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Ground-water investigations at White Sands Missile Range, New Mexico, July 1960 to June 1962

By

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Ground-water investigations at White Sands Missile Range, New Mexico, July 1960 to June 1962

By

James W. Hood

Abstract

White Sands Missile Range is in south-central New Mexico. It is a north-trending tract about 100 miles long and 30 miles wide. Installations of various size and function are scattered throughout the otherwise barren and unimproved range area. Water supply is a problem because of the erratic distribution of potable water.

Hydrologic work by the U.S. Geological Survey in the White Sands Missile Range from July 1960 to June 1962, made at the request of the U.S. Army Post Engineer, includes the seasonal measurements of water levels in the headquarters and other areas, the interpretation of water-level changes, the observation of drilling, the rehabilitation of production and observation wells, and a brief reconnaissance of the Salinas Peak and Rhodes Canyon Range Camp areas for the purpose of evaluating potential ground-water supplies.

The Geological Survey also furnished technical assistance to the Army during the drilling and testing of wells at the Gregg Site optical tracking installation, the Small Missile Range, the Hazardous Test Area, and the Stallion Range Center; and in the preparation of a master plan for water supply in the headquarters area.

Investigations in the Headquarters area show that water-level declines in production wells are accelerating as a result of the increasing use of water. Pumpage in 1962 was 2.8 times greater than in 1953. Non-pumping water levels declined 31 to 97 feet during that 9-year period. Rehabilitation does not result in complete restoration of yield of production wells, because of water level declines. The declining water level requires that pumps be lowered, periodically. New wells should be drilled away from the present well field, preferably to the north.

In the area immediately west of the Small Missile Range, the saturated water-bearing rocks of the valley fill are more than 450 feet thick, and lie on bedrock at about 750 ft below land surface. The water is suitable for domestic use but it is very hard. Properly constructed production wells should produce 500 gpm (gallons per minute), or more, of water.

In the Hazardous Test area water is in bedrock, mainly granite, and where water can be obtained from shattered or weathered zones, yields amount to 10 gpm or less. The amount of water in storage is small and prolonged pumping probably would lead to depletion despite the rapid rate of recharge when rains occur.

Water supplies are non-potable at both Gregg site and Stallion Range Center. The valley fill at Gregg site contains much fine-grained sand to about 500 feet, and mainly clay from 500 to 1,000 feet. The section below the water table, from 213 to 500 feet, can yield about 600 gpm with less than 90 feet of drawdown. At Stallion Range Center, the permeable valley fill mainly is between 500 and 750 feet. The supply well yields about 200 gpm with 150 feet, or less, of drawdown.

Reconnaissance in the Salinas Peak area shows that the few water sources there are related to structural distortions of the rocks. The principal aquifers are upper Paleozoic limestones and sandstones that as a whole have low permeability and contain non-potable water. It is probable that water supplies for that area must be obtained elsewhere.

In the vicinity of Rhodes Canyon Range Camp the most probable source of potable water is the large compound fan west and northwest of the Camp. No potable water is likely to be found at the Camp.

Introduction

This report presents the results of hydrologic studies made by the U.S. Geological Survey from June 1952 to July 1960 in parts of the White Sands Missile Range, at the request of the U.S. Army Post Engineer.

This work of the Geological Survey was confined mostly to technical assistance and advice to the Army on water development and well rehabilitation in specific parts of the White Sands Missile Range. The data accumulated, however, added significantly to the general knowledge of ground-water at White Sands Missile Range.

Investigations by the Geological Survey from July 1960 to June 1962 included the seasonal measurement of water levels in the headquarters and other areas, the interpretation of water level changes, the observation of drilling, the rehabilitation of production and observation wells, and brief reconnaissance in the Salinas Peak area to evaluate potential ground-water supplies.

The Geological Survey also advised the Army about the water requirements and the need for a ground-water investigation at a proposed lunar base; the possibility of installing production wells at the headquarters area golf course and at Rhodes Canyon Range Center; the need for monitoring controls at an experimental demineralization plant at Stallion Range Center; and in the preparation of a master plan for water supply in the headquarters area.

The master plan for a water supply in the missile range was prepared by personnel of the Post Engineer Office and required several man-weeks of effort by personnel from the Survey. The master plan provides for a long-range, orderly collection of ground water data at the Missile Range and for concurrent installation of production wells, pipelines, and storage and distribution facilities when such facilities are needed, based on projections of demands. In addition to water-supply development, provisions are made for experimentation in the use of floodwater to augment the natural recharge to the ground water in the area.

Location and extent of White Sands Missile Range and the areas studied

White Sands Missile Range is in south-central New Mexico. It is a north-trending tract about 100 miles long and 30 miles wide (fig. 1). The missile range is mostly in the Tularosa Basin, but

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

it also extends over the San Andres Mountains into the Jornada del Muerto. Installations of various size and function are scattered throughout the otherwise barren and unimproved range area. Water supply is a problem at many of these installations, because of the erratic distribution of potable water. Figure 1 shows the locations of areas studied from July 1960 to June 1962.

The headquarters area contains the largest working force and the largest resident population. The demand for water is, therefore, greatest at the headquarters area. The area is at the southwest corner of the missile range and is in a reentrant on the east side of the Organ Mountains. The headquarters area, including the locations of wells and the general geology, is shown in figure 2.

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

Figure 1.--Map of White Sands Missile Range, N. Mex., showing locations of sites and areas described.

2.--Map of the headquarters area and vicinity, White Sands Missile Range, N. Mex., showing geology and well and spring locations, 1962.

System of numbering wells and springs

Wells and springs described in this report are numbered according to the method used by the Geological Survey and the New Mexico State Engineer throughout New Mexico. The numbers are based on the location within the sub-divisions of standard public land surveys. By means of this system a number both designates a given well or spring and locates its position to the nearest 10-acre tract. All numbers in this report are for wells south of the New Mexico base line and east of the New Mexico principal meridian.

A location number is divided by periods into four segments: The first segment denotes the township; the second segment denotes the range, and the third segment denotes the section. The fourth segment of the location number consists of three digits and denotes the particular 10-acre tract in which the point is located. For this purpose, the section is divided into four quarters, number 1, 2, 3, and 4, for the northwest, northeast, southwest, and southeast quarters respectively. The first digit of the fourth segment gives the quarter section which is a tract of about 160 acres. Similarly the quarter section is divided into four 40-acre tracts numbered in the same manner. Finally the 40-acre tract is divided into four 10-acre tracts. Thus, in this report a well numbered 21.5.16.132 is in the NE$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 16, T. 21 S., R. 5 E. The letters a, b, c, ... are added to the fourth segment of the well number to designate the second, third, fourth, and succeeding wells in the same 10-acre tract. If a location cannot be determined accurately to a 10-acre tract, the third digit is a zero, and if it cannot be located accurately to a 40-acre tract, both the second and third digits are zeros; if, however, the location cannot be located more closely than the section, the fourth segment of the number is omitted. The letter "S" precedes spring numbers. The method of numbering sections in a township and tracts within a section is shown in figure 3.

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In addition, well numbers used by the U.S. Army Post Engineer are given.

Figure 3.--System of numbering wells and springs in New Mexico.

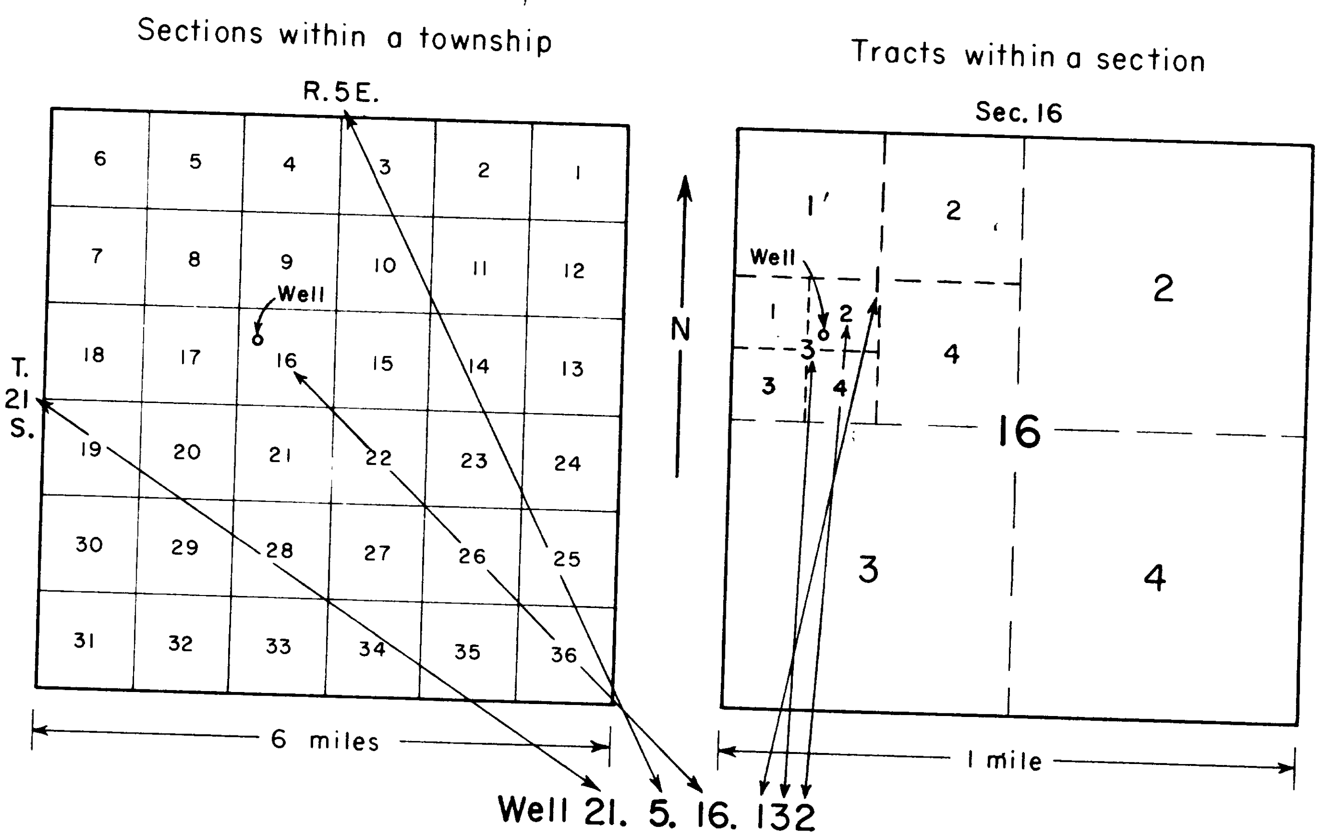

Figure 3.--System of numbering wells and springs in New Mexico.

Headquarters area

Observations of well-field conditions have been made at White Sands Missile Range since 1952, and have consisted of measuring water levels in observation and production wells and the recording of pumpage from production wells. Most of this work has been done on a bimonthly, and recently quarterly, schedule in the well field at the headquarters area. The measurements show the water-level declines caused by pumping water from the bolson fill in the headquarters area. Water levels in the area have declined at an accelerated rate as the use of ground water for domestic and landscaping supply has increased and the well field has been expanded to include more production wells.

Herrick (1955) projected future declines of water levels based on estimated or anticipated needs. Both the use of water and the water-level decline have exceeded his estimates. The resulting decrease in water storage near the production wells was affecting the yields of the shallower, older wells in 1962.

Effects of pumping supply wells

Water is pumped principally from ground-water storage in the headquarters area. The new well field (production wells numbered 10, 11, and 13 through 17) has been in production since the early 1950's when production from the old well field about 2 miles southeast of the headquarters area became inadequate. Water levels in the well field have been monitored in test wells since 1953 to determine the effects of pumping. Of the original 5 test wells, only wells T-4 and T-5 are still serviceable; T-6 and the new main gate well have been drilled to continue the monitoring of water levels. In addition to water-level measurements in the test wells, a continuous record of water levels is obtained from a water-stage recorder on production well 12.

White Sands personnel measure and report water levels in production wells each December or January when pumping from the well field is at a minimum. A summary of these water levels is tabulated below. The

Well no. (fig. 2)	Nonpumping water level in feet below land surface		Water level rise (+) or decline (-) in feet		
	December 1954	December 1962	1954-62	1960-61	1961-62
10	358.0	389.0	-31.0	- 8.4	+ 0.4
11	305.0	402.2	-97.2	- 2.0	- 7.2
13	310.0	325.5	-15.5	+ 3.3	- 3.0
14	357.0	402.0	-45.0	- 5.0	- 7.0
15	338.0	399.5	-61.5	-24.0	- 6.0
16	349.0	413.0	-64.0	-15.5	-13.0
17	-	393.3	-	- 9.4	- 1.3

average decline from 1954 to 1962 is about 50 feet. This decline undoubtedly includes some local pumping effects and some inefficiency of individual wells, but nonetheless represents a considerable added pumping lift. Water-level declines in any one well vary from year to year as a result of the staggered schedule of pumping established to prevent excessive drawdown in any one well.

Water levels in the test wells have shown the pattern of water level decline in and around the well field. Unfortunately, the test holes were poorly constructed. Very little record was obtained from well T-2 before it filled and wells T-3 and T-4 went dry in 1960 and 1961, respectively. Wells T-4 and T-5 are still serviceable and show but little effect of pumping, probably because they, like T-6, are remote from the heavily pumped area. Water levels have risen in old production wells 4 (in the old well field) and 12, (in new field) probably because the wells have not yet fully recovered from pumping.

The hydrograph of well T-1, and graph of pumpage from the production wells, show the decline of water levels as pumpage has increased (fig. 4). A summary of water-level changes in the test

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and observation wells is tabulated below:

Well no. (fig. [illegible])	Depth to water, in feet, below land surface				Water level rise (+), or decline (-), in feet		
	Date	Depth	Date	Depth	1961	1962	For period indicated
T-1	1-25-55	400.18	9- -61	dry at 418.57	--	-	-18.39 (1955-61)
T-3	1-25-55	388.93	9- -60	dry at 400	-	-	-11.1 (1955-60)
T-4	1-25-55	223.43	1- 3-63	224.06	-0.12	-0.03	- .63 (1955-63)
T-5	1-25-55	270.48	1- 3-63	271.38	+ .14	- .16	- .90 (1955-63)
T-6	1-17-61	202.51	1- 3-63	203.50	- .39	- .60	- .99 (1961-63)
Gate	1- 5-60	359.58	1- 3-63	367.65	-3.00	-2.50	- 8.07 (1960-63)
4	1-25-55	221.09	1- 4-63	219.82	+1.02	+ .69	+ 1.27 (1955-63)
12	1- 5-60	277.78	1- 5-63	276.50	+ .56	+ .15	+ 1.28 (1960-63)

Figure 4.--Water-level decline in test well T-1 and pumpage from production wells in White Sands Missile Range, Headquarters area.

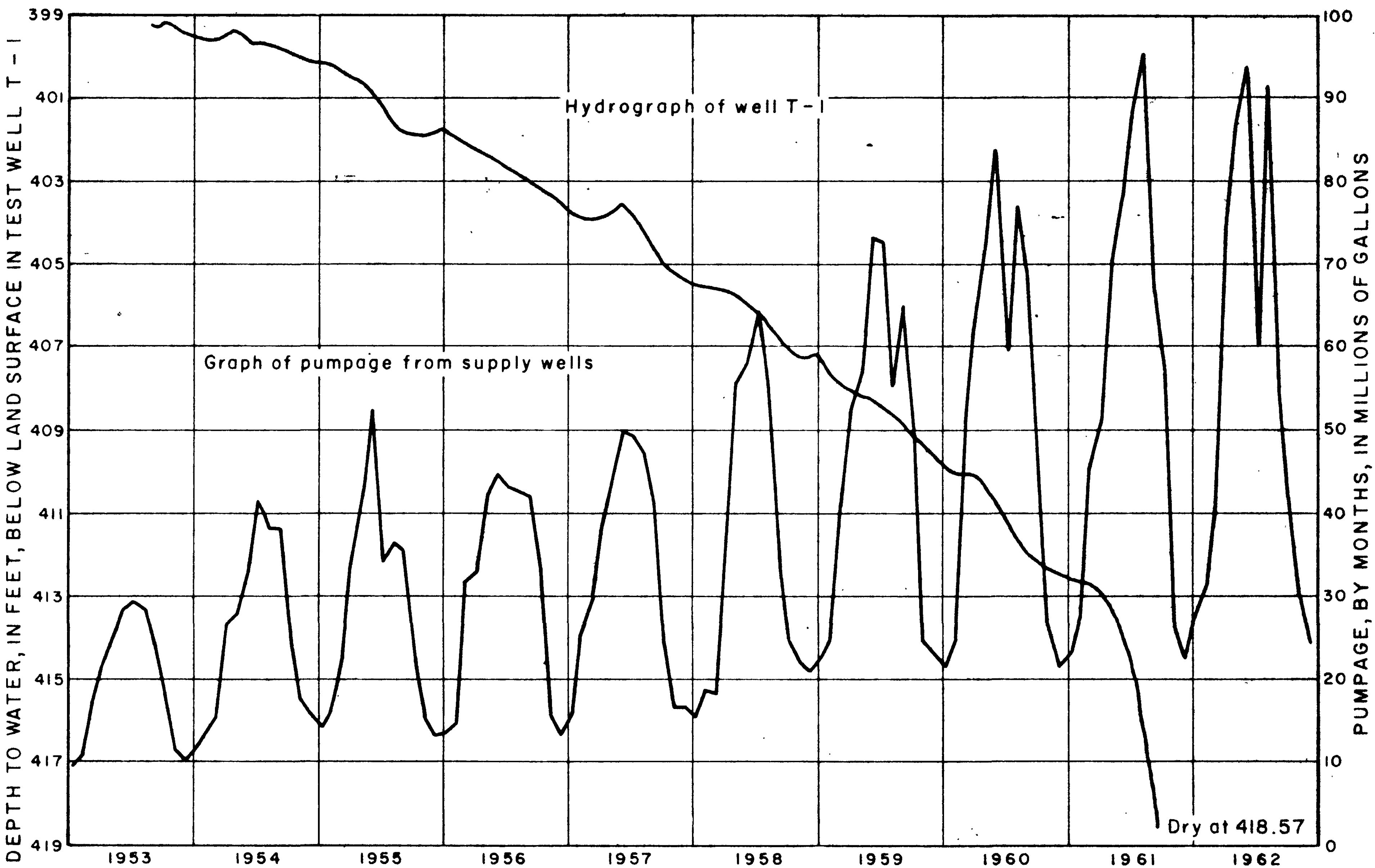

Figure 4.--Water level decline in test well T-1 and pumpage from production wells in White Sands Missile Range, Headquarters Area.

Pumpage has increased with time as shown by the graph of pumpage (fig. 4). Pumpage in 1962 was about 2.8 times as much as in 1953. Not only has the base rate of pumping increased but the peak rate of pumping also has increased sharply since 1958. The peak rate of water use is in summer when large amounts of water are required for cooling plants, recreation, and lawn watering.

New supply wells will be needed as the demand continues to increase, because the existing wells were operated at near their capacity during the time of this study. According to the Post Engineer's Office, future development of the headquarters well field will be in the area west and north of the present well field (fig. 2).

Production-well rehabilitation

The well field north of the headquarters area has been used since 1948. Well 10, the first well of this well field, was installed in 1948 and by the end of 1954 wells 11 through 16 had been added to the system. Well 17 was added to the system in 1960. The yields of the wells diminished as time passed, and gravel began to enter well 14 along with the water. The decreased yields were due to the decline of water levels in the well field, the deterioration of the pumps, the plugging of the well screens with scale, the partial plugging of the gravel pack by silt, and by partial filling of the wells with material that passed through the screens but was not pumped out.

A program of production-well rehabilitation has evolved, wherein each well is rehabilitated periodically to increase the yield. The procedure generally consists of the following:

1) The pump is removed and the casing is examined with a borehole television camera; 2) material filling the well is loosened and bailed out of the well; 3) an acid or other treating chemical is introduced into the well to loosen scale and clean the gravel pack; 4) the well casing is mechanically cleaned inside by scraping or brushing the screen sections; 5) the well is surged with tightly fitting surge blocks to promote redevelopment; 6) the materials that enter the well during the treatment are bailed out periodically; 7) gravel is added to the gravel pack as needed; 8) a test pump is installed and the well developed by pumping and surging; 9) the well is test pumped; 10) the test pump is removed, the well cleaned out again, and the casing again examined with a borehole television camera; 11) the production pump and a new air line are installed.

Not all the steps are performed during every rehabilitation operation because of the differences in the condition of the well.

Wells 10, 14, and 16 were partly or completely rehabilitated during 1961-62. The results indicate a need for replacement wells.

