GROUND WATER CONDITIONS IN THE VICINITY OF PARSHALL, MOUNTRAIL COUNTY, NORTH DAKOTA

SWCC PROJECT NO.791

BY

R. W. SCHMID, GEOLOGIST

WITH

PUMP TEST ANALYSIS

BY

VICTOR E. ZIEGLER, OPERATIONS ENGINEER

NORTH DAKOTA GROUND WATER STUDIES

NO. 41

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NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

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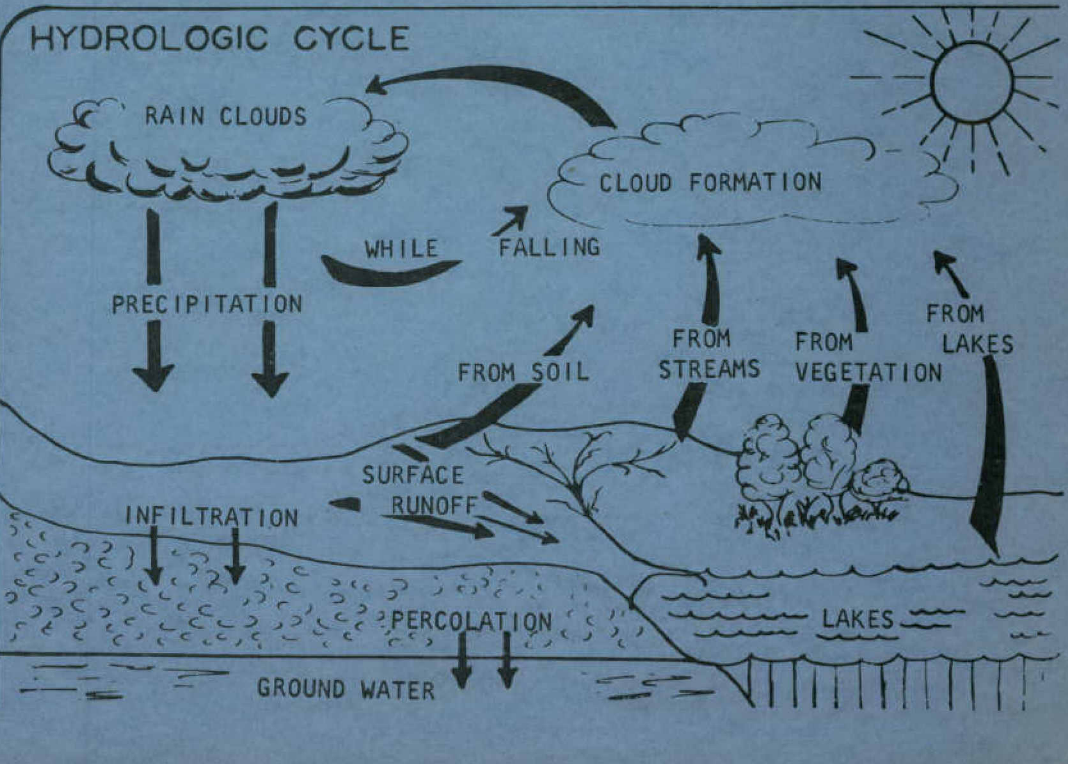

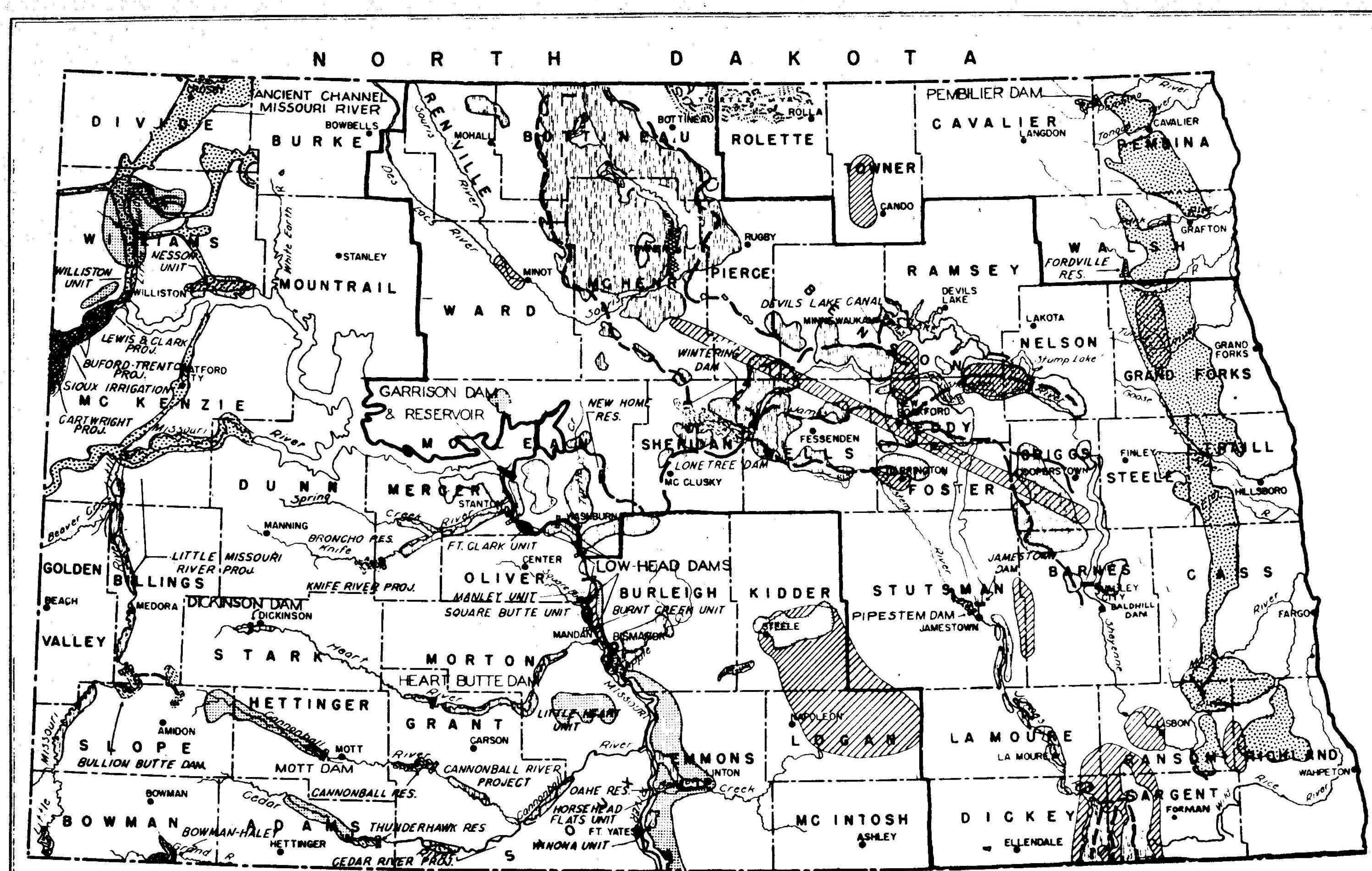

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

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AREAS CONSIDERED IRRIGABLE

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BASIC DATA TABLES
AND ILLUSTRATIONS

GROUND WATER CONDITIONS IN THE VICINITY OF PARSHALL

MOUNTRAIL COUNTY, NORTH DAKOTA

INTRODUCTION

The City of Parshall, population 1216 (1960 census), is in the southeastern part of Mountrail County. The area of study, approximately 75 square miles, is shown on figures 1 and 2. The city is situated 1½ miles south of State Highway 23 on State Highway 37 and is served by the Soo Line Railroad.

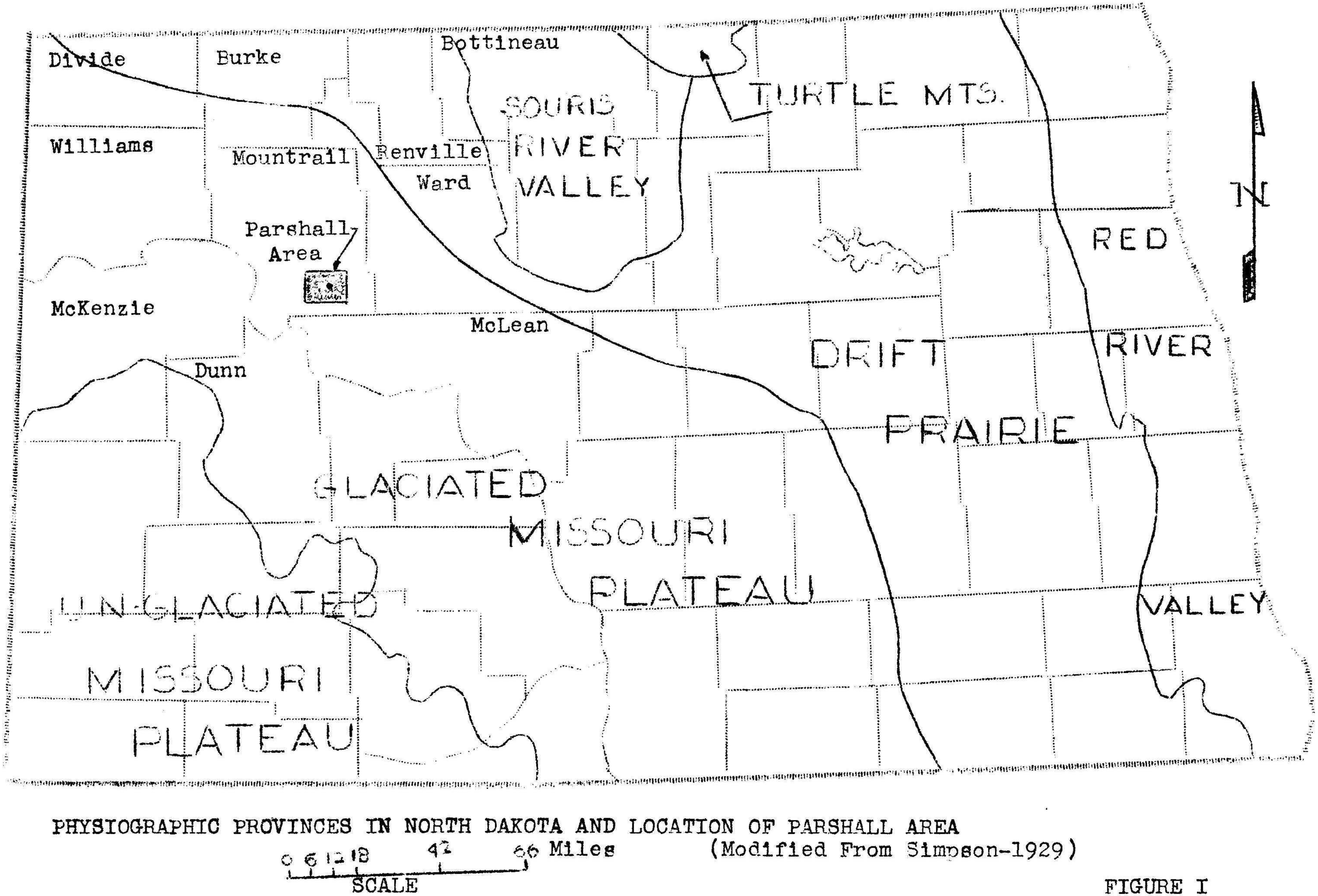
Parshall has had water problems for a number of years. In the 1930's many wells in the area went dry as a result of a regional lowering of the water table some 25 to 30 feet. The quality of water in the area is rather poor; water from a city well drilled in 1959 contained 3913 ppm (parts per million) of dissolved solids. A ground water study became imperative when the city was chosen as the site of a Family Mobile Home Park for personnel of the Boeing Company, Aero-Space Division, who will be working on missile installations in the area. The purpose of this study has been to determine the availability of an adequate supply of potable ground water for the City of Parshall.

An agreement for a cooperative ground water survey was signed September 20, 1961 by the City of Parshall and the North Dakota State Water Conservation Commission. On October 30, 1961 the study was initiated and continued through the winter when the weather modified sufficiently to make drilling feasible. The field work for this report consisted primarily of test drilling, a pumping test that was conducted on one of the city wells, and collection of water samples for analysis.

Simpson (1929, p. 174-177) discussed the ground water resources of Mountrail County briefly in a general study of the whole state. Robinove, Langford and

Brookhart (1958, 72 p) discussed water containing more than 1000 ppm of dissolved solids.

The cooperation of the city council, residents of Parshall, and of farmers in the area was of considerable assistance to this project. The pump test was set up and supervised by Victor E. Ziegler, Operations Engineer, North Dakota State Water Conservation Commission, who also compiled and calculated the pump test data. (Page 11). Lewis Knutson, driller operating a state-owned Failing 1500 rotary drill rig, did the test drilling. Water analyses were made by Howard Hammond of the State Laboratories Department and Ken Kary of the State Department of Health.



