

A LARGE INDUSTRIAL WATER SUPPLY  
FOR THE CITY OF MEDICINE HAT

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by

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## INDEX

	Page
Introduction .....	1
Location and description of area tested .....	1
Pump test results	
General statement .....	2
Hydrologic boundaries and aquifer coefficients .....	3
Estimated future water levels .....	4
Estimated future water levels in a three well system ..	6
Chemical characteristics of infiltrated water .....	9
Temperature of infiltrated water .....	9
Effect of changing river level upon groundwater level .....	10
Recommended well construction and well field design .....	11
Conclusions .....	12
Literature references .....	13

### Appendices:

- A. Logs of test holes
- B. Pump test data
- C. Chemical analysis.

## A LARGE INDUSTRIAL WATER SUPPLY FOR THE CITY OF MEDICINE HAT

### Introduction:

This report deals with the results of the search for a large industrial water supply which was carried out by the Research Council of Alberta, upon request of the City of Medicine Hat.

Based upon previous investigations, advice was given to test the groundwater occurrences of Police Point, a meander terrace of the South Saskatchewan River, located approximately 1/2 mile east of the City of Medicine Hat. This terrace was expected to consist of fairly coarse gravel which (if extending below river level) might be saturated with water.

Test drilling confirmed this opinion and a pump test was conducted to determine the potential groundwater supply from this aquifer.

The results proved to be satisfactory, and an adequate industrial supply can be developed.

### Location and description of area tested: (see figure 1)

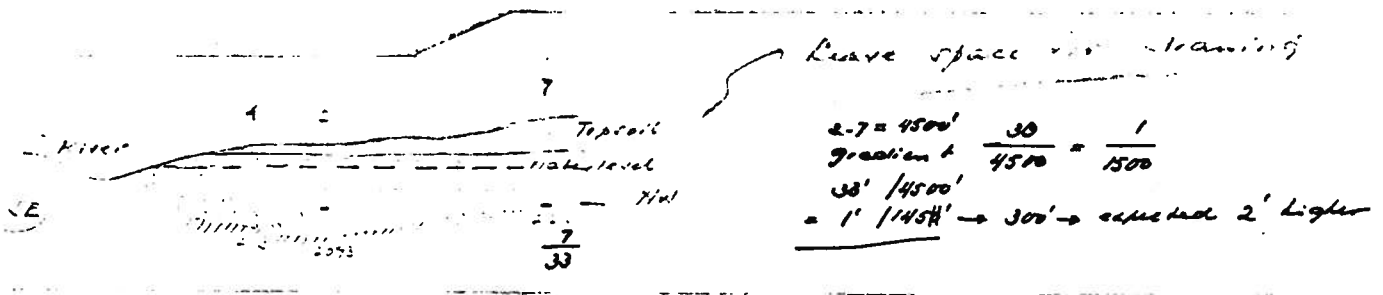
Police Point is a fair-sized meander terrace along the northern shore of the South Saskatchewan River.

In order to establish the geologic and hydrologic characteristics of this terrace, 5 x 6-inch test holes were drilled and 2 holes to the water table were excavated by hand. Data on the drilled test holes as reported by Renbar Drilling Co. are given in Appendix A.

The terrace is covered by 10 feet of sandy top soil, below which a thick gravel deposit occurs. The gravel is medium-sized at the top, and becomes gradually coarser towards the bottom. The thickness of the deposit appeared to vary from 39 feet

in test hole #1 to only 19 feet in test hole #4. In test holes #1 and 2, bedrock was reached at 55 and 58 feet; in well #4, however, bedrock was already reached at 37 feet. This suggests the presence of a channel-like depression, and it is believed from this and other evidence that the centre line of this channel extends in a North-South direction. Testhole #2 was drilled on or near this centre line.

On the basis of test drilling inland (#7) there appears to be a rise in bedrock and a lateral change from coarse gravel to very fine gravel and sand. A schematic cross-section of this situation is given below.



The test holes were leveled, and a groundwater gradient of 1/500 from SW toward NE could be established. This gradient indicates that part of the river water is taking a shortcut through the gravels of the terrace. Any well, obtaining its water from this reservoir, can easily supply all desired quantities of water, provided that the aquifer can transmit them. The second part of the investigation, therefore, dealt with the ability of the aquifer to transmit water.

