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REPORT OF INVESTIGATIONS

FOR INDUSTRIAL GROUNDWATER SUPPLY

FOR THE

CITY OF RED DEER

38 - 27 - W4

MAY, 1961

J. Tóth

Alberta
RESEARCH COUNCIL

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ILLUSTRATIONS

REPORT OF INVESTIGATIONS FOR INDUSTRIAL GROUNDWATER SUPPLY FOR THE CITY OF RED DEER
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A. Introduction

I. Purpose of the test program

The test program carried out in March and April, 1961 was to evaluate the groundwater potential of the area on the west bank of the Red Deer River north of the City of Red Deer. It was hoped that a groundwater supply of at least one million Imperial gallons per day could be obtained. The program was set up in such a way that it would provide supplementary data to information obtained from previous investigations performed both for the City of Red Deer and for the Joffre Oil Field Operators.

II. Location

In this report the same numbering of the test sites and test holes has been maintained as that used in the private report submitted by the Research Council of Alberta, Groundwater Division, to the City Engineer of the City of Red Deer on February 3, 1961.

In total, three test sites have been investigated by means of shallow drilling. The locations of the test sites are as follows:

Site I: NE 1/4 of Sec. 21; SE 1/4 of Sec. 28 and NE 1/4 of Sec. 28, Tp. 38, R. 27, W. 4th Mer.

Site IV: SW 1/4 of Sec. 34, Tp. 38, R. 27, W. 4th Mer.

Site V: NE 1/4 of Sec. 33, Tp. 38, R. 27, W. 4th Mer.

The locations of the test sites and test holes are shown in figure 1.

B. Geology

The 1961 test program has confirmed the picture of the geology in general, and it gave also new results regarding more specific geological details.

To the north of the City, the Red Deer River follows the course of a preglacial channel cut into the bedrock Paskapoo formation. This channel has been filled with fluviatile, glacial and fluvio-glacial material which is still unconsolidated. The general geological situation is illustrated on the block diagram of figure 2.

The uppermost bed, a widespread gravel layer is generally covered by loam, 5 to 15 feet thick. The composition of the gravel is rather nonhomogeneous: it varies from argillaceous and sandy to quite clean gravel. The gravel is fairly well sorted, although boulders of 12 to 15 inches in diameter have been found. The grains are spherical and well rounded. It is believed that this material was reworked several times by action of ice and water, and finally was deposited during postglacial stages of the Red Deer River. This gravel layer covers almost the entire flat portion of the present valley with a thickness varying between 0 and 30 feet. Part of it is below average river level but at many locations the whole formation lies above river level.

A channel has been found cut deeply into the bedrock, in the main preglacial valley. In this channel the gravel layer discussed above is not immediately underlain by bedrock but by a dense clay formation of about 30 feet thick. This clay probably represents a lake deposit, laid down during the time when the ancient Red Deer River was obstructed by ice in the area of the present confluence of the Red Deer and Blindman Rivers (Figs. 2 and 3).

Under the clay a second gravel layer has been found, composed of very clean, well sorted gravel. The pebbles are well rounded, and the thickness of this layer varies between 8 and 25 feet. The width of this deposit does probably nowhere exceed 600 - 700 feet. In a few test holes (1960-3; I-7; I-6) a thin layer of sandy clay was found underlying the second - or lower - gravel. Elsewhere bedrock immediately underlies this gravel.

The bedrock in the area is the Paskapoo formation which consists of shale and lenses of sandstone.

The continuation of the deep channel could not be found in any of the test holes north of the 1960 test site. As an explanation for this the possibility is offered that immediately north of this test site the channel turns sharply eastwards. In the vicinity of the Joffre Operator's well field the clay layer between the upper and lower gravel thins out allowing the two gravel formations to form one thick layer. To the southeast of the 1960 test site the channel has been traced as far as the west bank of the present Red Deer River, where at test hole I-7 all the characteristics of the channel described above are fully developed. It appears that the second gravel must cross the Red Deer River at test site I at a level of about 40 feet lower than the present average river level. The situation described in these paragraphs is illustrated in figures 2 and 3.

C. Hydrology

I. General

The possibility of obtaining the required large groundwater supply of at least one million gpd from the bedrock is precluded because of the characteristic low permeability of the Paskapoo formation (ranging generally from less than 1 gpd/ft^2 up to 50 gpd/ft^2). On the other hand there are two potential aquifers, namely, the upper and lower gravel layers discussed above, and it has been shown that these are of restricted areal extent. The upper one ends against the bedrock walls of the ancient valley to the west and is bounded by the present river bed to the east (Fig. 2).

The lower gravel is even more confined as it is located within the deepest part of the old meander bed cut into the bottom of the valley. This situation implies that if no recharge from the river takes place, then these aquifers will behave hydrologically as a bedrock aquifer in that their ultimate yield is determined by the amonnt of recharge that can be derived from the adjoining bedrock. It is therefore obvious that recharge from the river has to be achieved in order that these gravels may be utilized to their full extent. In cases where the upper gravel extends below river level this situation can indeed be created by means of so-called "induced infiltration". By lowering the water-table adjacent to a body of surface water a gradient is established toward the point where the lowering takes place, and this process is generally referred to as "induced infiltration".

II. Pump tests and hydrologic potentials

a. Lower Gravel

Initially the lower gravel was looked upon as having better prospects than the upper one, because of its grain size and better sorting, as well as its greater thickness and lower position relative to the river, which would provide a greater pressure head in production wells.

In order to establish whether there was any connection between the river and this aquifer, two F-type recorders were installed. One was put on a shallow hole drilled immediately adjacent to the edge of the river, and was operating as a river gaging station. The other recorder was set up on the well I-7 which was completed in the lower gravel. The graphs of 7-day simultaneous recordings are presented in figure 4. Quite obviously there is no correlation between the changes in the piezometric surface of the lower aquifer and the fluctuations of the river level. The most striking feature of difference in the behavior of the two water surfaces is that the definitely declining river stage does not affect the piezometric surface in the well. On the basis of the results obtained from the one-week recordings it is almost certain that a hydrologic connection does not exist between the river and the aquifer. Nevertheless, a pump test has been conducted in order to evaluate the hydrologic characteristics of the lower aquifer in case artificial recharge should be considered.

Well I-3 was pumped for 48 hours at an average pumping rate of about 61.5 Imp. gpm. Measurements of water level were taken in the pumping well and in the observation wells, I-6, I-7, I-8 and I-9, all of which were slotted across the lower gravel. The drawdown curves obtained from the observation wells and from the pumping well are presented in figure 5. The increasing slope of the time-drawdown curves points to the depletion of the aquifer. The general trend of depletion has been confirmed by plotting the drawdown values v $\frac{r^2}{t}$ on log log paper, where r is the distance between an observation well and the pumping well and t is the time elapsed from the start of the pumping (Fig. 6). In spite of the fact that the lower gravel is an artesian aquifer this plot shows an approximately straight line instead of the type-curve of Theis. This means that the aquifer is limited by impermeable boundaries and that no considerable amount of recharge takes place. By projecting the drawdown - $\frac{r^2}{t}$ line back to the drawdown value, which is available only to the top of the aquifer, it was possible to compute the time that would be required to pull down the water level to the top of the aquifer.

