

STETTLER REPORT

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INTRODUCTION

A study of the groundwater resources of the Stettler area was undertaken by the Research Council of Alberta in 1957, after the town of Stettler requested assistance to determine whether large quantities of groundwater could be obtained in the vicinity of Stettler. This report deals with the groundwater geology and hydrology in the vicinity of Stettler; it will be included in a more comprehensive report of the entire Stettler area to be published later this year. This report is not intended for public distribution although the information and conclusions contained herein are available to anyone upon request.

GROUNDWATER GEOLOGY AND HYDROLOGY

Geology and Groundwater

Groundwater geology is the study of those physical properties of rocks which control the occurrence of groundwater. All rocks, either unconsolidated or consolidated, which lies below the water table, below a depth of about 10 feet at Stettler, are saturated with water which occupies the small interstices or open spaces between the particles making up the rock. Where these interstices are interconnected, the water is free to move through the rock under the influence of differential hydrostatic pressure and the rock is said to be permeable. Because the permeability of the material that a well is completed in directly determines the rate at which water may be produced, geologic studies are directed mainly toward locating highly permeable strata by studying the physical characteristics of the rocks themselves and their depositional and post-depositional history. Regional changes in permeability are readily delineated by geologic methods, these methods however, are less adaptable to determine local changes in permeability which may also be very significant.

Stettler is underlain by consolidated sedimentary rocks (commonly termed "bedrock") which geologists have named the Edmonton formation. These sediments were deposited

around the margin of the sea which covered Alberta several million years ago. The Edmonton formation is overlain by unconsolidated sediments deposited by continental glaciers which advanced over Alberta in the past and melted or retreated from this area about 10,000 years ago. During the time interval following the retreat of the sea which covered Alberta and preceding the advent of glaciation the bedrock surface was eroded by streams and rivers forming a mature topographic surface characterized by low upland areas separating broad valleys. The Buffalo Lake channel which trends eastward through Buffalo Lake is one of these ancient channels, which has been completely filled with glacial deposits so that its course is no longer evident from the surface topography.

The more permeable sediments, for example, sand and gravel deposits in the glacial drift and sandstone beds in the Edmonton formation through which water is readily transmitted are termed aquifers. Geologic mapping has been carried out employing subsurface data to delineate the major potential aquifers in the Stettler area.

The Edmonton formation is the uppermost bedrock formation in the Stettler area. It is made up of interbedded sandstone, sandy shale and shale, with minor coal seams and ironstone concretions. Formations underlying the Edmonton formation contain water that is brackish to salty and unfit for human consumption. The upper surface of the bedrock is an erosional surface, as already described, which slopes downward to the north toward the Buffalo Lake channel. The Buffalo Lake channel is the major bedrock channel; tributary channels include the Erskine channel and the Lehurst channel.

The Edmonton formation dips westward at about 20 feet per mile. Consequently the depth to a given marker horizon in the Edmonton formation will increase to the west.

The Edmonton formation has been subdivided into three members, the upper Edmonton member, the middle Edmonton member, and the lower Edmonton member. The upper Edmonton

member has been eroded from all but the extreme southwest part of the Stettler area. The middle Edmonton member is the most productive part of the Edmonton formation, and where it forms the subcrop, wells yielding up to 60 gpm. may be completed in the bedrock. The Edmonton formation dips west, and the erosional surface of the bedrock slopes downward toward the north. Therefore, the middle Edmonton member has been removed by erosion east of a northwest trending line which passes about one mile east of Stettler. East of this line water wells completed in the bedrock obtain water from the lower Edmonton member, and generally wells may be expected to yield less than 5 gpm.

The top of the lower Edmonton member at Stettler is a rock unit about 20 feet thick consisting of dark grey to black, moderately hard shale which may contain numerous fossils, and up to four beds of black limestone about one foot thick. It may be recognized in the cutting samples from test holes and by the change in drilling rate, as it is penetrated by the drill for it is generally harder than the overlying and underlying material. This rock unit constitutes an important marker horizon at Stettler, as it is very unlikely that sufficient water for a municipal supply well will be obtained at a greater depth from the lower Edmonton member. The only bedrock aquifer in which municipal supply wells can be economically located is the middle Edmonton member.