Pump test results

a. General statement:

For test purposes, well #2 was equipped with a suction pump powered by a tractor. During 46 hours this well discharged 275 Imperial gallons per minute. Test holes #1, 3, and 4 provided the necessary observation data. No changes in

water level were recorded in holes #5, 6, and 7. Water level measurements were done by electric as well as steel tape. Pump test data are given in Appendix B.

Thanks to the excellent assistance given by the City of Medicine Hat, the test could be conducted without interruption.

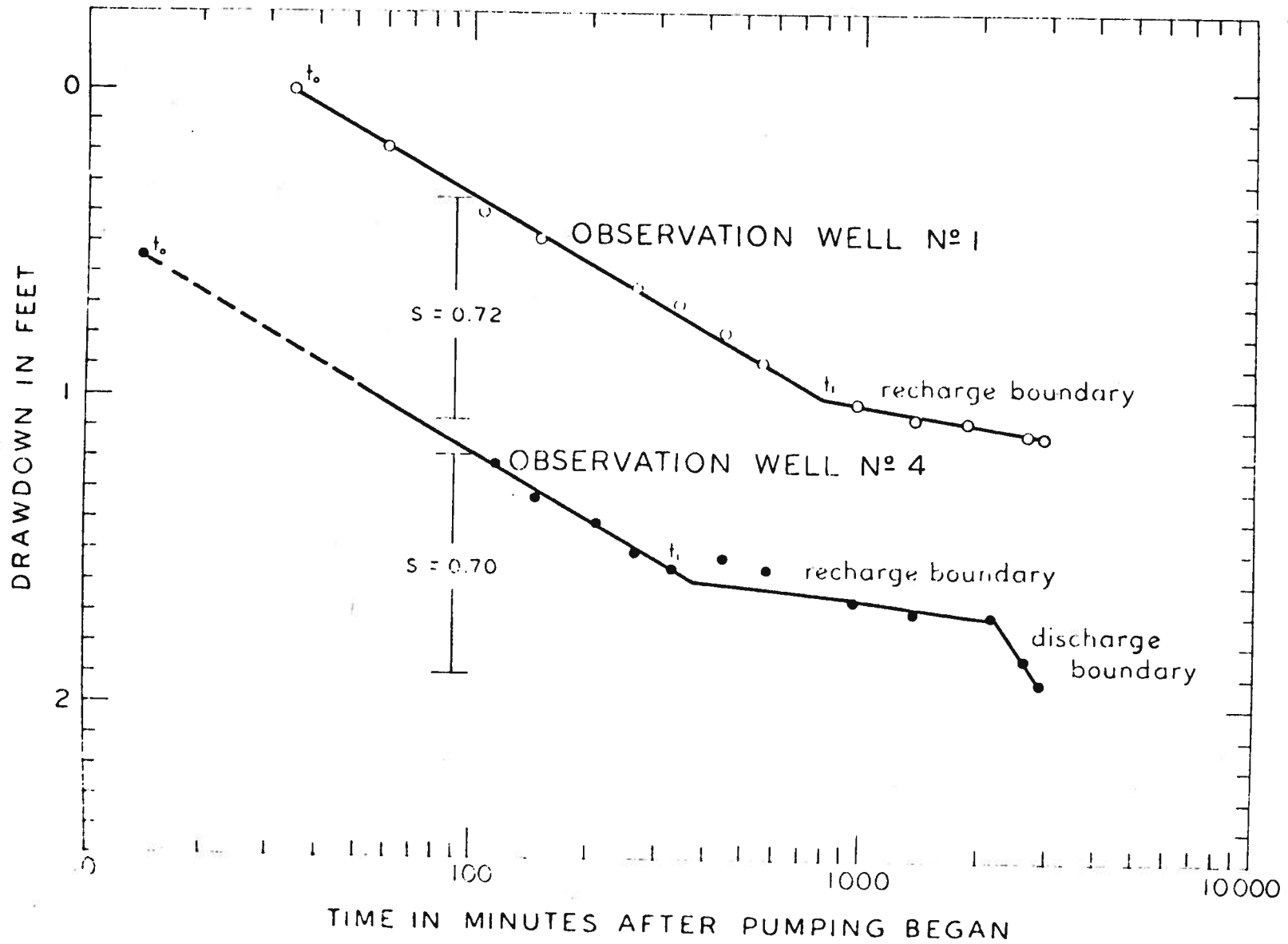
b. Hydrologic boundaries and aquifer coefficients

