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PRELIMINARY RESULTS OF THE INVESTIGATION OF THE SALINE-WATER RESOURCES IN THE HUECO BOLSON NEAR EL PASO, TEXAS

By

M. E. Davis and E. R. Leggat
United States Geological Survey

Prepared by the U.S. Geological Survey
in cooperation with
The Texas Water Development Board and
The City of El Paso

1967

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LOCATION OF THE AREA

The Hueco Bolson, as defined in this report, is in the extreme western part of Texas and includes that part of El Paso County between the Franklin and Hueco Mountains north of the Rio Grande (fig. 1).

PURPOSE AND SCOPE OF THE INVESTIGATION

The principal source of water for the city of El Paso, including the needs for industry and military establishments, is ground water from the Hueco Bolson. Data collected since 1935 show that the amount of water withdrawn from the bolson each year for the past 30 years has exceeded the natural recharge. The ground water is being mined, and the city is using every available source of fresh water within a reasonable distance.

Recognizing the needs for additional sources of water, the city proposed a study of the saline water resources of the Hueco Bolson as a potential source of fresh water through desalination.

The purpose of this report is to describe the methods used in investigating the saline-water resources and to present the results obtained from a geophysical survey and a deep test well. A more detailed discussion of the field procedures and interpretation of the geophysical surveys is being prepared for future publication.

METHODS OF INVESTIGATION

The first step in the study of the saline water was to determine by geophysical methods the thickness and extent of the alluvial or unconsolidated materials underlying the Hueco Bolson. The geophysical surveys were made by the Regional Geophysics Branch of the Geological Survey. Initially, a gravity survey was made by the Regional Geophysics Branch of the Geological Survey of most of the Hueco Bolson in El Paso County to determine the configuration of the bedrock (fig. 1). From these data, lines were laid out for a seismic survey, which consisted of one 20-mile, east-west refraction profile about 3 miles south of the Texas-New Mexico State line and two shorter lines in the south-eastern part of El Paso County (fig. 2).

Reversed profiles about 5 miles long were shot along the lines of survey. The recording unit recorded on photographic paper the output of 12 vertical seismometers evenly spaced along a cable at intervals of 650 feet.

The procedure for shooting a profile was as follows: The cable was laid at one end of the profile and the output from a dynamite charge exploded at each end of the profile was recorded. The cable was then moved forward 7,150 feet and the previous shot points at each end of the profile were reshot. This procedure of reshooting at the same shot points and moving the cable was continued along the entire distance of the profile. In addition, intermediate shots at about 7,150-foot intervals were used to record velocity changes occurring in the shallow sediments. The dynamite charges, loaded in holes approximately 14 feet deep, varied from 50 to 600 pounds.

On an experimental basis, a resistivity survey was made to determine the effect of the fresh water-salt water interface and the bedrock configuration on electrical soundings. This survey was also made by the Regional Geophysics Branch. One line of this survey was along Horizon Boulevard in the southeastern part of El Paso County, another line was along the western end of the northern eastward-trending seismic line (fig. 2). Two types of electrode configuration were used: (1) Schlumberger and (2) equatorial. Quantitative interpretations were made by matching theoretical sounding curves to the field curves. This technique permits location of unit (geoelectric) that have similar resistivities (expressed in ohmmeters) from sounding to sounding.

The drilling of a deep test well was an integral part of the preliminary investigation of the saline-water resources of the Hueco Bolson. The purpose of the test hole was five-fold: (1) To provide information for a more precise interpretation of the gravity, seismic, and resistivity data; (2) to determine the chemical quality of the water and to relate the salinity to depth; (3) to determine the physical and hydrologic properties of the alluvial material; (4) to determine the thickness and depth of the bolson sediments; and (5) to estimate the volume of water containing 1,000 to 5,000 ppm (parts per million) dissolved solids. The location of the test hole in the NW$\frac{1}{4}$ of the NE$\frac{1}{4}$ of Sec. 19, Blk. 80, Township 1, was based on initial seismic field investigations which showed that the depth to bedrock probably was less than 5,000 feet. In addition, the test-hole site was along a 20-mile, eastward-trending seismic refraction profile 3 to 6 miles south of the Texas-New Mexico State line on land owned by the El Paso Public Service Board.

