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Hydrogeology of the Edson area, Alberta

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In Memoriam

This report and the enclosed hydrogeological map are dedicated to the memory of John (Jack) A. Tarbet 1921 - 1979

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ABSTRACT

The hydrogeology of the Edson map area can be discussed with respect to three physiographic regions: the Interior Plains, the Rocky Mountain Foothills, and the front ranges of the Rocky Mountains.

In the Interior Plains, fractured sandstones of the Paskapoo Formation are the most important bedrock aquifers. Transmissivity for this formation ranges from less than 1.5 m^2/d to over 100 m^2/d, depending on the degree of fracturing. Safe yield values range from 0.1 L/s to 38 L/s. The buried Edson valley aquifer is the most important surficial aquifer in the area with transmissivity values between 150 m^2/d and 1200 m^2/d and safe yields from 8 L/s to 38 L/s.

In the foothills, the Paskapoo Formation is also the main bedrock aquifer but is slightly less productive with transmissivity values of 1.5 m^2/d to 15 m^2/d and safe yields of 0.4 L/s to 2 L/s. The most important surficial aquifers in the foothills are outwash gravels between Brule and Gregg Lakes. These aquifers have been assigned safe yields of 2 L/s to 38 L/s.

In the Rocky Mountains bedrock aquifers exist because of fractures. Depending on the rock types, safe yields can range from 0.1 L/s to 2.0 L/s. Surficial deposits in the Rocky Mountains are mainly recent alluvium or glaciofluvial deposits. Southwest of Brule Lake these deposits are assigned a safe yield of 8 L/s to 38 L/s.

Hydrochemistry is discussed according to categories. Groundwaters of the area are generally of good quality.

Bedrock groundwaters are of three basic types:

1. Ca, Mg-HCO_3, CO_3 from shallow bedrock aquifers;
2. Na, K-HCO_3, CO_3 from moderately deep to deep bedrock aquifers; and
3. mixed types dominated by sulfates from various bedrock aquifers.

Total dissolved solids content (TDS) of bedrock waters ranges from 200 to 1000 mg/L.

Drift waters are usually of the Ca, Mg-HCO_3 type with varying amounts of sulfates (up to 40% epm). The maximum TDS of drift waters is 700 mg/L.

Seventy-five percent of spring discharges are Ca, Mg-HCO_3 groundwaters with TDS ranging from 100 to 1000 mg/L. Of these, ninety percent have TDS of less than 50 mg/L.

INTRODUCTION

The Edson map area comprises approximately 14 750 km^2 between 116 and 118 degrees west longitude and 53 and 54 degrees north latitude. According to the National Topographic System, the area is designated as map 83F and includes Townships 46 to 58 and Ranges 14 to 28, west of the fifth meridian.

The towns of Edson (pop. 5015) and Hinton (pop. 7390) contain approximately 90 percent of the area's population. The remaining population is distributed in small settlements, such as Marlboro, Robb, Brule and Cadomin, along Highways 16, 40 and 47, or in the farming district north and northeast of Edson. A small portion (650 km^2) of Jasper National Park occupies the southwest corner of the map area and W.A. Switzer Provincial Park is 10 km northwest of Hinton. Numerous small settlements in the south-central portion of the area, which formed the well known "Coal Branch," are ghost towns. An excellent summary of the history of the area was given by Dumanski *et al.* (1972).

The economy of the area is based primarily on the industries of coal mining, pulp and paper manufacturing, oil and gas development and exploration, farming and tourism. Two mines are currently supplying coking coal to primarily foreign markets. Small logging operations have existed in the area for many years, but in 1957 a pulp mill at Hinton became a major factor in that town's development. Edson has benefited from the presence of numerous oil and gas fields. The main agricultural area is in the lowlands to the north and northeast of Edson. Tourism is a significant industry because the area is near Jasper National Park and the Miette Hot Springs resort.

Hydrogeological mapping was completed in 1975 and consisted of sampling and describing wells and natural hydrogeological features by means of road, fixed wing and rotary wing traverses. A program of aquifer testing and well drilling was also completed in 1975.

The hydrogeological data distribution is generally poor, except in the vicinity of Edson and along Highway 16, and is shown on the data density side map of the accompanying hydrogeological map. Fortunately, many water supply wells associated with oil rig sites and an abundance of springs sampled during 1975 enhanced the distribution of hydrogeological data. Even so, large portions of the area are devoid of hydrogeological information, and the reader of the report or its accompanying map should expect to find qualitative evaluations there.

The most important use of groundwater in the area is the development of a buried valley aquifer for use by the town of Edson. Groundwater has a nuisance value at various coal mines where open pit dewatering is required to control groundwater inflow. The town of Hinton uses the Athabasca River for its water supply. Of the remaining small villages in the area, approximately half use groundwater. Numerous oil rigs and oil and gas plants use groundwater for domestic and industrial purposes.

PREVIOUS WORK

Lindsay *et al.* (1963) and Dumanski *et al.* (1972) completed soil surveys and land evaluations for the Hinton-Edson area. Dumanski and Pawluk (1971) studied the unique soils near Hinton.

Numerous coal deposits have been found near the Rocky Mountains, so the geology of the area has been extensively mapped since the turn of the century. Dowling (1910, 1911), MacVicar (1916), Rutherford (1925, 1928), MacKay (1929a, 1929b, 1930, 1943), Irish (1945, 1947), Lang and Brown (1943) and Lang (1947) mapped and studied the coal-bearing Foothills region. Pearson (1960) commented on the coal deposits in the Wildhay River District. Irish (1965) completed the geologic map for the Rocky Mountain Foothills. Mountjoy (1960) and Price and Mountjoy (1970) completed detailed studies of the stratigraphy and structure of portions of the Rocky Mountains. Carrigy and Mellon (1964), Mellon (1967), Wall (1967), Carrigy (1970, 1971), Yurko (1976) and Holter *et al.* (1975) studied the Upper Cretaceous and Tertiary rocks of the map area. Roed (1968) described the surficial geology of the Hinton-Edson area and Bayrock and Reimchen (1975) mapped the surficial geology of the foothills and Rocky Mountains of the Edson area as part of a larger study.

The first documented hydrogeological work in the map area was by the Research Council of Alberta in connection with locating a water supply for the town of Edson (Farvolden, 1959; Lennox, 1966). This early work led to the discovery of a buried preglacial valley that contained significant aquifers immediately south of the town (Lennox, 1966; Vanden Berg and Lennox, 1968; Gabert and

Roed, 1968; Nielsen, 1969). Two basins, Cache Percotte and Tri-creek, were studied by Stevenson (1969) and Currie (1976), respectively. Barnes (1977, 1978), Tokarsky (1977), Ozoray (1972) and Bernard (1977) completed hydrogeological reports in adjoining areas. Dalal (1977) described the aquifer characteristics and yield parameters of shallow bedrock in the northeastern two-thirds of the area. Various hydrogeological consultants have reported on industrial and domestic groundwater supplies and open pit dewatering designs in the map area.

ACKNOWLEDGMENTS

Assistance during fieldwork was provided by A. Beerwald, G.P. Dalal, G. Jean and J. Tarbet. The Blue Lake Center supplied storage space during field operations. Drill stem test data and chemical analyses were supplied by the Energy Resources Conservation Board. Chemical analyses were performed at the Alberta Research Council Geochemical Laboratory. Important computer manipulation and plotting of data was completed by C. Newton and P. Redberger of the Alberta Research Council Computing Department.

R. Stein critically reviewed the manuscript.

TOPOGRAPHY, DRAINAGE AND VEGETATION

The Edson map area is part of the MacKenzie River drainage system and (with the exception of the extreme southeastern corner, which is drained by the North Saskatchewan River) is drained to the north and east by the Athabasca River. The four main tributaries of the Athabasca River, in the area, are the Wildhay, Berland, McLeod and Pembina Rivers.

Elevation in the map area ranges from 850 m in the east to above 2600 m in the Rocky Mountains. Using the physiographic classification of Dumanski *et al.* (1972), the area contains two physiographic regions (Interior Plains and Western Cordillera) each with two divisions (Alberta Plains, Alberta Plateau Benchlands and Rocky Mountain Foothills, Rocky Mountains, respectively). The following discussion of physiography and vegetation has been modified from Dumanski *et al.* (1972).

The Alberta Plains occur in the east central portion of the area, as a lowland (elevation 1036 m or less) within a 15 to 25 km radius of Edson.

The most common trees are aspen poplar, lodgepole pine and white spruce in well-drained locations, and black spruce, tamarack, white spruce, and balsam poplar in poorly drained locations. Most of the area's agriculture takes place in this physiographic division.

The Alberta Plateau Benchlands occupy half of the map area between the Alberta Plains and the Rocky Mountain Foothills. Elevation range of this division is moderate (914 m to 1340 m) and the most common landforms are long plateaus that are remnants of a Tertiary landscape. Bedrock outcrops are common only at high elevations and most of the division is mantled by glacial drift. In well-drained locations, vegetation consists of lodgepole pine with minor aspen and balsam poplar. Poorly drained areas and muskegs are characterized by black spruce, tamarack, lodgepole pine, birch and balsam poplar.

The Rocky Mountain Foothills are found in a southeast to northwest trending strip in the southwest portion of the map area. The eastern and western edges of this division coincide with the towns of Robb and Cadomin, respectively. Elevation ranges between 1158 and 1676 m in a series of parallel ridges that conform to geologic strike of the underlying strongly folded sediments. General drainage is to the northeast and comprises a trellis pattern perpendicular and parallel to the regional geological strike. Vegetation consists predominantly of lodgepole pine with some white and black spruce and minor aspen, balsam poplar and birch.

The Rocky Mountains trend northwest to southeast through the southwest corner of the area and are almost entirely contained in Jasper National Park. These mountains are characterized by extreme relief and elevations range from 1524 to 2620 m. Drainage is to the northwest and southeast into the Athabasca River. At lower elevations, vegetation is similar to the foothills division, while at increasing elevations, Engelmann spruce grow in association with alpine fir and lodgepole pine.

Currie (1976), related vegetation cover to groundwater movement in a foothills environment. Many of his observations are applicable to the three eastern physiographic regions in the map area. In general, vegetation in groundwater recharge areas corresponds to that in well-drained areas and vegetation in groundwater discharge areas is similar to poorly drained locations. Vegetation in recharge areas consists of two associations: lodgepole pine—brome grass—bearberry and white spruce—pine—bilberry—

green moss. In the Alberta Plains, aspen is generally the dominant tree in recharge areas. These two associations indicate a depth to the water table of 1.3 to 5 m. In groundwater discharge areas of reasonable size, the black spruce—fir—hair cap—sphagnum moss and sedge—willow—swamp birch associations are most common and indicate a depth to the water table of 0 to 0.8 m.

LAND USE

Using the surface disposition map and associated reports prepared for the Hinton/Yellowhead Regional Land Use Study (Thomas *et al.,* 1975), the land use within the Edson map area, excluding Jasper National Park, can be analyzed. About eight percent of the area is used for agriculture, which is confined almost entirely to the Alberta Plains physiographic division. Although mineral extraction accounts for only four percent of the land use, it is an important economic factor in the area's development. Logging is extremely important in the area and accounts for forty-nine percent of the area's land disposition. Thirty-nine percent of the area is Crown land, which may or may not be traversed by transportation or communication lines. Recreational use and surface rights (usually buildings) account for less than one percent of land disposition.

CLIMATE

According to the Koeppen climatic classification, the map area falls within the D (cold snowy forest) zone. The D category, also described as microthermal, indicates that the average temperature of the warmest month is above 10°C, and that of the coldest month is below -3°C. The D category is further subdivided and the complete climatic symbol, D_c, for the Edson area, also indicates cool summers with mean temperatures of the warmest month below 22°C, and less than four months with mean temperatures of 10°C or more. The Rocky Mountains physiographic division of the area cannot be included in this classification.

Long-term meteorological stations are located at Entrance and Edson, and are supplemented by seven Alberta Forestry Lookouts at which meteorological records are taken for five months annually. The meteorological side map indicates the locations of these stations as well as the data available. January is the coldest month (Edson mean temperature -14.4°C; Entrance mean temperature -11.7°C), and July is the warmest month (Edson mean temperature 18.9°C; Entrance mean temperature 15°C), with the duration of the frost free period (minimum daily temperature above 0°C) being between 60 and 80 days in recent years. Based on precipitation data and Longley (1972), isohyets shown on the side map indicate that precipitation in the area varies from approximately 508 mm near Hinton to over 610 mm on the elevated areas north of Edson and near the Coal Branch. Isohyets suggest a correlation between elevation and precipitation. This is corroborated by a plot of station elevation versus average total precipitation for the months of May to September (figure 1).

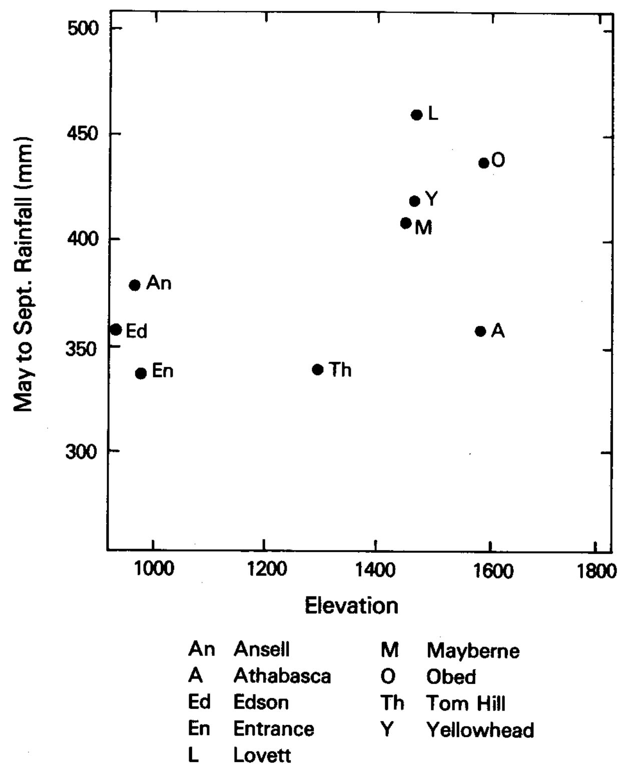


FIGURE 1. Precipitation: elevation relationship, Edson area

Potential evapotranspiration at the two long-term meteorological stations slightly exceeds the mean precipitation during the growing season (May to September). Thus an annual soil moisture deficit of about 50 mm probably exists over much of the map area. Annual potential evapotranspiration figures were calculated by the Thornthwaite method, and agree closely with those shown by Laycock (1967).