If the available drawdown is 25 feet, then for the observation well with r = 50 feet:

$$\frac{r^2}{t} = 23 \times 10^{-2} \ \frac{ft^2}{min}$$

$$t = \frac{25 \times 10^4}{23} = 1.09 \times 10^4 \ min.$$

$$\underline{t = 7.6 \text{ days}}$$

For the wells with r = 200 feet:

$$\frac{r^2}{t} = 35 \times 10^{-1} \ \frac{ft^2}{min}$$

$$t = \frac{40 \times 10^3}{35 \times 10^{-1}} = \frac{40}{35} \ 10^4 = 1.140 \times 10^4 \ min$$

$$\underline{t = 7.9 \text{ days}}$$

If pumping were continued beyond this time of about 7.75 days then the lower gravel would become a free-watertable aquifer and probably would be depleted at a slightly decreasing rate. The amount of water that could be withdrawn by lowering the water level to the top of the gravel is approximately 600,000 Imp. g.

(However, the behavior of this gravel after becoming a free-watertable aquifer cannot be exactly predicted from the information obtained concerning its artesian character. Attaining the watertable-state was prevented by the low capacity of the pump. Considering these facts, the conclusions to be drawn below are valid only as long as the aquifer behaves as an artesian one.)

Because of the very complicated character of the time-drawdown curves, caused by the combined effects of several impermeable boundaries, no exact computations could be made regarding the hydrologic constants of the aquifer. It was, however, possible to estimate the transmissibility of the lower gravel from the early part of the time-drawdown curves. The transmissibility (T) has thus been estimated at 25,000 Imp. gpd/ft. This gives for permeability per foot of aquifer thickness, a value of 1,000 Imp. gpd/ft^2. However, because of the very good material of the aquifer and because of the fact that the cone of depression, measured in observation wells, was quite flat, this figure seems to be lower than the one expected. But, even by assuming the value of 25,000 gpd/ft for transmissibility, the aquifer would be suitable for artificial recharge, if its volume were larger. Using, however, the figure of 60,000 Imp. gallons for the usable volume of the lower gravel body, the residence time of the water artificially recharged into the gravel, would be about 1/2 day if pumped out a few hundred feet farther away at a rate of 1 mgpd. This time interval would be inadequate to eliminate the fluctuations in the temperature of the river water.

Artificial recharge could be applied by conventional means, either by recharge wells or by water spreading. Discussion of the specific advantages or disadvantages of either method is beyond the scope of this report.

In summary, it can be said that the lower gravel formation is incapable of supplying the required 1 mgpd. of water. Artificial recharge is probably equally unsuitable because of the high costs of construction and maintenance of such a program and because it probably would not result in the desired cooling effect.

b. Upper Gravel

The prospects in the upper gravel at test site I seem to be much better. For the test of this aquifer, well #I-8 was used (Fig. 1). The elevations of the top and bottom of the upper gravel are 2776 feet and 2755 feet, respectively, above mean sea level, i.e. 12 feet and 33 feet below surface, at this location. The total thickness of the gravel is 21 feet. At the time of the test the elevation of the river stage was about 2776 feet. The static level in the well was at 2775.35 feet above sea level or 12.65 feet below surface. From these figures a saturated-gravel thickness of 20.35 feet can be calculated.

A 36-hour pump test has been conducted on well #I-8. The pumping rate increased from 84 gpm. at the first minute to 104 gpm. by the tenth minute of the test and it gradually dropped to 84 gpm. by the 22nd hour of pumping and remained the same until the end of the test. For reasons of convenience a conservative value of 85 gpm. has been taken as the average pumping rate in the calculation. The time-drawdown curve (Fig. 7) shows a rapid decline during the ~~final~~ first 5 minutes of pumping. Between 5 and 40 minutes it becomes more flat, and finally the curve becomes a horizontal line which indicates that the pumping level stabilized at 3.2 feet drawdown.

From the stabilized water-level the specific capacity of the well can be computed in the following manner: assuming that well-loss has been negligible, which thus keeps the calculation conservative, the specific capacity is

$$Q_s = \frac{Q}{s} = \frac{85}{3.2} = 27 \text{ gpm/ft},$$ which means that the well can produce 27 gpm. per foot of stabilized drawdown. The available drawdown has

been taken at 60% of the saturated thickness (20.35 feet), and is thus 12.4 feet. Thus a conservative estimate of the capacity of this well is:

$$Q \cong 12.4 \cdot 27 = 330 \text{ gpm.}$$

or $$Q = 475{,}000 \text{ gpd.}$$

However, if an allowance is made for 1 foot of well loss - which is probably still too low - the specific capacity will be:

$$Q = \frac{85}{2.2} = 39 \text{ gpm/ft}$$

in which case the capacity of the well would be:

$$Q = 12.4 \cdot 39 = 480 \text{ gpm}$$

or $$Q = 690{,}000 \text{ gpd.}$$

It should be mentioned that the river stage and the non-pumping level in the well are close to each other. Thus, although no recordings have been made in order to establish the possible connection, there is good reason to believe that the decrease in declivity of the drawdown curve is caused by the fact that the cone of depression reached the river and induced infiltration became effective.

Another favorable condition is that the river stage has been the lowest for 20 years at the time of the pump test. This means that one can assume an average river level that is several feet higher than at the present state, and every additional foot of rise in water level may improve the specific capacity by at least 27 gpm., i.e. by 39,000 gpd.

From the second limb of the time-drawdown curve (Fig. 7) the transmissibility and permeability of the aquifer have been computed:

T = 64,100 Imp. gpd/ft

P = 3,150 Imp. gpd/ft.

Similar values have been reported from the test sites of the Joffre Operators.

The possibility of locating more production wells in the area also has been considered. It has been computed that, assuming an average transmissibility value of 60,000 gpd/ft, a specific yield of 15%, and a stabilized pumping level in each well after one day pumping, the interference between wells located 700 feet apart is approximately 0.3 feet (Fig. 8). Taking into account the variation in the thickness of the aquifer and the interference of pumping levels, the construction of three vertical production wells will be necessary in order to provide the required amount of water. One should be located at the site of present test hole I-8, and two others at 700 feet and at 1,400 feet southward from the first one. The locations of the proposed production wells are shown on Figure 1.

The calculation of the total yield, both for a specific yield of 27 gpm/ft and of 39 gpm/ft for all three wells is summarized in the following table:

		Well No. 1	Well No. 2	Well No. 3	Total yield of the 3 wells
Saturated thickness in feet		20.35	13	14	
Interference with the 2 other wells in feet		0.3	0.6	0.3	
Available draw-down in feet		20 · 0.6 = 12	12.4 · 0.6 = 7.4	13.7 · 0.6 = 8.2	
if specific yield is 27 gpm/ft	yield	324 gpm = 465,000 gpd	200 gpm = 288,000 gpd	221 gpm = 318,000 gpd	1,511,000 I.gpd
if specific yield is 39 gpm/ft		470 gpm = 676,000 gpd	280 gpm = 404,000 gpd	320 gpm = 460,000 gpd	1,540,000 I.gpd

III. Quality

A graph of the minimum, average and maximum values through a one-year period of recording of the main chemical constituents of the river water at Red Deer is presented in Figure 9. The data are taken from the Water Survey Report No. 7, 1951-52, of the Department of Mines and Technical Surveys, Mines Branch, Industrial Mineral Division, by J. F. J. Thomas.