PHYSIOGRAPHIC PROVINCES IN NORTH DAKOTA AND LOCATION OF PARSHALL AREA

(Modified From Simpson-1929)

FIGURE I

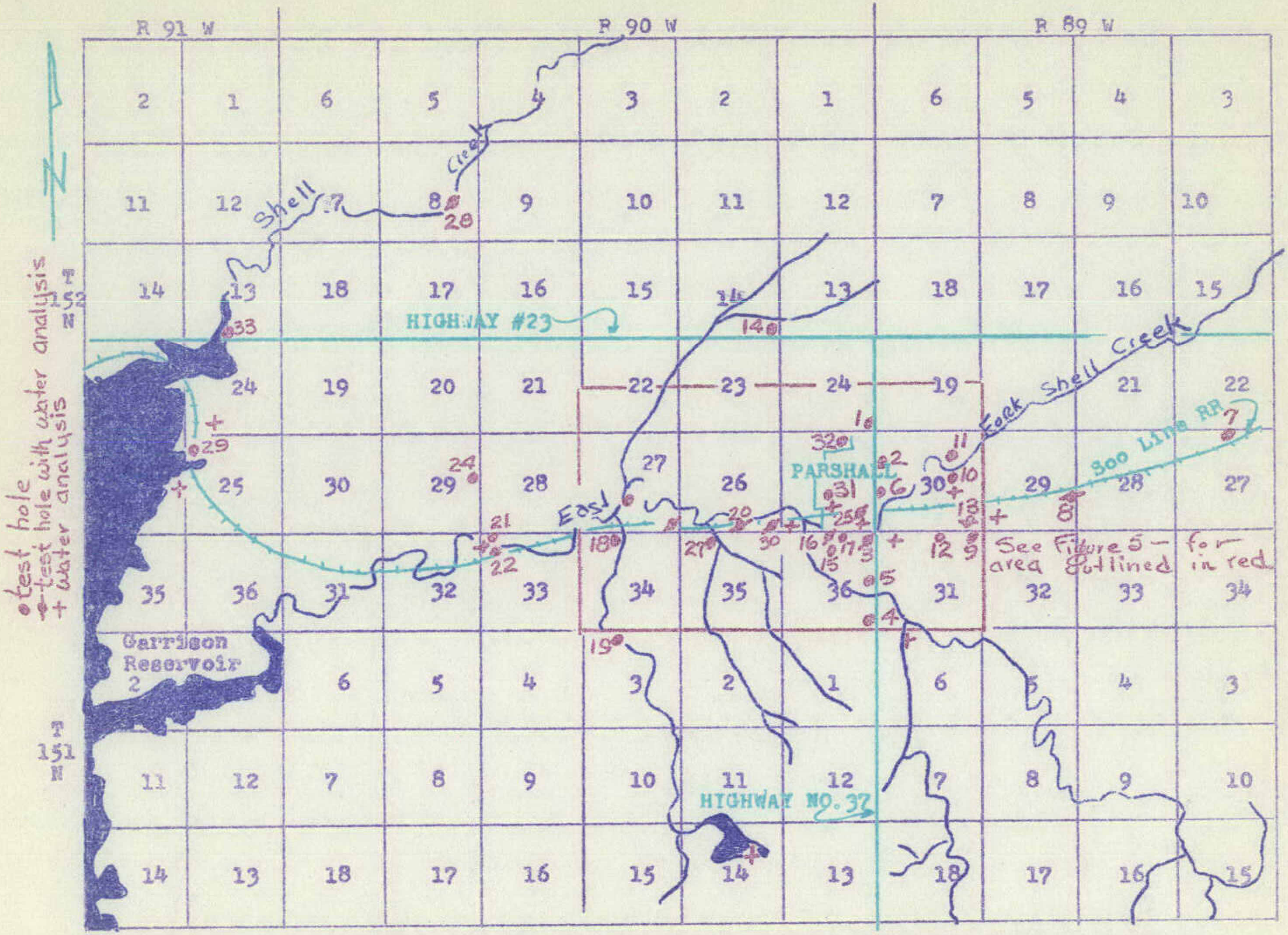


FIGURE IX - MAP OF THE PARSHALL AREA SHOWING TEST HOLE AND WATER SAMPLE LOCATIONS

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is illustrated in figure 3 and is based upon the location of the well within the grid established by the U. S. Bureau of Land Management's survey of the area. The first numeral denotes the township north of the base line which extends laterally across the middle of Arkansas; the second numeral denotes the range west of the fifth principal meridian, and the third numeral denotes the section in which the well is located. The letters a, b, c, and d, designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections (10-acre tracts). Thus, well 152-90-24ddd is in the SE¼SE¼SE¼ of Sec. 24, T. 152 North, R. 90 W. Similarly, well 162-69-8ddc is the well located in the SW¼SE¼SE¼ of Sec. 8, T. 162 N., R. 69 W.

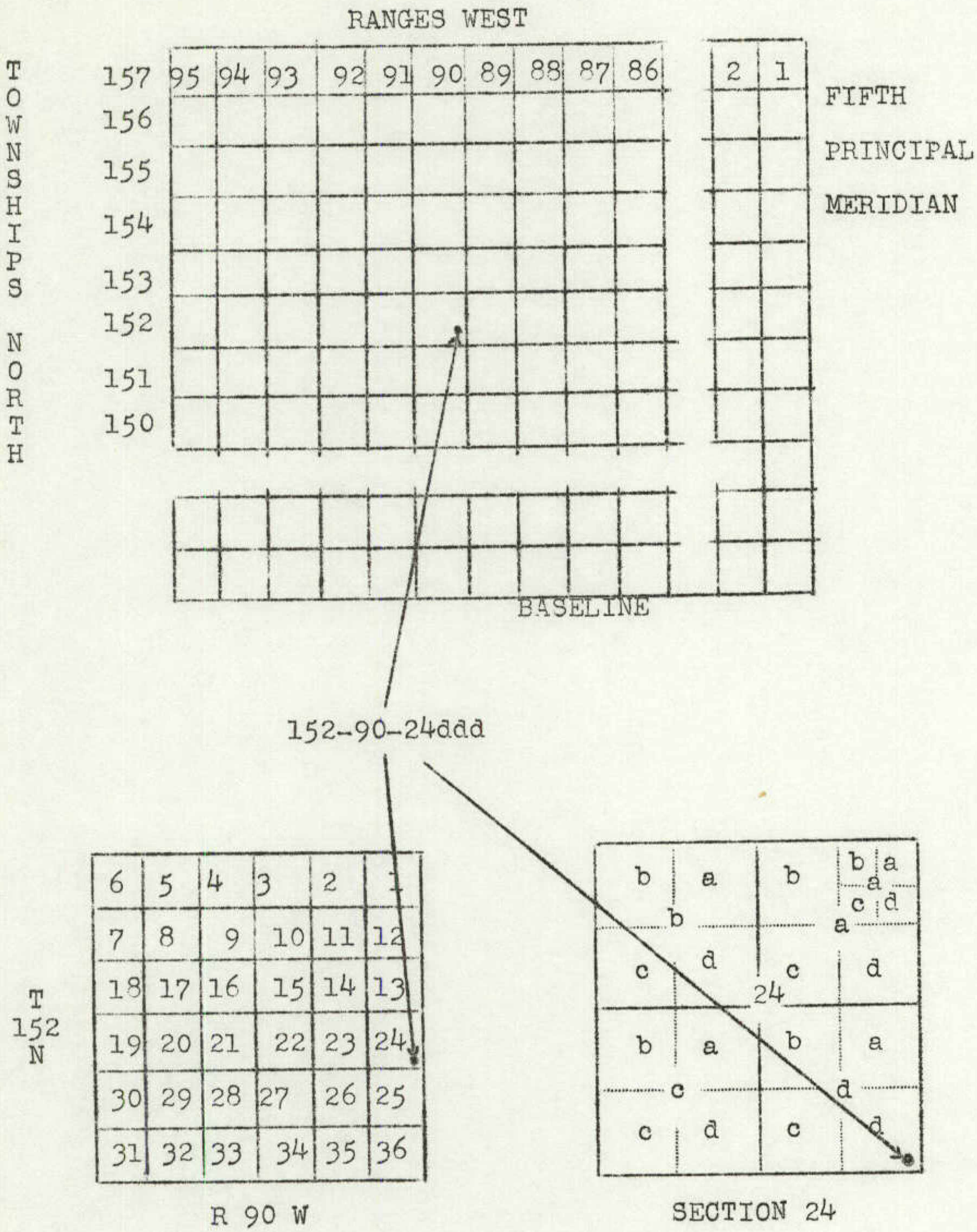


FIGURE III -SKETCH ILLUSTRATING WELL NUMBERING SYSTEM

PHYSIOGRAPHY AND GEOLOGY

The area studied is located in the glaciated Missouri Plateau Section of the Great Plains physiographic province, according to Fenneman (1931, p. 72-79). Prior to glaciation topography of the area resembled that of the unglaciated Missouri Plateau section which lies 30 to 35 miles southwest of the study area. The subduing effect of glaciation is seen by a comparison of the two sections (figure 1).

Elevations in the area range from less than 1850 feet above sea level near the Garrison Reservoir to more than 2100 feet on the prairie just north of Parshall, giving an areal relief of over 250 feet. Local relief is 70 feet or less per mile.

Runoff from the report area flows into the Garrison Reservoir. East Fork Shell Creek drains most of the area, an unnamed creek drains a few square miles between East Fork Shell Creek and Shell Creek, which drains the northwest corner of the area studied.

In preglacial time the Tongue River Formation of the Fort Union Group was evidently eroded down to a rugged topography in the vicinity of Parshall (Figure 4 and 6a). Across this erosional surface there were two distinct advances of glacial ice during the Wisconsin Stage of the Pleistocene Epoch. The deposits of these two advances make up the drift cover in the Parshall area; five other advances in the state didn't reach the area under consideration (Lempke and Colton, 1958, p. 41-57). The earliest glacial drift in this area, Iowan (?) drift, is overlain by Tazewell (?) drift which forms the now subdued surface of the area. As mapped by Lempke and Colton those deposits tentatively classified as Tazewell (?) drift extend from the Max Moraine, just northeast of Plaza, to a few miles southwest of the Missouri River. Southwest, beyond the Tazewell (?) drift border, lie the remnants of the earlier Iowan (?) drift. Tazewell (?)

and Iowan (?) drift are undifferentiated in this study.

As the two ice sheets advanced through the Parshall area they deposited a considerable thickness of till, sand and gravel in the preglacial canyon, (Figure 4) thereby reducing relief in this locality from 150 feet to 70 feet within a mile (Figure 6a). The present day East Fork Shell Creek Valley at Parshall has nearly 100 feet of glacial drift or fill at one location (T. H. 31-791, 152-90-25 dbc).

An anomalous 6 foot thickness of the Tongue River Formation within the glacial drift of test hole 16-791 (152-90-36abb) could have resulted from a landslide or slump of the steep sides of the canyon or, more likely, from a short (mile or less) movement as a block, with other glacial debris, lodged in the ice as the glacier advanced to the southwest across the preglacial canyon.

Melt water from the retreating glaciers and, more recently, runoff have eroded and deposited material in the two major stream valleys, East Fork Shell Creek and Shell Creek.

