TEXAS DEPARTMENT OF WATER RESOURCES

LP-104

SIMULATED EFFECTS OF GROUND-WATER PUMPING IN PORTIONS OF THE HUECO BOLSON IN TEXAS AND MEXICO DURING THE PERIOD 1973 THROUGH 2029

By

Tommy R. Knowles and Henry J. Alvarez

August 1979

TABLE OF CONTENTS

TABLES

FIGURES

TABLE OF CONTENTS (Cont'd.)

Introduction

Ground Water from the Hueco Bolson is essential to the economic development of the El Paso-Ciudad Juarez area; and, although the supply of fresh ground water in the bolson is large, the amount withdrawn annually exceeds the natural recharge. This dependence on ground water to meet the area's expanding municipal and industrial water requirements is of concern, not only to area residents, but also to municipal, state, and federal governments.

Previous Investigations

In 1965 the U.S. Geological Survey (USGS), in cooperation with the city of El Paso and the Texas Water Development Board which was a predecessor of the Texas Department of Water Resources (TDWR), developed an electrical-analog model to better define the bolson aquifer and simulate responses of the reservoir to various plans of future ground-water development. That work was reported on by Leggat and Davis (1966). The straightening and concrete lining of a segment of the Rio Grande in 1969 reduced the effectiveness of the model to predict the results of a particular plan of development. Rather than rebuild the analog model to accommodate this change, the cooperators decided to develop a two-layer digital model of the aquifer which, in addition to simulating hydraulic-flow patterns, could later be used to model changes in ground water quality.

The area of the Hueco Bolson covered by the digital model includes all of El Paso County between the Franklin and Hueco Mountains in extreme west Texas, and extends northward into New Mexico and southward into Mexico. The population of this area in 1970 was about 752,000. Results of this digital model study have been published by the USGS (Meyer, 1976). The report presented: (1) results of a steady-state analysis to determine the distribution and amount of recharge necessary to maintain the steady-state hydrologic conditions that existed in 1903; and (2) the results of a nonsteady-state analysis for 1903-36, 1903-58, and 1903-73. Comparisons of water-level maps (1903 and 1936) and water-level decline maps (1903-58 and 1903-73) produced by the digital model with maps prepared from field data for the same periods were used to calibrate the model. After calibration, the model was used to predict the effects of additional development during the period 1973-90. The model incorporates geologic and hydrologic data to simulate (1) the hydrologic regime of the area, (2) response to pumping from wells in both the mesa and artesian areas of the Hueco Bolson, and (3) variable rates of leakage between the two aquifers (alluvium and bolson deposits) and between the alluvium and the Rio Grande. Well locations and pumpage estimates utilized in the USGS simulations were derived in cooperation with the city of El Paso.

Purpose and Scope of This Report

The Texas Water Development Board developed ground water pumpage projections for the El Paso area for use in its draft report titled "Continuing Water Resources Planning and Development For Texas", completed in 1977. These projections of annual pumpage extended through the year 2030. Previously, pumpage projections for this area through 1990 had been prepared by the Survey as described by Meyer (1976), and projections through 2020, although unpublished, had been provided by the Survey to the Board in computer-card format. The Board's new projections of annual pumpage significantly exceeded those of the Survey. Consequently, this study was considered essential for the purpose of determining the impact that the greater expected pumpage rates would have on the ground-water resources of the El Paso area. The Survey's digital computer model was utilized for the analysis, and aside from applying the new pumpage projections during aquifer simulation, all other parameters that had been utilized earlier by the Survey were employed in this study, including a recharge rate of 5,640 acre-feet per year.

Methods and Procedures

A graph (Figure 1) was constructed to show the difference between the Board's (now the Department's) projected average rates of pumpage from the Hueco Bolson in Texas and those projected by the Survey, and to assist in determining how pumpage should be distributed or assigned to the various cells during computer simulations of the aquifer. The graph illustrates that the Department's pumpage projections generally exceed those of the Survey such that the Department's projection for 2020 exceeds that of the Survey by over 70 percent. Twelve periods of pumpage to be simulated were established by the Department (Table 1), and the distribution of pumpage for the first seven periods was made based on well development patterns used by the Survey in its model study. The USGS distribution and corresponding Department pumpage are as follows: USGS 1973-1989 pumpage distribution for TDWR Pumpage Periods 1 and 2 (1973-74 and 1975-79); USGS 1990-2009 pumpage distribution for TDWR Pumpage Periods 3, 4, and 5 (1980-84, 1985-89, and 1990-94); USGS 2010-2019 pumpage distribution for TDWR Pumping Periods 6 and 7 (1995-99 and 2000-04). TDWR pumpages for these periods were assigned by comparing the total TDWR pumpage for each pumping period to the total cumulative pumpage of the preceeding period and proportionately assigning the difference (increased pumpage) to the previous cumulative pumpage value of each cell. Only those cells activated by the Survey were utilized in these simulations. It must be pointed out that in this analysis (1) Department pumpage projections for Texas shown on Table 1 exceed by about 1 percent those shown on Table IV-23.5, page IV-763 of Volume II of "Continuing Water Resources Planning and Development for Texas" (Texas Water Development Board draft report, 1977), (2) annual pumpage projections used by the Survey prior to 2014 for Ciudad Juarez were imposed on the model by the Department but much earlier than imposed by the Survey, and (3) the Department's own annual pumpage projections for Ciudad Juarez were imposed after 2014.