Well 10 (22.4.24.212)

Well 10 (22.4.24.212), the oldest well in the present headquarters well field, was scheduled for rehabilitation during the winter or spring of 1962. The rehabilitation was given special impetus when the yield diminished greatly. The specifications for the work included the general provisions previously listed and required the use of acid as the treating chemical. Work at the well site began on April 4, 1962.

When the contractor began to pull the pump from the well, the gravel envelope around the casing subsided about 4 feet. This subsidence in itself was not alarming, but coupled with later observations it indicated that the well casing and perforations were not in good condition. After the pump had been removed on April 5, the measured depth of the well was 467 feet, and the depth to water was 385.0 feet below the top of the casing. The strainer on the end of the pump was almost plugged with scale and rust fragments.

The contractor cleaned the loose material from the well to a depth of 487 feet below the top of the casing in 1½ hours. Gravel that apparently was a part of the original gravel pack was among the debris removed. The gravel envelope subsided another 1 to 2 feet while the well was being cleaned.

Subsequently, a casing scraper 10 inches in diameter was prepared and put into the well, but the tool would not go deeper than 174 feet. On April 9, an 8-inch scraper was prepared and put into the well. This smaller tool went down with some difficulty, and the casing from [illegible] to 485 feet was scraped. The material loosened by the scraper was removed to a depth of 487 feet. Again, the loose material contained gravel from the gravel pack. The water level at this time was 36[illegible] feet below the top of the casing. A closed-circuit television inspection was made April 1[illegible]. The following observations were made:

Observation	Depth
Above the water:	
Casing oval shaped	171
Casing broken and offset at weld	174
Casing broken and offset at weld	235
Top of perforations in casing. (Casing found to be perforated from 265 feet down to maximum depth observed.)	265
Casing broken and offset	280
Casing offset and oval shaped	314
Below the water table:	
Camera hung due to casing roughness	422
Break in casing	435
Camera hung	441
Break in casing	454
Camera hung	467
Break in casing	474
Casing oval shaped in cross section	481

Above the original water level (about 350 feet), the perforations were about one-fourth inch wide, clean, and in good condition. The casing was in good condition except for partings at welded joints. The casing condition worsened below the original water level, and below 375 feet the casing had deteriorated. Many of the perforations below 375 feet were enlarged greatly, some appearing in the television view to be as large as 1 inch wide. The casing was missing over an area of several square inches at the lowermost casing break below the water level.

The well was measured again on April 10 and was 487 feet deep. From this measurement it was inferred that additional fill would not enter the well as long as there were no vibrations or other disturbances. Operation of the pump, however, could cause a new influx of material into the well.

Rehabilitation was stopped, because of the danger to the well from further work. The production pump was reinstalled in the well, in spite of the risk, because the well was badly needed to maintain an adequate supply of water.

The new pump was installed April 26. The pump column and copper air line were 420 feet long, the pump assembly was 8 feet long, and the tail pipe and strainer extended 4 feet below the pump. The pump intake is 432 feet below the top of the casing, about 20 feet shallower than the intake of the old pump.

The new pump and air line were tested briefly April 27. The pump was operated for about 3 hours at 300 gpm (gallons per minute). The resulting drawdown was about 30 feet, indicating a specific capacity of 10 gpm per foot of drawdown. The water was free of suspended matter after 6 minutes of pumping and remained clear to the end of the test. The water temperature was 77°F.

Well 10 should be replaced as soon as feasible. In the meantime, the pumping rate probably should not exceed about 300 gpm. The well-field operators should examine the gravel feed lines periodically to see whether the gravel envelope subsides further, because entry of gravel into the well could damage the new pump. The pumping level also should be monitored carefully because of the shallow pump setting.

Well 14 (22.4.13.411)

Well 14 (22.4.13.411), put into operation in 1954, originally had a yield of 600 gpm and a 24-hour specific capacity of 8.5 gpm per ft of drawdown. Gravel began to enter the well in 1958, and a television inspection showed that the pump had worn a hole in the screen. The well was rehabilitated and placed in continuous use. The air line became plugged, and was replaced early in 1962. After the air line was replaced, measurements showed that the water level drew down excessively when the well was pumped at the normal production rate. The pumping rate was reduced to about 350 gpm and the pumping level rose to about 30 feet above the top of the pump.

Well 14 was treated with 1,000 gallons of acid and developed by surging and pumping with the production pump April 16-19, 1962. Half the acid was injected into the well at 11:50 a.m., and the well was surged with the pump at 5-minute intervals for an hour. The second half of the acid was injected at 2:20 p.m. and the well was surged about 1½ hours. The acid reacted vigorously in the well, as was shown by the large amount of vapor that blew steadily from the casing and cleanout lines. Surging and pumping was started at about 3:00 p.m. and the pumping level declined almost immediately to the top of the pump bowls. The gravel envelope slipped about 40 feet down the outside of the casing and pumping was interrupted long enough to measure the amount of subsidence and to replenish a part of the gravel. Pumping and surging continued until 10:00 p.m. April 16 and again from 8:15 a.m. to 3:00 p.m. April 17. The well then was pumped continuously until 7:00 p.m.

During pumping on April 16 the water carried out silt, sand, dissolved rust, and much coarse sand and gravel, none of which was larger than the size of the screen openings, which indicated that the screen was not breached. During pumping on April 17, the water continued to carry out coarse sand and gravel but at a greatly reduced rate. By 7:00 p.m., the water was clear of suspended matter.

The results of the acid treatment of the well and the subsequent pumping indicated that well 14 could produce about 400 gpm for limited periods. Under cyclic pumping, however, it was necessary to reduce the rate of pumping to about 385 gpm to maintain the pumping level well above the pump bowls. A pumping rate of 385 gpm was maintained through June 1962. This rate probably is about optimum for the well.

The treatment of well 14 with acid improved its productive capacity but did not restore its original rate of production. A full-scale rehabilitation probably would further improve the yield but not restore its original rate of production, because part of the aquifer in the vicinity of the well has been dewatered. Well 14 is equipped with screen that has internally projecting louvers that will require a loosely fitting surge block. Because of the loose fit, surging time for redevelopment probably should be about twice the usual time. Also, the pump should be set lower in the well to prevent the pumping water level from lowering to the pump bowls.

Well 16 (22.4.13.432)

Well 16 (22.4.13.432) was drilled in 1954 and was rehabilitated in May 1961. The pump was removed from the hole on May 4, at which time the depth to water was 403 feet below land surface. On May 5 the casing and screen were inspected with a closed-circuit television camera. The inspection showed little or no deterioration of the casing and screen other than encrustation of surfaces and some corrosion. Perforations in the upper part of the saturated zone, near the pump, mostly are open. Below about 600 feet, however, nearly all perforations were closed by encrustation. The odometer on the television apparatus indicated a depth of 773 feet, thus indicating that the well had filled about 113 feet.

Bailing began on May 8. The first material bailed consisted of silt and mud containing some flakes of rust, fine- to medium-grained sand, and some gravel but nothing larger than would pass through the screen. By the end of the working day the well had more fill in it than at the start of bailing because the bailer, in moving through the screen section, was developing the upper screened zone.

Bailing was continued on May 9 without making much headway in removing the fill from the well. The screen in the unfilled section was surged and scrubbed with a wire brush assembly on May 10-12. The fill was occasionally bailed from the well, which caused fine sand and a small amount of gravel that was small enough to pass through the screen to enter the well. The gravel pack subsided about a foot, which indicated that the gravel is entrained down to the water table.

A test pump was installed May 15-17, and 400 gallons of water containing 1,200 pounds of sodium hexametaphosphate was poured into the well, half into the casing and half into the pump column on May 18. The well was surged at 30-minute intervals through May 19.

The productivity capacity of the well was tested on May 22, after scraping, surging, bailing, and chemical treatment was finished. The well was tested with a deep-well turbine pump.

The pump was started at 8:10 a.m., and the well was surged for 15 minutes without discharging water. At 8:25 a.m. pumping at a steady rate of about 735 gpm was begun and continued to 1:30 p.m., at which time the pumping rate was reduced to about 545 gpm. Pumping was stopped at 6:25 p.m., and the rate of water-level recovery was measured until 8:40 a.m. May 23. The drawdown at the end of pumping 7 hours at 735 gpm was 30 feet, and the net drawdown at the end of pumping 10 hours was 21.5 feet (Fig. 5).

Figure 5 (caption on next page) belongs near here.

The water pumped from the well was cloudy or turbid, but contained less than 0.1 ml of sand per liter of water for 4 hours at the beginning of the test. During the remaining part of the test the water was clear and free of suspended matter. The temperature was 77°F.

The pump was pulled on May [illegible] and [illegible]. The well was then bailed but little material was recovered because the sand pump did not work satisfactorily.

Figure 5.--Water levels during drawdown and recovery and rate of discharge during performance test of well 16 (22.4.13.432), Headquarters well field, White Sands Missile Range, N. Mex., May 22-23, 1961.

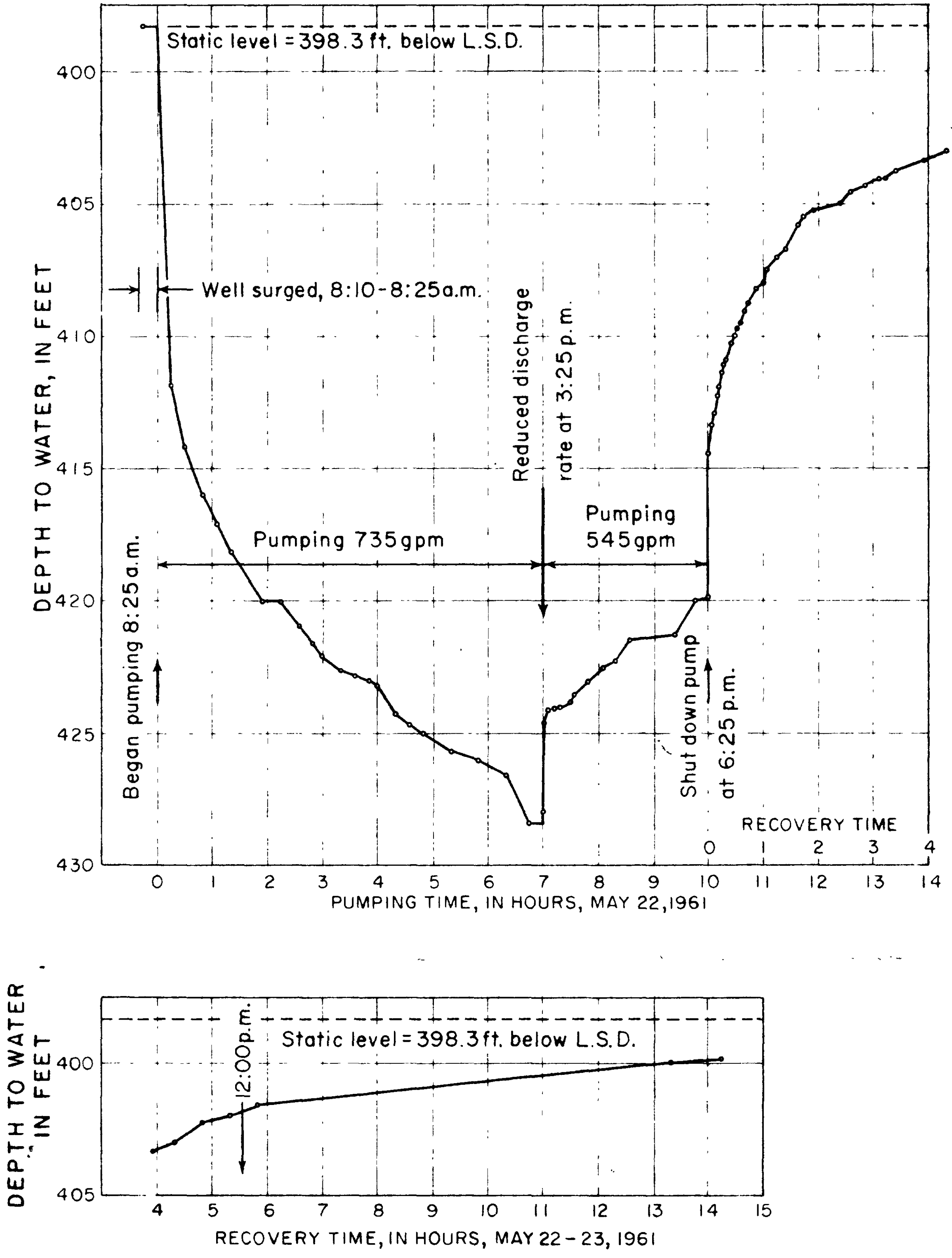

Figure 5.--Water levels during drawdown and recovery and rate of discharge during performance test of well 16 (22.4.13.432), Headquarters well field, White Sands Missile Range, N. Mex., May 22-23, 1961.

A second television inspection on May 29 showed that the hole was filled to 734 feet. The screens from the water level down to about 500 feet had been fairly well cleaned but could be further improved. From 500 to 734 feet the casing and screens had been partially cleaned but still contained many closed perforations. The one chemical treatment apparently was not sufficient. Moreover, the scrubbing operation was not completely successful, owing to the nature of the screen, in which the louvers extend inward and prevented the brushes from reaching the openings. That the lower part of the well does not contribute much water is shown by the residual content of phosphate compound in the water bailed from the well after prolonged pumping.

The following test results show the apparent effects of the rehabilitation of well 16. (Note: For similar well conditions and for a given length of pumping time, the specific capacity is less for a high rate of pumpage than for a low rate.):

Date	Rate of discharge (gpm)	Specific capacity for specified time			Remarks
		5 to 6 hours	10 hours	24 hours	
10- -54[a]	600	33	-	31	Test made shortly after well completed
4-19-61[a]	597	31	-	-	During regular cyclic well field operation
4-20-61[a]	609	-	22	-	Actual pumping time unknown, but is more than 6 and less than 24 hours
5-22-61	735	27	-	-	Test after rehabilitation
	674	-	31	-	Discharge rate is weighted average for 10 hours of pumping
	521	-	24	-	Discharge rate is instantaneous value, measured at end of 10 hours
6- -61[a]	824	31	-	-	Average for month, based on daily records
7-11-61[a]	824	28	-	-	During regular cyclic well field operation. Time not recorded but is 6 hours or more

a/ Data reported by Post Engineers, Utilities Branch, WSMR.

Although the figures for specific capacity as given above are not precisely comparable, the data indicate that the rehabilitation measurably improved the productive capacity of well 16.

The well might have produced more water had the contractor been able to clean out the fill in the well to the bottom of the casing and been able to completely clean the well screen.

The nature of the well screen interferred with thorough redevelopment. Future production wells should be designed with a screen that has no internal projections of the type in the internal shutter screen. These internal projections tend to deteriorate where the pump or pump column rests against them, because vibration of the pump causes mutual wear of the parts in contact. Future rehabilitation should include more than one chemical treatment to be fully effective, and the treatments preferably should be interrupted by periods of mechanical screen cleaning, surging, and bailing or pumping.

Test well rehabilitation

Five test wells were drilled in May, June, and July 1953 to obtain data about the water-bearing formation in the headquarters area and to use for water-level observations. Herr'ck (1955, p. 60) noted that test hole T-2 (22.4.13.233) had filled with sediment to above the water level and could not be used after July 1953. Water levels in the othe test wells declined during a period of years, and test wells T-1 (22.4.1.444) and T-3 (22.4.14.211) became partly filled with sediment. Early in 1960 only 1 to 2 feet of water remained in these two wells. Test holes T-1, T-2, and T-3 had to be cleaned of the material filling them in order to continue the water-level observations.

Test well T-1 was drilled 6 inches in diameter to a depth of 1,004 feet and cased to a depth of 450 feet with 4-inch casing. The bottom 100 feet of casing was perforated with torch-cut slots, and the bottom of the pipe was closed with a steel plug. By early in 1960 the well had filled with sediment to 413 feet below the land surface and about 1.3 feet below the water level.

Test well T-2 was drilled 6 inches in diameter to a depth of 1,000 feet and cased to a depth of 400 feet with 4-inch casing finished in the same manner as T-1. By 1960, the well had filled with sediment to 340 feet below the land surface and about 20 feet above the inferred water level.

Test well T-3 was drilled 6 inches in diameter to a depth of 875 feet and cased and finished in a manner similar to the first two wells to a depth of 450 feet. By 1960, the well was filled with sediment to 393 feet below the land surface and about 2.3 feet below the water level.

The Post Engineer Office awarded a contract to the Butte Pump Co., of Las Cruces, New Mexico, for cleaning test wells T-1, T-2, and T-3 in August 1960. The contract provided for cleaning the wells to the depth at which they were plugged, assuring that the perforations were open, and redeveloping the wells to provide a stable wall in each with a good hydraulic connection between the well and the aquifer. Each well was to be bailed for not more than 2 hours after redevelopment, during which time the bottom of the well should remain clean, and the water bailed should contain no more than 3 ml (milliliters) of suspended material per liter of water obtained from the bottom of the well.

Test well T-1 (22.4.1.444)

Cleaning of well T-1 began August 26, 1960. The material in the bottom of the well at a depth of 413 feet was hard, and water was required to start the cleaning operations. The first material recovered was very coarse. The well was cleaned to 428 feet by 5:05 p.m. August 29, but filled to 422 feet overnight and filled further despite continued cleaning August 30. Additional work through 10:30 a.m. September 1 produced no satisfactory results, and the cleaning equipment was moved.

The large amounts of sediment that entered the well came through slots in the casing. The casing had been perforated with an oxyacetylene torch, and the slots were cut about 6 inches long and ½-inch wide. The slots were irregular in size and some probably were 3/4-inch in width. The test well refilled when it was bailed because the water-bearing formation is comprised mostly of particles smaller than the slot dimensions.

An additional 2½ days of work was done at test well T-1 September 15, 16, and 20. Drilling mud was used to support the walls of the well and to keep the coarse-grained sediments in suspension. The well was cleaned from a measured depth of 415 feet to about 426 feet, but material refilled the well to 420.4 feet, and the cleaning was terminated.

Test well T-2 (22.4.13.233)

Cleaning of well T-2 began August 22, 1960. The material in the well was dry, and water was added to drill and bail out the loosened sediments. After the water table was reached, the fill was bailed without drilling. By 4:40 p.m. August 23 the well had been cleaned from 360 feet to a depth of 401.5 feet. The material removed from the hole consisted of very coarse sand, gravel, small pebbles, bits of glass, wire, and other substances.

The depth of the well was 391.5 feet and the depth to water was 355.06 feet below the top of the casing before further cleaning began August 24. Coarse sand and gravel, and some glass, was bailed from the well after the measurements were made. During August 24, the hole again was cleaned to 400 feet, but material continued to enter the casing, and the depth during most of the day varied from 391 to 397 feet. The water bailed during the afternoon contained about 4½ ml of sand and as much as 22 ml of silt per liter of water, measured in an Imhoff cone. The hole was 400 feet deep at 4:15 p.m.

On the morning of August 25 the hole was 400 feet deep, and bailing produced water laden with silt and very fine-grained sand. By 8:55 a.m., however, the well again produced large quantities of sand and gravel, and by 10:00 a.m. had filled 10 to 12 feet. By 2:30 p.m. the hole had filled 30 feet, to 370 feet, and at 4:15 p.m. was still that deep. During the afternoon, the driller would clean out a few feet of hole, which then would refill.

The depth to water in the well was 355.08 feet below the measuring point and the hole was 369.1 feet deep at 8:20 a.m. August 26. Efforts to clean the hole resulted only in the hole filling to 364 feet. Further cleaning operations removed 2 feet of fill. Owing to the amount of fill removed from the hole, it was apparent that further operations would not be fruitful.

On September 9, test hole T-2 again was sounded to a depth of 366 feet with a steel tape, the same depth measured at the end of cleaning operations. On September 14, the water level in the hole was 355.02 feet below the measuring point, on September 29, it was 355.52 feet.

Test well T-3 (22.4.14.211)

Cleaning operations began at T-3 at 11:00 a.m. on September 1, 1960. Problems were similar to those encountered at T-1 and T-2. The hole was 393 feet deep when work began and a maximum depth of 412 feet was reached during the course of 3½ days of work. The hole was 408 feet deep when cleaning operations were discontinued. The depth to water was 405.43 feet below the measuring point on September 29, 1960.

Drilling of test hole T-6 (22.4.14.133)

Adequate monitoring of the water-level changes in headquarters area required test holes to replace T-1, T-2, and T-3 which could not be rehabilitated. Test hole T-6 (22.4.14.144) was drilled at a new location, thereby extending the stratigraphic knowledge of the area as well as providing a permanent observation well. The location is about 0.6 mile southwest of test hole T-3 and a mile west of Headquarters well 13.