BEDROCK GEOLOGY

The structure and stratigraphy of the Rocky Mountains and Rocky Mountain Foothills shown on the geological side map and hydrogeological cross sections has basically been taken from the Geological Maps of Alberta (Green, 1972; Jackson, 1975) and Price and Mountjoy (1970). The geology shown has been extremely simplified and, on the cross sections, is basically schematic at depth.

Except for a distinction between the Paskapoo and Brazeau Formations (Jackson, 1975), and a change in the nomenclature of the physiographic divisions, the bedrock stratigraphy as outlined by Barnes (1977) has been used. Much of the discussion on the geology of the Rocky Mountains and the Rocky Mountain Foothills was adapted from Price and Mountjoy (1970) and Barnes (1977).

Price and Mountjoy (1970) described the regional geologic structure and evolution of the Rocky Mountains and indicate that there are basically two types of rock sequences present (i) a miogeosynclinal - shelf series that forms the Rocky Mountains proper, and (ii) a clastic wedge sequence that forms the foothills and plains regions.

The Rocky Mountains (divided into the Front Ranges and Main Ranges subprovinces by Price and Mountjoy) consist of Middle Cambrian to Jurassic rocks. The Main Ranges subprovince is not represented in the map area. The Front Ranges are characterized by Paleozoic carbonate rocks separated by valleys of less resistant Mesozoic shales and sandstones. Structurally, they are characterized by a series of southwest dipping thrust sheets. The boundary of the Front Ranges in the map area is slightly northeast of the Fiddle Range.

The Rocky Mountain Foothills are underlain by the Cretaceous portion of the clastic wedge sequence represented by the Lower Cretaceous Blairmore Group, Upper Cretaceous Alberta Group, the Upper Cretaceous to Tertiary Brazeau Formations, and minor occurrences of the Tertiary Paskapoo Formation. Lithologies are generally sandstones, shales and coal with minor limestone. Structurally, the foothills are dominated by folded, relatively flat, thrust faults. Folds within individual thrust sheets are broad open structures with a predominance of synclines. Inliers of Paleozoic carbonates and outliers of the Brazeau and Paskapoo Formations are common. Numerous economic deposits of coal occur in the foothills mainly in the Luscar, Brazeau and Paskapoo Formations. The northeastern boundary of the foothills occurs approximately along a line drawn between Hinton and Robb.

The Interior Plains are underlain by the Tertiary Paskapoo Formation, which is therefore the most important geological unit in this study. Using the stratigraphy as outlined by Irish (1970) and Holter *et al.* (1975), the base of this formation occurs at the top of the Battle Formation and includes the basal Scollard Member, which contains the Ardley coal zone. The Paskapoo Formation is a non-marine succession of sandstones, bentonitic shales and coal, and is well fractured in outcrop. Regionally, the formation has a shallow dip to the southwest, but in the Edson map area the strata are slightly upwarped due to their proximity to the Rocky Mountains. The resulting structure, referred to as the Alberta Syncline, causes northeasterly to near-horizontal dips over most of the area. The structure of the base of the Paskapoo Formation (Kneehills Tuff) is shown on the geological side map and indicates that the approximate thickness of the formation varies from 600 to 1100 m in the map area. In the plains and benchland portions of the map area, the depth to the Ardley coal zone (see geological side map) makes it uneconomical to mine with conventional methods. In the foothills, however, coal occurrences near Coal Valley, which are generally accepted to be Ardley seams, are currently being mined.

SURFICIAL GEOLOGY

The surficial geology of the plains portion of the Edson map area was described by Roed (1968, 1975), and that of the mountains-foothill portion by Bayrock and Reimchen (1975). Currie (1976) described the surficial geology of the Tri-creek Basin. The principal surficial deposits of the area, listed from oldest to youngest are preglacial gravels, till, glaciofluvial sediments, glaciolacustrine and outwash sediments, and recent deposits.

Preglacial sediments consist of Tertiary-Quaternary gravels, deposited by easterly flowing drainages. Roed (1975) described three preglacial gravel units, Tableland, Lowland and Buried Valley, which occur on the upland plateaus, in the Edson lowlands, and in buried preglacial drainages respectively. Tableland gravel can be up to 12 m thick; Lowland gravel up to 1.5 m thick.

Till is the most widespread glacial deposit and generally consists of boulders and pebbles in a silty clay matrix of varying carbonate content. Tills are of special interest because they represent deposits of both Cordilleran and Laurentide glaciers. While ground moraine is the common type of till deposit, hummocky, lobate end and lateral moraines are present locally. Glaciofluvial sediments, generally sand and gravel, occur as glacial outwash, meltwater channel deposits, eskers and kames. Outwash deposits occur primarily along the valleys of the Athabasca, Wildhay and Berland Rivers, along Jarvis and Pinto Creeks, and northwest of Wolf Lake. Esker and kame deposits occur sporadically on either side of the Athabasca River and near Maskuta Creek. Meltwater channel deposits occur along the Athabasca and Pembina Rivers and Dismal Creek.

Glaciolacustrine deposits occur mainly in the eastern half of the map area, and are composed of typical lake or deltaic sediments such as laminated or cross-bedded fine sand, clay and silt. Average thickness of these sediments is 6 m.

Recent deposits include aeolian, alluvial, colluvial and organic types. Active aeolian deposits, generally consisting of fine sand, are present east of Brule Lake, and inactive deposits occur south of the McLeod River between Marlboro and Rosevear.

Alluvial deposits occur in major present day river valleys and small streams as bars, low terraces and flood plains. These sediments are mainly a varying mixture of sand and gravel, and are usually in hydraulic connection with surface waters. Colluvium occurs mainly in the mountains and foothills as wedge shaped deposits of talus and cliff debris caused by mass wasting along valley sides. Although colluvium has a high permeability, it is generally well drained and unsaturated. Organic deposits of peat occur mainly in muskegs and are widespread in the western half of the map area. Local areas of patterned ground exist in these deposits.

HYDROGEOLOGY

GENERAL AND MAP CONSTRUCTION DETAILS

Previous hydrogeological work in the map area has concentrated on groundwater exploration and development of the Edson buried valley aquifer and on basin studies. A 1975 hydrogeologic survey was mainly concentrated in the plains and foothills portions of the area, and consisted of surveying and sampling wells and springs. Hydrogeological data for the map area are fairly numerous but poorly distributed. Of the approximately 1000 wells present in the area, which are mainly concentrated along Highway 16, about 850 have water level data, 510 (120 in drift and 390 in bedrock) have been sampled, and 200 have some information concerning yield of groundwater. Approximately 250 springs were observed during airborne traverses in 1975, and about 150 of these were sampled.

Distribution of the hydrogeological data is awkward, and substantial interpretation was used in the construction of the hydrogeological map and cross sections. The abundance of springs surveyed in 1975 helped in this regard, especially in delineating yield and chemical zonation. Several important assumptions were made regarding the hydrogeology, and the reader should be familiar with these in order to better understand map construction. The main bedrock aquifer in the area is the Paskapoo Formation. This formation is nearly always fractured in outcrop and, if well fractured at depth, forms a very productive aquifer. Nonfractured Paskapoo forms only a moderate aquifer, and its bentonitic and shale facies is a poor aquifer. Obviously, some assumptions were required to indicate the depth and extent of fracturing in an area of fractured Paskapoo Formation. It has been assumed that in areas where wells yield more than 1 litre per second (L/s), the Paskapoo Formation supplies groundwater mainly through fractures. The degree and amount of fracturing determines well yields above this value. In general, the Paskapoo Formation is an aquifer because it is fractured and the intergranular hydraulic conductivity is low. Drill stem test data generally supports this interpretation. On cross section B-B', for example, drill stem test (dark yellow yield zone) indicates that Paskapoo sandstone at a depth of 280 m has a hydraulic conductivity of 7 x 10^{-3} m/day. Such values probably indicate intergranular hydraulic conductivity, and are important in constructing yield zones at depth. High yielding areas of the Paskapoo Formation have not been horizontally extended much beyond data location. Fracturing encountered in a well is assumed to extend to 100 m at which point the rock is classified as a moderate to poor (0.1 to 0.4 L/s) aquifer for 60 m, and ultimately as a poor aquifer (< 0.1 L/s) at about 160 m below ground surface. Where fracturing is not present, the particular yield category was continued to 160 m below surface and then changed to the poor aquifer category. In the mountain and foothills portions of the map area, where all bedrock aquifers exist because of fracturing, there is proof that high yielding zones extend to depths of at least 160 m and they have, therefore, been extended to this depth converting to lower yield categories.

Substantial interpretation was also involved in the delineation of drift aquifers. Based on the work in the Edson valley aquifer and the occurrence of thalwegs in the map area (Roed, 1968), the approximate location of possible buried valley deposits is known. These were assumed, rather optimistically, to be aquifers with good possible yields. Likewise, all glacial outwash and recent alluvium have been assumed to be high yielding. As many of these deposits may be limited in extent, placing them in a high yield category indicates their highly transmissive nature rather than an accurate estimate of twenty-year safe yield. The uncertainty of the above assumptions, both for bedrock and drift aquifers, is indicated by placing them in a possible rather than probable yield category.

BEDROCK

Hydrogeology of the bedrock is discussed considering the three physiographic divisions of the area.

Interior Plains

In the plains portion of the map area, and indeed in the total map area, the Paskapoo Formation is the most important bedrock source of groundwater. On visual inspection the intergranular hydraulic conductivity of this formation appears low and fortunately it is fractured both in outcrop and at depth over most of the area. Depending on the amount and frequency of fracturing, the Paskapoo can be classified as a series of near surface, moderate to high yielding aquifers. The orientation of bedrock fracturing in the area (Babcock, 1974) is generally perpendicular and parallel to the Rocky Mountains. Numerous high yielding aquifer zones in the Paskapoo appear to parallel the Rocky Mountains and are probably well-fractured sandstone units.

Local evidence suggests that high yielding aquifer zones occur in proximity to the drift-bedrock contact and glacial fluvial features such as meltwater channels. These zones are caused by weathering and flushing of fractures in an existing fractured aquifer. This is especially true of the bedrock immediately below the buried Edson valley aquifer and along the Sundance Creek meltwater channel. Outlining these higher yielding areas was aided by the numerous springs present in the area that have variations corresponding to the variation of well yields. Thus, the flow rate of springs generally agrees with twenty-year safe yields in the surrounding bedrock. Background twenty-year safe yield values of moderately fractured Paskapoo strata are thought to be in the range of 0.4 to 2 L/s, and this is easily seen on the main map. Locally, and superimposed on this yield range, are more fractured and perhaps weathered zones, which form aquifers with twenty-year safe yields in the range of 2 to 38 L/s. Such zones are common near Edson and trending northwest-southeast through the Bickerdike-Marlboro and Obed areas. At the latter they coincide locations with well-fractured Paskapoo outcrops along Highway 16 near Medicine Lodge. Conversely, spot localities of unfractured Paskapoo with twenty-year safe yields of 0.1 to 0.4 L/s occur, probably more frequently than has been shown between these linear high yield zones. Dalal (1977), in discussing the hydrogeology of shallow Paskapoo Formation in the area, compiled maps of various parameters pertaining to these aquifers.

The depth to the top of the first producing aquifer in the Paskapoo Formation (figure 2) ranges between 20 and 30 m. Yields in this depth range are generally greater than 1 L/s. Transmissivity for Paskapoo aquifers generally ranges from less than 1.5 m^2/day to over 100 m^2/day, but can be as high as 1000 m^2/day. Storativity values range from 5×10^{-5} to 10^{-4}, indicating that locally most aquifers are confined to varying degrees.

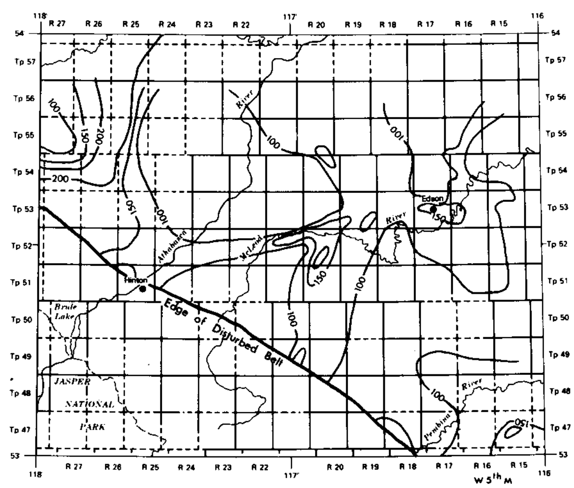


FIGURE 2. Average aquifer depth (metres below ground surface)

Drawdown response of many aquifers in the Paskapoo Formation conforms to the Theis non-equilibrium type curve during aquifer testing. Dalal (1977) described four basic types of time-drawdown response for these aquifers and attempted to group aquifers by required time for time-drawdown data to conform to this curve. More recent analysis of aquifer test results in fractured Paskapoo Formation indicates that time-drawdown data also conform very closely to the fissure flow and pure flow type curves of Streltsova (1976).

Groundwater flow within the Paskapoo Formation is thought to consist of a series of local and intermediate flow systems. These are short, characterized by rapid groundwater movement, and are superimposed on a larger groundwater flow system, which is in a regional recharge configuration to the northeast and east. Local areas of groundwater discharge are evident as springs, soapholes, muskeg and hummocky terrain. Local flow systems in the sub-horizontal sandstones and shales probably occur with the well-fractured sandstone units acting as "collectors" for the downward moving groundwaters of overlying units. Groundwater movement through these permeable sandstones is rapid and emerges on hillsides and slopes as contact springs and in lower areas as soapholes, hummocky terrain, or muskeg. Groundwaters that escape these sandstone "collectors" and continue downward form intermediate flow systems which discharge at regional topographic lows such as the Athabasca River or Edson Lowlands. Lastly, groundwaters, which contribute to regional flow systems, are thought to discharge in the area northeast and east of the map area. Non-pumping potentiometric contours are shown on the main map and generally are representative of the first aquifer encountered in the Paskapoo Formation. Groundwater movement closely follows topography and is towards the Edson Lowland and then to the east.

