RESEARCH COUNCIL OF ALBERTA

Preliminary Report 62-5

RECONNAISSANCE GROUNDWATER STUDY
SWAN HILLS AND ADJACENT AREAS, ALBERTA

by

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Research Council of Alberta
Edmonton, Alberta
1962

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RECONNAISSANCE GROUNDWATER STUDY SWAN HILLS AND ADJACENT AREAS, ALBERTA

Abstract

This report presents preliminary information concerning the nature and occurrence of groundwater in the Swan Hills and adjacent areas, Alberta. Information included in the report consists of records of water wells, flowing seismic shot holes, and water quality analyses. In addition, a discussion of the geology, hydrology, aquifer testing, and well completion methods is presented.

To delineate the groundwater potential in specific areas, adequate test drilling and aquifer testing should be carried out to evaluate the areal distribution and thickness of aquifers, and their hydrologic characteristics.

Preliminary estimates indicate that the Cretaceous and Tertiary geologic environment is favorable for yielding groundwater in amounts up to 100 gallons per minute from a single water well. Larger quantities of groundwater may be present in surficial and buried sand and gravel deposits.

INTRODUCTION

This report presents preliminary information concerning the nature and occurrence of groundwater in the Swan Hills, Virginia Hills, Judy and Carson Creeks, and Kaybob oilfield areas of northern Alberta. These preliminary data are presented to serve as a guide in the search for groundwater to be used for pressure maintenance of the oil fields in this area.

Information included in this report consists of records of the water wells that have been drilled in the area, records of flowing seismic shot holes, and a discussion of the geology and aquifer testing methods. In addition, water well completion methods are discussed. Chemical analyses of groundwater and of some surface waters of the rivers and streams in the area are also included.

Most of the water well information, which is quite scanty, has been gathered since 1957, when widespread interest was focused on the oil-producing portions of the Swan Hills area, now the third-largest producing oil field in Canada.

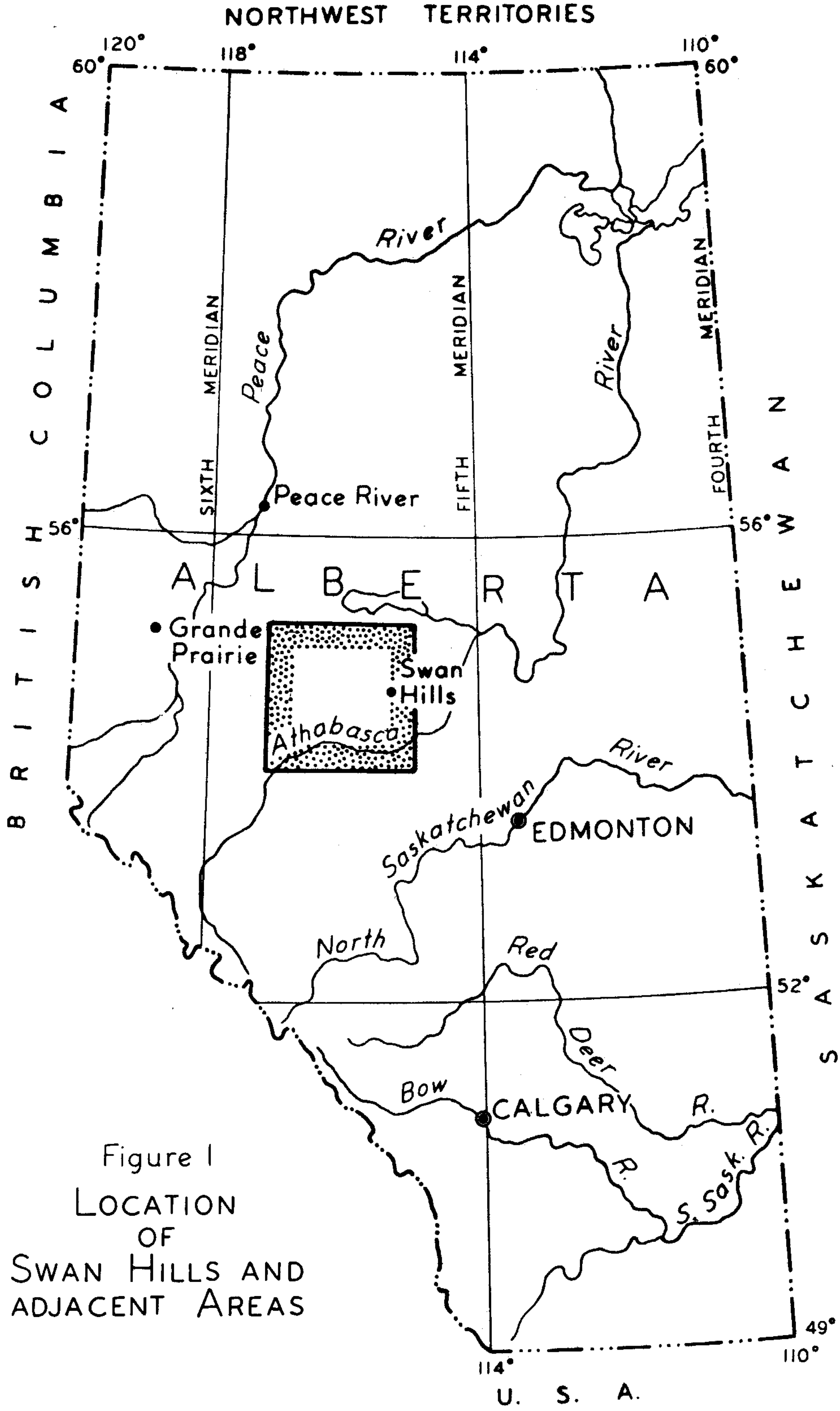

Figure I

LOCATION OF SWAN HILLS AND ADJACENT AREAS

Location

The Swan Hills area includes ranges 7 to 21 of townships 59 to 73, west of the Fifth Meridian (figure 1). The total area comprises about 8,100 square miles.

Climate

The climate of the Swan Hills area is similar to that of most of the Western Canada prairie. It is classified as a subarctic humid microthermal climate (Dept. of Mines and Technical Surveys, 1957, p. 30). The mean annual precipitation is about 18 inches (Dept. of Mines and Technical Surveys, 1957, p. 25).

Physiography

The Swan Hills, which commence twenty to thirty miles south of Lesser Slave Lake (elevation about 1,900 feet above sea level) rise to over 4,130 feet above sea level at Wallace Mountain, their highest point. They form an east-trending upland extending for 50 miles, steep on the north side facing Lesser Slave Lake and rolling on the southern flanks to the Athabasca River, which cuts across the southern portion of the area. The summit of the upland, although irregular in outline, is relatively flat, and lies at elevations ranging between 3,900 feet and 4,100 feet above sea level; the upland area thus lies between 2,000 and 2,200 feet above Lesser Slave Lake.

In the southwestern portion of the map-area lie the Virginia Hills, a much more subdued feature than the Swan Hills. Many rivers and streams dissect and drain the Swan Hills area in all directions. The major rivers are the Swan, Assineau, and Driftpile Rivers which empty into Lesser Slave Lake; the Iosegun and Goose Rivers which empty into the Little Smoky River; and the Freeman and Morse Rivers which empty into the Athabasca River. Small bogs, swamps and lakes are scattered throughout the area. The largest lakes are Snipe, Iosegun, and Meekwap lakes in the northwestern portion of the map-area. The largest lake in the central part of the Swan Hills area is Freeman Lake which lies at an elevation of about 3,600 feet above sea level on the southern slope of the Swan Hills in township 66, range 11. The whole area has a dense forest cover and in places is quite swampy. The combination of considerable flank relief, forest, and swamp, in places makes well site access roads in the area difficult to construct.

Maps and Accessibility

Access to the Swan Hills and Judy Creek oil fields can be made from a new all-weather gravelled highway that runs from Fort Assiniboine to the new townsite of Swan Hills. The Judy Creek oil field can also be reached from Whitecourt. The Virginia Hills and Carson Creek oil fields can be reached from Highway 43, northwest of Whitecourt. Private roads are maintained to many of the oil fields. These roads, under dry-weather conditions, are easily passable. Accessibility is best during the winter when the ground is frozen and poorest during spring breakup.

Up-to-date maps can be obtained from the Department of Lands and Forests in Edmonton (scale 1 inch to 4 miles) and these show oil well site roads, locations of seismic trails, oil and gas pipe lines, telephone lines, bridges, air strips, and lookout towers. The map sheets showing the access roads in the Swan Hills area are sheets 83 J, K, N, and O.

Previous Work

The earliest geological work of any consequence carried out in the Swan Hills area was that of Allan in 1918. He traversed the area and recorded his observations in Geological Survey of Canada Summary Report for 1918.

No additional geological work was done until the 1950's when oil exploration crews commenced work in the area. With the discovery of oil, considerable interest developed and oil fields have been subsequently established.

A test drilling program in which the writer was engaged to locate a suitable groundwater supply for the new townsite of Swan Hills was carried out in April, 1959.

Acknowledgments

The writer would like to thank the oil companies and water well drillers who co-operated generously in supplying much valuable information.

GEOLOGY

Introduction

The Swan Hills area is underlain by a series of nonmarine sandstones, shales, coals, and gravels of Cretaceous and Tertiary ages. The bedrock strata dip southwest into the Alberta syncline and thicken in the same direction. Exposures of bedrock can be found along the river valleys of the area, and along the uplands. Many recent exposures of sandstone, shale, and coal are visible in cuts along well site access roads. In many places the sandstones and shales along the uplands are capped by a veneer of coarse boulders and cobbles ranging from 1 or 2 feet up to 15 feet thick.

Surficial deposits of till, sand, gravel, silt, and clay are found on the flanks of the Swan Hills 600 to 800 feet lower than the upland areas. Some buried gravel deposits have been reported during the course of oil well drilling.

Cretaceous Strata

Belly River Formation

Below the Edmonton formation Allan (1919, p. 13 c) recognized a series of beds of freshwater origin containing seams of coal, which he thought corresponded to part of the Belly River series in central Alberta. He called these beds the "Sawridge formation". Recognition of continuity between these two groups of strata has resulted in an application of the term "Belly River" in the Swan Hills area.

Edmonton Formation

Allan (1919, p. 11 c) recognized the Edmonton formation equivalent beds in the Swan Hills. He placed the boundary between the Edmonton and the overlying Tertiary strata at about 3,300 feet above sea level on the Driftpile River, and estimated that about 650 feet of Edmonton formation were present. The following is a brief description given by Allan:

> The beds consist chiefly of sandstones, massive and thin-bedded, sometimes weathered into large nodular masses, arenaceous shales with bands of clay-ironstone nodules enclosing fragments of plants, semi-indurated clays, calcareous clay lenses in the shale and shaly sandstone, and numerous thin seams of coal. The thickest seams appear to lie at the top and also towards the base of the beds placed in this formation.

Tertiary Strata

Paskapoo Formation

Allan (1919, p. 10 c) described beds in the summit area of the Swan Hills that could be correlated with the Paskapoo formation farther south in Alberta. The total thickness of the strata amounted 1,020 feet. The following is the description of the Paskapoo beds given by Allan:

> The beds are varied in character, but indurated and semi-indurated clays, clay shales, arenaceous shales, thin beds of hard and soft grey and ferruginous sandstones, and hard scaly, highly calcareous shales predominate. The hard, calcareous shales form creamy coloured escarpments at various points around the summits of the upland, and are prominently exposed in House mountain and Deer mountain. Laminae of coal and thin layers of lignitic shale are common; also thin layers of dark shale enclosing carbonized and silicified fragments of wood 0 to 3 feet in length, 1 foot in width, and compressed to one inch or less, occur about the middle of the formation. There are certain beds of clay shales which absorb water and become soft, greasy, greenish muds.