Drilling was started October 25, 1960, and the work, including test pumping, was finished on November 19. (See table 1.) The hole was drilled by the hydraulic-rotary method. An electrical resistivity log of the hole was made November 4, and the hole then was cased with 515 feet of 6-inch casing, of which 105 feet was torch-perforated at selected intervals. (See fig. 6.)

Figure 6 (caption on next page) belongs near here.

Figure 6.--Electric log of test hole T-6.

Table 1.--Log of materials penetrated by test well T-6 (22.4.14.133)

Headquarters area, White Sands Missile Range, New Mexico.

Material	Thickness (feet)	Depth (feet)
Sand, fine to very coarse, granitic debris	15	15
Sand, fine to very coarse, and bit-cut fragments of larger rocks	10	25
Sand, fine to very coarse	5	30
Sand, fine to very coarse, and bit-cut fragments of larger rocks	5	35
Sand, fine to very coarse, some silt, and bit-cut fragments of larger rocks	5	40
Sand, fine to very coarse	10	50
Sand, very fine to very coarse, and silt	5	55
Sand, fine to very coarse, and some bit-cut fragments of larger rocks	5	60
Sand, fine to very coarse, some red clay or silt, and bit-cut fragments of larger rocks	20	80
Sand, fine to very coarse	5	85
Sand, fine to very coarse, and some bit-cut fragments of larger rocks	5	90
Sand, fine to very coarse, some red clay or silt, and bit-cut fragments of larger rocks	5	95
Sand, fine to very coarse	5	100
Sand, fine to very coarse, and several pebbles	5	105
Sand, fine to very coarse, and some bit-cut fragments of larger rocks	5	110
Sand, fine to very coarse, several pebbles, and some bit-cut fragments of larger rocks	5	115

Table 1.--Log of materials penetrated by well T-6 (22.4.14.133)

Headquarters area, White Sands Missile Range, New Mexico. - Continued

Material	Thickness (feet)	Depth (feet)
Sand, fine to very coarse, and bit-cut fragments of larger rocks	10	125
Sand, fine to very coarse	15	140
Sand, fine to very coarse, and bit-cut fragments of larger rocks	10	150
Sand, fine to very coarse	5	155
Sand, fine to very coarse, and small bit-cut flakes of larger rocks	10	165
Sand, fine to very coarse	5	170
Sand, fine to very coarse and bit-cut fragments of larger rocks. Grain size mainly coarse	5	175
Sand, coarse, with small amounts of fine- to very coarse sand	15	190
Sand, mainly coarse, and bit-cut fragments of larger rocks	10	200
Sand, fine to very coarse, and bit-cut fragments of larger rocks	5	205
Sand, fine to very coarse, some small pebbles and bit-cut fragments of larger rocks	25	230
Sand, fine to very coarse, and bit-cut fragments of larger rocks	5	235
Sand, medium to coarse	5	240
Sand, very fine to coarse	35	275
Sand, very fine to coarse and some bit-cut fragments of larger rocks	5	280

Table 1.--Log of materials penetrated by well T-6 (22.4.14.133)

Headquarters area, White Sands Missile Range, New Mexico. - Continued

Material	Thickness (feet)	Depth (feet)
Sand, very fine to very coarse	5	285
Sand, very fine to very coarse, and some bit-cut fragments of larger rocks	5	290
Sand, very fine to coarse	10	300
Sand, very fine to coarse, and some bit-cut fragments of larger rocks	5	305
Sand, very fine to coarse, bit-cut fragments of larger rocks, and small bits of steel from drill bit	5	310
Sand, fine to medium, and bits of steel	5	315
Sand, fine to medium, small pebble, and bits of steel	5	320
Sand, fine to coarse, and bits of steel	5	325
Sand, fine to coarse, and bit-cut fragments of larger rocks	10	335
Sand, fine to coarse, bit-cut fragments of larger rocks, and bits of steel	5	340
Sand, fine to coarse, bit-cut fragments of larger rocks, and a little brown clay	5	345
Sand, fine to coarse, and bits of steel	5	350
Sand, fine to coarse, bit-cut fragments of larger rocks, and bits of steel	10	360
Sand, fine to coarse, much bit-cut rock, and bits of steel	5	365
Sand, fine to coarse, bit-cut rock, and bits of steel	5	370
Sand, fine to coarse, much bit-cut rock, and bits of steel	10	380
Sand, mainly very coarse, and much bit-cut fragments of larger rocks	35	415

Table 1.--Log of materials penetrated by well T-6 (22.4.14.133)

Headquarters area, White Sands Missile Range, New Mexico. - Concluded

Material	Thickness (feet)	Depth (feet)
Sand, medium, and much bit-cut rock	5	420
Sand, mainly very coarse, and much bit-cut rock	25	445
Sand, mainly very coarse, and much bit-cut rock. Samples have a uniform dark gray-brown color. Many large bit-cut chips from 490 to 500 feet.	55	500
Igneous rock, mainly bit-cut chips of brown, fine; many chips have distinct conchoidal fracture	15	515
		Total depth

Note: During course of drilling it was observed that much very fine sand and apparently some clay was carried away in the drilling mud. Almost all sand grains are angular to subangular because the parent rock is nearby. Grain sizes from [illegible] to [illegible] probably were reduced from original size by slow grinding from a worn and broken bit. Rock chips, noted as "bit-cut" are the result of the reduction of boulders and other large particles in the fan debris, these larger particles increased in number with depth to the vicinity of the bedrock top at about 490 feet, thus the increase in the amount of bit-cut material. A part of the erosional debris apparently was partly cemented, as shown by the relatively clean hole prior to setting casing.

After casing was set, the drilling mud was bailed from the hole, and the hole was developed by surging and bailing for 18 hours at which time the sand and mud content of the water had diminished appreciably. One hundred pounds of sodium hexametaphosphate was put into the hole, and a test pump was installed. The test hole was surged and pumped for 10 hours until the water was clear of suspended matter.

The hole was tested on November 18 by pumping at approximately 160 gpm for 11½ hours (fig. 7). The shape of the drawdown curve,

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Figure 7 (caption on next page) belongs near here.

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shown in figure 7, and the very rapid recovery after pumping stopped indicated that the pumping water level was greatly influenced by progressively greater entrance losses at the casing perforations. If the large drawdown at the end of the pumping period had been due to depletion of the water-bearing material, the recovery curve would have been much flatter, and recovery to the static level would have required a much longer time than 3 hours.

The data obtained from the test is not considered adequate for the computation of a value for the coefficient of transmissibility because of the large screen losses. The formation, however, is very permeable, as indicated by a 6-hour specific capacity of about 25 gpm per foot of drawdown in the test hole. One or more wells of moderate yield, in the order of 200 to 400 gpm, probably can be obtained in the area near T-6 because the water-bearing formation is coarse grained and is saturated through a thickness of about 290 feet. This interpretation, however, should be supported by further development and testing of T-6 and, possibly, further exploratory drilling.

Figure 7.--Water levels during drawdown and recovery and rate of discharge during performance test of test well T-6 (22.4.14.133), Headquarters area, White Sands Missile Range, N. Mex.

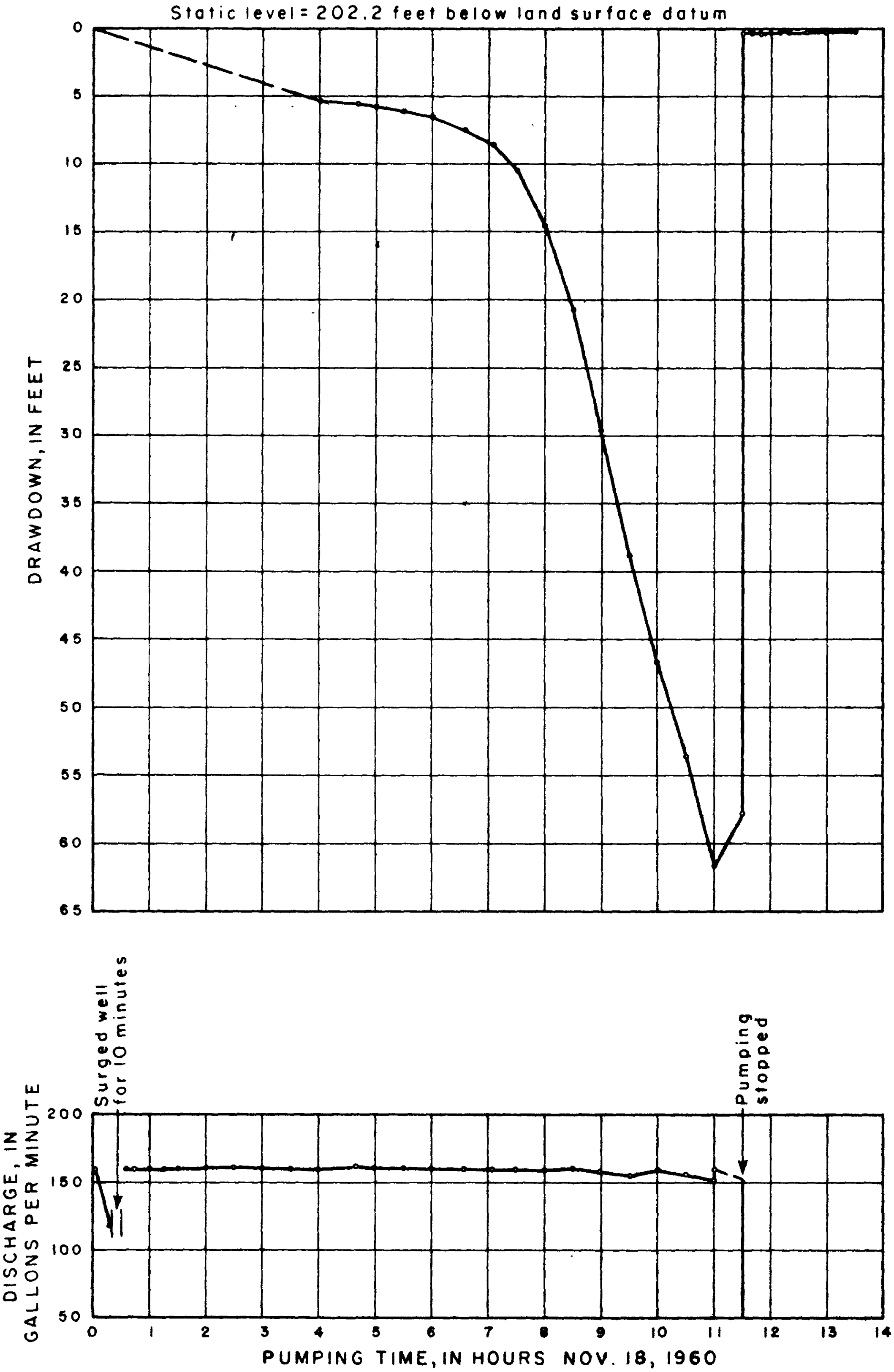

Figure 17.--Water levels during drawdown and recovery and rate of discharge during performance test of test well T-6 (22.4.14.133), Headquarters area, White Sands Missile Range, N. Mex.

Test hole T-6 penetrated about 290 feet of very coarse-grained fan deposits that lie on igneous bedrock. The 6-inch casing was perforated at selected intervals below the water level, which was approximately 202 feet below the land surface.

Water from the test hole is comparable in chemical quality to that from the headquarters well field. (See table 2.)

A test hole in the NE$\frac{1}{4}$NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 11, T. 22 S., R. 4 E. in addition to T-6 would not only yield new data, but also would help evaluate any recharge experiment made in the area. This location is near but not in the sites of flood-control and recharge structures suggested by Herrick (1960, fig. 1).

Gregg test and production wells

The Integrated Range Mission at White Sands Missle Range, in cooperation with the New Mexico State University, was preparing in 1961 to experiment with cooling the land surface around an optical tracking station. The purpose of the experiment was to suppress heat waves that distort telescopic images during the tracking of missiles. The cooling was to be accomplished by growing salt-tolerant vegetation around the station, because it was inferred that fresh water would not be available at the desired site. If vegetation could not be grown, the land surface was to be cooled by flooding; both methods would require relatively large quantities of water.

The Gregg Site optical tracking station was to be used for this experiment. The optical laboratory is in the SE¼NW¼SE¼ sec. 8, T. 22S., R. 6 E.

Two wells were drilled at Gregg Site, a test well and later a production well. The test well was drilled by the hydraulic-rotary method during August 9-12, 1961, to a depth of 1,010 feet. Samples of the drill cuttings were collected for each 10-foot thickness of the bolson fill penetrated by the bit. An induction-electrical log of the interval from 100 to 1,008 feet was run August 12 (fig. 8). A

Figure 8 (caption on next page) belongs near here.

water sample was obtained August 18, 1961, through the drill stem from the interval 281-300 feet, using a double packer. Subsequently, the test hole was cased with 8-inch casing to a depth of 500 feet. Perforated zones were selected from the data on the geophysical log. The test hole was cleaned out by jetting because large quantities of fine sand had been pulled into the casing by bailing operations. A turbine pump was set at 490 feet in the test hole on September 6, and the hole was developed for approximately 8 hours by surging and pumping. Throughout the development period the pumped water contained large quantities of very fine sand and silt. At the end of 8 hours of pumping and surging the specific capacity was about 11½ gpm per foot of drawdown and the rate of pumping was about 175 gpm.

A performance test was made September 7 from 9:00 a.m. to 5:00 p.m. on the test well. The sand content ranged from 30 to 40 ml per liter. The test was controlled poorly owing to sand clogging the orifice of the manometer tube. The specific capacity, in general, was commensurate with that given above. A water sample was collected at the end of the pumping period.

Figure 8.--Induction-Electric log of Gregg test well (22.6.8.414), White Sands Missile Range, N. Mex.

A production well was drilled about 4 feet south of the test hole and was completed to a depth of 478 feet. The hole was 27 3/4 inches in diameter and was cased with 14-inch casing perforated in the same zones as used in the test well (fig. 8). The annular space between the casing and the wall of the hole was gravel-packed by the hydraulic method. Drilling and gravel packing were completed October 23 and the well was cleaned out by jetting, and was developed by surging and pumping October 27-29. Large quantities of fine sand were removed from the well during development and gravel was added to the gravel pack to replace the sand removed by surging and pumping.

During the drilling of the test hole, samples were taken for each 10-foot interval from 130 to 1,010 feet below land surface. A description of the samples is given in table 3. An important feature of the samples, not obvious in the geophysical log, is the break in lithology at a depth of about 500 feet. The bolson fill above a depth of about 500 feet, though fine-grained, contains a large amount of fine to very fine sand. The particle size of the section above 500 feet generally coarsens upward toward the land surface. Most of the clays are sandy and soft.

Below a depth of about 500 feet, the fill consists almost entirely of clay. Although some of the clay is sandy, and a few thin beds of gravel were logged, any material coarser than clay probably is in a matrix of clay. Some of the clay beds are soft, but most are firm, and several beds are so dry and compact that they seem to be flakv and brittle. (See table 3.)

Table 3.--Log of materials penetrated by Gregg test well (22.5.8.14), White Sands Missile Range, New Mexico

Materials	Thickness (feet)	Depth (feet)
Samples missing	130	130
Sand, tan, silty, very fine to coarse, and some caliche	10	140
Sand, tan, silty, very fine	10	150
Silt and very fine sand, tan	10	160
Sand, tan, silty, very fine, with some caliche and a few very small gravel	30	190
Sand, tan, silty, very fine, with some caliche, very small gravel, and tan clay	30	220
Clay, brown, sandy, and small particles of caliche	30	250
Clay, brown, sandy, partly plastic, with greenish reduction spots, and few very small gravel	10	260
Clay, brown sandy, partly plastic, with greenish reduction spots	10	270
Sand, very fine to medium, and brown-red clay	10	280
Clay, red, sandy, and fragments of caliche	10	290
Clay, red-brown, very sandy, and fragments of caliche	20	310
Sand, very fine to medium, with fragments of caliche and lumps of clay	50	360
Clay, brown-red, very sandy	30	390
Sand, very fine to medium, much tan to red clay, and small grains of caliche	40	430

Table 3.--Logs of materials penetrated by Gregg test well (22.6.8.414), White Sands Missile Range, New Mexico - Continued

Materials	Thickness (feet)	Depth (feet)
Clay, brown, sandy	10	440
Sand, very fine to medium, or very sandy clay, with fragments of caliche and lumps of red to brown clay. Very sandy 470-80 ft.	40	480
Clay, brown, plastic, slightly sandy with greenish reduction spots	30	510
Clay, brown sandy	10	520
Clay, brown to tan, with fragments and lumps of red and greenish-gray clay; some very fine-grained sand and a fragment of limestone gravel	20	540
Clay, as from 520-to 540, but sandier; fragment of small gravel	10	550
Clay, as from 520 to 540	10	560
Clay, as from 540 to 550	10	570

Note: Most, if not all, rock types noted probably are in strata 6 inches thick, or more. Drill bit moves downward sporadically, first slowly, then very fast. The rapid drilling is in the soft clay, and the slow rate in the occasional beds of hard caliche.

Materials	Thickness (feet)	Depth (feet)
Clay, red to brown, compact, some greenish clay and considerable amount of very fine sand	20	590
Clay, very soft, and fragments of compact red clay. Rapid drilling rate	20	610
Clay, soft, and some very fine gravel	10	620
Clay, soft, slightly sandy	10	630
Clay, soft, and very fine gravel	10	640

Table 3.--Log of materials penetrated by Gregg test well (22.6.8.414),

White Sands Missile Range, New Mexico - Concluded

Materials	Thickness (feet)	Depth (feet)
Clay, [illegible], with small lumps and flakes of greenish and dark brown compact clay, and considerable amounts of very fine sand.	10	650
Clay, tan, very sandy	20	670
Clay, tan, very compact, and some caliche	10	680
Clay, tan, soft, sandy, with some lumps of compact red clay and chips of sandy caliche	60	740
Clay, slightly sandy	40	780
Clay, tan, sandy, very soft	10	790
Clay, tan, sandy, very soft, and small [illegible] fragments of caliche (?). Lithologic change	110	900
Clay, tan, very sandy, soft	10	910
Clay, tan, sandy, soft and some green clay fragments	10	920
Clay, tan slightly sandy, soft, with greenish reduction spots	30	950
Clay, red, compact, with greenish reduction spots. Some clays are almost [illegible] in appearance	60	1,010
		Total depth

The section of fill penetrated by the test well at Gregg Site contained more sand than was expected. All of the fill was expected to be like that below a depth of about 500 feet, which is similar to the section penetrated by test drilling in areas to the northeast and south of the site. The sandy section above a depth of about 500 feet probably resulted from relative uplift of the mountains. The uplift renewed the steep gradient and caused deposition of coarse debris farther out in the basin, just as more recent uplift has renewed fan building along the major fault near the Headquarters area.

Measurements of the depth to water indicate that the static level in the Gregg test well is about 213 feet below land surface. The altitude of the land surface, estimated from a topographic map, is 4,020 feet; the water-surface altitude is 3,807 feet. The water surface at Gregg Site is lower than at test hole 5 (22.5.20.111), altitude 3,880 feet, and test hole 4 (22.5.16.111), altitude 3,828 feet, which are to the west between the headquarters area and Gregg Site. The difference between the altitude of the water at Gregg Site and at test holes 4 and 5 establishes a continuous slope of the water table from the Headquarters well field to the main part of the Tularosa Basin near Gregg Site. No reliable data are available east of Gregg Site, but the water table in the vicinity of Gregg Site probably is the lowest in the basin at the latitude of the White Sands Headquarters.

A performance test was made on the production well at Gregg Site October 30 from 9:50 a.m. to 8:50 p.m. The rate of discharge was maintained at an average rate of 4[illegible]0 gpm for three hours, 598 gpm during the next 3 hours, and 76[illegible] gpm for the last 5 hours of the 11-hour pumping period. The discharge was measured by means of a pipe orifice and the drawdown was measured with a calibrated electric water level detector. During the recovery period it was found that the calibration of the electric line had changed, and the measurement of residual drawdown is considered to be accurate only for the last 110 minutes. Sand content of the water was measured by means of an Imhoff cone. The results of the several measurements are shown in figures 9, 10, and 11.

Figure 9 (caption on next page) belongs near here.

10 (caption on next page) belongs near here.

11 (caption on next page) belongs near here.

Figure 9.--Drawdown and residual drawdown in Gregg well (22.6.8.414), White Sands Missile Range, N. Mex., during performance test on October 30, 1961.

10.--Rate of discharge and sand content of water pumped from Gregg well (22.6.8.414), White Sands Missile Range, N. Mex., during performance test on Oct. 30, 1961.