Utilizing this procedure, the Department's pumpage projections for the first seven pumping periods (1973-2004) were applied to the model. This resulted in simulated water levels which were used to construct a projected saturated thickness map (Figure 2) of the fresh-water portion of the Bolson through the year 2004. This was done to determine the best possible locations (cells) to which pumpage should be imposed during the remaining five pumping periods (2005-29). The following will represent the first deviation from the usage of the pumpage distribution established by the USGS in its model study.

For pumping periods 8 and 9 (2005-2014), two-thirds of the increased pumpage for Texas for each period was proportionately assigned to those cells utilized by the USGS which were located within the El Paso city limits (excluding Fort Bliss) and had a projected 2004 saturated thickness (Figure 2) of 600 feet or more. The remaining one-third of the increased pumpage for Texas for each period was proportionately assigned to cells utilized by the USGS which were located within the El Paso city limits (excluding Fort Bliss) and had a projected 2004 saturated thickness (Figure 2) of more than 300 but less than 600 feet. Pumpage in the remaining cells utilized by the USGS but not included in the above apportionment (including Fort Bliss and Ciudad Juarez) was held constant (the same cumulative pumpage as the previous period). These cells generally occurred in areas having a saturated thickness of less than 300 feet.

Survey values for Ciudad Juarez's average annual rate of pumpage were utilized but imposed much earlier in the following manner: 1973 through 1979, 49 ft^3/s; 1980 through 1994, 64 ft^3/s; and 1995 through 2014, 76 ft^3/s. Pumpages for the period 2015 through 2029 shown on Table 1 were obtained from extending a straight-line projection of a graph of Ciudad Juarez's average annual rate of pumpage after 1980. These projections were employed in imposing the Department's increased pumpage for pumping periods 10, 11, and 12 to those cells in Mexico previously utilized by the USGS. These cells generally occur within the areas having a saturated thickness of less than 300 feet. Increased pumpage in the Texas portion of the Hueco Bolson for these same periods (10, 11, and 12)was distributed in the same manner as described for pumping period 8 and 9.

Following completion of the final run covering the period 2005-2029, a graph (Figure 3) was constructed to illustrate the cumulative ground-water requirements (pumpages) which were placed on the Hueco Bolson for the period 1975 to 2030 and what porportions of these requirements would be supplied by various components of the region's hydrologic systems. The graph shows that most of the ground water will be obtained from storage depletion in the Bolson deposits and that percolation from the Rio Grande will contribute significant quantities of water. Table 2 shows the significance of seepage from the Rio Grande to the alluvium and leakage from the alluvium into the Bolson deposits.

To examine the effects of the simulated pumpage pattern on the Bolson's water levels, and whether this pattern would result in an efficient development of the ground-water resources, several illustrations were made. These consisted of two east-west cross-sections (Figures 4 and 5), a north-south section (Figure 6), one northwest-southeast section along the Rio Grande (Figure 7), a projected saturated thickness map of the sediments containing fresh water in the Bolson in 2029 (Figure 8), and a map showing the projected water levels in the Bolson for 2029 (Figure 9). The locations of the cross sections (Figures 4, 5, 6, and 7) are shown on Figure 9 and 10. All of the illustrations indicate that the simulated pumpage distribution patterns afford efficient development of the Bolson's ground-water resources. In addition, Table 3 indicated that sufficient fresh ground water remains available in the bolson deposits to meet the area's needs through 2029.

Two additional illustrations were constructed to show the effects that lining a portion of the Rio Grande with concrete had upon water levels in the alluvium and Bolson deposits. The first (Figure 10) illustrates dramatic water-level declines in the alluvium in the immediate vicinity of the lined portion of the river followed by a mounding effect of the water levels immediately downstream of the lining. The second illustration (Figure 11) shows in cross section the projected attitude of water levels in 2029 for the alluvium and Bolson deposits respectively immediately downstream of the lined portion of the river. The sections show a large mounding of water levels in both the alluvium and the Bolson deposits as a result of seepage from the river. The location of the two sections in Figure 11 are shown on Figures 10 and 9 respectively.

Conclusion and Recommendations

It should be pointed out that certain aspects of the aquifers were not included in the model. For example, the alluvial aquifer which is represented by layer one in the model study is generally considered to occur to a depth of 200 feet below land surface. However, no lower limits of layer one water levels were incorporated into the model. Therefore water levels in excess of 200 feet in depth occur such as those shown in the vicinity of the lined portion of the Rio Grande in Figure 7.

Originally it was planned to subject the model to several additional patterns of pumpage distributions utilizing the TDWR pumpage projections presented in this analysis. However, since the resulting illustrations indicate that the methods, procedures, and distribution already applied result in an efficient development of the ground-water resources of the Bolson, no further analyses were attempted.

The availability of fresh ground water to meet the projected needs of the El Paso area remains of primary concern. Although current TDWR pumpage projections exceed the previous projections of the USGS, the Department's analysis indicate that approximately 3.7 million acre-feet of fresh water will remain in storage in the Texas portion of the Hueco Bolson through 2029. Nevertheless, the long-range future of this area will undoubtedly include recycling and reuse of some of its present fresh ground-water resources, the desalination of some additional poorer quality ground waters of which very great quantities are available for development, and likely the importation of still additional waters from outside the immediate area.