Drilling of the test hole by the El Paso Public Service Board began on Mar. 29, 1966, and was terminated at a depth of 4,363 feet on May 17, 1966, because of a lack of funds. During the drilling, samples of water were collected from several depth intervals, and samples of the materials penetrated were collected at 10-foot intervals from the land surface to the bottom of the hole. The specific conductance of the drilling mud was monitored during drilling to determine the intervals at which changes in salinity occurred. When the total depth was reached, the test hole was logged by dual induction--laterolog, borehole compensated sonic log, gamma ray log, caliper log, and compensated formation density log (gamma gamma). On the basis of the dual induction-laterolog, cores taken from selected intervals by a sidewall coring device were analyzed in the Geological Survey Laboratory to determine physical and hydrologic properties. Two other cores were obtained with a conventional core barrel.

During the drilling, a water sample was collected from each of five widely separated zones to determine the chemical quality of the water and the relationship between quality and depth. The results of the chemical analyses are given in table 1. Of the five samples, three were collected by a modified drill-stem testing tool consisting of a rubber packer mounted on a sliding mandrel, below which was attached a 20-foot length of perforated pipe. The weight of the drill pipe caused the packer to expand against the wall of the well, isolating the sand interval to be tested from the overlying materials. Water was pumped from the well by forcing compressed air down a small-diameter pipe within the drill pipe. The sample was collected only after the water became relatively clear and free of sediment and after the conductivity of the water was relatively stable. The last two samples were collected by a Johnston oil-field drill-stem tester. In this type of tool, the water from the sand to be tested enters the drill pipe under its own hydrostatic pressure, rising in the tool to approximately the same level as in the formation (bolson sediments). When the pressure has become stabilized, the tool is closed, and the partially filled drill pipe is brought to the surface. The initial and final hydrostatic pressures are automatically recorded. Generally, the sample at the bottom of the tool is taken for analysis; however, to be relatively certain that this sample is representative of the interval tested, the conductivity of the water from each length of drill-stem pipe is measured.

Table 1.--Chemical analyses of water from city of El Paso deep test well

Producing interval	761-786	1,225-1,250	1,724-1,749	2,167-2,182	2,835-2,856	686-710	800-820
Date of collection	Mar. 31, 1966	Apr. 4, 1966	Apr. 8, 1966	Apr. 22, 1966	May 2, 1966	May 23, 1966	May 23, 1966
Silica (SiO_2)	31	29	12	20	14	24	32
Iron (Fe)	-	0.11	0.22	0.49	0.19	0.48	0.00
Manganese (Mn)	0.01	.91	1.4	.58	1.4	-	-
Calcium (Ca)	63	1,270	2,250	2,950	2,000	55	49
Magnesium (Mg)	14	186	115	578	125	7.4	11
Sodium (Na)	204	2,600	5,260	12,100	7,550	184	198
Potassium (K)	11	23	28	48	34	9.8	10
Bicarbonate (HCO_3)	59	41	33	34	10	85	72
Sulfate (SO_4)	23	668	1,820	2,250	1,690	56	55
Chloride (Cl)	415	6,360	11,000	23,900	14,300	322	354
Fluoride (F)	.6	-	-	-	-	.6	.6
Nitrate (NO_3)	2.0	-	-	-	-	3.2	2.5
Dissolved solids	805	11,200	20,500	41,900	25,700	704	747
Hardness as $CaCO_3$	214	3,940	6,090	9,740	5,500	168	168
Specific conductance ($K \times 10_5$ at 25°C)	1,550	18,100	31,000	60,900	38,300	1,310	1,400
pH	8.5	6.4	6.4	7.1	5.0	8.1	7.3
Boron (B)	.05	.21	.25	.00	3.0	-	-
Temperature (°F)	-	-	-	*95	*102	-	-
Static level (ft)	335	361	350	360	795	330	331

* Bottom hole temperature.