The Edmonton formation is overlain by glacial drift deposited over the irregular bedrock surface. The thickness of glacial drift is extremely variable, ranging from 5 to 50 feet thick south of Stettler, and from 100 to 250 feet thick north of Stettler. The glacial drift is made up principally of clayey till, containing minor lenses of sand and gravel. The only potential aquifers in the glacial drift are:

- (a) sand and gravel deposits along the course of bedrock channels, now buried by up to 250 feet of glacial drift,
- (b) outwash sand deposits, deposited during the last phase of deglaciation, overlying glacial drift.

Occurrences of both types were tested during this study. A total of 12 test holes were drilled to test the sand and gravel deposits in the Buffalo Lake channel, 10 miles north of Stettler, and at the east end of Buffalo Lake.

About 20 feet of very fine grained sand was encountered immediately overlying the bedrock in five test holes drilled at the east end of Buffalo Lake. The sand deposit found at the east end of Buffalo Lake is discontinuous as no sand was found in two test holes. The other five test holes drilled to test the channel directly north of Stettler did not encounter any sand or gravel in the channel. At the sites tested, it is unlikely that wells capable of yielding more than a few gallons per minute could be developed. Further test drilling to locate coarser granular deposits along this channel is not recommended at this time. An extensive outwash sand deposit in Tp. 38, Rs. 20 and 21, was also tested by drilling at seven sites. This outwash sand deposit was found to be made up principally of fine-grained sand, in which high capacity wells could not be completed.

The only bedrock channels in the area which were not test drilled are the Erskine channel which extends northward from Erskine to Buffalo Lake, and the Leahurst channel which is now occupied by Red Willow Creek. Both channels are minor tributaries to the Buffalo Lake channel.

There appears to be little well sorted coarse sand or gravel associated with the glacial deposits in the Stettler area, and therefore, there is little chance of obtaining large quantities of groundwater from the glacial drift. The only possibilities not yet investigated include the tributary bedrock channels, and the possibility of obtaining induced infiltration from Buffalo Lake through shallow sand deposits around the southern shore of the lake. Either of these prospects would require extensive testing to evaluate their potential.

Hydrology

The regional hydrology of the Edmonton formation is relatively straightforward as the entire formation behaves as a single homogeneous aquifer. The piezometric surface map, constructed by contouring the elevation to which water rises in wells throughout the area, shows that the configuration of the piezometric surface conforms to the present day topography and that the regional direction of groundwater movement is northward toward the Buffalo Lake channel. This bedrock channel behaves as an underground drain carrying groundwater eastward to the Battle River. Red Willow Creek is an affluent stream throughout its course; that is, groundwater discharges into the creek rather than water from the creek seeping into the ground. The piezometric surface has a definite gradient and the groundwater flow system is in dynamic equilibrium, that is, on a regional scale the recharge to the flow system is balanced by a corresponding discharge from the flow system. Because the piezometric surface conforms to the present topography this recharge must be due to local infiltration of water to the groundwater system on upland areas, and discharge from the groundwater flow system in lowland areas.

The amount of recharge is not known but it is probably low (in the order of one inch per year). There are no water level records available from the Stettler area to indicate whether or not any regional changes in the elevation of the piezometric surface have occurred because of climatic variations in the average annual precipitation. It is felt, however, that regional variations due to this cause will be very small.

At Stettler groundwater withdrawal since 1905 has disrupted the dynamic equilibrium of the groundwater flow system and created a pronounced depression in the piezometric surface. In the vicinity of Stettler, all groundwater movement is directed toward the centers of pumping within the town. The maximum velocity of groundwater movement in the Edmonton formation in the cone of influence is very low, estimated to be less than 0.5 feet per day, except in the immediate vicinity of producing wells where it would be somewhat higher.