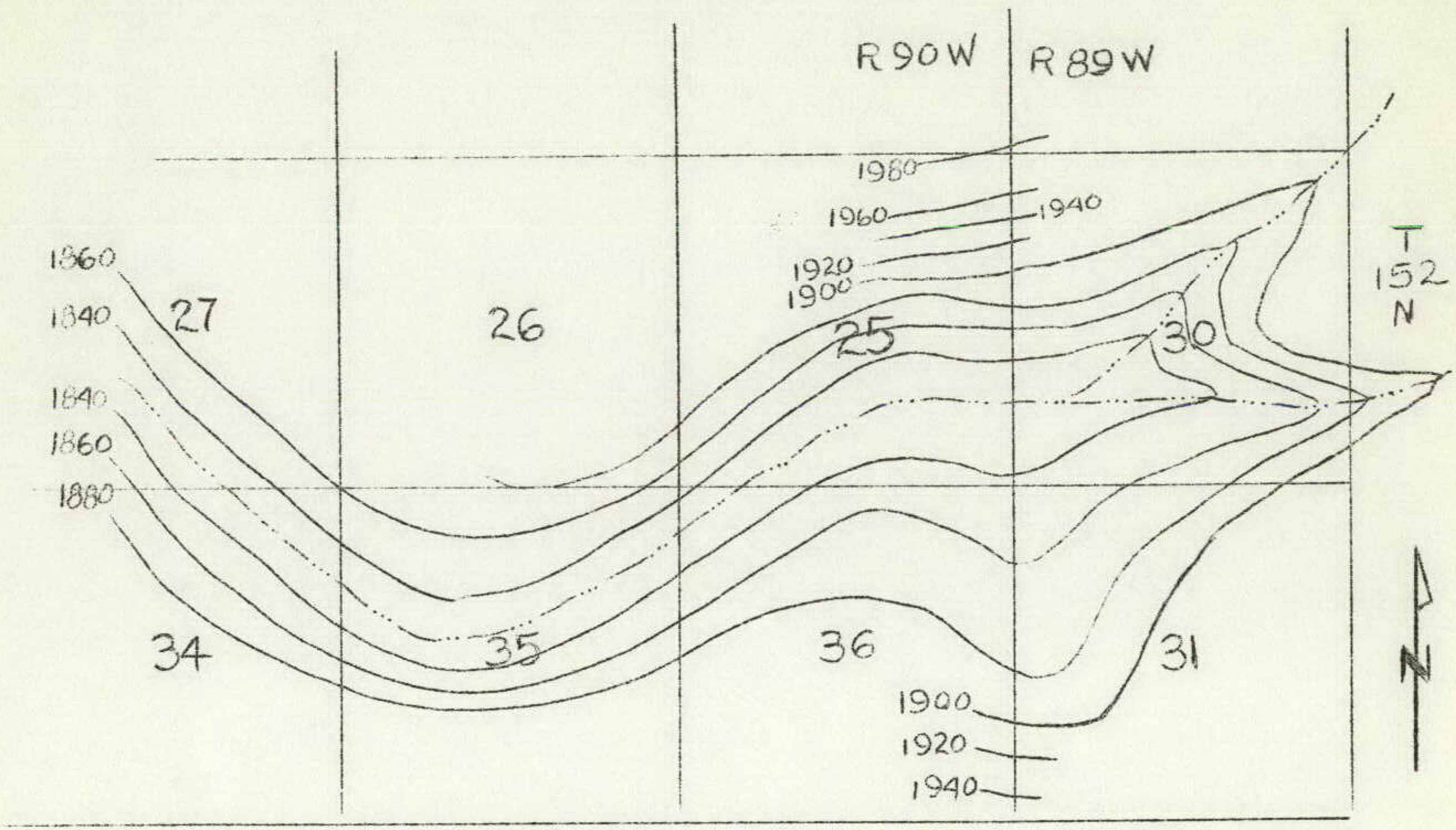


FIGURE IV - PREGLACIAL TOPOGRAPHY IN THE IMMEDIATE VICINITY OF PARSHALL

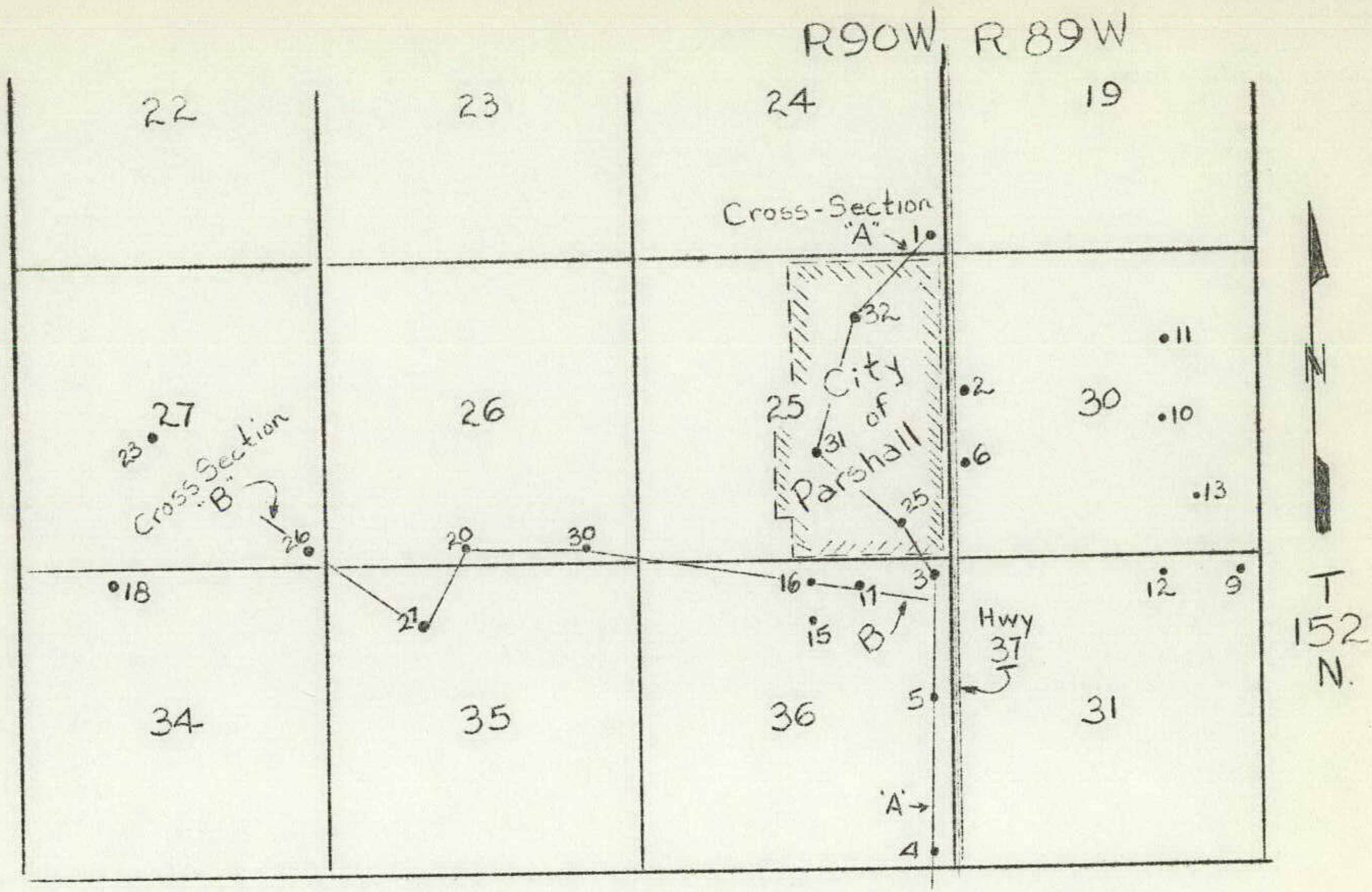


FIGURE V - LOCATION OF CROSS-SECTIONS IN THE IMMEDIATE VICINITY OF PARSHALL

HYDROLOGY

Ground water movements in the Parshall area can only be surmised but the rather closely spaced drilling and numerous water analyses are an adequate base for a few conclusions.

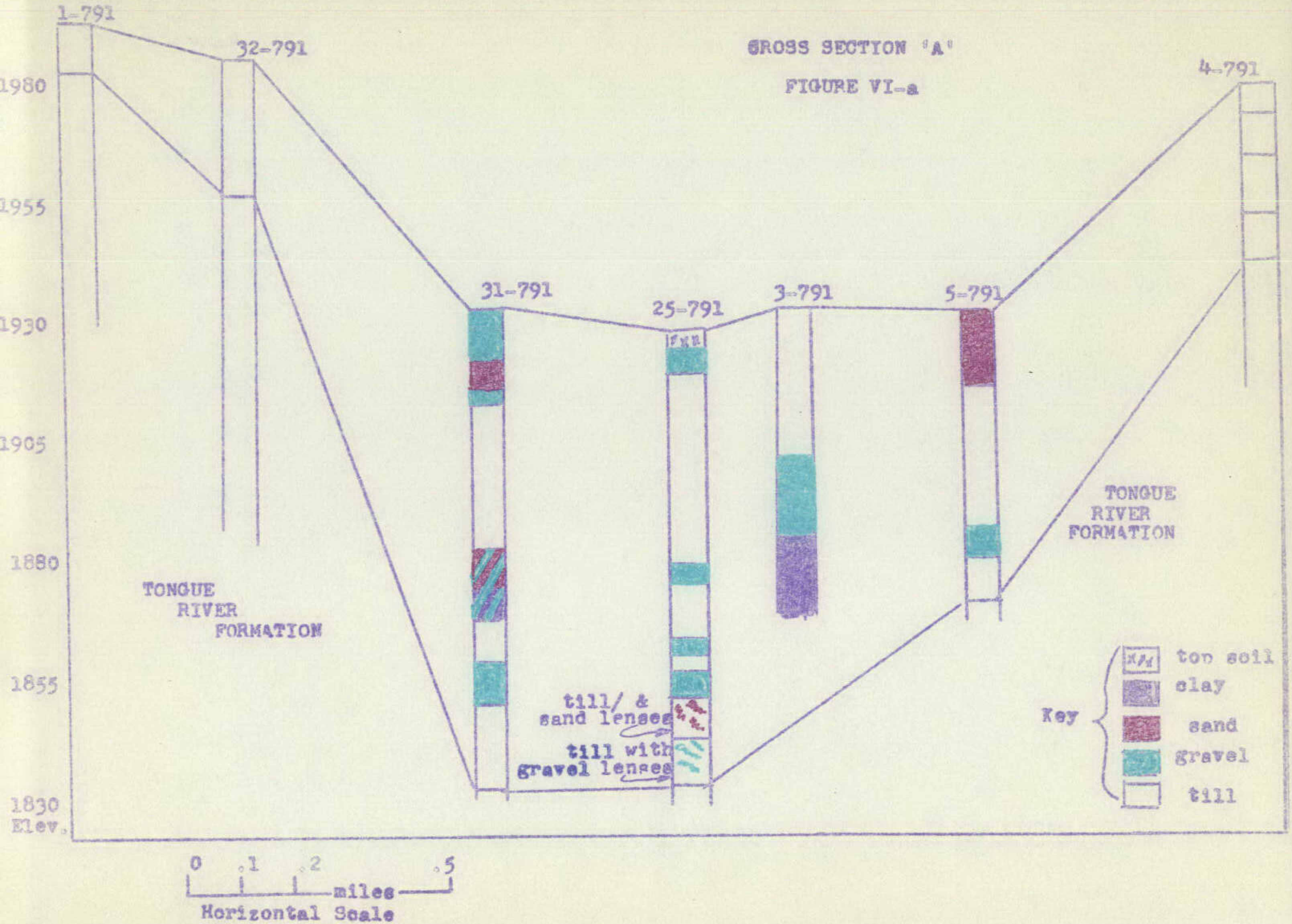
Permeable zones occur within the glacial drift, probably as lenses of sand and gravel surrounded by less permeable till. The results of the pumping test (page 11), indicate that some of these lenses are hydraulically connected and there is evidently flow into the permeable zones or lenses from the artesian aquifers of the Tongue River Formation. The steep slopes of the preglacial canyon would readily allow considerable artesian pressure to be dissipated into the lenticular permeable zones of the glacial drift. The four present city wells are obtaining water from these lenses within the drift.

The movement of water from the Tongue River Formation into the glacial drift probably accounts for the rather poor quality of water in the city wells (table 1). The schoolhouse well or City Well No. 4 (152-90-25dbc) has a greater aquifer thickness (T. H. 31-791) than has City Well No. 2 (T. H. 25-791 & A25-791) (Figure 5 a); it also has somewhat better quality water (table 1). City officials stated that the school well tended to rust out rather rapidly. This corrosion should not occur because of the water quality, but is probably due to electrolysis caused by an electrical leak, possibly faulty pump motor ground or iron bacteria action (Hammond and Kary, oral communications).

The test holes depicted in Figure 6-b and Ivol Bartleson's slaughterhouse well are probably all in the same shallow aquifer. Five water analyses from the open pit coal mine (152-89-6bb) and the eastern portion of this aquifer, as far west as the slaughterhouse well (152-90-25ccc) all show over 3000 ppm total solids. This seems to indicate that, between surface stream flow and ground water movement, Tongue River Formation water from the area of the open pit coal mine contaminates ground and surface water at least as far away as the slaughterhouse. At the slaughterhouse the highly mineralized water is becoming diluted by less mineralized water from East Fork Shell Creek and ground water from other sources, possibly surface recharge from rain water.

The western portion of this shallow aquifer, near test holes 26, 27, 20 and 30-791, is recharged differently from the eastern portion. The test holes contained water that is only moderately mineralized (2014, 1275, and 1214 ppm total solids). This may be due to recharge entering from the surface in the valley and on the south slope of the valley. The area of the aquifer is small, approximately one mile long and one-half mile wide, but it has excellent permeability and recharge.

