of 34,000, classifying it as "highly brackish" water.

1.2 Membrane Technology

The most common process for reducing salinity of brackish groundwater is reverse osmosis (Hammer, Veissman, 1993). During osmosis, water flows from a lower salt concentration through a membrane into a higher salt concentration to try to achieve equilibrium. The membrane allows water to flow through it while blocking ions. Applying pressure to the side with the larger sodium content can stop or reverse this process. By exceeding the osmotic pressure, the water can be forced from the saline