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# GROUNDWATER GEOLOGY AND HYDROLOGY OF EAST-CENTRAL ALBERTA

by

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## ABSTRACT

East-central Alberta covers an area of about 17,000 square miles. Two thirds of the area is drained by the North Saskatchewan River, and the remaining one third by the Beaver River.

The bedrock units in east-central Alberta are the Lea Park, the Belly River, the Bearpaw, and the Edmonton Formations. The Lea Park Formation, underlying the northeast region, is a blue to black marine shale and, apart from occasional sandstone beds or lenses, is a poor source of groundwater supply. The Belly River Formation consists of an undivided series of thin alternating sandstones, siltstones, shales, sandy shales, and coal seams in the west region and is divided into a number of distinct alternating continental sandstone and marine shale members in the southeast region. This formation is a poor source of groundwater supply in the west region but is a moderately good source in the southeast region. The Ribstone Creek and Birch Lake Sandstone Members, which occur in the southeast region, are the most important aquifers in east-central Alberta. These aquifers have some wells yielding up to 100 gallons per minute, and locally it may be possible to obtain 150 gallons per minute. From the Bearpaw Formation, a blue to black marine shale, no groundwater is obtained in this area. The Edmonton Formation, a lithologically similar deposit to the undivided part of the Belly River Formation, has poor groundwater potential in east-central Alberta.

Unconsolidated glacial deposits, chiefly till, and some sorted sands and gravels overlie the bedrock throughout the entire area. The till is a poor source of groundwater supply and is suited largely to meeting domestic requirements only, but the sand and gravel deposits, depending on their extent, thickness and permeability, may provide sufficient water for small industrial consumption. The sand and gravel deposits within buried or partly buried preglacial valleys have good groundwater potential, and the supplies may range from domestic to industrial.

Study of the shape of the piezometric surface shows that the movement of groundwater is from centres of high to areas of low relief, with the overall movement of groundwater being toward the east.

Hydrographs, drawn from records of monthly measurements of shallow wells in the area, show that water levels fluctuate in response to changes in precipitation and temperature. These hydrographs help to confirm reports that groundwater supplies from shallow aquifers are uncertain if recharge by precipitation does not occur at regular intervals. Hydrographs drawn from the records of automatic recorders on deep wells terminated in the Ribstone Creek and Birch Lake Sandstones indicate that withdrawal of groundwater does not exceed the potential available for development.

The chemical quality of the groundwaters falls largely within the "saline" category as total dissolved solids commonly exceed 1,000 parts per million. However, much of the water is passed as suitable for human consumption because of the absence of supplies of better-quality water. The number of wells with water that is detrimental to health is assumed to be low.

Groundwater from bedrock aquifers is commonly soft to moderately soft, and only in part of the area from townships 48 to 54, ranges 1 to 8, is it commonly hard enough to require softening. The sulfate and chloride contents of the water from some wells exceed the potable limits of concentration for these constituents, and in many cases the iron and sodium contents of the water are quite high. The amount of sodium present makes many bedrock waters unsuitable or of doubtful quality for use in irrigation. The water from glacial-drift aquifers is very hard and requires softening for domestic and industrial use. The iron, sulfate, and nitrate contents commonly exceed the suggested concentration limits for potable water.

## INTRODUCTION

The purpose of this report is to summarize existing data on east-central Alberta concerning public, industrial and private water wells and to correlate these data with pertinent information supplied by oil companies and with the results of local detailed and reconnaissance groundwater surveys carried out during the summers of 1957 to 1961 inclusive. The available data have been evaluated in order to outline areas of large, moderate and small groundwater supply. The report has also been designed to delineate those parts of east-central Alberta where further detailed studies are necessary for a better understanding of the groundwater resources, particularly for the development of moderate supplies of water for municipal and light-industrial uses.

### Methods of Investigation

For an understanding of the geology of east-central Alberta, reference was made to geological reports and maps and to lithologic and electric logs. Air photos were used to supplement the field studies.

Existing well records on file in the Research Council and supplied by water-well drillers, oil companies, and private well owners were assembled as the basis of this report. Also used were data in water-supply papers published by the Geological Survey of Canada, and from local detailed areal investigations. Additional information was collected by visiting district health units, from which sources most of the data on the chemistry of the groundwaters were obtained and by visiting municipal district, town and village secretaries and by measuring water levels in wells on reconnaissance field trips.

The elevations of most wells were estimated from available topographic maps.

Hydrographs of stream flows for the North Saskatchewan and Battle Rivers and for deep and shallow observation wells have been plotted to obtain estimates of the amounts of surface runoff and groundwater discharge, and to support comments on the effects of both natural and artificial discharge on regional and local water-level fluctuations.

## Previous Investigations

A survey of the groundwater resources of east-central Alberta was begun in 1930 by Dr. R. L. Rutherford, Assistant Professor of Geology, University of Alberta, assisted by J. Tatham, who made trips in the central and southern parts of the area along the routes shown (Fig. 1). Investigations were also carried out by the Geological Survey of Canada in the early 1930's and most of their data were collected in 1935. Some of this information has since been published by the Geological Survey of Canada. Information has been selected from two of these papers (Hume and Hage, 1947a, b).

