Report 77-1

Hydrogeology of the Lesser Slave Lake Area, Alberta

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Alberta Research Council
1978

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ABSTRACT

The hydrogeology of the Lesser Slave Lake area (NTS 83O) is described. Data are unevenly distributed and have been supplemented with field observations and a test drilling program during 1974. A large amount of interpretation was involved in the construction of the hydrogeological map and profiles.

The most important aquifers in the area are basal or near-basal sands and gravels occurring in preglacial drainage networks. They have been assigned a 20-year safe yield of 25 to 500 igpm (approximately 2 to 38 l/sec).

The most important bedrock aquifers are sandstones and coals of the Wapiti Formation which have been assigned a 20-year safe yield of 5 to 25 igpm (approximately 0.4 to 2 l/sec).

Water chemistry is variable and total dissolved solids contents range from 200 to 2000 ppm in the drift and nonmarine strata. Iron concentrations are usually very high. Groundwaters are generally of the Ca or Na/HCO_3+CO_3 type with local areas of (1) Ca or Na/SO_4 types attributed to high sulfate contents in till, and (2) Na+Ca/Cl types attributed to contamination from deeper marine strata. These deeper marine rocks contain highly saline waters of the Na/Cl type.

INTRODUCTION

This report and the enclosed map describe, at a regional and provisional level, the hydrogeology of the Lesser Slave Lake map area (NTS 83O) which includes Tps 69 to 81 and Rs 1 to 13, W 5th Mer. In addition, a provisional bedrock topography map of the area has been produced, and will be published separately (Vogwill, in prep.).

The most important towns in the map area are Slave Lake (pop. 3250), Smith (pop. 450) and Kinuso (pop. 275). The remaining population is concentrated in small settlements along the southern shore of Lesser Slave Lake or in the Gift Lake Métis Colony No. 3. The main industries of the area are either petroleum-generated, logging, or agricultural. Portions of four oil or gas fields (Swan Hills, Mitsue, Nipisi, and Marten Hills) are located in the area. Nipisi and Mitsue are serviced from the town of Slave Lake.

METHODS AND DATA AVAILABILITY

Existing data are very limited and were supplemented by fieldwork and test drilling during the summer and fall of 1974. Even with this additional information, large regions of the map area are devoid of any hydrogeological information, and the reader should expect to find extensive interpretation in the final map.

Field observations consisted mainly of collecting water samples and existing well data by boat and helicopter. A test drilling program of eight wells and exploratory holes was completed.

PREVIOUS WORK

The geology of portions of the Lesser Slave Lake area has been described by McConnell (1890), Allan (1918), Allan and Rutherford (1934), and Greiner (1950). Both the Alberta Study Group (1953) and Burk (1963), in studying the Cretaceous stratigraphy in the Peace River region and west-central Alberta, respectively, have extended cross sections into the southern portion of the area. The Geological History of Western Canada (McCrossan and Glaister, eds., 1964) also describes portions of the area. Campbell (1972) studied coal occurrences in the Smith-Athabasca area.

Very little work on the hydrogeology of the Lesser Slave Lake area has been done. Jones (1962) studied a small portion of the area. Tokarsky (1965) reported on a test drilling program and well survey conducted on the Sucker Creek Indian Reserve and to the east for the Lesser Slave Lake Indian Agency. The Groundwater Development Branch of Alberta Environment has conducted test drilling on Métis Colony No. 3 near the settlement of Gift Lake. Clissold (1971) reported on aquifer test results north of Lesser Slave Lake.

The Alberta Research Council (Wynnyk *et al.*, 1963) completed an exploratory soil survey in map areas NTS 83O, 83P, and 73M in 1956.

ACKNOWLEDGMENTS

Mr. A. Beerwald, Alberta Research Council, completed a large portion of the field work and data compilation.

Luscar Ltd., Manalta Coal, and the Alberta Energy Resources Conservation Board supplied valuable information.

Amoco Canada Ltd. supplied information on water wells at Utikuma Lake.

Alberta Forest Service, Slave Lake, supplied some field equipment and storage facilities.

J. W. Warehime completed the test drilling program.

G. F. Ozoray, R. Stein, and R. G. Barnes reviewed and edited the manuscript. A. Campbell and R. Green completed final editing.

PHYSIOGRAPHY

The map area consists of portions of the Swan Hills, Utikuma, and Pelican Mountains Uplands and the Lesser Slave Lake Lowlands. Locally, four units are recognizable.

Unit 1 - In the southern one third of the area, well dissected, irregular uplands — the northern limit of the Swan Hills — form prominent plateaus. The highest of these plateaus, House Mountain (3950 ft or 1200 m AMSL), represents a Tertiary erosion surface. To the north and east, the land surface descends abruptly in a step-like series of plateaus at elevations of 3500 ft (1065 m) AMSL, 3000 ft (915 m) AMSL, and 2500 to 2700 ft (760 to 820 m) AMSL which radiate as distinct spurs. Marten Mountain and the plateau to the east represent portions of these uplands which have been disconnected by the broad valley occupied by Lesser Slave Lake.

Unit 2 - To the north and east of these uplands, and generally below 2500 ft (760 m) AMSL, the land surface descends gently towards a broad alluvial valley outlined by the 2000 ft (610 m) elevation contour. This valley is partially occupied by Lesser Slave Lake and extends eastward nearly to Smith and then swings south to meet the Athabasca River valley. The deltas of the Swan and Driftpile Rivers form large irregularities along the southern boundary of this unit. The lowest elevation in the area is the Athabasca River at Smith (1800 ft or 550 m AMSL).

Unit 3 - The north-central portion of the area consists of flat, poorly drained muskeg containing many lakes. This unit generally lies between 2000 ft (610 m) and 2300 ft (700 m) AMSL, and slopes to the north and east.

Unit 4 - In the northwest and northeast corners of the area, glacial disintegration and outwash features have produced a rolling topography modified by conical hills and sinuous ridges of sand, gravel, and silt. Such landscapes occur between Salt Prairie and Gift Lake, and around Doucette Fire Tower. Elevations in this unit range from 2000 ft (610 m) to 2400 ft (730 m) AMSL.

LAND USE

Using the Regional Surface Disposition Map of the Lesser Slave Lake region prepared by Collins (1975) the following general distribution of land use can be calculated:

(1) Agricultural use occupies approximately 5 percent of the area and is confined mainly to physiographic unit 2.
(2) Logging operations and timber leases occupy 9 percent of the area and occur within physiographic units 1, 2, and 4.
(3) Native Reserves occupy 6 percent of the area and occur mainly in physiographic units 2 and 4.
(4) Petroleum, coal, and gravel leases occupy approximately 5 percent of the area and occur in physiographic units 1, 2, and 4.

The remaining 75 percent of the area has no land use commitment except for transport and communication lines.

The following excerpts from the summarizing statements of Collins are very relevant to the area.

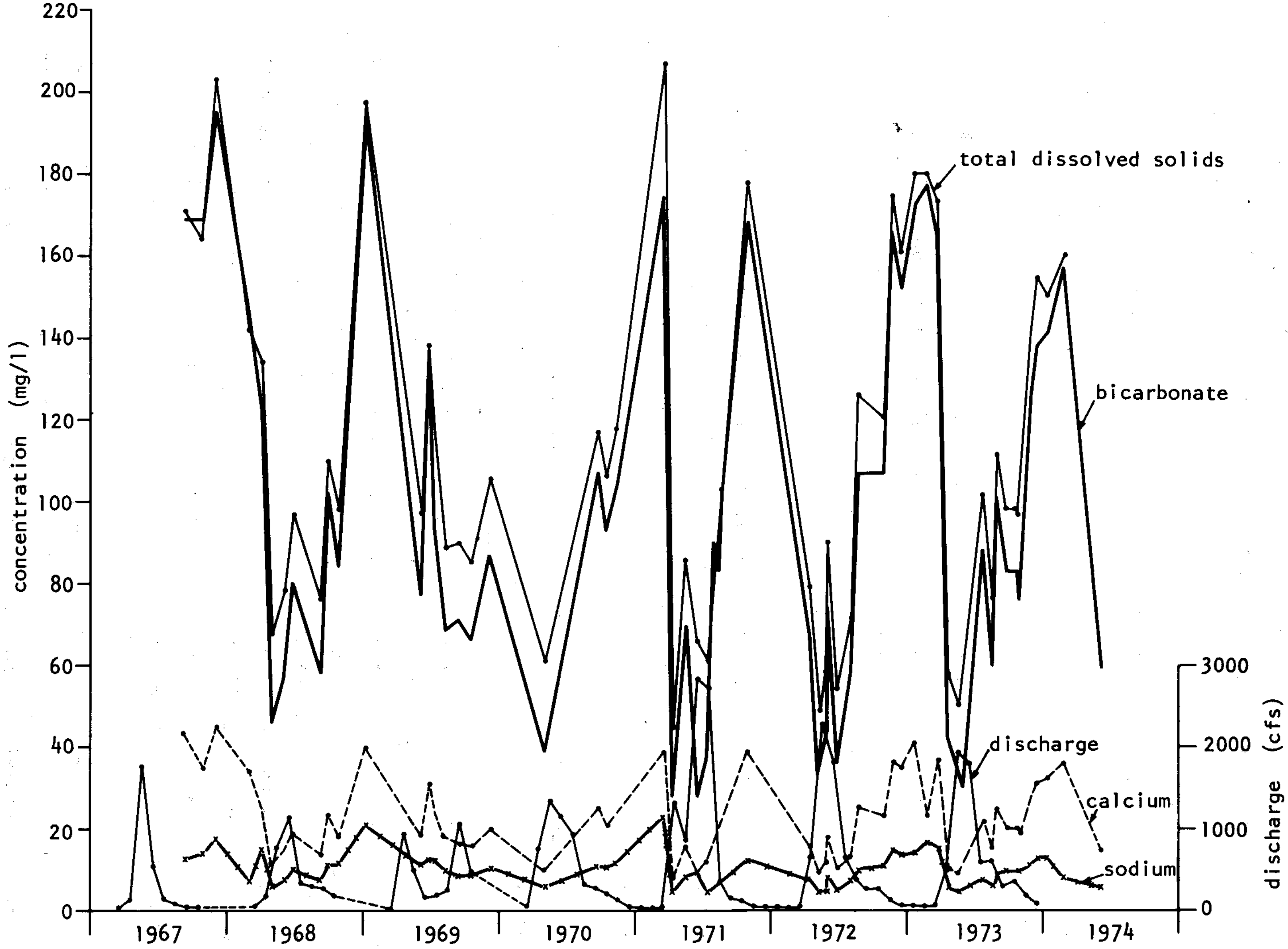
> The major features of land use in the area... are
> -the relatively small percentage of the area which is under agricultural use, and its very concentrated and localized distribution
> -the importance of timbering activities...
> -the large oil and gas developments in the area
> -the importance of native settlements in the area...
> -the sparse under-developed transport and communications network
> -the predominance of natural vegetation... Between 80% and 85% of the area is probably in its natural state.