All the town supply wells obtain water from the middle Edmonton member. The wells are artesian, that is the water rises above the depth at which it is encountered, and characteristically have a low available drawdown, that is the water does not rise far above the top of the aquifer.

The parameters employed to quantitatively evaluate the productivity of an aquifer are the transmissibility and the storage coefficient. The transmissibility, T , is the product of the permeability and the thickness of the aquifer; in its numerical form it is expressed as the number of gallons which may be transmitted through a vertical strip of aquifer one foot wide in one day, under a hydraulic gradient of 1 foot per foot. The storage coefficient is a dimensionless expression of the volume of water released from storage, from a vertical prism of unit cross-sectional area having a height equal to the thickness of the aquifer, when the hydrostatic pressure is reduced one foot. These aquifer coefficients may be determined directly from a pumping test from the drawdown observed in one or more observation wells at a known radius of the pumping well. In this study the transmissibility and storage coefficient were determined from pumping test data by the Theiss non-equilibrium equation; the mathematical expression for this is contained in Appendix B.

Summary

Field investigations to date have shown that there is no aquifer in the Stettler area in which wells capable of yielding more than 100 gpm. could be completed. Further, it is unlikely that additional exploration would materially alter this conclusion. It is therefore certain that the middle Edmonton member aquifer represents the best prospect for the development of additional groundwater for the town of Stettler for the following reasons:

- (a) additional development may take place near the town,
- (b) wells yielding up to 60 gpm. may be located by proper testing procedures,

- (c) exploration and well completion costs are low,
- (d) this aquifer may be expected to produce water of the same quality as that currently utilized.

Before proceeding with a detailed discussion of the geology and hydrology of the middle Edmonton member aquifer at Stettler, a brief review of the groundwater exploration since 1957 is in order.

GROUNDWATER EXPLORATION, 1957

Well No. 11 (Fig. 1), located in the southwest part of Stettler, was drilled in July, 1957 and placed on production in January, 1958, after extensive testing had been completed. The sample log and completion history are included in Appendix A. The well was initially drilled to a depth of 300 ft. to test the lower Edmonton member which was found to be unproductive. Consequently, the hole was plugged back to 150' and the well completed in the middle Edmonton member.

Three pumping tests were run, at 26 g.p.m., for three days, 40 g.p.m. for one day, and 60 g.p.m. for 10 hours. The average aquifer coefficients obtained were used to determine that the maximum safe pumping rate should not exceed 39 g.p.m. The pump was adjusted to this rate in 1958, however, because the well cannot be produced continuously at this time as the available reservoir storage is limited, the average continuous production is now about 26 g.p.m.

The well was properly completed and developed; the pumping tests indicate a moderately high well efficiency. The well efficiency does not appear to have decreased significantly in two years of operation. The drilling and testing of this well completed the exploration activity for 1957.

An automatic water level recorder was installed on Well No. 6 to provide a continuous record of water level fluctuations in the Stettler well field. Meters were installed on all supply wells in 1956 and daily production records have been maintained since that time.

GROUNDWATER EXPLORATION, 1958

The writer outlined a test drilling program to consist of three test holes (Fig. 1) to evaluate the possibility of locating additional supply wells on the east side of town. This testing program was planned to complete the evaluation of the amount of groundwater available within the town limits that could be developed without new extensions to the distribution system.

The testing program conclusively indicated that:

- (a) supply wells could not be completed east of Main St. because of changes in the geology,
- (b) little advantage is to be gained by drilling replacement wells at the same location as old supply wells in which the production has markedly declined.

STETTLER 1958-1: This test hole, located in the northeast part of town was drilled, tested, and abandoned in August 1958. The hole produced less than 1 g.p.m. on a bail test. The lower Edmonton member is unproductive at this location also. Sand was encountered in the glacial drift in this test hole but was not tested; the sand is fine-grained, and probably has a limited areal distribution.