In addition to Allan's information, recent subsurface data indicate that in the Swan Hills area there are thick sands at the base of the Paskapoo formation - a feature noted in other areas of Paskapoo formation outcrops (Rutherford, 1928, p. 12).

Upper Tertiary Strata

Allan (1919, p. 12 c) described a bed of coarse gravels varying from a few inches up to 15 feet in thickness and overlying the Paskapoo formation. These gravels consist for the most part of waterworn pebbles of almost pure white to yellow quartzite up to 6 inches in diameter. They are quite widespread, especially on the southern slopes of the Swan Hills, in places forming a thin veneer. Allan indicated that they might be preglacial in age and could possibly be correlated with the Miocene gravels capping similar uplands in the Cypress and Hand Hills elsewhere in Alberta. Russell (1958, p. 3) has suggested that fossil evidence from the Hand Hills conglomerate indicates a late Tertiary age for these strata and not Miocene as previously thought.

Recent Deposits

Surficial Deposits

Deposits of glacial gravels, sands, silts, clays, and till flank the summit of the Swan Hills but do not occur on the upland plateau. Generally these deposits lie at elevations below 3,500 feet. According to Allan (1919, p. 12 c) the summit and plateau of the Swan Hills appear not to have been glaciated.

Recent alluvial terraces of sand and gravel occur along the many rivers and streams of the area. Sand dunes that are found in many areas have been derived from glacial outwash materials.

Structure

Allan (1919, p. 10 c) noted that the strata in the upland regions lie in a general horizontal position or with a slight dip of a few feet per mile to the south and southwest. He noted local rolls of minor importance.

In addition to the regional structure, Allan (1919, p. 10 c) noticed that large-scale slumped blocks were present along the large trunk valleys of the area. Some block were up to 100 feet in thickness, about 1,000 feet in depth, and one-quarter to three-quarters of a mile in length. This phenomenon was also noted during the present study, and its presence in many cases could lead to difficulty in local stratigraphic correlation, specifically that of shallow aquifers.

HYDROLOGY

General Statement

The hydrologic characteristics of an aquifer are commonly expressed in terms of the coefficients of transmissibility and storage (Theis, 1935). These constants may be determined from the analysis of aquifer pumping test data, which can also be used to determine the location and effect of hydrologic boundaries that affect groundwater movement. Observations of the changing water level in the pumping well alone are sufficient for the calculation of the coefficient of transmissibility, but one or more observation wells are required if the coefficient of storage is to be calculated. The number of observation wells selected is dependent on the complexity of the hydrologic situation. In general, this number increases along with the number of known local hydrologic boundaries that may have an effect on the pump test. Such boundaries include lateral changes in permeability within an aquifer and boundaries between an aquifer and any body of water, such as a lake or stream, serving as a source of recharge.

The coefficient of transmissibility of an aquifer is defined as the rate of flow of water in gallons per day through a vertical strip of the aquifer one foot wide under a unit hydraulic gradient. Stated in another way, the transmissibility is the product of the thickness and the permeability of the aquifer.

The coefficient of storage is defined as the amount of water, in cubit feet, that will be released from storage in a vertical column of an aquifer with a height equal to the thickness of the saturated portion of the aquifer, divided by the product of the cross-sectional area of the column and the change in head causing the release of water from storage.

For artesian conditions, the values of the storage coefficient lie somewhere between 1×10^{-3} and 1×10^{-4}. Most commonly a storage coefficient of about 5.0×10^{-4} has been observed for Alberta Cretaceous and Tertiary confined aquifers.

Theis Nonequilibrium Formula

The nonequilibrium formula (Theis, 1935) expressing the drawdown in the vicinity of a pumping well, is used in calculating the coefficients of transmissibility and storage. This formula cannot be used in the analysis of water level variations in the pumping well but is applicable to those in any observation well. The formula is based on certain assumptions: (1) the aquifer is homogeneous and isotropic; (2) the aquifer has infinite areal extent; (3) the discharge well penetrates and receives water from the entire thickness of the aquifer; (4) water taken from storage in the aquifer is discharged instantaneously with a decline in head; (5) the coefficient of transmissibility is constant at all times and at all places; and (6) the diameter of the well is infinitely small. The nonequilibrium formula may be written:

$$s = \frac{114.6\ Q}{T} W(u) \qquad (1)$$

where $$W(u) = \int_{u}^{\infty} \frac{e^{-x}}{x}\, dx$$

$$= -0.577216 - \log_e u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} - \frac{u^4}{4.4!} + \ldots \qquad (2)$$

and $$u = \frac{1.56^{*}\ r^2 S}{Tt}$$

s = drawdown in feet at the observation well
Q = discharge of well in imperial gallons per minute (gpm)
T = coefficient of transmissibility, in imperial gallons per day per foot (gpd/ft)
r = distance in feet from the observation well to the pumping well
S = coefficient of storage (dimensionless)
t = time in days since pumping started

Values of W(u) for values of the argument u from 10^{-15} to 9.9 have been worked out by Wenzel (1942, p. 88).

Determination of T and S, using the Theis nonequilibrium equation, involves a process of curve-matching (see Todd, 1959, p. 90), the first curve representing the observation well results and the second a standard W(u) curve.

Strictly, the Theis equation and equations derived from it are not applicable if there is natural recharge to the aquifer. Generally, in Alberta, however, natural recharge contributes so little to storage during the period of the usual pump test that, provided there are no hydrologic boundaries to be taken into account, the Theis equation may be used to deduce the aquifer constants. When this is the case, the fact that natural recharge may become a significant factor during the production life of a well merely represents a safety factor of undetermined magnitude in the calculation of the safe pumping rate for this period.

Modified Nonequilibrium Formula

The modified Theis equation developed by Jacob (1950) is derived from the Theis nonequilibrium equation. This equation is useful in analyzing the drawdown measurements in a pumping well and, in certain cases, the measurements in observation wells, in order to compute the coefficient of transmissibility of the aquifer.

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* 1.56 is the value for imperial gallons, as compared to 1.87 when U.S. gallons are used in the calculations.

This formula is stated:

$$T = \frac{264\ Q}{\Delta s} \qquad (4)$$

where Δs = drawdown in feet in the well per log cycle of time, and T and Q are as previously defined in equation (1).

In using the modified formula to determine T, drawdown is plotted against time on semilogarithmic paper, the latter being plotted on the logarithmic scale.

Theis Recovery Formula

The Theis recovery formula, used in analyzing the recovery of a previously pumping well, is almost identical to equation (4):

$$T = \frac{264\ Q}{\Delta s'} \qquad (5)$$

where $\Delta s'$ = residual drawdown in feet per log cycle of time. This formula is applied in a similar way to equation (4).

Well and Well Field Design

The aquifer coefficients, T and S, which can be determined only by properly designed pumping and recovery tests, are used to estimate the amount of water that can be produced safely over a given period of time from a well or wells completed in the aquifer. When two or more wells are involved, mutual interference among wells can be calculated. Such calculations are essential if well spacings and production rates are to be selected that will result in the most efficient utilization of the groundwater resources. This is true not only for the development of municipal supplies, but also for the development of supply wells for oil field pressure maintenance. In the former case, it is customary in Alberta to base calculations on a safe production period of 20 years; in the latter, the period may range from 5 to 40 years.

When sufficient data are available, equation (1), into which the values of T and S derived from the pump test are substituted, is used to calculate well spacings and safe production rates. If, however, the hydrologic information is limited, more approximate methods must be used, and they generally result in estimates of these quantities that are somewhat less precise. This situation would arise, for example, if a test were conducted, without observation wells, in an aquifer in which there were no nearby producing wells.

The following equation, derived from the Theis modified nonequilibrium equation (4), is useful for computing the safe pumping rate for such a well:

$$Q_s = \frac{T \times H}{1848} \qquad (6)$$

where Q_s = safe production rate in imperial gallons per minute
H = total available drawdown
T = transmissibility determined from pumping test

The equation is derived by substituting $H/7$ for Δs, in equation (4), thus stipulating that it takes seven log cycles of time, or 20 years, for the total available drawdown to be used up. This method of computation may be used only for a single well. It does not take into account well loss, interference between wells or the storage coefficient, and thus at best can serve only as a useful guide. Commonly, but not always, a safety factor of 0.7 is used in determining the final safe rate. Its use depends on the type of available data and the purpose for which the well might be used.

An example of the calculation of the interference between wells and of safe pumping rates, based on pumping test results for a municipal supply well in the new Town of Swan Hills, is given in appendix A. The safe pumping rate, calculated using the Theis nonequilibrium formula, is compared with that computed by equation (6).

Pump Tests in Confined Aquifers

In the Swan Hills area, confined aquifers are limited to sandstone beds and coal seams in the Paskapoo, Edmonton, and Belly River formations. The water in a confined aquifer is under pressure and rises above the aquifer to some height in a well perforating it. To evaluate the hydrologic conditions and determine the aquifer coefficients, generally a minimum of one pumping well and one observation well is required. In some cases more observation wells may be required, especially when hydrologic boundaries are encountered. The minimum length of time for the test should be 48 hours.

Aquifers of this nature commonly require well spacings of 1,000 to 2,000 feet or more to produce water safely.

Pump Tests in Unconfined Aquifers

In the Swan Hills area, groundwater also occurs in unconfined or water table aquifers, in which the water is not under pressure and where the water level in a well represents the true elevation of the water table. When a well in such an aquifer is pumped, part of the aquifer is actually dewatered to provide water to the well. The most common aquifers of this type are the sands and gravels in alluvial terraces adjacent to rivers and streams in which the water table fluctuates with changes in river or stream flow.

The arrangement of the observation wells about a pumping well completed in an unconfined aquifer is more complex than that for a confined aquifer and requires more observation wells, the number depending upon the geologic and hydrologic situation.

There is no set minimum length of time a pumping test has to be carried out for an unconfined aquifer, but measurements of the drawdowns in the pumping and observation wells have to be taken for a sufficient period of time to ensure that equilibrium conditions have been established, that is, the water levels have become stabilized, usually for a minimum period of 24 hours. The total length of a pumping test in an unconfined aquifer may range from several days to a week or more. Only after the necessary basic data have been collected can a well or system of wells be satisfactorily designed.

Step Drawdown Tests for Wells in Confined and Unconfined Aquifers

To evaluate the efficiency of a water well and its degree of development, a step drawdown test (Bruin and Hudson, 1958) is usually carried out on the completed production well after the constant rate pumping test. This is a short 3-hour test. The procedure is outlined in appendix B.

The information obtained from the step drawdown test will indicate whether more development should be carried out in order to obtain maximum efficiency, or whether the well is being pumped at too high a rate, thus causing turbulent flow. In particular, the latter effect may be important in the case of a screened well.

Apparent Transmissibilities

Farvolden (1961, p. 10), in a recent study of water wells used in secondary recovery in the Pembina oil field, has suggested a classification of the Tertiary Paskapoo formation strata on the basis of aquifer characteristics determined from recovery measurements and pumping test data. The aquifer has been divided into areas of different "apparent transmissibility" and hence of different groundwater potential. His conclusions were based on the drawdown during a production test that is conducted on nearly every water well after it is completed. The reports of these tests state only the initial or static water level in the well and the water level at the end of the test, along with the pumping rate that was used.

The drawdown at the end of each test was plotted against the logarithm of the time of the test in minutes and the transmissibility calculated according to the modified Theis equation. The classification in table 1 is modified from Farvolden (1961, p. 10).