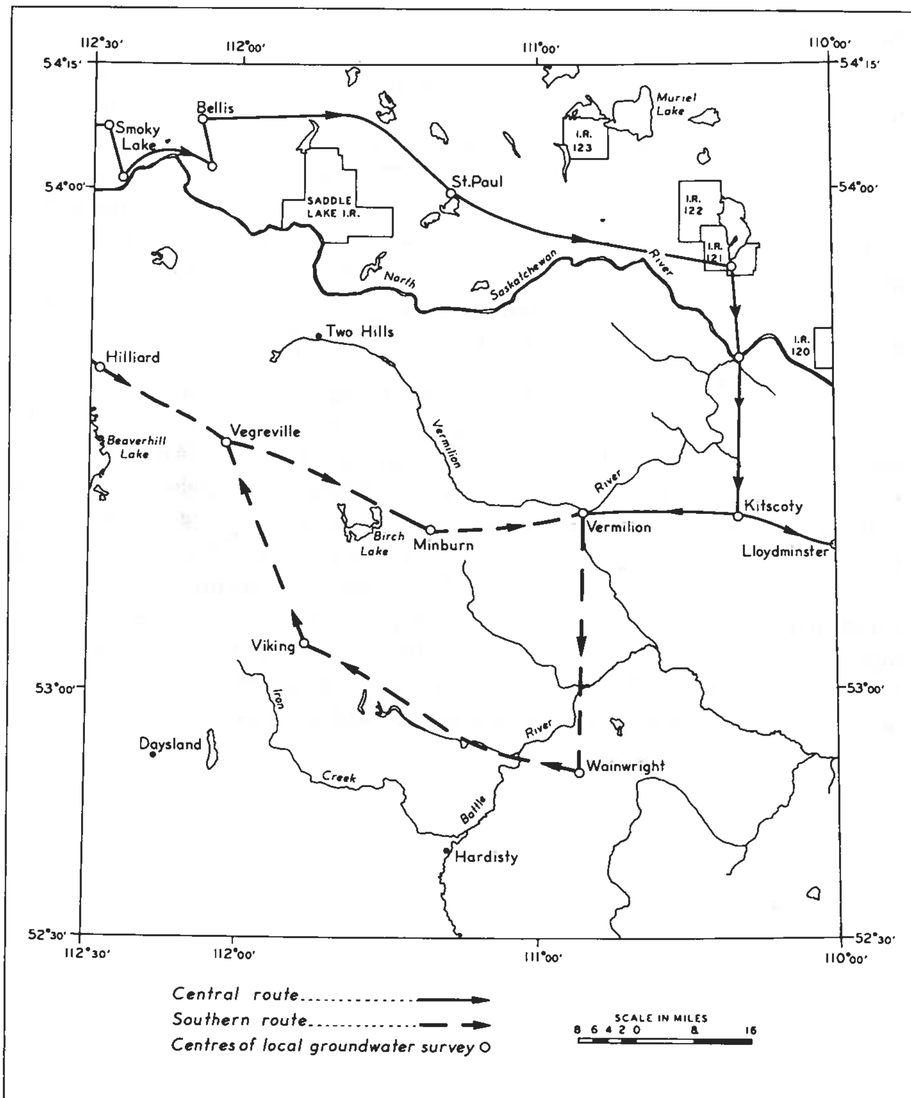


*FIGURE 1. Groundwater survey routes of 1930.*

Though some local groundwater problems were given consideration in the 1940's and early 1950's, no further serious attempts to study the groundwater resources of the area were made until 1956, when provincial groundwater investigations were initiated by the Groundwater Division of the Research Council of Alberta. A report by Foster and Farvolden (1958) has been published subsequently which makes general reference to the area. Two articles referring to specific areas of east-central Alberta have been recently published (Le Breton, 1963a, b). Local reports of areal surveys are on file at the Research Council outlining groundwater prospects in the vicinity of certain towns and villages in east-central Alberta.

### Acknowledgments

The author sincerely wishes to acknowledge the guidance given by R. N. Farvolden, former head of the Groundwater Division, Research Council of Alberta, whose advice and counsel during the first three years of work on this survey proved invaluable. The survey was completed under the supervision of W. A. Meneley and D. H. Lennox, to whom the author is also indebted. The author also wishes to acknowledge the helpful information supplied by water-well drillers, oil companies, municipal districts, town and village officials, and private well owners, without whose co-operation this report would not have been possible.

The section on chemistry of the groundwaters in east-central Alberta is based on about 600 chemical analyses of water made by Mr. C. E. Noble, Provincial Analyst, and his staff, Industrial Laboratories, Edmonton. The vast majority of these analyses were collected from the Minburn-Vermilion and Vegreville Health Units and refer largely to the territories covered by these health units. The writer is very grateful to the respective sanitary inspectors, Mr. W. Boulton and Mr. J. Donnan, for permitting him to go through the appropriate files, and for supplying land locations for many analyses, thus greatly assisting in the work of plotting the data. The writer also wishes to thank Mr. J. Donnan for his comments on possible causes and treatment of nitrate contamination in water wells.

# GEOGRAPHY

## Location and Extent of the Area

The area studied lies between parallels of latitude 52°15′ and 55° north, and between meridians of longitude 110° and 112°30′ west. On the basis of the land-survey system adopted in Alberta, it lies within townships 38 to 69, ranges 1 to 17, west of the fourth meridian* (Fig. 2). The total area is about 17,000 square miles. However, in this report emphasis is placed on the developed part, covering about 12,000 square miles, which is that part of the area south of township 62. The topographical and geological map sheets for the area are listed in appendix A.

## Topography and Drainage

East-central Alberta is part of the Plains region of Alberta and lies within the drainage basins of the North Saskatchewan and Beaver Rivers (Fig. 3). The important tributaries of the former river are the Battle and Vermilion Rivers and, of the latter, the Sand River. Elevations in the area in general decrease from west to east (Fig. 14) and the topography is gently undulating to rolling with some extensive flat-lying areas. The lowest elevation, about 1,600 feet above sea level, is in the North Saskatchewan River valley where the river crosses the Alberta-Saskatchewan boundary in Sec. 25, Tp. 51, R. 1. The highest elevations, over 2,700 feet above sea level, are in Tp. 38, Rs. 13 to 17. Most of the area, however, lies between 2,100 and 2,400 feet above sea level.

Valleys described as spillways and stream-trench systems (Gravenor and Bayrock, 1956), mostly containing only temporary or misfit streams, are common in the area. Along with other features, such as many isolated hillocks called kames, and former lake beds, they owe their existence to glaciation and deglaciation (Gravenor, 1956).

The Beaver River basin lying to the north of township 60 is largely bush covered. It is in this part of the area that the majority of the large lakes and much of the surface water occur. Many rivers and streams drain into and from these lakes, and ultimately discharge their waters into the Beaver River. In contrast, most of the area within the North Saskatchewan River basin, which lies to the south of township 60, has been cleared and settled. This part of the area is characterized by smaller lakes and fewer rivers and streams than the Beaver River basin. The surface drainage is poorly integrated over the North Saskatchewan River basin and much of the surface runoff finds its way into minor internal drainage basins.

* Unless otherwise stated, all locations given in this report are west of the fourth meridian.