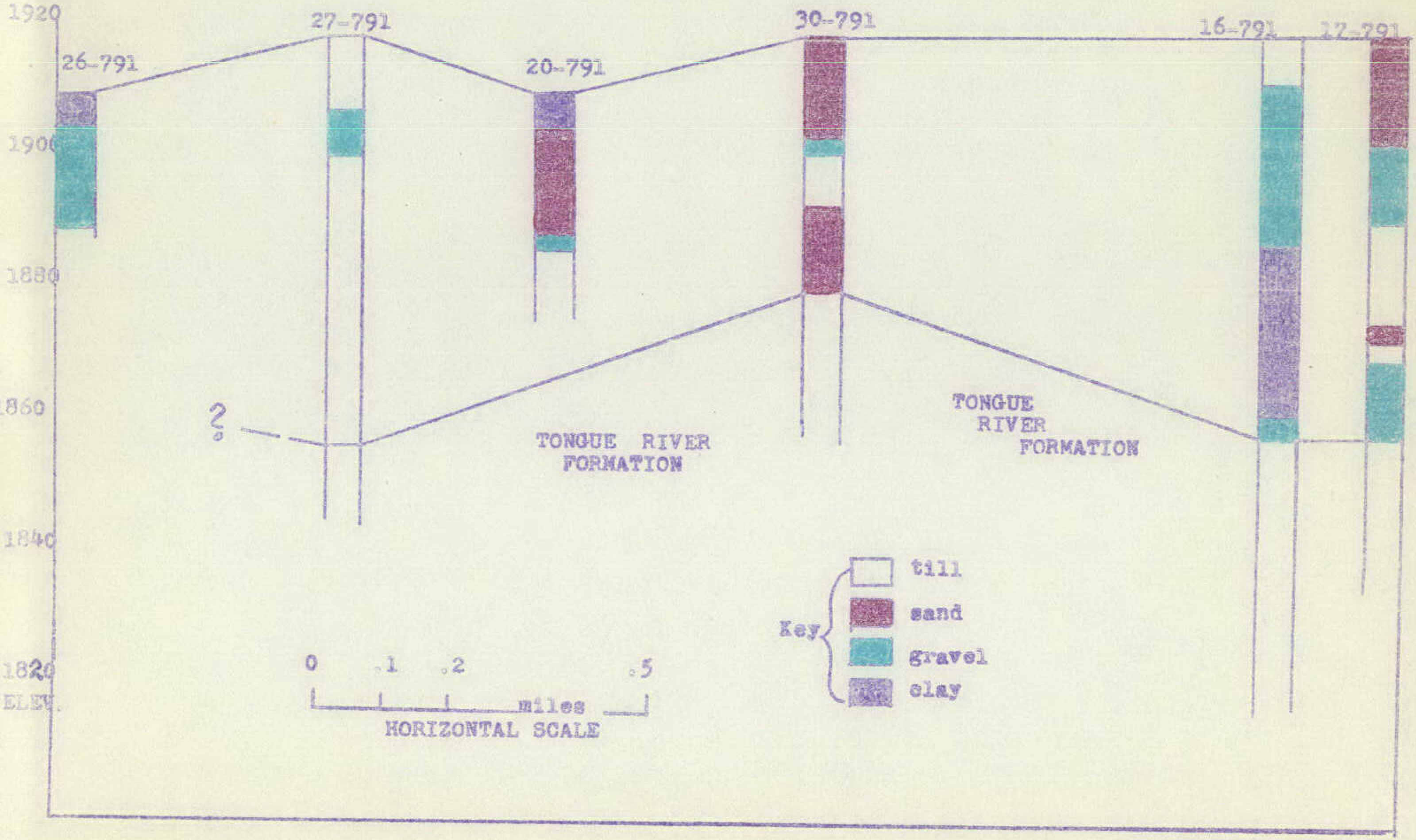
Aquifers encountered in test holes 28-791 (152-90-8acd), 33-791 (152-91-13ccd) and 29-791 (152-91-25bbd) (table 3) are probably capable of producing more water than the two areas mentioned above but the mediocre water quality of these test hole areas and their distance from Parshall make them no more favorable than the poorer producing areas closer to Parshall.



CROSS SECTION 'A'
FIGURE VI-a
1-791
32-791
31-791
25-791
3-791
5-791
4-791
1980
1955
1930
1905
1880
1855
1830
Elev.
TONGUE RIVER FORMATION
TONGUE RIVER FORMATION
till/ & sand lenses
till with gravel lenses
Key
top soil
clay
sand
gravel
till
0
.1
.2
.5
miles
Horizontal Scale

CROSS SECTION B

FIGURE VI-b



WATER QUALITY

Chemical-analysis data (table 1) of 32 water samples from the Parshall area indicates the quality is quite poor in most respects (table 2). The source for the water samples collected from the open pit coal mine (151-89-6bbb), John Bartleson spring (151-90-14aca), and the spring (152-90-33caa) is probably permeable zones in the Tongue River Formation. The sample from the East Fork Shell Creek (152-90-33bbb) was taken while the creek was running on January 31, 1962 and its analysis should give an idea of the quality of water of the various springs that flow into the creek. The analyses of the remaining samples, from 1 seep (near T. H. 10-791), 9 test holes and 9 wells, are fairly representative of the quality of water found in the glacial sands and gravels of the area. These glacial drift aquifers contain water ranging from 886 ppm to 3913 ppm total dissolved solids. These readings are rather high when compared with the water quality standards (table 2). In actual practice, however, water of 2000 ppm total solids can be used if no better quality is available. The high sulphate content of water from this area is also very undesirable.

RECOMMENDATIONS

For immediate (summer 1962) usage there are two areas that should be investigated by a reputable well driller in conjunction with the city's engineer.

One area consists of the lenticular aquifers in glacial drift at depths up to 75 or 85 feet that are within the city limits. It is the writers belief that the additional aquifer thickness at test hole 31-791 over test holes 25 and A25-791, plus the better quality water from City Well No. 4 over City Well No. 2 indicate that the City of Parshall should investigate the area near the school well (City Well No. 4). The danger in this area is that under heavy pumping such as is anticipated the water quality could get poorer over a period of years.

The second area is the western portion of the shallow aquifer, i. e. test holes 26, 20 and 30-791. The average water quality from this area is considerably better than the present city wells. Although contamination of such a shallow aquifer is possible, analyses show only traces of nitrates or none at all. The permeability of the sand and gravel is excellent and rainfall and runoff from the south provide a considerable amount of recharge. The water table was quite high this winter (1961-1962) despite the very dry year of 1961. This area could be connected to the present city water system by only 3/4 to 1½ miles of pipe line.

When the Garrison Reservoir reaches its full elevation the area near test hole 29-791 may receive recharge from the reservoir thereby making it an excellent aquifer from both the quality, which is not doubtful, and quantity standpoints.

The first and second areas are the only known locations feasible under present conditions unless the city wishes to go further than the 6½ miles to the area of test hole 29-791.

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Fenneman, N. M., 1931, Physiography of Western United States: New York, McGraw-Hill, p. 72-79.

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Robinove, C. J., Langford R. H., and Brookhart, J. W., 1958, Saline Water Resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 1428, 72 p.

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PUMP TEST ANALYSIS
BY
Victor E. Ziegler, Operation Engineer

A pumping test was made of the existing city wells on February 13-15, 1962 by personnel of the Commission staff in an attempt to learn more about the aquifer in which the wells are developed and to determine interference conditions that exist between the present wells to provide clues for minimum wells spacings on future wells that may be constructed to meet the city's water supply needs.

The pumping test was conducted by pumping City well #2 at a rate of approximately 30 gallons per minute. This was accomplished by choking down the maximum capacity of the pump by partially closing the valves between the well and the water supply line. As a result the pump operated at a higher head than under its normal operating conditions. The gallonage pumped was recorded by a 3 inch Sparling Hershey water meter which is located in City Well House #1. A total of 41,987 gallons were pumped during a continuous constant pumping of 23 hours and 50 minutes.

Observations of the drawdown effect due to pumping were made on the pumped well, City Well #2, an observation well, A, located 50 feet from the pumped well, and on City Well #1, located 240 feet from the pumped well. Another observation well, B, drilled 100 feet from the pumped well could not be used for pumping records as it developed an artesian condition and flowed at a rate of about 1 gallon per minute during the entire pumping test. Pumping had no effect on its behavior and, according to the observations taken on the other wells, did not have any influence on any of the other observed wells. The artesian condition must have come from the sands below the gravel lenses in which the current City wells are developed and these sands lie just above the bedrock formation in the area. (Figure 7).

After pumping was stopped, observations were also made on the recovery of the water table in the same wells that were observed during pumping. The readings were taken for a period of 26 hours and in all cases the water level had recovered to a higher elevation than was observed at the time pumping was started. A check with city water department officials revealed that a water break had occurred the previous week and as a result all wells had been pumped and were not shut off until approximately 24 hours before the pumping test was started by personnel from the State Water Commission. This was a necessity as the city officials had to replenish their water supply to its maximum in order to allow a storage reserve so that the pumping test could be conducted for the 48 hour time period.

The results of the pumping data were compiled by the graphical method known as Jacobs Formula, which is a variation of the Theis Formula and is based on the nonequilibrium equation commonly used in groundwater hydrology analyses. The nonequilibrium equation assumes that an aquifer behaves under certain assumptions and fixed conditions. Basically, this equation is based on the following assumptions:

1. The water bearing formations are uniform in character and permeability in both a horizontal and vertical plane.

2. The formation has the same thickness in all places.

3. The formation extends indefinitely in all directions from the pumped well.

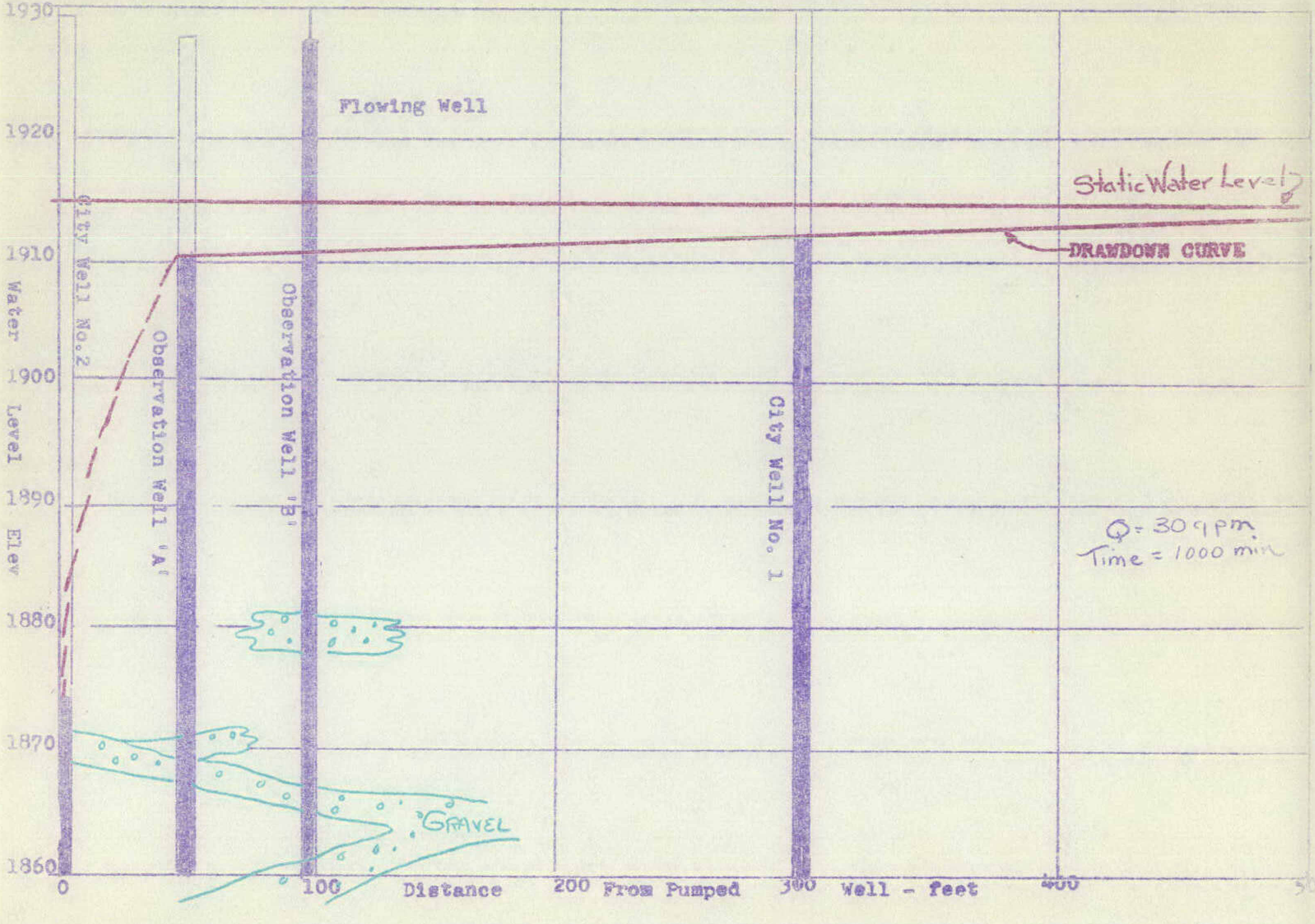
4. The formation receives no recharge from any source.