Table 1. Classification of apparent transmissibilities

POOR	0 - 300 gpd/ft. Some success can be expected with developing wells that will produce adequate quantities of water for injection supply (200 - 400 bpd*). This development is possible only where the hydraulic head within the aquifer is high, so that the available drawdown is large. The cone of influence does not interfere too much with neighboring wells.
GOOD	300 - 1,000 gpd/ft. In a "good" area more water can be withdrawn from wells than in a "poor" area, but the cone of influence has a much greater radius and the influence on production of distant wells is greater. This influence may be real and measurable, but not harmful to any well owner.
VERY GOOD	1,000 - 3,000 gpd/ft. Most wells of this classification are capable of producing more than 2,000 bpd or 50 gpm, and are usually completed in thick massive sandstone beds of the Paskapoo formation.

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* bpd = barrels per day. 1 barrel = 35 imperial gallons.
1 gpm = 41.1 bpd.

The few apparent transmissibility values that are available for the Swan Hills area are presented in table 2 and have been plotted on the accompanying map (plate 1), for areal comparison. At the present time the data are too sparse to delineate "poor", "good" and "very good" areas.

Table 2. Apparent transmissibilities, Swan Hills area
(data obtained from drillers' logs)

Lsd.	Sec.	Tp.	R.	Apparent transmissibility (gpd/ft)
12	29	61	18	792
4	16	62	19	650
4	10	63	10 ?	1056
4	30	63	10	2640
16	31	63	10	116
4	33	63	10	17
4	13	63	11	310
10	13	63	12	396
10	24	63	12	1130
2	6	64	10	440
10	6	64	10	282
4	11	64	10	94
4	22	64	11	57
10	26	64	11	2640
10	27	64	11	34
4	29	64	11	158
4	31	64	12	180
2	34	64	14	140
NE 1/4	18	64	18	1980
2	4	64	19	264
4	16	65	13	660
4	19	65	13	2640
-	14	66	10	1131
-	14	66	10	1320
	14	66	10	485
SW 1/4	23	66	10	790
4	4	67	11	264
SE 1/4	33	70	10	21
16	30	72	21	35
7	25	73	12	112
12	26	73	12	845

Generally, the apparent transmissibility values calculated from water well drillers' bail and pumping test data are lower than the actual transmissibility values calculated from tests in which complete series of water level measurements are available.

In most cases, the aquifer constants in the Swan Hills area, up to date, have been computed from water wells that have been finished for oil rig water supplies. These wells are generally considered to be only temporary and, consequently, proper well development, completion practices, and aquifer testing have not been carried out on the majority.

Results from a pump test on one of the water wells for the new Town of Swan Hills can be used (appendix A) to demonstrate that the calculated apparent transmissibility computed from a single measurement of drawdown of the water level at the end of a given period of time, at a known pumping rate, may be only about 35 per cent of the transmissibility computed from a properly carried out aquifer pumping test. The computed apparent transmissibility was 790 gpd/ft, while the actual transmissibility, estimated from an aquifer pumping test, was 2,200 gpd/ft. Other pump tests indicate that it can be an even smaller fraction of the true transmissibility.

Figure 2 is a diagrammatic comparison of the transmissibility computed from a single drawdown measurement and of that obtained from a series of measurements from a proper pumping test carried out over a period of 24 hours. In this example the apparent transmissibility is about 80 per cent too low.

The apparent transmissibilities plotted on plate 1 should be considered only as a rough guide, as adequate testing at each water well site has to be carried out before any precise prediction can be made of the amount of groundwater that can be developed. Apparent transmissibilities are useful only on a general comparative basis and when the bail or pumping tests have been carried out over the same time interval.

As the search for groundwater in the Swan Hills area progresses and proper aquifer pumping tests are carried out, the actual transmissibility values can be plotted, and these will give a more precise picture of favorable trends for groundwater exploration, development, and production.

Vertical Head Loss

Generally, as the depths of the wells increase, there is a significant decrease in the static water level, so that groundwater production costs increase with depth. If a near-surface aquifer can be developed, it is more desirable than developing an aquifer at depth.

Head changes that take place with increasing depth are generally as follows: for wells drilled on or near topographic highs, the available head decreases with depth; for wells drilled in topographic lows, the head increases with depth. In the Swan Hills area most wells will probably be drilled on or

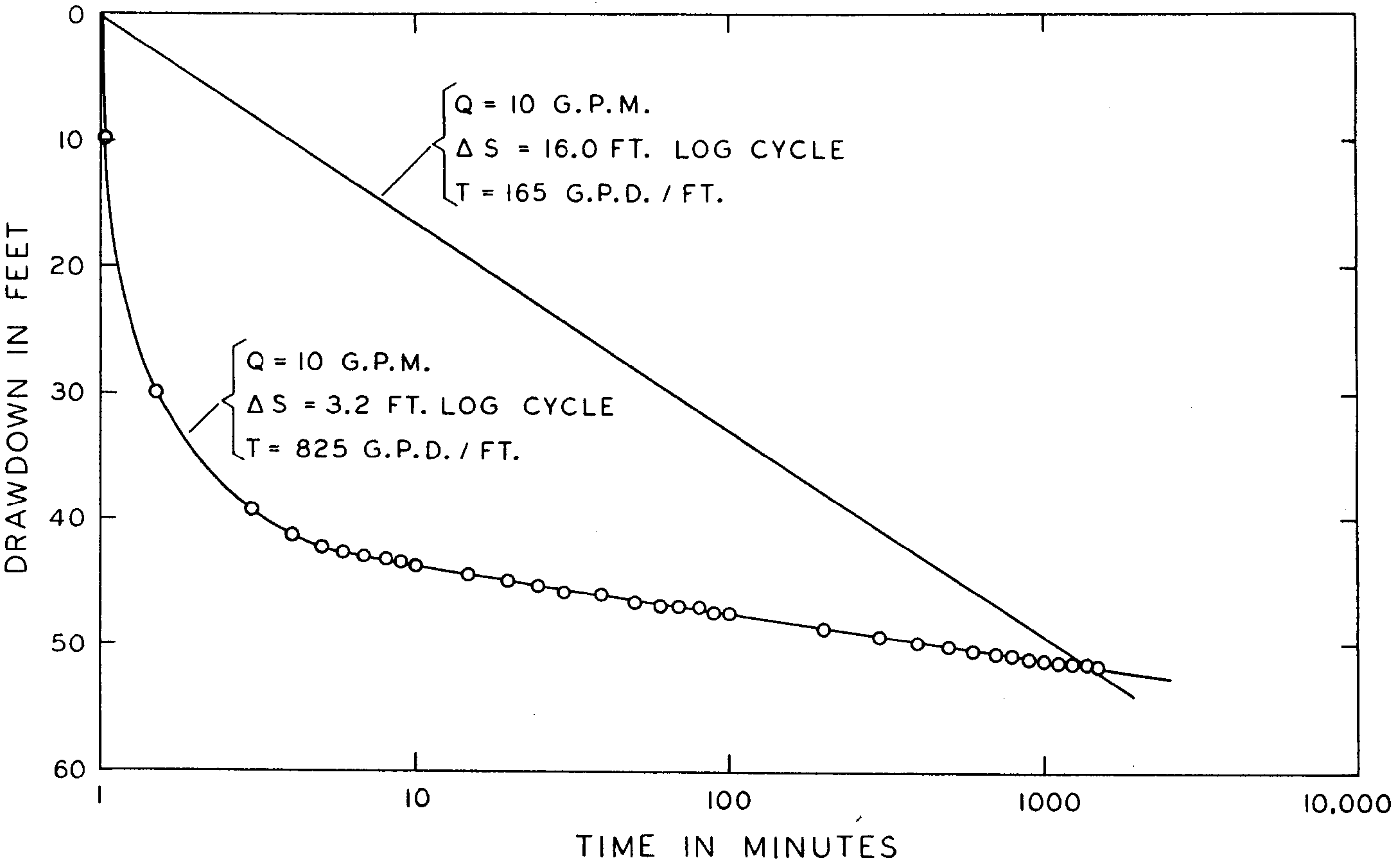

Figure 2. Apparent and actual transmissibility

near topographic highs, and thus head loss with depth is more likely to be encountered. In other words, the amount of available drawdown will usually decrease with depth. Farvolden (1961, p. 16) has discussed this phenomenon in the Pembina district, and Meyboom (1961) in the Calgary district.

An important feature to be watched for is that of thief sands; that is, a sand may have a lower hydrostatic head than a water-producing sand above it. If an aquifer is developed above such a zone, and if the well is drilled deeper in search of a lower zone to increase production, water may then be lost to the lower (thief) sand (Bennett and Patten, 1960).

Groundwater Recharge

In any aquifer the amount of groundwater that can be permanently produced without taking water from groundwater storage and lowering the water level in the wells is the amount of water that enters the aquifer as natural recharge. At present, insufficient data are available for the Swan Hills area to permit the making of quantitative estimates of the amount of groundwater that can be obtained per square mile. As more groundwater development work is done, and additional information becomes available on water level fluctuations in observation wells, it will be possible to construct a piezometric surface for the area. For this purpose, a fairly extensive network of wells will be needed because of the considerable topographic relief, and because of the lateral changes in the continuity of aquifers.

It is suggested that one observation well per township, with or without a water level recorder, in each aquifer that is developed for a water supply for pressure maintenance of oil wells, would help to give the required information for determining the amount of groundwater recharge and discharge. This should be in addition to production and water level records kept on supply wells. In addition, some consideration should be given to the collection of meteorological data throughout the whole year in the Swan Hills area. Stream gauges should also be established on some of the rivers to measure their discharge.

AQUIFER POTENTIALS IN THE SWAN HILLS

Edmonton and Belly River Formations

In other areas of the Province, wells in the Edmonton and Belly River formations are generally capable of producing up to 20 gpm. It seems reasonable to suggest that wells in these strata in the Swan Hills area on the basis of their apparent transmissibilities should be capable of providing comparable amounts of water. The aquifers should, however, be tested thoroughly at each site.

Paskapoo Formation

From preliminary tests in the area, the groundwater potential of the Paskapoo formation is considered to be quite good for quantities up to 100 gpm from one water well (4,100 bpd). The thick basal sands in the Swan Hills area are potentially high producers. The new Town of Swan Hills has water wells completed in thin sandstones of the Paskapoo formation and the present production of each of the town wells is about 20 gpm.

Alluvial Terraces

It may be possible to develop very high-capacity wells in alluvial terrace sands and gravels by induced infiltration adjacent to present rivers and streams. If there is a sufficient saturated thickness, production of a water well completed in sands and gravels could be in excess of 100 gpm.

Buried Valleys

Buried valleys containing sands and gravels may possibly be present in areas away from the summit of the Swan Hills. At present there are no definitely known valleys, but some oil well drillers have reported gravels and sands at depth in some areas. Where these are found, potential groundwater production could be quite large. Records of seismic shot hole logs may show locations of some of these buried gravels.

WATER COMPOSITION

The composition of groundwater shows considerable variation throughout Alberta and depends on the type of materials that the groundwater has encountered in its migration to the water-bearing zone. The amounts of the individual dissolved mineral constituents and various combinations of the constituents are usually expressed in water analyses in parts per million (ppm).

Generally in Alberta hard waters occur in glacial and Recent deposits, and soft water in the bedrock. Fresh water percolating downward through the glacial materials picks up calcium and magnesium. When these hard waters enter bedrock containing a high content of the clay mineral montmorillonite, the calcium and magnesium are exchanged for sodium and the water becomes softer.

A comparison of chemical analyses of groundwater from the Paskapoo formation (new Town of Swan Hills water supply) with water analyses from the Morse and Freeman Rivers is shown in table 3.