11.--Computation of the coefficient of transmissibility of the bolson fill in the vicinity of Gregg well, White Sands Missile Range, N. Mex., using residual drawdown after pumping test on Oct. 30, 1961.

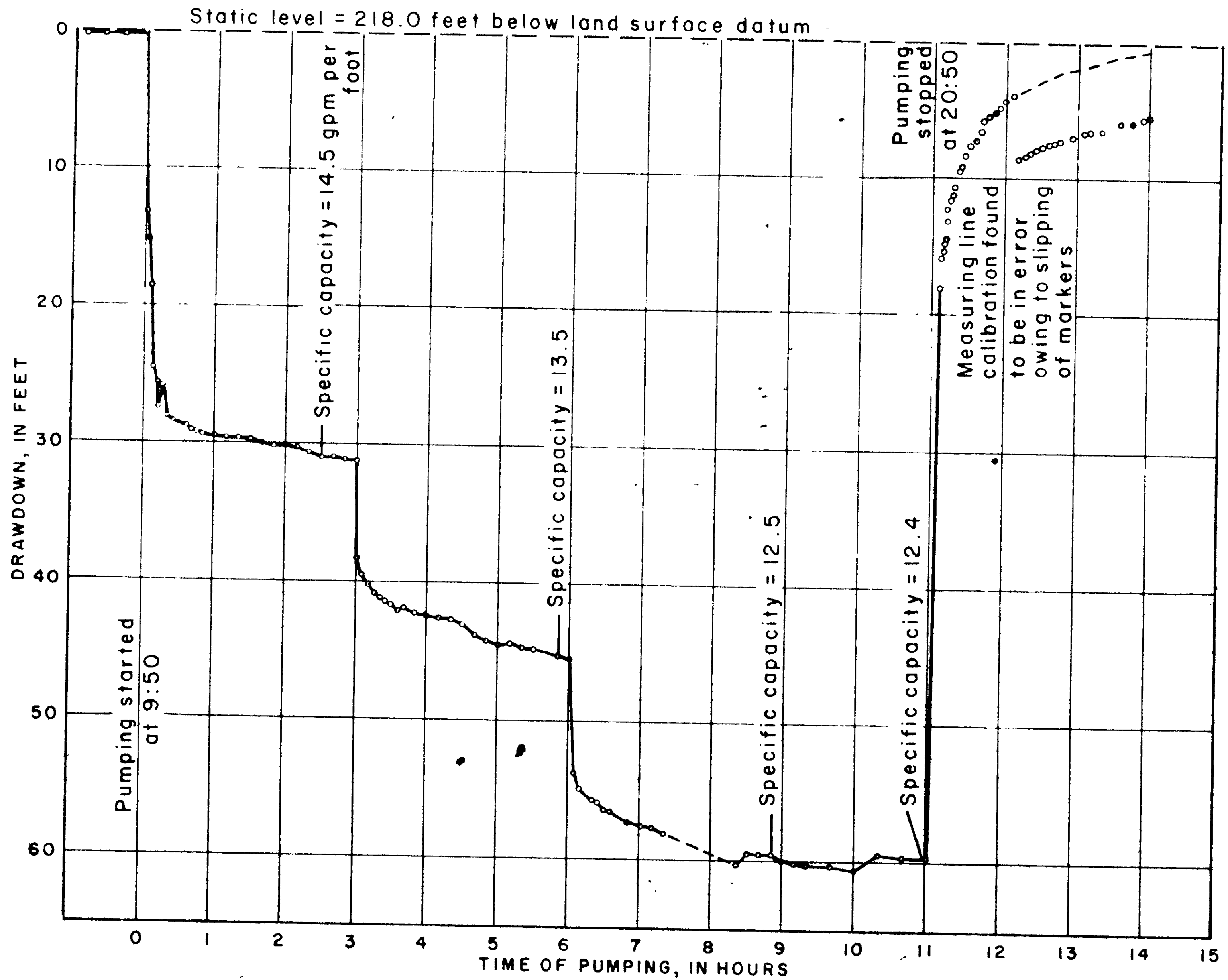

Figure 9.--Drawdown and residual drawdown in Gregg well (22.(28.41b), White Sands Missile Range, N. Mex., during performance test on Oct. 30, 1961.

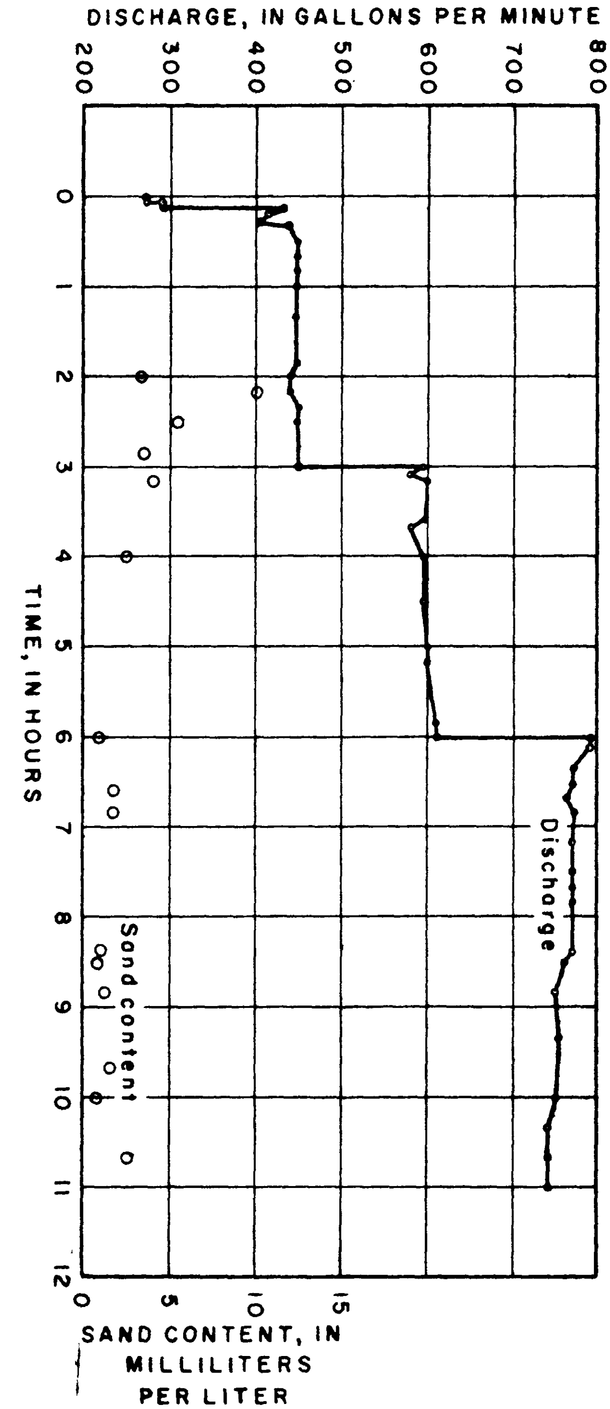

Figure 10.--Rate of discharge and sand content of water pumped from Gregg well (22.6.8.414), White Sands Missile Range, N. Mex., during performance test on Oct. 30, 1961.

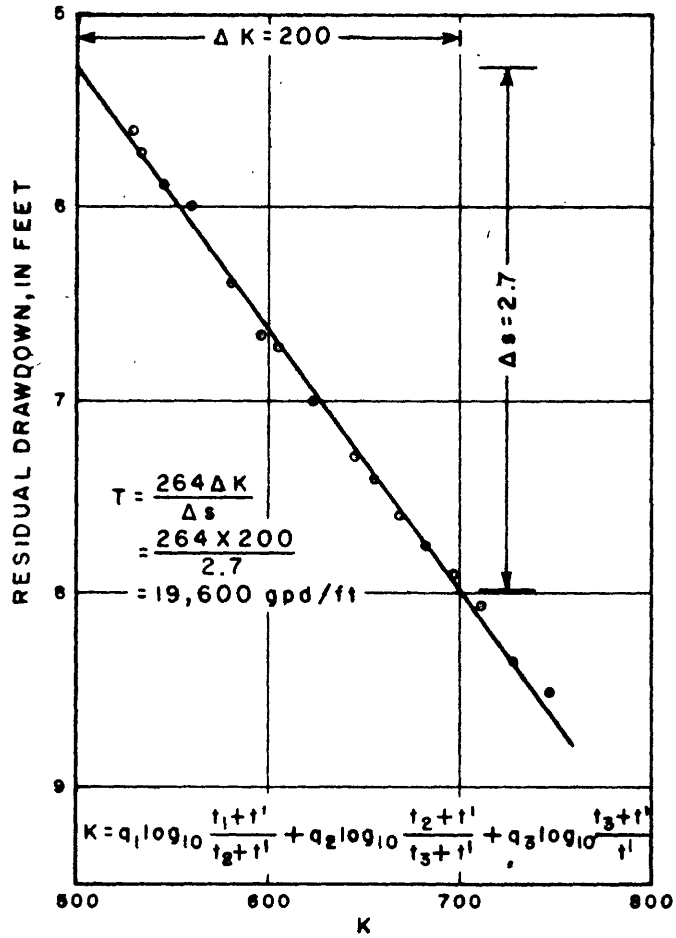

Figure 11.--Computation of the coefficient of transmissibility of the bolson fill in the vicinity of Gregg well, White Sands Missile Range, N. Mex. using residual drawdown after pumping test on Oct. 30, 1961.

The specific capacity of the production well was 12.4 gpm per foot at the end of the pumping period, while the well was being pumped at a rate of about 740 gpm. The coefficient of transmissibility as determined from the residual drawdown (fig. 11) and adjusted for the stepwise increase in pumping rate is 19,600 gpd (gallons per day) per foot. These data indicate that the well can sustain pumping rates of several hundred gallons per minute for prolonged periods of time. The figure for transmissibility shows that the formation can transmit large amounts of water to the well when the water level is lowered by pumping.

For the intended purpose of the well, a pumping rate of 600 gpm would be adequate. At that rate, the well could be pumped for prolonged periods with a pump setting of about 300 feet.

The well produced sand throughout the performance test. The amount produced (fig. 10) was generally less than 5 ml per liter. Even in these quantities, however, it would be best to pump the well to waste for a short period each time the pump is started, to avoid filling the storage reservoir or plugging the distribution system.

Ground water from the Gregg Site area is unsuitable for almost any present use other than cooling the ground by flooding, which is the intended alternate use. The analyses of samples of water from the test hole and the production well show that water as shallow as 500 feet, or about 30 feet below the water table, contains about 8,900 ppm of dissolved solids and has a percent sodium of 72 (table 4), and that water from below 500 feet contains about 15,000 ppm of dissolved solids and a percent sodium of 70. The water is somewhat unusual in that it is a sodium sulfate water, whereas most highly mineralized waters in southern New Mexico are either calcium magnesium sulfate or sodium chloride waters.

Small Missile Range Area

The principal work area in the Small Missile Range is a group of buildings in sec. 15, T. 21. S., R. 5 E. The potable water suply for the area in 1961 came from a shallow well (21.5.11.411) that had been yielding water since 1952. The original yield of the well was 15 gpm. However, by 1961, the yield was only 10 gpm and was inadequate for the needs of the area. Attempts to rehabilitate the well were unsuccessful.

Well 21.5.15.411 is shallow and the water from it is potable. Reportedly the aquifer is fine sand. However, a deep well at this location probably would yield water inferior to that from the shallow zone. Investigations were made upslope towards the mountains to the west in sections 16 and 17, where the probability of obtaining potable water from coarse sand and gravel is greater. (See fig. 2.)

The locations for test drilling were about a mile east of a fault scarp that extends northeastward through the NE cor. sec. 21, T. 21 S., R. 5 E. West of the fault a pediment slope extends into a reentrant in the mountain front through which arroyos carry runoff to the flats. The pediment is cut on granite and is covered by only a few feet of overburden. East of the fault, which has a vertical displacement of more than 1,000 feet, the bolson fill is thick.

The contract for test drilling in the Small Missile Range was for one to four test holes, each 350 to 600 feet deep. The holes were to be drilled with cable tools and the hole diameter was to be adequate for 6-inch casing.

Test well SMR-1 (21.5.16.132)

Drilling of well SMR-1 began June 3 and was completed June 25, 1960. The first water was found at 285-90 feet. The hole was drilled to 600 feet but was cased with 6-inch casing only to 473 feet below land surface. A total of one hundred twenty-eight feet of the casing was slotted opposite selected zones. (See fig. 12.)

Figure 12 (caption on next page) belongs near here.

The slots were cut approximately one-eighth inch wide and 4 inches long, staggered in rows, 12 slots per foot.

On June 22, 1960 the well was surged with a tight-fitting surge block. The fill washed into the hole was bailed out until the quantity of material pulled into the well by the surge blocks diminished noticeably. The total surging time was 18 hours.

Figure 12.--Induction-Electric log of test well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex.

The well was equipped with a 5-inch turbine pump powered by an internal-combustion engine and was test pumped June 24 and 25, 1960. Discharge was measured with a pipe orifice and the water level while pumping was measured with an electric water-level detector. The well was pumped at two rates of discharge: about 100 gpm and 150 gpm.

The drawdown at the end of 4 hours pumping at about 100 gpm was 17.3 feet, indicating a specific capacity of 5.9 gpm per foot. The gross drawdown after pumping an additional 7 3/4 hours was 27.8 feet, indicating a specific capacity of about 4.5 gpm per foot for a weighted average discharge of 124 gpm or 5.6 gpm per foot for an instantaneous rate of 156 gpm.

The pumped water was brown with silt and sand but began to clear about an hour after pumping started; and by the 6th hour of pumping the water had cleared of suspended matter. Field determinations of specific conductance show that the chemical quality did not change appreciably during the test. The temperature of the water was 80°F

The water level and rate of discharge during the test are shown in figure 13. The coefficient of transmissibility computed from

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Figure 13 (caption on next page) belongs near here.

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data given in figure 14 is about 7,900 gpd per foot.

Figure 14. (caption on next page) belongs near here.

Figure 13.--Water level during drawdown and recovery, and the rate of discharge during performance test of well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex.

14.--Computation of the coefficient of transmissibility, using residual drawdown after performance test of SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex.

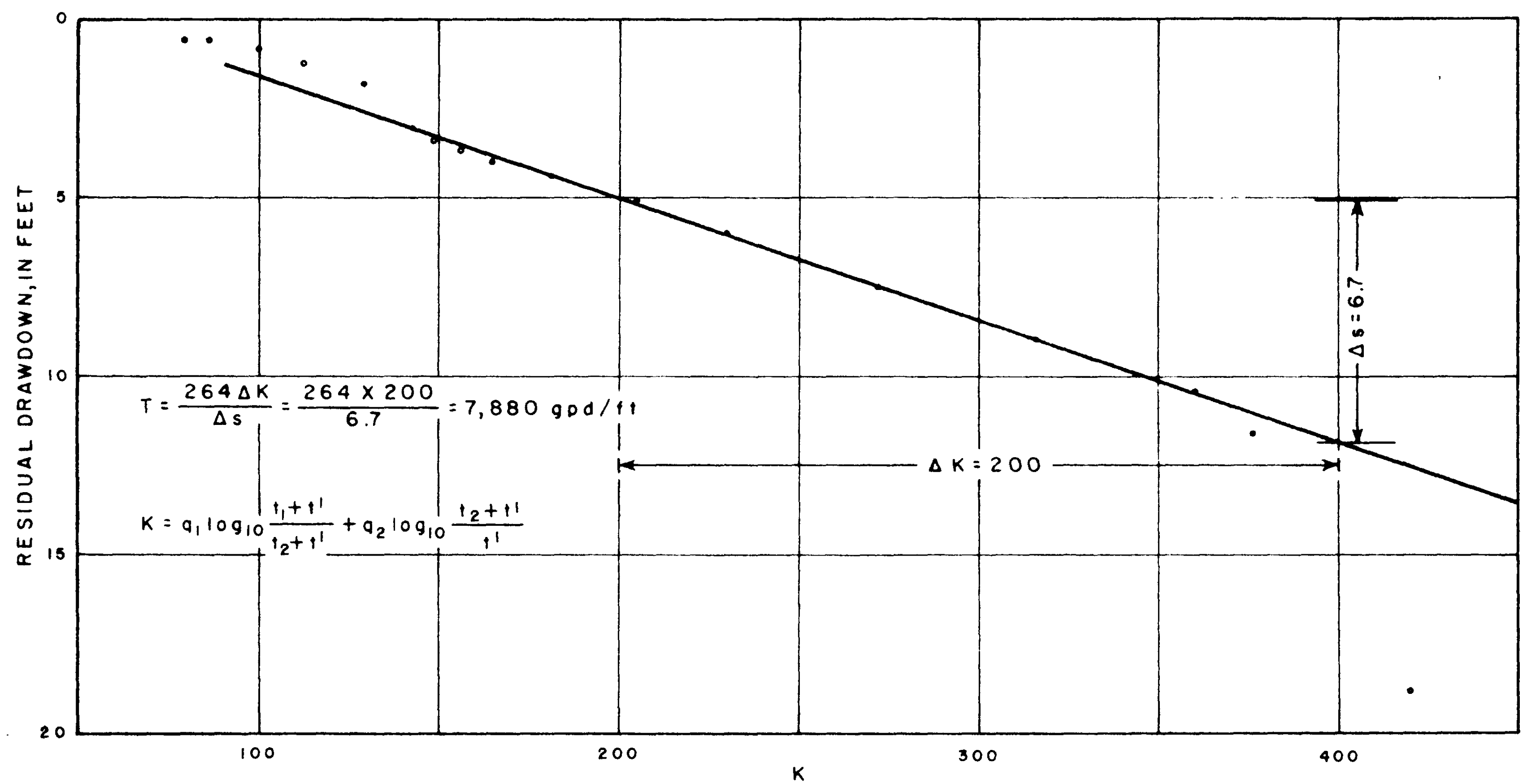

Figure 14.--Computation of the coefficient of transmissibility, using residual drawdown after performance test of well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex.

Test well SMR-2 (21.5.17.424)

Drilling of well SMR-2 began at the end of June 1960, and was finished at the end of September. The first water was found at 305 feet below land surface.

The driller had much difficulty with the walls of the hole until temporary 8-inch casing was set at about 620 feet. Drilling to 765 feet then proceeded without appreciable difficulty, and 6-inch casing was installed in the lower zone.

The well was surged and cleaned out. During these operations the surge block became stuck near the bottom of the 8-inch casing. The 8-inch casing was removed from the hole to free the block. The casing was reinstalled and the hole was cleaned out to bottom by September 9. The well finally was cased with 8-inch casing to about 608 feet below land surface and 6-inch casing from 598 to 747 feet. These casings were perforated from 295 to 588 feet, and from 608 to 715 feet.

A Gamma Ray-Neutron log was made of the completed hole (fig. 15).

Figure 15 (caption on next page) belongs near here.

The logging tool reached a depth of 755 feet, indicating that the walls in the lower part of the hole did not cave readily.

The annular space between the 8-inch casing and the wall of the hole was filled with gravel by pouring the gravel into the space at the surface and then bailing the well to settle the gravel. The well initially required about 9 cubic yards of gravel.

Figure 15.--Gamma Ray-Neutron log of test well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex.

The well was developed by surging first the 8-inch casing and then the 6-inch casing with closed surge blocks and bailing out the fill that was pulled through the perforations. During the 50 hours of working time required for development, the process of surging filled the 6-inch casing with debris, and the fill at one time extended 15 feet or more above the top of the 6-inch casing. The large amount of perforated pipe passed much debris, especially in the depth interval from 500 to 600 feet. Development and final cleaning was completed by Sept. 26, and the test pump was installed on September 27.

Test well SMR-2 was pumped September 29 to obtain its yield and drawdown and the coefficient of transmissibility of the aquifer. The equipment was that used for testing well SMR-1. The well was pumped 11 hours and 41 minutes, at which time the test was terminated because the motor stopped. The pumping rate was difficult to adjust during the test because the motor ran irregularly and stopped twice. Three rates of discharge were used: 116, 147, and 172 gpm (weighted average). (See fig. 15.)

At the end of 201 minutes of pumping at about 116 gpm, the instantaneous value for specific capacity was 12.7 gpm per foot of drawdown. After pumping for an additional 280 minutes at an average rate of 147 gpm, the specific capacity was about 12.3 gpm per foot, and near the end of the test the instantaneous value for specific capacity was 11.7 gpm per foot (fig. 15).

When pumping began, the pumped water was charged with brown silt and fine to coarse sand. After 26 minutes of pumping, the concentration of suspended matter had diminished to 1.0 ml per liter, and after 3 hours of pumping it had diminished to 0.1 ml per liter. The water during the remainder of the test continued to carry about 0.1 per liter of suspended matter. Field measurements of specific conductance showed that the water remained constant in chemical quality. The water temperature was 84°F.