Most of the project's groundwater exploration was in Paskapoo aquifers and consisted of four drilling and aquifer testing localities as well as approximately 35 aquifer tests in existing wells. The two most impressive sites were drilled during Dalal's (1977) project and were located at 10-34-54-20 W5 and 6-29-53-15 W5. Both locations had pumping and observation wells completed in well-fractured sandstone aquifers which had approximate twenty-year safeyields of 18.5 to <33 L/s respectively.

Rocky Mountain Foothills

Hydrogeological data are generally scarce and much interpretation was necessary. Representative sections through the foothills are shown in the west and south portions of cross sections D-D′ and C-C′ respectively. Any bedrock aquifers present in the foothills exist because of fracturing; intergranular hydraulic conductivity of these sediments is thought to be insignificant. Because of fracturing, yields are highly variable (even within the same rock units) and hydraulic conductivities are extremely anisotropic. The depth of significant fracturing is not known, but extensive drilling and testing near Luscar suggest that 160 m below surface may be a reasonable depth and this has been used on the hydrogeological cross sections. There is also evidence to suggest that wells completed in synclinal structures have higher yields than those in anticlinal structures and this is shown schematically on appropriate hydrogeological cross sections.

In the foothills, the Paskapoo Formation occurs as a folded outlier between Entrance and Coal Valley. Well-fractured sandstones and shales of this formation have been assigned a twenty-year safe yield of 0.4 to 2 L/s and generally have transmissivities in the range 1.5 to 15 m²/day.

The shales of the Alberta Group are probably the least fractured rocks in the foothills, and consequently are the poorest aquifers with twenty-year safe yields of less than 0.4 L/s. Currie (1976) calculated this value for the Alberta Group in the Tri-creek Basin and indicated transmissivities of 1 to 3.5 m²/day.

The fractured shales and sandstones of the Brazeau Formation, the most common rock unit in the foothills, have been assigned twenty-year safe yield categories of either 0.1 to 0.4 L/s. Currie (1976) and various consultants found similar yield values for the Brazeau Formation but it is thought that the lower yield category is the more representative. Transmissivity of the Brazeau Formation generally ranges between 0.8 and 3.7 m²/day.

The fractured sandstones of the Luscar Formation, within the Blairmore Group, are probably the best aquifers in the foothills. As near surface coal deposits are associated with these sandstones, mining operations in this formation generally require dewatering schemes to control groundwater inflow. That portion of this formation between Luscar and Folding Mountain has been assigned a twenty-year safe yield of 2 to 8 L/s while other portions of the Blairmore Group are within the 0.4 to 2 L/s yield category. Transmissivities of aquifers within the Luscar Formation, near Luscar, range from 1.5 to 150 m²/day.

Groundwater movement in the foothills portion of the area occurs along fractures and bedding plains and, as such, probably limits the majority of groundwater flow to 160 m below ground surface. The magnitude and frequency of fracturing probably determines whether groundwater movement in these rocks conforms to theoretical descriptions. Because of the limited depth of fracturing, flow systems are short and shallow and groundwater movement is relatively rapid. Currie (1976) described the groundwater movement in Tri-creek Basin as being along fractures and bedding plains and felt that the zone of most active groundwater flow was less than 90 m below surface. Most groundwater is discharged into local topographic lows and large amounts of regional recharge to the plains is not envisaged.

Rocky Mountains (Front Ranges)

The hydrogeology of this portion of the map area is the least understood and suitable data are not readily available. In addition, the Front Ranges form such a small proportion of the area that they are the least important portion of this study and hydrogeological cross sections were not extended into them. Barnes (1977) described the hydrogeology of the Rocky Mountains to the west and south of the area. Bernard (1977) assigned yield categories to some bedrock units in the extreme southwest of the present map area.

The Front Ranges comprise highly faulted and folded rocks of Paleozoic and Mesozoic age. Aquifers exist due to fracturing associated with the highly complex geologic structure. The structural repetition of the Blairmore Group ensures that at least one moderately yielding rock unit is present and it has been assigned to a twenty-year safe yield category of either 0.1 to 0.4 or 0.4 to 2 L/s. Upper Paleozoic rocks have been assigned to yield categories depending on their topographic positions and access rather than strictly on their hydraulic characteristics. Many aquifers may be inaccessible because of extreme relief and large unsaturated zones may exist. Generally these rocks have been assigned to either the 0.1 to 0.4 or less than 0.1 L/s categories. Exceptions to these yields, although not observed except at Miette Hot Springs, are found in karst areas and in topographically low areas that intersect large thrust faults. The flow rates of the three springs that comprise Miette Hot Springs range from 2 to 7 L/s. Barnes (1977) mentioned both of these features, in relation to springs, for the Brazeau-Canoe River area. Although it is generally thought that flow systems in the Front Ranges are local in scale, these thrust zones, generally forming valleys, serve as regional conduit collectors for deeper, more mineralized (and sometimes hot) groundwaters. Thus, although most active groundwater flow takes place above and immediately below topographic lows in the Front Ranges, evidence of deeper flow systems parallel to geological strike exist. van Everdingen (1972), using temperatures of the groundwater at Miette Hot Springs (Tp 48, R 26), calculated a minimum depth of circulation of about 1500 m.

SURFICIAL DEPOSITS

Near surface preglacial Tableland and Lowland gravels have limited groundwater potential due to a small saturated thickness caused by high topographic position and limited areal extent. Potential yield of these gravel caps has not been considered in the delineation of yield zones. However, if these gravels occur at depth in thalwegs, they are extremely productive aquifers. The buried Edson valley aquifer occurs in such a position (central portion of Tp 53, R 17) and is the source of water for the town of Edson. The aquifer consists of sand and gravel, 30 to 40 m below ground surface, whose known occurrence is in a 20 km portion of northeast to southwest trending thalweg 1 km south of Edson. Maximum thickness of the aquifer is 6 m and numerous aquifer tests indicate transmissivity between 150 to 1200 m², storativity from 10^{-3} to 10^{-2}, leaky confined conditions, and a twenty-year safe yield category of 8 to 38 L/s. Also, because the McLeod River has locally downcut into the aquifer, surface water can be induced to recharge the aquifer (Gabert and Roed, 1968; Nielsen, 1969) under pumping conditions. Wells completed in the Paskapoo bedrock under this aquifer indicate a downward hydraulic gradient. Bedrock under and near this valley is extremely fractured and contains very productive aquifers.

Using the thalweg locations of Roed (1968) and Gabert and Roed (1968), potential buried valley aquifers were delineated, and have been placed in the yield ranges of 2 to 8 L/s or 0.4 to 2 L/s. In some areas, notably the valleys of the Athabasca and Wildhay Rivers, thalwegs are also shown but the occurrence of preglacial deposits is less certain because of possible reworking by glaciofluvial and alluvial processes. Groundwater flow systems developed within buried valley aquifers are relatively local in extent because of the probability of hydraulic connection with present-day rivers. Groundwater movement in the known buried valley aquifers near Edson is to the northeast and parallel to the McLeod River valley.

Glaciofluvial and alluvial deposits are also promising surficial aquifers. Glaciofluvial sand and gravel deposits occur mainly in the valleys of the Wildhay and Athabasca Rivers and in the southeast corner of the map area. These aquifers have been assigned to the 2 to 8 or 8 to 38 L/s yield category depending on the existence of good well information. Currie (1976) assigned glaciofluvial deposits in the Tri-creek Basin to the 0.4 to 8 L/s yield range. Terrace outwash gravels along the Athabasca River are considered moderate aquifers because of topography and are thus placed in the 0.4 to 2 L/s category. Recent alluvial deposits are good aquifers if they are in hydraulic connection with surface water. Generally, alluvium in the major river valleys was placed in the 2 to 8 L/s yield category because of lack of well data. Where wells exist, for example southwest of Brule Lake, the more realistic yield category of 8 to 38 L/s has been used. Bernard (1977) indicated that the alluvial sands and gravels of the Athabasca River valley could be expected to yield 10 L/s. Groundwater movement in glaciofluvial and alluvial aquifers is determined by the topography in and near the major river valleys.

Any vertical combination of recent alluvium, glaciofluvial deposits, and buried valley deposits is considered a very prospective situation for groundwater development. Any location at which a vertical combination (overlying or underlying) of these deposits exists was placed in the 8 to 38 L/s yield category. Notable areas in this category are south and east of Brule Lake, the Wildhay River, Jarvis Creek valleys, the Athabasca River valley, at the intersection of the Berland and Wildhay Rivers, near the junction of the McLeod and Embarras Rivers, and finally where the buried Edson valley aquifer underlies the McLeod River.

Other surficial deposits namely glacial till, glaciolacustrine deposits, aeolian deposits, colluvial deposits and organic accumulations, were not generally considered to constitute potential aquifers. Accordingly these were placed in lower yield categories (generally 0.1 to 0.4 L/s) and should not be considered for the development of long-term groundwater supplies. Possible exceptions are aeolian deposits near Brule Lake and colluvial deposits in the Front Ranges but even in these cases the limited areal extent of these deposits is unfavorable.

Many flowing seismic shotholes are found in the map area. These shotholes most probably occur because of the confining nature of glacial till overlying bedrock in a groundwater discharge configuration and distinct local sand and gravel layers that occur within the glacial till. If in either of these conditions, the shothole penetrates to an appropriate depth, artesian flow results and is probably short-lived due to hole caving. Artesian flows are generally less than 0.8 L/s and should not be considered, in most cases, an indication of large groundwater yields.

SPRINGS

One interesting feature of the hydrogeology of the Edson area is its large number of groundwater discharge features, generally in the form of springs. During the 1975 field season, approximately 250 springs were observed and 150 were sampled. The locations, estimated flow rates and hydrochemistry of selected springs are shown on the hydrogeological map and cross sections. To determine the location of all springs, the reader must cross reference the data density and hydrochemical side maps, and the main map and cross sections. Photos of various springs are shown at the back of the report and the trilinear plot of spring hydrochemistry is shown in figure 8.

In general, the springs of the area can be classified into four groups, which, in order of decreasing occurrence are: boulder-tufa, boulder, soaphole-ungulate lick, and sulfur. The classification is largely based on descriptive features that can be readily observed in the field.

Boulder-Tufa Springs (Photos 1, 2, 3 and 4)

Barnes (1977) described the occurrence of these springs in the Mount Robson-Wapiti area. In the Edson area, they are easily the most abundant type of groundwater discharge feature and occur throughout the Interior Plains and Foothills. Their name derives from the fact that their drainage path is generally composed of large rounded boulders encrusted with cream to buff tufa deposits. Easily seen from the air because of the light-colored tufa, these springs are most abundant in the central foothills and usually occur at abrupt steepenings of slope often associated with the edge of the Tertiary plateau. Travelling through the upper, weathered portion of the bedrock (usually Paskapoo Formation), these groundwaters are rich in calcium bicarbonate (figure 9), which precipitates when the groundwater cascades from the discharge point. Erosion of the outlet often causes numerous abandoned discharge channels to form. Lakes are often supported by numerous springs. Radio carbon age dating of the tufa sample from a spring northwest of Edson indicated an age of 9560 $\pm$190 years B.P.

Boulder-tufa springs are considered representative of the discharge of calcium bicarbonate groundwater from short, local flow systems developed in the uppermost fractured Tertiary bedrock. Flow rates vary from 0.4 to 8 L/s and temperature from 3 to 10°C. Butterwort *(Pinguicula Vulgaris L.)* is a very common plant in the calcareous soils near these springs.

Boulder Springs
(Photo 5)

These springs are generally similar to the rock debris type as described by Currie (1976) in the Tri-creek Basin. Boulder springs are most common in the foothills and generally occur in areas where topographic gradients decrease, such as the bottoms and sides of major valleys. Because groundwater discharge does not cascade and is therefore not violently aerated, the boulder-strewn discharge paths of these springs are not tufaceous but are characterized by a continuous pavement of large, rounded, lichen-covered boulders and bleached wood fragments. The source of the boulders is generally glacial outwash or alluvial deposits. The most prominent boulder springs occur in the Jarvis Creek valley (Tp 52, R 26) and in Gregg Lake as both surface and submarine features along the east and west shorelines.

The hydrochemistry of boulder springs is similar to that of boulder-tufa springs since both discharge mainly calcium bicarbonate water (figure 9). Boulder springs have flow rates between 0.4 and 12 L/s, groundwater temperatures between 2 and 8°C, and are thought to be representative of shallow bedrock flow.

Soaphole-Ungulate Licks
(Photos 6, 7 and 8)

Currie (1976) and Barnes (1977) discussed these discharge features. Soaphole springs, which are developed throughout the area, usually occur in areas of flat topography underlain by silts and clays of glacial origin. Soaphole springs form a mounded area of quick ground supported by upward moving groundwater and are usually surrounded by reeds and tussock grass. Very large soaphole springs can form features properly described as discharge meadows. Due to a large number of animal tracks present, it is thought that ungulates show a definite preference to drink at these discharges, presumably because of the high sodium content of the groundwater. Often there is an association of hummocky ground (Currie, 1976), discharge meadow and soaphole development.

The discharge rate from soaphole springs is smaller than other types and generally ranges up to 1 L/s. Groundwater temperature ranges from 5 to 10°C. Soaphole springs generally represent the discharge of sodium-rich bedrock groundwater (generally more than 50% epm), which has higher than background values of sulfate.

Large slides and semi-circular slumps (Photo 8) in the northwest corner of the area generally represent the discharge of bedrock groundwater on steep slopes through a covering of glacial silts and clays. Many of these slide areas appear to be ungulate licks, have low flow rates (0.1 to 0.4 L/s) and have quick ground at the base.

Sulfur Springs

The term sulfur springs is used to denote places at which groundwater with a relatively high sulfate (15 to 30% epm of anions) content is discharged. The character of these springs changes drastically between the Interior Plains and the Front Ranges and in most cases it is thought that they represent the discharge of relatively deep bedrock groundwater. Often the increased sulfate content accompanied by an increase in sodium content with the result that sulfur springs may also be ungulate licks.