Table 3. Water analyses

	Parts per million		
	New Town of Swan Hills	Morse River	Freeman River
Total solids	288	188	130
Ignition loss	46	102	74
Hardness	10	80	50
Sulfates	38	23	16
Chlorides	trace	trace	trace
Alkalinity	170	80	50
Nature of alkalinity	Bic. Na	Bic. Ca & Mg	Bic. Ca & Mg
Nitrites	nil	nil	trace
Nitrates	nil	nil	trace
Iron	0.6	2.0	1.0
Remarks	Soda 11.9 grains/gallon		

WATER WELL DRILLERS' LOGS AND RECORDS OF FLOWING SEISMIC SHOT HOLES

Water well drillers' logs submitted from the Swan Hills area are presented in appendix D. The corresponding well locations are plotted on the accompanying map (plate 1) along with the locations of flowing seismic short holes (1954 to 1961). In addition, apparent transmissibilities are plotted for the water wells for which they are available.

RECOMMENDATIONS AND CONCLUSIONS

Preliminary information indicates that the Cretaceous and Tertiary geologic environment is favorable for yielding groundwater in amounts up to 100 gpm from a single water well for pressure maintenance of oil fields in the Swan Hills area. Larger quantities of groundwater may be present in surficial and buried sand and gravel deposits.

Adequate test drilling and aquifer testing should be carried out to evaluate the areal distribution and thickness of the aquifers and their hydrologic characteristics. Proper water well development procedures should be used at all times to develop the groundwater resources to their maximum. Complete aquifer pumping test records should be submitted along with the regular "Completion and Testing Report for Wells Drilled to Supply Water for Injection Purposes" supplied by the Oil and Gas Conservation Board, in order that the true transmissibilities and storage coefficients of the aquifers can be computed. This will be of considerable help in delineating favorable areas for groundwater development. In addition, it will be useful in the estimation of the safe spacing between wells and determination of the amount of interference between adjacent wells.

Observation wells should be located on a spacing of one per township in each aquifer to keep a check on the water levels in the aquifers as development proceeds.

Electric logging of oil field development wells before the surface casing is put in would aid considerably in the location and correlation of shallow potential aquifers from which groundwater might be developed. This procedure would cause little inconvenience and would aid considerably in the development of groundwater in the Swan Hills area for pressure maintenance.

REFERENCES CITED

Ahrens, T. P. (1957): Well design criteria; Water Well J. Sept. and Nov., reprint, 8 pages.

Allan, J. A. (1919): Geology of the Swan Hills in Lesser Slave Lake district, Alberta; Geol. Surv. Can. Summ. Rept. 1918, pt. C, p. 7c-13c.

Allan, J. A. and Rutherford, R. L. (1934): Geology of central Alberta; Alberta Sci. Indust. Res. Coun. Rept. 30, 41 pages.

Anderson, K. E. (1955): Water well handbook; Missouri Water Well Drillers Assoc., Rolla, Missouri, 199 pages.

Atlas of Canada (1957): Dept. Mines and Technical Surveys, Geographical Br., p. 25 and 30.

Babbit, H. E. and Doland, J. J. (1955): Water supply engineering; McGraw-Hill Book Co., Inc., New York, 608 pages.

Bennett, G. D. and Patten, E. P. (1960): Borehole geophysical methods for analyzing specific capacity of multiaquifer wells; U. S. Geol. Surv. Water Supply Paper 1536-A, 25 pages.

Bruin, J. and Hudson, H. E. Jr. (1958): Selected methods for pumping test analysis; Illinois State Geol. Surv. Rept. Investig. 25, 2nd printing, 54 pages.

Farvolden, R. N. (1961): Groundwater resources Pembina area, Alberta; Res. Coun. Alberta Prelim. Rept. 61-4, 25 pages.

Jacob, C. E. (1950): Flow of ground water; in Engineering hydraulics (H. Rouse, ed.), John Wiley and Sons, New York, p. 321 - 386.

Meyboom, P. (1961): Groundwater resources of the City of Calgary and vicinity; Res. Coun. Alberta Bull. 8, 72 pages.

Russell, L. S. (1958): A horse astragalus from the Hand Hills conglomerate of Alberta; Nat. Mus. Can., Nat. History Paper No. 1, 3 pages.

Rutherford, R. L. (1928): Geology of the area between north Saskatchewan and McLeod Rivers, Alberta; Alberta Sci. Indust. Res. Coun. Rept. 19, 37 pages.

Theis, C. V. (1935): The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage; Trans. Am. Geophys. Union, Vol. 16, p. 519 - 524.

Todd, D. K. (1959): Ground water hydrology; John Wiley & Sons, Inc., New York, 336 pages.

Wenzel, L. K. (1942): Methods for determining permeability of water-bearing materials; U. S. Geol. Surv. Water Supply Paper 887, 192 pages.

APPENDIX A. Aquifer Analysis, New Town of Swan Hills

The transmissibility and storage coefficient were determined from the results of pumping tests carried out on the preliminary test holes (April, 1959) and from the production tests of the first production well for the new Town of Swan Hills (December, 1959): The Theis nonequilibrium and the Theis modified nonequilibrium equations were used in the computations.

Transmissibility of aquifer = 2,200 gpd/ft
Storage coefficient = 5.5×10^{-4}
Static level of water well = 212 feet
Total available drawdown to the top of the aquifer = 84 feet

Water production is from a sandstone aquifer in the Paskapoo formation at the 296 to 315 foot interval.

Interference Calculations, New Town of Swan Hills

Using the Theis nonequilibrium formula, equation (1), tables 4 and 5 have been calculated. Table 4 shows what the drawdown of the water level in an observation well will be at radial distances of 0.25, 100, 1000 feet away from a pumping well, for pumping rates of 15, 30 and 40 gpm and for periods of 2 years and 20 years.

Table 4. Water levels

Time: 2 years

r	u	W(u)*	Drawdown at 15 gpm	Drawdown at 30 gpm	Drawdown at 40 gpm
0.25 ft.	3.3×10^{-11}	23.5573	18.4 ft.	36.8 ft.	49.2 ft.
100 ft.	5.6×10^{-6}	11.5155	9.0 ft.	18.0 ft.	24.0 ft.
1000 ft.	5.6×10^{-4}	6.9109	5.4 ft.	10.8 ft.	14.4 ft.

Time: 20 years

r	u	W(u)*	Drawdown at 15 gpm	Drawdown at 30 gpm	Drawdown at 40 gpm
0.25 ft.	3.3×10^{-12}	25.8599	20.2 ft.	40.4 ft.	52.0 ft.
100. ft.	5.6×10^{-7}	13.8181	10.8 ft.	21.6 ft.	28.8 ft.
1000 ft.	5.6×10^{-5}	9.2130	7.2 ft.	14.3 ft.	19.2 ft.

* Values of W(u) obtained from Wenzel tables (Wenzel, 1942, p. 88).

Figure 3 is the graphical portrayal of the drawdown (constructed from the values in table 4) of the water level at different pumping rates (15, 30 and 40 gpm). This graph then can be used to estimate what the drawdown of the water levels would be at other distances from the pumping well in the new Town of Swan Hills.

Next, an interference table (table 5) can be constructed in order to find out what the effect on the water level in the original pumping well will be if an additional well is constructed 1000 feet away, and pumped at the same rate. Conversely, the effect on the new well of pumping the old well can also be determined.

Table 5. Interference tables

Continuous pumping at 15 gpm

	2 years	20 years
Drawdown in pumping well (self-caused)	18.4 ft.	20.2 ft.
Drawdown caused by addition of second well of same capacity 1000 feet away	5.4 ft.	7.2 ft.
Well loss	10.3 ft.	10.3 ft.
Total drawdown	34.1 ft.	37.7 ft.

Continuous pumping at 30 gpm

	2 years	20 years
Drawdown in pumping well (self-caused)	36.8 ft.	40.4 ft.
Drawdown caused by addition of second well of same capacity 1000 feet away	10.8 ft.	14.3 ft.
Well loss	20.5 ft.	20.5 ft.
Total drawdown	68.1 ft.	75.2 ft.

Continuous pumping at 40 gpm

	2 years	20 years
Drawdown in pumping well (self-caused)	49.2 ft.	52.0 ft.
Drawdown caused by addition of second well of same capacity 1000 feet away	14.4 ft.	19.2 ft.
Well loss	27.2 ft.	27.2 ft.
Total drawdown	90.8 ft.	98.4 ft.

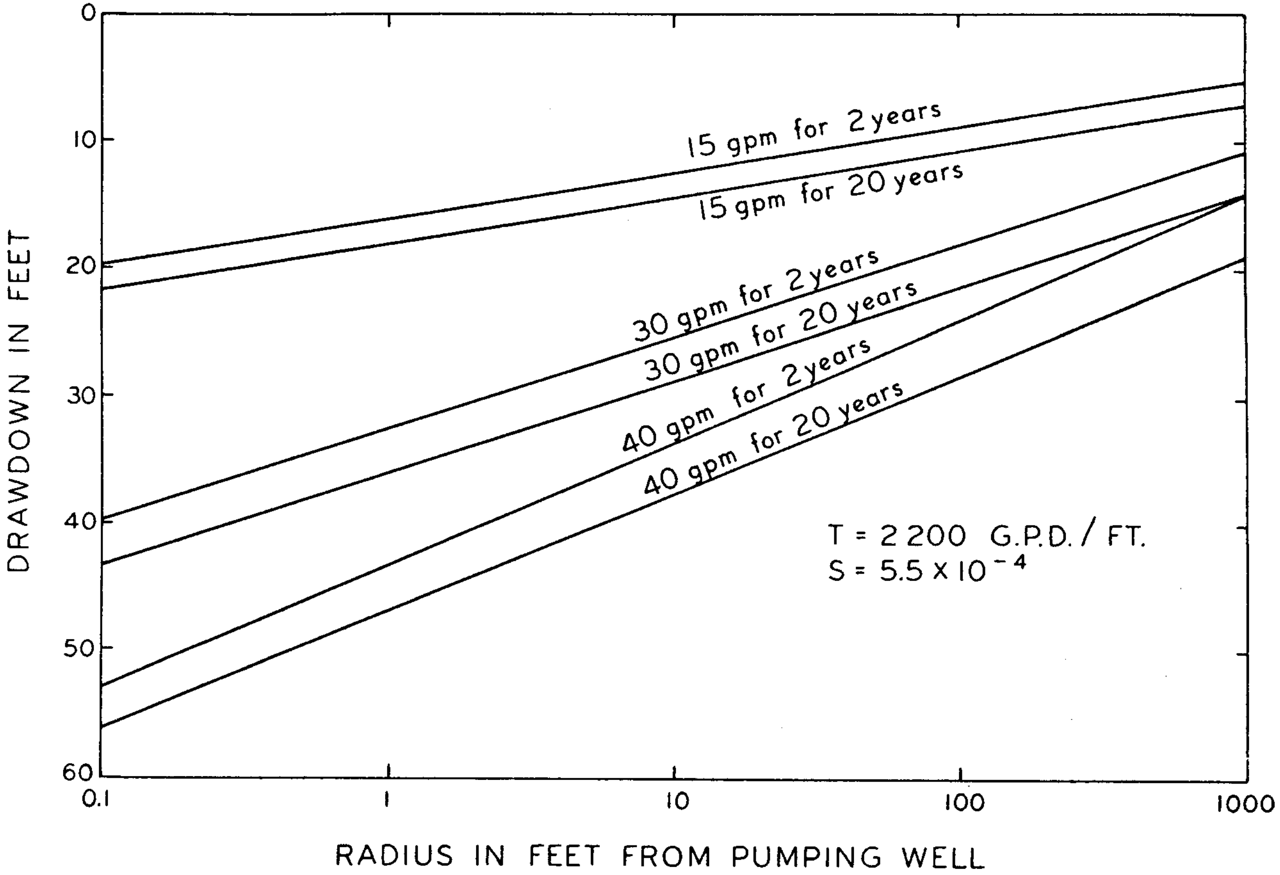

Figure 3. Time, distance drawdown graph

The total drawdown in the well (table 5) is the sum of the self-caused drawdown, the well loss, and the interference due to a second pumping well. The self-caused drawdown was computed from equations 1 and 2, using an effective radius for the well itself, of 0.25 feet.