DRAINAGE

The Lesser Slave Lake map area is part of the Mackenzie drainage system and is drained by two major Alberta river systems - the Peace and Athabasca.

To the north and west of Lesser Slave Lake, drainage is generally to the northeast into rivers such as the Willow, Utikuma, and Nipisi which join the Wabasca River, a major tributary of the Peace River.

Lesser Slave Lake and rivers draining the north slopes of the Swan Hills are part of the Athabasca River system. Important rivers such as the Swan, Driftpile, and Saulteaux flow north and are then deflected into the Athabasca River via Lesser Slave Lake and Lesser Slave River.



Data source: Environment Canada, Inland Waters Directorate

FIGURE 1. Monthly discharge and chemical concentrations of HCO_3*, TDS, Ca, and Na, Swan River at Kinuso*

In the uplands present-day drainages are dendritic and deeply incised, and have a low bifurcation ratio, indicating little control by the underlying geology. Below 2500 ft (760 m) AMSL, rivers become noticeably meandering and are generally underfit in broad open valleys. Muskegs are found at any level and within any physiographic unit. Ribbed fen patterns are common on all upland plateaus and in the Saulteaux River area southwest of Smith.

Numerous lakes, presumably of glacial origin, occur within the area, Lesser Slave and Utikuma Lakes being the largest. All lakes are shallow; Lesser Slave Lake is only 65 ft deep (20 m) at its deepest point. The greatest number of lakes occur in the northeast portion of the area.

Figure 1, a hydrograph of the Swan River at Kinuso during the period 1964-1974, also shows monthly variations in river water quality. Annual peak flows generally occur during May and June and are accompanied by an improvement in river water quality.

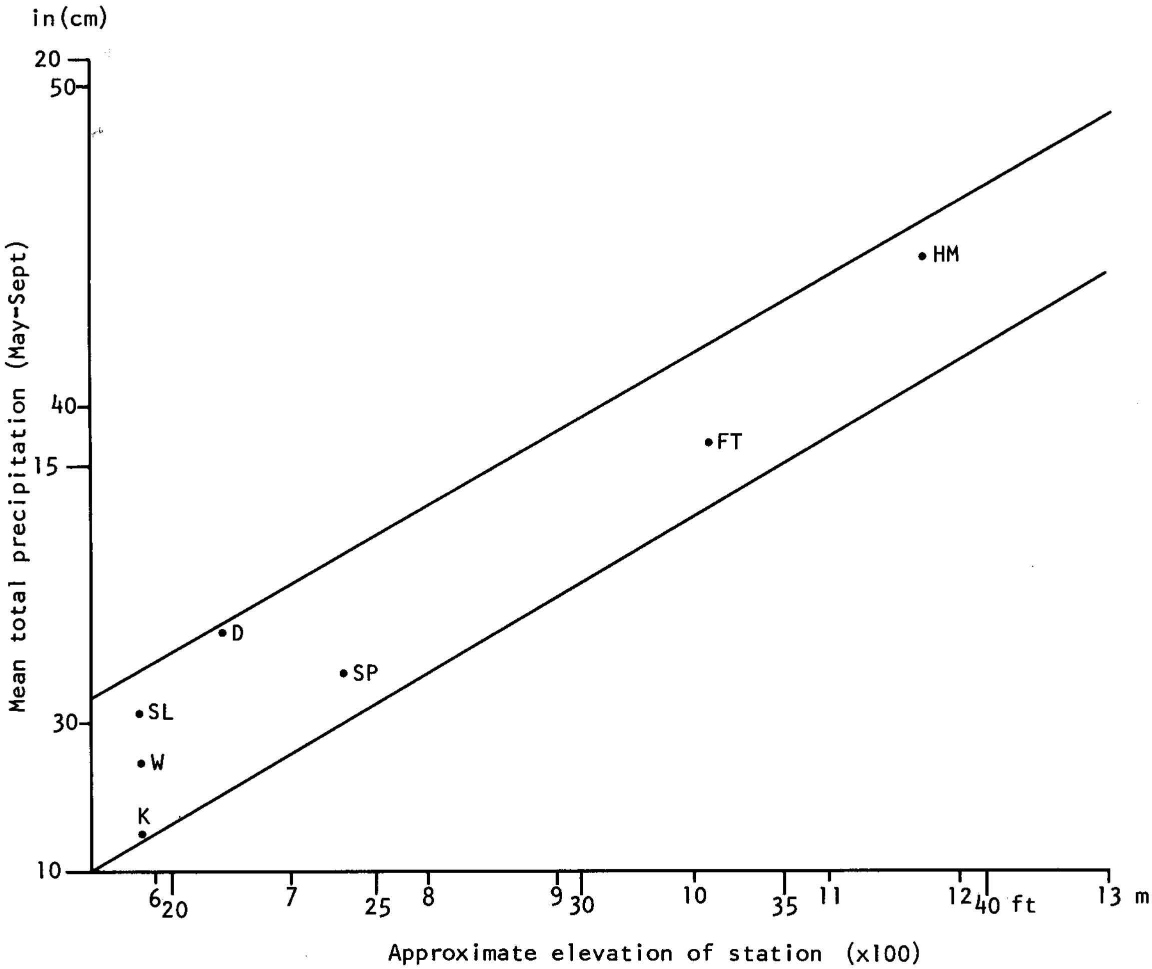
CLIMATE

Köppen's climatic classification denotes the Lesser Slave Lake area as Humid Microthermal — a rain-snow climate with cold winters. More specifically, the climate is Sub-Arctic (a climate with cool, short summers and with only one to three months having a mean temperature above 50°F or 10°C).

Climatological data are presented on the meteorological side map. The annual mean daily temperature at Slave Lake is 33°F (0.6°C). Extreme daily means occur in July (60°F or 15.5°C) and in January (0°F or -17.7°C). Similar figures are recorded for Kinuso and Wagner. Alberta Forest Service stations indicate that above 3000 ft (915 m) AMSL, high mean daily temperatures recorded in July are slightly lower at 57° to 58°F (13.8° to 14.4°C). Annual precipitation in the area varies between 18 in (457 mm) in the lowlands to approximately 22 in (559 mm) at House Mountain. Isohyets have been modified slightly from Longley (1972). In his figure 47, Longley used supplemental data from Alberta Forest Service stations to give "a better understanding of precipitation in the northern areas of Alberta" and more specifically to indicate the fact that precipitation varies with elevation. This latter fact is well illustrated in the Lesser Slave Lake area during the months May to September (Fig. 2).

Annual potential evapotranspiration varies from 20 in (508 mm) in the lowlands to 16 to 18 in (406 to 457 mm) in the uplands. Annual potential evapotranspiration figures were calculated by the Thornthwaite method and agree closely with those shown by Laycock (1967) for the Prairie Provinces, except at House Mountain where a moisture surplus was calculated. All other areas show a soil moisture deficit of up to 5 in (127 mm).

Symbol	Station	Location (Tp, R)	Approximate Elevation
SL	Slave Lake	73-6	1910 ft (582 m)
W	Wagner	73-7	1920 ft (585 m)
K	Kinuso	73-10	1930 ft (588 m)
D	Doucette	79-2	2135 ft (651 m)
SP	Salt Prairie	77-12	2425 ft (739 m)
FT	Flattop	71-6	3310 ft (1009 m)
HM	House Mtn.	70-11	3850 ft (1174 m)



Precipitation data - Alberta Forestry Service

FIGURE 2. Precipitation-elevation relationship, Lesser Slave Lake area

VEGETATION

Vegetation in the area is mainly forest and muskeg.