When pumping begins in a well, an area of reduced pressure occurs around the well. The shape of the area is one of an inverted cone and it is therefore called the cone of depression. Since this cone is expanding during pumping, its rate of growth can be observed in the observation wells and these data are basic for further calculations on aquifer coefficients. To this end, several methods are developed (Theis and Wenzel; Jacob and Cooper) all assuming that the aquifer is of infinite areal extent. However, the aquifer of Police Point is bounded by one and probably more hydrologic boundaries. As the cone of depression, ~~it~~ eventually intersects such a boundary, and two situations are possible:

1. The drawdown decreases (positive boundary)
2. The drawdown increases (negative boundary)

A semilogarithmic plot of the drawdown versus the elapsed time of the pump test, clearly shows the existence of one positive boundary and probably one negative boundary (see figure 2). The positive boundary is in this case the South Saskatchewan River, over which surface no drawdown occurs. This situation is described as an interference with a recharging image well. The image well is considered to be twice as far from the pumping well as the positive boundary, and is recharging at a constant rate, equal to the discharge of the pumping well. Because of the interference with this image

FIGURE 2



well, the cone of depression of the pumping well becomes distorted and the hydraulic gradient between the well and the river becomes steeper than in other directions. Due to this steepened gradient, more water will move into the aquifer, until an equilibrium condition between discharge and recharge is reached. This mechanism is called induced infiltration.

A possible second boundary of Police Point aquifer is a negative one, in which case the cone of depression intersects a less permeable part of the formation. Although it was impossible to give an exact location, it is believed that the finer inland deposits count for this boundary.

The following hydrologic coefficients were to be determined:

- T, Coefficient of transmissibility of the aquifer. Defined as the rate of flow of water in gallons per day which will flow through one foot width of a given aquifer with a unit hydraulic gradient under prevailing conditions.
- S, Coefficient of storage. Defined as the net quantity of water in cubic feet released from storage from a vertical column of aquifer one foot square and the height of the saturated portion of the aquifer, when the hydraulic pressure on the column is reduced one foot of water under prevailing conditions.

Average aquifer coefficients, as determined from the pump test, are:

T 120,000 gallons per day per foot

S approximately 20%

These can be considered to be very good. Based on these values, predictions can be made about the performance of an aquifer.