It can be expected that the total hardness of the water to be pumped from the wells will be slightly higher than that of the river water, but in general the quality of the induced water will be quite uniform.

IV. Temperature

The temperature of the river water varies between 33°F and 64°F through the year. The water obtained from the wells will also show seasonal variations of temperature but of less magnitude. The farther the wells are located from the effective line source, i.e. the river, the less the temperature variation will be. It is estimated that at the location recommended in this report the temperature will vary between 40°F and 50°F.

D. Summary and Recommendations

The possibility has been investigated of obtaining at least one million Imp. gallons per day of water at the west side of the Red Deer River at approximately 1 mile north of the City of Red Deer by means of induced infiltration from the river.

Different sites have been tested, from which only test site I has proven to be sufficiently valuable to warrant further testing. At test site I two potential aquifers have been encountered. The lower one is confined and has no more recharge than that from the adjoining bedrock. The small volume does not seem to justify the costs of artificial recharge. The upper gravel aquifer has a direct connection with the river, which has been proven by the stabilized pumping level. Based on values of available drawdown ranging from 7.4 to 12 ft., it has been computed that the minimum total production of three vertical wells in this aquifer is 1,071,000 Imp. gpd.

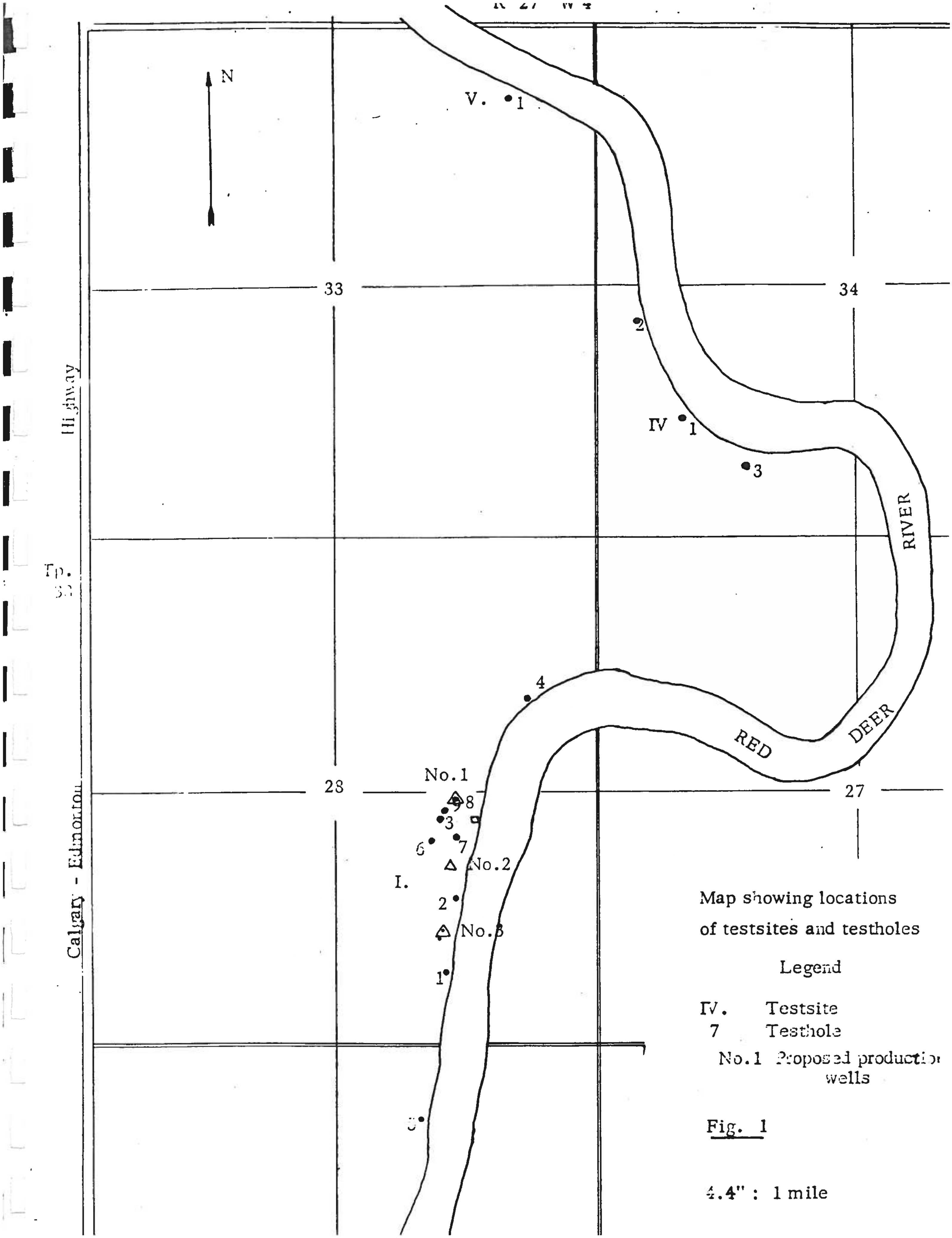
The temperature of the water will follow the annual fluctuations of the temperature of the river water, but the extremes will be less. It probably will range from 40°F to 50°F.

The average chemical quality of the water obtained from the wells will be the same as that of the river water, but turbidity, pollution and contamination will be very low or possibly absent.

The production of the wells could be increased by locating them closer to the river which, however, would be disadvantageous with respect to the cooling and filtering effect within the aquifer.

It is recommended that three production wells be constructed at the locations given on the map (Fig. 1). Firstly, No. 1 well should be completed. At least a 12" casing should be used and the well should be screened with a No. 60 slot screen of 20 ft. length and of 12" diameter. The top of the screen should be set at 14 feet below surface and when completed this well should be pump tested. Based on the information obtained from this pump test, decision could be taken as to the construction of the two other production wells. The construction and completion of the first well should be such that, if required, it could be maintained as a permanent production well.