5. The pumped well penetrates the entire thickness of the water bearing formation.

6. The water flows from the formation into the well immediately with the lowering of the water table.

PARSHALL PUMP TEST
CROSS SECTION
February 13-15, 1962

FIGURE VII



These conditions are not always present and as a result the data from an actual pump test may not fit the theoretical solution.

The Jacob Method is a graphical method based on the condition that the "cone of depression" or area of influence when plotted on a distance drawdown curve on rectangular coordinates is parabolic in nature. It so happens that if these same results are plotted on semi-logarithmic paper the parabola becomes a straight line which has a definite slope. This slope is the hydraulic gradient created by the pumping and is used to determine the hydraulic characteristics of the particular aquifer and is known as $\triangle$ s.

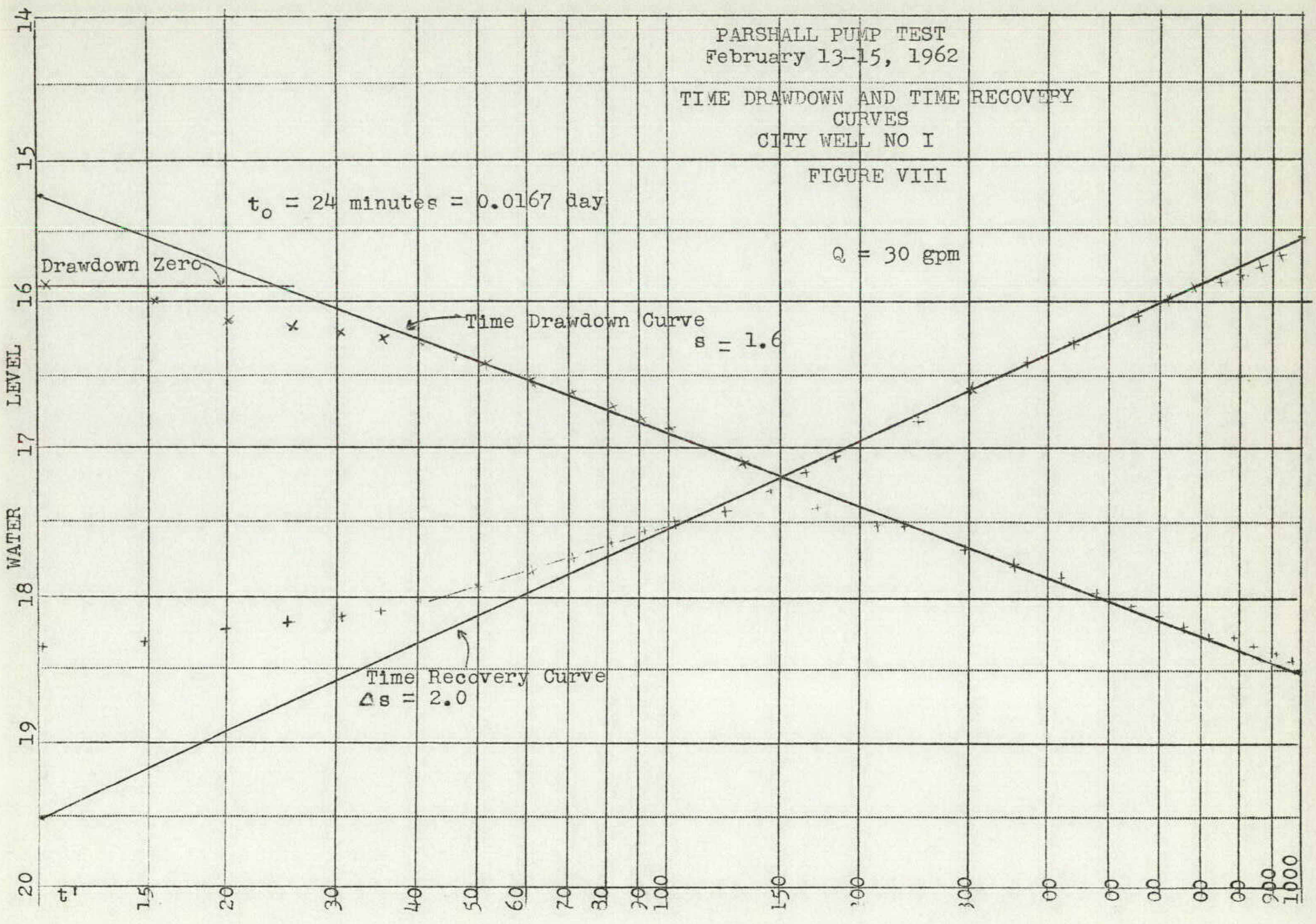
Knowing the slope, $\triangle$ s, which in this report is expressed as the change in drawdown in feet per log cycle, one can then determine the transmissibility and the storage coefficient of the aquifer. (Figure 8) These two factors describe the movement of water through the aquifer.

The transmissibility of the aquifer can be calculated by the formula; $T = \frac{264Q}{\triangle s}$ where Q is the pumping rate in gallons per minute, $\triangle$ s is the hydraulic slope taken from the graph, 264 is a conversion constant, and T is the transmissibility expressed in gallons per day per foot of aquifer. Based on the results of the pumping test, as illustrated in Figure 8, the $\triangle$ s for the aquifer is 1.6 feet, according to the time drawdown curve. The pumping rate for the test was 30 gallons per minute. Using the above formula one would find the transmissibility to be 4950 gallons per day per foot. $T = \frac{264 \times 30}{1.6} = 4{,}950$ gal/day/ft. This is the transmissibility of the aquifer based on data taken at City Well #1. The transmissibility of the aquifer based on data at City Well #2 is 4400 gal/day/ft. (Figure 10). These results compare favorably and can be assumed to be a fair representation of the capability of the aquifer since both City Wells #1 and #2 have been in use for several years and can be assumed to be fully developed. The data from Observation Well, A, (Figure 11) would indicate a transmissibility of 3150 gal/day/ft. which is considerably lower and is probably indicating that the observation well is not fully developed thus giving a lesser water bearing characteristic of the aquifer.

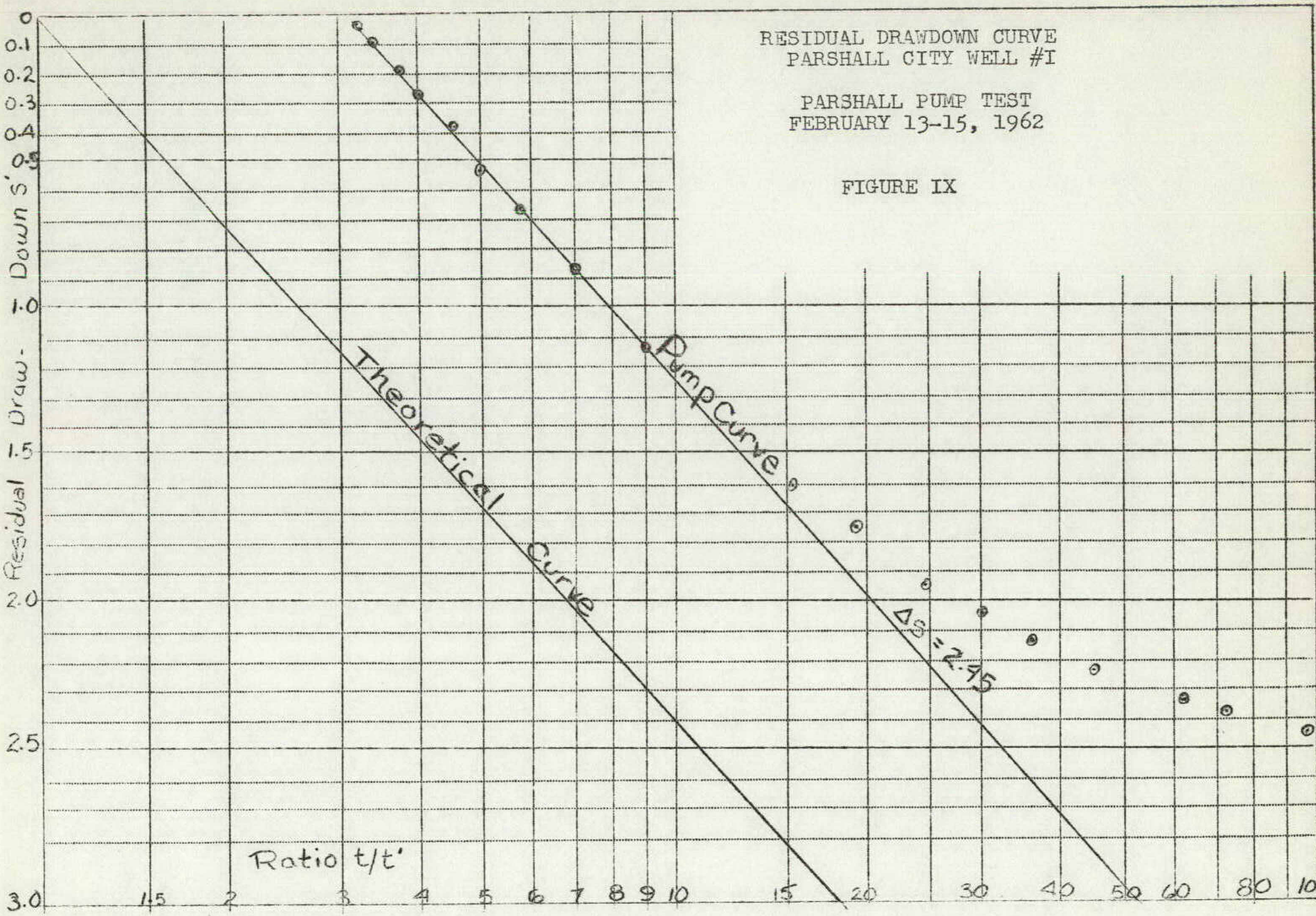
From the transmissibility, one can go one step further and calculate the storage coefficient of the aquifer. This can be obtained from the formula: $s = \frac{0.3\ T\ t_o}{r^2}$, where T is the transmissibility, t_o is the time on the graph at zero drawdown, (Figure 8) in fractions of a day, and r is the distance of the observation well to the pumped well. The storage coefficient for the Parshall aquifer is 0.0043. $s = \frac{0.3 \times 4{,}950 \times 0.0167}{240 \times 240} = 0.0043$

Knowing the coefficient of storage, in this case, is of little benefit as the aquifer is limited in size. It merely indicates that the aquifer is confined and reacts as an artesian aquifer as artesian aquifers have a storage coefficient range of 0.0001 to 0.003.

If one examines the graphs, Figures 8, 10 and 11, you will note that the data obtained from the pumping test does not exactly conform to the original theory. As a result, a residual drawdown curve, Figure 9, was plotted on the data from City Well #1 to give possible clues as to the reason for the variation from the theoretical concept. The residual drawdown is the actual measured difference between the static water table and the water level in the well at any given time during the recovery of the well after pumping has stopped. The residual drawdown curve is made by plotting the measured residual drawdown against a ratio of time since pumping started, t, to time after pumping stopped, t'. If the curve conditions for the residual drawdown curve fit the assumptions mentioned earlier in the report, the line will pass through one, upper left hand corner of Figure 9. This is not the case as it passes through 3.1 which indicates that the aquifer was probably receiving recharge during the pumping test. (See Hydrology for possible recharge source, page 6).