In the Interior Plain and foothills, sulfur springs occur in similar topographic positions to boulder springs. They are generally of low flow rate (0.4 to 0.8 L/s) and their most distinguishing features are a fetid odor and white sulfur precipitate.

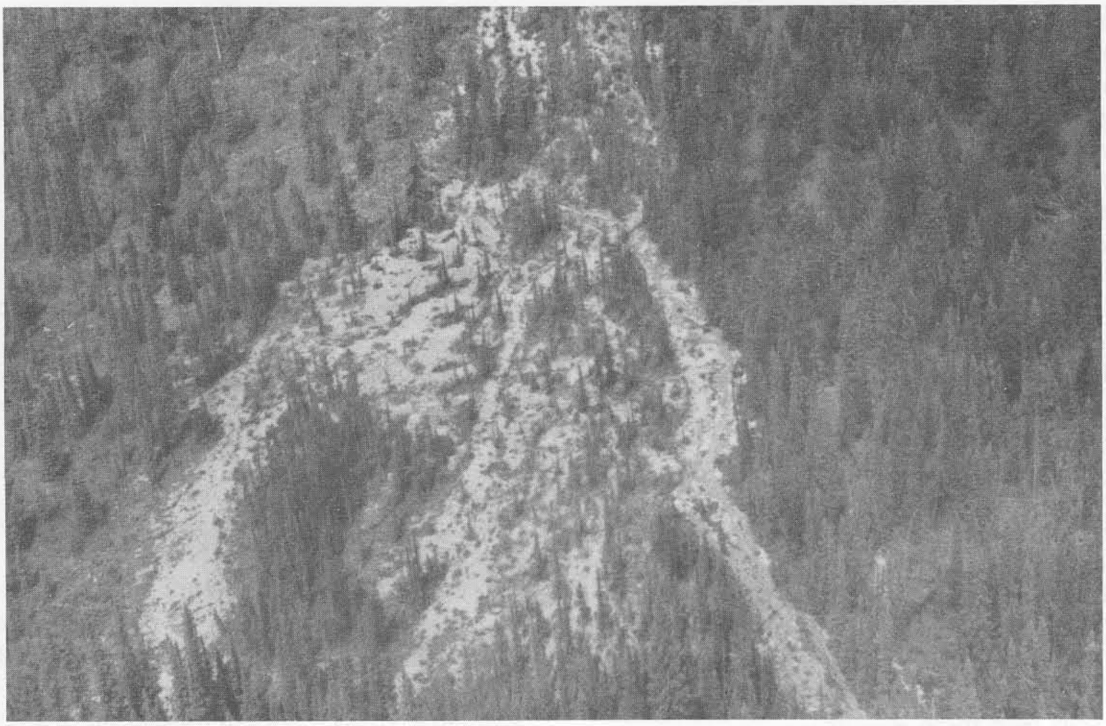


PHOTO 1. Boulder-tufa spring from the air. (Township 51, Range 23)

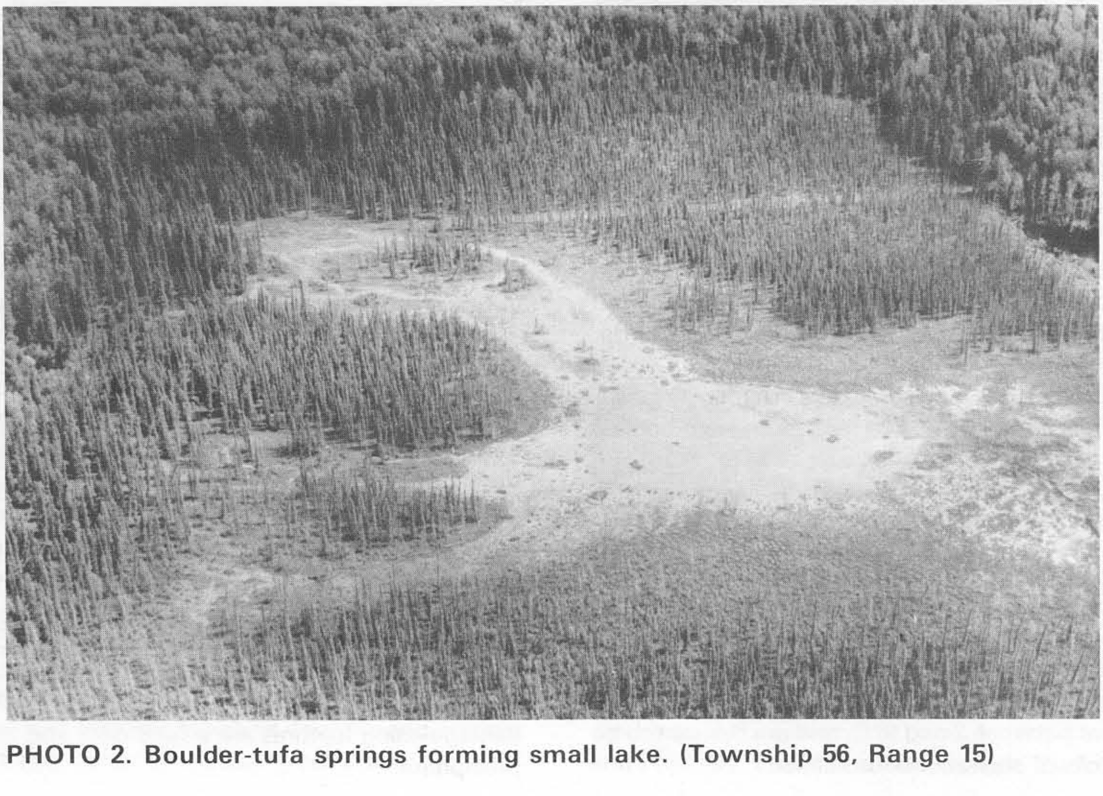


PHOTO 2. Boulder-tufa springs forming small lake. (Township 56, Range 15)

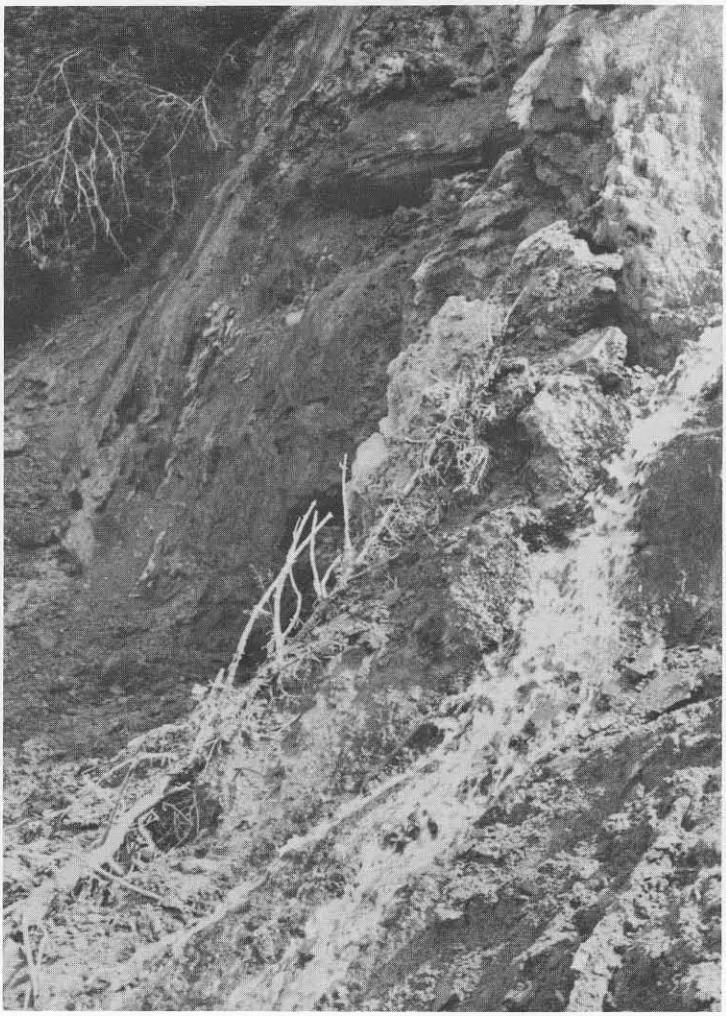


PHOTO 3. Springs depositing tufa. McLeod River Valley.
(Township 52, Range 17)

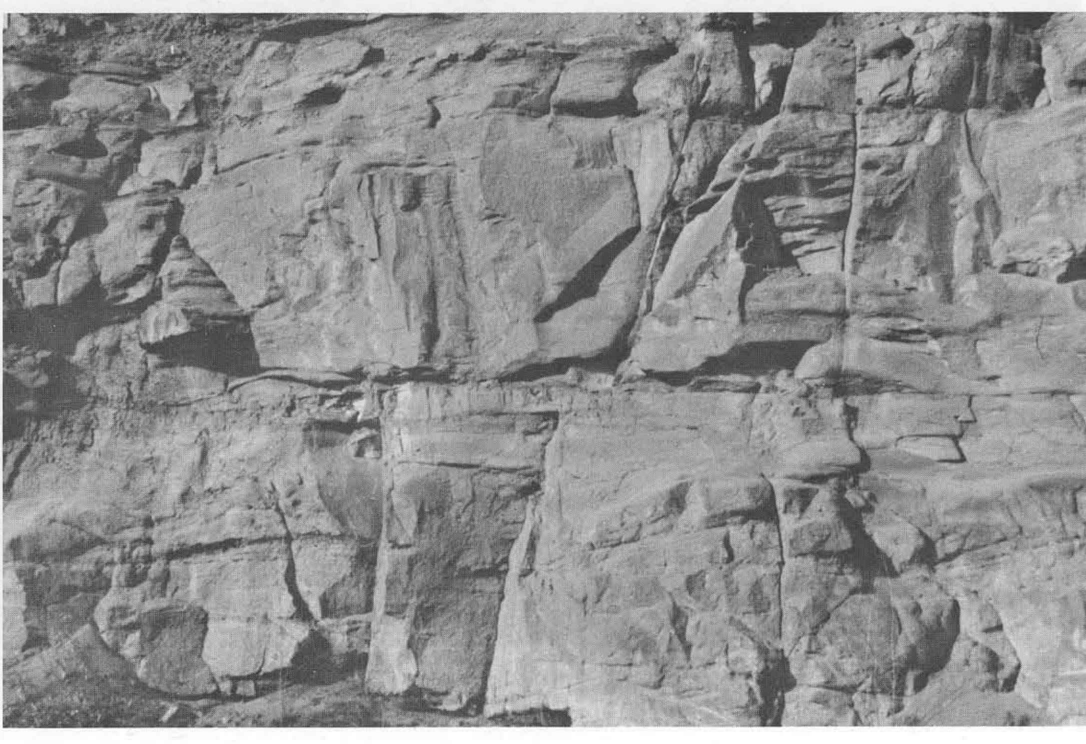


PHOTO 4. Outcrop of fractured Paskapoo sandstone on Highway 16.
(Township 52, Range 21)

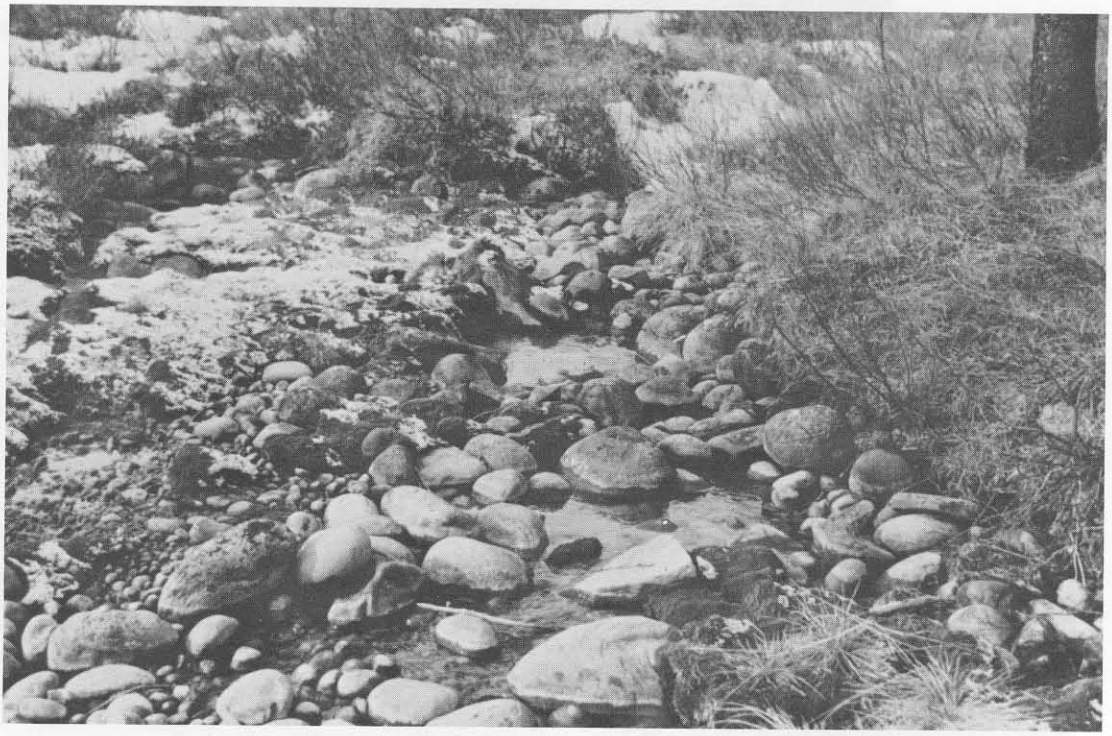


PHOTO 5. Boulder spring on west shore of Jarvis Lake. (Township 52, Range 26)

PHOTO 6. Mounded soaphole spring near Oldman River. (Township 55, Range 23)

PHOTO 7. Numerous soaphole springs forming large discharge meadow. (Township 49, Range 17)

PHOTO 8. Large slide in glaciolacustrine silts and clays caused by groundwater discharge near Wildhay River. (Township 55, Range 25)

In the Front Ranges, sulfur springs are generally much larger and can be indicative of the draining of conduit-type thrust faults. Barnes (1976) described the occurrence of ten sulfur springs, along the Colin Thrust, including the well-known sulfur springs on Highway 16, northeast of Jasper. van Everdingen (1972) describes these latter springs and gives a detailed description of the well-known

Miette Hot Springs 11 km southeast of Pocahontas. Miette Hot Springs, the only natural hot springs in the Edson map area, have an average temperature of 50°C, average total dissolved solids content of 1900 mg/L and discharge a calcium magnesium sulfate bicarbonate water. These springs are also a result of structural control and represent the lowest exposure of a plunging anticline in the Rundle Group. The temperature and chemical composition of these hot springs indicate a great depth of circulation.