J. Toth,
Groundwater Geophysicist.



Map showing locations of testsites and testholes

Fig. 1

4.4" : 1 mile

BLOCK DIAGRAM OF THE BURIED PRECLACIAL CHANNEL

TESTSITE No. 1

1961

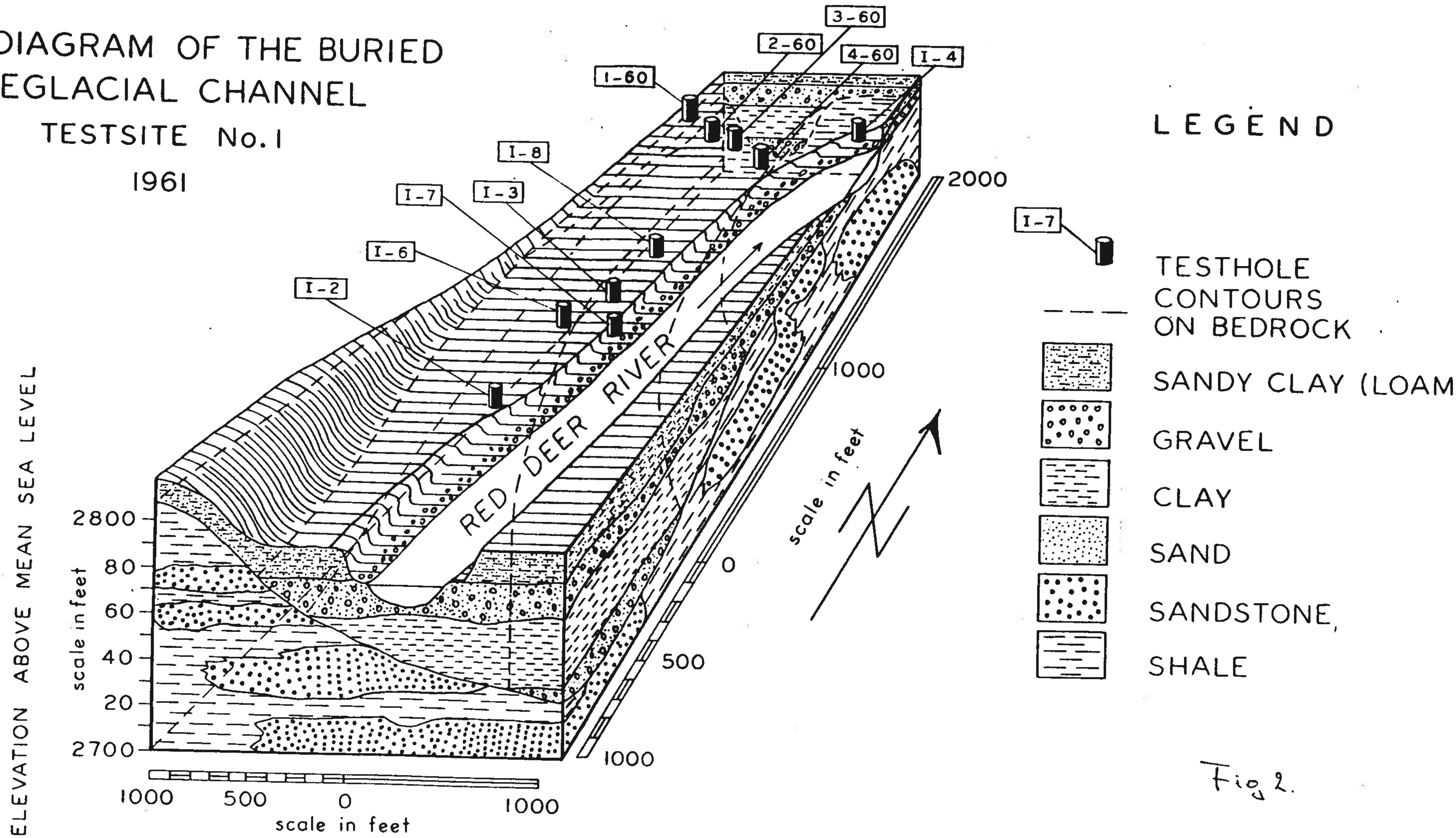
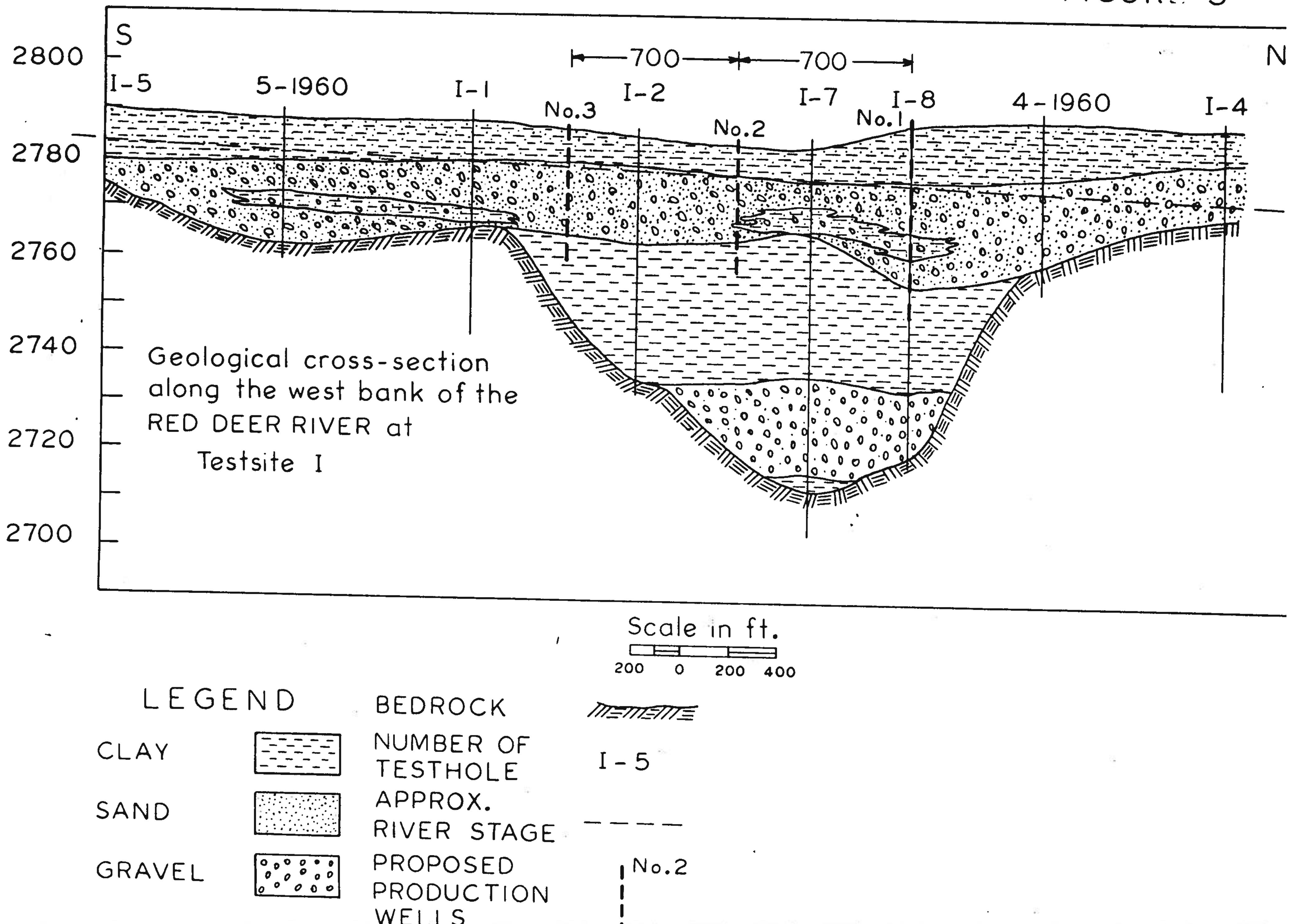
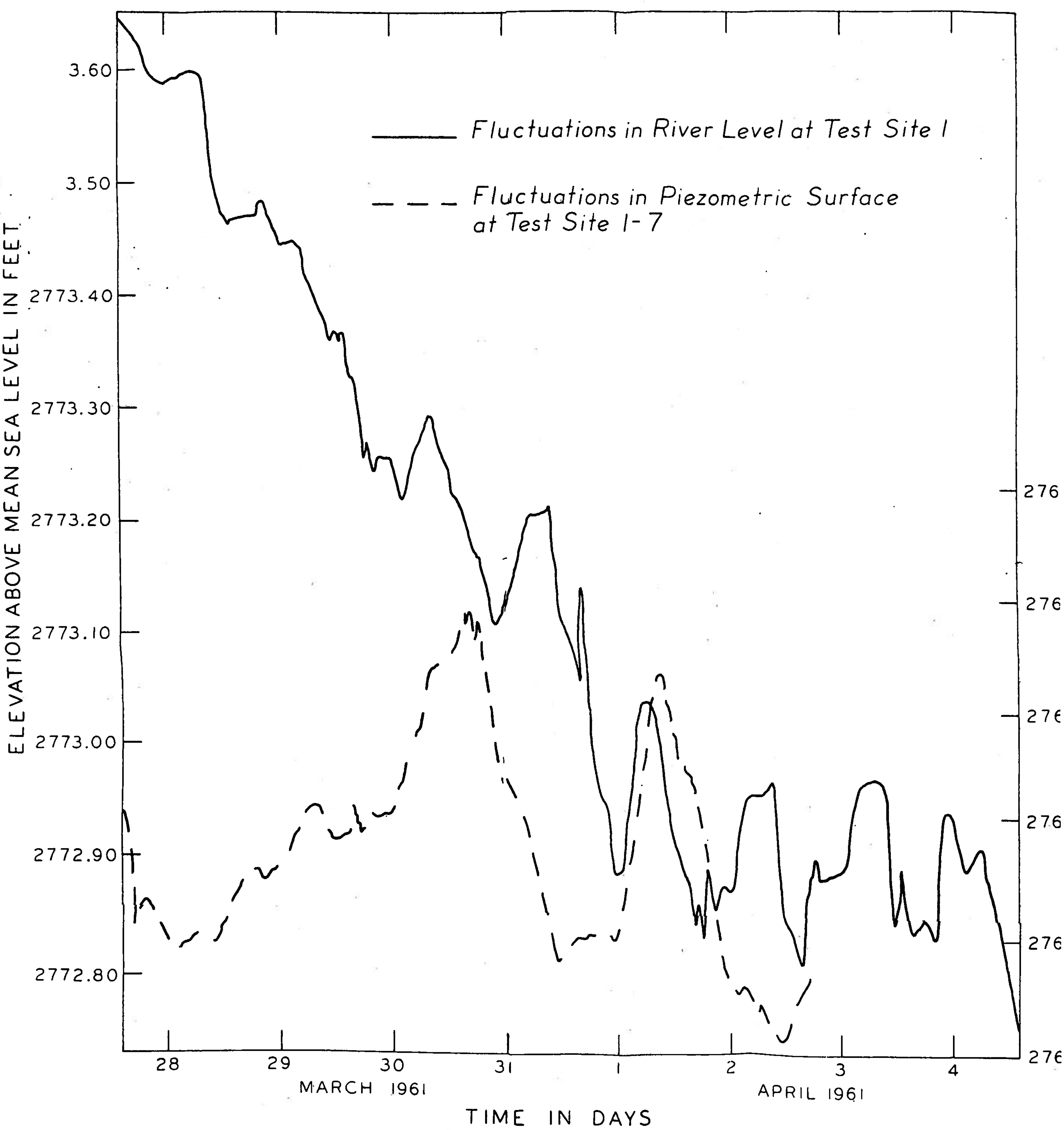