Cameron (1912) gives a very detailed account of forest cover in the area.

FOREST

In most of the lowlands, excluding muskeg, aspen is predominant and is mixed with balsam poplar, white spruce, and birch. On alluvial floodplains, black cottonwood and balsam poplar predominate and may reach heights of 100 ft (30 m). In most lowlands, willow is very common and usually occurs as small bushes or as larger trees in thickets. Large stands of white spruce occur on north-facing slopes south of Slave Lake.

On the upland slopes to the south, and near Marten Mountain, lodgepole pine predominates and is intermixed with jackpine. On the upland plateaus, lodgepole pine and balsam fir occur on gravel terrains while black spruce is common in wet areas.

MUSKEGS

Muskegs and bogs are widely distributed. Wynnyk *et al.* (1963) describe two types of bogs in the area — moss and sedge. Moss bogs (muskeg) predominate in the north, on all high plateaus, and around the Saulteaux River, and are characterized by sphagnum moss, black spruce, labrador tea, and minor tamarack. Ribbed fen patterns are common and polygonal-patterned ground (6 mi west of Smith) can occur. Sedge bogs are common immediately southeast of Slave Lake. They are characterized by sedges and marsh reedgrass with tree coverings of black spruce and tamarack.

Correlation between groundwater movement and vegetation is subdued. Regional recharge areas are obviously the high plateaus and are thus characterized by a pine-deciduous association. Local recharge points, usually sandy morainal ridges or hills, support jackpine with minor aspen. Most regional groundwater discharge points are effectively masked by thick drift. Occasionally, however, regional groundwater discharge points are present around the base of the uplands and are of the discharge meadow type in which mats of vegetation (mainly grasses) grow in quick ground supported by upwelling groundwaters. Large numbers of phreatophytes such as cow parsnip and white spruce, occurring on the slopes south of Lesser Slave Lake, may also reflect groundwater discharge or a near-surface water table.

GEOLOGY

BEDROCK

The bedrock geology of the area is shown both on the geological side map and hydrogeological cross sections. Approximately 450 electric logs, mainly of petroleum wells and structure testholes, were used to construct structure contours for tops of major formations and marker horizons. The regional strike and dip of all units is slightly north of west and to the southwest.

To the depth of investigation, the area is underlain by marine and nonmarine strata of Early to Late Cretaceous age. These contain, in part, three important marker horizons: the Base of the Fish Scale Zone, Second White Specks, and the First White Specks. The Lower Cretaceous rocks are mainly marine shales and sandstones of the upper portion of the Mannville Group and the lower portion of the Colorado Group. Included (depending on location) are the Spirit River, Grand Rapids, Peace River, Joli Fou, Pelican, Shaftesbury, and La Biche Formations.

Upper Cretaceous rocks are represented by the marine shales or sandstones of the (depending on location) Shaftesbury and Dunvegan Formations and the Smoky Group (which includes the Bad Heart sandstone) or upper Colorado Group-Lea Park Formation and the nonmarine shales, sandstones, and coal beds of the Wapiti Formation.

The Tertiary Paskapoo Formation is found only on House Mountain.

A provisional bedrock topography map of the area (Vogwill, in prep.) shows that a preglacial drainage system cut deeply into older marine shales under Lesser Slave Lake and east of Utikuma Lake. In the former location, the Bad Heart sandstone has been removed. Palynological determinations of samples (Singh, 1975) obtained in Alberta Research Council testholes are shown in the appendix and generally substantiate the expected bedrock geology. Of particular interest is a sample taken from an outcrop of crossbedded sandstone with shale at SW quarter, Sec 30, Tp 72, R 5 just east of Slave Lake ski hill. Palynology indicates that the shale is near the base of the Wapiti; therefore this outcrop could be basal Wapiti sandstone and substantiate boundaries shown by Green (1972). Greiner (1950) mentions blocks of crossbedded sandstones near the railroad embankment in Tp 73, R 7, west of Canyon Creek, and infers they may be basal Wapiti Formation.

SURFICIAL GEOLOGY

Very little work on the surficial geology of the area has been done. Kathol and McPherson (1974) mapped surficial deposits around House Mountain. On a more regional scale, Allan (1918) and Greiner (1950) commented on surficial deposits, while St. Onge and Richard (1967) mapped the area to the south.

Glacial deposits mantle the entire area except in uplands where bedrock outcrops. Glacial flutings and linear ice disintegration ridges indicate that glaciation was from the northeast. Glacial till is the most common unit and occurs mainly as ground or hummocky disintegration moraine. Hummocky disintegration moraine occurs between Salt Prairie and Gift Lake, near Doucette Fire Tower, and west of House Mountain. Ice disintegration ridges and their remnants have been seen on the plateau east of Marten Mountain and near Otauwau Lake. Ground moraine is the more common type of till and is most abundant in the uplands. If very weathered, a stony ground moraine may be and economic source of aggregate. Good cross sections of this till may be seen along the Swan River.

Glaciolacustrine deposits occur along the Swan Hills road near the House Mountain turnoff and south of Delorme Lake (Tp 70, R 3). In addition, glaciolacustrine deposits occur at depth interbedded with till in the preglacial valleys between Smith and High Prairie and eastwards from Gift Lake.

Glaciofluvial deposits are not common and may only occur as lenses in disintegration moraine areas and associated outwash channels.

The approximate distribution of surface sands and gravels has been shown by Vogwill (in prep.). These deposits are, at least in part, potentially economic sources of aggregate. Sand and gravel lenses in hummocky tills are very common due to local outwash features. Outwash channels are present around the periphery of dead ice moraines and occur near Otauwau Lake, 6 mi (10 km) northeast of Salt Prairie Fire Tower, south of Gift Lake, and from Florida Lake south to Otauwau River and then east through Parker Lake. Most high plateaus are capped with quartzite cobbles in a sandy matrix. These represent either in situ Tertiary gravels unaffected by glaciation, or reworked Tertiary gravels; these gravels may be seen in long sinuous ridges east of Marten Mountain. Surface gravels are much more common on the south slopes of the Swan Hills (R. Green, pers. comm.), and this is also true for the Marten Hills where thick sand and gravel deposits are especially common between the Driftwood River and eastern edge of the area.

Sand dunes are present along the Lesser Slave River, Athabasca River, and the southeast shore of Lesser Slave Lake. At the first two locations the dune sands are derived either from alluvium or sandy areas of glaciolacustrine deposits.

Raised beach deposits are common along the north shore of Lesser Slave Lake indicating former lake levels up to 2300 ft (701 m) AMSL or about 400 ft above the present-day level. With such a high water level only the Swan and Marten Hills would be free of glaciolacustrine deposits.

As previously mentioned, preglacial drainage systems cut deeply into the Cretaceous shales and contain basal and near-basal sands and gravels. These are shown on the Lesser Slave Lake provisional topography map (Vogwill, in prep.) and the main hydrogeological map.

Three major preglacial drainage systems are present in the area:

(1) *The High Prairie Buried Valley system*: enters the map area southwest of Smith and drains west under Lesser Slave Lake to High Prairie; drift cover 250 to 500 ft (76 to 152 m);

(2) *The Atikameg Buried Valley system*: the main tributary of the Misaw buried valley (W. Ceroici, pers. comm.) draining northwest and north through the Red Earth area; begins near Gift Lake and drains east to Utikuma Lake and northwest to the Muskwa River, where it joins the Misaw buried valley system; drift cover 250 to 750 ft (76 to 229 m);

(3) *The Doucette Buried Valley system*: begins southwest of McConachie Lake (Tp 79, R 5) and drains east and northeast along Willow River to Wabasca Lakes; drift cover 450 to 650 ft (137 to 198 m).

There is some doubt whether the basal sands and gravels of these systems are preglacial, because they contain, in part, Precambrian Shield material. A notable exception was found in Alberta Research Council testhole 73-11 on the Driftpile River delta where only coarse quartzite cobbles were encountered at a depth of 450 ft (137 m). Jones (1966) considered that the main channel features of the Peace River district are preglacial and that contamination of preglacial materials may have taken place during the first ice advance.

All present-day drainage follows the same flow directions as the preglacial drainage systems except in the case of the High Prairie system. A cross section along this buried valley (Fig. 3) indicates a very low gradient to the west. Although an outlet for this buried valley was not found during test drilling in the Winagami (NTS 83N) area (D. Borneuf, pers. comm.) it is probable that it continues to the Peace River. Blockage of this channel during glaciation and deglaciation by till, alluvial, and lacustrine deposits resulted in reversal of drainage from Lesser Slave Lake to the Athabasca River.

HYDROGEOLOGY

GENERAL

Hydrogeological data distribution is uneven and large areas with no data are common. The data density side map indicates those data points used to construct the hydrogeological main map and cross sections. Only 32 aquifer yield control points are available, consisting of both reliable aquifer tests and short-term apparent transmissivity estimates (Ozoray, 1977). As a result, calculations of 20-year safe yields have involved a large amount of interpretation using lithologs, electric logs, spring flow rates, and the bedrock topography map. Groundwater flow systems shown on the cross sections are highly qualitative. Springs, flowing shotholes, and areas of artesian flow were the main features used in constructing and representing groundwater flow systems.

The main lithologies are shown on the main map.