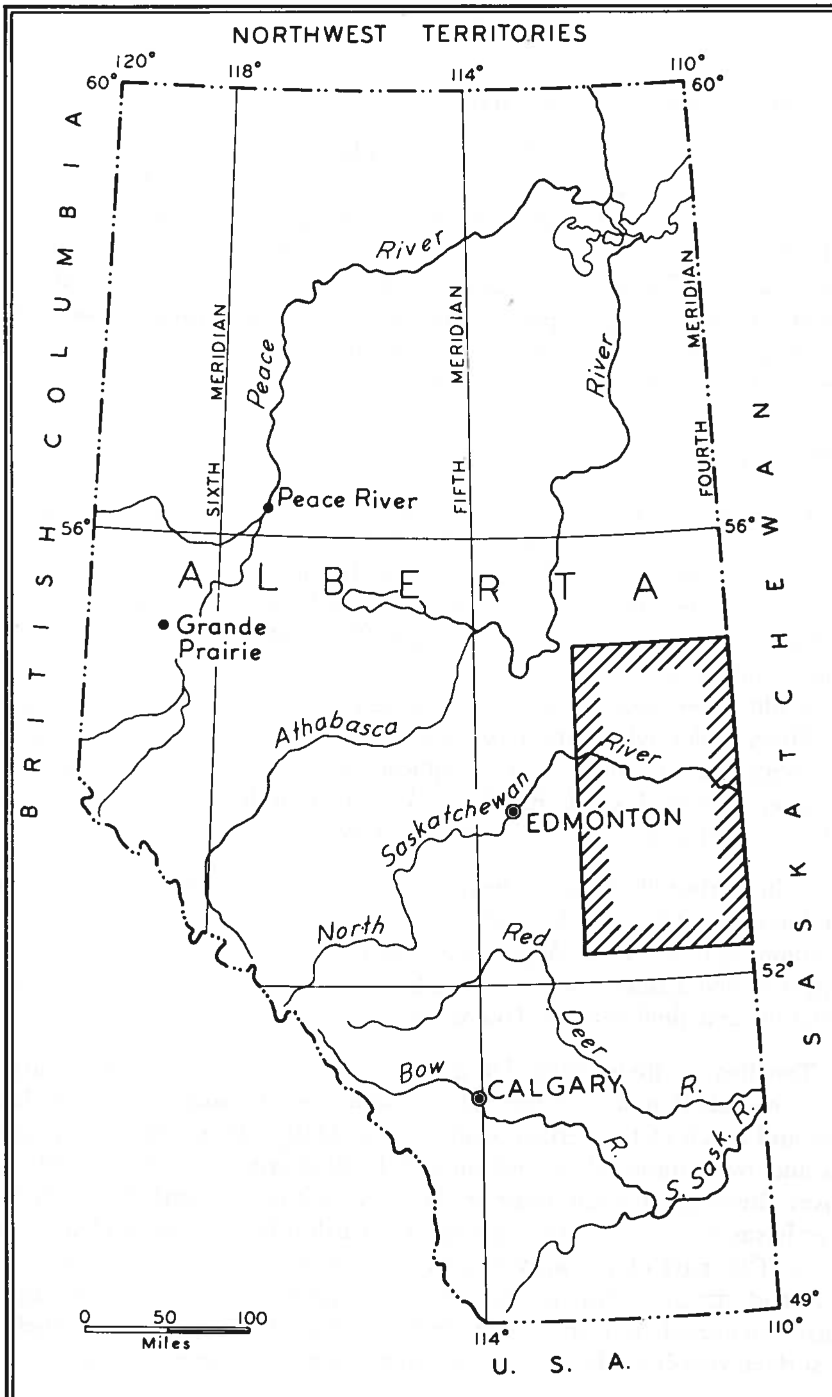


*FIGURE 2. Map showing location and extent of the area.*

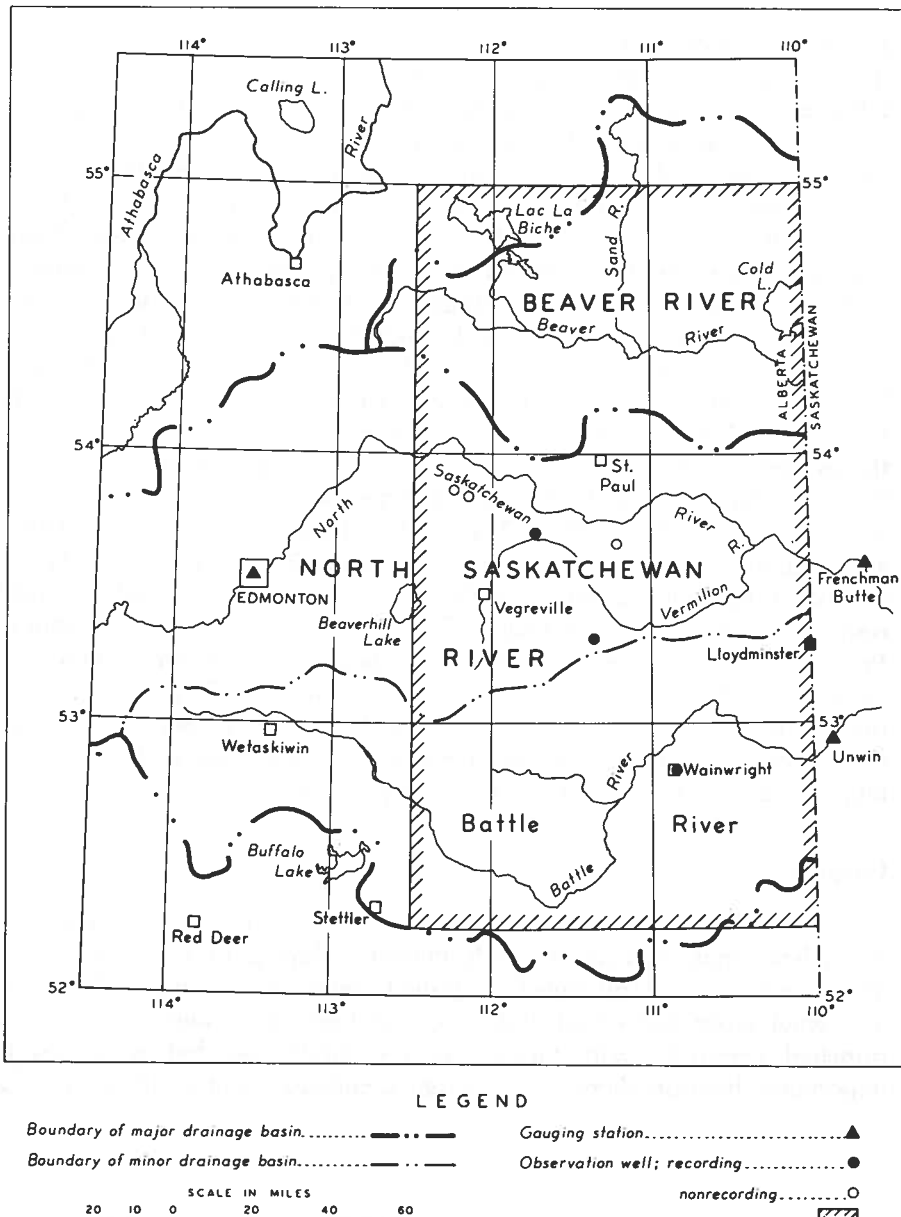


FIGURE 3. *Drainage basins of east-central Alberta.*

## Climate

The climate of the area is humid continental, based on Koppen's classification (Can. Dept. Mines Tech. Surv., 1957). The temperature ranges between extremes of 90°F* in the summer and —35°F* in the winter, and the average precipitation is about 16 inches* per year. For more complete information see figure 4. The spring of the year is short and precipitation may fall as rain or snow. It is about this time of the year that winds are most common, are fairly strong, and are most effective in causing evaporation of snow or surface water. The average wind velocity is 9.8 mph†. The summer is moderately dry and warm, with its growing season being influenced by killing frosts, which may occur as late as June or as early as September. The average relative humidity is 66.5 per cent†. The successful growth of the grain crops is largely dependent upon the amount of moisture in the month of June, and this is normally sufficient to germinate the seed. Though the precipitation during the summer generally occurs as rain, very localized hail storms may sometimes occur. These are most common in the southeast part of the area and may cause serious damage to the grain. July and August provide the hot growing weather with temperatures often between 75°F and 85°F. The fall is mild to cool with several frosts, and, as in the spring of the year, precipitation occurs as rain or snow. Winds during the summer and fall are lighter, averaging 8.1 mph† and 8.3 mph† respectively. The winter is long and cold, lasting for about five months. Precipitation during this season is almost entirely in the form of snow, and temperatures frequently range between 15°F and —10°F. The stillness of the air, or general occurrence of only light winds, averaging 7.7 mph† during the winter makes the cold far more tolerable. The average relative humidity during the winter season is 86 per cent†.

## Commerce

The economic activities of east-central Alberta are predominantly dependent upon agriculture, with industry playing only a minor role. The area is particularly suited to grain farming and raising of livestock. The chief crops are wheat and oats, and beef cattle and hogs are the principal livestock. Dairy farming is also carried on, but is limited in importance because there are no large population centres to serve. The

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* The above figures have been obtained from the meteorological records for the years 1956 to 1960, for the weather station at Vermilion.

† The figures for wind velocities and relative humidities were obtained by personal communication with Mr. Van Volkenburg, Meteorological Branch, Department of Transport.

average farm size is about 450 acres*. The industrial pursuits of the area are related to the exploration for oil and natural gas, and are accompanied by some oil refining, or are based upon agriculture — chiefly

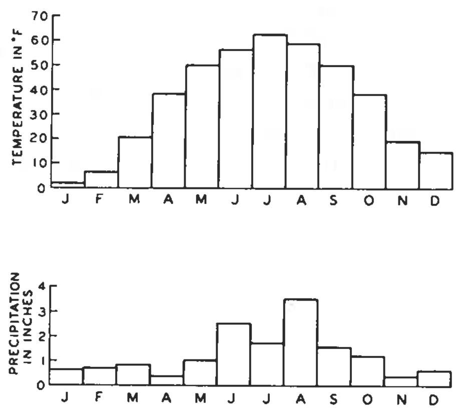


*FIGURE 4. Histograms showing average monthly temperature and precipitation at Vermilion, Alberta.*

slaughtering of livestock and milling of grain. Because of the prime importance of agriculture, the population of east-central Alberta is only 75,000*, and the size of most communities is small, the population figures being mostly between 200 and 700.