Fig. 2.

FIGUR.. 3



Geological cross-section along the west bank of the RED DEER RIVER at Testsite I



Fluctuations in River Level at Test Site I
Fluctuations in Piezometric Surface at Test Site I-7
ELEVATION ABOVE MEAN SEA LEVEL IN FEET
3.60
3.50
2773.40
2773.30
2773.20
2773.10
2773.00
2772.90
2772.80
276
276
276
276
276
276
28
29
30
31
1
2
3
4
MARCH 1961
APRIL 1961
TIME IN DAYS

FIG.4

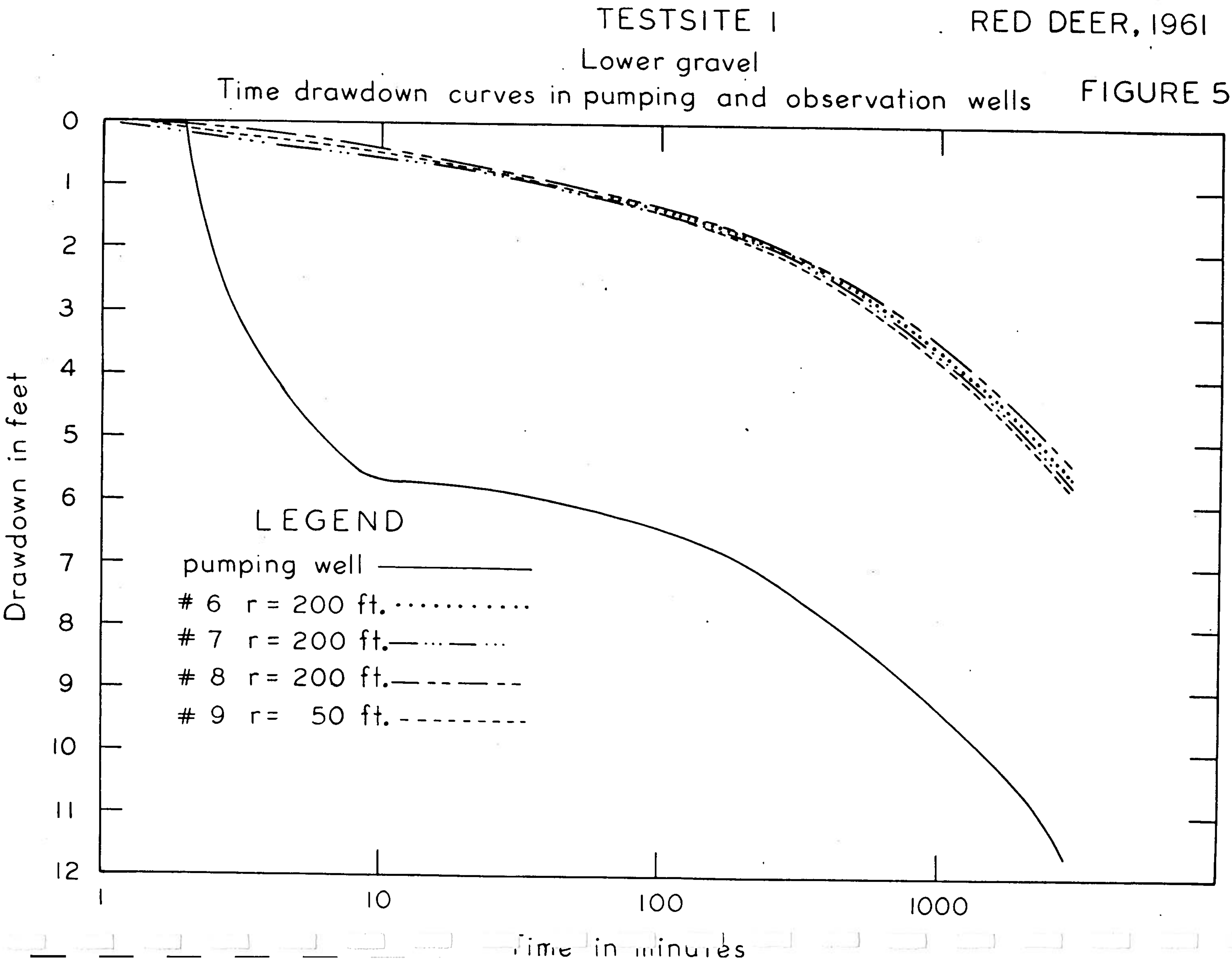
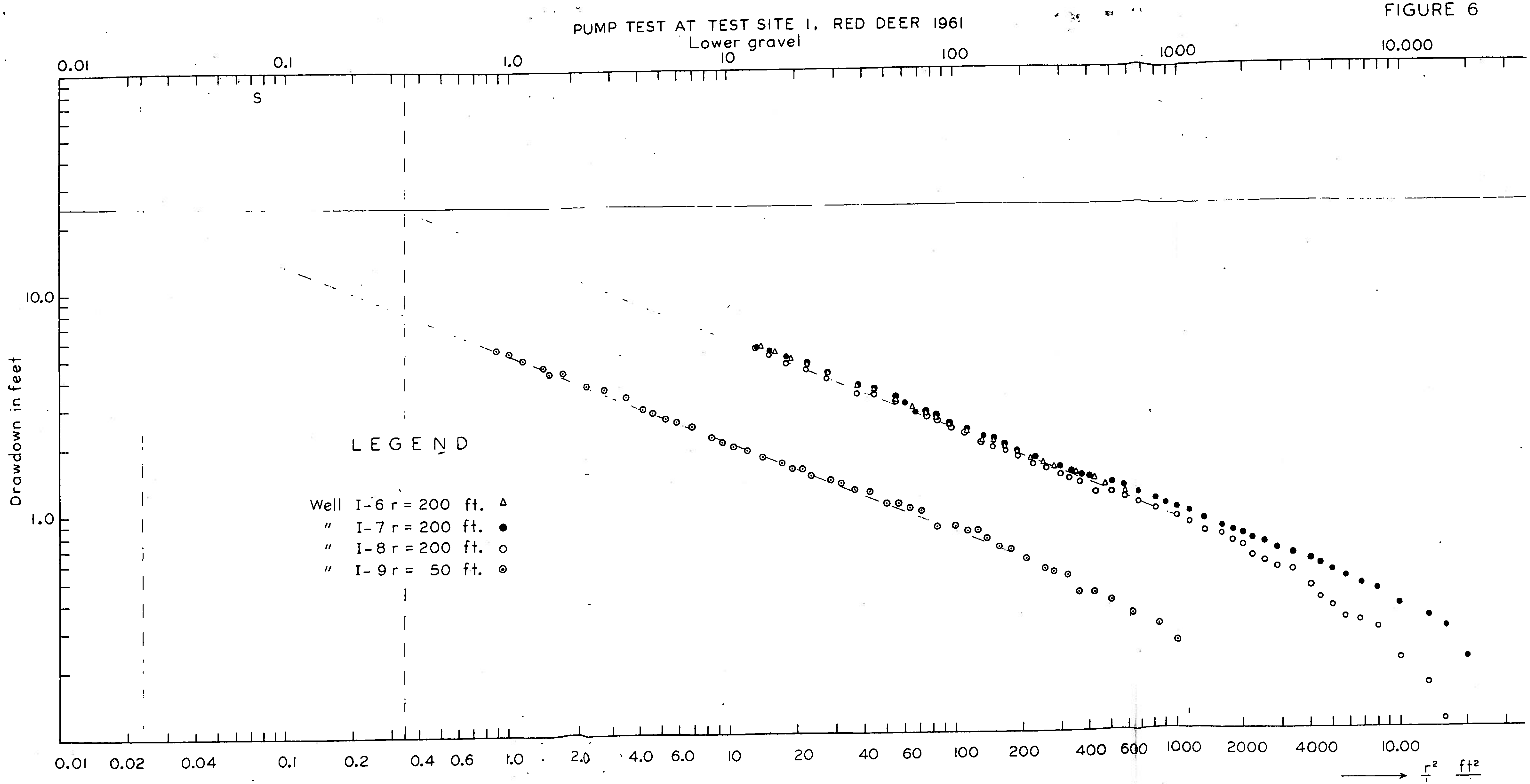

TESTSITE I
RED DEER, 1961
Lower gravel
Time drawdown curves in pumping and observation wells
FIGURE 5
Drawdown in feet
0
1
2
3
4
5
6
7
8
9
10
11
12
LEGEND
pumping well
6 r = 200 ft.
7 r = 200 ft.
8 r = 200 ft.
9 r = 50 ft.
1
10
100
1000
Time in minutes

FIGURE 6



PUMP TEST AT TEST SITE I, RED DEER 1961
Lower gravel
0.01
0.1
1.0
10
100
1000
10.000
S
10.0
1.0
Drawdown in feet
LEGEND
Well I-6 r = 200 ft. △
" I-7 r = 200 ft. ●
" I-8 r = 200 ft. ○
" I-9 r = 50 ft. ⊙
0.01
0.02
0.04
0.1
0.2
0.4
0.6
1.0
2.0
4.0
6.0
10
20
40
60
100
200
400
600
1000
2000
4000
10.00
r²/t ft²

Pump test RED DEER April 28-29, 1961
Pumping well I-8 Upper gravel
Q_{ave} = 85 gpm.