BEDROCK

Cretaceous marine shales form an effective lower limit for groundwater availability due to low permeabilities and adverse hydrochemistry. Deep groundwaters are highly saline and are represented where possible on the hydrogeological cross sections. Upper Cretaceous sandstone formations (Dunvegan and Bad Heart) do have significant permeabilities but probably contain saline groundwaters. The Bad Heart sandstone has its greatest potential in the Salt Prairie area (Tp 77, R 13) where it is near the surface. However, a well at Grouard Mission (Tp 75, R 14) penetrating the Bad Heart sandstone at about 250 ft (76 m) below ground surface yielded groundwater with a high total dissolved solids and sulfate content. Bad Heart Formation groundwaters probably deteriorate with depth on the south side of Lesser Slave Lake (cross section C-C').

Little is known about groundwater flow systems in these deeper strata. Locally, upward flows exist in the bedrock under Lesser Slave Lake and upward-moving,more saline groundwaters are the probable cause of chlorides in the deeper flowing wells at Faust and Driftpile.

The most important bedrock aquifers are sandstones, coal, and fractured shales of the Upper Cretaceous Wapiti Formation. Little information is available on yields from these aquifers, but they have been placed in the 5 to 25 igpm (approximately 0.4 to 2 l/sec) yield category based on lithology, spring flow rates, and some yield information from near House Mountain. Local occurrences of near-surface coal beds in the Wapiti Formation may increase yields to the upper limit of this category. The approximate locations of these areas are indicated by the depiction of coal in the aquifer lithology on the main map. The basal Wapiti sandstone may also constitute an important aquifer between Kinuso and Mitsue Lake. This horizon was encountered in Alberta Research Council testhole 72-5 at about 80 ft (24 m) and was approximately 120 ft (37 m) thick. Unfortunately, it was not tested for yield.

Springs and flowing shotholes are common in the upland areas underlain by Wapiti Formation. Springs issue either from bedrock outcrops or occur as discharge meadows at lower elevations. Springs associated with bedrock outcrops are usually of the contact type and may represent gravity drainage of aquifers. Discharge meadows, however, probably represent discharging Wapiti Formation groundwaters of a more regional nature. Springs and seeps are responsible, at least partially, for the large amounts of slumping and sliding occurring in the upland valleys.

To construct water table or piezometric contours for bedrock is not possible at present due to lack of data. The high plateaus are regional recharge points for the area. Groundwater travels downward and laterally and discharges as springs in areas of bedrock outcrop, or as seeps and discharge meadows where the drift cover is breached. Due to the regional southwest dip and variable lithology of the Wapiti Formation, groundwater divides may not coincide with surface water divides. Numerous flowing shotholes on the flanks of upland areas reflect local discharge areas confined by glacial till.

SURFICIAL DEPOSITS

Basal or near-basal sands and gravels, occurring in preglacial drainage systems, are the most important aquifers in the map area. Their approximate distribution has been shown by the author on the bedrock topography map of the area. These deposits have been placed in 25 to 100 igpm (2 to 8 l/sec) or 100 to 500 igpm (8 to 38 l/sec) yield categories depending on the availability of reliable aquifer tests, electric logs, and tentative available drawdowns. A notable exception exists near the west side of Utikuma Lake where about 13 wells produce 2½ million gallons of groundwater per day (11.3 million l/day) for oil recovery purposes. Permeabilities in these sands and minor gravels are in the order of 300 to 500 igpd/ft^2 (1.7 to 2.8 x 10^{-4} m/sec) with available heads of about 400 ft (122 m). This gives 20-year safe yield values of well over 500 igpm (38 l/sec) for many of the wells. However, it is doubtful whether this amount of water could be withdrawn from individual wells due to the fine grain size of the aquifer locally. Basal sands and gravels in Alberta Research Council testhole 79-12 at the Gift Lake airstrip were pump tested for 1500 min at 40 igpm (3 l/sec), for 30 ft (9 m) of drawdown, and gave a calculated 20-year safe yield of 125 igpm (9 l/sec). Basal quartzitic gravel in Alberta Research Council testhole 73-11 yielded a flow of 75 igpm (6 l/sec). Subsequent pump testing could not stop the flow due to limited pump capacity (65 igpm or 5 l/sec). "Uncontrollable" flows have also been reported from sands and gravels at 400 to 500 ft (122 to 152 m) below ground surface northwest of Doucette Fire Tower.

Above the basal and near-basal sands and gravels, alternating glaciolacustrine clays and tills (assigned to the yield category 1 to 5 igpm or approximately 0.4 to 2 l/sec) contain significant zones of gravelly glacial outwash. Clissold (1971) pump tested such a zone and reports average transmissivities of 2000 igpd/ft (3.45×10^{-4} m^2/sec), which gives a permeability of 140 igpd/ft^2 (7.92×10^{-5} m/sec) and a 20-year safe yield of 70 igpm (5 l/sec). Other areas where such zones may be significant are between Gift Lake and Doucette Fire Tower and the High Prairie Buried Valley. These zones have generally been assigned to 25 to 100 igpm (2 to 8 l/sec) yield categories.

Older alluvial deposits in the Swan and Driftpile River deltas may also be significant and have tentatively been assigned to the 5 to 25 igpm (0.4 to 2 l/sec) yield category. Such deposits were intersected in Alberta Research Council testhole 73-11 but were not tested.

Shallow surficial deposits (mainly till) are the most common source of groundwater along the southern shore of Lesser Slave Lake and generally give low yields adequate for individuals, but not considered important on a larger scale. Generally, they have been placed in the 1 to 5 igpm (0.4 to 2 l/sec) yield category.

Piezometric surface and water table contours have been constructed for the deep (basal and near-basal sand and gravel) and shallow drift (wells less than 50 ft or 15 m), respectively. Water table contours are a subdued reflection of topography and indicate a hydraulic connection with Lesser Slave Lake.

Piezometric surface contours of deeper drift indicate that most basal sands and gravels are under confining pressures sufficient to induce artesian flow. Areas of artesian flow exist at Faust, Utikuma Lake, northwest of Doucette Fire Tower, and along the western portion of the High Prairie Buried Valley. Generally, groundwater movement in the deeper drift is to the east-northeast in the northern portion of the map area, presumably toward bedrock lows at Red Earth and Wabasca. In the western portion of the High Prairie Buried Valley, (between Kinuso and High Prairie) groundwater moves laterally and upward into the drift (from the bedrock?) and then west towards High Prairie. The southeastern portion of this buried valley is in a recharging configuration and groundwater moves towards Lesser Slave Lake or towards Smith.

Springs in shallow drift are common and represent gravity flow of surface waters from muskegs, and similar sources, through permeable sands and gravels or, in some cases, under mats of vegetation.

Hummocky morainal terrains southwest of Gift Lake and Doucette Fire Tower are important recharge areas for deeper drift aquifers in the northern portion of the map area.

Discharge areas are not known but are assumed to be a considerable distance north of the map area. In addition, recharge from topographic highs such as the Marten Hills is important.

The main recharge area for the High Prairie Buried Valley seems to be the southeast corner of the map area and to the south. Discharge conditions are tentatively assumed to exist west of High Prairie.

HYDROCHEMISTRY

GENERAL

The hydrochemistry has been considered at three levels: surface waters, groundwaters less than 50 ft or 15 m (shallow drift), and groundwaters deeper than 50 ft or 15 m (deeper drift and Wapiti bedrock). Because of data distribution, the latter generally represents groundwaters 200 to 500 ft (61 to 152 m) below surface. Chemical analyses of deeper formation fluids were also studied and contour values of the total dissolved solids of these waters are shown, wherever possible, on the hydrogeological cross sections. Major cation and anion distribution, as well as total dissolved solids contours, are shown on the hydrochemical side maps. Data density maps indicate the distribution of data.

SURFACE WATER

Surface waters in the map area are generally of the Ca,Mg/HCO_3 type and have total dissolved solids of less than 200 ppm (Fig. 4). Notably different are local acidic muskeg waters (pH between 3.5 and 4.5) which contain no bicarbonate, between 15 and 25 percent nitrates, high sulfates, and some high chlorides.

Figure 1 shows a 7-year graph of discharge versus ion concentrations of Swan River water near Kinuso. The groundwater component of flow exerts a considerable influence on the water quality, especially in the winter when it constitutes a high proportion of total flow. The Swan River flows mainly over Wapiti Formation strata which contain high sodium bicarbonate groundwaters.

Surface waters generally have iron concentrations ranging from 0.1 to 5 ppm.

SHALLOW DRIFT AND SPRINGS

These groundwaters have HCO_3+CO_3 or SO_4 as the dominant anions.