* Information supplied by R. Huene, Alberta Bureau of Statistics, Department of Industries and Labour.

## GEOLOGY

Because the geology of an area exerts the controlling influence upon the amount of available groundwater, an examination of the bedrock geology and surficial deposits is essential. The bedrock formations (Fig. 5) of interest in this report are entirely of late Cretaceous age and are mostly obscured by overlying deposits of glacial drift. The geologic maps (Appendix A) of the area record the ascending stratigraphic succession as Lea Park Formation, Ribstone Creek Formation, Grizzly Bear Formation, Birch Lake Formation, Pale and Variegated Beds—referred to as the Oldman Member of the Belly River Formation by Shaw and Harding (1954)—Bearpaw Formation and Edmonton Formation. Below the Lea Park Formation lies the Colorado Formation. The geology has been described in reports

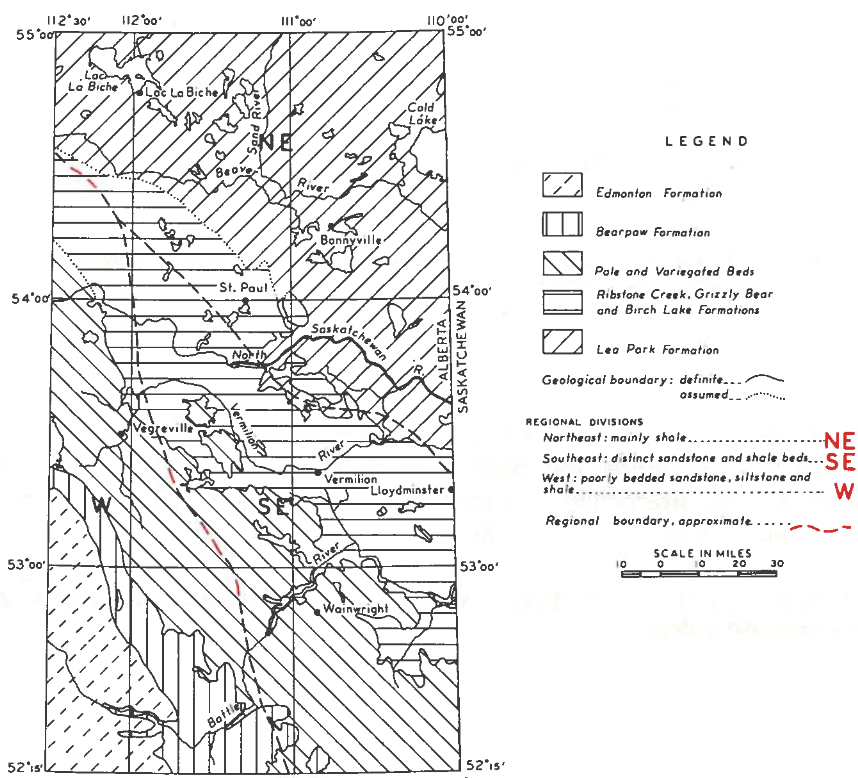


*FIGURE 5. Geologic map of east-central Alberta.*

by Slipper (1917), Allan (1918), Hume (1936) and Hume and Hage (1941). Additional information on the subsurface geology based upon electric-log studies has led to the publication of articles by Nauss (1945) and Shaw and Harding (1954) presenting a modification of the stratigraphic column for east-central Alberta as compared to that in earlier reports and geological maps of the area. Table 1 presents the stratigraphic succession adapted, with additions, from Shaw and Harding (1954). This succession is largely applicable to an area from townships 38 to 56 between ranges 1 and 17 in the area of study. Some lithologic logs (Appendix B) have been selected from records submitted by water-well drillers.

The depositional environment of the bedrock aquifers of east-central Alberta was predominantly continental. In this environment were deposited the coal seams and, in addition, the commonly dirty or bentonitic, fine- to medium-grained sands comprising the hard and soft sandstone beds. The bedrock geology of the area shows significant lateral variations as illustrated by the section in figure 6, and on this basis the area can be divided into three regions: a northeast region, a west region, and a southeast region (Fig. 5). In the northeast region, the bedrock consists almost entirely of shale, the Lea Park Formation, with local dirty sandstone beds or lenses. In the west region, the upper Cretaceous strata consist of thin, alternating, fine- to medium-grained bentonitic sandstones, siltstones, shales, sandy shales, carbonaceous shales, and coal seams. These strata are grouped together as the so-called undivided Belly River Formation. In the southeast region are a series of alternating continental sandstones and marine shale tongues, and these are grouped together as the divided part of the Belly River Formation. The shales, known as Shandro, Vanesti, Mulga and Grizzly Bear, represent marine incursions from the north and northeast and are extensions of the Lea Park Formation into the southeast region. The Brosseau, Victoria, Ribstone Creek, and Lower and Upper Birch Lake Sandstones represent successive periods of continental conditions. They are also the major aquifers of east-central Alberta.

The Ribstone Creek Sandstone is the most important sandstone member of the Belly River Formation and so it is discussed in some detail. This sandstone subcrops beneath the glacial drift in the Lloydminster area, where it is encountered at depths ranging from 50 to 150 feet below ground level. Its thickness in this area varies from 0 to 150 feet and averages about 100 feet. At any particular location, the Ribstone Creek Sandstone consists of a succession of interbedded sandstone, silty sandstone and siltstone strata. Samples from the sandstone show it to be grey, brown, and green, and composed largely of fine- to medium-sized grains cemented with calcite. The degree of cementation ranges from poor to complete. The degree of sorting in the sandstone is variable. In the Two Hills area, the Ribstone Creek Sandstone is a light-blue, hard or soft bentonitic sandstone.

**Table 1. Stratigraphic Units and their Water-yielding Properties, East-Central Alberta**

| System | Series | Formation | Member | Thickness (feet) | Description | Permeability | Groundwater Potential | Well Yields (gpm) |
|---|---|---|---|---|---|---|---|---|
| Tertiary | Pleistocene | Wisconsin? | — | 0-250 | Till | Low | Suited to domestic and small stock supplies | Commonly less than 3 |
| | | | | | Dune sand | Low | Suited to domestic and stock supplies | Up to 5* |
| | | | | | "Quicksand" | Low | Suited to domestic and stock supplies | Up to 5* |
| | | | | | Sand and gravel | High | Suited to domestic, stock, municipal and industrial supplies | Up to 350 |
| | | Preglacial valley deposits | — | ? | River silt, sand and gravel | Low to high | Suited to domestic, stock, municipal and industrial supplies | Up to 350 |
| Cretaceous | Montanan | Edmonton | — | ? | Argillaceous sandstone beds, dark, bentonitic shale and coal seams | Low | Suited to domestic and small stock supplies | Commonly less than 5 |
| | | Bearpaw | — | ? | Grey to dark shale, brownish and green sand, ironstone nodules | Low | Suited to domestic supplies only | 1* |
| | | Belly River | Oldman | ? | Undivided series of alternating thin soft and hard sandstone beds, shale, siltstone, carbonaceous shale and coal seams | Low | Suited to domestic and small stock supplies | Commonly less than 5 |
| | | | Upper Birch Lake | 0-50 | Grey, brownish-yellow, medium-grained sandstones with siltstone beds | Medium | Suited to domestic, stock and municipal supplies | Up to 20* |
| | | | Mulga | 0-45 | Grey shale, siltstone lenses and carbonaceous shale | Low | Suited to domestic supplies only | 1* |