The depth to water and the rate of discharge during pumping on Sept. 29, 1960 are given in figure 16, and the specific capacity during

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Figure 16 (caption on next page) belongs near here.

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pumping and the residual drawdown after pumping stopped are given in figure 17. The coefficient of transmissibility was computed from data

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Figure 17 (caption on next page) belongs near here.

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given in figure 18 and is approximately 20,000 gpd per foot.

Figure 18 (caption on next page) belongs near here.

Figure 16.--Water levels during drawdown and the rate of discharge during performance test of well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex.

17.--Specific capacity during test and residual drawdown after performance test of well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex.

18.--Computation of the coefficient of transmissibility using residual drawdown after performance test of well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex.

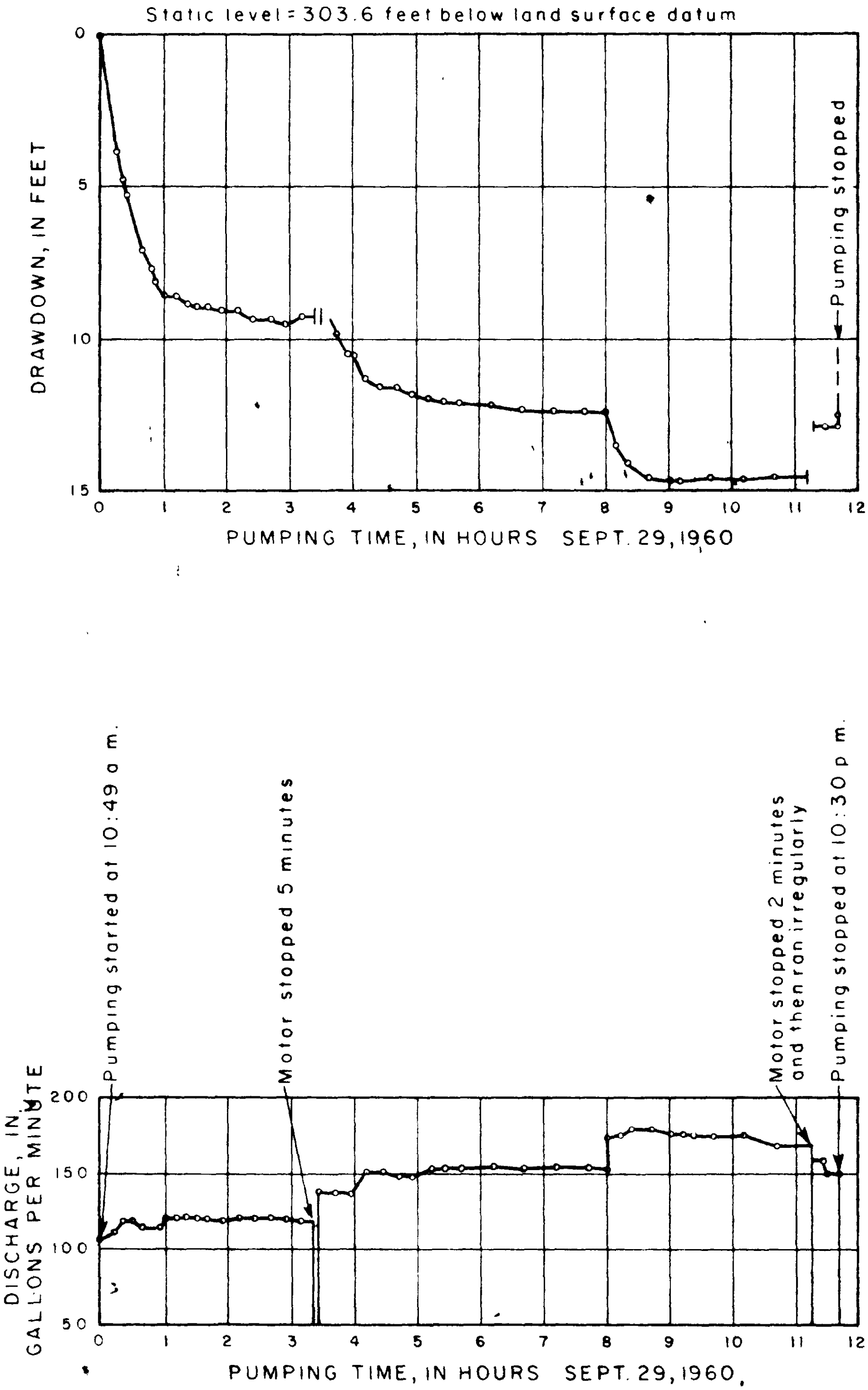

Figure 16.--Water levels during drawdown and the rate of discharge during performance test of well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex.

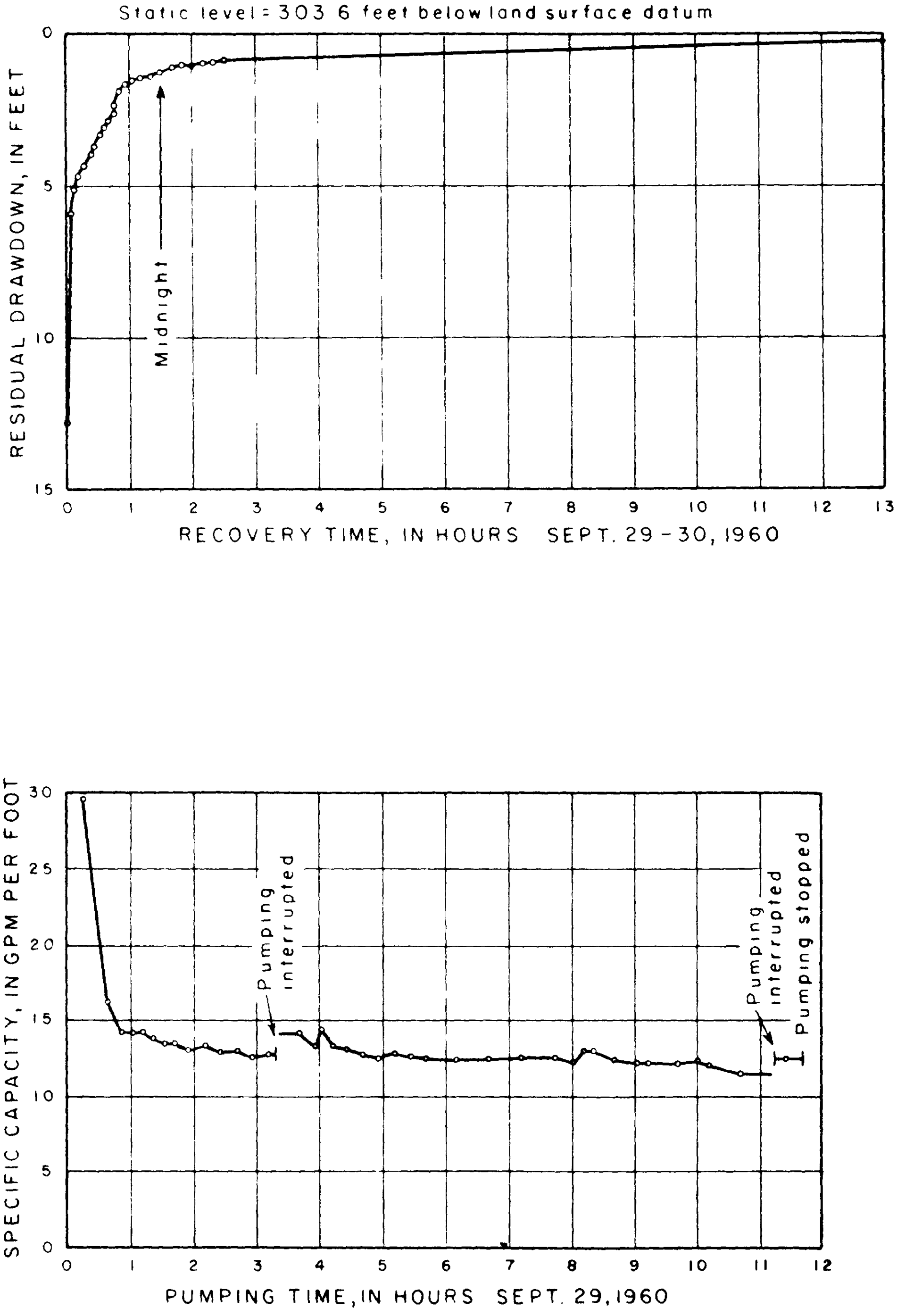

Figure 17.--Specific capacity during test and residual drawdown after performance test of well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex.

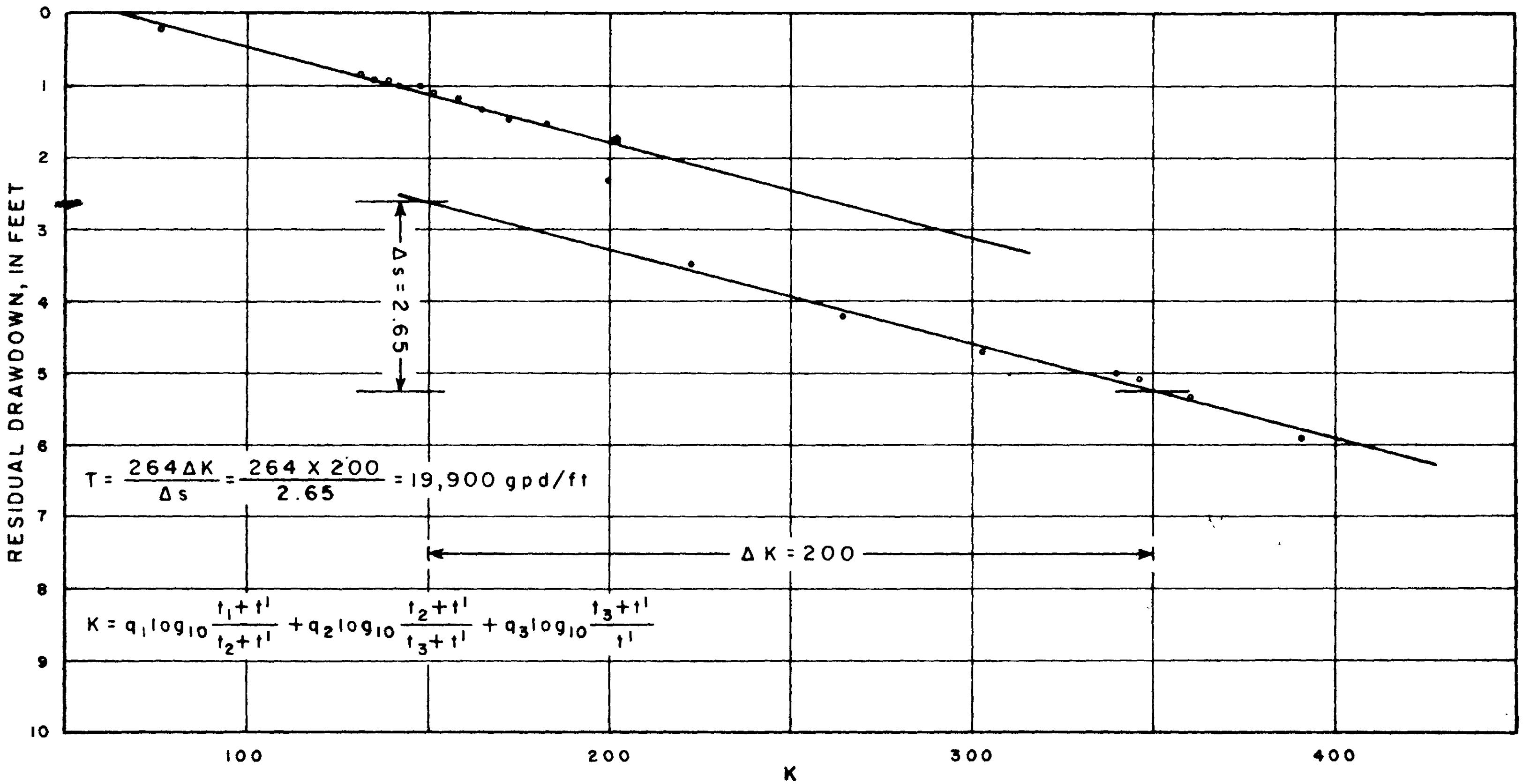

Figure 18.--Computation of the coefficient of transmissibility using residual drawdown after performance test of well SMR-2 (21.5.1.424), White Sands Missile Range, N. Mex..

Character of the bolson fill

The bolson fill in the Small Missile Range area is a mixture of debris from the rocks in the adjacent mountains. The drill cuttings, drilling time log and geophysical logs obtained from test wells SMR-1 and SMR-2 show that the fill from the land surface down to the zone 240-50 feet is mostly coarse-grained, and most individual grains are angular to sub-angular. The extremely angular fragments logged were parts of larger particles, such as boulders, that were broken up by the drill bit. The upper zone contained relatively small quantities of clay. Recognizable rock types in the fill were dolomite or dolomitic limestone, quartzite, quartz, feldspar, and chert. A considerable quantity of ferro-magnesian minerals were present as a very fine black sand. The lithologic break is shown in the sample logs, geophysical logs, and the drilling time log for SMR-1.

Clay and sand are the principal constituents of the fill below the lithologic break near 250 feet, although gravel also is present in appreciable quantities. Fill in the deeper zone is much finer, more distinctly bedded material. The grain size decreases as depth increases. In test well SMR-2, the driller reported drilling into bedrock at about 760 feet. He based this opinion on a change in drilling rate and formation hardness. Examination of the drill cuttings shows that the "bedrock" is a tightly cemented conglomerate. Bedrock probably is immediately below the zone in which drilling stopped, because a similar conglomerate overlies bedrock in the headquarters area.

The grain size of the bolson fill in a composite sample from the zone 360 to 445 feet in test well SMR-1 is shown in figure 19.

Figure 19 (caption on next page) belongs near here.

Logs of samples from test wells SMR-1 and SMR-2 are given in tables 5 and 6, respectively.

Figure 19.--Distribution of grain sizes in composite sample from the zone 300 to 445 feet in well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex. (Sieve analysis by Post Engineer Office, White Sands Missile Range.)

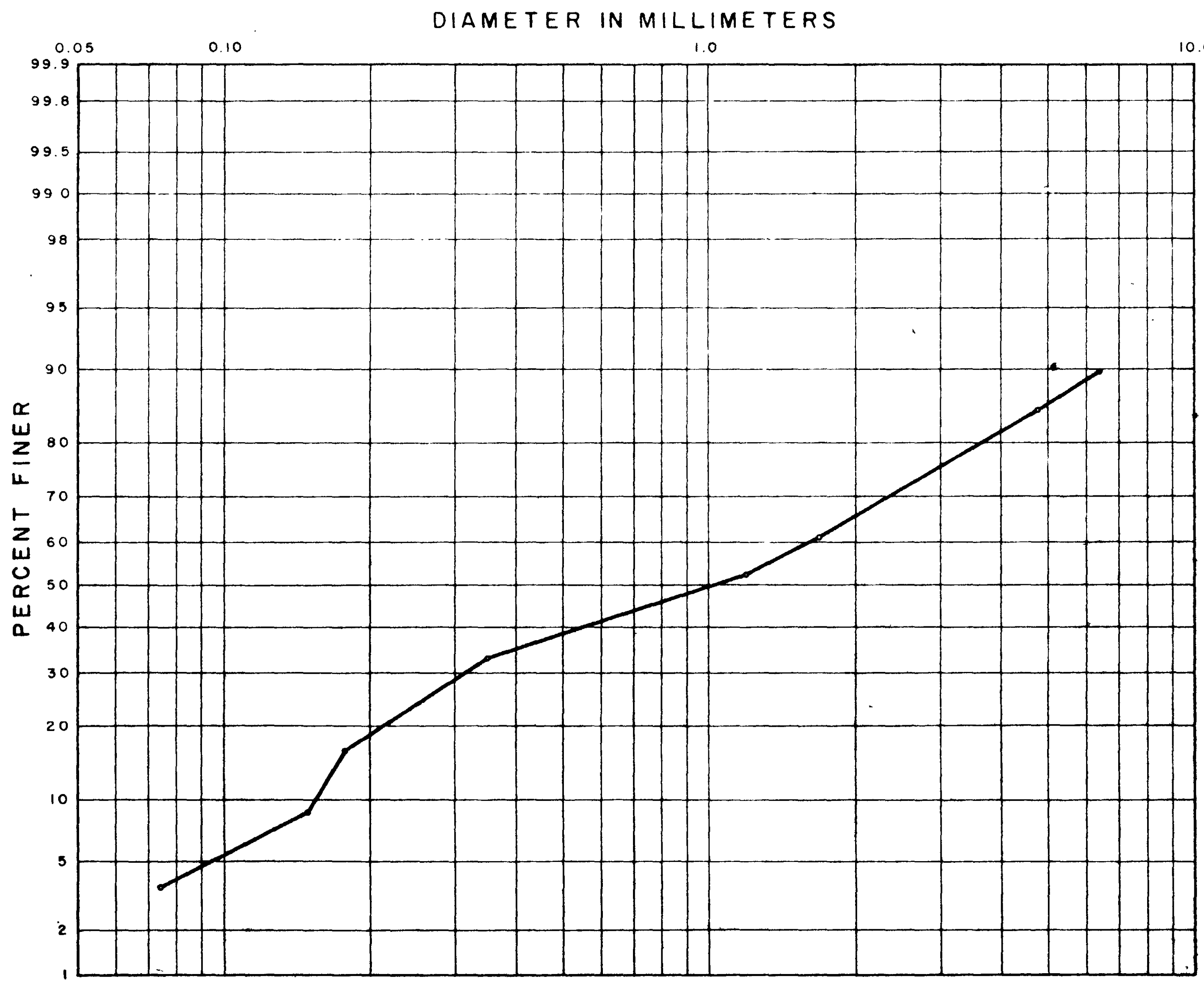

Figure 19.--Distribution of grain sizes in composite sample from the zone 300 to 445 feet in well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex. (Sieve analysis by Post Engineer office, White Sands Missile Range.)

Table 5.--Log of materials penetrated by test well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex.