Percent of total equivalents per million

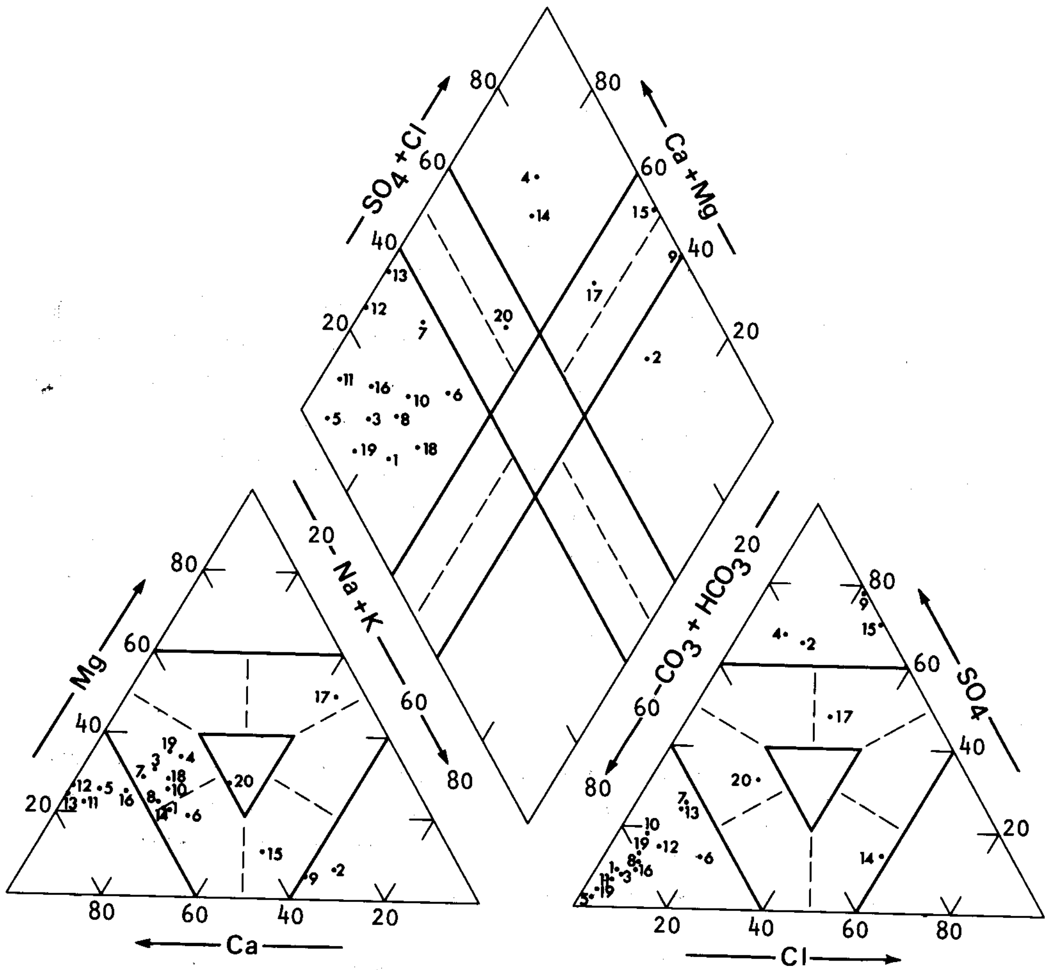


FIGURE 4. Trilinear diagram of selected surface waters, Lesser Slave Lake area

High sulfate groundwaters occur in recharge areas under hummocky disintegration morainal tills between Salt Prairie and Gift Lake and around Doucette Fire Tower. Partial chemical analyses of till extracts are shown in table 1 and indicate significant increases in all ions, especially calcium and sulfates, with depth. Soluble salts are leached from the upper soil horizons and are concentrated in a zone of accumulation within the seasonal zone of fluctuation of the water table. This phenomenon is more completely discussed by Rözkowski (1967) who states that in recharge areas of hummocky moraine,

"...the SO_4-Ca-Mg type of groundwater is already formed in the zone of aeration." and "The main anion is sulfate....The high concentration of this ion is a result of its presence in the easily soluble salts."

Concentration of sulfates, as gypsum, can be observed in road cuts in till along the Gift Lake Road.

Total dissolved solids contents in shallow drift generally decrease away from recharge areas of hummocky disintegration moraine due to:

(1) sulfate reduction and
(2) dilution of shallow groundwaters along their flow path by infiltrating waters from sloughs, etc.

All other shallow groundwaters in the map area (with minor exceptions) have HCO_3+CO_3 as the dominant anions.

Ca and Mg are the major cations in shallow drift groundwater and springs. In areas of Wapiti Formation groundwater discharge Na+K are predominant. These latter areas, which are salt licks for ungulates, are distributed around the bases of uplands and their chemistry is shown in figure 5.

Iron concentrations in the shallow drift and springs are usually high and range from 0.1 to 35 ppm.

DEEPER DRIFT AND WAPITI FORMATION

Bicarbonate and carbonate are the dominant anions throughout most of the deeper drift and Wapiti groundwaters. Locally, deep drift groundwaters are influenced by hummocky till and high sulfate groundwaters are present around Gift Lake and Doucette. Groundwaters with high chloride contents occur in the western portion of the High Prairie Buried Valley and may extend farther east than shown. These chlorides are probably derived from deeper, upward-moving saline groundwaters.

Table 1. Chemical Analyses on Till Samples Obtained from Auger Holes in Hummocky Moraine

Hole Number	Location	Depth interval in ft (m)	Electrical conductance mmhos/cm at 25°C	Na	K	Ca	Mg	SO_4
				ppm				
AH 25	15-3-77-13-W5	0-3 (0-0.9)	0.7	13.8	6.7	111	23	113
AH 25	15-3-77-13-W5	6-9 (1.8-2.7)	0.4	10.9	9.4	56	12.5	78
AH 25	15-3-77-13-W5	18-21 (5.5-6.4)	1.5	81	20.8	290	52	888
AH 24	1-2-79-13-W5	0-3 (0- 0.9)	0.4	9.4	1.9	60	10.5	43
AH 24	1-2-79-13-W5	9-12 (2.7-3.7)	0.8	16.3	12.3	110	24.5	331
AH 24	1-2-79-18-W5	18-21 (5.5-6.4)	3.1	46.9	49	550	121	1743
AH 8	10-6-79-2-W5	0-3 (0-0.9)	0.2	4.7	1.6	27.5	7.5	74
AH 8	10-6-79-2-W5	9-12 (2.7-3.7)	2.6	31.3	17.7	581	56	1955
AH 8	10-6-79-2-W5	18-21 (5.5-6.4)	2.6	12.5	24	587	63	1940

Drilling by Alberta Research Council

Analyses by Alberta Research Council Chemical Laboratory

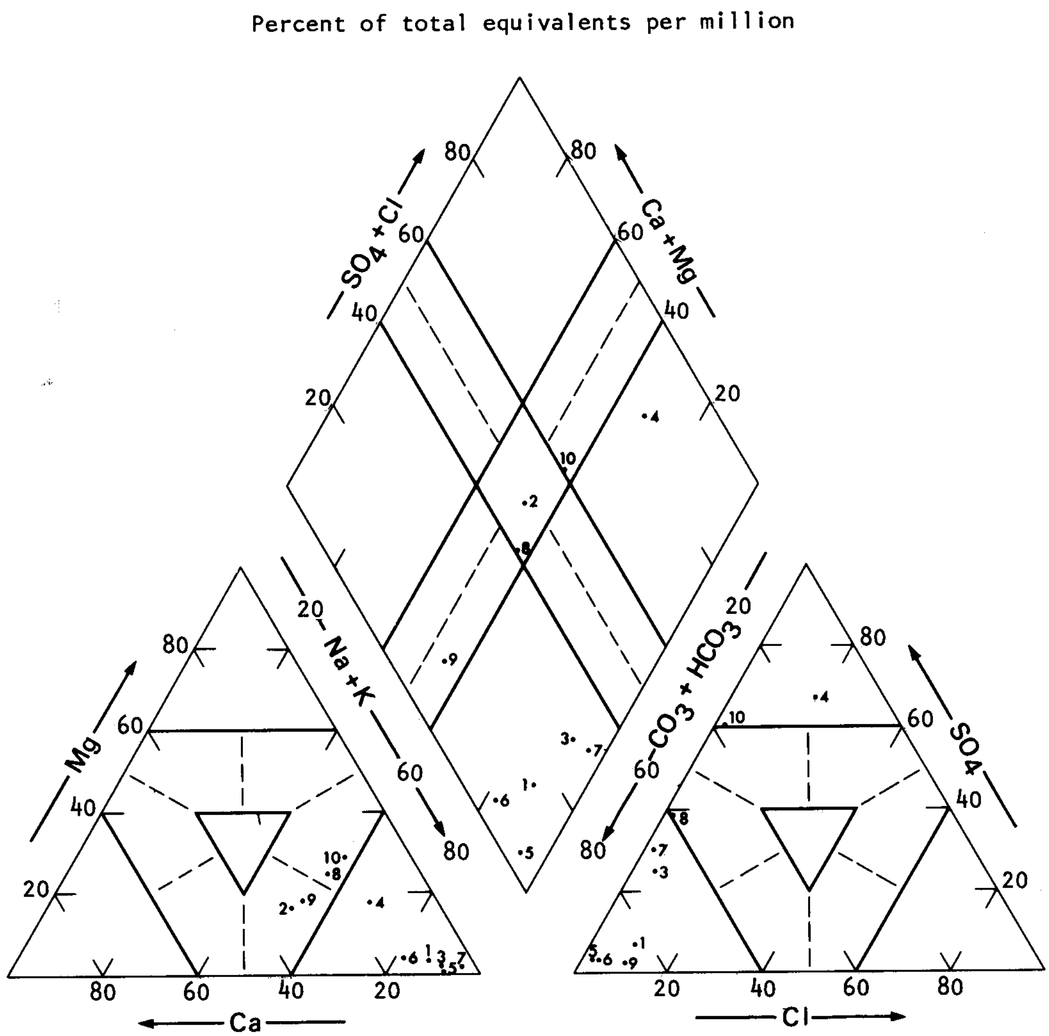


FIGURE 5. Trilinear diagram of hydrochemistry of discharge meadows (natural ungulate "Salt Licks") (probable discharge of Wapiti Formation groundwaters)