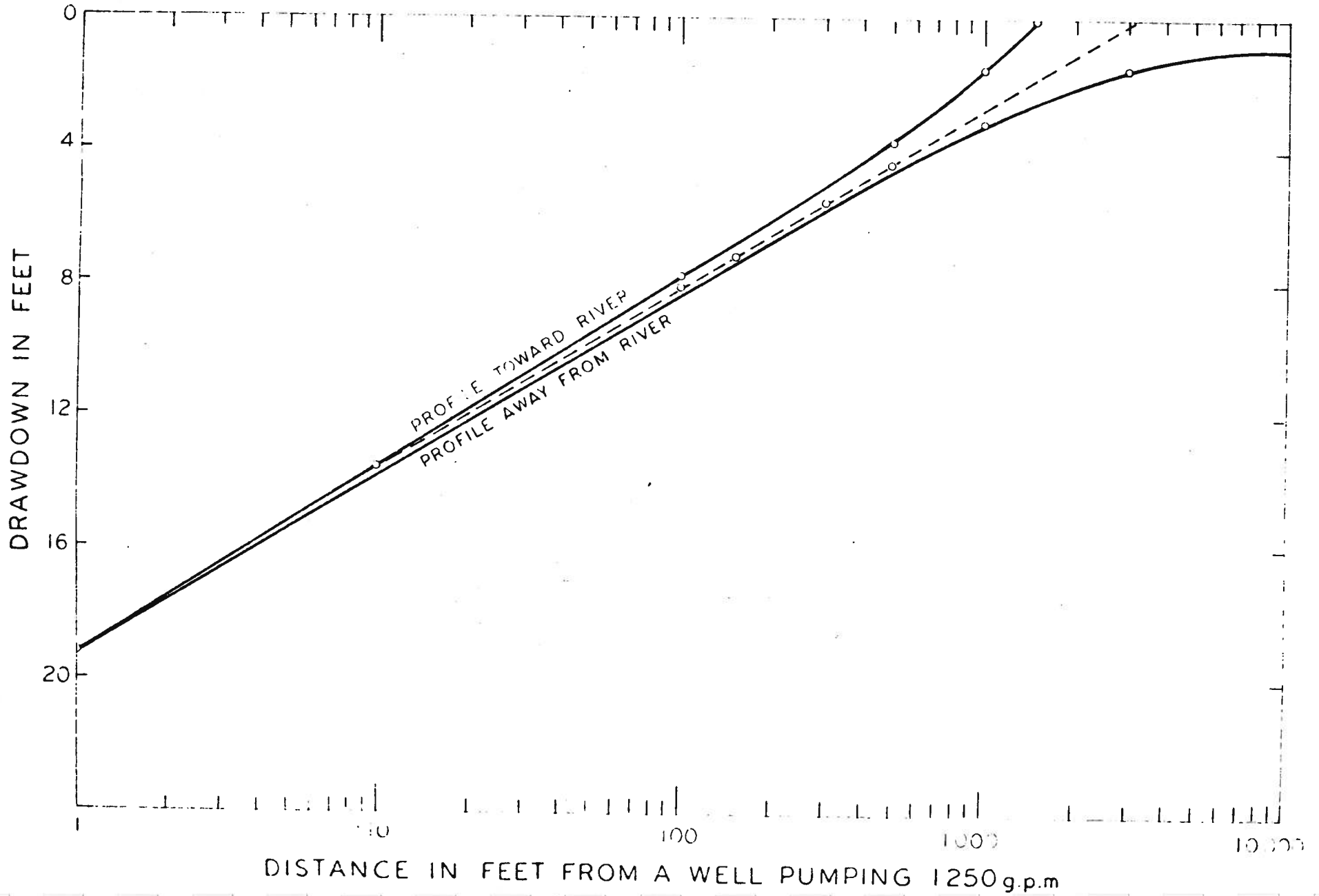
c. Estimated future water levels

In determining the drawdown in and near a pumped well, the following

equations are used:  $s = \frac{114,6 Q}{T} W(u)$        $u = \frac{1,87 r^2 S}{Tt}$

(the relationship between u and W(u) is given in standard tables).

FIGURE 3





By means of these equations the drawdown at any moment at any distance from a pumped well can be calculated. In the following example, one well is assumed, producing 1250 gpm, located at the site of test hole #2.

Drawdown Table

Distance from pumping well r feet	$r^2$	u	W(u)	Drawdown in feet after 1 day
1	1	$6,2 \times 10^{-8}$	16,20	19,06
10	100	$6,2 \times 10^{-6}$	11,41	13,57
100	10000	$6,2 \times 10^{-4}$	6,80	8,09
300	90000	$5,6 \times 10^{-3}$	4,24	5,48
500	250000	$1,5 \times 10^{-2}$	3,57	4,24

This graph is given as a dashed line in figure 3.