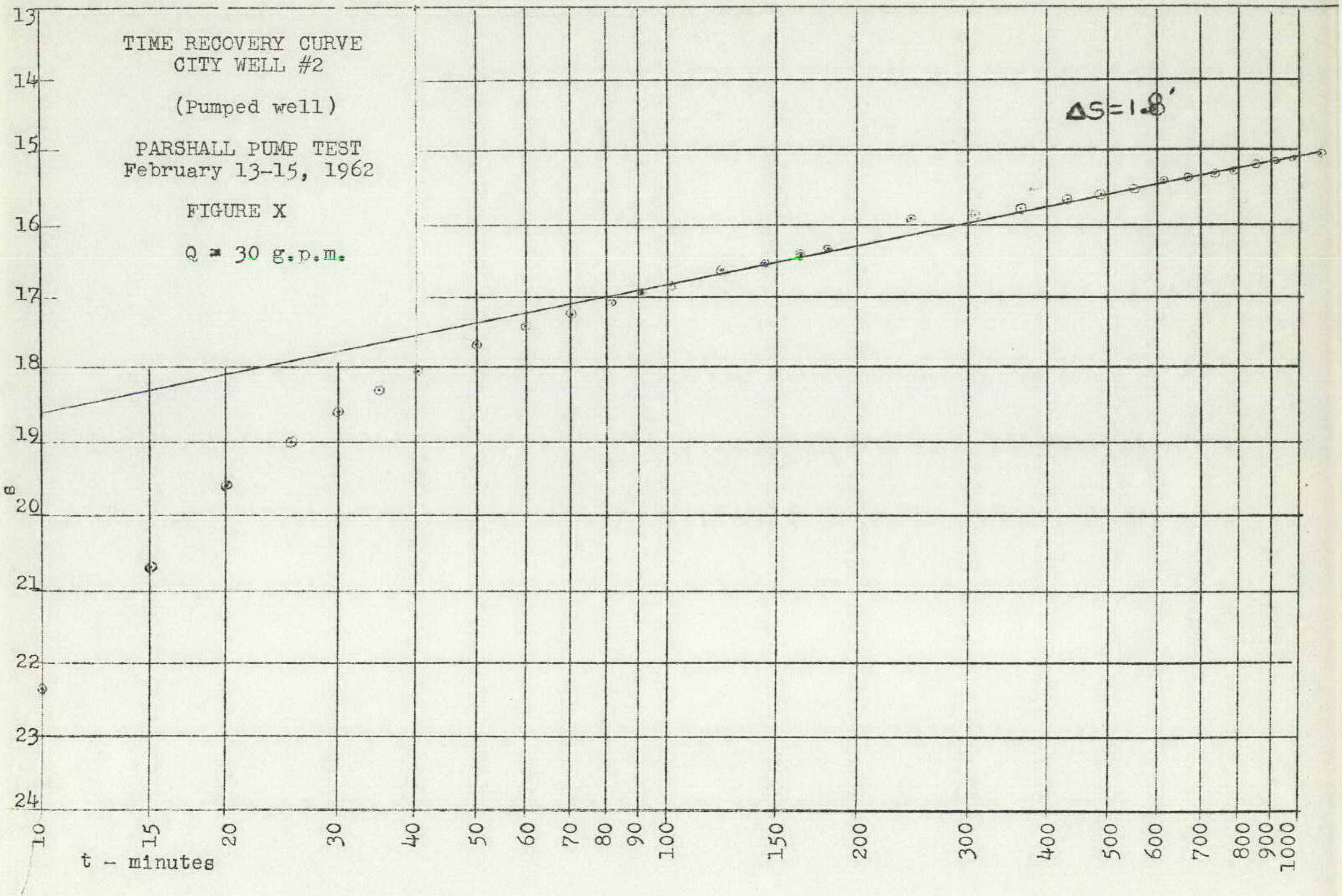
PARSHALL PUMP TEST
February 13-15, 1962
TIME DRAWDOWN AND TIME RECOVERY CURVES
CITY WELL NO I
FIGURE VIII
t_o = 24 minutes = 0.0167 day
Q = 30 gpm
Drawdown Zero
Time Drawdown Curve
s = 1.6
Time Recovery Curve
Δs = 2.0
WATER LEVEL
14
15
16
17
18
19
20
t'
15
20
30
40
50
60
70
80
90
100
150
200
300
1000



RESIDUAL DRAWDOWN CURVE
PARSHALL CITY WELL #I

PARSHALL PUMP TEST
FEBRUARY 13-15, 1962

FIGURE IX


TIME RECOVERY CURVE
CITY WELL #2
(Pumped well)
PARSHALL PUMP TEST
February 13-15, 1962
FIGURE X
Q = 30 g.p.m.
ΔS=1.8'
s
13
14
15
16
17
18
19
20
21
22
23
24
10
15
20
30
40
50
60
70
80
90
100
150
200
300
400
500
600
700
800
900
1000
t - minutes

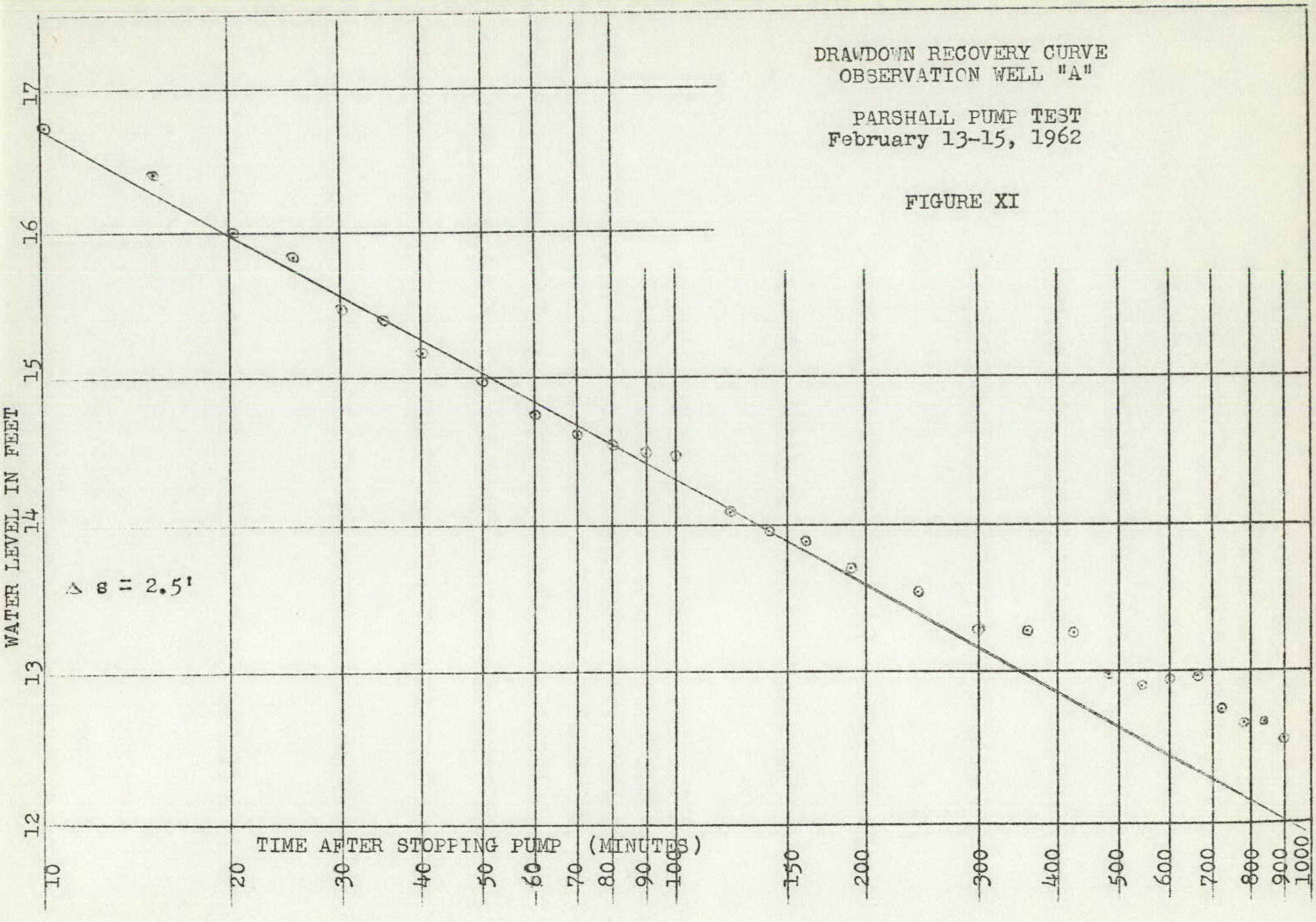
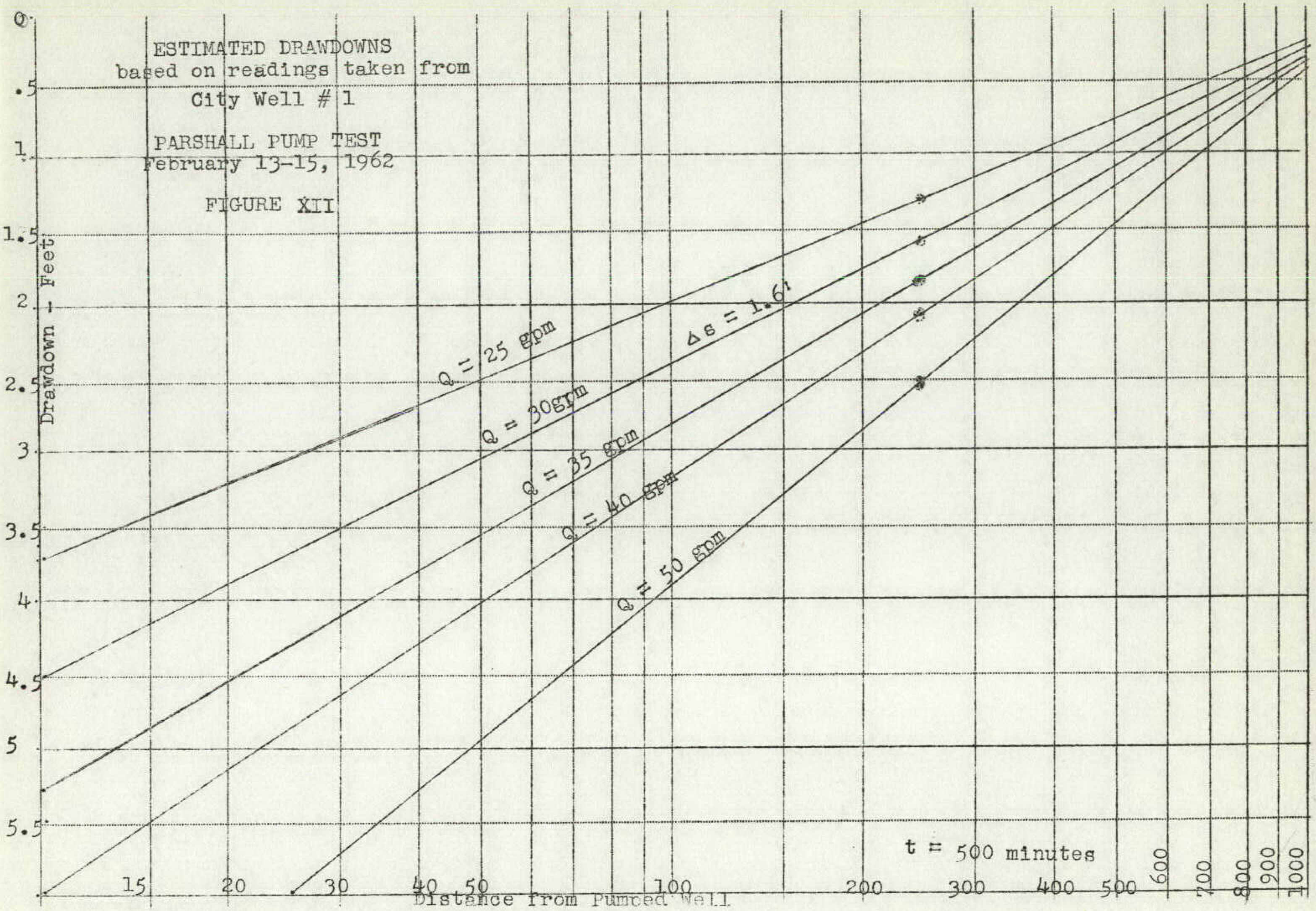

DRAWDOWN RECOVERY CURVE
OBSERVATION WELL "A"
PARSHALL PUMP TEST
February 13-15, 1962
FIGURE XI
WATER LEVEL IN FEET
TIME AFTER STOPPING PUMP (MINUTES)
Δ s = 2.5'
17
16
15
14
13
12
10
20
30
40
50
60
70
80
90
100
150
200
300
400
500
600
700
800
900
1000

Figure 12 was compiled in an effort to show anticipated drawdown at various pumping rates and the data from City Well #1 was used as a basis since this well should provide the most reliable data from the pump test. It will also show the possible interference that one could anticipate by enlarging the present well field and it also explains the reason for the intermittent pumping operation that takes place when all three of the present city wells are in operation. The curves compiled in Figure 12 are based on the principle that the drawdowns anticipated are directly proportional to the rate used in the pumping test. An example in applying this chart would be that if the drawdown in City Well #2 is 54 feet at 30 gallons per minute and City Well #1 is pumped at 40 gallons per minute one could expect the drawdown in City Well #2 to be increased by 2.1 feet or the drawdown or water level in City Well #2 would be 56.1 feet. The present conditions in City Well #2 indicate that the pump installed in the well is rated at 50 gallons per minute and as a result the drawdown during pumping is near the limits of the electric control shutoff for maximum drawdown. When City Well #1 is started the added drawdown due to its cone of influence causes the drawdown in Well #2 to exceed its allowed maximum and the automatic controls shut off the pumps and the intermittent operation results. This problem could be alleviated by having pumps with reduced capacities installed which would take into consideration the interference from adjoining wells so that they could operate continuously.