STETTLER 1958-2: (Well #1-A) This test hole was drilled 50 feet northeast of Well No. 1 which is the original supply well, to see whether production could be increased from new wells drilled adjacent to old wells. This well was completed at a depth of 162 feet in the middle and lower Edmonton members, and is capable of producing about 3 g.p.m. This

production rate is not significantly greater than that of Well No. 1 prior to its abandonment, although Well No. 1 was reported to be originally capable of producing 15 g.p.m. It is concluded that the decline in production of Well No. 1 is due principally to local depletion of the aquifer rather than to deterioration of the well.

STETTLER 1958-3: (Well #12) This test hole, located adjacent to the new skating rink, was drilled to a depth of 140 feet. This well produces entirely from the middle Edmonton member, as the top of the lower Edmonton member was encountered at 120 feet. A pump test was conducted and from this the maximum safe continuous production was calculated to be 36 g.p.m. The pump was adjusted to this setting and the well placed on production on October 6, 1958.

After Well No. 12 was placed on production, Well No. 5 was abandoned. The production history of No. 5 well had been unsatisfactory because of the low well efficiency caused excessive drawdown and cavitation. Chemical and bacteriological analyses of water from this well in 1957 showed a measurable nitrate concentration, but no bacteriological contamination. Because no other wells at Stettler yield water containing nitrates, it was felt that the nitrate concentration may have been caused by direct contamination of the well from an adjacent surface drain because the well was not properly completed. Consequently, when the well was abandoned it was grouted from the bottom up with a cement-sand slurry.

GROUNDWATER EXPLORATION, 1959

Groundwater exploration in 1957 and 1958 showed that no further wells could be located within the town limits. Because any extension of the distribution system outside the town limits would entail large capital expenditures an extensive testing program was undertaken to determine the best area for developing additional groundwater resources outside the town.

A total of seven test holes were drilled and tested (Fig. 1). One test hole (1959-2) was completed as a well to provide water for the cemetery. The remaining test holes were capped and will be used as observation wells to study the long term behaviour of the aquifer.

The exploration program to date has disclosed the presence of apparently systematic variations in the transmissibility of the middle Edmonton member. The isogram map (Fig. 1), shows the transmissibility variations; the transmissibility determined from pumping tests of the wells shown are indicated in brackets. Within the stippled areas wells may be completed which have an above average productive capacity. The high transmissibility within these zones appears to be due mainly to a greater number of sandstone beds present, and to a lesser extent due to the higher permeability of individual sandstone beds encountered.

Two zones of higher transmissibility have been discovered. Both are narrow (about 1/2 mile wide) and trend northwest. Both zones appear to be continuous along trend, but some variation in transmissibility may be expected to occur along trend.

The most easterly zone passes through the west side of Stettler, Wells No. 8, 9, 10, 11, and 12 are completed in this zone. South of Stettler, the cemetery well is also completed in this zone. Further development along the trend of this high permeability zone is not recommended for the following reasons:

- (1) the thickness of the middle Edmonton member decreases rapidly northwest of Stettler, where the upper part has been removed by erosion,
- (2) southeast of Stettler is somewhat more favorable but it is anticipated that the maximum production per well would not be greater than 30 g.p.m. because there is insufficient available drawdown, the most productive part of the aquifer being very near the surface,

(3) additional supply wells completed in this zone within or near Stettler would interfere with existing supply wells; the total production would not be significantly increased.

Another zone of higher transmissibility passes through the SW. 1/4, Sec. 1, Tp. 39, R. 20, W. 4 Mer. Three test holes were completed in this zone, 1959-5, 1959-6 and 1959-7; 1959-1 was drilled just east of the higher permeability development.

Wells in this area have a higher available drawdown because the most productive part of the middle Edmonton member is encountered at a greater depth, and the static water level is nearer the surface than in the town of Stettler. This means that wells in this area can be safely produced at a higher rate than those in Stettler. This is the best area for future groundwater development located during this testing program. Production testing indicates that a well field can be developed in the SW. 1/4, Sec. 1, Tp. 39, R. 20.