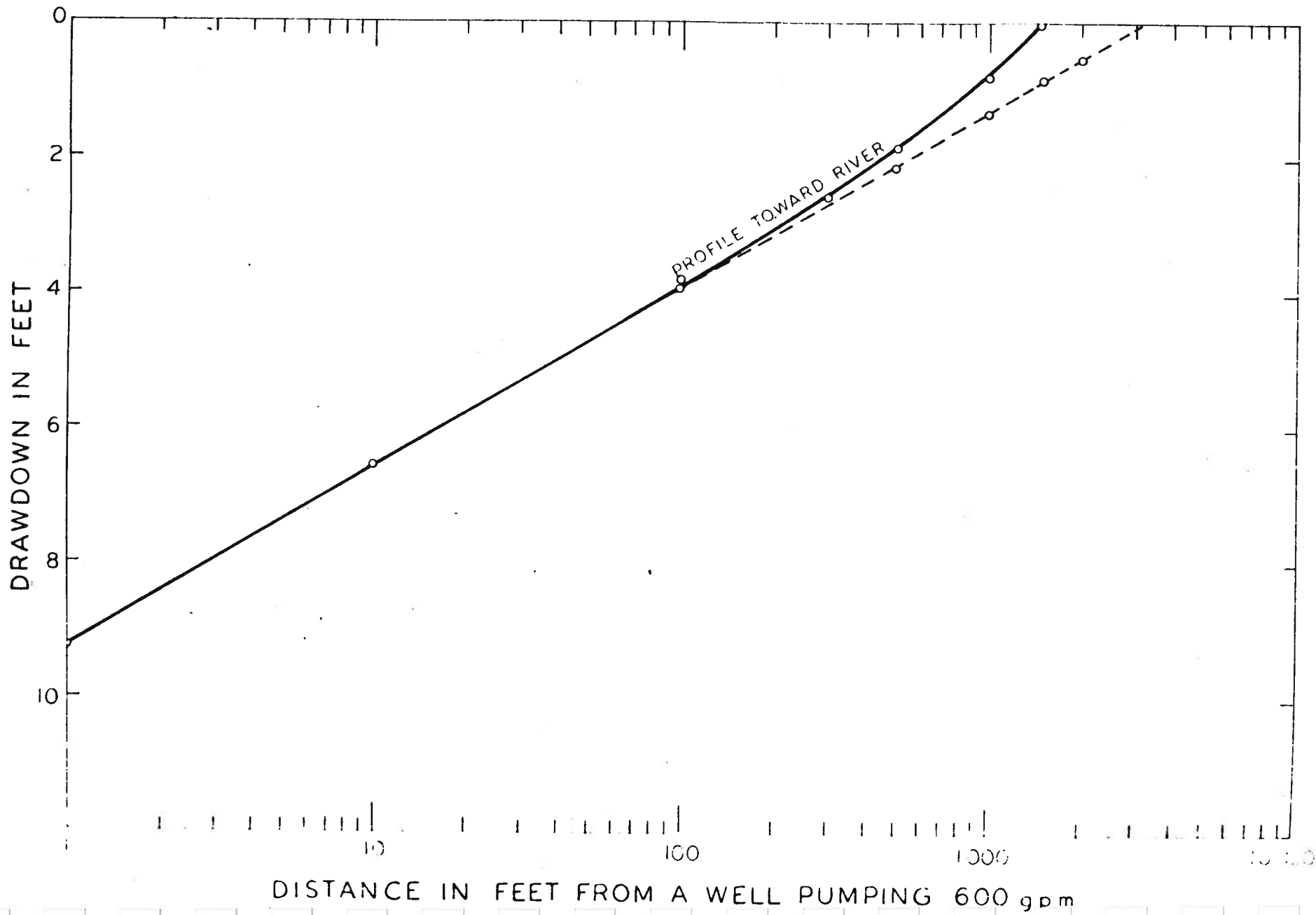
Because of the presence of a recharge boundary, this graph has to be corrected for the interference with the recharging image well.

Interference Table

Distance from pumping well r feet	Drawdown of pumping well in feet	Interference of image well in feet	Resulting drawdown in feet
1	-19,06	0,01	19,05
10	-13,57	0,10	13,47
100	-8,09	0,20	7,89
500	-4,24	0,50	3,74
1000	-2,70	1,10	1,60
1500	-1,80	1,80	0,00

This correction curve is given in figure 3, as profile toward river.

FIGURE 4



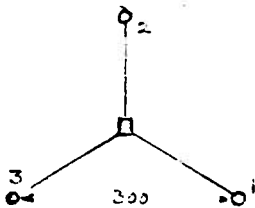
The actual drawdown in the pumped well is slightly more than calculated by the above-mentioned equations. An additional drawdown results from headloss during flow into the well and is generally called "well loss". The well loss during the pump test was probably 60% of the drawdown, as a result of the poor well construction. In a properly screened well, the well loss can be reduced to 5 - 15% of the calculated drawdown, which makes a total drawdown of 21 feet in this hypothetical well.

The available drawdown in test hole #2 was 39 feet, which proves the ability of this aquifer to produce such quantities of water.

d. Estimated future water levels in a three well system

If the desired industrial supply is obtained from a three well system, of which two wells are pumping continuously at a rate of 600 gpm, several combinations can be considered:

- 1) Three wells, arranged in a triangle, well spacing 300 feet.



In order to establish the water levels in this system, two factors must be considered.

- a. Drawdown in each well, caused by its own pumping.
- b. Interference between pumping wells.

The data of the following tables are all based on the drawdown curve which is given in figure 4. In all occasions pumping well #1 is assumed to be located at the site of test hole #2.

Interference Table

Interfering with	Well #1		Well #2		Well #3	
	distance	interf.	distance	interf.	distance	interf.
Well #1	-	-	300	2,75	300	2,70
Well #2	300	2,60	-	-	300	2,60
Well #3	-	-	-	-	-	-
Total interf.	2,60		2,75		5,30	
Own drawdown and well loss	11,00		11,00		0,00	
Total drawdown in feet	13,60		13,75		5,30	

Or generally speaking, the drawdown in the pumping wells is expected to be maximal 13,75 feet, whereas the interference in the non-pumping well is expected to be 5,30 feet.