| System | Series | Formation | Member | Thickness (feet) | Description | Permeability | Groundwater Potential | Well Yields (gpm) |
|---|---|---|---|---|---|---|---|---|
| Cretaceous | Montanan | Belly River | Lower Birch Lake | 0-115 | Massive, cross-bedded greenish-grey or buff-colored, medium- to fine-grained sandstone with hard concretionary nodules | Medium | Suited to domestic, stock, municipal and industrial supplies | Up to 150 |
| | | | Grizzly Bear | 0-140 | Dark blue marine shale with ironstone and sandstone nodules | Low | Suited to domestic supplies only | 1* |
| | | | Ribstone Creek | 0-150 | Grey, brown, green, blue, soft to hard, fine- to medium-grained sandstone and some shale | Medium | Suited to domestic, stock, municipal and industrial supplies | Up to 150 |
| | | | Vanesti | 0-140 | Grey shale with some thin fine-grained sandstone lenses | Low | Suited to domestic supplies only | 1* |
| | | | Victoria | 0-95 | Grey, fine- to medium-grained sandstone, silty sandstone and shale | Medium | Suited to domestic and stock supplies | Up to 20* |
| | | | Shandro | 0-85 | Grey shale, with some fine-grained sandstone lenses | Low | Suited to domestic supplies only | 1* |
| | | | Brosseau | 0-100 | Grey, fine- to medium-grained sandstone, silty sandstone and shale | Medium | Suited to domestic and small stock supplies | Up to 20* |
| | | Lea Park | — | 450-810 | Grey, blue and black shale with clay ironstone concretions, some fine-grained sandstone beds and lenses | Low | Suited to domestic supplies | Commonly less than 2 |

* Denotes estimated well-yields

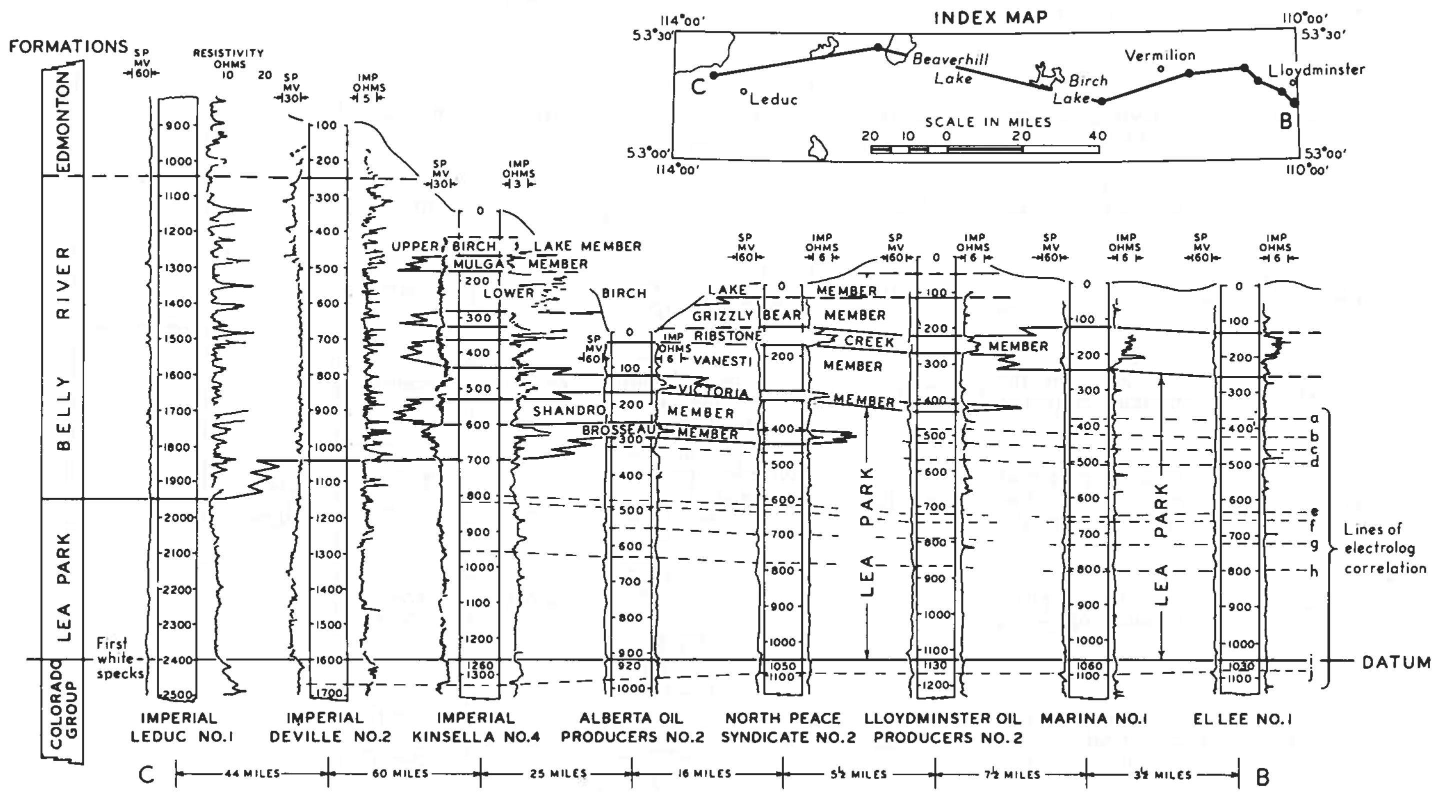


*FIGURE 6. Electric-log cross section showing bedrock geology (reproduced by permission, from Shaw and Harding, 1954).*

Three electric logs have been selected for a cross section (Fig. 7) ten miles long, illustrating differences in development of the sandstone beds in the Lloydminster area. Reference to other electric logs from the area demonstrates that these show the typical irregular occurrence and thickness of the sandstone beds. Another cross section (Fig. 8) of the Ribstone Creek Sandstone*, constructed from electric logs run by Elk Point Drilling Co. and the Research Council of Alberta, is shown for wells and test holes drilled in the Two Hills area. Information from oil- and water-well drilling in the Wainwright area shows that the Ribstone Creek Sandstone occurs about 300 to 400 feet below ground level. The regional dip of this sandstone is to the southwest at about 4 to 5 feet per mile. The lithology, configuration and distribution of the other sandstone members of the Belly River Formation is similar to that of the Ribstone Creek Sandstone. Of the other members, the Lower Birch Lake Sandstone is the next in importance.

### Structure and Bedrock Topography

The contour map of the Lea Park-Colorado contact (Fig. 9), drawn from data listed in the Schedules of Wells Drilled for Oil and Gas (Alberta. Oil and Gas Conservation Board, 1949-1957), is presented to portray the regional structure over much of east-central Alberta. The map shows the structure to be homoclinal, with the dip of the strata increasing from 7 to 14 feet per mile as the area is traversed from northeast to southwest, the regional strike being northwest. This structural effect, which may also be observed on a structural contour may of the Paleozoic surface (Hume and Hage, 1941), is reflected throughout the geologic column and produces a very similar structure in the uppermost strata in the area—those of the Belly River Formation.