Groundwater from an abandoned, burning underground coal mine near Luscar was reported in 1968 to have a temperature of 40.5°C and a very low sulfate content. This spring was not evident during the field season, but a cold spring very near the given location (W5 15-47-24) has sulfate content of 14 percent (epm).

HYDROCHEMISTRY

Hydrochemistry of the groundwaters of the Edson area is shown on the hydrochemical side maps, the cross sections, the data density side map and the three trilinear diagrams (combined fields only) of hydrochemistry of springs (figure 9), drift (figure 6), and bedrock (figure 3).

In addition, plots of hardness and total dissolved solids versus depth below surface were prepared for both bedrock (figures 4 and 5) and drift (figures 7 and 8). These plots may aid prospective groundwater users to forecast the type of groundwater at a particular depth or location.

BEDROCK

Bedrock groundwater generally has a greater variation in chemical constituents than that of springs or surficial deposits. As with other groundwater types, however, carbonate-bicarbonate comprises over 60 percent of anions in 90 percent of all bedrock groundwater. Because the cations are more variable, there are three basic types of bedrock groundwater:

1. A Ca, Mg-HCO_3, CO_3 type occurs throughout the area and represents groundwater in shallow fractured bedrock. Thirty percent of the bedrock groundwaters are of this type. Hardness generally ranges from 200 to 400 mg/L (figure 4) and total dissolved solids content from 200 to 700 mg/L (figure 5).
2. An Na, K - HCO_3, CO_3 type is most representative of moderate to deep bedrock in the area and approximately 60 percent of the bedrock groundwater samples are of this type. The hydrochemical side map indicates that this water type occurs mainly in groundwater discharge areas and in the major river valleys. Because of higher sodium content, hardness is generally less than 100 mg/L while total dissolved solids contents of up to 1000 mg/L reflect the deeper, more mineralized nature of these groundwaters. It is interesting to note that the 500 mg/L content of total dissolved solids generally coincides with a change in dominant cations.
3. Approximately 10 percent of the bedrock groundwater can be classified as a mixed type, dominated by sulfate anions and either Ca, Mg or Na, K cations.

   The $NaSO_4$ groundwater is generally more prevalent in the Front Ranges and may be of very deep origin. In the Interior Plains and foothills, the cations are more mixed and these groundwaters are often found in discharge areas. Numerous high sulfate groundwaters exist in and near the Edson valley aquifer.

   These mixed types have a large range in hardness (25 to 300 mg/L) and total dissolved solids (300 to 2700 mg/L). $NaSO_4$ groundwater between Shiningbank Lake (Tp 56, R 14) and Sang Lake (Tp 53, R 15) occur in a major groundwater discharge area and have the highest total dissolved solids content of any groundwaters in the map area.

SURFICIAL DEPOSITS

The hydrochemical side map and figures 6, 7 and 8 indicate the hydrochemistry of groundwater in the surficial deposits.

With only the occasional exception, groundwater in the surficial deposits is a calcium magnesium bicarbonate type with varying amounts (up to 40% epm) of sulfate. The hydrochemical side map indicates several areas, generally in deep surficial deposits in a groundwater discharge configuration, where sodium-rich bedrock

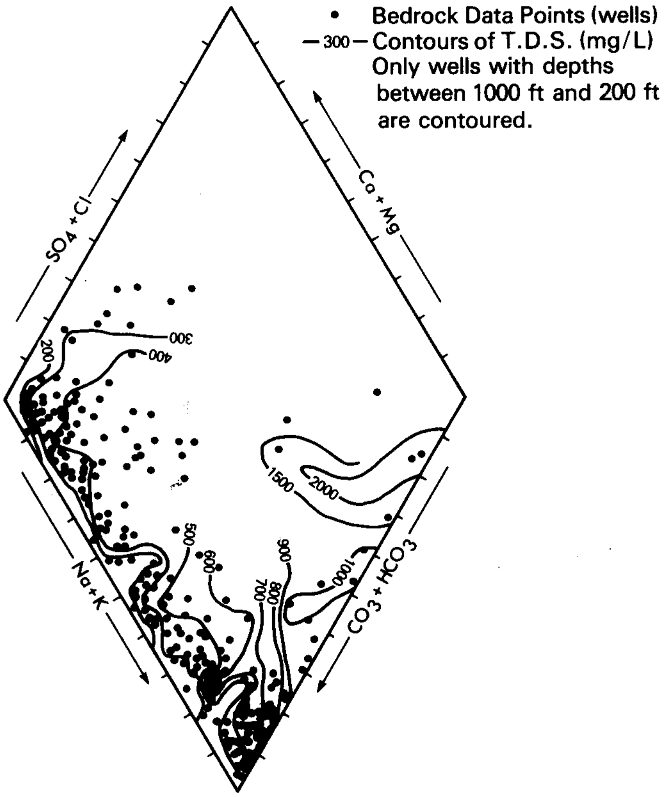


FIGURE 3. Bedrock hydrochemistry: combined field of trilinear diagram

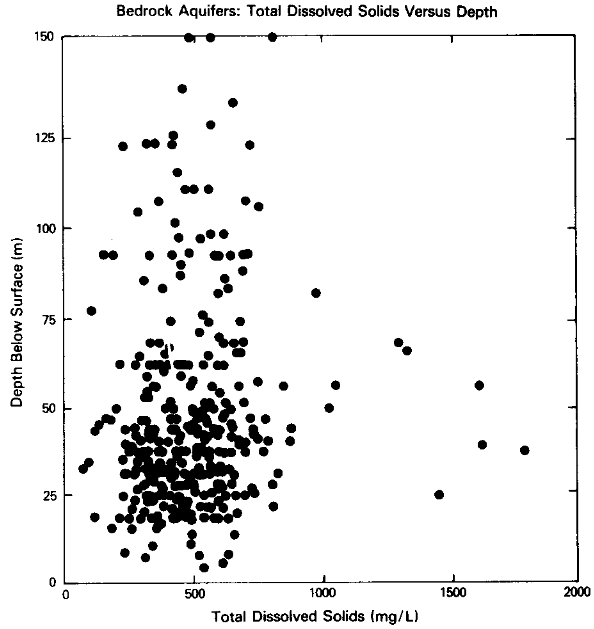


FIGURE 5. Bedrock hydrochemistry: total dissolved solids versus depth below surface

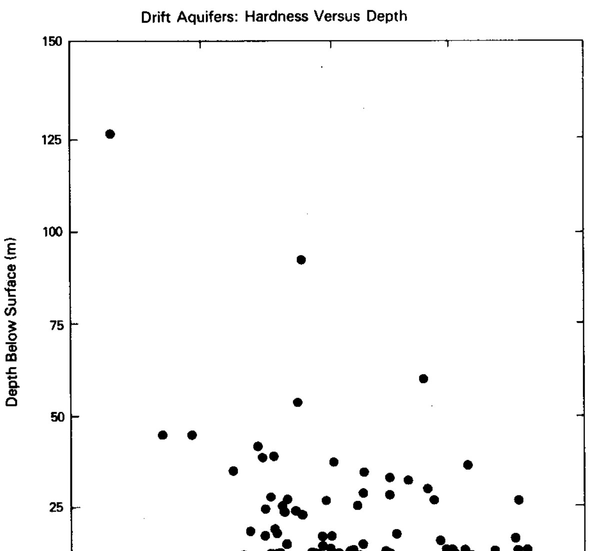


FIGURE 4. Bedrock hydrochemistry: hardness versus depth below surface

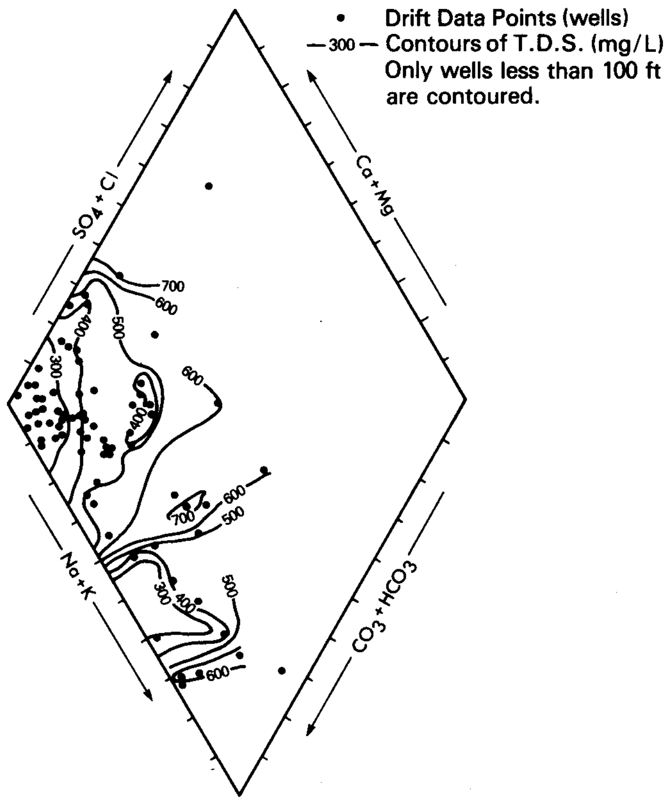


FIGURE 6. Drift hydrochemistry: combined field of trilinear diagram

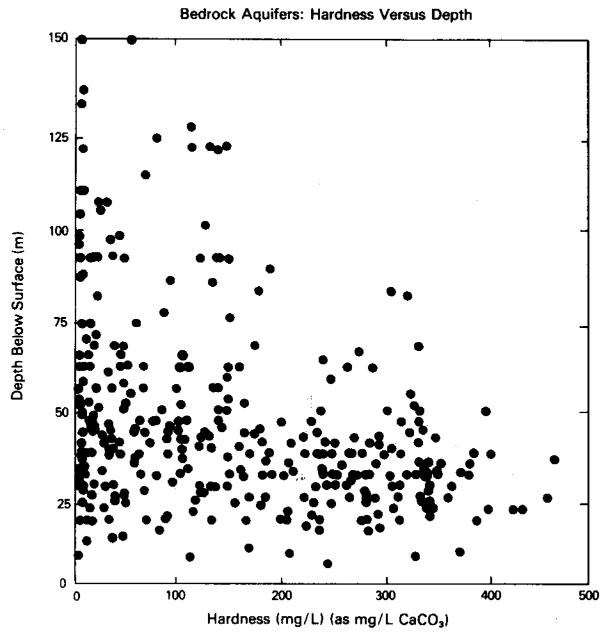


FIGURE 7. Drift hydrochemistry: hardness versus depth below surface

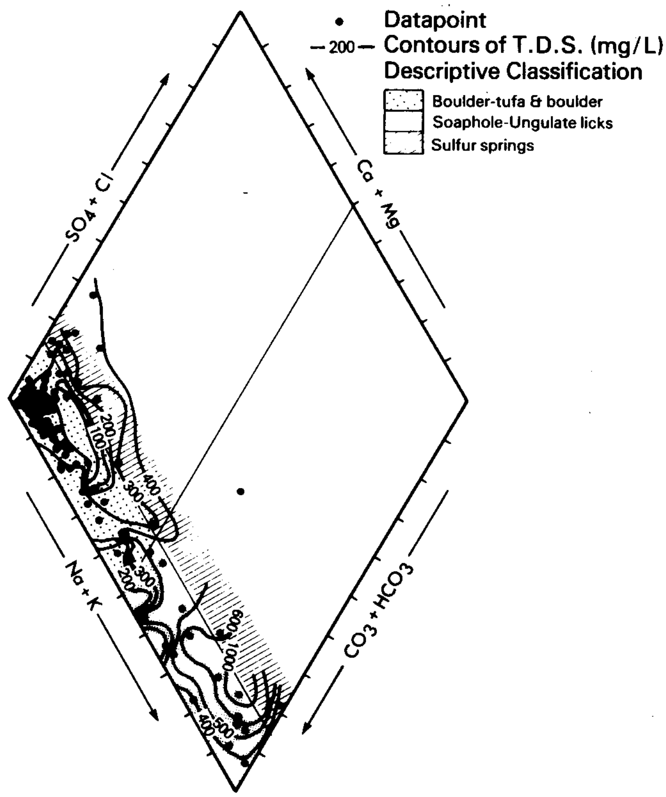


FIGURE 9. Spring hydrochemistry: combined field of trilinear diagram

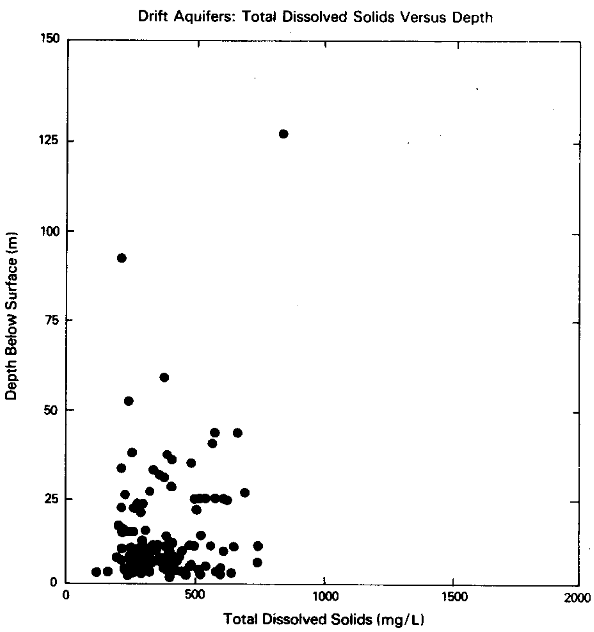


FIGURE 8. Drift hydrochemistry: total dissolved solids versus depth below surface

groundwaters have changed the hydrochemistry within these surficial deposits. The two most important such areas are the buried Edson valley aquifer and small, deep surficial aquifers in the Athabasca River valley northeast of Hinton. Figure 6 indicates that this sodium enrichment leads only to a slight increase in total dissolved solids content. Sulfate content is generally highest in shallow wells (less than 5 m) completed in till and glaciofluvial sediments. Sulfate content at this depth is probably related to the gypsum content of these sediments within the annual phreatic range.