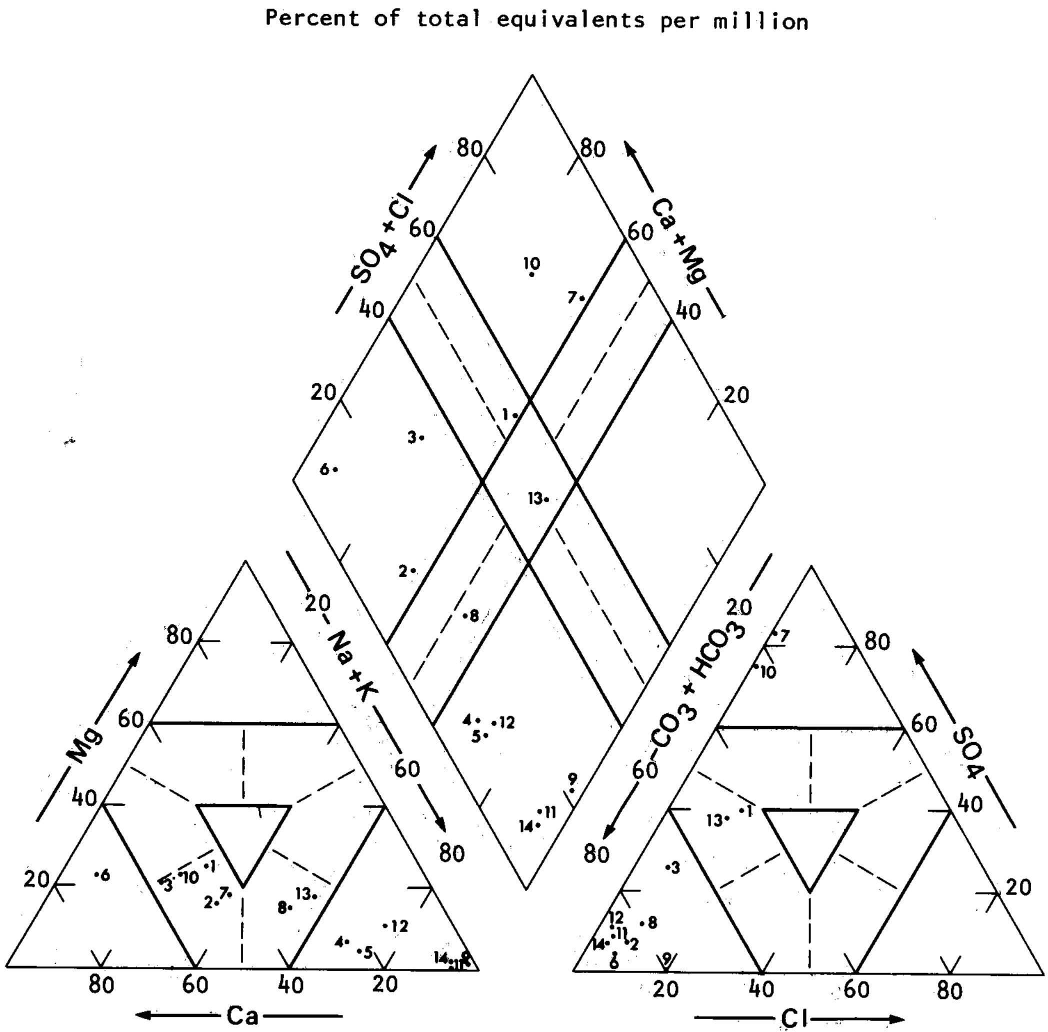


FIGURE 6. Trilinear diagram of Wapiti Formation groundwaters and shallow drift groundwaters over Wapiti Formation

The cations Na+K and Ca+Mg are distributed fairly evenly in deeper drift groundwaters. Areas near Gift Lake and Smith have high Na+K, probably indicating relatively shallow marine shales. High Na+K in the western end of the High Prairie Buried Valleys are derived from upward-moving bedrock groundwaters.

Na+K and HCO_3+CO_3 are the dominant ions in Wapiti Formation groundwater, some of which are represented in figure 6. Total dissolved solids generally increase away from recharge areas. Iron concentrations are generally high and range from 0.1 to 10 ppm.

CONCLUSIONS

The Lesser Slave Lake area contains substantial reserves of potable or near-potable groundwaters.

The most important aquifers in the area are in the drift. Basal and near-basal sands and gravels occur in preglacial drainage networks and have sustainable 20-year yields of 100 to 500 igpm (approximately 8 to 38 l/sec) or 25 to 100 igpm (approximately 2 to 8 l/sec). Many of these aquifers exhibit flowing conditions and may be capable of producing over 500 igpm (38 l/sec) from individual wells.

Sandstones, coal, and to a lesser extent, fractured shales of the Wapiti Formation are the most important bedrock aquifers in the area and have been assigned to the 5 to 25 igpm (0.4 to 2 l/sec) 20-year safe yield category. The basal Wapiti Formation sandstones may be of particular importance where they occur at shallow depths south of Lesser Slave Lake.

The Upper and Lower Cretaceous strata underlying the Wapiti Formation are not considered significant aquifers due to low permeabilities and high groundwater salinities.

Unfortunately, because of adverse hydrochemistry, mainly in the form of high iron contents, nearly all groundwaters in the area require some chemical treatment to be completely suitable for domestic purposes. These high iron concentrations, especially along the southern shore of Lesser Slave Lake, have necessitated using spring waters or building surface water reservoirs to supply villages. These are the most viable solutions while demand is low, but if demand increases, and if a water supply from Lesser Slave Lake is not feasible, deeper aquifers have potential and should be considered.

Chemical treatment of groundwater used for industrial purposes may also be necessary especially where iron and sulfur bacteria are present.

REFERENCES

Alberta, Government and University (1969): Atlas of Alberta; University Press in association with University of Toronto Press.

Alberta Study Group (1953): Lower Cretaceous of the Peace River region; *in* Ralph Leslie Rutherford Memorial Volume, Western Canada Sedimentary Basin Symposium, American Association of Petroleum Geologists, Tulsa, p. 268-278.

Allan, J. A. (1918): Geology of the Swan Hills; Geological Survey of Canada Summary Report, Part C, p. 7c-12c.

Allan, J. A. and R. L. Rutherford (1934): Geology of Central Alberta; Research Council of Alberta Report 30, 41 pages.

Badry, A. (1972): A legend and guide for the preparation and use of the Hydrogeological Information and Reconnaissance map series; Research Council of Alberta Report 72-12, 96 pages.

Burk, C. F. Jr. (1963): Structure, isopach, and facies maps of Upper Cretaceous marine succession, west-central Alberta and adjacent British Columbia, Geological Survey of Canada Paper 62-31, 9 pages.

Cameron, D. Roy (1912): Report on timber conditions around Lesser Slave Lake; Department of the Interior, Forestry Branch, Report No. 29, 54 pages.

Campbell, J. D. (1972): Coal occurrences Athabasca-Smith area, Alberta; Research Council of Alberta Report 72-10, 34 pages.

Clissold, R. (1971): Testing of groundwater north of Lesser Slave Lake; unpublished report, 41 pages.

Collins, S. J. (1975): Surface disposition and general land use in the Lesser Slave Lake area; Department of Municipal Affairs, Research Planning Section, Interim Report, 37 pages.

Green, R. (1972): Geological map of Alberta; Research Council of Alberta map.

Greiner, H. R. (1950): Geology of the Swan Hills; unpublished report, 31 pages.

Hem, J. D. (1959): Study and interpretation of the chemical characteristics of natural water; United States Geological Survey Water Supply Paper 1473, 269 pages.

Jones, J. F. (1962): Reconnaissance groundwater study Swan Hills and adjacent areas, Alberta; Research Council of Alberta Report 62-5, 43 pages.

———— (1966): Geology and groundwater resources of the Peace River district, northwestern Alberta; Research Council of Alberta Bulletin 16, 143 pages.

Kathol, C. P. and R. A. McPherson, (1974): Susceptibility of geologic deposits to erosion in the House Mountain area, Alberta; Alberta Research Report 74-5, 33 pages.

Laycock, A. H. (1967): Water deficiency and surplus patterns in the Prairie Provinces: Regina; Prairie Provinces Water Board, Report No. 13, 185 pages.

Longley, R. W. (1972): The climate of the prairie provinces; Environment Canada, Atmospheric Environment, Climatological Studies, No. 13, 79 pages.

McConnell, R. G. (1890-91): Report on a portion of the district of Athabasca comprising the country between Peace River and Athabasca River north of Lesser Slave Lake; Geological Survey of Canada Annual Report (new series), Vol. 5, Pt. 7.

McCrossan, R. G. and R. P. Glaister, eds. (1964): Geological history of Western Canada; Alberta Society of Petroleum Geologists, 232 pages.