The bedrock topography corresponds quite closely to the present-day topography. The significant differences occur where the valleys of preglacial rivers and streams have been buried beneath the cover of glacial drift along part or all of their length. Where such infilling occurs, present-day rivers and streams commonly follow different courses.

### Glacial Drift

The glacial features in east-central Alberta that are of considerable areal extent are ground moraine and "dead-ice" moraine. These areas of moraine consist of deposits of till, which is composed of poorly sorted to unsorted silt, clay, and boulders, with lenses of sand and gravel. Other glacial features of minor areal extent include spillways, stream-trench systems and outwash plains. As a result of a study by Ellwood (1961), a map of the surficial geology is available for the area covered by the Vermilion map sheet (Sectional Sheet No. 316).

* Additional work may prove that part of this sandstone belongs in the Lower Birch Lake Member.

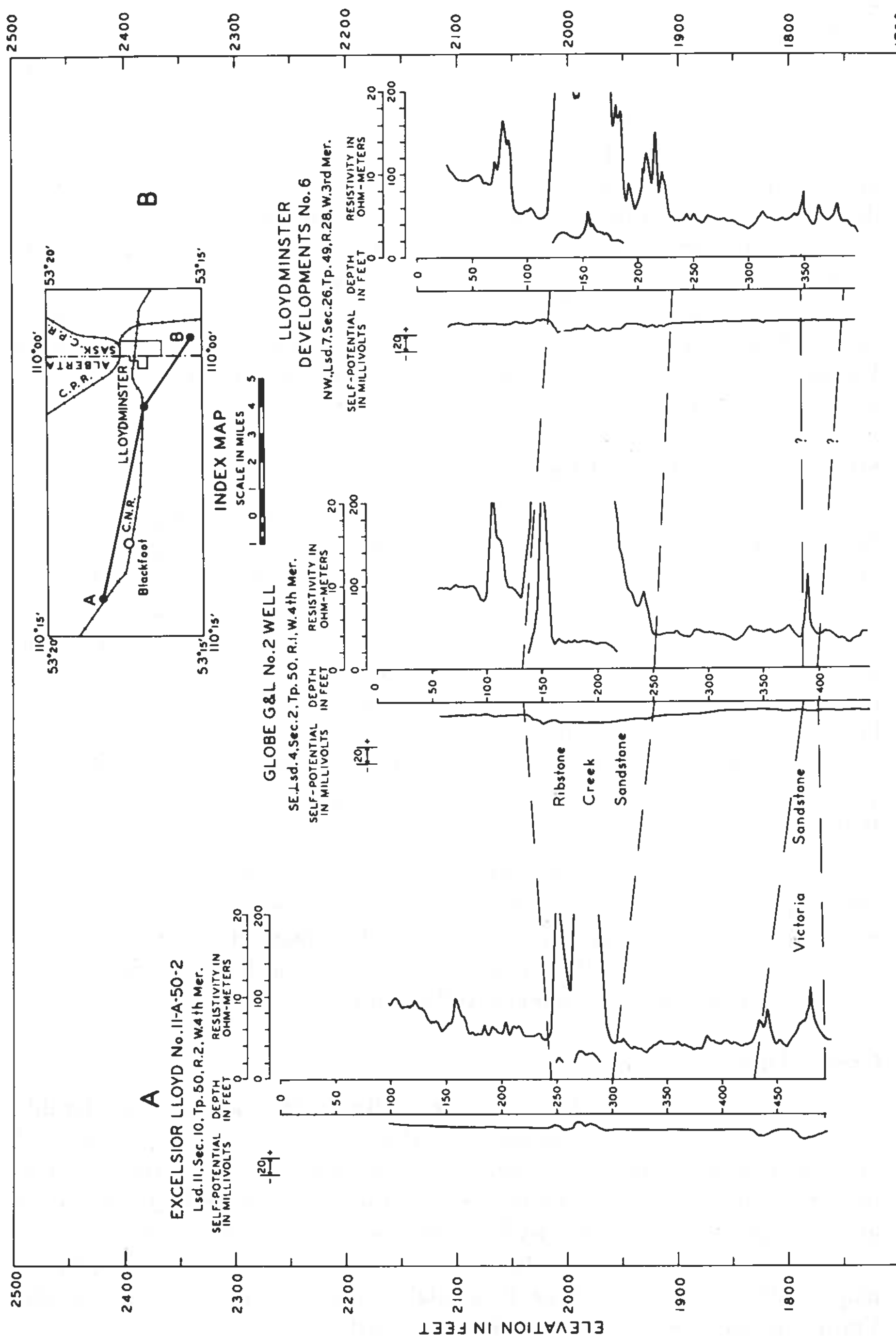


*FIGURE 7. Electric-log cross section of the Ribstone Creek Sandstone, Lloydminster area.*

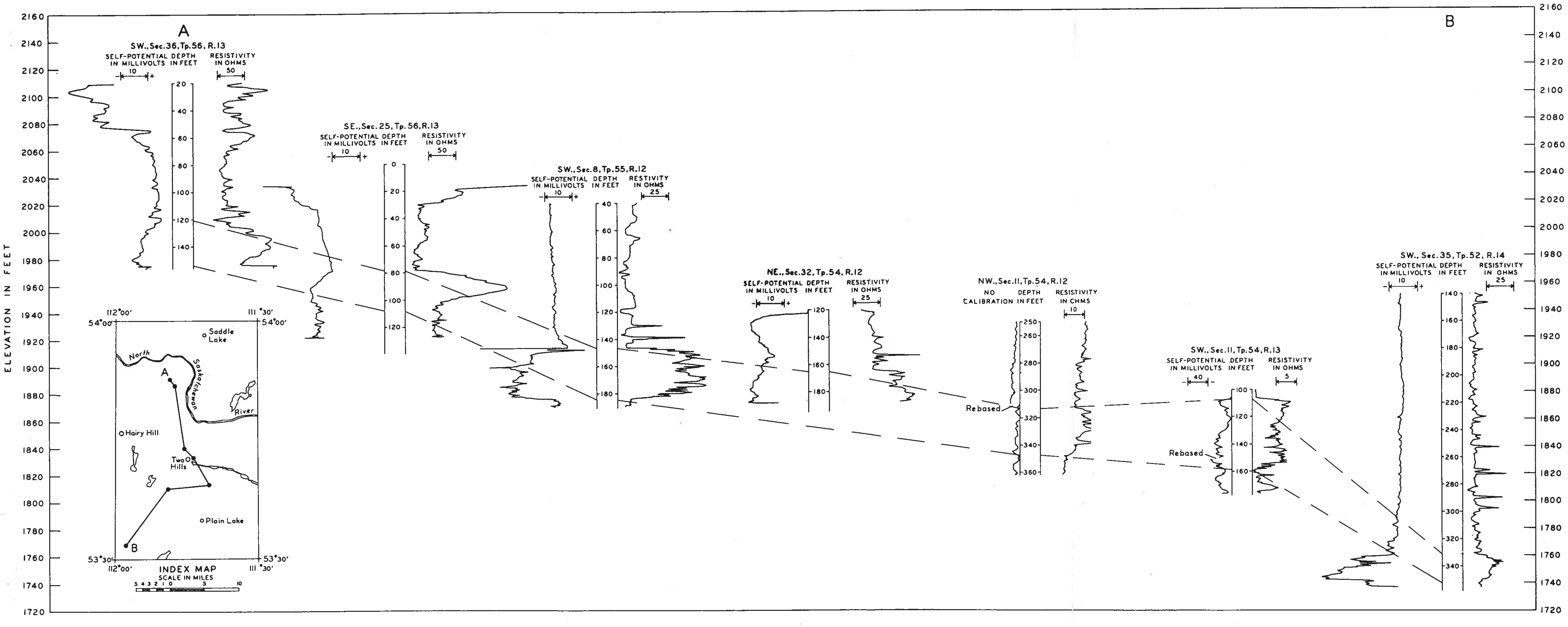


*FIGURE 8. Electric-log cross section of the Ribstone Creek Sandstone, Two Hills area.*