Since the present digital computed model does not consider water-quality data in concert with hydraulic-flow patterns, we recommend that the next phase of model study of the Hueco Bolson be a simulation of water-quality changes in the alluvium and Bolson deposits based on past, present, and anticipated ground-water development.

References

Leggat, E. R., and Davis, M. E., 1966, Analog model study of the Hueco Bolson near El Paso, Texas: Texas Water Development Board Report 28.

Meyer, W. R., 1976, Digital model for simulated effects of ground-water pumping in the Hueco Bolson, El Paso area, Texas, New Mexico, and Mexico: U.S. Geological Survey Water-Resources Investigations 58-75.

Texas Water Development Board, 1977, Continuing water resources planning and development for Texas: Texas Water Development Board draft report, Volumes 1 and 2.

TABLE 1

Projected Average Rates of Ground-Water Pumpage from the Hueco Bolson (including Mexico) for the Period January 1973 Through December 2029

Pumping Period	Time Interval	Average Pumpage Rate in Texas		Average Pumpage Rate in Mexico		Average Total Pumpage Rate	
		acre-ft/yr	ft^3/s	acre-ft/yr	ft^3/s	acre-ft/yr	ft^3/s
1	1973-1974	73,600	102	35,700	49	109,300	151
2	1975-1979	83,500	115	35,700	49	119,200	164
3	1980-1984	97,000	134	46,600	64	143,600	198
4	1985-1989	114,100	158	46,500	64	160,600	222
5	1990-1994	135,400	187	46,500	64	181,900	251
6	1995-1999	156,600	216	54,800	76	211,400	292
7	2000-2004	184,200	254	54,800	76	239,000	330
8	2005-2009	217,900	301	54,800	76	272,700	377
9	2010-2014	252,700	349	54,800	76	307,500	425
10	2015-2019	287,400	397	56,100	77	343,500	474
11	2020-2024	322,000	445	58,800	81	380,800	526
12	2025-2029	356,600	493	61,400	84	418,000	577

TABLE 2

Projected Average Rates of Seepage from the Rio Grande and Leakage Between Aquifers

Period	Average rate of seepage into alluvium from Rio Grande (acre-ft/yr)	Average rate of leakage from alluvium into Bolson deposits (acre-ft/yr)
1973-1974	13,700	34,500
1975-1979	18,100	37,300
1980-1984	25,200	45,900
1985-1989	31,200	50,300
1990-1994	36,900	55,500
1995-1999	43,600	63,200
2000-2004	50,300	67,700
2005-2009	56,300	79,800
2010-2014	66,000	76,800
2015-2019	68,000	82,900
2020-2024	74,800	89,000
2025-2029	83,000	97,600