It is the opinion of the writer on the basis of the pump test that if the City Officials ever anticipate expansion of the present well field that they space their future wells not less than 600 feet from any existing wells to somewhat reduce the interference effects the wells would have on each other. It is also recommended that future pump installation be put in at approximately 60% of the maximum pumping capacity. Generally speaking, a pump test run on a new well is made while other wells in a well field are shut off and as a result the maximum gallonage is higher since it does not reflect the true conditions under which the well will operate because no interference is present as when the adjacent wells are in operation. A new pump installed based on this initial data then suddenly becomes overrated for the well and as a result the new well is taxed heavily during pumping and could even cause a well failure due to the added burden placed upon it should the automatic safety controls normally installed in city wells fail to function.

It should also be pointed out that the pump test should probably have been run for a longer period of time to better predict the safe withdrawals that can be made on the aquifer but the results to point out the current interference between wells and that in the future greater spacing of wells should be kept in mind.


ESTIMATED DRAWDOWNS
based on readings taken from
City Well # 1
PARSHALL PUMP TEST
February 13-15, 1962
FIGURE XII
Drawdown - Feet
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
Q = 25 gpm
Q = 30gpm
Q = 35 gpm
Q = 40 gpm
Q = 50 gpm
Δs = 1.6
t = 500 minutes
15
20
30
40
50
100
200
300
400
500
600
700
800
900
1000
Distance from Pumped Well

REFERENCES

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Charting Performance of Water Wells, Johnson National Drillers Journal, Vol. 31, No. 3, (1959).

Cooper, H. H. and Jacob, C. E., A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History, Transactions American Geophysical Union, Vol. 27 (1946), Washington, D. C.

Jacob, C. E., Recovery Method of Determining Permeability, Unpublished Memorandum, (1946).

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TABLE 1.-------

Analyses in parts per million except pH

Location	Sample Source	Depth (feet)	Analyst a/	Iron Fe	Calcium Ca	Magnesium Mg	Sodium Na
151-89 6 bb	Open Pit Coal Mine		State				
151-90-14aca	John Bartleson	Spring	Health	0.2	13	9	502
152-89-29ccc	Spencer Estvold	30	State	1.2			
152-89-29dad	T. H. 8-791	54	State	2			
152-89-30dbd	Seepage on E. Fork Shell Creek		State	0.8			
152-89-30ddb	T. H. 13-791	71	Health	3.6	20	41	735
152-89-31bbb	Caroline Nelson	30	State				
152-90- 8acd	T. H. 28-791	38	State	2.7			
			Health	2.3	52	30	437
152-90-25ccc	Slaughterhouse	14	Health	8.4	188	104	540
152-90-25dbc	City Well #4		State	2			
152-90-25d	City (Feb. 2,1962)		State	1.5			
152-90-25ddc	T.H. 25-791 (Flow)	125	State	19.4			
152-90-25ddc	City Well #2	77	State e/	2.7			
152-90-26cdd	T. H. 20-791	17	State	2.5			
152-90-26ddc	T. H. A30-791	17	State	1.1			
			Health	.8	48	22	378
152-90-27ddd	T. H. 26-791	12	State	1.6			
			Health	2.3	80	36	305
152-90-33bbb	East Fork Shell Creek		State	0.8			
152-90-33caa		Spring	State	0.4			
152-90-36aaa	T. H. 3-791	63	Health f/	2	29	29	793
152-90-36abb	T. H. A16-791	34	Health	2.8	108	86	691
152-90-36abb	City (Aug. 26, 1959)g/	60	Health f/	1.3	92	62	938
152-91-24cdd	Edward Evenson	60	State	2.7			
152-91-26add	Gehard Stenerson	70	State	0.9			
			Health	0.25	48	30	238

a/ Analyses done by the State Laboratories Department (State) or North Dakota State Department of Health (Health).

b/ North Dakota State Department of Health analyses converted from HCO_3,

c/ State Health Department TDS are obtained by summation of ions while the State Laboratories Department obtains TDS by evaporation or in some cases TDS are calculated from Electrical Conductivity. The evaporation method gives the most reliable results.

d/ Calculated from Electrical Conductivity.

e/ Average of 4 analyses of samples taken during pump test of Well #2.

f/ Average of 2 analyses.

g/ This well was closed down as a result of these analyses.

Chemical Analyses of Water From the Parshall Area

Bicarbonate b/ $CaCO_3$	Carbonate $CaCO_3$	Sulphate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3	Total Hardness $CaCO_3$	Total Dissolved Solids c/	pH
		2113				940	3826 d/	
691	Absent	450	2		Absent	70	1818	7.95 @ 20°C
772	Absent	1411	42		4	680	2856	7.4 @ 23°C
936	Absent	1006	28		Absent	340	2324	7.6 @ 23°C
860	Absent	1177	28		Absent	640	2394	7.2 @ 23°C
651	Trace	1100	20	0.4	4	220	2713	8.55 @ 20°C
		963				260	2965 d/	
608	Absent	535	6		Absent	252	1387	7.6 @ 20°C
632	Absent	550	25		Trace	255	1843	7.7 @ 25°C
795	Absent	1200	20		Trace	900	3022	7.65 @ 25°C
780	Absent	578	16		Absent	230	1712	7.5 @ 25°C
883	Absent	904	28		Trace	260	2275	8 @ 23°C
1,480	Absent	Trace	176		Trace	100	2416	8.2 @ 21°C
833	Absent	850	70		Absent	230	2225	7.5 @ 21°C
692	Absent	928	42		Trace	272	2041	7.6 @ 23°C
452	Absent	562	8		Absent	220	1275	7.5 @ 20°C
460	Absent	550	5		Trace	210	1564	7.65 @ 25°C
372	Absent	592	2		Absent	348	1214	7.5 @ 20°C
385	Absent	600	Trace		Trace	350	1491	7.65 @ 25°C
912	Absent	607	28		Trace	268	1810	7.8 @ 23°C
716	Absent	531	28		Trace	220	1503	7.6 @ 23°C
809	Absent	1050	12		Trace	193	2898	8.3 @ 20°C
715	Trace	1340	15	0.4	4	625	3116	8.2 @ 20°C
905	Absent	1640	16	0.4	22/Absent	483	3913	7.35
776	Absent	689	12		Trace	148	1827	7.6 @ 20°C
452	Absent	315	8		Trace	248	886	7.5 @ 20°C
470	Absent	280	5		11	240	1185	7.2 @ 25°C

TABLE 2.--Water Quality Standards
From North Dakota State Department of Health
Sanitary Engineering Services

Characteristic	Permissible Concentrations (Parts per million except pH)	Objections To Excessive Concentrations
Iron (Fe)	0.3	Esthetic Staining of Laundry
Magnesium (Mg)	125	Possible Laxative Effect
Sodium (Na)	250	Possible Physiological Effect
Sulphates (SO_4)	250	Possible Laxative Effect
Chloride (Cl)	250	Possible Laxative Effect
Fluoride (F)	1.5	Mottled Teeth
Nitrate (NO_3)	43.4	Possible Physiological Effect (toxic to infants)
Total Solids	1000-1500	Possible Laxative Effect
pH	Less than 10.6	Possible Laxative Effect

TABLE 3.--Logs of Test Holes

Formation	Material	Thickness (feet)	Depth (feet)
	151-90-3baa **T. H. 19-791**		
Glacial Drift:			
	Sand, gravelly to clayey, oxidized.......	6	6
	Till, light olive brown, oxidized........	6	12
	Till, olive gray.........................	19	31
	Sand, very fine to coarse................	5	36
Tongue River Formation:			
	Lignite..................................	3	39
	Clay, greenish gray to light bluish gray.	13½	52½
	152-89-27abb **T. H. 7-791**		
Glacial Drift:			
	Gravel, fine to coarse, sandy, oxidized..	8	8
	Till, moderate yellowish brown, oxidized.	4	12
	Till, olive gray.........................	20	32
	Sand, medium to very coarse, gravelly....	7	39
	Till, olive gray.........................	10	49
Tongue River Formation:			
	Clay, dark greenish gray, lignite seams..	3½	52½
	152-89-29dad **T. H. 8-791**		
Glacial Drift:			
	Gravel, fine to coarse, sandy, oxidized..	12	12
	Till, olive gray	34	46
	Gravel, fine to very coarse, sandy.......	8	54*
Tongue River Formation:			
	Clay, brownish gray and grayish blue green with lignite frag...............	19½	73½

*Water analysis

Formation	Material	Thickness (feet)	Depth (feet)

152-89-30aca
T. H. 11-791
Elevation 1949 ft.

Glacial Drift:			
	Topsoil, black..........................	2	2
	Sand, medium to very coarse, gravelly, and clay; oxidized..................	9	11
	Gravel, fine to coarse, sandy and sparse clay..........................	5	16
	Till, olive gray, shale granules........	6	22
	Sand, medium to very coarse with clay layers, olive gray..................	7	29
	Till, olive gray, sand lenses...........	13	42
	Till, olive gray........................	17	59
	Till, olive gray, gravelly..............	3	62
Tongue River Formation:			
	Sandstone, greenish gray, fine grained..	3	65

152-89-30bcc
T. H. 2-791
Elevation 1941 Ft.

Glacial Drift:			
	Till, moderate yellowish brown, oxidized	20	20
	Till, olive gray........................	10	30
	Sand, medium to coarse..................	4	34
	Till, olive gray; fine gravel...........	7	41
	Gravel, fine to coarse, sandy...........	5	46
	Till, olive gray........................	5	51
Tongue River Formation:			
	Sandstone, greenish gray, very fine lignitic seams with olive gray shale.	12	63

152-89-30cbc
T. H. 6-791
Elevation 1927 Ft.

Glacial Drift:			
	Sand, fine to very coarse, clayey to gravelly............................	4	4
	Till, moderate yellowish brown, oxidized	1	5
	Till, olive gray to dark greenish gray..	20	25
	Sand, very fine to very coarse, clayey..	2	27
	Till, olive gray........................	2	29
	Sand, medium to very coarse, gravelly...	5	34

Formation	Material	Thickness (feet)	Depth (feet

152-89-30cbc
(Continued)

	Till, olive gray, shale granules........	5	39
	Gravel, fine, sandy.....................	3	42
	Till, olive gray........................	25	67
	Gravel, fine to medium, sandy...........	2	69
	Till, olive gray........................	7	76
	Sand, very fine to very coarse..........	13	89
	Sand, gravel & clay.....................	6	95
Tongue River Formation:			
	Shale, medium light gray................	10	105

152-89-30dba
T. H. 10-791
Elevation 1933 Ft.

Glacial Drift:			
	Sand, gravelly to clayey................	6	6
	Gravel, fine to coarse, sandy, darkstain	5	11
	Till, olive gray........................	6	17
	Sand, fine to very coarse, gravelly.....	22	39
Tongue River Formation:			
	Clay, light olive to greenish gray.......	24	63

152-89-30ddb
T. H. 13-791
Elevation 1936 Ft.

Glacial Drift:			
	Till, moderate yellowish brown, oxidized	11	11
	Till, yellowish gray, oxidized..........	5	16
	Till, olive gray........................	34	50
	Gravel, fine to coarse, sand............	11	61
	Sand, medium to very coarse, gravel.....	10	71*
	Clay (No sample)........................	2	73

152-89-31aaa
T. H. 9-791
Elevation 1964 Ft.