Ozoray, G. (1977): Nomogram for determination of apparent transmissivity; *in* Contributions to the Hydrogeology of Alberta, Alberta Research Council Bulletin 35, p. 13-17.

Piper, A. M. (1944): A graphic procedure in the geochemical interpretation of water analyses; American Geophysical Union Transactions, Vol. 25, p. 914-923.

Rözkowski, A. (1967): The origin of hydrochemical patterns in hummocky moraine; Canadian Journal of Earth Sciences, Vol. 4, 27 pages.

Singh, C. (1975): Palynological determinations of samples, Lesser Slave Lake area, Alberta; Alberta Research Council Memorandum, 3 pages.

St. Onge, D. A. and S. H. Richard (1967): Surficial geology of NTS 83J, Whitecourt; unpublished map.

Tokarsky, O. (1965): Sucker Creek Indian Reserve — Test drilling program; unpublished Research Council of Alberta Report.

Vogwill, R. I. J. (in prep.): Provisional bedrock topography, Lesser Slave Lake, NTS 83O, Alberta; Alberta Research Council map.

Wynnyk, A., J. Lindsay, P. Heringa, and W. Odynsky, (1963): Exploratory soil survey of Alberta map sheets 83O, 83P, and 73M; Research Council of Alberta Soil Survey Report 64-1, 53 pages.

APPENDIX A

KEY TO SAMPLE NUMBERS SHOWN IN FIGURES 4, 5, 6

FIGURE 4

Sample No.	Location (W 5th Mer)	Remarks
1	01-30-69-03	Plants: water arum and marsh cinquefoil
2	11-36-69-09	Acidic muskeg waters, 19 percent NO_3
3	13-03-70-03	Muskeg water
4	04-35-71-02	Acidic muskeg, 22 percent NO_3, no HCO_3
5	16-27-72-03	Small tributary of Lesser Slave River
6	02-24-71-06	Florida Lake, water arum, 9 percent NO_3
7	02-33-72-05	Muskeg drainage, water arum, marsh cinquefoil
8	02-20-75-02	Headwaters Driftwood River, acidic, 20 percent sodium
9	15-19-75-04	Acidic muskeg, 21 percent NO_3
10	13-28-75-08	Small drainage
11	12-36-77-08	Muskeg
12	10-27-77-10	Slough
13	04-13-78-03	Tributary of Willow River
14	13-26-78-05	Acidic muskeg
15	04-34-80-03	Acidic muskeg, 29 percent NO_3
16	10-32-73-09	Tributary of Swan River
17	01-20-77-04	Acidic muskeg, 15 percent NO_3
18	01-29-76-05	Headwaters Cabin Creek
19	14-07-72-04	Borrow Pit; plant: Colt's foot
20	15-30-80-03	Lake, sulfur bacteria

FIGURE 5

Sample No.	Location (W 5th Mer)	Remarks
1	02-03-70-04	Discharge meadow, fetid odor, 1 igpm
2	10-33-70-04	Discharge meadow
3	10-12-71-06	Springs, animal tracks
4	08-14-71-06	Discharge meadow
5	12-31-72-08	Discharge meadow, tussocks
6	10-10-72-10	Discharge meadow, tussocks
7	06-23-74-03	Discharge meadow, fetid odor, 2 igpm
8	NE-23-75-13	Discharge meadow
9	13-08-79-04	Discharge meadow, animal tracks
10	15-30-80-03	Small seepage, soaphole, animal tracks

FIGURE 6

Sample No.	Location (W 5th Mer)	Remarks
1	09-23-69-08	Spring from Wapiti Formation through drift
2	10-23-69-08	Spring from Wapiti Formation, coal
3	08-35-69-09	Auger hole 18, drift over Wapiti Formation
4	03-05-70-10	Well, Wapiti Formation
5	01-06-70-10	Well, Wapiti Formation
6	16-01-71-04	Auger hole 14, drift over Wapiti Formation
7	11-08-72-03	Auger hole 1, drift over Wapiti Formation
8	13-31-73-07	Small drainage from Wapiti Formation
9	13-10-73-11	Well at Faust, near Wapiti Formation
10	05-05-73-13	Auger hole 20, drift over Wapiti Formation
11	04-28-74-04	Well, Wapiti Formation
12	10-11-74-05	Auger hole 5, drift over Wapiti Formation, base of Marten Hills
13	01-23-75-02	Auger hole 3, drift over Wapiti Formation, top of Marten Hills
14	12-24-70-11	Well, Wapiti Formation

APPENDIX B

ALBERTA RESEARCH COUNCIL TESTHOLES

AR 72-11

Location: Lsd 13, Sec 35, Tp 72, R 11, W 5th Mer
Total depth: 495 ft (151 m)

Depth (feet)	Lithology
0-30	Drift, silty clay with rock fragments, tan to brown
	Wapiti Formation
30-140	Shale, silty, grey to blue grey, minor coal
	Lea Park Formation
140-386	Shale, grey
386-495	Shale, grey blue to grey

Pump testing: Nil, very little potential.
Palynology: 270 to 280 ft; brackish uppermost Lea Park Formation.
Status: Abandoned.

AR 73-11

Location: Lsd 16, Sec 31, Tp 73, R 11, W 5th Mer
Total depth: 434 ft (132 m)

Depth (feet)	Lithology
0-75	Clay, green grey and sand, blue grey, medium-coarse
75-170	Clay, green grey, contorted
170-406	Clay, green grey, and sand and/or gravel layers throughout; good sands, 175-185, 250-275, 295-310, 380-395
406-434	Mainly gravel, with minor clay and sand layer; gravel, mainly white quartzite

Pump testing: Pump tested 4 hr at 65 igpm, well still flowing at 10 igpm.
Palynology: 430 ft, nonmarine; Wapiti Formation.
Status: Flowing at 75 igpm, being used for stock and domestic purposes.

AR 79-12

Location: Lsd 13, Sec 22, Tp 79, R 12, W 5th Mer
Total depth: 500 ft (152 m)

Depth (feet)	Lithology
0-80	Till, brown tough clay with pebbles and boulders
80-130	Mainly clay, grey, can be silty; lacustrine?
130-135	Gravel and sand; outwash?
135-280	Clay, grey, sticky; occasional pebble
280-300	Gravel and sand
300-500	Shale, grey, marine with minor sandstone layers; bedrock Smoky Group

Pump testing: Gravel 280 to 300 tested for 1500 min at 40 igpm, static water level 72 ft, total drawdown at end of test 30 ft. Q_{20} of 120 igpm, transmissivity 1190 igpd/ft.
Palynology: 300 to 310, marine; uppermost Smoky Group.
Status: Cased, will be used to supply forestry camp.

AR 76-13

Location: Lsd 16, Sec 33, Tp 76, R 13, W 5th Mer
Total depth: 452 ft (138 m)

Depth (feet)	Lithology
0-20	Till, brown, clayey and sandy
20-160	Clay, dark grey, sticky, can be silty
160-230	Gravel, with interbedded clay and sand
	Smoky Group
230-450	Bedrock, dark grey marine shales
450-452	Bad Heart Sandstone, medium to coarse, pyritic, and quartzitic

Pump testing: Nil. Airlifted for 2 hr at 18 igpm, hole caving badly. Water level 115 ft below surface, ½ hr after stopped airlifting.
Palynology: 350 ft, marine; uppermost Smoky Group.
Status: Abandoned.

AR 74-4

Location: SW quarter, Sec 28, Tp 74, R 4, W 5th Mer
Total depth: 460 ft (140 m)

Depth (feet)	Lithology
0-4	Till, brown, clayey
4-460	Alternating bentonitic sandstones and shales, minor coal; Wapiti Formation

Pump testing: Nil. Hole caving badly. Static water level approximately 24 ft.
Palynology: None.
Status: Abandoned.

AR 79-2

Location: Lsd 16, Sec 6, Tp 79, R 2, W 5th Mer
Total depth: 465 ft (142 m)

Depth (feet)	Lithology
0-20	Till; brown pebbly clay
20-40	Clay, grey, sticky
40-110	Sand, minor gravels and clay, dark grey
110-130	Clay, grey
130-145	Gravel, angular
145-270	Clay, grey, sticky and gravel and sand
270-325	Clay, grey, sticky
325-345	Gravel, angular, some sand; outwash?
345-465	Mainly blue-grey clay, hard drilling

Pump testing: Gravel and sand, 325 to 345 tested at 5 igpm, drew down to pump (set at 319 ft) in 17 min. Poor results partially due to well completion. Static water level 200 ft.
Palynology: None.
Status: Cased, will be used for fire tower supply.

AR 72-3

Location: Lsd 2, Sec 4, Tp 72, R 3, W 5th Mer

Total depth: 355 ft (108 m)

Depth (feet)	Lithology
0-40	Sand and gravel, clayey near base
40-260	Clay, grey to dark grey, can be sandy, pebbly throughout
260-300	Clay, grey, with gravel layers
300-340	Clay, grey, sticky
340-355	Gravel, some sand and clay

Pump testing: Nil. Airlifted for ½ hr, hole caving badly but substantial water returns.

Palynology: None.

Status: Abandoned.