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INTERPRETATION OF RESULTS

Gravity and Seismic Surveys

A Bouguer anomaly map was constructed on the basis of about 420 gravity stations (fig. 1). The major feature of the map is the 50

Figure 1 (caption on next page) belongs near here.

milligal gravity minimum trending northward about 6 to 8 miles east of the Franklin Mountains. The gravity data were used to locate lines for the seismic survey.

The results of the seismic and gravity surveys are shown on figures 2 and 3. Figure 2 shows the configuration of a depth to the bedrock under-

Figure 2 (caption on next page) belongs near here.

lying the Hueco Bolson. The map shows a deep northward trending trough, the axis of which lies about 4 to 5 miles east of the Franklin Mountains. A comparison of figures 1 and 2 shows that the bedrock trough, as computed from seismic data, is displaced about 3 miles west of the large gravity low (fig. 1). The reason for this displacement is not known definitely, but Mattick (written communication, October 1966) suggests that it may be due to the granitic rocks, which are exposed on the west side of the bolson, dipping under the limestone which underlies the bolson deposits at or near the axis of the trough. If so, there is a possibility of a basement fault at the axis of the trough. Figure 2 shows also that the slope of the bedrock surface is steeper on the western side of the trough than on the eastern side. Figure 2 should be used with caution because the data are not sufficiently accurate to determine precise depths to bedrock except along the upper (profiles 15-18) and middle (profiles 21-23) seismic lines (fig. 2).

Figure 1. Bouguer anomaly map of the Hueco Bolson.

Figure 2. Map showing approximate depth to bedrock in the Hueco Bolson.

Figure 3 is a cross section along profile A-A' located about 3

Figure 1 (caption on next page) belongs near here.

miles south of the Texas-New Mexico state line. It was computed from seismic data. The dashed lines indicate calculated travel paths for seismic rays refracted along the basement or bedrock surface. Four major refracting horizons in the bolson fill with average velocities of about 2000, 6500, 6820, 7600, and 9400 feet per second were recorded. The average velocities recorded on the sonic log of the El Paso test well are shown in figure 3 directly below the well location. Comparison of the velocities shows that those of the sonic log are in good agreement with those of the major seismic refracting units. The velocity of the bedrock was about 16,000 feet per second, a reasonable range for velocity in either limestone or granite.

The seismic records for the lower seismic line were inadequate for the construction of a cross section (Mattick, written communication, November 1966).

Figure 3. Seismic refraction profile along line A-A', 3 miles south of the Texas-New Mexico State line.

Electrical Resistivity

Electrical soundings were made in two areas of the Hueco Bolson (fig. 2) on an experimental basis to determine if electrical soundings could furnish information on the fresh water-salt water interface and on the bedrock configuration. The results of these soundings are shown by means of cross sections B-B' and C-C' (fig. 4).

Figure 4 (caption on next page) belongs near here.

Section B-B', a profile along the western end of the northern seismic line (fig. 2), shows the position of the fresh water-salt water interface in that part of the city of El Paso well field between War Highway and U.S. Highway 54. The interface dips gently eastward toward the center of the bolson at about 2 degrees. On the basis of the dual induction laterolog from the city of El Paso deep test well and the depth of the fresh water-salt water interface as determined from the resistivity data, the interface probably represents the approximate boundary between water having less than 5,000 ppm (parts per million) and more than 5,000 ppm dissolved solids. Actually, water containing more than 1,000 ppm dissolved solids is not considered fresh water, but for the purposes of this discussion, the term "fresh water" as it is applied to the interface is defined as water having less than 5,000 ppm dissolved solids. The 5,000 ppm dissolved-solids value represents the upper limit of salinity in water that the city of El Paso considers suitable for desalination. In the deep test well, this interface occurs at a depth of about 1,050 feet. The depth to bedrock in section B-B' could not be determined from electrical soundings because of equipment problems and because of the high conductivity of the saline-water layer.

Figure 4. Electrical resistivity profile along lines B-B' and C-C'.