Figures 6 and 8 indicate that the maximum total dissolved solids content for surficial groundwater is 700 mg/L, but that about 90 percent of the groundwater has a content less than 500 mg/L. The very shallow, sulfate-rich groundwater seems to have a much greater affect on the total dissolved solids content than does the cation exchange process.

SPRINGS

Approximately 75 percent of the springs in the area discharge calcium magnesium bicarbonate groundwater. According to the classification adopted for the hydrochemical side maps, all springs discharge groundwater with carbonate-bicarbonate content greater than 60 percent of total anions. Because of this, it can be assumed that most of the springs sampled represent bedrock groundwater, the percentage of sodium and potassium of total cations being an indication of the depth of origin. Spring waters derived from deep bedrock have a higher concentration of sodium and total dissolved solids.

Figure 9 indicates the distribution of springs according to hydrochemistry in the Edson area. The anion content of these discharges is always carbonate-bicarbonate rich with varying minor amounts (up to about 20%) of sulfate. As a general rule, sulfate content increases in the Foothills and Front Ranges compared to the Interior Plains. Cation content varies widely and depends on the depth of origin of the discharging groundwater. High calcium plus magnesium content indicates short flow through shallow bedrock. High sodium plus potassium content indicates flow from deeper bedrock. Total dissolved solids content of springs in the area ranges from 100 to 1000 mg/L, but 90 percent of these groundwaters have concentrations below 500 mg/L. The total dissolved solids exceed 500 mg/L if sodium plus potassium exceeds 70 percent of total cations. An increase in sulfate content is generally accompanied by an increase in total dissolved solids.

CONCLUSIONS

Because the Edson map area spans three physiographic divisions, the hydrogeology is highly variable and extremely interesting. Groundwater is assumed to be an important component of future growth and development and the object of this report has been to describe the hydrogeology and groundwater resources in a practical manner so that the enclosed hydrogeological map can be useful in the future development of the area. The most obvious present and future use of groundwater is as a water source for individuals, municipalities, campgrounds, coal mining developments and petroleum exploration and development. In this regard, the groundwater resources of the area are basically untapped and represent a significant renewable resource.

Results of this project indicate that the pertinent conclusions are:

Regionally, groundwater is in a downward moving or recharging configuration. Short, rapidly moving, local and intermediate flow systems exist in the fractured rocks of the area and these factors ensure that groundwater is generally low in mineralization.

Permeability of bedrock in the area is primarily due to fracturing. The Paskapoo Formation contains the most widespread and important bedrock aquifers and the plains portion of the area is for this reason the most prospective for the development of shallow (20 to 60 m) bedrock groundwater in moderate quantities (1 to 40 L/s).

Because of a wide range of lithology, surficial deposits contain aquifers that are highly variable in terms of extent, aquifer parameters, groundwater availability and hydrochemistry. Glacial till and glaciolacustrine deposits are the most widespread but contain no aquifers. The most promising drift aquifers occur in valleys, either present-day or preglacial, and generally consist of buried sand and gravel deposits, glacial outwash, and recent alluvium. These probably represent the highest-yielding aquifers in the area.

Groundwater quality is generally good within the area except in shallow surficial deposits, which are not considered important aquifers. Some significant aquifers contain groundwater with high hardness.

In the plains portion of the area, groundwater supplies can be located in fractured bedrock or in surficial deposits that occur in preglacial or present-day valleys. In the foothills, bedrock, with the exception of the Luscar Formation, will not supply large quantities of groundwater and commercial users are advised to explore the recent alluvium of present-day rivers.

REFERENCES

Babcock, E.A. (1974): Jointing in central Alberta; Canadian Journal of Earth Sciences, Vol. 11, pp. 1181-1186.

Barnes, R.G. (1977): Hydrogeology of the Mount Robson-Wapiti area, Alberta; Alberta Research Council Report 76-5, 33 pages.

Barnes, R.G. (1978): Hydrogeology of the Brazeau-Canoe River area, Alberta; Alberta Research Council Report 77-5, 32 pages.

Bayrock, L.A. and T.H.F. Reimchen (1975): Surficial geology and erosion potential, foothills of Alberta north of 52° latitude; unpublished report, Bayrock and Reimchen Surficial Geology Ltd., Vancouver, 35 pages.

Bernard, D.W. (1977): Hydrogeology of highway corridors, Jasper National Park; Alberta Research Council, Open File Report 1977-8, 34 pages.

Carrigy, M.A. (1970): Proposed revision of the boundaries of the Paskapoo Formation in the Alberta plains; Bulletin of Canadian Petroleum Geology, Vol. 18, No. 2, pp. 156-165.

Carrigy, M.A. (1971): Lithostratigraphy of the Uppermost Cretaceous (Lance) and Paleocene strata of the Alberta plains; Alberta Research Council Bulletin 27, 153 pages.

Carrigy, M.A. and G.B. Mellon (1964): Authigenic clay mineral cements in Cretaceous and Tertiary sandstones of Alberta; Journal of Sedimentary Petrology, Vol. 34, No. 3, pp. 461-472.

Currie, D.V. (1976): Hydrogeology of the Tri-creek Basin, Alberta; Alberta Research Council Bulletin 33, 67 pages.

Dalal, G.P. (1977): Computation of aquifer parameters and potential safe pumping rates for shallow bedrock, Edson, NTS 83F, Alberta; Alberta Research Council Internal Report.

Dowling, D.B. (1910): Coal fields south of the Grand Trunk Pacific Railway, in the foothills of the Rocky Mountains, Alberta; Geological Survey of Canada, Summary report 1909, pp. 139-151.

Dowling, D.B. (1911): Coal fields of Jasper Park, Alberta; Geological Survey of Canada, Summary Report 1910, pp. 150-168.

Dumanski, J. and S. Pawluk (1971): Unique soils of the foothills region, Hinton, Alberta; Canadian Journal of Soil Science, Vol. 51, pp. 351-362.

Dumanski, J., T.M. Macyk, C.F. Veauvy, and J.D. Lindsay (1972): Soil survey and land evaluation of the Hinton-Edson area, Alberta; Alberta Institute of Pedology Report No. S-72-31, 119 pages.

Farvolden, R.N. (1959): Edson report; Alberta Research Council, Open File Report 1959-3, 9 pages.

Gabert, G.M. and M.A. Roed (1968): Bedrock topography and surficial aquifers, Edson area, Alberta; Alberta Research Council Report 68-1, 9 pages.

Green, R. (1972): Geological map of Alberta, Alberta Research Council, Map 35, Scale 1:1 267 000.

Holter, M.E., J.R. Yurko and M. Chu (1975): Geology and coal reserves of the Ardley Coal Zone of central Alberta; Alberta Research Council Report 75-7, 41 pages.

Irish, E.J.W. (1945): Geology, Pedley sheet; Geological Survey of Canada Map 838A, scale 1 inch = 1 mile.

Irish, E.J.W. (1947): Geology, Gregg Lake sheet; Geological Survey of Canada Map 899A, scale 1 inch = 1 mile.

Irish, E.J.W. (1965): Geology of the Rocky Mountain foothills, Alberta Geological Survey of Canada Memoir 334, 241 pages.

Irish, E.J.W. (1970): The Edmonton Group of south-central Alberta; Bulletin of Canadian Petroleum Geology, Vol. 18, No. 2, pp. 125-155.

Jackson, P.C. (1975): Geological highway map of Alberta; Canadian Society of Petroleum Geologists, Geological highway map series, scale 2 inches = 25 miles.

Lang, A.H. (1947): Brule and Entrance map-areas, Alberta; Geological Survey of Canada Memoir 244, 65 pages and Geological Survey of Canada Maps 843A and 905A, scale 1 inch = 1 mile.

Lang, A.H. and R.A.C. Brown (1943): Geology, Drinnan to Brule Lake; Geological Survey of Canada Preliminary Map 44-11A.

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

Lennox, D.H. (1966): The preglacial Edson Alberta buried valley aquifer; Alberta Research Council Open File Report 1966-2, 5 pages.

Lindsay, J.D., A. Wynnyk and W. Odynsky (1963): Exploratory soil survey of Alberta map sheets 83L, 83K, 83F and 83J; Alberta Research Council Preliminary Soil Survey Report 64-2, 53 pages.

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

MacKay, B.R. (1929a): Brule mines coal area, Alberta; Geological Survey of Canada Summary Report 1928-B, 29 pages.

MacKay, B.R. (1929b): Geology, Cadomin sheet, Alberta; Geological Survey of Canada Map No. 209A, scale 1 inch = 1 mile.

MacKay, B.R. (1930): Stratigraphy and structure of bituminous coal fields in the vicinity of Jasper Park, Alberta, Canadian Institute of Mining and Metallurgy Bulletin, No. 222, pp. 1306-42.

MacKay, B.R. (1943): Geology, foothills belt of central Alberta; Geological Survey of Canada preliminary Map 43-3, scale 1 inch = 2 miles.

MacVicar, J. (1916): Coal areas in the Foothills between Athabasca and Smoky Rivers, Alberta; Geological Survey of Canada, Map 1668.

Mellon, G.B. (1967): Stratigraphy and petrology of the Lower Cretaceous Blairmore and Mannville Groups, Alberta foothills and plains; Alberta Research Council Bulletin 21, 270 pages.

Mountjoy, E.W. (1960): Geology, Miette sheet; Geological Survey of Canada Map 40-1959, scale 1 inch = 1 mile.

Nielsen, G.L. (1969): Edson aquifer testing program, Edson, Alberta; Alberta Department of Agriculture, Water Resources Division, Soils, Geology and Groundwater Branch, Edmonton, Alberta. Report No. 1067, 69 pages.

Ozoray, G.F. (1972): Hydrogeology of the Wabamun Lake area, Alberta; Alberta Research Council Report 72-8, 17 pages.

Pearson, G.R. (1960): Lower Cretaceous coal deposits in the foothills between Sheep Creek and Wildhay River, Alberta; field trip guide book, Edmonton Geological Society, pp. 72-81.

Price, R.A. and E.W. Mountjoy (1970): Geologic structure of the Canadian Rocky Mountains between Bow and Athabasca Rivers—a progress report; Geological Association of Canada, Spec. Paper No. 6, pp. 7-27, and Figure 2-1.

Roed, M.A. (1968): Surficial geology of the Edson-Hinton area, Alberta; Unpublished PhD thesis, University of Alberta, Edmonton.

Roed, M.A. (1975): Cordilleran and Laurentide multiple glaciation, west-central Alberta, Canada; Canadian Journal of Earth Sciences, Vol. 12, No. 9, 23 pages.

Rutherford, R.L. (1925): Geology of the foothills belt between McLeod and Athabasca Rivers, Alberta; Alberta Research Council Report No. 11, 61 pages.

Rutherford, R.L. (1928): Geology of the area between North Saskatchewan and McLeod Rivers, Alberta, Alberta Research Council Report No. 19, 37 pages.

Stevenson, D.R. (1969): Hydrogeology of the Cache Percotte Basin, Alberta, Canada; Alberta Research Council Open File Report 1969-10, 58 pages.

Streltsova, T. (1976): Hydrodynamics of groundwater flow in a fractured formation; Water Resources Research, Vol. 12, No. 3, 9 pages.

Thomas, J.G., R.R. Erickson, W.W. Warren and C.T. Hack (1975): Hinton-Yellowhead regional land use study; Alberta Municipal Affairs Report, 87 pages.

Thornthwaite, C.W. and J.R. Mather (1957): Instructions and tables for computing potential evapotranspiration and the water balance; Drexel Institute of Technology, Publications in Climatology, Vol. X, No. 3, 289 pages.

Tokarsky, O. (1977): Hydrogeology of the Iosegun Lake area, Alberta; Alberta Research Council Report 76-2, 10 pages.

Vanden Berg, A. and D.H. Lennox (1968): Safe yield of a well-field in a leaky artesian strip aquifer; Groundwater, Vol. 6, No. 2, pp. 30-36.

van Everdingen, R.O. (1972): Thermal and mineral springs in the southern Rocky Mountains of Canada; Environment Canada, 151 pages.

Wall, J.H. (1967): Cretaceous Foraminifera of the Rocky Mountain Foothills, Alberta; Alberta Research Council Bulletin 20, 185 pages.

Yurko, J.R. (1976): Deep Cretaceous coal resources of the Alberta Plains; Alberta Research Council, Earth Sciences Report 75-4, 47 pages.

LEGEND

Isohyet, mean annual precipitation in inches (cm) .... —24(61)—

Mean annual precipitation in inches (cm)

- 15 to 20 inches (38 to 51 cm)
- 20 to 25 inches (51 to 64 cm)

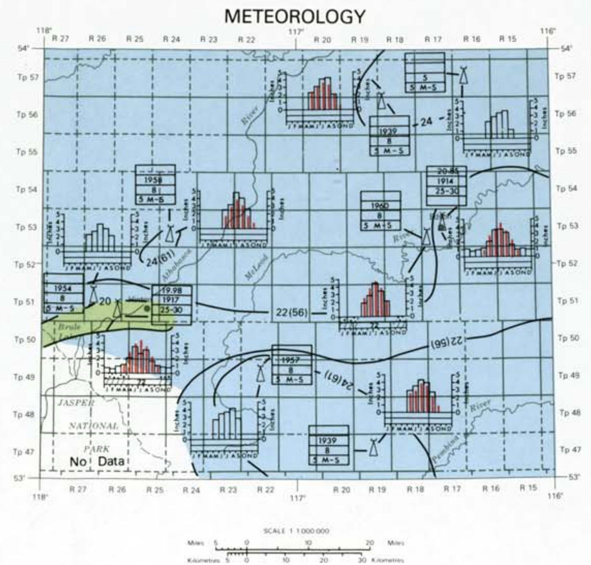
Meteorological station ....