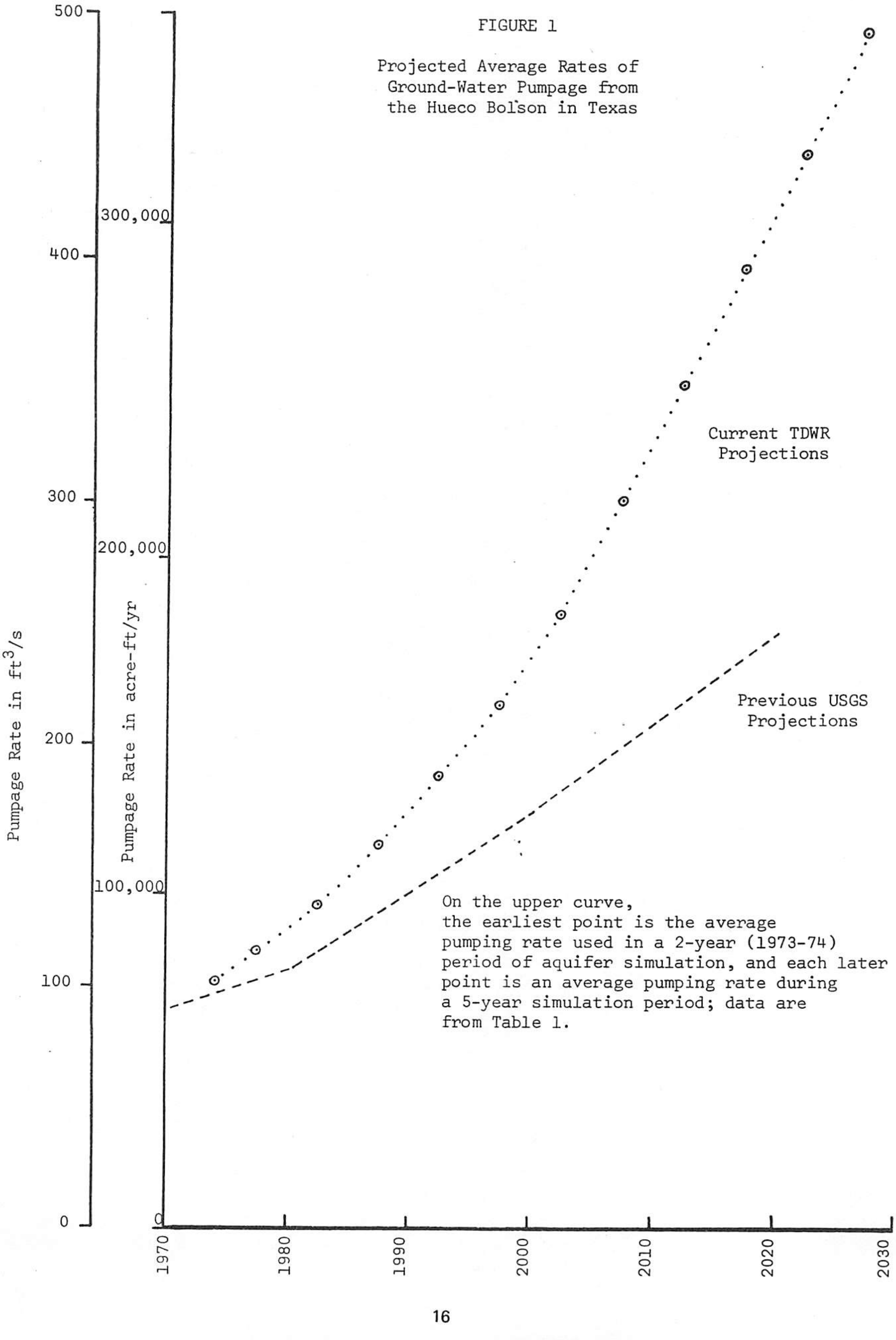
TABLE 3

Projected Amounts of Fresh Water in Storage in the Texas Part of the Bolson, and Amounts Removed from Storage in Texas and from the Entire Bolson (Excluding Alluvium)

Period	Amount of fresh water in storage in Texas at end of period in acre-ft	Amount removed from storage during period in acre-ft	
		Texas only	Entire Bolson
1973-1974	10,606,000	96,000	139,600
1975-1979	10,339,000	267,000	384,700
1980-1984	10,014,000	325,000	462,500
1985-1989	9,637,900	376,100	528,000
1990-1994	9,195,400	442,500	609,700
1995-1999	8,679,900	515,500	753,700
2000-2004	8,075,600	604,300	866,200
2005-2009	7,381,100	694,500	937,200
2010-2014	6,552,400	828,700	1,143,000
2015-2019	5,634,500	917,900	1,278,300
2020-2024	4,661,600	972,900	1,440,100
2025-2029	3,699,400	962,200	1,589,500