Material	Thickness (feet)	Depth (feet)
Soil, full of sand and gravel. Fragments are angular	5	5
Gravel, pebbles, and some very coarse sand	5	10
Sand, fine- to very coarse-grained, and gravel	5	15
Sand, coarse- to very coarse-grained, gravel and small pebbles	5	20
Sand, very fine- to very coarse-grained, gravel, and small pebbles	5	25
Sand, very fine- to very coarse-grained, and small gravel. Pebbles at 35 and 55 feet	30	55
Sand, very fine- to very coarse-grained, very small gravel and some tan clay	15	70
Sand, fine- to very coarse-grained, and small gravel partly bit-cut	15	85
Sand, fine- to very coarse-grained, gravel, and small pebbles	20	105
Sand, fine- to very coarse-grained, small gravel and a large pebble or two	10	115
Sand, fine- to very coarse-grained, and small bit-cut gravel	10	125
Clay, silty brown, very fine- to very coarse-grained sand and some small gravel	5	130

Table 5.--Log of materials penetrated by test well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Sand, very fine- to very coarse-grained, silty brown clay and some small gravel	10	140
Clay, silty, yellow-brown, very fine- to very coarse-grained sand, and small bit-cut gravel	5	145
Sand, fine- to very coarse-grained, small bit-cut gravel, and yellow-brown clay	5	150
Clay, silty yellow-brown, and very fine- to very coarse-grained sand	5	155
Sand, coarse-grained, gravel, and small pebbles	5	160
Sand, fine- to very coarse-grained, gravel and small pebbles	5	165
Sand, very fine- to very coarse-grained, some small pebbles, and silty clay	5	170
Clay, silty, yellow-brown, very fine- to very coarse-grained sand, and a few pebbles	5	175
Clay, silty yellow-brown, very fine- to very coarse-grained, and few small gravel	5	180
Sand, coarse- to very coarse-grained, and bit-cut gravel. Some silt	15	195
Clay, silty, yellow-brown, very fine- to very coarse-grained sand, and bit-cut gravel	10	205

Table 5.--Log of materials penetrated by test well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Sand, very fine- to very coarse-grained, small gravel, and some clay	5	210
Sand, fine- to very coarse-grained and some clay	10	220
Sand, very fine- to very coarse-grained, small gravel, and some clay	10	230
Clay, yellow-brown, some sand, and very small bit-cut gravel	10	240
Clay, sandy yellow-brown	5	245
Clay, sandy yellow-brown, and very fine- to very coarse-grained sand	10	255
Sand, very fine- to very coarse-grained and some clay	5	260
Sand, fine- to very coarse-grained, and gravel	5	265
Sand, fine to very coarse-grained, gravel and small pebbles	5	270
Clay, sandy tan	10	280
Sand, medium- to very coarse-grained, pebbles, and tan clay	5	285
Clay, sandy tan	5	290
Sand, medium- to coarse-grained, bit-cut pebbles, and tan clay	5	295
Sand, fine-grained to fine-grained gravel, and bit-cut pebbles	5	300

Table 5.--Log of materials penetrated by test well SMR-1 (21.5.16.132), White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Silt, tan, and fine- to coarse-grained sand	5	305
Sand, coarse-grained	5	310
Sand, coarse-grained, gravel, and small pebbles	20	330
Gravel and pebbles	5	335
Sand, coarse-grained, gravel, small pebbles, and tan clay	10	345
Sand, coarse-grained, gravel, and pebbles	5	350
Sand, medium-grained to medium bit-cut gravel	10	360
Sand, medium-grained to medium bit-cut gravel, and tan silt	10	370
Clay, silty tan, and fine- to medium-grained sand	10	380
Sand, fine- to medium-grained, and silty tan clay. About 50% each	10	390
Clay, silty tan	5	395
Sand, medium- to coarse-grained, and tan silt	5	400
Sand, medium- to coarse-grained, tan silt, and some small gravel	20	420
Clay, silty tan, and medium- to very coarse-grained sand	5	425
Clay, silty tan, medium- to very coarse-grained sand, and small pebbles	5	430
Clay, silty tan, and medium- to very coarse-grained sand	5	435

Table 5.--Log of materials penetrated by test well SMR -1 (21.5.16.132), White Sands Missile Range, N. Mex. - Concluded

Material	Thickness (feet)	Depth (feet)
Clay, sandy tan, and bit-cut gravel	5	440
Clay, sandy tan, bit-cut gravel, and large pebbles	5	445
Gravel, bit-cut, small pebbles, and sandy brown clay	15	460
Clay, sandy brown, sand, and bit-cut gravel	10	470
Clay, sandy brown, sand, bit-cut gravel, and small pebbles	15	485
Clay, sandy brown, sand, bit-cut gravel, and large pebbles	5	490
Clay, sandy tan, and fine-grained gravel	5	495
Clay, sandy tan	5	500
Clay, sandy brown, sand and bit-cut gravel	10	510
Sand, bit-cut gravel, and large pebbles	5	515
Clay, brown, bit-cut gravel, and large pebbles	5	520
Clay, brown, sand, and small gravel (bit-cut at 540 feet)	30	550
Clay, sandy brown	5	555
Clay, sandy brown, and some coarse-grained sand	20	575
Clay, sandy brown, coarse-grained sand, and some small gravel	20	595
Clay, sandy brown, coarse-grained sands, small gravel, and large pebbles	5	600

Table 6.--Log of materials penetrated by test well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex.

Material	Thickness (feet)	Depth (feet)
Silt, reddish-brown. Complete grain-size range through pebbles. Much sub-angular debris	15	15
Silt, reddish-brown, sand and gravel, with more silt and clay in lower part of section	15	30
Gravel, small sub-angular silt and clay	5	35
Gravel, small sub-angular, very coarse-grained sand and tan clay	5	40
Gravel, small sub-angular, pebbles, very coarse-grained sand, and tan clay	5	45
Pebbles, bit-cut, gravel, and very coarse-grained sand	5	50
Pebbles, bit-cut, gravel, very coarse-grained sand, and tan clay	5	55
Sand, very coarse-grained, small gravel, and tan clay	5	60
Sand, fine- to very coarse-grained, and small gravel	15	75
Sand, fine- to very coarse-grained, small gravel, pebbles and tan silt	10	85

Table 6.--Log of materials penetrated by test well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Sand, fine- to very coarse-grained and small gravel	5	90
Sand, fine- to very coarse-grained, small gravel, small pebbles, and tan silt	20	110
Sand, fine- to very coarse-grained, small gravel, and tan silt	10	120
Sand, fine- to very coarse-grained, small gravel, and small pebbles	5	125
Sand, fine- to very coarse-grained, small gravel and tan silt. Sample 135-140 feet missing	25	150
Sand, very coarse-grained, small gravel and a pebble	10	160
Silt, tan, very coarse-grained sand, small gravel and pebbles	10	170
Gravel, small, with some silt and fine-grained sand	10	180
Gravel, small, small pebbles, and some silt and fine-grained sand	5	185
Gravel, small, silt, fine-grained sand, and brown clay	5	190
Silt, brown, and fine- to very coarse-grained sand	5	195
Sand, coarse- to very coarse-grained, and brown silt	5	200

Table 6.--Log of materials penetrated by test well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Sand, coarse- to very coarse-grain cemented, and brown silt	5	205
Silt, tan to brown, very coarse-grained sand, and pebbles	5	210
Sand, fine- to very coarse-grained, small gravel and silt	10	220
Sand, fine- to very coarse-grained, small gravel, silt and very small pebbles	5	225
Sand, fine- to very coarse-grained, small gravel, silt, and large pebbles	5	230
Sand, very coarse-grained, gravel, and small pebbles	5	235
Sand, very coarse-grained, gravel, small pebbles, and much tan silt	10	245
Silt, tan, very fine-grained sand, small pebbles	5	250
Silt, tan, and very coarse-grained sand	15	265
Silt, tan, very coarse-grained sand, and small pebbles	5	270
Silt, tan, and very coarse-grained sand	10	280
Samples missing	15	295
Silt, tan, and very coarse-grained sand	5	300
Clay, yellow-brown, in lumps	5	305
Sand, medium- to coarse-grained, small gravel, pebbles, and small amount of clay	5	310
Clay, sandy yellow-brown, in lumps	5	315

Table 6.--Log of materials penetrated by test well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Clay, with much included small gravel, and a pebble	10	325
Clay, very sandy brown, and small gravel	5	330
Clay, very sandy, brown, in lumps, and a pebble	5	335
Clay, sandy brown, and medium- to coarse-grained sand	5	340
Clay, sandy brown, in lumps, and fine-grained gravel	5	345
Sand, silty, medium- to coarse-grained, and small gravel	5	350
Clay, yellow-brown, and medium- to coarse-grained sand	5	355
Clay, sandy, light-brown, stiff	5	360
Clay, sandy, light-brown, stiff, and fine-grained gravel	10	370
Clay, sandy, light-brown, in lumps	5	375
Sand, medium- to coarse-grained, fine-grained gravel, and a lump of sandy brown clay	10	385
Clay, sandy brown	5	390
Clay, and coarse-grained sand	5	395
Clay, sandy light-brown, in lumps, and some pebbles	5	400

Table 6.--Log of materials penetrated by test well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Clay and fine- to coarse-grained sand	5	405
Clay, sandy light-brown, in lumps	5	410
Clay, yellow-brown. Almost no coarser material	5	415
Clay, light-brown, coarse-grained sand and small gravel	15	430
Sand, medium- to coarse-grained and some yellow clay	5	435
Clay, light brown, and coarse-grained sand. Clay firmer than above. A few pebbles	15	450
Clay, light brown, some coarse-grained sand, and fine gravel	5	455
Clay, yellow-brown	5	460
Clay, yellow	5	465
Clay, brown, and very fine- to coarse-grained sand	5	470
Clay, yellow-brown, and very fine- to coarse-grained sand	15	485
Clay, yellow-brown, very fine- to very coarse-grained sand, small gravel, and small pebbles	10	495
Clay, yellow-brown, fine-grained sand to fine-grained gravel	5	500
Clay, brown and fine-grained gravel	10	510

Table 6.--Log of materials penetrated by test well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Sand, very fine- to very coarse-grained, small gravel, and tan clay	10	520
Clay, brown, and very fine-grained sand to fine-grained gravel	10	530
Clay, sandy brown	5	535
Clay, sandy brown, and very coarse-grained sand	5	540
Gravel, fine-grained, and sandy brown clay	5	545
Sand, medium- to very coarse-grained, fine-grained gravel, and brown clay	30	575
Clay, sandy brown	15	590
Sand, fine- to very coarse-grained, and sandy brown clay	5	595
Clay, sandy brown	5	600
Sand, medium- to very coarse-grained, and sandy brown clay	5	605
Clay, sandy brown	5	610
Sand, medium- to very coarse-grained, small gravel, and brown clay	5	615
Clay, sandy brown, medium- to very coarse-grained sand, and small gravel	10	625
Sand, very fine- to very coarse-grained, small gravel, and silty brown clay	10	635

Table 6.--Log of materials penetrated by test well SMR-2 (21.5.17.424), White Sands Missile Range, N. Mex. - Concluded

Material	Thickness (feet)	Depth (feet)
Clay, brown, sand, and small gravel-one pebble	20	655
Clay, sandy brown. Caliche fragments at 710 feet	60	715
Clay, sandy reddish-brown	15	730
Clay, brown, and very fine- to coarse-grained sand	5	735
Clay, sandy brown	10	745
Clay, brown, and very fine- to coarse-grained sand	5	750
Clay, sandy brown, medium- to very coarse-grained sand, and fine-grained gravel	5	755
Clay, sandy brown, and very coarse-grained sand	5	760
Sandstone, well-cemented, arkosic. Driller called this bedrock because of the hardness of the rock and the slowness of drilling	5	765

Ground water

The saturated bolson fill at the test sites is more than 450 feet thick. The top of the saturated zone is about 3,890 feet above mean sea level at test well SMR-1 and about 3,894 feet at SMR-2. These altitudes fit into the pattern of contours showing the shape of the water surface in the headquarters area and vicinity as described by Herrick (1958, plate 1). The source of water in the Small Missiles Range area is west of the well sites. Ground water moves east-southeastward from the well sites toward the flats of the Tularosa Basin and then moves southward. Recharge to the Small Missiles Range area comes partly from absorption of precipitation and subsequent underground transmission from the reentrant above the test well area, and partly from absorption of precipitation and arroyo flow in the vicinity of the test wells. Because the upper part of the reentrant is a granite pediment in which the water is in fractures in the granite, rather than in the overburden, recharge from this area probably is the lesser of the two amounts. The coarse-grained alluvium in the vicinity of the test wells, and upslope as far as the fault scarp mentioned previously, probably is the principal recharge area.

The quantity of recharge can be estimated from the slope of the water surface, the coefficient of transmissibility of the bolson fill, and the width of the area concerned. The water levels in the area have not been disturbed previously by pumping, so that the flow of water through the area should represent the amount of water entering the aquifer. The slope from SMR-1 to the production well at the Small Missile Range work area is 51 feet in 1.29 miles, or about 40 feet per mile. The coefficient of transmissibility was about 20,000 gpd per foot from the aquifer test at SMR-2. For a mile width of the aquifer the rate of flow = 20,000 x 40 = 800,000 gallons per day per mile, or about 900 acre-feet per year per mile. This figure is somewhat lower than the estimate by Herrick (1958, p. 54) for the headquarters area. The headquarters area, however, has a much larger recharge area and should have more recharge.

The coefficient of transmissibility at test well SMR-1 is about 7,900 gpd per foot for a saturated section approximately 200 feet thick. The coefficient of transmissibility at test well SMR-2 is about 20,000 gpd per foot for a saturated section about 450 feet thick. These figures are approximately comparable when related to thicknesses and also are comparable to those for the bolson fill in the headquarters area (Herrick, 1958, p. 104). The specific capacity for SMR-2 after pumping about 12 hours at 116 to 180 gpm was nearly 12 gpm per foot of drawdown. From these data, a production well in the Small Missile Range area drilled to a depth of about 750 feet should produce 500 gpm or more.

Chemical quality of ground water

The chemical quality of water obtained from SMR-1 and SMR-2 is comparable to the supply being used at the Small Missile Range in 1961 (table 7). The water is very hard, but the concentration of total dissolved solids is about 500 ppm and individual constituents are low in concentration. Although the concentration of dissolved solids in the Small Missile Range water is about twice that of water in the headquarters area, water from the test wells in the Small Missile Range area is not only potable, but is far superior to most water supplies used elsewhere in the Tularosa Basin.

Bicarbonate and sulfate are the principal anions. Calcium and magnesium are the principal cations. These ions are the reason for the relatively high figure of 350 to 400 ppm total hardness.

The fluoride concentration in the water from the Small Missile Range wells is 1.0 to 1.5 ppm. This concentration of fluoride is near the maximum permissible limit for children whose teeth are developing (Public Health Service). This fact should be considered before using water from the Small Missile Range as an auxiliary supply for the headquarters area.

Further exploration of water quality in the Small Missile Range area should be made before any large-scale development is planned. Little is known of the lateral distribution of the potable water, but it is known that the quality deteriorates eastward and with depth. This deterioration is demonstrated in the study by Herrick (1958) and is indicated by the results at Gregg site and by the geology of the lower parts of the Tularosa Basin where there are saline playas and lakes.

Hazardous Test Area

In July 1960, the Geological Survey was requested to investigate the possibility of obtaining 10 to 15 gpm of water in the northern part of the Hazardous Test Area. The water was intended to supply domestic needs for a planned small installation in the NW$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 24, T. 21 S., R. [illegible] E. Only the area north and northwest of the point of use was studied, because of its favorable topographic position.

During July and August 1960, brief reconnaissance in the Hazardous Test Area revealed only two wells that might supply the required amount of water. Other wells and the springs in the area were inoperative, dry, or yielded less than the required amount of water. Several old mine shafts in the area which might supply the required amount of water were not investigated because the water from the mines probably is polluted.

Geologic setting

Most of the Hazardous Test Area is a pediment developed on granite, gneiss, and schist (Herrick, 1960, fig. 2A).

The pediment is overlain by 1 to about 50 feet of soil, sand and gravel. The overburden is pierced locally by exposures of granite and other rocks, as in Mineral Hill and Rattlesnake Ridge, and the granite is exposed in numerous arroyo beds. The granite pediment is bounded on the north and west by sedimentary rocks in the San Andres Mountains and San Augustin Mountains, on the south by large hills such as Mineral Hill and Parker Hill, and on the east by a fault that trends north-northeast through the centers of sec. 30 and sec. 6, T. 21 S., R. 5 E.

Within the Hazardous Test Area, the granite is weathered at places to a depth of as much as 30 feet. The weathering is enhanced by a system of joints and by local shattered zones and small faults.

Ground water in the area

The few control points indicate that the overburden in the area does not contain water. Where water is found in wells and other excavations, it is in the igneous rock. Although a well drilled anywhere in the area probably would encounter some water, the maximum yields would be obtained in areas where the granite is shattered and where there has been a substantial amount of weathering. Maximum yields probably would not exceed 25 gpm.

The water table in the Hazardous Test Area slopes steeply southeastward in the same direction as the land surface. Although the depth to water is not uniform throughout the area, no well has a water level greater than about 100 feet below land surface. Most, if not all, of the water is stored in the near-surface zones of shattered and weathered rock. The amount of water stored in the area probably is small, because the granite contains water only in joints and other fractures. The overburden and the fractures in the granite have a large intake capacity, and water, when available, enters the system readily. The yields of heavily pumped wells in the Hazardous Test Area probably would diminish substantially during drouth, a time when water generally is most needed, because the storage capacity of the aquifer is low and the recharge is irregular.

Wells investigated

Construction data were collected and performance tests made on wells 21.4.11.311 and 21.4.22.222. Both wells are used from time to time to supply water for wildlife in the area; both wells are equipped with windmills. Supplementary data from Alamo Spring (21.5.7.431), obtained during a visit prior to the Hazardous Test Area study, also was used in evaluating the water resources of the area.

Well 21.4.11.311, on the east side of the Drop Test Tower site, is equipped both with a windmill and a gasoline engine. The well has 6-inch casing and is 198 feet deep. Depths to water in well 21.4.11.311 are as follows:

Date	Depth to water below land surface (feet)
2-12-53	110.9
7-12-60	70.6
7-14-60	70.7

The well probably has not been altered since the measurement in 1953 by Herrick (1960, table 4).

The well was tested July 14, 1960, utilizing the pump jack and engine. The well was pumped approximately 3 hours at the end of which time the water level had declined to the bottom of the pump intake and the pump ceased producing water. Pumping for 3 hours at 3 gpm produced 68 feet of drawdown or about 0.04 gpm per foot of drawdown. The well was not considered further because the yield was inadequate for the intended purpose.

Well 21.4.20.222 is west of the test houses in the Nike Zorhead Test Area and near the north end of Mineral Hill. In August 1961, the well was equipped only with a windmill, and was 80 feet deep. The well contains about 10 feet of 8-inch surface casing; below the pipe the granite in the wall of the hole is stable and requires no support.

The well was test pumped at a rate of 3 gpm for 5½ hours August 5, 1960, and the drawdown was 2.4 feet. (See fig. 20.)

Figure 20 (caption on next page) belongs near here.

The results of the test indicated that the well might meet the requirement of 10-15 gpm, and further work was planned. In addition to a longer, better-controlled pumping test, it was proposed that the well be deepened, because more of the fracture system in the granite might be penetrated and the yield of the well increased.

Figure 20.--Performance test of well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex., Aug. 5, 1960.

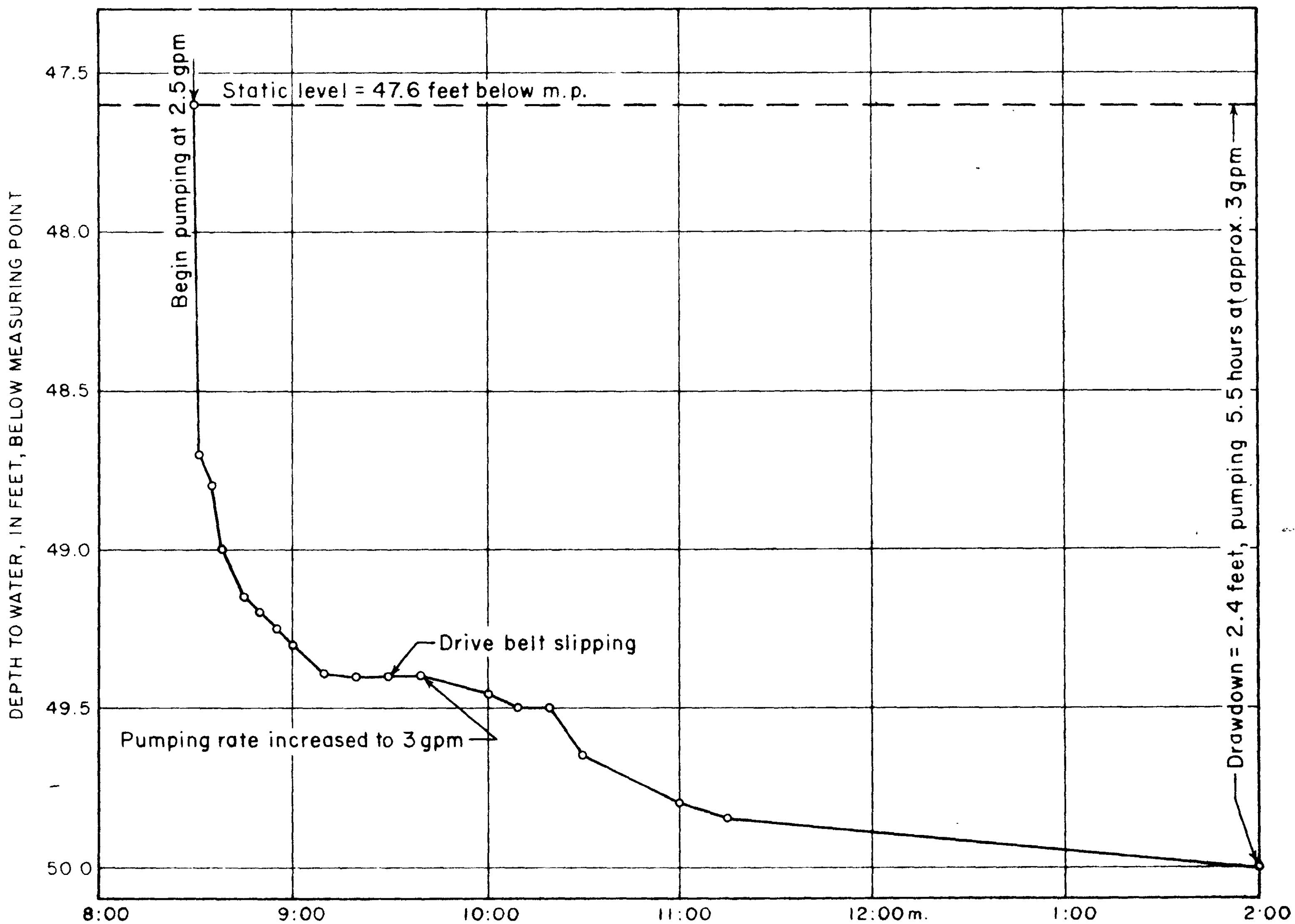

Figure 20.--Performance test of well 21.4.22.222, Hazardous Test Area,

White Sands Missile Range, N. Mex., August 5, 1960.