Glacial Drift:			
	Clay, yellowish gray, silty.............	6	6
	Till, moderate yellowish brown, oxidized	21	27
	Gravel, fine to coarse..................	5	32

*Water analysis

Formation	Material	Thickness (feet)	Depth (feet)
	152-89-31aaa (continued)		
	Gravel, fine to medium..................	6	38
	Gravel, fine to medium, clayey..........	7	45
	Clay (very poor samples)................	7½	52½
	152-89-31aba T. H. 12-791 Elevation 1940 Ft.		
Glacial Drift:			
	Topsoil, black..........................	2	2
	Till, moderate yellowish brown, oxidized.	14	16
	Till, yellowish gray, oxidized..........	7	23
	Till, olive gray........................	25	48
Tongue River Formation:			
	Clay, light to medium bluish gray........	15	63
	152-90-8acd T. H. 28-791		
Glacial Drift:			
	Silt, light olive gray, oxidized.........	6	6
	Gravel, fine to medium, sandy with dark stains on pebbles.....................	4	10
	Gravel, fine to coarse, sandy...........	28	38*
	Till, olive gray........................	27	65
	Sand, medium to very coarse, granules....	9	74
Tongue River Formation:			
	Clay, greenish gray	31	105
	152-90-14ddd T. H. 14-791		
Glacial Drift:			
	Till, grayish orange, gravel, oxidized...	8	8
Tongue River Formation:			
	Clay, moderate yellowish brown, oxidized.	4	12
	Clay, grayish yellow, oxidized..........	5	17
	Lignite.................................	2	19
	Clay, olive gray to light bluish gray and bluish green.....................	2	21

*Water analysis

Formation	Material	Thickness (feet	Depth (feet)
	152-90-24ddd T. H. 1-791 Elevation 1993 Ft.		
Glacial Drift:			
	Till, moderate yellowish brown, oxidized	9	9
Tongue River Formation:			
	Clay, dusky yellow, oxidized...........	7	16
	Clay, greenish gray....................	4	20
	Shale, grayish yellow and dusky yellow with lignitic seams..................	10	30
	Clay, greenish gray....................	16	46
	Sandstone, very fine to fine, medium bluish gray with lignitic seams......	12	58
	Shale, grayish yellow and dusky yellow with lignitic seams.................	5	63
	152-90-25abd T. H. 32-791 Elevation 1986 Ft.		
Glacial Drift:			
	Till, dark yellowish orange to moderate yellowish brown, oxidized............	28	28
Tongue River Formation:			
	Clay, light olive gray to olive gray with lignitic seams..................	10	38
	Clay, dusky yellow, sandy...............	4	42
	Shale, greenish gray....................	6	48
	Lignite................................	4	52
	Sandstone, medium bluish gray, fine......	13	65
	Shale, greenish gray, sandy with lignitic seams...............................	4	69
	Sand, grayish green, very fine to fine with shale moderate olive brown with lignitic seams................................	4	73
	Siltstone, pale green to dusky yellowish green with lignitic seams............	9	82
	Clay, light olive gray with lignitic seams	9	91
	Shale, greenish gray....................	9	100
	Sandstone, pale green, clayey...........	5	105

Formation	Material	Thickness (feet)	Depth (feet)
	152-90-25dbc **T. H. 31-791** **Elevation 1933 Ft.**		
Glacial Drift:			
	Gravel, fine to coarse, sandy, oxidized..	10	10
	Sand, fine to coarse, oxidized..........	7	17
	Rocks (?) probably very coarse gravel, oxidized............................	2	19
	Till, olive gray........................	30	49
	Sand, fine to very coarse with layers of fine to medium gravel.............	9	58
	Gravel, fine to medium, sandy with layers of pale olive clay..................	5	63
	Till, olive gray........................	9	72
	Gravel, fine to very coarse.............	8	80
	Till, brown black.......................	19	99
Tongue River Formation:			
	Shale, dark greenish gray...............	6	105
	152-90-25ddc **T. H. 25-791** **Elevation 1927 Ft.**		
Glacial Drift:			(flow)*
	Topsoil or fill, brownish black, sandy...	4	4
	Gravel, fine to coarse, sandy, oxidized..	4	8
	Till, olive gray........................	41	49
	Gravel, fine to medium..................	3	52
	Till, olive gray........................	11	63
	Gravel, fine, very sandy................	2	65
	Till, olive gray........................	3	68
	Gravel, fine to medium, sandy...........	5	73
	Till, olive gray with sand lenses........	10	83
	Till, olive gray with fine gravel lenses.	10	93
Tongue River Formation:			
	Clay, grayish green.....................	12	105
	152-90-25ddc **T. H. A 25-791** **Elevation 1927 Ft.**		
Glacial Drift:			
	Sand, very fine to medium, clayey, oxidized	4	4
	Gravel, fine to coarse, sandy, oxidized...	6	10
	Till, olive gray.........................	47	57

*Water Analysis

Formation	Materials	Thickness (feet)	Depth (feet)
	152-90-25ddc (continued)		
	Gravel, fine to medium..................	3	60
	Till, olive gray........................	1	61
	Gravel, fine, sandy.....................	2	63
	Till, olive gray with fine gravel lenses	9	72
	Gravel, fine to medium..................	7	79
	Till, olive gray with lenses of sand....	5	84

152-90-26cdd
T. H. 20-791
Elevation 1909 Ft.

Formation	Materials	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, medium gray, oxidized.............	5	5
	Sand, fine to very coarse, sparse clay..	6	11
	Sand, fine to very coarse, gravelly.....	10	21*
	Gravel, fine to coarse..................	2	23
	Till, olive gray........................	10	33

152-90-26ddc
T. H. 30-791**
Elevation 1918 Ft.

Formation	Materials	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Sand, fine to very coarse, gravelly, oxidized............................	15	15
	Gravel, fine to very coarse, oxidized...	2	17**
	Till, olive gray........................	8	25
	Sand, very fine to very coarse..........	13	38
Tongue River Formation:			
	Lignite with greenish gray clay lenses..	8	46
	Clay, olive gray with greenish gray areas	17	63

152-90-27caa
T. H. 23-791
Elevation 1905 Ft.

Formation	Materials	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, moderate yellowish brown, sandy, oxidized............................	5	5
	Clay, dark greenish gray to greenish gray, silty...............................	3	8
	Clay, yellowish gray, silty.............	3	11
	Till, olive gray,,,,,,,,,,,,,,,,,,,,,,,,	42	53

*Water analysis
**T. H. A 30-791 21' deep drilled for water sample.

Formation	Material	Thickness (feet)	Depth (feet)
	152-90-27caa (continued)		
	Gravel, fine to coarse.................	2	55
Tongue River Formation:			
	Lignite..............................	2	57
	Shale, dark greenish gray...............	7	64
	Clay, pale blue green, silty with greenish gray and dark greenish gray clay with lignite lenses............	18	82
	Sandstone, medium gray, very hard.......	2	84
	152-90-27ddd T. H. 26-791 Elevation 1909 Ft.		
Glacial Drift:			
	Clay, dusky yellow, oxidized...........	5	5
	Gravel, fine to coarse, sandy, oxidized.	2	7
	Gravel, fine to coarse, sandy..........	13	20*
	Till(?) rock at 22' abandoned hole......	2	22
	152-90-29add T. H. 24-791		
Glacial Drift:			
	Till, dark yellowish orange to moderate yellowish brown, oxidized...........	10	10
	Till, moderate yellowish brown to olive gray, partially oxidized............	52	62
	Clay, olive gray, limonitic areas.......	6	68
	Gravel, fine to medium, sandy, oxidized.	6	74
Tongue River Formation:			
	Sand, dusky yellow, clayey, oxidized....	12	86
	Sand, pale blue, clayey................	12	98
	Sandstone, very light gray.............	2	100
	Sand, greenish gray, clayey............	5	105
	152-90-33bbb T. H. 21-791		
Glacial Drift:			
	Clay, yellowish gray, sandy, oxidized...	4	4
	Gravel, fine to medium, sandy with medium gray stain on many pebbles..........	8	12

*Water analysis

Formation	Materials	Thickness (feet)	Depth (feet)
	152-90-33bbb (continued)		
Tongue River Formation: (?)			
	Clay, greenish gray (poor samples)......	21	33
	152-90-33bbc T. H. 22-791		
Glacial Drift:			
	Gravel, fine to very coarse, sandy, oxidized	23	23
Tongue River Formation:			
	Clay, greenish gray, (poor samples).....	37	60
	Sandstone...............................	2	62
	Clay, greenish gray.....................	1	63
	152-90-34bab T. H. 18-791 Elevation 1909 Ft.		
Glacial Drift:			
	Topsoil or fill.........................	3	3
	Till, grayish orange, oxidized..........	7	10
	Clay, dark yellowish orange, oxidized...	3	13
	Clay, olive gray........................	8	21
	Gravel, fine, sandy.....................	6	27
	Sand, clayey to gravelly, slightly oxidized clay........................	6	33
Tongue River Formation:			
	Clay, greenish gray, lignitic lenses.....	30	63
	152-90-35bac T. H. 27-791 Elevation 1918 Ft.		
Glacial Drift:			
	Till, dusky yellow, oxidized............	11	11
	Gravel, fine to coarse, sandy, oxidized..	7	18
	Till, olive gray........................	44	62
Tongue River Formation:			
	Shale, dark greenish gray...............	6	68
	Sandstone, greenish gray, fine to very fine................................	5½	73½

Formation	Material	Thickness (feet	Depth (feet)

152-90-36aaa
T. H. 3-791
Elevation 1932 Ft.

Glacial Drift:			
	Till, moderate yellowish brown, oxidized	16	16
	Till, olive gray, gravel...............	15	31
	Gravel, fine to coarse, sandy...........	10	41*
	Gravel, bouldery, poor samples..........	5	46
	Clay, light greenish gray to bluish gray, sandy, very poor samples............	17	63

152-90-3baba
T. H. 17-791
Elevation 1919 Ft.

Glacial Drift:			
	Sand, very fine to medium, silty, oxidized	6	6
	Sand, very fine to very coarse, silty.....	10	16
	Gravel, fine, very sandy.................	12	28
	Till, olive gray.........................	15	43
	Sand, medium to very coarse, granule gravel...............................	2	45
	Till, olive gray.........................	3	48
	Gravel, fine to medium, sandy............	12	60
Tongue River Formation:			
	Clay, greenish gray, lignitic seams.......	24	84

152-90-36abb
T. H. 16-791
Elevation 1919 Ft.

Glacial Drift:			
	Till, moderate yellowish brown, oxidized.	7	7
	Gravel, fine to medium, sandy, dark stained	24	31
	Clay, light bluish gray to medium bluish gray with brownish black clay with lignite seams (Tongue River Formation ??)	6	37
	Clay, olive gray.......................	20	57
	Gravel, fine to medium, sandy...........	3	60
Tongue River Formation:			
	Clay, light bluish gray with brownish black clay..............................	3	63
	Clay, pale green to grayish green with light olive gray sand stone..........	11	74
	Clay, greenish gray to dark greenish gray	31	105

*Water analysis

Formation	Material	Thickness (feet)	Depth (feet)
	152-90-36abb**		
	T. H. A16-791		
	Elevation 1919 Ft.		
Glacial Drift:			
	Sand, very fine to coarse, oxidized.....	5	5
	Gravel, fine, sandy, dark stained.......	6	11
	Gravel, fine to medium, sandy, dark stained............................	7	18
	Gravel, fine, sandy.....................	16	34*
	152-90-36abc		
	T. H. 15-791		
	Elevation 1950 Ft.		
Glacial Drift:			
	Topsoil, black.........................	2	2
	Gravel, fine, sandy, clayey, oxidized...	7	9
	Till, dark yellowish orange, oxidized...	9	18
	Gravel, fine to medium, sandy, oxidized.	2	20
	Till, olive gray.......................	60	80
Tongue River Formation:			
	Clay, greenish gray....................	4	84
	152-90-36add		
	T. H. 5-791		
	Elevation 1931 Ft.		
Glacial Drift:			
	Sand, very fine to coarse, silty, oxidized	7	7
	Sand, very fine to coarse, clayey........	4	11
	Sand, medium to very coarse, gravelly....	4	15
	Till, olive gray.........................	30	45
	Gravel, fine to medium, sandy............	5	50
	Till, light olive gray to olive gray.....	10	60
Tongue River Formation:			
	Shale, light bluish gray, silty, lignitic seams..............................	3	63

*Water analysis
**T. H. A16-791 150' south of 16-791 used to get water sample.

Formation	Material	Thickness (feet	Depth (feet)

152-90-36ddd
T. H. 4-791
Elevation 1977 Ft.

Glacial Drift:			
	Till, dark yellowish brown, sandy oxidized............................	6	6
	Till, moderate yellowish brown to dark yellowish orange, oxidized...........	8	14
	Till, dark yellowish brown to dusky yellowish brown, oxidized............	13	27
	Till, olive gray........................	10	37
Tongue River Formation:			
	Clay, light olive gray with lignite lenses................................	15	52
	Clay, pale blue green to grayish blue green................................	6	58
	Shale, light olive gray.................	5	63

152-91-13ccd
T. H. 33-791

Glacial Drift:			
	Sand, clayey to gravelly, oxidized......	5	5
	Sand, very fine to medium, clayey, partially oxidized..................	4	9
	Till, olive gray.......................	28	37
	Clay, olive gray to light olive gray....	7	44
	Gravel, fine to medium.................	15	59
	Till, olive gray to moderate olive brown	15	74
Tongue River Formation:			
	Shale, olive black with olive gray to greenish gray sandy clay; grayish green clay; and light olive brown silty clay.	10	84

152-91-25bbd
T. H. 29-791
Elevation Approximately
1855 Ft.

Glacial Drift:			
	Gravel, fine to coarse, sandy, oxidized..	8	8
	Till, moderate yellowish brown to dark yellowish orange, oxidized...........	5	13
	Till, olive gray........................	35	48
	Sand, gravelly..........................	4	52
	Gravel, fine to medium, sandy...........	16	68
Tongue River Formation:			
	Sandstone, greenish gray, very fine to fine	5½	73½