FIGURE 1

Projected Average Rates of Ground-Water Pumpage from the Hueco Bolson in Texas



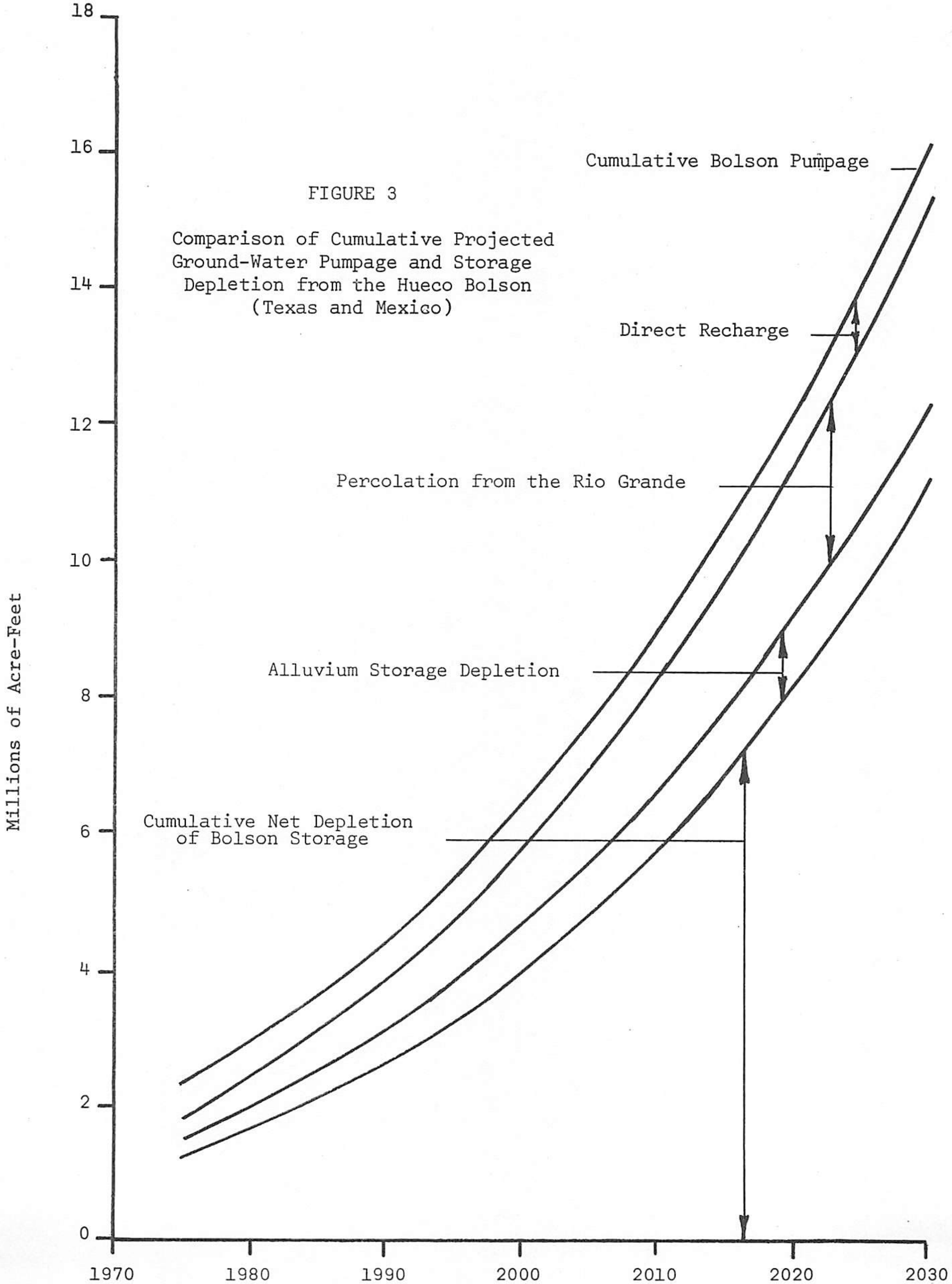


FIGURE 3
Comparison of Cumulative Projected Ground-Water Pumpage and Storage Depletion from the Hueco Bolson (Texas and Mexico)
Cumulative Bolson Pumpage
Direct Recharge
Percolation from the Rio Grande
Alluvium Storage Depletion
Cumulative Net Depletion of Bolson Storage
Millions of Acre-Feet
18
16
14
12
10
8
6
4
2
0
1970
1980
1990
2000
2010
2020
2030

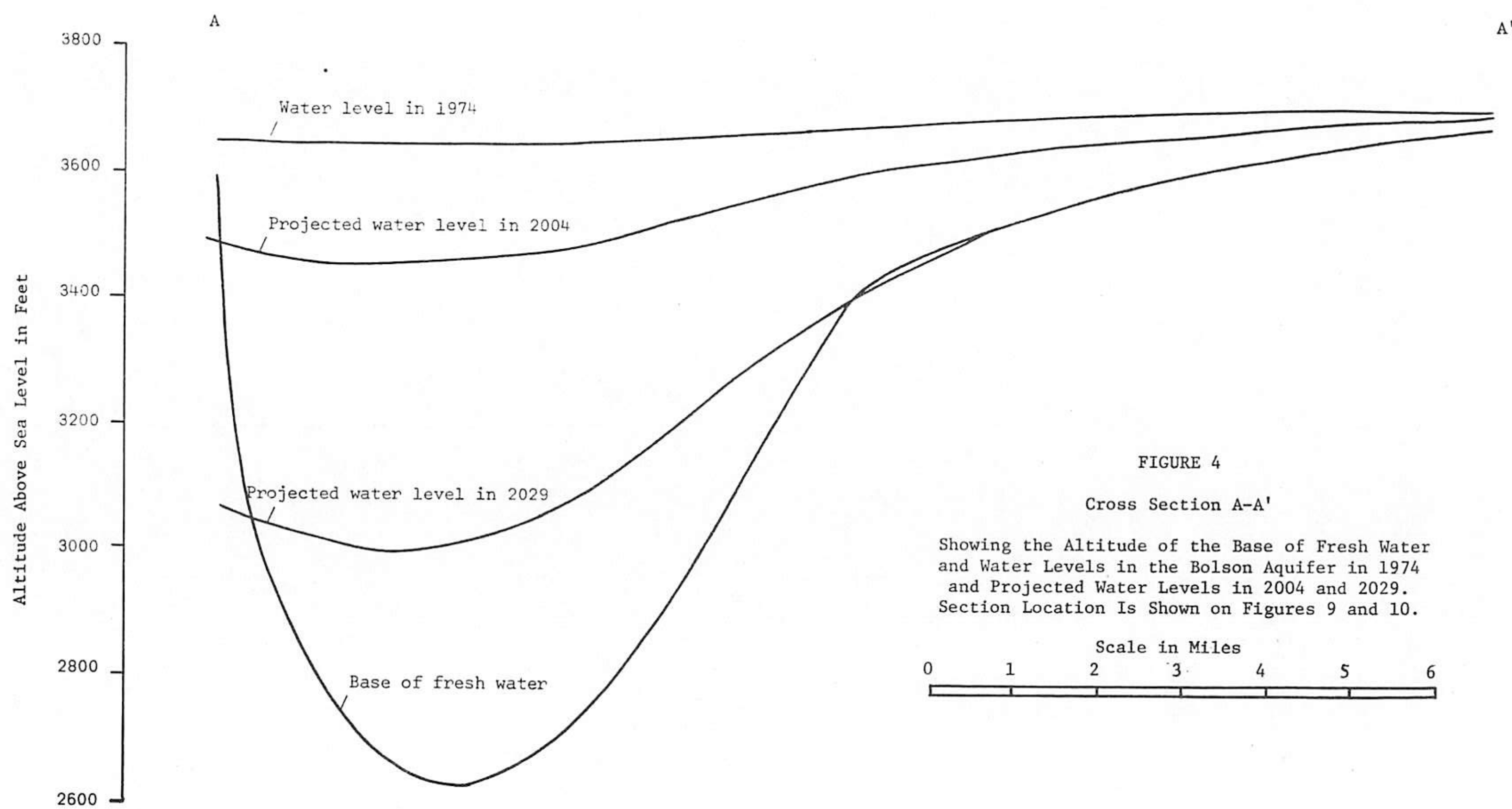


FIGURE 4

Cross Section A-A'

Showing the Altitude of the Base of Fresh Water and Water Levels in the Bolson Aquifer in 1974 and Projected Water Levels in 2004 and 2029. Section Location Is Shown on Figures 9 and 10.