2) Three wells, in a linear arrangement, well spacing 300 feet.



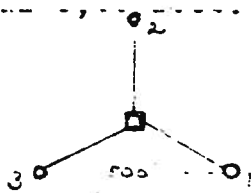
Interference Table

Interfering with	Well #1		Well #2		Well #3	
	distance	interf.	distance	interf.	distance	interf.
Well #1	-	-	300	2,70	600	1,90
Well #2	300	2,70	-	-	300	2,70
Well #3	-	-	-	-	-	-
Total interf.	2,70		2,70		4,60	
Own drawdown and well loss	11,00		11,00		-	
Total drawdown in feet	13,70		13,70		4,60	

Or, in case wells #1 and 3 are pumping, the total drawdown in #1 12,90; #2 5,30; #3 12,90.

The drawdown in the pumping wells is expected to be maximal 13,70 feet whereas the interference in the non-pumping well is expected to be maximal 5,30 feet.

3) Three wells, arranged in a triangle, well spacing  
500 feet.



Interference Table

Interfering with	Well #1		Well #2		Well #3	
	distance	interf.	distance	interf.	distance	interf.
Well #1	-	-	500	2, 10	500	2, 10
Well #2	500	2, 10	-	-	500	2, 10
Well #3	-	-	-	-	-	-
Total interf.	2, 10		2, 10		4, 20	
Own drawdown & Well loss	11, 00		11, 00		-	
Total drawdown in feet	13, 10		13, 10		4, 20	

4) Three wells in a linear arrangement, well spacing  
500 feet.



Interference Table

Interfering with	Well #1		Well #2		Well #3	
	distance	interf.	distance	interf.	distance	interf.
Well #1	-	-	500	2, 10	1000	1, 30
Well #2	500	2, 10	-	-	500	2, 10
Well #3	-	-	-	-	-	-
Total interf.	2, 10		2, 10		3, 40	
Own Drawdown & Well Loss	11, 00		11, 00		-	
Total drawdown in feet	13, 10		13, 10		3, 40	

Or, in case wells #1 and 3 are pumping, the total drawdown in both pumping wells is expected to be 12, 30 feet, and the drawdown in well #2 will be 4, 20 feet.

As might be seen from these tables, neither the array, nor the spacing of 300 or 500 feet, cause great differences in drawdown. It should be kept in mind, however,

### Chemical characteristics of infiltrated water

During the investigation, five water samples were taken. Nos. 1 and 2 were taken during the bail test of test hole #2, whereas nos. 3 and 4 were taken during the pump test, with a 24-hour interval. For the sake of comparison, sample #5 was taken from the South Saskatchewan River.

When percolating through the gravels, the river water picks up calcium and magnesium bicarbonates, which results in a higher alkalinity of the infiltrated water. The much higher chloride and sulphate content of the infiltrated water is probably a result of the semi-arid climate in this area. When the water starts to move faster (due to continuous pumping) these amounts are believed to decrease quite rapidly, and to approach the average chemical quality of the river. The sulphate content of the fourth sample already indicates this tendency.

Although no bacteriological samples were taken, no examples are known of this type of aquifer to be contaminated.