It should be pointed out that the Intervening zones of lower permeability do not behave as hydrologic boundaries as there is still groundwater movement through the low permeability zones. The productive capacity of any well in this aquifer depends primarily upon the transmissibility of the aquifer in the immediate vicinity of the well and is not greatly influenced by changes in transmissibility at greater distances from the well. The sole purpose of locating wells only in zones of higher transmissibility is to increase the operational efficiency of the well field by permitting withdrawal of the same amount of water from the fewer wells producing at a higher rate.

EVALUATION OF HYDROLOGIC DATA

The aquifer coefficients were determined from several pumping tests. The best pumping test results were obtained from a three-day test conducted on test hole 1959-5, using Test Holes 1959-7, 1959-6, 1959-1 and two private wells as observation wells. The aquifer coefficients calculated from this test are: transmissibility $T = 3120$ gpcf, and storage coefficient,

$S_1 = 9.0 \times 10^{-4}$. Because this test was conducted under better conditions than any other pumping test, it is felt that these values for the aquifer coefficients obtained provide the most reliable values for the aquifer coefficients for the higher permeability zones. These values are closely comparable to the values obtained from pump tests of wells 11 and 12, using No. 6 as an observation well which yielded calculated values of $T = 4000$ gpdf and $S = 4.6 \times 10^{-4}$. The values for the aquifer coefficients $T = 3120$ gpdf and $S = 9.0 \times 10^{-4}$ are employed for all further calculations.

The aquifer coefficients determined may be employed to predict the short term performance of wells in this aquifer, however, it is felt that the predicted well performance is likely to be too pessimistic when production is considered over a period of many years. The major source of error occurs in the determination of the storage coefficient.

The storage coefficient may also be calculated if the volume of the cone of depression caused by production, and the total production from the well field can be determined. At Stettler there is insufficient data and only a crude approximation of the cone of depression can be obtained. Likewise, the cumulative water production from wells within the town can only be crudely approximated, since production records have been maintained only since 1956. The storage coefficient calculated ranges from 1.0×10^{-1} to 5×10^{-2} . This calculated value is larger by a factor of 100 than the value for the storage coefficient determined from pumping tests.

The influence of production from town supply wells on the observation wells was calculated in order to obtain what would be in effect a longer term pumping test. The drawdown component of Wells 7, 8, 9 and 10, Well No. 5, Well No. 11, Well No. 12, and the trailer court well were calculated separately and combined to produce the calculated drawdown curve of Well No. 6 shown in Figure 4. The observed depth to water curve was compiled from water level records maintained on this well.

The calculated curve follows the observed curve closely until June 1959, thereafter the observed curve falls above the calculated curve. More data are required before it can be determined whether this departure is significant, however, this type of departure would be expected to occur if there is recharge to the aquifer by leakage of the confining beds of the aquifer.

If there is water entering the aquifer in this way the cone of influence of the well field will have a finite radius and production wells will drawdown and approach an equilibrium at which the water produced is balanced by vertical leakage. It may require several years to approach equilibrium if the production remains constant.

The amount of vertical leakage is very small. If it is assumed that production prior to 1946 was obtained entirely from storage without vertical leakage, then the amount of vertical leakage since 1946 would be in the order of 0.002 gallons/day ft². This is a very low figure, and from the geological characteristics of the confining beds it is entirely conceivable that this amount of leakage can and does occur.

It is concluded therefore, that the transmissibility of the middle Edmonton member, in the zones of higher transmissibility discovered to date is about 3120 gpcf. The storage coefficient of the aquifer is about 9.0×10^{-4} , but it is almost certain that the aquifer is not an ideal aquifer but that there is vertical leakage, which in effect is directly added to the storage coefficient.

Hydrologic calculations based upon these aquifer coefficients provide a prediction of the future aquifer performance that represents a conservative estimate.

DESIGN OF PROPOSED WEST-STETTLER WELL FIELD

Design

The most efficient well field will be one from which the maximum amount of water may be withdrawn from the aquifer by means of the minimum number of wells. In order to

achieve this design it is necessary to completely understand the hydrologic behavior of the aquifer when wells are pumped for long periods of time. At Stettler there is insufficient data upon which to base an exact design, however, if it is assumed that the aquifer is an ideal artesian aquifer, and that all water produced is derived from storage within the aquifer that is there is no recharge or leakage to the aquifer, then the design will be safe as this is the least favorable combination of factors that may occur.