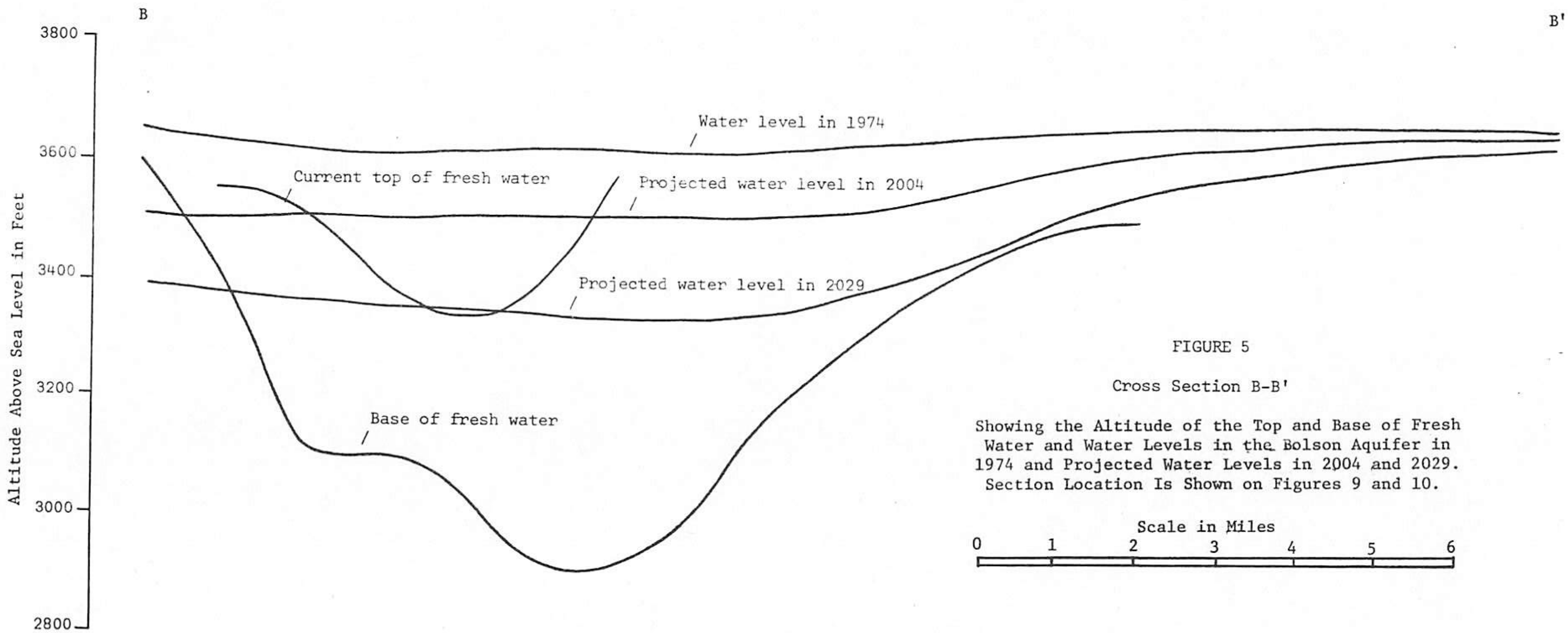


FIGURE 5

Cross Section B-B'

Showing the Altitude of the Top and Base of Fresh Water and Water Levels in the Bolson Aquifer in 1974 and Projected Water Levels in 2004 and 2029. Section Location Is Shown on Figures 9 and 10.