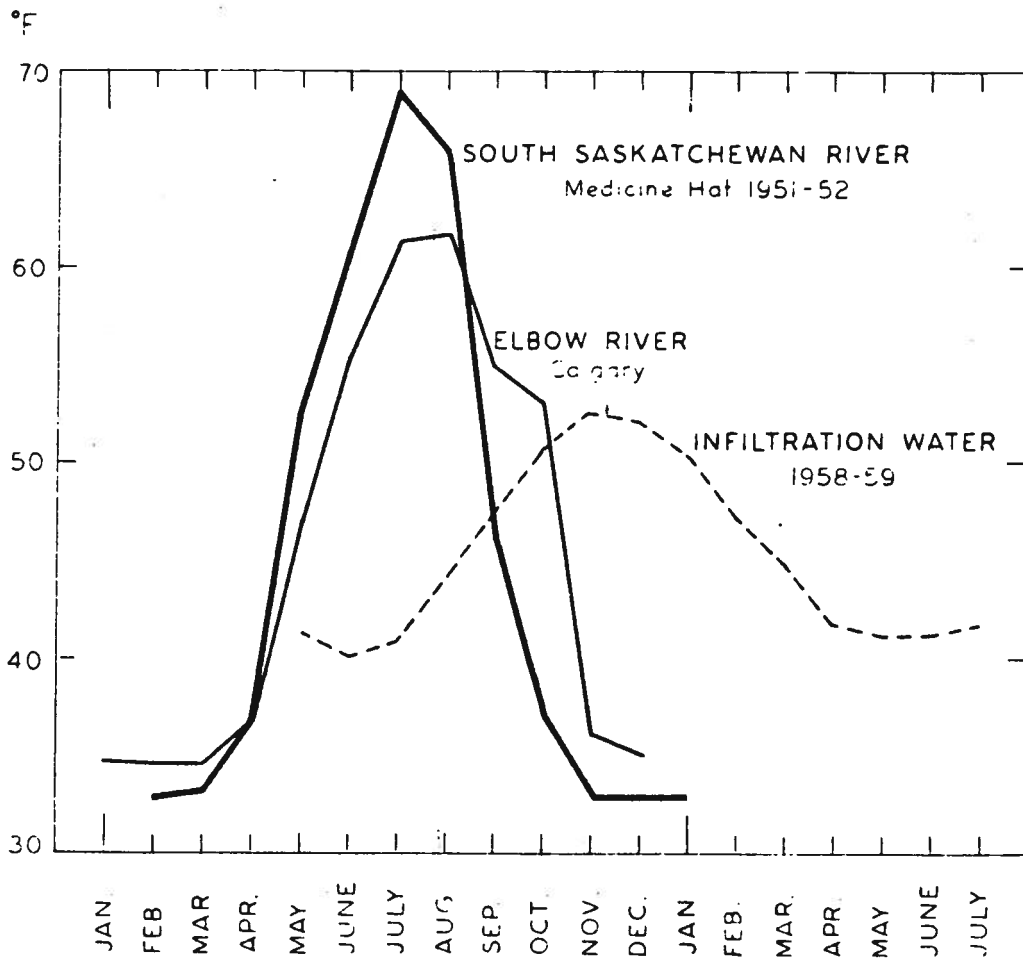
### " The temperature of infiltrated water

The relationship between temperature of surface water and the temperature of infiltrated water is very complex. Raphael G. Kazmann (1948) mentions several factors that are influencing the temperature of infiltrated water.

1. The mixing of groundwater with infiltration water .
2. The admixture of river waters of different temperatures while en route to the well.
3. The heat storage of the aquifer and the underlying rocks .
4. The conduction of heat upward and laterally within the aquifer, due to temperature gradients .

FIGURE 5

AVERAGE MONTHLY TEMPERATURES OF RIVER WATER AND INFILTRATION WATER



As a net result of these processes the aquifer produces water, that is cooler than the warmest river water, but warmer than the river lows.

For comparison, a graph is given of river temperatures of the Elbow River in Calgary (a 10-year average) and the monthly average temperature of infiltrated water, obtained from the same river (see figure 5). In the same figure, the river temperature during 1951-52 of the South Saskatchewan River in Medicine Hat is given.

Measurements taken during the pump test showed a temperature of 46°F. It seems justified to expect an annual range in groundwater temperature from 55°F during December to 40°F during May and June.

Resulting from this temperature fluctuation, the coefficient of the viscosity will change from 1,50 centipoise during summertime, to 1,21 centipoise during winter. This decrease in velocity will result in a larger flux of water toward the well during the winter months, which phenomenon may cause the winter drawdown to be 0,5 foot less than calculated.

#### Effects of changing river level upon the groundwater level

The aquifer of Police Point appeared to be under water table conditions. Any change in river level will, therefore, be reflected in the groundwater level.

Although no recent gauge recordings from the South Saskatchewan River were available, it is believed that the average annual river fluctuation is approximately 15 feet, having its maximum stage during May and early June, and its minimum during December and January. The largest fluctuation ever recorded is 30 feet (1905 flood and 1942 drought), but the saturated part of the aquifer is sufficiently thick to deal even with emergency situations like this.



The groundwater level during August probably represents the average situation. During the winter months, however, the groundwater level may well be expected to be 5 to 7 feet lower. This, however, is no precise figure, only a reasonable guess.

Recommended well completion and well field design

A correctly-developed well will produce more water per dollar of cost than any other type of well.