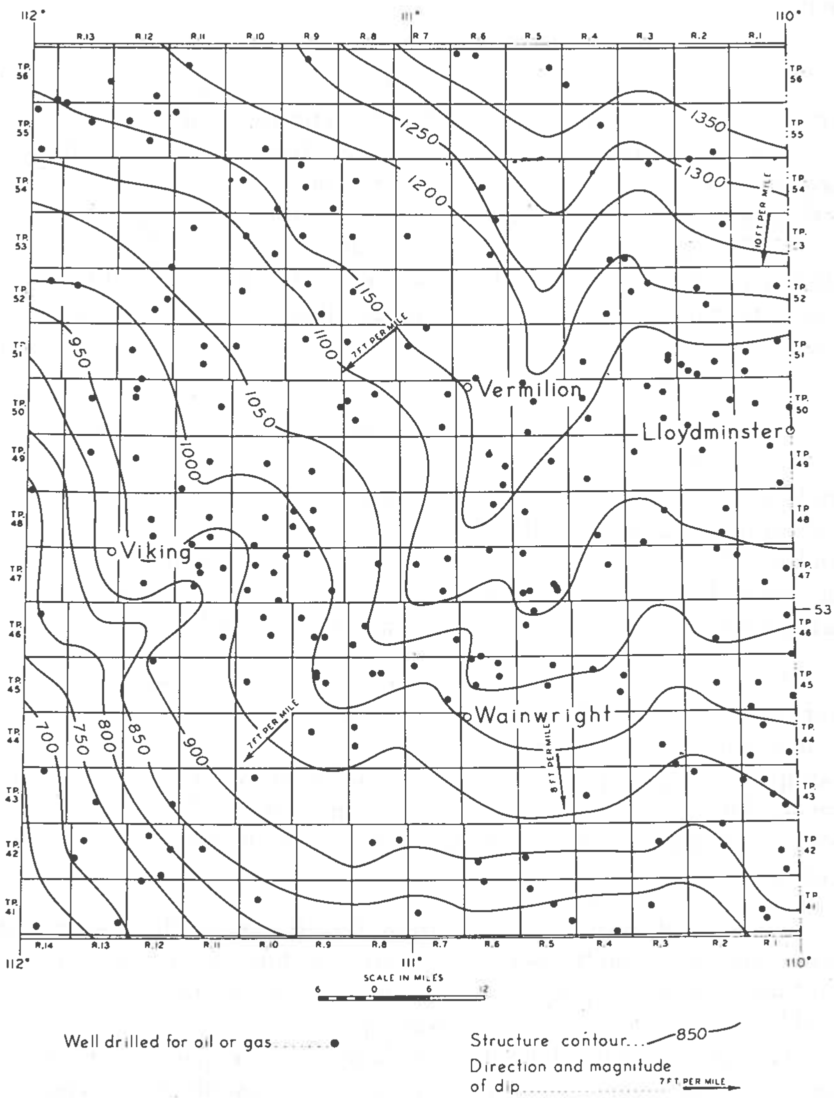


*FIGURE 9. Structure-contour map of the Lea Park-Colorado contact.*

## GROUNDWATER GEOLOGY AND HYDROLOGY

### Source, Occurrence and Movement of Groundwater

It may be considered that the contained waters in bedrock aquifers at the time of deposition in a continental environment were fresh to brackish in nature. Following uplift and erosion of the strata above sea level, local precipitation has been slowly freshening and replacing the original formation waters in the shallower zones, mainly to depths of 300 to 400 feet. In a few instances, well waters with high salt content—over 750 ppm (parts per million)—are known to occur. This may indicate that increasing salinity may be expected locally due to migration of water from surrounding marine shales. In localities where the saline groundwaters are shallow, however, it may be attributed to extremely limited movement of groundwater since uplift and erosion.

The sources from which groundwater supplies are obtained are: fine- to medium-grained, clean or dirty, hard or soft sandstone beds, coal seams and "quicksands" in the bedrock; sand and gravel deposits in the till, stream-trench systems, and spillways; dune sand, outwash sand and gravel, and "quicksands" in the glacial drift; sand and gravel deposits within buried or partly buried preglacial river valleys; and sand and gravel deposits adjacent to rivers and lakes, permitting induced infiltration.

Groundwater occurs in the pore spaces of the materials composing the various strata. The differences between the strata as reservoirs of groundwater depend upon porosity, which is the percentage of the total volume occupied by open spaces. Porosity is controlled by the shape and arrangement, the degree of sorting, and the cementation of the rock materials. Porosity is high in well-sorted deposits and low in poorly sorted or highly cemented deposits.

The rate of movement of groundwater—the permeability—through the strata depends upon the degree of interconnection between the pore spaces and the sizes of the particles comprising the strata. Silts and clays, though highly porous, have such small pore spaces that a very large percentage of the water contained in them is bound to the particles by forces of molecular adhesion, and such materials are described as being impermeable. Coarse gravels with large openings permitting water to move freely are said to be highly permeable.

### Bedrock Aquifers

East-central Alberta can be divided into three regions with distinct differences in bedrock groundwater resources. It is not surprising that these correspond to the previously described regional geologic subdivisions (Fig. 5), because the geologic environment exercises a marked influence upon the quantity of groundwater available. A brief summary of the groundwater properties of the bedrock aquifers is given in table 1.

The northeast region is classed as very poor and may almost be disregarded when bedrock supplies are being considered. This part of the area is underlain by the Lea Park Formation which consists almost entirely of shale. The groundwater supplies that are obtained come from sandstone lenses or silty sandstone beds with very low permeability. This limits wells to very low yields, suited to supply domestic requirements* only. The production of these wells may range from only a few gallons per day (gpd) to about 2 gallons per minute (gpm). Quite often these wells may be pumped dry under normal conditions of usage.

In the west region, which is underlain by the undivided Belly River Formation, groundwater prospects are distinctly better than in the northeast region. Supplies of groundwater from wells in this region may be sufficient to satisfy domestic and limited livestock requirements†. However, many of these wells may also be pumped dry under normal conditions of usage. The low yields of wells in this area, which are estimated from the existing bail- and pump-test data to be less than 5 gpm, are due to the groundwater sources being largely thin, fine-grained sandstones of limited areal extent and low permeability.

The southeast region has the greatest groundwater potential in east-central Alberta. This region is underlain by the divided part of the Belly River Formation, of which the Ribstone Creek and Lower Birch Lake Sandstone Members are the most important aquifers.

Data pertaining to the hydrologic properties of the Ribstone Creek Sandstone aquifer have been mostly obtained from the Lloydminster area, with some from the Wainwright and Two Hills areas. Wells completed in the upper part of the Ribstone Creek Sandstone are believed to be capable of providing more than ample supplies of water for domestic and livestock requirements. Many of these wells in the Lloydminster area are from 100 to 150 feet deep. For the upper 50 feet of this aquifer safe well-yields are estimated to be less than 25 gpm. Data supplied from tests conducted in the military camp at Wainwright record water-bearing sandstone from 362 to 370 feet deep, at an elevation of 1,902 to 1,894 feet above sea level. The safe yield, based on a specific capacity of 0.15 gallons per minute per foot (gpm/ft) of drawdown, was calculated to be 36 gpm.