Perry Bros. Drilling Co. contracted to deepen well 21.4.22.222 to 130 feet and to test pump the well for 12 hours. Prior to deepening the well was tested by bailing and subsequently measuring the rate of recovery. The bailer had a capacity of 21 gallons and the well was bailed 9 times in 6 minutes, or at a rate of about 32 gpm. Figure 21

Figure 21 (caption on next page) belongs near here.

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shows recovery measurements after the bailing test. The residual drawdown was 0.45 foot 20 minutes after the very short period of bailing.

The deepening of well 21.4.22.222 began October 8, 1960, and ended October 12. The samples of the drill cuttings (table 8) indicate the rock penetrated was granite from 80 to 125 feet and a dark, fine-grained, igneous rock from 125 to 130 feet. The deepening of the well caused no change in water level in the well.

Figure 21.--Recovery of water level after bailing well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex., Oct. 6, 1960.

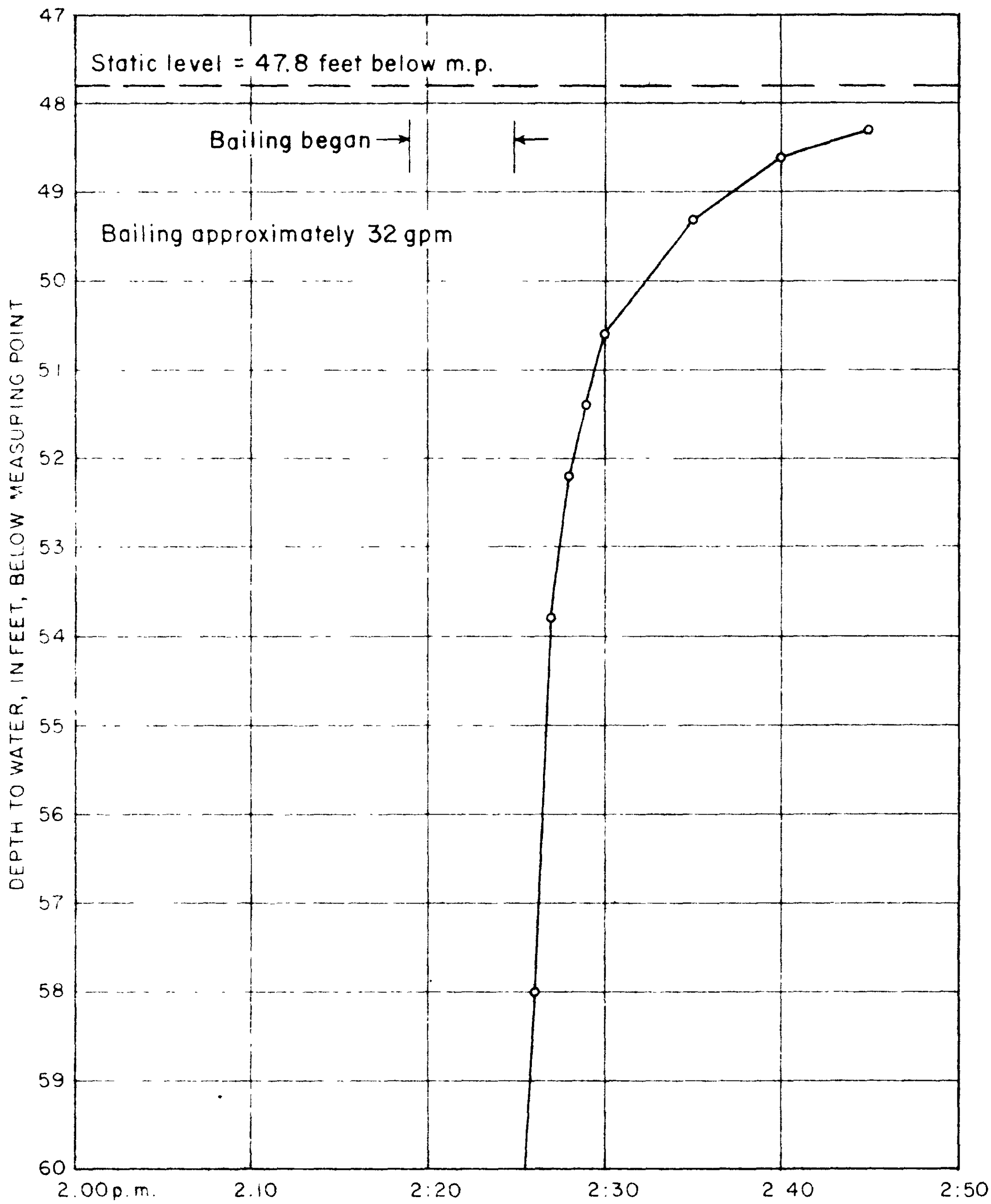

Figure 21.--Recovery of water level after bailing well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex., October 6, 1960.

Table 8.--Log of materials penetrated by well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex.

(Stock well deepened from 80 to 130 feet, October 1960.)

	Thickness (feet)	Depth (feet)	Drilling time (minutes)
Bottom of existing well	-	80	-
"Granite", mainly quartz and feldspar with a low percentage of ferromagnesian minerals	10	90	210
"Granite", as above. Drilling cuttings finer	5	95	95
"Granite", quartz and feldspar, with increased ferromagnesian mineral content. Cuttings coarser	15	110	300
"Granite", as from 95 to 110 feet. Cuttings very fine-grained	5	115	120
"Granite", as from 110 to 115	10	125	110
Igneous rock, dark gray. Texture very fine-grained but rock is holocrystalline. Approximately 50% ferromagnesian minerals	5	130	50

The well was test pumped for [illegible] hours October 13, 1960. A cylinder pump [illegible]9 inches long and 2 3/4 inches in diameter was set about 116 feet below land surface. The pump was operated by the drilling rig, and the water was brought to the surface in a 4-inch pipe. Measurements of depth to water during the pumping test and the subsequent recovery were made with an electric water-level indicator. The rate of discharge was measured with a 5-gallon bucket and stopwatch. Measurements during the test are shown in figure 22. The depths to water shown in the figure have been

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Figure 22 (caption on next page) belongs near here.

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corrected so as to be comparable with depths to water shown in figures 20 and 21.

Figure 22.--Water levels during drawdown and recovery and rate of discharge during performance test of well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex., Oct. 13-14, 1960.

Data in figure 22 show that well 21.4.22.222 can produce approximately 10 gpm for periods of at least 12 hours, or about 7,200 gallons, without a large drawdown. The well, however, cannot yield much more than 10 gpm without large drawdown and probable temporary exhaustion of the supply after a few hours of pumping. Twelve hours pumping at an average rate of about 11 gpm produced a drawdown of 12.2 feet, a specific capacity of 0.9 gpm per foot of drawdown. This figure for specific capacity is comparable with that obtained from the test on August 5, 1960 and shows that deepening the well did not increase the productive capacity of the well.

The residual drawdown, approximately 17 hours after pumping stopped, was about 1.6 feet, a significant part of the total drawdown and the residual drawdown still was relatively large several days after the test. The storage area contributing water to the well is limited, and continuous day-to-day pumping of well 21.4.22.222 might seriously deplete the water in storage during dry periods.

Chemical quality of water

Two samples of water were obtained from well 21.4.22.222, one sample before deepening the well and one afterwards. The analyses of the samples, and one of water from Alamo Spring are given in table 9. The analyses of water from well 21.4.22.222 show that deepening the well did not change significantly the chemical character of the water. The analyses in table 9 and those from samples collected by Herrick (1960, table 6) show that ground water in the Hazardous Test Area is low in mineral content, but is slightly hard. The water is chemically suitable for drinking but contains about 5 ppm fluoride and about 20 ppm nitrate. The water should not be consumed by persons whose teeth still are developing. The waters probably should be examined for bacteriological purity because the nitrate content is so high.

A proposed expansion of Rhodes Canyon Range Camp (pole 1788) in 19[illegible] raised the potential water use at the camp about 17,000 gpd, or about [illegible] gpm for a 16-hour pumping day. Ground water at the camp site is impotable, and potable water for domestic use is brought to the camp in tank trucks; the cost of hauling the additional water would be excessive.

In the west-central Tularosa Basin, saline ground water is present close to the mountain front. This probably is because most of the central and southern San Andres Mountains are relatively low and therefore receive less rain than the higher mountains to the north and the ranges on the east side of the basin. Recharge to ground water is small because the amount of precipitation is small.

A well, about [illegible] miles south of the camp and shown on the Black Top Mountain topographic map as the G Henderson well (14.5.8.321), yields water containing about 6,000 ppm of total solids of which about 2,[illegible]00 ppm is chloride. The depth to water is reported to be 54 feet below land surface.

The fill for several miles east and south of the camp probably is saline as evidenced by the saline residue in the low areas.

To the west and northwest of Rhodes Canyon Range camp, conditions are such that the occurrence of potable water is probable. The mountain area from Rhodes Canyon north and northeast to Salinas Peak includes some of the highest peaks in the mountain range and the range is widest there. Thus, precipitation and resulting recharge to the bolson fill should be somewhat greater than in the area to the south. Most of the gypsiferous rocks in this area, occur in the backslope and are breached only by the largest canyons in their uppermost drainage.

The McDonald South well (13.5.29.341) has a reported water level of 100 feet below land surface. Soldiers from Rhodes Canyon camp reportedly used water from the well before potable water was trucked to the camp. Records of other wells finished in the bolson fill west of the range camp are not available. The inferred potable water at well 13.5.29.341 and the runoff from the mountains indicate the large composite fans reaching from Rhodes Canyon northward to the base of Salinas Peak may contain coarse-grained debris that will yield an appreciable quantity of potable water.

Selection of a test well site is complicated by an inferred variable thickness of the alluvial fan deposits, owing to faults in the underlying bedrock. The bedrock faults are suggested by the extensive cross faults of the mountain mass and by faults cutting the pediment surface at the foot of Salinas Peak. Consolidated rocks crop out in the fan area only in the pediment. A system of down-stepped blocks from the mountain mass into the basin, such as is present elsewhere in the Tularosa Basin, is likely. The thickness of the fill cannot be estimated. Three test-hole sites are proposed for drilling in the following order: 1) NW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 12, T. 13 S., R. 4 E. north of State Road 52 on the upthrown side of a probable fault; 2) NE$\frac{1}{4}$NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 18, T. 13 S., R. 5 E. north of State Road 52 on the downthrown side of a probable fault; and 3) NW$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 5, T. 13 S., R. 5 E. Specifications for the first site probably should call for a minimum of 300 feet and a maximum of 1,000 feet in depth, drilling to be stopped if bedrock is penetrated to a depth of 10 feet. The other two sites should be drilled to 1,000 feet or bedrock, whichever is shallower. Drilling also should be stopped in the event that saline water is found.

Reconnaissance of ground-water supplies in the vicinity of Salinas Peak

Potable water was needed in 1960 to supply the Salinas Peak instrumentation site and Salinas Camp, a maintenance troop shelter adjacent to the Peak. The water was being hauled by tank trucks from Murray well (8.5.32.431), which also is the source of water for Stallion Range Center and other installations in northern White Sands Missile Range. Murray well is about 20 miles, airline distance, from Salinas Peak, and trucks hauling water to the installation had to travel about twice the airline distance, mostly over unpaved roads, and had to climb more than 2,000 feet in elevation to Salinas Camp, and more than [illegible],000 feet to the top of the peak itself.

The demand for water at Salinas Peak and Salinas Camp, in 1960, fluctuated from as little as 1,000 gallons per week to more than 4,000 gallons per day when the troop shelter was in use and work was being done at the instrumentation site. Planned demands in 1961 were 3,000 to 5,000 gpd, but future demand may grow to as much as 20,000 gpd.

A reconnaissance was made of about 65 square miles in parts of T. 11 S., Rs. 3-5 E., and in parts of the adjacent townships (fig. 23).

Figure 23 (caption on next page) belongs near here.

The area is a part of the backslope of the San Andres Mountains, a faultblock range, the steep side of which faces eastward. The mountains trend generally northward, but in the study area they are offset eastward. The San Andres Mountains have a general altitude of 6,000 to 7,500 feet, but Salinas Peak has an altitude of 8,958 feet. The upper parts of both the cuesta face and the backslope of the mountains are deeply dissected by canyons that in places have almost sheer walls. In most of the mountains, the routing of drainage and the land forms are greatly influenced by the geologic structure and the diverse lithologic character of the rocks. Silvertop Mountain, for example, is capped by a resistant igneous sill. Most canyons are developed along faults or strike valleys. (See figs. 23 and 24.)

Figure 24 (caption on next page) belongs near here.

The San Andres Mountains in the study area are high, but receive relatively small amounts of precipitation, as indicated by the vegetation, which in most parts of the study area is only a sparse to moderate cover of juniper that generally does not retard runoff from the rocky slopes. On the lower slopes desert vegetation is sparse, and the alluvium in the relatively level valleys as in Thoroughgood Canyon in sec. 7, T. 11 S. R. 5 E., contain arroyos with cut banks 5 to 30 feet deep.

Figure 23.--Locations of wells and springs in Salinas Peak area and vicinity, White Sands Missile Range, N. Mex.

24.--Geologic map of the Salinas Peak area and vicinity, White Sands Missile Range, N. Mex.

General geology

The following description of the geology of the area is largely adapted from Weir (Weir, J. E., *in* Herrick and others, 1961). In the general area of study, sedimentary rocks rest on Precambrian igneous and metamorphic rocks that are exposed in the base of the San Andres Mountain front (fig. 2[illegible]). The sedimentary rocks range in age from Cambrian to Permian. Some Quaternary alluvium is present locally in stream valleys but for the most part it is thin, and is not known to be water-bearing. In the immediate area of study, the dense and generally impermeable pre-Pennsylvanian rocks are buried deeply and probably contain little water. The water-bearing formations in the study area are in a section of sedimentary rocks less than 5,000 feet thick that, unfortunately, contain chemical precipitates such as gypsum as well as clastic rocks.

The formations that are potential sources of potable water near Salinas Peak are, in ascending order, the Pennsylvanian part of the Magdalena Group and the Abo Formation of Permian age.

The Magdalena Group consists chiefly of the Sandia Formation and overlying Madera Formation. In the Salinas Peak area underlying thin beds of limestone and compact shale of Mississippian and Devonian age have been mapped with the Magdalena. The Magdalena is more than 1,000 feet thick and may approach 3,000 feet in thickness. The group crops out in a broad band that strikes northeastward across the area. The rocks are exposed both in the face of the mountains and on the backslope. They consist chiefly of limestone in the lower part and massive limestone with some interbedded shale in the upper part.

The rocks of the Magdalena Group are dense and have low permeability, except where the rocks have been fractured. Ground water in the group is poor in quality owing to small local deposits of sulfate minerals as vein or fracture fillings.

The Abo Sandstone of Permian age consists chiefly of red to purplish-red sandstone and mudstone, most of which is fine-grained and well consolidated. The formation crops out as a nearly continuous band west and northwest of the Magdalena rocks. Although the Abo is stratigraphically higher than the Magdalena, in most areas in the San Andres Mountains it is well down the backslope, and only the sandstone units generally are exposed, the shale or mudstone units having been eroded and covered in valleys.

Igneous rocks that affect the ground water conditions cap Salinas Peak and adjacent peaks (fig. 24) of the San Andres Mountains over a distance of about 8 miles. The igneous rock is cream to pink in color, fine-grained, and contains small phenocrysts. It is rather homogeneous in gross appearance at most locations where it was examined on Salinas Peak.

The igneous rocks possibly are thickest at Salinas Peak, and they thin with distance from the peak, particularly northward. The intrusive igneous rocks cap the San Andres range and mantle a considerable area of potential ground-water intake, where precipitation is greatest. The igneous rocks weather readily to a slabby rubble to depths of 1 to 5 feet, and they are jointed below the weathered zone. These rocks probably are permeable only in fault zones, and relatively little water can be transmitted downward through them to the underlying sedimentary rocks.

The San Andres Mountains consist of a series of faultblocks that reach from Mockingbird Gap in T. 9 S., southward about 70 miles to Black Mountain, near the Small Missile Range in T. 21 S. Although structural features differ locally, the range is primarily a cuesta that faces eastward toward the Tularosa Basin and slopes more gently westward, where the consolidated rocks disappear beneath the alluvium of the Jornado del Muerto. From Mockingbird Gap southward the east base of the mountains marks a major fault or fault system that has a vertical displacement of more than 4,000 feet near Salinas Peak.

A system of transverse faults strikes northwestward in the Salinas Peak area, more or less normal to both the formational contacts and the major fault system at the base of the mountains. The larger faults of this transverse system, shown in figure 24, have vertical displacements of a few feet to several hundred feet; for example, along the fault that trends northward through sec. 7, T. 11 S., R. 5 E., the Magdalena Group is in horizontal contact with the San Andres Limestone. Both the sedimentary and the igneous rocks are fractured adjacent to these transverse faults.

Ground-water

Data relating directly to the occurrence of ground water in the Salinas Peak area was obtained for 11 wells and 2 springs (table 10). All these sources are on the backslope of the mountains. Water sources on the east face of the mountains were not visited because they are relatively inaccessible and time for the study was short. For comparative purposes, data on the wells and springs visited, reported data on the water sources on the east slopes of mountains, and data for the Murray well, the Cain Ranch headquarters well, and the Hardin Ranch well, all of which are outside the area studied, are included in table 10.

All 13 wells and springs visited, except Martin well, Grapevine well, and Grapevine Springs, are in a state of disrepair, because the wells and springs were primarily sources of water for stock, which no longer are raised in the area. The three exceptions are wells kept in operating condition to provide water for wildlife in the area. Several wells, for example 12.2.13.213, had been sealed, so that measurements could not be made.

Ground-water in the wells that were visited was generally less than 100 feet below land surface (fig. 23). These shallow depths to water beneath the steep slope of the land surface give the illusion of a steeply-sloping water table. However, an areally extensive water table probably does not exist, and most ground water moves downward from the higher elevations through the system of faults. Every water source adjacent to Salinas Peak that was visited is related to a structural zone. A water table possibly exists in each discrete fault block, but, because the water-bearing rocks have a low permeability, the most readily available water should be found in the vicinity of faults. An illustration is Smith well (11.4.29.141), which is in a fault zone where the Abo abuts rocks of Pennsylvanian age in a stream valley. At the well site, the water level is shallow because of the topographically low position.

The potential yield of the formations to wells cannot be estimated accurately. The only wells in the area are stock wells that are pumped at rates of only 1 to 5 gpm. The Magdalena Group and the Abo Formation generally are compact formations having low permeability. Where shattered or attacked by solution, the same rocks, however, conceivably could produce several hundred gallons per minute to a well. The quantity of water in storage is unknown also. If, however, the principal supplies are obtained from the narrow zones of faults and adjacent shattered rock and the remaining part of the formation has a low transmissibility, extensive pumping would lower water levels in the production well rapidly and the water in storage would diminish just as rapidly. The quantity of water in storage probably fluctuates widely from one year to the next owing to differences in the rate of recharge, which generally is small.

The Abo Sandstone probably is the better aquifer of the two formations considered here because it has some intergranular porosity and because the quality of water in it is better.

Chemical quality of the ground water

The only potable ground water sampled in the Salinas Peak area was that from Grapevine Spring (S12.4.2.141). Wells and springs elsewhere in the area yield water containing from 1,500 to more than 2,000 ppm of dissolved solids, of which the sulfate content amounts to 500 ppm or more. All the water is very hard. The water from the Abo Formation seemingly is the best obtainable from a given area, but the overall chemical quality of water deteriorates from the crest of the mountain to the northwest, toward the Jornada del Muerto.

The ground water sampled, with the exception of that from Grapevine Spring, is not suitable for human consumption, owing to the sulfate content of the water (table 10A).

Water suitable for use by military personnel probably is not present in the Salinas Peak area in quantities adequate for the needs of Salinas Peak Site and Salinas Camp.

Exploration for ground-water supplies

Test holes may be necessary in the Salinas Peak area to prove the conclusions reached in this report. Also, production wells that yield impotable water may be needed if suitable demineralizing equipment becomes available. Test holes at potential production well sites should be drilled not only where geologic and hydrologic data indicate an adequate supply of water can be obtained but also where the pumped water can be transmitted easily to Salinas Camp. In this area such sites are restricted, owing to the terrain, to Grapevine Canyon, along the access road to Salinas Camp.