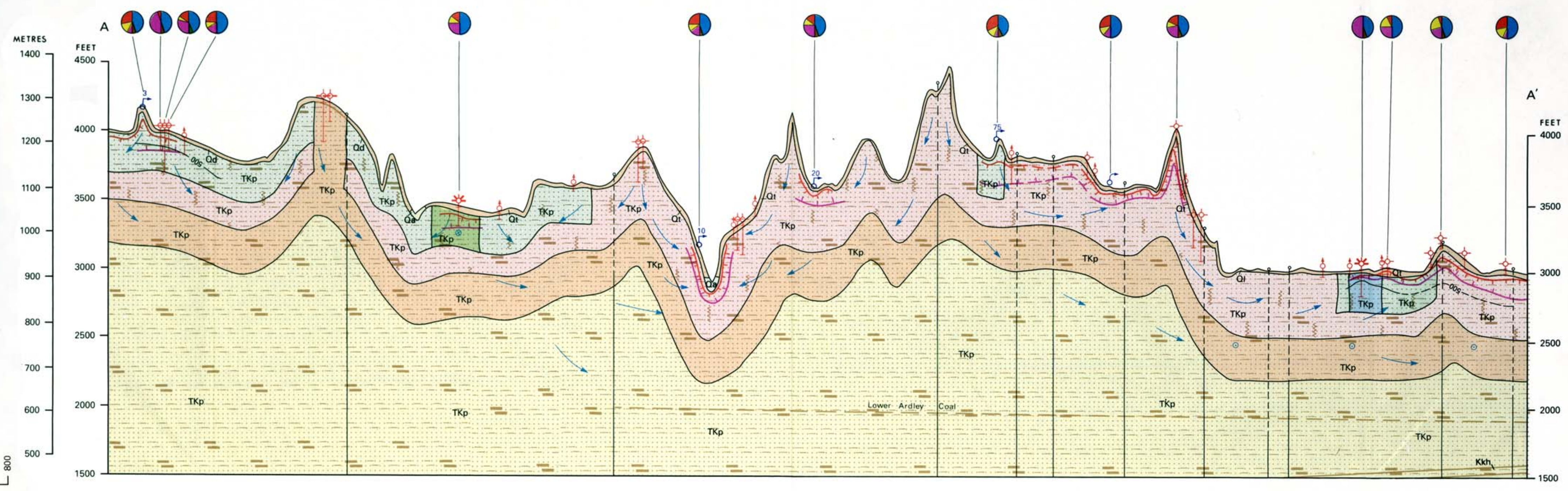
Standard rain gauge only ....

Precipitation data:

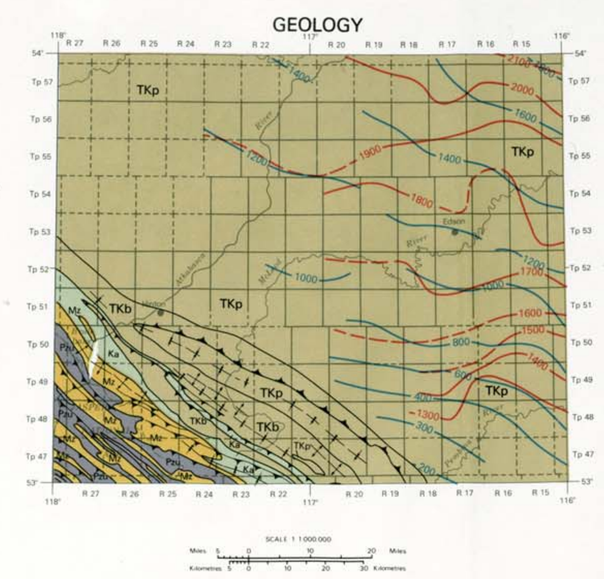
- Mean annual precipitation estimated in inches (cm)
- Year of commencement of observations 1957
- Number of years in average 8
- Months of record if not yearly .... 5 M-S
- Mean monthly potential evapotranspiration
- Mean monthly precipitation
- Period when surface is usually snow covered
- Period with mean daily temperatures below freezing
- Figure indicates percentage of mean annual precipitation falling as rain

METEOROLOGY





GEOLOGY



LEGEND

Paskapoo Formation: *thick-bedded, calcareous, cherty sandstone;*
TKp *siltstone and mudstone; minor conglomerate, limestone, coal and tuft beds; nonmarine*

Brazeau Formation: *gray, fine-grained, feldspathic sandstone with*
TKb *hard calcareous beds; laminated silstone and gray silty shale; deltaic to marine*

Alberta Group: *Fissile, silty shale; some thin-bedded, fine-*
Ka *to medium-grained, cherty sandstone (Blackstone Formation) – thick-bedded, well-sorted, quartzose sandstone' shale and carbonaceous shale; siltstone and thin coal beds (Cardium Formation) – dark grey fissile shale and silstone; thin beds of concretionary ironstone (Wapiabi Formation)*

Undifferentiated Mezosoic: *thick-bedded, cherty, calcareous sandstone;*
Mz *calcareous shale, coal, minor conglomerates (Lower Cretaceous); black shale, minor sandstone (Jurassic); siltstone, minor limestone (Triassic)*

Upper Paleozoic: *quartzose sandstone and siltstone, minor carbonates*
Pzu *(Pennsylvanian-Permian); limestone and siltstone (Mississippian); dolomite and limestone (Devonian)*

Lower Paleozoic: *dolomite (Silurian); dolomite, limestone, minor*
Pzl *quartzite and shale (Ordovician); massive and flaggy dolomite limestone and minor shale, quartzite, minor shale and limestone (Cambrian)*

Structure contour on top of Lower Ardley Coal Zone .... —1900—

Structure contour on top of Kneehills Tuff (Whitemud and Battle Formation) .... —1800—

Rock unit boundary ....

Axis of syncline ....

Axis of anticline ....

Thrust fault (teeth on upper plate) ....

Geology after R. Green (1970): Geological map of Alberta

MAIN MAP LEGEND

Topography

Surface contours and elevation in feet (interval 500 feet) ....

Geology

Geological boundary ....

Fault, with direction of movement ....

Fold axis ....

QUATERNARY

Qa	Alluvial deposits
Qd	Unconsolidated deposits
Qt	Till
Ql	Lacustrine clays, silts

TERTIARY-CRETACEOUS

TKp	Paskapoo Formation
TKb	Brazeau Formation

CRETACEOUS

Kwb	Whitemud and Battle Formations
Kwt	Wapiti Formation
Ka	Alberta Group
Kkh	Kneehills Tuff

MESOZOIC

Mz	Undifferentiated Lower Cretaceous, Jurassic and Triassic Strata

PALEOZOIC

Pzu	Undifferentiated Upper Paleozoic Strata
Pzl	Undifferentiated Lower Paleozoic Strata

Lithology

Sand and gravel ....

Sandstone ....

Sandstone, bentonitic ....

Siltstone ....

Shale ....

Limestone ....

Fractured rocks ....

Coal ....

Hydrography

Lake or slough, perennial ....

Marsh, muskeg ....

Stream, perennial ....

Stream, intermittent ....

Surface water divide ....

Area of noticeable salt precipitates ....

Hydrogeology

Spring, flow rate unknown ....

Spring, flow rate in igpm (L/sec) ....

Nonpumping water level contour (elevation in feet followed by metres in brackets); defined, approximate .... 3000(915) Upward flow / Downward flow

Direction of groundwater flow ....

Component of groundwater flow perpendicular to profile:
out of profile (towards reader) ....
into profile (away from reader) ....

Component of groundwater flow parallel to profile ....

Groundwater divide ....

Boundary of area of artesian flow ....

Groundwater Probability†

Range of average expected yield of wells in imperial gallons per minute (L/sec)

Probable: estimated from quantitative information (pump tests, bail tests, etc.)
Possible: estimated from qualitative information (flow regime, lithology, etc.)

more than 500	(›38)
100-500	(8-38)
25-100	(2-8)
5-25	(0.4-2)
1-5	(0.1-0.4)
‹1	(‹0.1)

Yield area boundary ....

† The indicated average expected yields to wells are predications based on the best data available at the time of map compilation, due to data shortcomings and special conditions, local discrepancies between predicated and actual yields are inevitable. Multiaquifer completion may be necessary to obtain the yield indicated.

Wells and Other Artificial Works

Depth scale

FEET 0, 100, 200, 300, 400 — Depth to water; Depth of well or seismic shot hole

Water well, nonflowing ....

Water well, flowing ....

Water well, non-producing ....

Alberta Research Council test well .... ARC

Water well, 20-year safe yield calculated from apparent transmissivity ....

Water well, 20-year safe yield calculated from a good bail test or a short pump test ....

Water well, 20-year safe yield calculated from a pump test of sufficient length to reflect regional hydraulic conditions ....

Adjacent wells ....

Seismic shothole reported to have flowed ....

Exploratory testhole reported to have flowed ....

Exploratory testhole for coal ....

Depth of exploratory well ....

The vertical line portion of oil, gas, or other exploratory test well symbols indicates the well depth; the dashed portion indicates the surface casing interval where applicable or where known.
Note: On the main map exploratory wells appear as point symbols only.

Line of hydrogeological profile .... A A'

Hydrochemistry

Calcium; Magnesium; Sodium + potassium; Carbonate + bicarbonate; Sulfate; Chloride; 0; 50%; 100%; Cations | Anions

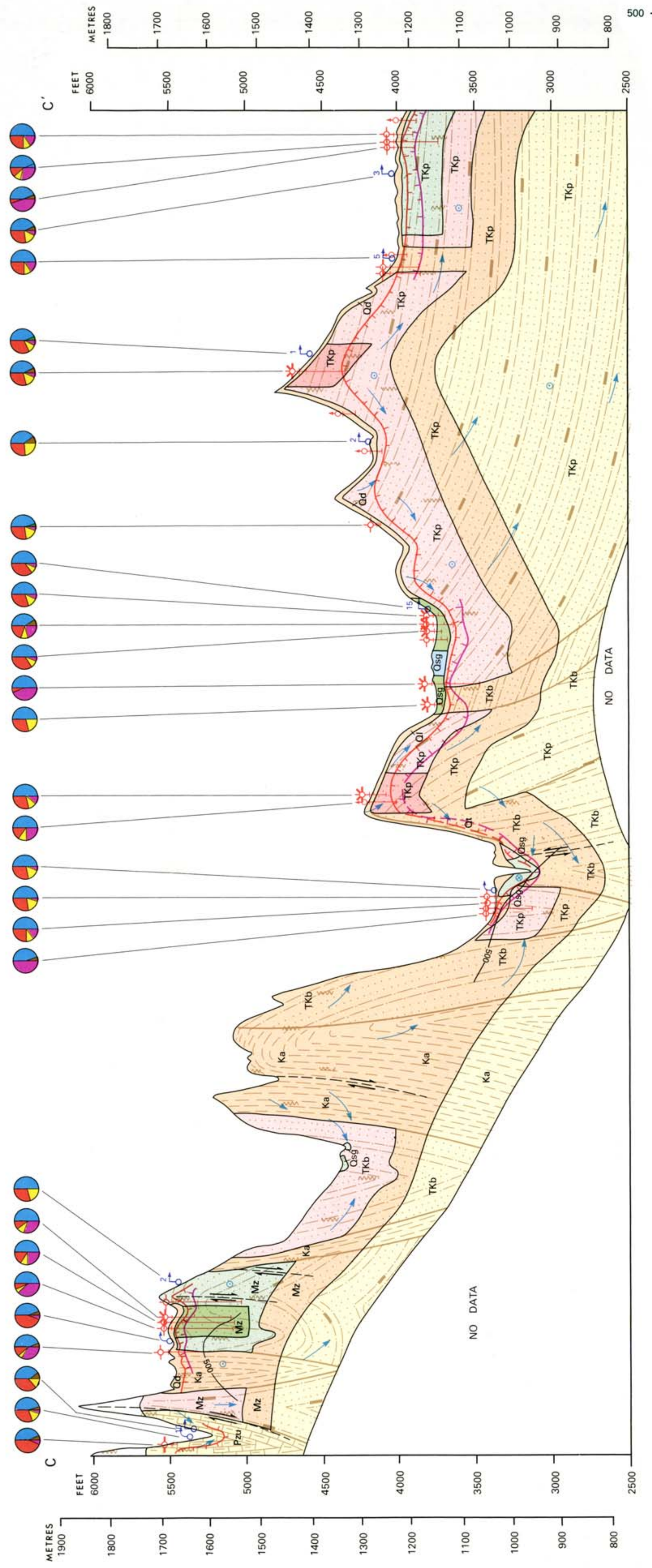
Note: When the yellow Mg pie sector is absent, Ca + Mg are represented as a unit by the red pie sector.