The total well loss has to be estimated, in the absence of step drawdown data. The methods used is that of Bruin and Hudson (1958, p. 21). In estimating the well loss, it is assumed that the aquifer will not become clogged, causing the well to deteriorate, so that the well efficiency will not change with time.

Table 5 indicates that continuous pumping of water at 40 gpm from both wells over a period of 20 years will cause the water levels to be drawn down about 98 feet, which amount is greater than the total available drawdown of 84 feet. Therefore the pumping rate has to be decreased. Generally it is common practice never to allow more than 70 per cent of the total available drawdown in a well to be used up. In this case the 70 per cent drawdown is about 59 feet; therefore the pumping rate should be reduced to below 30 gallons per minute per well.

Equation (6) was also used to determine the safe pumping rate and a value of 100 gpm was obtained. As was previously stated, the use of this equation implies the neglect of well loss, interference between wells, and the storage coefficient. With a safety factor of 0.7, the safe rate for a single well is still 70 gpm which is considerably higher than the safe rate given by the more precise calculations based on equation (1).

APPENDIX B. Aquifer Testing

After a test hole for groundwater is drilled, a bail test is generally performed by the driller to obtain an initial estimate of the productivity of the aquifer. Usually, however, a bail test does not provide sufficient information concerning the behavior of the aquifer at high pumping rates under conditions of continuous production. It is nevertheless very useful to indicate whether the aquifer is worth pump testing and if so, what pump setting and pumping rate are probably required to test the aquifer adequately. Furthermore, bailing a well is the most widely applied method of "cleaning a well up" or developing it. Drilling mud, cuttings, and muddy water are removed from the walls of the hole and from the aquifer adjacent to the hole, thus permitting water to flow more readily into the well. Bailing to develop the well should precede the actual bail test; sufficient time should be allowed (preferably overnight) to permit the water level in the well to rise to its static water level before the bail test begins.

Bail Test Procedure

The recommended procedure for bail testing an aquifer, usually carried out by the water well driller, is given below:

1. Measure the depth to the water after the well has been undisturbed for several hours.

2. Start bailing at a constant rate; record the time the bailing starts, the number of full bailers each minute and the volume of water that each bailer contains.

3. The bailer should be lowered to the bottom of the hole at each trip. This will develop the well and permit a constant bailing rate to be maintained. Bailing should be continued for at least two hours, or until the water level is so near the bottom that only partially full bailers are pulled. If this happens, bailing should be stopped.

4. Record the time when the last bailer is pulled and begin taking water level measurements immediately to determine the rate of recovery; the exact time that the water level is measured should be recorded, and readings should be taken at the intervals stated below, after the bailings stops:

   (a) every minute from 1 to 10 minutes
   (b) every 5 minutes from 10 to 30 minutes
   (c) every 10 minutes from 30 minutes to 2 hours.

If a measurement is missed, continue with the next. In some tests, for example, it may be possible to get readings only every 2 minutes immediately after the bailing stops. This information can be used to calculate a preliminary value of aquifer transmissibility and consequently well capacity. An example of this type of calculation is given in figure 4.

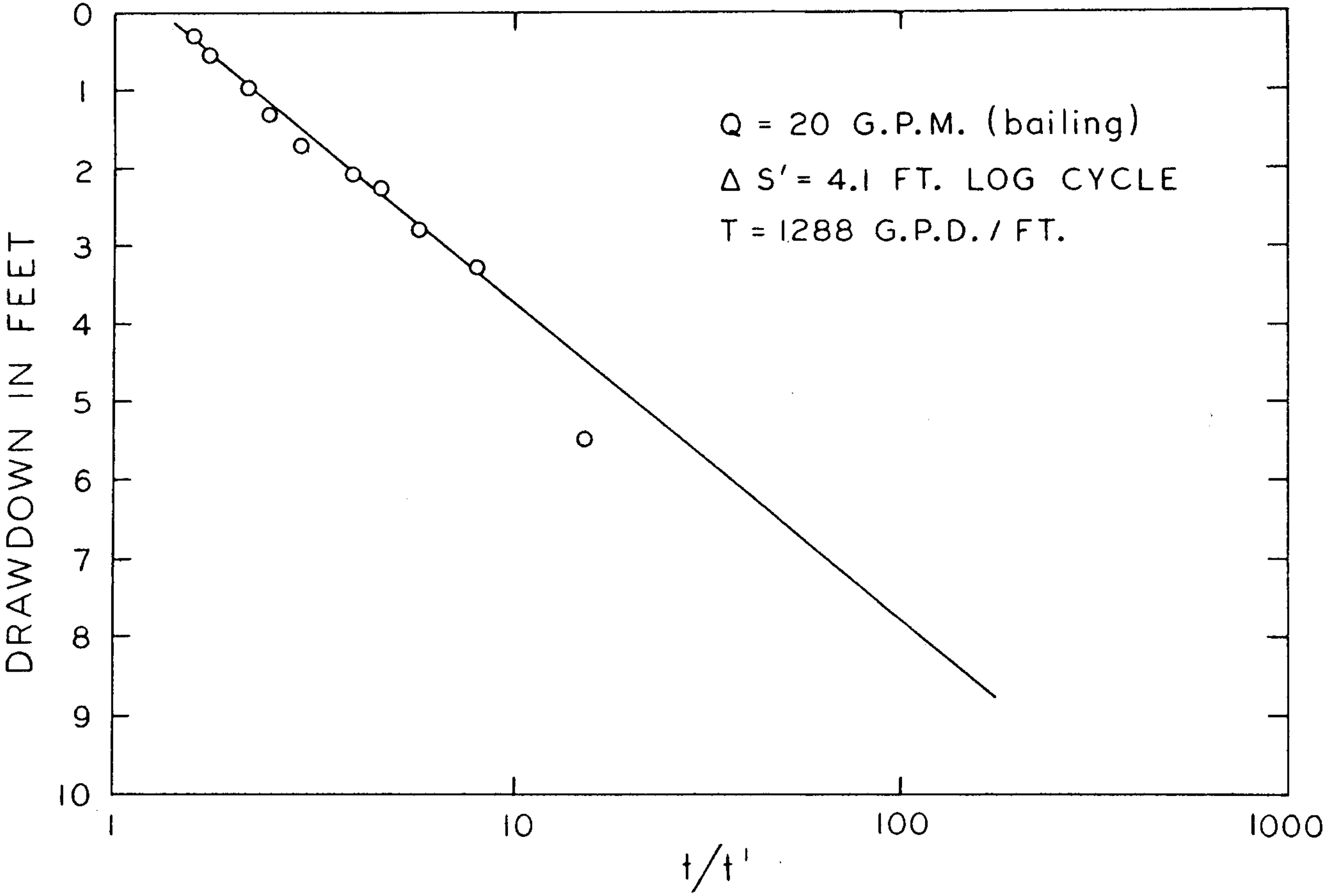

Figure 4. Bail test transmissibility

In some instances the aquifer is capable of transmitting water so rapidly that bailing (maximum rate around 20 to 40 gpm) will have very little effect on the water level. In such a case a pump will have to be installed and run without a prior bail test.

Pump Testing

The most important factor in running a good pumping test is to obtain a pump that will produce at a constant rate with a lift equal to the pump setting at the maximum available drawdown in the well. The desired pumping rate may be calculated from bail test results or estimated from previous production records and well history.

If the pumping rate varies by more than 5 per cent during the test the results cannot be reliably interpreted. Another important factor is that any wells within 1000 feet which are producing a significant amount of water, particularly if production is intermittent, will also interfere with the test and may make the results obtained impossible to interpret. If at all possible, arrangements should be made to have such wells either shut down or produce at a constant rate for several days before the pumping test is to be started. If this cannot be done, the effects of nearby pumping wells on the water level in the well to be pumped should be observed for 2 to 3 days before the test begins, by taking periodic water level measurements by the wetted tape method.

Pump Test Procedure

1. Measure the static water level in the well to be pumped, and in all observation wells, every 2 to 3 hours for 24 hours preceding the test to determine the magnitudes of water level fluctuations. Use the wetted tape method if at all possible and record the depths to water and exact times of the measurements on the log sheet, in the appropriate columns.

2. Measure the static water levels immediately before the test starts.

3. Start the pump and record the exact time. This time is zero time (t = 0) and all later times are measured from it. Measure the depths to water, and record the exact time that each measurement is taken, spacing the measurements, if possible, in the following manner:

   (a) every minute from 1 to 10 minutes
   (b) every 5 minutes from 10 to 30 minutes
   (c) every 10 minutes from 30 minutes to 1 hour
   (d) every 15 minutes from 1 hour to 2 hours
   (e) every 30 minutes from 2 hours to 4 hours
   (f) every 60 minutes from 4 hours to 12 hours
   (g) every 120 minutes from 12 hours to 24 hours
   (h) if the test is longer than 24 hours, take measurements every 4 hours until 36 hours, and every 6 hours until 48 hours.

For confined aquifers, the pumping test will usually end at 48 hours. It may take several days or longer to establish equilibrium conditions in the wells, which are necessary when treating data from unconfined aquifers. Water level measurements should be taken every 12 hours after 48 hours, until the end of the test in the case of unconfined aquifers.

4. Pumping should continue at a constant rate for the duration of the test. If field conditions make it impossible to run the test at a constant rate for the recommended period of 48 hours, in the case of the confined aquifer a shorter test may provide sufficient information.

5. When the pump is shut off, start taking water level measurements immediately to determine the rate of recovery, following the same procedure used to determine the rate of recovery after bail testing. This is particularly important if the pumping rate has varied slightly during the course of the test, as the average pumping rate can be used with these data, thus minimizing any errors that might have been introduced. Recovery measurements should be taken for a minimum period of 12 hours and preferably until the water levels approach the original non-pumping or static levels. See figure 5 for an example of such pumping test data. This information, properly collected, can be used in the calculation of the design for the well system.

Pumping Rate Determination

For pumping tests that are run at rates of up to 100 gpm, the most satisfactory and simplest method of determining the rate is to discharge the pumped water into a container that has a known volume (i.e. a 45-gallon oil drum), and record the time required to fill the container.

If the pumping rate exceeds 100 gpm, it generally has to be determined in one of the following ways:

(1) by standard orifice fittings on the discharge pipe;
(2) by measuring the flow with a weir; or
(3) by measuring the flow with a flowmeter on the discharge pipe.

All discharge pipes should have gate or globe valve with which to regulate the flow.

The pumping rate should be checked at regular intervals throughout the test, preferably at about the same time that the water level measurements are made. This will enable a close watch to be kept on the pump, so that adjustments can be made if there is a marked decline or increase in the rate.

These methods of measuring flow rates are outlined in any standard water supply engineering text or water well driller's handbook (Babbitt and Doland, 1955, or Anderson, 1955).