AR 72-5

Location: SW quarter, Sec 7, Tp 72, R 5, W 5th Mer

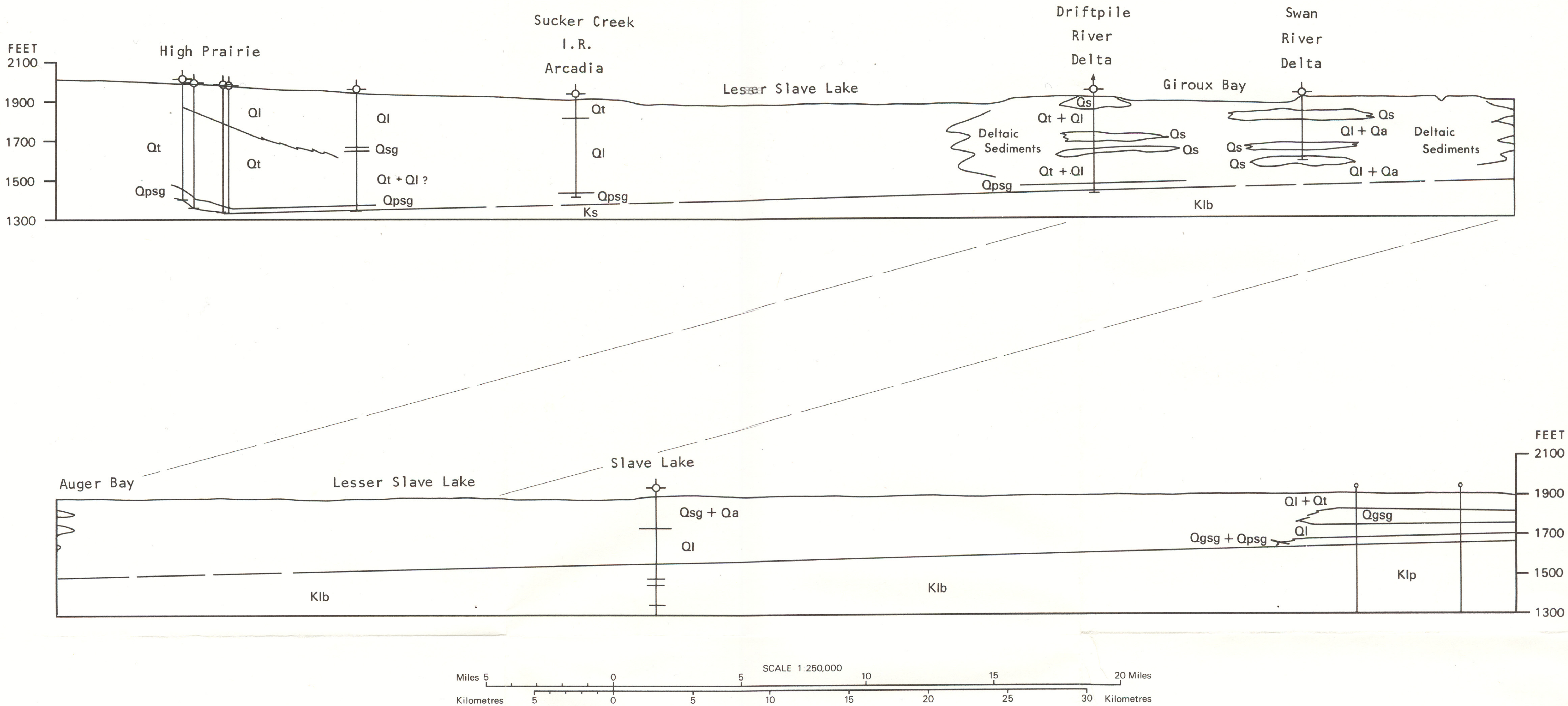
Total depth: 400 ft (122 m)

Depth (feet)	Lithology
0-30	Till
30-90	Sand and gravel, and grey clay
	Wapiti Formation
90-212	Alternating grey-green sandstones and grey shales; massive sandstones at 100-150 and 185-208 interpreted as basal Wapiti sandstones
	Lea Park Formation
212-400	Grey marine shales, minor sandstones

Pump testing: This well was not pump tested because of equipment problems but it shows very good potential from the basal Wapiti sandstones.

Palynology: 210 to 220 ft, brackish phase; uppermost Lea Park.

Status: Abandoned.



LEGEND

Quaternary

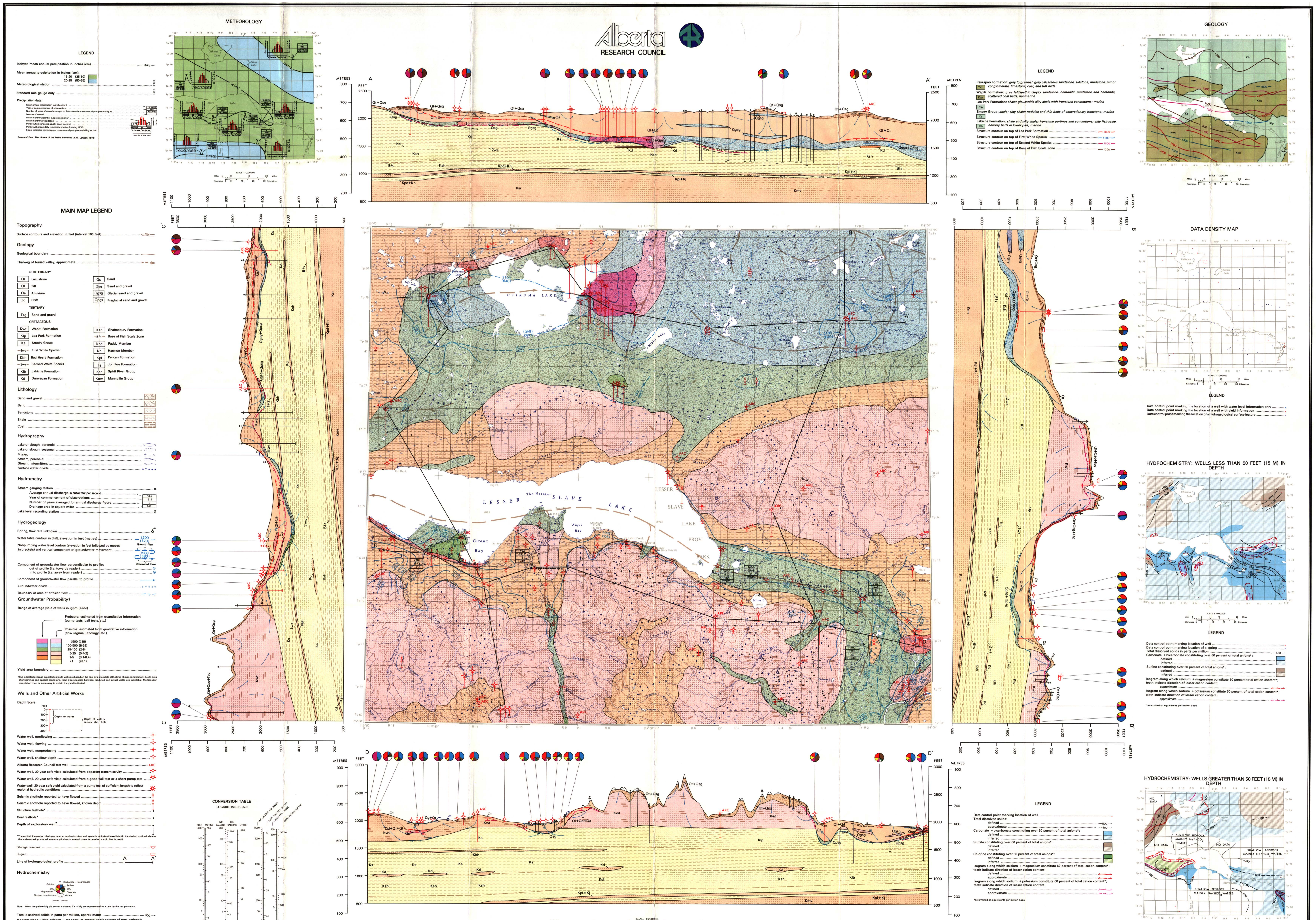
Ql - lacustrine silts & clays
Qa - alluvium, deltaic
Qs - sand, outwash
Qt - till
Qsg - sand and gravel
Qpsg - Saskatchewan Sands and Gravels
Qgsg - glacial sand and gravel

Cretaceous

Klp - Lea Park - shales marine
Klb - La Biche - shales marine, minor sandstone
Ks - Smoky Group - shales marine

Vertical exaggeration 1cm = 200 feet

FIGURE 3. Cross section, High Prairie-Slave Lake Buried Valley



All elevations in feet above mean sea level.

Vertical exaggeration of the hydrogeological profiles is approximately 40X.

An expanded legend and explanatory notes (Earth Sciences Report 72-12) is available from Publications, Alberta Research Council, 11315 - 87 Avenue, Edmonton, Canada, T6G 2C2.

Map to accompany Report 77-1.

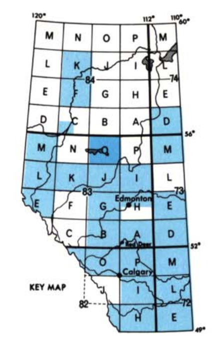
Hydrogeology by R.I. Vogwill.

Drawn by R. W. Swenson.

Cartographic editing by A.R. Campbell.

HYDROGEOLOGICAL MAP LESSER SLAVE LAKE ALBERTA

NTS 83-O



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