The immediate area of Salinas Camp (NW¼SE¼SE¼ sec. 36, T. 11 S., R. 4 E.) does not seem promising; however, a test hole there would determine the aquifer possibilities, and if water were obtained, the supply would be at the point of use. A test hole 500 feet deep probably would be adequate.

One test hole farther down Grapevine Canyon is considered to be adequate to determine aquifer possibilities in the general area. The SW¼NE¼SW¼ sec. 35, T. 11 S., R. 4 E. is selected for geologic and access reasons. The site is on the access road at its intersection with the side canyon that contains Grapevine Spring. At this site there is adequate room off the road for drilling, and it is on or adjacent to one of the major transverse faults that cross the mountain range. A test-hole depth of 500 feet probably would be adequate.

Alternate sources outside the Salinas Peak area

Two possible sources of potable ground water adjacent to the Salinas Peak area have been considered. Weir (Herrick and others, 1961) suggested the exploration of the large alluvial fan in the southeastern part of T. 9 S., R. 4 E.; this area is somewhat nearer to Salinas Peak than the Murray well area. The second potential source area is at the base of Salinas Peak and southward to the mouth of Rhodes Canyon. Although the alluvial fans at the base of Salinas Peak are seemingly a source of potable water, nothing firm is known about ground-water conditions there, and a supply must be proved by test drilling. Supplying the Salinas Peak installations from the latter area still would require a large lift, but the distance of haulage is diminished considerably.

Well to supply non-potable water at Stallion Range Center

Stallion Range Center is a small administrative and service installation near the north end of White Sands Missile Range (fig. 1). The center has troop-housing and shop facilities for the several operating branches of the missile range. Because the center is in an isolated area that contains little potable water, the continuous demand for water has required the hauling of large quantities of water from distant sources.

In 1960, water for all purposes at Stallion Range Center was hauled by a fleet of tank trucks from Murray well (8.5.32.431) about 22 miles to the southeast. This well had a marginal yield with respect to the demand placed on it.

In June and July 1960, a well for non-potable water supply was drilled to reduce the demand on Murray well and the expense of haulage. The non-potable water can be used for fire protection, operation of sewage facilities, and other uses in which water quality is not an important consideration.

The non-potable water well (6.3.5.232) is in Stallion Range Center, adjacent to the Post Engineers storage yard, between the yard and the center's water storage tanks.

Well construction

Drilling of well 6.3.5.232 began on June 13, and ended on July 25, 1960. The well was drilled to a depth of 500 feet with a cable-tool drilling rig. The hole was cased to bottom, the lower 100 feet of casing having been torch slotted. The well was tested for yield July 7, 1960. The yield was inadequate; therefore, the casing was pulled and the well was deepened to 750 feet, and was again tested for yield August 1, 1960. (See tables 11 through 14.)

The well, as finished, is an 8-inch hole 750 feet deep cased with 400 feet of blank 6-inch pipe and 350 feet of 6-inch pipe torch-perforated with ¼-inch slots, 12 per foot at the bottom. After casing was installed to bottom, the well was surged and bailed for 24 hours.

Table 11.--Log of materials penetrated by well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex.

Material	Thickness (feet)	Depth (feet)
Samples missing	20	20
Sand, very fine to medium, and small gravel of volcanic rocks	20	20
Sand, very fine to medium, small gravel of volcanic rocks, and some clay	10	50
Sand, fine to very coarse, and small gravel of volcanic rocks	40	90
Clay, silty, tan, and very small gravel of volcanic rocks	20	110
Sand, medium to very coarse, small volcanic gravel, and tan silt	10	120
Clay, tan	10	130
Sand, medium to very coarse, small volcanic gravel, and tan silt	10	140
Clay, tan, sand, medium to very coarse, small volcanic gravel, and tan silt. Less gravel.	20	160
Clay, red to tan, small gravel and large pebbles of volcanic rocks	10	170
Silt, tan, some very coarse sand, and a small pebble	10	180
Clay, red to tan, and pebbles	10	190
Sand, very fine and red-brown silt, with a small amount of very coarse sand and small gravel	10	200
Clay, red-brown silty	20	220
Clay, red, and included crystals of selenite	10	230
Clay, red, and included crystals of selenite with some gravel	10	240
Clay, very silty tan, and very coarse sand	10	250

Table 11.--Log of materials penetrated by well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex. - Continued

Material	Thickness (feet)	Depth (feet)
Sand, very coarse, very small gravel, and tan silt	10	260
Clay, red, very coarse sand, very small gravel and tan silt	10	270
Clay, white, very coarse sand, very small gravel, and tan silt	5	275
Clay, tan and white, silty	5	280
Clay, tan silty, and a small amount of very coarse sand	14	294
Silt, tan to cream	6	300
Clay, tan silty	20	320
Silt, brown, and very fine sand. Some very coarse sand	18	338
Silt, brown, very fine sand,some very coarse sand, and small volcanic gravel	9	347
Clay, tan, very silty	5	353
Clay, tan very silty, very coarse sand and small gravel	22	375
Silt, very fine sand, and very silty tan clay	5	380
Sand, very fine to very coarse, and small gravel	20	400
Sand, very fine to very coarse, small gravel, and brown silt. Some clay 430-435.	50	450
Samples missing	58	508
Sand, medium to very coarse, and small gravel	4	512
Sand, medium- to very coarse-grained, small gravel and small pebbles	11	523
Sand, very coarse and gravel	5	528
Sand, fine to coarse	5	532

Table 11.--Log of materials penetrated by well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex. - Concluded

Material	Thickness (feet)	Depth (feet)
Sand, medium to coarse, and brown clay	7	539
Sand, fine to very coarse	5	544
Sand, fine to very coarse and small gravel	31	575
Clay, brown, fine to very coarse sand and small gravel	5	580
Silt, brown and very fine to coarse sand	30	610
Sand, very coarse, and small gravel	5	615
Sand, very coarse, small gravel, and brown silt	5	620
Sand, very coarse, gravel and small pebbles	15	635
Sand, fine to very coarse, and brown clay	30	665
Sand, very coarse, small gravel and brown silt. Some clay from 693-to 700, and a large pebble 705-10	45	710
Sand, very coarse, gravel and small pebbles. General grain sizes somewhat smaller 725-30, and one large pebble 735-740	30	740
Sand, medium to very coarse and gravel	10	750

Notes: All clays were calcareous. Clay, silt, and sand below 400 feet are uniformly coffee-brown in color All gravel and pebbles observed are detritus of "volcanics"; some are holocrystalline but very fine-grained, and some are glassy with very small phenocrysts. The general appearance of the volcanics is red-brown when wet, but a dusty lavender when dry.

Table 12.--Records of water levels measured in well 6.3.5.232 (non-potable supply), Stallion Range Center, White Sands Missile Range, N. Mex.

Date 1960	Water level below land-surface datum	Remarks
June 17,	266	Well 350 ft deep.
24	206.1	Well 500 ft deep prior to bailer test.
	352.0	Water level at end of bailer test.
July 7	206.5	Water level prior to pumping test.
	215.4	Water level measured approximately 4 hours after the end of $3\frac{1}{2}$-hour pumping test.
16	206.0	Well 620 ft deep.
26	203.8	Well 730 ft deep, water level measured approximately 3 days after drilling completed.
Aug. 1	203.8	Water level prior to pumping test.
	208.2	Water level measured 2 3/4 hours after the end of an 11-hour pumping test.

Table 14.--Records of field measurements of specific conductance and sand content of water pumped from well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex., July and August, 1960.

Date 1960	Time	Specific conductance 1/	Temperature °F	Sand content 2/ ml./liter
July 7,	11:09	-	76°	-
	11:30	-	-	<0.1
	11:45	2,500	-	<0.1
	12:15	-	80	-
	12:40	-	-	1.0
	13:00	3,500	82	-
	13:40	3,500	83	0.2
	14:00	-	83	<0.1
	14:25	3,300	84	0.1
Aug. 1	09:25	2,500	80	-
	10:30	2,500	-	-
	11:30	2,500	-	-
	11:35	-	80	-
	12:00	-	80	-
	12:30	2,450	-	-
	13:30	-	80	-
	15:05	2,500	80	-
	16:00	-	80	no sand
	19:00	2,500	80	-

1/ Specific conductance measured with Industrial Instruments, Inc., Model RD 104 Solobridge

2/ Measured with Imhoff cone

Performance tests

Two kinds of tests were made at well 6.3.5.232. The productivity of the unfinished well at various depths was tested with a bailer and the productivity of the finished well was tested with a deep-well turbine pump.

According to the contract specifications, each water-bearing bed was to be tested after the bed was penetrated by the drill. Brief bailing tests in well 6.3.5.232 indicated that extensive testing was not justified. When the well was 500 feet deep, the original contract depth, it was tested 1 hour by bailing June 29, 1961. The well was bailed at an average rate of about 30 gpm. The drawdown at the end of the hour was 146 feet, indicating a specific capacity of about 0.2 gpm per foot of drawdown. Although the indicated specific capacity was low, it was necessary to test the well under production conditions. The well was tested on July 7, 1960 after the casing and screen had been set and the well developed.

The pump was set at 480 to 490 feet, or about 10 feet above the bottom of the well, for the pumping test. The pump was powered by an internal combustion engine. Discharge was measured with a 55-gallon drum and stopwatch, and drawdown was measured during part of the test with an electric water-level indicator.

The test was started at 11:05 a.m. and ended at 2:34 p.m. when the engine stopped, a pumping period of 3 hours and 29 minutes. The time of pumping was not as long as planned, but it was adequate. During the test, drawdown could not be measured after the first 19 minutes; the water level had declined below a point at which the electric line would not pass to greater depths -- approximately 505 feet below the surface. The water discharged from the pump began surging, or fluctuating, about 65 minutes after pumping began, indicating that the pumping level was at the pump bowls, or 480-490 feet below the surface. This surging action continued until the end of the pumping period.

The rate of discharge was 29 gpm when the test began and the rate fluctuated from 21 to 34 gpm until the pumping level reached the bowls. The rate of discharge subsequently declined to about 10 gpm at the end of the test. The final specific capacity of the well was 0.37 gpm per foot of drawdown.

Sand content and specific conductance of the water were measured at intervals throughout the test. The water contained small quantities of sand throughout the test, but by the end of the test, the quantity was only about 0.1 milliliter. The chemical quality of the water remained nearly constant. A chemical analysis of a water sample taken from the well on July 7, 1960 is given in table 13.

A record of water-level drawdown and recovery and the rate of discharge are given in figure 25. An approximation of the coefficient

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Figure 25 (caption on next page) belongs near here.

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of transmissibility is given in figure 26.

Figure 26 (caption on next page) belongs near here.

The results of the test on July 7, 1960 indicated that the well, when 500 feet deep, was inadequate for the intended use. The well was deepened to 750 feet and again was tested on August 1, 1961.

The pump in well 6.3.5.232 was set with the bowls at 560 feet below the surface for the second performance test, and the pump was powered with the same engine used for the first test. The rate of discharge was measured with a pipe orifice, and drawdown was measured with an electric water-level indicator.

Figure 25.--Water levels and rate of discharge of well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex., July 7, 1960. Well was 500 feet deep at time of test.

26.--Recovery of water level, and computation of the coefficient of transmissibility after performance test of well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex. July 7, 1960.

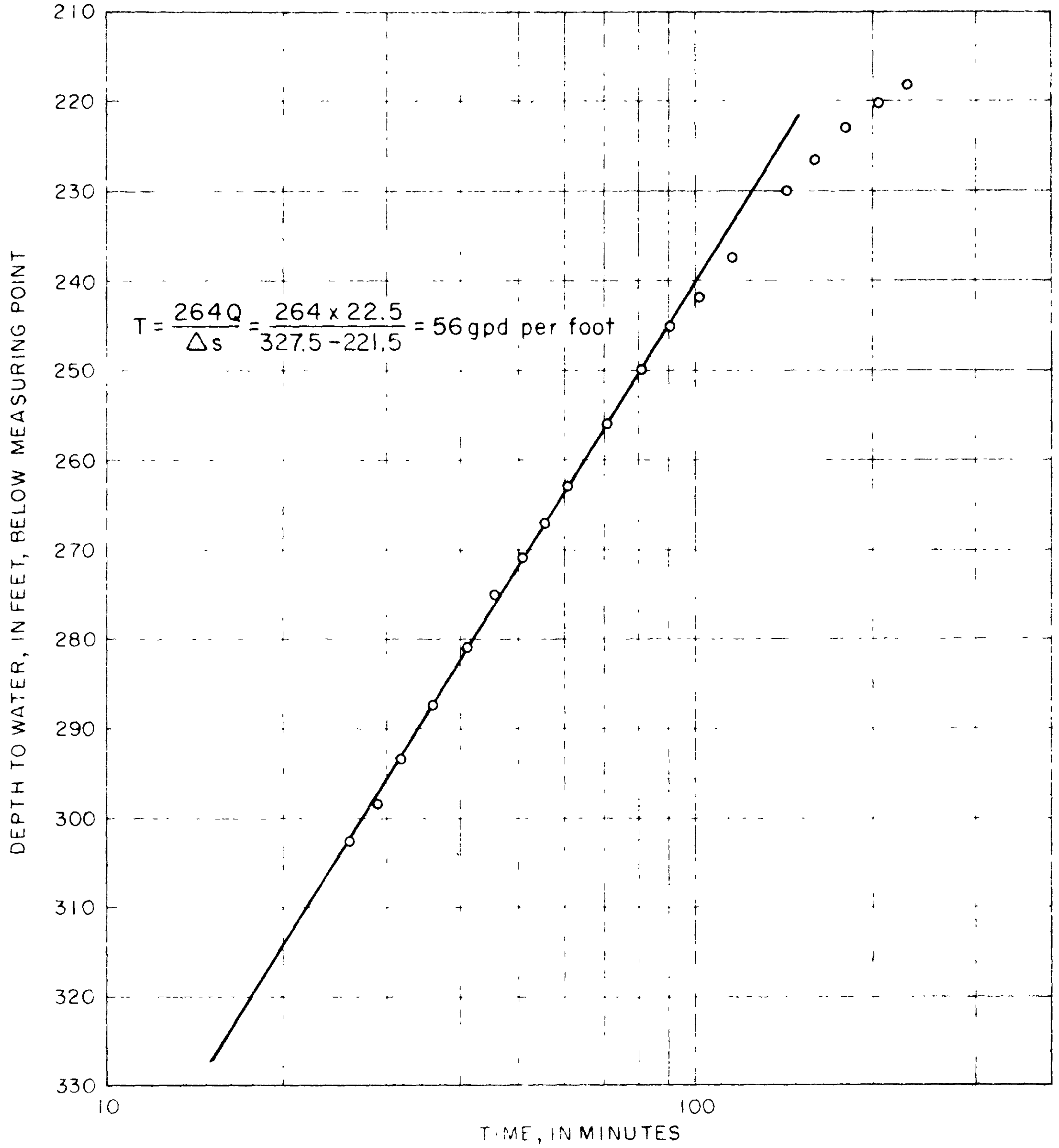

Figure 26 .--Recovery of water level, and computation of the coefficient of transmissibility after performance test of well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex., July 7, 1960.

The test was started at 9:16 a.m. and was ended at 8:15 p.m. The rate of discharge was increased at timed intervals to determine the well characteristics at different pumping rates. The discharge rate during each timed interval was held reasonably constant. The well was pumped at 60 gpm for 2 hours and at 100 gpm. 150 gpm, and 200 gpm for 3 hours each. At the end of the test, the pump was discharging 200 gpm and the drawdown was about 123 feet, indicating a specific capacity of 1.62 gpm per foot of drawdown, or slightly more than four times that obtained during the first performance test (fig. 27). The computed coefficient of transmissibility is

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Figure 27 (caption on next page) belongs near here.

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about 3,000 gpd per foot (fig. 28).

Figure 28 (caption on next page) belongs near here.

The water temperature was steady at 80°F, the water contained little or no sand, and the total chemical solids in the water varied little during the 11-hour period.

Figure 27.--Water levels, rate of discharge, and computation of specific capacity during performance test of well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex., August 1, 1960. Well was 750 feet deep, the final depth, at time of testing.

28.--Computation of the coefficient of transmissibility after performance test of well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex., August 1, 1960.

Chemical quality of the water

Water from well 6.3.5.232, at Stallion Range Center, is too highly mineralized for domestic consumption without some form of demineralization. The water contains more than the total dissolved solids recommended by the U.S. Public Health Service. (See table 13.) All the anions except sulfate are present only in low concentrations. Sulfate, together mainly with calcium and magnesium, are the principal chemical contaminants. The high calcium and magnesium content makes the water very hard.

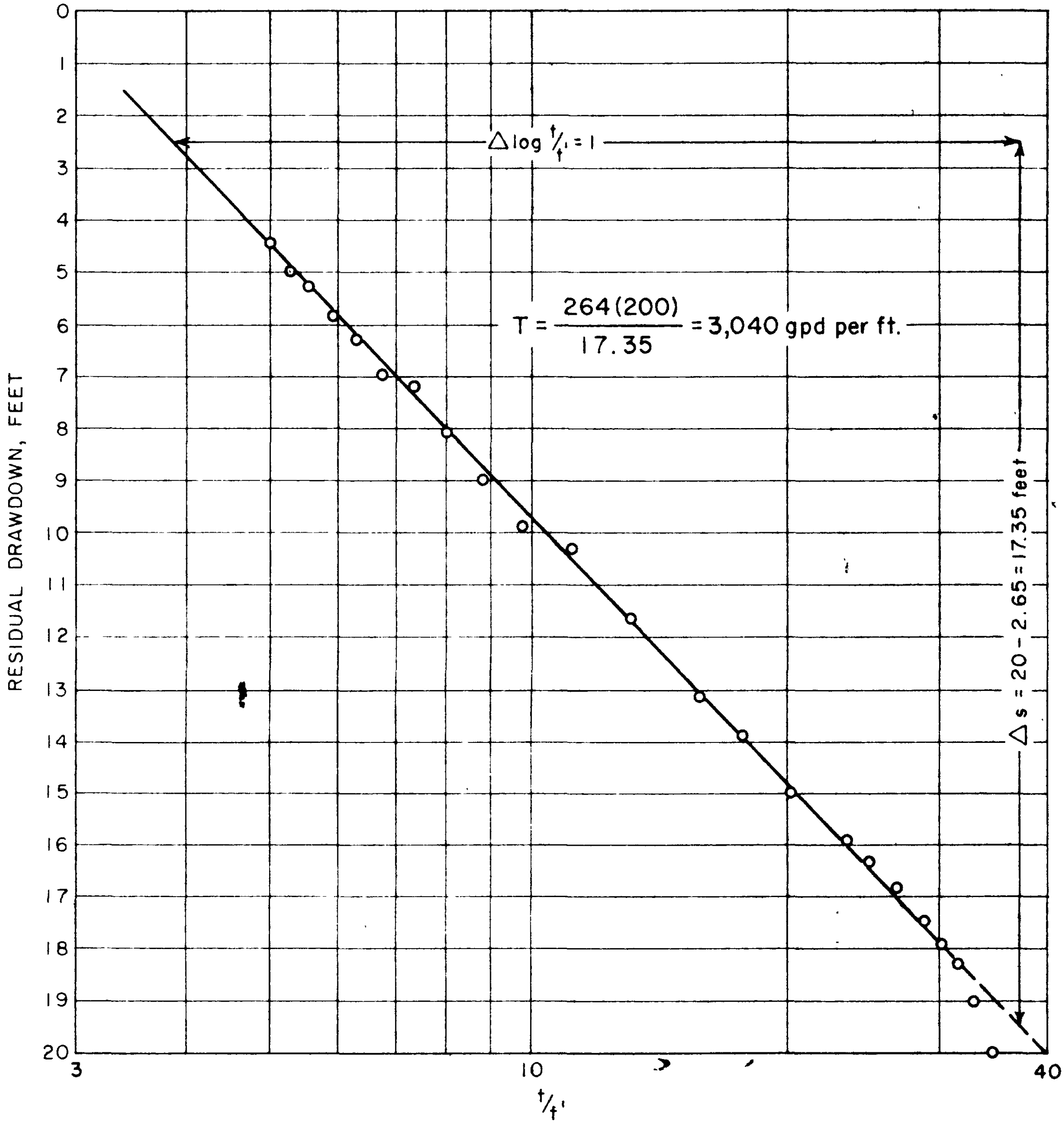

Figure 28.--Computation of the coefficient of transmissibility, after performance test of well 6.3.5.232, Stallion Range Center, White Sands Missile Range, N. Mex., August 1, 1960.