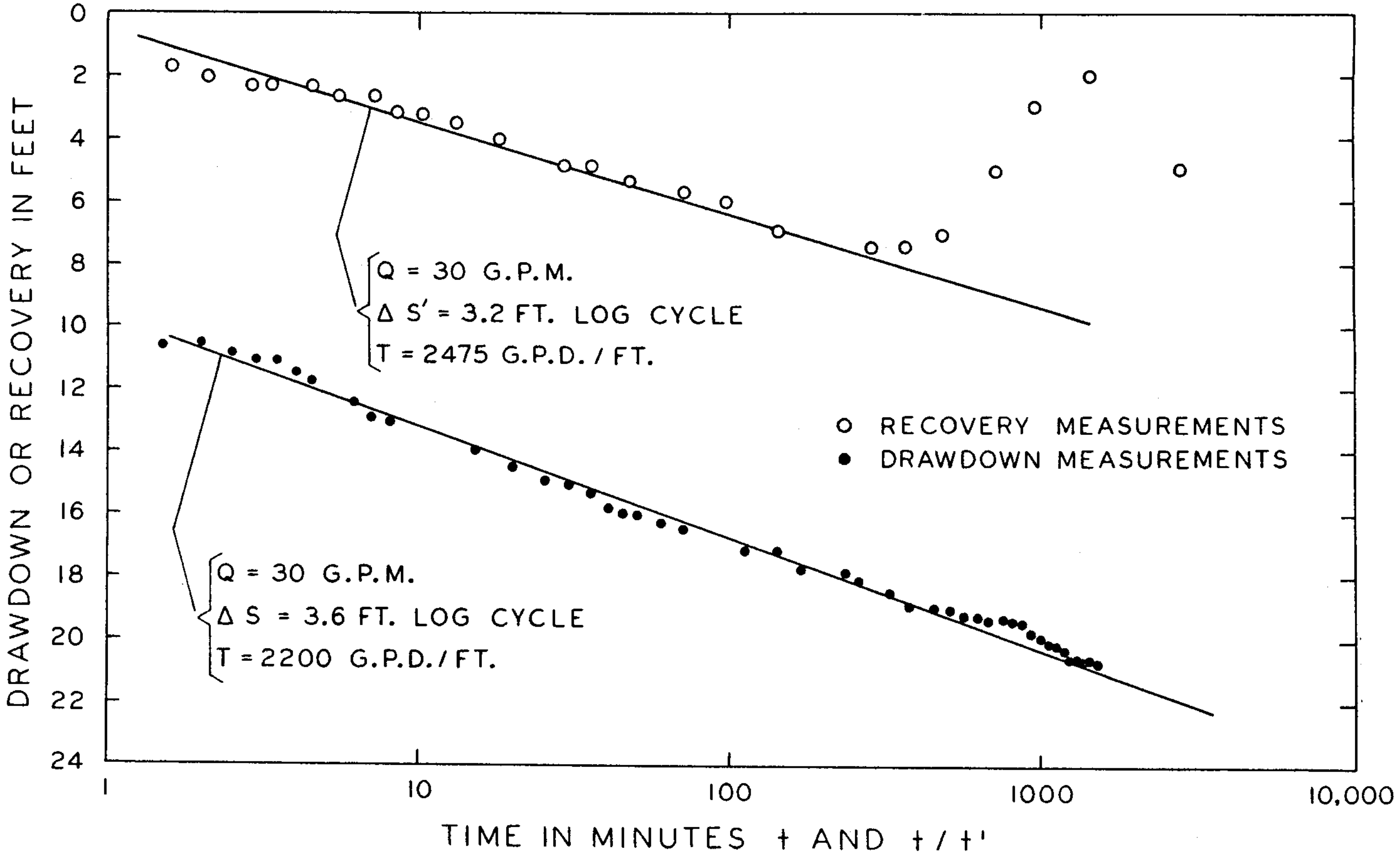

Figure 5. Recovery test transmissibility

Discharging Water

Pumped water that is being discharged should be directed away from the test site in such a manner that the least inconvenience will result. It should not be discharged in the immediate vicinity of the well site, because some of the water may leak back into the well, either through faulty well casing or through permeable ground. This discharged water would then give erroneous water level measurements and the pumping test data could not be relied upon for a suitable interpretation.

Step Drawdown Pumping Test

A step drawdown test is carried out on a completed production water well and all the water level measurements are made on the pumping well, either with an airline gauge or an electric tape.

In the step drawdown test, the well is pumped for successive one-hour periods, initially at one-third of the rate used in the constant rate drawdown test, during the second period at two-thirds of that rate, and finally at the full rate. If, for any reason, these periods or pumping rates cannot be adhered to exactly, the actual periods and rates should be accurately recorded.

During each one-hour period, the water level measurements are to be taken as outlined for the first hour of the constant rate pumping test.

APPENDIX C. Well Completions

Introduction

A well may be completed either in such a way that it draws water from only one aquifer or, alternatively, so that it draws water from two or more aquifers. In the latter case, the completion is known as a multiple completion. Whether the completion is single or multiple, however, the actual technique of completion depends on the aquifer or aquifers being developed.

Open Hole Completion

This type of well completion, which is the simplest available, is made where the mechanical constituents of the aquifer are sufficiently competent to stand by themselves, so that there is no danger of them slumping or running into the hole. Usually the casing is run to the top of the aquifer and set in place.

Screen or Screen and Gravel Pack Completion

A screened well completion is usually made where the aquifer constituents are not competent to stand by themselves. To develop this kind of aquifer a screen or combination of screen and sand or gravel pack will have to be installed. The size and type of screen is usually determined by having a particle size analysis (mechanical analysis) made on a bulk sample of the water-bearing formation. A screen that will hold back a certain proportion of the constituents of the aquifer is then designed for the particular range of particle sizes and sorting of the aquifer material. Most screen manufacturers will supply well screen design information.

In some instances it is necessary to install a combination of a screen and sand or gravel pack in order to develop a water-bearing zone. Both the screen and sand or gravel pack are designed from a particle size analysis of a bulk sample of the aquifer materials. See Ahrens (1957) for a comprehensive guide for the design of screened wells, and sand or gravel packs.

Completion Practices to Avoid

When completing water wells, it is best to avoid using slotted casing to obtain water from an aquifer, as the well efficiency is reduced considerably to about 5 to 10 per cent of what could be produced if the well were screened or developed open hole. With most slotted casing, the efficiency can reach a maximum of only about 15 per cent. If the aquifer is unconsolidated and contains fine sand, it will often run through slotted casing into the bore hole, cause plugging and often damage pumps.

Similarly, cementing casing across an aquifer, and then later perforating the casing, is not efficient. The cement is liable to seal off the aquifer and reduce the effective permeability of the formation; later perforating will thus not be of much value, and the efficiency is liable to be even less than that obtained by using slotted casing alone.

Development Practices

Most wells need adequate development before they can be test pumped and put into production. The time required to do this may be from one day to one week depending upon the particular situation. Development may involve:

(1) bailing
(2) surging
(3) acidizing
(4) use of detergents
(5) hydrofracturing
(6) screening
(7) screening and sand or gravel packing.

Most drillers are familiar with these development methods and should be encouraged to use them where necessary. Most cases of well failure can be attributed to faulty development procedures and well completion practices.

APPENDIX D. Water Well Records

Abbreviations: Lsd. - legal subdivision; NW, NE, SW, SE - quarter of section; Sec. - section; Tp. - township; R. - range; ss. - sandstone; sh. - shale; DD - drawdown

Location West of 5th Meridian											
Lsd.	Sec.	Tp.	R.	Year drilled	Depth of well (feet)	Depth to water (feet)	Depth to aquifer (feet)	Well diameter (inches)	Lithologic log (feet)	Pump or bail test	Driller
NE	25	59	7	1959	150	55	150	4	0-78 clay; 78-150 ss.	3 gpm, DD 76' in 6 hrs.	E. Jalbert
SW	1	59	10	1955	165	50	-	-	0-28 clay; 28-165 sh.	3 gpm, DD 20' in 5 hrs.	A. Wasmuth
NE	8	59	10	1955	113	80	-	-	0-80 clay; 80-113 sh.	3 gpm, DD 9' in 4 hrs.	A. Wasmuth
NE	14	59	10	1955	36	-	-	-	0-35 clay; 35-36 gravel		A. Wasmuth
	26	59	10	1955	185	80			0-95 clay; 95-185 sh.	3 gpm, DD 30' in 6 hrs.	A. Wasmuth
1	10	59	12	1957	230	140	200-300	3 1/2	0-14 sand; 14-20 clay; 20-230 ss.		E. Jalbert
	35	59	12	1960	280	180	-	-	0-30 sand; 30-38 fine sand; 38-82 sand; 82-155 clay; 155-189 gravel; 189-205 clay & sh.; 205-212 sh., 212-276 ss.; 276-280 sh.	Bailed 5 gpm for 3 hrs. DD negligible.	Danscot
	25	59	12	1960	240	60	185	6			
9	18	61	8	1959	143	20	-	6	0-60 gravel; 60-128 sand; 128-143 sh.	Pumped at 3 1/2 gpm for 40 hrs. DD 3' in 40 hrs., recovered to 20' in 3 mins.	Forrester
12	29	61	18	1960	116	55	89-110	7 7/8 6 1/8	0-28 clay; 28-30 gravel; 30-31 hard ss.; 31-40 sand & gravel; 40-50 clay; 50-60 sand; 60-84 soft clay; 84-89 sh.; 89-110 ss.; 110-116 sh.	Bailed at 30 gpm, DD to 75' in 1 1/2 hrs.	Coralta
4	16	62	19	1959	236	170	201-236	-	0-62 clay; 62-80 silty sand; 80-201 sh.; 201-236 ss.	Bailed at 15 gpm, DD to 180' in 30 min.	Coralta
		63	10	1959	250	-	-	-	0-36 sand; 36-100 blue clay; 100-140 clay & sh.; 140-220 sh. & sand; 220-240 sand & coal; 240-250 sh.	-	Danscot
4	13	63	11	1960	160	125	140-151	12- 6 1/8	0-5 clay & boulders; 5-41 sand; 41-140 sh.; 140-151 sand; 151-160 sh.	Bailed 20 gpm, DD to 130' in 1/2 hr.	Coralta
10	13	63	12	1959	240	70	80-240	-	0-12 clay & boulders; 12-65 sand; 65-80 sh.; 80-84 coal; 84-125 sh.; 125-128 ss.; 128-165 sh.; 165-170 sand & sh.; 170-190 sh.; 190-202 ss.; 202-207 sand; 207-218 sh.; 218-220 ss.; 220-240 ss.		Coralta
4	24	63	20	1959	136	-	82-129	6 1/8	0-10 silty sand; 10-13 ss.; 13-50 ss.; 50-55 ss.; 55-82 sh.; 82-90 sand; 90-117 sandy sh.; 117-129 sand; 129-136 sh.	Bailed at 25 gpm for 1 hr. DD to 75' in 1 hr.	Coralta
10	24	63	12	1960	100	38	45-100	12- 9- 6 1/8	0-18 clay & boulders; 18-46 sandy clay & sand; 46-48 ss.; 48-85 ss. & sh.; 85-96 sh.; 96-100 hard ss.	Bailed at 30 gpm, DD to 48' in 1/2 hr.	Coralta
8	28	63	3	1958	163	30	90-155	6 1/4- 6 3/4	0-30 boulder clay; 30-90 sh.; 90-95 ss.; 95-110 sh.; 110-115 ss.; 115-150 sh.; 150-155 ss.; 155-163 sh.	Bailed at 30 gpm, DD 15' in 2 hrs., recovered to 30' in 20 mins.	Coralta