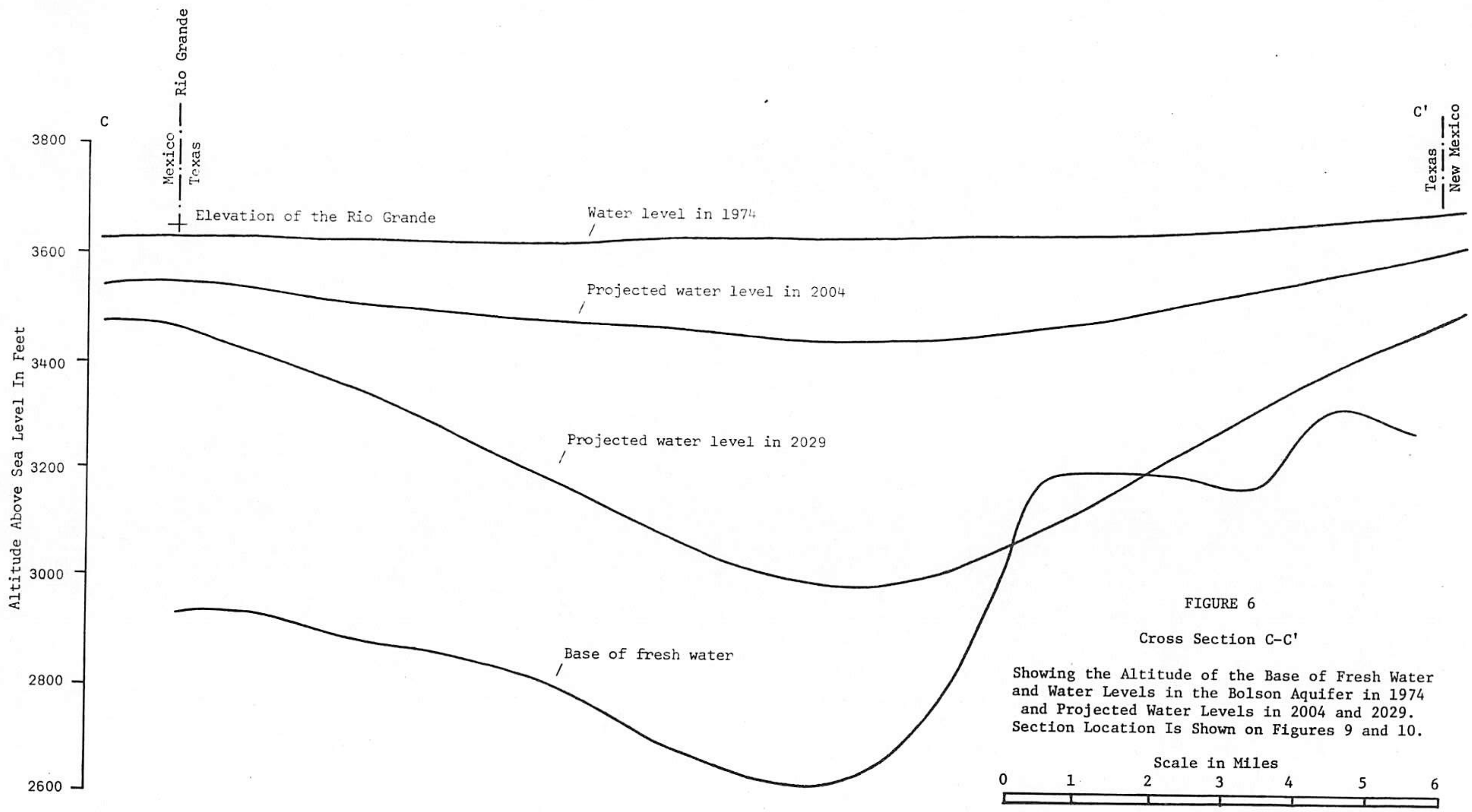


FIGURE 6

Cross Section C-C'

Showing the Altitude of the Base of Fresh Water and Water Levels in the Bolson Aquifer in 1974 and Projected Water Levels in 2004 and 2029. Section Location Is Shown on Figures 9 and 10.