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* "Domestic requirements" is used to refer to quantities sufficient for rural or individual (private) municipal household needs.

† "Limited livestock requirements" is used to refer to quantities sufficient to supply about 20 to 30 head of cattle, some hogs and poultry.

Because complete pump-test data were not supplied for the wells near Wainwright, safe yields had to be based upon the specific capacities. Use of this method for calculating safe yields is not recommended, except in those cases where data are inadequate, because it assumes that the water level in the well has stabilized. This assumption is almost always unjustified in the case of bedrock aquifers in Alberta, because water levels are observed to decline slowly even after extended pumping periods. Such results indicate withdrawal of water from storage faster than the rate at which it is being recharged. Calculation of the safe well-yield must take account of the declining water-level, if a reliable estimate is to be made. Thus, the safe well-yields based on specific capacities are suspect. Safe yields based on adequate data assume a gradual decline of the water level for a period of 20 years of continuous pumping.

In order to obtain supplies of water for industrial requirements from the Ribstone Creek Sandstone, it appears that wells have to be completed in the lower part of this aquifer. At Lloydminster, the depths of wells in this aquifer range from 150 to 260 feet. Their yields are reported to be from 25 to 120 gpm. These figures are for wells which belong to the city of Lloydminster and to Excelsior and Husky Oil Refineries, and the wells are located within and to the north and west of the city limits. However, test drilling carried out to the south and east of the city located wells estimated to meet only domestic and farm requirements. Calculations based on available bail- and pump-test data give transmissibility* figures ranging from 800 to 4,700 gallons per day per foot (gpd/ft) and averaging about 3,400 gpd/ft, and safe well-yields of 25 to 100 gpm. From work recently carried out in the Two Hills area, a transmissibility of 4,000 gpd/ft was obtained and a safe well-yield of 100 gpm.

Further information from the military camp at Wainwright shows a safe well-yield of 124 gpm based upon a specific capacity of 0.42 gpm/ft of drawdown. This well is in a sandstone bed encountered at 350 to 380 feet below ground level, or at an elevation of 1,853 to 1,823 feet above sea level, in the lower part of the Ribstone Creek Sandstone.

The amount of pump-test data available on the Lower Birch Lake Sandstone is much less than for the Ribstone Creek Sandstone. Drilling records again show that there are two distinct producing zones within this aquifer. A six-hour pump test of Wainwright town well No. 6, completed in the lower zone about 240 feet below ground level, gave transmissibilities of 1,500 and 2,600 gpd/ft for drawdown and recovery respectively. This indicated safe yields of 80 and 150 gpm respectively. Less complete information on one of the Canadian National Railways' wells completed in sandstone beds from 170 to 189 feet and 190 to 191 feet deep, and believed

* Transmissibility is a product of the permeability of an aquifer multiplied by its thickness.

to be in the upper zone of the Lower Birch Lake Sandstone, indicates that this well has a reported safe yield of 250 gpm. This calculation is based upon a specific capacity of 2.8 gpm/ft of drawdown. A comparison between the town and the railway wells, based on their specific capacities, shows that both wells have a maximum capacity of 250 gpm. No similar comparisons can be made for transmissibility or permeability because of lack of sufficient pump-test data and information on the thicknesses of the aquifers. However, it may be possible that both wells have a similar safe yield of 150 gpm. Though the main producing zone in the Canadian National Railways' well was reported to be the one foot of sandstone at 190 feet, it is believed that the section from 170 to 189 feet is the main producing zone.

The town of Wainwright has its wells completed in the lower zone because the water is very much softer than in the upper zone (see chemical analyses listed in Appendix C). Locally, drilling down to this lower sandstone sometimes presents difficulties, which arise in trying to "mud off" the upper zone. Evidence regarding the availability of groundwater shows the town of Wainwright to be the most favorably situated of the population centres in east-central Alberta for obtaining groundwater supplies for municipal and industrial purposes. From the data available, wells producing about 100 gpm can be obtained from both the Lower Birch Lake and Ribstone Creek Sandstones in the vicinity of Wainwright.

### Apparent-Transmissibility Values for Bedrock Aquifers

The apparent-transmissibility map (Fig. 10) is based on a very limited amount of bail- and pump-test data but, nevertheless, it gives additional support to the validity of dividing the area into three regions with distinct differences in bedrock groundwater resources. The transmissibility values, on which the ranges shown on the map are based, are for wells that may, in some cases, only partially penetrate the aquifer. In some instances the value may be a compound transmissibility for a few minor sandstone lenses and coal seams as well as for other less permeable materials. Also, many of the values for bailed wells will be for only partially developed test holes, well development being completed by the owner, who allows the pump to run continuously for several hours or days. Although these may only be termed apparent-transmissibility values, they have been utilized to illustrate differences in the hydrologic properties of the bedrock aquifers of each region. The northeast region is notable for the low number of bedrock wells. Recorded transmissibilities are less than 60 gpd/ft. In the west region, transmissibilities are commonly less than 100 gpd/ft, but the number of bedrock wells is much higher. In the southeast region, values commonly range from 100 to 300 gpd/ft, with the highest values so far recorded being 4,700 gpd/ft for the Ribstone Creek Sandstone and 2,600 gpd/ft for the Lower Birch Lake Sandstone.

Comparison of apparent-transmissibilities for aquifers in the Paskapoo Formation in the Pembina area (Farvolden, 1961b) with those of the aquifers of east-central Alberta show the latter to be much poorer sources of groundwater supply. However, the southeast region compares favorably with those parts of the Pembina area delineated as "Good." Locally, this region may have values comparable to some of those represented by the "Very Good" areas. The figures of 2,600 to 4,700 gpd/ft obtained in the southeast region are high for bedrock aquifers in Alberta, but elsewhere in east-central Alberta the values are probably below average.

### Glacial Drift and Bedrock Channel Aquifers

The groundwater prospects in the glacial drift and preglacial river valleys range from poor to excellent. Locally, drift and channel aquifers may be expected to be some of the most highly productive sources of groundwater. This is illustrated on figure 11, which is based upon the map of the surficial geology of the Vermilion area by Ellwood (1961).

Most of east-central Alberta is covered by till containing water-bearing sand and gravel lenses. Only domestic supplies and limited livestock-supplies of groundwater may be expected from such sources. Very many wells terminated in the till yield only 200 to 600 gpd*, and frequently are reported to be pumped dry. These reports from well owners and well drillers are substantiated by short pump-tests carried out in the Two Hills area (Fig. 12). For two of these tests (A, C) the results show that little more water was obtained during the period of pumping than the volume of water in the well. This is commonly the case. Because of the difficulties of obtaining water supplies in many areas, bored or dug wells about 2 to 3 feet in diameter are commonly found, most of which are completed in glacial-drift aquifers. These large-diameter wells are preferred to 4-inch drilled wells chiefly for the advantages of their storage capacity. However, the manner of completing bored wells may be partly responsible for their low yields from some aquifers. This is more fully considered under the section on "Well Completion".

Large quantities of water can be obtained only from the granular materials that occur in spillways, in stream-trench systems, in areas of outwash, and in buried or partly buried preglacial river valleys, in particular those that are adjacent to and below the level of large bodies of surface water. In each case, the well yield from these deposits will be dependent on the areal extent, thickness and permeability of the deposits. Because there is only a very limited amount of hydrologic data available on each of these types of aquifers, very little can be written about each source separately.

* 1 gpm = 1,440 gpd