		63	10	1959	200	80	-	6 1/8	0-35 sand; 35-105 blue clay; 105-150 sh.; 150-200 sand		Danscot
6	29	63	10	1959	295	180	275-290	7 7/8	0-100 clay; 100-140 sh.; 140-146 sand; 146-220 sand & sh.; 220-275 sh.; 275-290 sand; 290-295 sh.		Danscot
4	30	63	10	1959	110	28	-	6 1/4	0-50 clay; 50-70 sh.; 70-90 sand & sh.; 90-110 sand	25 gpm, DD 5' in 2 hrs. recovered to 28' in 20 min.	Danscot
6	30	63	10	1959	245	80	-	6 1/8	0-40 clay; 40-41 sand; 41-100 sh.; 100-101 coal; 101-150 sh.; 150-200 sand; 200-210 sh.; 210-245 sand	30 gpm, for 1 hr. DD negligible	Danscot
16	31	63	10	1959	184	38	70-174	6 1/4-4 1/4	0-60 clay & boulders; 60-70 sh.; 70-71 coal; 71-149 sh.; 149-150 coal; 150-172 sh.; 172-173 ss.; 173-174 coal; 174-184 soft sh.	-	Coralta
16	31	63	10	1959	250	38	103-231	-	0-10 clay & boulders; 10-70 clay; 70-103 sh.; 103-104 ss.; 104-105 coal; 105-115 sh.; 115-117 soft ss.; 117-125 sh.; 125-126 coal; 126-150 sh.; 150-152 coal; 152-157 sh.; 157-159 coal; 159-225 sh.; 225-231 ss.; 231-250 sh.	Bailed at 15 gpm, DD to 100' in 1 1/2 hrs.	Coralta
4	33	63	10	1959	390	90	100-390	9-6 1/8	0-50 clay; 50-75 blue clay; 75-105 soft sh.; 105-114 hard sh.; 114-170 ss.; 170-171 hard rock; 171-256 sh.; 256-258 ss.; 258-260 sh.; 260-261 ss.; 261-320 sh.; 320-342 sandy sh.; 342-344 ss.; 344-349 sandy sh.; 349-351 ss.; 351-380 sandy sh.; 380-390 sh.	Bailed at 4 gpm, DD to 200 ft. in 1 hr.	Coralta
2	6	64	10	1960	156	72 ?	72-142	7 7/8-6 1/4	0-10 clay; 10-14 sand; 14-26 soft sh. 26-34 sand; 34-72 soft sh.; 72-78 coal & ss.; 78-116 sh.; 116-120 ss.; 120-140 sh.; 140-142 ss.; 142-156 sh.	Bailed at 20 gpm, DD to 90' in 1/2 hr.	Coralta
10	6	64	10	1960	156	100	108-156	7 7/8-5	0-36 clay; 36-40 loose sand; 40-54 clay; 54-108 blue sh.; 108-119 sand; 119-123 sh.; 123-138 sand; 138-156 sand & gravel	Bailed at 15 gpm, DD to 126' in 1 1/2 hrs.	
4	11	64	10	1959	118	68	66-115	9	0-7 clay; 7-18 ss.; 18-66 soft sh.; 66-115 soft ss.; 115-118 sh.	Pumped at 10 gpm for 30 mins, DD to 110' in 10 mins.	Coralta
4	5	64	11	1960	274	-	24- 26 64-274	6 1/4-4 3/4	0-20 clay & boulders; 20-24 sh.; 24-26 ss.; 26-104 sh.; 104-105 coal; 105-151 sh.; 151-152 hard rock; 152-232 sh.; 232-234 coal; 234-243 sh.; 243-256 soft ss.; 256-274 sh.	Bailed at 4 gpm, DD 100% in 1/2 hr.	Coralta
4	22	64	11	1959	170	50	50-155	7 7/8-5 5/8	0-10 clay till; 10-16 brown clay; 16-45 sand; 45-57 sh.; 57-86 sand; 86-115 sh.; 115-117 ss.; 117-142 sh.; 142-144 coal; 144-152 sh.; 152-155 ss.; 155-170 sh.	Bailed at 10 gpm for 1 1/2 hrs. DD to 140' in 30 mins.	

APPENDIX D. Water Well Records (continued)

Abbreviations: Lsd. - legal subdivision
NW, NE, SW, SE - quarter of section
Sec. - section
Tp. - township
R. - range
ss. - sandstone
sh. - shale
DD - drawdown

Location West of 5th Meridian											
Lsd.	Sec.	Tp.	R.	Year drilled	Depth of well (feet)	Depth to water (feet)	Depth to aquifer (feet)	Well diameter (inches)	Lithologic log (feet)	Pump or bail test	Driller
10	27	64	11	-	175	33	55-175	9- 6 1/8	0-18 clay; 18-44 ss. & sandy clay; 44-70 sh.; 70-76 ss.; 76-112 sh.; 112-115 ss.; 115-156 sh. & ss. streaks; 156-162 ss.; 162-175 sh.	Bailed at 14 gpm for 45 mins, DD 100% in 30 mins. Pump set at 98'.	Coralta
4	29	64	11	1959	155	30	60-144	7 1/8- 5	0-46 clay; 46-60 sh.; 60-62 ss.; 62-85 sh.; 85-98 ss.; 98-110 sh.; 110-144 ss. & sh.; 144-155 sh.	Bailed at 30 gpm for 1 hr, DD to 120' in 30 mins.	Coralta
12	4	64	11	1961	730			12- 8 5/8- 5 1/2	0-12 silty sand; 12-81 clay; 81-82 rock; 82-87 grey clay; 87-89 coal; 89-113 sandy sh.; 113-385 sh.; carbonaceous partings; 385-462 grey sh.; 462-463 ss.; 463-720 fine to medium sand; 720-730 sh.	Not conducted	Michele
2	9	64	11	1961	865		155 505 430-505	14	10-26 clay; 26-60 grey sh.; 60-75 grey sandy sh.; 75-119 sh.; 119-155 sandy sh.; 155-155.5 gravel; 155-218 sh.; 218-218.5 ss.; 218.5-297 sh.; 297-305 ss.; 305-430 sh. & ss.; 430-505 med. sand, coal; 505-518 sh. & sandy coal; 518-593 black sh.; 593-712 ss.; 712-730 very sandy sh.; 730-765 shale	Not conducted	Michele
4	31	64	12	1960	98	45	75- 85	10- 6 1/4	0-15 clay; 15-20 coal; 20-45 soft sh.; 45-48 hard sh.; 48-75 sh.; 75-85 sand & coal; 85-98 sh.	Bailed at 15 gpm, DD to 78' in 1/2 hrs.	Coralta
NW	34	64	13	1959	233	70	223-233	6	223-233 ss.	Bailed at 8 gpm for 30 mins, DD to 90' in 15 mins.	Coralta
2	34	64	14	1960	115	68	52-112	10- 4 3/4	0-5 clay till; 5-43 soft clay; 43-52 hard clay; 52-86 sandy clay & sand; 86-97 shale; 97-112 sand (water); 112-155 shale	Bailed at 30 gpm for 45 mins, DD to 80' in 15 mins. Recovered to 68' in 5 mins.	
SE	20	64	14	1954	115	30	-	-	0-15 sand; 15-115 blue clay and sand	7 gpm for 48 mins, DD negligible	La Forge Bros.
NE	18	64	18	1960	110	43	76- 96	6 1/4- 5	0-30 clay; 30-45 sh.; 45-76 sandy sh.; 76-96 ss.; 96-110 sh.	Bailed at 45 gpm, DD to 60' in 1 hr.	Coralta
2	1	64	19	1960	240	-	170-180	5	0-170 clay; 170-180 quicksand; 180-240 clay	Bailed at 10 gpm, (60% sand) DD 100%.	Coralta
2	3	64	19	1959	286	30	160-162 265-274	4 1/4	0-19 clay; 19-42 sand; 42-119 clay & sand; 119-162 sh.; 162-230 sh. & coal; 230-265 fine sand; 265-270 ss.; 270-286 fine sand	Pumped at 162' at 3 gpm for 1 hr, DD 160' in 10 mins. Recovered to 27' pumped at 275 at 6 gpm. for 1 hr, DD to 240' in 30 mins. Recovered to 30' in 55 mins.	Kinsella

2	4	64	19	1959	160	30	130-160	-	0-35 clay; 35-65 sand; 65-70 clay; 70-95 sh.; 95-105 sh. & coal; 105-130 sh.; 130-160 sh. with sand stringers	10 gpm for 90 mins, DD to 50' in 90 mins. Recovered to 30' in 10 mins.	Big Indian
2	20	64	19	1959	320	-	285-320	7 7/8- 6 1/8	0-25 clay; 25-30 coal; 30-75 sh.; 75-80 ss.; 80-130 sh.; 130-134 coal; 134-172 sh.; 172-173 coal; 173-228 sh.; 228-229 ss.; 229-285 sh.; 285-320 ss. & sand	20 gpm for 1 hr, DD to 230' in 30 mins.	Coralta
10	26	64	20	1959	137	-	56-122	9- 5	0-15 clay; 15-45 sh.; 45-74 coal; 74-92 ss.; 92-117 sand & sh.; 117-122 ss.; 122-137 sh.	Bailed 20 gpm for 1 1/2 hrs, DD to 60'	Coralta
12	6	65	10	1961	850	313	Perforations at 166-171 205-210 328-338 357-367 Open hole from 503-735	13 5/8- 8 5/8- 6 1/4	0-50 clay & boulders; 50-95 clay & coal; 95-122 soft sh.; 122-130 coal; 130-161 soft sh.; 161-172 sand; 172-196 soft sh.; 196-212 sand; 212-328 sh.; 328-339 sand; 339-357 sh.; 357-367 sand; 367-500 sh.; 500-596 sand; 596-613 sh.; 613-625 sand; 625-646 sh.; 646-662 silty sand; 666-698 sh.; 698-714 sand; 714-725 sh.; 725-735 sand; 735-850 sh.	Pumped at 19 gpm, DD 77' in 5 1/2 hrs.	-
4	16	65	13	1960	136	65	96-126	12- 9- 6 1/8	0-22 clay; 22-25 gravel; 25-32 clay; 32-96 sh.; 96-106 quicksand; 106-122 sh.; 122-126 sand; 126-136 sh.	Bailed at 25 gpm, DD to 80' in 1/2 hrs. Recovered to 65'	Coralta
2	19	65	13	1960	140	-	85-133	10- 6 1/8	0-23 clay & boulders; 23-28 sh.; 28-85 sh.; 85-88 ss.; 88-110 sh.; 110-116 ss.; 116-130 sh.; 130-133 coal; 133-140 sh.	Bailed at 40 gpm, DD to 35' in 1/2 hr.	Coralta
4	19	65	13	1959	98	15	50- 98	6	0-18 clay & boulders; 18-26 sh.; 26-28 ss.; 28-35 sh.; 35-36 coal; 36-45 sh.; 45-98 sh. & ss.	Bailed at 40 gpm. for 1/2 hr, DD to 20' in 20 mins. Recovered to 15' in 1 min.	Coralta
NW	19	65	9	1960	170	108	157-159	6 1/8	0-33 clay & boulders; 33-112 blue clay; 112-157 sh.; 157-159 soft ss.; 159-170 sh.	2 gpm for 9 hrs, DD to 120'. Recovered to 108' in 30 mins.	McAuley
12	2	65	19	-	302	120	195-200 270-285	-	195-200 sand 270-285 sand	Bailed at 25 gpm, DD to 170'	-
2	3	65	19	-	215	18	-	-	-	Bailed at 25 gpm, DD to 130'	-
10	22	65	19	-	327	160	298-302	-	298-302 sand	Bailed at 12 gpm, DD to 260'	-
10	1	66	19	-	215	41	-	-	-	Bailed at 40 gpm, DD to 55'	-
	14	66	10	1959	300	180	258-275	9- 6 1/2	0-6 clay; 6-18 sand; 18-58 clay; 58-104 soft blue sh.; 104-118 sand; 118-140 blue sh.; 140-149 sand; 149-181 sh.; 181-186 sand; 186-258 sh.; 258-275 ss.; 275-300 sh.	Bailed at 25 gpm, DD to 210 in 3 1/4 hrs.	Coralta