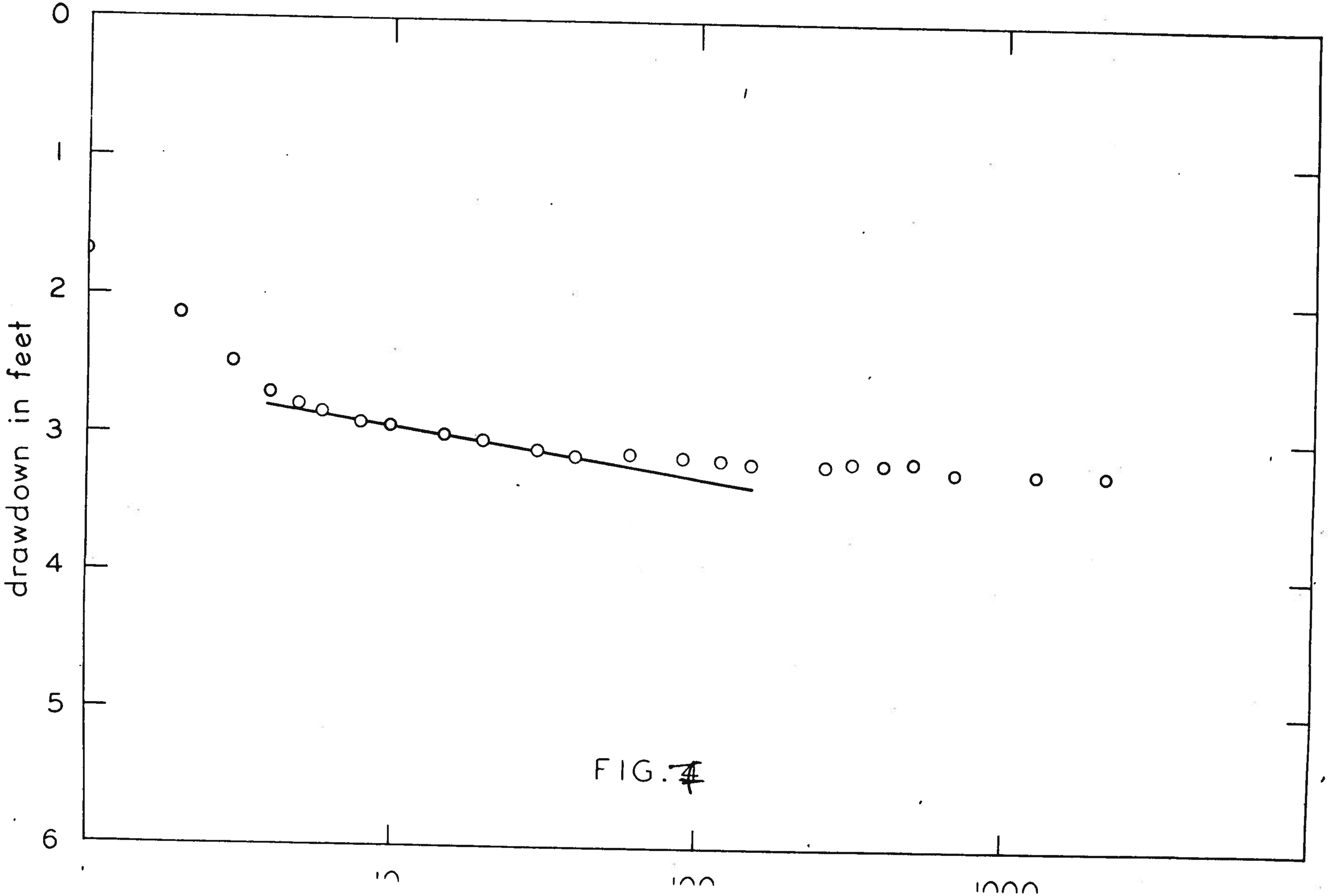
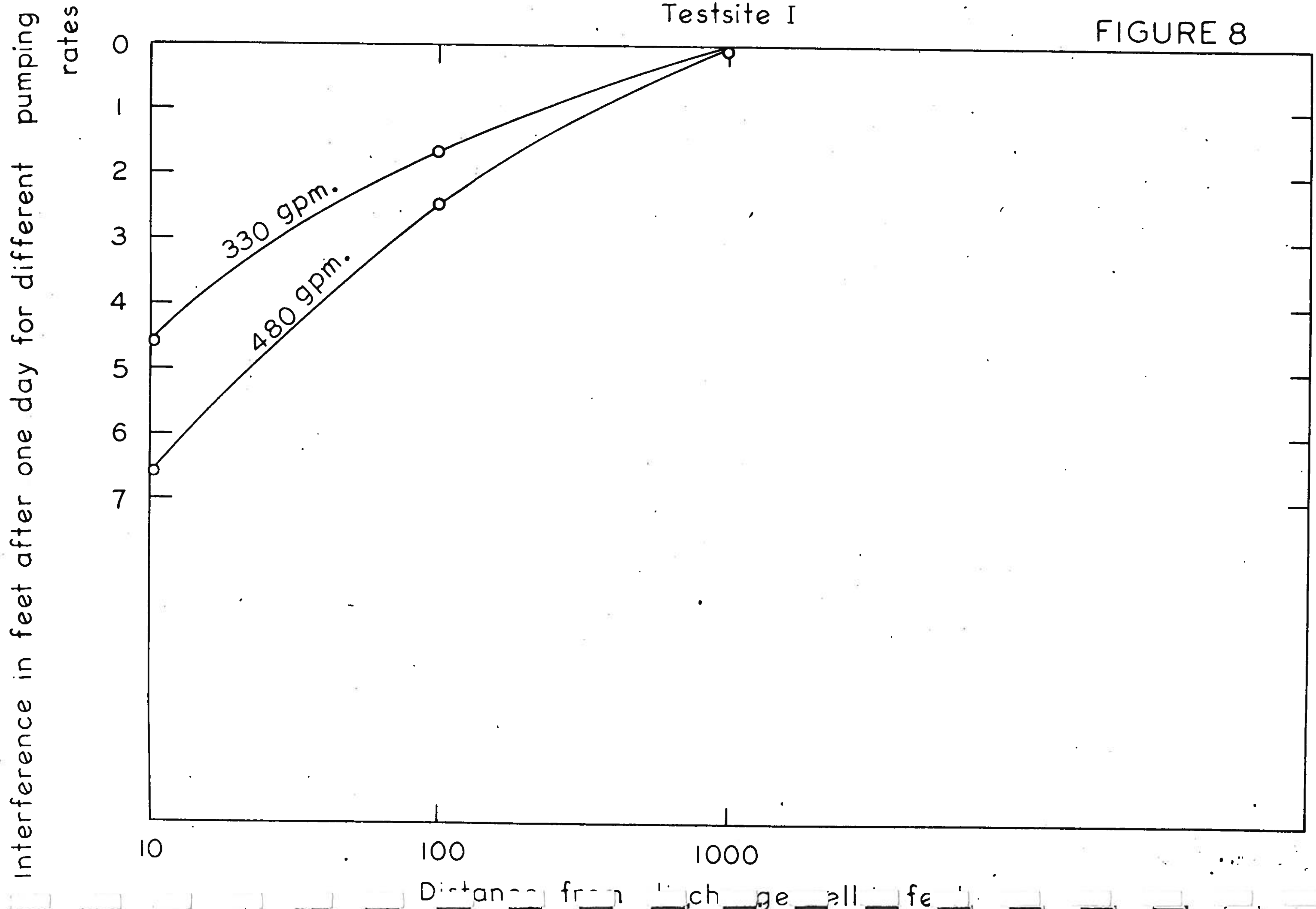