In unconsolidated materials, like the gravels of Police Point, the proper way to develop a well is to install a screen opposite the water-bearing formation.

Recommended is a 10-inch Slot No. 50 Johnson Everdur Well Screen, of which 20 feet should be installed, opposite the coarse and very coarse gravel. The total open area of such a screen is 2920 square inches, which is 3, 5 times as much as the total open area of a normal slotted casing. The advantages of a screen over a slotted casing are several:

1. Due to the high entrance velocity through a slotted casing, the water will deposit part of its mineral content on and around the well. This encrustation will severely limit the well production and eventually it has to be removed by acid treatment, which in turn will corrode the casing. Because of the larger total open area of a screen, the entrance velocity is reduced to such an extent, that encrustation is less likely to occur. If, however, an acid treatment is necessary, the screen will have considerable more resistance against this treatment than a steel casing.
2. The "well loss" with a screen will be 6 to 10 times less than if the well is finished with a slotted casing. This means a reduction in pumping costs of approximately 33.5¢ per day.

$$\left( \text{pumping cost per hour } \frac{600 \text{ gpm.} \times 4 \text{ feet} \times .746 \times 2¢ \text{ KWHr}}{3960 \times 75\% \text{ pump ef.} \times 90\% \text{ motor ef.}} \right)$$

Having two wells operating continuously, means an annual saving in pumping costs of \$244.00, if the wells are provided with a screen.

Well field design The location of the permanent wells seems to be most favorable within the loop formed by the road on Police Point (see figure 1). One of the wells can be located at or near the site of test hole #2. Since the exact position of a possible discharge boundary is unknown, a triangular well arrangement is preferred over a linear one. If a triangular arrangement is made, a well spacing of 500 feet should give the most satisfactory results.

No well should be located at a place where the bedrock is closer than 50 feet to the surface.

With the pump setting, two factors ought to be considered:

1. Estimated future water levels, respectively 13, 10 or 13.75 feet, depending upon the well spacing (see pages 6, 7 and 8).
2. Expected fluctuations in groundwater level, due to changes in river level. Expected minimum static level: 26 feet below surface.

These considerations make a total depth of 39.75 feet below surface at which the pump should be set.

Conclusions:

The results of this investigation show that the gravel aquifer at Police Point is capable of yielding at least 1.7 million gallons of water per day.

Respectfully submitted,



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APPENDIX A

Logs of testholes

(for location see figure 1)

Testhole # 1      0-10    sand and some gravel (topsoil)  
                    10-30    coarse gravel  
                    30-58    very coarse gravel and small pebbles.  
                    58-70    blue clay (bedrock)

Elevation top of casing : 2163.97

Waterlevel August 20 : 19.51

Well provided with unslotted casing.

Testhole # 2      0-12    sandy clay (topsoil)  
                    12-22    fine gravel and sand  
                    22-35    coarse gravel  
                    35-55    very coarse gravel and small pebbles.  
                    55-      blue clay (bedrock)

Elevation top of casing 2151.98    Surface elevation:

Waterlevel August 20: 7,12.

The well was provided with 20 feet of slotted casing and was bailed for two hours at a rate of 25 gpm, with a drawdown of 0.03 feet. During the bail test only a small amount of sand came out, indicating a relatively clear gravel. For test purposes, this well was equipped with a suction pump, powered by a tractor.

Testhole # 3      0-14    sandy clay (topsoil)  
                    14-20    fine gravel  
                    20-30    coarse gravel  
                    30-45    very coarse gravel and small pebbles.

Elevation top of casing 2160.52

Waterlevel August 20 17.39

The well did not reach bedrock and was provided with a slotted casing from 0-40 feet.

Testhole # 4      0-14    sandy clay (topsoil)  
                    14-20    fine gravel  
                    20-30    coarse gravel  
                    30-37    very coarse gravel  
                    37-      blue clay (bedrock)

Elevation top of casing 2164.35

Waterlevel August 20 19.51

The well was provided with an unslotted casing.

Testhole # 7:      0-40    fine sand and sandy clay (topsoil)  
                    40-60    sand  
                    60-123    sand and gravel  
                    123-      blue clay (bedrock)

Elevation 2249.80

No waterlevel recorded.

This testhole was not provided with a casing.

Testholes # 5 and # 6: were both excavated by hand, till the water-table was reached and equipped with an observation pipe.

During the pump test no noticeable change in waterlevel occurred in these holes.