APPENDIX D. Water Well Records (continued)

Abbreviations: Lsd. - legal subdivision
NW, NE, SW, SE - quarter of section
Sec. - section
Tp. - township
R. - range
ss. - sandstone
sh. - shale
DD - drawdown

Location West of 5th Meridian											
Lsd.	Sec.	Tp.	R.	Year drilled	Depth of well (feet)	Depth to water (feet)	Depth to aquifer (feet)	Well diameter (inches)	Lithologic log (feet)	Pump or bail test	Driller
	14	66	10	1959	321	212	-	-	-	30 gpm, DD to 20.5' in 24 hrs. Recovered 19' in 12 hrs.	Coralta
4	28	66	10	1959	198	100	79- 84 161-165	7 5/8- 6 1/8	0-5 sand; 5-12 clay; 12-27 soft ss.; 27-33 clay; 33-79 soft blue sh.; 79-84 loose sand; 84-122 sh.; 122-124 sh.; 124-141 sh.; 141-144 soft sand; 144-161 sh.; 161-165 sand; 165-174 sh.; 174-180 sand; 180-198 sh.	Bailed at 25 gpm	Coralta
4	33	66	10	1959	363	304	300-363	9- 6 1/8	0-9 gravel & boulders; 9-55 clay 55-93 soft sh.; 93-104 sand; 104-110 ss.; 110-123 sh.; 123-196 soft ss. & sandy sh.; 196-297 soft sh. & ss.; 297-300 ss.; 300-334 sh. & ss.; 334-337 coal; 337-363 ss. & sh.	10 gpm for 4 hrs, DD negligible	Coralta
4	33	66	10	1959	350	275	182-350	9- 7 7/8	0-7 boulders & gravel; 7-50 clay; 50-90 sh.; 90-102 sand; 102-109 ss.; 109-190 sandy clay; 190-196 sh.; 196-198 ss.; 198-270 sh.; 270-292 sh. & ss.; 292-296 ss.; 296-315 sh. & ss.; 315-330 sh.; 330-334 coal; 334-342 sh.	Bailed at 15 gpm for 1 hr. DD negligible	Coralta
4	33	66	10	1959	298	-	162-298	10- 6 1/8- 5	0-8 clay & boulders; 8-102 clay; 102-106 ss.; 106-115 sh.; 115-120 dry sand; 120-265 sh.; 265-285 sh. & ss.; 285-298 sh.	4 gpm for 1/2 hr, DD 100%	Coralta
4	33	66	10	1959	236	-	120-132 205-210	9- 6 1/8	0-5 boulder clay; 5-18 sand; 18-60 clay; 60-65 sand; 65-120 clay; 120-132 sand (water); 132-141 clay; 141-144 ss.; 144-184 sh.; 184-185 ss.; 185-205 sh.; 205-210 sand (water); 210-236 sh.	20 gpm for 1 hr, DD to 200' in 1/2 hr.	Coralta
4	34	66	10	1959	360	-	-	8 5/8- 6 7/8	0-192 clay & boulders; 192-198 soft sh.; 198-263 sh. & coal; 263-269 sandy sh.; 269-278 sh.; 278-280 ss.; 280-315 sh.; 315-320 ss.; 320-342 sh.; 342-343 coal; 343-350 sh.; 350-357 coal; 357-360 sh.	3 gpm for 3 1/2 hrs, DD 100%	Coralta

	14	66	10	1959	321	210	280-315	11-6 1/8	0-14 clay & boulders; 14-45 clay; 45-85 sh.; 85-94 sand & coal; 94-137 sh.; 137-150 sand; 150-156 hard sand; 156-178 sh.; 178-184 sand; 184-280 sh.; 280-296 soft ss. & sh.; 296-315 ss.; 315-321 sh.	#1 25 gpm for 12 hrs. DD to 225' in 3 hrs. #2 pumped at 30 gpm for 24 hrs, DD to 232.5' in 20 hrs. Recovered to 213.5 in 15 1/3 hrs.	Coralta
2	20	66	10	1959	200	-	135-161	9-5 5/8	0-55 clay; 55-65 soft sh.; 65-92 sh.; 92-128 coal & sand; 128-135 sh.; 135-154 sandy sh.; 154-161 sand; 161-174 sandy sh. 174-200 sh.	20 gpm for 2 1/2 hrs, DD negligible	Coralta
10	20	66	10	1959	138	-	74-125	10-7 5/8	0-10 boulder clay; 10-20 clay; 20-22 sand (water); 22-35 clay; 35-41 sh.; 41-42 ss.; 42-50 sh.; 50-51 coal; 51-74 sh.; 74-125 sand; 125-138 sh.	30 gpm for 1 hr, DD to 75' in 20 mins.	Coralta
4	21	66	10	1959	164	36	78-162	10-7 7/8	0-78 clay; 78-94 sand (water); 94-138 sh.; 138-140 sand; 140-158 sh.; 158-162 ss.; 162-164 sh.	-	Coralta
SW	23	66	10	1960	345	241	246-345	-	0-6 sandy clay; 6-34 sand; 34-65 brown clay; 65-73 hard blue clay; 73-86 sh.; 86-126 blue sh.; 126-127 ss.; 127-143 blue sh.; 143-145 ss.; 145-173 sh.; 173-177 ss.; 177-248 sh.; 248-254 ss.; 254-263 sh.; 263-272 ss.; 272-291 sh.; 291-301 ss.; 301-323 sh.; 323-325 ss.; 325-345 sh.	#1 pumped at 20 gpm for 24 hrs, DD 31' in 8 mins. Recovered to 246' in 2 hrs. #2 pumped at 30 gpm for 24 hrs, DD 33' in 6 mins. Recovered to 246' in 2 hrs.	McAuley
10	27	66	10	1959	256	-	-	12-7 7/8-6 1/8	0-30 boulders; 30-41 gravel; 41-84 clay; 84-94 sand; 94-120 clay; 120-125 sand; 125-138 clay; 138-140 sand; 140-161 clay; 161-165 loose sand; 165-184 clay & sh.; 184-190 sh. & ss.	-	Coralta
2	9	66	11	1959	240	-	190-240	9-6 1/8	0-10 boulder clay; 10-30 clay; 30-65 sh.; 65-66 ss.; 66-75 sand; 75-115 sh.; 115-182 sand; 182-223 sh.; 223-233 sand; 233-240 sh.	Bailed at 10 gpm for 2 hrs, DD to 160 in 1 hr.	Coralta
10	26	66	19	1958	200	-	-	4 1/2	0-38 clay; 38-40 gravel; 40-76 blue clay; 76-95 sh.; 95-98 ss.; 98-130 sh.; 130-135 sand; 135-145 sh.; 145-153 sand; 153-160 sh.; 160-190 sandy sh.; 190-200 sh.	Pumped at 10 gpm for 1 hr, DD to 90' in 1 hr.	Big Indian
4	4	67	11	1958	237	118	118-125 180-215	12-6 1/4-4 3/4	0-12 boulder clay; 12-110 clay; 110-118 sh.; 118-125 sand; 125-130 sh.; 130-180 sandy sh.; 180-215 sand; 215-237 sh.	20 gpm for 45 mins, DD to 150' in 30 mins.	Coralta

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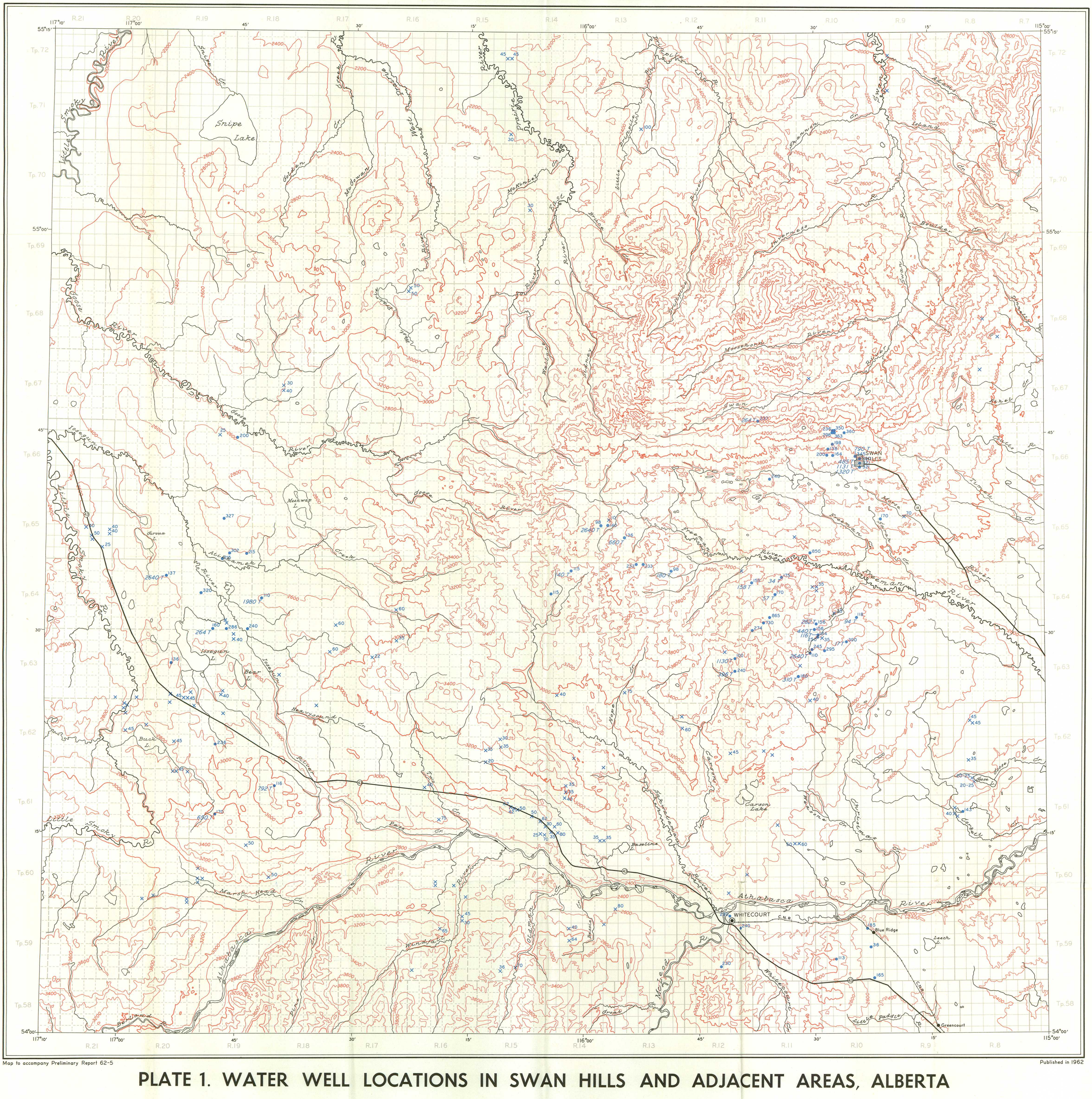

Map to accompany Preliminary Report 62-5

Published in 1962

PLATE 1. WATER WELL LOCATIONS IN SWAN HILLS AND ADJACENT AREAS, ALBERTA

WEST OF FIFTH MERIDIAN

Scale in Miles

2 1 0 2 4 6 8 10

EXPLANATION

Well location and depth in feet	●230
Flowing seismic shot hole and depth in feet	×50
Apparent transmissibility (gpd/ft.)	310 T

REFERENCE

Town, village or hamlet	▨ ◉ ●
Provincial highway	
Railway	
Stream	
Lake	
Township line (surveyed)	
Township line (unsurveyed)	
Section line (surveyed)	
Section line (unsurveyed)	
Contour (interval 200 feet)	3000