FIG. 4

Interference curves for the upper gravel of RED DEER

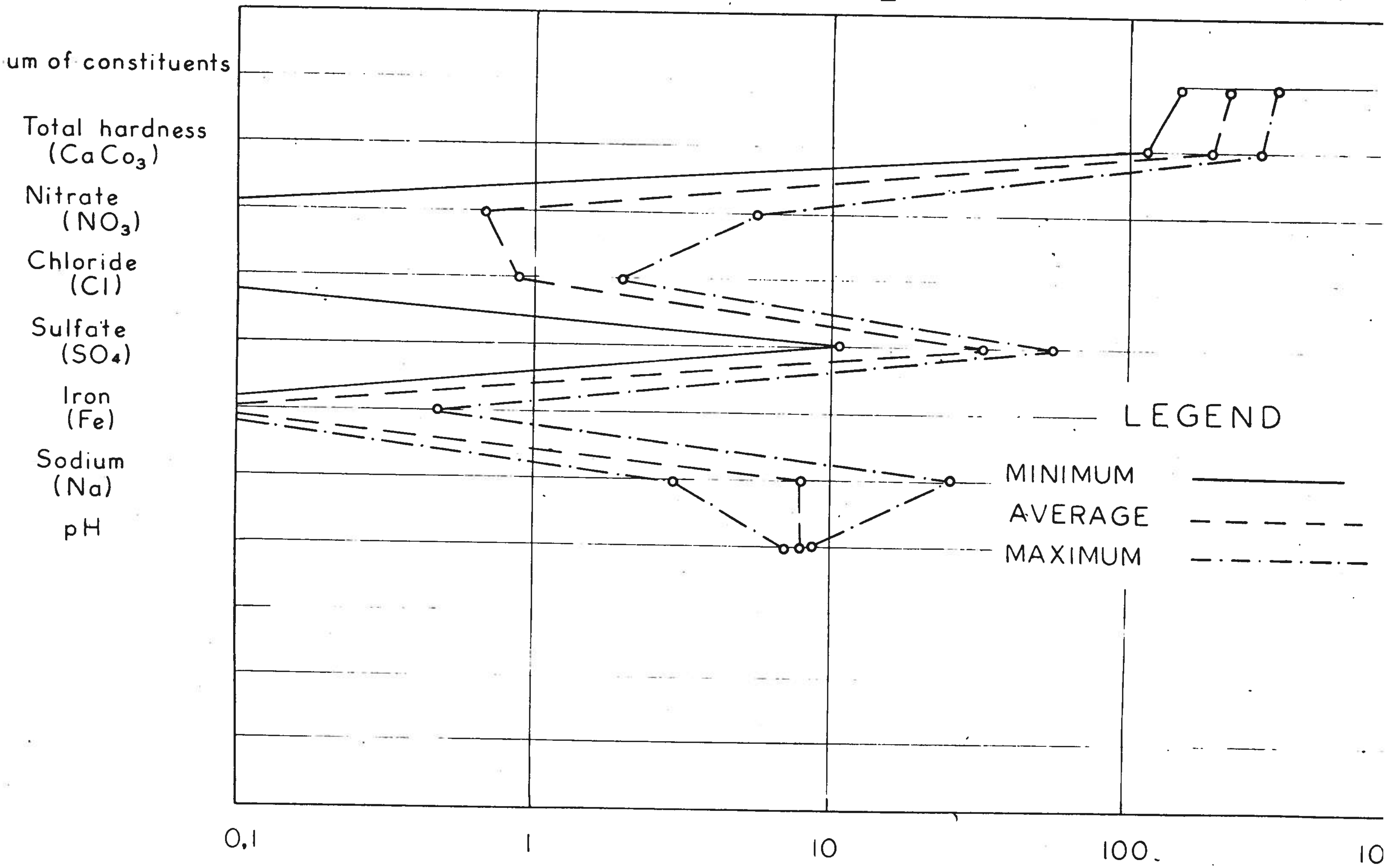
Testsite I

FIGURE 8



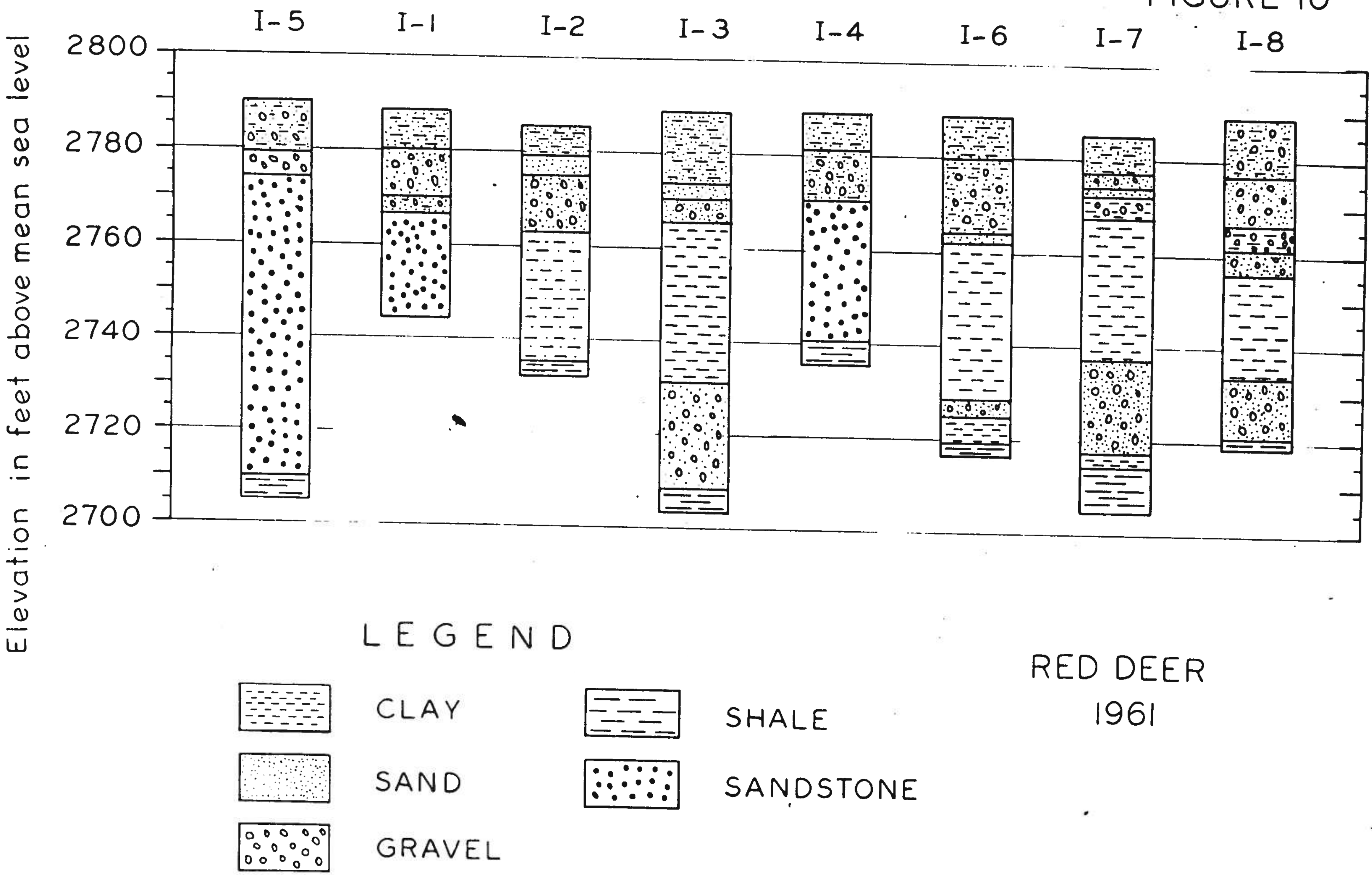
Limits of chemical composition of RED DEER RIVER water
1951 - 52

FIGURE 9



Lithological logs of testholes at Testside I

FIGURE 10



RED DEER
1961