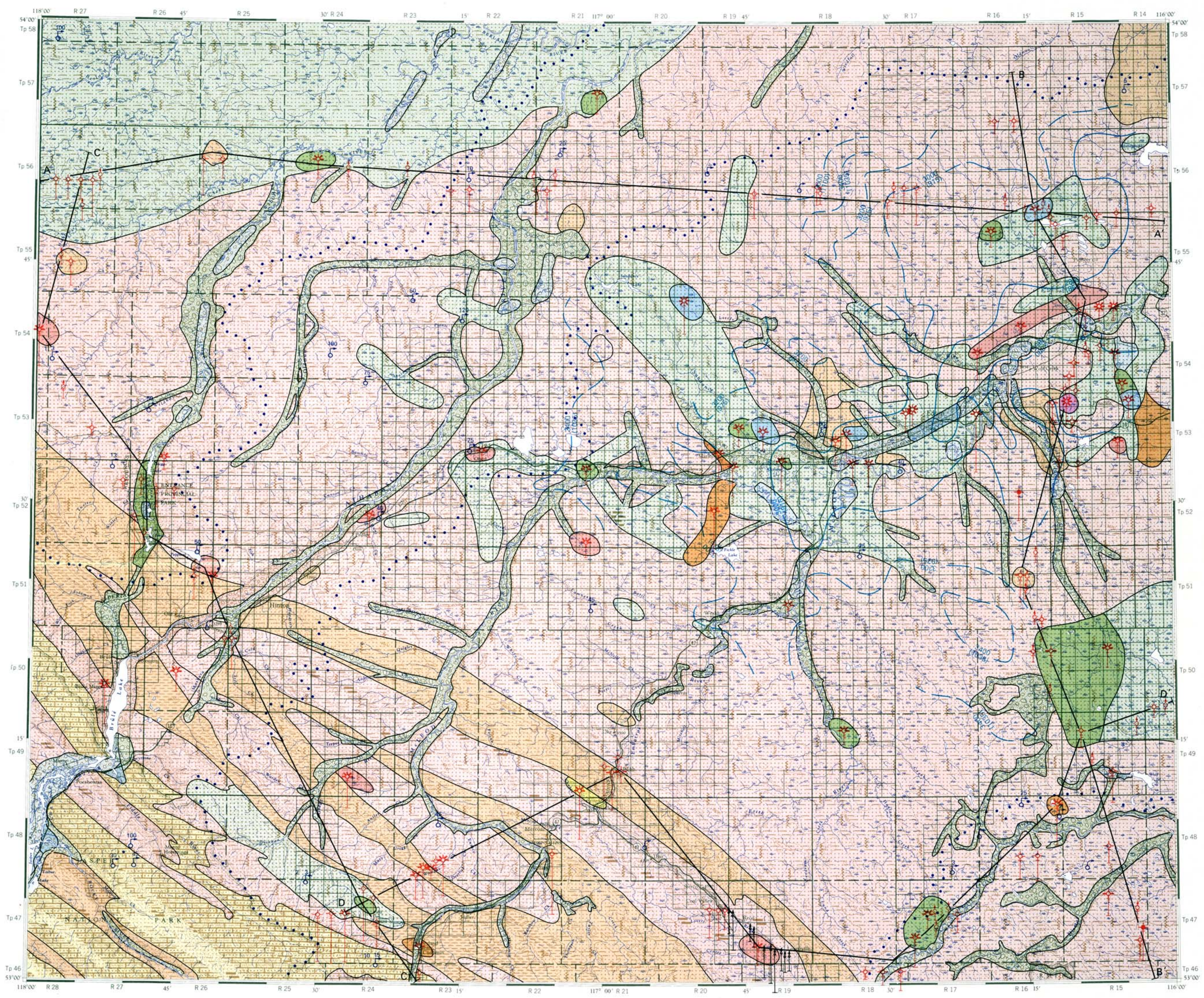
Total dissolved solids in parts per million:
defined .... —500—
approximate .... --500--

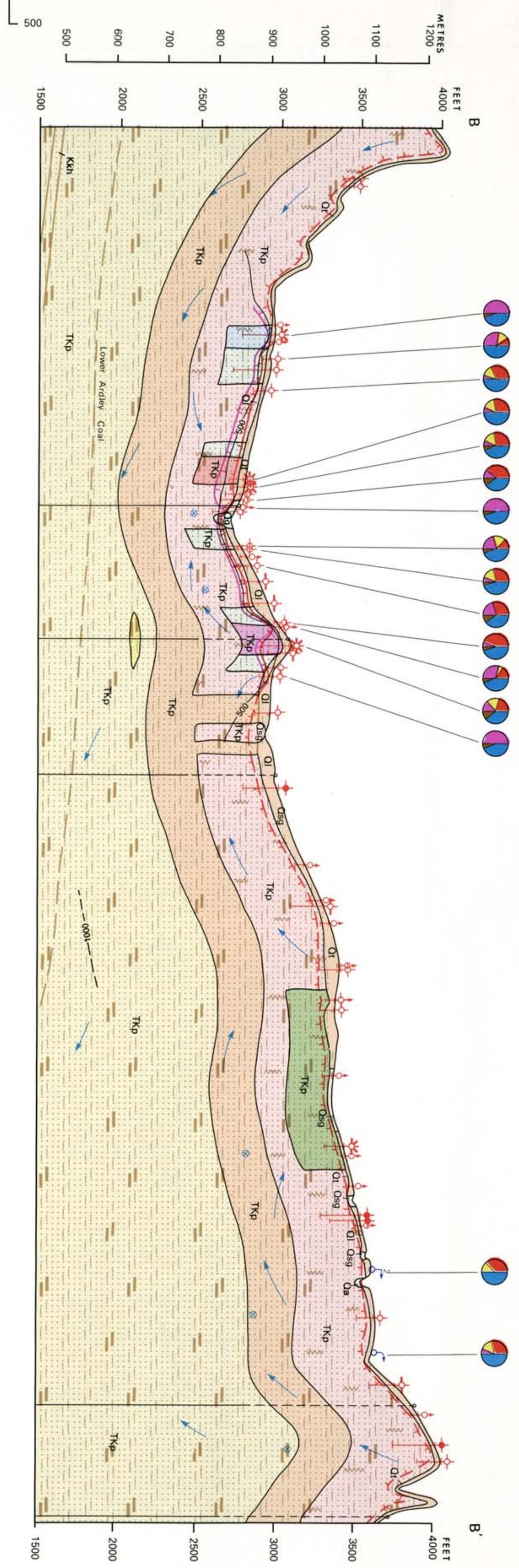
Isogram along which calcium + magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content:
defined: ....
approximate: ....

Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content:
defined: ....
approximate: ....

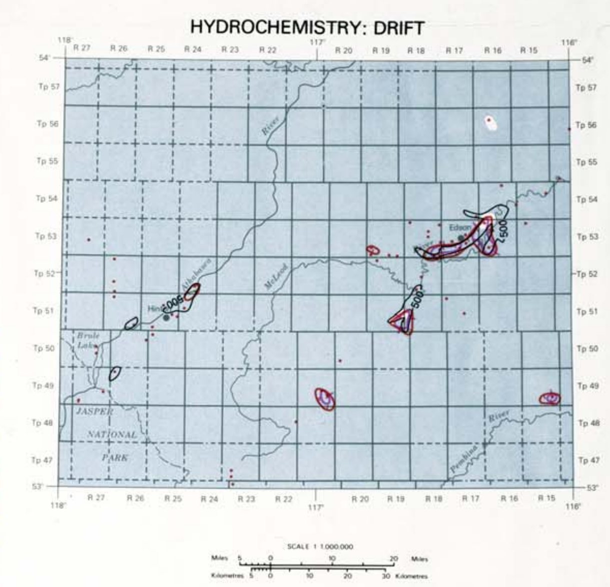
* determined on equivalents per million







HYDROCHEMISTRY: DRIFT



LEGEND

Data control point marking location of a well with a chemical analysis ....

Total dissolved solids in parts per million: defined, approximate .... —500—

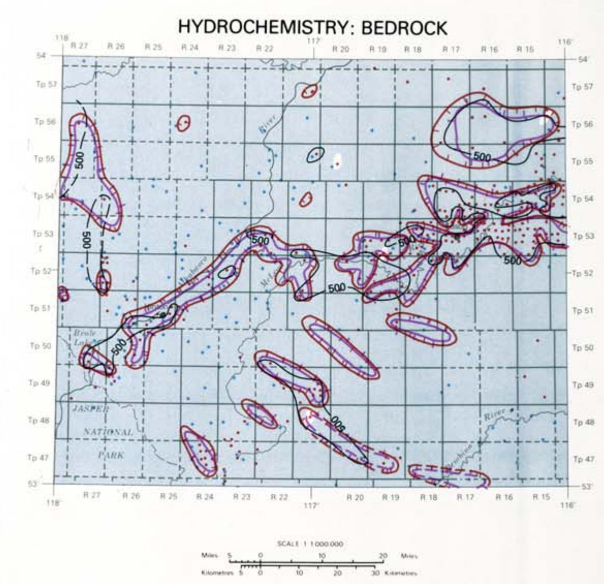
Carbonate + bicarbonate constituting over 60 percent of total anions* ....

Isogram along which calcium + magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content: defined, approximate ....

Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content: defined, approximate ....

* determined on equivalents per million basis

HYDROCHEMISTRY: BEDROCK



LEGEND

Data control point marking location of a well with a chemical analysis ....

Data control point marking location of a spring with a chemical analysis ....

Total dissolved solids in parts per million: defined, approximate ....

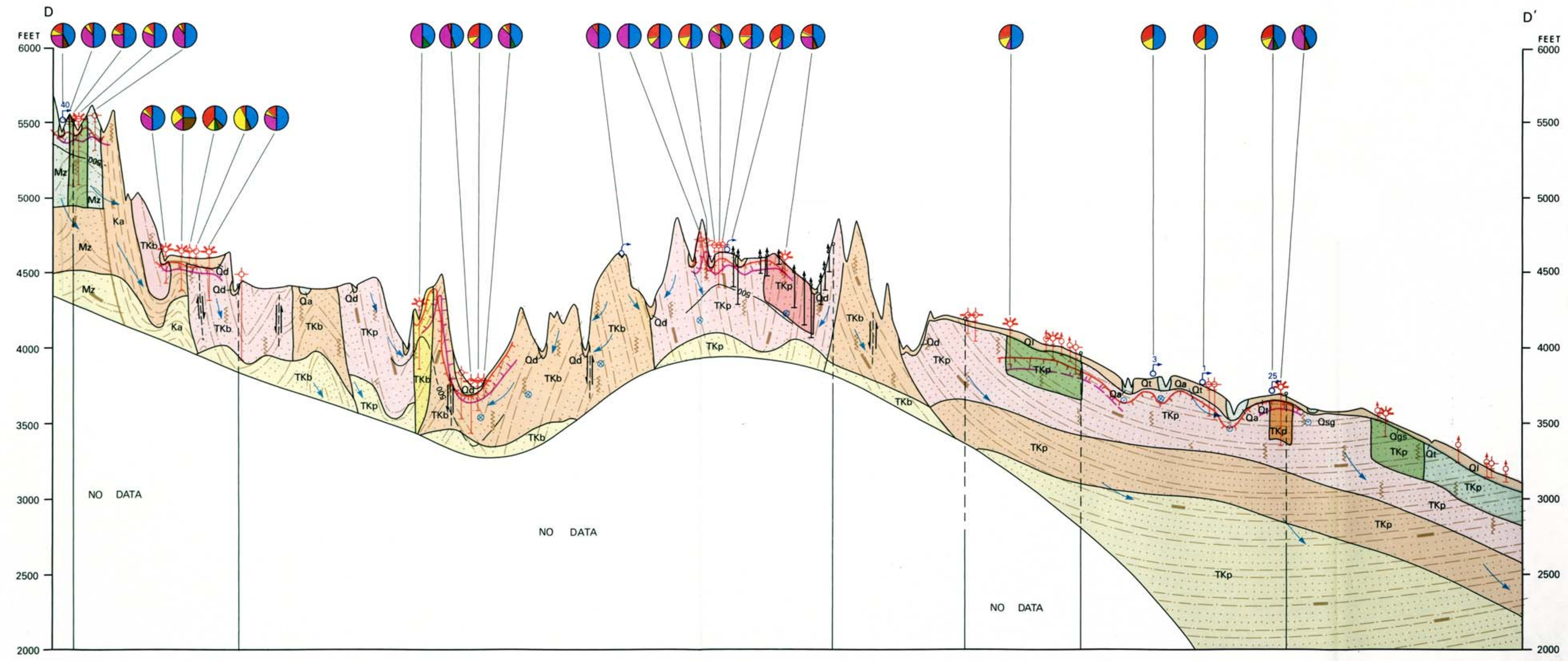
Carbonate + bicarbonate constituting over 60 percent of total anions* ....

Isogram along which calcium + magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content: defined, approximate ....

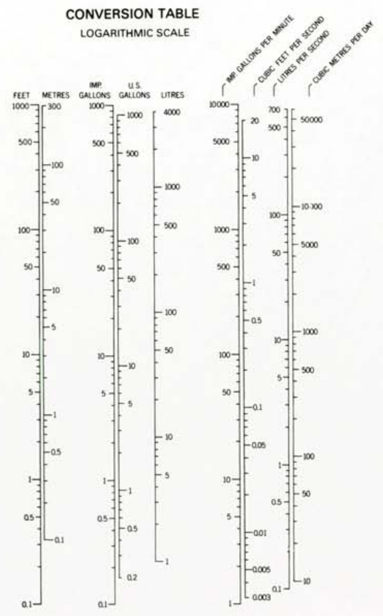
Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content: defined, approximate ....

* determined on equivalents per million basis

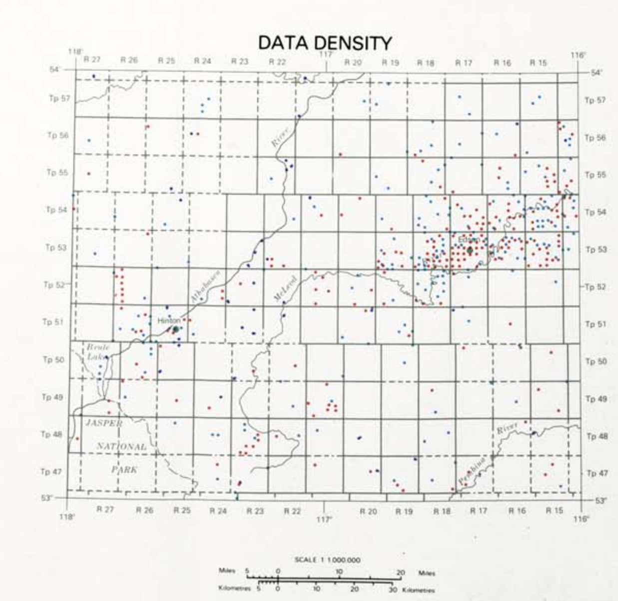
Alberta RESEARCH COUNCIL



CONVERSION TABLE
LOGARITHMIC SCALE



DATA DENSITY



LEGEND

Data control point marking location of a well with water level information only ....

Data control point marking location of a well with yield information ....

Data control point marking location of a surface hydrogeological feature ....

SCALE 1:250,000
Miles 5 0 5 10 15 20 Miles
Kilometres 5 0 5 10 15 20 25 30 Kilometres

All elevations in feet above mean sea level.

Vertical exaggeration of the hydrogeological profiles is approximately 40X.
An expanded legend and explanatory notes (Report 72-12) for use with this hydrogeological map series is available from Publications, Alberta Research Council, 11315-87 Avenue, Edmonton, Canada T6G 2C2.

Map to accompany Report 79-7

Hydrogeology by R.I.J. Vogwill and A.S.R. Beerwald

Drafted by J.K. Matthie

Cartographic editing by ARC Drafting Services

HYDROGEOLOGICAL MAP
EDSON
ALBERTA

83F

KEY MAP

Base map provided by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa, modified by Surveys Branch, Alberta Transportation, Edmonton

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