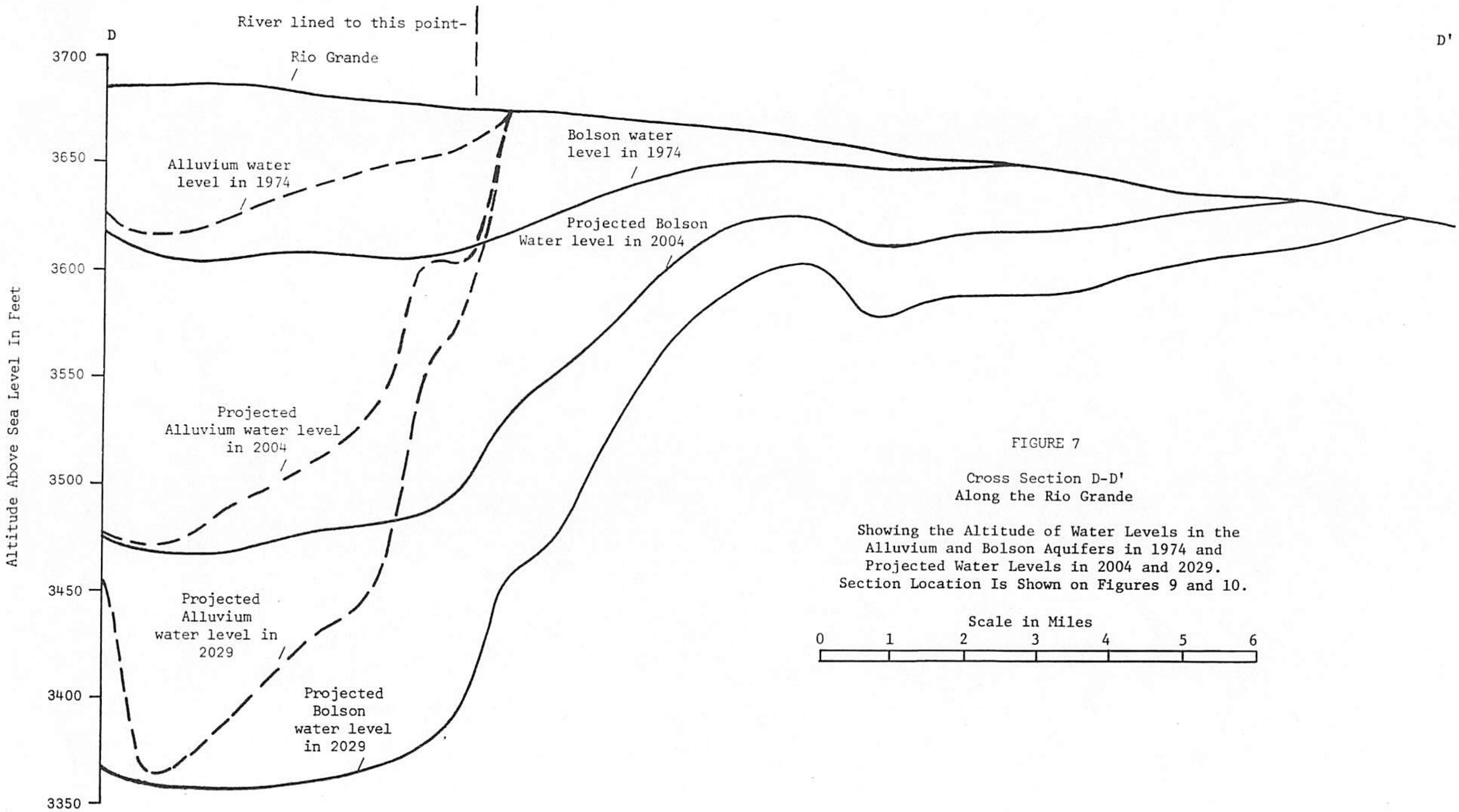


FIGURE 7

Cross Section D-D'
Along the Rio Grande

Showing the Altitude of Water Levels in the Alluvium and Bolson Aquifers in 1974 and Projected Water Levels in 2004 and 2029. Section Location Is Shown on Figures 9 and 10.

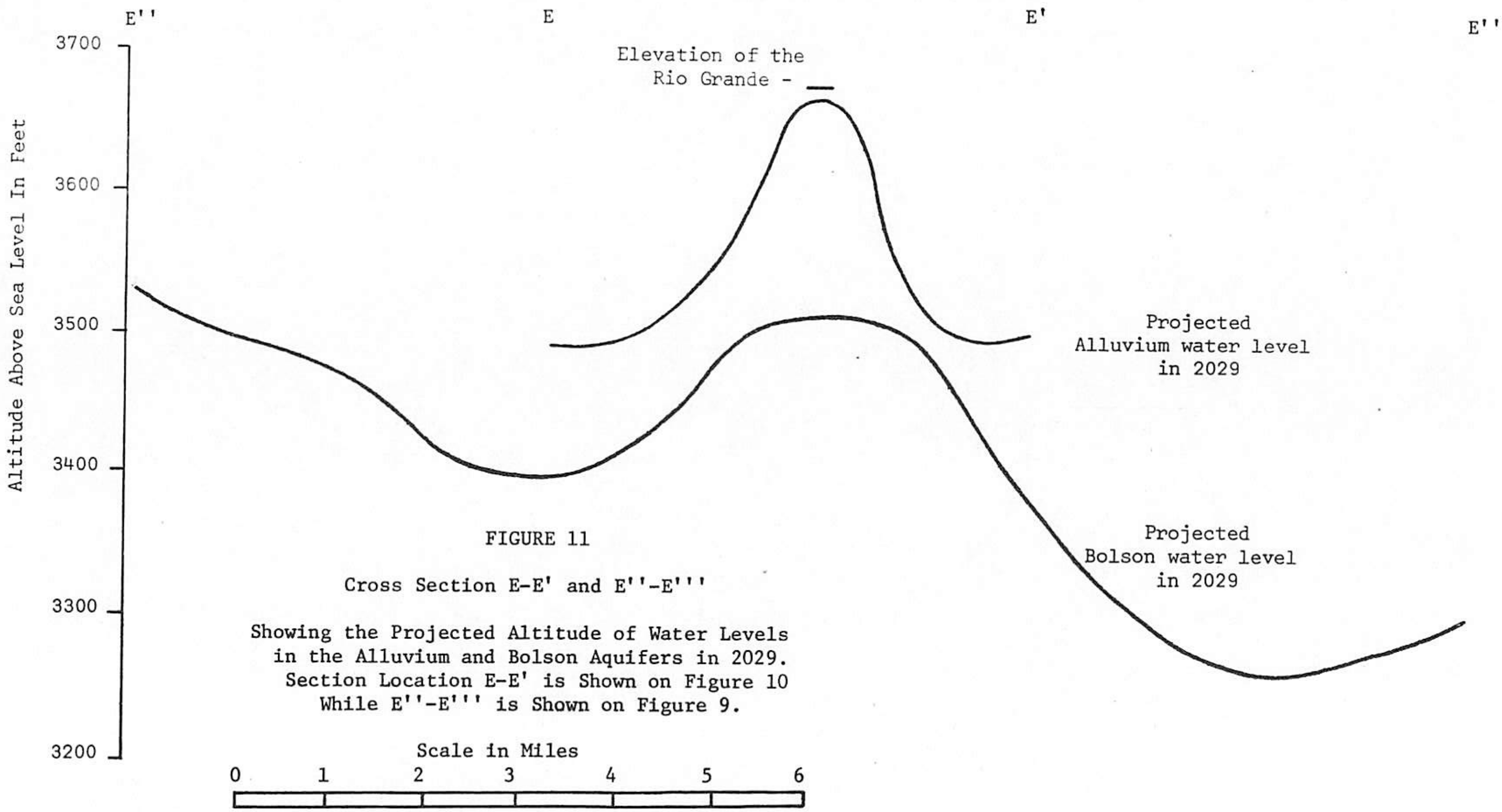


FIGURE 11

Cross Section E-E' and E''-E'''

Showing the Projected Altitude of Water Levels in the Alluvium and Bolson Aquifers in 2029. Section Location E-E' is Shown on Figure 10 While E''-E''' is Shown on Figure 9.