The aquifer coefficients determined from the pumping test of Test Hole 1959-5, ($T = 3120$ gpdf and $S = 9.0 \times 10^{-4}$) were used to design the well field. The individual pumping rate, total daily well production and well spacing, for various combinations of wells producing at different rates are shown in Table 1. It is evident that the optimum combination is to have two production wells, producing 60 lpm (173,000 lpd), spaced 2300 feet apart. The recommended location for these wells is on an east-west line immediately south of the Highway No. 12 right-of-way, in Lsd. 5 and 6, Sec. 1, Tp. 39, R. 20, W. 4th Mer., at the locations shown on Figure 2. This alignment will locate the wells perpendicular to the direction of groundwater flow.

If production wells are completed at the locations shown and produced continuously at 60 gpm each, then a cone of influence will develop rapidly around the well field. Figures 2 and 3 show the progressive development of the cone of influence, after production has continued for about 100 days, and 5 years. It is immediately evident from these figures that the cone of influence predicted from the assumption that the aquifer is an ideal artesian aquifer, is much deeper and more extensive than the cone of influence created by production within the existing Stettler well field. For this reason it is felt that the calculated drawdown or interference represents the maximum possible interference, and that the actual amount of interference will be much smaller or non-existent.

The actual configuration of the cone of influence should be observed as pumping progresses by means of periodic water level measurements in the existing observation wells.

This will serve two purposes:

- (a) the maximum actual interference at any point within the cone of influence may be estimated,
- (b) the amount of vertical leakage or recharge may be determined.

If the leakage is significant it may be feasible to locate two additional production wells pumping at about the same rate in the SW. 1/4, Sec. 1, to increase the total daily production to about 300,000 gpd. This, however, cannot be determined until production has continued for two to three years.

Table I
Production and Well Spacing Calculations

Number of Wells	Individual pumping rate	Well spacing	Total daily production	Length of gathering system	Length of gathering system (feet) 1,000 gals. production
1	80	0	115,000	11,000 *	95.5
2	60	2,300	173,000	13,300	77.0
3	60	>10,000	260,000	>31,000	>119
3	50	10,000	216,000	31,000	143
4	40	6,000	230,000	29,000	126

* Approximate distance from the existing water tower to the NE. corner Lsd. 6, Sec. 1, Tp. 39, R. 20, W. 4 Mer.

RECOMMENDED DEVELOPMENT PROCEDURE

It is recommended that two production wells be completed at the locations shown on Figure 2. These wells should be completed with 3-5/8 inch O.D. steel surface casing cemented or driven to bedrock, and finished either open hole or with a slotted liner, to a total depth of 160 to 170 feet. Each well, after an initial pumping test, should be equipped with a pump capable of producing 60 to 80 lpgm. Each well should be permanently equipped with a flow meter and an air-line gauge.

The maximum amount of hydrologic data will be obtained by the following procedures:

- (1) conduct one to ^{two} weekly production tests on each well separately, using the other production wells and existing test holes as observation wells,
- (2) after the wells are connected to the distribution system, the pumping rate of the wells should be adjusted so that these wells will produce sufficient water to supply the entire system when they are pumped continuously,
- (3) all wells in the town can then be shut down except for emergency production, unless one well is required for pressure maintenance in the distribution system in the north-west part of town,
- (4) this distribution of production should be maintained for as long as possible, at least for several months,
- (5) weekly water level measurements should be made in all observation wells, and production wells.

This procedure will supply the following data:

- (a) the actual configuration of the cone of influence in the west Stettler well field as pumping progresses will be measured, from this the feasibility of locating additional production wells in the SW. 1/4, Sec. 1 may be studied,
- (b) a recovery test of the entire Stettler well field will be possible, this should